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The Method of Charging for Electric Vehicles Using Power System of Gasoline Vehicles

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Summary

Despite the wide availability of electric vehicles (EVs) in the market, the reality is that charging stations are still lacking, and this gives rise to the need to develop and use other charging methods. "Emergency charging" means charging a vehicle after its battery has been completely discharged at a location where a vehicle charging system is not available. Thus, when it comes to the emergency charging of EVs, what is most important is the capacity to charge the battery, without the necessary charging infrastructure, rather than the timeliness of the charging process. Emergency charging of EVs is comparable to a situation, where a gasoline-powered vehicle runs out of battery and help is sought from a driver nearby to recharge the battery using jumper cables.

At present, an emergency charging system that could be used in the event of a complete discharge of the electric vehicle battery (EVB) and a car-to-car charging system are under development. There are currently far more gasoline-powered vehicles than EVs, and development of an emergency charging method using gasoline-powered vehicles is expected to facilitate the use of EVs. In this study, The control logic is designed to charge for the EV charging process by using 12V Power system of gasoline-vehicle, and the Matlab Simulink was used for a simulation.

Keywords: Electric Vehicle(EV), Electric Vehicle Service Equipment(EVSE), Emergency Charging, pilot duty for charging, On Board Charger(OBC)

1 Existing Emergency Charging System for EVs

The emergency charging method for EVs is applied in diverse ways as explained below, and recently, there has been research on ways to charge an EV by connecting it to another EV. The use of an emergency generator would require a heavy engine to be mounted in the vehicle, and there are currently an insufficient number of EVs to use a mobile emergency charging system. Also, the EV-to-EV charging system is still in the development stage, and in order for such system to be applicable, there is a need to modify the structure in order to output electric power from the EV power system. As a means to address these issues, the 12V power systems of gasoline-powered vehicles, which are already widely distributed, could be used to develop a charging module to perform emergency charging of EVs when their batteries are discharged.

Fig. 1 shows charging method when EV is full discharged.

Figure1: Charging method when EV is full discharged. (Potable engine Generator, mobile chargeable system)

2 On Board Charger(OBC) & Electric Vehicle Service Equipment(EVSE)

Many vehicle manufacturers have adopted the J1772 SAE standard for AC electrical connections to a vehicle. The same specifications also translate into international. The standard design of EV charging systems on the market at the time of this writing have the AC-DC converter for the battery charge system integrated into the vehicle, so only AC power is required. External DC-DC and charge circuitry is enabled on some vehicles, but this configuration is outside the scope of this design. To facilitate the power delivery to the vehicle, the Electric Vehicle Service Equipment (EVSE) sits between a stable grid connection and the vehicle, as Figure 2 shows.

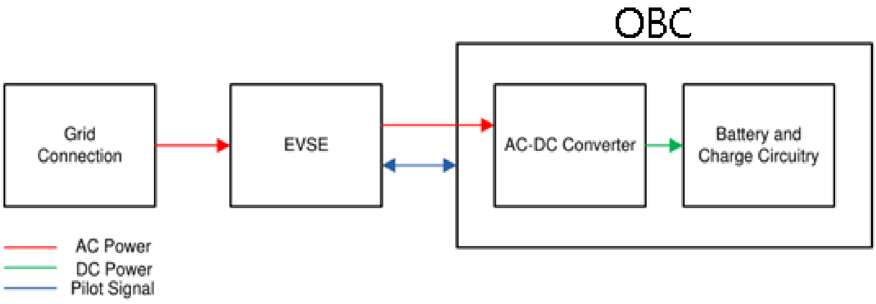


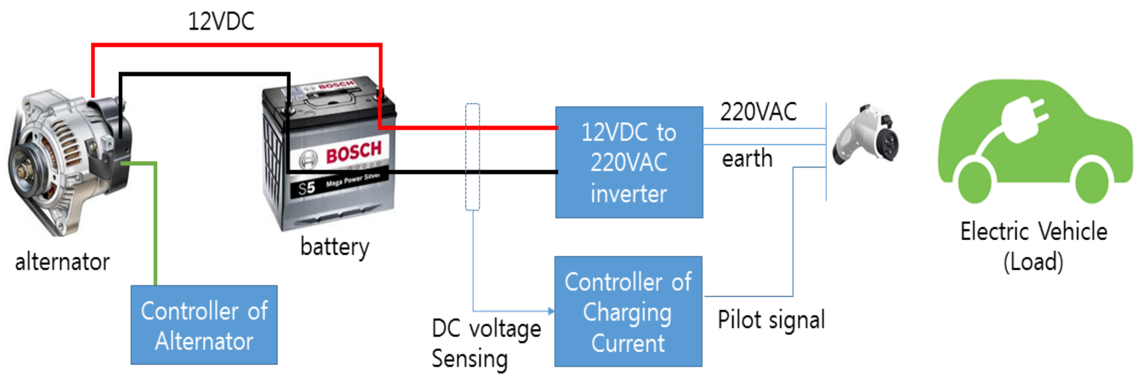
Figure 2: EVSE Position in Power Flow

3 Emergency Charging Module Using the 12V Power Systems of Gasoline-powered Vehicles

In the 12V power systems of gasoline-powered vehicles, the alternator and the battery are connected, as shown in the following figure, and the power generation capacity of the alternator and the battery capacity vary across the vehicles.

