Fuel Cell Test System Based on AVR Single-chip Computer

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***Abstract*—Fuel cell technology is considered to be the 21st century of choice for clean and efficient power generation technology, due to a fuel cell itself is a very complex physical and chemical process, the input output are different kinds of physical quantities, so a practical fuel cell must have accurate monitoring and control the performance of these physical quantities. Are briefly introduced in this paper the characteristic and principle of the fuel cell, the function of fuel cell system and the fuel cell test system are analyzed, and made a specific fuel cell test system implementation scheme. The system Atmega32 is the core, can finish the collection work of various data quantity very well, theapplication fuel cell inspection meter can complete to the battery voltage and the current measurement. This system has great flexibility, except for the detection of PEMFC, it can also be adapted to different types of fuel cell detection.**

Keywords-Fuel cell; Data acquisition; Serial communication; Detection system; Control.

I. INTRODUCTION

Fuel cell compared with the traditional energy of today, with many advantages, such as high energy conversion efficiency, can extract the hydrogen from other renewable resources, use of non pollution. Therefore, many countries around the world into a lot of human and financial resources to make research and development. Due to the fuel cell itself is a very complex physical and chemical process, the input output are different kinds of physical quantities, so a practical fuel cell must have precise monitoring and controlling the performance of these physical quantities. Tell from this meaning, fuel cell monitoring control system not only in the development stage of a fuel cell system is very important, even if is in the after put into use for is indispensable for maintain the normal work of the fuel cell. The fuel cell is directly converted into electricity by electrochemical method.. It does not process through the heat engine, high energy conversion efficiency (40% - 60%); environment friendly, almost no emissions of sulfur and nitrogen oxides; carbon dioxide emissions also than conventional power plants less 40% above. Because of these outstanding advantages, fuel cell technology is considered as the first clean and efficient power generation technology in twenty-first Century.

II. FUEL CELL PRINCIPLE

The fuel cell is a device that directly transforms the chemical energy of the fuel into electrical energy by electrochemical reaction.. The fuel cell is composed of platinum based metal as the anode, cathode and ion conducting electrolyte.. The hydrogen oxygen fuel cell, for example: when the anode and the cathode is connected with the load, hydrogen oxidation at the anode, oxygen is reduced at the cathode, anode to produce proton transmission through the isolation membrane to the cathode, cathode with oxygen to form water, electrons from the anode through the load flow to the cathode to form an electrical circuit, to generate electricity and drive load. The difference between the fuel cell and the primary battery and the two battery is that the battery can continuously provide the power to provide the fuel to the battery continuously.. And the final product of the battery reaction is only water, and the environment is not polluting. Its schematic diagram as shown.

Anodic reaction (battery cathode) :

$$H_2 \longrightarrow 2H^+ + 2e^- \tag{1}$$

Cathodic reaction (the positive electrode of the battery) :

$$2H^+ + \frac{1}{2}O_2 \longrightarrow H_2O + h\,e\,a \tag{2}$$

The general chemistr:

$$H_2 + \frac{1}{2}O_2 = H_2O \tag{3}$$

III. THE ANALYSIS OF THE FUEL CELL SYSTEM

A. System

Fuel cell system of PEM fuel cell system in addition to the core part of the cell stack, still need some auxiliary system to work normally.

1) The battery pack, it is the heart of the battery system, it converts the chemical energy of fuel into electricity output outward to load.

2) The supply of hydrogen and oxygen (air) system, the system function is to provide battery with fuel and oxidant;

3) Battery pack water and heat management subsystem, main is to make sure the battery internal water/heat balance state, control the temperature of the fuel cell in a proper range;

4) The output power adjustment system, including the stability of the dc voltage, overload protection and ac dc

variable communication subsystem to meet the needs of users;

5) Automatic control system, because of the fuel cell is a automatic generating equipment, so the function of automatic control subsystem is the key control parameters of each subsystem test, adjustment and control, to ensure that the battery system is stable, reliable operation. The system should also include the start of the battery system, Parking program and failure measures. From a hardware perspective, automatic control system by a variety of sensors, actuators, and executive control software.

