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Design of Energy Storage Management System Based on FPGA in Micro-Grid

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Abstract. Energy storage system is the core to maintain the stable operation of smart micro-grid. Aiming at the existing problems of the energy storage management system in the micro-grid such as Low fault tolerance, easy to cause fluctuations in micro-grid, a new intelligent battery management system based on field programmable gate array is proposed : taking advantage of FPGA to combine the battery management system with the intelligent micro-grid control strategy. Finally, aiming at the problem that during estimation of battery charge State by neural network, initialization of weights and thresholds are not accurate leading to large errors in prediction results, the genetic algorithm is proposed to optimize the neural network method, and the experimental simulation is carried out. The experimental results show that the algorithm has high precision and provides guarantee for the stable operation of micro-grid.

1. Introduction

With the environmental pollution and energy crisis is becoming increasingly serious, distributed smart micro grid has become the development trend of the future power industry and has attracted more and more countries' attention [1]. The reliability, service life and maintenance cost of the distributed micro-grid energy storage system are one of the major obstacles to the rapid development of micro-grid. Wind, light and other energy is more random, which seriously affected the stable operation of micro-grid. In order to improve the stability of micro grid operation, the following measures can be taken: (1) energy storage system with high energy density; (2) efficient storage management system [2]; (3) grid connected with large power grid.

At present, most researches on domestic energy storage management system are aimed at Vehicular power batteries [3-4], whose function and structure are similar. However, the operation mode and state of micro grid are much more complicated ,which directly leads to a circumstance that the management mode, operation strategy and control mechanism of the existing storage management system cannot meet the development needs of micro-grid .An efficient micro-grid energy storage management system should be able to achieve the coordination between the energy storage system and the micro-grid control strategy , protect the battery, extend its service life and maintain the stable operation of micro grid as soon as possible [5].

In this paper, a battery management system [6-8] is implemented successfully with distributed smart micro grid energy storage batteries based on the parallel operation and edge triggered characteristics of the field programmable gate array (FPGA). On the basis of realizing the basic function of battery
management system, the charge state estimation of lead-acid battery is also deeply studied which is important to ensure the stable operation of micro grid and the service life of the battery.

2. System Structure

2.1. Overall Frame and Layout

According to the size of the micro-grid, the energy storage system can be composed of dozens or even hundreds of batteries in series and parallel. The basic task of micro-grid battery management system is to harmoniously control the energy storage system, protect battery and prolong its service life. The structure of intelligent battery management system based on FPGA design is mainly composed of FPGA master controller, array switch, batteries and system bus. The system structure is shown in Fig. 1.

![Figure 1. Structure of battery management system based on FPGA](image)

2.2. System Function Analysis

The distributed smart micro grid battery management system has the functions of selective intelligent charge and discharge, data acquisition, battery charge status estimation, fault diagnosis, alarm, battery balance management and other functions. Compared with the traditional battery management system, the advantages are obvious. The first is system control logic combined with micro-grid control strategy. Through the online communication with the micro grid master MCU, we can judge the the operation state of the micro-grid and the charge state of the battery in real time to control the battery charge, discharge and the rest period. The second is Parallel control mechanism. It can process multiple signals to reduce the delay time which is very important to maintain the stable operation of micro-grid. The last is more flexibility. It is convenient to update and upgrade the system under different micro-grid control strategies to realize the management of energy storage system under various control strategies and shorten the development cycle.

3. Design of System Hardware and Software

3.1. System Hardware Design

According to the characteristics of distributed micro-grid itself and the function of battery management system, combined with the actual control object, using modular thinking, design the battery management system central controller and its peripheral circuit. FPGA, as the CPU of battery management system, is the core of the whole system, and uses Xilinx spartan-6 series. The switch between the battery pack
and the micro-grid is replaced by the IGBT, which can effectively shorten the impact time when the state changes. IGBT selects KWBW60N65S, the rise time is 50ns, the descent time is 55ns, can withstand the 650V voltage and 60A current. The driver module uses the EXB-841 driver IC of Japan Fuji Corp, the switching frequency is up to 40kHz, and the transmission voltage is -5~+15V. The voltage and temperature data acquisition module uses the battery monitoring chip BQ76PL536, and the current data acquisition uses Holzer sensor. The central controller and the monitoring interface of the battery system communicate with each other through RS232.

3.2. System Software Design

Battery management system software takes advantage of ISE Design Suite of Xilinx to provide the development environment for FPGA. System software uses modular programming for updates and upgrades and the program is written in Verilog language [9]. The central controller consists of three modules: main control module, battery charging module and battery discharging module.

The main control module contains the following tasks: bit machine communication, data acquisition, fault detection, fault alarm, data storage, information display and battery charge state (SOC) estimation, as shown in Fig. 2.

The main battery charging module and battery discharging module contain the following tasks: monitoring and judging the charge status of the battery and the state of the micro-grid, and sending the driving signal, as shown in Fig. 3.

![Figure 2. The software flow chart of master module](image-url)
4. SOC Algorithm and Experimental Verification

In this paper, CB12250-12V/25Ah lead-acid battery is seen as the object of verification. A large number of discharge experiments are carried out on battery packs and monomer batteries taking advantage of the IT8830B discharge device. The working principle of lead-acid battery and Charge and discharge characteristics are studied deeply. When using the neural network method to estimate the SOC value of the battery, its initial weight $w_{ij}$ and threshold $b_{ij}$ are random numbers. The network weights and thresholds obtained by this method are very sensitive to the training results, the speed of convergence and the error of the network. A genetic optimization BP neural network algorithm is proposed, and the BP neural network model is shown in Fig. 4.

![BP neural network model](image)

**Figure 4.** BP neural network model

When the weight and the width of the BP neural network are optimized by genetic algorithm, each individual in the population contains a network ownership value and a wide value. The individual fitness value is calculated by fitness function, and the genetic algorithm is used to find the optimal fitness value corresponding to individuals through selection, crossover and mutation operations. Finally, the
optimized initial weights and thresholds are used to train the network, thereby reducing the error of estimation.

![Figure 5. The relative error of SOC estimation.](image)

As shown in Fig. 5, the prediction error of the BP neural network and the neural network optimized by genetic algorithm are given respectively. Among them, Fig. 5 (a) is the prediction error of BP neural network, and Fig. 5 (b) is the prediction error of the optimized neural network. From the graph, compared with the BP network, the prediction error of the optimized neural network is obviously reduced, and the prediction result is more accurate. The correctness of neural network based on genetic algorithm is verified.

5. Conclusion

Based on the research on the existing battery management system, this paper proposes a design scheme for the distributed intelligent micro-grid battery management system. The coordinated control between battery pack and micro-grid is realized by FPGA. Finally, aiming at the problem that during estimation of battery charge State by neural network, initialization of weights and thresholds are not accurate leading to large errors in prediction results, the genetic algorithm is proposed to optimize the neural network method. The experimental data show that the algorithm can effectively approximate the actual value when the initial state of the battery is unknown, and the accuracy can meet the design requirements. It can provide a reliable guarantee for the stable operation of micro grid.

Acknowledgments

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