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Power Management Strategies for Hybrid Electric Vehicles

Mohamed R. El- Sharkawy[1] and Nouby M. Ghazaly[2]

[1]Automotive and Tractor Engneering Dept., Faculty of Engineering, Minia University,
El-Minia 61111, Egypt
elsharkawy44@gmail.com

[2]Mechanical Engineering Dept., Faculty of Engineering, South Valley University,
Qena-83523, Egypt
nouby.ghazaly@eng.svu.edu.eg

Abstract: Recently, a hybrid electric vehicle have been widely studied because of their potential to significantly improve fuel economy, reduce emissions and give a good performance by combining a smaller than normal engine with electric motors and an energy storage system. Due to the multiple-power-source nature, the complex configuration and operation modes, the control strategy of a hybrid vehicle become more complicated than that of an engine-only vehicle. The overall objective of this paper is to define power management strategies for hybrid electric vehicles and to control the power management that determines the proper power split between the motor and the engine in order to minimize fuel consumption and emissions.
Keywords: Hybrid vehicles, power management, control strategy.

1. Introduction

Hybrid vehicles are inherently more complicated and expensive than conventional vehicles. The reason for developing them is that it is- possible to make them, in some aspect, better than conventional vehicles. Today, the focus is on environmental impact and better is often defined as lower emissions and lower fuel consumption. Other considerations are that the vehicles should be as easy to handle as conventional vehicles and that they don't require a whole new infrastructure for fuel distribution [1:6].
For the reason that of the variations in hybrid electric vehicle (HEV) configurations, different power control strategies are necessary to regulate the power flow to and from different components. These control strategies aim to satisfy a number of goals for hybrid electric vehicles (HEVs) namely; maximum fuel economy, minimum emissions, minimum system cost, and good driving performance, while satisfying constraints such as drivability, charge sustaining and component reliability [7:12]. Hybrid vehicles can be "assembled" in different ways, referred to as hybrid architectures. The most common architectures are series, parallel, series-parallel and complex hybrid power control [13:18]. In the following sections the details of each type will be discussed.

2. Series Hybrid Power Control

In the series hybrid system, the power flow control can be illustrated by four operating modes, as shown in Figure 1. During startup, normal driving or acceleration of the series hybrid electric vehicles, both the engine (via the generator) and battery deliver electrical energy to the power converter, which then drives the electric motor and, hence, the wheels via the transmission, as shown in Figure 1 (a). At light load, the engine output is greater than that required to drive the wheels, so the generated electrical energy is also used to charge the battery until the battery capacity reaches a proper level, as shown in Figure 1 (b). During braking or deceleration, the electric motor acts as a generator which transforms the kinetic energy of the wheels into electricity, as shown in Figure 1 (c). In addition to, the battery can be charged by the engine via the generator and power converter, even when the vehicle comes to a complete stop, as shown in Figure 1 (d). For example, a similar power flow control system has been applied to the Toyota Coaster Hybrid Electric Vehicle.

Corresponding Author: Nouby M. Ghazaly

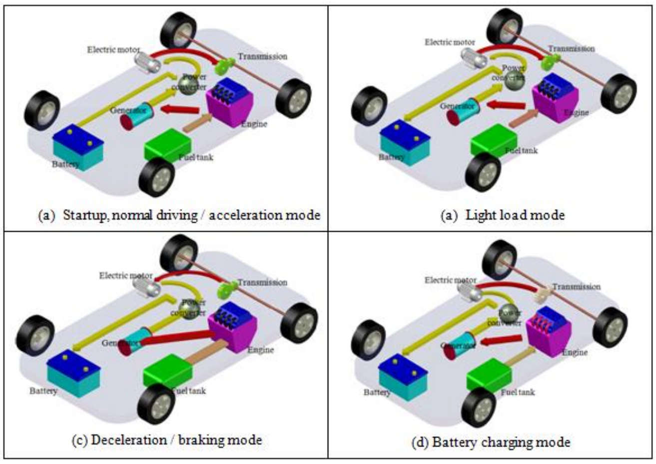

Figure 1: Series hybrid electric vehicle operating modes.

