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Control System of Zinc-air Battery Continuous Power Generation Device Based on Microcontroller

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The zinc-air battery with high energy, no pollution, stable discharge voltage and other unique advantages(Li et al. ,2011), in order to solve the problem of zinc electrode self-discharge, the zinc-air battery based on continuous device control system is designed, and the experimental study is carried out. The control device is composed of an unwinding mechanism, a rolling mechanism, transmission mechanism, positive and negative polar terminations and other mechanical structure, after analyzing the functional requirements of power generation device and determining the controlled objects, the overall control scheme of the experimental device is established. Using PIC16F877A microcontroller, stepper motor and its drive, relay, photoelectric encoder, the MCGS touch screen, etc. Stepper motor control drive system based on position feedback and speed feedback based of microcontroller is constructed. For stepper motor at low speed running state, study the control algorithm. By collecting and recording the battery discharge voltage, discharge current and the electrolyte temperature, the speed of the coil is adjusted, the steady control of the stepper motor is realized, and the purpose of stable power generation is achieved(Lu et al., 2012).

1. Introduction

In recent years, domestic and international is committed to research and develop zinc-air battery in all aspects. Zinc-air battery can not only be used as a small power supply, such as laptop computers, hearing aids and other mobile devices, but also can be used as power batteries in electric vehicles(Xin et all., 2014). Zinc-air is widely applied in foreign countries, the reason why it is not widely applied in our country is that in the process of using zinc-air battery the problem of zinc electrode self-discharge didn't get a good solution. In order to solve this problem, our country also in in-depth research.

For zinc-air battery research mainly divided into the following three directions, by optimizing the battery materials improves discharge performance, using structural optimization prolongs the service life, developing new zinc-air battery device. This topic according to the function requirements of zinc-air battery for power generation device, study the embedded control system based on zinc-air battery continuous power generation device, clear the controlled object, design the overall solution of the control system, including hardware system and software system, and through the test of the hardware circuit modules, to ensure the stability of the circuit module. And the stepper motor control algorithm, the closed-loop control system is carried the key research. Combined with the experiment analyze the relationship between voltage stability and movement speed stability of zinc sheet. Through the precise control of the speed of feedback and zinc position feedback speed, so as to realize the smooth power generating device. At the same time, this control system combined with the touch screen and other communications equipment, realize the good human-computer interaction function, through the PC interface and command button, good human-computer interaction function is realized. Finally, a relatively complete control system of the zinc-air battery continuous power generation device is formed to meet the functional requirements of the power generation device, to solve the problem of the zinc electrode self-discharge, and to realize the stable power generation of the generator.

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2. System composition

The zinc-air battery continuous power generation device mainly consists of a unwinding mechanism, a transmission mechanism, an air polar plate, a battery slot, a positive terminal, a rolling mechanism, a negative terminal and a box body, Figure 1 is the schematic diagram of the structure. This experiment device to realize in the movement of the zinc pole piece was to generate electricity (Sun et al., 2014). In the discharge process, the reaction of the zinc electrode in the electrolyte is slow and uniform motion, which ensures the full reaction of the electrochemical reaction, the zinc electrode is used as the anode to lose the electron, and the air electrode is used as the cathode to obtain the electron(Hernández-Fernández et al., 2010; Jencarova et al., 2012). When don't need electricity, the zinc electrode is quickly withdrawn from the electrolyte, and the electrochemical reaction is automatically stopped（Massimo, 2014）.

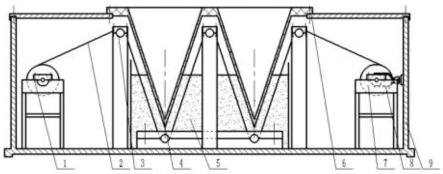


Figure 1: Structure diagram of zinc air battery continuous power plant: 1. Unwinding mechanism 2. Zinc electrode 3. Driving mechanism 4. Air electrode 5. The battery slot 6. Positive extreme 7. Coiling mechanism 8. Negative extreme 9. Box

According to the functional requirements of the power generation device, the overall scheme of the control system of the device is determined. Using PIC16F877A MCU, stepper motor and its drive, relay, photoelectric encoder, the MCGS touch screen, etc. Stepper motor control drive system based on position feedback and speed feedback based of microcontroller is constructed. Figure 2 the overall plan of the control system.

