

Development of Combined Control Unit for Hybrid Electric Vehicle

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Jeong Soo Eo, Youn Kwang Jung, Dae Ro Park and Chung Hi Lee
Hyundai-Kia R&D Center

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ABSTRACT

The main objective of the combined control unit is to develop a cost effective and optimal control system that manage the proper torque distribution and minimize the loss of communication delay caused by individual inter-controller cooperative control.

The control systems of the Hybrid Electric Vehicle (HEV) are more complicated than conventional vehicle. The major difference of HEV has Power Electronics (PE) system. The control systems of PE-part in the HEV are consisted with Hybrid Control Unit (HCU), Motor Control Unit (MCU) and Battery Management System (BMS) individually.

In this study, the controllers of PE system are combined into one PCB (1Board-1Micom). Vehicle-testing and dynamometer-testing results confirm that the combined control unit achieves approximately 45% cost and 47% weight reduction compare to the non-combined (Individual controllers) same hybrid vehicle.

INTRODUCTION

As vehicle development is becoming rapidly electronicalize, the number of electronic control units that are attached in the vehicles is increasing in an exponential manner. As the electronic control units increase in number, vehicle package problem are issued increasingly. Moreover, Cooperative Control is made more difficult due to the difference in the software structure by each electronic control unit. Moreover, development of each control unit have different platform, It brings the cost increasing of development. To overcome this problem, the global vehicle industry is focusing heavily on the combined configuration of the electronic control unit and development of standard software for vehicle. With the Japanese vehicle industry in the front, combination of the

electronic control unit is continuously investigated by getting classified into the system groups (power train, body, multimedia, safety etc.). This research focuses on integrating and configuring Power Electronics (PE) related controller among the hybrid vehicle controller that is being developed at our company. Integrated target controller includes hybrid vehicle controller (Hybrid control unit), Motor Control Unit, Battery Management System etc.

This journal is comprised as follows.

1. Our company's Combined Control Unit configuration measure is decided after analyzing the hybrid vehicle controller development trend.
2. Controller development process and engineering data management system (EDM) are developed for the development of decided Combined Control Unit development.
3. As for the combined target controller, HCU, MCU and BMS controller are combined in a sequential manner in line with the AutoSar specs.
4. HILS and Vehicle Test are conducted based on the verification and validation (V&V) standard for each stage (TDP) and conclusion is drawn out through final evaluation.

MAIN TEXT

2.1. TREND FOR THE DEVELOPMENT OF CONTROLLER FOR HYBRID VEHICLE

When the controller for each controller is combined into one controller, stability in controlling may be secured due to the decrease in the communication interface among the controllers. Optimal controller design is possible, and effects such as increase in the control's precision level and improve in the drivability may be expected.

Control Unit configuration, each company is adopting different combination structure depending on the combination strategy and location for attachment.

In case of the Company A, structure that combines the Hybrid Control Unit (HCU) and Motor Control Unit (MCU) like Fig.1 is adopted. This is the structure that is suitable for many cases compared to the Company B when it comes to the amount of motor used as the source of power. Of course, this is a structure where reduction in the vehicle's vibration through the Cooperative Control and Reaction force control with the motor is favorable. In case of A, however, there are instances in which Engine Control Unit (ECU) is combined instead of the Motor Control Unit combination when Motor Control Unit increases (at least three) Motor Control Unit.

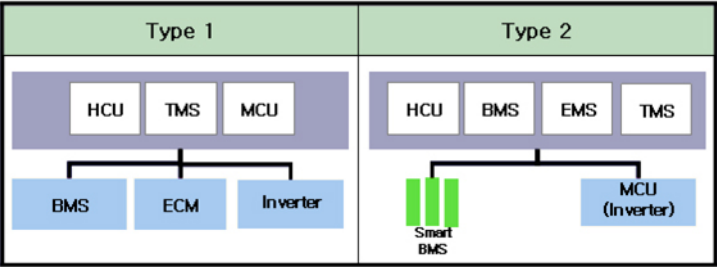


Fig.1. Combined Control Unit for A-Company

In case of the Company B, Hybrid Control Unit (HCU) and Engine Control Unit (ECU) are combined as shown on Fig. 2. This is a structure that is appropriate when the amount of use for the engine is considerable compared to the Company A. Power Electronics (PE) and PowerTrain (PT) is separated. Thus, this is a structure that is easy for the Fail Safety.