3. Parallel Hybrid Power Control

There are four operating modes of the parallel hybrid electric vehicle (HEV) as shown in Figure (2). During startup or full-throttle acceleration, both the engine and electric motor proportionally share the required power to motivate the vehicle. Typically, the relative distribution between the engine and the electric motor is 80% to 20%, as shown in Figure 2 (a). During normal driving, the engine solely supplies the necessary power to propel the vehicle, while the electric motor remains in the off mode, as shown in Figure 2 (b). During braking or deceleration, the electric motor acts as a generator to charge the battery via the power converter, as shown in Figure 2 (c). Since both the engine and electric motor are coupled to the same drive shaft, the battery can be charged by the engine via the electric motor when the vehicle is at light load, as shown in Figure 2 (d). For example, a similar power flow control system has been applied to the Honda Insight Hybrid Electric Vehicle.

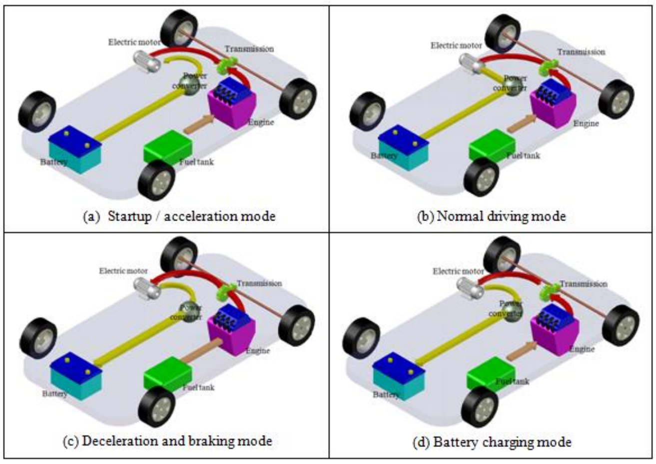

Figure 2: Parallel hybrid electric vehicle operating modes.

4. Series - Parallel Hybrid Power Control

The series-parallel hybrid system involves the features of series and parallel hybrids. Thus, there are many possible operating modes to perform its power flow control. Basically, they can be identified in two groups namely: Engine – Heavy mode and Electric – Heavy mode. The engine-heavy one denotes that the engine is more active than the electric motor for series parallel hybrid propulsion, whereas the electric-heavy one indicates that the electric motor is more active. Figure (3) shows the Engine-Heavy series-parallel hybrid system, in which there are six operating modes.

At startup, the battery solely provides the necessary power to propel the vehicle, while the engine is in the off mode, as shown in Figure 3 (a). During full throttle acceleration, both the engine and electric motor proportionally share the required power to propel the vehicle, as shown in Figure 3 (b). During normal driving, the engine solely provides the necessary power to propel the vehicle, while the electric motor remains in the off mode, as shown in Figure 3 (c). During braking or deceleration, the electric motor acts as a generator to charge the battery via the power converter, as shown in Figure 3 (d). For battery charging during driving, the engine not only drives the vehicle but also the generator to charge the battery via the power converter, as shown in Figure 3 (e). When the vehicle is at a standstill, the engine can maintain driving the generator to charge the battery, as shown in Figure 3 (f). For example, a similar power flow control system has been applied to the Nissan Tino Hybrid Electric Vehicle.