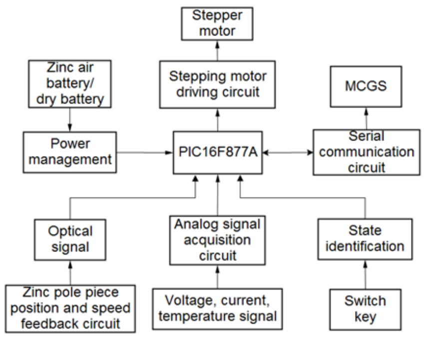


Figure 2: The diagram of Zinc-air batteries continuous power generation

3. Hardware circuit design of control system

3.1 Step motor control circuit

Stepper motor control circuit is used to control stepping motor start and stop and high or low speed movement, the stepper motor is controlled by the number of input pulses, the speed of the motor depends on the frequency of the pulse signal. The system uses 5V four phase six wire stepper motor, the stepper motor driver chip L298 and stepper motor control chip L297 combination of the way the development of stepper motor control circuit. As shown in Figure 3 and Figure 4.

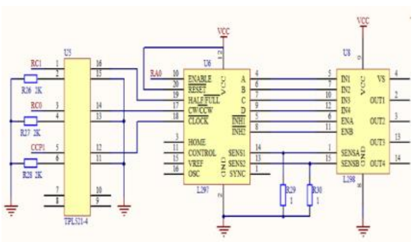


Figure 3: Stepper motor control circuit

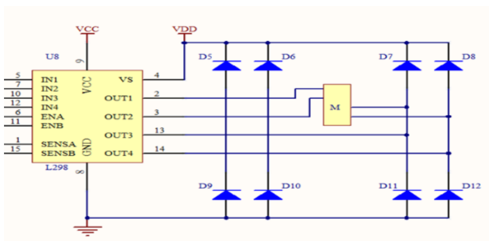


Figure 4: Step motor and L298 module connection diagram

3.2 Other circuit

Power circuit as the basis of the normal work of the hardware circuit, the need to MCU, stepper motors, encoders, touch screen and sensor provides power. Because of the difference of the supply voltage, taking into account the impact of the power supply, the transient response speed stability and other effects on the entire system performance, using LM2576S-5.0 series LM2576 chip will be DC power conversion.

The input circuit includes a key input circuit, an analog input circuit and an encoder signal input circuit. Button input circuit is used as a switch for the system to stop and run. Analog input circuit acquisition voltage signal, temperature signal and current signal. The analysis of these three kinds of signals can know the current state of the battery power. The encoder signal input circuit converts an electrical pulse into a digital quantity to feed back the speed and position of the zinc pole piece.

The communication circuit is connected to the Kunlun Beijing TPC7062TD model touch screen via 232 cables, which provides the possibility for the realization of human-computer interaction.

4. Software design of control system

4.1 Main program

Zinc air battery power plant control system under normal operating conditions, there are mainly the following processes：

1. Initial state of power, the main module of the system of each module of control and bisection module signal processing, by the external power supply provides the initial power. Run stepper motor control subroutine to realize high-speed rotation of the rolling motor, drag non discharge of zinc electrode movement, and shipped by line encoder input subroutine modules, by the position feedback change the speed of movement of the zinc electrode

2. Normal power generation state, the main module of the system to control the stepper motor subroutine. Through the speed feedback to make the winding motor moving at a constant speed, so as to realize the uniform motion of the zinc pole piece. Through the system PC MCGS touch screen real-time display of the discharge current, discharge voltage, zinc roll speed, waiting for the host computer to issue a discharge stop instructions.