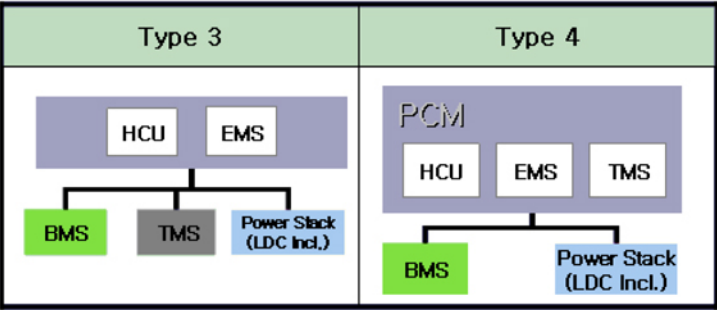


Fig.2. Combined Control Unit for B-Company

This research aims to combine the PE system controller as a means of combining that can assure ease of motor Cooperative Control and robustness of the Fail Safety, which are the strengths of each company. From our company's strategic aspect, combination with the PT system controller may be difficult to develop unified combination measures due to the different view point of business models due to the diverse vehicle types, regions and companies. And there is a

concern for overlap in investment. On the other hand, combination with the PE system controller is at a state in which development of the localized products is enabled due to many years of experience. Thus, our company can develop it on our own. Another strength is that it is possible to develop consistent combination measure regardless of the types of vehicles and regions. Moreover, it is not clear whether combination up to the Micro-Controller level when it comes to the composition at the inside of the Combined Control Unit of the above mentioned competitors took place. Purpose of the controller combination in this research is to combine the Power Electronics (PE) controller. Moreover, the principle is to combine all the controllers into one Micro-Controller. (Fig.3)

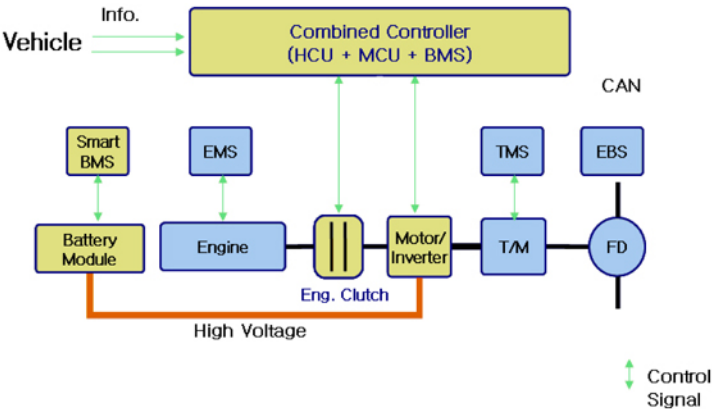


Fig.3. Decision making of Combined Control Unit in this study

2.2. DEVELOPMENT OF THE COMBINED CONTROL UNIT FOR HYBRID VEHICLE

First, controller development process is developed for the development of the vehicle optimization Combined Control Unit. Second, combination Architecture for the development of vehicle controller is configured. Third, basic software and application software that activates the system optimally that activate the hardware and hardware for the development of the Combined Control Unit platform is combined and developed. Fourth, verification method for verifying and evaluating the performance of the software and hardware, confirmed in a combined manner is researched. Lastly, reusability and reliability of the control are secured so that the above mentioned research results can be adopted to expand to our company's hybrid vehicle in a horizontal manner going forth.

2.2.1. DEVELOPMENT OF CONTROLLER DEVELOPMENT PROCESS

Fig. 4 describes the controller development process for the Combined Control Unit development with the V-Diagram. In this research, development environment adopted the Model Based Development (MBD) technique. Depending on situations, prompt development process circulation structure is configured through the embodiment and verification that use Rapid Prototyping (RP).