When there is a load on the 12V power system of a gasoline-powered vehicle, there is a need to control the output current to prevent an overload on the alternator, based on its power generation capacity. Because the alternator/battery output performance varies depending on the car model, using a charging current control logic accordingly can enable an efficient emergency charging process.

As explained in Chapter 2, in the case of slow-rate charging systems for vehicles, current control is possible depending on the control pilot signal. For application of this type of charging system, there is a need for a controller of charge current that can generate pilot signals to control the electric power from the power



systems of gasoline-powered vehicles.

Fig. 3 shows the conceptual diagram of an EV charging system, with a 220VAC inverter and a controller generating pilot control signals, that can use the power supply of a gasoline-powered vehicle.

Figure 3: The conceptual diagram of an EV charging system, with a 220VAC inverter and a controller

In case of charging an EV using the system shown in Fig. 3, electric current is sent to the inverter using the energy from the alternator and battery simultaneously. However, as the SOC of the battery drops, the voltage will fall, and at a certain point in time, the alternator will become the sole source of energy used to charge the EV. In this situation, depending on the capacity of the alternator, the charging process should be stopped to charge the battery, and charge the EV again, or use a control sequence to reduce the charging current, instead of stopping the charging process.

In order to develop such control sequence, the SOC data in connection with the voltage of lead-acid batteries used in gasoline-powered vehicles were examined. The following figure shows the approximate SOC of lead-acid batteries according to voltage.

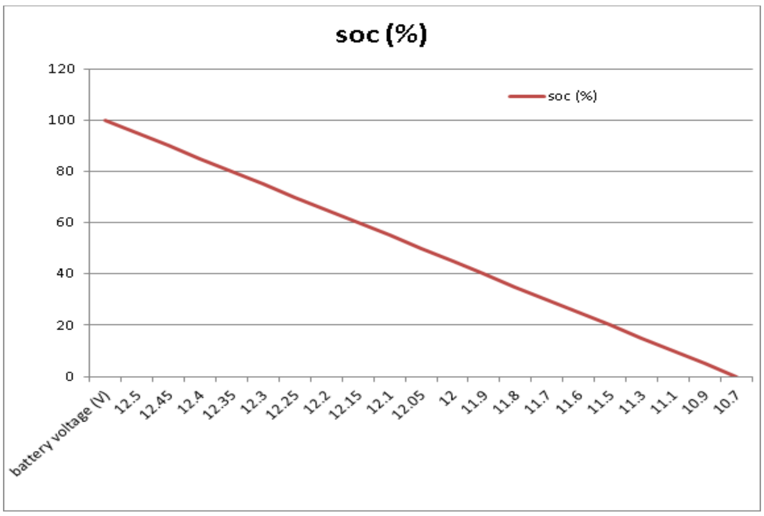


Figure 4: Relationship between battery voltage and SOC

The OBC voltage control is defined by the following equation, in accordance with the pilot control sequence of the J1772 protocol. Duty cycle is can be defined as follows.

$$\text{Duty cycle (pilot control) [\%]} = \text{Amps[A]} \;/\; 0.6 \quad (1)$$

Max. Amps in eq. (1) can be calculated by inverter power. So Max Duty cycle is can be defined as follows.

$$\text{Max. Amps[A]} = \text{Inverter Max. power[W]} \;/\; \text{voltage [VAC]} \quad (2)$$

$$\text{Max. Duty cycle (pilot control) [\%]} = \text{Amps[A]} \;/\; 0.6 \quad (3)$$

Equation (3) shows the maximum duty cycle value and the duty cycle value should be decreased according to the SOC of the battery.

