Test of battery internal resistance

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Abstract. Responding the problem in the measurement of battery internal resistance that it is difficult to improve the accuracy because of the power supply ripple and many other factors, a method used chaotic oscillator is studied. Using the principle that chaotic oscillator is sensitive to initial value this method simplifies the measuring circuit and ignores the anti-interference circuit. To combine the good inhibitory effect on noise to AC internal resistance detection method, the on-line detection is realized.

1. Introduction

In early 1992, Birx showed chaotic oscillator and complex mappings prior to the feedback network (CMFFNS) used in weak signal detection. In recent years, Wang Guanyu showed chaotic oscillator array method of detection of weak signal frequency. As the solar energy conversion backup, battery is the important guarantee of power output when the sun light is lack. So it becomes the important work that the effective maintenance quality of battery. It can be a very good mastery of the current work capacity by measuring the internal resistance of storage battery. But the battery resistance is not a constant. It changed with the working state of battery and the environmental conditions, especially when the battery remaining capacity is less than 40%. Battery resistance is very small (generally speaking, the battery capacity greater, the resistance smaller.). So it is difficult to measure the internal resistance technically with the outside interference and noise.

Under certain conditions chaotic system has noise immunity and it is sensitive with small signals. Even if the signal amplitude is lesser, it also can be made that the phase transition of system essentially. Then the weak signal can be detected from the noise. Because of the good properties of chaotic systems, it can reduce and even ignore the circuit design anti-interference using chaos detection system to realize the battery resistance testing. Then impedance measurements are simple, rapid and low cost.

2. Chaotic oscillator theory
2.1 Chaotic oscillator Duffing equation
The movement in chaos system is random, but the equation describing the movement is determined. The Duffing equation is chosen as the chaotic system equations detecting of weak periodic small signal under the background of strong noise.

The Duffing equation
\[ \ddot{x} + k \dot{x} + \alpha x + \beta x^3 = 0 \]  \hspace{1cm} (1)

is a motion equation of description of the nonlinear elastic system. Where \( k \) is the damping ratio, \( \alpha x + \beta x^3 \) is non-elastic restoring force, \( \ddot{x} \) is the second derivative of \( x \) and \( \dot{x} \) is the first derivative of \( x \). When external force \( \gamma \cos(\omega t) \) in Duffing equation, the equation turns into
\[ \ddot{x} + k \dot{x} + \alpha x + \beta x^3 = \gamma \cos(\sigma t) \]  \hspace{1cm} (2)

The analysis shows that the system characteristics mainly depends on the elastic recovery force when the signal in equation (1) is determined. So \( \alpha \) and \( \beta \) are the keys of Duffing equation detecting weak periodic small signal. Through the research Duffing equation turns to be that
\[ \ddot{x} + k \dot{x} - x + x^3 = \gamma \cos(\sigma t) \]  \hspace{1cm} (3)

when \( \alpha = -1 \) and \( \beta = 1 \). Then the weak periodic small signal can be realized exactly.

2.2 Detection principle of chaos Duffing oscillator equation
The parameters value of \( k \) and \( \gamma \) is the key of that the chaotic Duffing oscillator is in the state of chaotic or periodic. In order to the better calculation and simulation, equation (3) turns to that:
\[
\begin{cases}
\dot{x} = y \\
\dot{y} = x - ky + y \cos(\sigma t)
\end{cases}
\]  \hspace{1cm} (4)

According to the melnikov equation, the chaos threshold of Duffing oscillator equation is that:
\[ \frac{\gamma_c}{k} \geq R = \frac{J_a}{J_1} = 1.6769 \]  \hspace{1cm} (5)

In this equation, \( \gamma_c \) is small signal threshold amplitude cycle, \( k=0.5, \quad \omega = 1 \text{rad/s}, \)
\[ J_a = \int_0^{\pi} x^2(t) \, dt \quad \text{and} \quad J_1 = \int_0^{\pi} x(t) \cos(t) \, dt \].

There is the only determined corresponding threshold with the changing \( k \), therefore, this paper study the change of state of chaos in the condition of \( k=0.5 \). For chaotic system, it is in the movement that the threshold is \( \gamma_c \), where in the critical point of cycle mode and chaos state. Adding weak periodic small signal \( x(t) \) to the testing strong noise, chaos Duffing oscillator equation turns into
\[
\begin{cases}
\dot{x} = y \\
\dot{y} = x - ky + x^3 + \gamma \cos(\sigma t) + x_n(t)
\end{cases}
\]  \hspace{1cm} (6)

In this equation, \( x_n(t) = a \cos(t) + k \cdot \text{randn} \), \( \text{randn} \) is the generated function of matlab gaussian white noise. The equation is getted according the equation (5)
\[ \dot{y} = x - ky + x^3 + \gamma_c \cos(t) + x_n(t) \]
According to the characteristics of chaotic systems, chaos system will be periodic from the original state when $\gamma > \gamma_c$. And it will be chaotic from the periodic state when $\gamma < \gamma_c$. So the mixing system will be periodic state when $\gamma_c + a > \gamma_c$ in equation (6). Then the detection of weak small cycle signal will be realized in the strong noise conditions.

