Wheel Robert Energy Management System Based on Intelligent

LOU WENZHONG YU XIULI
School of Mechartonic Engineering
Beijing Institute of Technology
5 South Zhongguancun St.,Beijing 100081
Beijing.China

Abstract: – Energy management embodies engineering, design, applications, operation, and maintenance of electrical power systems to provide optimal use of the electrical energy. The key element of the energy management process is the identification and analysis of energy conservation opportunities. This paper utilized the characteristic of a digital signal processor TMS320LF2407, a novel Wheel Robert energy management system is designed. The mission of the energy management system, so called Intelligent Energy Management System, is to enable the Wheel Robert to be driven in an economically and environmentally friendly way while satisfying the operator's performance demand. This system can check and measure the parameters of the battery, such as the voltage, current and temperature. Accurate surplus electric consumption prediction of battery by ANN, and fast charging of the permanent pulse real-timely, etc. Simulation work is carried out for the validation of proposed energy management system, and the results reveal its viability for energy management of a novel Wheel Robert.

Index Terms: - Wheel Robert, EMS, DSP, ANN, SOC（State of Charge）

1 Introduction

Energy management embodies engineering, design, applications, operation, and maintenance of electrical power system to provide for the optimal use of the electrical energy. Optimal in this case refers to the design or the modification of a system to use minimum overall energy where the potential or real energy savings are justified on an economic or cost benefit basis. Optimization also involves factors such as comfort, healthful working conditions, the practical aspects of productivity, aesthetic acceptability of the space, and public relations.

Wheel Robert presents a number of challenging issues in connection with their design and operation. In particular, management of energy is essential element in the implementation of Wheel Robert, where the power source must be used according to the man's demand and the specific features of the environment situation. Since the battery usage are primary factors to be considered in the operation of Wheel Robert, development of energy management strategy for this emerging class of application has received a great deal of attention. In Wheel Robert energy management system, the most important thing is to precisely estimate the state of charge (SOC) of the storage battery .

Any process requires a certain minimum consumption of energy. Energy additions beyond this minimum require an evaluation of the incremental cost of more efficient or techniques versus the resulting energy savings or costs. In order to address these issues, an extensive set of studies has been conducted over the past decade and a half. A number of these studies present classical or fuzzy logic based on PID strategies while several have made use of optimal control theory. In the world quite commonly used methods include：ampere-time method，open-circuit voltage method，electrolyte density method， charge and discharge conservation method….. These methods have some limitation, due to storage battery charging or discharging process with many parameters uncertain.

Along with the digital signal processing technology (DSP) rapid development, there are some intelligent

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algorithms which used to estimate the SOC of storage battery appearing. Because SOC is a function with parameters (discharging current, voltage, temperature parameters), this paper utilizes the neural network (NN) can approach the performance of any function with multiply inputs and output parameters, can forecast the battery discharging capacity size in different discharging current, voltage and temperature condition. Moreover, applying the high speed DSP chip and the high frequency switch to realize the storage battery fast charging, avoids being over-charged or over-discharged is harmful to the battery cycle-life. The entire EMS using the modular design, Includes parameters (battery voltage, electric current, temperature data) sampling module, DSP central controls module, Fast charging module, Alarm and the display module and so on.

The aim of this paper is to describe the underlying framework for implementation of each of these components and the manner in which they function together to address the problem of energy management and the application of the intelligence algorithm ANN.

2 Data Sampling Module

r This part is used to monitor the using information of storage battery, in order to convenient the person to monitor condition of storage battery. The variables supervised includes the battery voltage, temperature, and the charging electric current.

A/D circuit sample and convert the corresponding sensor feedback data, A/D will output the conversion data TTL to CPU. On the one hand, CPU will carry on the data display. On the other hand, CPU will process the data to obtain the corresponding storage battery control signal. In the voltage and electric current data sampling circuit design, Hall sensor was applied. Hall sensor based on the electromagnetism transforms principle. Its most excellent place is survey loop circuit and the main loop circuit isolation, the main loop breaks down cannot cause survey loop breaks down, surveys loop cannot bring the disturbance to main loop. LM35 series integration temperature sensor was selected as temperature sensor. It's a precise integrated temperature sensor. It is directly taking Celsius degree not the absolute temperature as the standard. Its linear proportional coefficient is 10mV/°C. Its measuring accuracy achieves 0.5 °C in 25°C , the non-linear error typical value is ± 1/4°C. It is a higher measuring accuracy . This measuring accuracy satisfies the system request. Simultaneously it also has the lower output resistance characteristic, when load current is 1mA, output resistance only is 0.1Ω. Its operating current scope from 400μA~5mA, operating temperature scope is -55 °C ~+150°C.

