Wind-based Flow Battery Energy Storage Control System

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ABSTRACT

A methanesulfonate lead flow battery (MLB) stack under control is proposed. The same electrolyte was used as both the negative and positive electrodes without film separation avoiding maintenance costs and short life. MLB is designed and related charging discharging character is studied. Furthermore, the remote island case study is given and related control system is implemented. Wind turbine determines the volatility and uncertainty of wind power unit mass grid, which will seriously affect the power system operation state, wind power grid problem increasingly prominent. So that it will solve off-grid, abandoned wind and other problems that Non-grid wind power using local storage by methanesulfonate lead flow battery stack.

INTRODUCTION

Energy is the material basis for the survival and development of human society, and the shortage of fossil fuels worldwide has become increasingly serious, power is a clean energy, easy to use, has an extremely important role in modern society. However, with the increasing growth of China's GDP, electricity supply and demand highlights with the increasingly serious problem of power grid reliability, poor flexibility, and low energy utilization. The key to solving this problem lies in wind energy, solar energy is widely used. But conventional power control system is difficult to follow the fluctuations of wind power and photovoltaic power generation. The construction of ancillary storage power station is an effective way to save energy and breakthrough the dilemma. At the same time, many times "power shortage" phenomenon takes place in Yangtze and Pearl River Delta of China. Therefore, if we can be created "Valley of charging peak discharge" of energy storage power station, which will have a broad market space. Flow battery energy storage power station is accepted because of low manufacturing cost, large storage capacity, high conversion efficiency, flexible design and siting, and many other advantages. The key technology of flow battery system is:① Suitable battery charge and discharge systems;② Efficient, stable and long life power stacks.[1]
BATTERY THEORY

In recent years, the University of Southampton began a series of studies on lead-acid batteries. Positive and negative electrode use the same electrolyte without a new lead-acid battery separator design model, which makes this new lead-acid batteries not only cost savings and simpler structure, but also have traditional large current discharge capacity advantages of lead-acid batteries, its energy efficiency is much higher than conventional lead-acid batteries (nearly 80%). University of Southampton has developed 3kW lead-based batteries for C-TECH Company. University of California and General Atomics is developing 20kW lead-based batteries in support of the US Department of Energy, has not been reported. Only Beijing University of Chemical Technology of Science, Shenyang Polytechnic University, Xi’an University of Technology and other colleges and universities has just covered this area in China. It is understood that there are no reports of power prototype.\[1\]

For the leveling of output power fluctuations of renewable energy sources, electricity power storage, including the redox flow battery as a strong candidate, are investigated. We have proposed the lead methanesulfonate redox flow battery on the basis of Input-output ratio. Lead satisfies the necessary condition for the excellent active material for the redox flow battery, i.e. the two battery reactions are reversible. Since the energy efficiency of charge-discharge cycles depends on the reversibility of the battery reactions, the Lead battery is expected to be of higher charge-discharge performance at a large current density even compared with the existing vanadium redox flow battery.\[2\]

Methanesulfonate lead single flow storage power plant system have many advantages such as low cost, power design flexibility, high efficiency and long charge-discharge cycle life, which can solve the shortages of mechanical energy storage site, such as inflexible, high-cost and long construction period, and also avoid the disadvantage of tradition chemical energy storage, such as maintenance costs high, short life problems. Methanesulfonate lead single flow battery is a new type of battery energy storage power station. It adopted soluble acid methyl lead (II) as the electrolyte, soluble Pb (II) reduction in the negative electrode surface to form a metal Lead oxide in the anode surface to form a solid PbO2 when charging, an electrical potential difference (1.7V). Charge and discharge reaction can be expressed as:

The electrochemical reaction of Anode:

\[ \text{Pb}^{\text{disch arg e}} \xrightarrow{\text{ch arg e}} \text{Pb}^{2+} + 2e^- \]  

(1)

The electrochemical reaction of Cathode:

\[ \text{PbO}_2 + 4H^+ \xrightarrow{\text{disch arg e}} \text{Pb}^{2+} + 2H_2 \]  

(2)

The overall reaction:

\[ \text{PbO}_2 + 4H^+ + 2e^- \xrightarrow{\text{disch arg e}} \text{Pb}^{2+} + 2H_2O \]  

