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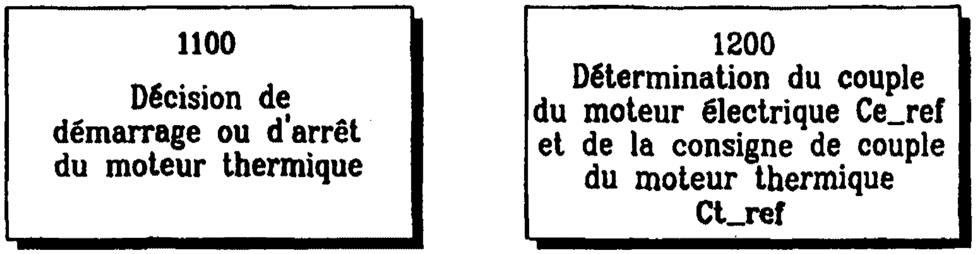
(54) Titre: VEHICULE AUTOMOBILE A MOTORISATION HYBRIDE



1100...DECISION TO START OR TO STOP HEAT ENGINE
1200...DETERMINATION OF THE ELECTRIC ENGINE TORQUE Ce-ref AND SET POINT OF HEAT ENGINE TORQUE Ct-ref

(57) Abstract

The invention concerns a motor vehicle with dual engine system comprising an electric engine and a heat engine, wherein a central management unit executes a first task (1200) including the determination of a torque which each engine must provide to supply an engine torque in conformity with the torque requested by the driver, and wherein the heat engine can be stopped. The invention is characterised, at least for some operating modes, the central unit executes a second task (1100) during which the decision to stop or to start the heat engine is taken, and the first and second tasks are executed in parallel, the execution frequency of the second task being less frequently operated than the first.

(57) Abrégé

L'invention propose un véhicule automobile à motorisation hybride comportant un moteur électrique et un moteur thermique, du type dans lequel une unité centrale de gestion exécute une première tâche (1200) comportant la détermination du couple que doit fournir chaque moteur pour fournir un couple moteur conforme à un couple demandé par le conducteur, et du type dans lequel le moteur thermique est susceptible d'être arrêté, caractérisé en ce que, au moins pour certains modes de fonctionnement, l'unité centrale exécute une deuxième tâche (1100) au cours de laquelle est décidé l'arrêt ou le démarrage du moteur thermique, et en ce que la première et la deuxième tâche sont exécutées en parallèle, la fréquence d'exécution de la deuxième tâche étant inférieure à celle de la première tâche.

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Véhicule automobile à motorisation hybride

L'invention concerne un véhicule automobile à motorisation hybride comportant des moyens perfectionnés de gestion de l'énergie.

L'invention concerne plus particulièrement un véhicule automobile à motorisation hybride, du type dans lequel un ensemble motopropulseur comporte un moteur électrique et un moteur thermique qui sont susceptibles de contribuer à l'entraînement du véhicule, et du type dans lequel une unité centrale de gestion exécute une première tâche comportant la détermination du couple que doit fournir chaque moteur pour que l'ensemble motopropulseur fournisse au véhicule un couple moteur conforme à un couple demandé par le conducteur du véhicule, et du type dans lequel le moteur thermique est susceptible d'être arrêté, le véhicule étant alors entraîné par le seul moteur électrique alimenté en courant électrique par une batterie d'accumulateurs.

Dans la recherche de véhicules moins polluants que les véhicules automobiles ne comportant qu'un unique moteur thermique, les véhicules à motorisation hybride se présentent comme une alternative particulièrement intéressante aux véhicules strictement électrique.

En effet, ces derniers présentent l'avantage de n'émettre par eux-mêmes aucune substance toxique tout en étant à la fois particulièrement silencieux et économiques à l'usage. Cependant, les véhicules électriques ne tirent leur énergie que des seules batteries d'accumulateurs qu'ils embarquent avec eux. Or, étant données les faibles performances des batteries d'accumulateurs actuellement connues, du moins celles susceptibles d'être utilisées à un coût raisonnable dans un véhicule automobile, les véhicules électriques ne peuvent emmagasiner qu'une quantité d'énergie relativement faible, en dépit d'une masse conséquente, ce qui leur confère à la fois une faible autonomie et de faibles performances.

Aussi, la solution d'une motorisation hybride comportant un moteur thermique susceptible de participer à l'entraînement du véhicule permet de réaliser des véhicules présentant des performances et une autonomie bien plus élevée, satisfaisante pour un usage normal du véhicule.

Il existe deux types principaux de véhicules hybrides.

Dans les véhicules hybrides série, seul le moteur électrique est susceptible d'entraîner directement les roues motrices du véhicule, éventuellement au travers d'une boîte de vitesses, d'un différentiel et/ou d'un embrayage. Le moteur électrique tire son énergie d'une batterie d'accumulateurs rechargée d'une génératrice électrique qui est entraînée par le moteur thermique.

Dans un tel type de véhicule hybride, le moteur électrique est donc toujours en fonctionnement et le moteur thermique peut soit être arrêté, le véhicule fonctionnant alors en mode électrique pur, soit être mis en marche de manière que la génératrice produise de l'électricité en vue d'alimenter le moteur électrique et/ou de recharger les batteries.

Dans un véhicule hybride parallèle, le moteur thermique et le moteur électrique sont tous les deux reliés, généralement par un système de boîte de vitesses à deux entrées, aux roues motrices du véhicule. Généralement, un embrayage est interposé entre chaque moteur et les roues motrices pour permettre le désaccouplement du moteur lorsque celui-ci n'est pas utilisé pour l'entraînement. Les véhicules automobiles de type hybride parallèle peuvent donc être entraînés soit à l'aide du seul moteur électrique, soit à l'aide du seul moteur thermique, ou encore à l'aide des deux moteurs simultanément. Par ailleurs, dans certaines configurations, il est possible d'utiliser le moteur électrique pour assurer le démarrage du moteur thermique et le moteur électrique peut aussi être « inversé » de telle sorte que, le moteur thermique entraînant en rotation le moteur électrique, éventuellement en même temps qu'il entraîne en rotation les roues motrices du véhicule, assure le rechargement des batteries.

Il est à noter qu'il existe une variante de réalisation des véhicules hybrides en parallèle dans lesquels chacun des deux moteurs thermique et électrique est accouplé non pas à un même essieu, mais à des essieux différents.

Quel que soit le type de véhicule hybride envisagé, il est donc nécessaire de gérer le plus efficacement possible la commande de chacun des moteurs thermique et électrique pour assurer l'entraînement du véhicule selon les desiderata du conducteur qui détermine à chaque instant le couple moteur nécessaire à l'avancement du véhicule pour assurer l'accélération ou la décélération du véhicule, ou le maintien du véhicule à une vitesse stabilisée.

Notamment, le choix de l'utilisation ou non du moteur thermique est particulièrement crucial car il permet de déterminer l'autonomie du véhicule, ses performances, tout cela dans la mesure où la mise en route du moteur thermique est effectivement possible, ce qui peut par exemple être interdit dans certaines zones au trafic particulièrement dense ou à certaines périodes pour limiter la pollution.

Par ailleurs, il est nécessaire que les transferts de répartition de la puissance fournie par chacun des moteurs se fassent de manière « transparente » pour le conducteur, c'est-à-dire en ne produisant qu'un minimum de perturbations et d'à-coups.

Aussi, l'invention propose un véhicule automobile du type décrit précédemment, caractérisé en ce que, au moins pour certains modes de fonctionnement de l'ensemble motopropulseur, l'unité centrale exécute une deuxième tâche au cours de laquelle est décidé l'arrêt ou le démarrage du moteur thermique, en ce que la première tâche et la deuxième tâche sont exécutées en parallèle, et en ce que la fréquence d'exécution de la deuxième tâche est inférieure à celle de la première tâche.

Selon d'autres caractéristiques de l'invention :

- le conducteur peut imposer à l'ensemble motopropulseur un mode de fonctionnement électrique dans lequel le moteur thermique est arrêté ;
- le conducteur peut imposer à l'ensemble motopropulseur un mode de fonctionnement de régénération dans lequel le moteur thermique est utilisé notamment pour assurer le rechargement de la batterie ;
- le conducteur peut imposer à l'ensemble motopropulseur un mode de fonctionnement hybride dans lequel l'unité centrale exécute la deuxième tâche au cours de laquelle est décidé l'arrêt ou le démarrage du moteur thermique ;
- la décision d'arrêt ou de démarrage du moteur thermique est prise notamment en fonction d'un niveau de charge de la batterie ;
- le démarrage du moteur thermique est décidé ou confirmé lorsque le niveau de charge de la batterie est inférieur à un niveau de seuil bas, et en ce que l'arrêt du moteur thermique est susceptible d'être décidé ou d'être confirmé lorsque le niveau de charge de la batterie est supérieur à un niveau de seuil haut ;
- la décision d'arrêt ou de démarrage du moteur thermique est prise notamment en fonction du couple instantanée demandé par le conducteur ;

- la décision d'arrêt ou de démarrage du moteur thermique est prise notamment en fonction du couple moyen demandé par le conducteur pendant un intervalle de temps prédéterminé précédant de la décision ;

- le démarrage du moteur thermique est décidé ou confirmé lorsque le couple instantané demandé par le conducteur est supérieur à un niveau de seuil haut, et en ce que l'arrêt du moteur thermique est susceptible d'être décidé ou d'être confirmé lorsque le couple instantané et le couple moyen demandés par le conducteur sont inférieurs à un niveau de seuil bas ;

- l'arrêt du moteur thermique est décidé ou confirmé lorsque, à la fois, le niveau de charge de la batterie est supérieur à un niveau de seuil haut et le couple instantané et le couple moyen demandés par le conducteur sont inférieurs à un niveau de seuil bas ;

- la décision d'arrêt ou de démarrage du moteur thermique est prise notamment en fonction d'un écart entre le couple demandé par le conducteur et le couple effectivement fourni par l'ensemble motopropulseur ;

- en fonctionnement du mode de fonctionnement sélectionné par le conducteur, il est fixé un niveau de consigne de charge de la batterie ;

- l'ensemble motopropulseur est un ensemble hybride en série dans lequel les roues motrices du véhicule sont entraînées exclusivement par le moteur électrique qui est alimentée par du courant électrique provenant soit de la batterie soit d'une génératrice entraînée par le moteur thermique ;

- il est déterminé la puissance électrique à fournir à la batterie en fonction d'un écart entre les niveaux réel et de référence de la batterie, en tenant compte de valeurs limites de puissance de charge et de décharge de la batterie ;

- le démarrage du moteur thermique est déterminé en fonction de la puissance électrique à fournir à la batterie, de la puissance électrique absorbée par le moteur électrique et en fonction d'un écart entre la valeur du couple demandé par le conducteur et la valeur du couple fourni par le moteur électrique ;

- il est déterminé un niveau de consigne de la puissance fournie par la génératrice en fonction de la puissance réelle fournie par la génératrice, de la puissance réelle fournie par la batterie, et de la puissance à fournir à la batterie, en tenant compte la puissance maximale susceptible d'être fournie par la génératrice ;

- il est déterminé une puissance électrique nécessaire en fonction du couple moteur demandé par le conducteur, en tenant compte, au moins lorsque ce couple est supérieur en valeur absolue à une valeur minimale, d'un rendement du moteur électrique ;

- il est déterminé une valeur de consigne du couple fourni par le moteur électrique en fonction du couple moteur demandé par le conducteur multiplié par, au moins lorsque la puissance électrique nécessaire est supérieure en valeur absolue à une valeur de seuil, du rapport de la puissance électrique susceptible d'être fournie au moteur électrique divisée par la puissance électrique nécessaire, la puissance électrique susceptible d'être fournie au moteur électrique tenant compte de la puissance électrique nécessaire, de la puissance réelle fournie par la génératrice, de la puissance susceptible d'être fournie par la batterie, et de la puissance maximale susceptible d'être absorbée par le moteur ;

- l'ensemble motopropulseur est un ensemble hybride en parallèle dans lequel le moteur électrique et le moteur thermique entraînent chacun soit au moins une même roue motrice soit des roues motrices différentes ;

- l'ensemble motopropulseur fonctionne en mode de régénération, le moteur électrique ne délivre un couple moteur que si le conducteur provoque une hausse brutale du couple demandé ;

- lorsque l'ensemble motopropulseur fonctionne en mode de régénération, le moteur thermique est commandé pour fournir un couple maximal ;

- lorsque l'ensemble motopropulseur fonctionne en mode hybride et que le niveau de charge de la batterie est précédemment devenu inférieur à un niveau de seuil bas et n'a pas encore dépassé un niveau de seuil haut, le moteur thermique est commandé pour fournir un couple de consigne au moins égal à un couple optimal correspondant à des conditions de rendement optimales du moteur thermique ;

- lorsque l'ensemble motopropulseur fonctionne en mode hybride et que le couple instantané demandé par le conducteur est précédemment devenu supérieur à un niveau de seuil haut sans être redevenu inférieur à un niveau de seuil bas en même temps que le niveau moyen est inférieur au niveau de seuil bas, le moteur thermique est commandé pour fournir un couple de consigne au moins égal à une valeur filtrée du couple demandé par le conducteur ; et

- si une valeur filtrée du couple demandé par le conducteur est supérieure au couple maximal du moteur thermique, le moteur électrique est sollicité pour fournir, dans la mesure du possible, la quantité de couple manquante.

D'autres caractéristiques et avantages de l'invention apparaîtront à la lecture de la description détaillée qui suit pour la compréhension de laquelle on se reportera aux dessins annexés dans lesquels :

- la figure 1 est une vue schématique illustrant l'architecture d'un véhicule automobile à motorisation hybride, de type parallèle ;
- la figure 2 est une vue similaire à celle de la figure 1 illustrant un véhicule hybride de type série ;
- les figures 3A à 3K sont des organigrammes illustrant une première stratégie de gestion d'un véhicule hybride conforme aux enseignements de l'invention, plus particulièrement destinée à un véhicule hybride de type parallèle ; et
- les figures 4A à 4H illustrent un organigramme d'une stratégie de gestion selon l'invention, plus particulièrement destinée à un véhicule de type hybride en série.

Dans un véhicule à motorisation hybride en parallèle, du type de celle illustrée à la figure 1, un moteur thermique 10 et un moteur électrique 12 sont tous les deux susceptibles d'entraîner directement les roues motrices du véhicule.

Le moteur thermique 10 est généralement un moteur à combustion interne du type à pistons alternatifs ou à piston rotatif ou encore de type turbine. Il est alimenté en énergie sous forme chimique par un carburant liquide ou gazeux de type hydrocarbure.

Le moteur électrique 12 est relié électriquement à une batterie d'accumulateurs 16 porté par le véhicule, éventuellement par le biais d'un convertisseur onduleur 17. Les deux moteurs 10, 12 entraînent chacun en rotation un arbre d'entrée 18, 20 d'un organe de répartition de puissance 22 dont le ou les arbres de sortie 24 entraînent en rotation les roues motrices. L'organe de distribution de puissance 22 peut comporter par exemple une boîte de vitesses, un différentiel et on peut choisir d'interposer entre l'un au moins des moteurs et l'arbre d'entrée 18, 20 correspondant, un dispositif d'embrayage 25 qui permet d'accoupler ou de désaccoupler à volonté le moteur par rapport à l'organe de distribution de puissance 22.

Le véhicule ainsi équipé peut donc être entraîné soit à l'aide du seul moteur thermique 10, soit à l'aide du seul moteur électrique 12, soit à l'aide des deux moteurs simultanément. Éventuellement, le moteur thermique peut voir sa puissance répartie entre d'une part l'entraînement des roues motrices 14, et d'autre part l'entraînement en rotation du moteur électrique « inversé » qui se transforme alors en une génératrice électrique susceptible de recharger la batterie d'accumulateurs 16.

De même, le moteur électrique 12 peut éventuellement être utilisé pour démarrer le moteur thermique 10.

Dans le véhicule hybride de type série qui est illustré à la figure 2, seul le moteur électrique 12 est relié directement aux roues motrices, éventuellement par le biais d'un organe de distribution de puissance (non représenté). Le moteur électrique 12 peut être alimenté en énergie électrique par la batterie d'accumulateurs 16 ou par une génératrice électrique 26 qui est entraînée par le moteur électrique 12.

Dans tous les cas, il peut être prévu des convertisseurs onduleur 17 et redresseur 19 si le moteur électrique doit être alimenté en courant alternatif.

De préférence, pour assurer la gestion de l'entraînement du véhicule, chacun des éléments principaux du véhicule est pourvu d'une unité locale de commande, chacune de ces unités locales étant à son tour commandée par une unité centrale de gestion qui permet de centraliser à la fois les informations concernant l'état de chacun des organes, des informations quant à l'état du véhicule et aussi des informations quant aux souhaits du conducteur.

L'unité centrale de gestion a notamment pour but de commander les deux moteurs 10, 12 de manière à utiliser au mieux l'énergie du véhicule qui est stockée soit sous la forme électrique dans les batteries, soit sous la forme de carburant de type hydrocarbure. Cette gestion a aussi pour but de répondre à tout moment de la manière la plus satisfaisante possible aux souhaits du conducteur quant à l'accélération et à la décélération du véhicule, ce souhait étant de préférence représenté par un couple moteur Cdemandé au niveau des roues motrices.

Deux tâches principales sont exécutées cycliquement par l'unité centrale de gestion, à savoir d'une part la décision du démarrage ou de l'arrêt du moteur thermique 10 et, d'autre part, la détermination des consignes du couple ou de la puissance que doivent fournir le moteur électrique et le moteur thermique pour assurer l'entraînement du véhicule conformément aux souhaits du conducteur.

Selon l'invention, ces deux tâches sont effectuées en parallèle et elles sont exécutées à des fréquences différentes.

Ainsi, la tâche consistant à déterminer les consignes de couple à fournir par le moteur électrique et le moteur thermique sera par exemple exécutée toutes les quarante millisecondes tandis que la tâche de décision du démarrage ou de l'arrêt du moteur thermique sera par exemple effectué toutes les secondes.

En découplant de la sorte ces deux tâches, on parvient à obtenir une gestion de la puissance fournie par l'ensemble motopropulseur constitué par les deux moteurs 10, 12 qui permet de répondre de manière quasi instantanée aux sollicitations du conducteur. De plus, en rendant la décision de démarrage et d'arrêt du moteur thermique indépendante de la gestion instantanée de la puissance, on évite de multiplier ces phases d'arrêt et de démarrage qui sont à la fois des sources de pollution accentuées et des sources d'instabilité quant à la puissance totale fournie par les moteurs qui peut se traduire par des à-coups ressentis par le conducteur et les passagers du véhicule.

La stratégie de gestion du véhicule hybride selon l'invention sera plus particulièrement décrite ci-après selon deux modes de réalisation dont l'un est plus particulièrement adapté à un véhicule hybride de type parallèle illustré à la figure 1, et dont l'autre est plus particulièrement adapté à un véhicule hybride de type série illustré à la figure 2.

La première de ces deux stratégies fait appel à une série de variables qui sont regroupées et explicitées dans le tableau ci-dessous.

Notation	Signification	Unités
C1 à C4	Constantes permettant de calculer Cbas et Chaut en fonction de jauge_batterie	Nm
Cbas	Seuil de couple inférieur pour la détermination de th_roulage	Nm
Cdemandé	Couple demandé par le conducteur (positif pour l'accélération, négatif pour la décélération)	Nm
Cdemandé_filtre1	Valeur filtrée à temps de réponse rapide de Cdemandé	Nm
Cdemandé_filtre2	Valeur filtrée à temps de réponse lent de Cdemandé	Nm
Ce_ref	Consigne de couple du moteur électrique (Positif pour la traction. négatif pour le freinage récupératif)	Nm
Cel_freinage_max	Couple de freinage récupératif maximum admissible par le moteur électrique (négatif)	Nm
Cel_traction_max	Couple de traction maximum admissible par le moteur électrique (positif)	Nm
Cemax	Couple électrique maximum compte tenu de l'état de la batterie et de mode_selectionne (positif)	Nm
Cemin	Couple électrique minimum compte tenu de l'état de la batterie et de mode_selectionne (négatif)	Nm
Chaut	Seuil de couple supérieur pour la détermination de th_roulage	Nm
Ct_maximum	Couple maximum du moteur thermique. utilisé en mode Régénération	Nm
Ct_optimal	Couple du moteur thermique correspondant à sa consommation spécifique minimale	Nm
Ct_ref	Consigne de couple du moteur thermique (Positif pour la traction. négatif pour le frein moteur)	Nm
Ct_ref_int	Estimation intermédiaire de la valeur de Ct_ref	Nm
Ct_ref1	Estimation intermédiaire de la valeur de Ct_ref	Nm
Cth_freinage_max	Couple de frein moteur maximum admissible par le moteur thermique (négatif)	Nm
Cth_traction_max	Couple de traction maximum admissible par le moteur thermique (positif)	Nm
Ctmax	Couple électrique maximum compte tenu de mode_selectionne (positif)	Nm
Ctmin	Couple électrique minimum compte tenu de mode_selectionne (négatif)	Nm
D_inf	Valeur intermédiaire dans le calcul de Ct_ref	Nm
D_sup	Valeur intermédiaire dans le calcul de Ct_ref	Nm
Demande_électrique	Demande de démarrage du moteur électrique	Booléen
Demande_thermique	Demande de démarrage du moteur thermique	Booléen
Hyst_mode_batterie	Grandeur intermédiaire pour la détermination de th_récupération	

	(Electrique. Hybride)	
Hyst_mode_couple	Grandeur intermédiaire pour la détermination de th_roulage (Electrique. Hybride)	-
jauge_batterie	Etat de charge de la batterie de traction	%
Kickdown demandé	Demande de complément d'accélération électrique (mode Régénération)	Booléen
mode_selectionne	mode de fonctionnement sélectionné par le conducteur (Electrique. Hybride ou Régénération)	-
N	Vitesse de rotation du moteur électrique	rad/s
PbatMaxD	Puissance maximale de décharge de la batterie de traction (positive)	W
PbatmaxR	Puissance maximale de recharge de la batterie de traction (négative)	W
Re_inf	Valeur intermédiaire dans le calcul de Ct_ref (Cf. schéma ci-dessous)	Nm
Re_sup	Valeur intermédiaire dans le calcul de Ct_ref (Cf. schéma ci-dessous)	Nm
Rt_inf	Valeur intermédiaire dans le calcul de Ct_ref (Cf. schéma ci-dessous)	Nm
Rt_sup	Valeur intermédiaire dans le calcul de Ct_ref (Cf. schéma ci-dessous)	Nm
seuil_jauge_bas	Seuil bas de jauge batterie pour la détermination de th_récupération	%
seuil_jauge_haut	Seuil Faut de jauge batterie pour la détermination de th_récupération	%
th_récupération	Détermine si le moteur thermique contribue à recharger la batterie	Booléen
th_régénération	Détermine si le moteur thermique contribue à recharger fortement la batterie	Booléen
th_roulage	Détermine si le moteur thermique contribue à assurer le roulage	Booléen

Sur la figure 3A, on a illustré les deux tâches principales qui sont exécutées en parallèle l'une par rapport à l'autre, à des fréquences différentes. Bien entendu, les fréquences de 1 hertz et de 25 hertz données ici pour d'une part la tâche 1100 de décision de mise en route et d'arrêt du moteur thermique, et d'autre part la tâche 1200 détermination des consignes de couple des moteurs 10,12 sont des exemples non limitatifs qui permettent d'illustrer le choix selon lequel la seconde de ces fréquences est largement supérieure à la première.

Chacune des tâches 1100 et 1200 illustrées sur ces figures est décomposée en des tâches de niveau inférieur qui seront explicitées en référence aux figures 3B à 3K.

L'étape 1100 de décision de démarrage ou d'arrêt du moteur thermique est explicitée sur la figure 3B. Tout d'abord, aux étapes 1101 et 1102, il est calculé deux valeurs filtrées du couple Cdemandé demandé par le conducteur. Les filtres utilisés sont par exemple des filtres du premier ordre, de type passe-bas. La première valeur Cdemandé_filtre1 correspond à une moyenne de Cdemandé sur un intervalle très court précédant l'instant du calcul et reste représentative de la valeur instantanée Cdemandé. Au contraire, la valeur Cdemandé_filtre2 correspond à une valeur moyenne écrêtée de Cdemandé et elle est donc représentative d'une tendance à moyen terme de la demande de couple formulée par le conducteur.

Une fois ces deux valeurs calculées, sont exécutées trois tâches de niveau inférieur au cours desquelles sont déterminées des variables booléennes intermédiaires : th_roulage (tâche 1110), th_récupération (tâche 1120), th_régénération, demande_électrique et demande_thermique (tâche 1130).

Ces tâches de niveau inférieur seront explicitées par la suite.

Une fois ces valeurs déterminées, il est effectué à l'étape 1103 un test pour vérifier si le moteur thermique 10 est disponible, c'est-à-dire s'il est en état de délivrer un couple moteur. Dans l'affirmative, les variables booléennes qui viennent d'être calculées sont conservées telles que, sinon, comme on peut le voir à l'étape 1104, les valeurs booléennes th_roulage, th_régénération et th_récupération sont forcées à zéro.

La tâche 1110 de détermination de la valeur de la variable booléenne th_roulage est décrite maintenant en référence à la figure 3C. A l'étape 1111, il est tout d'abord calculé deux niveaux de seuil Cbas et Chaut auxquels vont être comparées les valeurs filtrées du couple demandé. Ces valeurs de seuil sont notamment déterminées en fonction de l'état de charge jauge_batterie de la batterie 16.

A l'étape 1112, on vérifie tout d'abord si la valeur filtrée Cdemandé_filtre1, représentative du couple instantané demandé par le conducteur, est supérieure au niveau de seuil supérieur Chaut. Dans l'affirmative, une variable booléenne intermédiaire hyst_mode_couple est forcée à la valeur « hybride » à l'étape 1113. Dans la négative, à l'étape 1114, on vérifie si les deux valeurs filtrées du couple demandé Cdemandé_filtre1 et Cdemandé_filtre2 sont inférieures simultanément au niveau inférieur de couple Cbas. Dans l'affirmative, la valeur booléenne hyst_mode_couple est forcée à l'étape 1115 à la valeur « électrique ». Dans la négative, la variable booléenne hyst_mode_couple n'est pas modifiée.

A l'étape 1116, on vérifie alors si la variable booléenne hyst_mode_couple est égale à la valeur « hybride ». Dans l'affirmative, la valeur booléenne th_roulage est forcée à 1 à l'étape 1118. Dans la négative, la valeur booléenne th_roulage est forcée à zéro à l'étape 1117.

La tâche 1120 de détermination de la valeur de la variable booléenne th_récupération sera maintenant décrite en référence à la figure 3D. A l'étape 1121, il est tout d'abord vérifié si l'état de charge de la batterie 16, représentée par la variable jauge_batterie, est inférieur à un niveau de seuil inférieur seuil_jauge_bas. Dans l'affirmative, une variable booléenne hyst_mode_batterie est forcée à la valeur « hybride » à l'étape 1122. Dans la négative, on vérifie à l'étape 1123 si la valeur jauge_batterie est supérieure à un niveau de seuil supérieur seuil_jauge_haut. Dans l'affirmative, la variable booléenne hyst_mode_batterie est forcée à la valeur « électrique » à l'étape 1124. Dans la négative, la variable hyst_mode_batterie conserve la même valeur qu'au cours de l'exécution précédente de la tâche.

A l'étape 1125, il est vérifié si la variable hyst_mode_batterie est égale à la valeur « hybride ». Dans l'affirmative, la valeur th_récupération est forcée à la valeur 1 à l'étape 1127. Dans la négative, cette variable est forcée à la valeur nulle à l'étape 1126.

La tâche 1130 est décrite en référence à la figure 3E. Cette tâche a pour but de déterminer la valeur des variables booléennes th_régénération, demande_électrique et demande_thermique.

Selon un aspect de l'invention, la stratégie de gestion de l'ensemble motopropulseur du véhicule hybride qui est ici proposée permet au conducteur de sélectionner un parmi trois modes de fonctionnement de l'ensemble motopropulseur.

Dans un mode électrique, le conducteur interdit l'utilisation du moteur thermique. Les variables booléennes hyst_mode_couple et hyst_mode_batterie sont forcées à la variable « électrique », la variable demande_électrique est forcée à la valeur « vrai », la variable demande_thermique est forcée à la valeur « faux » et la variable th_régénération est forcée à la valeur « 0 ».

Le conducteur peut aussi sélectionner un mode de fonctionnement en régénération de l'ensemble motopropulseur. Ce mode de fonctionnement impose à l'ensemble motopropulseur la mise en route du moteur thermique pour assurer, en plus de l'entraînement du véhicule, la recharge de la batterie 16. Les variables booléennes hyst_mode_couple et hyst_mode_batterie sont dans ce cas forcées à la valeur « hybride ». Les variables booléennes demande_électrique et demande_thermique sont forcées à la valeur « vrai » tandis que la variable th_régénération est forcée à la valeur « 1 ».

Le conducteur peut aussi sélectionner un mode de fonctionnement hybride de l'ensemble motopropulseur. Dans ce mode de fonctionnement, le moteur thermique 10 ne sera utilisé qu'en cas de besoin, ainsi que cela sera vu par la suite.

Dans ce mode, la variable demande_électrique est forcée à la valeur « vrai ». La variable demande_thermique est forcée à la valeur « vrai » si l'une ou l'autre des variables hyst_mode_batterie et hyst_mode_couple sont égales à la valeur « hybride ». Sinon, la variable demande_thermique est forcée à la valeur « faux ». La variable th_régénération est forcée à la valeur « 0 ».

Il va maintenant être décrit, en référence aux figures 3F à 3K, la deuxième tâche principale 1200 de cette première stratégie de gestion d'un véhicule hybride, cette deuxième tâche étant exécutée à une fréquence suffisamment rapide pour pouvoir satisfaire la demande du conducteur.

Cette deuxième tâche 1200, qui consiste en la détermination des couples de consigne Ce_ref et Ct_ref du moteur électrique et du moteur thermique, comporte elle-même deux tâches de niveau inférieur 1210 et 1220 qui seront explicitées respectivement aux figures 3G à 3H et 3I à 3K.

Comme on peut le voir à la figure 3G, la tâche 1210 a pour but la détermination de couples moteur limite pour le moteur électrique et le moteur thermique. A l'étape 1211, il est tout d'abord vérifié si le moteur thermique est disponible. Dans l'affirmative, des variables de couple limite Ctmax et Ctmin du moteur thermique se voient attribuer respectivement les valeurs Cth_traction_max et Cth_freinage_max qui sont liées notamment au régime et à la température du moteur utilisé. Dans la négative, les valeurs de Ctmax et Ctmin sont forcées à zéro à l'étape 1213.

A l'étape 1214, il est ensuite vérifié si le moteur électrique est disponible. Dans la négative, les variables Cemax et Cemin sont forcées à zéro à l'étape 1217.

Dans l'affirmative, la variable Cemin se voit attribuée à l'étape 1215 la plus grande de deux valeurs parmi :

- une valeur Cel_freinage_max, qui dépend notamment de la tension d'alimentation et de la température du moteur ;

- PbatmaxR X $\frac{1}{N}$.

La valeur du couple maximum du moteur électrique est déterminée à la tâche 1216 qui est décomposée sur la figure 3H. En effet, il est tout d'abord testé à l'étape 1216a si la variable th_régénération est égale à 1, c'est-à-dire si le conducteur a sélectionné le mode de fonctionnement en régénération de l'ensemble motopropulseur. Dans l'affirmative, on peut voir que la valeur de Cemax est forcée à zéro à l'étape 1216c, sauf si le conducteur, comme cela est vérifié à l'étape 1216b, effectue une manoeuvre de kickdown par laquelle il augmente de manière importante et rapide le couple demandé. Cette manoeuvre correspond généralement à un enfoncement rapide de la pédale d'accélérateur.

Dans ce cas, ou en cas de réponse négative au test de l'étape 1216a, la valeur Cemax est fixée à l'étape 1216d à la plus petite des valeurs :

- PbatmaxD x $\frac{1}{N}$
- Cel_traction_max.

La tâche 1220 de calcul des consignes de couple Ce_ref et Ct_ref illustrée à la figure 3I comporte deux sous-tâches 1221 et 1222 qui seront décrites respectivement en regard des figures 3J et 3K. La sous-tâche 1221 consiste en le calcul d'une valeur intermédiaire Ct_ref_int. Pour cela, il est d'abord déterminé, à l'étape 1221a, une valeur Ct_ref1 qui est égale à la plus grande de trois valeurs :

- th_roulage x Cdemandé
- th_régénération x Ct_maximum
- th_récupération x Ct_optimal.

A l'étape 1221c, cette variable Ct_ref1 est filtrée par un filtre du premier ordre de type passe-bas pour donner la variable intermédiaire Ct_ref_int.

L'étape 1222 d'ajustement de Ce_ref et de Ct_ref sera maintenant décrite en regard de la figure 3K. A l'étape 1222a, on fixe tout d'abord la valeur de Ct_ref à la valeur Ct_ref_int déterminée plus haut. Puis, à l'étape 1222b, il est vérifié si cette valeur est supérieure à la valeur Ctmax. Dans l'affirmative, à l'étape 1222c, Ct_ref est forcée à la valeur Ctmax et Rt_sup est forcée à la valeur nulle. Dans la négative, à l'étape 1222d, la valeur de Rt_sup est fixée à la différence de Ctmax-Ct_ref.

Dans les deux cas de réponse à l'étape 1222b, il est ensuite vérifié à l'étape 1222e si la valeur de Ct_ref est inférieure à la valeur de Ctmin. Dans l'affirmative, à l'étape 1222f, Ct_ref est forcée à la valeur Ctmin et Rt_inf est forcée à zéro. Dans la négative, Rt_inf est fixée égale à la différence entre Ct_ref et Ctmin à l'étape 1222g.

Dans les deux cas de réponse à l'étape 1222e, Ct_ref est alors forcée à la valeur Cdem-Ct_ref, Re_sup est forcée à la valeur Cemax-Ce_ref et la variable Re_inf est forcée à la valeur Ce_ref-Cemin à l'étape 1222h.

Ensuite à l'étape 1222i, il est vérifié si la valeur de Re_sup est négative. Dans la négative, il est procédé directement au passage 1222o. Dans l'affirmative, à l'étape 1222j, la variable D_sup est fixée à la valeur Rt_sup+Re_sup, la variable Ce_ref est fixée à la valeur Cemax, la valeur Re_sup est fixée à zéro et la variable Re_inf est fixée à la valeur de la différence entre Cemax et Cemin. Alors, à l'étape 1222k, on vérifie si la valeur D_sup est négative. Dans l'affirmative, à l'étape 1222l, la variable Ct_ref est fixée à la valeur Ct_max et la variable Rt_sup est fixée à zéro ; sinon, à l'étape 1222m, la variable Ct_ref est fixée à la valeur Ctmax-D_sup et la variable Rt_sup est fixée à la valeur D_sup.

Dans les deux cas de réponse à l'étape 1222k, ainsi que dans le cas d'une réponse négative au test de l'étape 1222i, il est alors vérifié à l'étape 1222o si la variable Re_inf est négative. Dans l'affirmative, à l'étape 1222p, la variable D_inf est fixée à la valeur Rt_inf+Re_inf, la variable Ce_ref est fixée égale à la valeur Cemin, la variable Re_sup est fixée égale à la différence de Cemax moins Cemin et la variable Re_inf est fixée à la valeur nulle.

Alors, à l'étape 1222q, il est vérifié si la variable D_inf est négative. Dans l'affirmative, à l'étape 1222s, la variable Ct_ref est fixée égale à la valeur Ctmin et la variable Rt_inf est fixée à la valeur nulle. Dans la négative, la variable Ct_ref est fixée égale à la valeur Ctmin+D_inf et la variable Rt_inf est fixée égale à la valeur D_inf.

Dans la négative, il est procédé directement à la fin de la tâche.

Comme on peut le voir de la description détaillée de cette première stratégie de gestion du véhicule hybride, lorsque le conducteur a sélectionné le mode de fonctionnement hybride pour l'ensemble motopropulseur, le démarrage du moteur thermique est demandé, lors de la tâche 1130, si l'une des variables hyst_mode_batterie et hyst_mode_couple est égale à la valeur « hybride ». Si ni l'une, ni l'autre ne sont à la valeur hybride, le moteur thermique est arrêté.

Ainsi, on peut déduire de l'étape 1213 que le moteur thermique peut démarrer si le conducteur sollicite un couple demandé à la roue suffisamment élevé pour que la variable Cdemandé_filtre1 soit supérieure au niveau du seuil haut Chaut. De même, on peut déduire des étapes 1122 et 1121 que le moteur thermique est démarré lorsque le niveau de charge de la batterie devient inférieur à un niveau de seuil inférieur. Toutefois, avec cette première stratégie, l'arrêt du moteur thermique n'est provoqué que lorsqu'à la fois les conditions de l'étape 1114 et de l'étape 1123 sont vérifiées, c'est-à-dire lorsque la batterie atteint un état de charge supérieur à un niveau de seuil supérieur et lorsque, à la fois, les valeurs filtrées instantanées et moyennes du couple demandé par le conducteur sont inférieures à un niveau de seuil bas.

Ainsi, selon cette stratégie, on voit que la décision de démarrage du moteur thermique dépend notamment du niveau de charge de la batterie, du couple instantané demandé par le conducteur, et du couple moyen demandé par le conducteur.

On peut également constater que, lorsque l'ensemble motopropulseur fonctionne en mode hybride, la valeur du couple Ct_ref qui sera demandé au moteur thermique dépend des variables th_roulage et th_récupération déterminées par les tâches 1110 et 1120. Ainsi, lorsque le niveau de charge de la batterie est précédemment devenu inférieur à un niveau de seuil bas et qu'il n'a pas encore dépassé un niveau de seuil haut, il ressort de la tâche 1120 que la valeur de th_récupération est égale à 1 de sorte que la valeur intermédiaire Ct_ref1 calculée à l'étape 1221b ne peut être inférieure au couple Ct_optimal que fournit le moteur lorsqu'il est commandé dans des conditions de rendement optimales. La valeur Ct_ref du couple de consigne imposé au moteur thermique ne peut donc pas descendre en dessous d'un niveau correspondant à ce couple optimal.

Au contraire, toujours lorsque le conducteur a sélectionné le mode de fonctionnement hybride du groupe motopropulseur, il ressort de la tâche 1110 que, lorsque la condition de l'étape 1112 a été remplie et tant que celle de l'étape 1114 ne l'a pas été, la valeur de la variable th_roulage est égale à 1 si bien que, dans ces conditions, la valeur de

Ct_ref1 calculée à l'étape 1221b ne peut être inférieure au couple demandé par le conducteur.

Par ailleurs, il ressort de la tâche 1222 que si la valeur filtrée Ct_ref_int du couple demandé par le conducteur dépasse le seuil Ctmax du couple susceptible d'être fourni par le moteur thermique, le moteur électrique est sollicité à l'étape 1222h pour fournir le couple manquant, ceci dans la limite des possibilités du moteur électrique et de la batterie.

Il sera maintenant décrit plus particulièrement en référence aux figures 4A à 4H une deuxième stratégie de gestion d'un véhicule hybride selon l'invention destiné plus particulièrement à être appliqué dans le cadre d'un véhicule hybride de type série. Cette deuxième stratégie fait appel à une série de variables qui sont regroupées et explicitées dans le tableau ci-dessous.

Notation	Signification	Unités
Cdemandé ou Cdem	couple demandé par le conducteur (positif pour l'accélération, négatif pour la décélération)	Nm
Ce_ref	Consigne de couple du moteur électrique (Positif pour la traction. négatif pour le freinage récupératif)	Nm
Ecart_C	Ecart entre Cref et Cdemandé	Nm
Ecart_prestation	Valeur filtrée de Ecart_C	Nm
Ecart_soc	Ecart entre soc et soc_ref	%
GE_demandé	Demande de démarrage ou d'arrêt du moteur thermique pour entraîner la génératrice électrique	Booléen
Ibat	Courant débité par la batterie (décharge : positif. charge : négatif)	A
Ige	Courant débité par la génératrice électrique (positif)	A
Mode_sélectionné	Mode de fonctionnement sélectionné par le conducteur (Électrique. Hybride ou Régénération)	-
N	Vitesse de rotation du moteur électrique	rad/s
Pbat_demandé	Puissance demandée à la batterie de traction (décharge : positif, charge : négatif)	W
Pbat_possible	Part de Pbat_demandé que peut fournir la batterie	W
PbatmaxD	Puissance maximale de décharge de la batterie de traction (positive)	W
PbatnaxR	Puissance maximale de recharge de la batterie de traction (négative)	W
Pel	Puissance absorbée par le moteur électrique (traction: positif. freinage récupératif : négatif)	W
Pel_demandé	Puissance électrique nécessaire pour fournir Cdemandé	W
Pel_filtreA	Valeur filtrée à temps de réponse rapide de Pel	W
Pel_filtreB	Valeur filtrée à temps de réponse lent de Pel	W
Pel_possible	Part de Pel_demandé que le système peut fournir	W
Pge_demA	Estimation intermédiaire de la valeur de Pge_ref	W
Pge_demB	Valeur de la puissance demandée à la génératrice électrique déterminant Arrêt GE demandé et Démarrage GE demandé	W
Pge_max	Puissance maximale que peut fournir la génératrice électrique	W
Pge_mini	Puissance minimale que peut fournir la génératrice électrique	W
Pge_ref	Consigne de puissance de la génératrice électrique	W

Pmec	Puissance mécanique fournie par le moteur électrique	W
Pmec_demandé	Puissance mécanique à fournir correspondant à Cdemandé	W
Pmini	Seuil de valeur absolue de la puissance en deçà duquel R n'est pas calculé	W
Pmoteur_max	Puissance maximale que peut absorber ou restituer le moteur électrique	W
R	Rendement du moteur électrique utilisé en génératrice	-
R_filtre	Valeur filtrée de R	-
soc	Etat de charge de la batterie de traction *(state of charge)*	%
soc_ref	Etat de charge de référence de la batterie de traction	%
U	Tension de la batterie de traction	%

Comme on peut le voir sur la figure 4A, l'unité centrale de gestion de l'ensemble motopropulseur est chargée de l'exécution de trois tâches principales. La première 2100 de ces tâches consiste ici dans la détermination de la consigne de couple du moteur électrique. Elle est exécutée par exemple toutes les quarante millisecondes, c'est-à-dire à une fréquence de 25 hertz. En parallèle, est exécutée la deuxième tâche 2200 qui consiste en la décision de démarrage ou d'arrêt du moteur thermique. Sa période est d'une seconde et sa fréquence de 1 hertz.

Il est par ailleurs prévu une troisième tâche principale 2300, elle aussi exécutée en parallèle, et au cours de laquelle est déterminée la consigne de puissance de la génératrice électrique Pge_ref. Sa période d'exécution est par exemple de 500 millisecondes, correspondant à une fréquence de 2 hertz pour tenir compte de l'inertie de l'ensemble formée par le moteur thermique et la génératrice.

La première de ces tâches principales est décrite en référence à la figure 4B. Comme on peut le voir sur cette figure, la tâche 2100 de détermination de la consigne de couple du moteur électrique Ce_ref commence par l'exécution de la sous-tâche 2110 de calcul de la puissance électrique nécessaire Pel_demandé.

Cette sous-tâche est décrite en référence à la figure 4C. Tout d'abord, à l'étape 2111, il est déterminé la valeur Pel de la puissance absorbée par le moteur électrique. Cette puissance est positive lorsque le moteur assure l'entraînement du véhicule et elle est négative lorsque, au cours d'un ralentissement du véhicule, le moteur électrique est utilisé en tant que génératrice pour recharger la batterie 16. Cette valeur Pel est égale à la tension du réseau d'alimentation électrique multiplié par la somme des courants fournis par la batterie d'une part et par la génératrice électrique d'autre part.

A l'étape 2112, la puissance mécanique fournie par le moteur électrique Pmec est définie comme étant le produit du couple de consigne Ce_ref par la vitesse de rotation N du moteur électrique 12. A l'étape 2113, la puissance mécanique demandée Pmec_demandé est définie comme étant égale au couple Cdemandé par le conducteur multiplié par la vitesse N de rotation du moteur électrique. A l'étape 2114, il est déterminé si la valeur absolue de la puissance mécanique Pmec est supérieure à une valeur de seuil Pmini. Dans l'affirmative, on définit à l'étape 2115 un rendement du moteur électrique qui est égal à la valeur absolue du rapport de la puissance électrique Pel divisée par la puissance mécanique Pmec. Dans la négative, la valeur de ce rendement est fixée arbitrairement à 1 à l'étape 2116.

A l'étape 2117, il est déterminé une valeur filtrée R_filtre de ce rendement, par exemple à l'aide d'un filtre du premier ordre.

A l'étape 2118, la puissance électrique demandée Pel_demandé est déterminée comme étant le produit de la valeur filtrée du rendement par la puissance mécanique demandée.

L'exécution de la tâche 2100 de détermination de la consigne de couple du moteur électrique se poursuit alors à l'étape 2101 au cours de laquelle on vérifie si la valeur absolue de la puissance électrique demandée est supérieure à un niveau de seuil Pmini. Dans la négative, le couple de consigne Ce_ref est fixé égal au couple demandé par le conducteur. Dans l'affirmative, il est d'abord déterminé la puissance Pge fournie par la génératrice. Si celle-ci débite un courant Ige, cette puissance vaut U fois Ige.

A l'étape 2103, il est calculé la puissance de traction que doit fournir la batterie 16. Cette valeur Pbat_demandé est égale à la puissance électrique nécessaire pour fournir le couple demandé moins la puissance fournie par la génératrice. A l'étape 2104, on détermine la puissance susceptible d'être fournie par la batterie comme étant la valeur minimale entre les deux valeurs suivantes :

- la puissance maximale de décharge de la batterie (PbatmaxD) et
- la valeur minimale entre
  - * la puissance demandée à la batterie (Pbat_demandé) ;
  - * la puissance maximale de recharge de la batterie (PbatmaxR).

A l'étape 2105, il est alors déterminé la puissance électrique que peut fournir le système, cette valeur étant la plus petite des deux valeurs suivantes :

- la puissance maximale du moteur thermique Pmoteur_max ; et
- la somme de la puissance susceptible d'être fournie par la batterie (Pbat_possible) avec la puissance fournie par la génératrice Pge.

Alors à l'étape 2106, le couple de référence Ce_ref est déterminé comme étant le produit du couple demandé par le conducteur par le rapport de la puissance électrique que peut fournir le système divisée par la puissance électrique demandée.

La deuxième tâche principale 2200 de cette seconde stratégie de gestion d'un véhicule hybride consiste en la décision de démarrage ou d'arrêt du moteur thermique. Comme on peut le voir à la figure 4C, cette tâche 2200 commence par l'exécution de la tâche 2310 de calcul de la puissance de recharge de la batterie qui est illustrée à la figure 4G. Comme on peut le voir sur cette figure, il est donc déterminé, aux étapes 2312, 2313, 2314 un état de charge de référence Soc_ref en fonction du mode de fonctionnement sélectionné par le conducteur du véhicule. A l'étape 2315, il est déterminé une valeur d'écart entre cet état de charge de référence Soc_ref et l'état de charge réel. A l'étape 2316, la puissance batterie demandée est définie comme étant une valeur filtrée de cet écart, par exemple par un filtre du premier ordre.

Toutefois, à l'étape 2317, il est vérifié que cette valeur calculée de la puissance de recharge de la batterie n'excède pas les puissances limites de charge et de décharge de la batterie, auquel cas la puissance de recharge de la batterie est forcée à l'une de ces valeurs limites.

La tâche de décision de démarrage ou d'arrêt du moteur thermique se poursuit alors à l'étape 2201 dans laquelle est déterminée la puissance électrique Pel de la même manière que vu plus haut à l'étape 2111. Cette puissance électrique est filtrée par un filtre du premier ordre pour obtenir à l'étape 2202 la variable Pel_filtreB.

Il est ensuite procédé à un calcul de l'écart entre le couple demandé par le conducteur et le couple effectivement appliqué aux roues motrices par le moteur électrique. Ce calcul de la valeur écart_prestation fait l'objet de la tâche 2210 illustrée à la figure 4E dans laquelle on peut voir que cette valeur est obtenue par le filtrage au travers d'un filtre de premier ordre de la différence entre le couple demandé par le conducteur Cdemandé et le couple fourni par le moteur électrique Ce_ref.

La tâche de décision du démarrage ou de l'arrêt du moteur thermique se poursuit à l'étape 2203 en déterminant la valeur de la puissance demandée à la génératrice électrique Pge_demB. Cette valeur est égale à une somme pondérée des valeurs précédemment calculées Pbat_demandé, Pel_filtreB et Ecart_prestation. À l'étape 2204, il est vérifié si cette valeur Pge_demB est supérieure à une valeur de seuil Pge_mini et si, en même temps, le mode de fonctionnement sélectionné par le conducteur est différent du moteur électrique. Si cette double condition est vérifiée, alors la variable booléenne GE_demandé est forcée à la valeur « vrai » et le moteur thermique est alors démarré pour fournir du courant électrique. Au contraire, si la double condition de l'étape 2204 n'est pas remplie, la variable GE_demandé est forcée à la valeur « faux » à l'étape 2206 si bien que le moteur thermique est commandé à l'arrêt.

Lorsque le moteur thermique est démarré, il est alors possible de le commander pour qu'il entraîne la génératrice électrique de telle manière que celle-ci produise une puissance suffisante. A cet effet, il est calculé à la tâche 2300 une valeur de consigne de la puissance de la génératrice électrique Pge_ref. Cette tâche, illustrée à la figure 4F, commence par l'exécution de la tâche de niveau inférieur 2310 qui a été décrite précédemment et qui consiste en le calcul de la puissance de recharge de la batterie. Ensuite, à l'étape 2301, il est calculé la puissance électrique Pel absorbée par le moteur électrique de la même manière que cela a été vu aux étapes 2201 et 2111. Cette valeur est alors filtrée à l'étape 2302, par exemple par un filtre du premier ordre, pour donner une valeur intermédiaire Pel_filtreA. A l'étape 2303, il est déterminé la somme pondérée Pge_demA de la puissance de recharge de la batterie Pbat_demandé avec la valeur Pel_filtreA calculée à l'étape 2302. A l'étape 2304, la puissance de consigne de la génératrice électrique Pge_ref est définie comme étant la plus petite de la valeur Pge_demA, calculée à l'étape 2303, et de la puissance maximale susceptible d'être fournie par la génératrice Pge_max.

Comme on peut le voir des étapes 2203, 2204, 2205 et 2206, la décision d'un démarrage du moteur thermique dépend notamment des trois paramètres suivants :

- l'état de charge de la batterie, car la valeur Pbat_demandé est calculée notamment en fonction de l'écart entre l'état de charge réel de la batterie et un état de charge de référence (voir étapes 2315, 2316, 2317) ;
- le couple moteur demandé, car la valeur Ecart_prestation dépend bien entendu de ce couple demandé (voir étapes 2211 et 2212) ; et
- l'écart entre la prestation fournie par le système et celle demandée par le conducteur.

REVENDICATIONS

1. Véhicule automobile à motorisation hybride, du type dans lequel un ensemble motopropulseur comporte un moteur électrique (12) et un moteur thermique (10) qui sont susceptibles de contribuer à l'entraînement du véhicule, et du type dans lequel une unité centrale de gestion exécute une première tâche (1200, 2100) comportant la détermination du couple que doit fournir chaque moteur pour que l'ensemble motopropulseur fournisse au véhicule un couple moteur conforme à un couple demandé (Cdemandé) par le conducteur du véhicule, et du type dans lequel le moteur thermique (10) est susceptible d'être arrêté, le véhicule étant alors entraîné par le seul moteur électrique (12) alimenté en courant électrique par une batterie d'accumulateurs (16),

caractérisé en ce que, au moins pour certains modes de fonctionnement (hybride) de l'ensemble motopropulseur, l'unité centrale exécute une deuxième tâche (1100, 2200) au cours de laquelle est décidé l'arrêt ou le démarrage du moteur thermique, en ce que la première tâche et la deuxième tâche sont exécutées en parallèle et en ce que la fréquence d'exécution de la deuxième tâche est inférieure à celle de la première tâche.

2. Véhicule automobile selon la revendication 1, caractérisé en ce que le conducteur peut imposer à l'ensemble motopropulseur un mode de fonctionnement électrique dans lequel le moteur thermique (10) est arrêté.

3. Véhicule automobile selon l'une quelconque des revendications précédentes, caractérisé en ce que le conducteur peut imposer à l'ensemble motopropulseur un mode de fonctionnement de régénération dans lequel le moteur thermique (10) est utilisé notamment pour assurer le

rechargement de la batterie (16).

4. Véhicule automobile selon l'une quelconque des revendications précédentes, caractérisé en ce que le conducteur peut imposer à l'ensemble motopropulseur un mode de fonctionnement hybride dans lequel l'unité centrale exécute la deuxième tâche au cours de laquelle est décidé l'arrêt ou le démarrage du moteur thermique.

5. Véhicule automobile selon la revendication 4, caractérisé en ce que la décision d'arrêt ou de démarrage du moteur thermique (10) est prise notamment en fonction d'un niveau de charge (jauge_batterie, soc) de la batterie (16).

6. Véhicule automobile selon la revendication 5, caractérisé en ce que le démarrage du moteur thermique (10) est décidé ou confirmé lorsque le niveau de charge (jauge_batterie) de la batterie (16) est inférieur à un niveau de seuil bas (seuil_jauge_bas), et en ce que l'arrêt du moteur thermique (10) est susceptible d'être décidé ou d'être confirmé lorsque le niveau de charge de la batterie est supérieur à un niveau de seuil haut (seuil_jauge_bas).

7. Véhicule automobile selon l'une quelconque des revendications 4 à 6, caractérisé en ce que la décision d'arrêt ou de démarrage du moteur thermique (10) est prise notamment en fonction du couple instantané (Cdemandé_filtre1) demandé par le conducteur.

8. Véhicule automobile selon l'une quelconque des revendications 4 à 7, caractérisé en ce que la décision d'arrêt ou de démarrage du moteur thermique (10) est prise notamment en fonction du couple moyen (Cdemandé_filtre2) demandé par le conducteur pendant un intervalle de temps prédéterminé précédant de la décision.

9. Véhicule automobile selon la revendication 7 prise en combinaison avec la revendication 8, caractérisé en ce que le

démarrage du moteur thermique (10) est décidé ou confirmé lorsque le couple instantané (Cdemandé_filtre1) demandé par le conducteur est supérieur à un niveau de seuil haut (Chaut), et en ce que l'arrêt du moteur thermique (10) est susceptible d'être décidé ou d'être confirmé lorsque le couple instantané (Cdemandé_filtre1) et le couple moyen (Cdemandé_filtre2) demandés par le conducteur sont inférieurs à un niveau de seuil bas (Cbas).

10. Véhicule automobile selon la revendication 6 prise en combinaison avec la revendication 9, caractérisé en ce que l'arrêt du moteur thermique (10) est décidé ou confirmé lorsque, à la fois, le niveau de charge (jauge_batterie) de la batterie (16) est supérieur à un niveau de seuil haut (seuil_jauge_haut) et le couple instantané (Cdemandé_filtre1) et le couple moyen (Cdemandé_filtre2) demandés par le conducteur sont inférieurs à un niveau de seuil bas (Cbas).

11. Véhicule automobile selon l'une quelconque des revendications 4 à 10, caractérisé en ce que la décision d'arrêt ou de démarrage du moteur thermique (10) est prise notamment en fonction d'un écart (Ecart_prestation) entre le couple demandé (Cdemandé) par le conducteur et le couple effectivement fourni par l'ensemble motopropulseur.

12. Véhicule automobile selon l'une quelconque des revendications précédentes prise en combinaison avec l'une au moins des revendications 2 à 4, caractérisé en ce que, en fonctionnement du mode de fonctionnement sélectionné par le conducteur, il est fixé un niveau de consigne de charge (soc_ref) de la batterie (16).

13. Véhicule automobile selon l'une quelconque des revendications précédentes, caractérisé en ce que l'ensemble motopropulseur est un ensemble hybride série dans lequel les roues motrices du véhicule sont entraînées exclusivement par

le moteur électrique (12) qui est alimenté par du courant électrique provenant de la batterie (16) qui est rechargée par une génératrice (26) entraînée par le moteur thermique (10).

14. Véhicule automobile selon la revendication 13 prise en combinaison avec la revendication 12, caractérisé en ce qu'il est déterminé la puissance électrique (Pbat_demandé) à fournir à la batterie (16) en fonction d'un écart (Ecart_soc) entre les niveaux réel (soc) et de référence (soc_ref) de charge de la batterie, en tenant compte de valeurs limites de puissance de charge (PbatmaxR) et de décharge (PbatmaxD) de la batterie (16).

15. Véhicule automobile selon la revendication 14, caractérisé en ce que le démarrage du moteur thermique (10) est déterminé en fonction de la puissance électrique (Pbat_demandé) à fournir à la batterie (16), de la puissance électrique absorbée (Pel_filtreB) par le moteur électrique (12) et en fonction d'un écart (Ecart_prestation) entre la valeur du couple demandé par le conducteur et la valeur du couple fourni par le moteur électrique (12).

16. Véhicule automobile selon la revendication 14 ou 15, caractérisé en ce qu'il est déterminé un niveau de consigne (Pge_ref) de la puissance fournie par la génératrice (26) en fonction de la puissance réelle (U*Ige) fournie par la génératrice (26), de la puissance réelle (U*Ibat) fournie par la batterie (16), et de la puissance (Pbat_demandé) à fournir à la batterie (16), en tenant compte la puissance maximale (Pge_max) susceptible d'être fournie par la génératrice (26).

17. Véhicule automobile selon l'une quelconque des revendications précédentes 13 à 15, caractérisé en ce qu'il est déterminé une puissance électrique nécessaire (Pel_demandé) en fonction du couple moteur (Cdemandé) demandé par le conducteur, en tenant compte, au moins lorsque ce couple est

supérieur en valeur absolue à une valeur minimale, d'un rendement du moteur électrique (R).

18. Véhicule automobile selon la revendication 16, caractérisé en ce qu'il est déterminé une valeur de consigne (Cref) du couple fourni par le moteur électrique (12) en fonction du couple moteur demandé par le conducteur multiplié par, au moins lorsque la puissance électrique nécessaire (Pel_demandé) est supérieure en valeur absolue à une valeur de seuil (Pmini), du rapport de la puissance électrique (Pel_possible) susceptible d'être fournie au moteur électrique (12) divisée par la puissance électrique nécessaire (Pel_possible), la puissance électrique (Pel_possible) susceptible d'être fournie au moteur électrique (12) tenant compte de la puissance électrique nécessaire (Pel_demandé), de la puissance réelle (Pge) fournie par la génératrice, de la puissance (Pbat_possible) susceptible d'être fournie par la batterie (16), et de la puissance maximale (Pmoteur_max) susceptible d'être absorbée par le moteur.

19. Véhicule automobile selon l'une quelconque des revendications 1 à 12, caractérisé en ce que l'ensemble motopropulseur est un ensemble hybride en parallèle dans lequel le moteur électrique (12) et le moteur thermique (10) entraînent chacun soit au moins une même roue motrice soit des roues motrices différentes.

20. Véhicule automobile selon la revendication 19 prise en combinaison avec la revendication 3, caractérisé en ce que lorsque l'ensemble motopropulseur fonctionne en mode de régénération, le moteur électrique (10) ne délivre un couple moteur que si le conducteur provoque une hausse brutale du couple demandé (kickdown).

21. Véhicule automobile selon l'une des revendications 19 ou 20 prise en combinaison avec la revendication 3,

caractérisé en ce que lorsque l'ensemble motopropulseur fonctionne en mode de régénération, le moteur thermique (10) est commandé pour fournir un couple maximal (Ct_maximum).

22. Véhicule automobile selon l'une quelconque des revendications 19 à 21 prise en combinaison avec la revendication 4, caractérisé en ce que lorsque l'ensemble motopropulseur fonctionne en mode hybride et que le niveau de charge (jauge_batterie) de la batterie (16) est précédemment devenu inférieur à un niveau de seuil bas (seuil_jauge_bas) et n'a pas encore dépassé un niveau de seuil haut (seuil_jauge_haut), le moteur thermique (10) est commandé pour fournir un couple de consigne (Ct_ref1) au moins égal à un couple optimal (Ct_optimal) correspondant à des conditions de rendement optimales du moteur thermique.

23. Véhicule automobile selon l'une quelconque des revendications précédentes 19 à 22 prise en combinaison avec la revendication 4, caractérisé en ce que lorsque l'ensemble motopropulseur fonctionne en mode hybride et que le couple instantané (Cdemandé_filtre1) demandé par le conducteur est précédemment devenu supérieur à un niveau de seuil haut (Chaut) sans être redevenu inférieur à un niveau de seuil bas (Cbas) en même temps que le niveau moyen (Cdemandé_filtre2) est inférieur au niveau de seuil bas (Cbas), le moteur thermique (10) est commandé pour fournir un couple de consigne au moins égal à une valeur filtrée du couple demandé par le conducteur.

24 Véhicule automobile selon l'une quelconque des revendications précédentes 19 à 23, caractérisé en ce que, si une valeur filtrée (Ct_ref_int) du couple demandé par le conducteur est supérieure au couple maximal (Ct_max) du moteur thermique (10), le moteur électrique (12) est sollicité pour fournir, dans la mesure du possible, la quantité de couple manquante (Cdem - Ctref).

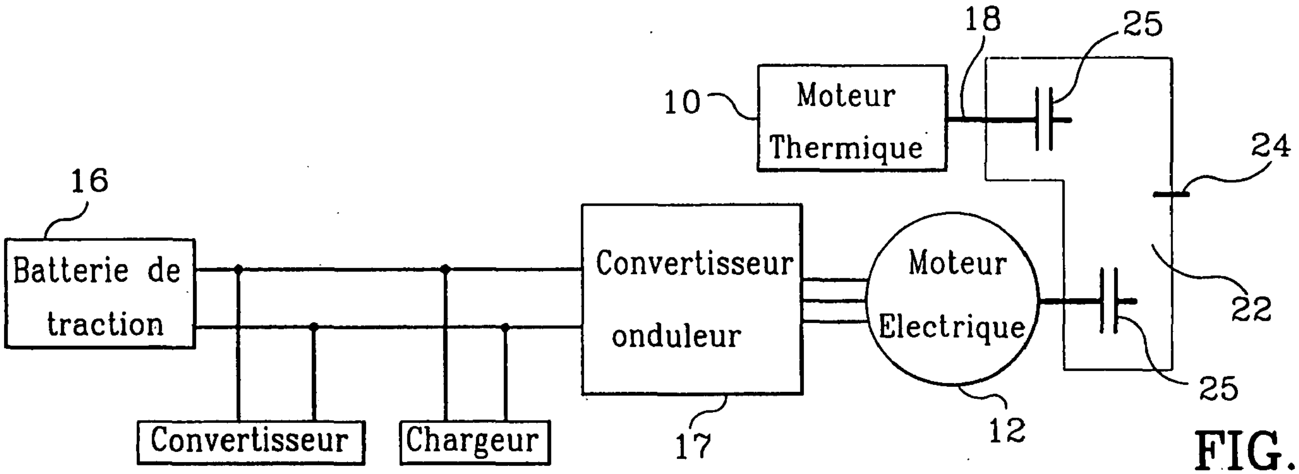

10
Moteur Thermique
18
25
24
22
25
16
Batterie de traction
Convertisseur onduleur
17
Moteur Electrique
12
Convertisseur
Chargeur

FIG.1

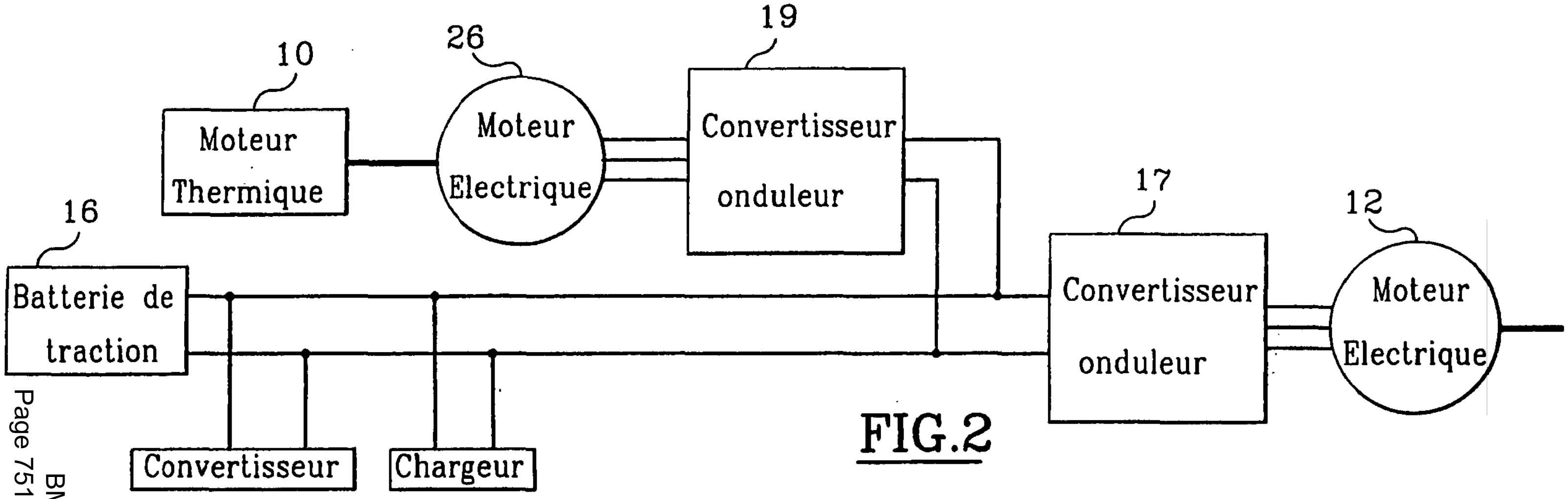

10
Moteur Thermique
26
Moteur Electrique
19
Convertisseur onduleur
17
Convertisseur onduleur
12
Moteur Electrique
16
Batterie de traction
Convertisseur
Chargeur

FIG.2

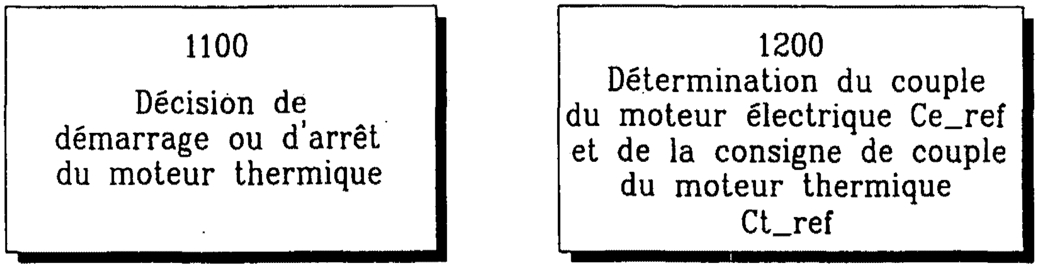

1100
Décision de démarrage ou d'arrêt du moteur thermique
1200
Détermination du couple du moteur électrique Ce_ref et de la consigne de couple du moteur thermique Ct_ref

FIG.3A

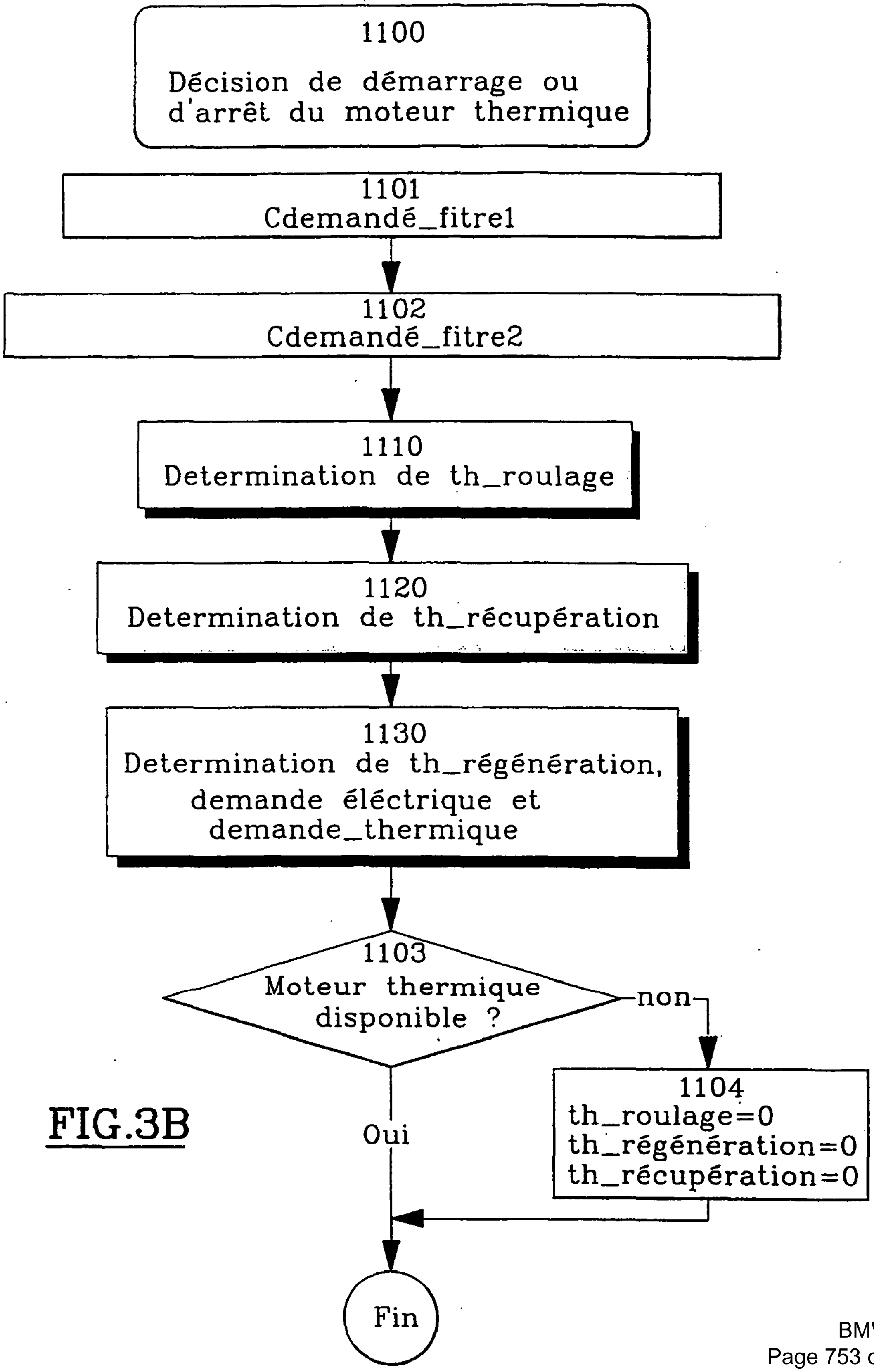

1100
Décision de démarrage ou d'arrêt du moteur thermique
1101
Cdemandé_fitre1
1102
Cdemandé_fitre2
1110
Determination de th_roulage
1120
Determination de th_récupération
1130
Determination de th_régénération, demande éléctrique et demande_thermique
1103
Moteur thermique disponible ?
non
Oui
1104
th_roulage=0
th_régénération=0
th_récupération=0
Fin

FIG.3B

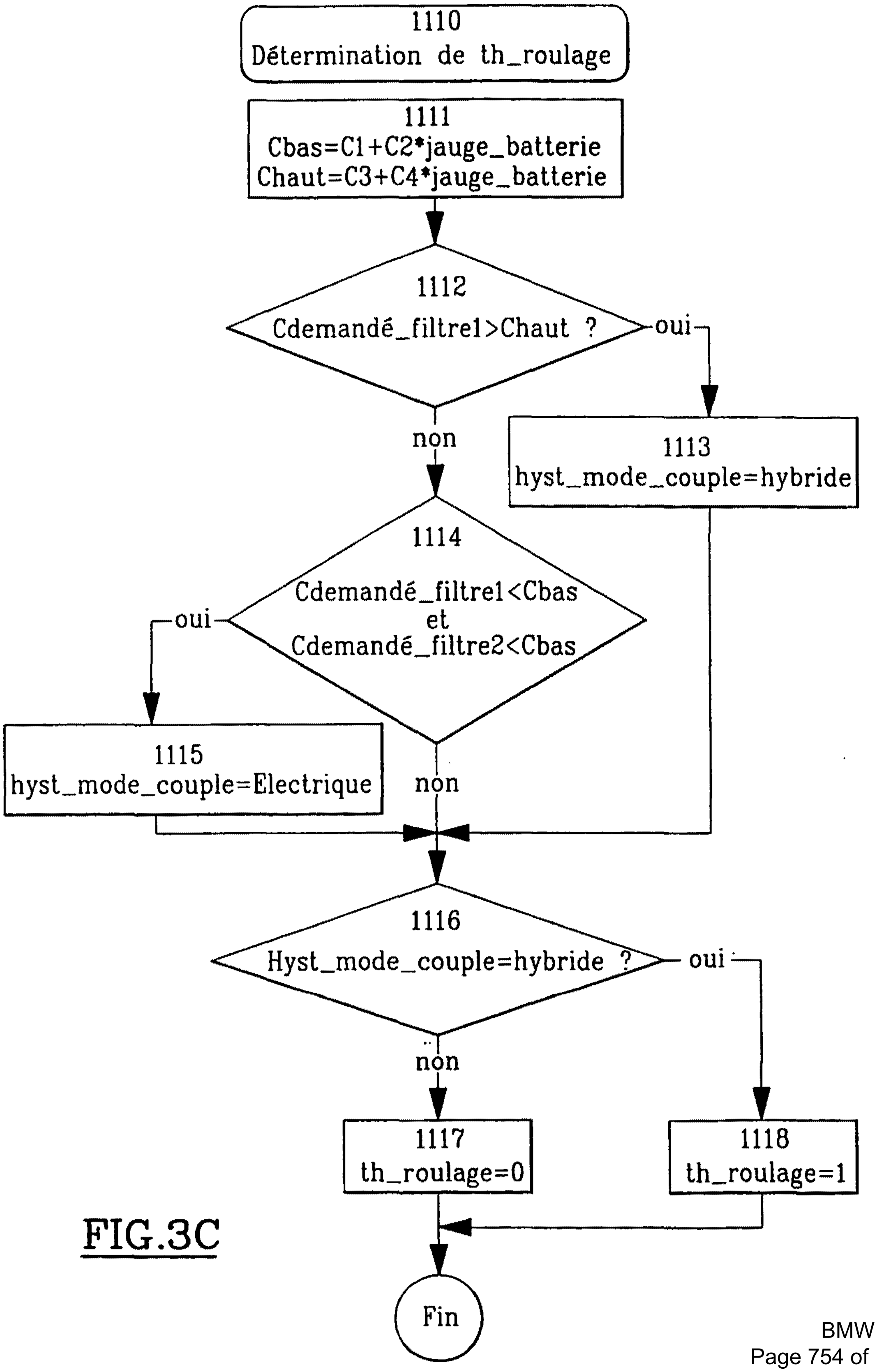

1110
Détermination de th_roulage
1111
Cbas=C1+C2*jauge_batterie
Chaut=C3+C4*jauge_batterie
1112
Cdemandé_filtre1>Chaut ?
oui
non
1113
hyst_mode_couple=hybride
1114
Cdemandé_filtre1<Cbas
et
Cdemandé_filtre2<Cbas
oui
1115
hyst_mode_couple=Electrique
non
1116
Hyst_mode_couple=hybride ?
oui
non
1117
th_roulage=0
1118
th_roulage=1
Fin

FIG.3C

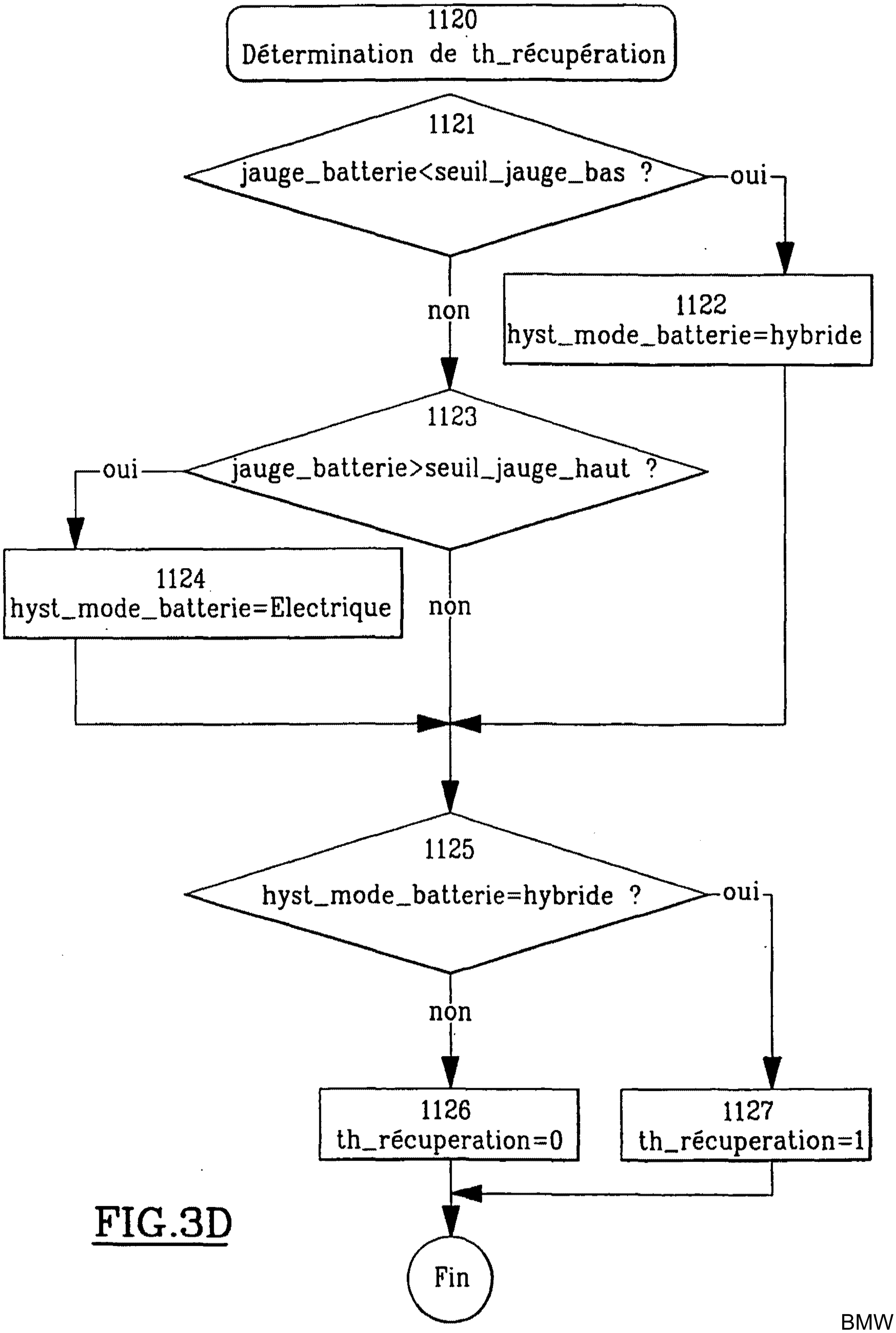
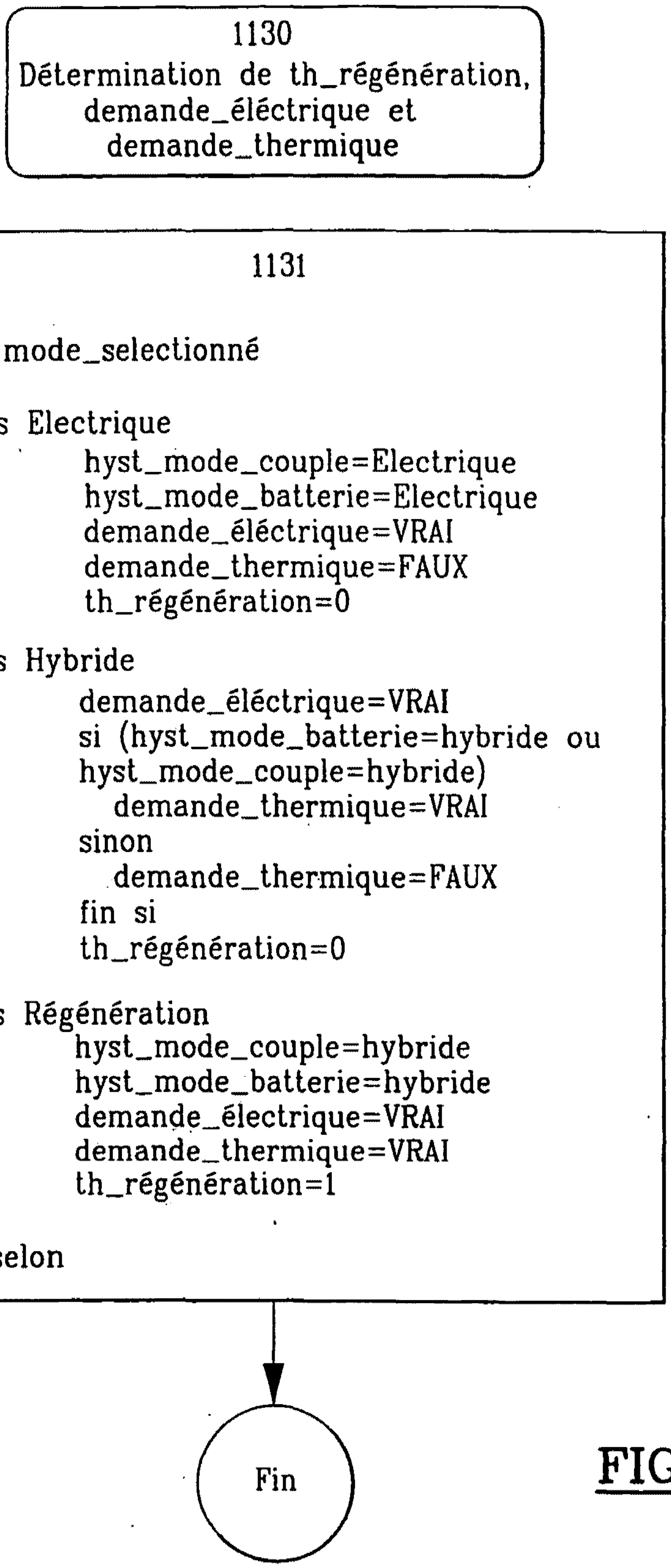

1120
Détermination de th_récupération
1121
jauge_batterie<seuil_jauge_bas ?
oui
non
1122
hyst_mode_batterie=hybride
1123
jauge_batterie>seuil_jauge_haut ?
oui
non
1124
hyst_mode_batterie=Electrique
1125
hyst_mode_batterie=hybride ?
oui
non
1126
th_récuperation=0
1127
th_récuperation=1
Fin

FIG.3D



```
selon mode_selectionné

  cas Electrique
        hyst_mode_couple=Electrique
        hyst_mode_batterie=Electrique
        demande_éléctrique=VRAI
        demande_thermique=FAUX
        th_régénération=0

  cas Hybride
        demande_éléctrique=VRAI
        si (hyst_mode_batterie=hybride ou
        hyst_mode_couple=hybride)
          demande_thermique=VRAI
        sinon
          demande_thermique=FAUX
        fin si
        th_régénération=0

  cas Régénération
        hyst_mode_couple=hybride
        hyst_mode_batterie=hybride
        demande_électrique=VRAI
        demande_thermique=VRAI
        th_régénération=1

 fin selon
```

FIG.3E

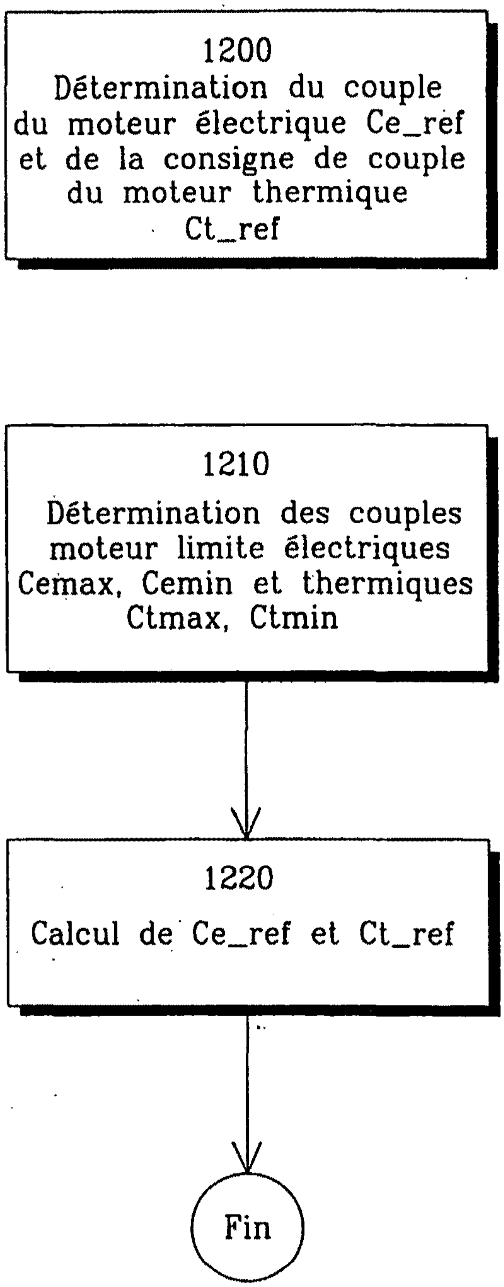

1200
Détermination du couple du moteur électrique Ce_ref et de la consigne de couple du moteur thermique Ct_ref
1210
Détermination des couples moteur limite électriques Cemax, Cemin et thermiques Ctmax, Ctmin
1220
Calcul de Ce_ref et Ct_ref
Fin