3. Stop generating state, unwinding mechanism high speed reverse rotation. The speed of the unwinding motor controlled by position feedback. Finally the zinc pole piece is completely pulled out.

4.2 Step motor control subroutine

Stepper motor control subroutine as the most important function of the main program, in addition to achieves the basic functions and determines the quality of the final results. Therefore, through the analysis of the following aspects determined step stepper motor control of sub procedures.

(1) The motion of the stepper motor

This system by stepping motor drives the zinc plate into the battery slot for discharge and withdrawn from the battery slot end discharge reaction. So the movement process of step motor is in essence to realize high and low speed switching, with constant speed in a low speed and positive and negative switching. The motion process of the stepper motor in automatic mode is shown in Figure 5.

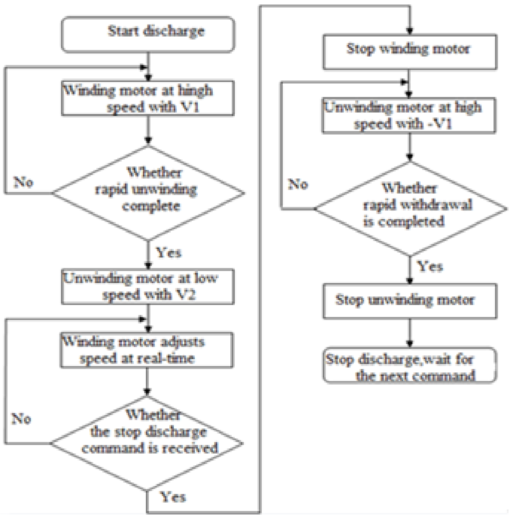


Figure 5: Stepper motor sports flowchart

(2)The realization of position feedback and speed feedback of zinc electrode
Through a photoelectric encoder mounted on the transmission shaft to realize the feedback control, the use of photoelectric conversion principle of the angle displacement changes for the corresponding electric pulse, and to digital output (Zhou et al., 2011). This system uses A, B dual phase signal input count to achieve accurate positioning and speed feedback.
For precise positioning, the input pulse n is counted by the software, so as to determine the actual position. When the coil is in place, the count value is:

N=(4X600XS)/R

Among them, S is the linear distance from the initial position to the normal discharge position, and the R is the radius of the drive shaft of the encoder.
For the feedback speed, rolling at low speed, delay at regular intervals by the software for calculation, the change of the n value Δ n can be concluded the zinc pole piece line speed.
(3) Discharge termination voltage and movement speed of zinc air battery
According to the principle of the discharge reaction of zinc air battery and the relationship between the movement speed of the zinc electrode and the zinc sheet, the relationship between the final discharge current and the motion speed of the zinc sheet is obtained. The actual work process would be affected by the air flow, electrolyte concentration and other reasons, participate in the reaction of zinc accounted for 20% of actual zinc tablets to 32%. In order to ensure the full reaction, lower limit of 20% zinc speed should be selected, so the initial movement speed of the zinc is:

V2=(5I)/(ksq)

In order to ensure the stability of the zinc air battery power generation, the system takes the 1.05 V ~ 1.15 V as the standard, as the voltage of the final discharge of zinc air battery.
(4) Stepping motor control algorithm
Zinc air battery power generation system using 28BYJ-48-5V stepper motor, which belongs to the five line four phase system, the step angle is 1.8, the maximum speed of 600RPM.
Set the maximum speed V1 for the stepper motor rotation when the maximum speed of 600RPM, the minimum speed V2 for the low speed rotation when the minimum speed of 6RPM. In the case of the maximum speed, the number of pulses per second is:

P1=(600/60)X(360/1.8)=2000

In the case of the minimum speed, the number of pulses per second is:

P1=(6/60)X(360/1.8)=20

Namely in the speed of 600r/min when the pulse frequency is 2000 HZ, at the speed of 6r/min, the pulse frequency is 20 HZ.
PIC16F877A microcomputer CCP1 produce square wave signal control stepping motor. Choose single chip microcomputer frequency is 4 MHZ, internal instruction cycle for 1μs, TMR1 using internal timing and frequency CCP1 preset calculation is as follows:
(1)f1=2000 Hz, Square-wave cycleT1=500 μs, Preset value of CCP1 is 250, High level time is 250 μs.
(2)f1=20 Hz, Square-wave cycleT1=500 μs, Preset value of CCP1 is 25000, High level time is 25000 μs.