B. The Physical State of Fuel's Impact on Performance

The physical state of the fuel (temperature, humidity, purity, pressure, etc.), electrical load, heat load, and the conditions of the environment can affect the working state of the fuel cell. For fuel, different types of fuel have different calorific values. Even the same type of fuel, in the different humidity, under the pressure of the fuel, the reaction of the situation may change with the time of the changes. The fluctuation of electrical load seriously affects the performance of the battery. And, in the power supply process, each part of the response to transient changes are different. Environmental conditions have a serious impact on the performance of the battery. Such as: air temperature and pressure will affect the content of oxygen. Because of the PEM fuel cell for proton exchange membrane to maintain certain humidity, so must the input fuel cell reaction air humidification, then the relative humidity of the air also on the battery performance will play a key role. Fig .1 , Fig .2 shows the characteristic

Curves of fuel cell at different temperatures and pressures.

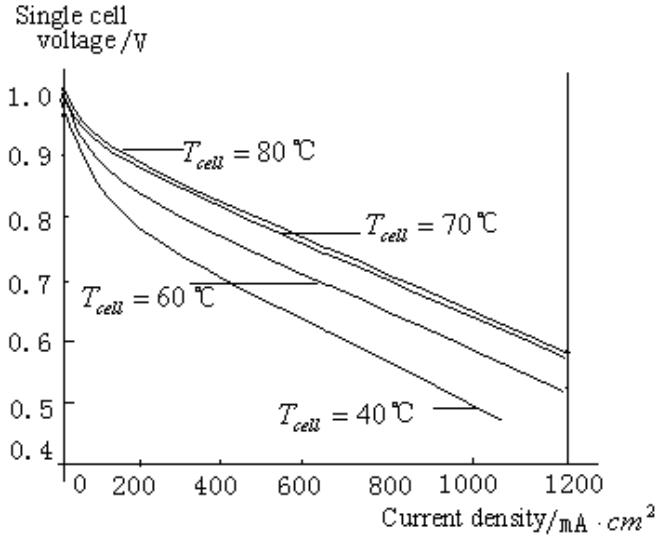

Figure 1. Temperature on the performance of the battery

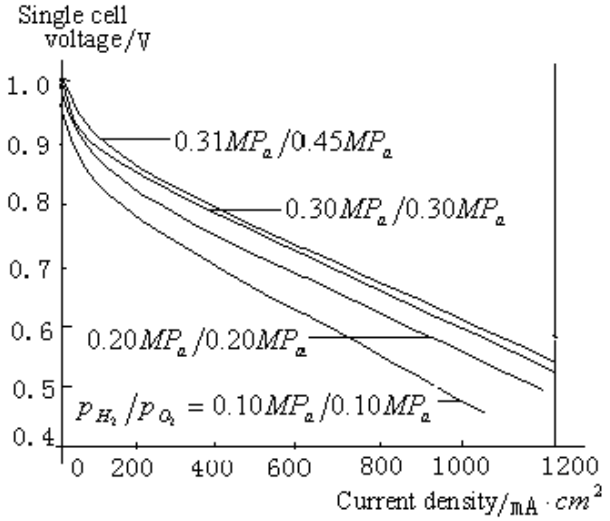

Figure 2. Pressure on the performance of the battery

Therefore, the development of a reasonable test method and evaluation method requires that every parameter is measured. In addition, some parameters must be controlled, so as to determine the causes of the fuel cell performance.

IV. THE HARDWARE DESIGN OF FUEL CELL TEST SYSTEM

A. Block Diagram Of Fuel Cell Test System

The diagram of the fuel cell test system is shown in Fig .3.

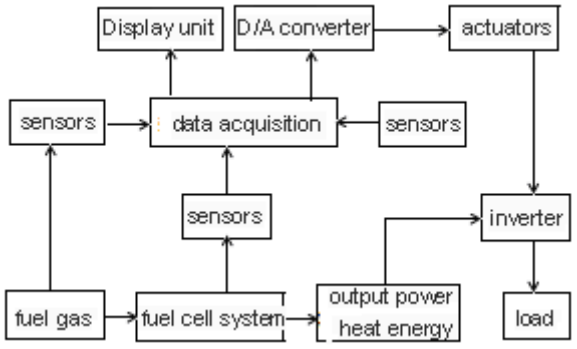

Figure 3. Fuel cell test system schematic diagram

As shown in Fig .3 shows, the fuel cell test system is mainly composed of industrial computer, sensors, data acquisition part, and the executing agency. In this system, sensors used to detect need to test the various physical quantities, send test results to data acquisition system, industrial control is the core of the test system, which receives data from the data acquisition system, and analyze them, according to the result of analysis to control the actuator to complete the corresponding action.