FIG.3F

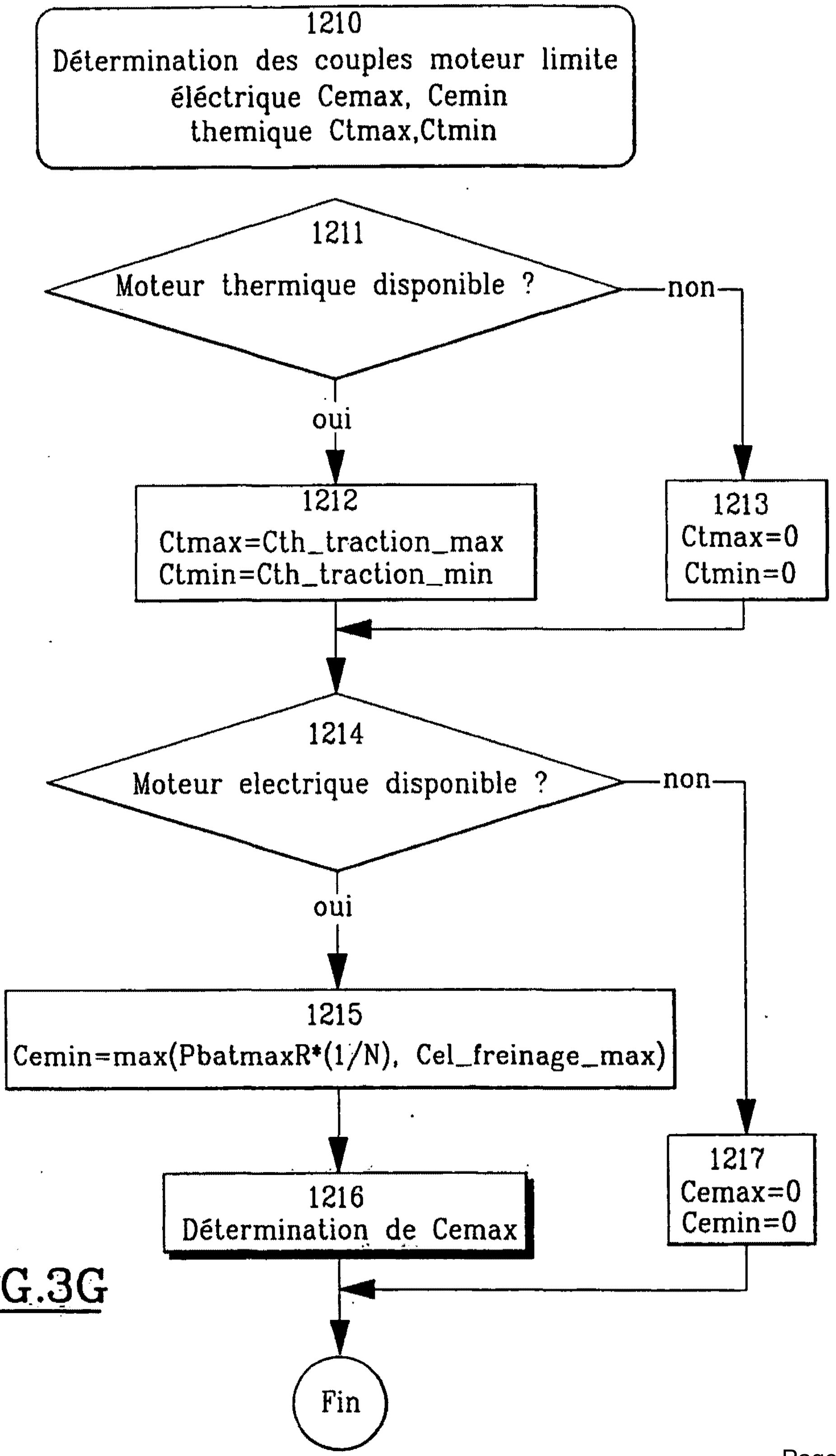

1210
Détermination des couples moteur limite éléctrique Cemax, Cemin themique Ctmax,Ctmin
1211
Moteur thermique disponible ?
non
oui
1212
Ctmax=Cth_traction_max
Ctmin=Cth_traction_min
1213
Ctmax=0
Ctmin=0
1214
Moteur electrique disponible ?
non
oui
1215
Cemin=max(PbatmaxR*(1/N), Cel_freinage_max)
1216
Détermination de Cemax
1217
Cemax=0
Cemin=0
Fin

FIG.3G

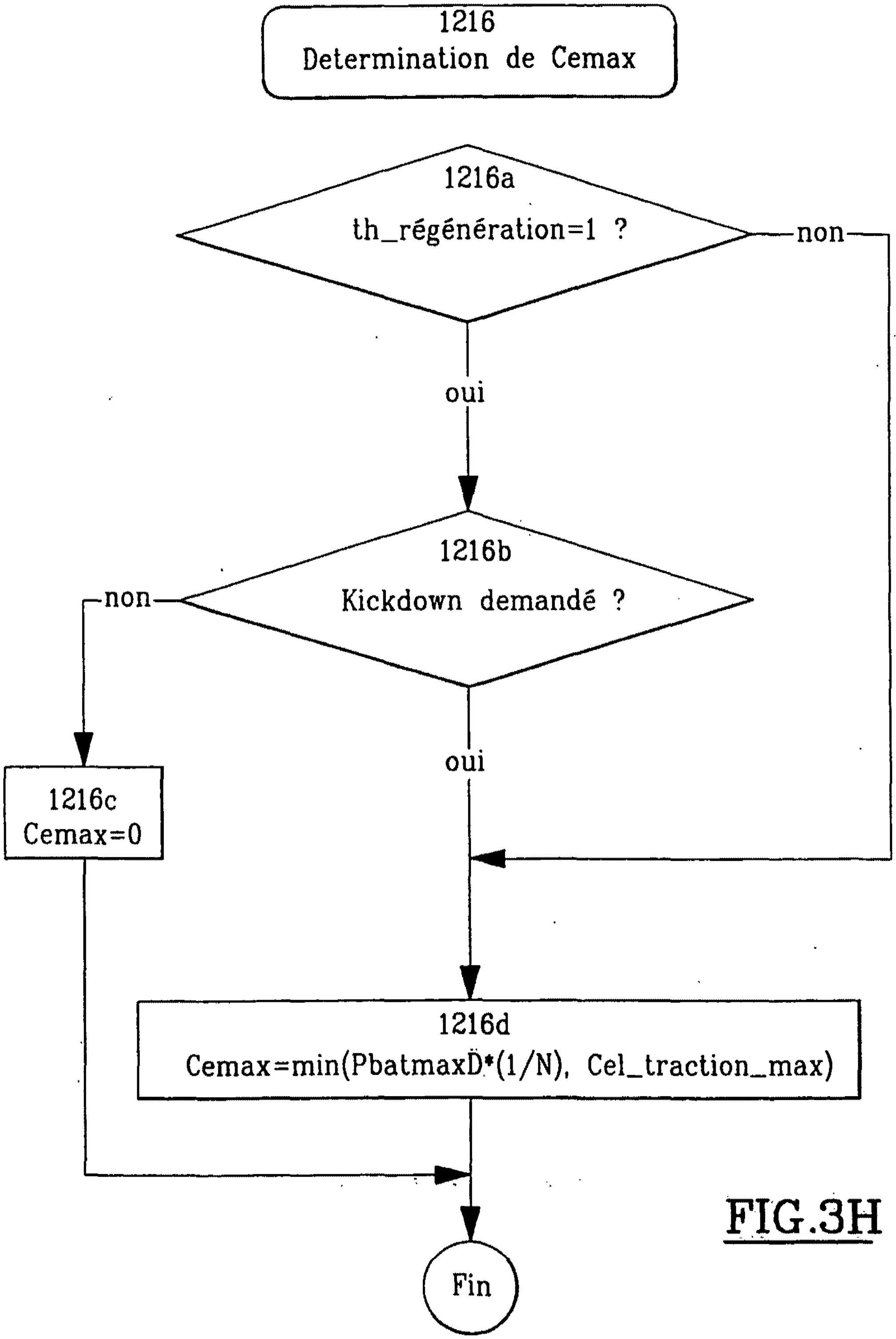

1216
Determination de Cemax
1216a
th_régénération=1 ?
non
oui
1216b
Kickdown demandé ?
non
oui
1216c
Cemax=0
1216d
Cemax=min(PbatmaxD*(1/N), Cel_traction_max)
Fin

FIG.3H

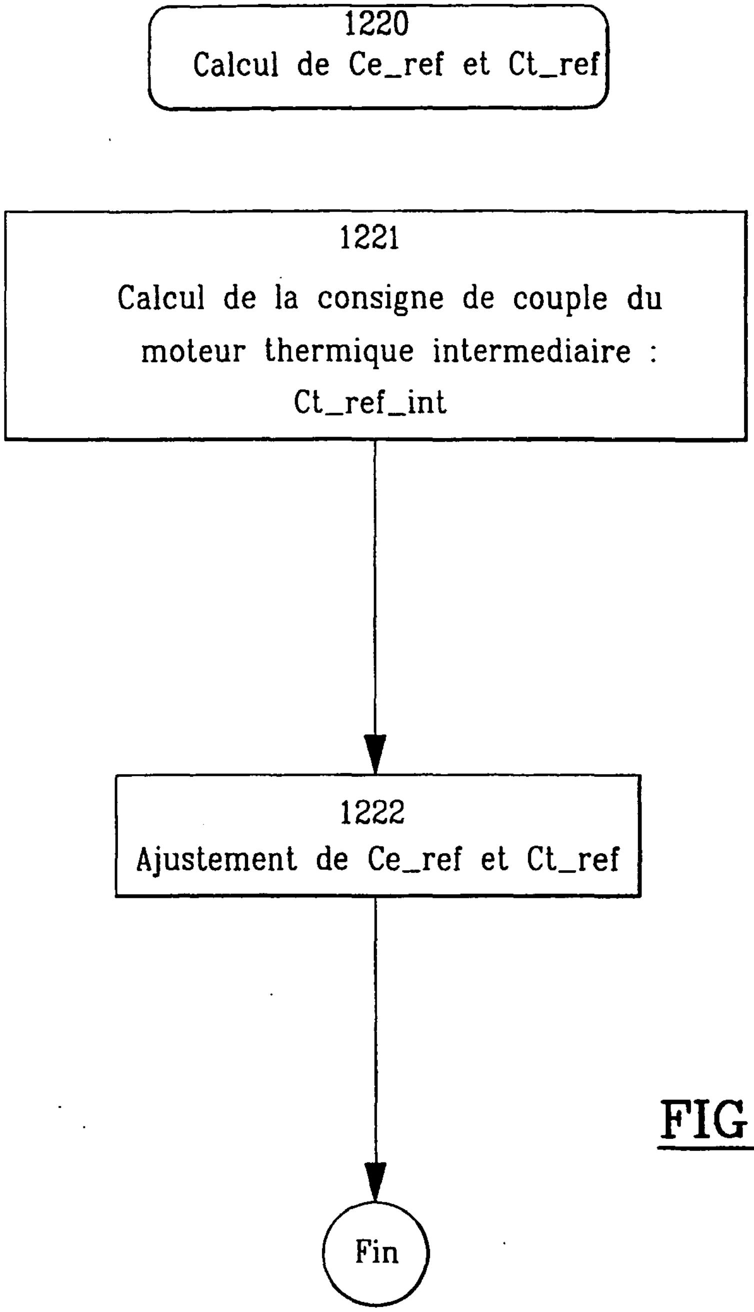

1220
Calcul de Ce_ref et Ct_ref
1221
Calcul de la consigne de couple du moteur thermique intermediaire : Ct_ref_int
1222
Ajustement de Ce_ref et Ct_ref
Fin

FIG.3I

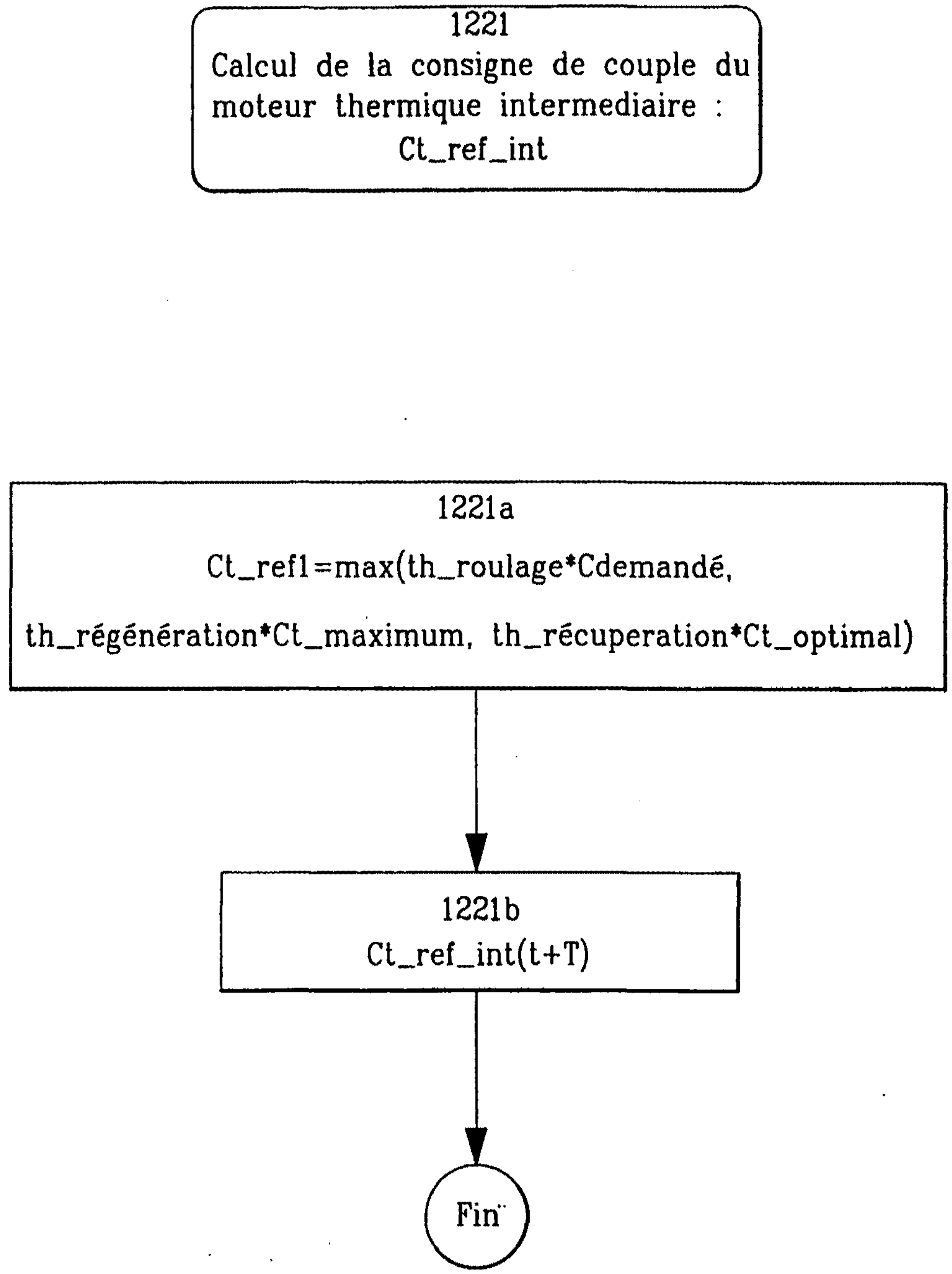

1221
Calcul de la consigne de couple du moteur thermique intermediaire : Ct_ref_int
1221a
Ct_ref1=max(th_roulage*Cdemandé,
th_régénération*Ct_maximum, th_récuperation*Ct_optimal)
1221b
Ct_ref_int(t+T)
Fin

FIG.3J

FIG.3K

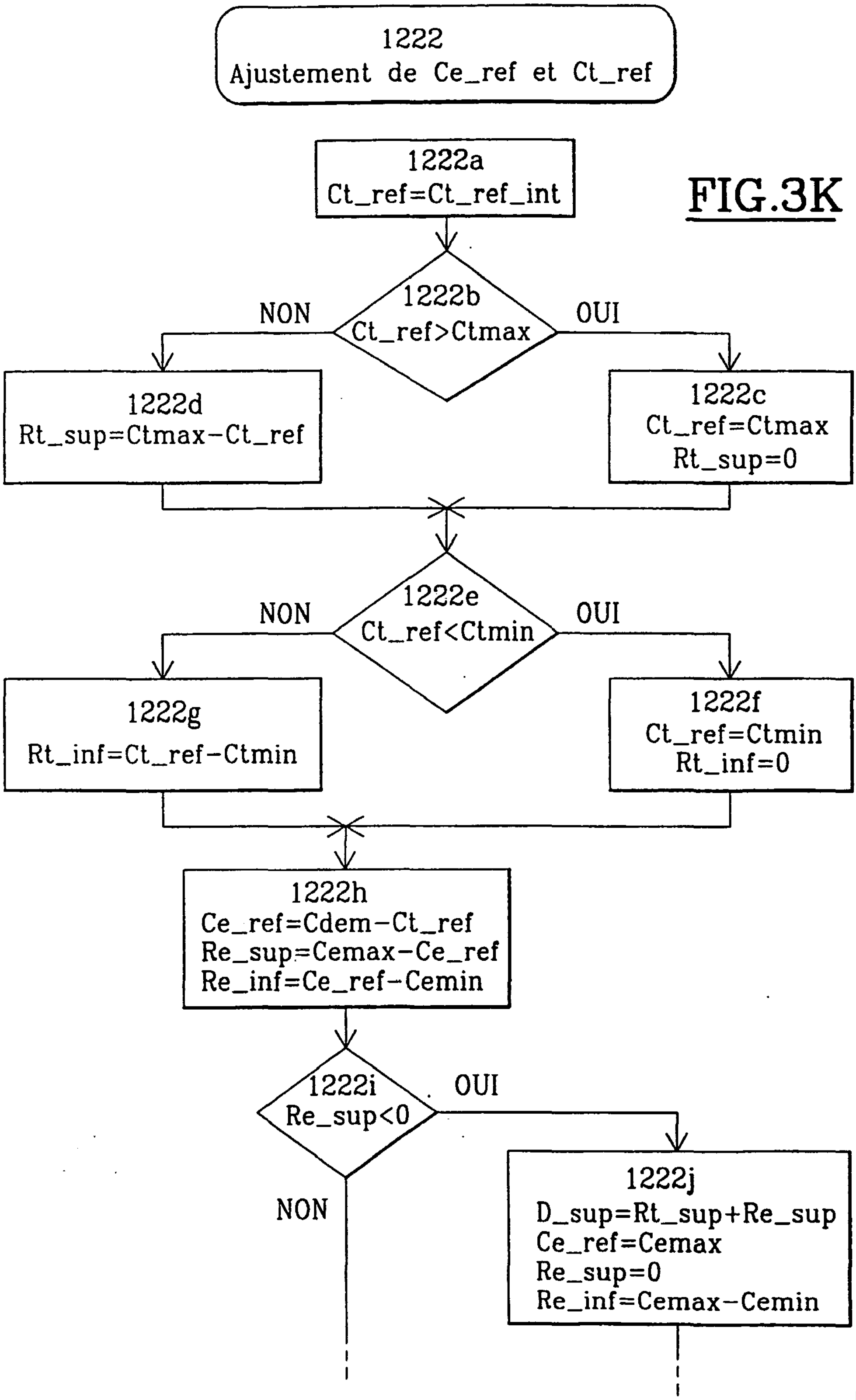
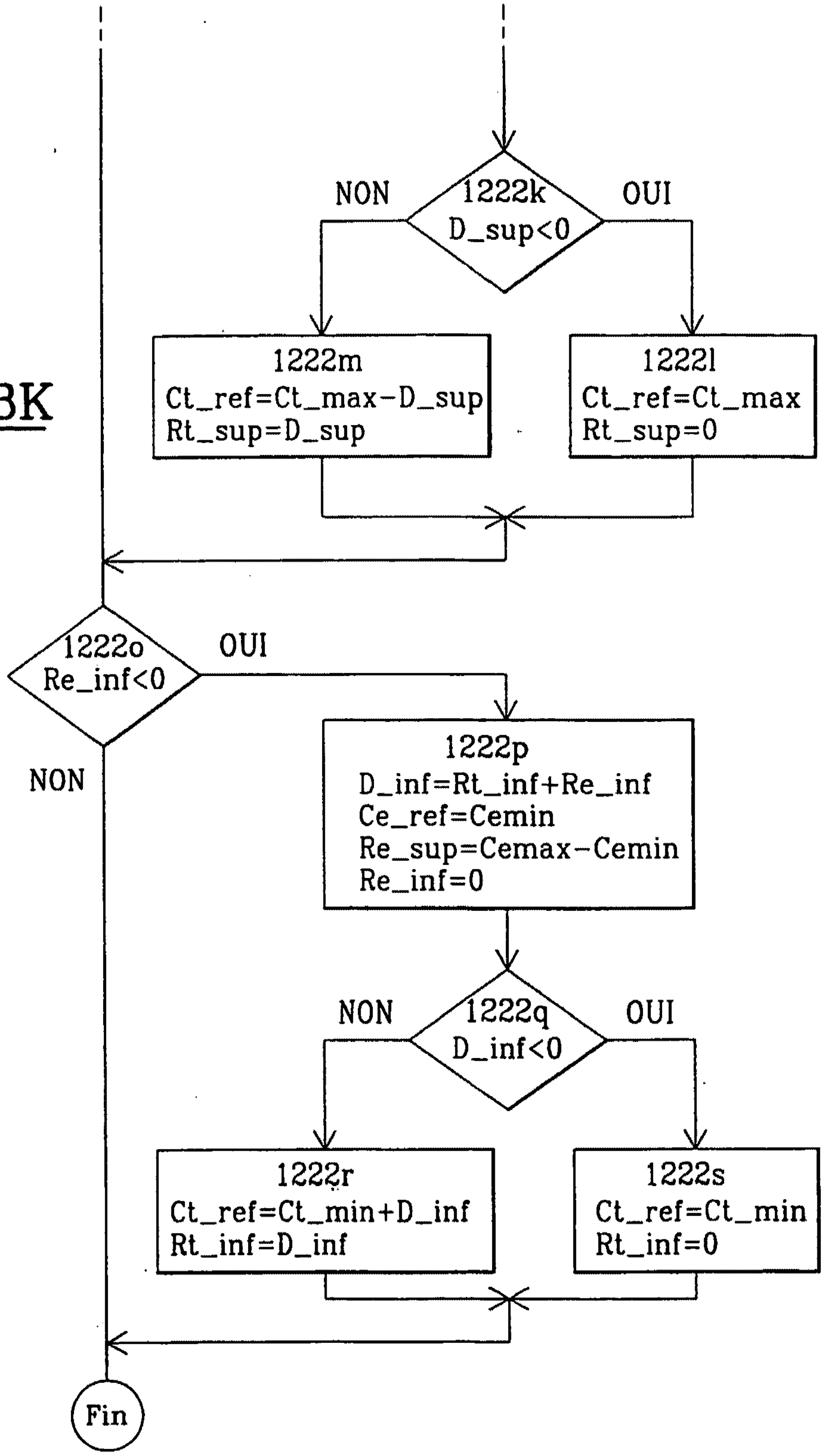

1222
Ajustement de Ce_ref et Ct_ref
1222a
Ct_ref=Ct_ref_int
1222b
Ct_ref>Ctmax
NON
OUI
1222d
Rt_sup=Ctmax-Ct_ref
1222c
Ct_ref=Ctmax
Rt_sup=0
1222e
Ct_ref<Ctmin
NON
OUI
1222g
Rt_inf=Ct_ref-Ctmin
1222f
Ct_ref=Ctmin
Rt_inf=0
1222h
Ce_ref=Cdem-Ct_ref
Re_sup=Cemax-Ce_ref
Re_inf=Ce_ref-Cemin
1222i
Re_sup<0
OUI
NON
1222j
D_sup=Rt_sup+Re_sup
Ce_ref=Cemax
Re_sup=0
Re_inf=Cemax-Cemin

FIG.3K


NON
1222k
D_sup<0
OUI
1222m
Ct_ref=Ct_max-D_sup
Rt_sup=D_sup
1222l
Ct_ref=Ct_max
Rt_sup=0
1222o
Re_inf<0
OUI
NON
1222p
D_inf=Rt_inf+Re_inf
Ce_ref=Cemin
Re_sup=Cemax-Cemin
Re_inf=0
NON
1222q
D_inf<0
OUI
1222r
Ct_ref=Ct_min+D_inf
Rt_inf=D_inf
1222s
Ct_ref=Ct_min
Rt_inf=0
Fin

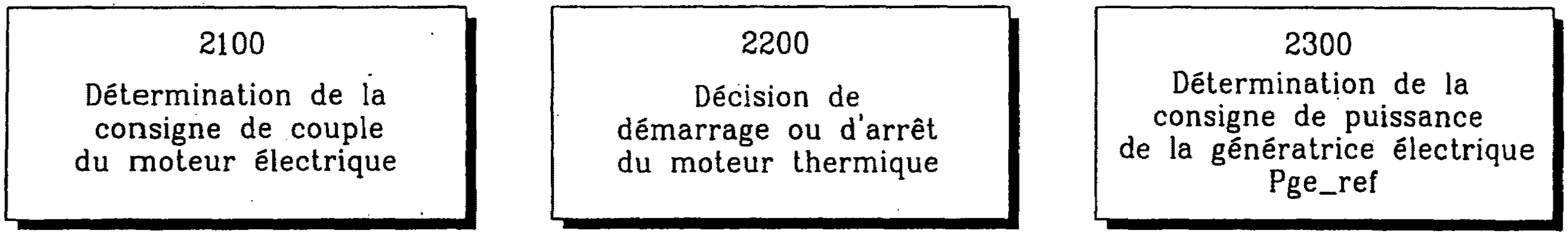

2100
Détermination de la consigne de couple du moteur électrique
2200
Décision de démarrage ou d'arrêt du moteur thermique
2300
Détermination de la consigne de puissance de la génératrice électrique Pge_ref

FIG.4A

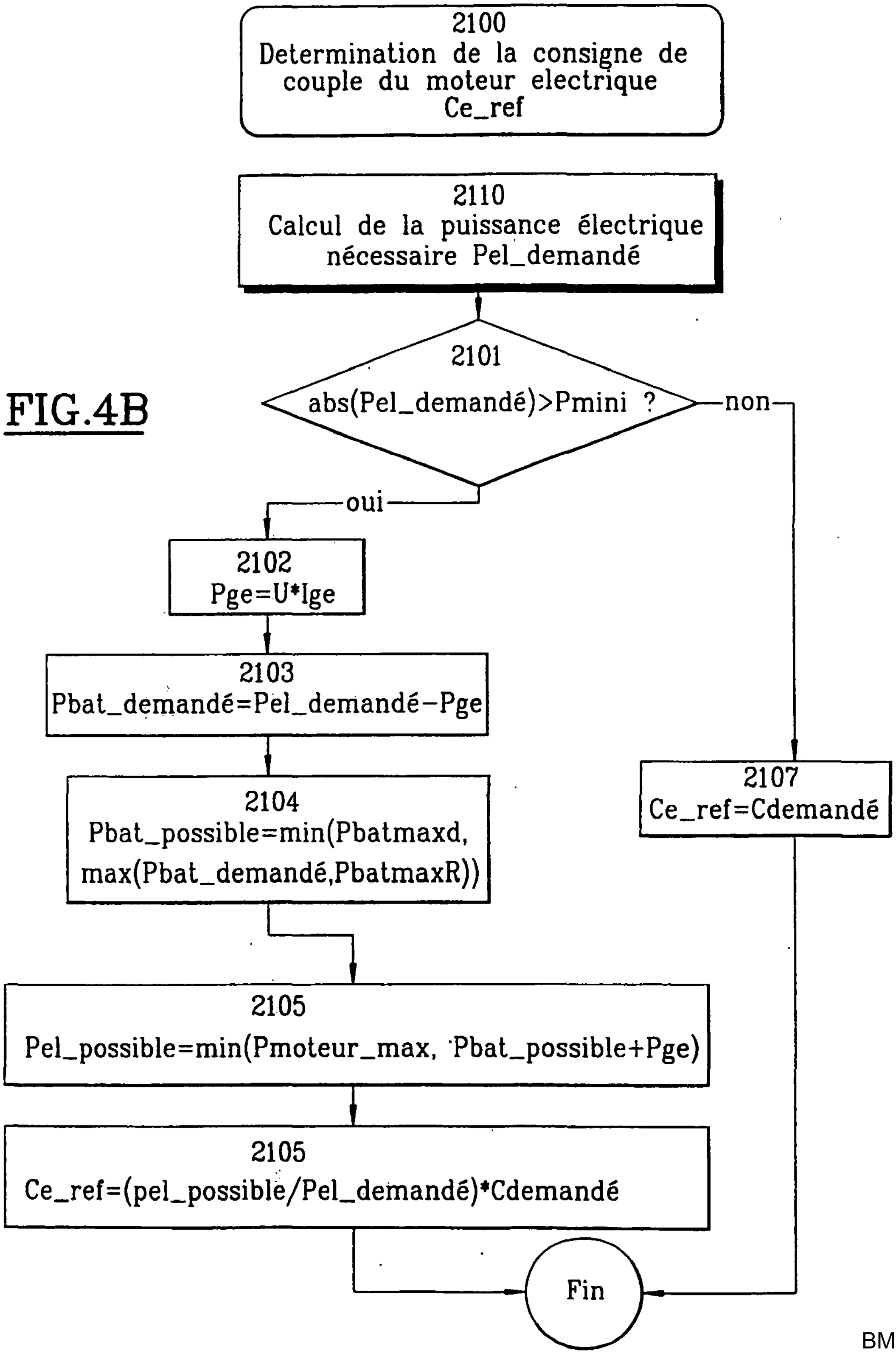

2100
Determination de la consigne de couple du moteur electrique Ce_ref
2110
Calcul de la puissance électrique nécessaire Pel_demandé
2101
abs(Pel_demandé)>Pmini ?
non
oui
2102
Pge=U*Ige
2103
Pbat_demandé=Pel_demandé−Pge
2104
Pbat_possible=min(Pbatmaxd, max(Pbat_demandé,PbatmaxR))
2105
Pel_possible=min(Pmoteur_max, Pbat_possible+Pge)
2105
Ce_ref=(pel_possible/Pel_demandé)*Cdemandé
2107
Ce_ref=Cdemandé
Fin

FIG.4B

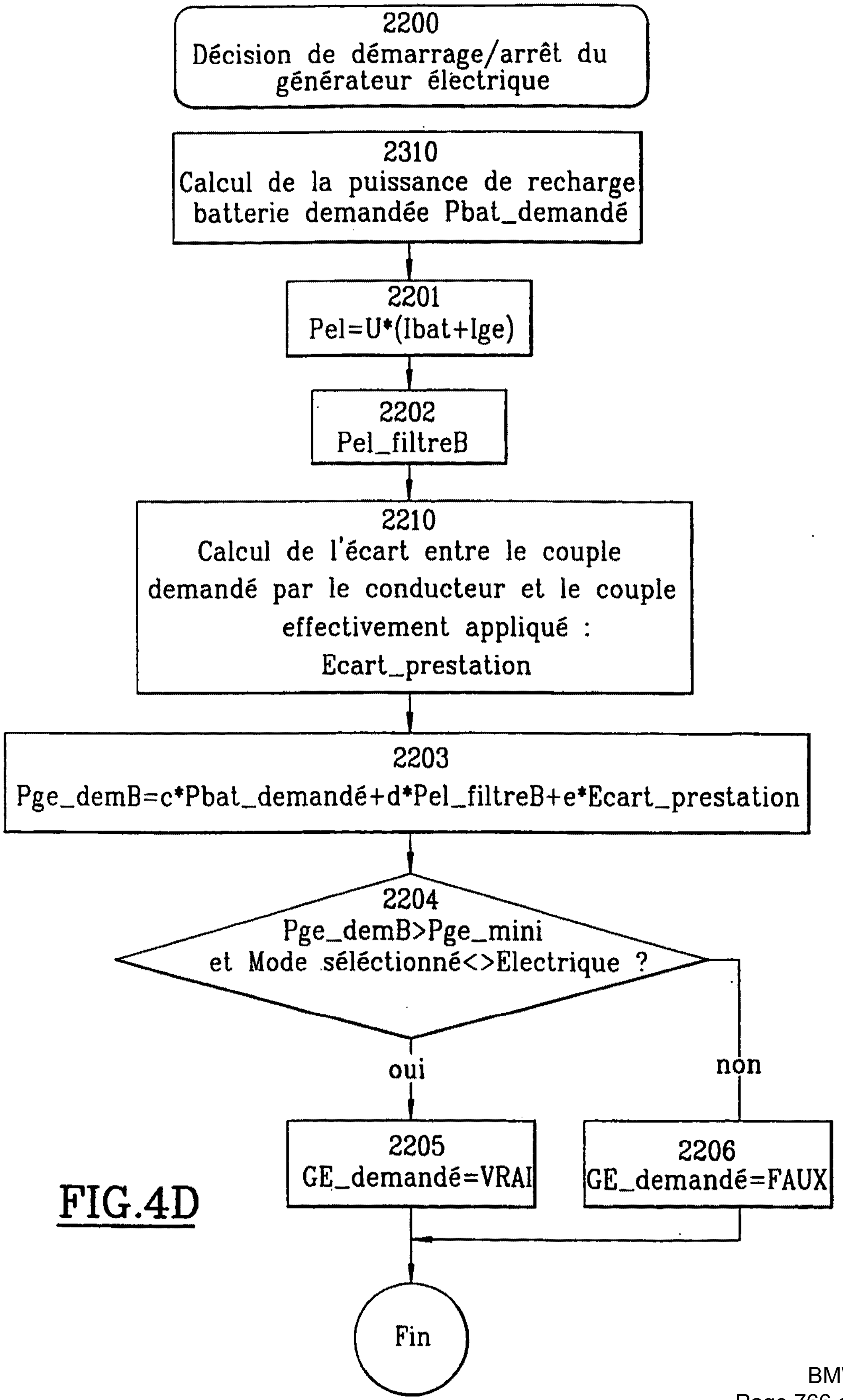

2200
Décision de démarrage/arrêt du générateur électrique
2310
Calcul de la puissance de recharge batterie demandée Pbat_demandé
2201
Pel=U*(Ibat+Ige)
2202
Pel_filtreB
2210
Calcul de l'écart entre le couple demandé par le conducteur et le couple effectivement appliqué : Ecart_prestation
2203
Pge_demB=c*Pbat_demandé+d*Pel_filtreB+e*Ecart_prestation
2204
Pge_demB>Pge_mini
et Mode séléctionné<>Electrique ?
oui
non
2205
GE_demandé=VRAI
2206
GE_demandé=FAUX
Fin

FIG.4D

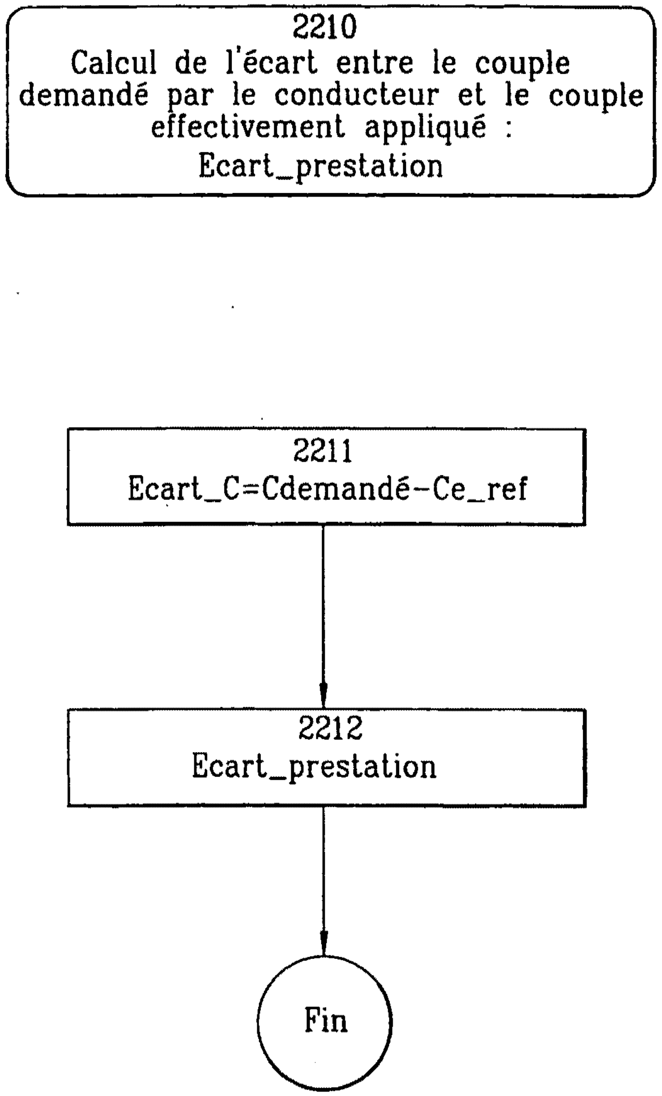

2210
Calcul de l'écart entre le couple demandé par le conducteur et le couple effectivement appliqué :
Ecart_prestation
2211
Ecart_C=Cdemandé-Ce_ref
2212
Ecart_prestation
Fin

FIG.4E

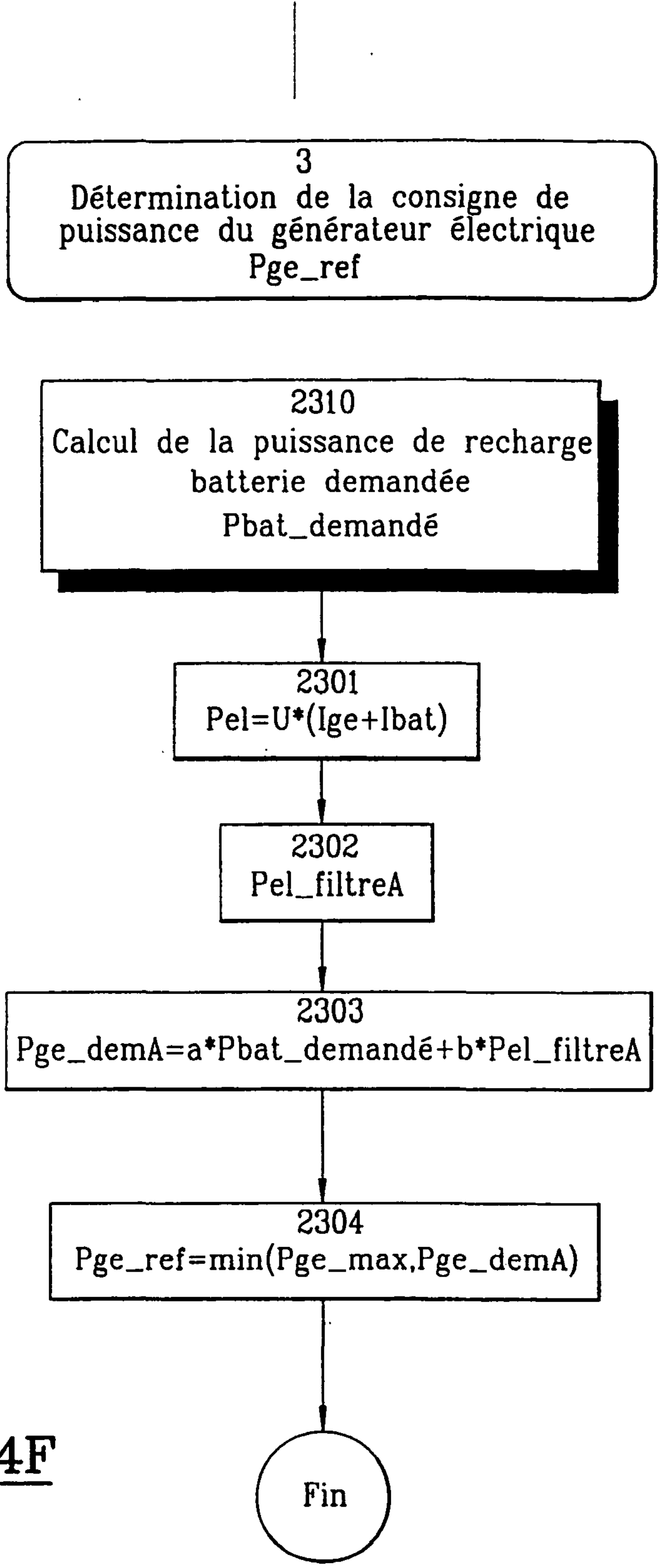

3
Détermination de la consigne de puissance du générateur électrique
Pge_ref
2310
Calcul de la puissance de recharge batterie demandée
Pbat_demandé
2301
Pel=U*(Ige+Ibat)
2302
Pel_filtreA
2303
Pge_demA=a*Pbat_demandé+b*Pel_filtreA
2304
Pge_ref=min(Pge_max,Pge_demA)
Fin

FIG.4F

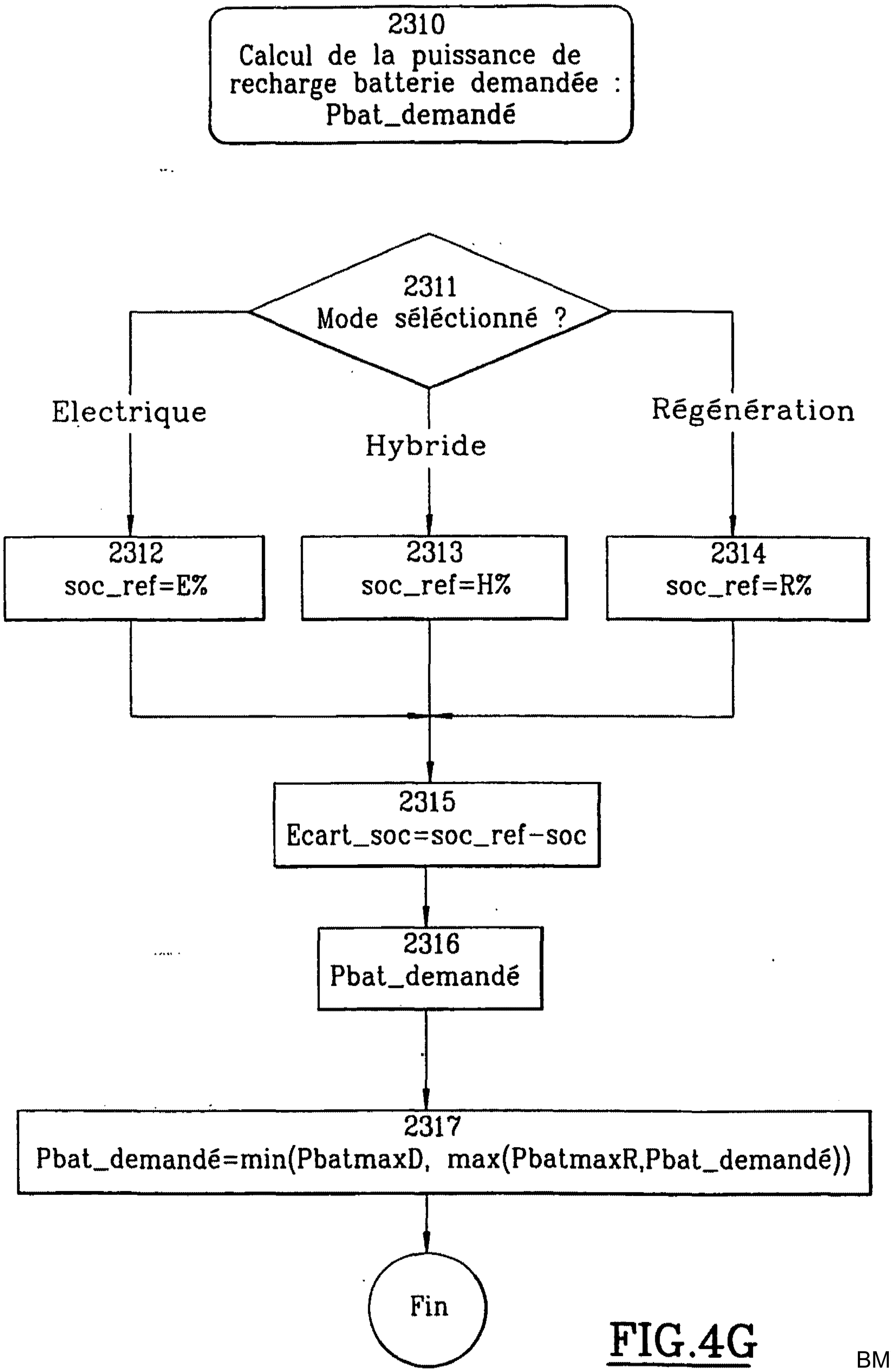

2310
Calcul de la puissance de recharge batterie demandée : Pbat_demandé
2311
Mode séléctionné ?
Electrique
Hybride
Régénération
2312
soc_ref=E%
2313
soc_ref=H%
2314
soc_ref=R%
2315
Ecart_soc=soc_ref-soc
2316
Pbat_demandé
2317
Pbat_demandé=min(PbatmaxD, max(PbatmaxR,Pbat_demandé))
Fin

FIG.4G

INTERNATIONAL SEARCH REPORT

International Application No
PCT/FR 98/02403

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60K6/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60K B60L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 197 12 246 A (TOYOTA MOTOR CO LTD) 6 November 1997	1,19
Y	see page 2, line 19 - line 29; claims 1,4-7; figures 6,7	13
A	see page 3, line 28 - line 44 ---	2-4
Y	EP 0 781 680 A (DENSO CORP) 2 July 1997	13
A	see page 3, line 10 - line 38; claim 1; figure 1 ---	1-4,19
A	DE 43 24 010 A (DAIMLER BENZ AG) 19 January 1995 see column 1, line 21 - column 2, line 15 see column 3, line 10 - line 17; figure 1 see column 8, line 18 - line 34 -----	1-4,13, 19

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search 15 February 1999	Date of mailing of the international search report 22/02/1999
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Daehnhardt, A

Form PCT/ISA/210 (second sheet) (July 1992)

RAPPORT DE RECHERCHE INTERNATIONALE

mande Internationale No
PCT/FR 98/02403

A. CLASSEMENT DE L'OBJET DE LA DEMANDE
CIB 6 B60K6/04

Selon la classification internationale des brevets (CIB) ou à la fois selon la classification nationale et la CIB

B. DOMAINES SUR LESQUELS LA RECHERCHE A PORTE

Documentation minimale consultée (système de classification suivi des symboles de classement)
CIB 6 B60K B60L

Documentation consultée autre que la documentation minimale dans la mesure où ces documents relèvent des domaines sur lesquels a porté la recherche

Base de données électronique consultée au cours de la recherche internationale (nom de la base de données, et si réalisable, termes de recherche utilisés)

C. DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie °	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
X	DE 197 12 246 A (TOYOTA MOTOR CO LTD) 6 novembre 1997	1,19
Y	voir page 2, ligne 19 - ligne 29; revendications 1,4-7; figures 6,7	13
A	voir page 3, ligne 28 - ligne 44 ---	2-4
Y	EP 0 781 680 A (DENSO CORP) 2 juillet 1997	13
A	voir page 3, ligne 10 - ligne 38; revendication 1; figure 1 ---	1-4,19
A	DE 43 24 010 A (DAIMLER BENZ AG) 19 janvier 1995 voir colonne 1, ligne 21 - colonne 2, ligne 15 voir colonne 3, ligne 10 - ligne 17; figure 1 voir colonne 8, ligne 18 - ligne 34 -----	1-4,13, 19

☐ Voir la suite du cadre C pour la fin de la liste des documents

☒ Les documents de familles de brevets sont indiqués en annexe

° Catégories spéciales de documents cités:

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"E" document antérieur, mais publié à la date de dépôt international ou après cette date
"L" document pouvant jeter un doute sur une revendication de priorité ou cité pour déterminer la date de publication d'une autre citation ou pour une raison spéciale (telle qu'indiquée)
"O" document se référant à une divulgation orale, à un usage, à une exposition ou tous autres moyens
"P" document publié avant la date de dépôt international, mais postérieurement à la date de priorité revendiquée

"T" document ultérieur publié après la date de dépôt international ou la date de priorité et n'appartenenant pas à l'état de la technique pertinent, mais cité pour comprendre le principe ou la théorie constituant la base de l'invention
"X" document particulièrement pertinent; l'inven tion revendiquée ne peut être considérée comme nouvelle ou comme impliquant une activité inventive par rapport au document considéré isolément
"Y" document particulièrement pertinent; l'inven tion revendiquée ne peut être considérée comme impliquant une activité inventive lorsque le document est associé à un ou plusieurs autres documents de même nature, cette combinaison étant évidente pour une personne du métier
"&" document qui fait partie de la même famille de brevets

Date à laquelle la recherche internationale a été effectivement achevée 15 février 1999	Date d'expédition du présent rapport de recherche internationale 22/02/1999
Nom et adresse postale de l'administration chargée de la recherche internationale Office Européen des Brevets, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fonctionnaire autorisé Daehnhardt, A

1

Formulaire PCT/ISA/210 (deuxième feuille) (juillet 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

ɜrnational Application No
PCT/FR 98/02403

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19712246 A	06-11-1997	JP 9257121 A JP 9322312 A	30-09-1997 12-12-1997
EP 0781680 A	02-07-1997	JP 9203332 A US 5789881 A	05-08-1997 04-08-1998
DE 4324010 A	19-01-1995	NONE	

RAPPORT DE RECHERCHE INTERNATIONALE

Renseignements relatifs aux membres de familles de brevets

mande Internationale No

PCT/FR 98/02403

Document brevet cité au rapport de recherche	Date de publication	Membre(s) de la famille de brevet(s)	Date de publication
DE 19712246 A	06-11-1997	JP 9257121 A JP 9322312 A	30-09-1997 12-12-1997
EP 0781680 A	02-07-1997	JP 9203332 A US 5789881 A	05-08-1997 04-08-1998
DE 4324010 A	19-01-1995	AUCUN	

Motor vehicle with hybrid motorization

The invention relates to a motor vehicle with hybrid motorization comprising refined power management means.

The invention relates more particularly to a motor vehicle with hybrid motorization, of the type in which a powertrain assembly comprises an electric engine and a heat engine which are able to contribute to the driving of the vehicle, and of the type in which a central management unit executes a first task comprising determining the torque that each engine must supply for the powertrain assembly to supply the vehicle with a motive torque conforming to a torque requested by the driver of the vehicle, and of the type in which the heat engine is able to be stopped, the vehicle then being driven only by the electric engine powered by electric current from a battery.

In the search for vehicles that are less polluting than the motor vehicles that comprise only a single heat engine, vehicles with hybrid motorization appear as a particularly interesting alternative to strictly electric-powered vehicles.

In practice, the latter offer the advantage of not themselves emitting any toxic substances while being both particularly silent and economic to use. However, the electric vehicles take their power only from the accumulator batteries that they have on board. Now, given the poor performance levels of currently known accumulator batteries, at least those able to be used at reasonable cost in a motor vehicle, electric vehicles can store only a relatively low quantity of energy, despite a consistent weight, which gives them both poor autonomy and poor performance.

Thus, the hybrid motorization solution comprising a heat engine able to participate in the driving of the vehicle makes it possible to produce vehicles offering far higher performance and autonomy levels, satisfactory for normal use of the vehicle.

There are two main types of hybrid vehicles.

In series hybrid vehicles, only the electric engine is able to directly drive the drive wheels of the vehicle, possibly through a gearbox, a differential and/or a clutch. The electric engine takes its power from a battery charged by an electric generator which is driven by the heat engine.

In this type of hybrid vehicle, the electric engine is therefore always operating and the heat engine can be either stopped, with the vehicle then operating in pure electric mode, or running so that the generator produces electricity to power the electric engine and/or charge the batteries.

In a parallel hybrid vehicle, the heat engine and the electric engine are both linked, normally via a two-input gearbox, to the drive wheels of the vehicle. Normally, a clutch is placed between each engine and the drive wheels to enable the engine to be decoupled when the latter is not used for driving purposes. The parallel hybrid type motor vehicles can therefore be driven using only the electric engine, or using only the heat engine, or even using both engines simultaneously. Moreover, in certain configurations, it is possible to use the electric engine to start the heat engine and the electric engine can also be "inverted" so that, the heat engine rotating the electric engine, possibly at the same time as it is rotating the drive wheels of the vehicle, is responsible for charging the batteries.

It should be noted that there is a variant of the parallel hybrid vehicles in which each of the two heat and electric engines is coupled not to the same axle, but to different axles.

Whatever the type of hybrid vehicle considered, it is therefore necessary to manage as effectively as possible the control of each of the heat and electric engines to ensure that the vehicle is driven according to the needs of the driver who at all times determines the motive torque needed to propel the vehicle to accelerate or decelerate the vehicle, or maintain the vehicle at a steady speed.

In particular, the choice of whether or not to use the heat engine is particularly crucial because it can be used to determine the autonomy of the vehicle, its performance levels, all in as much as the starting of the heat engine is actually possible, which can, for example, be prohibited in certain areas where traffic is particularly dense or at certain periods to limit pollution.

Moreover, it is necessary for the power distribution transfers supplied by each of the engines to be conducted "transparently" for the driver, that is, producing a minimum of disturbances and jerks.

Thus, the invention proposes a motor vehicle of the type described previously, characterized in that, at least for certain operating modes of the powertrain assembly, the central unit executes a second task during which it is decided to stop or start the heat engine, in that the first task and the second task are executed in parallel and in that the frequency of execution of the second task is less than that of the first task.

According to other characteristics of the invention:

- the driver can impose on the powertrain assembly an electric operating mode in which the heat engine is stopped;

- the driver can impose on the powertrain assembly a regeneration operating mode in which the heat engine is used in particular to charge the battery;

- the driver can impose on the powertrain assembly a hybrid operating mode in which the central unit executes the second task during which it is decided to stop or start the heat engine;

- the decision to stop or start the heat engine is taken in particular according to a state of charge of the battery;

- the starting of the heat engine is decided or confirmed when the state of charge of the battery is less than a low threshold level, and the stopping of the heat engine is able to be decided or confirmed when the state of charge of the battery is greater than a high threshold level;

- the decision to stop or start the heat engine is taken in particular according to the instantaneous torque requested by the driver;

- the decision to stop or start the heat engine is taken in particular according to the average torque requested by the driver during a predetermined time interval preceding the decision;

- the starting of the heat engine is decided or confirmed when the instantaneous torque requested by the driver is greater than a high threshold level, and in that the stopping of the heat engine is able to be decided or confirmed when the instantaneous torque and the average torque requested by the driver are less than a low threshold level;

- the stopping of the heat engine is decided or confirmed when, at the same time, the state of charge of the battery is greater than a high threshold level and the instantaneous torque and the average torque requested by the driver are less than a low threshold level;

- the decision to stop or start the heat engine is taken in particular according to a difference between the torque requested by the driver and the torque actually supplied by the powertrain assembly;

- during operation of the operating mode selected by the driver, a charge set point level of the battery is fixed;

- the powertrain assembly is a series hybrid assembly in which the drive wheels of the vehicle are driven exclusively by the electric engine which is powered by electric current from either the battery or from a generator driven by the heat engine;

- the electrical power to be supplied to the battery is determined according to a difference between the real and reference states of charge of the battery, taking into account limiting charge and discharge power values of the battery;

- the starting of the heat engine is determined according to the electrical power to be supplied to the battery, the electrical power absorbed by the electric engine and according to a difference between the value of the torque requested by the driver and the value of the torque supplied by the electric engine;

- a set point level for the power supplied by the generator is determined according to the real power supplied by the generator, the real power supplied by the battery, and the power to be supplied to the battery, taking into account the maximum power able to be supplied by the generator;

- a necessary electrical power is determined according to the motive torque requested by the driver, taking into account, at least when this torque is greater as an absolute value than a minimum value, the efficiency of the electric engine;

- a set point value for the torque supplied by the electric engine is determined according to the motive torque requested by the driver multiplied, at least when the necessary electrical power is greater as an absolute value than a threshold value, by the ratio of the electrical power able to be supplied to the electric engine divided by the necessary electrical power, the electrical power able to be supplied to the electric engine taking into account the necessary electrical power, the real power supplied by the generator, the power able to be supplied by the battery, and the maximum power able to be absorbed by the engine;

- the powertrain assembly is a parallel hybrid assembly in which the electric engine and the heat engine each drive either at least one and the same drive wheel or different drive wheels;

- the powertrain assembly operates in regeneration mode, the electric engine delivers a motive torque only if the driver provokes an abrupt rise in the requested torque;

- when the powertrain assembly is operating in regeneration mode, the heat engine is ordered to supply a maximum torque;

- when the powertrain assembly is operating in hybrid mode and the state of charge of the battery has previously fallen below a low threshold level and has not yet exceeded a high threshold level, the heat engine is ordered to supply a set point torque at least equal to an optimal torque corresponding to optimal efficiency conditions of the heat engine;

- when the powertrain assembly is operating in hybrid mode and the instantaneous torque requested by the driver has previously risen above a high threshold level without returning below a low threshold level at the same time as the average level is less than the low threshold level, the heat engine is ordered to supply a set point torque at least equal to a filtered value of the torque requested by the driver; and

- if a filtered value of the torque requested by the driver is greater than the maximum torque of the heat engine, the electric engine is called upon to supply, as far as possible, the quantity of torque lacking.

Other features and advantages of the invention will become apparent from reading the detailed description that follows, which should be interpreted with reference to the appended drawings in which:

- figure 1 is a schematic view illustrating the architecture of a motor vehicle with hybrid motorization, of parallel type;

- figure 2 is a view similar to that of figure 1 illustrating a series type hybrid vehicle;

- figures 3A to 3K are flow diagrams illustrating a first strategy for the management of a hybrid vehicle according to the teachings of the invention, more specifically intended for a parallel type hybrid vehicle; and

- figures 4A to 4H illustrate a flow diagram of a management strategy according to the invention, more specifically intended for a series type hybrid vehicle.

In a vehicle with parallel hybrid motorization, of the type of the one illustrated in figure 1, a heat engine 10 and an electric engine 12 are both able to directly drive the drive wheels of the vehicle.

The heat engine 10 is normally an internal combustion engine with reciprocating pistons or rotary pistons or even of turbine type. It is powered chemically by a hydrocarbon type liquid or gas fuel.

The electric engine 12 is electrically linked to a battery 16 borne by the vehicle, possibly via an inverting converter 17. The two engines 10, 12 each rotate an input shaft 18, 20 of a power distribution unit 22 of which the output shaft(s) 24 rotate the drive wheels. The power distribution unit 22 can comprise, for example, a gearbox, a differential and, optionally, placed between at least one of the engines and the corresponding input shaft 18, 20, a clutch device 25 which is used to couple or decouple at will the engine from the power distribution unit 22.

The duly equipped vehicle can therefore be driven either using only the heat engine 10, or using only the electric engine 12, or using both engines simultaneously. If necessary, the heat engine can have its power distributed between on the one hand driving the drive wheels 14, and on the other hand rotating the "inverted" electric engine which is then converted into an electricity generator for charging the battery 16.

Similarly, the electric engine 12 can, if necessary, be used to start the heat engine 10.

In the series type hybrid vehicle illustrated in figure 2, only the electric engine 12 is linked directly to the drive wheels, possibly via a power distribution unit (not shown). The electric engine 12 can be powered with electrical energy by the battery 16 or by an electricity generator 26 which is driven by the electric engine 12.

In all cases, inverting 17 and rectifying 19 converters can be provided if the electric engine needs to be powered by alternating current.

Preferably, to manage the driving of the vehicle, each of the main elements of the vehicle is provided with a local control unit, each of these local units being in turn controlled by a central management unit which is used to centralize the information concerning the status of each of the units, information concerning the status of the vehicle and information concerning the requirements of the driver.

The main purpose of the central management unit is to control the two engines 10, 12 so as to make best use of the energy of the vehicle that is stored either in electrical form in the batteries, or in the form of hydrocarbon fuel. Another aim of this management is to respond at all times in the most satisfactory way possible to the requirements of the driver concerning acceleration and deceleration of the vehicle, this requirement preferably being represented by a motor torque Trequested on the drive wheels.

Two main tasks are executed cyclically by the central management unit, namely, on the one hand the decision to start or stop the heat engine 10 and, on the other hand, the determination of the torque or power set points that the electric engine and the heat engine must supply in order to drive the vehicle according to the requirements of the driver.

According to the invention, these two tasks are performed in parallel and they are executed at different frequencies.

Thus, the task involving determining the torque set points to be supplied by the electric engine and the heat engine will, for example, be executed every 40 milliseconds whereas the task for deciding to start or stop the heat engine will, for example, be performed every second.

Decoupling these two tasks in this way provides for a management of the power supplied by the powertrain assembly formed by the two engines 10, 12 which responds virtually instantaneously to the instructions of the driver. Furthermore, making the decision to start and stop the heat engine independently of the instantaneous power management prevents these start and stop phases, which are both aggravated sources of pollution and sources of instability to the total power supplied by the engines, which can be reflected in jerks felt by the driver and the passengers of the vehicle, from being multiplied.

The management strategy for the hybrid vehicle according to the invention will be more specifically described below according to two embodiments, one of which is more particularly suited to a parallel type hybrid vehicle illustrated in figure 1, and the other of which is more particularly suited to a series type hybrid vehicle illustrated in figure 2.

The first of these two strategies uses a series of variables which are listed and explained in the table below.

Notation	**Meaning**	**Units**
C1 to C4	Constants for calculating Tlow and Thigh according to battery gauge	Nm
Tlow	Lower torque threshold for determining h_running	Nm
Trequested	Torque requested by the driver (positive for acceleration, negative for deceleration)	Nm
Trequested_filter1	Rapid response time filtered value of Trequested	Nm
Trequested_filter2	Slow response time filtered value of Trequested	Nm
Te_ref	Electric motive torque set point (positive for traction, negative for regenerative braking)	Nm
Tel_braking_max	Maximum regenerative braking torque allowable by the electric engine (negative)	Nm
Tel_traction_max	Maximum traction torque allowable by the electric engine (positive)	Nm
Temax	Maximum electric torque given the state of the battery and mode_selected (positive)	Nm
Temin	Minimum electric torque given the state of the battery and mode_selected (negative)	Nm
Thigh	Upper torque threshold for determining h_running	Nm
Th_maximum	Maximum torque of the heat engine, used in Regeneration mode	Nm
Th_optimal	Torque of the heat engine corresponding to its minimum specific consumption	Nm
Th_ref	Heat motive torque set point (positive for traction, negative for engine braking)	Nm
Th_ref_int	Intermediate estimate of the Th_ref value	Nm
Th_ref1	Intermediate estimate of the Th_ref value	Nm
Th_braking_max	Maximum engine braking torque allowable by the heat engine (negative)	Nm
Th_traction_max	Maximum traction torque allowable by the heat engine (positive)	Nm
Thmax	Maximum electrical torque given mode_selected (positive)	Nm

Thmin	Minimum electrical torque given mode selected (negative)	Nm
D lower	Intermediate value in calculating Th ref	Nm
D higher	Intermediate value in calculating Th ref	Nm
Request electric	Electric engine start request	Boolean
Request heat	Heat engine start request	Boolean
Battery_mode_hyst	Intermediate quantity for determining h_recovery (electric, hybrid)	-
Torque_mode_hyst	Intermediate quantity for determining h_running (electric, hybrid)	-
battery gauge	State of charge of the traction battery	%
Kickdown requested	Request for additional electrical acceleration (regeneration mode)	Boolean
mode_selected	Operating mode selected by the driver (electrical, hybrid or regeneration)	-
N	Electric motor rotation speed	rad/s
PbatMaxD	Maximum discharge power of traction battery (positive)	W
PbatmaxR	Maximum recharge power of traction battery (negative)	W
Re_lower	Intermediate value in calculating Th_ref (see diagram below)	Nm
Re_upper	Intermediate value in calculating Th_ref (see diagram below)	Nm
Rh_lower	Intermediate value in calculating Th_ref (see diagram below)	Nm
Rh_upper	Intermediate value in calculating Th_ref (see diagram below)	Nm
gauge_low_threshold	Battery gauge low threshold for determining h_recovery	%
gauge_high_threshold	Battery gauge high threshold for determining h_recovery	%
h_recovery	Determines whether the heat engine contributes to charging the battery	Boolean
h_regeneration	Determines whether the heat engine contributes to strongly charging the battery	Boolean
h running	Determines whether the heat engine contributes to running	Boolean

Figure 3A illustrates the two main tasks that are executed in parallel with each other, at different frequencies. Of course, the frequencies of 1 Hertz and 25 Hertz given here for on the one hand the task 1100 for deciding to start or stop the heat engine, and on the other hand the task 1200 for determining the torque set points of the engines 10, 12 are nonlimiting examples used to illustrate the choice according to which the second of these frequencies is significantly greater than the first.

Each of the tasks 1100 and 1200 illustrated in these figures is broken down into lower level tasks which will be explained with reference to figures 3B to 3K.

The step 1100 for deciding to start or stop the heat engine is explained in figure 3B. First of all, in the steps 1101 and 1102, two filtered values of the torque Trequested requested by the driver are calculated. The filters used are, for example, first order filters, of low-pass type. The first value Trequested_filter1 corresponds to an average of Trequested over a very short interval preceding the time of calculation and remains representative of the instantaneous value Trequested. However, the value Trequested_filter2 corresponds to a smoothed average value of Trequested and is therefore representative of a medium term trend of the torque request expressed by the driver.

Once these two values have been calculated, three lower level tasks are executed in which are determined the intermediate boolean variables: h_running (task 1110), h_recovery (task 1120), h_regeneration, request_electric and request_heat (task 1130).

These lower level tasks will be explained below.

Once these values have been determined, a test is carried out in step 1103 to check whether the heat engine 10 is available, that is, whether it is in a state to deliver a motive torque. If it is, the boolean variables that have just been calculated are retained unchanged, otherwise, as can be seen in step 1104, the boolean values h_running, h_regeneration and h_recovery are forced to zero.

The task 1110 for determining the value of the boolean variable h_running is now described with reference to figure 3C. In the step 1111, two threshold levels Tlow and Thigh, with which the filtered values of the requested torque will be compared, are first calculated. These threshold values are mainly determined according to the state of charge battery_gauge of the battery 16.

In the step 1112, a check is first of all made to see whether the filtered value Trequested_filter1, representative of the instantaneous torque requested by the driver, is greater than the upper threshold level Thigh. If it is, an intermediate boolean variable torque_mode_hyst is forced to the value "hybrid" in the step 1113. If not, in the step 1114, a check is made to see whether the two filtered values of the requested torque Trequested_filter1 and Trequested_filter2 are both simultaneously lower than the lower torque level Tlow. If they are, the boolean value torque_mode_hyst is forced in the step 1115 to the value "electric". If not, the boolean variable torque_mode_hyst is unchanged.

In the step 1116, a check is then made to see whether the boolean variable torque_mode_hyst is equal to the value "hybrid". If it is, the boolean value h_running is forced to 1 in the step 1118. If not, the boolean value h_running is forced to zero in the step 1117.

The task 1120 for determining the value of the boolean variable h_recovery will now be described with reference to figure 3D. In the step 1121, a check is first carried out to see whether the state of charge of the battery 16, represented by the variable battery_gauge, is less than a lower threshold value gauge_low_threshold. If it is, a boolean variable battery_mode_hyst is forced to the value "hybrid" in the step 1122. If not, a check is made in the step 1123 to see whether the battery_gauge value is greater than an upper threshold level gauge_high_threshold. If it is, the boolean variable battery_mode_hyst is forced to the value "electric" in the step 1124. If not, the variable battery_mode_hyst retains the same value as during the previous execution of the task.

In the step 1125, a check is made to see whether the variable battery_mode_hyst is equal to the value "hybrid". If it is, the h_recovery value is forced to the value 1 in the step 1127. If not, this variable is forced to the value zero in the step 1126.

The task 1130 is described with reference to figure 3E. The purpose of this task is to determine the value of the boolean variables h_regeneration, request_electric and request_heat.

According to an aspect of the invention, the management strategy for the powertrain assembly of the hybrid vehicle that is proposed here is used by the driver to select one of three operating modes for the powertrain assembly.

→ In an electric mode, the driver prohibits the use of the heat engine. The boolean variables torque_mode_hyst and battery_mode_hyst are forced to the variable "electric", the variable request_electric is forced to the value "true", the variable request_heat is forced to the value "false" and the variable h_regeneration is forced to the value "0".

The driver can also select a regeneration operating mode for the powertrain assembly. This operating mode forces the powertrain assembly to start the heat engine in order, in addition to driving the vehicle, to charge the battery 16. The boolean variables torque_mode_hyst and battery_mode_hyst are in this case forced to the value "hybrid". The boolean variables request_electric and request_heat are forced to the value "true" while the variable h_regeneration is forced to the value "1".

The driver can also select a hybrid operating mode for the powertrain assembly. In this operating mode, the heat engine 10 will be used only if needed, as will be seen below.

In this mode, the variable request_electric is forced to the value "true". The variable request_heat is forced to the value "true" if one or other of the variables battery_mode_hyst and torque_mode_hyst is equal to the value "hybrid". Otherwise, the variable request_heat is forced to the value "false". The variable h_regeneration is forced to the value "0".

There now follows a description, with reference to figures 3F to 3K, of the second main task 1200 of this first strategy for managing a hybrid vehicle, this second task being executed at a frequency fast enough to be able to satisfy the requirements of the driver.

This second task 1200, which consists in determining the set point torques Te_ref and Th_ref for the electric engine and the heat engine, itself comprises two lower level tasks 1210 and 1220 which will be explained respectively in Figures 3G to 3H and 3I to 3K.

As can be seen in Figure 3G, the purpose of the task 1210 is to determine the limiting motive torques for the electric engine and the heat engine. In the step 1211, a check is first of all made to see whether the heat engine is available. If it is, limiting torque variables Thmax and Thmin for the heat engine are respectively assigned the values Th_traction_max and

Th_braking_max which are linked in particular to the speed and the temperature of the engine used. If not, the values of Thmax and Thmin are forced to zero in the step 1213.

In the step 1214, a check is then made to see whether the electric engine is available. If not, the variables Temax and Temin are forced to zero in the step 1217.

If it is, the variable Temin is assigned in the step 1215 the higher of the following two values:

- a value Tel_braking_max, which depends in particular on the power supply voltage and temperature of the engine;
- PbatmaxR X $\frac{1}{N}$.

The maximum torque value of the electric engine is determined in the task 1216 which is broken down in figure 3H. In practice, a check is first of all carried out in the step 1216a to see whether the variable h_regeneration is equal to 1, that is, whether the driver has selected the regeneration operating mode for the powertrain assembly. If so, it can be seen that the value of Temax is forced to zero in the step 1216c, unless the driver, as is checked in the step 1216b, performs a kickdown maneuver by which he significantly and quickly increases the requested torque. This maneuver normally corresponds to a rapid depression of the accelerator pedal.

In this case, or in the case of a negative response to the test of step 1216a, the value Temax is set in the step 1216d to the smaller of the values:

- PbatmaxD x $\frac{1}{N}$.

- Tel_traction_max.

The task 1220 for calculating torque set points Te_ref and Th_ref illustrated in figure 3I comprises two sub-tasks 1221 and 1222 which will be described respectively in light of figures 3J and 3K. The subtask 1221 consists in calculating an intermediate value Th_ref_int. For this, a value Th_ref1, which is equal to the greatest of the following three values:

- h_running x Trequested
- h_regeneration x Th_maximum
- h_recovery x Th_optimal,

is first of all determined in the step 1221a.

In the step 1221c, this variable Th_ref1 is filtered by a low-pass type first-order filter to give the intermediate variable Th_ref_int.

The step 1222 for adjusting Te_ref and Th_ref will now be described with reference to figure 3K. In the step 1222a, the value of Th_ref is first of all set to the value Th_ref_int determined above. Then, in the step 1222b, a check is made to see whether this value is greater than the value Thmax. If it is, in the step 1222c, Ct_ref is forced to the value Thmax and Rh_upper is forced to the value zero. If not, in the step 1222d, the value of Rh_upper is set to the difference of Thmax-Th_ref.

In both cases of response to the step 1222b, a check is then carried out in the step 1222e to see whether the value of Th_ref is lower than the value of Thmin. If it is, in the step 1222f, Th_ref is forced to the value Thmin and Rh_lower is forced to zero. If not, Rh_lower is set to be equal to the difference between Th_ref and Thmin in the step 1222g.

In both cases of response to the step 1222e, Th_ref is then forced to the value Treq-Th_ref, Re_upper is forced to the value Temax-Te_ref and the variable Re_lower is forced to the value Te_ref-Temin in the step 1222h.

Then, in the step 1222i, a check is made to see whether the value of Re_upper is negative. If not, the procedure goes direct to the step 1222o. If it is, in the step 1222j, the variable D_upper is set to the value Rh_upper+Re_upper, the variable Te_ref is set to the value Temax, the value of Re_upper is set to zero and the variable Re_lower is set to the value of the difference between Temax and Temin. Then, in the step 1222k, a check is made to see whether the value D_upper is negative. If it is, in the step 1222l, the variable Th_ref is set to the value Th_max and the variable Rh_upper is set to zero; otherwise, in the step 1222m, the variable Th_ref is set to the value Thmax-D_upper and the variable Rh_upper is set to the value D_upper.

In both cases of response to the step 1222k, and in the case of a negative response to the test of step 1222i, a check is then made in the step 1222o to see whether the variable Re_lower is negative. If it is, in the step 1222p, the variable D_lower is set to the value Rh_lower+Re_lower, the variable Te_ref is set to be equal to the value Temin, the variable Re_upper is set to be equal to the difference of Temax minus Temin and the variable Re_lower is set to the value zero.

Then, in the step 1222q, a check is made to see whether the variable D_lower is negative. If it is, in the step 1222s, the variable Th_ref is set to be equal to the value Th_min and the variable Rh_lower is set to the value zero. If not, the variable Th_ref is set to be equal to the value Thmin+D_lower and the variable Rh_lower is set to be equal to the value D_lower.

If not, the procedure goes direct to the end of the task.

As can be seen from the detailed description of this first hybrid vehicle management strategy, when the driver has selected the hybrid operating mode for the powertrain assembly, the starting of the heat engine is requested, in the task 1130, if one of the variables battery_mode_hyst and torque_mode_hyst is equal to the value "hybrid". If neither one nor the other is set to the value "hybrid", the heat engine is stopped.

Thus, it can be deduced from step 1213 that the heat engine can start if the driver commands a torque requested of the wheel that is high enough for the variable Trequested_filter1 to be greater than the high threshold level Thigh. Similarly, it can be deduced from the steps 1122 and 1121 that the heat engine is started when the state of charge of the battery falls below a lower threshold level. However, with this first strategy, the stopping of the heat engine is provoked only when both the conditions of the step 1114 and of the step 1123 are satisfied, that is, when the battery reaches a state of charge greater than a higher threshold level and when, at the same time, the instantaneous and average filtered values of the torque requested by the driver are less than a low threshold level.

2 values for threshold

Thus, according to this strategy, it can be seen that the decision to start the heat engine depends in particular on the state of charge of the battery, the instantaneous torque requested by the driver and the average torque requested by the driver.

It can also be observed that, when the powertrain assembly is operating in hybrid mode, the value of the torque Th_ref which will be requested of the heat engine depends on the variables h_running and h_recovery determined by the tasks 1110 and 1120. Thus, when the state of charge of the battery has previously fallen below a low threshold level and has not yet exceeded a high threshold level, the outcome of the task 1120 is that the value of h_recovery is equal to 1 such that the intermediate value Th_ref1 calculated in the step 1221b cannot be lower than the torque Ct_optimal supplied by the engine when it is ordered in optimal efficiency conditions. The value Th_ref of the set point torque imposed on the heat engine cannot therefore fall below a level corresponding to this optimal torque.

However, again when the driver has selected the hybrid operating mode for the powertrain assembly, the outcome of the task 1110 is that, when the condition of the step 1112 has been satisfied and that of the step 1114 has not, the value of the variable h_running is equal to 1 so that, in these conditions, the value of Th_ref1 calculated in the step 1221b cannot be less than the torque requested by the driver.

Moreover, the outcome of the task 1222 is that if the filtered value Th_ref_int of the torque requested by the driver exceeds the threshold Thmax of the torque able to be supplied by the heat engine, the electric engine is required in the step 1222h to supply the lacking torque, and this within the limits of the capabilities of the electric engine and the battery.

There now follows a description, with reference to figures 4A to 4H, more particularly of a second strategy for managing a hybrid vehicle according to the invention intended more specifically for a series type hybrid vehicle. This second strategy uses a series of variables that are listed and explained in the table below.

Notation	**Meaning**	**Units**

Trequested or Treq	Torque requested by the driver (positive for acceleration, negative for deceleration)	Nm
Te_ref	Torque set point of the electric engine (positive for traction, negative for regenerative braking)	Nm
Difference T	Difference between Tref and Trequested	Nm
Service_ difference	Filtered value of Difference_T	Nm
Difference soc	Difference between soc and soc ref	%
GE_requested	Request to start or stop the heat engine for driving the electricity generator	Boolean
Ibat	Current output by the battery (discharge: positive, charge: negative)	A
Ige	Current output by the electricity generator (positive)	A
Mode_selected	Operating mode selected by the driver (electric, hybrid or regeneration)	-
N	Rotation speed of the electric engine	rad/s
Pbat_requested	Power requested of the traction battery (discharge: positive, charge: negative)	W
Pbat possible	Proportion of Pbat requested that the battery can supply	W
PbatmaxD	Maximum discharge power of the traction battery (positive)	W
PbatmaxR	Maximum charge power of the traction battery (negative)	W
Pel	Power absorbed by the electric engine (traction: positive, regenerative braking: negative)	W
Pel requested	Electrical power required to supply Crequested	W
Pel filterA	Rapid response time filtered value of Pel	W
Pel_filterB	Slow response time filtered value of Pel	W
Pel possible	Proportion of Pel requested that the system can supply	W
Pge reqA	Intermediate estimate of the Pge ref value	W
Pge_reqB	Value of the power requested of the electricity generator determining Stop GE requested and start GE requested	W
Pge max	Maximum power that the electricity generator can supply	W
Pge min	Minimum power that the electricity generator can supply	W
Pge ref	Power set point of the electricity generator	W
Pmec	Mechanical power supplied by the electric engine	W
Pmec_requested	Mechanical power to be supplied corresponding to Trequested	W

Pmin	Absolute value threshold of the power below which R is not calculated	W
Pengine_max	Maximum power that the electric engine can absorb or restore	W
R	Efficiency of the electric engine used as a generator	-
R filter	Filtered value of R	-
soc	State of charge of the traction battery	%
soc ref	Reference state of charge of the traction battery	%
U	Traction battery voltage	%

As can be seen in figure 4A, the central management unit of the powertrain assembly is required to execute three main tasks. The first 2100 of these tasks consists in this case in determining the torque set point of the electric engine. It is executed, for example, every 40 milliseconds, that is, at a frequency of 25 hertz. The second task 2200, which consists in deciding to start or stop the heat engine, is executed in parallel. Its interval is one second and its frequency is 1 hertz.

There is also a third main task 2300, which is also executed in parallel, and during which the power set point of the electricity generator Pge_ref is determined. Its execution period is, for example, 500 milliseconds, corresponding to a frequency of 2 hertz to take account of the inertia of the assembly formed by the heat engine and the generator.

The first of these main tasks is described with reference to figure 4B. As can be seen in this figure, the task 2100 for determining the torque set point of the electric engine Te_ref begins with the execution of the sub-task 2110 for calculating the necessary electrical power Pel_requested.

This sub-task is described with reference to figure 4C. First of all, in the step 2111, the value Pel of the power absorbed by the electric engine is determined.

This power is positive when the engine is driving the vehicle and is negative when, during a slowing down of the vehicle, the electric engine is used as a generator to charge the battery 16. This value Pel is equal to the voltage of the electrical power supply network multiplied by the sum of the currents supplied by the battery on the one hand and by the electricity generator on the other hand.

In the step 2112, the mechanical power supplied by the electric engine Pmec is defined as being the product of the set-point torque Te_ref multiplied by the rotation speed N of the electric engine 12. In the step 2113, the mechanical power requested Pmec_requested is defined as being equal to the torque Trequested by the driver multiplied by the rotation speed N of the electric engine. In the step 2114, it is determined whether the absolute value of the mechanical power Pmec is greater than a threshold value Pmin. If it is, in the step 2115, an efficiency of the electric engine is defined which is equal to the absolute value of the ratio of the electrical power Pel divided by the mechanical power Pmec. If not, the value of this efficiency is set arbitrarily to 1 in the step 2116.

In the step 2117, a filtered value R_filter of this efficiency is determined, for example using a first order filter.

In the step 2118, the electrical power requested Pel_requested is determined as being the product of the filtered value of the efficiency multiplied by the mechanical power requested.

The execution of the task 2100 for determining the torque set-point for the electric engine is then continued in the step 2101 during which a check is made to see whether the absolute value of the electrical power requested is greater than a threshold level Pmin

If not, the set-point torque Te_ref is set to be equal to the torque requested by the driver. If it is, the power Pge supplied by the generator is first of all determined. If the latter is outputting a current Ige, this power is U times Ige.

In the step 2103, the traction power that the battery 16 must supply is calculated. This value Pbat_requested is equal to the electrical power needed to supply the torque requested minus the power supplied by the generator. In the step 2104, the power able to be supplied by the battery is determined as being the minimum value between the two following two values:

- the maximum discharge power of the battery (PbatmaxD) and

- the minimum value between:

  * the power requested of the battery (Pbat_requested);

  * the maximum charge power of the battery (PbatmaxR).

In the step 2105, the electrical power that the system must supply is then determined, this value being the smaller of the following two values:

- the maximum power of the heat engine Pengine_max; and

- the sum of the power able to be supplied by the battery (Pbat_possible) and the power supplied by the generator Pge.

Then, in the step 2106, the reference torque Te_ref is determined as being the product of the torque requested by the driver multiplied by the ratio of the electrical power that the system can supply divided by the electrical power requested.

The second main task 2200 of this second hybrid vehicle management strategy consists in deciding to start or stop the heat engine. As can be seen in figure 4C, this task 2200 begins with the execution of the task 2310 to calculate the charge power of the battery which is illustrated in figure 4G. As can be seen in this figure, in the steps 2312, 2313, 2314, a reference state of charge Soc_ref is determined according to the operating mode selected by the driver of the vehicle. In the step 2315, a difference value between this reference state of charge Soc_ref and the real state of charge is determined. In the step 2316, the battery power requested is defined as being a filtered value of this difference, for example using a first order filter.

However, in the step 2317, a check is made to ensure that this calculated battery charge power value does not exceed the limiting battery charge and discharge powers, in which case the battery charge power is forced to one of these limit values.

The task for deciding to start (4D) or stop the heat engine then continues at step 2201 in which the electrical power Pel is determined in the same way as seen above in the step 2111. This electrical power is filtered by a first order filter to obtain, in the step 2202, the variable Pel_filterB.

A calculation is then made to work out the difference between the torque requested by the driver and the torque actually applied to the drive wheels by the electric engine. This calculation of the value service_difference is the subject of the task 2210 illustrated in figure 4E in which it can be seen that this value is obtained by filtering, through a first order filter, the difference between the torque requested by the driver Trequested and the torque supplied by the electric engine Te_ref.

The task for deciding to start or stop the heat engine continues with the step 2203 by determining the value of the power requested of the electricity generator Pge_reqB. This value is equal to the weighted sum of the previously calculated values Pbat_requested, Pel_filterB and Service_difference. In the step 2204, a check is made to see whether this value Pge_reqB is greater than a threshold value Pge_min and if, at the same time, the operating mode selected by the driver is other than the electric engine mode. If this dual condition is satisfied, then the boolean variable GE_requested is forced to the value "true" and the heat engine is then started to supply the electric current. If not, if the dual condition of the step 2204 is not satisfied, the variable GE_requested is forced to the value "false" in the step 2206 so that the heat engine is ordered to stop.

When the heat engine is started, it is then possible to control it so that it drives the electricity generator so that the latter produces a sufficient power. To this end, in the task 2300, a power set point value of the electricity generator Pge_ref is calculated. This task, illustrated in figure 4F, begins with execution of the lower level task 2310 which was described previously and consists in calculating the battery charge power. Then, in the step 2301, the electrical power Pel absorbed by the electric engine is calculated, in the same way as was seen in the steps 2201 and 2111. This value is then filtered in the step 2302, for example via a first-order filter, to give an intermediate value Pel_filterA. In the step 2303, the weighted sum Pge_reqA of the battery charge power Pbat_requested is determined with the value Pel_filterA calculated in the step 2302. In the step 2304, the set-point power of the electricity generator Pge_ref is defined as being the smaller of the value Pge_reqA, calculated in the step 2303, and the maximum power able to be supplied by the generator Pge_max.

As can be seen in the steps 2203, 2204, 2205 and 2206, the decision to start the heat engine depends in particular on the following three parameters:

- the state of charge of the battery, because the value Pbat_requested is calculated in particular according to the difference between the real state of charge of the battery and a reference state of charge (see steps 2315, 2316, 2317);

- the motive torque requested, because the value Service_difference depends naturally on this requested torque (see steps 2211 and 2212); and

- the difference between the service supplied by the system and that requested by the driver.

CLAIMS

1. A motor vehicle with hybrid motorization, of the type in which a powertrain assembly comprises an electric engine (12) and a heat engine (10) which are able to contribute to the driving of the vehicle, and of the type in which a central management unit executes a first task (1200, 2100) comprising determining the torque that each engine must supply for the powertrain assembly to supply the vehicle with a motive torque conforming to a torque requested (Trequested) by the driver of the vehicle, and of the type wherein the heat engine (10) is able to be stopped, the vehicle then being driven only by the electric engine (12) powered by electric current from a battery (16),
characterized in that, at least for certain (hybrid) operating modes of the powertrain assembly, the central unit executes a second task (1100, 2200) during which it is decided to stop or start the heat engine, in that the first task and the second task are executed in parallel and in that the frequency of execution of the second task is less than that of the first task.

2. The motor vehicle as claimed in claim 1, characterized in that the driver can impose on the powertrain assembly an electric operating mode in which the heat engine (10) is stopped.

3. The motor vehicle as claimed in either of the preceding claims, characterized in that the driver can impose on the powertrain assembly a regeneration operating mode in which the heat engine (10) is used in particular to charge the battery (16).

4. The motor vehicle as claimed in any one of the preceding claims, characterized in that the driver can impose on the powertrain assembly a hybrid operating mode in which the central unit executes the second task during which it is decided to stop or start the heat engine.

5. The motor vehicle as claimed in claim 4, characterized in that the decision to stop or start the heat engine (10) is taken in particular according to a state of charge (battery_gauge, soc) of the battery (16).

6. The motor vehicle as claimed in claim 5, characterized in that the starting of the heat engine (10) is decided or confirmed when the state of charge (battery_gauge) of the battery (16) is less than a low threshold level (gauge_low_threshold), and in that the stopping of the heat engine (10) is able to be decided or confirmed when the state of charge of the battery is greater than a high threshold level (gauge_low_threshold).

