Proceedings of the 17th World Congress
The International Federation of Automatic Control
Seoul, Korea, July 6-11, 2008

A study of predicting model of an electrical energy balance for a conventional vehicle

Sungtae Kim*, Seungmyun Chung,*
Wanjae Shin, Jebeen Lee****

**Automotive Electronics R&D Center, Hyundai Motor Co.*
Gyeonggi-Do, Korea (Tel:82-31-368-7481; e-mail: bruins@ hyundai-motor.com).
**e-mail: nickchung@hyundai-motor.com*
***e-mail:downer2k@hyundai-motor.com, **e-mail: jblee@hyundai-motor.com*

Abstract: To the automobile the various electricity and electronic devices are increasing recently, it is difficult for predicting the electric energy balance. This paper is for a simulation program of electrical power system for a conventional vehicle. The electrical power system of vehicle is composed of battery, alternator and electric loads. Major components of the vehicle electrical power system are battery and alternator. The battery modeling is applied by an equivalent circuit method on a basis of lab test data. The simulation results are verified by the experimental data from the vehicle and this simulation program can be applied to other kinds of vehicles by obtaining of extensive test data.

1. INTRODUCTION

In order to avoid the over/under design problems of electrical power systems in vehicles, an easy-to-use and inexpensive simulation program may be needed. This paper is for a simulation program of the electrical power system in vehicle implemented on a PC by a basis of MATLAB/Simulink.

The electrical power system of a vehicle consists of a battery, an alternator, and electrical loads. To improve the flexibility and easy usage of the simulation program, the program is organized in modular structures. Two major components of the electrical power system are a battery and an alternator. Electrical power system simulations are heavily dependent on the battery model, which is the most complex component to simulate. A simple, fast, and effective equivalent circuit model structure for lead-acid batteries was implemented to facilitate the battery model part of the system model.

The purpose of this study is to shorten the development process, reduce the development cost, and also improve reliability.

2. Simulation of electrical power system in vehicle

2.1 Battery Model

A physical system lead-acid battery model was created using Simulink. The battery model is designed to accept inputs for current and ambient temperature. As initial conditions, there are SOC and electrolyte temperature. The outputs are voltage, SOC, and electrolyte temperature.

A diagram of the overall battery model structure is shown in Fig. 1. The battery model contains three major parts: a thermal model, a charge and capacity model, and an equivalent circuit model. The thermal model tracks electrolyte temperature, and depends on thermal properties and losses in the battery. The charge and capacity model tracks the battery's state of charge (SOC), depth of charge remaining with respect to discharge current (DOC), and the battery's capacity. The charge and capacity model depends on temperature and discharge current. The battery circuit equations model simulates a battery equivalent circuit. The equivalent circuit depends on battery current and several nonlinear elements.

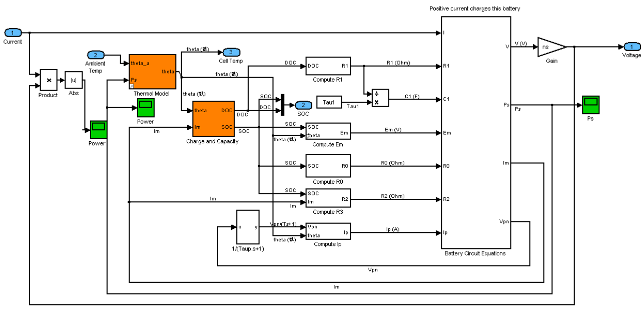

Fig. 1 Simulink model structure of battery

The structure of the battery circuit equations in Fig. 1 is a simple nonlinear equivalent circuit, shown in Fig. 2. This approach is a modelling method of electrochemical batteries suitable for the use of the electrical engineer. The structure did not model the internal components of the lead-acid battery; rather it empirically approximated the behaviours seen at the battery terminals. The test data for this modelling are very important for the accuracy of this model. The structure consisted of two main parts: a main branch which approximated the battery dynamics under most conditions, and a parasitic branch which accounted for the battery behaviour at the end of a charge. The model did have some underlying complexity as a result of nonlinear, time-varying parameter values for the circuit elements.

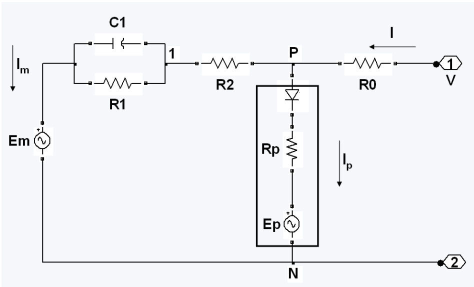

Fig. 2 Electric equivalent circuit for lead-acid battery

2.2 Alternator Model

When the engine is running, the alternator supplies the electrical power required by the other electrical devices. In this study, the alternator was modelled using statistical method, which gives very good fit. The statistical data from lab test was used to predict output.