B. Choice of Industrial Computer

By IPC-880 EVOC company production of the (R) Pentium 4 microprocessor and 2.0GHz frequency, 2G ram is

used in the system, from the performance to meet the large amount of data, fast processing.

C. Data Acquisition Card:

The fuel cell testing system needs to collect a lot of data. The data obtained by the sensor is generally standard electrical signal, and can be sent to the data acquisition card directly. If it is not a standard signal, it is also required to preprocess (enlarge or convert). In this system we use data acquisition card:

PCL-813, A/D conversion card is the 32 channel single ended isolated, the main role is to complete the fuel cell simulation of the detection work, the detection results of the industrial computer. PCL-813 each channel can achieve high voltage isolation. 500VDC high-voltage isolation can protect the PC and peripherals caused by high voltage input damage. In addition, each channel two DC - DC converter and software programmable gain control, the system more stable and flexible.

PCL-733, 32 isolated bidirectional digital input channels, can detect the running state of the fuel cell, in a timely manner to timely detection of data sent to the IPC, to make corresponding adjustment.

PCL-726, 6 channel, 12 bit analog output card (D/A). Use it to the results of the industrial computer processing output to the executive body, to control the actuator to make the appropriate action to ensure fuel cell security work.

PCL-734, 32 way isolated digital output card, the output driver is strong, the output channel high voltage isolation can reach DC 1000V, wide output range DC 5~40V. When the abnormal reaction of fuel cell occurs, the main responsibility of the fuel cell is emergency shutdown, and the damage of fuel cell is prevented..

D. Sensor Selection

In any test system, the sensor is essential. It can convert various types of physical quantities to standard electrical signals.. Currently, there is no accepted commercial to sensors work in a fuel cell gas environment, in the fuel cell test system, measurement of physical quantities is very complex, hence the need for the large number of sensors. However, the problem is more than that, because the fuel cell involves a complicated physical and chemical reaction, the working condition is harsher, it is also very high for the sensor requirements. In addition to the general situation of the selection of the sensor constraints, but also to consider the accuracy, life, reliability and cost of these four aspects. In this system, we have chosen the sensor, which can meet the needs of the whole system.

V. FUEL CELL INSPECTION GAUGE

A. Use Reason

The PEM fuel cell each film can only generate about 1 volts of the voltage, so the use of fuel cells is often a stack of hundreds of film (called fuel cell group). The working status of each film is directly affected by the working status of the whole battery group. So it is necessary to monitor the voltage of each film in time. If a piece of film of the voltage changes (generally considered is lower than 0.4 V), means that the film appeared problem, need emergency shutdown operation (by IPC instructions) to the battery pack, otherwise it will lead to the collapse of the cell stack. In order to better detection of fuel cell of each single battery voltage, prevent the occurrence of reverse polarity. We have developed a single-chip microcomputer to control the data acquisition module -- fuel cell patrol instrument, in the running on batteries, use it to detect the battery voltage of each battery group, once a battery voltage dropped to a certain value (such as 0.4V), open cell, and examined.