7. The motor vehicle as claimed in any one of claims 4 to 6, characterized in that the decision to stop or start the heat engine (10) is taken in particular according to the instantaneous torque (Trequested_filter1) requested by the driver.

8. The motor vehicle as claimed in any one of claims 4 to 7, characterized in that the decision to stop or start the heat engine (10) is taken in particular according to the average torque (Trequested_filter2) requested by the driver during a predetermined time interval preceding the decision.

9. The motor vehicle as claimed in claim 7 taken in combination with claim 8, characterized in that the starting of the heat engine (10) is decided or confirmed when the instantaneous torque (Trequested_filter1) requested by the driver is greater than a high threshold level (Thigh), and in that the stopping of the heat engine (10) is able to be decided or confirmed when the instantaneous torque (Trequested_filter1) and the average torque (Trequested_filter2) requested by the driver are less than a low threshold level (Tlow).

10. The motor vehicle as claimed in claim 6 taken in combination with claim 9, characterized in that the stopping of the heat engine (10) is decided or confirmed when, at the same time, the state of charge (battery_gauge) of the battery (16) is greater than a high threshold level (gauge_high_threshold) and the instantaneous torque (Trequested_filter1) and the average torque (Trequested_filter2) requested by the driver are less than a low threshold level (Tlow).

11. The motor vehicle as claimed in any one of claims 4 to 10, characterized in that the decision to stop or start the heat engine (10) is taken in particular according to a difference (Service_difference) between the torque requested (Trequested) by the driver and the torque actually supplied by the powertrain assembly.

12. The motor vehicle as claimed in any one of the preceding claims taken in combination with at least one of claims 2 to 4, characterized in that, during operation of the operating mode selected by the driver, a charge set point level (soc_ref) of the battery (16) is fixed

13. The motor vehicle as claimed in any one of the preceding claims, characterized in that the powertrain assembly is a series hybrid assembly in which the drive wheels of the vehicle are driven exclusively by the electric engine (12) which is powered by electric current from the battery (16) which is charged by a generator (16) driven by the heat engine (10).

14. The motor vehicle as claimed in claim 13 taken in combination with claim 12, characterized in that the electrical power (Pbat_requested) to be supplied to the battery (16) is determined according to a difference (Difference_soc) between the real (soc) and reference (soc_ref) states of charge of the battery, taking into account limiting charge (PbatmaxR) and discharge (PbatmaxD) power values of the battery (16).

15. The motor vehicle as claimed in claim 14, characterized in that the starting of the heat engine (10) is determined according to the electrical power (Pbat_requested) to be supplied to the battery (16), the electrical power absorbed (Pel_filterB) by the electric engine (12) and according to a difference (Service_difference) between the value of the torque requested by the driver and the value of the torque supplied by the electric engine (12).

16. The motor vehicle as claimed in claim 14 or 15, characterized in that a set point level (Pge_ref) for the power supplied by the generator (26) is determined according to the real power (U*Ige) supplied by the generator (26), the real power (U*Ibat) supplied by the battery (16), and the power (Pbat_requested) to be supplied to the battery (16), taking into account the maximum

power (Pge_max) able to be supplied by the generator (26).

17. The motor vehicle as claimed in any one of the preceding claims 13 to 15, characterized in that a necessary electrical power (Pel_requested) is determined according to the motive torque (Crequested) requested by the driver, taking into account, at least when this torque is greater as an absolute value than a minimum value, the efficiency of the electric engine (R).

18. The motor vehicle as claimed in claim 16, characterized in that a set point value (Tref) for the torque supplied by the electric engine (12) is determined according to the motive torque requested by the driver multiplied, at least when the necessary electrical power (Pel_requested) is greater as an absolute value than a threshold value (Pmin), by the ratio of the electrical power (Pel_possible) able to be supplied to the electric engine (12) divided by the necessary electrical power (Pel_possible), the electrical power (Pel_possible) able to be supplied to the electric engine (12) taking into account the necessary electrical power (Pel_requested), the real power (Pge) supplied by the generator, the power (Pbat_possible) able to be supplied by the battery (16), and the maximum power (Pengine_max) able to be absorbed by the engine.

19. The motor vehicle as claimed in any one of claims 1 to 12, characterized in that the powertrain assembly is a parallel hybrid assembly in which the electric engine (12) and the heat engine (10) each drive either at least one and the same drive wheel or different drive wheels.

20. The motor vehicle as claimed in claim 19 taken in combination with claim 3, characterized in that when the powertrain assembly is operating in regeneration mode, the electric engine (10) delivers a motive torque only if the driver provokes an abrupt rise in the requested torque (kickdown).

21. The motor vehicle as claimed in either of claims 19 and 20, taken in combination with claim 3, characterized in that when the powertrain assembly is operating in regeneration mode, the heat engine (10) is ordered to supply a maximum torque (Th_maximum).

22. The motor vehicle as claimed in any one of claims 19 to 21 taken in combination with claim 4, characterized in that when the powertrain assembly is operating in hybrid mode and the state of charge (battery_gauge) of the battery (16) has previously fallen below a low threshold level (gauge_low_threshold) and has not yet exceeded a high threshold level (gauge_high_threshold), the heat engine (10) is ordered to supply a set point torque (Th_ref1) at least equal to an optimum torque (Th_optimal) corresponding to optimal efficiency conditions of the heat engine.

23. The motor vehicle as claimed in any one of the preceding claims 19 to 22 taken in combination with claim 4, characterized in that when the powertrain assembly is operating in hybrid mode and the instantaneous torque (Trequested_filter1) requested by the driver has previously risen above a high threshold level (Thigh) without returning below a low threshold level (Tlow) at the same time as the average level (Trequested_filter2) is less than the low threshold level (Tlow), the heat engine (10) is ordered to supply a set point

torque at least equal to a filtered value of the torque requested by the driver.

24. The motor vehicle as claimed in any one the preceding claims 19 to 23, characterized in that, if a filtered value (Th_ref_int) of the torque requested by the driver is greater than the maximum torque (Th_max) of the heat engine (10), the electric engine (12) is required to supply, wherever possible, the quantity of torque lacking (Treq - Thref).

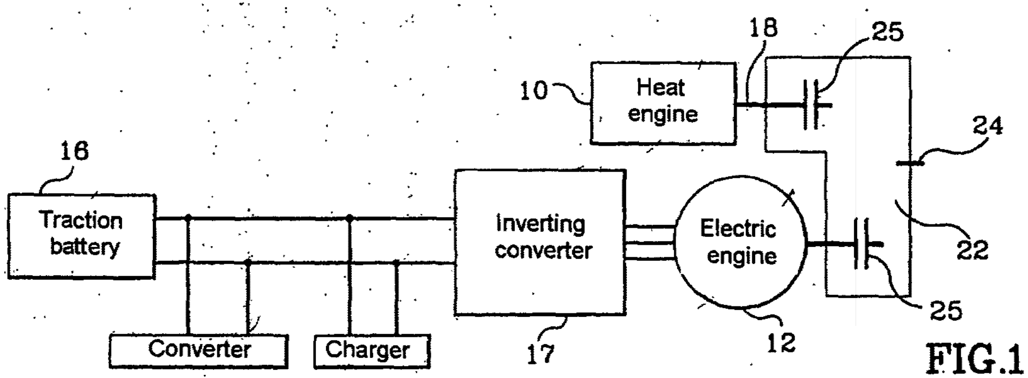


FIG.1

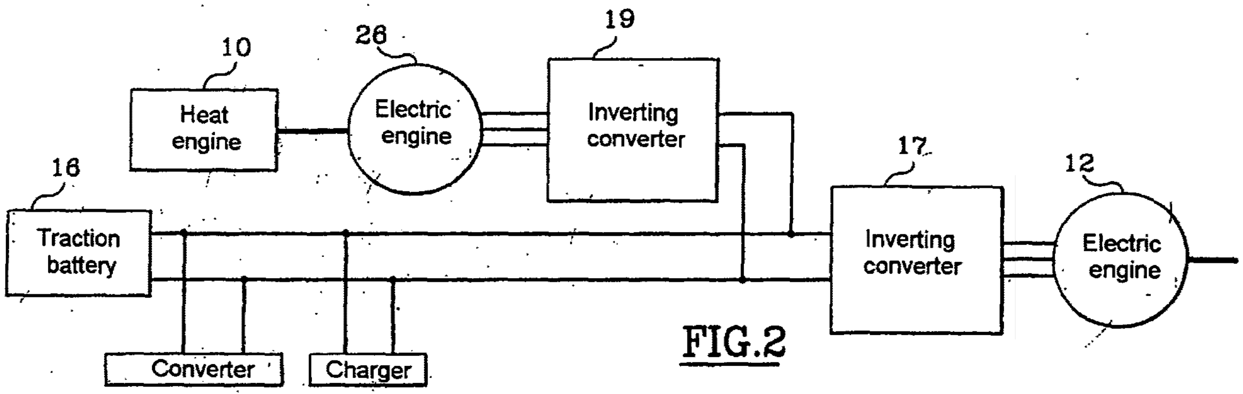


FIG.2

REPLACEMENT SHEET (RULE 26)

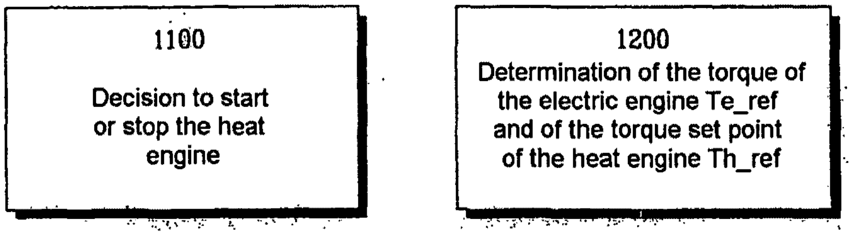

1100
Decision to start or stop the heat engine
1200
Determination of the torque of the electric engine Te_ref and of the torque set point of the heat engine Th_ref

FIG.3A

Trequested = torque required by driver

is engine running?

is engine charging battery?

is ICE stopping charging battery?

can ICE deliver torque?

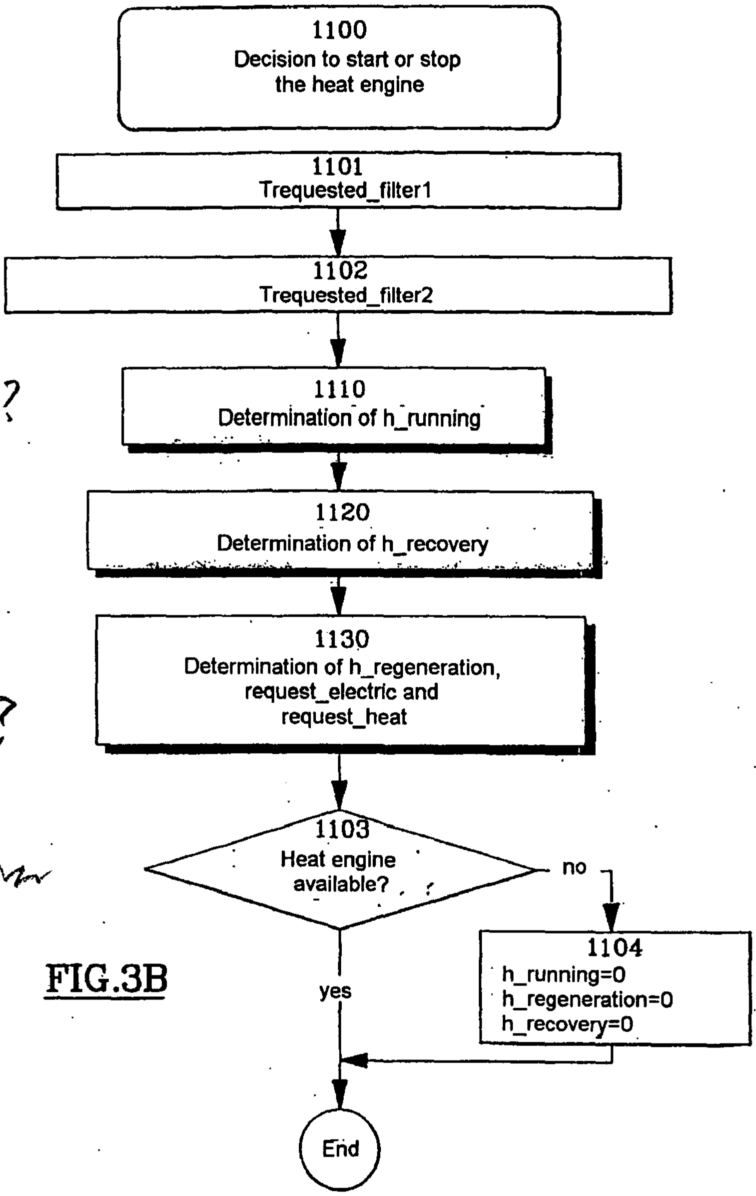


FIG.3B

ICE run between
these values

Tlow + Thigh => det. by SoC

14: 1° - why?

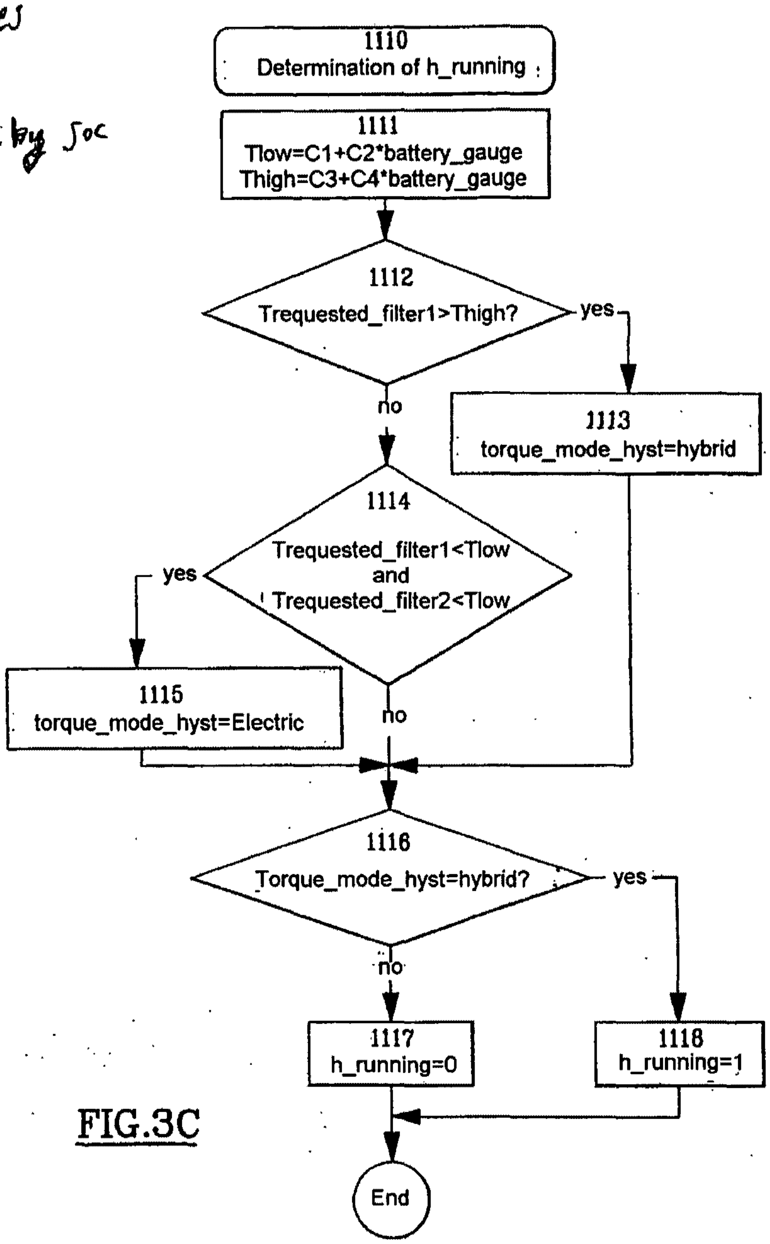


FIG.3C

whether engine is to charge battery

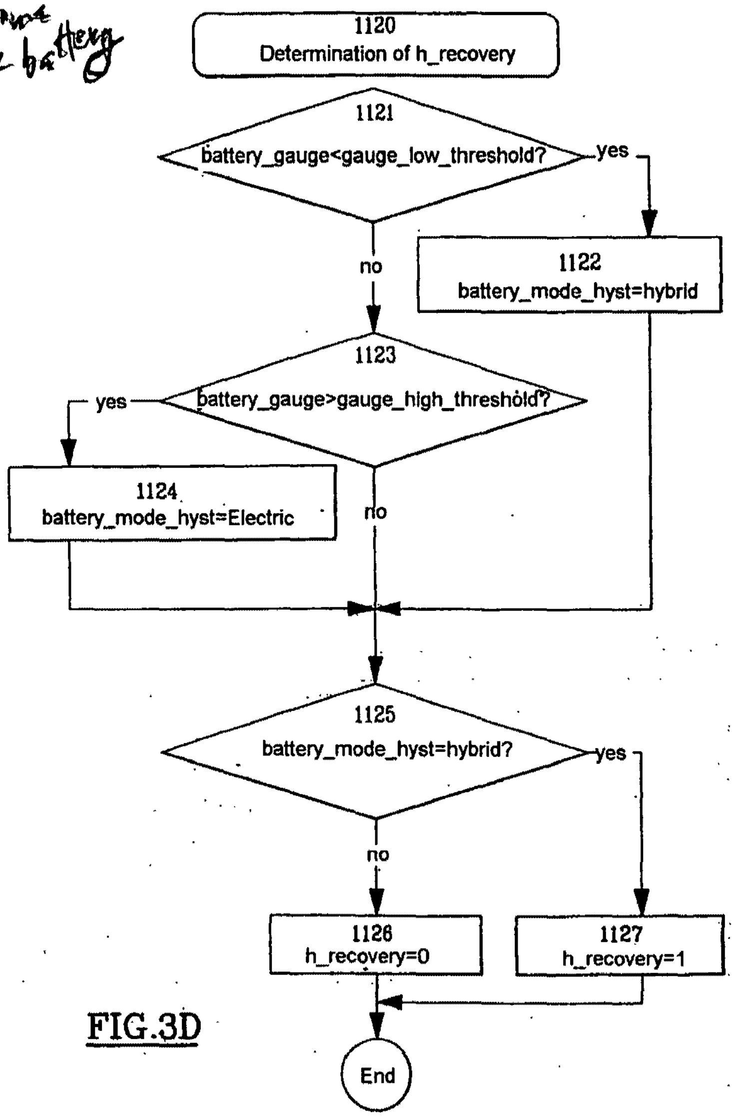
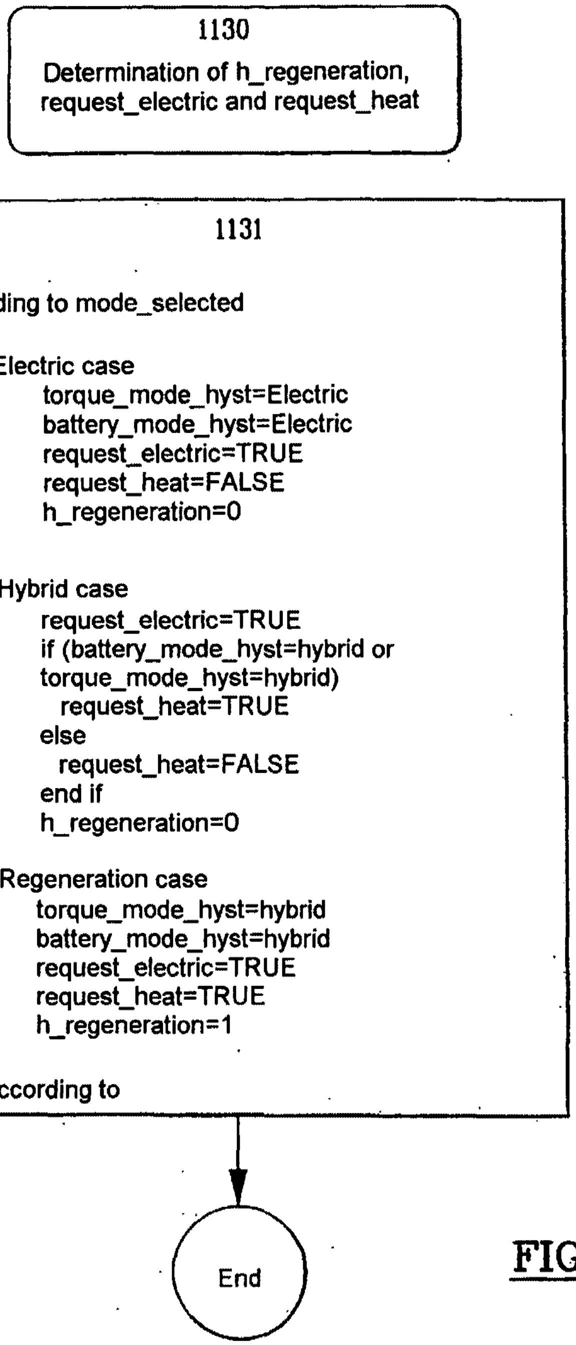


FIG.3D



```
according to mode_selected

      Electric case
           torque_mode_hyst=Electric
           battery_mode_hyst=Electric
           request_electric=TRUE
           request_heat=FALSE
           h_regeneration=0


      Hybrid case
           request_electric=TRUE
           if (battery_mode_hyst=hybrid or
           torque_mode_hyst=hybrid)
             request_heat=TRUE
           else
             request_heat=FALSE
           end if
           h_regeneration=0

      Regeneration case
           torque_mode_hyst=hybrid
           battery_mode_hyst=hybrid
           request_electric=TRUE
           request_heat=TRUE
           h_regeneration=1

end according to
```

FIG.3E

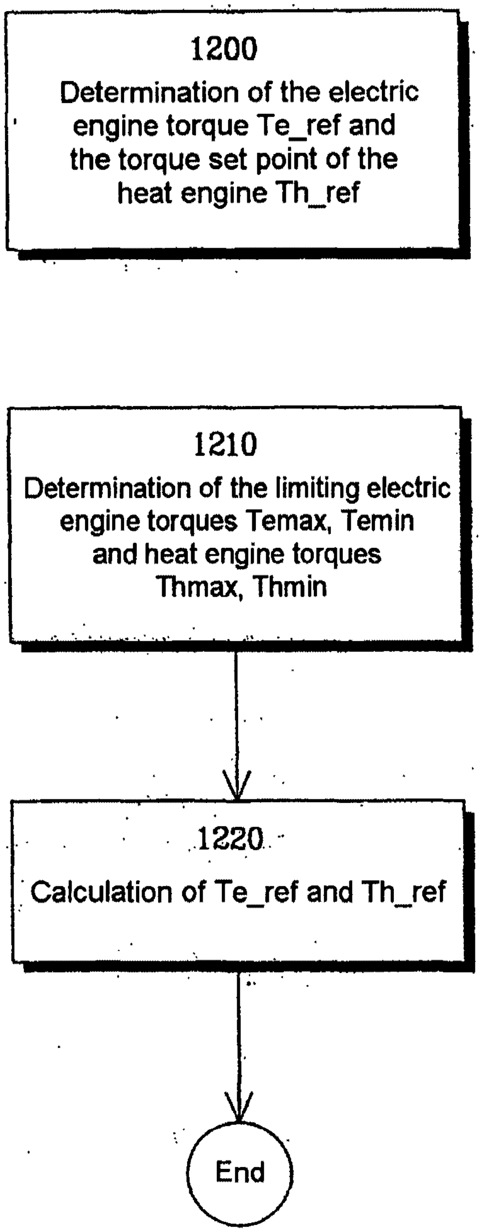
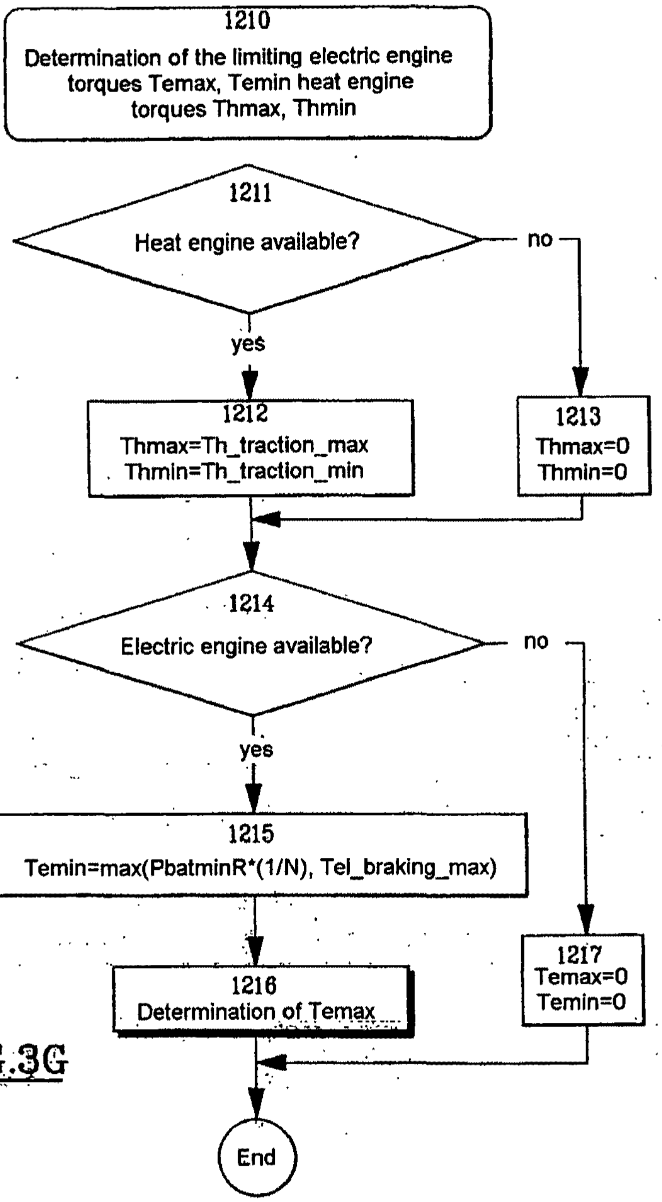

1200
Determination of the electric engine torque Te_ref and the torque set point of the heat engine Th_ref
1210
Determination of the limiting electric engine torques Temax, Temin and heat engine torques Thmax, Thmin
1220
Calculation of Te_ref and Th_ref
End

FIG.3F



1210
Determination of the limiting electric engine torques Temax, Temin heat engine torques Thmax, Thmin
1211
Heat engine available?
no
yes
1212
Thmax=Th_traction_max
Thmin=Th_traction_min
1213
Thmax=0
Thmin=0
1214
Electric engine available?
no
yes
1215
Temin=max(PbatminR*(1/N), Tel_braking_max)
1216
Determination of Temax
1217
Temax=0
Temin=0
End

FIG.3G

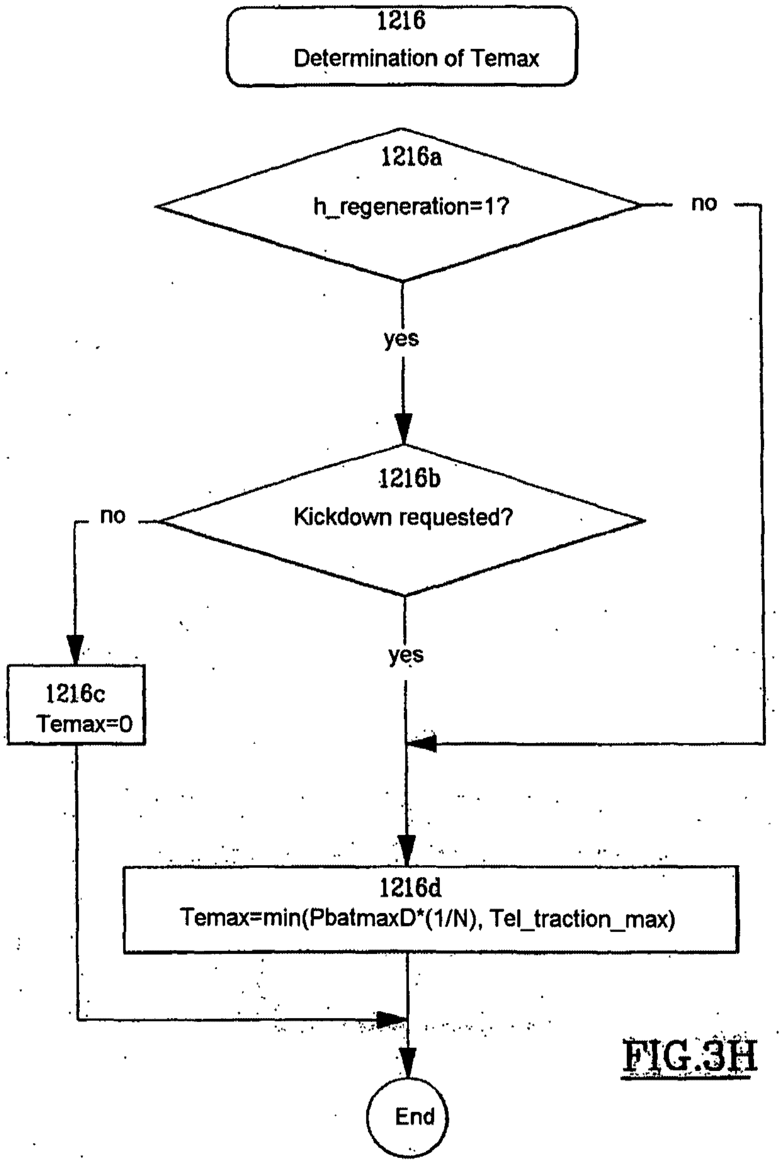

1216
Determination of Temax
1216a
h_regeneration=1?
no
yes
1216b
Kickdown requested?
no
yes
1216c
Temax=0
1216d
Temax=min(PbatmaxD*(1/N), Tel_traction_max)
End

FIG.3H

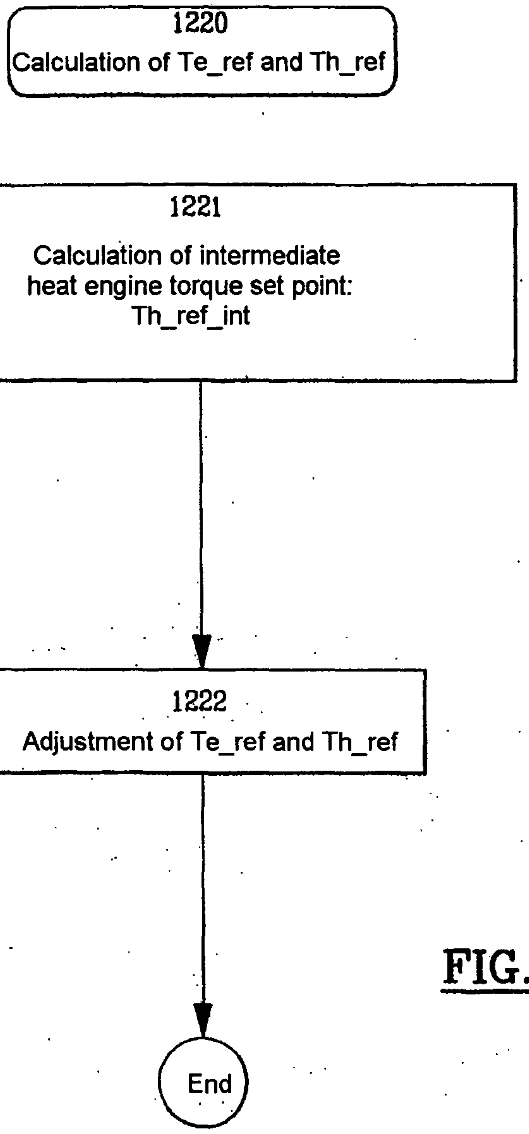

1220
Calculation of Te_ref and Th_ref
1221
Calculation of intermediate heat engine torque set point: Th_ref_int
1222
Adjustment of Te_ref and Th_ref
End

FIG.3I

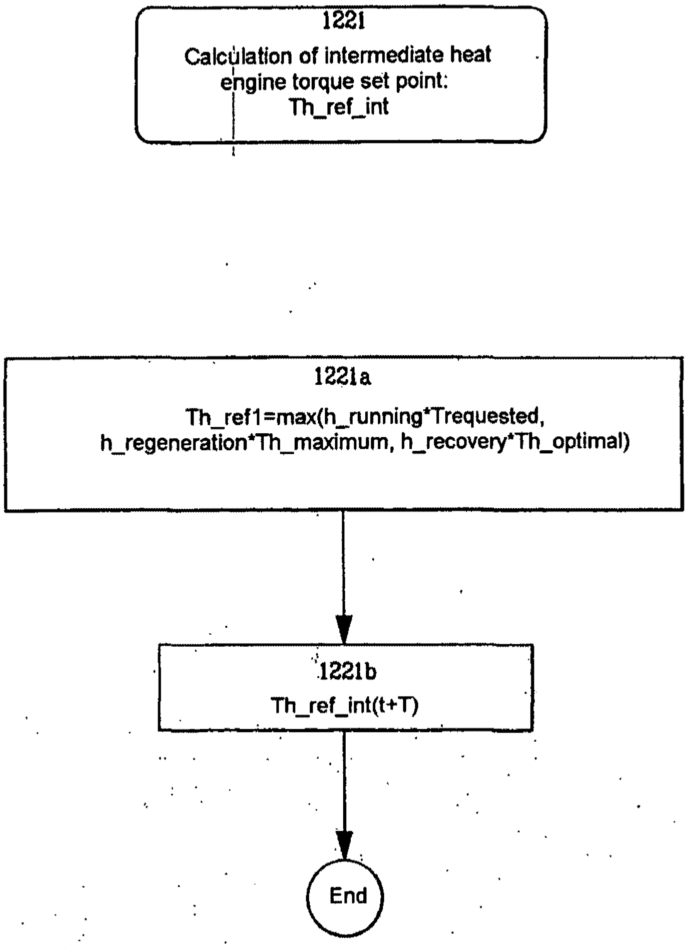

1221
Calculation of intermediate heat engine torque set point: Th_ref_int
1221a
Th_ref1=max(h_running*Trequested, h_regeneration*Th_maximum, h_recovery*Th_optimal)
1221b
Th_ref_int(t+T)
End

FIG.3J

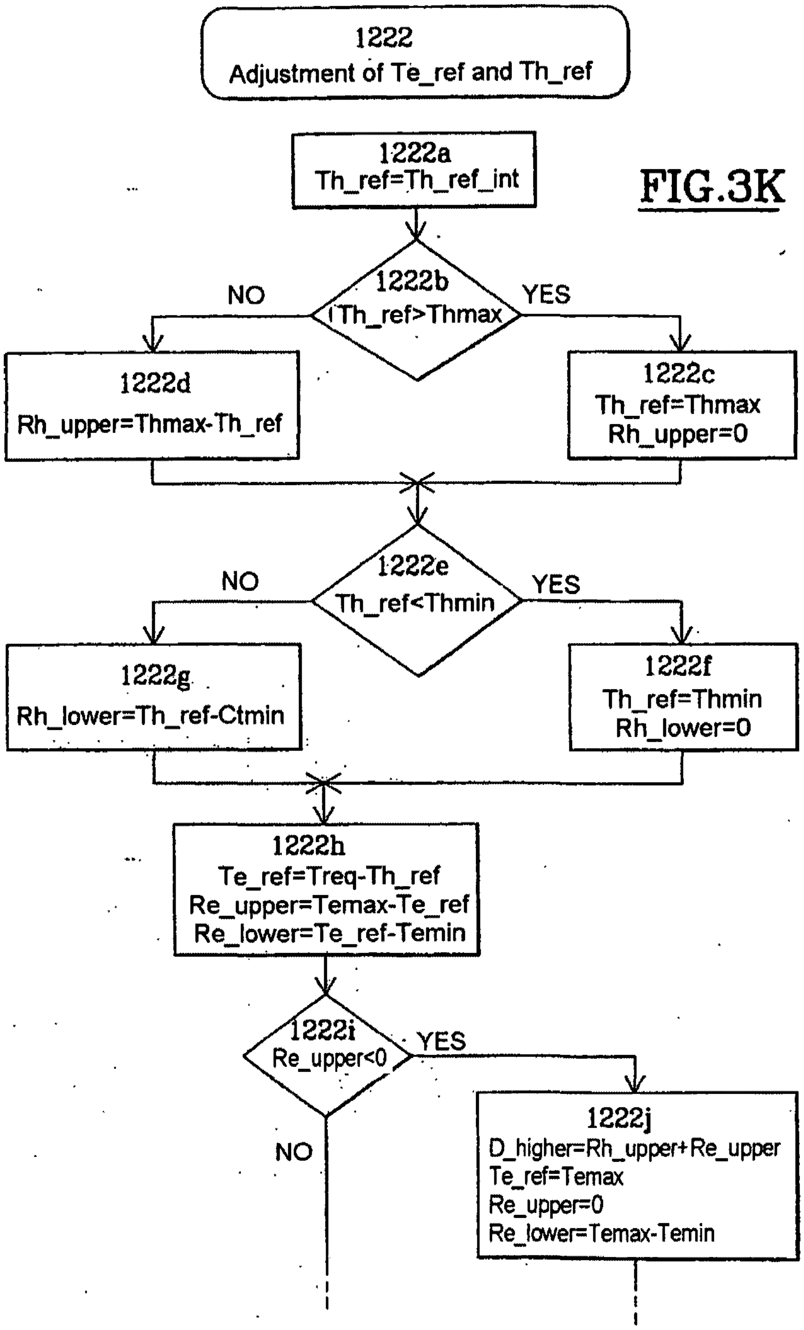
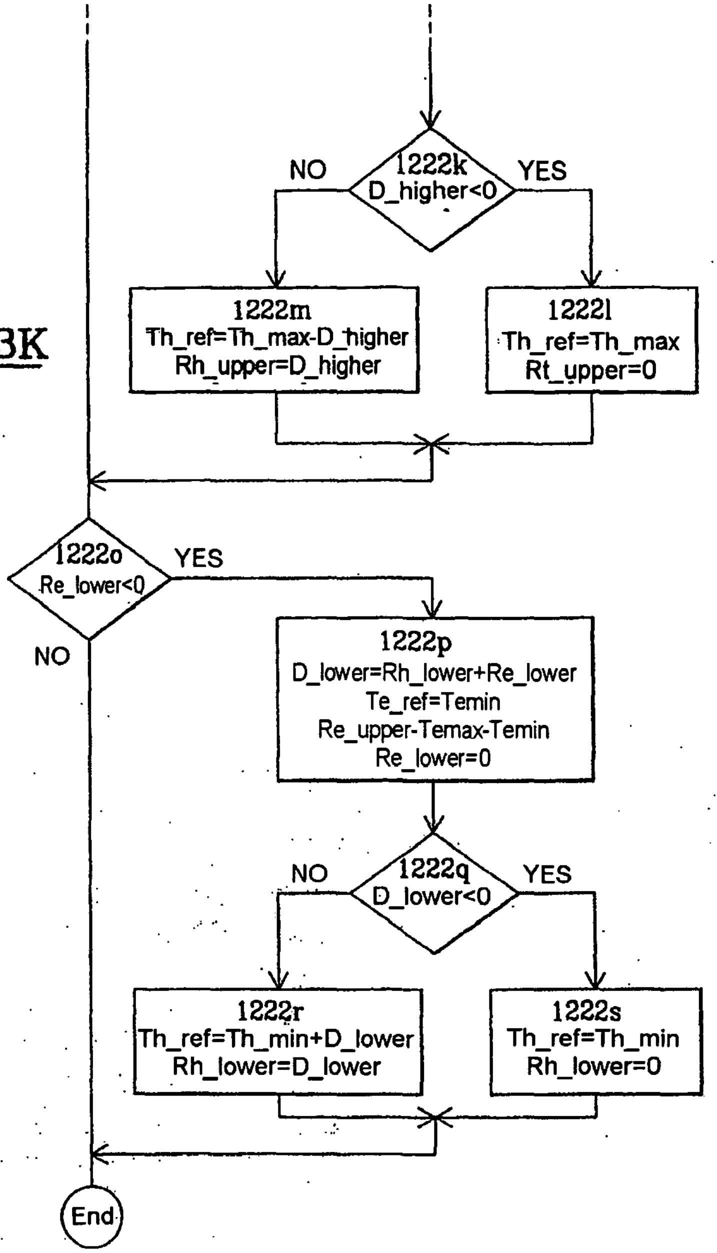

1222
Adjustment of Te_ref and Th_ref
1222a
Th_ref=Th_ref_int
1222b
Th_ref>Thmax
NO
YES
1222d
Rh_upper=Thmax-Th_ref
1222c
Th_ref=Thmax
Rh_upper=0
1222e
Th_ref<Thmin
NO
YES
1222g
Rh_lower=Th_ref-Ctmin
1222f
Th_ref=Thmin
Rh_lower=0
1222h
Te_ref=Treq-Th_ref
Re_upper=Temax-Te_ref
Re_lower=Te_ref-Temin
1222i
Re_upper<0
YES
NO
1222j
D_higher=Rh_upper+Re_upper
Te_ref=Temax
Re_upper=0
Re_lower=Temax-Temin

FIG.3K

FIG.3K


1222k
D_higher<0
NO
YES
1222m
Th_ref=Th_max-D_higher
Rh_upper=D_higher
1222l
Th_ref=Th_max
Rt_upper=0
1222o
Re_lower<0
YES
NO
1222p
D_lower=Rh_lower+Re_lower
Te_ref=Temin
Re_upper-Temax-Temin
Re_lower=0
1222q
D_lower<0
NO
YES
1222r
Th_ref=Th_min+D_lower
Rh_lower=D_lower
1222s
Th_ref=Th_min
Rh_lower=0
End

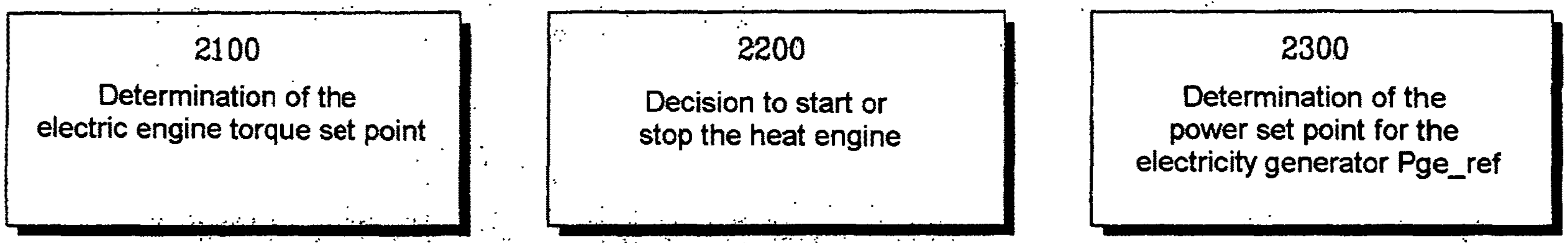
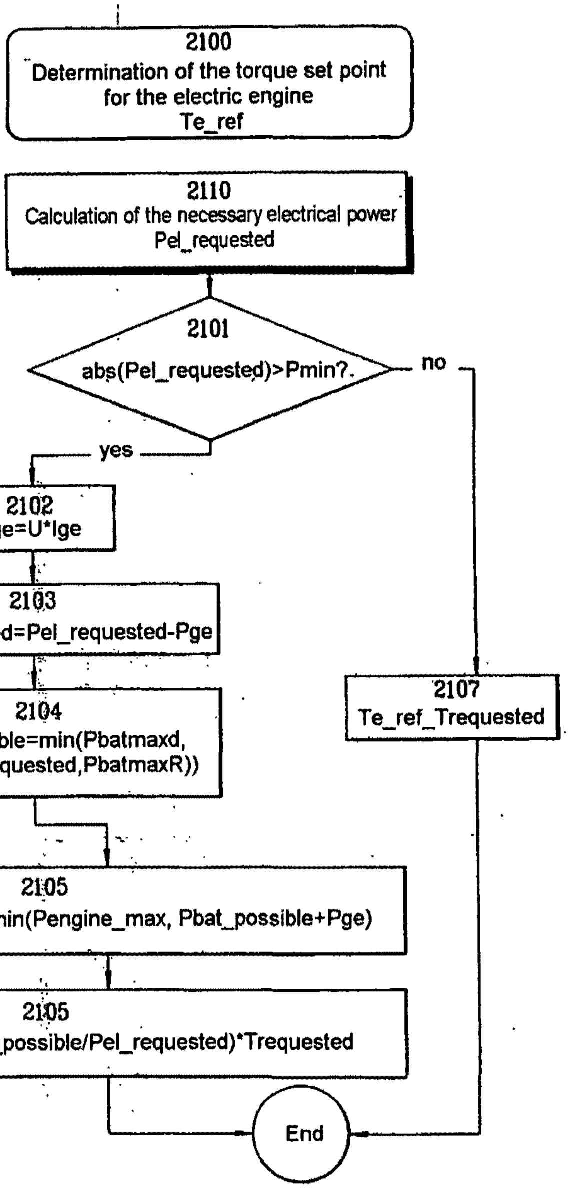

2100
Determination of the electric engine torque set point
2200
Decision to start or stop the heat engine
2300
Determination of the power set point for the electricity generator Pge_ref

FIG.4A

FIG.4B


2100
Determination of the torque set point for the electric engine Te_ref
2110
Calculation of the necessary electrical power Pel_requested
2101
abs(Pel_requested)>Pmin?.
no
yes
2102
Pge=U*Ige
2103
Pbat_requested=Pel_requested-Pge
2104
Pbat_possible=min(Pbatmaxd, max(Pbat_requested,PbatmaxR))
2105
Pel_possible=min(Pengine_max, Pbat_possible+Pge)
2105
Te_ref=(pel_possible/Pel_requested)*Trequested
2107
Te_ref_Trequested
End

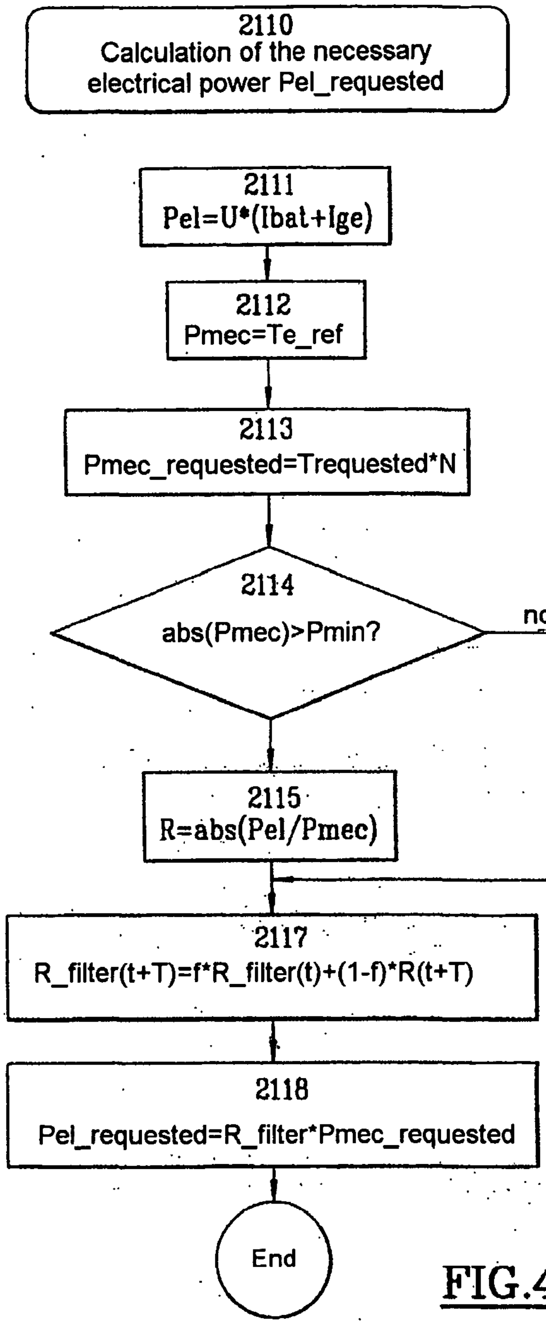

2110
Calculation of the necessary electrical power Pel_requested
2111
Pel=U*(Ibat+Ige)
2112
Pmec=Te_ref
2113
Pmec_requested=Trequested*N
2114
abs(Pmec)>Pmin?
no
2115
R=abs(Pel/Pmec)
2116
R=1
2117
R_filter(t+T)=f*R_filter(t)+(1-f)*R(t+T)
2118
Pel_requested=R_filter*Pmec_requested
End

FIG.4C

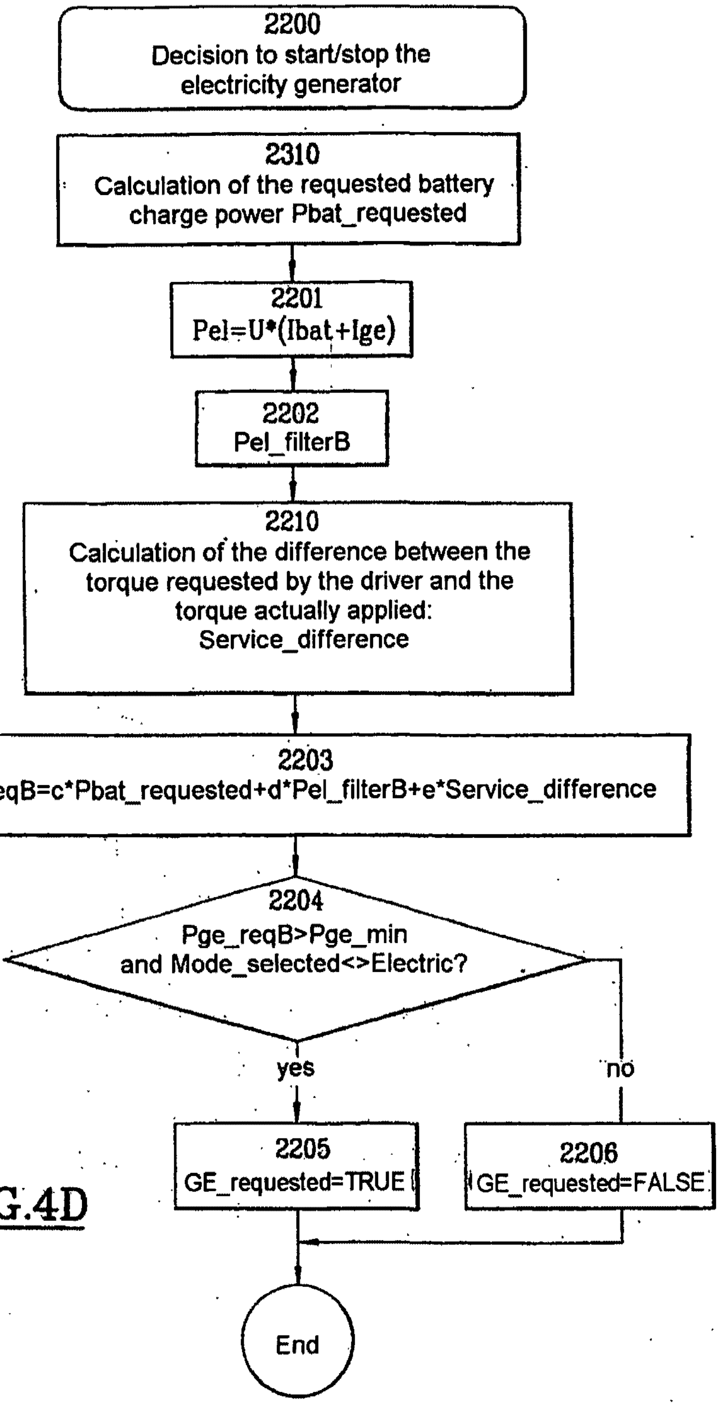

2200
Decision to start/stop the electricity generator
2310
Calculation of the requested battery charge power Pbat_requested
2201
Pel=U*(Ibat+Ige)
2202
Pel_filterB
2210
Calculation of the difference between the torque requested by the driver and the torque actually applied: Service_difference
2203
Pge_reqB=c*Pbat_requested+d*Pel_filterB+e*Service_difference
2204
Pge_reqB>Pge_min and Mode_selected<>Electric?
yes
no
2205
GE_requested=TRUE
2206
GE_requested=FALSE
End

FIG.4D

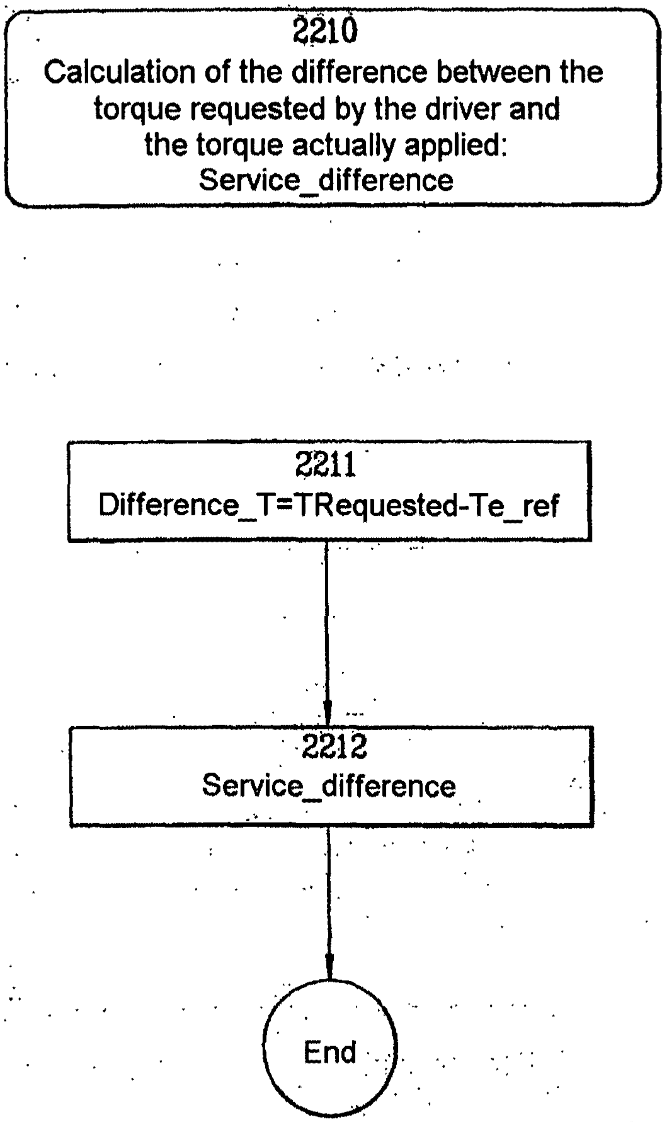

2210
Calculation of the difference between the torque requested by the driver and the torque actually applied: Service_difference
2211
Difference_T=TRequested-Te_ref
2212
Service_difference
End

FIG.4E

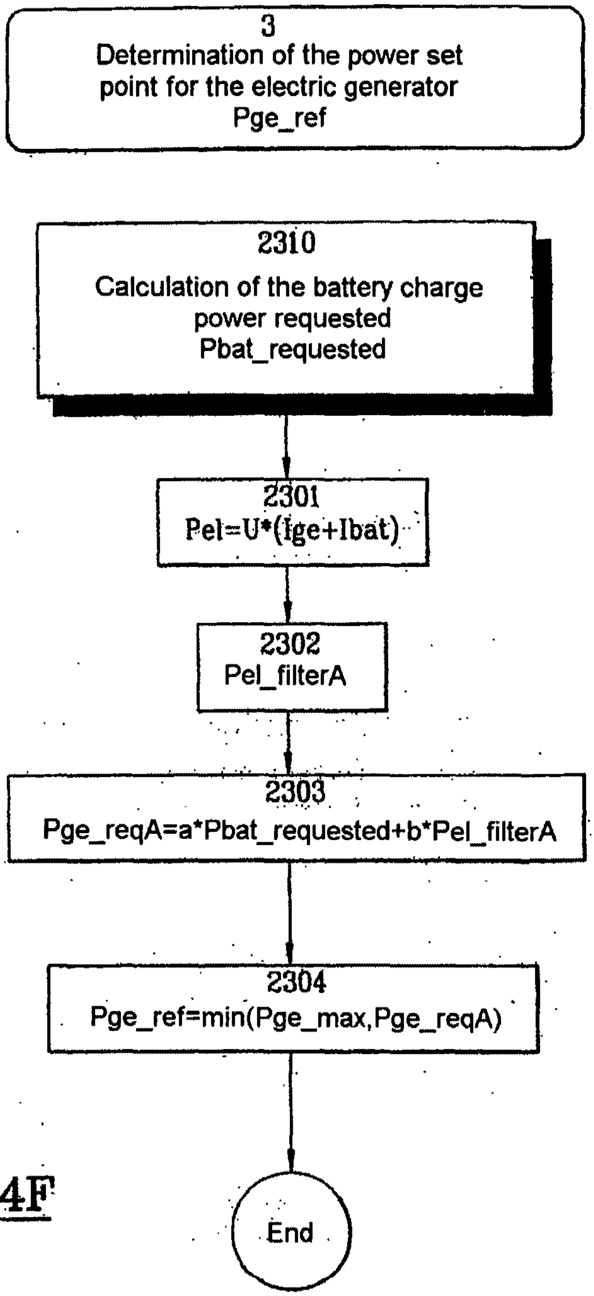

3
Determination of the power set point for the electric generator Pge_ref
2310
Calculation of the battery charge power requested Pbat_requested
2301
Pel=U*(Ige+Ibat)
2302
Pel_filterA
2303
Pge_reqA=a*Pbat_requested+b*Pel_filterA
2304
Pge_ref=min(Pge_max,Pge_reqA)
End

FIG.4F

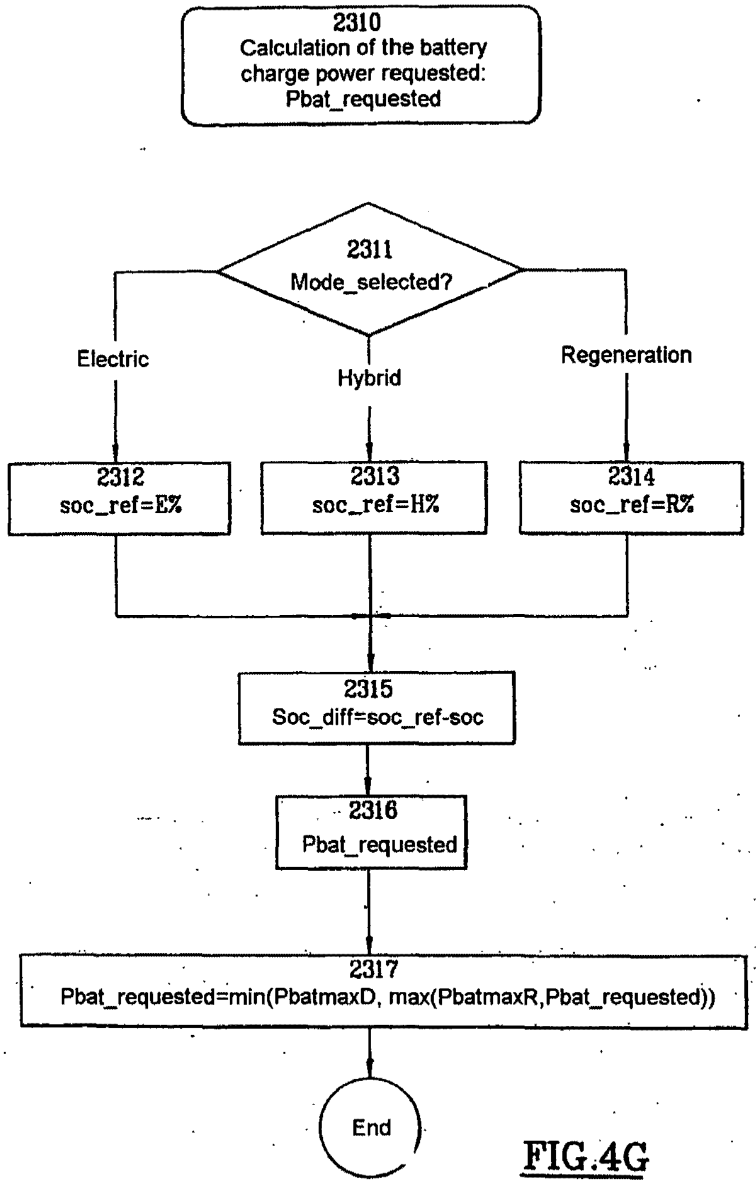

2310
Calculation of the battery charge power requested: Pbat_requested
2311
Mode_selected?
Electric
Hybrid
Regeneration
2312
soc_ref=E%
2313
soc_ref=H%
2314
soc_ref=R%
2315
Soc_diff=soc_ref-soc
2316
Pbat_requested
2317
Pbat_requested=min(PbatmaxD, max(PbatmaxR,Pbat_requested))
End

FIG.4G

Translator's Report/Comments

Your ref: P038141EP:REJ/GJS/CLM Your order of (date) 25/05/05

In translating the above text we have noted the following apparent errors/unclear passages:

Page/line*	Comment
4/26 5/7-8	"et en ce que l'arrêt..." should read "et l'arrêt ..."
12 (table)	"Seuil Faut de jauge" → "Seuil haut de jauge"
14/6	"valeur booléenne hyst_mode_couple" should read "variable booléenne ..."
14/11-12	"valeur booléenne th_roulage" should read "variable booléenne ..."
14/30	"la valeur th_récupération" should read "la variable th_récupération"
15/12	"variable « électrique »" should read "valeur « électrique »"
29/19	"seuil_jauge_bas" should perhaps read "seuil_jauge_haut"
5/21 30/25-26	"en fonctionnement du mode de ..." should perhaps read "en fonction du mode de ..."

* This identification refers to the source text. Please note that the first paragraph is taken to be, where relevant, the end portion of a paragraph starting on the preceding page. Where the paragraph is stated, the line number relates to the particular paragraph. Where no paragraph is stated, the line number refers to the page margin line number.

TRC1 1.7.92

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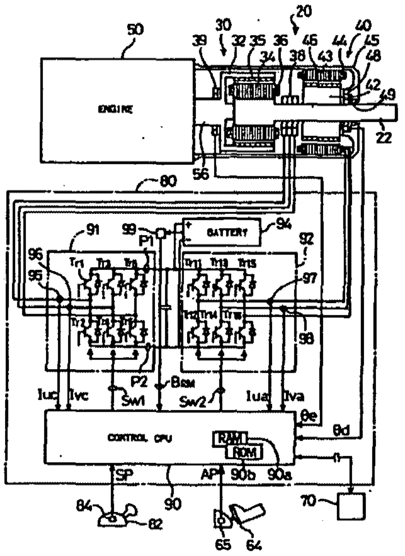
(54) Hybrid vehicle power output apparatus and method of controlling the same at engine idle

(57) A power output apparatus (20) of the invention includes an engine (50), a clutch motor (30), an assist motor (40), and a controller (80) for controlling the clutch motor (30) and the assist motor (40). In response to an engine stop signal to stop operation of the engine (50), the controller (80) successively lowers a torque command value of the clutch motor (30) and a target engine torque and a target engine speed of the engine (50) to make the engine (50) kept at an idle. The assist motor (40) is controlled to use power stored in a battery (94) and make up for a decrease in torque output to a drive shaft (22) accompanied by the decrease in torque command value of the clutch motor (30). When the engine (50) falls in the idling state, supply of fuel into the engine (50) is stopped to terminate operation of the engine (50). In this state, the drive shaft (22) is driven and operated only by the torque of the assist motor (40), which is generated by the power stored in the battery (94). This control procedure can stop the engine (50) without varying the torque output to the drive shaft (22).

Fig. 1



EP 0 743 211 A2

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2.13.8/3.4

Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to a power output apparatus and a method of controlling the same. More specifically, the invention pertains to a power output apparatus for efficiently transmitting or outputting a power from an engine to a drive shaft and a method of controlling such a power output apparatus.

Description of the Related Art

In proposed power output apparatuses mounted on a vehicle, an output shaft of an engine is electromagnetically connected to a drive shaft linked with a rotor of a motor via an electromagnetic coupling, so that power of the engine is transmitted to the drive shaft (as disclosed in, for example, JAPANESE PATENT LAYING-OPEN GAZETTE No. 53-133814). When the revolving speed of the motor, which starts driving the vehicle, reaches a predetermined level, the proposed power output apparatus supplies an exciting current to the electromagnetic coupling in order to crank the engine, and subsequently carries out fuel injection into the engine as well as spark ignition, thereby starting the engine and enabling the engine to supply power. When the vehicle speed is lowered and the revolving speed of the motor decreases to or below the predetermined level, on the other hand, the power output apparatus stops the supply of exciting current to the electromagnetic coupling as well as fuel injection into the engine and spark ignition, thereby terminating operation of the engine.

In the known power output apparatus described above, the torque output to the drive shaft is significantly varied at the time of starting and stopping the engine. This results in a rough ride. At the time of starting the engine, the torque output from the motor is used to crank the engine, and the torque output to the drive shaft is decreased by the amount required for cranking. At the time of stopping the engine, the supply of exciting current is stopped while the power from the engine is transmitted to the drive shaft via the electromagnetic coupling, and the torque output to the drive shaft is decreased by the amount of power transmitted from the engine. Such a fall in output torque occurs unexpectedly since the driver does not determine the time of starting or stopping the engine. Compared with the expected variation, the unexpected variation in output torque to the drive shaft gives a greater shock to the driver, thereby resulting in a rough drive.

SUMMARY OF THE INVENTION

The object of the invention is thus to provide a power output apparatus which can transmit or output a power from an engine to a drive shaft at a high efficiency.

Another object of the invention is to stop the engine without varying the torque output to the drive shaft, and a method of controlling such a power output apparatus.

The above and other related objected are realized at least partly by a first power output apparatus for outputting a power to a drive shaft. The first power output apparatus comprises: an engine having an output shaft; engine driving means for driving the engine; a first motor comprising a first rotor connected with the output shaft of the engine and a second rotor connected with the drive shaft, the second rotor being coaxial to and rotatable relative to the first rotor, whereby power is transmitted between the output shaft of the engine and the drive shaft via an electromagnetic connection of the first rotor and the second rotor; a first motor-driving circuit for controlling degree of electromagnetic connection of the first rotor and the second rotor in the first motor and regulating rotation of the second rotor relative to the first rotor; a second motor connected with the drive shaft; a second motor-driving circuit for driving and controlling the second motor; a storage battery being charged with power regenerated by the first motor via the first motor-driving circuit, being charged with power regenerated by the second motor via the second motor-driving circuit, discharging power required to drive the first motor via the first motor-driving circuit, and discharging power required to drive the second motor via the second motor-driving circuit; power decrease signal detection means for detecting power decrease signal to decrease power output from the engine; driving circuit control means for, when the power decrease signal detection means detects the power decrease signal, controlling the first motor-driving circuit in response to the signal to gradually decrease the degree of electromagnetic connection of the first rotor with the second rotor in the first motor and controlling the second motor-driving circuit to enable the second motor to use power stored in the storage battery and make up for a decrease in power transmitted by the first motor accompanied by the decrease in degree of electromagnetic connection; and engine power decreasing means for controlling the engine driving means to decrease the power output from the engine with the decrease in the degree of electromagnetic connection of the first rotor with the second rotor accomplished by the driving circuit control means.

The first power output apparatus of the invention can efficiently transmit or output the power from the engine to the drive shaft by the functions of the first and the second motors. In response to the power decrease signal, the degree of electromagnetic coupling of the first rotor with the second rotor in the first motor is gradually decreased. The second motor is then controlled to make up for the decrease in transmitted power, which is accompanied by the decrease in degree of electromagnetic coupling, with the power stored in the secondary cell. This structure effectively decreases the power output from the engine without varying the power output to the drive shaft.

In accordance with one aspect of the first power output apparatus, the power decrease signal detection means comprises means for detecting an engine stop signal to stop operation of the engine, and the engine power decreasing means comprises means for controlling the engine driving means to stop supply of fuel into the engine and terminate operation of the engine when the driving circuit control means releases the electromagnetic connection of the first rotor with the second rotor in the first motor.

In accordance with one aspect, the present invention is directed to a second power output apparatus for outputting a power to a drive shaft. The second power output apparatus comprises: an engine having an output shaft; engine driving means for driving the engine; a complex motor comprising a first rotor connected with the output shaft of the engine, a second rotor connected with the drive shaft being coaxial to and rotatable relative to the first rotor, and a stator for rotating the second rotor, the first rotor and the second rotor constituting a first motor, the second rotor and the stator constituting a second motor; a first motor-driving circuit for driving and controlling the first motor in the complex motor; a second motor-driving circuit for driving and controlling the second motor in the complex motor; a storage battery being charged with power regenerated by the first motor via the first motor-driving circuit, being charged with power regenerated by the second motor via the second motor-driving circuit, discharging power required to drive the first motor via the first motor-driving circuit, and discharging power required to drive the second motor via the second motor-driving circuit; power decrease signal detection means for detecting power decrease signal to decrease power output from the engine; driving circuit control means for, when the power decrease signal detection means detects the power decrease signal, controlling the first motor-driving circuit in response to the signal to gradually decrease the degree of electromagnetic connection of the first rotor with the second rotor in the first motor and controlling the second motor-driving circuit to enable the second motor to use power stored in the storage battery and make up for a decrease in power transmitted by the first motor accompanied by the decrease in degree of electromagnetic connection; and engine power decreasing means for controlling the engine driving means to decrease the power output from the engine with the decrease in the degree of electromagnetic connection of the first rotor with the second rotor accomplished by the driving circuit control means.

The second power output apparatus of the invention can efficiently transmit or output the power from the engine to the drive shaft by the functions of the first motor, which consists of the first rotor and the second rotor of the complex motor, and the second motor, which consists of the second rotor and the stator. In response to the power decrease signal, the degree of electromagnetic coupling of the first rotor with the second rotor in the first motor is gradually decreased. The second motor is then controlled to make up for the decrease in transmitted power, which is accompanied by the decrease in degree of electromagnetic coupling, with the power stored in the secondary cell. This structure effectively decreases the power output from the engine without varying the power output to the drive shaft. The structure including the first motor and the second motor integrally joined with each other realizes a compact power output apparatus.

In accordance with one aspect of the second power output apparatus, the power decrease signal detection means comprises means for detecting an engine stop signal to stop operation of the engine, and the engine power decreasing means comprises means for controlling the engine driving means to stop supply of fuel into the engine and terminate operation of the engine when the driving circuit control means releases the electromagnetic connection of the first rotor with the second rotor in the first motor.

In accordance with another aspect, the invention is also directed to a third power output apparatus for outputting a power to a drive shaft. The third power output apparatus comprises: an engine having an output shaft; engine driving means for driving the engine; a first motor comprising a first rotor connected with the output shaft of the engine and a second rotor connected with the drive shaft, the first motor being coaxial to and rotatable relative to the first rotor, whereby power is transmitted between the output shaft of the engine and the drive shaft via an electromagnetic connection of the first rotor and the second rotor; a first motor-driving circuit for controlling degree of electromagnetic connection of the first rotor and the second rotor in the first motor and regulating rotation of the second rotor relative to the first rotor; a second motor connectied with the output shaft of the engine; a second motor-driving circuit for driving and controlling the second motor; a storage battery being charged with power regenerated by the first motor via the first motor-driving circuit, being charged with power regenerated by the second motor via the second motor-driving circuit, discharging power required to drive the first motor via the first motor-driving circuit, and discharging power required to drive the second motor via the second motor-driving circuit; power decrease signal detection means for detecting power decrease signal to decrease power output from the engine; engine power decreasing means for, when the power decrease signal detection means detects the power decrease signal, controlling the engine driving means in response to the signal to gradually decrease the power output from the engine; and driving circuit control means for controlling the first motor-driving circuit and the second motor-driving circuit to enable the first motor and the second motor to use power stored in the storage battery and make up for the decrease in power output from the engine accomplished by the engine power decreasing means.

The third power output apparatus of the invention can efficiently transmit or output the power from the engine to the drive shaft by the functions of the first and the second motors. In response to the power decrease signal, the power output from the engine is gradually decreased. The first motor and the second motor are then controlled to make up for the decrease in power output from the engine with the power stored in the secondary cell. This structure effectively decreases the power output from the engine without varying the power output to the drive shaft.

In accordance with one aspect of the third power output apparatus, the driving circuit control means comprises meane for controlling the first motor-driving circuit to enable the first motor to make up for a decrease in revolving speed of the output shaft of the engine among the decrease in power output from the engine, and controlling the second motor-driving circuit to enable the second motor to make up for a decrease in torque among the decrease in power output from the engine. In this structure, the power decrease signal detection means comprises meane for detecting an engine stop signal to stop operation of the engine, and the engine power decreasing means comprises meane for controlling the engine driving means to stop supply of fuel into the engine and terminate operation of the engine when the power output from the engine becomes equal to zero.

In accordance with still another aspect, the invention also provides a fourth power output apparatus for outputting a power to a drive shaft. The fourth power output apparatus comprises: an engine having an output shaft; engine driving means for driving the engine; a complex motor comprising a first rotor connected with the output shaft of the engine, a second rotor connected with the drive shaft being coaxial to and rotatable relative to the first rotor, and a stator for rotating the first rotor, the first rotor and the second rotor constituting a first motor, the first rotor and the stator constituting a second motor; a first motor-driving circuit for driving and controlling the first motor in the complex motor; a second motor-driving circuit for driving and controlling the second motor in the complex motor;

a storage battery being charged with power regenerated by the first motor via the first motor-driving circuit, being charged with power regenerated by the second motor via the second motor-driving circuit, discharging power required to drive the first motor via the first motor-driving circuit, and discharging power required to drive the second motor via the second motor-driving circuit; power decrease signal detection means for detecting power decrease signal to decrease power output from the engine; engine power decreasing means for, when the power decrease signal detection means detects the power decrease signal, controlling the engine driving means in response to the signal to gradually decrease the power output from the engine; and driving circuit control means for controlling the first motor-driving circuit and the second motor-driving circuit to enable the first motor and the second motor to use power stored in the storage battery and make up for the decrease in power output from the engine accomplished by the engine power decreasing means.

The fourth power output apparatus of the invention can efficiently transmit or output the power from the engine to the drive shaft by the functions of the first motor, which consists of the first rotor and the second rotor of the complex motor, and the second motor, which consists of the first rotor and the stator. In response to the power decrease signal, the power output from the engine is gradually decreased. The first motor and the second motor are then controlled to make up for the decrease in power output from the engine with the power stored in the secondary cell. This structure effectively decreases the power output from the engine without varying the power output to the drive shaft. The structure including the first motor and the second motor integrally joined with each other realizes a compact power output apparatus.

In accordance with one aspect of the fourth power output apparatus,the driving circuit control means comprises means for controlling the first motor-driving circuit to enable the first motor to make up for a decrease in revolving speed of the output shaft of the engine among the decrease in power output from the engine, and controlling the second motor-driving circuit to enable the second motor to make up for a decrease in torque among the decrease in power output from the engine. In this structure,the power decrease signal detection means comprises means for detecting an engine stop signal to stop operation of the engine, and the engine power decreasing means comprises means for controlling the engine driving means to stop supply of fuel into the engine and terminate operation of the engine when the power output from the engine becomes equal to zero.

The above objects are also realized at least partly by a first method of controlling a power output apparatus for outputting a power to a drive shaft. The first method comprises the steps of: (a) providing an engine having an output shaft; engine driving means for driving the engine; a first motor comprising a first rotor connected with the output shaft of the engine and a second rotor connected with the drive shaft, the first motor being coaxial to and rotatable relative to the first rotor, whereby power is transmitted between the output shaft of the engine and the drive shaft via an electromagnetic connection of the first rotor and the second rotor; a second motor connected with the drive shaft; and a storage battery being charged with power regenerated by the first motor, being charged with power regenerated by the second motor, discharging power required to drive the first motor, and discharging power required to drive the second motor; (b) detecting power decrease signal to decrease power output from the engine; (c) controlling the first motor in response to the power decrease signal, to gradually decrease the degree of electromagnetic connection of the first rotor with the second rotor in the first motor; (d) controlling the second motor to enable the second motor to use power stored in the storage battery and make up for a decrease in power transmitted by the first motor accompanied by the decrease in degree of electromagnetic connection; and (e) controlling the engine driving means to decrease the power output from the engine with the decrease in degree of electromagnetic connection of the first rotor with the second rotor accomplished in the step (c).

In accordance with one aspect of the first method, the power decrease signal detected represents an engine stop signal to stop operation of the engine, and the step (e) further comprises the step of controlling the engine driving means to stop supply of fuel into the engine and terminate operation of the engine when the electromagnetic connection of the first rotor with the second rotor in the first motor has been decreased to a release position in response to the engine stop signal.

In accordance with one aspect, the invention is also directed to a second method of controlling a power output apparatus for outputting a power to a drive shaft. The second method comprises the steps of: (a) providing an engine having an output shaft; engine driving means for driving the engine; a first motor comprising a first rotor connected with the output shaft of the engine and a second rotor connected with the drive shaft, the second rotor being coaxial to and rotatable relative to the first rotor, whereby power is transmitted between the output shaft of the engine and the drive shaft via an electromagnetic connection of the first rotor and the second rotor; a second motor connected with the output shaft of the engine; and a storage battery being charged with power regenerated by the first motor, being charged with power regenerated by the second motor, discharging power required to drive the first motor, and discharging power required to drive the second motor; (b) detecting power decrease signal to decrease power output from the engine; (c) controlling the engine driving means in response to the power decrease signal, to gradually decrease the power output from the engine; and (d) controlling the first motor and the second motor to enable the first motor and the second motor to use power stored in the storage battery and make up for the decrease in power output from the engine accomplished in the step (c).

In accordance with one aspect of the second method, the step (d) further comprises the steps of: (e) controlling the first motor to enable the first motor to make up for a decrease in revolving speed of the output shaft of the engine among the decrease in power output from the engine; and (f) controlling the second motor to enable the second motor to make up for a decrease in torque among the decrease in power output from the engine.

These and other objects, features, aspects, and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view illustrating structure of a power output apparatus 20 as a first embodiment according to the present invention;

Fig. 2 is a cross sectional view illustrating detailed structures of a clutch motor 30 and an assist motor 40 included in the power output apparatus 20 of Fig. 1;

Fig. 3 is a schematic view illustrating general structure of a vehicle with the power output apparatus 20 of Fig. 1 incorporated therein;

Fig. 4 is a graph showing the operation principle of the power output apparatus 20;

Fig. 5 is a flowchart showing a torque control routine executed by the controller 80;

Fig. 6 is a flowchart showing essential steps of controlling the clutch motor 30 executed by the controller 80;

Figs. 7 and 8 are flowcharts showing essential steps of controlling the assist motor 40 executed by the controller 80;

Fig. 9 is a flowchart showing an engine stop-time torque control routine executed by the controller 80;

Fig. 10 is a flowchart showing essential steps of controlling the assist motor 40 executed by the controller 80 when the engine 50 stops operation;

Fig. 11 schematically illustrates a power output apparatus 20A as a modification of the first embodiment;

Fig. 12 schematically illustrates structure of another power output apparatus 20B as a second embodiment according to the present invention;

Fig. 13 is a flowchart showing a torque control routine executed by the controller 80 in the second embodiment;

Fig. 14 is a flowchart showing an engine stop-time torque control routine executed by the controller 80 in the second embodiment;

Fig. 15 schematically illustrates a power output apparatus 20C as a modification of the second embodiment; and

Fig. 16 schematically illustrates a power output apparatus 20D as another modification of the second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a schematic view illustrating structure of a power output apparatus 20 as a first embodiment according to the present invention; Fig. 2 is a cross sectional view illustrating detailed structures of a clutch motor 30 and an assist motor 40 included in the power output apparatus 20 of Fig. 1; and Fig. 3 is a schematic view illustrating a general structure of a vehicle with the power output apparatus 20 of Fig. 1 incorporated therein. The general structure of the vehicle is described first as a matter of convenience.

Referring to Fig. 3, the vehicle is provided with an engine 50 driven by gasoline as a power source. The air ingested from an air supply system via a throttle valve 66 is mixed with fuel, that is, gasoline in this embodiment, injected from a fuel injection valve 51. The air/fuel mixture is supplied into a combustion chamber 52 to be explosively ignited and burned. Linear motion of a piston 54 pressed down by the explosion of the air/fuel mixture is converted to rotational motion of a crankshaft 56. The throttle valve 66 is driven to open and close by an actuator 68. An ignition plug 62 converts a high voltage applied from an igniter 58 via a distributor 60 to a spark, which explosively ignites and combusts the air/fuel mixture.

Operation of the engine 50 is controlled by an electronic control unit (hereinafter referred to as EFIECU) 70. The EFIECU 70 receives information from various sensors, which detect operating conditions of the engine 50. These sensors include a throttle valve position sensor 67 for detecting the position of the throttle valve 66, a manifold vacuum sensor 72 for measuring a load applied to the engine 50, a water temperature sensor 74 for measuring the temperature of cooling water in the engine 50, and a speed sensor 76 and an angle sensor 78 mounted on the distributor 60 for measuring the revolving speed and rotational angle of the crankshaft 56. A starter switch 79 for detecting a starting condition ST of an ignition key (not shown) is also connected to the EFIECU 70. Other sensors and switches connecting with the EFIECU 70 are omitted from the drawings.

The crankshaft 56 of the engine 50 is linked with a drive shaft 22 via a clutch motor 30 and an assist motor 40 (described later in detail). The drive shaft 22 further connects with a differential gear 24, which eventually transmits the torque output from the drive shaft 22 of the power output apparatus 20 to left and right driving wheels 26 and 28. The clutch motor 30 and the assist motor 40 are driven and controlled by a controller 80. The controller 80 includes an internal control CPU and receives inputs from a gearshift position sensor 84 attached to a gearshift 82 and an accelerator position sensor 65 attached to an accelerator pedal 64, as described later in detail. The controller 80 sends and receives a variety of data and information to and from the EFIECU 70 through communication. Details of the control procedure including a communication protocol will be described later.

Referring to Fig. 1, the power output apparatus 20 essentially includes the engine 50, the clutch motor 30 with an outer rotor 32 and an inner rotor 34, the assist motor 40 with a rotor 42, and the controller 80 for driving and controlling the clutch motor 30 and the assist motor 40. The outer rotor 32 of the clutch motor 30 is mechanically connected to the crankshaft 56 of the engine 50, whereas the inner rotor 34 thereof is mechanically linked with the rotor 42 of the assist motor 40.

As shown in Fig. 1, the clutch motor 30 is constructed as a synchronous motor having permanent magnets 35 attached to an inner surface of the outer rotor 32 and three-phase coils 36 wound on slots formed in the inner rotor 34. Power is supplied to the three-phase coils 36 via a rotary transformer 38. A thin laminated sheet of non-directional electromagnetic steel is used to form teeth and slots for the three-phase coils 36 in the inner rotor 34. A resolver 39 for measuring a rotational angle θe of the crankshaft 56 is attached to the crankshaft 56. The resolver 39 may also serve as the angle sensor 78 mounted on the distributor 60.

The assist motor 40 is also constructed as a synchronous motor having three-phase coils 44, which are wound on a stator 43 fixed to a casing 45 to generate a rotating magnetic field. The stator 43 is also made of a thin laminated sheet of non-directional electromagnetic steel. A plurality of permanent magnets 46 are attached to an outer surface of the rotor 42. In the assist motor 40, interaction between a magnetic field formed by the permanent magnets 46 and a rotating magnetic field formed by the three-phase coils 44 leads to rotation of the rotor 42. The rotor 42 is mechanically linked with the drive shaft 22 working as the torque output shaft of the power output apparatus 20. A resolver 48 for measuring a rotational angle θd of the drive shaft 22 is attached to the drive shaft 22, which is further supported by a bearing 49 held in the casing 45.

The inner rotor 34 of the clutch motor 30 is mechanically linked with the rotor 42 of the assist motor 40 and further with the drive shaft 22. When the rotation and axial torque of the crankshaft 56 of the engine 50 are transmitted via the outer rotor 32 to the inner rotor 34 of the clutch motor 30, the rotation and torque by the assist motor 40 are added to or subtracted from the transmitted rotation and torque.

While the assist motor 40 is constructed as a conventional permanent magnet-type three-phase synchronous motor, the clutch motor 30 includes two rotating elements or rotors, that is, the outer rotor 32 with the permanent magnets 35 and the inner rotor 34 with the three-phase coils 36. The detailed structure of the clutch motor 30 is described with the cross sectional view of Fig. 2. The outer rotor 32 of the clutch motor 30 is attached to a circumferential end of a wheel 57 set around the crankshaft 56, by means of a pressure pin 59a and a screw 59b. A central portion of the wheel 57 is protruded to form a shaft-like element, to which the inner rotor 34 is rotatably attached by means of bearings 37A and 37B. One end of the drive shaft 22 is fixed to the inner rotor 34.

A plurality of permanent magnets 35, four in this embodiment, are attached to the inner surface of the outer rotor 32 as mentioned previously. The permanent magnets 35 are magnetized in the direction towards the axial center of the clutch motor 30, and have magnetic poles of alternately inverted directions. The three-phase coils 36 of the inner rotor 34 facing to the permanent magnets 35 across a little gap are wound on a total of 24 slots (not shown) formed in the inner rotor 34. Supply of electricity to the respective coils forms magnetic fluxes running through the teeth (not shown), which separate the slots from one another. Supply of a three-phase alternating current to the respective coils rotates this magnetic field. The three-phase coils 36 are connected to receive electric power supplied from the rotary transformer 38. The rotary transformer 38 includes primary windings 38a fixed to the casing 45 and secondary windings 38b attached to the drive shaft 22 coupled with the inner rotor 34. Electromagnetic induction allows electric power to be transmitted from the primary windings 38a to the secondary windings 38b or vice versa. The rotary transformer 38 has windings for three phases, that is, U, V, and W phases, to enable the transmission of three-phase electric currents.

Interaction between a magnetic field formed by one adjacent pair of permanent magnets 35 and a rotating magnetic field formed by the three-phase coils 36 of the inner rotor 34 leads to a variety of behaviors of the outer rotor 32 and the inner rotor 34. The frequency of the three-phase alternating current supplied to the three-phase coils 36 is generally equal to a difference between the revolving speed (revolutions per second) of the outer rotor 32 directly connected to the crankshaft 56 and the revolving speed of the inner rotor 34. This results in a slip between the rotations of the outer rotor 32 and the inner rotor 34. Details of the control procedures of the clutch motor 30 and the assist motor 40 will be described later based on the flowcharts.