3 Storage Battery SOC Forecast

As stated in the introductory remarks, a number of studies on energy management for different purposes have been performed in the past. In particular, fuzzy logic based energy management strategies are proposed in several studies. In addition, research on optimal energy management in Wheel Robert has also focused on the application of dynamic programming**.** These approaches are based on a fixed operate cycle due to the inherent characteristics of optimal control theory and dynamic programming[2][7]. Due to the inherent characteristics of the operating process itself, however, it is not easy to generate an optimal control strategy given the unknown nature of the operating situation. Under limited or uncertain information on (future) operating situation, classical optimal control theory cannot be readily applied to this situation. Instead of using classical optimal control theory, alternative optimization techniques are preferable. The studies cited above, however, do not fully address the problem of operating situation awareness within the overall energy management strategy. The approach proposed here on the other hand, hereafter referred to as intelligent energy management system, is driven by a combination of information regarding the state of charge of the battery, the person demand as well as information extracted through on-line operate cycle analysis. The development of intelligent energy management system is an extension of previous research by the authors on fuzzy control for Wheel Robert.

3.1 Intelligent Energy Management System Architecture

In this study, we are adding capabilities to achieve an intelligent energy management system— forecast of the storage battery SOC by ANN for Wheel Robert in consideration of operating situation that the Wheel Robert is subjected. The essential function of intelligent energy management system is to identify the operating situation and to provide this knowledge to a system that makes intelligent decisions with respect to charge sustenance tasks. The architecture of the intelligent energy management system is shown in Fig. 1[4].

After gathers storage battery each parameter, it need to calculate the SOC of storage battery. SOC can not be obtained directly, It only can be inferred by measuring the storage battery parameters, including voltage, current, temperature, inside resistance and so on. NN itself with many characteristics, such as nonlinear, multi-input and multi-output, the learning and generalization ability, which enables it to have the outstanding curve approaches performance, thus ,to have the superiority than traditional method in the battery capacity estimates[6].

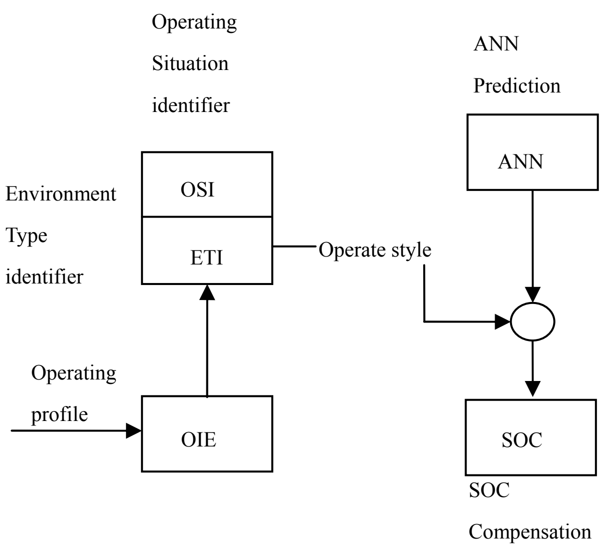

Fig.1 Intelligent Energy Management System Architecture

According to the Kolmogorov Theorey, one 3 layers feedforward network has the ability to approaches any precision continuous functions. The input vector of input layer is [x1, x2, x3], x1 is the battery discharging current value (I), x2 is the discharging voltage value (U), x3 is the storage battery temperature value (T). The output layer only has one node (Y), and it is regarded as the storage battery discharging capacity. The matrix [w_i j_k] selects 3 targets(battery voltage, electric current, temperature), there are values at some time, namely the input layer neuron nodes are 3. One output, namely this time battery SOC hidden layer uses the Transig activation function, the output layer uses the purely linearity activation function. The activation function is a core with neuron and network, the ability and the effect which the network solves the question is not only related with network structure but also decided by the activation function which used in the very great degree. When we forecast the SOC, activation function between the input layer and the hidden layer uses the tangent Sigmoid founction[1], the hidden layer and output level use linearity function. Massive experiments were did on FenJiang colloid long life battery HL70-12, one 3-8-1 one hidden layer uses the Levenherg-Marquardt algorithm NN was established. Network structure is shown in Fig.2.