3. Solar battery essential resistance measurements

Solar battery essential resistance measurement is a complicated process. The common methods mainly are the density, opening voltage, dc discharging and communication.

The methods of density estimate the essential resistance mainly through measuring of the density of battery electrolyte. The method usually is used to measure the impedance of lead-acid batteries in open style, apparently not the sealed lead-acid batteries.

The methods of open circuit voltage estimate the essential resistance by measuring terminal voltage of battery with poor precision even the wrong conclusion. Because even in the condition of a small capacity battery, the terminal voltage filling can still be very normal in the floating state.

The voltage changes when step current $I$ flows in batteries with the method of DC discharge. The changes of battery voltage $\Delta U$ decreases with the shorter time measurement. This shows that $\Delta U$ value contains the concentration polarization composition reduced which indicates that the concentration polarization composition the shorter containing in $\Delta U$ reduced. The measured value $\Delta U$ is unchanged when the measuring time less than 1ms.

The method of DC discharge is that the change voltage $\Delta U$ between 0.5ms-1.0ms is measured during constant current $I$ discharging. And then calculate the ohm resistance by $r=\Delta U/I$. The main defects of the methods are as following. Friet this measurement must be realized in the condition of static or offline. So the online measurement can't be really realized. Then this will inevitably bring security hidden danger of equipment operation. It is still unknown whether so huge current affects the dc system when it is static. The system will be in more safe hidden trouble during weaning if it is a long time measurement. Second the battery is damaged with huge discharge current and some even hundreds of ampere. Communication is one of the important electrochemical measurements. The feedback voltage is measured through exerting a small low-frequency current to the battery.

Calculate the essential resistance through the ratio between voltage and their phase separation. The battery electrodes are porous and connected by more pieces of electrodes in parallel, so its equivalent circuit of exchange impedance is extremely complex. Therefore treating porous battery electrodes is based on the theoretic analysis results of planar electrode.

4. Battery essential resistance testing principle based on chaotic system

4.1 Alternating method of battery essential resistance testing

When using controlled current $\Delta I = I_{max} \sin (2\pi ft)$, $\Delta U = U_{max} \sin (2\pi ft + \phi)$ the impedance
is $Z(f) = \frac{U_{\text{max}}}{I_{\text{max}}} e^\phi$. It is in connection with the frequency and $|Z| = U/I$ with phase angle $\phi$. In theoretic field, essential resistance can be measured measuring the voltage change from the alternating current signal fed into battery.

$$R = \frac{U_{AV}}{I_{AV}}$$

(7)

In this equation, $U_{AV}$ is the average of ac voltage detection. $I_{AV}$ is the present average of alternating current signal. Alternating method is good at that it doesn’t need electric discharge during the measuring process, and repeated the measurement conveniently. But because the signal amplitude fed into is limited and the resistance is weak, response signal of amplitude the battery is small. Then it is easy interfered, especially in the online measurement disturbance. Therefore the anti-interference ability of alternating method is weak, and is vulnerable to external noise. So alternating method needs to eliminate power supply ripple and other sources. Chaotic oscillator model testing techniques is used to eliminate the influence factors. Specific means are that the battery ends on $I_s$ constant current source, through the data acquisition card collecting the battery voltage $U_o$ into the computer, and get into chaotic oscillator model. Then test the battery ends voltage and get the essential resistance by $Z = \frac{U_o}{I_s}$.

4.2 Design structure of essential resistance based on chaos

Study design of excitation device, and special to be fed into the battery is controlled by alternating current signal sampling card by measuring the battery voltage signal. The internal structure of the test design is shown in figure 1.

![Figure 1. System diagram](image)

This structure is mainly by the sinusoidal signal generator, coupling drive circuit, constant-current power amplifier circuit, control circuit, constant flow data acquisition circuit and chaotic system simulation model.

4.3 Battery resistance measurement principle

![Figure 2. Measuring principle diagram of resistance four-wire method](image)

Normally solar battery resistance is very small, at about milliohm, so the impedance measurement line can ignore. So using four-wire method for measuring the driving current loop, and induced voltage circuit. After four line method measuring principle shows in
4.4 Chaotic system

![Duffing oscillator simulation model](image)

**Figure 3.** Duffing oscillator simulation model

Duffing oscillator simulation model in the system of chaotic systems shows in figure 3.

![Output waveform](image)

(a) waveform of output x  
(b) waveform of output y

**Figure 4.** Output waveform

The output of output x is in the cycle state of the Duffing system, and the output of output y is in the chaos state of the Duffing system. Therefore, the waveforms of output x and output y are extracted. Then the state of Duffing system is judged according to the relationships between the waveforms and their phase track. So select appropriate system parameter, and get the testing voltage value according to the figure 4.

5. Discussion and conclusion

An effective essential resistance detection method is achieved using ac impedance method and Duffing chaos system. Simulation results show that this method not only can more easily detect internal storage battery essential resistance and can accomplish the on-line detection.

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