As mentioned above, the clutch motor 30 and the assist motor 40 are driven and controlled by the controller 80. Referring back to Fig. 1, the controller 80 includes a first driving circuit 91 for driving the clutch motor 30, a second driving circuit 92 for driving the assist motor 40, a control CPU 90 for controlling both the first and second driving circuits 91 and 92, and a battery 94 including a number of secondary cells. The control CPU 90 is a one-chip microprocessor including a RAM 90a used as a working memory, a ROM 90b in which various control programs are stored, an input/output port (not shown), and a serial communication port (not shown) through which data are sent to and received from the EFIECU 70. The control CPU 90 receives a variety of data through the input/output port. The input data include a rotational angle θe of the crankshaft 56 of the engine 50 from the resolver 39, a rotational angle θd of the drive shaft 22 from the resolver 48, an accelerator pedal position AP (pressing amount of the accelerator pedal 64) from the accelerator position sensor 65, a gearshift position SP from the gearshift position sensor 84, clutch motor currents Iuc and Ivc from two ammeters 95 and 96 in the first driving circuit 91, assist motor currents Iua and Iva from two ammeters 97 and 98 in the second driving circuit 92, and a residual capacity BRM of the battery 94 from a residual capacity meter 99. The residual capacity meter 99 may determine the residual capacity BRM of the battery 94 by any known method; for example, by measuring the specific gravity of an electrolytic solution in the battery 94 or the whole weight of the battery 94, by computing the currents and time of charge and discharge, or by causing an instantaneous short-circuit between terminals of the battery 94 and measuring an internal resistance against the electric current.

The control CPU 90 outputs a first control signal SW1 for driving six transistors Tr1 through Tr6 working as switching elements of the first driving circuit 91 and a second control signal SW2 for driving six transistors Tr11 through Tr16 working as switching elements of the second driving circuit 92. The six transistors Tr1 through Tr6 in the first driving circuit 91 constitute a transistor inverter and are arranged in pairs to work as a source and a drain with respect to a pair of power lines P1 and P2. The three-phase coils (U,V,W) 36 of the clutch motor 30 are connected via the rotary transformer 38 to the respective contacts of the paired transistors. The power lines P1 and P2 are respectively connected to plus and minus terminals of the battery 94. The first control signal SW1 output from the control CPU 90 successively controls the power-on time of the paired transistors Tr1 through Tr6. The electric current flowing through each coil 36 undergoes PWM (pulse width modulation) to give a quasi-sine wave, which enables the three-phase coils 36 to form a rotating magnetic field.

The six transistors Tr11 through Tr16 in the second driving circuit 92 also constitute a transistor inverter and are arranged in the same manner as the transistors Tr1 through Tr6 in the first driving circuit 91. The three-phase coils (U,V,W) 44 of the assist motor 40 are connected to the respective contacts of the paired transistors. The second control signal SW2 output from the control CPU 90 successively controls the power-on time of the paired transistors Tr11 through Tr16. The electric current flowing through each coil 44 undergoes PWM to give a quasi-sine wave, which enables the three-phase coils 44 to form a rotating magnetic field.

The power output apparatus 20 thus constructed works in accordance with the operation principles described below, especially with the principle of torque conversion. By way of example, it is assumed that the engine 50 driven by the EFIECU 70 rotates at a revolving speed Ne equal to a predetermined value N1. While the transistors Tr1 through Tr6 in the first driving circuit 91 are in OFF position, the controller 80 does not supply any current to the three-phase coils 36 of the clutch motor 30 via the rotary transformer 38. No supply of electric current causes the outer rotor 32 of the clutch motor 30 to be electromagnetically disconnected from the inner rotor 34. This results in racing the crankshaft 56 of the engine 50. Under the condition that all the transistors Tr1 through Tr6 are in OFF position, there is no regeneration of energy from the three-phase coils 36, and the engine 50 is kept at an idle.

As the control CPU 90 of the controller 80 outputs the first control signal SW1 to control on and off the transistors Tr1 through Tr6 in the first driving circuit 91, a constant electric current is flown through the three-phase coils 36 of the clutch motor 30, based on the difference between the revolving speed Ne of the crankshaft 56 of the engine 50 and a revolving speed Nd of the drive shaft 22 (that is, difference Nc (=Ne-Nd) between the revolving speed of the outer rotor 32 and that of the inner rotor 34 in the clutch motor 30). A certain slip accordingly exists between the outer rotor 32 and the inner rotor 34 connected with each other in the clutch motor 30. At this moment, the inner rotor 34 rotates at the revolving speed Nd, which is lower than the revolving speed Ne of the crankshaft 56 of the engine 50. In this state, the clutch motor 30 functions as a generator and carries out the regenerative operation to regenerate an electric current via the first driving circuit 91. In order to allow the assist motor 40 to consume energy identical with the electrical energy regenerated by the clutch motor 30, the control CPU 90 controls on and off the transistors Tr11 through Tr16 in the second driving circuit 92. The on-off control of the transistors Tr11 through Tr16 enables an electric current to flow through the three-phase coils 44 of the assist motor 40, and the assist motor 40 consequently carries out the power operation to produce a torque.

Referring to Fig. 4, while the crankshaft 56 of the engine 50 is driven at a revolving speed N1 and a torque T1, energy in a region G1 is regenerated as electric power by the clutch motor 30. The regenerated power is supplied to the assist motor 40 and converted to energy in a region G2, which enables the drive shaft 22 to rotate at a revolving speed N2 and a torque T2. The torque conversion is carried out in the manner discussed above, and the energy corresponding to the slip in the clutch motor 30 or the revolving speed difference Nc (=Ne-Nd) is consequently given as a torque to the drive shaft 22.

In another example, it is assumed that the engine 50 is driven at a revolving speed Ne=N2 and a torque Te=T2, whereas the drive shaft 22 is rotated at the revolving speed N1, which is greater than the revolving speed N2. In this state, the inner rotor 34 of the clutch motor 30 rotates relative to the outer rotor 32 in the direction of rotation of the drive shaft 22 at a revolving speed defined by the absolute value of the revolving speed difference Nc (=Ne-Nd). While functioning as a normal motor, the clutch motor 30 consumes electric power to apply the energy of rotational motion to the drive shaft 22. When the control CPU 90 of the controller 80 controls the second driving circuit 92 to enable the assist motor 40 to regenerate electrical energy, a slip between the rotor 42 and the stator 43 of the assist motor 40 makes the regenerative current flow through the three-phase coils 44. In order to allow the clutch motor 30 to consume the energy regenerated by the assist motor 40, the control CPU 90 controls both the first driving circuit 91 and the second driving circuit 92. This enables the clutch motor 30 to be driven without using any electric power stored in the battery 94.

Referring back to Fig. 4, when the crankshaft 56 of the engine 50 is driven at the revolving speed N2 and the torque T2, energy in the sum of regions G2 and G3 is regenerated as electric power by the assist motor 40 and supplied to the clutch motor 30. Supply of the regenerated power enables the drive shaft 22 to rotate at the revolving speed N1 and the torque T1.

Other than the torque conversion and revolving speed conversion discussed above, the power output apparatus 20 of the embodiment can charge the battery 94 with an excess of electrical energy or discharge the battery 94 to supplement the electrical energy. This is implemented by controlling the mechanical energy output from the engine 50 (that is, the product of the torque Te and the revolving speed Ne), the electrical energy regenerated or consumed by the clutch motor 30, and the electrical energy regenerated or consumed by the assist motor 40. The output energy from the engine 50 can thus be transmitted as power to the drive shaft 22 at a higher efficiency.

The torque conversion discussed above is implemented by a torque control process illustrated in the flowchart of Fig. 5. The torque control routine of Fig. 5 is executed to control the torque while the battery 94 is not charged or discharged.

When the program enters the torque control routine, the control CPU 90 of the controller 80 first receives data of revolving speed Nd of the drive shaft 22 at step S100. The revolving speed Nd of the drive shaft 22 can be computed from the rotational angle θd of the drive shaft 22 read from the resolver 48. The control CPU 90 then reads the accelerator pedal position AP from the accelerator position sensor 65 at step S101. The driver steps in the accelerator pedal 64 when feeling insufficiency of output torque. The value of the accelerator pedal position AP accordingly corresponds to the desired output torque (that is, torque of the drive shaft 22) which the driver requires. At subsequent step S102, the control CPU 90 computes a target output torque (torque of drive shaft 22) Td* corresponding to the input accelerator pedal position AP. The target output torque Td* is also referred to as the output torque command value. Output torque command values Td* have previously been set for the respective accelerator pedal positions AP. In response to an input of the accelerator pedal position AP, the output torque command value Td* corresponding to the input accelerator pedal position AP is extracted from the preset output torque command values Td*.

At step S103, an energy Pd to be output to the drive shaft 22 is calculated according to the expression Pd=Td*xNd, that is, multiplying the extracted output torque command value Td* (of the drive shaft 22) by the input revolving speed Nd of the drive shaft 22. The program then proceeds to step S104 at which the control CPU 90 sets a target engine torque Te* and a target engine speed Ne* of the engine 50 based on the output energy Pd thus obtained. Here it is assumed that all the energy Pd to be output to the drive shaft 22 is supplied from the engine 50. Since the energy supplied by the engine 50 is equal to the product of the torque Te and the revolving speed Ne of the engine 50, the relationship between the output energy Pd and the target engine torque Te* and the target engine speed Ne* can be expressed as Pd=Te*xNe*. There are, however, numerous combinations of the target engine torque Te* and the target engine speed Ne* satisfying the above relationship. In this embodiment, an optimal combination of the target engine torque Te* and the target engine speed Ne* is selected in order to realize operation of the engine 50 at the possible highest efficiency.

At subsequent step S106, the control CPU 90 sets a torque command value Tc* of the clutch motor 30, based on the target engine torque Te* set at step S104. In order to keep the revolving speed Ne of the engine 50 at a substantially constant level, it is required to make the torque of the clutch motor 30 balance the torque of the engine 50. The processing at step S106 accordingly sets the torque command value Tc* of the clutch motor 30 equal to the target engine torque Te* of the engine 50.

After setting the torque command value Tc* of the clutch motor 30 at step S106, the program proceeds to steps S108, S110, and S111 to control the clutch motor 30, the assist motor 40, and the engine 50, respectively. As a matter of convenience, the control operations of the clutch motor 30, the assist motor 40, and the engine 50 are shown as separate steps. In the actual procedure, however, these control operations are carried out comprehensively. For example, the control CPU 90 simultaneously controls the clutch motor 30 and the assist motor 40 by interrupt process, while transmitting an instruction to the EFIECU 70 through communication to control the engine 50 concurrently.

The control of the clutch motor 30 (step S108 of Fig. 5) is implemented according to a clutch motor control routine illustrated in the flowchart of Fig. 6. When the program enters the clutch motor control routine, the control CPU 90 of the controller 80 first reads a rotational angle θd of the drive shaft 22 from the resolver 48 at step S112 and a rotational angle θe of the crankshaft 56 of the engine 50 from the resolver 39 at step S114. The control CPU 90 then computes a relative angle θc of the drive shaft 22 and the crankshaft 56 by the equation of θc=θe-θd at step S116.

The program proceeds to step S118, at which the control CPU 90 receives inputs of clutch motor currents Iuc and Ivc, which respectively flow through the U phase and V phase of the three-phase coils 36 in the clutch motor 30, from the ammeters 95 and 96. Although the currents naturally flow through all the three phases U, V, and W, measurement is required only for the currents passing through the two phases since the sum of the currents is equal to zero. At subsequent step S120, the control CPU 90 executes transformation of coordinates (three-phase to two-phase transformation) using the values of currents flowing through the three phases obtained at step S118. The transformation of coordinates maps the values of currents flowing through the three phases to the values of currents passing through d and q axes of the permanent magnet-type synchronous motor and is executed according to Equation (1) given below:

$$\begin{bmatrix} Idc \\ Iqc \end{bmatrix} = \sqrt{2} \begin{bmatrix} -\sin(\theta c - 120) & \sin \theta c \\ -\cos(\theta c - 120) & \cos \theta c \end{bmatrix} \begin{bmatrix} Iuc \\ Ivc \end{bmatrix} \qquad (1)$$

The transformation of coordinates is carried out because the currents flowing through the d and q axes are essential for the torque control in the permanent magnet-type synchronous motor. Alternatively, the torque control may be executed directly with the currents flowing through the three phases. After the transformation to the currents of two axes, the control CPU 90 computes deviations of currents Idc and Iqc actually flowing through the d and q axes from current command values Idc* and Iqc* of the respective axes, which are calculated from the torque command value Tc* of the clutch motor 30, and determines voltage command values Vdc and Vqc for the d and q axes at step S122. In accordance with a concrete procedure, the control CPU 90 executes operations following Equations (2) and Equations (3) given below:

$$\Delta Idc = Idc^* - Idc \qquad (2)$$

$$\Delta Iqc = Iqc^* - Iqc$$

$$Vdc = Kp1 \cdot \Delta Idc + \Sigma Ki1 \cdot \Delta Idc \qquad (3)$$

$$Vqc = Kp2 \cdot \Delta Iqc + \Sigma Ki2 \cdot \Delta Iqc$$

wherein Kp1, Kp2, Ki1, and Ki2 represent coefficients, which are adjusted to be suited to the characteristics of the motor applied.

The voltage command value Vdc (Vqc) includes a part in proportion to the deviation ΔI from the current command value I* (first term in right side of Equation (3)) and a summation of historical data of the deviations ΔI for 'i' times (second term in right side). The control CPU 90 then re-transforms the coordinates of the voltage command values thus obtained (two-phase to three-phase transformation) at step S124. This corresponds to an inverse of the transformation executed at step S120. The inverse transformation determines voltages Vuc, Vvc, and Vwc actually applied to the three-phase coils 36 as given below:

$$\begin{bmatrix} Vuc \\ Vvc \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos \theta c & -\sin \theta c \\ \cos(\theta c - 120) & -\sin(\theta c - 120) \end{bmatrix} \begin{bmatrix} Vdc \\ Vqc \end{bmatrix} \qquad (4)$$

$$Vwc = -Vuc - Vvc$$

The actual voltage control is executed through on-off operation of the transistors Tr1 through Tr6 in the first driving circuit 91. At step S126, the on- and off-time of the transistors Tr1 through Tr6 in the first driving circuit 91 is PWM (pulse width modulation) controlled in order to attain the voltage command values determined by Equation (4) above.

The torque command value Tc* is positive when a positive torque is applied to the drive shaft 22 in the direction of rotation of the crankshaft 56. By way of example, it is assumed that a positive value is set to the torque command value Tc*. When the revolving speed Ne of the engine 50 is greater than the revolving speed Nd of the drive shaft 22 on this assumption, that is, when the revolving speed difference Nc (=Ne-Nd) is positive, the clutch motor 30 is controlled to carry out the regenerative operation and produce a regenerative current corresponding to the revolving speed difference Nc. When the revolving speed Ne of the engine 50 is less than the revolving speed Nd of the drive shaft 22, that is, when the revolving speed difference Nc (=Ne-Nd) is negative, on the contrary, the clutch motor 30 is controlled to carry out the power operation and rotate relative to the crankshaft 56 in the direction of rotation of the drive shaft 22 at a revolving speed defined by the absolute value of the revolving speed difference Nc. For the positive torque command value Tc*, both the regenerative operation and the power operation of the clutch motor 30 implement the identical switching control. In accordance with a concrete procedure, the transistors Tr1 through Tr6 of the first driving circuit 91 are controlled to enable a positive torque to be applied to the drive shaft 22 by the combination of the magnetic field generated by the permanent magnets 35 set on the outer rotor 32 with the rotating magnetic field generated by the currents flowing through the three-phase coils 36 on the inner rotor 34 in the clutch motor 30. The identical switching control is executed for both the regenerative operation and the power operation of the clutch motor 30 as long as the sign of the torque command value Tc* is not changed. The clutch motor control routine of Fig. 6 is thus applicable to both the regenerative operation and the power operation. Under the condition of braking the drive shaft 22 or moving the vehicle in reverse, the torque command value Tc* has the negative sign. The clutch motor control routine of Fig. 6 is also applicable to the control procedure under such conditions, when the relative angle θc is varied in the reverse direction at step S126.

Figs. 7 and 8 are flowcharts showing details of the control process of the assist motor 40 executed at step S110 in the flowchart of Fig. 5. Referring to the flowchart of Fig. 7, when the program enters the assist motor control routine, the control CPU 90 first receives data of revolving speed Nd of the drive shaft 22 at step S131. The revolving speed Nd of the drive shaft 22 is computed from the rotational angle θd of the drive shaft 22 read from the resolver 48. The control CPU 90 then receives data of revolving speed Ne of the engine 50 at step S132. The revolving speed Ne of the engine 50 may be computed from the rotational angle θe of the crankshaft 56 read from the resolver 39 or directly measured by the speed sensor 76 mounted on the distributor 60. In the latter case, the control CPU 90 receives data of revolving speed Ne of the engine 50 through communication with the EFIECU 70, which connects with the speed sensor 76.

A revolving speed difference Nc between the input revolving speed Nd of the drive shaft 22 and the input revolving speed Ne of the engine 50 is calculated according to the equation Nc=Ne-Nd at step S133. At subsequent step S134, electric power (energy) Pc regenerated or consumed by the clutch motor 30 is calculated according to Equation (5) given as:

$$Pc = Ksc \times Nc \times Tc \qquad (5)$$

wherein Ksc represents the efficiency of regenerative operation or power operation in the clutch motor 30. The product NcxTc defines the energy corresponding to the region G1 in the graph of Fig. 4, wherein Nc and Tc respectively denote the revolving speed difference and the actual torque produced by the clutch motor 30.

At step S135, a torque command value Ta* of the assist motor 40 is determined by Equation (6) given as:

$$Ta^* = ksa \times Pc/Nd \qquad (6)$$

wherein ksa represents the efficiency of regenerative operation or power operation in the assist motor 40. The torque command value Ta* of the assist motor 40 thus obtained is compared with a maximum torque Tamax, which the assist motor 40 can potentially apply, at step S136. When the torque command value Ta* exceeds the maximum torque Tamax, the program proceeds to step S138 at which the torque command value Ta* is restricted to the maximum torque Tamax.

After the torque command value Ta* is set equal to the maximum torque Tamax at step S138 or after the torque command value Ta* is determined not to exceed the maximum torque Tamax at step S136, the program proceeds to step S140 in the flowchart of Fig. 8. The control CPU 90 reads the rotational angle θd of the drive shaft 22 from the resolver 48 at step S140, and receives data of assist motor currents Iua and Iva, which respectively flow through the U phase and V phase of the three-phase coils 44 in the assist motor 40, from the ammeters 97 and 98 at step S142. The control CPU 90 then executes transformation of coordinates for the currents of the three phases at step S144, computes voltage command values Vda and Vqa at step S146, and executes inverse transformation of coordinates for the voltage command values at step S148. At subsequent step S150, the control CPU 90 determines the on-and off-time of the transistors Tr11 through Tr16 in the second driving circuit 92 for PWM (pulse width modulation) control. The processing executed at steps S144 through S150 is similar to that executed at steps S120 through S126 of the clutch motor control routine shown in the flowchart of Fig. 6.

The assist motor 40 is subject to the power operation for the positive torque command value Ta* and the regenerative operation for the negative torque command value Ta*. Like the power operation and the regenerative operation of the clutch motor 30, the assist motor control routine of Figs. 7 and 8 is applicable to both the power operation and the regenerative operation of the assist motor 40. This is also true when the drive shaft 22 rotates in reverse of the rotation of the crankshaft 56, that is, when the vehicle moves back. The torque command value Ta* of the assist motor 40 is positive when a positive torque is applied to the drive shaft 22 in the direction of rotation of the crankshaft 56.

The control of the engine 50 (step S111 in Fig. 5) is executed in the following manner. In order to attain stationary driving at the target engine torque Te* and the target engine speed Ne* (set at step S104 in Fig. 5), the control CPU 90 regulates the torque Te and the revolving speed Ne of the engine 50 to make them approach the target engine torque Te* and the target engine speed Ne*, respectively. In accordance with a concrete procedure, the control CPU 90 sends an instruction to the EFIECU 70 through communication to regulate the amount of fuel injection or the throttle valve position. Such regulation makes the torque Te and the revolving speed Ne of the engine 50 eventually approach the target engine torque Te* and the target engine speed Ne*.

This procedure enables the output (TexNe) of the engine 50 to undergo go the free torque conversion and be eventually transmitted to the drive shaft 22.

Charging control of the battery 94 starts when the residual capacity BRM of the battery 94 becomes equal to or less than a charge-initiating value BL, which has previously been set as a value requiring the charging process. Charging energy Pbi required for charging the battery 94 is added to the output energy Pd calculated at step S103 in the torque control routine of Fig. 5. The processing at step S104 and subsequent steps is executed with the newly set output energy Pd. On the other hand, the charging energy Pbi is subtracted from the power Pc of the clutch motor 30 calculated at step S134 in the assist motor control routine of Fig. 7. The processing at step S135 and subsequent steps is executed with the newly set clutch motor power Pc. This procedure enables the battery 94 to be charged with the charging energy Pbi.

On the other hand, discharge control of the battery 94 starts when the residual capacity BRM of the battery 94 becomes equal to or more than a discharge-initiating value BH, which has been set as a value requiring the discharging process. A discharging energy Pbo required for discharging the battery 94 is subtracted from the output energy Pd calculated at step S103 in the torque control routine of Fig. 5. The processing at step S104 and subsequent steps is executed with the newly set output energy Pd. On the other hand, the discharging energy Pbo is added to the power Pc of the clutch motor 30 calculated at step S134 in the assist motor control routine of Fig. 7. The processing at step S135 and subsequent steps is executed with the newly set clutch motor power Pc. This procedure enables the battery 94 to be discharged with the discharging energy Pbo.

Discharge control of the battery 94 is implemented, for example, by terminating the operation of the engine 50 and allowing the vehicle to be driven only by the power from the battery 94. Driving the vehicle with the power discharged from the battery 94 under the non-driving condition of the engine 50 starts when the residual capacity BRM of the battery 94 becomes equal to or greater than the discharge-initiating value BH, which has been set as a value requiring the discharging process, or when the driver gives a clear instruction to start the discharging process. An engine stop-time torque control routine illustrated in the flowchart of Fig. 9 is executed to terminate operation of the engine 50 and drive the vehicle with the power stored in the battery 94. In place of the torque control routine of Fig. 5, the engine stop-time torque control routine of Fig. 9 is executed repeatedly at predetermined time intervals when the controller 80 receives a battery discharge signal representing that the residual capacity BRM of the battery 94 becomes equal to or greater than the discharge-initiating value BH or a clear instruction from the driver as a stop signal to stop operation of the engine 50.

When the program enters the engine stop-time torque control routine, the control CPU 90 first receives data of accelerator pedal position AP from the accelerator position sensor 65 at step S160 and computes an output torque command value Td* corresponding to the input accelerator pedal position AP at step S162. The torque command value Tc* of the clutch motor 30 is compared with a subtraction amount ΔTc at step S164. In order to gradually decrease the output energy Pd of the engine 50 to the non-loading state, the torque command value Tc* of the clutch motor 30 acting as the torque Te of the engine 50 is gradually decreased by subtraction amounts ΔTc. The subtraction amount ΔTc is determined depending upon the interval of executing this routine and the performance of the clutch motor 30 and the engine 50. When this routine is activated for the first time in response to the stop signal to stop operation of the engine 50, the torque command value Tc* of the clutch motor 30 is generally greater than the subtraction amount ΔTc since the clutch motor 30 transmits the torque Te of the engine 50 to the drive shaft 22.

When the torque command value Tc* of the clutch motor 30 is greater than the subtraction amount ΔTc, the program proceeds to step S166 at which the control CPU 90 subtracts the subtraction amount ΔTc from the torque command value Tc* set in the previous cycle of this routine to determine a new torque command value Tc* of the clutch motor 30 as expressed by Equation (7) given below:

$$\text{New } Tc^* = \text{Previous } Tc^* - \Delta Tc \qquad (7)$$

At subsequent step S168, the control CPU 90 further calculates the torque command value Ta* of the assist motor 40 by subtracting the new torque command value Tc* from the output torque command value Td* as expressed by Equation (8) given below:

$$Ta^* = Td^* - Tc^* \qquad (8)$$

The control CPU 90 computes a new output energy Pd of the engine 50 by subtracting a subtraction amount ΔPd from the output energy Pd set in the previous cycle of this routine at step S170. The output energy Pd of the engine 50 is decreased by the subtraction amount ΔPd every time when this routine is executed. The output energy Pd thus gradually decreases to the non-loading state. In this embodiment, in order to allow the target engine torque Te* and the target engine speed Ne* of the engine 50 to gradually approach the idling state, the subtraction amount ΔPd is set to be a little greater than the value calculated according to Equation (9) given below:

$$\Delta Pd = \Delta Tc \times Ne \qquad (9)$$

At step S172, the control CPU 90 sets the target engine torque Te* and the target engine speed Ne* of the engine 50, based on the torque command value Tc* of the clutch motor 30 and the output energy Pd of the engine 50 respectively set at steps S166 and S170. The target engine torque Te* is set equal to the torque command value Tc* of the clutch motor 30 in order to effect stable rotation of the engine 50. The target engine speed Ne* is calculated according to Equation (10) given below:

$$Pd = Te^* \times Ne^* \qquad (10)$$

As described previously, the subtraction amount ΔPd is set to be a little greater than the product of the subtraction amount ΔTc and the revolving speed Ne of the engine 50 in this embodiment. This means that the target engine speed Ne* is set to be a little smaller than the actual revolving speed Ne of the engine 50. Provided that the subtraction amount ΔTc is set equal to the value calculated by Equation (9), the target engine speed Ne* is equal to the actual revolving speed Ne of the engine 50. In this case, the revolving speed Ne of the engine 50 is unchanged while the target engine torque Te* is decreased.

After setting the torque command values Tc* and Ta* and the target engine torque Te* and the target engine speed Ne*, the control CPU 90 controls the clutch motor 30 (step S174), the assist motor 40 (step S176), and the engine 50 (step S178) to attain these values. The control of the clutch motor 30 executed at step S174 follows the clutch motor control routine shown in the flowchart of Fig. 6. The repeated execution of the engine stop-time torque control routine makes the target engine speed Ne* of the engine 50 equal to or less than the revolving speed Nd of the drive shaft 22. Under such conditions, the clutch motor 30 is controlled with the power stored in the battery 94 to attain the revolving speed (Nd-Ne) at the torque command value Tc*.

The control of the assist motor 40 executed at step S176 follows an assist motor control routine shown in the flowchart of Fig. 10, instead of the assist motor control routine of Figs. 7 and 8. The processing executed at steps S190 through S197 in the assist motor control routine of Fig. 10 is identical with the processing executed at steps S136 through S150 in the assist motor control routine of Figs. 7 and 8. Since the torque command value Ta* of the assist motor 40 has been set in the engine stop-time torque control routine of Fig. 9, the processing for determining the torque command value Ta* in the assist motor control routine of Figs. 7 and 8 is not required. Power regenerated by the clutch motor 30 is not sufficient for PWM (pulse width modulation) control of the assist motor 40 to give voltages corresponding to the preset torque command value Ta*. The deficiency is supplied by the power stored in the battery 94.

Irrespective of the output energy Pd of the engine 50, the torque output to the drive shaft 22 as a result of the torque control becomes equal to the output torque command value Td*, which is the sum of the torque command value Tc* of the clutch motor 30 and the torque command value Ta* of the assist motor 40. The output torque depends upon the accelerator pedal position AP. As long as the accelerator pedal position AP is kept unchanged, the repeated execution of this routine does not vary the torque output to the drive shaft 22.

As the engine stop-time torque control routine is repeatedly executed, the torque command value Tc* of the clutch motor 30 becomes equal to or less than the subtraction amount ΔTc at step S164. Under such conditions, the engine 50 is kept substantially at an idle and the vehicle is driven substantially only by the torque Ta of the assist motor 40. When the program recognizes this state, the control CPU 90 sets the torque command value Tc* of the clutch motor 30 equal to zero at step S180. The control CPU 90 further sets the torque command value Ta* of the assist motor 40 equal to the output torque command value Td* at step S182 and allocates the value '0' to both the target engine torque Te* and the target engine speed Ne* of the engine 50 at step S184. After the processing at steps S180 through S184, the program goes to steps S174 through S178 to control the clutch motor 30, the assist motor 40, and the engine 50 as described previously. The procedure of engine stop-time torque control completely releases the electromagnetic coupling of the drive shaft 22 with the crankshaft 56 via the clutch motor 30, stops operation of the engine 50, and enables the vehicle to be driven only by the torque Ta of the assist motor 40, which is generated by the power stored in the battery 94.

As discussed above, the power output apparatus 20 of the first embodiment can stop operation of the engine 50 without varying the output torque to the drive shaft 22. Namely the structure of the embodiment prevents the unexpected variation in torque output to the drive shaft 22 and ensures a good ride. The fixed output torque to the drive shaft 22 effectively prevents undesirable vibrations of the vehicle. The energy output from the engine 50 is used as the power in the process of stopping operation of the engine 50. This further enhances the energy efficiency.

In the power output apparatus 20 of the first embodiment, the engine stop-time torque control routine of Fig. 9 is repeatedly executed when the controller 80 receives a battery discharge signal representing that the residual capacity BRM of the battery 94 becomes equal to or greater than the discharge-initiating value BH or a clear instruction on from the driver as a stop signal to stop operation of the engine 50. Alternatively, the same routine may be executed repeatedly when the battery discharge signal or the clear instruction from the driver is input as an energy decrease signal representing that the output energy Pd of the engine 50 has decreased. In the latter case, at step S164 in the flowchart of Fig. 9, the torque command value Tc* of the clutch motor 30 is compared with the decreased target engine torque Te* of the engine 50, which is calculated from the decreased output energy Pd of the engine 50, instead of with the subtraction amount ΔTc. When the torque command value Tc* is greater than the decreased target engine torque Te*, the program executes the processing at steps S166 through S178. When the torque command value Tc* becomes equal to the decreased target engine torque Te*, on the other hand, the program executes only step S168 prior to the processing at steps S174 through S178. This structure can decrease the output energy Pd of the engine 50 without varying the output torque to the drive shaft 22.

In the structure of the power output apparatus 20 shown in Fig. 1, the clutch motor 30 and the assist motor 40 are separately attached to the different positions of the drive shaft 22. Like a modified power output apparatus 20A illustrated in Fig. 11, however, the clutch motor and the assist motor may integrally be joined with each other. A clutch motor 30A of the power output apparatus 20A includes an inner rotor 34A connecting with the crankshaft 56 and an outer rotor 32A linked with the drive shaft 22. Three-phase coils 36A are attached to the inner rotor 34A, and permanent magnets 35A are set on the outer rotor 32A in such a manner that the outer surface and the inner surface thereof have different magnetic poles. An assist motor 40A includes the outer rotor 32A of the clutch motor 30A and a stator 43 with three-phase coils 44 mounted thereon. In this structure, the outer rotor 32A of the clutch motor 30A also works as a rotor of the assist motor 40A. Since the three-phase coils 36A are mounted on the inner rotor 34A connecting with the crankshaft 56, a rotary transformer 38A for supplying electric power to the three-phase coils 36A of the clutch motor 30A is attached to the crankshaft 56.

In the power output apparatus 20A, the voltage applied to the three-phase coils 36A on the inner rotor 34A is controlled against the inner-surface magnetic pole of the permanent magnets 35A set on the outer rotor 32A. This allows the clutch motor 30A to work in the same manner as the clutch motor 30 of the power output apparatus 20 shown in Fig. 1. The voltage applied to the three-phase coils 44 on the stator 43 is controlled against the outer-surface magnetic pole of the permanent magnets 35A set on the outer rotor 32A. This allows the assist motor 40A to work in the same manner as the assist motor 40 of the power output apparatus 20. The torque control routine of Fig. 5 and the engine stop-time torque control routine of Fig. 9 are also applicable to the power output apparatus 20A shown in Fig. 11, which accordingly implements the same operations and exerts the same effects as those of the power output apparatus 20 shown in Fig. 1.

As discussed above, the outer rotor 32A functions concurrently as one of the rotors in the clutch motor 30A and as the rotor of the assist motor 40A, thereby effectively reducing the size and weight of the whole power output apparatus 20A.

Fig. 12 schematically illustrates an essential part of another power output apparatus 20B as a second embodiment of the present invention. The power output apparatus 20B of Fig. 11 has a similar structure to that of the power output apparatus 20 of Fig. 1, except that the assist motor 40 is attached to the crankshaft 56 placed between the engine 50 and the clutch motor 30. In the power output apparatus 20B of the second embodiment, like numerals and symbols denote like elements as those of the power output apparatus 20 of Fig. 1. The symbols used in the description have like meanings unless otherwise specified.

The following describes the essential operation of the power output apparatus 20B shown in Fig. 12. By way of example, it is assumed that the engine 50 is driven with a torque Te and at a revolving speed Ne. When a torque Ta is added to the crankshaft 56 by the assist motor 40 linked with the crankshaft 56, the sum of the torques (Te+Ta) consequently acts on the crankshaft 56. When the clutch motor 30 is controlled to produce the torque Tc equal to the sum of the torques (Te+Ta), the torque Tc (=Te+Ta) is transmitted to the drive shaft 22.

When the revolving speed Ne of the engine 50 is greater than the revolving speed Nd of the drive shaft 22, the clutch motor 30 regenerates electric power based on the revolving speed difference Nc between the revolving speed Ne of the engine 50 and the revolving speed Nd of the drive shaft 22. The regenerated power is supplied to the assist motor 40 via the power lines P1 and P2 and the second driving circuit 92 to activate the assist motor 40. Provided that the torque Ta of the assist motor 40 is substantially equivalent to the electric power regenerated by the clutch motor 30, free torque conversion is allowed for the energy output from the engine 50 within a range holding the relationship of Equation (11) given below. Since the relationship of Equation (11) represents the ideal state with an efficiency of 100%, (TcxNd) is a little smaller than (TexNe) in the actual state.

$$Te \times Ne = Tc \times Nd \qquad (11)$$

Referring to Fig. 4, under the condition that the crankshaft 56 rotates with the torque T1 and at the revolving speed N1, the energy corresponding to the sum of the regions G1+G3 is regenerated by the clutch motor 30 and supplied to the assist motor 40. The assist motor 40 converts the received energy in the sum of the regions G1+G3 to the energy corresponding to the sum of the regions G2+G3 and transmits the converted energy to the crankshaft 56.

When the revolving speed Ne of the engine 50 is smaller than the revolving speed Nd of the drive shaft 22, the clutch motor 30 works as a normal motor. In the clutch motor 30, the inner rotor 34 rotates relative to the outer rotor 32 in the direction of rotation of the drive shaft 22 at a revolving speed defined by the absolute value of the revolving speed difference Nc (=Ne-Nd). Provided that the torque Ta of the assist motor 40 is set to a negative value, which enables the assist motor 40 to regenerate electric power substantially equivalent to the electrical energy consumed by the clutch motor 30, free torque conversion is also allowed for the energy output from the engine 50 within the range holding the relationship of Equation (11) given above.

Referring to Fig. 4, under the condition that the crankshaft 56 rotates with the torque T2 and at the revolving speed N2, the energy corresponding to the region G2 is regenerated by the assist motor 40 and consumed by the clutch motor 30 as the energy corresponding to the region G1.

The control procedure of the second embodiment discussed above follows the torque control routine shown in the flowchart of Fig. 13. When the program enters the torque control routine, the control CPU 90 of the controller 80 first executes the processing of steps S200 through S208, which is identical with that of steps S100 through S104 in the flowchart of Fig. 5. The control CPU 90 reads the revolving speed Nd of the drive shaft 22 at step S200 and the accelerator pedal position AP at step S202, and calculates the output torque command value Td* from the input accelerator pedal position AP at step S204. The control CPU 90 then computes the energy Pd to be output from the drive shaft 22 based on the calculated output torque command value Td* and the input revolving speed Nd of the drive shaft 22 at step S206, and sets the target engine torque Te* and the target engine speed Ne* of the engine 50 at step S208.

At subsequent step S210, the control CPU 90 computes the torque command value Ta* of the assist motor 40 according to Equation (12) given as:

$$Ta^* = Ksc \times (Td^* - Te^*) \qquad (12)$$

At step S212, the torque command value Tc* of the clutch motor 30 is calculated from the torque command value Ta* of the assist motor 40 thus obtained according to Equation (13) expressed as:

$$Tc^* = Te^* + Ta^* \qquad (13)$$

The control CPU 90 controls the clutch motor 30 at step S214, the assist motor 40 at step S216, and the engine 50 at step S217 based on the torque command values Ta* and Tc*, the target engine torque Te*, and the target engine speed Ne* thus obtained. The concrete procedure of the clutch motor control (step S214) is identical with that described above according to the flowchart of Fig. 6, whereas the concrete procedure of the engine control (step S217) is identical with that of the first embodiment discussed above. The assist motor control executed at step S216 essentially follows the processing of steps S192 through S196 in the assist motor control routine of Fig. 10, except that the rotational angle θe of the crankshaft 56 of the engine 50 measured with the resolver 39 is processed in place of the rotational angle θd of the drive shaft 22. This modification is ascribed to the position of the assist motor 40, which is attached to the crankshaft 56.

The power output apparatus 20B of the second embodiment can effectively control charge and discharge of the battery 94. The vehicle may be driven only by the power stored in the battery 94 while operation of the engine 50 stops. The following describes the procedure of terminating operation of the engine 50 and driving the vehicle with the power discharged from the battery 94, based on an engine-stop time torque control routine of the second embodiment shown in the flowchart of Fig. 14. Like the similar routine of the first embodiment, the engine stop-time torque control routine of Fig. 14 is executed repeatedly at predetermined time intervals, in place of the torque control routine of Fig. 13, when the controller 80 receives a battery discharge signal representing that the residual capacity BRM of the battery 94 becomes equal to or greater than the discharge-initiating value BH or a clear instruction from the driver as a stop signal to stop operation of the engine 50.

When the program enters the engine stop-time torque control routine, the control CPU 90 first receives data of accelerator pedal position AP from the accelerator position sensor 65 at step S220 and computes the output torque command value Td* corresponding to the input accelerator pedal position AP at step S222. The output energy Pd of the engine 50 is compared with a threshold value Pdref at step S224. The threshold value Pdref is set to be a little greater than the output energy Pd of the engine 50 at an idle. When this routine is activated for the first time in response to the stop signal to stop operation of the engine 50, the output energy Pd is generally greater than the threshold value Pdref since the vehicle is driven by the power output from the engine 50.

When the output energy Pd is greater than the threshold value Pdrefat step S224, the program proceeds to step S226 at which the control CPU 90 subtracts the subtraction amount ΔPd from the output energy Pd set in the previous cycle of this routine to determine a new output energy Pd. At subsequent step S228, the control CPU 90 sets a target engine torque Te* and a target engine speed Ne* of the engine 50 by considering the efficiency of the engine 50 and other conditions according to Equation (14) given below:

$$Pd = Te^* \times Ne^* \tag{14}$$

It is preferable that the target engine torque Te* and the target engine speed Ne* are set to gradually attain the idling state of the engine 50. The torque command value Ta* of the assist motor 40 is computed at step S230 according to Equation (15) given below:

$$Ta^* = Td^* - Te^* \tag{15}$$

whereas the torque command value Tc* of the clutch motor 30 is set equal to the output torque command value Td* at step S232.

The control CPU 90 executes control of the clutch motor 30 (step S234), control of the assist motor 40 (step S236), and control of the engine 50 (at step S238), which are identical with the processing executed at step S214 through S217 in the torque control routine of Fig. 13.

The repeated execution of this routine makes the target engine speed Ne* of the engine 50 equal to or less than the revolving speed Nd of the drive shaft 22. Under such conditions, the clutch motor 30 is controlled with the power stored in the battery 94 to attain the revolving speed (Nd-Ne) at the torque command value Tc*. Power regenerated by the clutch motor 30 is not sufficient for PWM control of the assist motor 40 to give voltages corresponding to the preset torque command value Ta*. The deficiency is supplied by the power stored in the battery 94.

Irrespective of the decrease in output energy Pd of the engine 50, the torque output to the drive shaft 22 as a result of the torque control becomes equal to the output torque command value Td*, which depends upon the accelerator pedal position AP. As long as the accelerator pedal position AP is kept unchanged, the repeated execution of this routine does not vary the torque output to the drive shaft 22.

As the engine stop-time torque control routine is repeatedly executed, the output energy Pd of the engine 50 becomes equal to or less than the threshold value Pdref at step S224. Under such conditions, the engine 50 is kept substantially at an idle. When the program recognizes this state, the control CPU 90 sets the target engine torque Te* and the target engine speed Ne* of the engine 50 equal to zero at step S240, sets the torque command value Ta* of the assist motor 40 equal to the output torque command value Td* at step S242, and sets the torque command value Tc* of the clutch motor 30 equal to the output torque command value Td* at step S244. This is followed by the control of the clutch motor 30 (step S234), the assist motor 40 (step S236), and the engine 50 (step S238). The procedure of engine stop-time torque control terminates operation of the engine 50 and enables the vehicle to be driven by the torque Tc of the clutch motor 30, which is generated by the power discharged from the battery 94. The assist motor 40 receives the reaction force of the torque command value Tc* output from the clutch motor 30 to the drive shaft 22. When the engine 50 stops operation, the revolving speed Ne of the engine 50 becomes equal to zero and a constant current, which can generate a torque against the torque command value Tc*, flows through the three-phase coils of the assist motor 40. The crankshaft 56 is accordingly electromagnetically-locked by the assist motor 40.

As discussed above, the power output apparatus 20B of the second embodiment can stop operation of the engine 50 without varying the output torque to the drive shaft 22. Namely the structure of the second embodiment prevents the unexpected variation in torque output to the drive shaft 22 and ensures a good ride. The fixed output torque to the drive shaft 22 effectively prevents undesirable vibrations of the vehicle.

In the power output apparatus 20B of the second embodiment, the engine stop-time torque control routine of Fig. 14 is repeatedly executed when the controller 80 receives a battery discharge signal representing that the residual capacity BRM of the battery 94 becomes equal to or greater than the discharge-initiating value BH or a clear instruction on from the driver as a stop signal to stop operation of the engine 50. Alternatively, the same routine may be executed repeatedly when the battery discharge signal or the clear instruction from the driver is input as an energy decrease signal representing that the output energy Pd of the engine 50 has decreased. In the latter case, at step S224 in the flowchart of Fig. 14, the output energy Pd of the engine 50 is compared with a target output energy Pd* of the engine 50, instead of with the threshold value Pdref. When the output energy Pd is greater than the target output energy Pd*, the program executes the processing at steps S226 through S238. When the output energy Pd becomes equal to the target output energy Pd*, on the other hand, the program executes steps S230 through S238. This structure can decrease the output energy Pd of the engine 50 without varying the output torque to the drive shaft 22.

In the power output apparatus 20B of Fig. 12 given as the second embodiment discussed above, the assist motor 40 is attached to the crankshaft 56 placed between the engine 50 and the clutch motor 30. Like another power output apparatus 20C illustrated in Fig. 15, however, the engine 50 may be interposed between the clutch motor 30 and the assist motor 40, both of which are linked with the crankshaft 56.

In the power output apparatus 20B of Fig. 12, the clutch motor 30 and the assist motor 40 are separately attached to the different positions of the crankshaft 56. Like a power output apparatus 20D shown in Fig. 16, however, the clutch motor and the assist motor may integrally be joined with each other. A clutch motor 30D of the power output apparatus 20D includes an outer rotor 32D connecting with the crankshaft 56 and an inner rotor 34 linked with the drive shaft 22. Three-phase coils 36 are attached to the inner rotor 34, and permanent magnets 35D are set on the outer rotor 32D in such a manner that the outer surface and the inner surface thereof have different magnetic poles. An assist motor 40D includes the outer rotor 32D of the clutch motor 30D and a stator 43 with three-phase coils 44 mounted thereon. In this structure, the outer rotor 32D of the clutch motor 30D also works as a rotor of the assist motor 40D.

In the power output apparatus 20D, the voltage applied to the three-phase coils 36 on the inner rotor 34 is controlled against the inner-surface magnetic pole of the permanent magnets 35D set on the outer rotor 32D. This allows the clutch motor 30D to work in the same manner as the clutch motor 30 of the power output apparatus 20B shown in Fig. 12. The voltage applied to the three-phase coils 44 on the stator 43 is controlled against the outer-surface magnetic pole of the permanent magnets 35D set on the outer rotor 32D. This allows the assist motor 40D to work in the same manner as the assist motor 40 of the power output apparatus 20B. The torque control routine of Fig. 13 and the engine stop-time torque control routine of Fig. 14 are also applicable to the power output apparatus 20D shown in Fig. 16, which accordingly implements the same operations and exerts the same effects as those of the power output apparatus 20B shown in Fig. 12.

Like the power output apparatus 20A shown in Fig. 11, in the power output apparatus 20D of Fig. 16, the outer rotor 32D functions concurrently as one of the rotors in the clutch motor 30D and as the rotor of the assist motor 40D, thereby effectively reducing the size and weight of the whole power output apparatus 20D.

There may be many other modifications, alternations, and changes without departing from the scope or spirit of essential characteristics of the invention. It is thus clearly understood that the above embodiments are only illustrative and not restrictive in any sense.

The gasoline engine driven by means of gasoline is used as the engine 50 in the above power output apparatuses. The principle of the invention is, however, applicable to other internal combustion engines and external combustion engines, such as Diesel engines, turbine engines, and jet engines.

Permanent magnet (PM)-type synchronous motors are used for the clutch motor 30 and the assist motor 40 in the power output apparatuses described above. Other motors such as variable reluctance (VR)-type synchronous motors, vernier motors, d.c. motors, induction motors, superconducting motors, and stepping motors may be used for the regenerative operation and the power operation.

The rotary transformer 38 used as means for transmitting electric power to the clutch motor 30 may be replaced by a slip ring-brush contact, a slip ring-mercury contact, a semiconductor coupling of magnetic energy, or the like.

In the above power output apparatuses, transistor inverters are used for the first and the second driving circuits 91 and 92. Other examples applicable to the driving circuits 91 and 92 include IGBT (insulated gate bipolar mode transistor) inverters, thyristor inverters, voltage PWM (pulse width modulation) inverters, square-wave inverters (voltage inverters and current inverters), and resonance inverters.

The battery 94 may include Pb cells, NiMH cells, Li cells, or the like cells. A capacitor may be used in place of the battery 94.

Although the power output apparatus is mounted on the vehicle in the above embodiments, it may be mounted on other transportation means like ships and airplanes as well as a variety of industrial machines.

The scope and spirit of the present invention are limited only by the terms of the appended claims.

Claims

1. A power output apparatus for outputting power to a drive shaft, said power output apparatus comprising:

an engine having an output shaft;
engine driving means for driving said engine;

a first motor comprising a first rotor connected with said output shaft of said engine and a second rotor connected with said drive shaft, said second rotor being coaxial to and rotatable relative to said first rotor, whereby power is transmitted between said output shaft of said engine and said drive shaft via an electromagnetic connection of said first rotor and said second rotor;
a first motor-driving circuit for controlling degree of electromagnetic connection of said first rotor and said second rotor in said first motor and regulating rotation of said second rotor relative to said first rotor;
a second motor connected with said drive shaft;
a second motor-driving circuit for driving and controlling said second motor;
a storage battery being charged with power regenerated by said first motor via said first motor-driving circuit, being charged with power regenerated by said second motor via said second motor-driving circuit, discharging power required to drive said first motor via said first motor-driving circuit, and discharging power required to drive said second motor via said second motor-driving circuit;
power decrease signal detection means for detecting power decrease signal to decrease power output from said engine;
driving circuit control means for, when said power decrease signal detection means detects the power decrease signal, controlling said first motor-driving circuit in response to said signal to gradually decrease the degree of electromagnetic connection of said first rotor with said second rotor in said first motor and controlling said second motor-driving circuit to enable said second motor to use power stored in said storage battery and make up for a decrease in power transmitted by said first motor accompanied by the decrease in degree of electromagnetic connection; and
engine power decreasing means for controlling said engine driving means to decrease the power output from said engine with the decrease in the degree of electromagnetic connection of said first rotor with said second rotor accomplished by said driving circuit control means.

2. A power output apparatus in accordance with claim 1, wherein said power decrease signal detection means comprises means for detecting an engine stop signal to stop operation of said engine; and

wherein said engine power decreasing means comprises means for controlling said engine driving means to stop supply of fuel into said engine and terminate operation of said engine when said driving circuit control means releases the electromagnetic connection of said first rotor with said second rotor in said first motor.

3. A power output apparatus for outputting power to a drive shaft, said power output apparatus comprising:

an engine having an output shaft;
engine driving means for driving said engine;
a complex motor comprising a first rotor connected with said output shaft of said engine, a second rotor connected with said drive shaft being coaxial to and rotatable relative to said first rotor, and a stator for rotating said second rotor, said first rotor and said second rotor constituting a first motor, said second rotor and said stator constituting a second motor;
a first motor-driving circuit for driving and controlling said first motor in said complex motor;
a second motor-driving circuit for driving and controlling said second motor in said complex motor;
a storage battery being charged with power regenerated by said first motor via said first motor-driving circuit, being charged with power regenerated by said second motor via said second motor-driving circuit, discharging power required to drive said first motor via said first motor-driving circuit, and discharging power required to drive said second motor via said second motor-driving circuit;
power decrease signal detection means for detecting power decrease signal to decrease power output from said engine;
driving circuit control means for, when said power decrease signal detection means detects the power decrease signal, controlling said first motor-driving circuit in response to said signal to gradually decrease the degree of electromagnetic connection of said first rotor with said second rotor in said first motor and controlling said second motor-driving circuit to enable said second motor to use power stored in said storage battery and make up for a decrease in power transmitted by said first motor accompanied by the decrease in degree of electromagnetic connection; and
engine power decreasing means for controlling said engine driving means to decrease the power output from said engine with the decrease in the degree of electromagnetic connection of said first rotor with said second rotor accomplished by said driving circuit control means.

4. A power output apparatus in accordance with claim 3, wherein said power decrease signal detection means comprises means for detecting an engine stop signal to stop operation of said engine; and

wherein said engine power decreasing means comprises means for controlling said engine driving means to stop supply of fuel into said engine and terminate operation of said engine when said driving circuit control means releases the electromagnetic connection of said first rotor with said second rotor in said first motor.

5. A power output apparatus for outputting power to a drive shaft, said power output apparatus comprising:

an engine having an output shaft;
engine driving means for driving said engine;
a first motor comprising a first rotor connected with said output shaft of said engine and a second rotor connected with said drive shaft, said first motor being coaxial to and rotatable relative to said first rotor, whereby power is transmitted between said output shaft of said engine and said drive shaft via an electromagnetic connection of said first rotor and said second rotor;
a first motor-driving circuit for controlling degree of electromagnetic connection of said first rotor and said second rotor in said first motor and regulating rotation of said second rotor relative to said first rotor;
a second motor connectied with the output shaft of said engine;
a second motor-driving circuit for driving and controlling said second motor;
a storage battery being charged with power regenerated by said first motor via said first motor-driving circuit, being charged with power regenerated by said second motor via said second motor-driving circuit, discharging power required to drive said first motor via said first motor-driving circuit, and discharging power required to drive said second motor via said second motor-driving circuit;
power decrease signal detection means for detecting power decrease signal to decrease power output from said engine;
engine power decreasing means for, when said power decrease signal detection means detects the power decrease signal, controlling said engine driving means in response to said signal to gradually decrease the power output from said engine; and
driving circuit control means for controlling said first motor-driving circuit and said second motor-driving circuit to enable said first motor and said second motor to use power stored in said storage battery and make up for the decrease in power output from said engine accomplished by said engine power decreasing means.

6. A power output apparatus in accordance with claim 5, wherein said driving circuit control means comprises meane for controlling said first motor-driving circuit to enable said first motor to make up for a decrease in revolving speed of the output shaft of said engine among the decrease in power output from said engine, and controlling said second motor-driving circuit to enable said second motor to make up for a decrease in torque among the decrease in power output from said engine.

7. A power output apparatus in accordance with claim 6, wherein said power decrease signal detection means comprises meane for detecting an engine stop signal to stop operation of said engine; and

wherein said engine power decreasing means comprises meane for controlling said engine driving means to stop supply of fuel into said engine and terminate operation of said engine when the power output from said engine becomes equal to zero.

8. A power output apparatus for outputting power to a drive shaft, said power output apparatus comprising:

an engine having an output shaft;
engine driving means for driving said engine;
a complex motor comprising a first rotor connected with said output shaft of said engine, a second rotor connected with said drive shaft being coaxial to and rotatable relative to said first rotor, and a stator for rotating said first rotor, said first rotor and said second rotor constituting a first motor, said first rotor and said stator constituting a second motor;
a first motor-driving circuit for driving and controlling said first motor in said complex motor;
a second motor-driving circuit for driving and controlling said second motor in said complex motor;
a storage battery being charged with power regenerated by said first motor via said first motor-driving circuit, being charged with power regenerated by said second motor via said second motor-driving circuit, discharging power required to drive said first motor via said first motor-driving circuit, and discharging power required to drive said second motor via said second motor-driving circuit;
power decrease signal detection means for detecting power decrease signal to decrease power output from said engine;

engine power decreasing means for, when said power decrease signal detection means detects the power decrease signal, controlling said engine driving means in response to said signal to gradually decrease the power output from said engine; and

driving circuit control means for controlling said first motor-driving circuit and said second motor-driving circuit to enable said first motor and said second motor to use power stored in said storage battery and make up for the decrease in power output from said engine accomplished by said engine power decreasing means.

9. A power output apparatus in accordance with claim 8, wherein said driving circuit control means comprises means for controlling said first motor-driving circuit to enable said first motor to make up for a decrease in revolving speed of the output shaft of said engine among the decrease in power output from said engine, and controlling said second motor-driving circuit to enable said second motor to make up for a decrease in torque among the decrease in power output from said engine.

10. A power output apparatus in accordance with claim 9, wherein said power decrease signal detection means comprises means for detecting an engine stop signal to stop operation of said engine; and

wherein said engine power decreasing means comprises means for controlling said engine driving means to stop supply of fuel into said engine and terminate operation of said engine when the power output from said engine becomes equal to zero.

11. A method of controlling a power output apparatus for outputting power to a drive shaft, said method comprising the steps of:

(a) providing an engine having an output shaft; engine driving means for driving said engine; a first motor comprising a first rotor connected with said output shaft of said engine and a second rotor connected with said drive shaft, said first motor being coaxial to and rotatable relative to said first rotor, whereby power is transmitted between said output shaft of said engine and said drive shaft via an electromagnetic connection of said first rotor and said second rotor; a second motor connected with said drive shaft; and a storage battery being charged with power regenerated by said first motor, being charged with power regenerated by said second motor, discharging power required to drive said first motor, and discharging power required to drive said second motor;
(b) detecting power decrease signal to decrease power output from said engine;
(c) controlling said first motor in response to the power decrease signal, to gradually decrease the degree of electromagnetic connection of said first rotor with said second rotor in said first motor;
(d) controlling said second motor to enable said second motor to use power stored in said storage battery and make up for a decrease in power transmitted by said first motor accompanied by the decrease in degree of electromagnetic connection; and
(e) controlling said engine driving means to decrease the power output from said engine with the decrease in degree of electromagnetic connection of said first rotor with said second rotor accomplished in said step (c).

12. A method in accordance with claim 11, wherein the power decrease signal detected represents an engine stop signal to stop operation of said engine,

said step (e) further comprising the step of controlling said engine driving means to stop supply of fuel into said engine and terminate operation of said engine when the electromagnetic connection of said first rotor with said second rotor in said first motor has been decreased to a release position in response to the engine stop signal.

13. A method of controlling a power output apparatus for outputting power to a drive shaft, said method comprising the steps of:

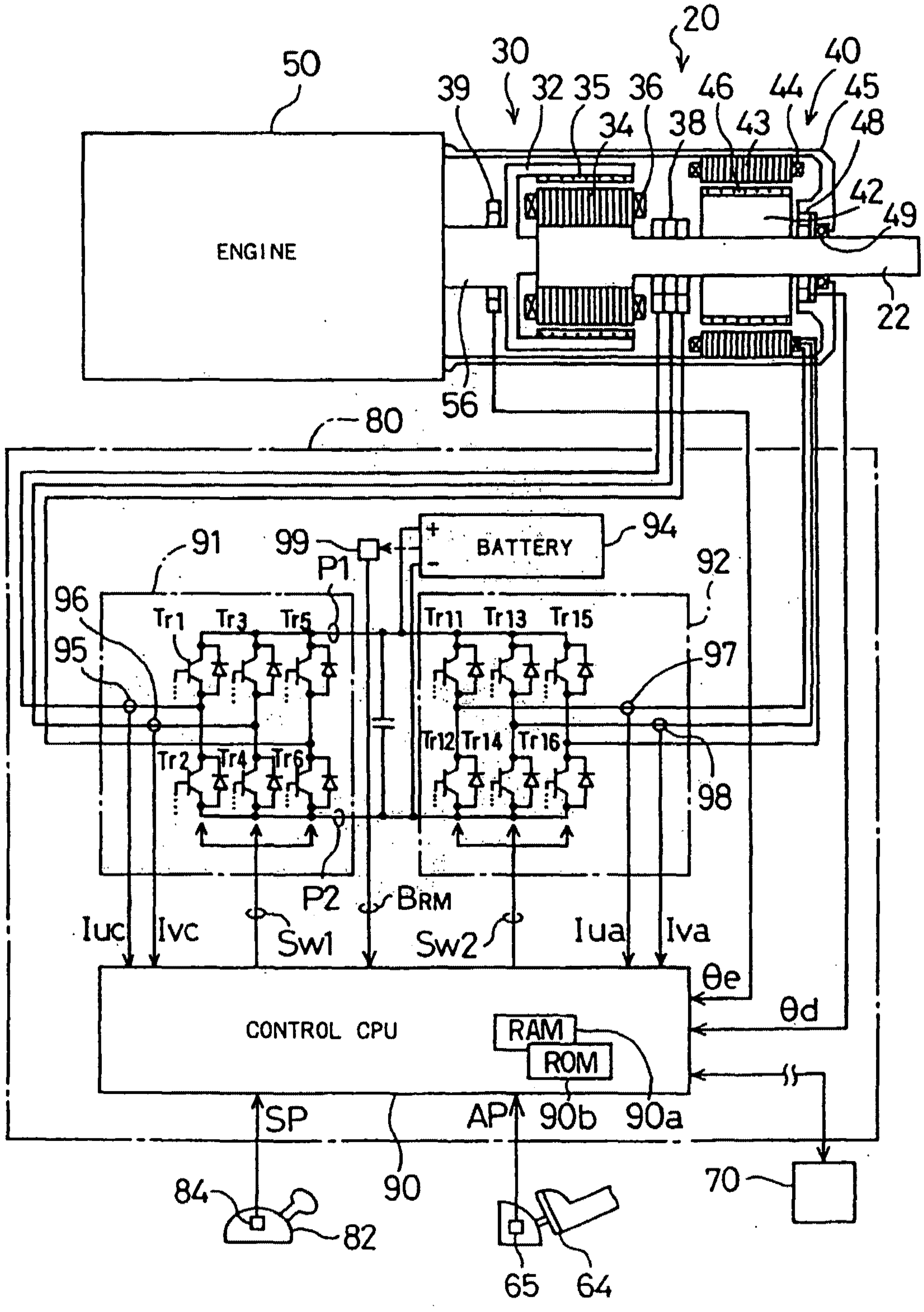
(a) providing an engine having an output shaft; engine driving means for driving said engine; a first motor comprising a first rotor connected with said output shaft of said engine and a second rotor connected with said drive shaft, said second rotor being coaxial to and rotatable relative to said first rotor, whereby power is transmitted between said output shaft of said engine and said drive shaft via an electromagnetic connection of said first rotor and said second rotor; a second motor connected with the output shaft of said engine; and a storage battery being charged with power regenerated by said first motor, being charged with power regenerated by said second motor, discharging power required to drive said first motor, and discharging power required to drive said second motor;
(b) detecting power decrease signal to decrease power output from said engine;
(c) controlling said engine driving means in response to the power decrease signal, to gradually decrease the power output from said engine; and

(d) controlling said first motor and said second motor to enable said first motor and said second motor to use power stored in said storage battery and make up for the decrease in power output from said engine accomplished in said step (c).

14. A method in accordance with claim 13, wherein said step (d) further comprises the steps of:

(e) controlling said first motor to enable said first motor to make up for a decrease in revolving speed of the output shaft of said engine among the decrease in power output from said engine; and
(f) controlling said second motor to enable said second motor to make up for a decrease in torque among the decrease in power output from said engine.

Fig. 1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42
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ENGINE
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91
99
BATTERY
94
92
P1
96
95
Tr1
Tr3
Tr5
Tr11
Tr13
Tr15
97
Tr2
Tr4
Tr6
Tr12
Tr14
Tr16
98
P2
BRM
Iuc
Ivc
Sw1
Sw2
Iua
Iva
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CONTROL CPU
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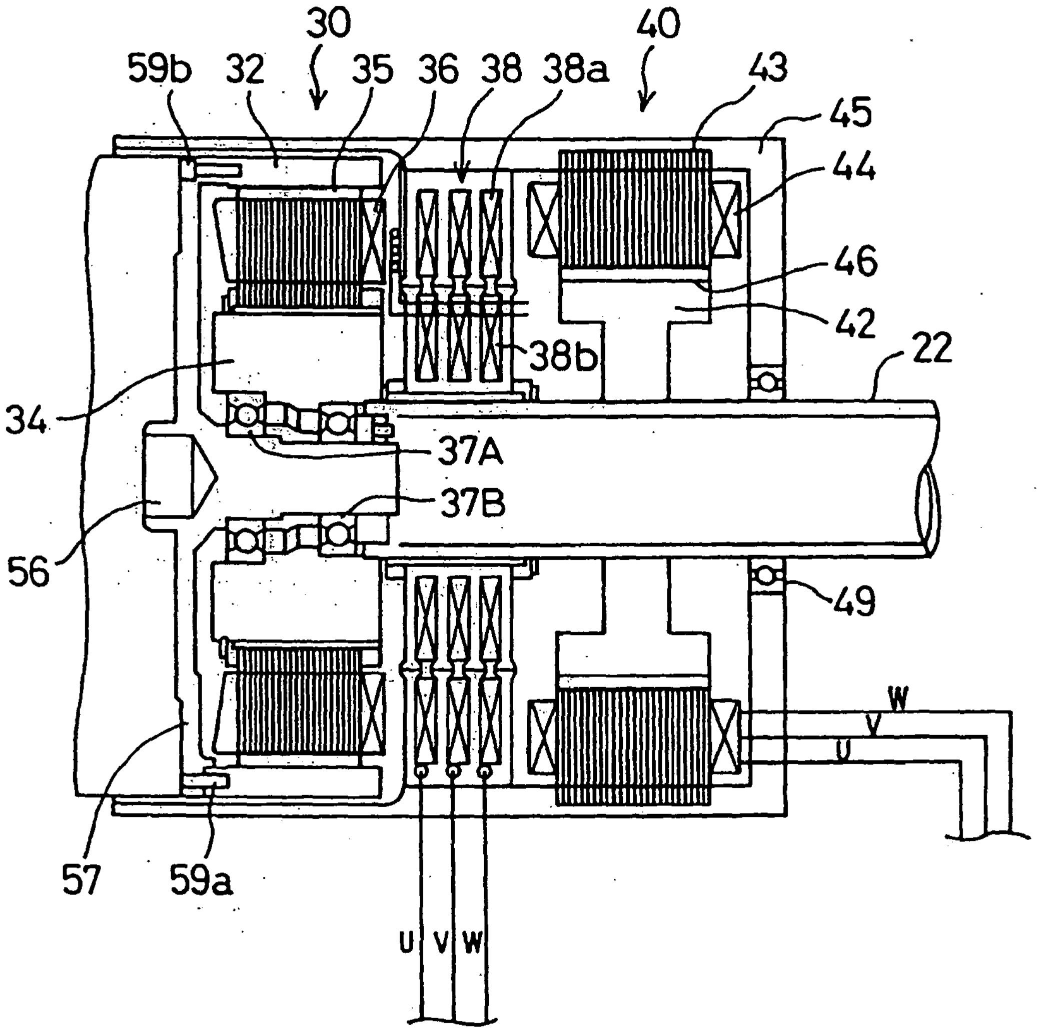
90a
84
90
70
82
65
64

Fig. 2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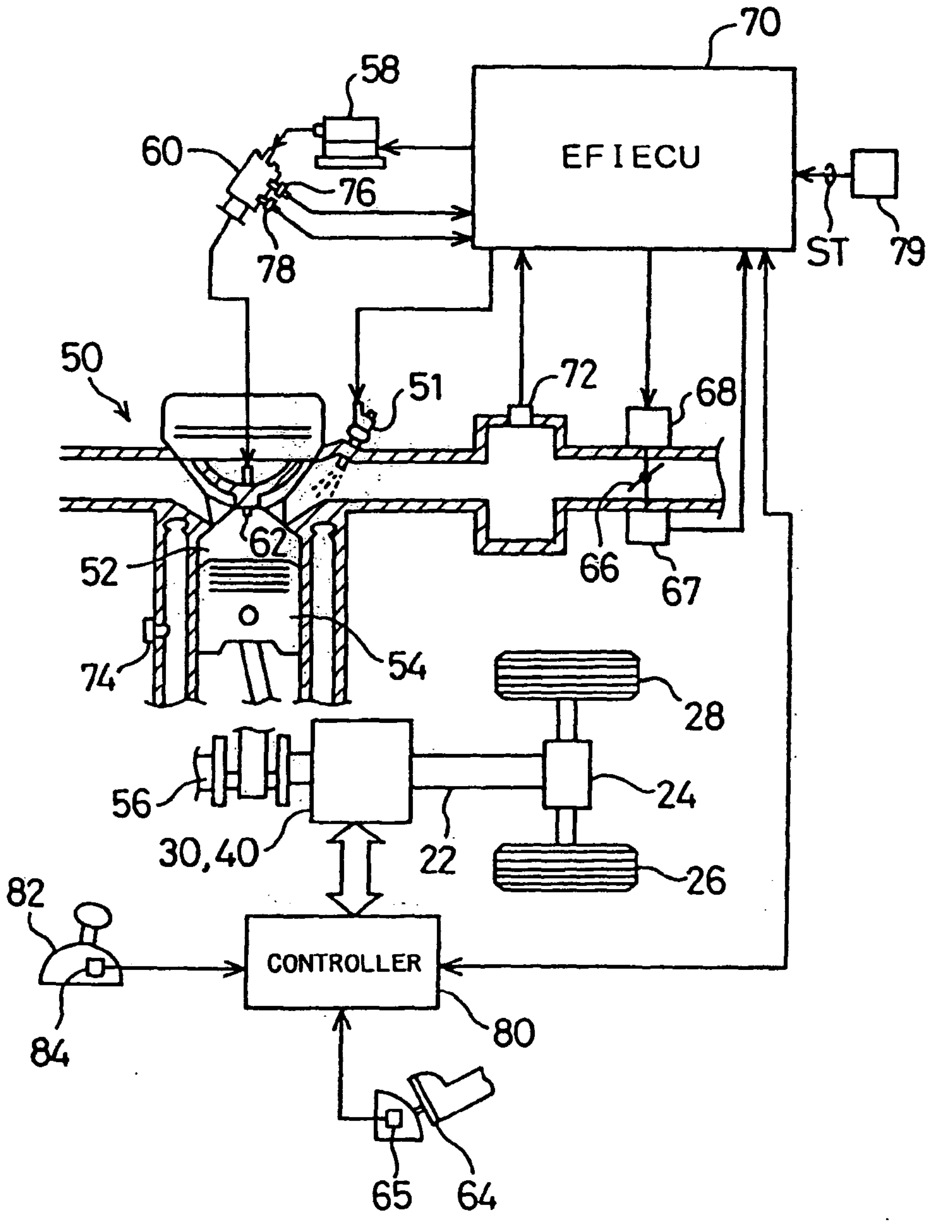
40
59b
32
35
36
38
38a
43
45
44
46
42
22
38b
34
37A
37B
56
49
W
V
U
57
59a
U
V
W

Fig. 3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EFIECU
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60
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78
ST
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51
72
68
62
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30,40
22
26
82
CONTROLLER
84
80
65
64

Fig. 4

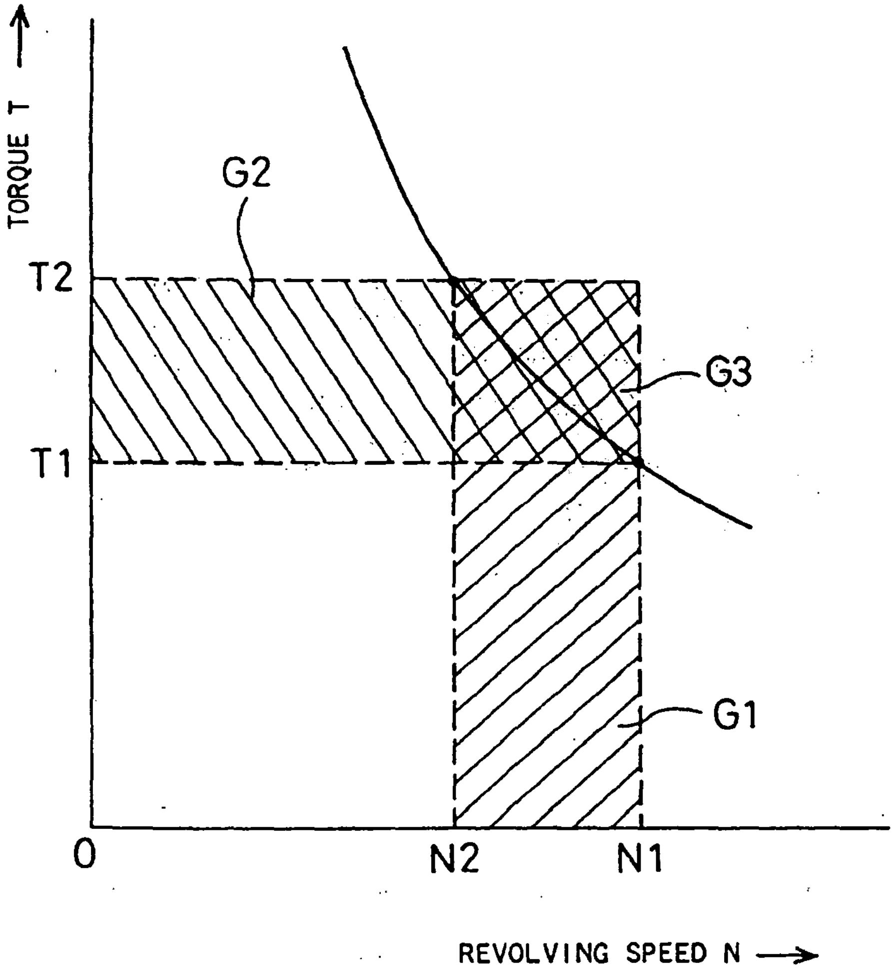


Fig. 5

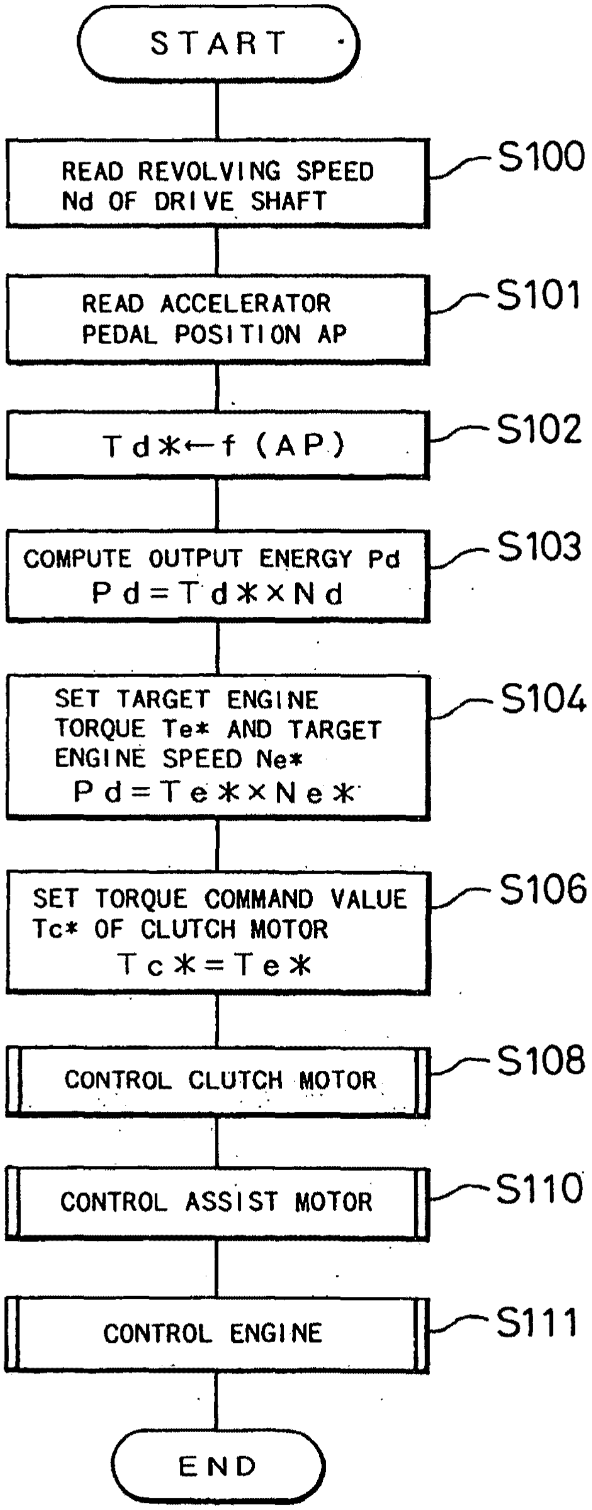

START
READ REVOLVING SPEED Nd OF DRIVE SHAFT
S100
READ ACCELERATOR PEDAL POSITION AP
S101
Td＊←f (AP)
S102
COMPUTE OUTPUT ENERGY Pd
Pd=Td＊×Nd
S103
SET TARGET ENGINE TORQUE Te＊ AND TARGET ENGINE SPEED Ne＊
Pd=Te＊×Ne＊
S104
SET TORQUE COMMAND VALUE Tc＊ OF CLUTCH MOTOR
Tc＊=Te＊
S106
CONTROL CLUTCH MOTOR
S108
CONTROL ASSIST MOTOR
S110
CONTROL ENGINE
S111
END

Fig. 6

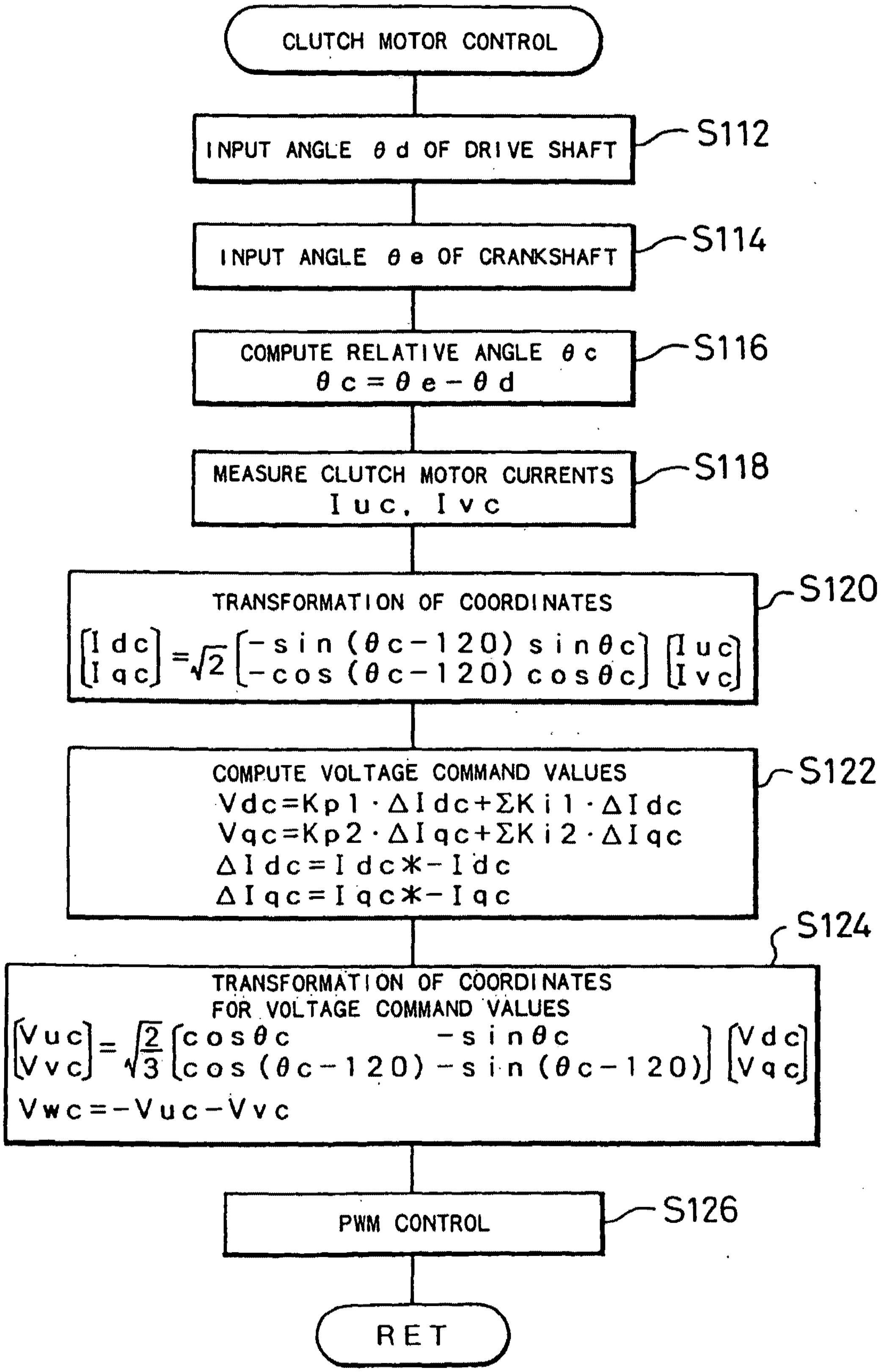

CLUTCH MOTOR CONTROL
INPUT ANGLE θd OF DRIVE SHAFT
S112
INPUT ANGLE θe OF CRANKSHAFT
S114
COMPUTE RELATIVE ANGLE θc
θc=θe−θd
S116
MEASURE CLUTCH MOTOR CURRENTS
Iuc, Ivc
S118
TRANSFORMATION OF COORDINATES
[Idc; Iqc] = √2 [−sin(θc−120) sinθc; −cos(θc−120) cosθc] [Iuc; Ivc]
S120
COMPUTE VOLTAGE COMMAND VALUES
Vdc=Kp1·ΔIdc+ΣKi1·ΔIdc
Vqc=Kp2·ΔIqc+ΣKi2·ΔIqc
ΔIdc=Idc*−Idc
ΔIqc=Iqc*−Iqc
S122
S124
TRANSFORMATION OF COORDINATES
FOR VOLTAGE COMMAND VALUES
[Vuc; Vvc] = √(2/3) [cosθc −sinθc; cos(θc−120) −sin(θc−120)] [Vdc; Vqc]
Vwc=−Vuc−Vvc
PWM CONTROL
S126
RET

Fig. 7

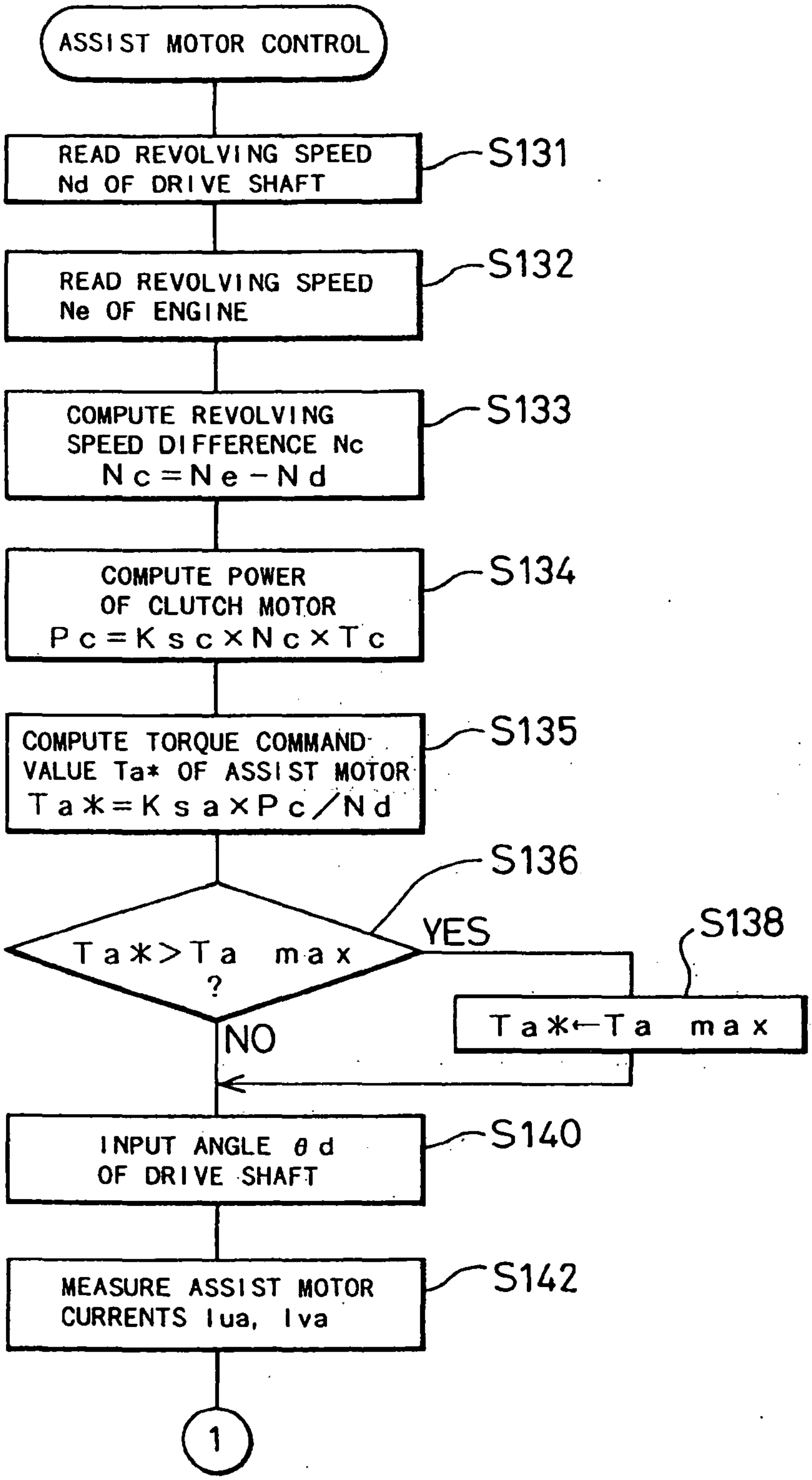

ASSIST MOTOR CONTROL
READ REVOLVING SPEED Nd OF DRIVE SHAFT
S131
READ REVOLVING SPEED Ne OF ENGINE
S132
COMPUTE REVOLVING SPEED DIFFERENCE Nc
Nc=Ne−Nd
S133
COMPUTE POWER OF CLUTCH MOTOR
Pc=Ksc×Nc×Tc
S134
COMPUTE TORQUE COMMAND VALUE Ta* OF ASSIST MOTOR
Ta*=Ksa×Pc/Nd
S135
Ta*>Ta max ?
S136
YES
NO
Ta*←Ta max
S138
INPUT ANGLE θd OF DRIVE SHAFT
S140
MEASURE ASSIST MOTOR CURRENTS Iua, Iva
S142
1

Fig. 8

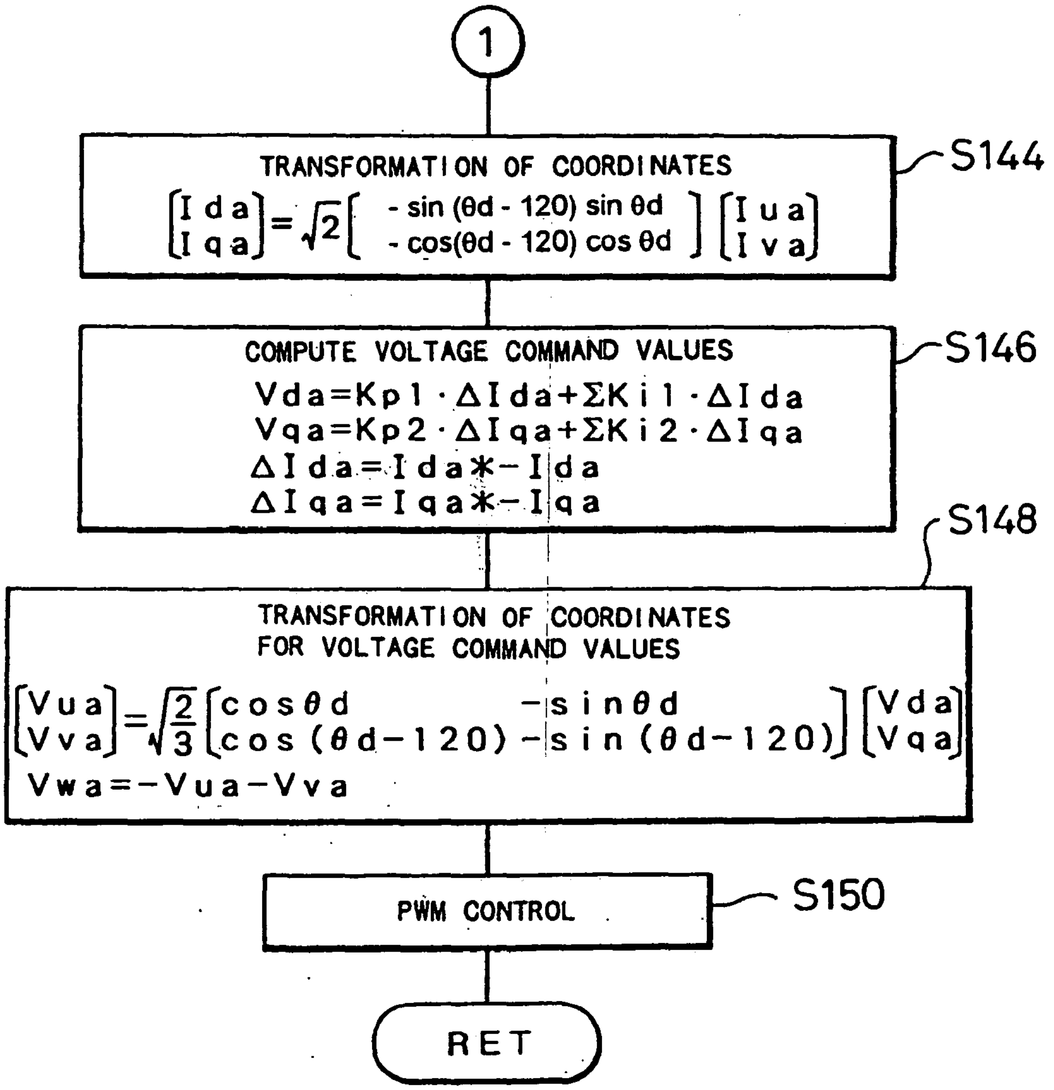

1
TRANSFORMATION OF COORDINATES
[Ida; Iqa] = √2 [-sin(θd - 120) sin θd; -cos(θd - 120) cos θd] [Iua; Iva]
S144
COMPUTE VOLTAGE COMMAND VALUES
Vda=Kp1·ΔIda+ΣKi1·ΔIda
Vqa=Kp2·ΔIqa+ΣKi2·ΔIqa
ΔIda=Ida*−Ida
ΔIqa=Iqa*−Iqa
S146
S148
TRANSFORMATION OF COORDINATES FOR VOLTAGE COMMAND VALUES
[Vua; Vva] = √(2/3) [cosθd −sinθd; cos(θd−120) −sin(θd−120)] [Vda; Vqa]
Vwa=−Vua−Vva
PWM CONTROL
S150
RET