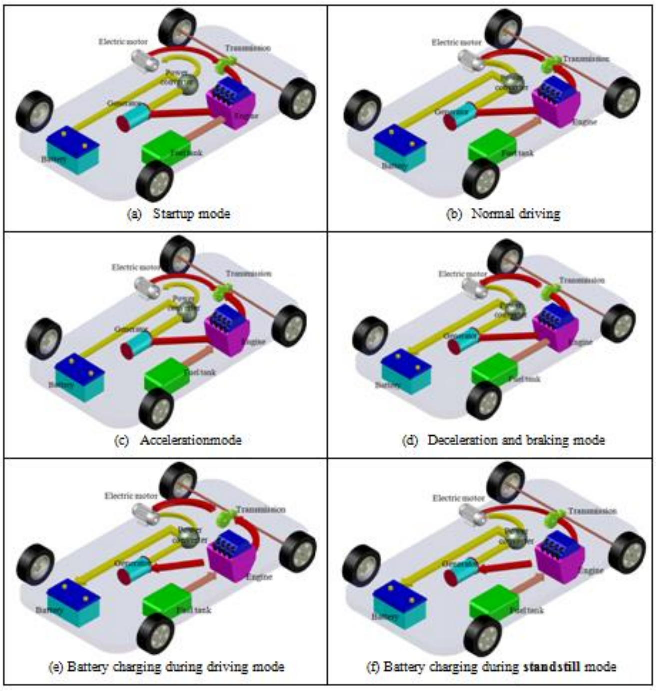

Figure 3: Series - parallel hybrid electric vehicle operating modes (Engine – Heavy operating mode).

On the other hand, Figure (4) shows a relatively electric-heavy series-parallel hybrid system, in which there are six operating modes. During startup and driving at light load, the battery solely feeds the electric motor to propel the vehicle, while the engine is in the off mode, as shown in Figure 4 (a). For both full throttle acceleration and normal driving, both the engine and electric motor work together to propel the vehicle, as shown in Figure 4 (b). The key difference is that the electrical energy used for full throttle acceleration comes from both the generator and battery, whereas that for normal driving is solely from the generator driven by the engine, as shown in Figure 4 (c). Notice that a planetary gear is usually employed to split the engine output, hence to propel the vehicle and to drive the generator. During braking or deceleration, the electric motor acts as a generator to charge the battery via the power converter, as shown in Figure 4 (d). In addition, for battery charging during driving, the engine not only drives the vehicle, but also the generator to charge the battery, as shown in Figure 4 (e). When the vehicle is at a standstill, as shown in Figure 4 (f) the engine can maintain driving the generator to charge the battery [5]. For example, a similar power flow control system has been applied to the Toyota Prius Hybrid Electric Vehicle.

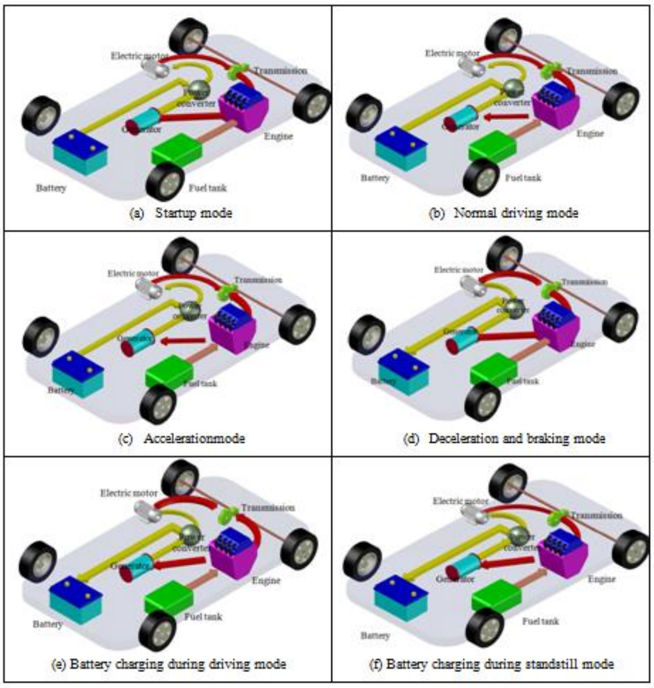

Figure 4: Series - parallel hybrid electric vehicle operating modes (Electric – Heavy operating mode).