<figure 4 here>

Process development that can manage the Control System Requirement Specification, Control Function Requirement Specification, Concept Design Document, Detail Design Document, V&V Test result, Function Description sheet, control model and source code, which are the key outputs of the controller development, in an organic manner is a requirement for the effective development. When specs change during the development process, each process is managed in a linked manner to produce final source code. Thus, discord among the model and requirements can be prevented.

Development of the process management tool for the structured management of the development outputs and for the effective development is composed of the tool chain as shown on Fig. 5.

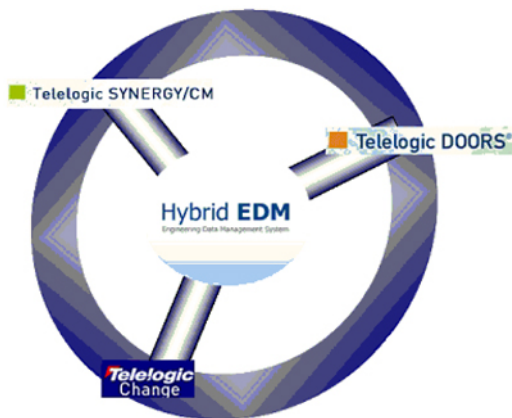


Fig.5. EDM Tool Chain for the Combined Control Unit

Results obtained through the development of the controller development environment are as follows.

1. Process definition for the CMMI model based standard development and development of the data management system

⇒ Securing data history and Traceability (Requirement, Configuration, Change management)

2. Combined output management through EDM server (existing practice of managing individual PC) and support for Multi-Tasking

3. Standardization of the outputs for the required specs and S/W development and increase in the reusability of the outputs

4. Mutual linked management of the required specs, control model, S/W and test data

2.2.2. Vehicle controller development

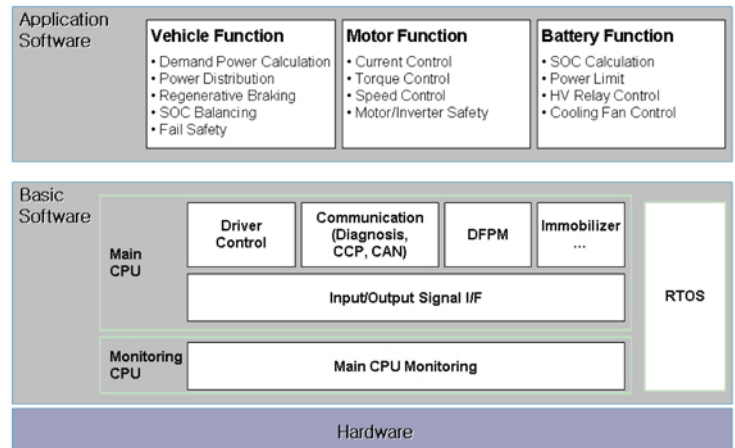


Fig.6. Concept diagram of software platform

Combined Control Unit configuration in this research is composed of the Hardware, Basic Software, Application Software (HCU+MCU+BMS) as shown on Fig. 6. Fig 7 demonstrates vehicle controller Architecture. It is configured with the combined model that can be used in all hybrid systems, and it is also configured so that it can be used again in case of system change.

<figure 7 here>

Development of optimal Combined Control Unit, which is the ultimate goal of this research operates the above mentioned control algorithm optimally. The purpose lies in the development of the most effective operation control strategy among powertrain parts and electric power parts.

Fuel economy optimization in the hybrid vehicle, needs to be selected by factoring in the vehicle system effect when it comes to the vehicle operating point by the motor and engine. The factors that can exert influence at this time are the battery charging effect (fchg), discharge effect (fdch) factor, EV and the juncture for switching HEV mode (PEV-HEV).

As for the hybrid vehicle's system effect and if at the discharge state,

$$\frac{P_{wheel}}{P_{fuel}(\tau_{engine}, \omega_{engine}) + \frac{P_{battery}(\tau_{motor}, \omega_{motor})}{f_{dch}}}$$

Equivalent fuel power

If charged,

$$\frac{P_{wheel} - f_{chg} \cdot P_{battery}(\tau_{motor}, \omega_{motor})}{P_{fuel}(\tau_{engine}, \omega_{engine})}$$

Equivalent wheel power

These can be represented as above mentioned.