Fig. 9

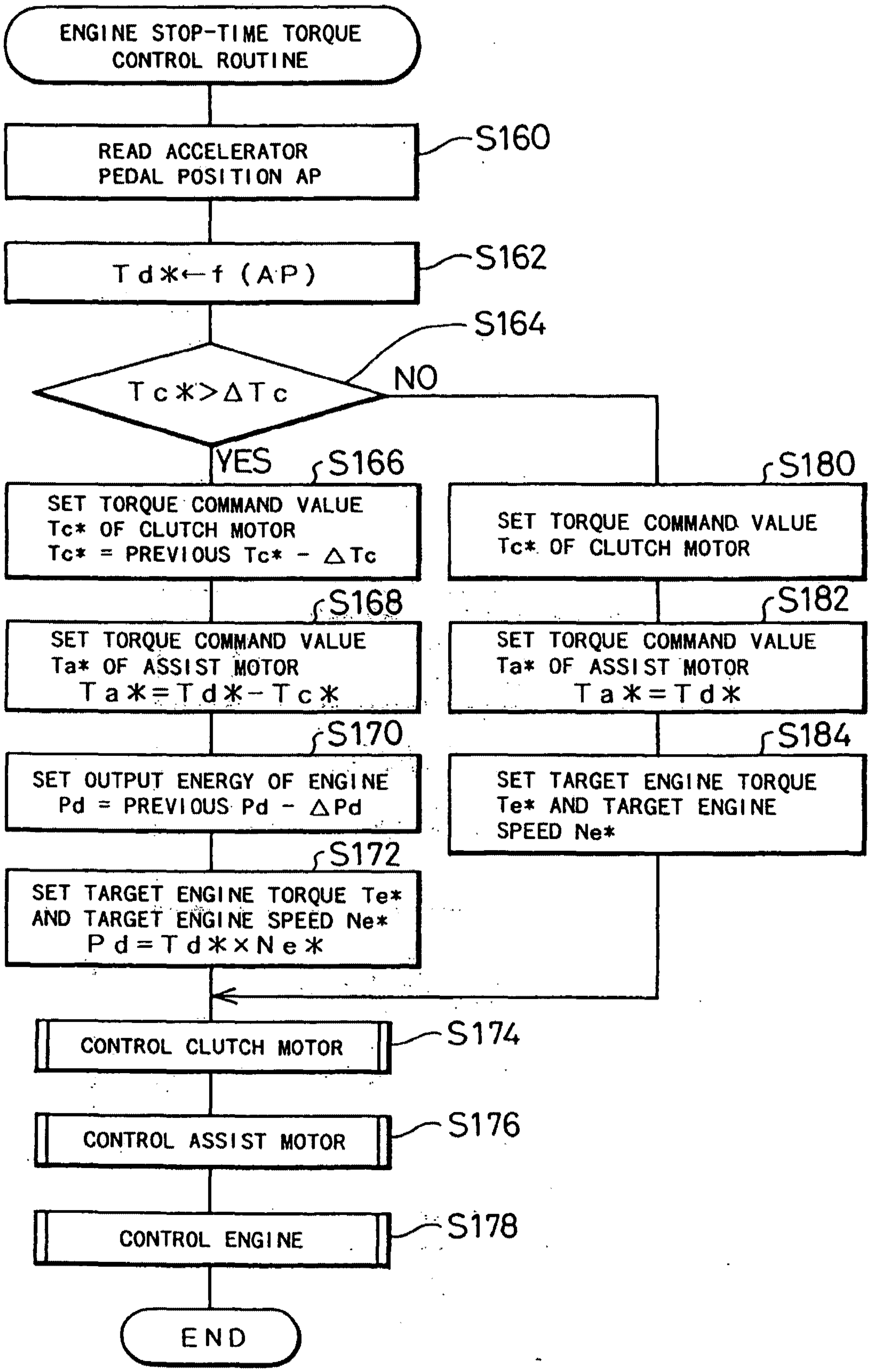

ENGINE STOP-TIME TORQUE CONTROL ROUTINE
READ ACCELERATOR PEDAL POSITION AP
S160
Td*←f (AP)
S162
Tc*>ΔTc
S164
NO
YES
S166
SET TORQUE COMMAND VALUE Tc* OF CLUTCH MOTOR Tc* = PREVIOUS Tc* − ΔTc
S168
SET TORQUE COMMAND VALUE Ta* OF ASSIST MOTOR Ta*=Td*−Tc*
S170
SET OUTPUT ENERGY OF ENGINE Pd = PREVIOUS Pd − ΔPd
S172
SET TARGET ENGINE TORQUE Te* AND TARGET ENGINE SPEED Ne* Pd=Td*×Ne*
S180
SET TORQUE COMMAND VALUE Tc* OF CLUTCH MOTOR
S182
SET TORQUE COMMAND VALUE Ta* OF ASSIST MOTOR Ta*=Td*
S184
SET TARGET ENGINE TORQUE Te* AND TARGET ENGINE SPEED Ne*
CONTROL CLUTCH MOTOR
S174
CONTROL ASSIST MOTOR
S176
CONTROL ENGINE
S178
END

Fig. 10

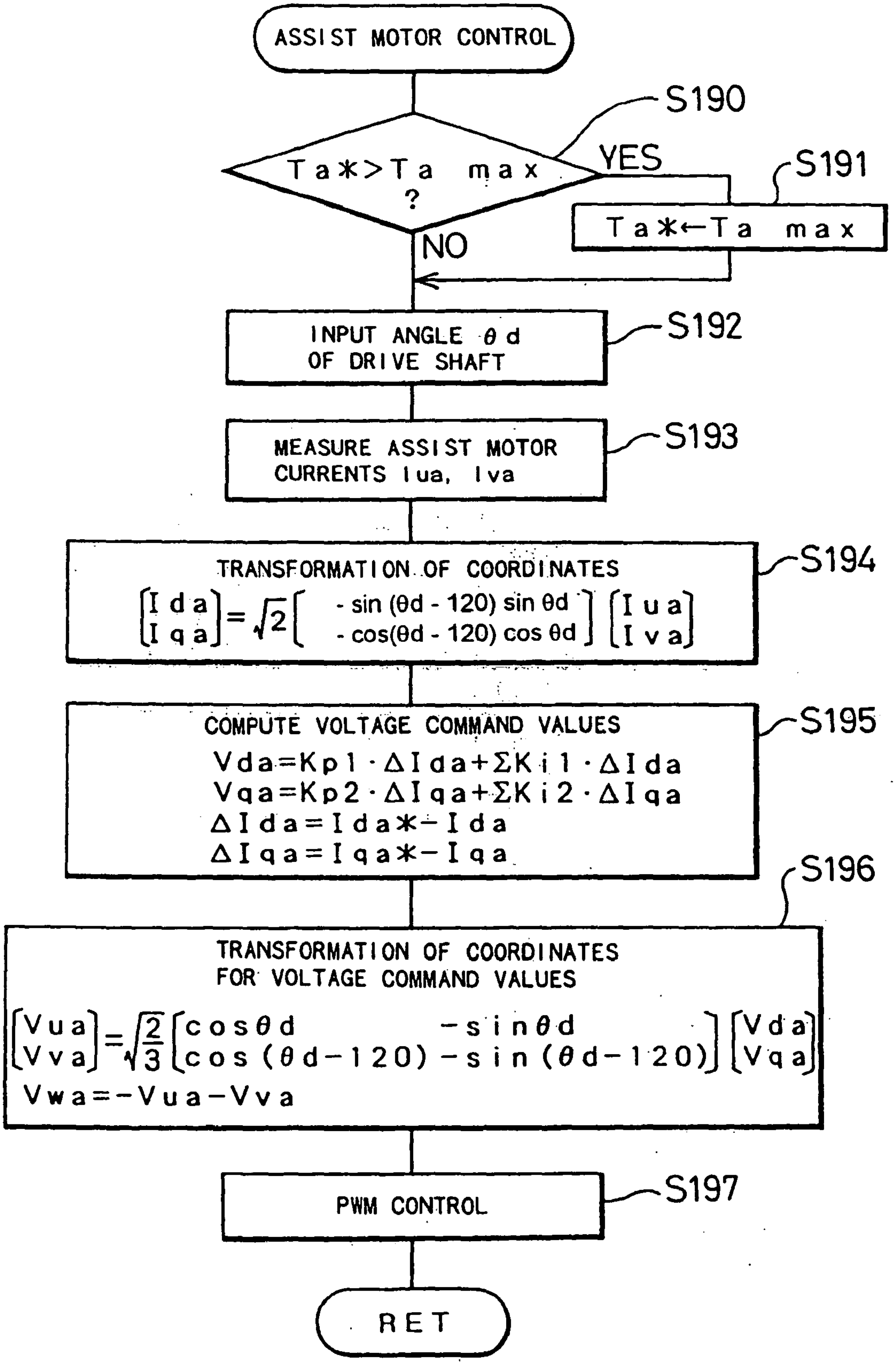

ASSIST MOTOR CONTROL
S190
Ta*>Ta max ?
YES
NO
S191
Ta*←Ta max
S192
INPUT ANGLE θd OF DRIVE SHAFT
S193
MEASURE ASSIST MOTOR CURRENTS Iua, Iva
S194
TRANSFORMATION OF COORDINATES
$\begin{bmatrix} Ida \\ Iqa \end{bmatrix} = \sqrt{2} \begin{bmatrix} -\sin(\theta d - 120) & \sin\theta d \\ -\cos(\theta d - 120) & \cos\theta d \end{bmatrix} \begin{bmatrix} Iua \\ Iva \end{bmatrix}$
S195
COMPUTE VOLTAGE COMMAND VALUES
$Vda = Kp1 \cdot \Delta Ida + \Sigma Ki1 \cdot \Delta Ida$
$Vqa = Kp2 \cdot \Delta Iqa + \Sigma Ki2 \cdot \Delta Iqa$
$\Delta Ida = Ida* - Ida$
$\Delta Iqa = Iqa* - Iqa$
S196
TRANSFORMATION OF COORDINATES FOR VOLTAGE COMMAND VALUES
$\begin{bmatrix} Vua \\ Vva \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta d & -\sin\theta d \\ \cos(\theta d - 120) & -\sin(\theta d - 120) \end{bmatrix} \begin{bmatrix} Vda \\ Vqa \end{bmatrix}$
$Vwa = -Vua - Vva$
S197
PWM CONTROL
RET

Fig. 13

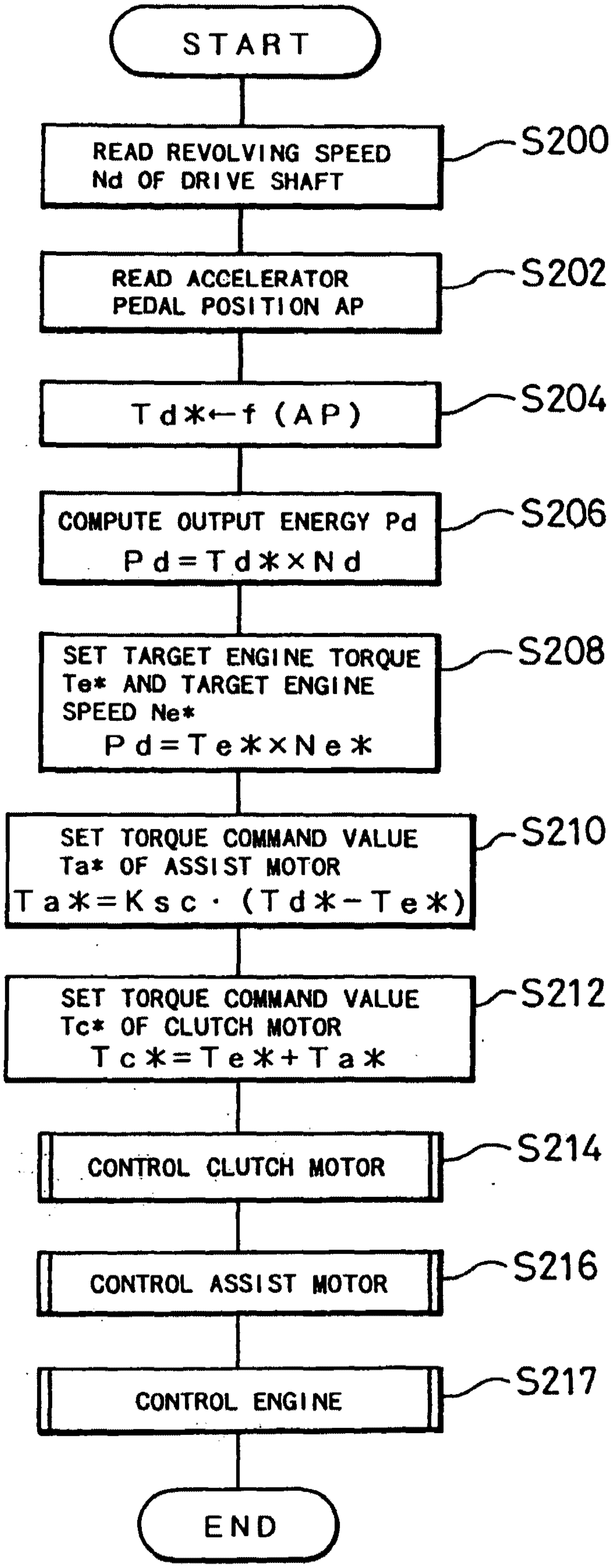

START
READ REVOLVING SPEED Nd OF DRIVE SHAFT
S200
READ ACCELERATOR PEDAL POSITION AP
S202
Td*←f (AP)
S204
COMPUTE OUTPUT ENERGY Pd
Pd=Td*×Nd
S206
SET TARGET ENGINE TORQUE Te* AND TARGET ENGINE SPEED Ne*
Pd=Te*×Ne*
S208
SET TORQUE COMMAND VALUE Ta* OF ASSIST MOTOR
Ta*=Ksc·(Td*−Te*)
S210
SET TORQUE COMMAND VALUE Tc* OF CLUTCH MOTOR
Tc*=Te*+Ta*
S212
CONTROL CLUTCH MOTOR
S214
CONTROL ASSIST MOTOR
S216
CONTROL ENGINE
S217
END

Fig. 11

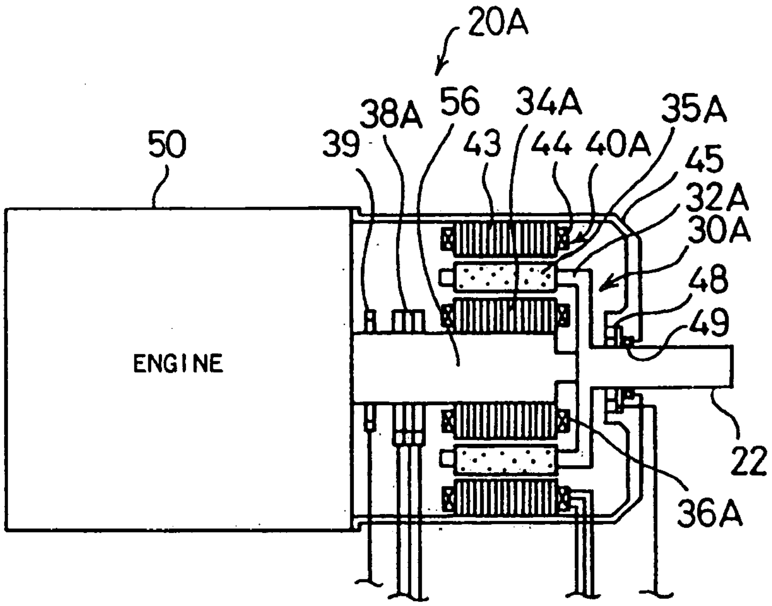
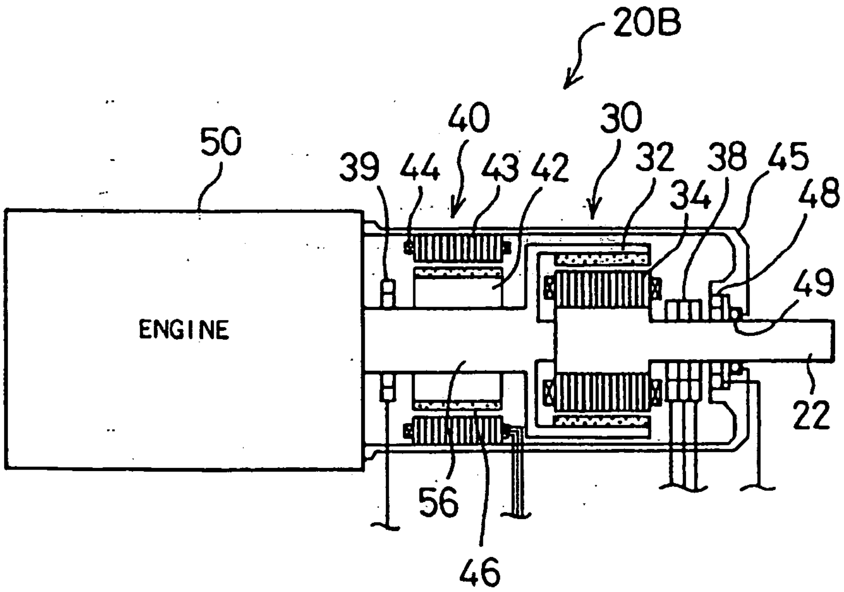

20A
50
39
38A
56
43
34A
44
40A
35A
45
32A
30A
48
49
ENGINE
22
36A

Fig. 12


20B
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32
38
45
34
48
49
ENGINE
22
56
46

Fig. 14

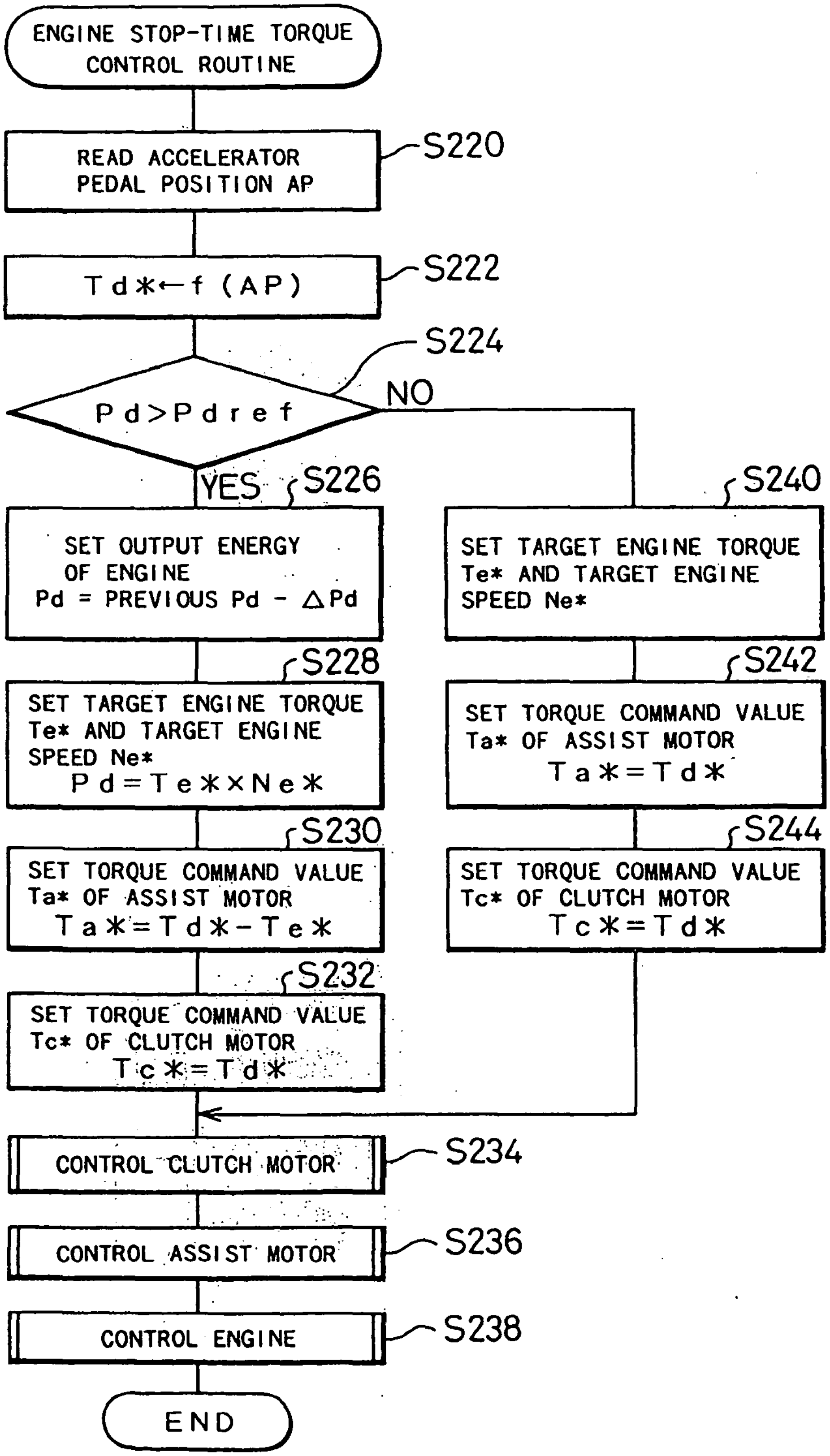
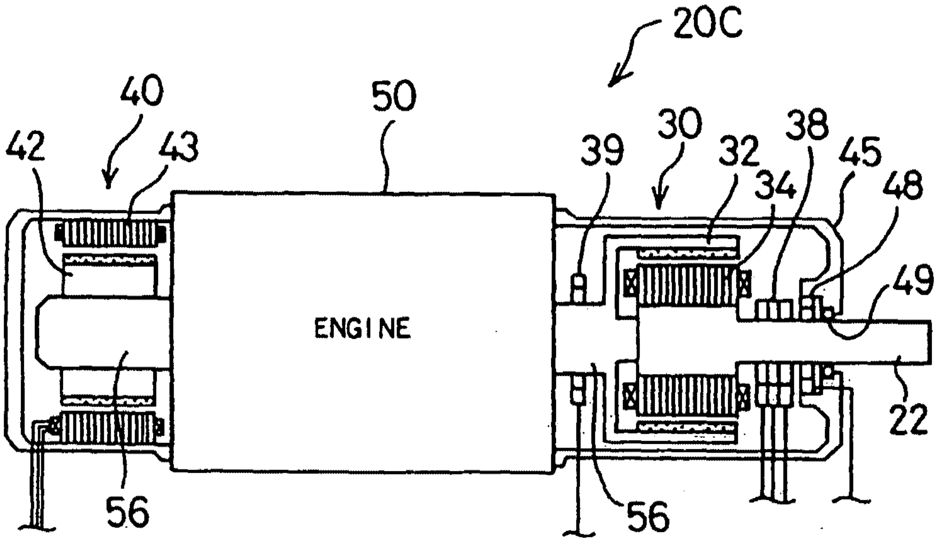

ENGINE STOP-TIME TORQUE CONTROL ROUTINE
READ ACCELERATOR PEDAL POSITION AP
S220
Td*←f (AP)
S222
S224
Pd>Pdref
NO
YES
S226
SET OUTPUT ENERGY OF ENGINE Pd = PREVIOUS Pd - ΔPd
S228
SET TARGET ENGINE TORQUE Te* AND TARGET ENGINE SPEED Ne* Pd=Te*×Ne*
S230
SET TORQUE COMMAND VALUE Ta* OF ASSIST MOTOR Ta*=Td*-Te*
S232
SET TORQUE COMMAND VALUE Tc* OF CLUTCH MOTOR Tc*=Td*
S240
SET TARGET ENGINE TORQUE Te* AND TARGET ENGINE SPEED Ne*
S242
SET TORQUE COMMAND VALUE Ta* OF ASSIST MOTOR Ta*=Td*
S244
SET TORQUE COMMAND VALUE Tc* OF CLUTCH MOTOR Tc*=Td*
CONTROL CLUTCH MOTOR
S234
CONTROL ASSIST MOTOR
S236
CONTROL ENGINE
S238
END

Fig. 15


20C
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43
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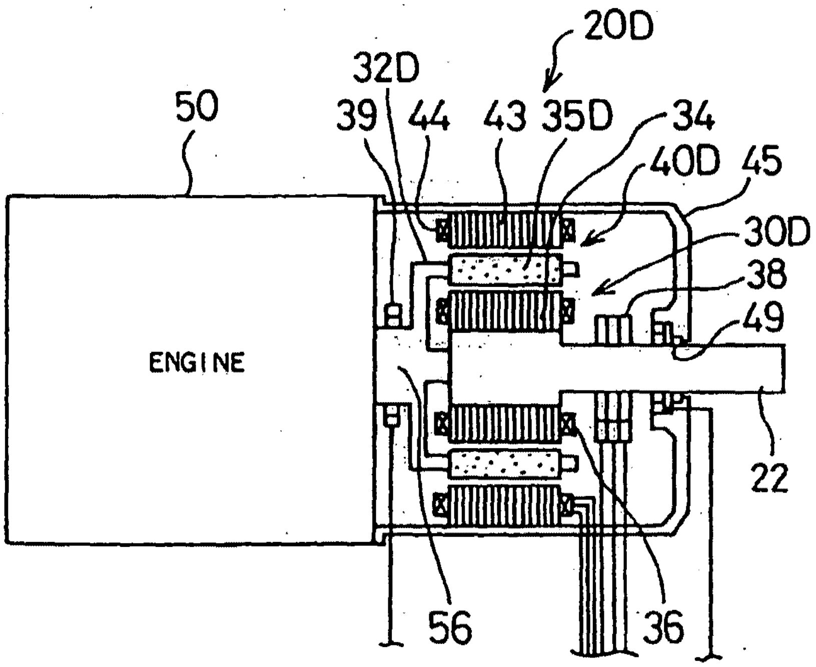
32
38
34
45
48
49
ENGINE
22
56
56

Fig. 16


20D
32D
50
39
44
43
35D
34
40D
45
30D
38
49
ENGINE
22
56
36

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 8009

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	AU 58401 73 A (STEPHEN JOHN ELLIOTT) * claim 1; figure 2 * ---	1,3,5,8,11,13	B60K6/04
Y A	EP 0 645 278 A (TOYOTA MOTOR CO LTD) * page 3, line 23 - line 31; claims 1,3,6 * ---	1,3,5,8,11,13	
A	US 3 623 568 A (MORI YOICHI) * column 11, line 45 - line 71; claim 1 * ---	1-14	
A	DE 30 25 756 A (HIENZ GEORG) * figures * ---	1,3,5,8,13	
E	EP 0 725 474 A (NIPPON DENSO CO) * claims 1,18,25,26 * -----	1,3,5,8	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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B60L
H02K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 January 1998	Bufacchi, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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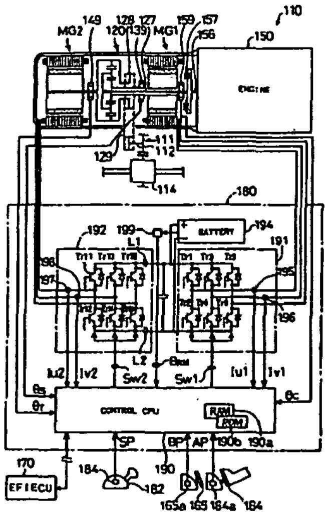
(54) Power output apparatus, engine controller, and methods of controlling power output apparatus and engine

(57) A power output apparatus 110 includes a planetary gear 120 having a planetary carrier, a sun gear, and a ring gear, an engine 150 having a crankshaft 156 linked with the planetary carrier, a first motor MG1 attached to the sun gear, and a second motor MG2 attached to the ring gear. In response to an engine operation stop instruction, the power output apparatus 110 stops a fuel injection into the engine 150 and controls the first motor MG1, in order to enable a torque acting in reverse of the rotation of the crankshaft 156 to be output to the crankshaft 156 via the planetary gear 120 and a carrier shaft 127 until the revolving speed of the engine 150 becomes close to zero. This structure allows the revolving speed of the engine 150 to quickly approach to zero.

Fig. 1



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Description

1.Field of the Invention

The present invention relates to an engine controller, a power output apparatus, and methods of controlling an engine and the power output apparatus. More specifically the present invention pertains to a technique of stopping the operation of an engine in a system including the engine for outputting power through combustion of a fuel and a motor connected to an output shaft of the engine via a damper as well as to a technique of stopping the operation of an engine in a power output apparatus for outputting power to a drive shaft.

2. Description of the Related Art

Known power output apparatuses for carrying out torque conversion of power output from an engine and outputting the converted power to a drive shaft include a combination of a fluid-based torque converter with a transmission. In such a power output apparatus, the torque converter is disposed between an output shaft of the engine and a rotating shaft linked with the transmission, and transmits the power between the rotating shaft and the output shaft through a flow of the sealed fluid. Since the torque converter transmits the power through a flow of the fluid, there is a slip between the output shaft and the rotating shaft, which leads to an energy loss corresponding to the slip. The energy loss is expressed as the product of the revolving speed difference between the rotating shaft and the output shaft and the torque transmitted to the output shaft, and is consumed as heat.

In a vehicle with such a power output apparatus mounted thereon as its power source, at the time when there is a large slip between the rotating shaft and the output shaft, that is, when a significantly large power is required, for example, at the time of starting the vehicle or running the vehicle on an upward slope at a low speed, a large energy loss in the torque converter undesirably lowers the energy efficiency. Even in a stationary driving state, the efficiency of power transmission by the torque converter is not 100%, and the fuel consumption rate in the conventional power output apparatus is thereby lower than that in a manual transmission.

In order to solve such problems, the applicants have proposed a system that does not include the fluid-based torque converter but has an engine, a planetary gear unit as three shaft-type power input/output means, a generator, a motor, and a battery and outputs the power from the motor to the drive shaft by utilizing the power output from the engine or electric power stored in the battery (JAPANESE PATENT LAYING-OPEN GAZETTE No. 50-30223). In this reference, however, there is no description of the control procedure when the operation of the engine is stopped.

In this power output apparatus, the output shaft of the engine and the rotating shaft of the motor are mechanically linked with each other by the three shaft-type power input/output means, and thus mechanically constitute one vibrating system. When the engine is an internal combustion engine, for example, a torque variation due to a gas explosion or reciprocating motions of the piston in the internal combustion engine causes torsional vibrations on the output shaft of the internal combustion engine and the rotating shaft of the motor. When the natural frequency of the shaft coincides with the forcible frequency, a resonance occurs. This may result in a foreign noise from the three shaft-type power input/output means and even in a fatigue destruction of the shaft in some cases. Such a resonance occurs in many cases at a revolving speed lower than the minimum of an operable revolving speed range of the engine, although it depends upon the type of the engine and the structure of the three shaft-type power input/output means.

The resonance of the torsional vibrations that may occur in the system at the time of stopping the operation of the engine is observed not only in the power output apparatus but in any driving system, wherein the output shaft of the engine and the rotating shaft of the motor are mechanically linked with each other. The primary countermeasure against these troubles is that the output shaft of the engine and the rotating shaft of the motor are mechanically linked with each other via a damper. The dampers having a significant effect on reduction of the amplitude of the torsional vibrations, however, require a special damping mechanism. This increases the required number of parts and makes the damper undesirably bulky. The small-sized simply-structured dampers, on the other hand, have little effects.

The motor is generally under the PI control. In the procedure of outputting a torque from the motor to the output shaft of the engine and thereby positively stopping the operation of the engine, the I term (integral term) may result in undershooting the output shaft of the engine, which causes a vibration of the whole driving system. When the driving system is mounted, for example, on a vehicle, the vibration due to undershooting is transmitted to the vehicle body and makes the driver uncomfortable.

SUMMARY OF THE INVENTION

One object of the present invention is to provide a power output apparatus for outputting power from an engine to a drive shaft with a high efficiency, as well as a method of controlling such a power output apparatus.

Another object of the present invention is to provide a control technique of stopping the operation of an engine in a power output apparatus, which includes the engine, three shaft-type power input/output means, and two motors.

Still another object of the invention is to provide a power output apparatus which can prevent a resonance of torsional vibrations that may occur in the system when the operation of the engine is stopped, as well as to provide a method of controlling such a power output apparatus.

In the process of applying a torque from the motor to the output shaft of the engine to stop the operation of the engine, the control procedure of the motor may cause the revolving speed of the output shaft of the engine to undershoot and become smaller than zero. This may result in undesirable vibrations of the whole power output apparatus. In case that the power output apparatus is mounted on a vehicle, for example, the vibrations due to the undershoot are transmitted to the vehicle body and makes the driver uncomfortable.

This problem, that is, the resonance of torsional vibrations that may occur in the system in the course of stopping the operation of the engine, is not restricted to the power output apparatus, but arises in any driving system wherein the output shaft of the engine and the rotating shaft of the motor are mechanically connected to each other. The primary countermeasure against this problem is that the output shaft of the engine and the rotating shaft of the motor are mechanically linked with each other via a damper. The dampers having a significant effect on reduction of the amplitude of the torsional vibrations, however, require a special damping mechanism. This increases the required number of parts and makes the damper undesirably bulky. The small-sized simply-structured dampers, on the other hand, have little effects.

This problem is found not only in the structure that directly outputs power but in the structure of series hybrid that has a motor and a generator directly connected to each other and obtains a torque by the motor driven by means of the electric power generated by the generator while the vehicle is on a run.

SUMMARY OF THE INVENTION

One object of the present invention is thus to provide a power output apparatus that prevents resonance of torsional vibrations which may occur in a system in the course of stopping the operation of an engine, as well as a method of controlling such a power output apparatus.

Another object of the present invention is accordingly to reduce vibrations that may occur in the course of stopping the operation of an engine.

Still another object of the present invention is thus to provide an engine controller that prevents resonance of torsional vibrations which may occur in a system in the course of stopping the operation of an engine, irrespective of the type of a damper, as well as a method of controlling the engine.

At least part of the above and the other related objects is realized by a power output apparatus for outputting power to a drive shaft, which includes: an engine having an output shaft; a first motor having a rotating shaft and inputting and outputting power to and from the rotating shaft; a second motor inputting and outputting power to and from the drive shaft; three shaft-type power input/output means having three shafts respectively linked with the drive shaft, the output shaft, and the rotating shaft, the three shaft-type power input/output means inputting and outputting power to and from a residual one shaft, based on predetermined powers input to and output from any two shafts among the three shafts; fuel stop instruction means for giving an instruction to stop fuel supply to the engine when a condition of stopping operation of the engine is fulfilled; and stop-time control means for causing a torque to be applied to the output shaft of the engine and thereby restricting a deceleration of revolving speed of the output shaft to a predetermined range in response to the instruction to stop the fuel supply to the engine, so as to implement a stop-time control for stopping the operation of the engine.

The present invention is also directed to a method of controlling such a power output apparatus. The method controls the power output apparatus, which includes: an engine having an output shaft; a first motor having a rotating shaft and inputting and outputting power to and from the rotating shaft; a second motor inputting and outputting power to and from the drive shaft; and three shaft-type power input/output means having three shafts respectively linked with the drive shaft, the output shaft, and the rotating shaft, the three shaft-type power input/output means inputting and outputting power to and from a residual one shaft, based on predetermined powers input to and output from any two shafts among the three shafts. The method includes the steps of:

giving an instruction to stop fuel supply to the engine when a condition of stopping operation of the engine is fulfilled; and
causing a torque to be applied to the output shaft of the engine and thereby restricting a deceleration of revolving speed of the output shaft to a predetermined range in response to the instruction to stop the fuel supply to the engine, so as to implement a stop-time control for stopping the operation of the engine.

When the condition to stop the operation of the engine is fulfilled, the power output apparatus of the present invention gives an instruction to stop fuel supply to the engine and carries out the stop-time control. The stop-time control applies a torque to the output shaft of the engine and thereby restricts the deceleration of the revolving speed of the output shaft to a predetermined range, so as to stop the operation of the engine. The torque may be applied from either the first motor or the second motor to the output shaft of the engine.

This procedure restricts the deceleration of the revolving speed of the output shaft to a predetermined range and enables the revolving speed of the output shaft to quickly pass through a range of torsional vibrations. This structure also saves the consumption of electric power by the motor.

A variety of structures may be applied to the stop-time control. One available structure carries out open-loop control of the torque applied to the output shaft. In this case, the power output apparatus further includes target torque storage means for determining a time-based variation in target value of the torque applied to the output shaft of the engine, based on a behavior at the time of stopping the operation of the engine. The stop-time control means has means for driving the first motor, as the stop-time control, to apply a torque corresponding to the target value to the output shaft of the engine along a time course after the stop of the engine via the three shaft-type power input/output means.

This structure does not carry out the feedback control based on the revolving speed of the output shaft and accordingly reduces the variation in torque on the drive shaft without causing a variation in torque due to the state of the power output apparatus or an external disturbance. Even when the revolving speed of the output shaft is significantly different from a target revolving speed (generally equal to zero under the condition of the vehicle at a stop), this structure does not execute the feedback control based on the revolving speed difference to output a large torque and thus effectively saves the consumption of electric power.

In order to optimize such open-loop control, the power output apparatus may further include: deceleration computing means for computing the deceleration of revolving speed of the output shaft during the course of the stop-time control; learning means for varying a learnt value according to the deceleration computed by the deceleration computing means and storing the learnt value; and deceleration range determination means for determining the predetermined range in the stop-time control carried out by the stop-time control means, based on the learnt value stored by the learning means. This structure learns the range of deceleration and thereby realizes the preferable control.

In accordance with another possible application, the power output apparatus further includes revolving speed detection means for measuring the revolving speed of the output shaft, and the stop-time control means has means for driving the first motor, as the stop-time control, in order to enable the revolving speed of the output shaft measured by the revolving speed detection means to approach a predetermined value via a predetermined pathway. The predetermined pathway represents a time course of revolving speed of the output shaft of the engine after the stop of fuel supply to the engine.

In response to the instruction to stop the operation of the engine, the power output apparatus of this structure enables the revolving speed of the output shaft of the engine to approach a predetermined value via a predetermined pathway. The revolving speed of the output shaft of the engine can be made to reach the predetermined value within a short time or within a relatively long time by regulating the predetermined pathway. In case that the predetermined value is equal to zero, the rotation of the output shaft of the engine can be stopped quickly or gently.

In the power output apparatus of this structure, the stop-time control may drive the first motor to apply a torque in reverse of the rotation of the output shaft via the three shaft-type power input/output means to the output shaft, until the revolving speed of the output shaft measured by the revolving speed detection means becomes coincident with the predetermined value. This structure enables the revolving speed of the output shaft of the engine to approach the predetermined value more quickly. When a specific revolving speed range that causes a resonance of a torsional vibration exists between the predetermined value and the revolving speed of the output shaft of the engine at the time when the instruction to stop the operation of the engine is given, the structure allows the revolving speed of the output shaft of the engine to swiftly pass through this specific range and thereby effectively prevents a resonance.

In the power output apparatus of this structure, as part of the stop-time control, the first motor may be driven to apply a predetermined torque in the direction of rotation of the output shaft via the three shaft-type power input/output means to the output shaft, when the revolving speed of the output shaft measured by the revolving speed detection means decreases to a reference value, which is not greater than the predetermined value. This structure prevents the revolving speed of the engine from undershooting and reduces the possible vibration in the course of stopping the rotation of the output shaft.

A variety of techniques may be applied to determine the reference value. One possible structure computes the deceleration of revolving speed of the output shaft during the course of the stop-time control, and sets a larger value to the reference value against a greater absolute value of the deceleration. The larger reference value for the greater deceleration effectively prevents the revolving speed of the output shaft from undershooting. Another possible structure determines the magnitude of a braking force applied to the drive shaft during the course of the stop-time control, and sets a larger value to the reference value when the braking force detection means determines that the braking force has a large magnitude. During application of the braking force, it can be assumed that a large force is applied to stop the engine. The larger reference value accordingly prevents the revolving speed of the output shaft from undershooting.

In the power output apparatus of the present invention, the stop-time control means may drive the first motor to make the power input to and output from the rotating shaft equal to zero. The first motor does not consume any electric power, so that this structure improves the energy efficiency of the whole power output apparatus. Since the first motor does not forcibly change the driving state of the output shaft of the engine, the torque shock due to an operation stop of the engine can be effectively reduced. The engine and the first motor are stably kept in the driving state having the least sum of the energies consumed thereby (for example, the frictional work).

In the power output apparatus of the present invention, the predetermined value may be a revolving speed that is lower than a resonance range of torsional vibrations in a system including the output shaft and the three shaft-type power input/output means. This structure effectively prevents torsional vibrations.

In accordance with another preferable structure, the second motor is driven to continue power input and output to and from the drive shaft, when the instruction to stop the operation of the engine is given in the course of continuous power input and output to and from the drive shaft. This structure enables the operation of the engine to be stopped while the power is continuously input to and output from the drive shaft. The input and output of the power to and from the drive shaft is implemented by the second motor.

The present invention is also directed to an engine controller having an engine for outputting power through combustion of a fuel and a motor connected to an output shaft of the engine via a damper. The engine controller controls operation and stop of the engine and includes: fuel stop means for stopping fuel supply to the engine when a condition to stop the operation of the engine is fulfilled; and stop-time control means for causing a torque to be applied to the output shaft of the engine and thereby restricting a deceleration of revolving speed of the output shaft to a predetermined range in response to the stop of fuel supply to the engine, so as to implement a stop-time control for stopping the operation of the engine.

The present invention is further directed to a method of controlling stop of an engine, which outputs power through combustion of a fuel and has an output shaft connected to a motor via a damper. The method includes the steps of:

> stopping fuel supply to the engine when a condition to stop operation of the engine is fulfilled; and causing a torque to be applied to the output shaft of the engine and thereby restricting a deceleration of revolving speed of the output shaft to a predetermined range in response to the stop of fuel supply to the engine, so as to implement a stop-time control for stopping the operation of the engine.

The engine controller and the corresponding method of the present invention controls stop of the engine that has an output shaft connected to a motor via a damper, and reduces the torsional vibrations that may occur on the output shaft of the engine connected to the motor via the damper. When the condition to stop the operation of the engine is fulfilled, the engine controller stops the fuel supply to the engine and applies a torque to the output shaft of the engine, thereby restricting the deceleration of the revolving speed of the output shaft to a predetermined range and stopping the operation of the engine. The torsional vibrations on the output shaft tend to occur at a predetermined deceleration. The restriction of the deceleration of the revolving speed of the output shaft to the predetermined range thus effectively reduces the torsional vibrations.

A variety of structures may be applied to the stop-time control that restricts the deceleration of the revolving speed of the output shaft to a predetermined range. One available structure carries out open-loop control that specifies a variation in target value of the torque applied to the output shaft along the time axis. In this case, the engine controller further includes target torque storage means for determining a time-based variation in target value of the torque applied to the output shaft of the engine, based on a behavior at the time of stopping the operation of the engine. The stop-time control means has means for driving the motor, as the stop-time control, to apply a torque corresponding to the target value to the output shaft of the engine along a time course after the stop of the engine.

This structure does not carry out the feedback control based on the revolving speed of the output shaft and accordingly does not vary the torque applied to the output shaft by an external disturbance. Even when the revolving speed of the output shaft is significantly different from a target revolving speed (generally equal to zero under the condition of the vehicle at a stop), this structure does not execute the feedback control based on the revolving speed difference to output a large torque and thus effectively saves the consumption of electric power.

In order to optimize such open-loop control, the engine controller may further include: deceleration computing means for computing the deceleration of revolving speed of the output shaft during the course of the stop-time control; learning means for varying a learnt value according to the deceleration computed by the deceleration computing means and storing the learnt value; and deceleration range determination means for determining the predetermined range in the stop-time control carried out by the stop-time control means, based on the learnt value stored by the learning means. This structure learns the range of deceleration and thereby realizes the preferable control.

In accordance with another possible application, the engine controller further includes revolving speed detection means for measuring the revolving speed of the output shaft, and the stop-time control means has means for driving the motor, as the stop-time control, in order to enable the revolving speed of the output shaft measured by the revolving speed detection means to approach a predetermined value via a predetermined pathway. The predetermined pathway represents a time course of revolving speed of the output shaft of the engine after the stop of fuel supply to the engine.

In response to the instruction to stop the operation of the engine, the engine controller of this structure enables the revolving speed of the output shaft of the engine to approach a predetermined value via a predetermined pathway. The revolving speed of the output shaft of the engine can be made to reach the predetermined value within a short time or within a relatively long time by regulating the predetermined pathway. In any case, the deceleration is restricted to a predetermined range that is out of a specific range causing torsional vibrations on the output shaft.

In the engine controller of this structure, the stop-time control may drive the motor to apply a torque in reverse of the rotation of the output shaft to the output shaft, until the revolving speed of the output shaft measured by the revolving speed detection means becomes coincident with the predetermined value. This structure enables the revolving speed of the output shaft of the engine to approach the predetermined value more quickly. When a specific revolving speed range that causes a resonance of a torsional vibration exists between the predetermined value and the revolving speed of the output shaft of the engine at the time when the instruction to stop the operation of the engine is given, the structure allows the revolving speed of the output shaft of the engine to swiftly pass through this specific range and thereby effectively prevents a resonance.

In the engine controller of this structure, as part of the stop-time control, the motor may be driven to apply a predetermined torque in the direction of rotation of the output shaft to the output shaft, when the revolving speed of the output shaft measured by the revolving speed detection means decreases to a reference value, which is not greater than the predetermined value. This structure prevents the revolving speed of the engine from undershooting and reduces the possible vibration in the course of stopping the rotation of the output shaft.

A variety of techniques may be applied to determine the reference value. One possible structure computes the deceleration of revolving speed of the output shaft during the course of the stop-time control, and sets a larger value to the reference value against a greater absolute value of the deceleration. The larger reference value for the greater deceleration effectively prevents the revolving speed of the output shaft from undershooting.

In the engine controller of the present invention, the predetermined value may be a revolving speed that is lower than a resonance range of torsional vibrations in a system including the output shaft and a rotor of the motor. This structure effectively prevents torsional vibrations.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 schematically illustrates structure of a power output apparatus 110 embodying the present invention;

Fig. 2 is an enlarged view illustrating an essential part of the power output apparatus 110 of the embodiment;

Fig. 3 schematically illustrates general structure of a vehicle with the power output apparatus 110 of the embodiment incorporated therein;

Fig. 4 is a graph showing the operation principle of the power output apparatus 110 of the embodiment;

Fig. 5 is a nomogram showing the relationship between the revolving speed and the torque on the three shafts linked with the planetary gear 120 in the power output apparatus 110 of the embodiment;

Fig. 6 is a nomogram showing the relationship between the revolving speed and the torque on the three shafts linked with the planetary gear 120 in the power output apparatus 110 of the embodiment;

Fig. 7 is a flowchart showing an engine stop control routine executed by the control CPU 190 of the controller 180;

Fig. 8 is a map showing the relationship between the time counter TC and the target revolving speed Ne* of the engine 150;

Fig. 9 is a flowchart showing a required torque setting routine executed by the control CPU 190 of the controller 180;

Fig. 10 shows the relationship between the revolving speed Nr of the ring gear shaft 126, the accelerator pedal position AP, and the torque command value Tr*;

Fig. 11 is a flowchart showing a control routine of the first motor MG1 executed by the control CPU 190 of the controller 180;

Fig. 12 is a flowchart showing a control routine of the second motor MG2 executed by the control CPU 190 of the controller 180;

Fig. 13 is a nomogram showing the state when the engine stop control routine of Fig. 7 is carried out for the first time;

Fig. 14 is a nomogram showing the state when the processing of steps S106 through S116 in the engine stop control routine has repeatedly been executed;

Fig. 15 is a nomogram showing the state when the revolving speed Ne of the engine 150 becomes equal to or less than the threshold value Nref;

Fig. 16 shows variations in revolving speed Ne of the engine 150 and torque Tm1 of the first motor MG1;

Fig. 17 is a flowchart showing a modified engine stop control routine;

Fig. 18 schematically illustrates another power output apparatus 110A as a modified example;

Fig. 19 schematically illustrates still another power output apparatus 110B as another modified example;
Fig. 20 schematically illustrates structure of another power output apparatus 110' as a second embodiment according to the present invention;
Fig. 21 illustrates an exemplified structure of an open-close timing changing mechanism 153;
Fig. 22 is a flowchart showing an engine stop control routine carried out in the second embodiment;
Fig. 23 is a graph showing the reduction torque STGmn plotted against the vehicle speed;
Fig. 24 is a graph showing the processing time mntg of slower speed reduction plotted against the vehicle speed;
Fig. 25 is a flowchart showing an open-loop control routine;
Fig. 26 is a flowchart showing a processing routine to prevent undershoot;
Fig. 27 is a graph showing an example of the control process carried out in the second embodiment;
Fig. 28 schematically illustrates structure of a four-wheel-drive vehicle with a power output apparatus 110C incorporated therein; and
Fig. 29 schematically illustrates another power output apparatus 310 as another modified example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

One mode of carrying out the present invention is described as a preferred embodiment. Fig. 1 schematically illustrates structure of a power output apparatus 110 embodying the present invention; Fig. 2 is an enlarged view illustrating an essential part of the power output apparatus 110 of the embodiment; and Fig. 3 schematically illustrates general structure of a vehicle with the power output apparatus 110 of the embodiment incorporated therein. The general structure of the vehicle is described first for the convenience of explanation.

Referring to Fig. 3, the vehicle is provided with an engine 150 which consumes gasoline as a fuel and outputs power. The air ingested from an air supply system via a throttle valve 166 is mixed with a fuel, that is, gasoline in this embodiment, injected from a fuel injection valve 151. The air/fuel mixture is supplied into a combustion chamber 152 to be explosively ignited and burned. Linear motion of a piston 154 pressed down by the explosion of the air/fuel mixture is converted to rotational motion of a crankshaft 156. The throttle valve 166 is driven to open and close by an actuator 168. An ignition plug 162 converts a high voltage applied from an igniter 158 via a distributor 160 to a spark, which explosively ignites and combusts the air/fuel mixture.

Operation of the engine 150 is controlled by an electronic control unit (hereinafter referred to as EFIECU) 170. The EFIECU 170 receives information from various sensors, which detect operating conditions of the engine 150. These sensors include a throttle valve position sensor 167 for detecting a valve travel or position of the throttle valve 166, a manifold vacuum sensor 172 for measuring a load applied to the engine 150, a water temperature sensor 174 for measuring the temperature of cooling water in the engine 150, and a speed sensor 176 and an angle sensor 178 mounted on the distributor 160 for measuring the revolving speed (the number of revolutions per a predetermined time period) and the rotational angle of the crankshaft 156. A starter switch 179 for detecting a starting condition ST of an ignition key (not shown) is also connected to the EFIECU 170. Other sensors and switches connecting with the EFIECU 170 are omitted from the illustration.

The crankshaft 156 of the engine 150 is linked with a planetary gear 120, a first motor MG1, and a second motor MG2 (described later) via a damper 157 that reduces the amplitude of torsional vibrations occurring on the crankshaft 156. The crankshaft 156 is further connected to a differential gear 114 via a power transmission gear 111, which is linked with a drive shaft 112 working as the rotating shaft of the power transmission gear 111. The power output from the power output apparatus 110 is thus eventually transmitted to left and right driving wheels 116 and 118. The first motor MG1 and the second motor MG2 are electrically connected to and controlled by a controller 180. The controller 180 includes an internal control CPU and receives inputs from a gearshift position sensor 184 attached to a gearshift 182, an accelerator position sensor 164a attached to an accelerator pedal 164, and a brake pedal position sensor 165a attached to a brake pedal 165, as described later in detail. The controller 180 sends and receives a variety of data and information to and from the EFIECU 170 through communication. Details of the control procedure including a communication protocol will be described later.

Referring to Fig. 1, the power output apparatus 110 of the embodiment primarily includes the engine 150, the damper 157 for connecting the crankshaft 156 of the engine 150 to a carrier shaft 127 so as to reduce the amplitude of the torsional vibrations of the crankshaft 156, the planetary gear 120 having a planetary carrier 124 linked with the carrier shaft 127, the first motor MG1 linked with a sun gear 121 of the planetary gear 120, the second motor MG2 linked with a ring gear 122 of the planetary gear 120, and the controller 180 for driving and controlling the first and the second motors MG1 and MG2.

The following describes structure of the planetary gear 120 and the first and the second motors MG1 and MG2 based on the drawing of Fig. 2. The planetary gear 120 includes the sun gear 121 linked with a hollow sun gear shaft 125 which the carrier shaft 127 passes through, the ring gear 122 linked with a ring gear shaft 126 coaxial with the carrier shaft 127, a plurality of planetary pinion gears 123 arranged between the sun gear 121 and the ring gear 122 to revolve around the sun gear 121 while rotating on its axis, and the planetary carrier 124 connecting with one end of the carrier shaft 127 to support the rotating shafts of the planetary pinion gears 123. In the planetary gear 120, three shafts, that is, the sun gear shaft 125, the ring gear shaft 126, and the carrier shaft 127 respectively connecting with the sun gear 121, the ring gear 122, and the planetary carrier 124, work as input and output shafts of the power. Determination of the power input to or output from any two shafts among the three shafts automatically determines the power input to or output from the residual one shaft. The details of the input and output operations of the power into and from the three shafts of the planetary gear 120 will be discussed later. Resolvers 139, 149, and 159 for measuring rotational angles θs, θr, and θc of the sun gear shaft 125, the ring gear shaft 126, and the carrier shaft 127 are respectively attached to the sun gear shaft 125, the ring gear shaft 126, and the carrier shaft 127.

A power feed gear 128 for taking out the power is linked with the ring gear 122 and arranged on the side of the first motor MG1. The power feed gear 128 is further connected to the power transmission gear 111 via a chain belt 129, so that the power is transmitted between the power feed gear 128 and the power transmission gear 111.

The first motor MG1 is constructed as a synchronous motor-generator and includes a rotor 132 having a plurality of permanent magnets 135 on its outer surface and a stator 133 having three-phase coils 134 wound thereon to form a revolving magnetic field. The rotor 132 is linked with the sun gear shaft 125 connecting with the sun gear 121 of the planetary gear 120. The stator 133 is prepared by laying thin plates of non-directional electromagnetic steel one upon another and is fixed to a casing 119. The first motor MG1 works as a motor for rotating the rotor 132 through the interaction between a magnetic field produced by the permanent magnets 135 and a magnetic field produced by the three-phase coils 134, or as a generator for generating an electromotive force on either ends of the three-phase coils 134 through the interaction between the magnetic field produced by the permanent magnets 135 and the rotation of the rotor 132.

Like the first motor MG1, the second motor MG2 is also constructed as a synchronous motor-generator and includes a rotor 142 having a plurality of permanent magnets 145 on its outer surface and a stator 143 having three-phase coils 144 wound thereon to form a revolving magnetic field. The rotor 142 is linked with the ring gear shaft 126 connecting with the ring gear 122 of the planetary gear 120, whereas the stator 14 is fixed to the casing 119. The stator 143 of the motor MG2 is also produced by laying thin plates of non-directional electromagnetic steel one upon another. Like the first motor MG1, the second motor MG2 also works as a motor or a generator.

The controller 180 for driving and controlling the first and the second motor MG1 and MG2 has the following configuration. Referring back to Fig. 1, the controller 180 includes a first driving circuit 191 for driving the first motor MG1, a second driving circuit 192 for driving the second motor MG2, a control CPU 190 for controlling both the first and the second driving circuits 191 and 192, and a battery 194 including a number of secondary cells. The control CPU 190 is a one-chip microprocessor including a RAM 190a used as a working memory, a ROM 190b in which various control programs are stored, an input/output port (not shown), and a serial communication port (not shown) through which data are sent to and received from the EFIECU 170. The control CPU 190 receives a variety of data via the input port. The input data include a rotational angle θs of the sun gear shaft 125 measured with the resolver 139, a rotational angle θr of the ring gear shaft 126 measured with the resolver 149, a rotational angle θc of the carrier shaft 127 measured with the resolver 159, an accelerator pedal position AP (step-on amount of the accelerator pedal 164) output from the accelerator position sensor 164a, a brake pedal position BP (step-on amount of the brake pedal 165) output from the brake pedal position sensor 165a, a gearshift position SP output from the gearshift position sensor 184, values of currents Iu1 and Iv1 from two ammeters 195 and 196 disposed in the first driving circuit 191, values of currents Iu2 and Iv2 from two ammeters 197 and 198 disposed in the second driving circuit 192, and a remaining charge BRM of the battery 194 measured with a remaining charge meter 199. The remaining charge meter 199 may determine the remaining charge BRM of the battery 194 by any known method; for example, by measuring the specific gravity of an electrolytic solution in the battery 194 or the whole weight of the battery 194, by computing the currents and time of charge and discharge, or by causing an instantaneous short circuit between terminals of the battery 194 and measuring an internal resistance against the electric current.

The control CPU 190 outputs a first control signal SW1 for driving six transistors Tr1 through Tr6 working as switching elements of the first driving circuit 191 and a second control signal SW2 for driving six transistors Tr11 through Tr16 working as switching elements of the second driving circuit 192. The six transistors Tr1 through Tr6 in the first driving circuit 191 constitute a transistor inverter and are arranged in pairs to work as a source and a drain with respect to a pair of power lines L1 and L2. The three-phase coils (U,V,W) 134 of the first motor MG1 are connected to the respective contacts of the paired transistors in the first driving circuit 191. The power lines L1 and L2 are respectively connected to plus and minus terminals of the battery 194. The control signal SW1 output from the control CPU 190 thus successively controls the power-on time of the paired transistors Tr1 through Tr6. The electric currents flowing through the three-phase coils 134 undergo PWM (pulse width modulation) control to give quasi-sine waves, which enable the three-phase coils 134 to form a revolving magnetic field.

The six transistors Tr11 through Tr16 in the second driving circuit 192 also constitute a transistor inverter and are arranged in the same manner as the transistors Tr1 through Tr6 in the first driving circuit 191. The three-phase coils

(U,V,W) 144 of the second motor MG2 are connected to the respective contacts of the paired transistors in the second driving circuit 191. The second control signal SW2 output from the control CPU 190 thus successively controls the power-on time of the paired transistors Tr11 through Tr16. The electric currents flowing through the three-phase coils 144 undergo PWM control to give quasi-sine waves, which enable the three-phase coils 144 to form a revolving magnetic field.

The following describes the operation of the power output apparatus 110 of the first embodiment having the above construction. In the following discussion, the term 'power' is expressed by the product of the torque acting on a shaft and the revolving speed of the shaft and represents the magnitude of energy output per unit time. The term 'power state' denotes a driving point defined by a combination of the torque and the revolving speed that gives a certain power. There are, however, numerous combinations of the torque and the revolving speed to define a driving point that gives a certain power. The power output apparatus is controlled based on the energy flow at each moment, in other words, based on the energy balance per unit time. The term 'energy' herein is thus used as the synonym of 'power' and represents energy per unit time. In the same manner, both the terms 'electric power' and 'electrical energy' represent electrical energy per unit time.

The power output apparatus 110 of the embodiment thus constructed works in accordance with the operation principles discussed below, especially with the principle of torque conversion. By way of example, it is assumed that the engine 150 is driven at a driving point P1 of the revolving speed Ne and the torque Te and that the ring gear shaft 126 is driven at another driving point P2, which is defined by another revolving speed Nr and another torque Tr but gives an amount of energy identical with an energy Pe output from the engine 150. This means that the power output from the engine 150 is subjected to torque conversion and applied to the ring gear shaft 126. The relationship between the torque and the revolving speed of the engine 150 and the ring gear shaft 126 under such conditions is shown in the graph of Fig. 4.

According to the mechanics, the relationship between the revolving speed and the torque of the three shafts in the planetary gear 120 (that is, the sun gear shaft 125, the ring gear shaft 126, and the carrier shaft 127) can be expressed as nomograms illustrated in Figs. 5 and 6 and solved geometrically. The relationship between the revolving speed and the torque of the three shafts in the planetary gear 120 may be analyzed numerically through calculation of energies of the respective shafts, without using the nomograms. For the clarity of explanation, the nomograms are used in this embodiment.

In the nomogram of Fig. 5, the revolving speed of the three shafts is plotted as ordinate and the positional ratio of the coordinate axes of the three shafts as abscissa. When a coordinate axis S of the sun gear shaft 125 and a coordinate axis R of the ring gear shaft 126 are positioned on either ends of a line segment, a coordinate axis C of the carrier shaft 127 is given as an interior division of the axes S and R at the ratio of 1 to ρ, where ρ represents a ratio of the number of teeth of the sun gear 121 to the number of teeth of the ring gear 122 and expressed as Equation (1) given below:

$$\rho = \frac{\text{the humber of teeth of the sun gear}}{\text{the humber of teeth of the ring gear}} \tag{1}$$

As mentioned above, the engine 150 is driven at the revolving speed Ne, while the ring gear shaft 126 is driven at the revolving speed Nr. The revolving speed Ne of the engine 150 can thus be plotted on the coordinate axis C of the carrier shaft 127 linked with the crankshaft 156 of the engine 150, and the revolving speed Nr of the ring gear shaft 126 on the coordinate axis R of the ring gear shaft 126. A straight line passing through both the points is drawn, and a revolving speed Ns of the sun gear shaft 125 is then given as the intersection of this straight line and the coordinate axis S. This straight line is hereinafter referred to as a dynamic collinear line. The revolving speed Ns of the sun gear shaft 125 can be calculated from the revolving speed Ne of the engine 150 and the revolving speed Nr of the ring gear shaft 126 according to a proportional expression given as Equation (2) below. In the planetary gear 120, the determination of the rotations of the two gears among the sun gear 121, the ring gear 122, and the planetary carrier 124 results in automatically setting the rotation of the residual one gear.

$$Ns = Nr - (Nr - Ne)\,\frac{1+\rho}{\rho} \tag{2}$$

The torque Te of the engine 150 is then applied (upward in the drawing) to the dynamic collinear line on the coordinate axis C of the carrier shaft 127 functioning as a line of action. The dynamic collinear line against the torque can be regarded as a rigid body to which a force is applied as a vector. Based on the technique of dividing the force into two different parallel lines of action, the torque Te acting on the coordinate axis C is divided into a torque Tes on the coordinate axis S and a torque Ter on the coordinate axis R. The magnitudes of the torques Tes and Ter are given by Equations (3) and (4) below:

$$Tes = Te \times \frac{\rho}{1+\rho} \tag{3}$$

$$Ter = Te \times \frac{1}{1+\rho} \tag{4}$$

The equilibrium of forces on the dynamic collinear line is essential for the stable state of the dynamic collinear line. In accordance with a concrete procedure, a torque Tm1 having the same magnitude as but the opposite direction to the torque Tes is applied to the coordinate axis S, whereas a torque Tm2 having the same magnitude as but the opposite direction to a resultant force of the torque Ter and the torque that has the same magnitude as but the opposite direction to the torque Tr output to the ring gear shaft 126 is applied to the coordinate axis R. The torque Tm1 is given by the first motor MG1, and the torque Tm2 by the second motor MG2. The first motor MG1 applies the torque Tm1 in reverse of its rotation and thereby works as a generator to regenerate an electrical energy Pm1, which is given as the product of the torque Tm1 and the revolving speed Ns, from the sun gear shaft 125. The second motor MG2 applies the torque Tm2 in the direction of its rotation and thereby works as a motor to output an electrical energy Pm2, which is given as the product of the torque Tm2 and the revolving speed Nr, as a power to the ring gear shaft 126.

In case that the electrical energy Pm1 is identical with the electrical energy Pm2, all the electric power consumed by the second motor MG2 can be regenerated and supplied by the first motor MG1. In order to attain such a state, all the input energy should be output; that is, the energy Pe output from the engine 150 should be equal to an energy Pr output to the ring gear shaft 126. Namely the energy Pe expressed as the product of the torque Te and the revolving speed Ne is made equal to the energy Pr expressed as the product of the torque Tr and the revolving speed Nr. Referring to Fig. 4, the power that is expressed as the product of the torque Te and the revolving speed Ne and output from the engine 150 driven at the driving point P1 is subjected to torque conversion and output to the ring gear shaft 126 as the power of the same energy but expressed as the product of the torque Tr and the revolving speed Nr. As discussed previously, the power output to the ring gear shaft 126 is transmitted to a drive shaft 112 via the power feed gear 128 and the power transmission gear 111, and further transmitted to the driving wheels 116 and 118 via the differential gear 114. A linear relationship is accordingly held between the power output to the ring gear shaft 126 and the power transmitted to the driving wheels 116 and 118. The power transmitted to the driving wheels 116 and 118 can thus be controlled by adjusting the power output to the ring gear shaft 126.

Although the revolving speed Ns of the sun gear shaft 125 is positive in the nomogram of Fig. 5, it may be negative according to the revolving speed Ne of the engine 150 and the revolving speed Nr of the ring gear shaft 126 as shown in the nomogram of Fig. 6. In the latter case, the first motor MG1 applies the torque in the direction of its rotation and thereby works as a motor to consume the electrical energy Pm1 given as the product of the torque Tm1 and the revolving speed Ns. The second motor MG2, on the other hand, applies the torque in reverse of its rotation and thereby works as a generator to regenerate the electrical energy Pm2, which is given as the product of the torque Tm2 and the revolving speed Nr, from the ring gear shaft 126. In case that the electrical energy Pm1 consumed by the first motor MG1 is made equal to the electrical energy Pm2 regenerated by the second motor MG2 under such conditions, all the electric power consumed by the first motor MG1 can be supplied by the second motor MG2.

The above description refers to the fundamental torque conversion in the power output apparatus 110 of the embodiment. The power output apparatus 110 can, however, perform other operations as well as the above fundamental operation that carries out the torque conversion for all the power output from the engine 150 and outputs the converted torque to the ring gear shaft 126. The possible operations include an operation of charging the battery 194 with the surplus electrical energy and an operation of supplementing an insufficient electrical energy with the electric power stored in the battery 194. These operations are implemented by regulating the power output from the engine 150 (that is, the product of the torque Te and the revolving speed Ne), the electrical energy Pm1 regenerated or consumed by the first motor MG1, and the electrical energy Pm2 regenerated or consumed by the second motor MG2.

The operation principle discussed above is on the assumption that the efficiency of power conversion by the planetary gear 120, the motors MG1 and MG2, and the transistors Tr1 through Tr16 is equal to the value '1', which represents 100%. In the actual state, however, the conversion efficiency is less than the value '1', and it is required to make the energy Pe output from the engine 150 a little greater than the energy Pr output to the ring gear shaft 126 or alternatively to make the energy Pr output to the ring gear shaft 126 a little smaller than the energy Pe output from the engine 150. By way of example, the energy Pe output from the engine 150 may be calculated by multiplying the energy Pr output to the ring gear shaft 126 by the reciprocal of the conversion efficiency. In the state of the nomogram of Fig. 5, the torque Tm2 of the second motor MG2 may be calculated by multiplying the electric power regenerated by the first motor MG1 by the efficiencies of both the motors MG1 and MG2. In the state of the nomogram of Fig. 6, on the other hand, the torque Tm2 of the second motor MG2 may be calculated by dividing the electric power consumed by the first motor MG1 by the efficiencies of both the motors MG1 and MG2. In the planetary gear 120, there is an energy loss or heat loss due to a mechanical friction or the like, though the amount of energy loss is significantly small, compared with the whole amount of energy concerned. The efficiency of the synchronous motors used as the first and the second motors MG1 and MG2 is very close to the value '1'. Known devices such as GTOs applicable to the transistors Tr1 through Tr16 have extremely small ON-resistance. The efficiency of power conversion is thus practically equal to the value '1'. For the matter of convenience, in the following discussion of the embodiment, the efficiency is considered equal to the value '1' (=100%), unless otherwise specified.

The following describes a control procedure of stopping the operation of the engine 150 while the vehicle is at a run through the above torque control, based on an engine stop control routine shown in the flowchart of Fig. 7. The engine stop control routine of Fig. 7 is executed when the driver gives a switching instruction to the motor driving mode only with the second motor MG2 or when the control CPU 190 of the controller 180 carries out an operation mode determination routine (not shown) and selects the motor driving mode only with the second motor MG2.

When the program enters the engine stop control routine, the control CPU 190 of the controller 180 first outputs an engine operation stop signal to the EFIECU 170 through communication to stop the operation of the engine 150 at step S100. In response to the engine operation stop signal, the EFIECU 170 stops fuel injection from the fuel injection valve 151 and application of a voltage to the ignition plug 162 and fully closes the throttle valve 166. These processes stop the operation of the engine 150.

The control CPU 190 then reads the revolving speed Ne of the engine 150 at step S102. The revolving speed Ne of the engine 150 may be calculated from the rotational angle θc of the carrier shaft 127 read from the resolver 159, which is attached to the carrier shaft 127 connecting with the crankshaft 156 via the damper 157. Alternatively the revolving speed Ne of the engine 150 may be measured directly with the speed sensor 176 attached to the distributor 160. In the latter case, the control CPU 190 receives data of the revolving speed Ne from the EFIECU 170 connected to the speed sensor 176 through communication.

After receiving the revolving speed Ne of the engine 150, the control CPU 190 sets an initial value on a time counter TC based on the input revolving speed Ne at step S104. The time counter TC is an argument used to set a target revolving speed Ne* of the engine 150 at step S108 (described later) and is incremented at step S106 every time when the processing of steps S106 through S116 is repeated. The initial value on the time counter TC is set based on a map showing the relationship between the time counter TC as the argument and the target revolving speed Ne* of the engine 150, for example, a map shown in Fig. 8. In accordance with a concrete procedure, the value of the time counter TC corresponding to the input revolving speed Ne (target revolving speed Ne*) plotted on the ordinate is read from the map of Fig. 8.

The control CPU 190 increments the preset time counter TC at step S106, and sets the target revolving speed Ne* of the engine 150 corresponding to the incremented time counter TC using the map shown in Fig. 8 at step S108. In accordance with a concrete procedure, the target revolving speed Ne* corresponding to the time counter TC plotted on the abscissa is read from the map of Fig. 8. A process of determining the target revolving speed Ne* corresponding to the value 'TC+1', which is the initial value on the time counter TC plus one, is shown in the map of Fig. 8. The control CPU 190 subsequently receives the revolving speed Ne of the engine 150 at step S110, and sets a torque command value Tm1* of the first motor MG1 based on the input revolving speed Ne and the preset target revolving speed Ne* according to Equation (5) given below at step S112. The first term on the right side of Equation (5) is a proportional term to cancel the deviation of the actual revolving speed Ne from the target revolving speed Ne*, and the second term on the right side is an integral term to cancel the stationary deviation. K1 and K2 denote proportional constants.

$$Tm1^* \leftarrow K1(Ne^*-Ne)+K2\int(Ne^*-Ne)dt \qquad (5)$$

The control CPU 190 then sets a torque command value Tm2* of the second motor MG2 based on a torque command value Tr* to be output to the ring gear shaft 126 and the preset torque command value Tm1* of the first motor MG1 according to Equation (6) given below at step S114. The second term on the right side of Equation (6) represents a torque applied to the ring gear shaft 126 via the planetary gear 120 when the torque defined by the torque command value Tm1* is output from the first motor MG1 while the engine 150 is at a stop. K3 denotes a proportional constant. The proportional constant K3 is equal to one in the state of equilibrium on the dynamic collinear line in the nomogram. In a transient state in the course of stopping the operation of the engine 150, part of the torque output from the first motor MG1 is used to change the motion of the inertial system consisting of the engine 150 and the first motor MG1. The proportional constant K3 is accordingly smaller than one. A concrete procedure for accurately determining this torque calculates a torque (inertial torque) used to change the motion of the inertial system by multiplying a moment of inertia seen from the first motor MG1 of the inertial system by an angular acceleration of the sun gear shaft 125, subtracts the inertial torque from the torque command value Tm1*, and divides the difference by the gear ratio ρ. Since the torque command value Tm1* set by this routine is a relatively small value, the procedure of this embodiment utilizes the proportional constant K3 to simplify the calculation. The torque command value Tr* to be output to the ring gear shaft 126 is set based on the step-on amount of the accelerator pedal 164 by the driver according to a required torque setting routine shown in the flowchart of Fig. 9. The following discusses the procedure of setting the torque command value Tr*.

$$Tm2^* \leftarrow Tr^* - K3 \times \frac{Tm1^*}{\rho} \qquad (6)$$

The required torque setting routine of Fig. 9 is repeatedly executed at predetermined time intervals (for example, at every 8 msec). When the program enters the routine of Fig. 9, the control CPU 190 of the controller 180 first reads the revolving speed Nr of the ring gear shaft 126 at step S130. The revolving speed Nr of the ring gear shaft 126 may be calculated from the rotational angle θr of the ring gear shaft 126 read from the resolver 149. The control CPU 190 then reads the accelerator pedal position AP detected by the accelerator pedal position sensor 164a at step S132. The driver steps on the accelerator pedal 164 when feeling insufficiency of the output torque. The value of the accelerator pedal position AP accordingly represents the desired torque to be output to the ring gear shaft 126 and eventually to the driving wheels 116 and 118. The control CPU 190 subsequently determines the torque command value Tr*, that is, the target torque to be output to the ring gear shaft 126, based on the input revolving speed Nr of the ring gear shaft 126 and the input accelerator pedal position AP at step S134. Not the torque to be output to the driving wheels 116 and 118 but the torque to be output to the ring gear shaft 126 is calculated here from the accelerator pedal position AP and the revolving speed Nr. This is because the ring gear shaft 126 is mechanically linked with the driving wheels 116 and 118 via the power feed gear 128, the power transmission gear 111, and the differential gear 114 and the determination of the torque to be output to the ring gear shaft 126 thus results in determining the torque to be output to the driving wheels 116 and 118. In this embodiment, a map representing the relationship between the torque command value Tr*, the revolving speed Nr of the ring gear shaft 126, and the accelerator pedal position AP is prepared in advance and stored in the ROM 190b. In accordance with a concrete procedure, at step S134, the torque command value Tr* corresponding to the input accelerator pedal position AP and the input revolving speed Nr of the ring gear shaft 126 is read from the map stored in the ROM 190b. An example of available maps is shown in Fig. 10.

Referring back to the flowchart of Fig. 7, after setting the torque command value Tm1* of the first motor MG1 at step S112 and the torque command value Tm2* of the second motor MG2 at step S114, the program repeatedly executes a control routine of the first motor MG1 shown in the flowchart of Fig. 11 and a control routine of the second motor MG2 shown in the flowchart of Fig. 12 at predetermined time intervals (for example, at every 4 msec) through an interruption process, thereby controlling the first motor MG1 and the second motor MG2 to output the torques defined by the preset torque command values. The control procedures of the first motor MG1 and the second motor MG2 will be described later.

The control CPU 190 of the controller 180 then compares the revolving speed Ne of the engine 150 with a threshold value Nref at step S116. The threshold value Nref is set to be close to the target revolving speed Ne* of the engine 150 determined by the processing in the motor driving mode with only the second motor MG2. In this embodiment, the target revolving speed Ne* of the engine 150 determined by the processing in the motor driving mode with only the second motor MG2 is equal to zero, and the threshold value Nref is set to be close to zero. The threshold value Nref is smaller than the lower limit of a specific revolving speed range, in which the system connecting to the crankshaft 156 and the carrier shaft 127 linked with each other via the damper 157 causes a resonance. In case that the revolving speed Ne of the engine 150 is greater than the threshold value Nref, the program determines a transient state in the course of stopping the operation of the engine 150 and that the revolving speed Ne of the engine 150 is still not less than the lower limit of the specific revolving speed range that causes a resonance. The program accordingly returns to step S106 and repeats the processing of steps S106 through S116. Every time when the processing of steps S106 through S116 is repeated, the time counter TC is incremented and a smaller value is read from the map shown in Fig. 8 and set to the target revolving speed Ne* of the engine 150. The revolving speed Ne of the engine 150 thus decreases by a similar slope to that of the target revolving speed Ne* shown in the map of Fig. 8. In case that the slope of the target revolving speed Ne* is set to be not less than the slope of a natural variation in revolving speed Ne at the time of stopping the fuel injection to the engine 150, the revolving speed Ne of the engine 150 can be decreased abruptly. In case that the slope of the target revolving speed Ne* is set to be less than the slope of the natural variation in revolving speed Ne, on the contrary, the revolving speed Ne of the engine 150 can be decreased gently. In this embodiment, the slope of the target revolving speed Ne* is set to be not less than the slope of the natural variation in revolving speed Ne, on the assumption that the revolving speed Ne passes through the specific revolving speed range that causes a resonance.

In case that the revolving speed Ne of the engine 150 becomes equal to or less than the threshold value Nref at step S116, on the other hand, the program sets a cancel torque Tc to the torque command value Tm1* of the first motor MG1 at step S118, sets the torque command value Tm2* of the second motor MG2 according to Equation (6) given above at step S120, and waits for a predetermined time period at step S122. The cancel torque Tc prevents the revolving speed Ne of the engine 150 from taking a negative value, that is, undershooting. The reason why the revolving speed Ne of the engine 150 undershoots when the operation of the engine 150 is positively stopped by the first motor MG1 under the PI control, has been described previously.

After the predetermined time period has elapsed while the first motor MG1 outputs the cancel torque Tc, the program sets the torque command value Tm1* of the first motor MG1 equal to zero at step S124 and the torque command value Tm2* of the second motor MG2 equal to the torque command value Tr* at step S126. The program then exits from this routine and executes the processing in the motor driving mode with only the second motor MG2 (not shown).

The control operation of the first motor MG1 follows the control routine of the first motor MG1 shown in the flowchart of Fig. 11. When the program enters the routine of Fig. 11, the control CPU 190 of the controller 180 first receives the rotational angle θs of the sun gear shaft 125 from the revolver 139 at step S180, and calculates an electrical angle θ1 of the first motor MG1 from the rotational angle θs of the sun gear shaft 125 at step S181. In this embodiment, since a synchronous motor of four-pole pair (that is, four N poles and four S poles) is used as the first motor MG1, the rotational angle θs of the sun gear shaft 125 is quadrupled to yield the electrical angle θ1 ($\theta 1=4\theta s$). The CPU190 then detects values of currents Iu1 and Iv1 flowing through the U phase and V phase of the three-phase coils 134 in the first motor MG1 with the ammeters 195 and 196 at step S182. Although the currents naturally flow through all the three phases U, V, and W, measurement is required only for the currents passing through the two phases since the sum of the currents is equal to zero. At subsequent step S184, the control CPU 190 executes transformation of coordinates (three-phase to two-phase transformation) using the values of currents flowing through the three phases obtained at step S182. The transformation of coordinates maps the values of currents flowing through the three phases to the values of currents passing through d and q axes of the permanent magnet-type synchronous motor and is executed according to Equation (7) given below. The transformation of coordinates is carried out because the currents flowing through the d and q axes are essential for the torque control in the permanent magnet-type synchronous motor. Alternatively, the torque control may be executed directly with the currents flowing through the three phases.

$$\begin{bmatrix} Id1 \\ Iq1 \end{bmatrix} = \sqrt{2}\begin{bmatrix} -\sin(\theta 1-120) & \sin\theta 1 \\ -\cos(\theta 1-120) & \cos\theta 1 \end{bmatrix}\begin{bmatrix} Iu1 \\ Iv1 \end{bmatrix} \tag{7}$$

After the transformation to the currents of two axes, the control CPU 190 computes deviations of currents Id1 and Iq1 actually flowing through the d and q axes from current command values Id1* and Iq1* of the respective axes, which are calculated from the torque command value Tm1* of the first motor MG1, and subsequently determines voltage command values Vd1 and Vq1 with respect to the d and q axes at step S186. In accordance with a concrete procedure, the control CPU 190 executes arithmetic operations of Equations (8) and Equations (9) given below. In Equations (9), Kp1, Kp2, Ki1, and Ki2 represent coefficients, which are adjusted to be suited to the characteristics of the motor applied. Each voltage command value Vd1 (Vq1) includes a part in proportion to the deviation ΔI from the current command value I* (the first term on the right side of Equation (9)) and a summation of historical data of the deviations ΔI for 'i' times (the second term on the right side).

$$\Delta Id1 = Id1^{*} - Id1 \tag{8}$$

$$\Delta Iq1 = Iq1^{*} - Iq1$$

$$Vd1 = Kp1 \cdot \Delta Id1 + \Sigma\ Ki1 \cdot \Delta Id1 \tag{9}$$

$$Vq1 = Kp2 \cdot \Delta Iq1 + \Sigma\ Ki2 \cdot \Delta Iq1$$

The control CPU 190 then re-transforms the coordinates of the voltage command values thus obtained (two-phase to three-phase transformation) at step S188. This corresponds to an inverse of the transformation executed at step S184. The inverse transformation determines voltages Vu1, Vv1, and Vw1 actually applied to the three-phase coils 134 as expressed by Equations (10) given below:

$$\begin{bmatrix} Vu1 \\ Vv1 \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} \cos\theta 1 & -\sin\theta 1 \\ \cos(\theta 1-120) & -\sin(\theta 1-120) \end{bmatrix}\begin{bmatrix} Vd1 \\ Vq1 \end{bmatrix} \tag{10}$$

$$Vw1 = -Vu1 - Vv1$$

The actual voltage control is accomplished by on-off operation of the transistors Tr1 through Tr6 in the first driving circuit 191. At step S189, the on- and off-time of the transistors Tr1 through Tr6 in the first driving circuit 191 is PWM (pulse width modulation) controlled, in order to attain the voltage command values Vu1, Vv1, and Vw1 determined by Equations (10) given above.

It is assumed that the torque command value Tm1* of the first motor MG1 is positive when the torque Tm1 is applied in the direction shown in the nomograms of Figs. 5 and 6. For an identical positive torque command value Tm1*, the first motor MG1 is controlled to carry out the regenerative operation when the torque command value Tm1* acts in reverse of the rotation of the sun gear shaft 125 as in the state of the nomogram of Fig. 5, and controlled to carry out the power operation when the torque command value Tm1* acts in the direction of rotation of the sun gear shaft 125 as in the state of the nomogram of Fig. 6. For the positive torque command value Tm1*, both the regenerative operation and the power operation of the first motor MG1 implement the identical switching control. In accordance with a concrete procedure, the transistors Tr1 through Tr6 in the first driving circuit 191 are controlled to enable a positive torque to be applied to the sun gear shaft 125 by the combination of the magnetic field generated by the permanent magnets 135 set on the outer surface of the rotor 132 with the revolving magnetic field generated by the currents flowing through the three-phase coils 134. The identical switching control is executed for both the regenerative operation and the power operation of the first motor MG1 as long as the sign of the torque command value Tm1* is not changed. The control routine of the first motor MG1 shown in the flowchart of Fig. 11 is thus applicable to both the regenerative operation and the power operation. When the torque command value Tm1* is negative, the rotational angle θs of the sun gear shaft 125 read at step S180 is varied in a reverse direction. The control routine of the first motor MG1 shown in Fig. 11 is thus also applicable to this case.

The control operation of the second motor MG2 follows the control routine of the second motor MG2 shown in the flowchart of Fig. 12. The control procedure of the second motor MG2 is identical with that of the first motor MG1, except that the torque command value Tm2* and the rotational angle θr of the ring gear shaft 126 are used in place of the torque command value Tm1* and the rotational angle θs of the sun gear shaft 125. When the program enters the routine of Fig. 12, the control CPU 190 of the controller 180 first receives the rotational angle θr of the ring gear shaft 126 from the revolver 149 at step S190, and calculates an electrical angle θ2 of the second motor MG2 from the observed rotational angle θr of the ring gear shaft 126 at step S191. At subsequent step S192, phase currents Iu2 and Iv2 of the second motor MG2 are measured with the ammeters 197 and 198. The control CPU 190 then executes transformation of coordinates for the phase currents at step S194, computes voltage command values Vd2 and Vq2 at step S196, and executes inverse transformation of coordinates for the voltage command values at step S198. The control CPU 190 subsequently determines the on- and off-time of the transistors Tr11 through Tr16 in the second driving circuit 192 for the second motor MG2 and carries out the PWM control at step S199.

The second motor MG2 is also controlled to carry out either the regenerative operation or the power operation, based on the relationship between the direction of the torque command value Tm2* and the direction of the rotation of the ring gear shaft 126. Like the first motor MG1, the control process of the second motor MG2 shown in the flowchart of Fig. 12 is applicable to both the regenerative operation and the power operation. In this embodiment, it is assumed that the torque command value Tm2* of the second motor MG2 is positive when the torque Tm2 is applied in the direction shown in the nomogram of Fig. 5.