5. Complex Hybrid Power Control

The development of complex hybrid control has been focused on the dual axle propulsion system for hybrid electric vehicles. In this system, the front wheel axle and rear wheel axle are separately driven. There is no propeller shaft or transfer to connect the front and rear wheels, so it enables a more lightweight propulsion system and increases the vehicle packaging flexibility. Moreover, regenerative braking on all four wheels can significantly improve the vehicle fuel efficiency and, hence, the fuel economy. Firstly, The complex hybrid system can be divided into two basic modes, in the first mode the front wheel axle is propelled by a hybrid drive train, and the rear wheel axle is driven by an electric motor, and in the second mode the front wheel axle is driven by an electric motor, and the rear wheel axle is propelled by a hybrid drive train. Figure (5) illustrates the first mode of dual axle complex hybrid system, where the front wheel axle is propelled by a hybrid drive train, and the rear wheel axle is driven by an electric motor. There are six operating modes. During startup, the battery delivers electrical energy to feed both the front and rear electric motors to individually propel the front and rear axles of the vehicle, whereas the engine is in the off mode, as shown in Figure 5 (a). For full throttle acceleration, both the engine and front electric motor work together to propel the front axle, while the rear electric motor also drives the rear axle, as shown in Figure 5 (b). Notice that this operating mode involves three propulsion devices (one engine and two electric motors) to propel the vehicle simultaneously. During normal driving and battery charging, the engine output is split to propel the front axle and to drive the electric motor, which works as a generator to charge the battery, as shown in Figure 5 (c). The corresponding device to couple the engine mechanically, front electric motor and front axle altogether, is usually based on a planetary gear. When driving at light load, the battery delivers electrical energy to the front electric motor only to drive the front axle, whereas both the engine and rear electric motor are off, as shown in Figure 5 (d). During braking or deceleration, both the front and rear electric motors act as generators simultaneously to charge the battery, as shown in Figure 5 (e). A unique feature of this dual axle system is the capability of axle balancing, as shown in Figure 5 (f). In case the front wheels slip, the front electric motor works as a generator to absorb the change of engine output power. Through the battery, this power difference is then used to drive the rear wheels to achieve axle balancing. Recently, the Toyota Post-Prius HEV system, termed THS-C, has adopted this power flow control.

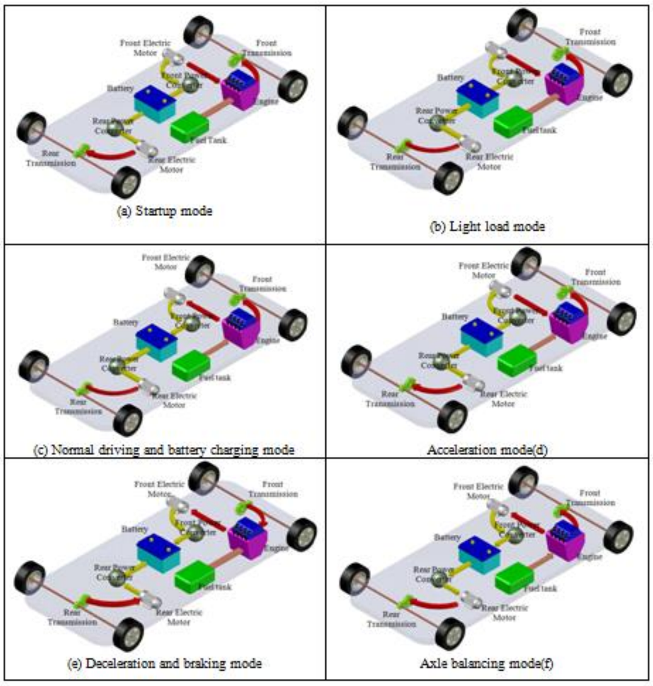

Figure 5: Dual axle complex hybrid electric vehicle operating modes (front - hybrid drive train, and the rear - electric motor).