3.3 Other subroutine

The control system comprises a host computer subroutine, uses MCGS touch screen to realize man-machine interaction, help to display the state of zinc plate movement, and zinc air battery power state. Encoder subroutines are written to solve the simple use of stepper motor accuracy is not high, through the encoder feedback, form the step motor closed-loop control system.

4. System test and result analysis

4.1 Step motor closed-loop control system test

As shown in Figure 6 for zinc air battery power device in the process of actual power, the change of zinc plate movement speed. the speed curve accurately reflect the zinc plate movement speed of zinc air battery power device in the working process ,namely when the initial power from low speed to high speed, until the zinc contact with the electrolyte to slow down to normal power at constant speed in a low speed.
The normal power generation device of zinc air battery, a key factor to ensure the stable output voltage is to control the velocity of the zinc electrode, according to the requirements, the system design of stepper motor closed-loop control system, which is validated by the experiment. When the transfer roller diameter is 10 mm,

zinc plate velocity is roughly v=3.14×10×3 mm/s=94.2 mm/s. In the normal power generation device during a period of 35 randomly selected time points, and record each selected time point rate, plot each sampling time zinc velocity curve, as shown in Figure 7. We can see that the actual velocity near the theoretical speed fluctuation from the formula, the relative error = (measured value - true value) / true value x 100%, calculate the relative error of the velocity, and draw the curve of the relative error as shown in Figure 8. The relative error is less than 1%, The control effect of stepping motor is ideal, so the zinc pole piece movement has high stability, can carry on the uniform motion.

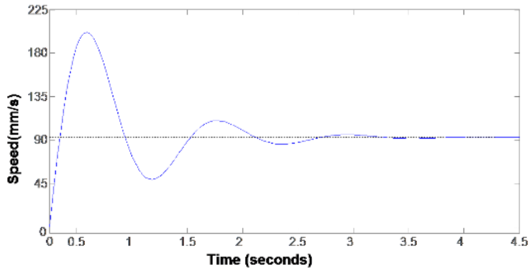
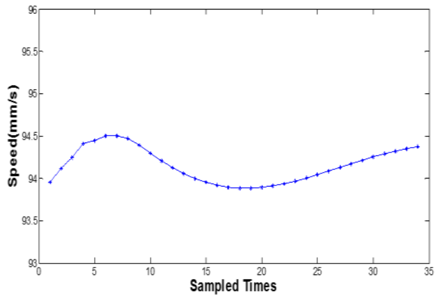


Figure 6: Movement speed change of zinc electrode in power generation



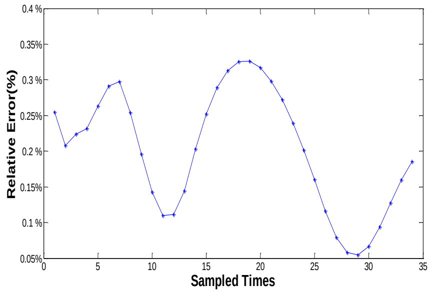
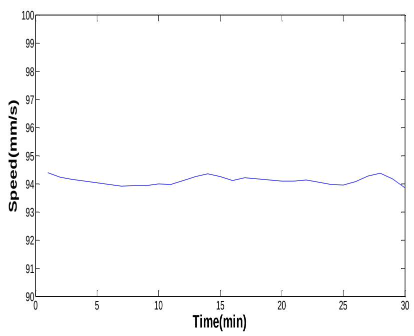