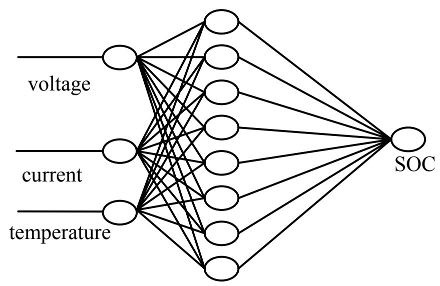

Fig.2 three layers neural network of storage battery

Fig. 3 shows the simulation result with the MATLAB6.5 environment. In the insufficient 500 time steps achieve requests precision.

```
P=load('f:/xl.txt');                % Load the training data
T=load('f:/t.txt');                 % Load the sample data
[pn,minp,maxp,tn,mint,maxt]=premnmx(P,T);
% process the sample data
net= newff(minmax(pn),[8 1],{ 'tansig' 'purelin'},'trainlm');  % Establish the nerve network
net=init(net);
net.trainParam.show=50;             % establish parameter
net.trainParam.goal=1e-6;
net.trainParam.epochs=1000;
[net,tr]=train(net,pn,tn);
```

```
an=sim(net,pn);
a=postmnmx(an,mint,maxt);
figure(1);plot(T,P,a,P);
```

3.2 Operating Information Extractor

The mission of operating Information extractor is to extract information related to the operating pattern for characterizing the (overall) operating situation. Extracted knowledge includes the assessment (characteristic) factors which are representative parameters describing the operating pattern. In our study, extracted information is used for the purpose of identifying operating situation and of developing knowledge bases (ANN) for the forecast of the battery SOC.

3.3 Environment Type identifier

The operator's intention to operate the Robert may be affected by the operating environment (more specifically, complex situations) which the operator is facing. Conceivably, different environment situations affect SOC of the battery even with the same operating conditions, In this study, it is intended to include the effect of environment situation on coulometry consumption in the design of the energy management system.

As one part of environment type identifier, the mission of operating situation identifier is to classify the current operating situation in terms of environment types combined with operating congestion levels. Information from operating situation identifier is utilized as one part of the inputs to the three layers neural network of storage battery.