(3)
With a molar ratio of 1:2, lead carbonate and methyl sulfonic acid, and adding an appropriate amount of deionized water to obtain methyl lead acid solution.

\[
\text{CH}_3\text{SO}_3\text{H} + \text{PbCO}_3 \rightarrow \text{Pb(CH}_3\text{SO}_3\text{)}_2 + \text{H}_2\text{O} + \text{CO}_2
\]  
(4)

Under normal temperature and pressure, a system can do the maximum power (W) equal to the process of change in Gibbs free energy (\( \Delta G \))

\[
W = -\Delta G
\]  
(5)

In the storage battery, it is assumed E is electrical potential difference across the anode and cathode, and then the charge (Q) through the use of this potential difference is:

\[
W = QG
\]  
(6)

Because of the external circuit storage batteries, charge transfer is achieved by electron transfer, it is:

\[
Q = nF, \quad F = \text{96485.3383±0.0083C/mol}
\]  
(7)

Where: n is the number of moles of Electronic transmission.

So that, we can get the maximum reversible voltage of battery:

\[
E = \frac{\Delta G}{nF}, \quad F = \text{96485.3383±0.0083C/mol}
\]  
(8)

Where: E is the maximum reversible voltage of battery; n is the number of moles of Electronic transmission.

According to the thermodynamic theory, Gibbs free energy change and participation substance's activity relationship is shown as follows under isothermal reversible conditions in chemical reaction.

\[
\Delta G_{\text{PbO}_2/\text{Pb(O)}_2} = \Delta G_{\text{PbO}_2/\text{Pb(O)}_2}^0 + \frac{2.3RT}{2F} \log \left( \frac{\text{Pb}^2+}{(\text{Pb})^2} \right)
\]  
(9)

There Nernst equation provides the relationship between the electrode potential E concentration and electrode process between participants.\[3\]

\[
E_{\text{opencircuit}} = E_{\text{PbO}_2/\text{Pb}^2+}^0 - E_{\text{Pb}^2+/\text{Pb}}^0 - \frac{2.3RT}{2F} \log C_{\text{Pb}^2+} + \frac{4.6RT}{F} \log C_{\text{H}^+}
\]  
(10)

**CONTROL SYSTEM DESIGN**

Methanesulfonate lead battery belong to a single flow battery system, that is a single tank, single pump, single cycle process, compared to the traditional dual flow system structure is more simple, and eliminates the use of film also simplifies the cycle. It make system integration more flexible during assembly because of the Independent of capacity and battery, which can select a single increase capacity without simultaneously changing the power. This system adopted peristaltic pump the solution is withdrawn from the reservoir tank to form cycle, which can control the flow and the speed. The battery will be assembled and sealed to connect it to the battery test system, the battery terminals are respectively connected to the positive and negative tester channel. Test equipment supports serial input and output, and a remote computer setup for battery the charge-discharge test, shown in Figure 1.\[3,4\]
After a large number of tests, charging characteristics of this flow battery as follows shown in Figure 2:

The technology is also particularly suited to islands and other regions of water shortages, lack of electricity, which can effectively solve the supply problem of energy and fresh water of islands, desert and other remote areas. In the situation of global energy and freshwater resources shortage, this technology integration has a very important strategic significance.

The fresh water purification is implemented based on methanesulfonate lead battery and external power supply using the control system shown in Figure 3. At first, the wind turbine and related battery stack is setup under the ground of the remote island to supply the purification equipment. The power generated from the wind turbine is stored in the methanesulfonate lead battery stack under the control system. When the purification equipment runs, the power supplement is analyzed depending on whether the battery is full or the voltage reaches the rated value. External power supply is only the alternatives. Then, the control system
analyzes the fan voltage to turn on or off the charge PWM, determine the battery voltage to open or close discharge PWM [5].

![Diagram](image)

**Figure 3.** Fresh water purification program logic based on wind energy.

**CONCLUSION**

Non-grid wind power solve off-grid, abandoned wind and other problems, and directly apply to desalination, reduce the use of coal-fired electricity network consumption and reduce greenhouse gas emissions, not only has considerable economic benefits, but also has good social and environmental benefits.

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