The following describes variations in revolving speed Ne of the engine 150 and torque Tm1 of the first motor MG1 during the control process to stop the engine 150, with the nomograms of Figs. 13 through 15 and the graph of Fig. 16. Fig. 13 is a nomogram showing the state when the engine stop control routine of Fig. 7 is carried out for the first time; Fig. 14 is a nomogram showing the state when the processing of steps S106 through S116 in the engine stop control routine has repeatedly been executed; and Fig. 15 is a nomogram showing the state when the revolving speed Ne of the engine 150 becomes equal to or less than the threshold value Nref. As discussed above, in this embodiment, the slope of the target revolving speed Ne* in the map of Fig. 8 is set to be not less than the slope of the natural variation in revolving speed Ne. As shown in Figs. 13 and 14, the torque Tm1 output from the first motor MG1 thus acts to forcibly decrease the revolving speed Ne of the engine 150. When the engine stop control routine is carried out for the first time, the torque Tm1 is applied in reverse of the rotation of the sun gear shaft 125, and the first motor MG1 accordingly functions as a generator. The revolving speed Ns of the sun gear shaft 125 then takes a negative value as shown in Fig. 14, and the first motor MG1 functions as a motor. At this moment, the first motor MG1 is under the PI control based on the revolving speed Ne of the engine 150 and the target revolving speed Ne*. The revolving speed Ne of the engine 150 thus varies with a little delay from the target revolving speed Ne* as shown in Fig. 16. As discussed previously with the nomogram of Fig. 6, the revolving speed Ns of the sun gear shaft 125 may take a negative value according to the revolving speed Ne of the engine 150 and the revolving speed Nr of the ring gear shaft 126 in the state prior to the output of an engine operation stop instruction. The nomogram of Fig. 14 may accordingly represent the state when the engine stop control routine is carried out for the first time. In this case, the first motor MG1 functions as a motor from the beginning.

In the state of the nomograms of Figs. 13 and 14, the fuel supply to the engine 150 is stopped, and no torque is accordingly output from the engine 150. The first motor MG1 outputs the torque Tm1 that forcibly reduces the revolving speed Ne of the engine 150, and a torque Tsc is then applied to the carrier shaft 127 as a reaction of the torque Tm1. The ring gear shaft 126, on the other hand, receives the torque Tm2 output from the second motor MG2 and a torque Tsr output via the planetary gear 120 accompanied by the torque Tm1 output from the first motor MG1. The torque Tsr applied to the ring gear shaft 126 can be calculated by taking into account the equilibrium on the dynamic collinear line and the variation in motion of the inertial system consisting of the engine 150 and the first motor MG1. The torque Tsr is almost equivalent to the second term on the right side of Equation (6). Namely the torque approximate to the torque command value Tr* is thus output to the ring gear shaft 126.

When the revolving speed Ne of the engine 150 becomes equal to or less than the threshold value Nref at step S116 in the engine stop control routine of Fig. 7, the first motor MG1 outputs the cancel torque Tc. The engine 150 accordingly stops without undershooting the revolving speed Ne of the engine 150 as shown by the broken lines in Fig. 16, and the operation mode is smoothly shifted to the motor driving mode with only the second motor MG2. In this embodiment, the torque command value Tm1* of the first motor MG1 is set equal to zero in the motor driving mode with only the second motor MG2. The dynamic collinear line is thus stably kept in the state having the least sum of the energy required for racing the engine 150 and the energy required for racing the first motor MG1. Since the engine 150 is a gasoline engine in the embodiment, the energy required for racing the engine 150, that is, the energy required for friction and compression of the piston in the engine 150, is greater than the energy required for racing the rotor 132 of the first motor MG1. The dynamic collinear line is accordingly in the state of stopping the engine 150 and racing the first motor MG1 as shown in the nomogram of Fig. 15. The cancel torque Tc output from the first motor MG1 is also shown in the nomogram of Fig. 15.

As discussed above, the power output apparatus 110 of the embodiment quickly reduces the revolving speed Ne of the engine 150 to zero in response to an instruction for stopping the operation of the engine 150. This allows the revolving speed Ne of the engine 150 to swiftly pass through the specific revolving speed range that causes a resonance of the torsional vibrations on the engine 150 and the first motor MG1 as the inertial mass. This results in enabling the simplified structure of the damper 157 for reducing the amplitude of the torsional vibrations.

In the power output apparatus 110 of the embodiment, the first motor MG1 outputs the cancel torque Tc in the direction of increasing the revolving speed Ne of the engine 150, immediately before the revolving speed Ne of the engine 150 becomes equal to zero. This structure effectively prevents the revolving speed Ne of the engine 150 from undershooting, thereby preventing occurrence of a vibration and a foreign noise due to undershooting.

The power output apparatus 110 of the embodiment uses the map wherein the slope of the target revolving speed Ne* is greater than the slope of the natural variation in revolving speed Ne of the engine 150 (for example, the map of Fig. 8), and accordingly enables the first motor MG1 to output the torque Tm1 that forcibly reduces the revolving speed Ne of the engine 150. In accordance with an alternative application, another map wherein the slope of the target revolving speed Ne* is less than the slope of the natural variation in revolving speed Ne of the engine 150 is used in place of the map of Fig. 8, so as to enable a gentle variation in revolving speed Ne of the engine 150. This alternative structure allows the revolving speed Ne of the engine 150 to be gently varied.

In accordance with still another possible application, another map wherein the slope of the target revolving speed Ne* is identical with the slope of the natural variation in revolving speed Ne of the engine 150 is used in place of the map of Fig. 8, so as to enable a natural variation in revolving speed Ne of the engine 150. In this case, the torque command value Tm1* of the first motor MG1 is set equal to zero when the operation of the engine 150 is stopped. The flowchart of Fig. 17 shows an engine stop control routine in this modified application. In this routine, the program sets the torque command value Tm1* of the first motor MG1 equal to zero at step S202 and sets the torque command value Tm2* of the second motor MG2 equal to the torque command value Tr* at step S210. No torque is accordingly output from the first motor MG1. While the kinetic energy of the engine 150 and the first motor MG1 is consumed by the friction and compression of the piston in the engine 150, the dynamic collinear line is shifted toward the state having the least sum of the energy required for racing the engine 150 and the energy required for racing the first motor MG1 (that is, the state in the nomogram of Fig. 15). When no torque is output from the first motor MG1, the first MG1 does not consume any electric power. This structure accordingly improves the energy efficiency of the whole power output apparatus. The engine stop control routine of Fig. 17 can be regarded as the processing routine in the motor driving mode with only the second motor MG2.

In the power output apparatus 110 of the embodiment, the target revolving speed Ne* of the engine 150 is set equal to zero in the motor driving mode with only the second motor MG2 and the threshold value Nref is then set approximate to or equal to zero. In accordance with another possible application, the target revolving speed Ne* of the engine 150 may be set equal to a specific value other than zero in the motor driving mode with only the second motor MG2. In this case, the threshold value Nref is set approximate to or equal to the specific value. By way of example, the idle revolving speed is set to the target revolving speed Ne* of the engine 150, and the threshold value Nref is set approximate to or equal to the idle revolving speed.

In the power output apparatus 110 of the embodiment discussed above, the control procedure is applied to regulate the revolving speed Ne of the engine 150 at the time of stopping the operation of the engine 150 while the vehicle is at a run, that is, while the ring gear shaft 126 rotates. The control procedure is also applicable to regulate the revolving speed Ne of the engine 150 at the time of stopping the operation of the engine 150 while the vehicle is at a stop, that is, while the ring gear shaft 126 does not rotate.

In the power output apparatus 110 of the embodiment, the torque command value Tm1* of the first motor MG1 and the torque command value Tm2* of the second motor MG2 are set in the engine stop control routine. In accordance with an alternative application, the torque command value Tm1* of the first motor MG1 is set in the control routine of the first motor MG1 and the torque command value Tm2* of the second motor MG2 in the control routine of the second motor MG2.

In the power output apparatus 110 of the embodiment, the power output to the ring gear shaft 126 is taken out of the arrangement between the first motor MG1 and the second motor MG2 via the power feed gear 128 linked with the ring gear 122. Like another power output apparatus 110A shown in Fig. 18 as a modified example, however, the power may be taken out of the casing 119, from which the ring gear shaft 126 is extended. Fig. 19 shows still another power output apparatus 110B as another modified example, wherein the engine 150, the planetary gear 120, the second motor MG2, and the first motor MG1 are arranged in this sequence. In this case, a sun gear shaft 125B may not have a hollow structure, whereas a hollow ring gear shaft 126B is required. This modified structure enables the power output to the ring gear shaft 126B to be taken out of the arrangement between the engine 150 and the second motor MG2.

The following describes another power output apparatus 110' as a second embodiment according to the present invention. The power output apparatus 110' of the second embodiment shown in Fig. 20 has a similar hardware structure to that of the power output apparatus 110 of the first embodiment, except that the engine 150 has an open-close timing changing mechanism 153 in the second embodiment. The difference in hardware structure, which is discussed below, leads to the different processing routines carried out by the controller 180.

Referring to Fig. 20, the open-close timing changing mechanism 153 adjusts the open-close timing of an intake valve 150a of the engine 150. Fig. 21 shows the detailed structure of the open-close timing changing mechanism 153. The intake valve 150a is generally opened and closed by a cam attached to an intake cam shaft 240, whereas an exhaust valve 150b is opened and closed by a cam attached to an exhaust cam shaft 244. An intake cam shaft timing gear 242 linked with the intake cam shaft 240 and an exhaust cam shaft timing gear 246 linked with the exhaust cam shaft 244 are connected with the crankshaft 156 via a timing belt 248, in order to open and close the intake valve 150a and the exhaust valve 150b at a timing corresponding to the revolving speed of the engine 150. In addition to these conventional elements, the open-close timing changing mechanism 153 further includes an OCV 254 that is connected with the intake cam shaft timing gear 242 and the intake cam shaft 240 via an oil pressure-driven VVT pulley 250 and functions as a control valve of input oil pressure of the VVT pulley 250. The VVT pulley 250 includes a set of movable pistons 252 that reciprocate in an axial direction by means of the oil pressure. The oil pressure input to the VVT pulley 250 is fed by an engine oil pump 256.

The open-close timing changing mechanism 153 works based on the following operation principle. The EFIECU 170 determines the open-close timing of the valve according to the driving conditions of the engine 150 and outputs a control signal to control the on-off state of the OCV 254. The output control signal varies the oil pressure input to the VVT pulley 250 and thereby shifts the movable pistons 252 in the axial direction. The movable pistons 252 have threads running in an oblique direction with respect to the axis. The movement in the axial direction accordingly causes rotation of the movable pistons 252 and changes the orientation of the intake cam shaft 240 and the intake cam shaft timing gear 242 connecting with the movable pistons 252. This results in varying the open-close timing of the intake valve 150a and changing the valve overlap. In the example of Fig. 21, the VVT pulley 250 is disposed only on the side of the intake cam shaft 240 and does not exist on the side of the exhaust cam shaft 244, so that the valve overlap is controlled by regulating the open-close timing of the intake valve 150a.

The controller 180 carries out the following control operation in the second embodiment. Fig. 22 is a flowchart showing an engine stop control routine carried out in the second embodiment. The engine stop control routine is executed at every 8 msec by the interrupting operation after the controller 180 determines that the engine 150 is to be stopped, based on the driving state of the vehicle and the remaining charge SOC of the battery 194, and sends a stop instruction to the EFIECU 170 so as to cease the fuel injection into the engine 150. When the program enters the routine of Fig. 22, the control CPU 190 of the controller 180 (see Fig. 1) sets a current target torque STG of the first motor MG1 to a variable STGold at step S300, sets a reduction torque STGmn at step S305, and sets a processing time mntg of slower speed reduction at step S310. The reduction torque STGmn is set in advance against the revolving speed Nr of the ring gear shaft 126, that is, the vehicle speed, as shown in the graph of Fig. 23. In accordance with a concrete procedure of this embodiment, at step S305, the reduction torque STGmn corresponding to the revolving speed Nr of the ring gear shaft 126 is read from a map that represents the relationship of Fig. 23 and is stored in advance in the ROM 190b. The reduction torque STGmn denotes a torque applied by the first motor MG1 to the carrier shaft 127 and thereby to the crankshaft 156, in order to reduce the revolving speed of the engine 150 under the ceasing condition of fuel injection. The processing time mntg of slower speed reduction represents a time period specified as a degree of relieving the reduction rate of the revolving speed in the speed reduction process of an open-loop control discussed later, in order to prevent a torque shock. The processing time mntg of slower speed reduction is set to a small value according to the revolving speed Nr of the ring gear shaft 126 as shown in the graph of Fig. 24. The revolving speed Nr of the ring gear shaft 126 corresponds to the vehicle speed, so that the longer processing time mntg of slower speed reduction is desirably set for the lower vehicle speed to relieve the reduction rate of the torque command value. This effectively prevents a torque shock. The processing time mntg will be discussed more in the open-loop control carried out at step S350.

After setting these variables, the control CPU 190 determines whether or not Condition 1 is fulfilled at step S320. Condition 1 represents a preset condition to allow a start of the engine stop control and is, in this embodiment, that 300 msec has elapsed since an instruction was given to cease the fuel injection to the engine 150. The instruction to cease the fuel injection may not cause an immediate decrease in output torque of the engine 150. The waiting time of 300 msec is thus to ensure that the output torque of the engine 150 has certainly been decreased. In response to an instruction of the EFIECU 170, after the fuel cutting operation, the engine 150 controls the open-close timing changing mechanism 153 to set the open-close timing of the valve to the greatest lag angle. Such setting decreases the load applied at the time of a restart of the engine 150 and reduces the shock in the process of motoring the engine 150. In case that Condition 1 is not fulfilled, the program proceeds to step S330 to continue the PID control based on the difference between the actual revolving speed and the target revolving speed of the engine 150 and keep the revolving speed of the engine 150.

In case that Condition 1 is fulfilled and a start of the engine stop control is allowed, on the other hand, the program proceeds to step S340 to compare the revolving speed Ne of the engine 150 with a predetermined value Nkn. The predetermined value Nkn used herein is a condition to stop the open-loop control when the execution of the engine stop control has lowered the revolving speed Ne of the engine 150. In this embodiment, the predetermined value Nkn is set equal to 200 rpm under the condition of the vehicle at a stop, 250 rpm under the condition of the vehicle on a run with the brake off, and 350 rpm under the condition of the vehicle on a run with the brake on. These values were experimentally determined to prevent the revolving speed of the engine 150 from undershooting.

In case that the engine speed Ne is not smaller than the predetermined value Nkn at step S340, the program proceeds to step S350 to carry out the open-loop control and reduce the engine speed. The open-loop control will be discussed later with the flowchart of Fig. 25. Execution of the open-loop control gradually decreases the revolving speed Ne of the engine 150. When the revolving speed Ne of the engine 150 has decreased to be lower than the predetermined value Nkn, it is determined whether or not the current target torque STG is substantially equal to zero at step S360. In case that the current target torque STG is not substantially equal to zero, the program proceeds to step S370 to carry out the processing to prevent the revolving speed of the engine 150 from undershooting.

After the processing at any one of steps S330, S350, S360, and S370, the program goes to step S380 to restrict the torque range and to step S390 to set a calculated target torque ttg subjected to the processing of torque range restriction to the target torque STG. The program then exits from this routine. The processing of torque range restriction limits the calculated target torque ttg to the rated torque range of the first motor MG1 or to an available torque range based on the remaining charge of the battery 194.

The above procedure is repeatedly executed to regulate the revolving speed of the engine 150. Until 300 msec has elapsed since a stop of fuel supply to the engine 150, the PID control is carried on to keep the engine speed at the target revolving speed (steps S320 and S330). After 300 msec has elapsed, the PID control is replaced by the open-loop control to apply a torque from the first motor MG1 to the output shaft of the engine 150 or the crankshaft 156 in reverse of the rotation of the crankshaft 156 and thereby reduce the revolving speed of the engine 150 in a predetermined range of deceleration (steps S320, S340, and S350). This process is shown by Section A of Fig. 27. When the revolving speed Ne of the engine 150 becomes lower than the predetermined value Nkn, the open-loop control is concluded and the processing is carried out to prevent undershoot (steps S320, S340, S360, and S370). This process causes the target torque to gradually decrease and approach zero as shown by Section B of Fig. 27.

The flowchart of Fig. 25 shows the details of the open-loop control executed at step S350. When the program enters the open-loop control routine, it is first determined whether the vehicle is at a stop or on a run at step S351. In case that the vehicle is on a run, the program proceeds to step S352 to carry out the processing of slower speed reduction using the target torque STGold and the reduction torque STGmn set at the start of the engine stop control and calculate a tentative target torque ttg. The processing of slower speed reduction is carried on for the processing time nmtg previously set according to the vehicle speed (see step S310 in the flowchart of Fig. 22 and Fig. 24). The processing of slower speed reduction mathematically represents an integration process, but may be realized by calculating the weighting average of the currently observed value and the target value in case that the processing is repeatedly executed at predetermined intervals like this embodiment. In this embodiment, the calculation of weighting average is carried out at every processing time nmtg and the weight added to the currently observed value is approximately one sixteenth the weight added to the target value. Immediately after the program enters the processing to stop the engine 150, the target torque STG is set up a specified value by the PIP control described above (see Fig. 22 step S330). The processing of slower speed reduction thus does not abruptly set the reduction torque STGmn to the target torque immediately after the start of the engine stop control but gradually makes the value of the tentative target torque ttg approach the reduction torque STGmn set based on the map of Fig. 23. The longer processing time nmtg of slower speed reduction is set for the lower vehicle speed. The tentative target torque ttg accordingly approaches the reduction torque STGmn at the gentler rate against the lower vehicle speed.

When it is determined that the vehicle is at a stop at step S351, on the other hand, there is no need of varying the processing time of slower speed reduction according to the vehicle speed. The program thus proceeds to step S353 to carry out the processing of slower speed reduction for a fixed processing time (128 msec in this embodiment). The difference of the processing at step S353 under the condition of the vehicle at a stop from the processing at step S352 under the condition of the vehicle on a run is that the reduction torque STGmn set according to the vehicle speed is replaced by the sum of the fixed reduction torque and a learnt value stgkg of the target torque. In accordance with a concrete procedure, at step S353, the processing of slower speed reduction is carried out using the current target torque STGold and the torque (-14+stgkg)-STGold. While the vehicle is on a run, the driver hardly feels the torque shock due to a stop of the engine 150. While the vehicle is at a stop, on the contrary, the driver readily feels the torque shock due to a stop of the engine 150. The program accordingly learns the behavior of reduction of the target torque under the condition of the vehicle at a stop, and thus enables the engine 150 to be stopped with substantially no undershoot. The concrete procedure of obtaining the learnt value stgkg will be discussed later.

The above processing is executed at predetermined intervals, so that the tentative target torque gradually approaches the reduction torque STGmn at the rate depending upon the processing time nmtg of slower speed reduction. After the tentative target torque ttg becomes coincident with the reduction torque STGmn, the first motor MG1 outputs a substantially fixed torque.

After the processing of slower speed reduction either under the condition of the vehicle on a run or under the condition of the vehicle at a stop, it is determined whether or not Condition 2 is fulfilled at step S354. Condition 2 includes the following three conditions:

(1) The revolving speed Ne of the engine 150 is not greater than 400 rpm;
(2) The vehicle is at a stop; and
(3) The learnt value stgkg has not yet been updated (that is, a flag Xstg representing execution of the learning process is not equal to one).

In case that any one of these three conditions is not fulfilled, the program immediately goes to NEXT and exits from this routine. In case that all the three conditions are fulfilled, on the other hand, the program halts the torque reduction and starts the processing to gradually decrease the target torque to zero. At step S355, a deceleration ΔN of the revolving speed is computed.

The deceleration ΔN of the revolving speed is defined as the difference between the previous revolving speed detected at a previous cycle and the current revolving speed detected at a current cycle. In this embodiment, detection of the revolving speed Ne is carried out at every 16 msec. The program then goes to step S356 to determine whether or not the deceleration ΔN of the revolving speed is within a range of -54 to -44. In case that the deceleration ΔN of the revolving speed is within this range, the program goes to NEXT and exits from this routine. In case that the deceleration ΔN of the revolving speed is greater than the value -44, a tentative learnt value tstg is decremented by one at step S357. In case that the deceleration ΔN of the revolving speed is smaller than the value -54, on the other hand, the tentative learnt value tstg is incremented by one at step S358. The procedure checks the reduction rate of the engine speed Ne in Section A of Fig. 27 and varies the tentative learnt value tstg in order to affect the learnt value stgkg in the process of determining the reduction torque under the condition of the vehicle at a stop in a next cycle of the open-loop control. In the case of the smaller reduction rate, such variation in tentative learnt value tstg increases the absolute value of the target reduction torque, which is a negative value and is expressed as (-14+stgkg)-STGold) calculated at step S353. In the case of the greater reduction rate, on the contrary, the variation decreases the absolute value. The reduction rate of the revolving speed Ne of the engine 150 at the time of stopping the engine 150 is accordingly adjusted to the appropriate range of -54 Nm/16 msec to -44 Nm/16 msec through the learning control.

The program then goes to step S359 to restrict the tentative learnt value tstg to a predetermined range and set the flag Xstg representing execution of the learning process equal to one. The procedure does not directly set the learnt value stgkg but sets the tentative learnt value tstg, in order to prevent the learnt value used for the processing of slower speed reduction (step S353) from being changed at every cycle of this open-loop control routine. The learnt value stgkg is used in a next cycle of the engine stop control.

The open-loop control routine discussed above is carried out after 300 msec has elapsed since a stop of fuel supply to the engine 150, and gradually increases the magnitude of the negative torque applied from the first motor MG1 to the output shaft of the engine 150 (that is, the torque applied in reverse of the rotation of the output shaft) toward the final torque determined according to the state of the vehicle, that is, at a stop or on a run. When the revolving speed Ne of the engine 150 gradually decreases as shown by Section A of Fig. 27 to or below 400 rpm, in case that the vehicle is at a stop, the learnt value tstg depends upon the deceleration ΔN of the revolving speed.

In case that the revolving speed Ne of the engine 150 gradually decreases and eventually becomes smaller than the predetermined value Nkn, the open-loop control is replaced by the processing to prevent undershoot (executed at step S370 in the flowchart of Fig. 22). The flowchart of Fig. 26 shows the details of the processing to prevent undershoot. When the program enters the routine of Fig. 26, the tentative target torque ttg is computed at step S371 according to the equation of:

$$ttg = STGold + 2\ [Nm]$$

It is then determined whether or not the calculated tentative target torque ttg is not greater than -2 at step S372. In case that ttg is greater than -2, the tentative target torque ttg is set equal to -2 at step S373. The processing of steps S372 and S373 accordingly sets the upper limit (=-2) of the tentative target torque ttg.

This procedure gradually decreases the magnitude of the torque, which has been applied to reduce the revolving speed Ne of the output shaft of the engine 150, within a range that does not exceed -2 [Nm]. The variation in tentative target torque ttg according to the above equation decrements the magnitude of the torque, which has acted in the direction of decelerating the output shaft of the engine 150, by 2 [Nm] at every 8 msec that is the interval of the interrupting process. The torque thus gradually approaches zero (see Section B of Fig. 27).

After the processing of either step S372 or step S373, it is determined whether or not the revolving speed Ne of the engine 150 is less than 40 rpm at step S374. In case that the revolving speed Ne of the engine 150 is less than 40 rpm, the program determines no further necessity of applying the braking torque to the output shaft of the engine 150, and sets the tentative target torque ttg equal to zero at step S375.

The program then goes to step S376 to determine whether or not Condition 3 is fulfilled. Condition 3 includes the following two conditions:

(1) The vehicle is at a stop; and
(2) The learnt value stgkg has been updated (that is, the flag Xstg representing execution of the learning process is equal to one).

In case that either one of these two conditions is not fulfilled, the program goes to NEXT and exist from this routine. In case that both the conditions are fulfilled, on the other hand, the program proceeds to step S377 to set the tentative learned value tstg to a learned value STGkg and to step S378 to reset the flag Xstg to zero. After the processing, the program exits from this routine.

The processing to prevent undershoot decreases the magnitude of the torque applied to the output shaft of the engine 150 toward -2 as shown by Section B of Fig. 27. When the revolving speed Ne of the engine 150 becomes less than 40 rpm, the braking torque is set equal to zero. This procedure effectively prevents the revolving speed Ne of the engine 150 from being lower than zero, that is, prevents undershoot.

The primary effects of the second embodiment are given below:

(1) While there is a requirement of continuous operation of the engine 150, the PID control is carried on to keep the revolving speed Ne of the engine 150 at a target revolving speed.
(2) when there is no requirement of continuous operation of the engine 150, the EFIECU 170 stops fuel supply to the engine 150. After 300 msec has elapsed since the stop of fuel supply, the open-loop control is carried out to cause the first motor MG1 to apply the torque in reverse of the rotation of the output shaft of the engine 150 to the carrier shaft 127, which is connected to the crankshaft 156 or the output shaft of the engine 150. The open-loop control does not execute the feed back control of the target torque of the first motor MG1 based on the deviation of the revolving speed Ne of the engine 150 from the target revolving speed (=0), but determines the target torque based on a predetermined algorithm. In the above embodiment, as shown in Fig. 27, the algorithm gradually increases the magnitude of the target torque at a predetermined rate. Such control effectively prevents a large torque from being abruptly applied in reverse of the rotation of the engine 150 at the time of stopping the engine 150 to cause a torque shock and worsen the drivability. As shown in Fig. 27, after the processing of slower speed reduction, the torque of a fixed magnitude is applied in reverse of the rotation of the output shaft of the engine 150. This makes the reaction torque constant and further improves the drivability.
(3) The first motor MG1 applies the torque in reverse of the rotation of the output shaft of the engine 150, so that the revolving speed Ne of the output shaft of the engine 150 is lowered at a predetermined deceleration (approximately -50 rpm/16 msec in this embodiment). The deceleration is limited to the range that does not cause torsional vibrations of the output shaft, and no torsional vibrations accordingly occur on the crankshaft 156 and the carrier shaft 127 connected to each other via the damper 157.

(4) When the revolving speed Ne of the engine 150 becomes lower than a predetermined level (400 rpm in this embodiment), in case that the vehicle is at a stop, the learning process is carried out to make the deceleration within a predetermined range in a next cycle of the engine stop control.

(5) When the revolving speed Ne of the engine 150 further decreases to or below the predetermined value Nkn (200 rpm through 350 rpm in this embodiment), the magnitude of the torque applied by the first motor MG1 is gradually decreased at a predetermined rate toward zero. This process effectively prevents the revolving speed Ne of the output shaft of the engine 150 from being lower than zero, that is, prevents the reverse rotation of the crankshaft 156. The crankshaft 156 is generally designed on the assumption of no reverse rotation. The reverse rotation of the crankshaft 156 may, for example, cause a lock of the lead angle in the open-close timing changing mechanism 153. In the structure of this embodiment, the magnitude of the torque applied to the output shaft of the engine 150 is decreased with a decrease in revolving speed Ne of the engine 150. When the revolving speed Ne of the engine 150 becomes lower than 40 rpm, the braking torque is set equal to zero. This structure effectively prevents the reverse rotation of the crankshaft 156.

(6) The predetermined value Nkn used as the criterion of the control procedure is set equal to 200 rpm under the condition of the vehicle at a stop, 250 rpm under the condition of the vehicle on a run with the brake off, and 350 rpm under the condition of the vehicle on a run with the brake on. This enables the torque applied to the output shaft of the engine 150 in the direction of reducing the revolving speed to be substantially constant irrespective of the driving state of the vehicle. The revolving speed of the engine 150 subjected to the open-loop control can thus been decreased gently to zero.

The power output apparatuses 110 and 110' of the first and the second embodiments and their modified examples discussed above are applied to the FR-type or FF-type two-wheel-drive vehicle. As shown in Fig. 28, however, a power output apparatus 110C given as another modified example is applied to a four-wheel-drive vehicle. In this structure, the second motor MG2 is separated from the ring gear shaft 126 and independently arranged in the rear-wheel portion of the vehicle, so as to drive the rear driving wheels 117 and 119. The ring gear shaft 126 is, on the other hand, connected to the differential gear 114 via the power feed gear 128 and the power transmission gear 111, in order to drive the front driving wheels 116 and 118. Either one of the engine stop control routines shown in Figs. 7 and 22 is also applicable to this structure.

The power output apparatus 110 of the embodiment and their modified examples discussed above are applied to the FR-type or FF-type two-wheel-drive vehicle. In another modified example of Fig. 28, however, a power output apparatus 110C is applied to a four-wheel-drive vehicle. In this structure, the second motor MG2 is separated from the ring gear shaft 126 and independently arranged in the rear-wheel portion of the vehicle, so as to drive the rear driving wheels 117 and 119. The ring gear shaft 126 is, on the other hand, connected to the differential gear 114 via the power feed gear 128 and the power transmission gear 111, in order to drive the front driving wheels 116 and 118. The engine stop control routine of Fig. 7 is also applicable to this structure.

Permanent magnet (PM)-type synchronous motors are used as the first motor MG1 and the second motor MG2 in the power output apparatus 110 of the embodiment. Any other motors which can implement both the regenerative operation and the power operation, such as variable reluctance (VR)-type synchronous motors, vernier motors, d.c. motors, induction motors, superconducting motors, and stepping motors, may, however, be used according to the requirements.

Transistor inverters are used as the fist and the second driving circuits 191 and 192 in the power output apparatus 110 of the embodiment. Other available examples include IGBT (insulated gate bipolar mode transistor) inverters, thyristor inverters, voltage PWM (pulse width modulation) inverters, square-wave inverters (voltage inverters and current inverters), and resonance inverters.

The battery 194 in the above embodiment may include Pb cells, NiMH cells, Li cells, or the like cells. A capacitor may be used in place of the battery 194.

In the power output apparatus 110 of the embodiment, the crankshaft 156 of the engine 150 is connected to the first motor MG1 via the damper 157 and the planetary gear 120. When the operation of the engine 150 is stopped, the variation in revolving speed Ne of the engine 150 is regulated by the output torque from the first motor MG1 via the planetary gear 120. Like another power output apparatus 310 shown in Fig. 29 as still another modified example, a crankshaft CS of an engine EG is directly connected to a rotating shaft RS of a motor MG via a damper DNP. The variation in revolving speed Ne of the engine EG is regulated by the motor MG when the operation of the engine EG is stopped. This structure exerts the same effects as those of the power output apparatus 110 of the above embodiment. In the above embodiments, the first motor MG1 and the second motor MG2 are arranged to be coaxial with the shaft of power transmission. The arrangement of these motors with respect to the shaft of power transmission may, however, be determined arbitrarily based on the design requirements.

The present invention is not restricted to the above embodiment or its modified examples, but there may be many modifications, changes, and alterations without departing from the scope or spirit of the main characteristics of the present invention. For example, although the power output apparatus is mounted on the vehicle in the above embodiment, it may be mounted on other transportation means like ships and airplanes as well as a variety of industrial machines.

It should be clearly understood that the above embodiment is only illustrative and not restrictive in any sense. The scope and spirit of the present invention are limited only by the terms of the appended claims.

Claims

1. A power output apparatus for outputting power to a drive shaft, said power output apparatus comprising:

   an engine having an output shaft;
   a first motor having a rotating shaft and inputting and outputting power to and from said rotating shaft;
   a second motor inputting and outputting power to and from said drive shaft;
   three shaft-type power input/output means having three shafts respectively linked with said drive shaft, said output shaft, and said rotating shaft, said three shaft-type power input/output means inputting and outputting power to and from a residual one shaft, based on predetermined powers input to and output from any two shafts among said three shafts;
   fuel stop instruction means for giving an instruction to stop fuel supply to said engine when a condition of stopping operation of said engine is fulfilled; and
   stop-time control means for causing a torque to be applied to said output shaft of said engine and thereby restricting a deceleration of revolving speed of said output shaft to a predetermined range in response to said instruction to stop the fuel supply to said engine, so as to implement a stop-time control for stopping the operation of said engine.

2. A power output apparatus in accordance with claim 1, said power output apparatus further comprising:

   target torque storage means for determining a time-based variation in target value of the torque applied to said output shaft of said engine, based on a behavior at the time of stopping the operation of said engine,
   wherein said stop-time control means comprises:

   means for driving said first motor, as said stop-time control, to apply a torque corresponding to said target value to said output shaft of said engine along a time course after the stop of fuel supply to said engine via said three shaft-type power input/output means.

3. A power output apparatus in accordance with claim 2, said power output apparatus further comprising:

   deceleration computing means for computing the deceleration of revolving speed of said output shaft during the course of said stop-time control;
   learning means for varying a learnt value according to the deceleration computed by said deceleration computing means and storing said learnt value; and
   deceleration range determination means for determining said predetermined range in said stop-time control carried out by said stop-time control means, based on said learnt value stored by said learning means.

4. A power output apparatus in accordance with claim 1, said power output apparatus further comprising:

   revolving speed detection means for measuring the revolving speed of said output shaft,
   wherein said stop-time control means further comprises:

   means for driving said first motor, as said stop-time control, in order to enable the revolving speed of said output shaft measured by said revolving speed detection means to approach a predetermined value via a predetermined pathway.

5. A power output apparatus in accordance with claim 1, said power output apparatus further comprising:

   revolving speed detection means for measuring the revolving speed of said output shaft,
   wherein said stop-time control means further comprises:

   means for driving said first motor, as said stop-time control, to apply a torque in reverse of the rotation of said output shaft via said three shaft-type power input/output means to said output shaft, until the revolving speed of said output shaft measured by said revolving speed detection means becomes coincident with said predetermined value.

6. A power output apparatus in accordance with claim 5, wherein said stop-time control means further comprises means for driving said first motor, as part of said stop-time control, to apply a predetermined torque in the direction of rotation of said output shaft via said three shaft-type power input output means to said output shaft, when the revolving speed of said output shaft measured by said revolving speed detection means decreases to a reference value, which is not greater than said predetermined value.

7. A power output apparatus in accordance with claim 5, said power output apparatus further comprising:

deceleration computing means for computing the deceleration of revolving speed of said output shaft during the course of said stop-time control; and
reference value setting means for setting a larger value to said reference value against a greater absolute value of the deceleration.

8. A power output apparatus in accordance with claim 5, said power output apparatus further comprising:

braking force detection means for determining magnitude of a braking force applied to said drive shaft during the course of said stop-time control; and
reference value setting means for setting a larger value to said reference value when said braking force detection means determines that the braking force has a large magnitude.

9. A power output apparatus in accordance with claim 5, wherein said predetermined value is a revolving speed that is lower than a resonance range of torsional vibrations in a system including said output shaft and said three shaft-type power input/output means.

10. A power output apparatus in accordance with claim 1, said power output apparatus further comprising:

second motor control means for driving said second motor to continue power input and output to and from said drive shaft, when said instruction to stop the operation of said engine is given in the course of continuous power input and output to and from said drive shaft.

11. An engine controller comprising an engine for outputting power through combustion of a fuel and a motor connected to an output shaft of said engine via a damper, said engine controller controlling operation and stop of said engine and comprising:

fuel stop means for stopping fuel supply to said engine when a condition to stop the operation of said engine is fulfilled; and
stop-time control means for causing a torque to be applied to said output shaft of said engine and thereby restricting a deceleration of revolving speed of said output shaft to a predetermined range in response to the stop of fuel supply to said engine, so as to implement a stop-time control for stopping the operation of said engine.

12. An engine controller in accordance with claim 11, said engine controller further comprising:

target torque storage means for determining a time-based variation in target value of the torque applied by said motor to said output shaft of said engine, based on a behavior at the time of stopping the operation of said engine,

wherein said stop-time control means comprises:

means for driving said motor, as said stop-time control, to apply a torque corresponding to said target value to said output shaft of said engine along a time course after the stop of fuel supply to said engine.

13. An engine controller in accordance with claim 12, said engine controller further comprising:

deceleration computing means for computing the deceleration of revolving speed of said output shaft during the course of said stop-time control;

learning means for varying a learnt value according to the deceleration computed by said deceleration computing means and storing said learnt value; and

deceleration range determination means for determining said predetermined range in said stop-time control carried out by said stop-time control means, based on said learnt value stored by said learning means.

14. An engine controller in accordance with claim 11, said engine controller further comprising:

revolving speed detection means for measuring the revolving speed of said output shaft,
wherein said stop-time control means further comprises:

means for driving said motor, as said stop-time control, in order to enable the revolving speed of said output shaft measured by said revolving speed detection means to approach a predetermined value via a predetermined pathway.

15. An engine controller in accordance with claim 11, said engine controller further comprising:

revolving speed detection means for measuring the revolving speed of said output shaft,
wherein said stop-time control means comprises:

means for driving said motor, as said stop-time control, to apply a torque in reverse of the rotation of said output shaft to said output shaft, until the revolving speed of said output shaft measured by said revolving speed detection means becomes coincident with said predetermined value.

16. An engine controller in accordance with claim 11, said engine controller further comprising:

revolving speed detection means for measuring the revolving speed of said output shaft,
wherein said stop-time control means further comprises means for driving said motor, as part of said stop-time control, to apply a predetermined torque in the direction of rotation of said output shaft to said output shaft, when the revolving speed of said output shaft measured by said revolving speed detection means decreases to a reference value, which is not greater than said predetermined value.

17. An engine controller in accordance with claim 15, said engine controller further comprising:

deceleration computing means for computing the deceleration of revolving speed of said output shaft during the course of said stop-time control; and

reference value setting means for setting a larger value to said reference value against a greater absolute value of the deceleration.

18. An engine controller in accordance with claim 15, wherein said predetermined value is a revolving speed that is lower than a resonance range of torsional vibrations in a system including said output shaft and a rotor of said motor.

19. A method of controlling a power output apparatus, which comprises: an engine having an output shaft; a first motor having a rotating shaft and inputting and outputting power to and from said rotating shaft; a second motor inputting and outputting power to and from said drive shaft; and three shaft-type power input/output means having three shafts respectively linked with said drive shaft, said output shaft, and said rotating shaft, said three shaft-type power input/output means inputting and outputting power to and from a residual one shaft, based on predetermined powers input to and output from any two shafts among said three shafts, said method comprising the steps of:

giving an instruction to stop fuel supply to said engine when a condition of stopping operation of said engine is fulfilled; and

causing a torque to be applied to said output shaft of said engine and thereby restricting a deceleration of revolving speed of said output shaft to a predetermined range in response to said instruction to stop the fuel supply to said engine, so as to implement a stop-time control for stopping the operation of said engine.

20. A method of controlling stop of an engine, said engine outputting power through combustion of a fuel and having an output shaft connected to a motor via a damper, said method comprising the steps of:

stopping fuel supply to said engine when a condition to stop operation of said engine is fulfilled; and

causing a torque to be applied to said output shaft of said engine and thereby restricting a deceleration of revolving speed of said output shaft to a predetermined range in response to the stop of fuel supply to said engine, so as to implement a stop-time control for stopping the operation of said engine.

Fig. 1

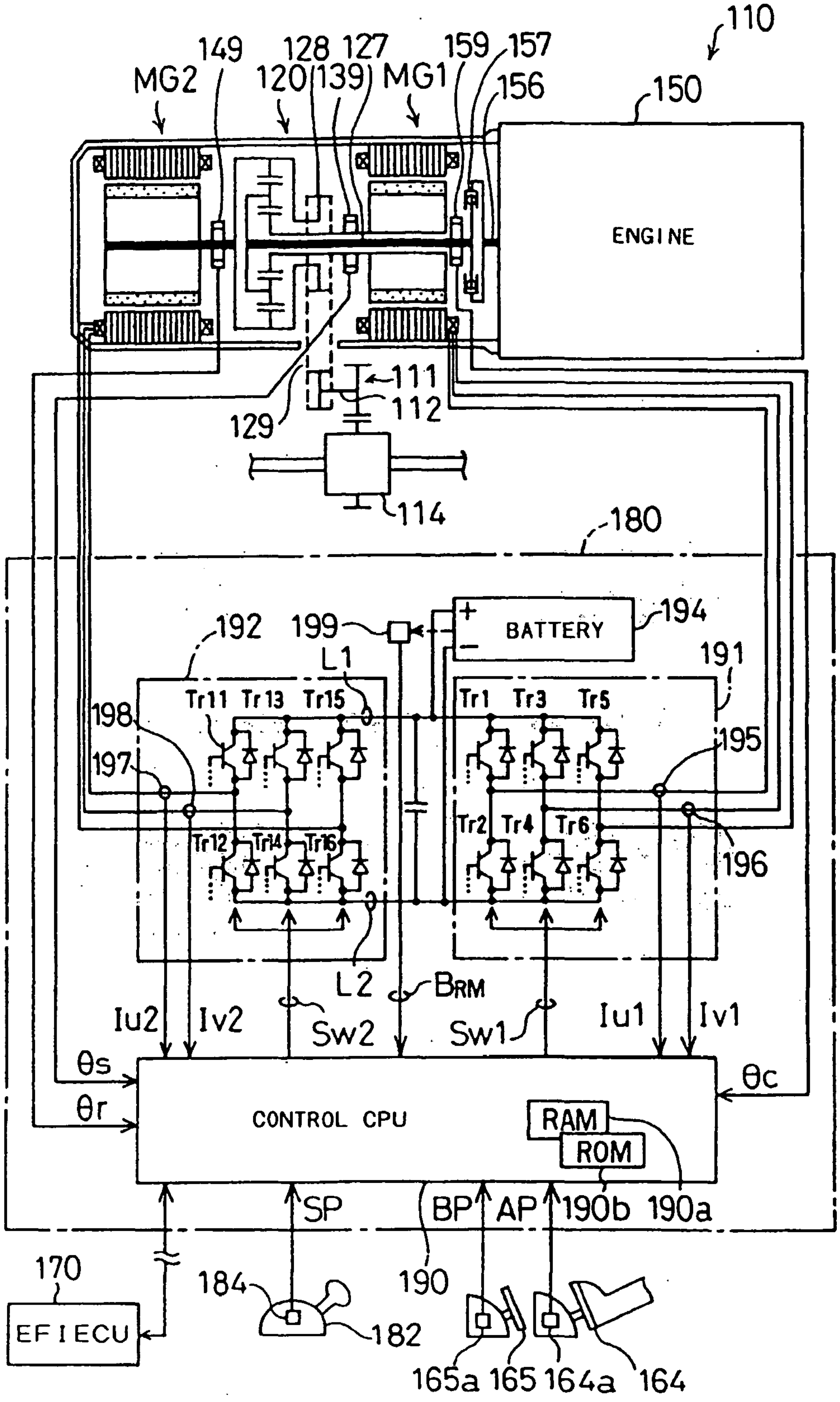

110
149
128
127
159
157
MG2
120
139
MG1
156
150
ENGINE
111
112
129
114
180
192
199
BATTERY
194
L1
191
Tr11
Tr13
Tr15
Tr1
Tr3
Tr5
198
195
197
Tr12
Tr14
Tr16
Tr2
Tr4
Tr6
196
L2
BRM
Iu2
Iv2
Sw2
Sw1
Iu1
Iv1
θs
θc
θr
CONTROL CPU
RAM
ROM
SP
BP
AP
190b
190a
170
184
190
EFIECU
182
165a
165
164a
164

Fig. 2

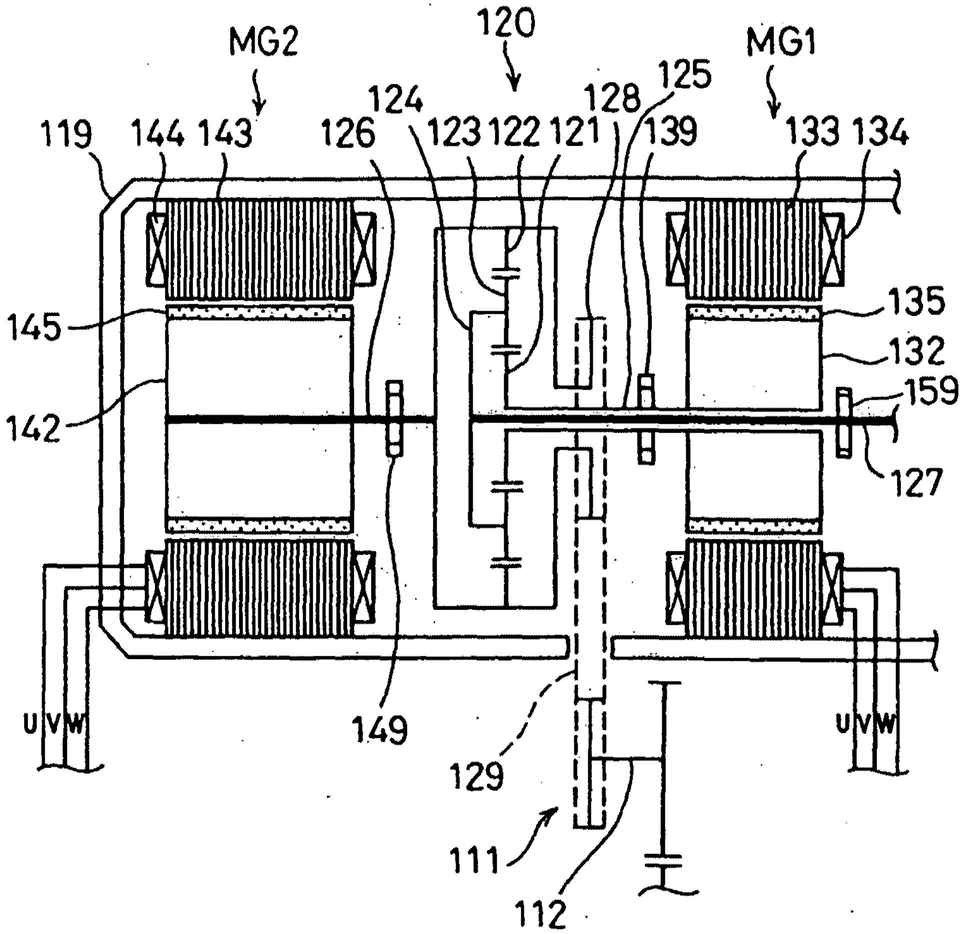

MG2
120
MG1
124
125
128
119
144
143
126
123
122
121
139
133
134
135
145
132
159
142
127
UVW
149
UVW
129
111
112

Fig. 3

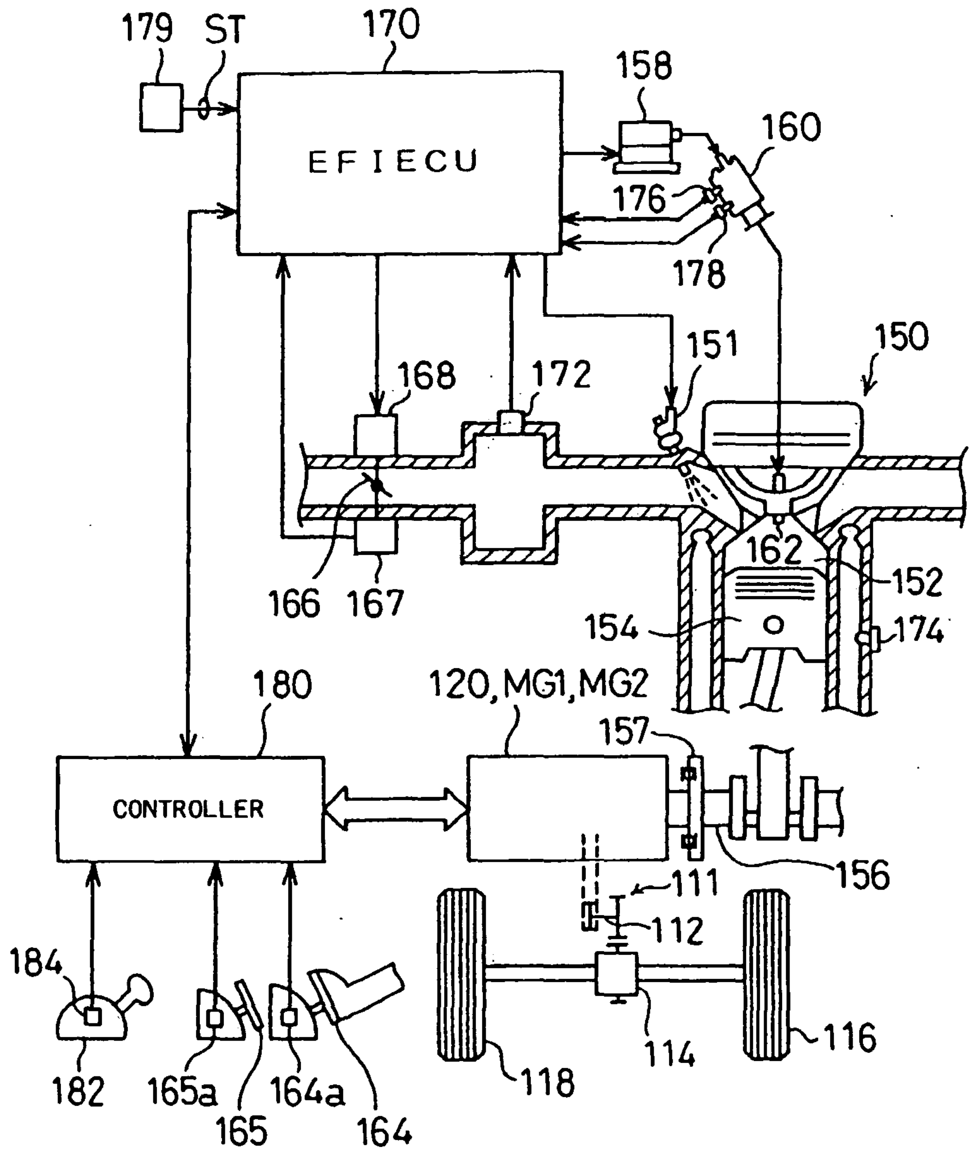

179
ST
170
EFIECU
158
160
176
178
151
150
168
172
166
167
162
152
154
174
180
CONTROLLER
120, MG1, MG2
157
156
111
112
114
116
118
184
182
165a
165
164a
164

Fig. 4

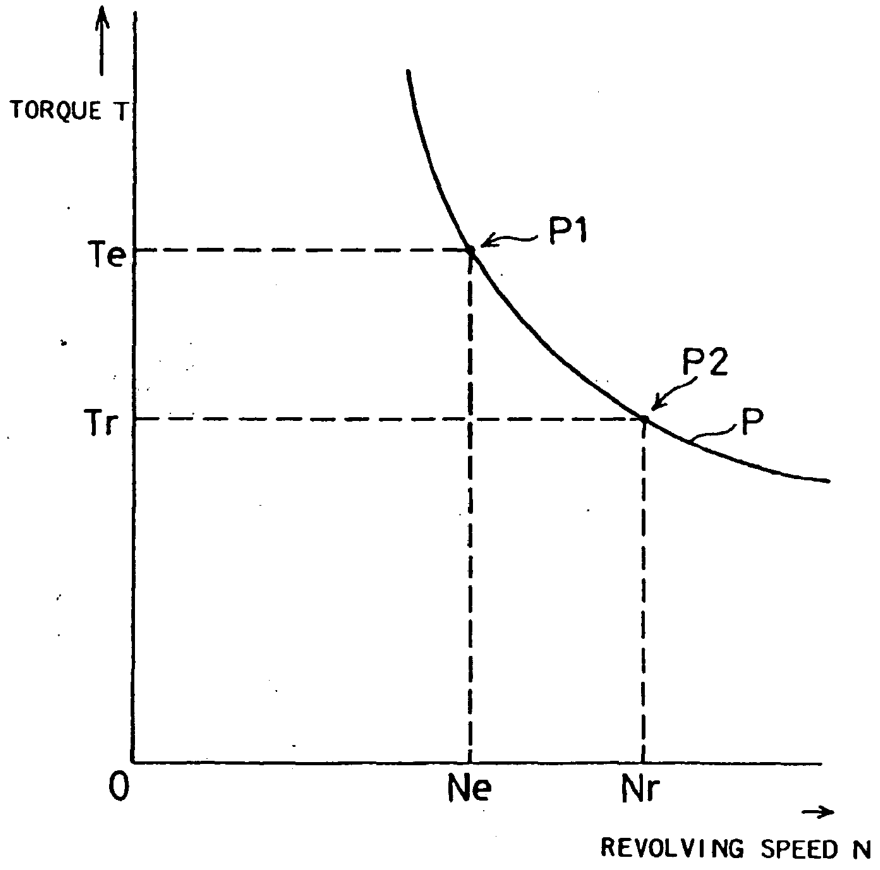


Fig. 5

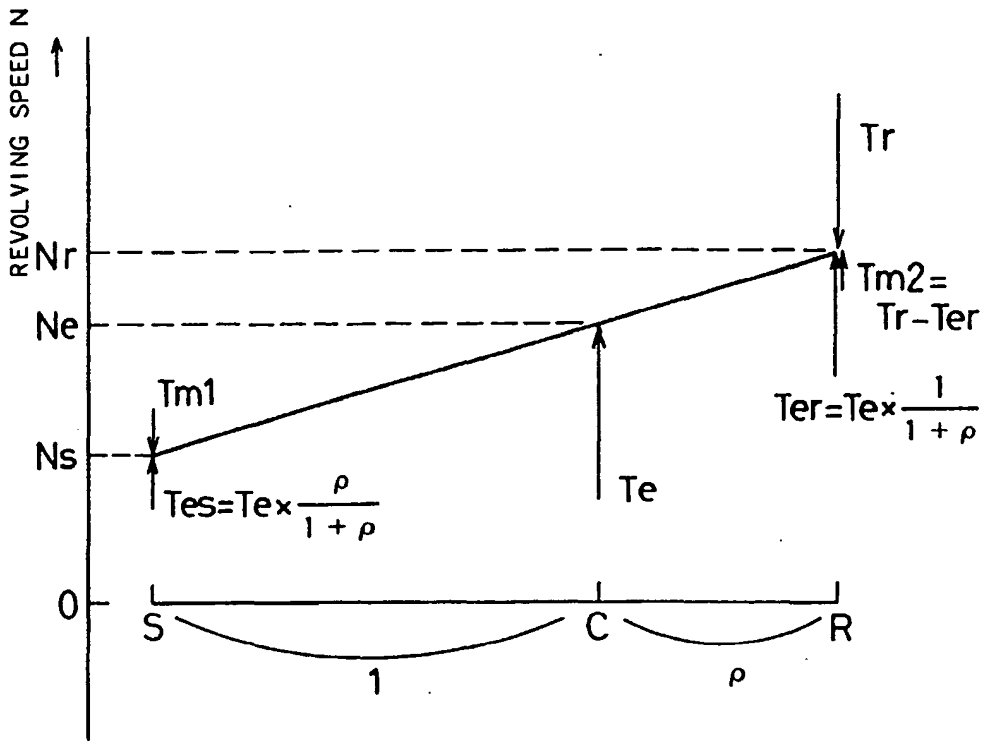

REVOLVING SPEED N
Tr
Nr
Ne
Ns
0
Tm2=
Tr-Ter
Tm1
Ter=Te×$\frac{1}{1+\rho}$
Tes=Te×$\frac{\rho}{1+\rho}$
Te
S
C
R
1
ρ

Fig. 6

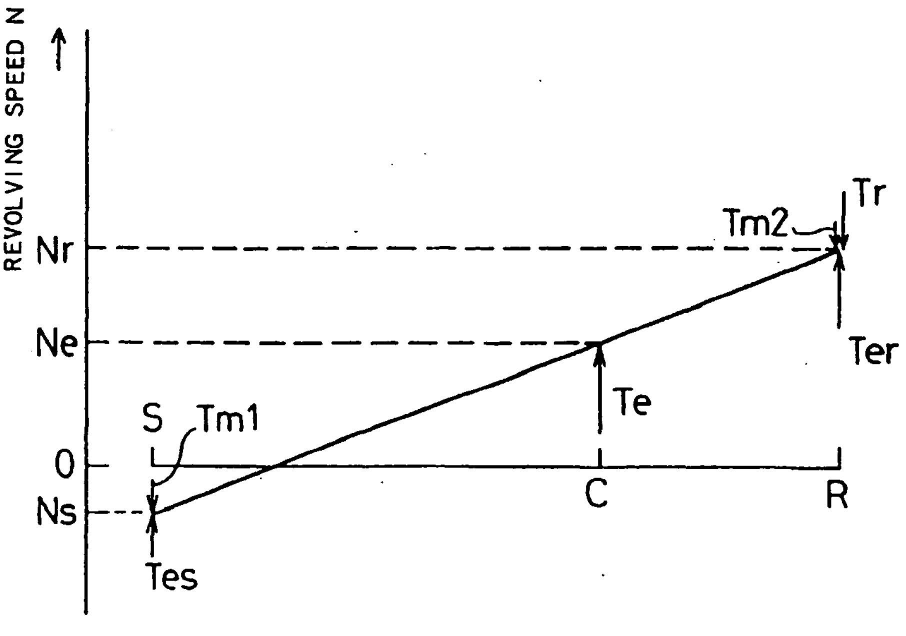

REVOLVING SPEED N
Tr
Tm2
Nr
Ne
Ter
Te
S
Tm1
0
Ns
C
R
Tes

Fig. 7

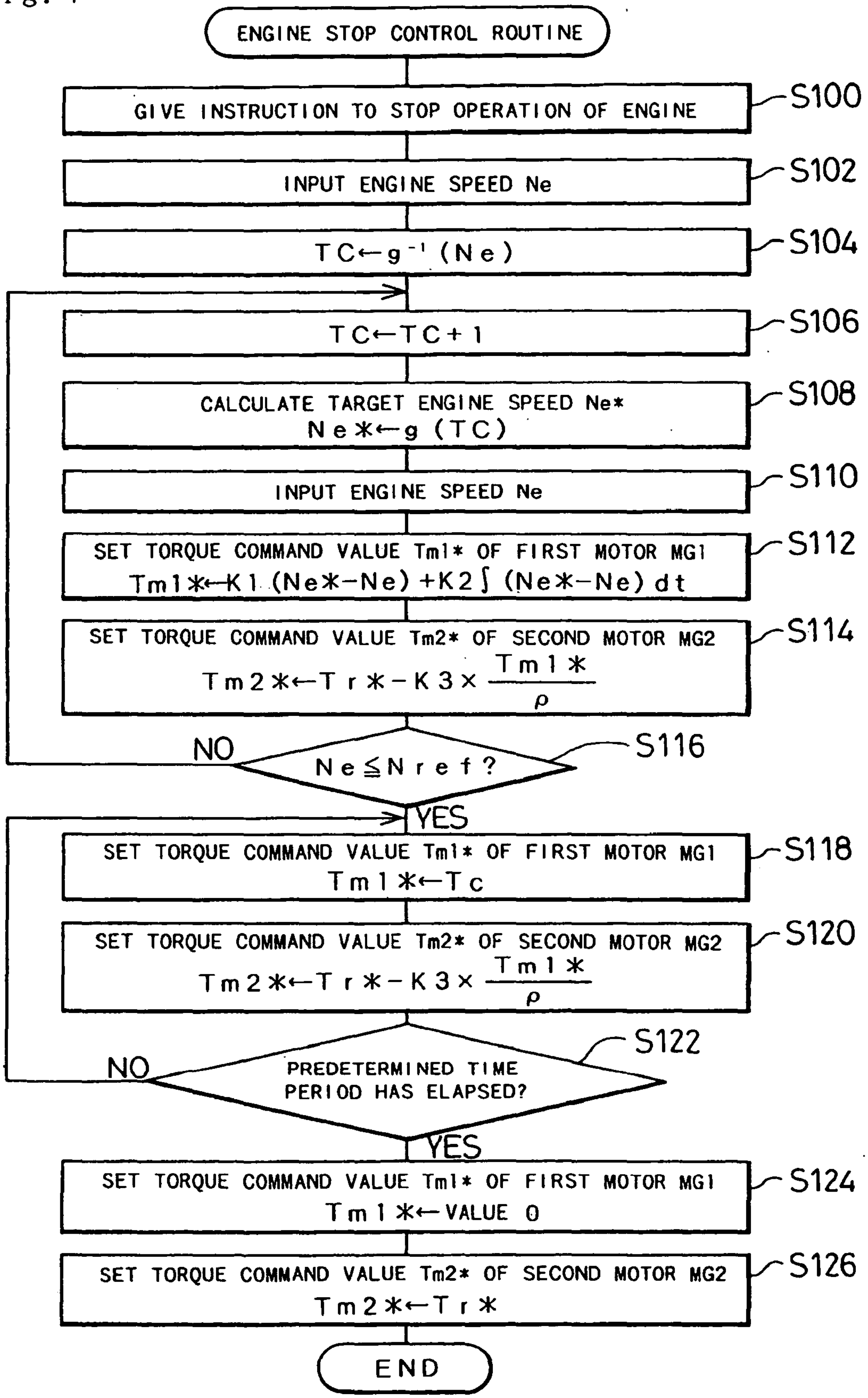

ENGINE STOP CONTROL ROUTINE
GIVE INSTRUCTION TO STOP OPERATION OF ENGINE
S100
INPUT ENGINE SPEED Ne
S102
TC←g⁻¹(Ne)
S104
TC←TC+1
S106
CALCULATE TARGET ENGINE SPEED Ne*
Ne*←g(TC)
S108
INPUT ENGINE SPEED Ne
S110
SET TORQUE COMMAND VALUE Tm1* OF FIRST MOTOR MG1
Tm1*←K1(Ne*−Ne)+K2∫(Ne*−Ne)dt
S112
SET TORQUE COMMAND VALUE Tm2* OF SECOND MOTOR MG2
Tm2*←Tr*−K3×Tm1*/ρ
S114
Ne≦Nref?
S116
NO
YES
SET TORQUE COMMAND VALUE Tm1* OF FIRST MOTOR MG1
Tm1*←Tc
S118
SET TORQUE COMMAND VALUE Tm2* OF SECOND MOTOR MG2
Tm2*←Tr*−K3×Tm1*/ρ
S120
PREDETERMINED TIME PERIOD HAS ELAPSED?
S122
NO
YES
SET TORQUE COMMAND VALUE Tm1* OF FIRST MOTOR MG1
Tm1*←VALUE 0
S124
SET TORQUE COMMAND VALUE Tm2* OF SECOND MOTOR MG2
Tm2*←Tr*
S126
END

Fig. 8

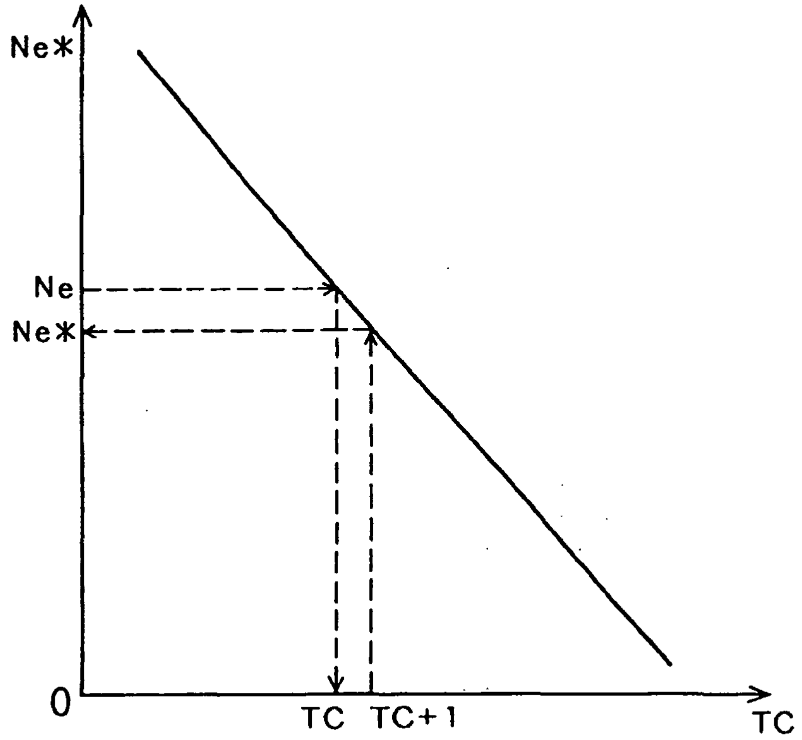


Fig. 9

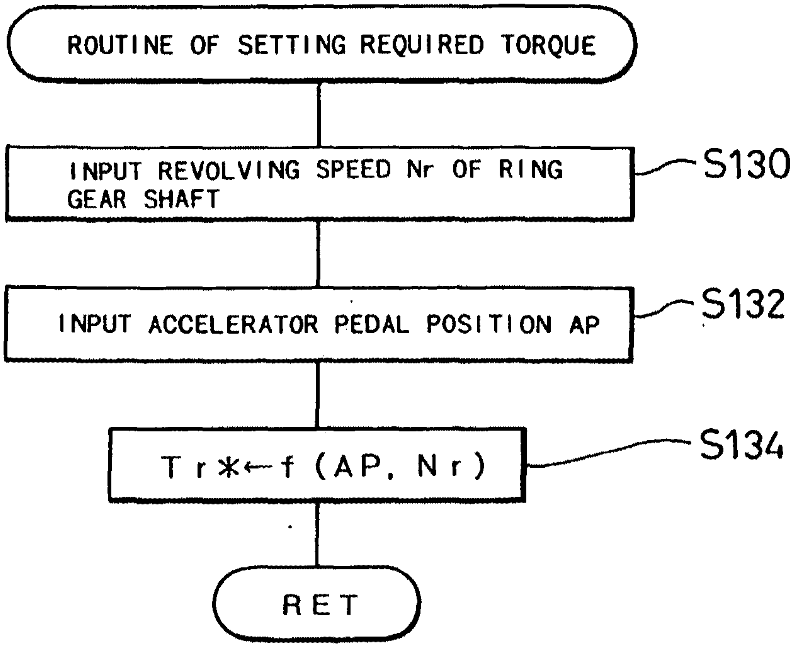

ROUTINE OF SETTING REQUIRED TORQUE
INPUT REVOLVING SPEED Nr OF RING GEAR SHAFT
S130
INPUT ACCELERATOR PEDAL POSITION AP
S132
Tr*←f (AP, Nr)
S134
RET

Fig. 10

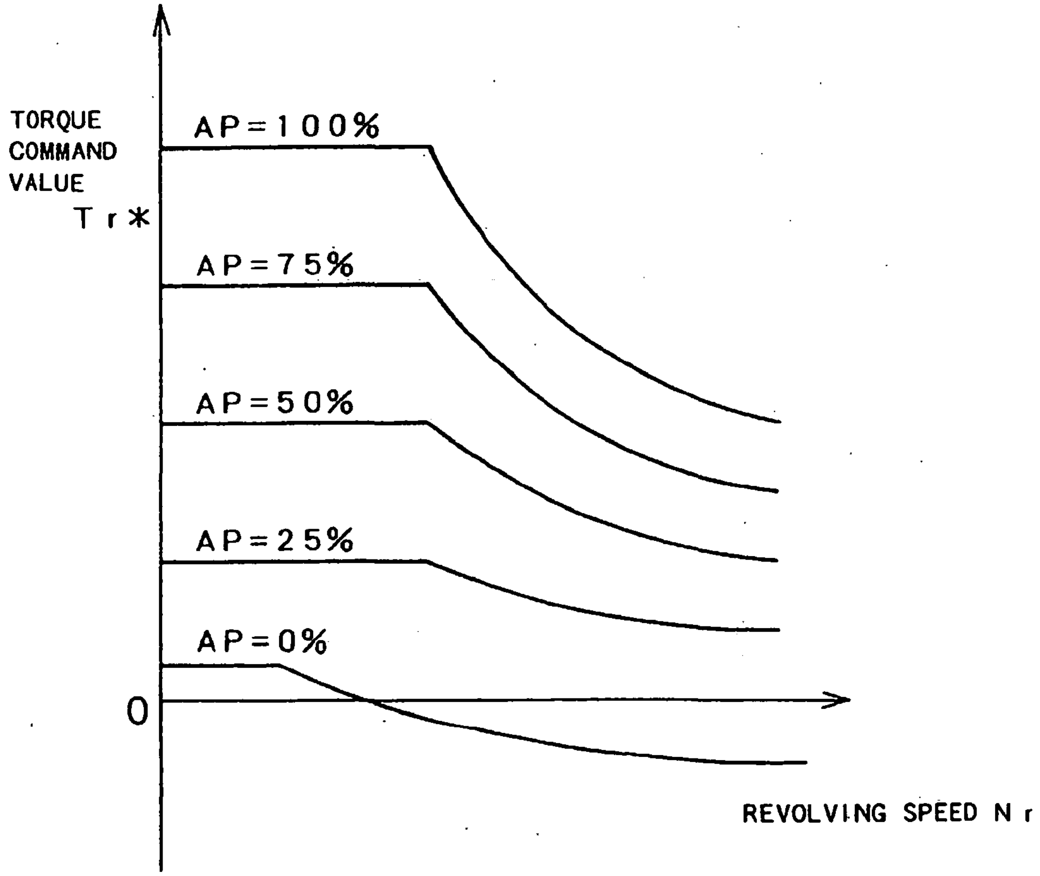

TORQUE
COMMAND
VALUE
T r *
AP=100%
AP=75%
AP=50%
AP=25%
AP=0%
0
REVOLVING SPEED N r

Fig. 11

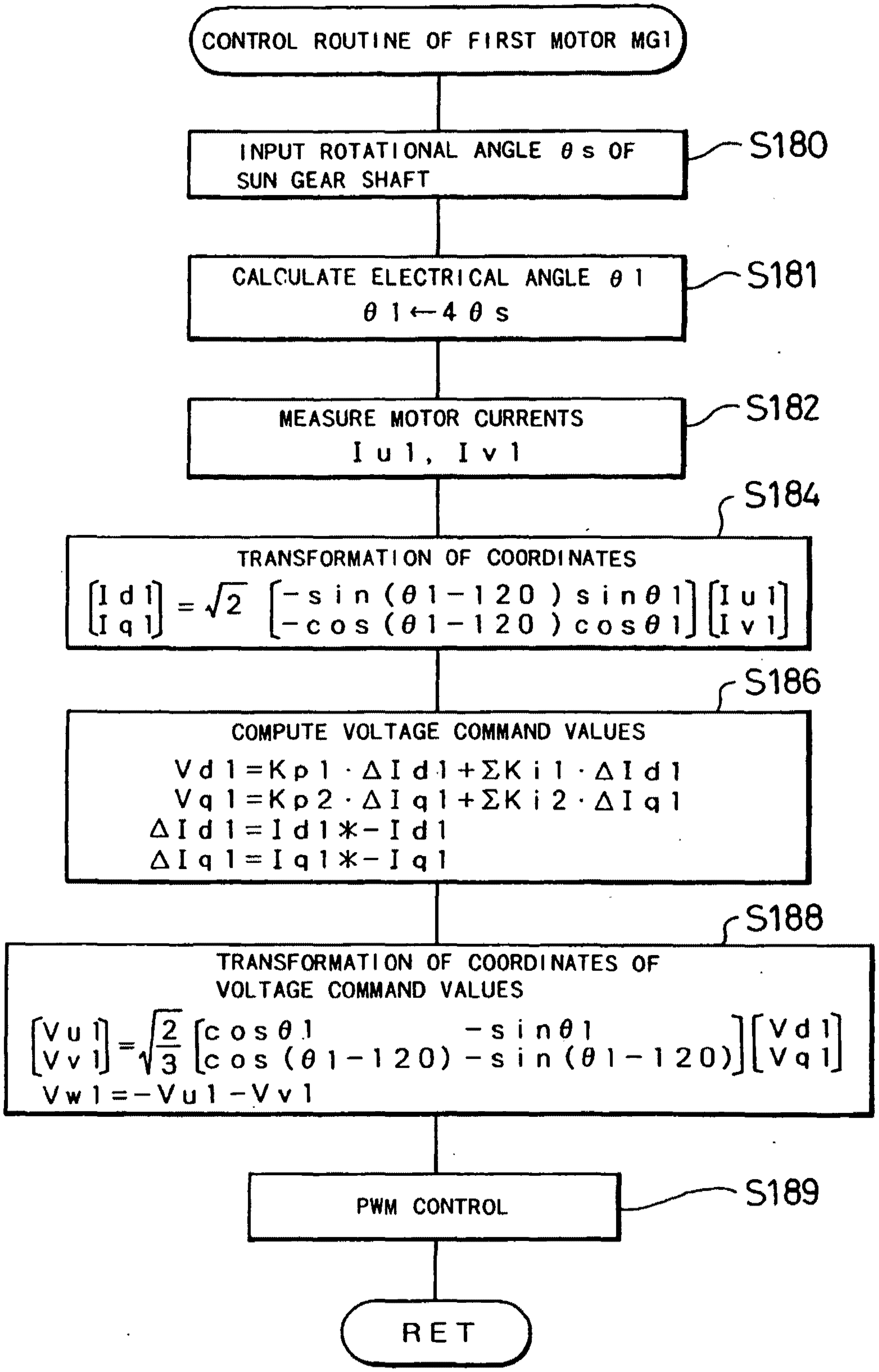

CONTROL ROUTINE OF FIRST MOTOR MG1
INPUT ROTATIONAL ANGLE θs OF SUN GEAR SHAFT
S180
CALCULATE ELECTRICAL ANGLE θ1
θ1←4θs
S181
MEASURE MOTOR CURRENTS
Iu1, Iv1
S182
S184
TRANSFORMATION OF COORDINATES
[Id1; Iq1] = √2 [−sin(θ1−120) sinθ1; −cos(θ1−120) cosθ1] [Iu1; Iv1]
S186
COMPUTE VOLTAGE COMMAND VALUES
Vd1=Kp1·ΔId1+ΣKi1·ΔId1
Vq1=Kp2·ΔIq1+ΣKi2·ΔIq1
ΔId1=Id1*−Id1
ΔIq1=Iq1*−Iq1
S188
TRANSFORMATION OF COORDINATES OF VOLTAGE COMMAND VALUES
[Vu1; Vv1] = √(2/3) [cosθ1 −sinθ1; cos(θ1−120) −sin(θ1−120)] [Vd1; Vq1]
Vw1=−Vu1−Vv1
PWM CONTROL
S189
RET

Fig. 12

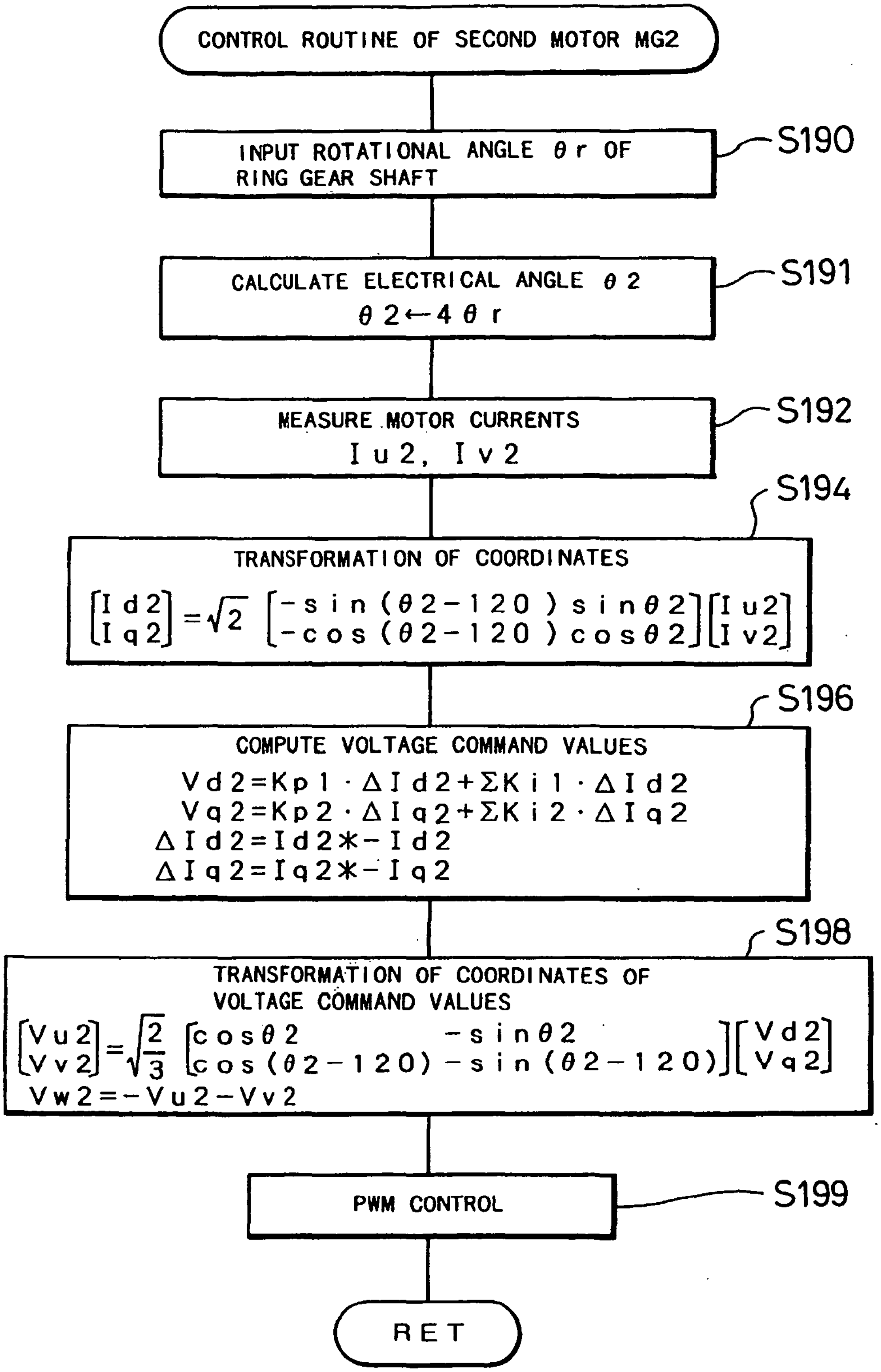

CONTROL ROUTINE OF SECOND MOTOR MG2
INPUT ROTATIONAL ANGLE θr OF RING GEAR SHAFT
S190
CALCULATE ELECTRICAL ANGLE θ2
$\theta 2 \leftarrow 4\theta r$
S191
MEASURE MOTOR CURRENTS
Iu2, Iv2
S192
S194
TRANSFORMATION OF COORDINATES
$\begin{bmatrix} Id2 \\ Iq2 \end{bmatrix} = \sqrt{2} \begin{bmatrix} -\sin(\theta 2-120) & \sin\theta 2 \\ -\cos(\theta 2-120) & \cos\theta 2 \end{bmatrix} \begin{bmatrix} Iu2 \\ Iv2 \end{bmatrix}$
S196
COMPUTE VOLTAGE COMMAND VALUES
$Vd2 = Kp1 \cdot \Delta Id2 + \Sigma Ki1 \cdot \Delta Id2$
$Vq2 = Kp2 \cdot \Delta Iq2 + \Sigma Ki2 \cdot \Delta Iq2$
$\Delta Id2 = Id2* - Id2$
$\Delta Iq2 = Iq2* - Iq2$
S198
TRANSFORMATION OF COORDINATES OF VOLTAGE COMMAND VALUES
$\begin{bmatrix} Vu2 \\ Vv2 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta 2 & -\sin\theta 2 \\ \cos(\theta 2-120) & -\sin(\theta 2-120) \end{bmatrix} \begin{bmatrix} Vd2 \\ Vq2 \end{bmatrix}$
$Vw2 = -Vu2 - Vv2$
PWM CONTROL
S199
RET

Fig. 13

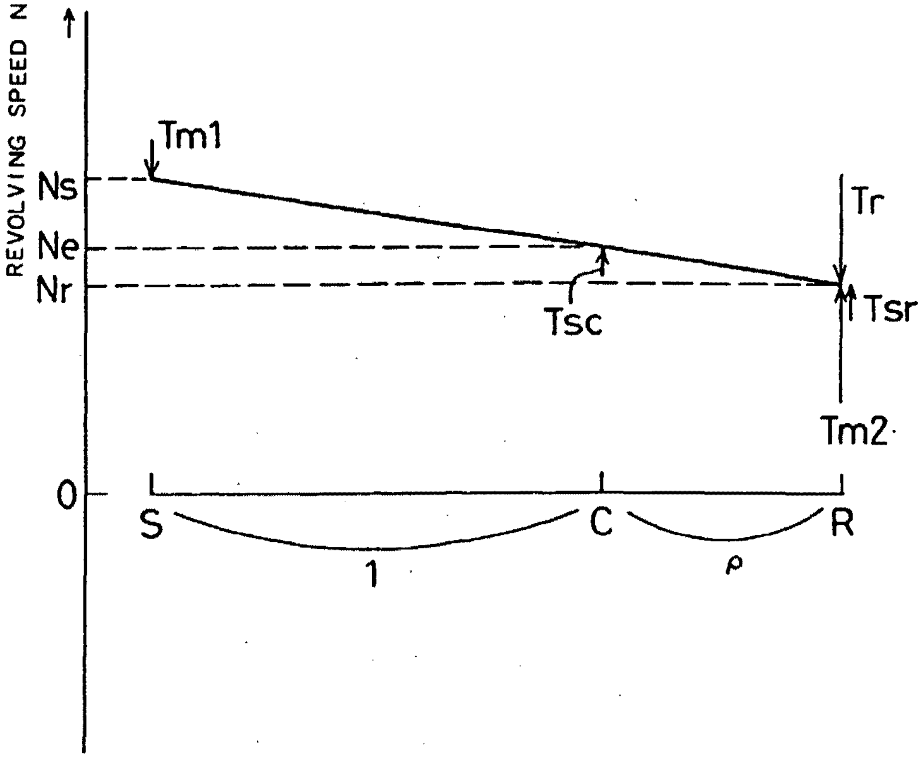

REVOLVING SPEED N
Tm1
Ns
Ne
Nr
Tr
Tsr
Tsc
Tm2
0
S
C
R
1
ρ

Fig. 14

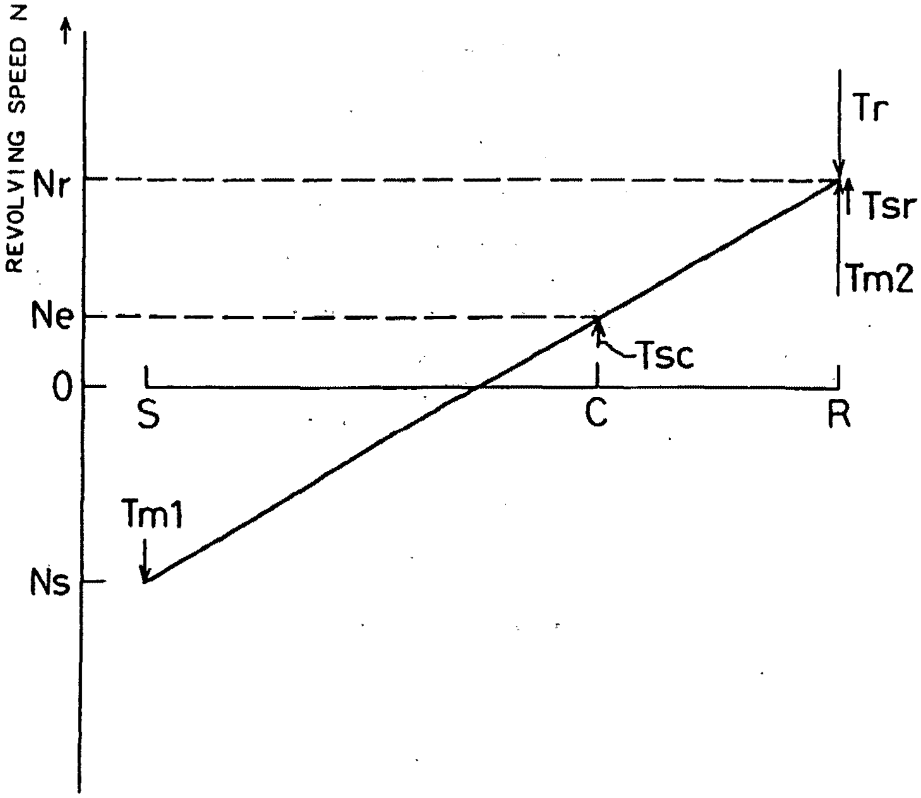

REVOLVING SPEED N
Tr
Nr
Tsr
Tm2
Ne
Tsc
0
S
C
R
Tm1
Ns

Fig. 15

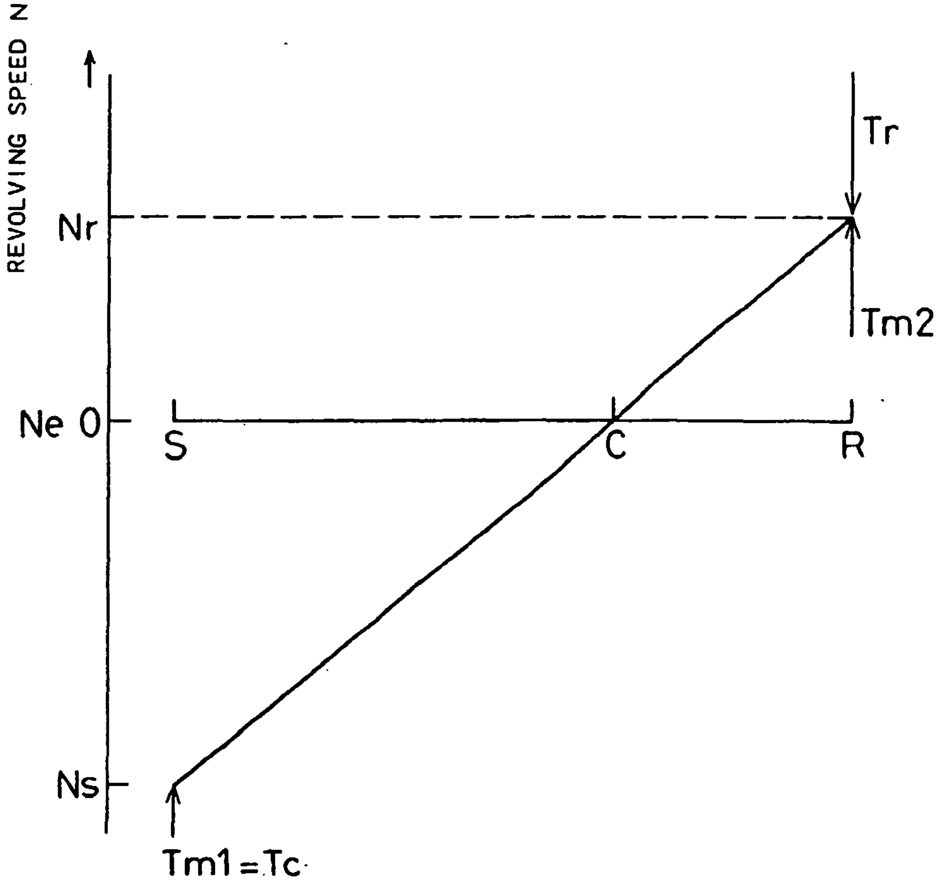


Fig. 16

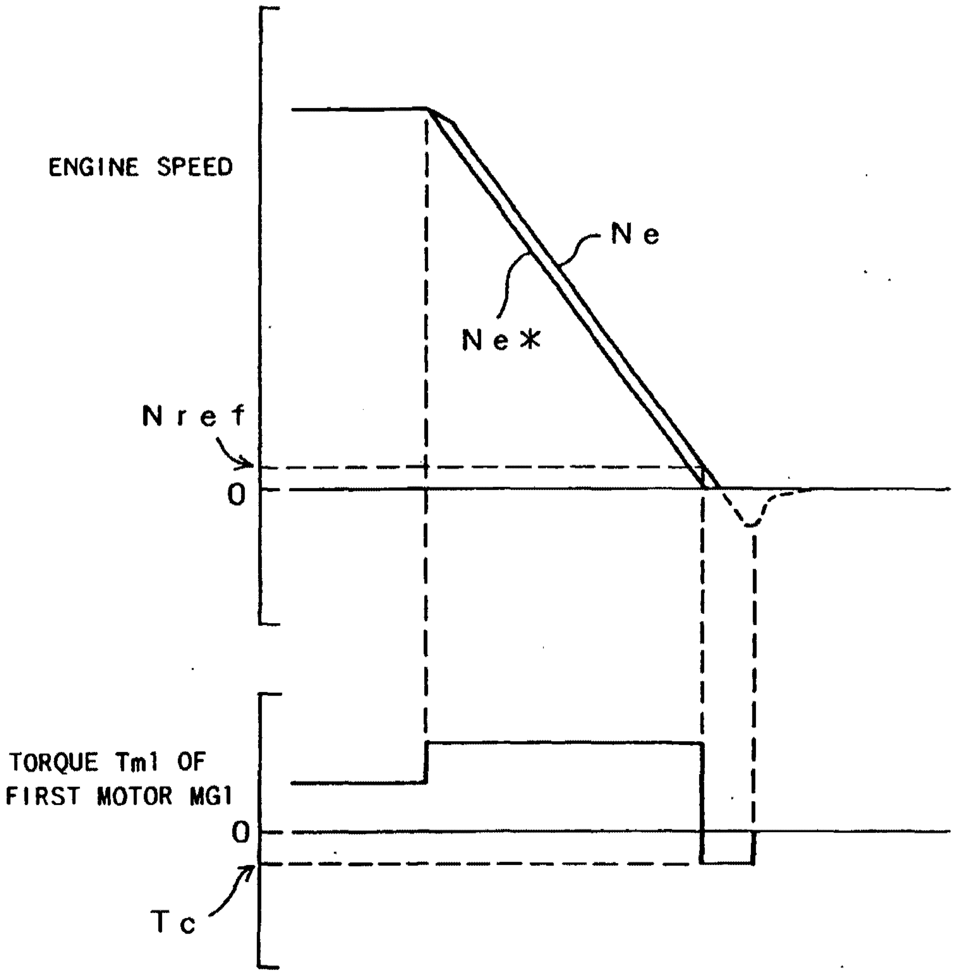


Fig. 17

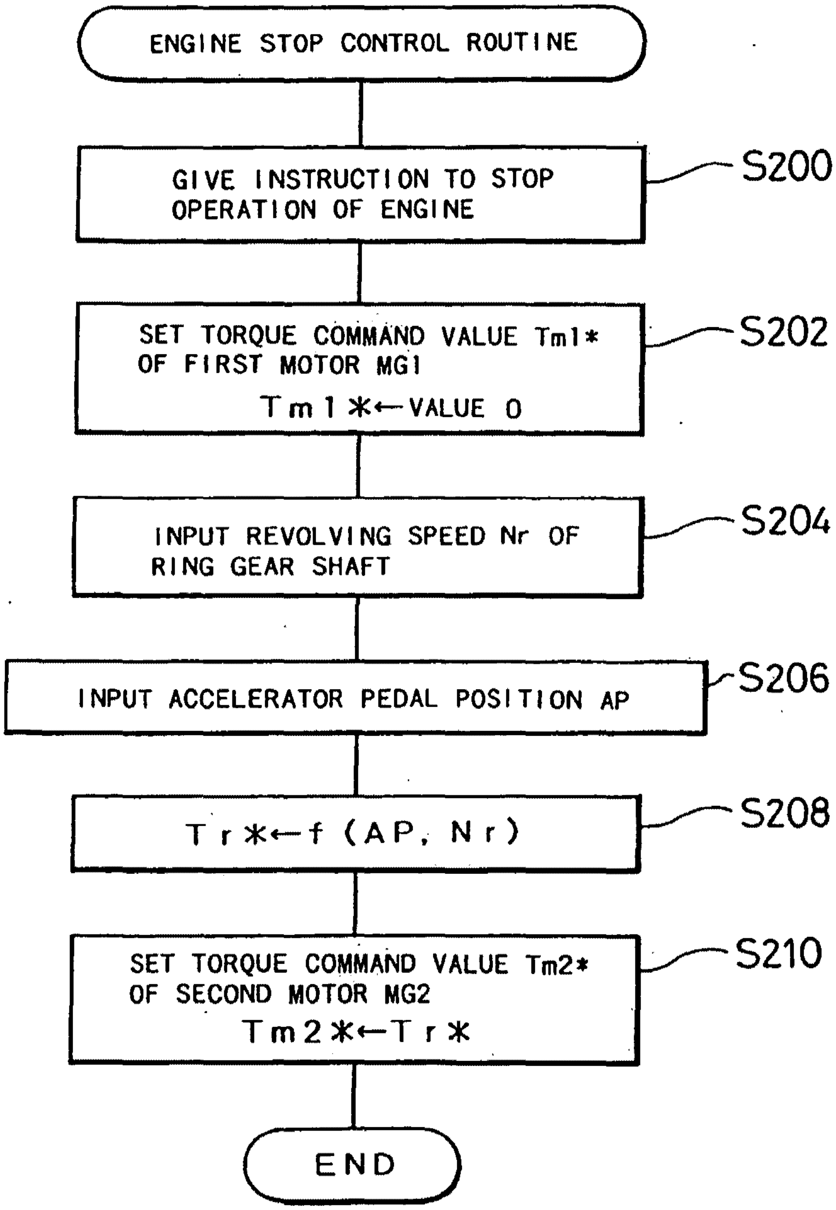

ENGINE STOP CONTROL ROUTINE
GIVE INSTRUCTION TO STOP OPERATION OF ENGINE
S200
SET TORQUE COMMAND VALUE Tm1* OF FIRST MOTOR MG1
Tm1*←VALUE 0
S202
INPUT REVOLVING SPEED Nr OF RING GEAR SHAFT
S204
INPUT ACCELERATOR PEDAL POSITION AP
S206
Tr*←f (AP, Nr)
S208
SET TORQUE COMMAND VALUE Tm2* OF SECOND MOTOR MG2
Tm2*←Tr*
S210
END

