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Research and Design of the Balanced Technology of Battery Management System in Wind Power Generation

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Abstract

This paper introduces the wind power battery management system design based on the equilibrium technology and the key problems affecting the battery performance, through the analysis of the SOC algorithm, using kalman filter to estimate the SOC, improved to control variables feasibility, provided data for the wind power system dispatcher reference, making the most suitable for the operation of power network dispatching strategy.

Keywords*: wind power generation; battery equalization; State of Charge (SOC)*

1. Introduction

With the continuous development of economy, growing demand for energy, in order to solve the problem of energy shortage and environmental pollution, renewable energy development and utilization gained wide attention. Compared to wind and other traditional energy sources, it has the following advantages: first, wind energy is widely dispersed, inexhaustible clean energy, unlimited; Secondly in some mountainous area or sparsely populated areas, laid high-voltage transmission lines will increase costs, especially in the complex terrain, power transmission reliability is reduced, which can adopt independent wind-light complementary system, in the form of a micro power grid to provide customers with secure power [1] [2], and the excess power can be stored by energy storage device, realized uninterrupted power supply. Its unique advantages are getting people favors, improved its position in the energy system, distributed scale expands unceasingly; the energy conversion efficiency is improved steadily.

2. The Current Situation of Domestic and Foreign

In wind power generation system, the energy storage system is one of the key step, using power battery energy storage is one of the most common way. In order to improve the stability of the energy storage system in the whole power supply system to ensure safe and reliable operation of the micro grid system, battery management system has become an indispensable link in real time online monitoring the various parameters of the power battery, the research of battery management system get wide attention in domestic and abroad [3].

(1) Battery management system research situation in foreign countries

Abroad, lithium batteries battery management system has certain development foundation. Villnova university and USNanocorp companies in the United States to battery SOC estimation and prediction model is put forward, Japan is still in the research of battery management system, Aerovironment companies in the United States has designed the Smart Guard high-performance battery management system.

(2) The research status of domestic battery management system

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Most early battery management system can only realize the collection of some basic parameters such as voltage, current capabilities, which cannot make estimates on battery charged state, especially in solving the monomer battery inconsistency caused by excessive charge and discharge [4], the gap with foreign has a certain distance. After continuous efforts and national policy support, in the late now battery management system have great progress in safety, reliability and prolonging the service life of power battery, *etc*.

3. The Technical Background

Battery Management System (BMS) is a comprehensive Management in the running state of power Battery Management System, the system can dynamically monitor the running status of power battery, in order to improve the performance and prolong the service life of the battery power battery as the Management objective [5]. System generally has the dynamic monitoring of total power battery voltage, busbar current, Cycle collection battery monomer battery voltage, temperature, On-line estimation of battery remaining power, thermal management and excessive charge and discharge protection function, according to the acquisition of monomer voltage to balancing control, real-time monitoring insulation characteristics of the system, Maximum use of the performance of the power battery, prolong the service life of power battery, micro power grid run stably and reliably as energy storage device of the power battery[6].

As the management object system to lithium iron phosphate battery, system to lithium iron phosphate batteries as the management object, in the hardware part of the configuration with bi-directional DCDC converter and a controller for DCDC module design [7], and then by DCAC bidirectional inverter in the power system, which can be directly to the micro electricity grid or through grid for battery charging. Wind power structure diagram shown in Figure 1.

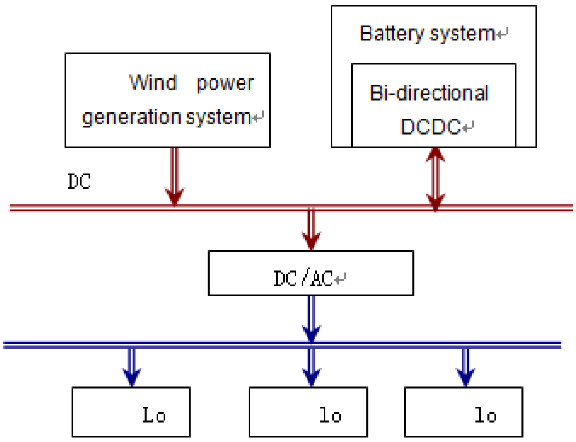

Figure 1. Wind Power Structure Diagram

4. System Design

Wind battery management system is consists of two subsystems: the battery management system and bidirectional DCDC control system.