As for the simulation technique for the fuel economy optimization, Genetic Algorithm is used as shown on Fig. 8. After stimulating the fuel economy and power performance, control logic was configured so that the optimal operating point can be factored in. The results of the simulation are shown on Fig. 9 when it comes to the mode switching and charge and discharge's optimal operating point.

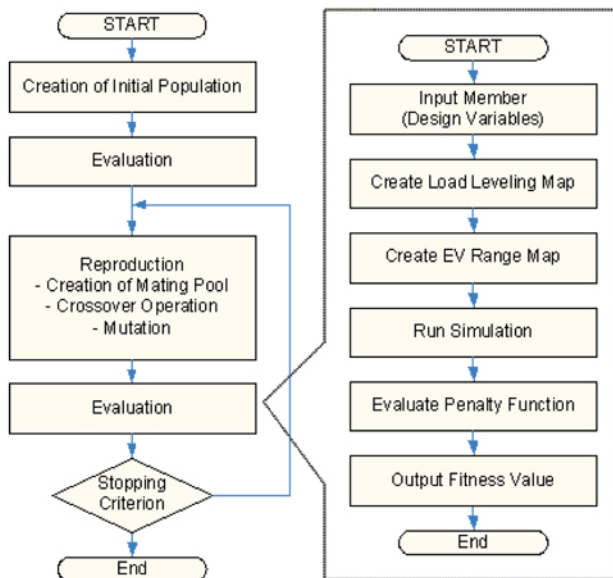


Fig.8. Genetic Algorithm

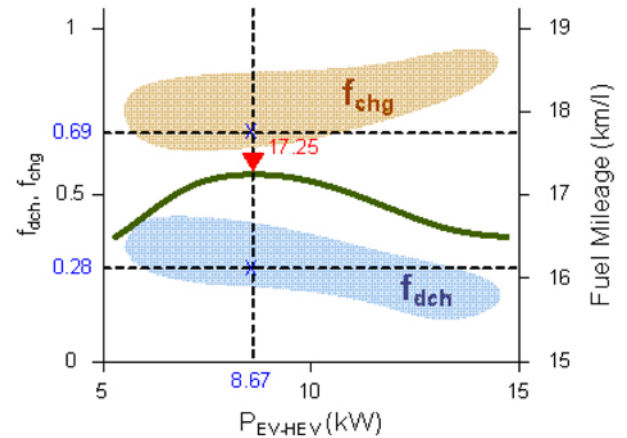


Fig. 9. Simulation Result

2.2.3. Combined Control Unit platform development

It can be classified into H/W platform Hardware and Basic Software.

First of all, required specs for combining the existing independent type of individual controllers as the hardware part is demonstrated on Table. 1. This shows the forecasted performance when combined with the I/O configuration and CPU load rate today by each controller. When combining today, estimated CPU load rate is about 100% and the purpose is to lower the ultimate target combined performance to within 70% in terms of the CPU load rate through the universal use of the software and making into library.

Table.1. Hardware requirement for Combined Control Unit

Items	HCU	MCU	BMS	Requirement
System Clock (MHz)	40	132	40	132
CPU	C167	MPC555x	C167	-
Communication	1 CAN	1 CAN	1 CAN	3 CAN
RAM	25Kbyte	45Kbyte	20Kbyte	80 Kbyte
Flash	0.7Mbyte	0.37Mbyte	0.3Mbyte	1.1Mbyte
A/D Input	5 : 10bit, 5V	10 (+6) : 10bit, 5V	5 : 10bit, 5V	20 (+6)
Timed Input	1	2	-	3
Timed Output (PWM)	1	10 (+7)	1	12 (+7)
Digital I/O	11	37 (+27)	10	58 (+27)
CPU Load (132MHz Substitution)	40.0 % (10.9 %)	90.8 % (81.7 %)	20.0 % (5.5 %)	70% Below (98.8 %)
Software Coding	Ascet SD	Manual C	Manual C	Simulink & Manual C

The combined hardware is configured into 1-Board/1-Micro controller as shown on Fig. 10, and the development will take so that it can be applied as the built in inverter or inverter that is attached from the outside according to the vehicle system placement.