Using the SOC data obtained based on the allowable power handling capacity of inverters and battery voltage, the duty cycle for controlling charge voltage is calculated as follows:

Table1: Duty cycle by Battery voltage

Battery voltage[V]	SOC [%]	Duty cycle value (Proposed) [%]
12.5	100	10% + (Duty converted from the maximum allowable voltage of inverter-10)%
12.25	75	10% + (Duty converted from the maximum allowable voltage of inverter -10)*0.5%
12	50	10% + (Duty converted from the maximum allowable voltage of inverter -10)*0.1%
11.5	25	10%
10.5	0	0

For example, let us suppose that an EV is being charged using a 3kW inverter and that the initial voltage of the battery was fully charged to over 12.5V. Then, when the voltage is 220VAC, it is possible for the current to be 13.63A(=3kW/220V). According to the J1772 protocol for the slow-rate charging system, the duty cycle corresponding to a current of 13.63A is 22.7%(=13.63/0.6). When the battery is charged to the maximum, the battery voltage will drop if the battery is being discharged at a greater degree than the amount of voltage generated by the alternator. In this case, the duty cycle is reduced, based on the level of decrease in the battery voltage, to a minimum of 10%. Afterwards, when the SOC falls below 25%, the charging process should be stopped temporarily until the alternator charges the battery to over 50%.

The table 2 and figure 5 show the duty cycle giving a current commend to the slow-rate charging system:

Table 2: Duty cycle value by battery voltage (e.g. 3kW inverter)

Battery voltage (V)	SOC (%)	Duty cycle value (Prop.) (%)
12.5	100	22.7
12.45	95	21.5
12.4	90	20.2
12.35	85	18.9

12.3	80	17.6
12.25	75	16.4
12.2	70	15.1
12.15	65	13.8
12.1	60	12.5
12.05	55	11.3
12	50	10.0
11.9	45	10.0
11.8	40	10.0
11.7	35	10.0
11.6	30	10.0
11.5	25	0.0
11.3	20	0.0
11.1	15	0.0
10.9	10	0.0
10.7	5	0.0
10.5	0	0.0

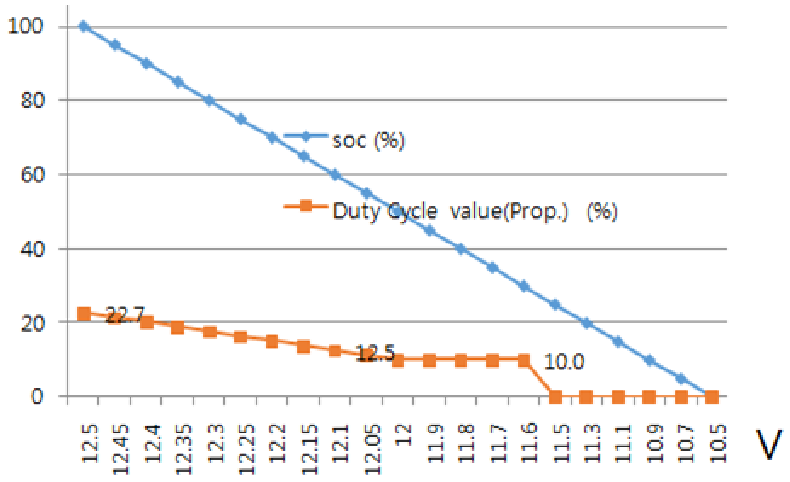


Figure 5: Duty cycle value by battery voltage (e.g. 3kW inverter)

4 Simulation

An EV charging system that can use the power supply of gasoline-powered vehicles was designed as shown in Fig. 3 using Matlab Simulink. The alternator and battery system of the gasoline-powered vehicle was designed based on the model provided by Matlab Simulink, while the slow-rate charging model for EVs was designed to allow variations in the charging current using the control pilot. Thus, it was designed to allow changes in the load using variable resistance, as shown in Fig. 6. The charging amount of EVs is adjusted, as the voltage of the power system of gasoline-powered vehicles is monitored, by the controller of charging current through PI control. When the target control voltage is set to 13V, the power is controlled at an output of approximately 80A. If the charging current is increased by force, then the voltage of the gasoline-powered vehicle power system drops below 13V.