Battery management system consists of an SOC unit (SOCU), one personal computer interface unit (HMIU1), three battery measurement unit (BMU) and six cell balancing unit (BBU) compositions. Bidirectional DCDC control system consists of a high-voltage measurement unit (HVMU), one DCDC control unit (HMIU2), and a bidirectional DCDC converter constituted. It uses distributed architecture design, each module is connected by CAN bus for data transmission. System configuration diagram shown in Figure 2

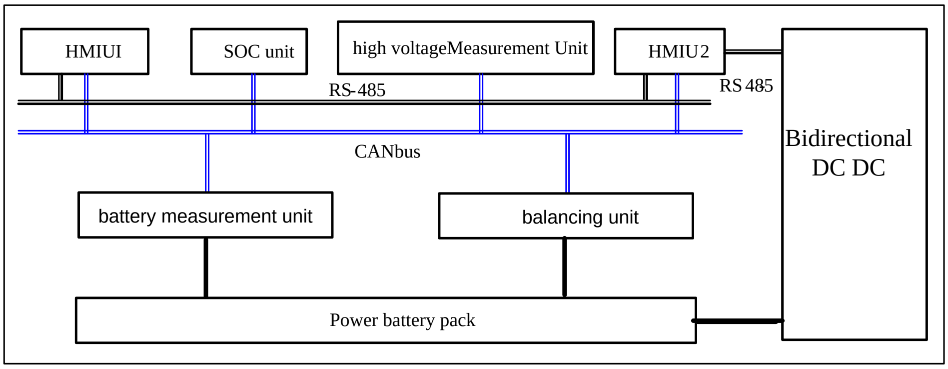

Figure 2. System Configuration Diagram

The system realizes the following functions:

(1)Realization of single cell voltage in real time cycle testing to ensure that the cells in the normal voltage range.

(2)Real-time monitoring of the temperature of the cells, cooling measures when the temperature exceeds the normal operating range of the battery pack and alarm status.

(3)Using the energy transfer equalization method to prevent inconsistencies of the cells to cause overcharge, over discharge, the battery pack to give the best care.

(4)Real-time detection of the battery terminal bus current and the use of SOC integration method for dynamic estimation Ah battery pack.

(5)Using CAN bus connection modules in the system, and real-time monitoring of the battery pack on man-machine interface module data (including battery SOC and bus voltage, single busbar current, voltage, temperature and working state of alarm status, bi-directional DCDC).

Battery management system specific functions of each module are as follows:

(1) SOC module:① monitoring the bus voltage of the battery low side, make sure the battery voltage so that is not too low or too high to cause internal damage. ② real-time monitoring battery bus current. When an over current, in time to cut off the charging and discharging relay system, based on the bus current collection, using real-time integration method to estimate the battery SOC (state of charge) Ah, real-time control the state of charge of the battery pack. ③ control bus terminal relay on and off. When the system is in normal operation, such as the bus voltage is too high or too low, SOC too high or too low, the insulation resistance is unsecured range situation, in time to cut off the bus access control relay, safety protection system. Because the system uses a distributed design approach, each module for data communication via CAN bus, SOC as a mission control center of the whole system, the use of TT CAN communication protocol control corresponding to each module to complete the task

(2) Equalization module: This module is based on the measurement data acquisition module cell voltage is calculated adjacent voltage differential, when the difference reaches a preset equalization requirements, microprocessor control module balancing energy transfer high-voltage battery to a low voltage battery until two single battery voltage difference is within a preset range of values.\

(3) DCDC control unit: In order to achieve the DCDC control, and then visualize the current operating state of the bidirectional DCDC, the module is designed with MODBUS communication interface used to connect bidirectional DCDC, which can set the output voltage DCDC operation, the maximum output current, minimum input maximum output voltage and current and other parameters, to prevent the emergence of DCDC over current

and overvoltage, system ensure safe and reliable work. By setting the high and low side voltage DCDC, you can decide the direction of movement of energy grid and the battery pack. This module is also designed with CAN bus communication interface, you can control the DC bus high and low end of the relay by the module off the situation, and then control the start and stop of the whole system.

(4) High-pressure measurement unit: the main achievement of the DC bus voltage of the high-pressure side, current detection, real-time monitoring of the size of the positive and negative bus insulation resistance, when the resistance value is lower than the system settings the system power protected to prevent lifting of personnel to operate an electric shock .