On the other hand, Figure (6) shows another dual axle complex hybrid system, where the front wheel axle is driven by an electric motor, and the rear wheel axle is propelled by a hybrid drive train, which have six operating modes. During startup, the battery delivers electrical energy only to the front electric motor, which, in turn, drives the front axle of the vehicle, whereas both the engine and rear electric motor are off, as shown in Figure 6 (a). Once the vehicle moves forwards, the battery also delivers electrical energy to the rear electric motor, which functions quickly to increase the engine speed, thus starting the engine, as shown in Figure 6 (b). For full throttle acceleration, the front electric motor drives the front axle, while both the engine and rear electric motor work together to propel the rear axle. Therefore, there are three propulsion devices (one engine and two electric motors) simultaneously propelling the vehicle, as shown in Figure 6 (c). During normal driving, the engine works alone to propel the rear axle of the vehicle, as shown in Figure 6 (d). During braking or deceleration, both the front and rear electric motors act as generators simultaneously to charge the battery, as shown in Figure 6 (e). For battery charging during driving, the engine output is split to propel the rear axle and to drive the rear electric motor, as shown in Figure 6 (f), which works as a generator to charge the battery [5]. Finally, the GM Precept HEV has adopted this power flow control system.

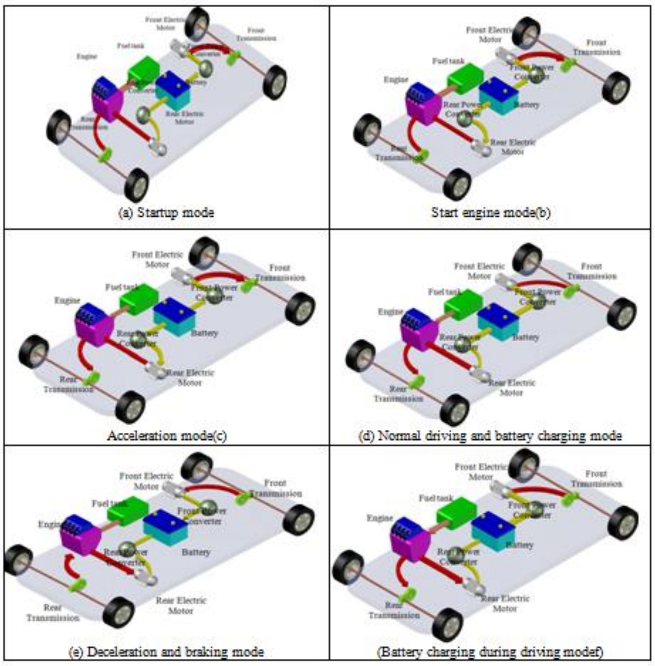

Figure 6: Dual axle complex hybrid electric vehicle operating modes (front - electric motor, and the rear hybrid drive train).

6. Conclusions

The main reason for doing research on hybrid vehicles is to make them better than conventional vehicles. A design method for the power management control algorithm for hybrid electric vehicles is developed by many researchers. The driver power demand is modeled as process to represent the future of the driver power request under various driving conditions. Control of power management in hybrid vehicle has been studied with different methods to obtain optimal driving conditions and to make the losses in the system as small as possible. The present work provides some insight into the optimal source of power in hybrid vehicles using power management technique. Moreover, using the previous power management strategies improve fuel economy, reduce emissions and give a good driving performance.

References

[1] Mikhail Granovskii, Ibrahim Dincer, Marc A. Rosen, " Economic and environmental comparison of conventional, hybrid, electric and hydrogen fuel cell vehicles", Journal of Power Sources, ELSEVIER, 2005.

[2] Essam M. M. Allam, Nabil M. Hammad, Ahmad A. A. Saad, and Shawki A. Abouel-Seoud, "A Small City Series Hybrid Electric Vehicle: Performance Evaluation", EET-2007 European Ele-Drive Conference, Brussels, Belgium, May 30 – June 01, 2007.

[3] Behnam Ganji and Abbas Z. Kouzani, " A Study on Look-ahead Control and Energy Management Strategies in Hybrid Electric Vehicles ", 2010 8th IEEE International Conference on Control and Automation Xiamen, China, June 9-11, 2010.