Fig. 18

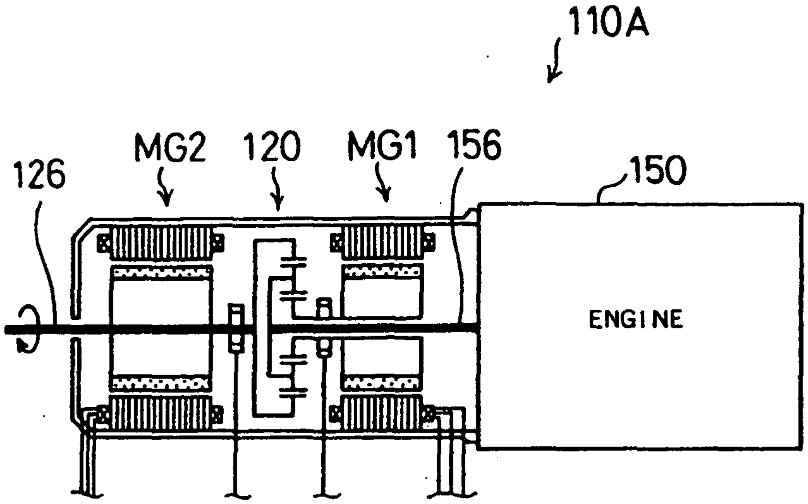

110A
126
MG2
120
MG1
156
150
ENGINE

Fig. 19

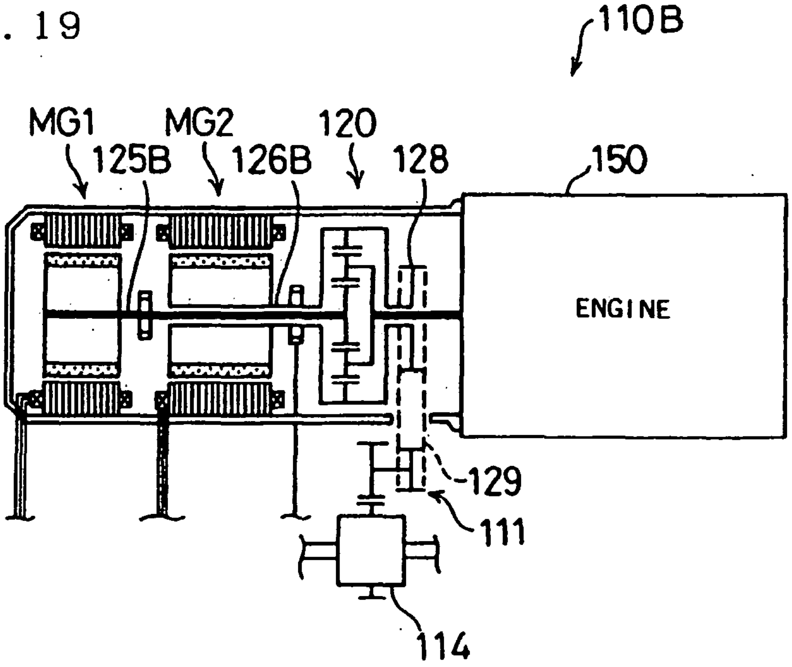

110B
MG1
125B
MG2
126B
120
128
150
ENGINE
129
111
114

Fig. 20

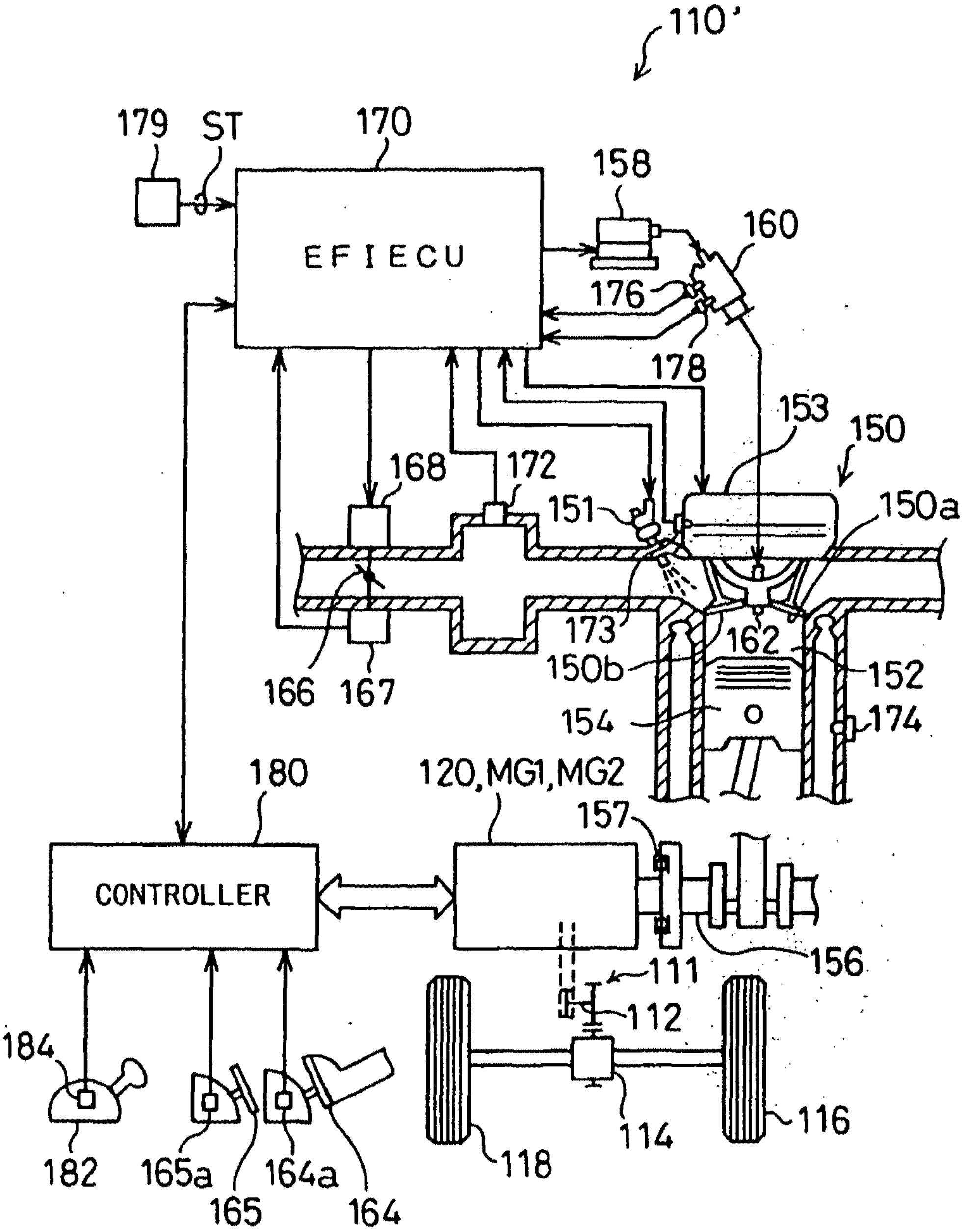

110'
179
ST
170
EFIECU
158
160
176
178
153
150
150a
168
172
151
173
162
152
150b
154
174
166
167
180
CONTROLLER
120,MG1,MG2
157
156
111
112
114
116
118
184
182
165a
165
164a
164

Fig. 21

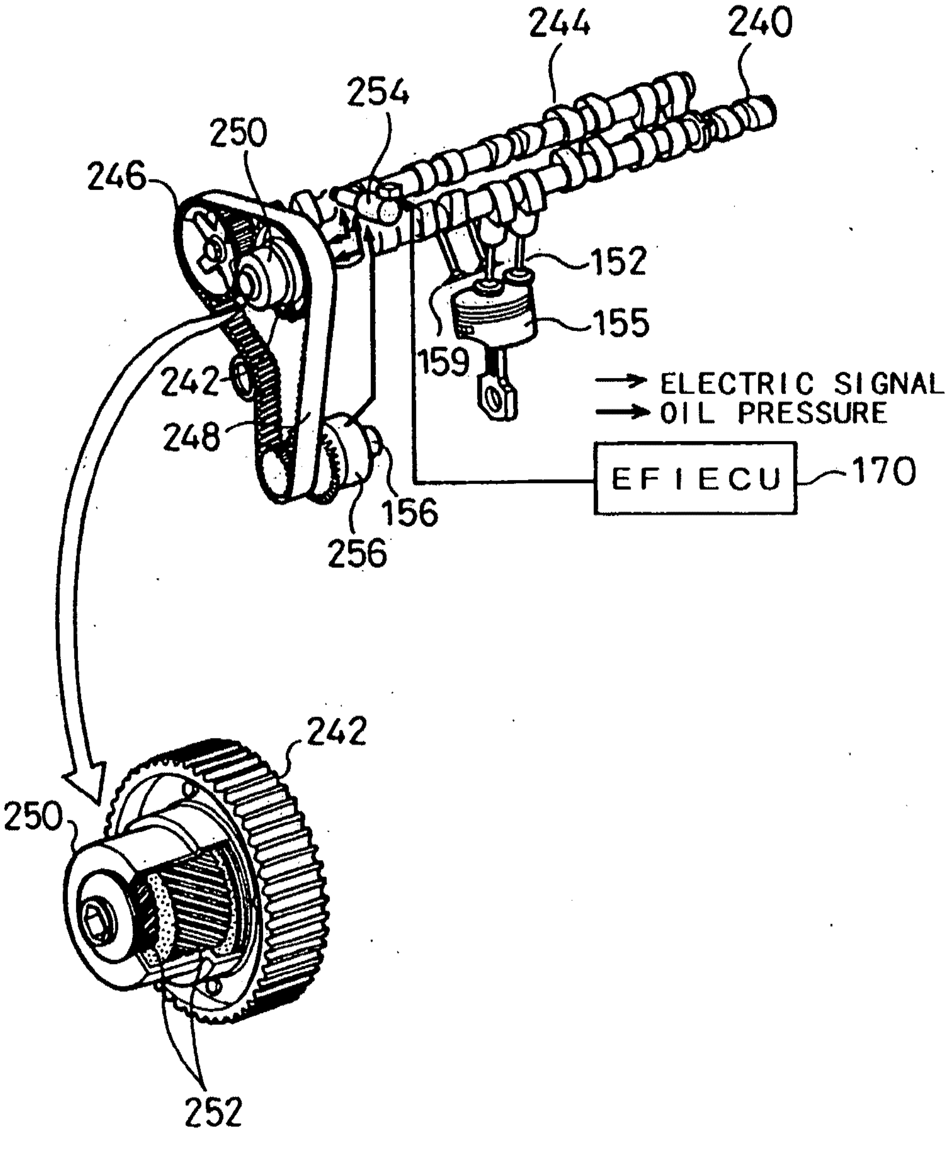

244
240
254
250
246
152
155
159
242
ELECTRIC SIGNAL
OIL PRESSURE
248
EFIECU
170
156
256
242
250
252

Fig. 22

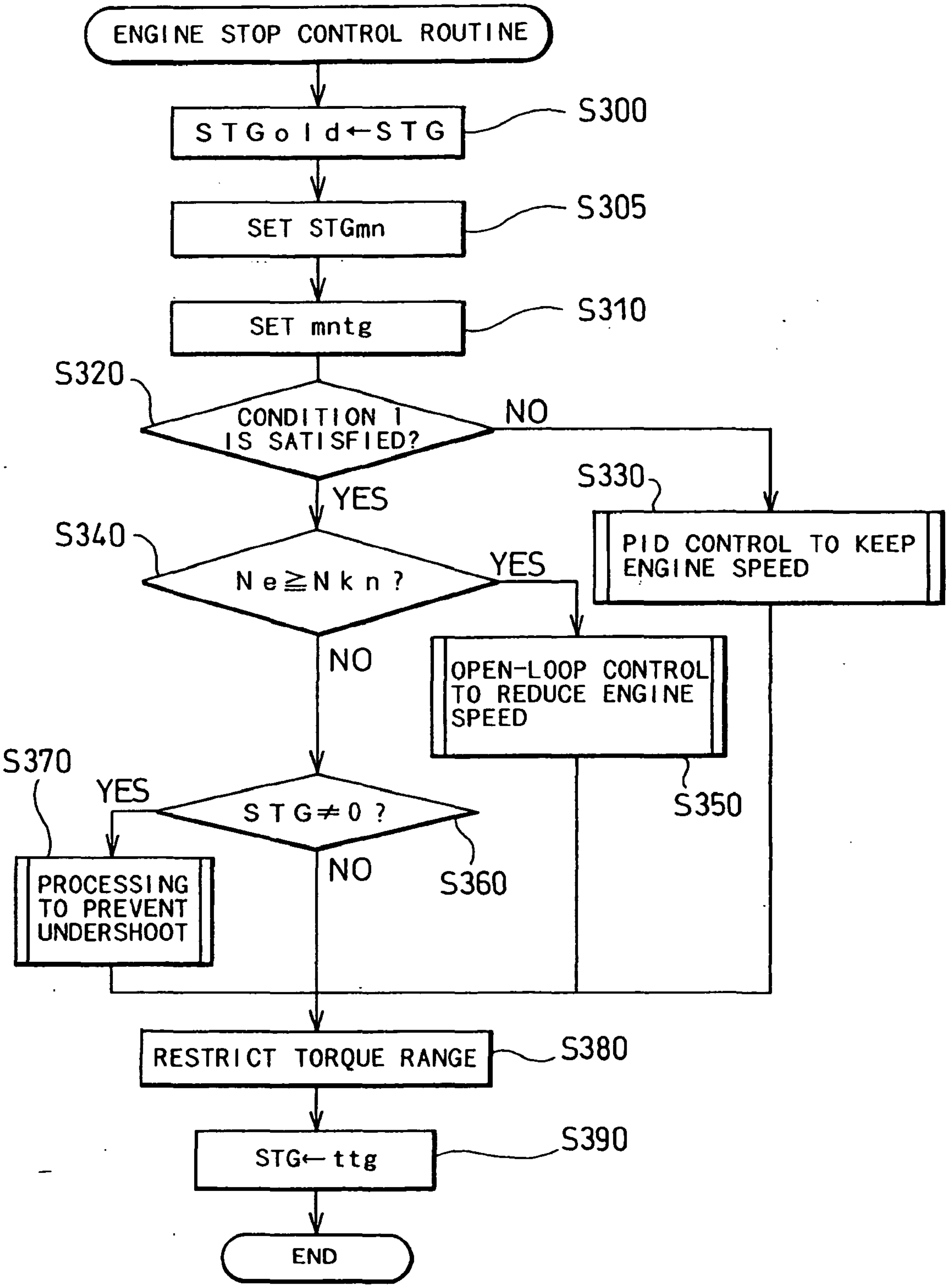

ENGINE STOP CONTROL ROUTINE
STGold←STG
S300
SET STGmn
S305
SET mntg
S310
S320
CONDITION 1 IS SATISFIED?
NO
YES
S330
PID CONTROL TO KEEP ENGINE SPEED
S340
Ne≧Nkn ?
YES
NO
OPEN-LOOP CONTROL TO REDUCE ENGINE SPEED
S350
S370
YES
STG≠0 ?
NO
S360
PROCESSING TO PREVENT UNDERSHOOT
RESTRICT TORQUE RANGE
S380
STG← ttg
S390
END

Fig. 23

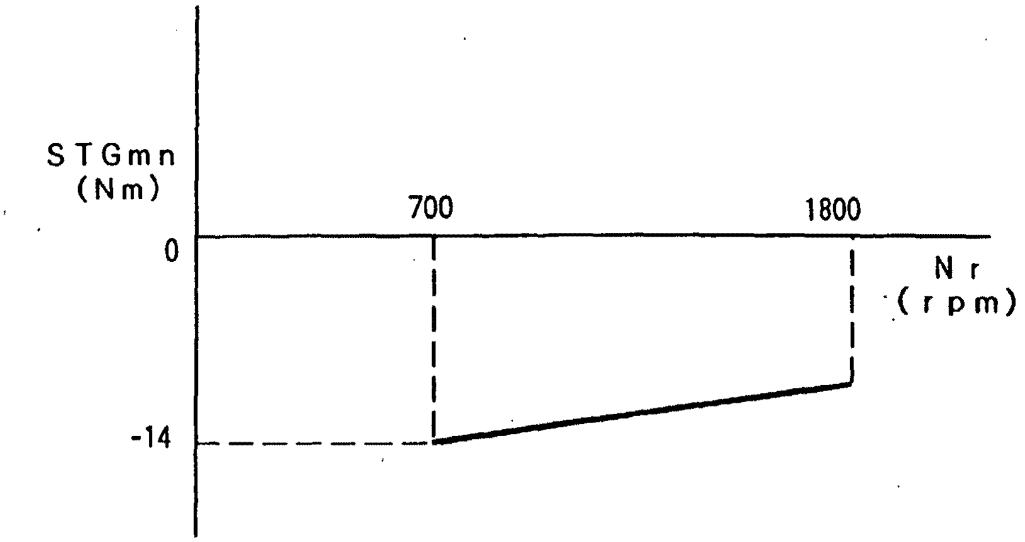


Fig. 24

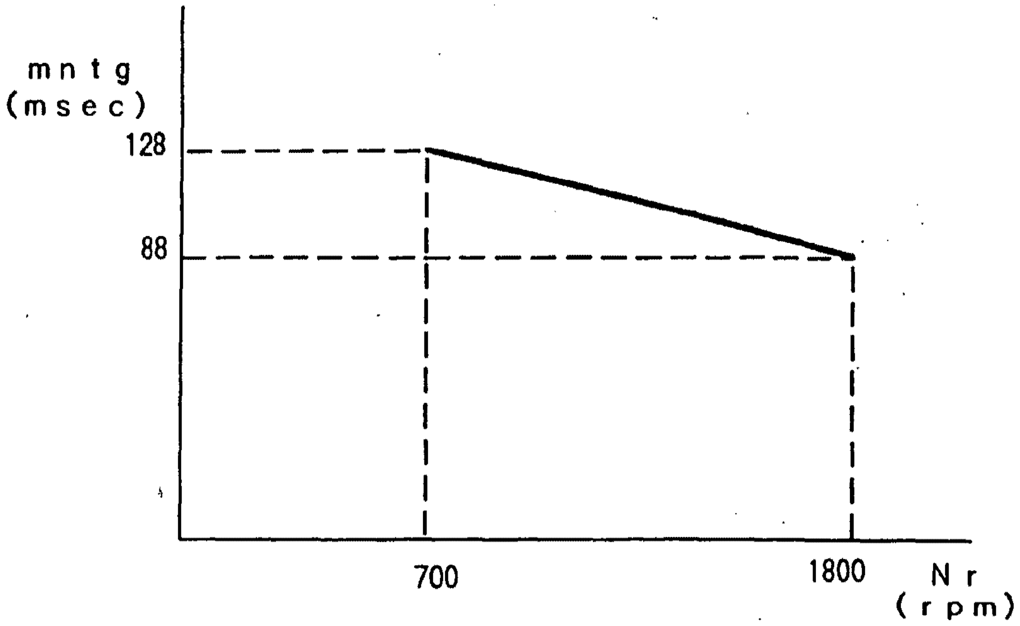


Fig. 25

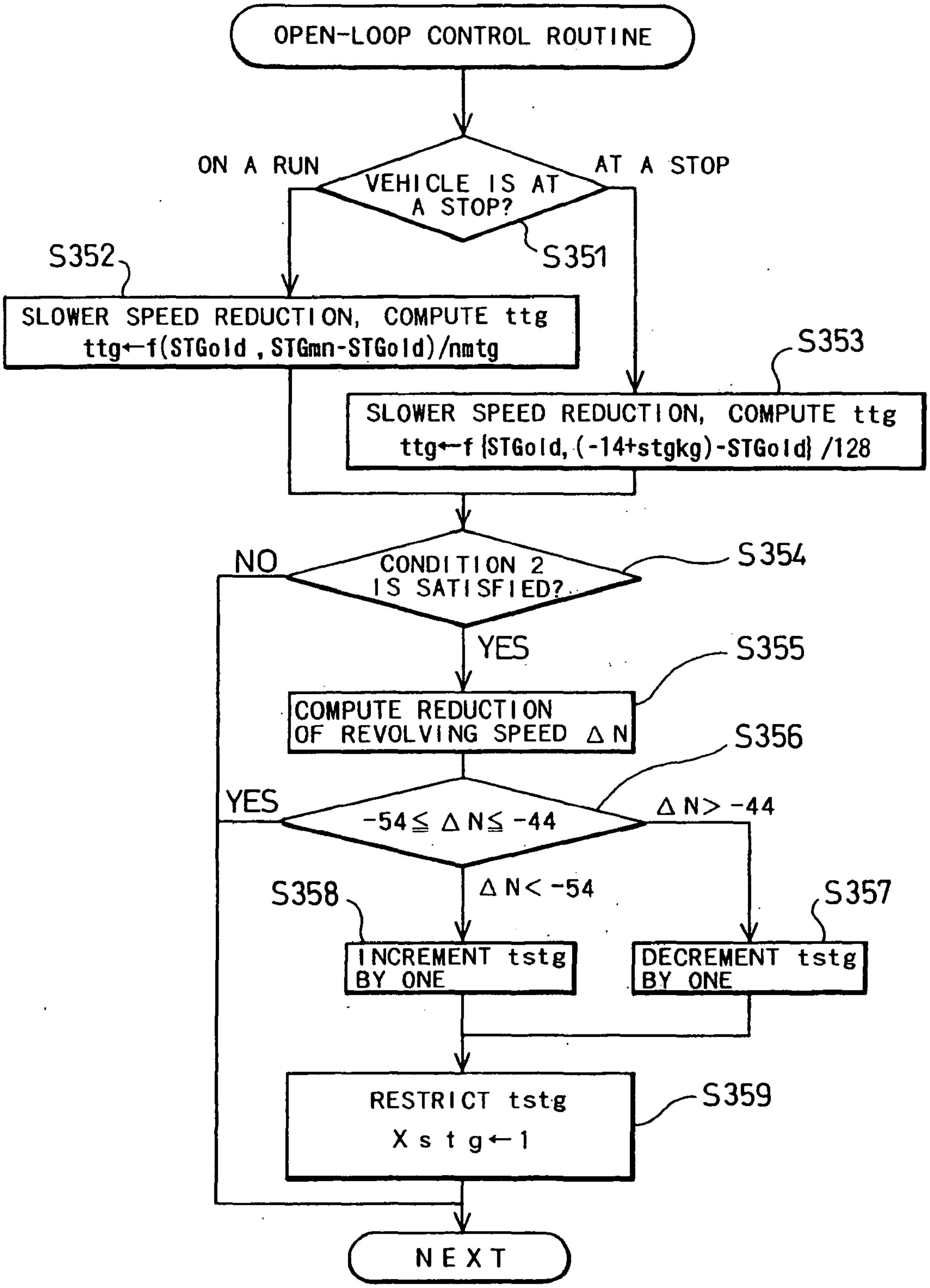

OPEN-LOOP CONTROL ROUTINE
VEHICLE IS AT A STOP?
ON A RUN
AT A STOP
S351
S352
SLOWER SPEED REDUCTION, COMPUTE ttg
ttg←f(STGold , STGmn-STGold)/nmtg
S353
SLOWER SPEED REDUCTION, COMPUTE ttg
ttg←f {STGold, (-14+stgkg)-STGold} /128
CONDITION 2 IS SATISFIED?
S354
NO
YES
S355
COMPUTE REDUCTION OF REVOLVING SPEED ΔN
S356
YES
-54≦ΔN≦-44
ΔN> -44
ΔN< -54
S358
INCREMENT tstg BY ONE
S357
DECREMENT tstg BY ONE
RESTRICT tstg
Xstg←1
S359
NEXT

Fig. 26

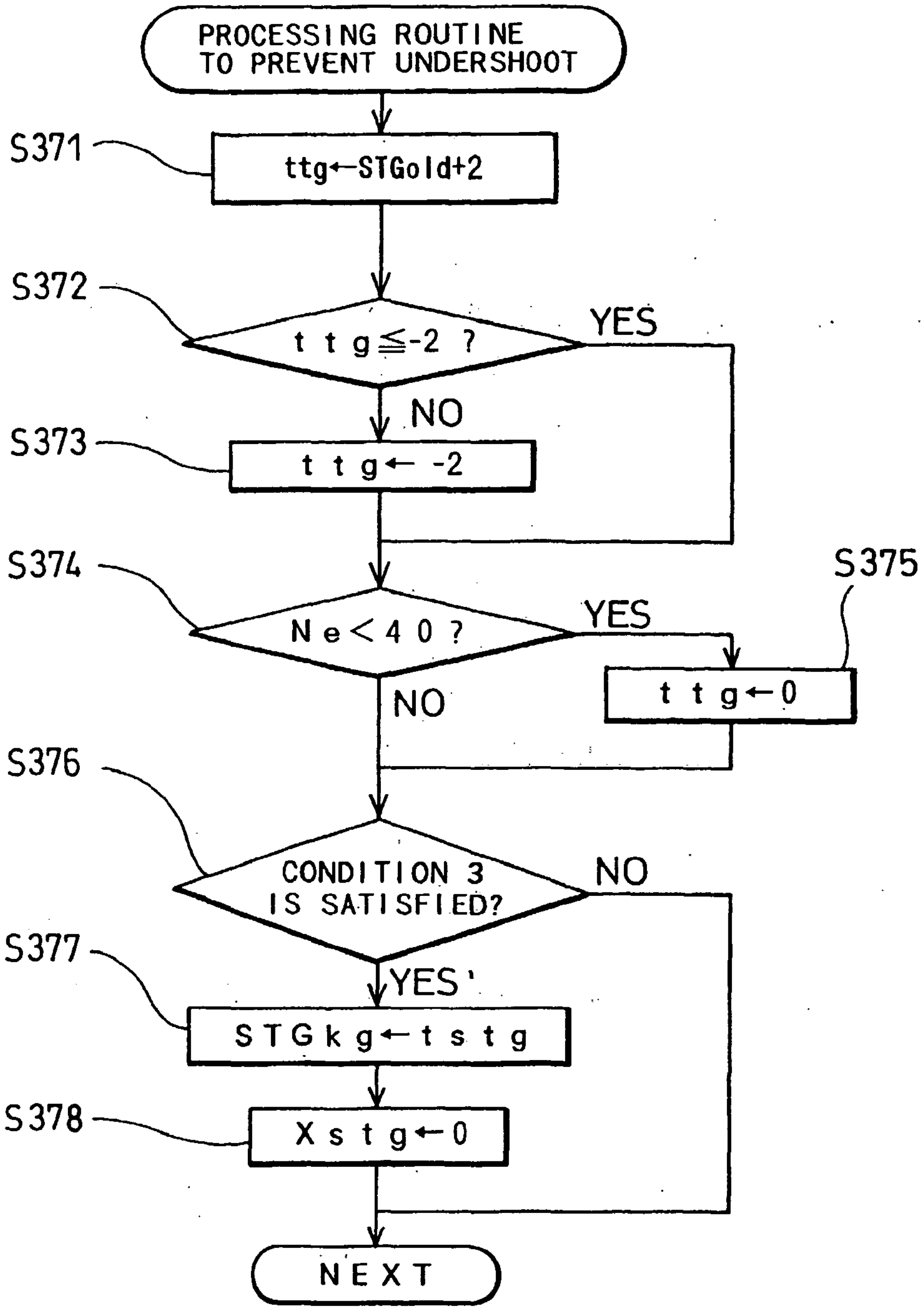

PROCESSING ROUTINE TO PREVENT UNDERSHOOT
S371
ttg←STGold+2
S372
ttg≦-2 ?
YES
NO
S373
ttg← -2
S374
Ne<40 ?
YES
NO
S375
ttg←0
S376
CONDITION 3 IS SATISFIED?
NO
YES
S377
STGkg←tstg
S378
Xstg←0
NEXT

Fig. 27

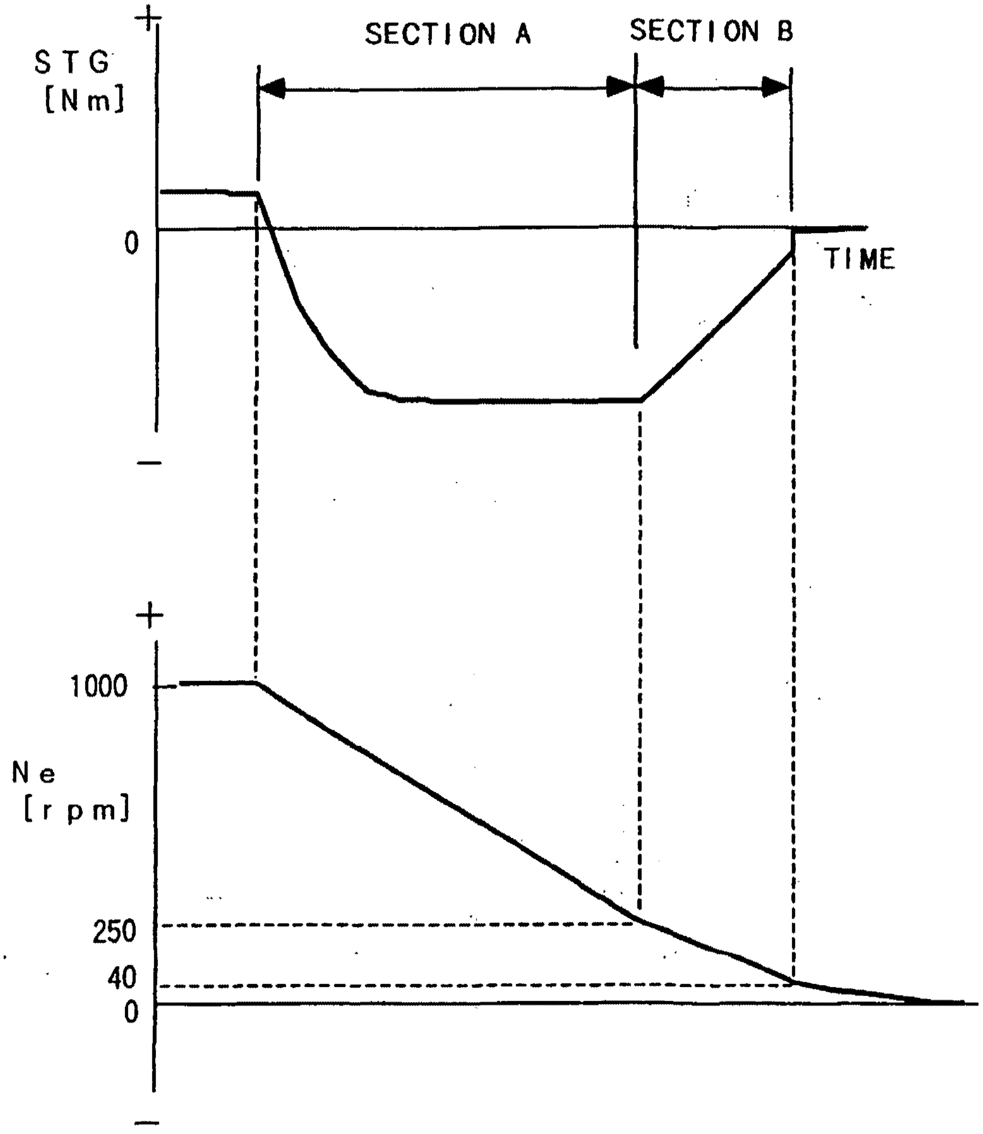
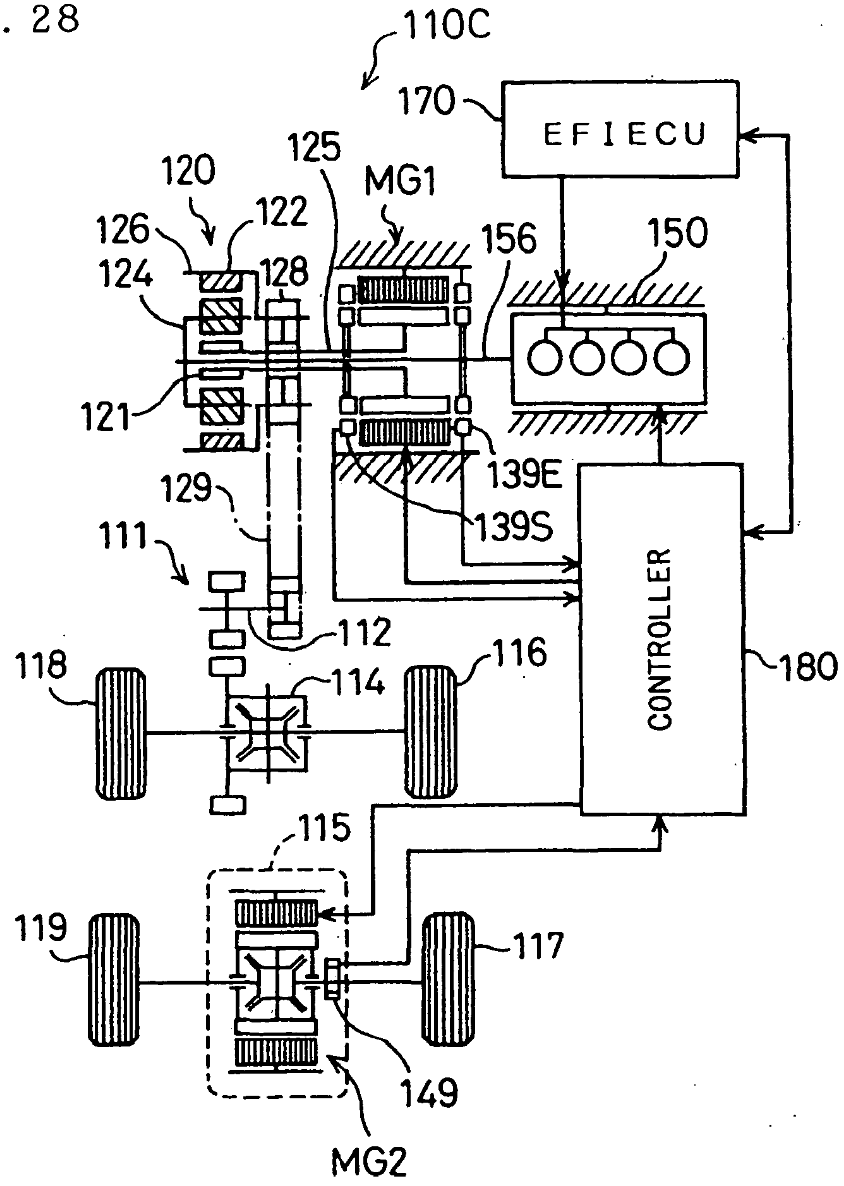


Fig. 28


110C
170
EFIECU
125
120
MG1
126
122
156
150
124
128
121
139E
129
139S
111
CONTROLLER
112
118
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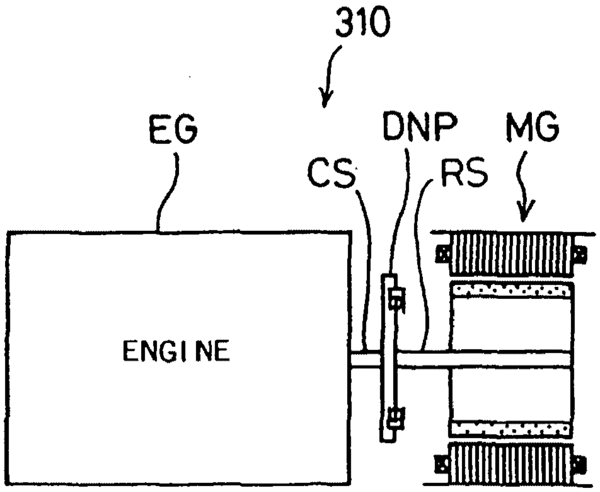
114
180
115
119
117
149
MG2

Fig. 29



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 11 8748

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 725 474 A (NIPPON DENSO CO) 7 August 1996 * column 6, line 44 - column 7, line 19; claims 1,18 *	1,11,19,20	B60K41/00 B60K6/04
A	US 4 407 132 A (HONDA SHOJI ET AL) 4 October 1983 * column 13, line 57 - column 14, line 37; figure 12B *	1,11,19,20	
P,A T	JP 08 295140 A (AQUEOUS RES:KK) 12 November 1996 * figures 2,7-9 * & US 5 788 006 A * claims 2,3 *	1,11,19,20	
P,A	DE 195 32 128 A (CLOUTH GUMMIWERKE AG) 6 March 1997 * claims 1,4,25; figures 7,8 *	1,11,19,20	
P,A	EP 0 743 211 A (TOYOTA MOTOR CO LTD) 20 November 1996 * claims 2,4,7,10,12,14; figures 9,14 *	1,11,19,20	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)**
P,A	EP 0 743 216 A (TOYOTA MOTOR CO LTD) 20 November 1996 * column 43, line 26 - line 35; claims 14,15 *	1,11,19,20	B60K B60L H02K F02D F16F F02B
T	EP 0 830 969 A (TOYOTA MOTOR CO LTD) 25 March 1998 * page 11, line 49 - line 51 * * page 12, line 44 - line 51; claims 10,11 *	1,11,19,20	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 April 1999	Bufacchi, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 97 11 8748

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23-04-1999

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		JP 9047011 A	14-02-1997
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		EP 0743208 A	20-11-1996
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RÉPUBLIQUE FRANÇAISE

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PARIS

⑪ N° de publication : **2 419 832**
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A1

DEMANDE DE BREVET D'INVENTION

㉑ N° 78 08080

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(54) **Moyens pour diminuer la consommation et la pollution des véhicules à moteur et pour augmenter temporairement leur puissance motrice.**

(51) Classification internationale (Int. Cl.^{2}). **B 60 K 1/00, 6/00; 17/00.**

㉒ Date de dépôt .... **16 mars 1978, à 17 h.**

㉝ ㉜ ㉛ Priorité revendiquée :

㊶ Date de la mise à la disposition du public de la demande .... **B.O.P.I. — «Listes» n. 41 du 12-10-1979.**

---

(71) Déposant : **BOCQUET Lucien Fernand François et DUPEYROL Alice Marie, résidant en France.**

(72) Invention de : **Lucien Fernand François Bocquet et Alice Marie Dupeyrol.**

(73) Titulaire : *Idem* (71)

(74) Mandataire : **Bocquet, Cidex 230 ter, Fréniches, 60640 Guiscard.**

D Vente des fascicules à l'IMPRIMERIE NATIONALE, 27, rue de la Convention — 75732 PARIS CEDEX 15

On cherche à diminuer la consommation et la pollution des véhicules à moteur et les constructeurs souhaiteraient pouvoir réduire la puissance et l'importance des moteurs tout en conservant suffisamment de puissance pour les accélérations et la conduite.

La présente invention a pour objet de donner une solution à ce problème.

Elle consiste à utiliser le moteur du véhicule pendant le maximum de de temps dans les meilleures conditions de rendement et de puissance par l'ensemble des moyens suivants et de leurs diverses liaisons mécaniques et électriques : le moteur du véhicule est accouplé à un générateur électrique branché sur une batterie d'accumulateurs ; cette batterie et ce générateur sont connectés à des moteurs électriques qui assurent la propulsion, le freinage à récupération d'énergie et la marche arrière, par l'intermédiaire d'une boîte de vitesse et d'un pont ; un embrayage ou un dispositif équivalent permet d'accoupler mécaniquement ou autrement le groupe moteur-générateur à la transmission de propulsion ; tous ces organes étant commandés par un appareillage approprié, manuel, automatique ou mixte, permettant d'effectuer les liaisons, mécaniques, électriques ou autres, de ces organes entre eux et aux transmissions de propulsion afin de réaliser dans les conditions optima exposées précédemment les modes de fonctionnements suivants:

1 - exclusivement électrique, le groupe générateur étant arrêté.

2 - électrique normal, avec le groupe en marche non embrayé sur la transmission.

3 - électrique à surpuissance temporaire, approximativement doublée en embrayant sur la transmission de propulsion le groupe, générateur débranché; ou, susceptible d'être triplée, moyennement des aménagements appropriés, générateur branché.

4 - mixte de croisière, réalisé de préférence lorsque le véhicule roule régulièrement à une vitesse correspondant sensiblement au régime optima, par embrayage du groupe sur la transmission, moteurs de propulsion débranchés, générateur branché; ce dernier travaillant alors, suivant la vitesse de marche, en moteur ou en générateur pour régulariser la marche au régime optima.

5 - mixte accéléré, comme 4, mais en changeant le rapport de vitesse pour passer au rapport supérieur losque le régime optima est atteint. Dans ce mode de fonctionnement la surpuissance est automatiquement réalisée par le générateur au moment du changement de rapport.

6 - classique, avec le groupe embrayé, générateur et moteurs débranchés.

7 - marche arrière et freinage électrique à récupération d'énergie, par inversion du sens de marche des moteurs.

En faisant l'examen comparatif des bilans de fonctionnement d'un tel véhicule et d'un véhicule classique on constate que les pertes de rendement dûes à la transformation électrique sont très inférieures aux gains de l'invention. Plus particulièrement dans le cas d'une circulation très difficile, avec marche exclusivement électrique sans pollution, dans laquelle il est possible, avec une batterie de capacité peu élevée,d'obtenir une autonomie de parcours de 5 à 10 Km pendant 5 à 10 minutes. Les meilleures conditions de marche sont celles du fonctionnement mixte dans lequel les pertes électriques sont réduites au minimum losque le débit du générateur est nul, sa tension à vide étant égale à la tension maxima de de la batterie. Le véhicule est alors propulsé avec la preque totalité de l'énergie mécanique du moteur et quand, par suite d'une augmentation des résistances à l'avancement, la vitesse de marche diminue,la puissance motrice s'accroît de la puissance fournie par le générateur.

Sur la planche unique annexéeont été représentées schématiquement deux réalisations non exclusives, des dispositions de l'invention : la Fig. 1 dans laquelle le moteur du véhicule, le générateur et les moteurs de propulsion ont des vitesse égales; la Fig. 2 dans laquelle, en vue d'un abaissements du poids et du prix, les organes électriques ont des vitesses plus élevées. Le moteur 1 du véhicule est accouplé au générateur électrique 2. Les moteurs électriques 3 assurent la propulsion par l'intermédiaire de l'arbre 4, la boîte de vitesse 5, le pont 6 et les transmissions 7. Les batteries sont figurées en 8, l'embrayage du moteur sur la propulsion en 9 et la capacité contenant l'appareillage de commande et de contrôle en 10. Sur la Fig. 2, le générateur 2 comporte deux enroulements égaux indépendants, chacun d'eux étant connecté à une demi-batterie 8. La propulsion est faite par deux moteurs 3, disposés sur un même axe. On pourra ainsi, sans interruption de charge,coupler en série ou en parallèle ces divers éléments au moyen d'un appareillage approprié et obtenir plusieurs vitesses électriques. Par exemple avec des demi-batteries de 12 volts et des moteurs de 24 volts il sera possible d'alimenter ceux-ci sous 6 , 12 ou 24 volts et obtenir 3 vitesses électriques qui, combinées à une boîte à 3 rapports donneront 9 allures de marche différentes.

Ces dispositions permettront de réaliser des véhicules économiques, de conduite agréable, ayant des couples de démarrage importants, de bonnes accélérations, une aptitude convenable en côte,des plafonds de vitesse plus élevés, capables de recharger leurs batteries pendant l'arrêt ou le stationnement et susceptibles de recevoir un équipement de marche semi-automatique peu coûteux. On peut, par exemple, concevoir 3 gammes: la première, de circulation urbaine ou encombrée à 11 , 22 et 44 Kmh; la seconde pour circulation banlieue ou promenade à 18 , 36 et 72 Kmh; la troisième pour les parcours routiers à 30 , 60 et 120 Kmh.

En principe seront utilisés, d'une part, des moteurs série et des génératrices shunt comportant éventuellement des dispositifs complémentaires d'excitation ou autres, couramment employés en commande électrique, et, d'autre part, les appareillages auxiliaires classiques nécessaires à leur fonctionnement.

Ces dispositions peuvent être appliquées à tous genres de véhicules à moteur , mais plus particulièrement à ceux de faible puissance ou de très petite cylindrée sans permis de conduire,auxquels elles apportent des améliorations modifiant totalement leurs performances en leur procurant ainsi des débouchés beaucoup plus importants.

Elles conviennent parfaitement aux véhicules de toutes puissances soumis à des arrêts fréquents de plus ou moins longue durée,comme les voitures de ramassage ou de livraison,de voyageurs de commerce,etc...

Elles s'appliquent également aux matériels,machines,appareils,dans lesquels on utilise diversement l'énergie d'un moteur et qui sont susceptibles d'exiger temporairement une puissance supérieure.

REVENDICATIONS

1 - Invention ayant pour objet de réduire la consommation et la pollution des véhicules à moteur et d'augmenter temporairement leur puissance motrice, caractérisée par l'utilisation, pendant le maximum de temps, du moteur du véhicule fonctionnant dans les meilleures conditions de rendement et de puissance, en employant l'ensemble des moyens suivants et leurs diverses liaisons électriques et mécaniques : le moteur du véhicule est accouplé à un générateur électrique branché sur une batterie d'accumulateurs; cette batterie et ce générateur sont connectés à des moteurs électriques qui assurent la propulsion, le freinage à récupération d'énergie et la marche arrière, par l'intermédiaire d'une boîte de vitesse et d'un pont; un embrayage ou un dispositif équivalent permet d'accoupler, mécaniquement ou autrement, le groupe moteur-générateur à la transmission de propulsion ; tous ces organes étant commandés par un appareillage approprié, manuel, automatique ou mixte, permettant d'effectuer les liaisons électriques, mécaniques ou autres, de ces organes entre eux et aux transmissions de propulsion, afin de réaliser dans les conditions optima exposées précédemment les modes de fonctionnement suivants :

1 - exclusivement électrique, le groupe moteur-générateur étant arrêté.

2 - électrique normal, le groupe en marche, non embrayé sur la transmission.

3 - électrique à surpuissance temporaire, approximativement doublée, en embrayant le groupe, générateur débranché, sur la transmission; ou susceptible d'être triplée, en embrayant le groupe, générateur branché.

4 - mixte de croisière, par embrayage du groupe sur la transmission; moteurs de propulsion débranchés, générateur branché; ce dernier travaillant alors, suivant la vitesse de marche, en moteur ou en générateur, pour régulariser la marche au régime optima;

5 - mixte accéléré, réalisé comme 4, mais en changeant le rapport de vitesse pour passer au rapport supérieur lorsque le régime optima est atteint. Dans ce mode de fonctionnement la surpuissance est automatiquement réalisée par le générateur lors du changement de rapport.

6 - classique, avec le groupe embrayé, générateur et moteurs débranchés.

7 - freinage électrique à récupération et marche arrière par inversion du sens de marche des moteurs.

2 - Ensemble suivant la rev. 1 caractérisé par 2 générateurs, 2 moteurs et 2 demi-batteries, pour obtenir, sans interrompre la charge, par des connexions appropriées et le montage série-parallèle de ces éléments, plusieurs vitesses de marche des moteurs électriques.

3 - Ensemble suivant les rev. 1 et 2 caractérisé, en vue d'une ...

amélioration du rendement et de l'encombrement, par le genre et la disposition des engrenages qu'il comporte, à savoir: pour la boîte de vitesse, seuls tournent les engrenages du rapport utilisé, les autres étant à l'arrêt; pour le pont, couple réducteur dont le pignon est un engrenage droit, hélicoïdal ou à chevrons et la roue un engrenage intérieur.

4 - Ensemble suivant les rev. 1 et 2, caractérisé par un appareillage automatique de mise en marche et d'arrêt du moteur-générateur pour la charge de la batterie en fonction de la charge de celle-ci, susceptible de fonctionner pendant l'arrêt, la marche ou le stationnement du véhicule.

5 - Ensemble suivant les rev. 1 et 2, caractérisé, pour réduire l'encombrement, par des générateurs et des moteurs comportant deux enroulements distincts sur un même rotor et dans une même carcasse.

6 - Ensemble suivant les rev. 1 et 2, caractérisé, en vue d'une diminution de poids, d'encombrement et de pertes de rendement, par des moteurs électriques et des générateurs à grande vitesse, et l'accouplement de ces derniers au moteur du véhicule au moyen d'un multiplicateur de vitesse.

7 - Ensemble suivant les rev. 1 et 2 dans lequel les rapports de la boîte de vitesse mécanique sont commandés manuellement, tandis que ceux de la combinaison électrique sont à commande automatique.

8 - Ensemble suivant la rev. 2, caractérisé, en vue d'une simplification, par un emploi partiel des dispositions de cette revendication, comme par exemple le montage série-parallèle de seulement les 2 moteurs de propulsion, ce qui réduit à 2 le nombre des régimes de marche obtenus.

Pl. unique 2419832

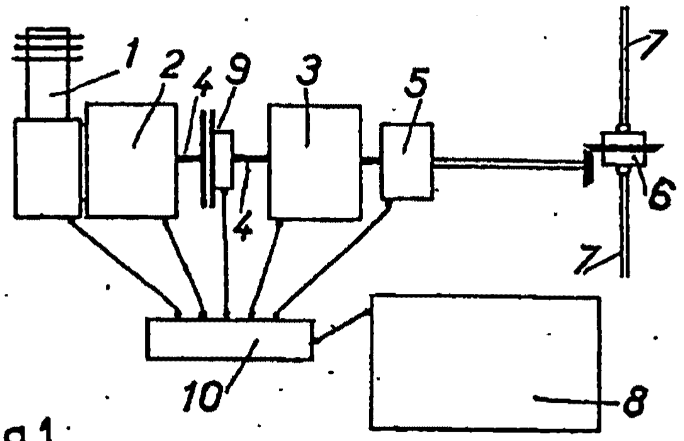

fig 1

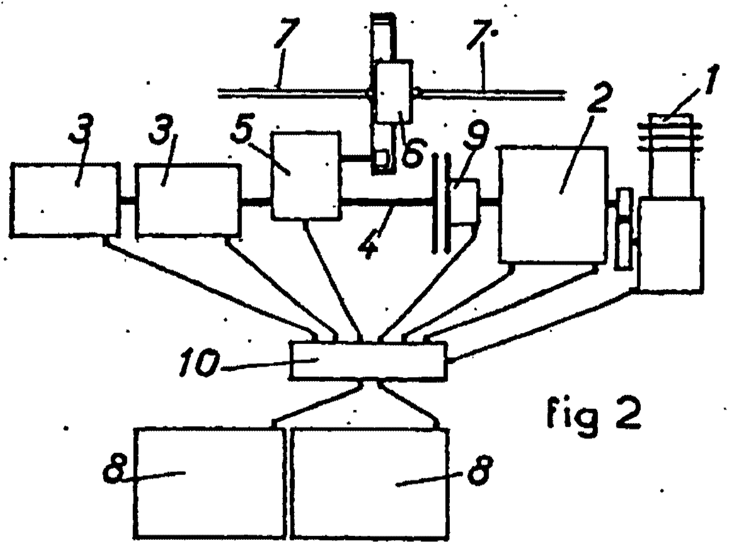

fig 2

TRANSPERFECT | TRANSLATIONS

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TransPerfect Translations, Inc.
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Washington, DC 20004

Sworn to before me this
1st day of March, 2004

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APPLICATION FOR A PATENT

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54 **Means of reducing the fuel consumption and pollution in motor vehicles and of temporarily increasing their engine power.**

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A search is underway to reduce fuel consumption and pollution by motor vehicles and manufacturers would like to be able to reduce the power and importance of engines, while retaining enough power for acceleration and driving.

The purpose of this invention is to provide a solution to this problem.

It consists of using the motor vehicle during the maximum time in the best conditions of fuel consumption and power by all of the following means and their various mechanical and electrical links: the vehicle's engine is directly connected to an electrical generator connected to a storage battery; this battery and the generator are connected to electric motors that provide the power, regenerative breaking, and moving in reverse gear, by means of a transmission and a bridge circuit; a clutch or an equivalent device to connect the motor-generator assembly to the power transmission, mechanically or otherwise; all of these units, being controlled by appropriate manual, automatic, or mixed equipment, allowing the manual, automatic, or other connections of these units to be carried out among themselves and to the transmission of power in order to carry out the following methods of operation in the optimum conditions as described above:

1 – exclusively electrical, the generator group being suppressed.

2 – normal electrical, with the group in operation, not engaged to the transmission.

3 – electrical with temporary emergency power, approximately doubled, by engaging the system on the transmission of power, with the generator disconnected; or, capable of being tripled by means of appropriate design with the generator connected.

4 – mixed at cruising speed, preferably done when the vehicle is moving steadily at a speed that corresponds closely to the optimal rate, by engaging the system on the transmission with the propulsion motors disconnected and the generator connected; the generator then operates according to the operating velocity, with the motor or the generator to stabilize the speed at the optimal level.

5 – mixed acceleration, like 4, but changing the velocity ratio in order to go to the higher ratio when the optimum rate is reached. In this method of operation, the emergency power is automatically achieved by the generator at the time when the ratio is changed.

6 – classic, with the system engaged and the generator and motors disconnected.

7 – reverse gear and regenerative electrical braking by reverse running of the motors.

In making a comparative examination in appraisal of the operation of such a vehicle and a classic vehicle, it is observed that the losses in efficiency due to the electrical transformation are much less than are the gains of the invention. In particular in the case of very difficult traffic, with exclusively electrical operation without pollution, in which it is possible with a low-capacity battery to make an autonomous trip of 5 to 10 kilometers in from 5 to 10 minutes. The best operating conditions are those with mixed functioning in which the electrical losses are reduced to a minimum when the output of the generator is nil, its empty voltage being equal to the maximum voltage of the battery. The vehicle is then powered with almost all of the mechanical energy of the engine and when, after an increase in resistance to the forward motion, the velocity decreases, the power of the engine increases from the energy provided by the generator.

In the only drawing attached, there is shown schematically two non-exclusive representations of the features of the invention: Fig. 1, in which the engine of the vehicle, the generator, and the propulsion motors have equal velocities; Fig. 2 in which, in view of a reduction in weight and in price, the electrical units have higher velocities. The engine 1 of the vehicle is connected to an electrical generator 2. The electrical motors 3 provide the power by means of the shaft 4, the gearbox 5, the bridge circuit 6, and the transmissions 7. The batteries are shown in 8, the clutch of the propulsion motor in 9 and the box containing the command and control instruments in 10. In Fig. 2, the generator 2 includes two equal and independent units, each of them connected to a half-battery 8; the power is achieved by two motors 3, arranged on the same axis. In this way, without interrupting the charge, these different units can be connected in series or in parallel, by means of appropriate instrumentation and achieve several electrical velocities. For example with 12 volt half-batteries and 24 volt motors it will be possible to supply them with 6, 12, or 24 volts and obtain 3 electrical velocities which, combined with 3-speed gearboxes velocities will give 9 different levels of performance.

These arrangements will allow the development of economical vehicles, easy to drive, with significant starting torque, a suitable response on inclines, higher velocity ceilings, able to recharge their batteries while stopped or parked, and able to receive inexpensive semi-automatic operating equipment. For example, three series appear possible: the first, in city or congested traffic at 11, 22, or 44 Kmh; the second for suburban or sightseeing traffic at 18, 36, and 72 Kmh; the third for highway trips at 30, 60, and 120 Kmh.

In principle, on the one hand, motors in series and generating shunts will be used possibly including excitation devices or other devices, currently used in electrical commands, and, on the other hand, the classic auxiliary instrumentation necessary for their operation.

These arrangements may be applied to all kinds of vehicles, but in particular to low-power vehicles or very few cylinders without a driver's license required, to which they will bring improvements that will completely change their performance, thereby providing them with much larger markets.

They are perfectly adapted to vehicles of any power that are subject to frequent long or short stops, such as pickup and delivery vehicles, traveling salespeople, etc.

They also apply to equipment, machines, and devices in which the energy of a motor is used in different ways and that are subject to a temporary need for greater power.

CLAIMS

1 – An invention whose purpose is to reduce fuel consumption and pollution of motor vehicles and to increase their engine power temporarily, characterized by the use, during the maximum period of time, of the engine of the vehicle operating in the best conditions of fuel consumption and power, using all of the following methods and their various electrical and mechanical links: the vehicle's engine is directly connected to an electrical generator connected to a storage battery; this battery and the generator are connected to electric motors that provide the power, regenerative breaking, and moving in reverse gear, by means of a transmission and a bridge circuit; a clutch or an equivalent device to connect the motor-generator assembly to the power transmission, mechanically or otherwise; all of these units, being controlled by appropriate manual, automatic, or mixed equipment, allowing the manual, automatic, or other connections of these units to be carried out among themselves and to the transmission of power in order to carry out the following methods of operation in the optimum conditions as described above:

1 – exclusively electrical, the engine-generator group being suppressed.

2 – normal electrical, with the group in operation, not engaged to the transmission.

3 – electrical with temporary emergency power, approximately doubled, by engaging the system on the transmission of power, with the generator disconnected; or, capable of being tripled by engaging the system with the generator connected.

4 – mixed at cruising speed, by engaging the system on transmission, with the propulsion motors disconnected and the generator connected; the generator then operates according to the operating velocity, with the motor or the generator to stabilize the speed at the optimal level.

5 – mixed acceleration, like 4, but changing the velocity ratio in order to go to the higher ratio when the optimum rate is reached. In this method of operation, the emergency power is automatically achieved by the generator at the time when the ratio is changed.

6 – classic, with the system engaged and the generator and motors disconnected.

7 – reverse gear and regenerative electrical braking by reverse running of the motors.

2 – A system according to claim 1, characterized by 2 generators, 2 motors, and 2 half-batteries in order to obtain by appropriate connections and the series-parallel assembly of these units several operating speeds from the electric motors, without interrupting the charge.

3 – A system according to claims 1 and 2, characterized in view

of an increase in fuel efficiency and the size, by the kind and layout of the gears that are included, namely: for the gearbox, only gears of the ratio that are turning are used, the others are stopped; for the bridge circuit, a reduction torque whose cog is a straight, helicoidal, or double helicoidal gear and the wheel an interior gear.

4 – A system according to claims 1 and 2, characterized by an automatic device for starting and stopping the motor-generator for charging the battery according to its charge level, capable of operating during stops, running, or parking of the vehicle.

5 – A system according to claims 1 and 2, characterized, in order to reduce the size, by generators and motors including two different units on the same rotor and in the same casing.

6 – A system according to claims 1 and 2, characterized, in order to reduce weight, size, and loss of fuel economy, by electric motors and very high-speed generators, and their connection to the vehicle's engine by means of a velocity multiplier.

7 – A system according to claims 1 and 2 in which the ratios of the mechanical gearbox are commanded manually, while those of the electrical system are commanded automatically.

8 – A system according to claims 1 and 2, by simplification through a partial use of the provisions of this claim, as for example by the series-parallel assembly of the 2 propulsion motors only, which reduces the number of operating systems used to 2.

Sole drawing

[see source for figures 1 and 2]

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(54)発明の名称　電気自動車用補機電池充電装置

㉑特　願　平1－261588
㉒出　願　平1（1989）10月6日

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明　細　書

1．発明の名称

電気自動車用補機電池充電装置

2．特許請求の範囲

キースイッチがオンされたときのみモータを駆動する主電池から、所定の値の直流電圧を取込んで異なる値の直流電圧に変換し、この変換により得られた直流電圧で補機電池を充電し、かつキースイッチを介して負荷を駆動するＤＣ－ＤＣコンバータと、

補機電池の電圧値を検知する電圧検知部と、

キースイッチがオンされているときに、前記電圧検知部が検知した電圧値に基づき、前記ＤＣ－ＤＣコンバータによる補機電池の充電動作を制御し、補機電池により駆動される充電制御部と、

を有する電気自動車用補機電池充電装置において、

前記電圧検知部により検知される補機電池の電圧値が、所定の基準電圧値以下に低下しており、かつキースイッチがオフされている所定の期間において、所定時間だけ、前記ＤＣ－ＤＣコンバータによる補機電池の充電を行わしめるように、前記充電制御部を動作させる充電指令部を含み、

補機電池の電圧値を検知し、この電圧値が所定の基準電圧値以下に低下している場合には、所定時間だけ、補機電池の充電を行うことを特徴とする電気自動車用補機電池充電装置。

3．発明の詳細な説明

〔産業上の利用分野〕

本発明は、主電池から取込んだ直流電圧を異なる値の直流電圧に変換し、補機電池を充電する電気自動車用補機電池充電装置に関する。

〔従来の技術〕

一般に電気自動車においては、電気自動車の走行に係るモータを駆動するために、所定の直流電圧を出力する主電池が搭載されている。また、この電気自動車においては、車載の電気機器を駆動するために、前記主電池とは異なる値の直流電圧を出力する補機電池が搭載されている。

また、主電池及び補機電池が搭載された電気自

動車には、該補機電池を充電するために、電気自動車用補機電池充電装置が搭載される。

第３図には、従来における電気自動車用補機電池充電装置の一構成例が示されている。

この図においては、主電池１０にはメインコンタクタ１２を介してモータ制御回路１４が接続され、該モータ制御回路１４には、電気自動車の走行駆動に係るモータ１６が接続されている。また、前記モータ制御回路１４には、該モータ制御回路１４を制御するインバータ回路、チョッパ回路等のモータ制御部１８が接続されている。

すなわち、前記主電池１０からメインコンタクタ１２を介して前記モータ制御回路１４に所定の値の直流電圧が供給されると、該モータ制御回路１４は、前記モータ制御部１８によりＰＷＭ制御等の制御に基づき、主電池１０から供給された直流電圧を所定の電力に変換してモーク１６に供給する。このことにより、前記モータ１６が駆動され、電気自動車が走行可能な状態となる。

前記主電池１０と補機電池２０との間には、従来例に係る電気自動車用補機電池充電装置２２が設けられている。この補機電池充電装置２２は、主電池１０から出力される直流電圧を補機電池２０を充電可能な直流電圧に変換するＤＣ－ＤＣコンバータ２４と、補機電池２０の出力電圧を検知し、この検知結果に基づきＤＣ－ＤＣコンバータ２４を制御するＤＣ－ＤＣコンバータ制御回路２６と、から構成されている。

前記ＤＣ－ＤＣコンバータ２４は、例えば実開昭４８－１１１８２７号公報に開示されたものと同様の構成を有しており、主電池１０から出力される直流電圧を交流化するインバータ部２８、該インバータ部２８から出力される電圧を変圧するトランス部３０、及び該トランス部３０から出力される電圧を整流して補機電池２０を充電可能な電圧を出力する整流部３２から構成されている。

すなわち、前記主電池１０から出力される直流電圧は、前述のようにメインコンタクタ１２を介してモータ制御回路１４に供給されると共に、ＤＣ－ＤＣコンバータ２４に内蔵されるインバータ部２８に入力され、順次、トランス部３０及び整流部３２に供給され、前記補機電池２０を充電可能な異なる値の直流電圧に変換される。そして、補機電池２０は、このようにしてＤＣ－ＤＣコンバータ２４から出力される直流電圧により充電される。

一方、前記補機電池２０は、直接にあるいはキースイッチ３４を介して車載の負荷に接続されており、また、キースイッチ３４を介してモータ制御部１８に接続されている。

すなわち、前述のようにしてＤＣ－ＤＣコンバータ２４から出力された直流電圧は、補機電池２０を充電すると共に、直接あるいはキースイッチ３４を介して車載の負荷及びモータ制御部１８に供給される。ここで、メインコンタクタ１２は、前記キースイッチ３４と連動してオン／オフするように構成されており、キースイッチ３４がオンされている場合、ＤＣ－ＤＣコンバータ２４又は補機電池２０から出力される直流電圧により、モータ制御部１８が駆動され、主電池１０からモータ制御回路１４に所定の直流電圧が供給されるため、モータ１６が駆動されることとなる。

一方、前述のように、この従来例に係る補機電池充電装置２２は、前記ＤＣ－ＤＣコンバータ２４に加えＤＣ－ＤＣコンバータ制御部２６を含んでおり、このＤＣ－ＤＣコンバータ制御部２６は、補機電池２０の電圧及び電流をそれぞれ検知する電圧検出アンプ３６及び電流検出アンプ３８と、該電圧検出アンプ３６及び電流検出アンプ３８の出力に基づき、パルスのデューティを決めるフィードバック部４０と、該フィードバック４２において決められたデューティにより、前記インバータ部２８に制御パルスを供給するパルス化回路４２と、から構成されている。

すなわち、前記補機電池２０の電圧は、前記電圧検出アンプ３６により検出され、増幅されてフィードバック部４０に供給される。同様に、前記補機電池２０の直流電流は、前記電流検出アンプ３８により検出され、増幅される。

次に、前記フィードバック部４０において、前

記電圧検出アンプ３６及び電流検出アンプ３８によりそれぞれ検出された補機電池２０の電圧及び電流に基づき、パルスのデューティが決定される。例えば、前記電圧検出アンプ３６の検出結果に基づき、補機電池２０の過電圧充電が防止されるようにデューティが算定され、同時に、電流検出アンプ３８の検出結果に基づき、ＤＣ－ＤＣコンバータ２４の最大出力電流を越えないようにデューティが算定される。そして、これらの２種類のデューティ、すなわち電圧検出アンプ３６及び電流検出アンプ３８のそれぞれの検出結果に基づいて算定されたデューティのうち、小さい方、すなわち補機電池２０の充電における電圧的及び電流的要請を両方共満たすデューティが選択され、前記パルス化回路４２に出力される。

前記パルス化回路４２においては、前記フィードバック部４０から供給されたデューティに基づきパルスが発生し、このパルスにより前記インバータ部２８の動作がＰＷＭ制御される。

従って、この従来例においては、補機電池２０の電圧及び電流に基づいて、ＤＣ－ＤＣコンバータ制御部２６によってＤＣ－ＤＣコンバータ２４が制御され、補機電池２０が充電されると共に、車載の負荷に所定の電圧が供給される。

この従来例においては、車載の負荷において消費される電流量がＤＣ－ＤＣコンバータ２４の出力能力以上である場合等において、補機電池２０が放電され、この放電により車載の負荷に電流が供給される。このとき、前記キースイッチ３４をオフすると、前記補機電池２０は、放電された状態で保持されることとなる。

このような動作が繰返され、補機電池２０がいわゆる過放電状態となると、該補機電池２０の電圧は、例えばモータ制御部１８を駆動するために必要な電圧以下に低下する可能性がある。このような電圧低下が生じた場合には、キースイッチ３４をオンし、モータ１６を駆動しようとしても、補機電池２０によるモータ制御部１８の駆動が行われないため、モータ１６の駆動、従って電気自動車の走行が不能となってしまう。

例えば、特開昭６４－８５５０２号公報には、「電気自動車の制御装置」として、キースイッチＯＮ後に補機電池の電圧を検出し、まずＤＣ－ＤＣコンバータを起動させ該補機電池を充電し、所定の電圧以上を確保してから車両駆動を指令するモータ制御部の電源を立ち上げる構成が示されている。

〔発明が解決しようとする課題〕

前述の特開昭６４－８５５０２号公報に開示された装置においては、ＤＣ－ＤＣコンバータは補機電池により作動に必要な電圧を供給されているため、該補機電池の電圧が停車中の電力消費など何らかの理由により著しく低下し、モータ制御部作動可能電圧はおろかＤＣ－ＤＣコンバータの起動に必要な電圧さえも確保されていない状態になったときに、目的とする車両起動を達成できないことがある。

本発明は補機電池電圧が常にＤＣ－ＤＣコンバータ及びモータ制御部の起動に必要な電圧を保てるように構成され、該補機電池電圧低下によるモ

ータの駆動再開不能状態を防止する電気自動車用補機電池充電装置を提供することを目的とする。

〔課題を解決するための手段〕

前記目的を達成するために本発明は、電圧検知部により検知される補機電池の電圧値が、所定の基準電圧値以下に低下しており、かつキースイッチがオフされている所定の期間において、所定時間だけＤＣ－ＤＣコンバータによる補機電池の充電を行わしめるように、ＤＣ－ＤＣコンバータを制御する充電制御部を動作させる充電指令部を含み、補機電池の電圧値を検知し、この電圧が所定の基準電圧値以下に低下している場合には、所定時間だけ補機電池の充電を行うことを特徴とする。

〔作用〕

本発明の電気自動車用補機電池充電装置においては、電圧検出部により補機電池の電圧が検知される。さらに、電圧検知部により検知された補機電池の電圧値が、所定の基準電圧値以下に低下している期間であって、かつキースイッチがオフされている所定の期間において、所定時間だけ充電

指令部が充電制御部に所定の動作を行わせる。この所定の動作とは、補機電池の充電を行わしめるよう、ＤＣ－ＤＣコンバータを制御する動作である。従って、キースイッチを再びオンした時確実にモータの駆動を再開することが可能となる。

〔実施例〕

以下、本発明の実施例を、図面に基づいて説明する。なお、第３図に示される従来例と同様の構成には同一の符号を付し、説明を省略する。

第１図には、本発明の第１実施例に係る電気自動車用補機電池充電装置の構成が示されている。

この実施例の電気自動車用補機電池充電装置４４は、第３図に示される従来例と同様のＤＣ－ＤＣコンバータ２４と、本発明の特徴的構成を含むＤＣ－ＤＣコンバータ制御部４６と、とから構成されている。

また、前記ＤＣ－ＤＣコンバータ制御部４６は、電圧検出アンプ３６の出力と所定の基準電圧とが入力されるヒステリシス特性を有するコンパレータ４８と、該コンパレータ４８のＨ／Ｌ２値の出力によりオン／オフされるトランジスタ５０と、を含んでいる。更に、前記トランジスタ５０のコレクタは前記フィードバック回路４０に接続されており、ＤＣ－ＤＣコンバータ制御部４６には、補機電池２０から直接に駆動電力が供給されている。

次に、この実施例の動作を説明する。

まず、キースイッチ３４がオンされている場合には、第３図に示される従来例と同様に、モータ１６の駆動、ＤＣ－ＤＣコンバータ２０による補機電池２０及び車載の負荷への電圧出力が行われる。

また、キースイッチ３４がオフされ、従ってモータ１６が駆動されていないときには、補機電池２０の電圧が電圧検出アンプ３６により検出され、さらにコンパレータ４８に入力される。前記コンパレータ４８においては、電圧検出アンプ３６の検出値が所定のしきい値V_Lと比較され、この比較の結果しきい値V_Lよりも電圧検出アンプ３６の検出値が低いとされた場合には、該コンパレータ４８の出力が例えばＨ値となり、トランジスタ５０がオンされる。前記トランジスタ５０がオンされると、前記フィードバック回路４０が駆動され、従って、ＤＣ－ＤＣコンバータ２４による補機電池２０の充電が行われる。

この後に、補機電池２０が充電され、従って電圧検出アンプ３６の検出値が増加していく。このとき、前記コンパレータ４８においては、電圧検出アンプ３６の検出値が所定のしきい値V_Hと比較される。このしきい値V_Hは、前記しきい値V_Lよりも大である。すなわち、コンパレータ４８は、ヒステリシス特性を有している。電圧検出アンプ３６の検出値の方が大であるとされた場合には、コンパレータ４８の出力が例えばＬ値となり、前記トランジスタ５０がオフされ、フィードバック回路４０の動作が停止する。従って、前記ＤＣ－ＤＣコンバータ２４による補機電池２０の充電が停止される。

この実施例においては、キースイッチ３４がオフされ、従って電気自動車が停止している際に補機電池２０の充電が行われるが、該補機電池２０の電圧を検知する電圧検出アンプ３６を含む構成に、モータ１６の停止中も電圧が供給され続けなければならない。第２図には、このような問題点について改良した、本発明の第２実施例に係る電気自動車用補機電池充電装置の構成が示されている。

この実施例においては、第１図の実施例と同様のトランジスタ５０には、補機電池２０にキースイッチ５２を介して接続されたリレー５４が接続されており、さらにこのリレー５４の一端は、該キースイッチ５２及びこれと連動するキースイッチ５６をバイパスするように、補機電池２０に接続されている。

まず、キースイッチ５２及びこれと連動するキースイッチ５６がオンされ、キースイッチ５２と連動するメインコンタクタ１２がオンされた場合には、主電池１０からモータ制御回路１４に所定の直流電圧が供給され、モータ制御部１８による制御に基づき、モータ１６が駆動される。

一方で、キースイッチ５２がオフされる場合には、それ以前に補機電池２０の電圧が電圧検出アンプ３６により検出され、該電圧が低下しているときは第１図に示される実施例と同様に、トランジスタ５０がオンされている。このとき、トランジスタ５０のコレクタは、リレー５４の駆動コイルに接続されており、該リレー５４の一端が補機電池２０と接続されているため、該リレー５４の駆動コイルに電流が流れ、リレー５４がオンされる。

さらに、これに伴い、キースイッチ５２がオフとなっても補機電池２０の電圧がリレー５４を介してＤＣ－ＤＣコンバータ制御部４６に供給され続けるため、該ＤＣ－ＤＣコンバータ４６によるＤＣ－ＤＣコンバータ２４の制御が行われ、補機電池２０が充電される。

また、前記コンパレータ４８は、ヒステリシス特性を有しているため、電圧検出アンプ３６の検出電圧値が所定のしきい値V_H以上になったときに、トランジスタ５０がオフされる。リレー５４がオフされ、従って、補機電池２０からＤＣ－ＤＣコンバータ４６への電圧供給が停止され、前記ＤＣ－ＤＣコンバータ２４による補機電池２０の充電が停止される。

この実施例によれば、第１図に示される実施例に比べ、ＤＣ－ＤＣコンバータ制御部４６の少なくとも一部が駆動される時間が限定される。すなわち、この時間は、キースイッチ５２のオフ後の所定時間、すなわちコンパレータ４８のヒステリシス特性によって決定される時間に限定されるため無駄な電力消費が制御できる。

〔発明の効果〕

以上説明したように、本発明の電気自動車用補機電池充電装置によれば、補機電池の著しい電圧低下を未然に防ぐことが可能でタイムリーで効率的な、補機電池の充電が行われるため、補機電池の過放電によるモータの再駆動不能状態が回避され、かつ回路効率の良い電気自動車用補機電池充電装置を得ることができる。

４．図面の簡単な説明

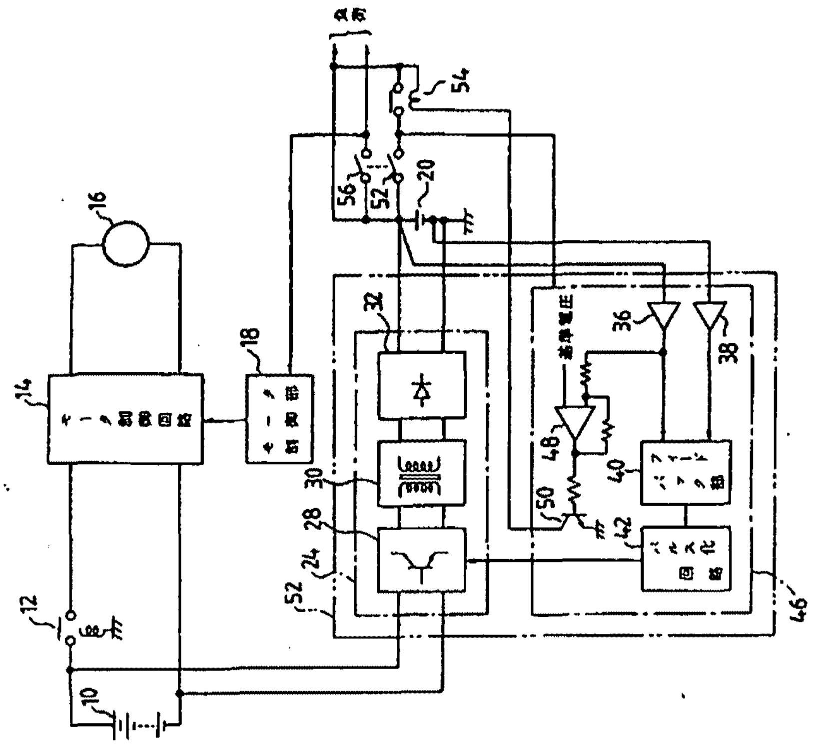
第１図は、本発明の第１実施例に係る電気自動車用補機電池充電装置の構成を示す構成図、

第２図は、本発明の第２実施例に係る電気自動車用補機電池充電装置の構成を示す構成図、

第３図は、従来の電気自動車用補機電池充電装置の一構成例を示す構成図である。

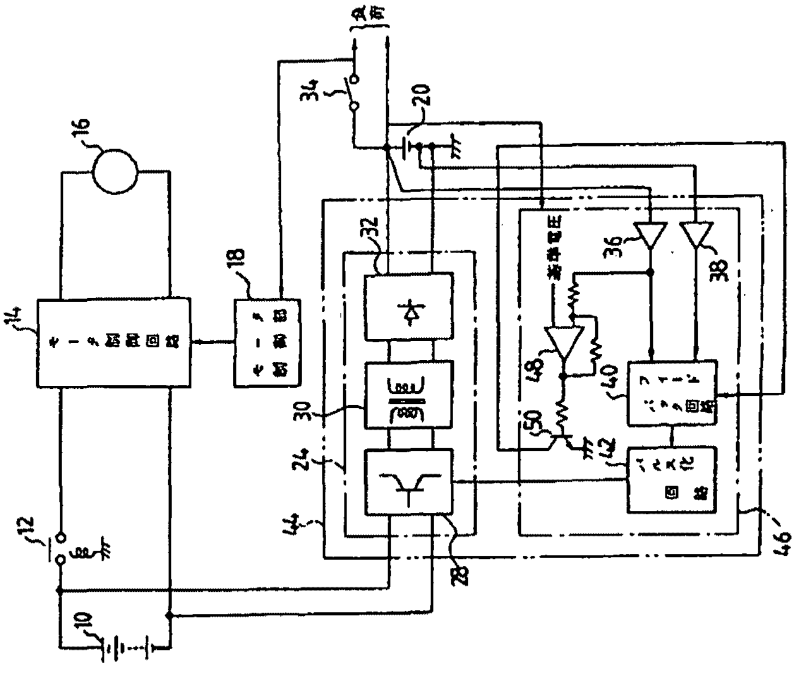
１０　…　主電池
１６　…　モータ
２０　…　補機電池
２４　…　ＤＣ－ＤＣコンバータ
３４，５２，５６　…　キースイッチ
３６　…　電圧検出アンプ
４０　…　フィードバック回路
４２　…　パルス化回路
４６　…　ＤＣ－ＤＣコンバータ制御部
４８　…　コンパレータ
５０　…　トランジスタ

出願人　トヨタ自動車株式会社
代理人　弁理士　吉　田　研　二
（外２名）［D-35］



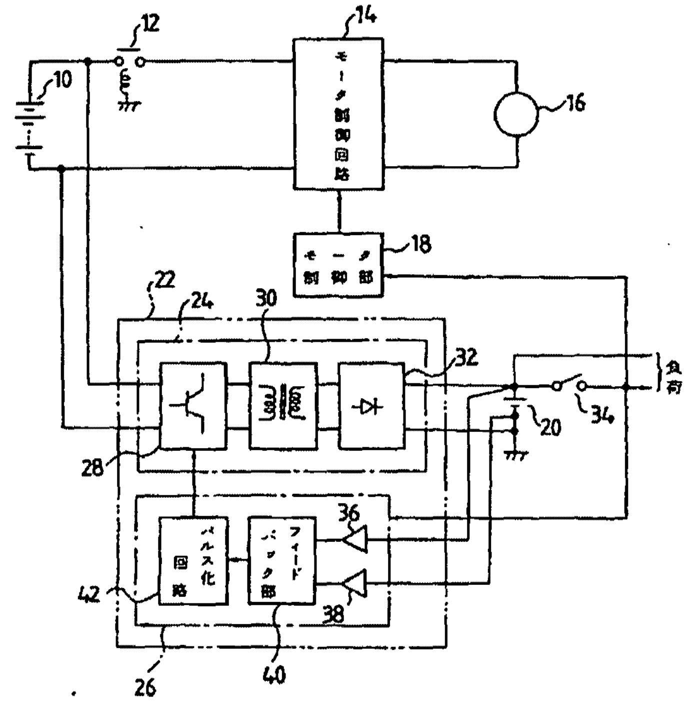
第2実施例の構成

第2図



第1実施例の構成

第1図


12
14
モータ制御回路
10
16
18
モータ制御部
22
24
30
32
負荷
34
20
28
36
パルス化回路
フィードバック部
42
38
26
40

従来例の構成

第3図

CERTIFICATION OF TRANSLATION

I, Christopher Field, a professional Japanese translator accredited by the American Translators Association, hereby attest that the attached translations from Japanese have been faithfully prepared to the best of my ability.