4.1. Battery Equalization Control

More battery power battery is commonly used in parallel manner, using the same model monomer battery, but in the process of production, such as temperature, used chemical materials may exist tiny differences, which can cause inconsistencies on the monomer battery parameters, embodied in the capacity, internal resistance, charge-discharge cut-off voltage, *etc*.

When the monomer battery series constitute a power battery pack, Parameters such as capacity and voltage of charging and discharging exists inconsistency ,which will lead to part overcharge in the process of charging battery ,excessive discharge phenomenon occurred in the discharge process . The overall performance of the battery pack Conform t "bucket law", the worst cells of the battery pack decide the overall performance of the battery pack. According to the monomer battery inconsistency caused harm, the most effective measure is to adopt a certain management technology to achieve energy balance between monomer batteries, which keep all monomer battery power uniformity in the process of charging and discharging.

4.2. Algorithm of SOC

SOC computing is the key and difficulties technology of system. To improve the SOC calculation and module battery performance testing, system mainly adopts the following several aspects of the technology.

(1) Under the dynamic condition ,SOC is mainly according to the current integral calculation, if current measurement error is larger, the current integral interval is too long, which will make the SOC computed cumulative error that leads to the calculated value of SOC gradually deviated from the actual value, in the early part of the management system running test, we used 250 ms integral step distance is adopted to improve the current integral, through comparison and analysis of the working condition of record, the average accumulative errors caused by per hour can reach 1%. In order to reduce the cumulative error, one is to improve the accuracy of current measurements, the second is to improve the sampling rate of current measurement, reducing the current integral interval. The linearity is adopted in this system is 0.1%, the accuracy of 0.2% hall current sensor, to complete the current measurements, the AD sampling period and current integral interval are 10 ms.

(2) Power battery at different temperatures, SOC is different with different ratio during charging and discharging, Charge and discharge the coulomb efficiency problems are exist. The larger error will be generated if only by a simple current integral calculation.

4.3. SOC Estimation Techniques

Battery charged state of (SOC) is an important parameter, describes the running state of the power battery, SOC reflects the percentage of dump energy of the battery [8]. Based on SOC value and other parameters of the current system, it can estimate the battery life, which has an important significance for the practical application system, the value of SOC is defined as the ratio of nominal capacity and battery SOC battery:

$$SOC = \frac{Q_c}{Q_n}$$

Qc for battery remaining capacity, Qn for nominal capacity of the battery

SOC estimation method is with integral method, the open circuit voltage method, kalman filtering method, *etc*., ampere-hour integral method refers to the inflow or outflow at a certain moment by accurate measurement of current of power battery and then reuse the idea of integral sum for estimating SOC[9], this method is simple, but the high requirement of flow measurement.

This paper adopts the SOC estimation method for integral method; the hall current sensor is used on current collection, which has the very high measurement precision and helpful to improve the SOC estimation accuracy.

Discharge eta coulomb efficiency ηis defined as a cell in a particular constant current and temperature constant discharge, until available at discharge,

η = Release the power/before discharge power battery, Charge coulomb efficiency is defined as the battery is charged in a specific charge current and temperature in empty battery condition, until before discharge capacity,

η = charge the power/battery power before discharge

In the system we work with the unit of battery development and production, under different temperature for the battery module in - 20 ℃, 50 ℃ to 10 ℃ temperature range interval, Measurement to 0.3 C, 0.7 C , 1 C, 1.5 C, 2 C, 2.5 C, 3 C SOC in the case of constant current charge and discharge, obtained the charge and discharge eta coulomb efficiency η which is the temperature T and current discrete model of the discrete model of the temperature T and current I.

$$\eta_{Ti,Ij} = f(T_{i,} i_j) \quad \text{(i=0,1,…,7;j=0,1,…,6)} \tag{1}$$

In practical applications, the available measured temperature T and current I, the charging and discharging efficiency determined by two-dimensional interpolation real-time to correct the current integral coefficient:

$$SOC = SOC_0 - \eta_{T,I} \int \frac{i(t)}{C_A} dt \tag{2}$$

SOC0 — initia lSOC CA — Battery capacity Ah

(1) Battery self-discharge in suspended state t also reduced SOC gradually, on condition the SOC can be forecast according to self-discharge power attenuation coefficient.

$$SOC_0 = SOC_{00} - k_{s,d} t_s \tag{3}$$

SOC00 — the initial state of charged on lay aside ;

Ksd — Self-discharge load power attenuation coefficient, %/day;

ts — Hold time;

Using the real-time clock to record electricity battery hold time, and according to the time set aside for SOC be amended accordingly.