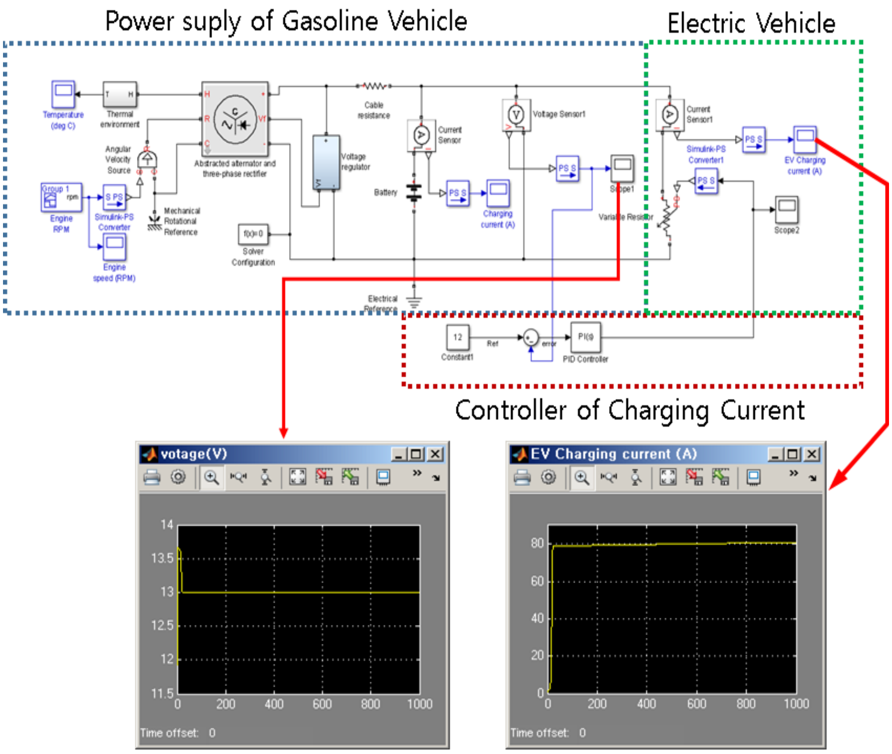


Figure 6: Simulation result using Matlab Simulink

In order to test the emergency charging system proposed, 16bit MCU manufactured by Infineon was used to fabricate an embedded board.

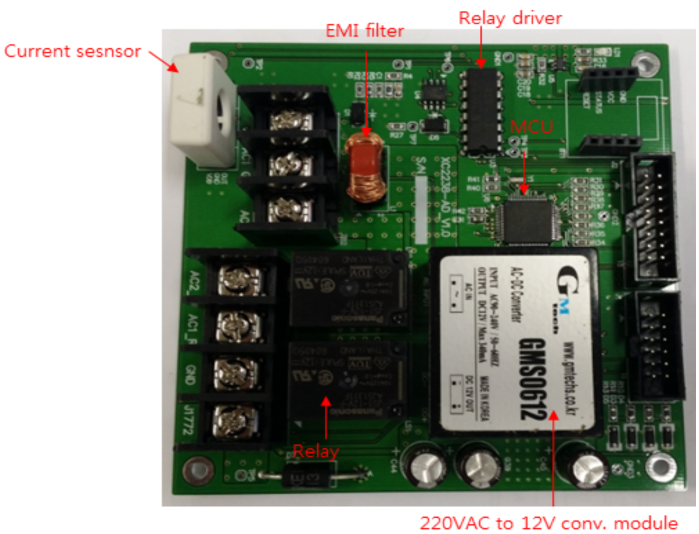


Figure 7: Charging control board for emergency charging

Based on the results of the test performed using a general 220VAC power outlet, it was determined that the current is 6.5A when the duty is 10%, as shown Fig. 8:

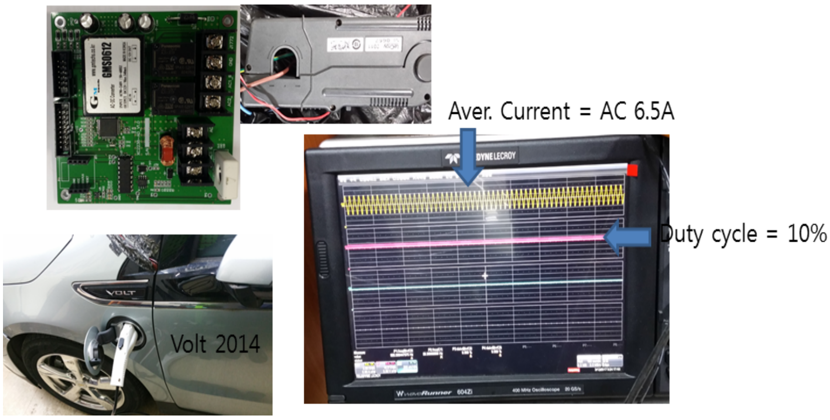


Figure 8: Testing of charger board

5 Conclusion

In this study, an EV charging system using the power supply of gasoline-powered vehicles in the event of an emergency was proposed. The electric power for charging EVs must be adjusted based on the alternator and battery capacity of the gasoline-powered vehicle being used; thus, a current control block was added to control the amount of electric current from the input of power supply from the gasoline-powered vehicle using PI control. A simulation was performed using Matlab Simulink, and the results showed that the system functioned properly. There are plans to design an inverter for charging EVs and use it together with the charging control board developed in this study to test the charging process, and to investigate the measures to determine the optimum value of the duty cycle in the future.

Acknowledgments

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