The alternator can be modelled according to the maximum available current. Fig. 3 shows model inputs and outputs. If the alternator maximum current is greater than the load current needed by the electrical devices, the alternator is modelled as a constant voltage source. In other case, e.g. the alternator maximum current is smaller than the load current, the alternator is modelled as a constant current source with maximum current.

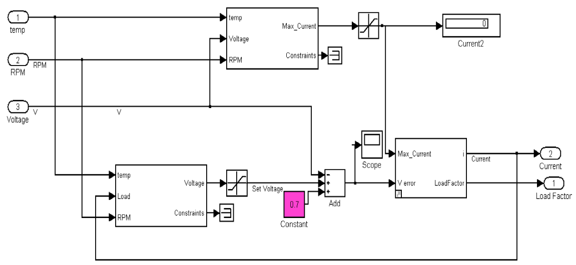

Fig. 3 Simulink model structure of alternator

2.3 Complete Electrical System Model

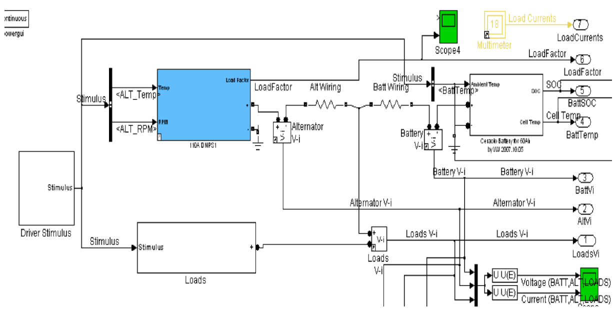

Fig. 4 Simulink model structure of electrical system

In Fig. 4, the Simulink model structure of complete electrical system is shown and this structure includes driving cycle, load cycle, and environment conditions as well as models of battery, alternator, and electrical loads.

The established model was compared with experimental data. As shown in Fig. 5, the measured data and the simulated data are closely correlated. A tracing of battery current is one of the most important things because the change of the SOC of the battery can be calculated through the tracing.

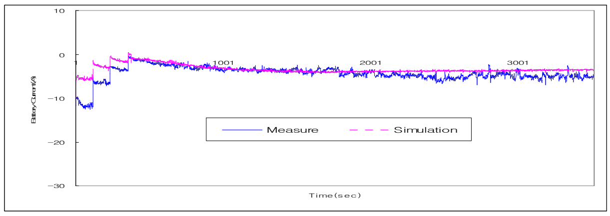

Fig. 5 Comparison between simulation and measurement of a battery current

If simulation conditions (driving cycle, load cycle, and environment conditions) and initial conditions are given, the simulation program can calculate the change of the battery SOC by tracing the battery current. As shown in Fig. 6, the simulation program can predict primary currents and voltages.

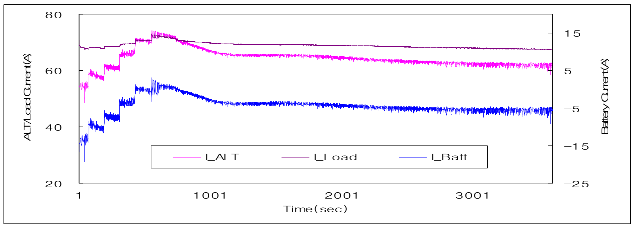

Fig. 6 Prediction of currents of battery, alternator, and electrical loads through simulation

6. CONCLUSIONS

The main object of this paper is to present a simulation environment that is suitable for supporting the development process of electrical power systems. A mathematical model and a statistical model for simulating the vehicle electrical power system are presented. The simulation program that includes above models is composed of an alternator, battery, and electrical loads. This program accurately depicts the performance of vehicle electrical power flows.

REFERENCES

Massimo Ceraolo(2002). New Dynamical Models of Lead-Acid Batteries. *IEEE TRANSACTIONS ON POWER SYSTEMS*, VOL. 15, NO.4.

R. Schottle, W. Muller, H. Meyer and E. Schoch(1997). Methods for the Efficient Development and Optimization of Automotive Electrical Systems. *SAE*, pp 39-49.

Stefano Barsali and Massimo Ceraolo(2002). Dynamical Models of Lead-Acid Batteries: Implementation Issues. *IEEE TRANSACTIONS ON ENERGY CONVERSION*, VOL. 17, NO.1.

W.T. Lee, H.J. Park, M.H. Sunwoo, B.S. Kim and D.H. Kim(2000). Development of a Vehicle Electric Power Simulator for Optimizing the Electric Charging System. *SAE*, pp 1-8.