(2) Performance attenuation correction

Internal chemical degradation caused during use will lead to the loss of capacity, the battery capacity increases with the number of cycles in start, and finally tended to decrease [10].

Therefore, the SOC calculation process should be correction cycle’s data based on the capacity of the battery manufacturer to provide CM:

$$SOC = SOC_0 - \eta_{T,I} \int \frac{i(t)}{C_m} dt \quad (4)$$

(3) After long-running, since the signal current cumulative effect, SOC will have a greater cumulative error, and direct to using the open circuit voltage to estimate the SOC, often affected by hold time and temperature, the effect is not very good. In the system, we are adopt the Kalman filter based on the estimated SOC equivalent circuit model identification method for departing from the true larger value of the SOC, tested and validated, and achieved good result, for the further improvement of SOC research and development of predicting methods laid the foundation.

The basic process of using the Kalman filter estimate of the SOC:

(a) Stablish power battery state equation and measurement equation

Let X_k = SOC_k,

let X_k = SOC_k, Then according to equation (4) to establish a current input, SOC state variables of zero-order hold sampling discrete state equation is:

$$X_{k+1} = X_K - \eta_{T,I} i_k \Delta t / C_M$$

Measurement equation is designed a mathematical model based on the battery SOC, current i, and the battery internal resistance R and other factors between the load voltage y, literature gives the main measurement equation several forms:

Shepherd model $y_K = K_0 - Ri_k - K_1 / X_K$

Unnewehr universal model: $y_K = K_0 - Ri_k - K_1 X_K$

Nernst model: $y_K = K_0 - Ri_k + K_1 \ln(X_K)$

Modified Nernst model: $y_K = K_0 - Ri_k + K_2 \ln(X_K) + \ln(1 - X_K)$

Combines several features of the above models, the battery system model is given as follows:

$$y_K = K_0 - Ri_k - K_1 / X_K - K_2 X_K + K_3 \ln(X_K) + K_4 \ln(1 - X_K)$$

Where: k is calculated using the model load voltage, Xk of SOC, ik is the load current, R is the internal resistance of the battery, and the other is model parameters. Battery measurement equation is:

$$C_K = \frac{dy_K}{dx_K} = K_1 / XK_2 - K_2 + K_3 / X_K - K_4 / \ln(1 - X_K)$$

(b) under different SOC conditions, using a single pulse, test data or typical operating conditions the collected composite cycle test pulse charging and discharging, by least squares regression excel tools, parametric measurement equation model (K0, R, K1, K2, K3, K4) are identified.

(c) Measurement equation model is obtained after the use of identification, in the state of operating conditions, using regular or irregular recursive Kalman filter algorithm to estimate the SOC, with the estimated value to correct the SOC

The basic calculation is as follows:

$$X_0 /_0 = SOC_0, P_0 /_0 = \text{var}(x_0) \quad P_{K/k-1} = (I - X_k C_k) P_{K/k-1}$$

$$X_k /_{k-1} = X_k /_{k-1} - \eta_{\tau,i} i_k \Delta t / C_M$$

$$P_k /_{k-1} = A_{k-1} P_{K-1/K-1} A_{K-1}^{\tau} + Q$$

$$Y_{k-1} = K_0 - Ri_{k-1} - k_1 / X_{k/k-1} - k_2 X_{k/k-1} + k_3 \ln(X_{k/k-1}) + k_4 \ln(1 - X_{k/k-1})$$

$$L_{k-1} = P_{k/k-1} C_k^{\tau} (C_k P_{k/k-1} C_k^{\tau} + R)^{-1}$$

$$X_{K/k-1} = X_{k/k-1} + L_{k-1}(U_{k-1} - y_{k-1})$$

$$P_{K/k-1} = (I - X_k C_k) P_{K/k-1}$$

K = 1, 2, 3 …

4.4. Software Development Environment

The software is written in C, using MCU C8051F500 as the core of a microcontroller, which is supported by the microcontroller line non-intrusive debugging, software development environment Hualong new integrated development environment Silicon Laboratories IDE [11], program downloader using U-EC6, supports single-step, continuous, set breakpoints and other debug mode, the software development process more flexible.