1. JP03-124201
2. JP51-103220
3. JP05-64531

Date: May 13, 2004

By:

5/13/04

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Japanese Laid-Open Patent Application 3-124201

Laid-Open: May 27, 1991

Filing Date: October 6, 1989

Applicant: Toyota Motor Corporation

Specification

1. Title of the Invention

AUXILIARY BATTERY CHARGING DEVICE FOR ELECTRIC AUTOMOBILE

2. Scope of the Claim

An auxiliary battery charging device for an electric automobile, comprising:

a DC-DC converter which intakes a direct current voltage of a predetermined value from a main battery driving a motor only when a keyswitch is turned on, converts it to a direct current voltage of a different value, charges an auxiliary battery by a direct current voltage which has been obtained by this conversion, and drives a load via the keyswitch;

a voltage detector which detects a voltage value of the auxiliary battery; and

a charging controller which, when the keyswitch is turned on, based on the voltage value detected by the voltage detector, controls a charging operation of the auxiliary battery by the DC-DC converter and is driven by the auxiliary battery; wherein there is included:

a charging instruction portion which operates the charging controller so as to, in a predetermined period in which the voltage value of the auxiliary battery to be detected by the voltage detector drops to a predetermined reference voltage value or less and the keyswitch is turned off, charge the auxiliary battery by the DC-DC converter for a predetermined time only;

wherein when the voltage value of the auxiliary battery is detected and this voltage value has deteriorated to a predetermined reference voltage value or less, charging of the auxiliary battery is performed for a predetermined time only.

3. Detailed Description of the Invention

[Industrial Use of the Invention]

This invention relates to an auxiliary battery charging device for an electric automobile which converts a direct current voltage taken from a main battery to a direct current voltage of a different value and charges an auxiliary battery.

[Prior Art]

In general, in order to drive a motor related to travel of an electric automobile, a main battery which outputs a predetermined direct current voltage is mounted on the electric automobile. Furthermore, in this electric automobile, in order to drive electric devices mounted on the automobile, an auxiliary battery is mounted, which outputs a direct current voltage of a value different from that of the main battery.

Additionally, in the electric automobile on which the main battery and the auxiliary battery are mounted, in order to charge the auxiliary battery, an electric automobile auxiliary battery charging device is mounted.

Fig. 3 shows a structural example of a conventional electric automobile auxiliary battery charging device.

In this diagram, a motor control circuit 14 is connected to a main battery 10 via a main contactor 12, and a motor 16 for driving the travel of an electric automobile is connected to the motor control circuit 14. Additionally, a motor controller 18 such as an inverter circuit, a chopper circuit or the like that controls the motor control circuit 14 is connected to the motor control circuit 14.

That is, when, based on control such as PWM control by the motor controller 18, a direct current voltage of a predetermined value is supplied to the motor control circuit 14 via the main contactor 12 from the main battery 10, the motor control circuit 14 converts the direct current voltage supplied from the main battery 10 to a predetermined voltage and supplies it to the motor 16. By so doing, the motor 16 is driven, and the electric automobile becomes mobile.

An auxiliary battery charging device 22 for an electric automobile related to a conventional example is disposed between the main battery 10 and the auxiliary battery 20. The auxiliary battery charging device 22 is constituted by a DC-DC converter 24, which converts a direct current voltage output from the main battery 10 to a direct current voltage which can charge the auxiliary battery 20, and a DC-DC converter control circuit 26, which detects an output voltage of the auxiliary voltage 20 and controls the DC-DC converter 24 based on this detection result.

The DC-DC converter 24 has the same structure as one disclosed in, for example, Japanese Laid-Open Utility Model Application 48-111827, and is constituted by an inverter 28 which converts a direct current voltage output from the main battery 10 into an alternating current voltage, a transformer 30 which changes a voltage that is output from the inverter 28, and a rectifier 32 which rectifies a voltage output from the transformer 30 and outputs a voltage which can charge the auxiliary battery 20.

That is, the direct current voltage output from the main battery 10 is supplied to the motor control circuit 14 via the main contactor 12 as mentioned above, and is input to the inverter 28 which is built into the DC-DC converter 24, is sequentially supplied to the transformer 30 and the rectifier 32, and is converted to a direct current voltage of a different value which can charge the auxiliary battery 20. The auxiliary battery 20 is then charged by a direct current voltage output from the DC-DC converter 24.

Meanwhile, the auxiliary battery 20 is connected to a load mounted on the automobile, directly or via a keyswitch 34, and is connected to the motor controller 18 via the keyswitch 34.

That is, as mentioned earlier, the direct current voltage output from the DC-DC converter 24 charges the auxiliary battery 20, and is supplied to a load mounted on the automobile and to the motor controller 18 directly or via the keyswitch. Here, the main contactor 12 is constituted so as to be turned on and off with the keyswitch 34. When the keyswitch 34 is turned on, the motor controller 18 is driven by direct current voltage output from the DC-DC converter 24 or the auxiliary battery 20, and a predetermined direct current voltage is supplied to the motor control circuit 14 from the main battery 10, so the motor 16 is driven.

Meanwhile, as mentioned above, the auxiliary battery charging device 22 of this conventional example includes the DC-DC converter controller 26 in addition to the DC-DC converter 24. The DC-DC converter controller 26 is constituted by a voltage detection amplifier 36 and an electric current detection amplifier 38 which detect a voltage and an electric current of the auxiliary battery 20, respectively, a feedback portion 40 which determines a pulse duty based on the output of the voltage detection amplifier 36 and the electric current detection amplifier 38, and a pulse circuit 42 which supplies a control pulse to the inverter 28 by a duty determined by the feedback 42 **[sic. "feedback portion 40"]**.

That is, the voltage of the auxiliary battery 20 is detected by the voltage detection amplifier 36, is amplified, and is supplied to the feedback portion 40. In the same manner, the direct current of the auxiliary battery 20 is detected by the electric current detection amplifier 38 and is amplified.

Next, in the feedback portion 40, based on the voltage and the electric current of the auxiliary battery 20 detected by the voltage detection amplifier 36 and the electric current detection amplifier 38, respectively, a pulse duty is determined. For example, based on the detection result of the voltage detection amplifier 36, a duty is calculated and determined so as to prevent excess voltage charging of the auxiliary battery 20. At the same time, based on the detection result of the electric current detection amplifier 38, a duty is calculated and determined so as to not exceed the maximum output electric current of the DC-DC converter 24. Additionally, the smaller duty, i.e., the duty which satisfies both the voltage and the electric current requirements for the charging of the auxiliary battery 20, is selected and output to the pulse circuit 42 from among the two types of duties, i.e., the duties calculated and determined based on the detection results of the voltage detection amplifier 36 and the electric current detection amplifier 38, respectively.

In this pulse circuit 42, a pulse is generated based on the duty supplied from the feedback portion 40, and the operation of the inverter 28 is PWM controlled by this pulse.

Therefore, in this conventional example, based on the voltage and the current of the auxiliary battery 20, the DC-DC converter 24 is controlled by the DC-DC converter controller 26, the auxiliary battery 20 is charged, and a predetermined voltage is supplied to a load mounted on the automobile.

In this conventional example, when an electric current amount to be consumed by the load mounted on the automobile is more than the output capability of the DC-DC converter 24, the auxiliary battery 20 is discharged, and electric current is supplied to a load mounted on the automobile by this discharging. At this time, when the keyswitch 34 is turned off, the auxiliary battery 20 is held in a discharged state.

When this operation is repeated, and the auxiliary battery 20 is in a so-called excess discharging state, the voltage of the auxiliary battery 20 can drop, e.g., to a voltage less than what is needed for driving the motor controller 18. When this type of voltage drop occurs, even if [a user} tries to turn on the keyswitch 34 and drive the motor 16, the driving of the motor controller 18 is not performed by the auxiliary battery 20, so driving of the motor 16, and hence, travel of the electric automobile, cannot be performed.

Japanese Laid-Open Patent Application 64-85502, for example, discloses a structure of a "electric automobile control device" which detects a voltage of an auxiliary battery after a keyswitch is turned on, and first activates a DC-DC converter, charges the auxiliary battery, ensures a predetermined voltage or more, and then turns on power of a motor controller which commands the driving of the automobile.

[Problems to be Resolved by the Invention]

In the device disclosed in the above-mentioned Japanese Laid-Open Patent Application 64-85502, the DC-DC converter is supplied with a voltage needed for an operation by an auxiliary battery, so when a voltage for the auxiliary battery significantly drops for some reason such as electricity consumption while the automobile is stopped such that not even a voltage needed for activation of the DC-DC converter or a voltage which can activate the motor controller are ensured, there are times that the goal of automobile activation cannot be accomplished.

An object of this invention is to provide an auxiliary battery charging device for an electric automobile in which an auxiliary battery voltage constantly maintains a voltage needed for activation of a DC-DC converter and a motor controller, and which prevents a state in which motor driving is impossible to restart due to the auxiliary battery voltage deterioration.

[Means of Solving the Problem]

In order to accomplish the above-mentioned objective, the present invention includes a charge command portion which operates a charging controller controlling the DC-DC converter so that, in a predetermined period in which a voltage value of an auxiliary battery to be detected by a voltage detector drops to a predetermined reference voltage value or less and a keyswitch is turned off, charging of an auxiliary battery by a DC-DC converter is performed for a predetermined time only, a voltage value of the auxiliary battery is detected, and when the voltage drops to a predetermined reference voltage value or less, charging of the auxiliary battery is performed for a predetermined time only.

[Operation]

In an auxiliary battery charging device for an electric automobile of this invention, a voltage of an auxiliary battery is detected by a voltage detector. Furthermore, in a predetermined period in which a voltage value of an auxiliary battery detected by a voltage detector drops to a predetermined reference voltage value or less, and in which a keyswitch is turned off, a charge command portion causes a charging controller to perform a predetermined operation for a predetermined time only. This predetermined operation is an operation which controls the DC-DC converter so as to charge the auxiliary battery. Therefore, it is possible to restart driving of the motor when the keyswitch is turned on again.

[Embodiments]

The following explains embodiments of this invention based on the drawings. Furthermore, the structure which is the same as in the conventional example shown in Fig. 3 uses the same symbols, so the explanation thereof is omitted.

Fig. 1 shows a structure of an auxiliary battery charging device for an electric automobile according to a first embodiment of this invention.

The auxiliary battery charging device for an electric automobile 44 of this embodiment is constituted by a DC-DC converter 24, which is the same as in the conventional example shown in Fig. 3, and a DC-DC converter controller 46, which includesthe characteristic structure of this invention.

Additionally, the above-mentioned DC-DC converter controller 46 includes a comparator 48, having a hysteresis characteristic, into which the output of a voltage detection amplifier 36 and a predetermined reference voltage are input, and a transistor 50 which is turned on and off by the output of an H/L2 value of the comparator 48. In addition, the collector of the transistor 50 is connected to the feedback circuit 40, and a driving electric power is directly supplied from the auxiliary battery 20 to the DC-DC converter controller 46.

The following explains the operation of this embodiment.

First, when the keyswitch 34 is turned on, the driving of the motor 16 and a voltage output to a load mounted on a vehicle and the auxiliary battery 20 by the DC-DC converter 20 **[sic. 24]** are performed in the same manner as in the conventional example shown in Fig. 3.

Additionally, when the keyswitch 34 is turned off, and hence the motor 16 is not driven, a voltage of the auxiliary battery 20 is detected by the voltage detection amplifier 36, and is input to the comparator 48. In the comparator 48, a detection value of the voltage detection amplifier 36 is compared with a predetermined threshold value V_L, and if the detection value of the voltage detection amplifier 36 is deemed to be lower than the threshold value V_L, the output of the comparator 48 becomes, for example, an H value, and the transistor 50 is turned on. When the transistor 50 is turned on, the feedback circuit 40 is driven, and charging of the auxiliary battery 20 is performed by the DC-DC converter 24.

After that, the auxiliary battery 20 is charged, and the detection value of the voltage detection amplifier 36 thus increases. At this time, in the comparator 48, a detection value of the voltage detection amplifier 36 is compared with a predetermined threshold value V_H. This threshold value V_H is larger than the threshold value V_L. That is, the comparator 48 has a hysteresis characteristic. If the detection value of the voltage detection amplifier 36 is deemed to be larger, the output of the comparator 48 becomes, for example, an L value, the transistor 50 is turned off, and the operation of the feedback circuit 40 stops. Charging of the auxiliary battery 20 by the DC-DC converter 24 is thus stopped.

In this embodiment, when the keyswitch 34 is turned off and the electric automobile thus stops, charging of the auxiliary battery 20 is performed. However, even during the stop of the motor 16, a voltage needs to be continuously supplied to the structure which includes the voltage detection amplifier 36 that detects a voltage of the auxiliary battery 20. Fig. 2 shows a structure of an auxiliary battery charging device for an electric automobile according to a second embodiment of this invention, which represents an improvement with respect to this type of problem.

In this embodiment, a relay 54 connected to the auxiliary battery 20 via the keyswitch 52 is connected to the transistor 50, which is the same as in the embodiment of Fig. 1, and one end of this relay 54 is connected to the auxiliary battery 20 so as to bypass the keyswitch 52 and a keyswitch 56 that operates in conjunction with the keyswitch 52.

First, when the keyswitch 52 and the keyswitch 56 that operates in conjunction with the keyswitch 52 are turned on, and the main contactor 12 that operates in conjunction with the keyswitch 52 is turned on, a predetermined direct current voltage is supplied to the motor control circuit 14 from the main battery 10 and the motor 16 is driven based on the control of the motor controller 18.

Meanwhile, when the keyswitch 52 is turned off, the voltage of the auxiliary battery 20 is detected by the voltage detection amplifier 36 in advance, and when the voltage drops the transistor 50 is turned on, in the same manner as in the embodiment shown in Fig. 1. At this time, the collector of the transistor 50 is connected to a driving coil of the relay 54, and one end of the relay 54 is connected to the auxiliary battery 20; therefore, an electric current flows to the driving coil of the relay 54, and the relay 54 is turned on.

Furthermore, along with this operation, even if the keyswitch 52 is turned off, the voltage of the auxiliary battery 20 continues to be supplied to the DC-DC converter controller 46 via the relay 54, so the DC-DC converter 24 is controlled by the DC-DC converter controller 46, and the auxiliary battery 20 is charged.

Furthermore, the comparator 48 has a hysteresis characteristic, so when a detection voltage value of the voltage detection amplifier 36 reaches a predetermined threshold value V_H or higher, the transistor 50 is turned off. The relay 54 is turned off; thus, a voltage supply to the DC-DC converter 46 from the auxiliary battery 20 stops, and charging of the auxiliary battery 20 by the DC-DC converter 24 stops.

According to this embodiment, compared to the embodiment shown in Fig. 1, the time in which at least part of the DC-DC converter controller 46 is driven is limited. That is, this time is limited to a predetermined time after the keyswitch 52 is turned off, i.e., the time which is determined by a hysteresis characteristic of the comparator 48, so wasteful electricity consumption can be controlled.

[Effects of the Invention]

As explained above, according to the auxiliary battery charging device of an electric automobile of this invention, it is possible to prevent significant voltage deterioration of the auxiliary battery in advance, and charging of the auxiliary battery is effectively performed in a timely manner; thus, a state in which it is impossible re-drive a motor due to excessive discharging of the auxiliary battery can be avoided, and an electric automobile auxiliary battery charging device with good circuit efficiency can be obtained.

4. Brief Description of the Drawings

Fig. 1 is a structural diagram showing the structure of an auxiliary battery charging device for an electric automobile according to a first embodiment of this invention.

Fig. 2 is a structural diagram showing the structure of an auxiliary battery charging device for an electric automobile according to a second embodiment of this invention.

Fig. 3 is a structural diagram showing a structural example of a conventional auxiliary battery charging device for an electric automobile.

10	Main battery
16	Motor
20	Auxiliary battery

24	DC-DC converter
34, 52, 56	Keyswitches
36	Voltage detection amplifier
40	Feedback circuit
42	Pulse circuit
46	DC-DC converter controller
48	Comparator
50	Transistor

⑲日本国特許庁（JP）　⑪特許出願公告

⑫特許公報（B2）　平5－64531

(51)Int.Cl.^{5}　識別記号　庁内整理番号　㉔㊹公告　平成5年(1993)9月14日
H 02 J 7/00　303 C　9060－5G
　R　9060－5G

発明の数 1 （全5頁）

(54)発明の名称　電気自動車の補機バッテリー充電装置

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㉒出　願　昭59(1984)9月20日　㊸昭61(1986)4月18日

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審査官　吉村　博之

(57)特許請求の範囲

1　車両の補機系に接続される相互に並列な補機バッテリーおよびDC－DCコンバータと、

該DC－DCコンバータの上記補機バッテリー接続端とは反対端に接続される主バッテリーとを備える電気自動車の補機バッテリー充電装置において、

前記主バッテリーに充電が実行されていることを検出する充電時検出手段と、

該充電時検出手段が充電時であることを検出したとき、前記DC－DCコンバータの前記車両の補機系および補機バッテリーに接続される出力の電圧値を降下させる電圧降下手段と、
を備えたことを特徴とする電気自動車の補機バッテリー充電装置。

発明の詳細な説明

［産業上の利用分野］

本発明は、電力を利用して走行する電気自動車において、その動力源である電動機に電力を供給する主バッテリーから、該電気自動車のワイパー、前照燈やコントロール装置等の補機系へ電力を供給する補機バッテリーへの充電を行う電気自動車の補機バッテリー充電装置に関する。

［従来技術］

従来、電気自動車も通常の内燃機関を備えた自動車同様に、ワイパー、前照燈や各種のコントロール装置等の電源となる補機バッテリーを搭載しており、駆動力源となる電動機の電源である主バッテリーの高電圧直流源からDC－DCコンバータを介して充電されるように構成されている。これにより補機バッテリーは、自動車の補機系へ常に電力を供給するとともに、従来の内燃機を備えた自動車の補機バッテリーがオルタネータを介して充電されると同様の電力供給を受けることができるのである。

［発明が解決しようとする問題点］

しかしながら上記のごときDC－DCコンバータを有する電気自動車の補機バッテリー充電装置は、下記する点で未だに充分なものとはいえなかつた。

即ち、低電圧の補機バッテリーにう電力を供給するために、高電圧の主バッテリーはDC－DCコンバータを介することで補機バッテリーの端子電圧よりも僅かに高い電圧に変圧されてその電力を補機バッテリーに伝送するのである。これにより補機バッテリーは常に充電を受けることができ、補機バッテリーが同時に負荷へ電力を供給しているときにはこの状態で補機バッテリーの充・放電は平衡して所期目的が達成できる。

しかし、車両が停車中であるときなど補機バッテリーの負荷が軽い状態では、補機バッテリーへと充電電圧がその端子電圧よりも高いため過充電の可能性があつた。車両が一時的に停車するときなど補機バッテリーの軽負荷状態が短い時間であれば補機バッテリーが過充電にまで至ることはないのであるが、主バッテリーの充電時には通常数

時間以上の長い時間を要し、この状態が持続されると補機バッテリーは過充電によるエネルギー損失を生じ、またガス発生による液減り等補機バッテリーの性能の劣化を招来するのである。

［問題点を解決するための手段］

本発明は、上記問題を解決するためになされたものであり、主バッテリー充電中であつても補機バッテリーに過充電を発生することなく、エネルギーの有効利用を図り、かつ補機バッテリーの性能劣下の生じることのない優れた電気自動車の補機バッテリー充電装置を提供することをその目的としている。

この目的達成のための本発明の構成は、第１図の基本的構成図に示すごとく、

車両の補機系に接続される相互に並列な補機バッテリーⅡおよびDC−DCコンバータⅢと、

該DC−DCコンバータⅢの上記補機バッテリー接続端とは反対端に接続される主バッテリーⅣとを備える電気自動車の補機バッテリー充電装置において、

前記主バッテリーⅣに充電が実行されていることを検出する充電時検出手段Ⅴと、

該充電時検出手段Ⅴが充電時であることを検出したとき、前記DC−DCコンバータⅢの前記車両の補機系Ⅰおよび補機バッテリーⅡに接続される出力の電圧値を降下させる電圧降下手段Ⅳとを備えたことを特徴とする電気自動車の補機バッテリー充電装置をその要旨としている。

［作用］

本発明の充電時検出手段とは、主バッテリーに充電が施されていることを検出するものである。従つて、車両の充電用のコンセントに外部の電源からの接続端子が接続されたとき、機械的スイッチが開閉するようにして検出するもの、あるいは主バッテリーの電流の流出、流入の方向を電気的に検出するもの、どのような構成であつてもよい。

また、電圧降下手段とは、上記充電時検出手段の主バッテリーが充電中であるとの検出結果に基づき、補機バッテリーの両端子間へ印加される主バッテリーの電力変換手段であるDC−DCコンバータ出力の電圧を、補機バッテリーの開放端子電圧近くまで降下させるものである。電圧の降下方法としては、DC−DCコンバータとして使用される電気回路に応じて最適の方法とすればよく、例えばパルス幅制御（以下PWMという）インバータ式コンバータであれば電力を伝える期間のパルス幅を短くする等の方法で簡単に達成できる。

以下、本発明をより具体的に説明するため実施例を挙げて詳述する。

［実施例］

第２図は本発明の電気自動車の補機バッテリー充電装置を搭載した電気自動車の一実施例回路ブロック図である。

図において１０が補機バッテリー充電装置を、２０が主バッテリー充電装置を表わしている。

補機バッテリー充電装置１０は、図示のごとく主バッテリー１１と、その主バッテリー１１の電力を補機バッテリー１２および補機系負荷１３へ変圧整流して供給するDC−DCコンバータ１４とを備えている。また、１５は充電コンセントで、後述する充電装置２０の充電プラグ２１が差し込まれると充電装置２０と主バッテリー１１とを電気的に接続するとともに内蔵する２接点型のスイッチ１６を切換える。このスイッチ１６とは、充電プラグ２１が充電コンセント１５に挿着された状態でｂ接点が閉成すると同時に他方の接点ａを開放し、逆に充電プラグ２１が引き抜かれると接点ａを閉成して接点ｂを開放するように操作される。１７はダイオード、１８はオペレーショナル・アンプ（以下、OPアンプという）をそれぞれ表わしており、スイッチ１６との組み合わせにより前述のDC−DCコンバータ１４の出力をフイードバックしてその出力電圧VOを制御している。DC−DCコンバータ１４のPWM制御部１４Ａは、このOPアンプ１８の出力電圧VPとその内部に有する基準電圧VBとを比較して、DC−DCコンバータ主回路１４Ｂを制御することによりDC−DCコンバータ１４の出力電圧VOを制御するのである。

充電装置２０は、商用電源２２の電力を主バッテリー充電に適した電圧に変圧し、整流したものを充電プラグ２１へ出力する充電器２３とから構成されるものである。

以上のごとく構成される本実施例の補器バッテリー充電装置１０は以下のように作動する。

まず、通常の作動状態にあり、充電装置２０と補機バッテリー充電装置１０とが分離されている

ときについて説明する。このとき、スイッチ16はa接点が閉成しており、OPアンプ18の非反転入力端子には実際のDC−DCコンバータ14の出力電圧VOよりもダイオード17の順方向電圧降下VD分だけ小さな電圧が入力されることになり、OPアンプ18の出力VPは電圧VD分だけ減少する。即ち、PWM制御部14Aの基準電圧VBと比較されるOPアンプ18の出力VPが減少するため、PWM制御部14AはDC−DCコンバータ主回路14Bをその出力電圧VOが上昇するべく作動させ、内部の基準電圧VBとDC−DCコンバータ14の出力電圧VOからダイオード17の電圧降下分VDを差し引いた値（VO−VD）とが一致するようにする。このときのDC−DCコンバータ14の出力電圧VO(＝VB＋VD）は補機バッテリー12の開放端子電圧より高く、通常状態の補機系負荷13の電力を充分に供給するとともに補機バッテリー12を充電できる程度の電位である。

一方、充電装置20と補機バッテリー充電装置10とが充電プラグ21、充電コンセント15によつて接続されるとき、即ち車両が停車中で補機系負荷13が軽いときには、スイッチ16のa接点が開放され、換つてb接点が閉成されるため補機バッテリー充電装置10は次のように作動する。

それまで、a接点を介して電圧VDだけ電圧降下したDC−DCコンバータ14の出力電圧VOを入力していたOPアンプ18の非反転入力端子は、一転してダイオード17を介さずして直接DC−DCコンバータ14の出力電圧VOを入力することとなる。従つて、OPアンプ18の出力も同様に電圧がVDだけ上昇するのである。これによりPWM制御部14Aはその内部の基準電圧VBよりもDC−DCコンバータ14の出力電圧VOが電圧VDだけ上昇したかのごとく作動し、DC−DCコンバータ14の出力電圧VOを電圧VDだけ降下させ、基準電圧VBと出力電圧VOとが等しくなるように、即ちVB＝VOとなるようにDC−DCコンバータ主回路14を制御する。

このときのDC−DCコンバータ14出力電圧VO(＝VB）が、主バッテリー11の充電中であり軽い状態の補機系負荷13に電力を供給するとともに、補機バッテリー12の端子電圧より僅かに高い電圧で補機バッテリー12を過充電にまで至らせることのない程度の電圧となるように予めPWM制御部の基準電圧VBが設定されるのである。

即ち、本実施例の補機バッテリー充電装置10は、補機系負荷13が重い状態である通常時には従来と同様に主バッテリー11からの電力を充分に補機系負荷13および補機バッテリー12へ供給するために補機バッテリー12の開放端子電圧よりも高い電圧に変圧している。これにより、補機バッテリー12は補機系負荷13が大電力を消費しているにも拘らず充電されることになる。

一方、車両が充電中になるとき、即ち補機系負荷13が軽くなり主バッテリー11の電力のほとんど全てが補機バッテリー12へ供給される状態になるときにはスイッチ16の切換えにより自動的にDC−DCコンバータ14の出力電圧VOはダイオードの順方向電圧降下分VDだけ降下される。その電圧VOは補機バッテリー12の開放端子電圧より僅かに高い状態にまで降下されることになり、補機バッテリー12は過充電されることなく、主バッテリー11の電力を有効利用するとともに補機バッテリー12の液減りや劣化を防止することができるのである。

また、第2図の回路ブロック図に示すごとく、本実施例の補機バッテリー充電装置10は、従来のDC−DCコンバータ14の出力電圧のフイードバック系にスイッチ16、ダイオード17およびOPアンプ18を中心とする簡単な比較回路を付加することだけでその目的を達成できる経済性、作業性に優れた装置となる。

〔発明の効果〕

以上実施例を挙げて詳述したごとく、本発明の電気自動車の補機バッテリー充電装置は、

車両の補機系に接続される相互に並列な補機バッテリーおよびDC−DCコンバータと、

該DC−DCコンバータの上記補機バッテリー接続端とは反対端に接続される主バッテリーとを備える電気自動車の補機バッテリー充電装置において、

前記主バッテリーに充電が実行されていることを検出する充電時検出手段と、

該充電時検出手段が充電時であることを検出したとき、前記DC−DCコンバータの前記車両の補

機系および補機バッテリーに接続される出力の電圧値を降下させる電圧降下手段と、
を備えたことをその要旨としている。

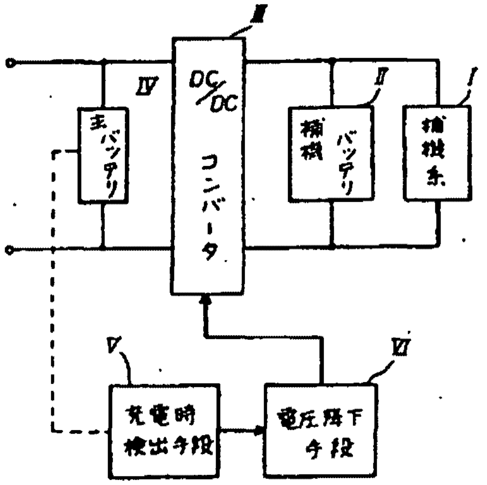
従つて、車両が走行中など通常の負荷状態であれば主バッテリーからの電力はDC－DCコンバータによつて補機バッテリーよりも高い電圧に変圧されて負荷および補機バッテリーに伝送されるので、補機バッテリーは充分に充電を受けることができるとともに高負荷に対処することができる。しかも、車両が充電中となり、負荷が軽い状態となつたことを充電時検出手段が検出すると、電圧降下手段によつて自動的に主バッテリーからの電力供給電圧は補機バッテリーよりも僅かに高い電圧にまで降下されて実行される。これにより、補機バッテリーは主バッテリーからの電力のほとんど全てを供給されるにも拘らず過充電に至ることはなく、主バッテリーの電力の有効利用が達成できることはもちろん、補機バッテリーの過充電による液減り等の性能の劣化を完全に回避できる優れた電気自動車の補機バッテリー充電装置となるのである。

図面の簡単な説明

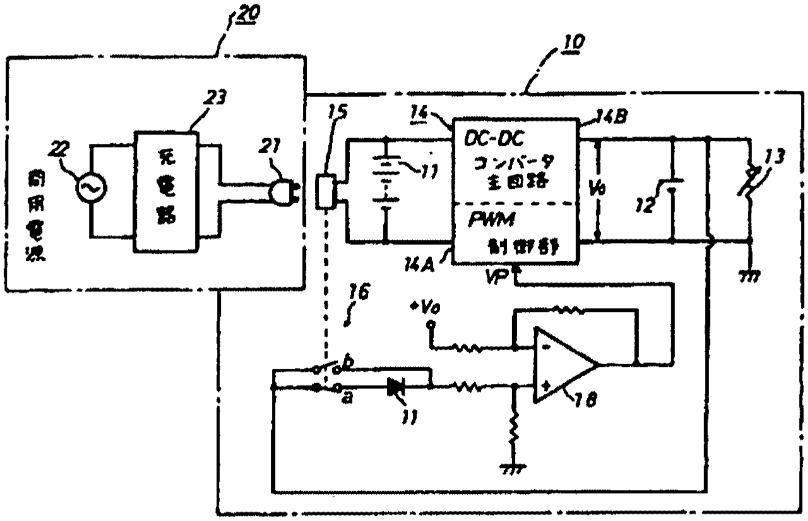
第１図は本発明の基本的構成図、第２図はその一実施例の回路ブロック図を示す。

Ⅰ……補機系、Ⅱ……補機バッテリー、Ⅲ……DC－DCコンバータ、Ⅳ……主バッテリー、Ⅴ……充電時検出手段、Ⅵ……電圧降下手段、１０……補機バッテリー充電装置、１１……主バッテリー、１２……補機バッテリー、１３……補機系負荷、１４……DC－DCコンバータ、１６……スイッチ、１７……ダイオード、１８……OPランプ、２０……充電装置。

第１図



第2図



10…補機バッテリー充電装置
11…主バッテリー
12…補機バッテリー
13…補機負荷
14…DC-DCコンバータ
20…充電装置

CERTIFICATION OF TRANSLATION

I, Christopher Field, a professional Japanese translator accredited by the American Translators Association, hereby attest that the attached translations from Japanese have been faithfully prepared to the best of my ability.

1. JP03-124201
2. JP51-103220
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(54) Title of Invention Accessory Battery Charger for Electric Vehicle

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(57) Scope of Claims

1. An accessory battery charger for an electric vehicle having an accessory battery and a DC-DC converter connected to an accessory system of the vehicle and being parallel with each other, and a main battery connected to an end of the DC-DC converter opposite from the end to which the accessory battery is connected, comprising:

a charge detection means that detects that the main battery is being charged; and

a voltage reduction means which, when the charge detection means detects that charging is underway, reduces the voltage value of the DC-DC converter output connected to the vehicle accessory system and accessory battery.

Detailed Description of the Invention

[Industrial Field of the Invention]

This invention relates to an accessory battery charger for an electric vehicle driven by electric power, which charges electricity from a main battery that supplies electricity to a motor that is the source of motive force, to an accessory battery that supplies electricity to an accessory system, such as wipers, head lamps, and control devices, of the electric vehicle.

[Conventional Art]

Conventionally, like automobiles equipped with an internal combustion engine, electric vehicles have an accessory battery that becomes a power source for wipers, head lamps, various control devices, and the like, and is structured such that the accessory battery is charged through a DC-DC converter from the high voltage, direct current power supply of the main battery, which is the power supply for the motor which constitutes the drive source. As a result, the accessory battery can always supply power to the accessory systems of the vehicle while receiving a supply of power in the same way as a conventional accessory battery in a vehicle equipped with an internal combustion engine is charged via an alternator.

[Problem Solved by the Invention]

However, the accessory battery charger of an electric vehicle having the above-described DC-DC converter was still not sufficient with respect to the following points.

That is, to supply power for a low voltage accessory battery, the high voltage main battery transmits the power to the accessory battery by having the DC-DC converter convert the voltage to one slightly higher than the terminal voltage of the accessory battery. As a result, the accessory battery can be always charged, and when the accessory battery supplies power to the load at the same time, charging and discharging the accessory battery in this condition can be balanced, to achieve the desired operation.

However, when the load of the accessory battery is light, such as when the vehicle is at a stop, there is a possibility of overcharging because the charging voltage on the accessory battery is higher than its terminal voltage. The accessory battery would not be overcharged if the accessory battery light-load state is short in duration, such as when the vehicle is temporarily at a stop. However, charging the main battery normally requires more than a few hours, and if this state is continued, energy losses occur due to the overcharging of the accessory battery, or fluids are lost due to the generation of gases, leading to the deterioration of accessory battery performance.

[Problem Resolution Means]

The present invention was undertaken in order to resolve the above-described problems; its object is to provide a superior electric vehicle accessory battery charging device which achieves effective energy use without overcharging of the accessory battery even during charging of the main battery, and with which no degradation of the accessory battery occurs.

To achieve the object, the essence of the present invention, as shown in the basic structural diagram of Fig. 1, is an accessory battery charger for an electric vehicle having an accessory battery II and a DC-DC converter III connected to an accessory system of the vehicle in parallel with each other, and a main battery IV connected to an end of the DC-DC converter III opposite from the end to which the accessory battery is connected, comprising:

a charge detection means V that detects that the main battery IV is being charged; and

a voltage reduction means IV [sic, Fig. 1 says "VI"] that reduces the value of the voltage output on the DC-DC connector III to which the accessory system I and the accessory battery II are connected when the charge detection means V detects that [the main battery IV] is being charged.

[Operation]

The charge detection means of this invention detects that the main battery is being charged. Therefore it may be any structure, such as one that detects charging when a connection terminal from an external power source is connected to an outlet for charging the battery of the vehicle through the opening or closing of a mechanical switch, or by electrically detecting the direction of incoming or outgoing electric current at the main battery.

Moreover, the voltage reduction means reduces the output voltage of the DC-DC converter, which is the power conversion means for the main battery, that is applied to both terminals of the accessory battery, to a voltage near the open terminal voltage of the accessory battery. This voltage reduction is performed based on a detection result by the above-described charge detection means that the main battery is being charged. An optimal method in accordance with the electric circuit used as the DC-DC converter may be used as the method for decreasing the voltage. This can be easily achieved by a method such as by shortening the pulse width of a period during which electricity is transmitted, if a pulse width modulation (hereinafter called PWM) inverter-type converter is used, for example.

Below the we describe the invention by explaining a detailed embodiment.

[Embodiment]

Fig. 2 is a circuit block diagram showing one embodiment of an electric vehicle equipped with an accessory battery charger for an electric vehicle according to this invention.

In the figure, 10 indicates the accessory battery charger, and 20 indicates a main battery charger.

Below we discuss the present invention in detail, citing embodiments for a more concrete explanation.

The hub 10, as shown in the figure, comprises a main battery 11 and a DC-DC converter 14 which changes the voltage and rectifies power from that main battery 11 and supplies it to the accessory battery 12 and the accessory system load 13. 15 is a charging outlet which electrically connects the charging device 20 and the main battery 11 when the charging device 20 charging plug 21 (described below) is inserted therein, at the same time switching a two contact switch 16. The switch 16 closes contact "b" and simultaneously opens contact "a" when the charging plug 21 is inserted into the charging outlet 15, and conversely closes contact "a" and opens contact "b" when the charging plug 21 is removed. 17 shows a diode, 18 an operational amplifier ("op ampp" below); [these] feed back the output of the above-described DC-DC converter 14 according to their combination with the switch 16, controlling the output voltage V0 thereof. The DC-DC converter 14 PWM control portion 14A compares the output voltage VP from the op ampp 18 with a base voltage VB contained therein, and controls the DC-DC converter 14 output voltage VO by means of controlling the DC-DC converter main circuit 14B.

The charging device 20 comprises a charger 23 which converts and rectifies power from a commercial power supply 22 to a voltage appropriate for charging the main battery and outputs it to the charging plug 21.

The accessory battery charging device 10 comprised as described above operates in the following manner.

First we shall discuss the normal operating state, in which the charging device 20 and the accessory battery charging device 10 are isolated. At this point, contact "a" on the switch 16 is closed, and a voltage which is smaller than the output voltage VO from the actual DC-DC converter 14 by just the voltage drop VD in the forward direction on the diode 17 is input to the non-inverting input terminal of the op amp 18, and the op amp 18 output VP falls by just the voltage VD. That is, because of the reduction in the output voltage VP on the op amp 18, which is compared with the PWM control section 14A base voltage VB, the PWM control section 14A causes the DC-DC converter main circuit 14B to operate in such a way that the output voltage VO thereof rises, and the internal base voltage VB now matches the value (VO-VD), which is the diode 17 voltage decline VD subtracted from the DC-DC converter 14 output voltage VO. The output voltage VO (= VB + VD) from the DC-DC converter 14 at this point is higher than the accessory battery 12 open terminal voltage, and is of enough potential to adequately supply power to the normal state accessory system load 13 as well as charge the accessory battery 12.

At the same time, when the charging device 20 and the accessory battery charging device 10 are connected by the charging plug 21 and the charging outlet 15, which is to say when the accessory system load 13 is light during vehicle stoppage, the switch 16 "a" contact is open and the "b" contact is closed, so that the accessory battery charging device 10 operates as follows.

The op amp 18 non-inverting terminal, to which the DC-DC converter 14 output voltage VO, which had fallen by a voltage VD, was applied via contact "a," now changes, such that the DC-DC converter 14 output voltage VO is output thereto without passing through the diode 17. Therefore the op amp 18 output similarly rises in voltage by VD. As a result, the PWM control section 14A operates as if the output voltage of the DC-DC converter 14 had risen by a voltage VD above its internal base voltage VB, causing the DC-DC converter 14 output voltage VO to fall by the voltage VD, so that the base voltage VB and the output voltage VO are equal – controlling the DC-DC converter 14, in other words, so that VB = VO.

The base voltage VB of the PWM controller is set in advance such that the output voltage VO (=VB) of the DC-DC converter 14 at this time is set to a voltage at a level wherein electricity is supplied to the accessory system load 13 that is lighter than that during the charging of the main battery 11, while it is slightly higher than the terminal voltage of the accessory battery 12 but does not cause the accessory battery 12 to be overcharged.

As in the past, at normal times when the accessory system load 13 is heavy, the accessory battery charging device 10 changes the power from the main battery 11 to a voltage which is higher than that of the accessory battery 12 open terminal voltage so as to sufficiently supply the accessory system load 13 and the accessory battery 12. By so doing, the accessory battery 12 is charged regardless of whether the accessory system load 13 is consuming a large amount of power.

On the other hand, when the vehicle is at a stop, that is, when the accessory system load 13 becomes light and almost all of the electricity from the main battery 11 is supplied to the accessory battery 12, the output voltage VO of the DC-DC converter automatically decreases by the forward voltage decrease VD of the diode due to the switching by the switch 16. Since the voltage VO is decreased to a state slightly higher than the open terminal voltage of the accessory battery 12, the electricity of the main battery 11 can be effectively utilized, and loss of fluid or deterioration of the accessory battery 12 can be prevented without overcharging the accessory battery 12.

As shown in the Fig. 2 circuit block diagram, the accessory battery charging device 10 of the present embodiment is an economically and operationally superior device which can be implemented by the addition of a simple comparator circuit consisting primarily of a switch 16 on a conventional DC-DC converter 14 feedback system, a diode 17, and an op amp 18.

[Efficacy of the Invention]

As described above with reference to the embodiment, the main point of this invention is that the accessory battery charger for an electric vehicle having an accessory battery and a DC-DC converter connected to an accessory system of the vehicle and being parallel with each other, and a main battery connected to an end of the DC-DC converter opposite from the end to which the accessory battery is connected, is comprised of:

a charge detection means that detects that the main battery is being charged; and

a voltage reduction means that reduces a voltage value of an output of the DC-DC connector to which the accessory system and the accessory battery are connected, when the charge detection means detects that [the main battery] is being charged.

Accordingly, because the electricity from the main battery is changed to a voltage higher than the accessory battery by the DC-DC converter and transmitted to the load and the accessory battery under a condition with a normal load, such as when the vehicle is being driven, the accessory battery can be sufficiently charged, and can handle high loads. In addition, when the charge detection means detects that the vehicle is being charged and that the load is light, the voltage of electricity supplied from the main battery is automatically decreased by the voltage reduction means to a voltage slightly higher than the accessory battery. As a result, the accessory battery charger for an electric vehicle [according to this invention] is excellent in that the accessory battery is not overcharged although almost all of electricity from the main battery is supplied thereto, and in that not only the electricity from the main battery can be effectively utilized, but also the deterioration of the accessory battery performance, such as fluid loss, due to overcharging the accessory battery can be entirely avoided.

Brief Description of Drawings

Fig. 1 is a basic structural diagram of this invention, and Fig. 2 is a circuit block diagram of one embodiment.

I...Accessory system; II...Accessory battery, III...DC-DC convert, IV...Main battery, V...Charge detection means, VI...Voltage reduction means, 10...Accessory battery charger, 11...Main battery, 12...Accessory battery, 13...Accessory system load, 14...DC-DC converter, 16...Switch, 17...Diode, 18...OP amp, and 20...Charger.

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公開実用 昭和51—103220

(1,500円)

実用新案登録願

昭和50年2月18日

特許庁長官 斎藤英雄 殿

1. 考案の名称

複合電気自動車の制御装置（フクゴウデンキジドウシャのセイギョソウチ）

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7字加入
6字 消
5字 消

50-021601

明　細　書

1.　考案の名称

複合電気自動車の制御装置

2.　実用新案登録請求の範囲

内燃機関の出力軸がクラッチを介して蓄電池の電力により動作する電動機の回転軸に連結され、前記内燃機関出力軸が発電機に連結されてそこで発電された電力を前記蓄電池に蓄電するようにされ、前記クラッチに油圧を導く油路に電気信号により切換動作するソレノイドバルブが挿入される複合電気自動車において、前記内燃機関出力軸と前記電動機回転軸にそれぞれその回転数を検出する検出器が設けられ、それらの検出器が両者の回転数を比較して電動機回転軸の方が内燃機関出力軸と等しいか、それより大

きい場合に電気信号を発生する比較器に接続され、該比較器の出力側が前記ソレノイドバルブのコイルにその電気信号により切換動作して前記油路を開くように接続され、前記比較器の出力側と前記油路に設けられて前記クラッチに供給される油圧がクラッチ係合油圧に達すると電気信号を発生する油圧スイッチとが、論理回路を介して前記発電機の界磁回路に、それらの比較器と油圧スイッチから共に電気信号が発生すると界磁回路を遮断するように接続されることを特徴とする複合電気自動車の制御装置。

3. 考案の詳細な説明

本考案は内燃機関と直流電動機により車両を駆動する複合電気自動車において、特に走行モード切換時に発電機の界磁電流が遮断される場

令のタイミング制御に関するものである。

近年省資源、大気汚染という社会問題を改善するため提唱された複合電気自動車は、駆動用の内燃機関と電動機および蓄電池を充電する発電機から成り次のような３つの走行モードを有する。即ち第１のモードは車両を電動機のみにより駆動し内燃機関は発電機による発電に使用するもの、第２のモードは車両の駆動を内燃機関のみにより行い発電機による発電と電動機による駆動作用を共に停止するもの、第３のモードは高速走行等の高負荷時のように車両を内燃機関と電動機の両者で駆動し、しかも発電機による発電作用も行うものである。

またこのような走行モードにおいて第１のモードから第２のモードに切換える場合は、内燃

機関と電動機のそれぞれの出力軸回転数が一致したとき、発電機の界磁電流、電動機の駆動電流を遮断すると共に、クラッチを係合して内燃機関の動力を車両駆動軸に伝達するようになつている。しかるにこの場合のクラッチは解放時にピストン室が空の状態になつており、係合時に油圧が供給されてクラッチ板を圧着することにより一体的に結合した状態になる迄には多少時間がかゝる。従つてこのようなクラッチの作動遅れを考慮しないで早めに発電機の界磁電流が遮断されると、内燃機関は一時的に無負荷状態になつて吹き上げ、騒音を発生したり構成部品の耐久性を低下する等の不具合を生じる。また逆に発電機の界磁電流を遮断するタイミングが遅れると、内燃機関は一時的に過負荷の状態

になつて同じような不具合を生じる。

本考案はこのような不具合を解消するもので、内燃機関と電動機の出力軸回転数が一致し、しかもクラッチの油圧が係合を達成する高い値に達した場合に発電機の界磁電流を遮断させる複合電気自動車の制御装置を提供することにある。

以下に本考案を図面の実施例により説明する。第1図により複合電気自動車の駆動系について説明すると、内燃機関1の出力軸2が湿式多板クラッチ型のクラッチ3を介して直流電動機4の回転軸5に連結され、また出力軸2が増速機6を介して発電機7の回転軸8に連結され、発電機7のブラシ側が蓄電池9を介して電動機4の電機子や界磁コイルに電気的に接続され、これらの出力軸2と回転軸5にそれぞれその回転

数を電気的に検出する検出器10，11が設けられる。またクラッチ3のピストン室からの油路12にはソレノイドバルブ13が接続され、そのバルブ13からの油路14に油溜15からポンプ16により汲み上げた油圧を調圧する調圧弁17が接続され、油路12にクラッチ油圧が所定の値に達すると電気信号を発生する油圧スイッチ18が設けられる。

次いで第2図により制御装置について説明すると、前述の回転数検出器10，11が比較器19に接続されて、両回転数の比較により電動機回転軸5の方が内燃機関出力軸2と等しいか、それより大きい場合に電気信号を出力するようになつている。この比較器19の出力側はANDゲート20の一方の入力側、電気信号が入力されると負荷に応じた電動機3の電流制御を解除するモー

タコントローラ21、電気信号が入力されると負荷に応じて内燃機関1の出力を制御させるエンジンコントローラ22およびORゲート23の一方の入力側に接続され、ANDゲート20の他方の入力側に前述の油圧スイッチ18が接続され、ORゲート23の他方の入力側に内燃機関1の出力軸回転数がその始動回転数下限値以下の場合に電気信号を出力する検出器24が接続されている。ANDゲート20の出力側は信号を反転するインバータ25を介してスイッチ用トランジスタ26のベースに接続され、このトランジスタ26のエミッタとコレクタが発電機7の界磁コイル27、バッテリ28、イグニッションスイッチに連動してONになるスイッチ29を介して閉じた回路を形成するように接続されている。更にORゲート23の出力側

は同様にスイッチ用トランジスタ30のベースに接続され、このエミッタとコレクタがソレノイドバルブ13のコイル31、バッテリ32、イグニッションスイッチに連動してONになるスイッチ33を介して閉じた回路を形成するように接続されている。

　このように構成されることにより、内燃機関1の始動時には検出器24からの信号によりトランジスタ30が導通してコイル31を励磁するようになり、このためソレノイドバルブ31が油路12と14を連通してクラッチ3に油圧を供給し係合した状態にする。そこで蓄電池9に蓄電された電力で電動機4が通常のガソリン自動車のスタータのように回転されると内燃機関1も動作しはじめ、それが完全にそれ自身で動作して所定

の回転数に達すると検出器24からは電気信号が出力しなくなる。そのためトランジスタ30は不導通しコイル31が消磁してソレノイドバルブ31は元の遮断状態に戻り、クラッチ3も排油により、解放状態になつて内燃機関出力軸2と電動機回転軸5を遮断する。従つて車両はモータコントローラ21で制御される電動機4の回転軸5のみにより駆動される。一方この場合に油圧スイッチ18からは電気信号が出力しないためインバータ25からの信号によりトランジスタ26は導通し、界磁コイル27に電流が流れて発電機7は発電可能な状態になつており、内燃機関1の出力軸2により増速機6を介して回転軸8と共に電機子が回転されるため、発電機7で発電され第1のモードになる。

次いでこのような第1のモードから第2のモードに切換えられる場合を第3図を用いて説明する。まず(a)の曲線n_5のように負荷に応じて増加する電動機回転軸5の回転数と、曲線n_2のように定速回転する内燃機関出力軸2の回転数が時間t_0で一致すると、比較器19から電気信号が出力する。そのため今度はモータコントローラ21により電動機4の動作は解除されてエンジンコントローラ22により内燃機関1の出力が負荷に応じて制御されるようになり、しかもORゲート23の出力信号で再びトランジスタ30が導通されて前述と同様にクラッチ3に油圧が供給される。しかるに時間t_0直後のようにクラッチ油圧が低く油圧スイッチ18から信号が出力されない場合は、引続いてANDゲート20からも信号が出

力されないため、トランジスタ26が導通状態を保つて内燃機関1により発電機7が発電作用を行つている。そして(c)のように時間t_1でクラッチ油圧が所定の係合油圧P_{00}に達して実質的にクラッチ板を係合するようになると、内燃機関出力軸2が電動機回転軸5と一体的に結合され、車両が内燃機関1によりのみ駆動される。またこのとき油圧スイッチ18から電気信号が出力されANDゲート20からも信号を出力するため、インバータ25によりトランジスタ26は不導通の状態になり(b)のように界磁コイル27へは界磁電流を流さなくなる。そこで発電機7は回転軸8が回転しても発電しなくなつて第2のモードになる。

以上説明したように本考案の制御装置による

と、第1のモードから第2のモードへの切換時に油圧スイッチ18でクラッチ3が完全に係合作用したことを確認して発電機7の界磁電流を遮断し、しかもその遮断動作を電気的に迅速に行うため、既に述べたようなタイミング不良による種々の不具合を完全に除去することができる。

4　図面の簡単な説明

第1図は本考案が適用される複合電気自動車の一例を示す構成図、第2図は本考案の制御装置を示す回路図、第3図の(a)ないし(c)は本考案による第1のモードから第2のモードへの切換時の動作特性を示す線図である。

1－内燃機関、2－出力軸、3－クラッチ、4－電動機、5－回転軸、6－増速機、7－発電機、9－蓄電池、10，11－検出器、12－油路、

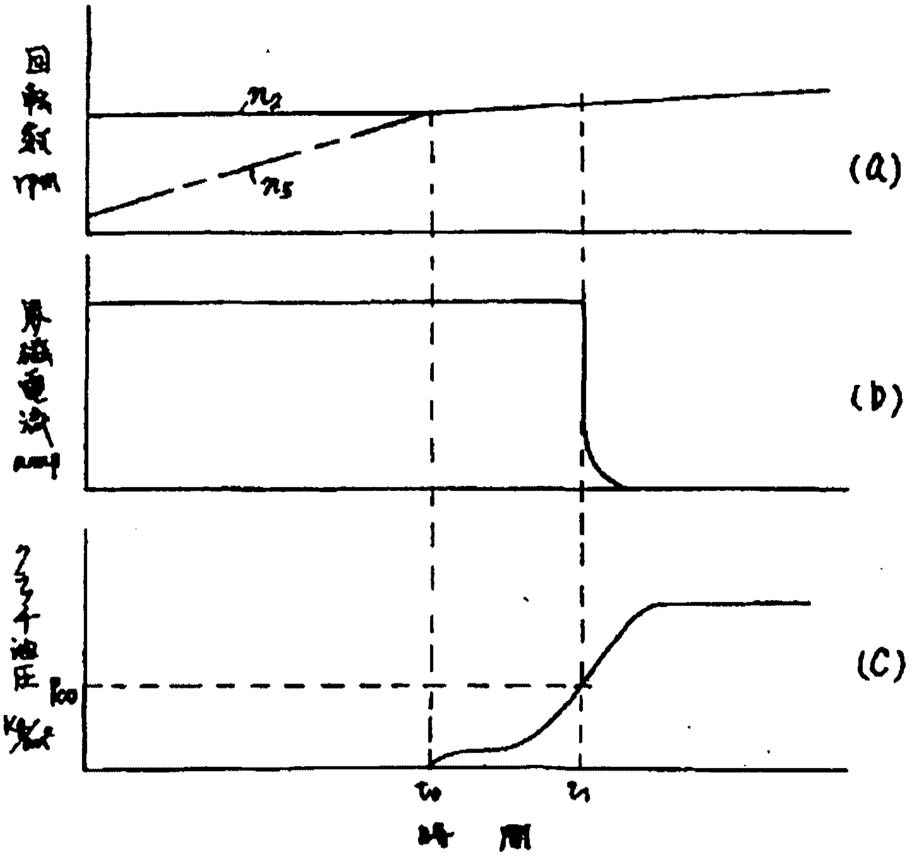
13－ソレノイドバルブ、18－油圧スイッチ、19－比較器、20－ANDゲート、25－インバータ、27－界磁コイル、31－コイル

実用新案
登録出願人　トヨタ自動車工業株式会社

代理人　石山　博

同　中平　治

第3図



1 0 3 2 2 0 2/2

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5. 添附書類の目録

(1) 願書副本 1通
~~( ) 出願審査請求書 1通~~
(2) 明細書 1通
(3) 図面 1通
(4) 委任状 1通
~~( ) 優先権主張書 通~~
~~( ) 優先権証明書及び訳文 各 通~~

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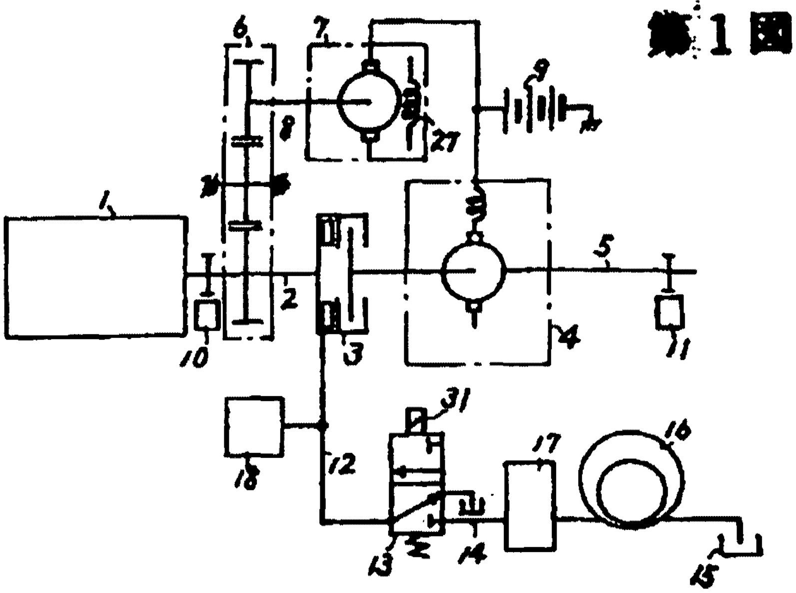
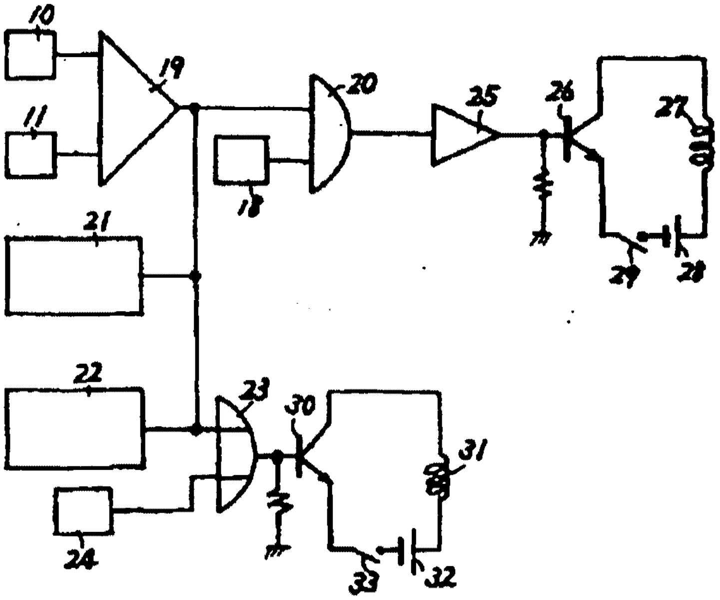
20

第1図



第2図



103220 $\frac{1}{2}$ 実用新案登録出願人 トヨタ自動車工業株式会社
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CERTIFICATION OF TRANSLATION

I, Christopher Field, a professional Japanese translator accredited by the American Translators Association, hereby attest that the attached translations from Japanese have been faithfully prepared to the best of my ability.

1. JP03-124201
2. JP51-103220
3. JP05-64531

Date: May 13, 2004

By: 5/13/04

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Japanese Laid-Open Utility Model Application 51-103220

Laid-Open: August 18, 1976

Filing Date: February 18, 1975

Applicant: Toyota Motor Corporation

SPECIFICATION

1. Title of the Invention

CONTROL DEVICE OF ELECTRIC HYBRID VEHICLE

2. Scope of the Claim

An electric hybrid vehicle in which an output shaft of an internal combustion engine is coupled to a rotation shaft of an electric motor which is operated by electric power of a battery via a clutch, the internal combustion engine output shaft is coupled to an electric generator, electricity generated by the generator is stored in the battery, and a solenoid valve which performs a switching operation in response to an electric signal is inserted in a hydraulic path which conducts hydraulic pressure to the clutch, wherein:

detectors which detect the respective rotation speeds of the internal combustion engine output shaft and the electric motor rotation shaft are respectively provided on the internal combustion engine output shaft and the electric motor rotation shaft, the detectors are coupled to a comparator which compares the respective rotation speeds and generates an electric signal when the rotation speed of the electric motor rotation shaft is equal to or larger than that of the internal combustion engine output shaft, an output side of the comparator is connected to a coil of the solenoid valve so as to open the hydraulic path by performing a switching operation in response to the electric signal, the output side of the comparator and a hydraulic pressure switch which generates an electric signal when a hydraulic pressure in the hydraulic path and supplied to the clutch reaches a clutch engagement hydraulic pressure are connected to a field circuit of the electric generator via a logic circuit so as to cut the field circuit when electric signals are generated from both the comparator and the hydraulic pressure switch.

3. Detailed Description of the Invention

This invention relates to an electric hybrid vehicle for driving a vehicle by an internal combustion engine and a direct current electric motor, and particularly to timing control when a field current of an electric generator is cut at the time of switching [between] travel modes.

Electric hybrid vehicles have been proposed in recent years in order to address the societal problems of diminishing fuel resources and air pollution, have an internal combustion engine and an electric motor for driving, and a generator for charging a battery, and have the following three modes. The first mode is a mode in which the vehicle is driven only by the electric motor, and the internal combustion engine is used for generating electricity via the generator. The second mode is a mode in which the vehicle is driven only by the internal combustion engine, and generation of electricity by the generator and driving by the electric motor are stopped. The third mode is a mode in which, at times of high load such as at high-speed travel of the vehicle, the vehicle is driven by both the internal combustion engine and the electric motor, and generation of electricity is also performed by the electric generator.

In these travel modes, when switching from the first mode to the second mode, when the output shaft rotation speed of the internal combustion engine and the output shaft rotation speed of the electric motor match, the field current of the generator and the drive current of the electric motor are cut, the clutch is engaged, and the motive force of the internal combustion engine is transmitted to the vehicle drive shaft. Therefore, in this case, when the clutch is released, the piston chamber is in an empty state, and at the time of engagement it takes some time before an integrated coupling state is accomplished by the supply of hydraulic pressure and pressure-engagement of the clutch plate. . Thus, if the field current of the electric generator is cut off early without considering this operational delay of the clutch, there are problems such as that the internal combustion engine will temporarily be in a non-load state and will rev up, generating noise, reducing component part durability, etc. Furthermore, if the timing of cutting the field current of the electric motor is delayed, the internal combustion engine will temporarily be in an excess load state, and the same type of problem will occur.

This invention is to solve this type of problem, and seeks to provide an electric hybrid vehicle control device which cuts the field current of an electric generator when an internal combustion engine rotation speed and an output shaft rotation speed of an electric motor match and the hydraulic pressure of the clutch has reached the high value at which engagement is achieved.

The following explains an embodiment of this invention with reference to the figures. According to Fig. 1, with respect to a drive system of an electric hybrid vehicle, an output shaft 2 of an internal combustion engine 1 is coupled to a rotation shaft 5 of a direct current electric motor 4 via a wet type multi-plate clutch 3. The output shaft 2 is coupled to a rotation shaft 8 of an electric generator 7 via a step-up gear 6. A brush side of the electric generator 7 is electrically connected to the armature, field coil, etc. of the electric motor 4 via a battery 9, and detectors 10, 11, which electrically detect the respective rotation speeds, are respectively disposed on the output shaft 2 and the rotation shaft 5. Furthermore, a solenoid valve 13 is connected to a hydraulic path 12 from a piston chamber of the clutch 3, and a pressure valve 17 which adjusts the hydraulic pressure [of hydraulic fluid] pumped by a pump 16 from a hydraulic fluid reservoir

15 is connected to a hydraulic path 14 from the valve 13. A hydraulic pressure switch 18 is provided which generates an electric signal when the clutch hydraulic pressure in the hydraulic path 12 reaches a predetermined value.

The following explains a control device with reference to Fig. 2. The rotation speed detectors 10, 11 are connected to a comparator 19, and an electric signal is output when the rotation speed of the electric generator rotation shaft 5 is equal to or larger than that of the internal combustion engine output shaft 2 according to the rotation speed comparison. The output side of this comparator 19 is connected to one input side of an AND gate 20, a motor controller 21 which releases an electric current control of the electric motor 3 according to load when an electric signal is input, an engine controller 22 which controls the output of the internal combustion engine 1 according to load when an electric signal is input, and one input side of an OR gate 23. The hydraulic pressure switch 18 is connected to the other input side of the AND gate 20. A detector 24 which outputs an electric signal when the output shaft rotation speed of the internal combustion engine 1 is a starting rotation speed minimum value or less is connected to the other input side of the OR gate 23. The output side of the AND gate 20 is connected to a base of a switching transistor 26 via an inverter 25 which inverts a signal. The emitter and collector of this transistor 26 are connected so that a closed circuit is formed via a field coil 27 of the electric generator 7, a battery 28, and a switch 29 which turns on together with the ignition switch. Additionally, the output side of the OR gate 23 is connected to the base of a switching transistor 30 in the same manner. The emitter and the collector of this transistor 30 are connected so that a closed circuit is formed via a coil 31 of the solenoid valve 13, a battery 32, and a switch 33 which turns on together with the ignition switch.

Thus, when the internal combustion engine 1 is started, the transistor 30 is made conductive by a signal from the detector 24, and the coil 31 is energized. Therefore, the solenoid valve 31 [sic. 13] connects the hydraulic paths 12 and 14, hydraulic pressure is supplied to the clutch 3, and the clutch 3 is engaged. Then, when the electric motor 4 is rotated by the electric power stored in the battery 9 as with a normal gasoline vehicle starter, the internal combustion engine 1 also begins to operate. When the internal combustion engine 1 is operates completely on its own and reaches a predetermined rotation speed, an electric signal is no longer output from the detector 24. Because of this, the transistor 30 becomes non-conductive, the coil 31 is de-energized, the solenoid valve 31 returns to the original cut-off state, the clutch 3 is placed in a released state due to evacuation of hydraulic fluid, and the internal combustion engine output shaft 2 and the electric motor rotation shaft 5 are disconnected. Therefore, the vehicle is driven by only the rotation shift 5 of the electric motor 4 controlled by the motor controller 21. Meanwhile, in this case, an electric signal is not output from the hydraulic pressure switch 18, so the transistor 26 is made conductive by a signal from the inverter 25, electric current flows through the field coil 27, and the electric generator 7 is in a state in which electricity can be generated. An armature is rotated by the output shaft 2 of the internal combustion engine 1 along with the rotation shaft 8 via the step-up gear 6, so the first mode is attained, in which electricity is generated by the electric generator 7.

Next, switching the mode from the first mode to the second mode is explained with reference to Fig. 3. First, if the rotation speed of the armature rotation shaft 5, which increases according to load as shown in curve n_5 of Fig. 3(a), and the rotation speed of the internal combustion engine output shaft 2, which is rotated at a constant speed as shown in curve n_2, match in a time t_0, an electric signal is output from the comparator 19. Because of this, the operation of the electric motor 4 is now released by the motor controller 21, and the output of the internal combustion engine 1 is becomes controlled by the engine controller 22 in accordance with load. Additionally, the transistor 30 is again made conductive by the output signal of the OR gate 23, and hydraulic pressure is supplied to the clutch 3 in the same manner as described before. Therefore, as at the time immediately after time t_0, if clutch hydraulic pressure is low and a signal is not output from the hydraulic pressure switch 18, a signal is also not output from the AND gate 20, so the transistor 26 keeps a conductive state, and the electric generator 7 generates electricity by means of the internal combustion engine 1. Additionally, as shown in Fig. 3(c), if the clutch hydraulic pressure reaches a predetermined engagement hydraulic pressure P_{C0} in a time t_1 and the clutch plate is substantially engaged, the internal combustion engine output shaft 2 is integrally coupled to the electric motor rotation shaft 5, and the vehicle is driven by only the internal combustion engine 1. In addition, at this time, an electric signal is output from the hydraulic pressure switch 18 and a signal is output from the AND gate 20, so the transistor 26 will be in a non-conductive state because of the inverter 25, and the field coil 27 ceases to conduct a field current, as shown in Fig. 3(b). Therefore, the electric generator 7 does not generate electricity even though the rotation shaft 8 is rotated, and the second mode is entered.

Thus, according to the control device of this invention, at the time of switching from the first mode to the second mode, it is confirmed by the hydraulic switch 18 that the clutch 3 is completely engaged, and the field current of the electric generator 7 is cut. Additionally, this cutting operation is electrically performed promptly, so it is possible to completely eliminate various problems due to the above-described timing failures.

4. Brief Description of the Drawings

Fig. 1 is a structural view showing an embodiment of an electric hybrid vehicle to which this invention is applied.

Fig. 2 is a circuit diagram showing a control device of this invention.

Figs. 3(a)-(c) are line diagrams showing operation characteristics at the time of switching from a first mode to a second mode according to this invention.

1.	Internal combustion engine
2.	Output shaft
3.	Clutch
4.	Electric motor
5.	Rotation shaft
6.	Step-up gear
7.	Electric generator
9.	Battery
10, 11	Detectors
12.	Hydraulic path
13.	Solenoid valve
18.	Hydraulic pressure switch
19.	Comparator
20.	AND gate
25.	Inverter
27.	Field coil
31.	Coil

(2,000円)

特　許　願（特許法第38条ただし書の規定による特許出願）

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特許庁長官　井土武久殿

1. 発明の名称

複合電気自動車用ギヤトレーン

2. 特許請求の範囲に記載された発明の数　3

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明　細　書

1　発明の名称

複合電気自動車用ギヤトレーン

2　特許請求の範囲

1　内燃機関からの入力軸、少くも3個の摩擦係合部材、結合可能な4個の要素を少くも有する遊星歯車装置及び出力軸から成るギヤトレーンに於て、前記遊星歯車装置の才1の要素が才1の摩擦係合部材を介して前記入力軸に連結され、才2の要素が前記出力軸に連結され、才3の要素が才2、才3の摩擦係合部材と発電機にもなり得る才1の直流電動機とに連結され、才4の要素が発電機にもなり得る才2の直流電動機に連結され、更に前記2個の直流電動機が電力の供給と受入れを可能に蓄電池と接続され、もつて内燃機関または直流電動機による単独の動力伝達と両者の組合わせによる動力伝達を可能に構成されたことを特徴とする複合電気自動車用ギヤトレーン。

2　前記2個の直流電動機が前記遊星歯車装置へ作用を及ぼさないように空転状態にされて、前記内燃機関の動力が前記摩擦係合部材の選択的な係合により前記遊星歯車装置へ与えられ、これにより前記出力軸に機関動力による少くも2段の変速比が得られることを特徴とする特許請求の範囲才1項記載の複合電気自動車用ギヤトレーン。

3　前記内燃機関の作動が停止されると共に、前記才3の摩擦係合部材の係合及び前記才1

の直流電動機の停止により前記遊星歯車装置のオ3の要素の回転が拘束されて、前記オ2の直流電動機の動力が前記オ4の要素に与えられ、これにより前記出力軸に電気動力による定められた変速比の前進速と後進速が得られることを特徴とする特許請求の範囲オ1項記載の複合電気自動車用ギヤトレーン。

4　前記内燃機関の動力がトルク制御されながら前記オ　の摩擦係合部材の係合を介して前記遊星歯車装置に与えられると共に、前記2個の直流電動機の動力が減速または増速制御されながら前記遊星歯車装置に与えられ、これにより前記出力軸に零からオーバドライブにわたる範囲の連続的な無段変速が得られ、且つ車両走行中に於て一方の直流電動機により前記蓄電池が充電され、電気動力により機関動力の負担の一部分を軽減するように調整されることを特徴とする特許請求の範囲オ1項記載の複合電気自動車用ギヤトレーン。

3　発明の詳細な説明

本発明は動力源にガソリン内燃機関と蓄電池を備えた電動機とを用いた複合電気自動車用ギヤトレーンに関するものである。

近年ガソリンエンジンを搭載した自動車の排気ガスによる大気汚染が、都市の稠密化とモータリゼーションの進展と共に大気中に拡散して無害化しきれずに蓄積し、直接人体に害になりまたは特殊な汚染物質が蓄積しあい地形や気象的に拡散を妨げる逆転層の現象条件と組合わさつて有害な作用をすることが明白な事実となつて現われ、現代文明の矛盾として問題化してきた。そこでこのような自動車排気ガスによる汚染防止対策として、行政上都市内の自動車の走行状態と一酸化炭素の排出量との関係により交通規制や立体交叉等の交通、道路対策がとられ、同時に排気ガス中の一酸化炭素、炭化水素、窒素酸化物、固体微粒子の有害成分の排出規制を強化する環境基準が制定されつゝある。このため自動車側に於ては、低汚染車と称してエンジンを改良し且つ排気ガスの浄化装置を開発して排気ガス中の有害成分の排出量を一定値以下に抑え、またはガスタービンエンジンや電池を備えた電動機等の無公害原動機を搭載した無公害車の開発が提案されているが、いずれもまだ一部の特殊用途車を除いて世界的に開発途上にあるのが現状と言える。

しかしこのような自動車の原動機に関する革命的な改善は優れた人間の英智と終りのない技術革新により順次その姿を現わすものと考えられるが、この究極の目的に向うワンステップとして少くもすでに人間の社会生活を脅かしている都市内での排気ガス公害を軽減する必要がある。

本発明の目的はガソリン内燃機関と蓄電池を備えた電動機とを搭載して複合電気自動車を構成し、これらの単独と両者の組合わせにより駆動して大気汚染の状態に応じて排気ガスの排出量を変化しながら走行可能なギヤトレーンを得ることにある。

以下に本発明を図面の実施例により説明する。

才1図に本発明の複合電気自動車用ギヤトレーンの一例が示され、才2図に才1図に於ける自動変速機構の具体的な実施例が示されており、これらの図に於てケース1は内部に変速機構を有し外部に電動機構を夫々有する。このようなケース1の内部に於て、ガソリン内燃機関2からの入力軸3は才1のクラッチ4のクラッチドラム5と才2のクラッチ6のクラッチハブ7に連結され、才1のクラッチ4のクラッチハブ8が才1の中間軸9を介して遊星歯車装置20の才1のサンギヤ21に連結され、才2のクラッチ6のクラッチドラム10が才2の中間軸11を介してその才2のサンギヤ22に連結され、更に才2のクラッチ6のクラッチドラム10とケース1との間にブレーキ12が設けられる。遊星歯車装置20は才1、才2のサンギヤ21，22と夫々一体化されて噛合うピニオンギヤ23，24を有し、これらのうちの才1のピニオンギヤ23にリングギヤ25が噛合い、両ピニオンギヤ23，24を支承するキャリヤ26が出力軸13に連結される。また入力軸3と出力軸13とに夫々オイルポンプ14，15が設けられ、これらのオイルポンプ14，15により生じた圧油が油圧制御回路（図示せず）を介してクラッチ4，6とブレーキ12とに選択的に供給され、才1のクラッチ4とブレーキ12に供給されて摩擦係合することにより才1のサンギヤ21の歯数Z_{21}と才2のサンギヤ22の歯数Z_{22}で定まる$1+\frac{Z_{22}}{Z_{21}}$の低速段の減速比が得られ、才1、才2のクラッチ4，6に供給されて摩擦係合することにより直結状態の高速段が得られるようになつている。

このような内燃機関用動力系路に電動機用動力系路が設けられるものであり、遊星歯車装置20の才2のサンギヤ22と一体的な才2の中間軸11及びリングギヤ25に夫々同じピッチ円径の伝達ギヤ30，31が設けられ、これらの伝達ギヤ30，31に回転方向を合せるため中間ギヤ32，33を介して夫々駆動ギヤ34，35が噛合つている。これらの駆動ギヤ34，35は夫々発電機にもなり得る直流電動機36，37を設けており、これらの直流電動機36，37と蓄電池38との間に電力の受渡しを可能に配線39，40が接続され、且つ励磁電流の増減と極性変更を行うコントローラ41，42を備える配線43，44が励磁側に接続されている。こうして才2の直流電動機37に蓄電池38から励磁電流が供給されて駆動ギヤ35を回転し、同時にブレーキ12に圧油が供給されて係合することにより遊星歯車装置20の才2のサンギヤ22の回転を拘束すると、才2のサンギヤ22の歯数Z_{22}、リングギヤ25の歯数Z_{25}、伝達ギヤ31の歯数Z_{31}及び駆動ギヤ35の歯数Z_{35}で定まる$(1+\frac{Z_{22}}{Z_{25}})\times\frac{Z_{31}}{Z_{35}}$の減速比が得られ、直流電動機37のトルクTに対して$(1+\frac{Z_{22}}{Z_{25}})\times\frac{Z_{31}}{Z_{35}}\times T$の出力トルクが取り出される。従つて減速比が一定の状態で、コントローラ42により励磁電流を変化することにより出力トルクの制御が行われ、且つコントローラ42により極性が反対にされることにより出力軸13は逆転して後進車になる。また直流電動機37の特性から、出力軸側より駆動されることにより直流電動機37は発電機として作

用し一種のエンジンブレーキの効果が得られると共に蓄電池38に充電することができるが、コントローラ42により励磁電流を切つてエンジンブレーキのない惰行が可能になる。

以上説明したように構成され且つ内燃機関及び電動機により夫々単独に駆動される本発明のギヤトレーンに於て、更に内燃機関2からの動力が才1のクラッチ4の作動により才1のサンギヤ21に与えられ、同時に直流電動機36または37からの動力が夫々才2のサンギヤ22またはリングギヤ23に与えられる複合駆動について説明する。このとき機関の絞り弁により機関動力の出力トルクが制御され、コントローラ41，42により直流電動機36，37はいずれも電動機または発電機として作動可能にされながらその回転速度を任意の傾きで減速または増速制御する。こうして出力トルク及び回転速度が制御された3個のギヤ21，22，23の組合わせにより、遊星歯車装置20はキヤリヤ24を介して出力軸13に広い変速域にわたる無段変速を出力するが、この場合才3図に示されるように才1の直流電動機36は入力軸3の回転速度の3倍から零に曲線aに沿つて直線的に減速され、才2の直流電動機37は入力軸3の回転速度の0.5倍で逆転した状態から、零を介して正転状態のその約2倍近くに曲線bに沿つて直線的に増加される。その結果出力軸13に入力軸3との回転数比である速度比が、零から才2の直流電動機37の回転が零の場合の0.3、両直流電動機36，37の回転速度が共に入力回転と等しい場合の1.0を経て才1の直流電動機36の回転が零の場合の1.5まで連続して取り出される。またこのような零からオーバードライブにわたる無段変速域に於て、速度比が0.3以下の場合は才2の直流電動機37が、0.3以上の場合は才1の直流電動機36が夫々発電機として動作し、この発電により得られた電気エネルギが蓄電池38に充電されることなくそのまま電動機動作に用いられる。

続く才4図にこの変速動作の速度比全域に於ける入力軸3と出力軸13との馬力の比で表わす効率が示されており、この図に於て機械部分の効率は100%にされ、電気部分の動力伝達効率をパラメータにしてその効率が80%の場合を曲線cで、50%の場合を曲線dで夫々示している。図から明らかのように速度比が約0.4になる迄は効率が急速に上昇し、その速度比以降になると電気部分の動力伝達効率が半分以下にならない限り80%以上確保し、曲線cの場合はほとんど100%に近い高効率を維持している。更に才5図に於ては電気部分の動力伝達効率に対し、出力軸13が停止している場合に得られるトルク比を表わすストールトルク比の関係が示されており、図から明白のように電気部分の動力伝達効率が0.6位い迄はトルク比の上昇が比較的緩慢であるが、その効率以降は急速に上昇し、車両発進時のような効率が零の場合は大きいトルク比を得ている。なおこのような複合駆動に於て、実施例は発電された電力を充電することなくそのまゝ電動機に用いているが、電気駆動に備えて発電された電力の一部分を車両走行中に於て

蓄電池38に貯えるようにすることも可能であり、急加速時の大トルクを内燃機関2からすべて供給することなくこの方式を用いて蓄電池38から補充することも可能であり、更にコントローラ41，42によりこの場合にも後進速が得られる。

このように通常の内燃機関駆動、電気駆動及び両者の複合駆動の3方式により駆動可能な本発明のギヤトレーンの夫々の使用態様を説明すると、都市内や大気汚染のひどい時間、場所に於ては勿論排気ガスの全く無い電気駆動方式が用いられ、このとき定められた一定の減速比で充分な駆動力を与えられながら走行される。次いで大気汚染が中程度の場合に於ては複合駆動方式が用いられることにより、内燃機関2の負担が蓄電池38からの電力の補充により軽減されて排気ガスの発生が改善され、無段変速により常時最も効率の良い状態で運転可能である。更に完全な郊外のように排気ガスが大気中に充分拡散される場所に於ては内燃機関駆動方式が用いられることにより、2段の変速比を有して充分な加速とレスポンスの良い走行が行われる。

また最後の才6図に於て遊星歯車装置20の他の実施例を前述と同一部分を省略して説明すると、図に於て別個に分割された2個のピニオンギヤ23′，24′が夫々サンギヤ21，22と噛合い、才2のピニオンギヤ23′がキャリヤ27を介して才1の中間軸9に連結され、才1のピニオンギヤ24′を支承するキャリヤ26′が才2のピニオンギヤ23′と噛合する才2のリングギヤ25に連結され、2個のクラッチ8，6とブレーキ12の選択的動作により内燃機関駆動方式に於て、直結とオーバドライブの2種の変速比が得られる。

以上説明したように本発明の複合電気自動車用ギヤトレーンによると、通常の内燃機関駆動方式に加えて、排気ガスの全くない電気駆動方式と排気ガスの発生が著しく減じられる複合駆動方式とを備えており、大気汚染が生じ易い時間や場所を走行する場合のその汚染を排気ガスそのものゝ排出量を減じ、または零にして有効に防止することができ、このとき自動車としての機能が充分に確保されている。また遊星歯車装置20の構成により複合駆動方式に於て電気部分の効率が低くてもギヤトレーン全体の効率は比較的高く、変速域の広い無段変速が得られ、且つ発進時のトルク比が大きいという利点を有する。更に車両走行中に於て蓄電池38を充電できるため、電気自動車で最大の難問題にされている長い充電時間が解消され、且つ各方式に於ける制御動作及び各方式への切換も容易に行われ得る。

4 図面の簡単な説明

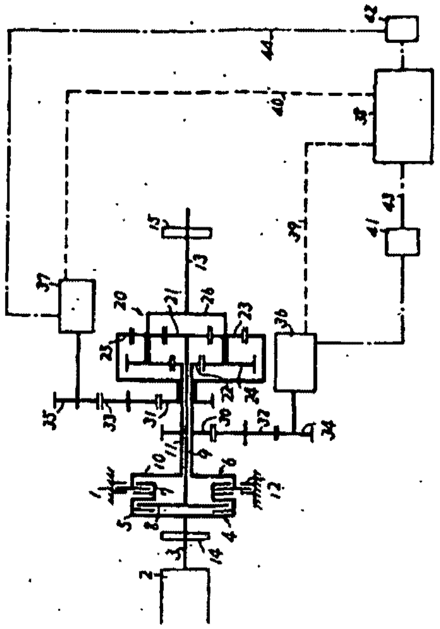
才1図は本発明のギヤトレーンの一例を示す構成図、才2図は才1図に於ける自動変速機構部分の構成を示す縦断面図、才3図は直流電動機の速度比とギヤトレーンの速度比との関係を示す線図、才4図はギヤトレーンの効率とその速度比の関係を電気部分の動力伝達効率をパラメータにして示す線図、才5図はストールトルク比と電気部分の動力伝達効率との関係を示す線図、才6図は本発明のギヤトレーンの他の例

を示す構成図である。

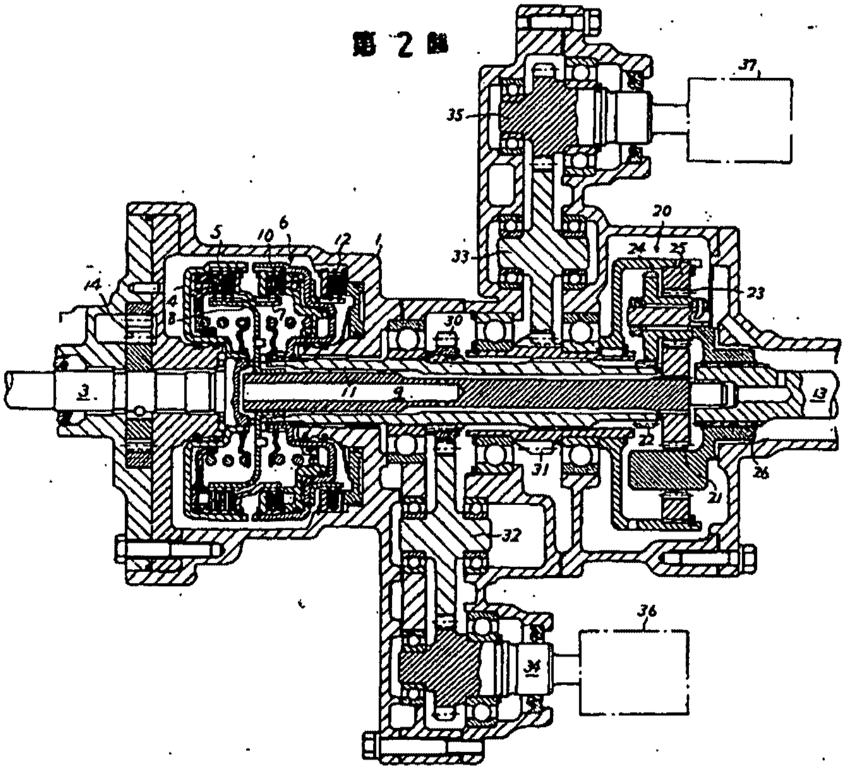
2	内燃機関
3	入力軸
4	才1のクラッチ
6	才2のクラッチ
12	ブレーキ
13	出力軸
20	遊星歯車装置
21	才1のサンギヤ
22	才2のサンギヤ
23	リングギヤ
24	キヤリヤ
36	才1の直流電動機
37	才2の直流電動機
38	蓄電池

(19)

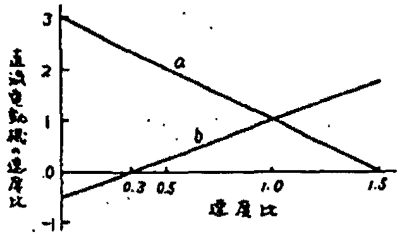
第1図



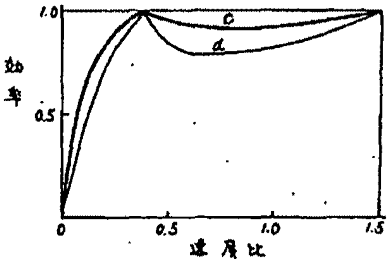
第2図



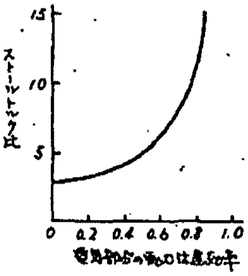
第 3 図



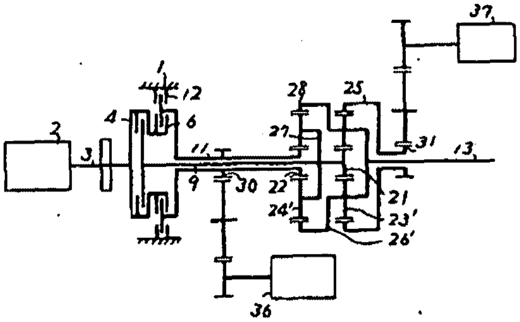
第 4 図



第 5 図



第 6 図



6. 添附書類の目録 /字訂正

(1) 願書副本 1 通
~~( ) 出願審査請求書 1 通~~ /行削除
(2) 明細書 1 通
(3) 図面 1 通
(4) 委任状 / 通
~~( ) 優先権主張書 1 通~~ 2行削除
~~( ) 優先権証明書及び訳文 各 通~~

7. 前記以外の~~発明者、特許出願人および~~代理人 /字訂正 /字削除

~~(1) 発 明 者~~ /行削除

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CERTIFICATION OF TRANSLATION

I, Christopher Field, a professional Japanese translator accredited by the American Translators Association, hereby attest that the attached translations from Japanese have been faithfully prepared to the best of my ability.

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