Figure 7: Motion velocity of zinc sheet at *Figure 8: Relative error of motion velocity of zinc sheet*
different sampling time

4.2 Continuous generation test of zinc air battery

In order to better detect zinc air battery power generation effect, three groups of experiments was conducted in the normal power generation process of zinc air battery, respectively, at different times of the selected 30 minute, record this time zinc pole piece movement speed and zinc air battery power voltage, as shown in Figure 9~ Figure 14 shows. Which can be observed, in zinc air battery power generation process, zinc sheet movement speed at about 94.2mm/s, velocity error is relatively small. The output voltage between 1.05v ~ 1.15V, voltage accuracy reached the 10mV, meet the demand of technology, has high precision for zinc air battery.



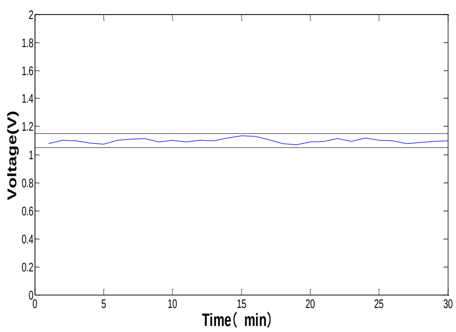


Figure 9: Times A sampling rate

Figure 10: Times A output voltage

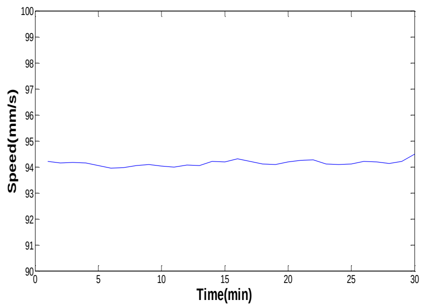


Figure 11: Times B sampling rate

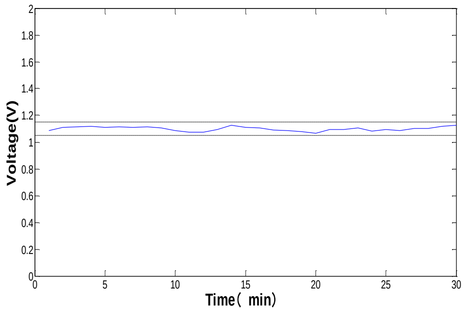


Figure 12: Times B output voltage

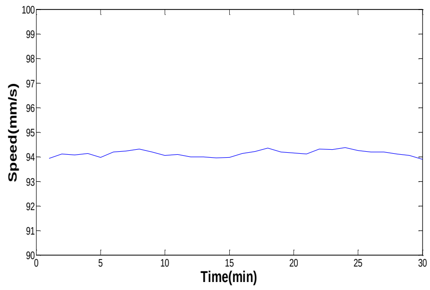


Figure 13: Times C sampling rate

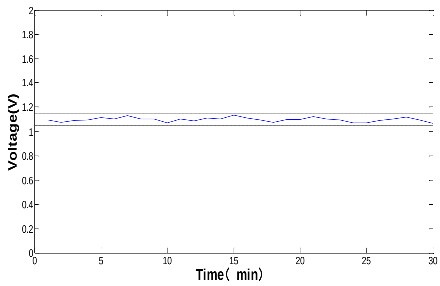


Figure 14: Times C output voltage

5. Conclusion

(1) The experiment device use feedback speed as feedback variables, compared with the set value, by step motor closed-loop control system, change the speed control of zinc plate movement speed, so as to realize the power of device requirements.

2) The experimental device, combined with the sampling parameters, to calculate and optimize the low speed operation of the zinc pole piece, to achieve the goal of the zinc pole piece in the movement of power generation.

(3) Through a variety of experiments, the experimental device can be very good to meet the zinc air battery continuous power generation process requirements, to achieve stable power generation device, with high accuracy and stability.

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