4.5. Equalization System Software Design

Write software code of the system are based on C8051F series MCU C language, because the equalization unit cannot be completed balancing task alone, the battery equalization control commands from the main control unit and the main control unit acquires cell voltage and temperature detected by the monomer unit and other information, this section describes the balancing unit software design of the modules. Algorithm flow of SOC module showed in Figure 3.

System initialization is to complete each module's operating mode configuration parameters, and to close the balance between all the monomers switch, then start the PWM signal generation module, the output PWM balance signal required, and then enter the main program loop, periodically execute commands balanced , according to the main control Equalize command unit sent periodically perform equalization operation between the neighboring single energy balance at least a continuation of 10S, to prevent voltage fluctuations due frequent start equilibrium condition occurs, the timer interrupt and CAN interrupt together [12] complete the synchronization timing established, to balance send control commands and to balance task receives status information.

SOC module sends the start frame to the bus, the use of packet filtering technology in the design, each module receives only a predetermined value equal to the packet, then the corresponding task processing packet information, greatly improving the utilization efficiency of the bus.

SOC control command module data structure is as follows:

```
Struct SOCU_Command
        { uchar cmd; // control command word
            //  bit0=0 -- No action;bit0=1 -- Software reset all units
//  bit1=0 -- No action;bit1=1 -- start AD conversion ofSingle battery voltage,
//  bit2=0 -- 18B20 temperature reading;bit2=1 -- Start 18B20 temperature conversion
//  Other bits reserved
uchar ttcan_cycl_count;   // TTCAN Cycle counter,
                      // each TTCAN Cycle +1,200 modulo。
uchar tmp_rd_id; // Read BMU temperature index, in the range: 0-19, the other value is invalid
                        // BMU sends a corresponding temperature measurement according to the index number
                      // Send each BMU a temperature measurement in a TTCAN cycles respectively,
                      // For read.of SOCU and HMIU
uchar blnc_id;     // Equalization control unit index,
                      // The index specifies equalization unit within the communication cycle to be controlled
                       // BBU_ctrl_id = 0, stop all equalization equalization unit
                       // BBU_ctrl_id = 1, No. 1 equalizer control unit
                       // BBU_ctrl_id = 2, No. 2 equalizer control unit
```

// ... ...
// BBU_ctrl_id = 16, 16, equalization control unit

uchar blnc_command ; // corresponds equalization unit BBU_ ctrl_id specified control command, specifically defined in the following command to define the SOC equalization control module control command data structure[13] .

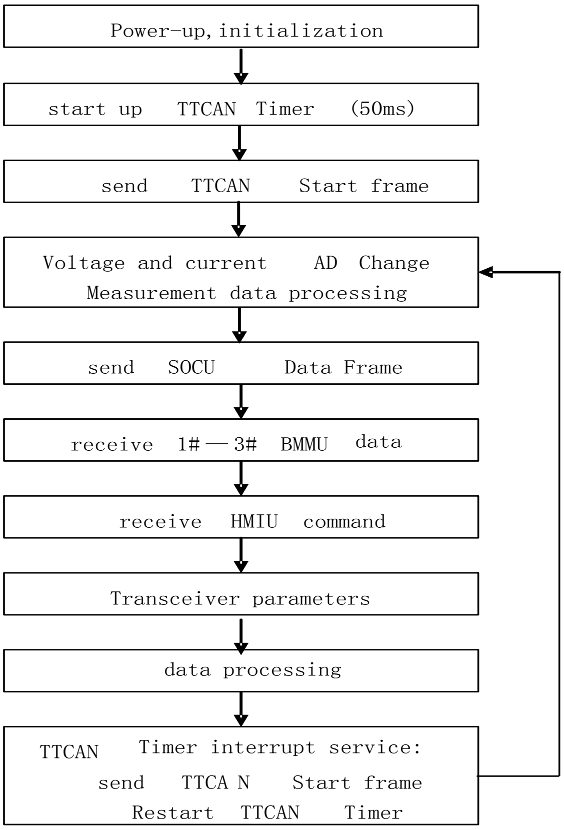

Figure 3. Algorithm Flow of SOC Module

4.6. Equalization Module Design

DCDC control module (HMIU2) for controlling and monitoring the working conditions of DCDC, including the real-time display of voltage, current information bidirectional DCDC high and low pressure side of the control relay switch status high and low side DC bus, manual control DCDC start and stop. This module is also provided with a remote control DCDC feature, select the Remote option interactive interface, and which can be remotely controlled DCDC work through this module Reserved RS-485 interface to connect a PC, set the DCDC converter operating mode and voltage current protection value.

