Advanced Science and Technology Letters
Vol.58 (Electrical Engineering 2014), pp.125-128
http://dx.doi.org/10.14257/astl.2014.58.27

Study on Power Control Algorithm for Torque Assist System

Gyoung-eun Kim[1] , Jae-woo Yoon[1], Byeong-woo Kim[2,*]

[1] Graduate School of Electrical Engineering, University of Ulsan, 93 Daehak-ro, Ulsan, Republic of Korea
gyg509@gmail.com , jaewoo127@naver.com
[2] School of Electrical Engineering, University of Ulsan, 93 Daehak-ro, Ulsan, Republic of Korea
bywokim@ulsan.ac.kr

Abstract. This paper presents a power control algorithm that will make it possible to apply a torque assist system (TAS) without reconfiguring the structure of an internal combustion engine (ICE) vehicle. The proposed algorithm considers the states of the motor starter generator (MSG) and energy storage, as well as the maximum efficiency of the engine. To optimize the engine efficiency under various driving conditions, the algorithm implements the gradient method of optimization technique. The use of the proposed algorithm will contribute to the research in this field by controlling the performance of the engine and MSG at efficient operating points to match the driver's demand outputs.

Keywords: Hybrid vehicle, torque assist system (TAS), Optimal control theory, Gradient method

1 Introduction

In recent years, the automotive industry has been expanding their support for and investment in the production of high-efficiency environmentally friendly vehicles because of the depletion of fossil fuels and tightened environmental regulations. Research is currently being conducted on hybrid vehicles, which reduce the load of the internal combustion engine by attaching an electric motor to the existing system, thereby achieving high energy efficiency [1].

The existing research has only focused on the conditions of the electric power source and energy storage device used in a hybrid vehicle to increase the fuel efficiency [2]. Therefore, research is required on power distribution control, which considers the conditions of all the power sources, including the electric power source and energy storage device.

This paper proposes a power control method for a hybrid system that applies the gradient method, which is one of the optimal control theories.

* Corresponding Author

ISSN: 2287-1233 ASTL

2 Power Control of Torque Assist System

As shown in Fig.1, the torque assist system (TAS) is an optimal system that replaces the conventional integrated starter alternator (ISA) to support the load of the vehicle engine based on the high-power-density motor starter generator (MSG) [3]. In order to apply the TAS, a power control algorithm must be developed for the vehicle to implement the optimal torque assist to increase fuel efficiency and functionality during driving.

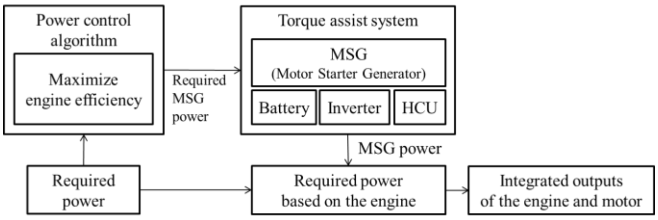

Fig. 1. Schematic diagram of a power control algorithm based on the TAS.

2.1 Efficiency Map of Power Source

Engine efficiency can be calculated using the fuel efficiency measure brake specific fuel consumption (BSFC), as shown in formula (1) [4]. Here, the value of 0.0122225 was applied to lower heating value (LHV) under the assumption that it is a gasoline engine. The efficiency of the motor can also be calculated using its output energy and energy loss, as shown in formula (2). An efficiency map of the engine and motor based on these calculations is shown in Fig.2 [5].

$$\eta_{engine} = 1/(BSFC \times LHV) \quad \textbf{(1)}$$

$$\eta_{MSG} = \frac{P_{MSG}}{P_{MSG} + W_{loss}} \times 100 \quad \textbf{(2)}$$

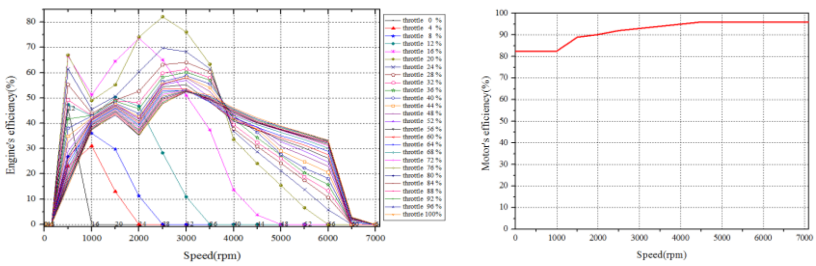

Fig. 2. Efficiency map of the engine and motor

2.2 Optimal Control Algorithm

In the optimal control strategy algorithm, the required output of the vehicle is determined based on the input from the accelerator pedal. The final output of the engine based on the required output is determined by the auxiliary output of the MSG in consideration of the maximum engine efficiency. In order to find the engine's optimal point of efficiency, the gradient method is applied, which is one of the optimal control theories [6].