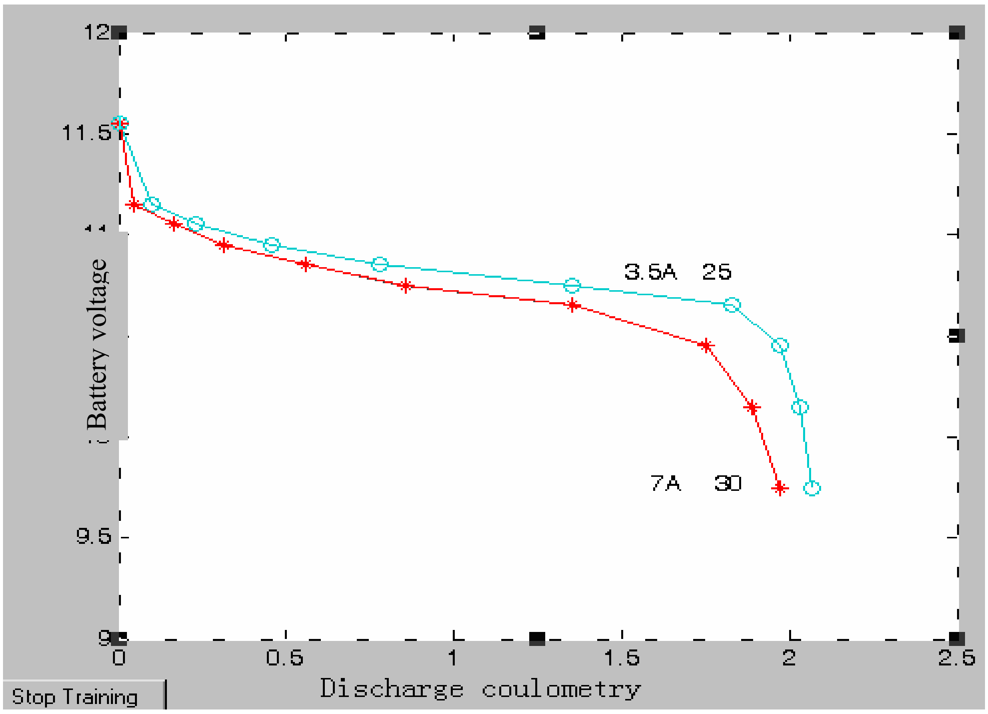

Fig. 3 actual measure and network simulation results

4 Storage Battery Fast Changing Control Circuit Design

The massive empirical data demonstrate, the Wheel Robert storage battery SOC often works in 50%～80%, if is lower than 50%, needs to use the mounted battery charger to charging the battery .Nowadays most popular charging method is based on ameliorating the traditional charging method to get a more better charging curve , such as split-rate constant-current charging 、 pulse charging 、 reflex charging 、 variable-current interval charging[3] and so on .Combine the characteristic of TMS320LF2407, this experiment uses the pulse constant-current split-phases faster charging method, chooses IGBT as the power switch component. Choose Japanese Fuji company's EXB841 as drive chip. The EXB841 is a hybrid IC capable of driving a large capacity and high speed IGBT (capacity below 300A/1200V, frequency below 40KHz). It has a built-in circuit which generates a +15V on-gate voltage to get a low on-voltage and -15V off-gate voltage to protect against malfunction in the off state needs a constant voltage supply from the 20V supply for IGBT gate turn-off.

The control circuit output signal delivers to EXB841's input pin (drive electric current requests 10mA). The EXB841 drive module outputs the positive drive pulse from 3 pin and negative drive pulse from 1 pin to the IGBT gate to turn on/off the IGBT. The control circuit is shown in figure 4:

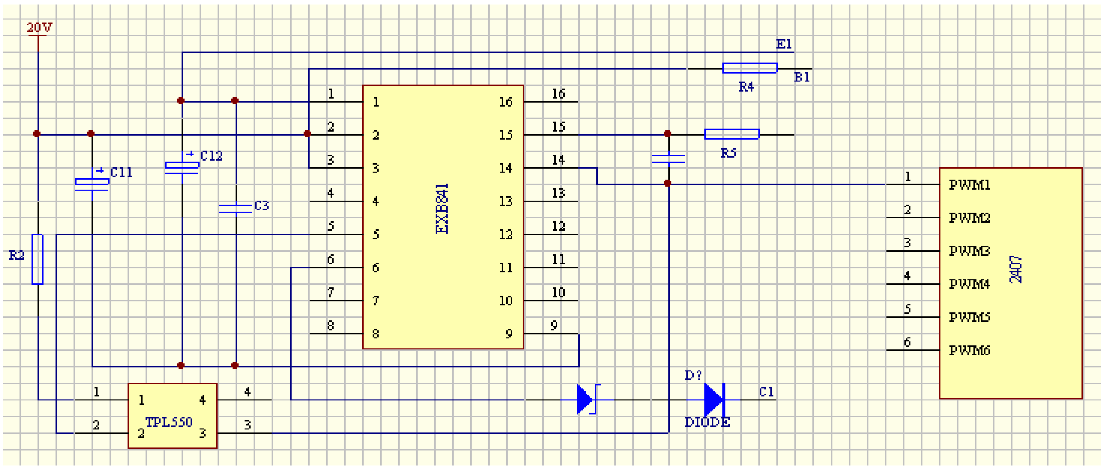

Fig.4 constant current pulses fast charging control circuit

5 Software Design

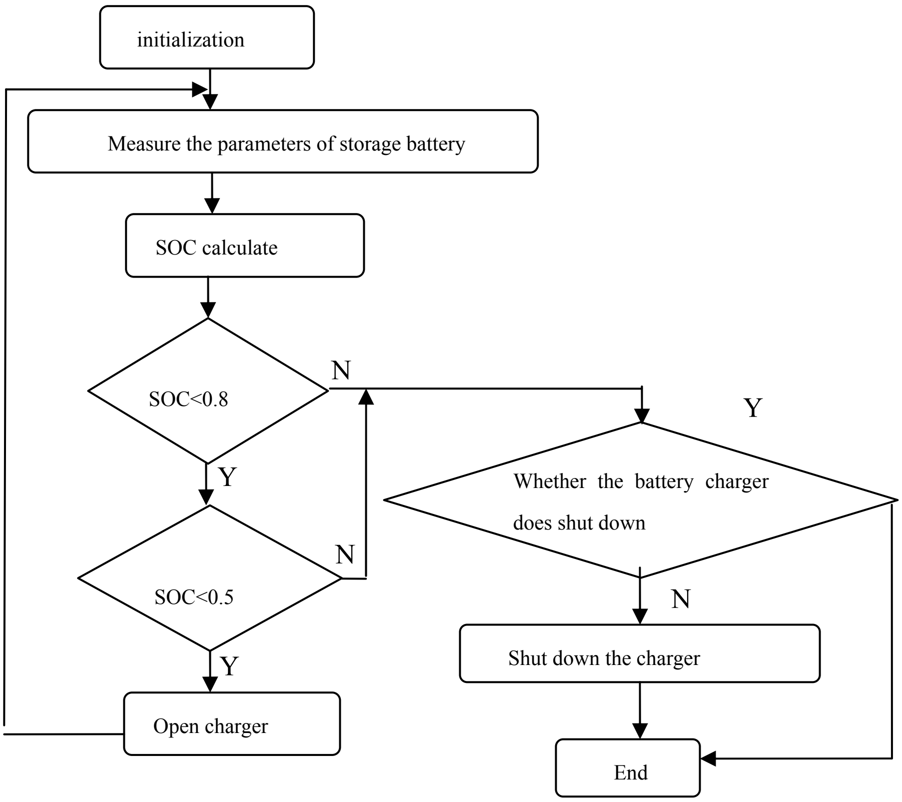

Fig. 5 program flow diagram

6 Conclusion

In this section, we present the simulation study on the evaluation of proposed energy management system of a Wheel Robert Simulation factors affecting performance of intelligent energy management system, The performance of it is affected by the parameters defined at each subsystem, such as short term of past operating history, information update period**,** and initial environment type setting as well **as** charge sustenance strategies proposed in this study.

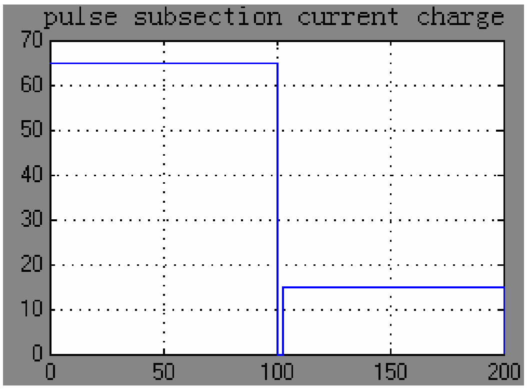

Fig. 6 pulse split-phases constant-current charging current

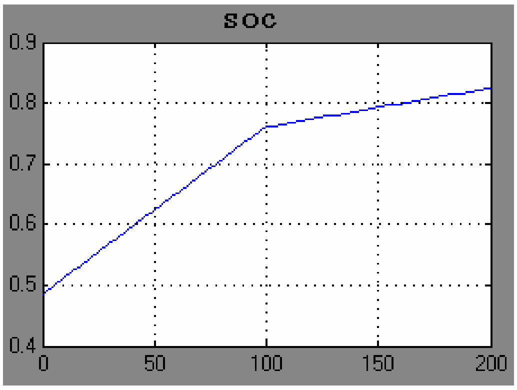

Fig. 7 battery State of Charge （SOC）

This paper established the battery model using MATLAB[4], simulated the pulse constant-current split-phases faster charging method put forward by the paper. Fig.6 and fig.7 show the simulation result. Fig.7 shows the average current which is pulse constant-current, the result shows that it can enable the SOC to achieve 80% about 175 seconds, which accord with the internationally fast charging time.

DSP processes these parameters quickly and precise Through real-time sampling every battery’s parameters [5], such as voltage 、 temperature、 charging and discharging current and so on … This system can realize forecasting the battery SOC, showing related information, preventing storage battery over-discharging harmful by promptly charging when SOC is low, managing Wheel Robert mounted power system on purpose to rational distribute electrical energy and realize the energy conservation goal finally .

In summary, from the investigation of the simulation results, one can see that this kind of algorithm performs well for energy management of a Wheel Robert in a unified framework for the operation of the battery task.

Reference

[1] Chang Xianqi, Chui Rong, Luo Xiaomin,data fusion based on fuzzy neural networks and evidential reasoning. Beijing University Publishing House,1999

[2] Detlef Heinemann, Dietrich Naunin “A Battery Management System for optimized Control and Diagnosis of Traction Batteries in Wheel Robert”, Technical University of Berlin Institute of Electronics and Lighting-Technology EVS16 Beijing 1999

[3] Hu Juqi , “storage battery electric quantity monitor technology research” , <<Electricity Technology>> 20036

[4] Xiaopeng Wang “A Modular battery Management System”, Ph.D. Dissertation, The University of Toledo, May 2001.

[5] Liu Heping , TMS320LF240X DSP the C language development applies Beijing: Beijing aerospace University publishing house 2003

[6] Lu Zhiying, based on heredity NN auto-adapted battery electrically charged condition estimate model <<power source technology>> 2004 9

[7] S . Delprat. T . M. Guerra, 1. Lauber, G. Paganelli. S. Rimaux, and E. Combes, "*Optimal control theory applied to a energy management system* ,' in *Pmc. hleniotionai Syrnp. on Auroniutive Technology* & *Aumnmion (ISATA 2000)*, 2000