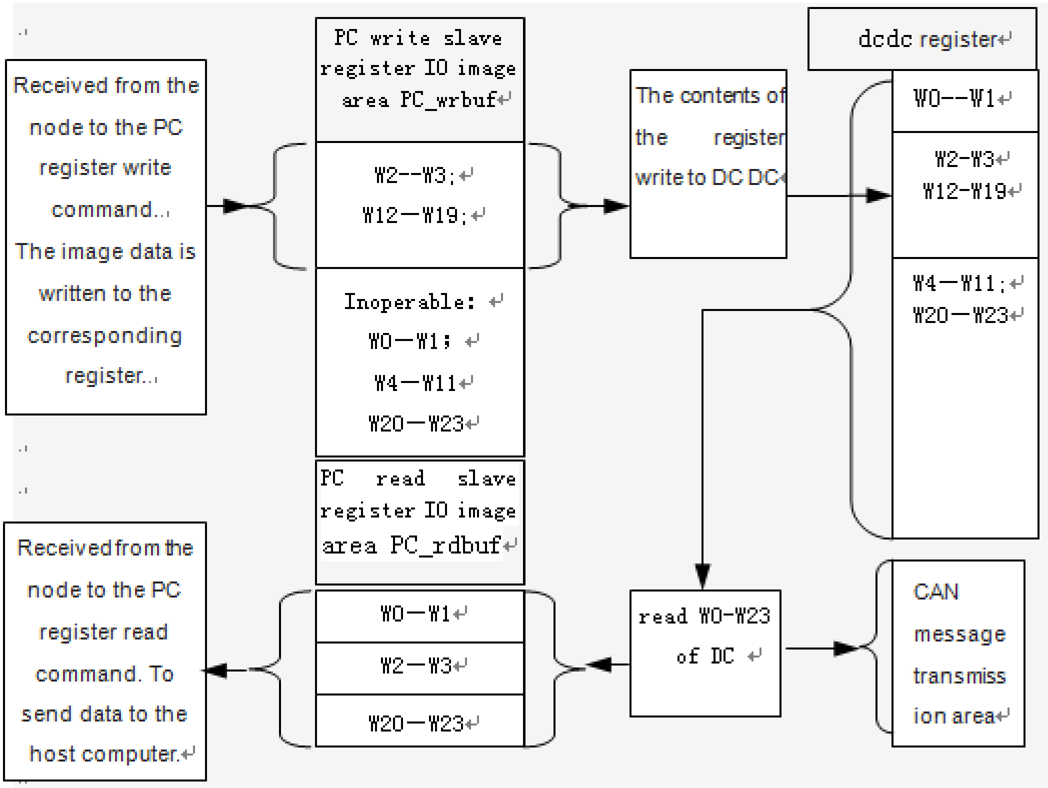

Figure 4. Bidirectional DCDC Literacy Flowcharts

In this module uses MODBUS communication using two buffers: PC relative terms, writes the register IO node image area PC_wrbuf and read from the register IO node image area PC_rdbuf. PC_wrbuf used to store data from a PC to write, writable register W2 - W3 and W12-W19; PC_rdbuf for storing data read out from the DCDC, W0-W23;

Two-way communication DCDC controller (HMIU2) and DCDC between MODBUS master mode, the corresponding port 1; HMIU2 communication with the host computer (PC) using the MODBUS way between the corresponding serial ports 2. Specifically write flow chart shown in Figure 4

5. Conclusion

Detailed description of the hardware and software analysis algorithm design of wind battery management system architecture and design of the overall system of the module carried on the balance control technology and the DCDC do in-depth research, this system is applied to wind power the formation of micro-network, but due to the experimental conditions, the external grid load simulation is now in operation, yet in the actual network of micro power battery charge and discharge management, require further experimental stud

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