別紙様式８

研　究　主　論　文　抄　録

論文題目　　Development of Simulation Model for Hybrid Electric Vehicle with Power Source Composed of Electric Double Layer Capacitor
（電気二重層キャパシタを用いたハイブリッド蓄電システムを有するハイブリッド電気自動車のシミュレーションモデルの開発）"

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主論文要旨

Chapter 1
According to International Energy Agency (IEA)'s latest report of CO2 Emission From Fuel Combustion, 23% of total CO2 emission stems from the transportation including motor vehicles. Therefore, in recent years since CO2 emission is directly related to global warming and economical use of energy problems, hybrid electric vehicles (HEV) which has less CO2 emission and higher energy efficiency than conventional vehicles are developed as a solution. Inside of a HEV, depending on the vehicle's running condition, power management is achieved among the parts of the vehicle such as engine, motor, battery, generator, etc.

Chapter 2
As a method in order to maintain running efficiency and increase fuel efficiency, for HEVs mainly there are 3 type of patterns of drive-trains such as series, parallel and parallel-series type . When looking into detail of any drive train pattern, a certain combination of internal combustion (IC) engine, motor, battery, and generator is found. Among those patterns, parallel-series type hybrid drive-train of a Toyota Prius car simulation which is developed with Matlab/Simulink tool is developed as an experimental environment in this work.

Chapter 3

Toyota Prius HEV contains a battery pack consisting of non-spillable 30 low voltage Nickel-Metal-Hydride (NiMH) battery modules that power the high voltage electrical subsystem with direct current (DC) . In the development and usage process of a HEV, according to hybrid electric vehicle report of investigation, several faults including short circuit causing huge damage to vehicle and may endanger the passengers . Some of short circuit fault occur in the battery pack caused by built-up heat together with voltage surge that led to insulation failure. This fault is occurred even the HEV battery pack is structured with a high voltage fuse providing short circuit protection.

More specifically about short circuit in HEVs, most a short circuit faults are triggered by different causes. The study model of Toyota Prius HEV contains two inverter and one DC/DC converter modules which are composed of several Isolated Gate Bipolar Transistors (IGBT) and Free-Wheeling Diodes (FWD). In HEVs, such power modules are applied water cooling so that their $\Delta Tjmax$ is around 50C and increase in this temperature may cause severe results. Also, hard environment conditions can add up plus risks. Furthermore, one another important issue about IGBT containing models are high surge voltage during the IGBT switching at high voltages stemming from the sharp changes in current and stray inductance. In the study system, IGBT containing inverter modules increase the voltage to feed motor. Accordingly, high voltages may decrease the soundness of the system against short circuit which is indispensable. However, generally the cause to the short circuit fault is partial deformation of battery pack separators, which creates local hot spots. Especially in case of Polyethylene or Polypropylene separator, this local hot spots give major damages to the separator since they undergo a shrinkage increasing the short circuit area. Besides, separator de-formation can also be caused by an external mechanical intervention such as in a crush. Short circuit fault is also possible to be encountered due to internal breakdown of the cell because of an impurity or incorrect power management topology of cell.

Chapter 4

In this study, during the acceleration and deceleration of the vehicle, short circuit faults in DC bus of the electrical subsystem of the study system are modeled and simulated. During these operations, certain fluctuations in battery DC bus voltage and power, battery state of charge (SOC), engine power and motor power etc. Take place. In this paper, we propose an electric power smoothing compensation system in-parallel connected to the battery pack and monitor the impact on the performance of HEV. This proposed system is composed of electric double layer capacitor (EDLC). It's well known that EDLCs have large capacitances and ability to charge/recharge rapidly. Besides, high power density rates and long charge/discharge cycle lifetime of EDLCs make them indispensable in recent power quality and energy sustainability issues as well as in electric vehicle (EV) applications. Since power source and its betterment is the most vital issue for an HEV, for the future of HEV industry, indications show that an increasing trend of high efficient battery systems and carbon ultra capacitors will most likely prevail not only the market but also the studies related to HEV power source technology development. Regarding this fact, demand for the batteries and supercapacitor storage systems in the world energy market in 2017 is expected to grow to 8 billion USD. When comparing a battery with an ultra-capacitor (EDLC), batteries have drawbacks of low power density and limited charge/discharge cycle life-times as well as long charging times and high temperature dependence. For the compensation of a HEV battery pack disadvantage, EDLCs with high power densities and higher repetitive charge/discharge life-times are required. Accordingly, EDLCs which are utilized in charge sustaining hybrid vehicles such as HEVs have low energy density ranging from 5 to 10 Wh/kg while having high power densities that are between 1-2 kW/kg. Ultra- capacitor introduction to HEV applications dates back to about 1990 and for the reasons counted above, studies related to ultra-capacitor are concentrated on better power and life-cycle characteristics.

Chapter 5

For most HEV applications, EDLC power capability is measured by high efficient power density. Thus, with an EDLC in the system, stable DC bus voltage can easily be obtained. Power peaks during the short circuit faults of HEV can be reduced considerably. Accordingly, power quality in the whole system is improved by smoothing the power fluctuations. Since the battery pack on a HEV is an electrochemical system which goes through an early deterioration by high charge/recharge cycle times, proposed EDLC system compensates the harmonic components of fluctuating power in the system and supplies the smooth component of power so that decrease in high charge/recharge cycle times yields a longer life-time for the battery pack .