As shown in Fig.3, assuming that the efficiency of the engine based on its speed and the driver's required output has a constant value of level c_k ($k = 0, 1, 2, \ldots$), multiple level sets can be constructed by connecting the corresponding values. The level set of the engine's efficiency value is calculated based on the vehicle's driving conditions, and the maximum value of $f(x - t\nabla f(x))$, which is a function of engine efficiency, is calculated by repeating the process shown in formula (5).

$$x^{(k)} = x^{(k-1)} - t_k \nabla f(x^{(k-1)}) \qquad k = 1,2,\ldots \tag{3}$$

When the maximum engine efficiency is determined, MSG provides torque assistance within the appropriate efficiency range to allow the engine efficiency to reach its maximum point. The results for the engine's maximum efficiency point based on the driving conditions, as calculated using this method, are shown in Fig.4.

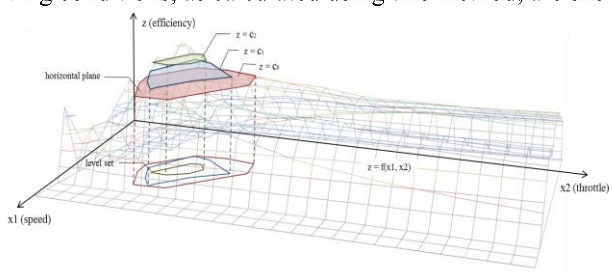

Fig. 3. Constructing level set corresponding to level c_k ($k = 0, 1, 2, \ldots$) for engine efficiency function f.

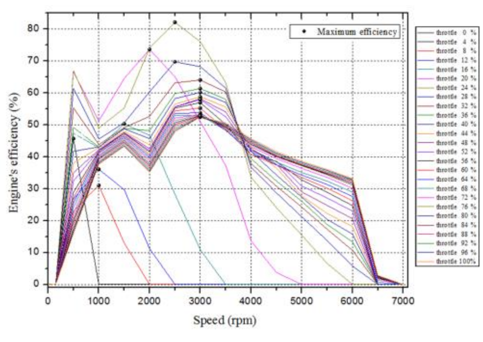

Fig. 4. Required power based on engine and maximum of engine efficiency.

3 Conclusion

This study proposed a power control method that enables the application of a TAS without changing the structure of a conventional internal combustion engine. The gradient method was used to find the maximum engine efficiency based on the driving conditions. By utilizing the proposed control method, the engine and electric power source can be controlled to operate at an efficient operating point based on the driver's required output. Furthermore, the results of this study are expected to contribute to hybrid vehicle power control studies that consider the overall efficiency of the vehicle. In future research, we plan on analyzing the vehicle's entire output torque through the power control algorithm, which takes into account the efficiencies of the two power sources.

Acknowledgments. Foundation item: This research was supported by the MSIP(Ministry of Science, ICT & Future Planning), Korea, under the C-ITRC(Convergence Information Technology Research Center) support program (NIPA-2013-H0401-13-1008) supervised by the NIPA(National IT Industry Promotion Agency).

References

1. Mehra, R., Davis, R.: A generalized gradient method for optimal control problems with inequality constraints and singular arcs. In: IEEE Trans. Automat. Contr. 17, pp. 69--79 (1972)
2. Fayazi, S. A., Farhangi, S., Asaei, B.: Fuel consumption and emission reduction of a mild hybrid vehicle. In: 34th Annu. Conf. IEEE Ind. Electron., pp. 216–221 (2008)
3. D'Alessandro, D.: Application of Microprocessor to Fuel Measurement System. In: IEEE Trans. Ind. Electron. IE-30, pp. 164—170 (1983)
4. Hangiu, R., Filip, A., Martis, C. S., Biro, K. A. Performance assessment of an integrated starter alternator for hybrid electric vehicles. In: Int. Conf. Expo. Electr. Power Eng. pp. 70—75 (2012)
5. Inkyo Choi, Hyeongjin Ham, H. L.: A Study on the Supervisory Algorithm considering Performance Deterioration for Series Hybrid Electric Vehicle. In: The Korean Society of Automotive Engineers, pp. 1049—1057 (2013)
6. Seungjae Yun, K. Y.: Comparative Study of Power Management Strategies for Series Hybrid Electric Vehicle. In: The Korean Society of Mechanical Engineers, pp. 945--950 (2011)

