

Modern Electric, Hybrid Electric, and Fuel Cell Vehicles

Fundamentals, Theory, and Design

Mehrdad Ehsani

Yimin Gao

Sebastien E. Gay

Ali Emadi

 **CRC PRESS**

**DOCKET
ALARM**

Find authenticated court documents without watermarks at docketalarm.com.

Modern Electric, Hybrid Electric, and Fuel Cell Vehicles

Fundamentals, Theory, and Design

Mehrdad Ehsani, Texas A&M University

Yimin Gao, Texas A&M University

Sebastien E. Gay, Texas A&M University

Ali Emadi, Illinois Institute of Technology



CRC PRESS

Boca Raton London New York Washington, D.C.

General Library System
University of Wisconsin - Madison
728 State Street
Madison, WI 53706-1494
U.S.A.

Library of Congress Cataloging-in-Publication Data

Modern electric, hybrid electric, and fuel cell vehicles: fundamentals, theory, and design/Mehrdad Ehsani ... [et al.].

p. cm. - (Power electronics and applications series)

Includes bibliographical references and index.

ISBN 0-8493-3154-4 (alk. paper)

1. Hybrid electric vehicles. 2. Fuel cells. I. Ehsani, Mehrdad. II. Title. III. Series.

TL221.15.G39 2004

629.22'93—dc22

2004054249

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

The consent of CRC Press LLC does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press LLC for such copying.

Direct all inquiries to CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

Visit the CRC Press Web site at www.crcpress.com

© 2005 by CRC Press LLC

No claim to original U.S. Government works

International Standard Book Number 0-8493-3154-4

Library of Congress Card Number 2004054249

Printed in the United States of America 1 2 3 4 5 6 7 8 9 0

Printed on acid-free paper

8

Parallel Hybrid Electric Drive Train Design

CONTENTS

8.1	Control Strategies of Parallel Hybrid Drive Train.....	261
8.1.1	Maximum State-of-Charge of Peaking Power Source (Max. SOC-of-PPS) Control Strategy	262
8.1.2	Engine Turn-On and Turn-Off (Engine-On-Off) Control Strategy	265
8.2	Design of Drive Train Parameters	266
8.2.1	Design of Engine Power Capacity.....	266
8.2.2	Design of Electric Motor Drive Power Capacity.....	268
8.2.3	Transmission Design	271
8.2.4	Energy Storage Design	272
8.3	Simulations	274
	References	276

Unlike the series hybrid drive train, the parallel hybrid drive train has features that allow both the engine and traction motor to supply their mechanical power in parallel directly to the driven wheels. The major advantages of parallel configuration over a series configuration are (1) generator is not required, (2) the traction motor is smaller, and (3) multi-conversion of the power from the engine to the driven wheels is not necessary. Hence, the overall efficiency can be higher.⁵ However, the control of the parallel hybrid drive train is more complex than that of a series hybrid drive train, due to the mechanical coupling between the engine and the driven wheels.

There are several possibilities for configurations in a parallel hybrid drive train, as mentioned in Chapter 5. But the design methodology for one particular configuration may be not applicable to other configurations and the design result for a particular configuration may be applicable for only a given operation environment and mission requirement. This chapter will focus on the design methodology of parallel drive trains with torque coupling, which operate on the electrically peaking principle; that is, the engine supplies its power to meet the base load (operating at a given

constant speed on flat and mild grade roads, or at the average of the load of a stop-and-go driving pattern) and the electrical traction supplies the power to meet the peaking load requirement. Other options, such as a mild hybrid drive train, are discussed in Chapter 9.

The base load is much lower than the peaking load in normal urban and highway driving, as mentioned in Chapter 5. This suggests that the engine power rating is lower than the electrical traction power rating. Due to the better torque-speed characteristics of the traction motor compared to the engine, the single-gear transmission for the traction motor might be the proper option. Thus, this chapter will focus on the design of the drive train as shown in Figure 8.1.

The design objectives are:

1. To satisfy the performance requirements (gradeability, acceleration, and maximum cruising speed)
2. To achieve high overall efficiency
3. To maintain the battery state-of-charge (SOC) at reasonable levels in the whole drive cycle without charging from outside the vehicle
4. To recover the brake energy.

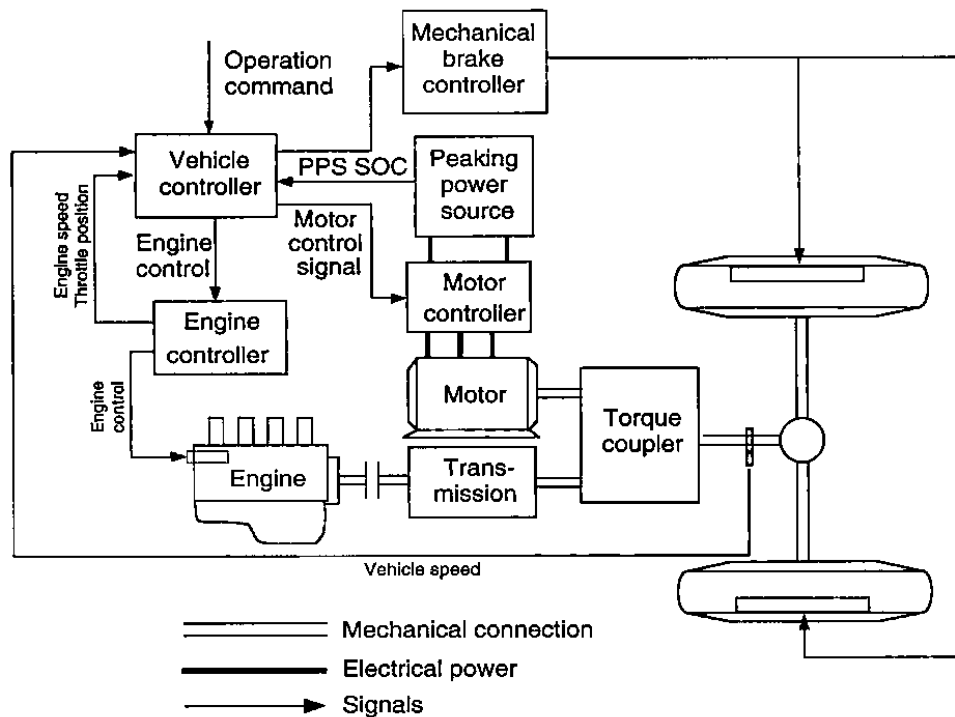


FIGURE 8.1 Configuration of the parallel torque-coupling hybrid drive train

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.