[4] Mohamed Mourad, " Improving the Performance of a Hybrid Electric Vehicle by Utilization Regenerative Braking Energy of Vehicle” International journal of energy and environment, Volume 2, Issue 1, pp.161-170, 2011.

[5] J. V. Mierlo, P. V. den Bossche, and G. Maggetto, “Analysis of hybrid drivetrain power management strategies in the view of dual use applications,” in 5th International AECV Conference, France, 2 - 5 June 2003.

[6] B. K. L. Rahman Z. and E. M., “A comparison study between two parallel hybrid control concepts,” in SAE 2000 World Congress, March 6-9 2000.

[7] N. Schouten, M. Salman, and N. Kheir, “Fuzzy logic control for parallel hybrid vehicles,” Control Systems Technology, IEEE Transactions on, vol. 10, no. 3, pp. 460–468, May 2002.

[8] K.T. Chau, Y.S. Wong, "Overview of Power Management in Hybrid Electric Vehicles", Energy Conversion and Management 43, 1951968, Hong Kong, China, 2001.

[9] Kevin j. Martin, "Plug-In Hybrid Electric Vehicle Control Strategies Utilizing Multiple Peaking Power Sources", Master of Applied Science, Windsor, Ontario, Canada, 2010.

[10] Iqbal Husain, "Electric and Hybrid Vehicles, Design Fundamentals", Book, Boca Raton London New York Washington, D.C, Published in the Taylor & Francis e-Library, 2005.

[11] Travis de Fluiter, "Design of Lightweight Electric Vehicles", thesis of Master degree, Hamilton, New Zealand, March 2008.

[12] Feng An, Anant Vyas, John Anderson, and Danilo Santini, "Evaluating Commercial and Prototype HEVs", SAE 2001 World Congress Detroit, Michigan, 2001.

[13] Fathollah Ommi, Golnaz Pourabedin, and Koros Nekofa, " Evaluation of Model and Performance of Fuel Cell Hybrid Electric Vehicle in Different Drive Cycles", International Journal of Applied Science, Engineering and Technology Vol. 5, No.4, 2009.

[14] Jan H. J. S. Thijssen, J. P. Mello, and J. R. L.inna, "Cost Competitiveness of Fuel Cell Vehicles Through

Novel Hybridization Approaches", 2003 SAE, World Congress Detroit, Michigan, 2003.

[15] Do Yang Jung, Baek Haeng Lee, Sun Wook Kim, "Development of battery management system for nickel-metal hydride batteries in electric vehicle applications", Journal of Power Sources 109 (2002) 1–10, Korea, January 2002.

[16] Musardo, C., Rizzoni, G., Guezennec, Y., Staccia, B., 2005. A-ECMS: an adaptive algorithm for hybrid electric vehicle energy management. European Journal of Control 11 (4–5), 509.

[17] Gong, Q., Li, Y., Peng, Z.R., 2008b. Trip-based optimal power management of plug-in hybrid electric vehicles. Vehicular Technology, I EEE Transactions on 57 (6), 3393–3401.

[18] Borhan, H.A., Vahidi, A., Phillips, A.M., Kuang, M.L., Kolmanovsky, I.V., 2009. Predictive energy management of a power-split hybrid electric vehicle. American Control Conference, ACC'09.IEEE, p. 3970.

Author Profile

Nouby M. Ghazaly is an assistant Professor in Department of Mechanical Engineering, South Valley University, Egypt. He received his BSc and MSc from Department of Automotive and Tractor Engineering, Minia University, Egypt in 1999 and 2003, respectively. He obtained his PhD from AU-FRG Institute for CAD/CAM, Faculty of Mechanical engineering, Anna University, India in 2011. He has to his credit a book and more than 35 research papers in refereed journals and international conferences in the areas of vehicle dynamics, noise and vibrations and Computer Aided Design. He is a member of Editorial Board and a Reviewer of several international journals and conferences. He is serving as a consulting engineer of ATALON for testing and consulting engineers, India since 2010.