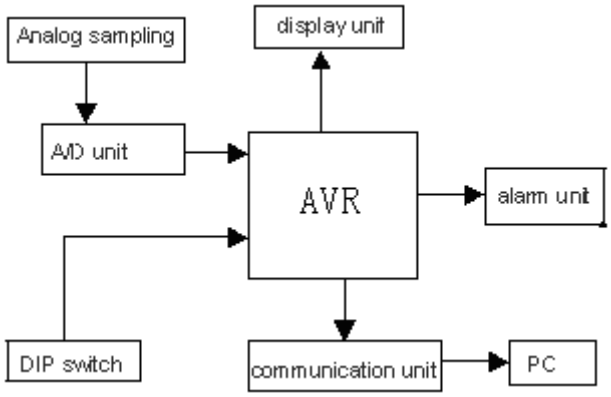

Figure 4. Inspection instrument structure

B. The Composition of the Inspection Instrument

The fuel cell inspection meter is the core of the AT89S51 microcontroller, the periphery has 12 bit A/D converter AD574, the multi-channel switch CD4051, uses the photoelectric isolation, guarantees the data accurately, reduces outside interference. Its structure is shown in Fig .4.

Fuel cell patrol instrument is through the voltage of each battery is detected to track the running state of the battery, guide the battery operation, through single day minimum voltage setting alarm value for battery alarm and control.

C. Communication of the Inspection Instrument

Inspection instrument operation is to communicate with the host computer through the RS-232 interface, communication baud rate setting for 2400Bit/s. The content of the communication with the following aspects: read and write inherent data and read test data. Inherent data have battery nodes and alarm voltage. The detection of a data read, read and writes data to the communication protocol. Inspection instrument of single battery voltage value mining binary coded transmission because of inspection instrument of single node voltage value is too large and just to record, did not control, purpose of doing so is to improve the transmission speed. Each of the data contains 8 bytes, the first 5 data bits, there is a decimal point, and the decimal point is fixed. Data bits followed two transmission is voltage or current. If it is 00h, transmission of data is current or voltage, the last byte is the parity bit to check the transmission of data is correct. Fuel cell sends data program flow as shown in Fig .5.

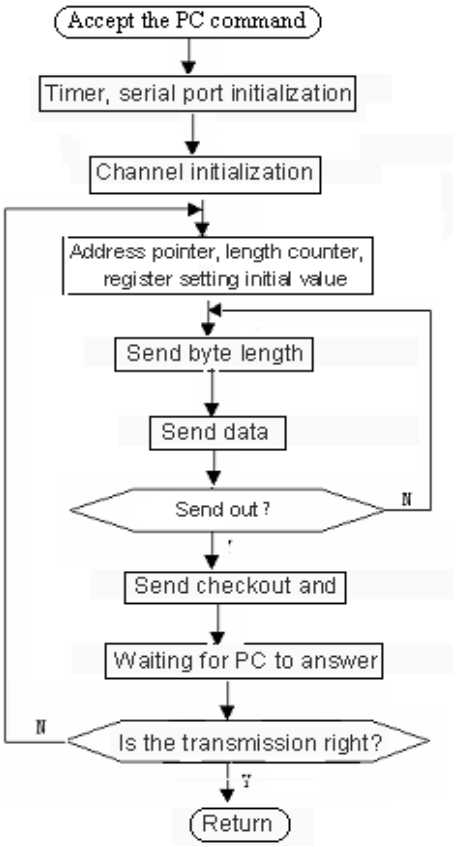

Figure 5. Fuel cell inspection instrument sends data program flow char

VI. SOFTWARE DESIGN AND PROCESS

A. Through the CD4097 Single Cell Selection Control Module

The low three bits of the B port are respectively connected to the coding control of the CD4097 layer, and the selection channels are controlled, the B port is 3, 4 and 5 bits are connected to the coding control end of the high CD4097.. Choose which group to control the selection of the channel to choose which group.

```
Rl=0xFFFF;
[P_IOB_Data]=R1; / / B port data vector set,
IOA low, output data
[P_IOB_Atrib]=R1; / / set attribute vector A port,
[P_IOB_Dir]=R1; / / set attribute vector A port set high
PP:R1+=1; / / strobe and strobe, word one analog channel
...
//CPU call processing module, analog-to-digital conversion module
JMP PP
```

B. Driver Digital Tube Display Module

Here for the reliability design of the transistor drive circuit of LED displays in each of the light emitting diode through 5 to 20 mA current to achieve the normal brightness, SPCE061A input current can reach 12mA and output up to 5mA, in fact, without driving circuit can reach normal brightness. The process showed that the use of dynamic, namely six display one by one rotation, the each sustained 1ms, 10ms or 20 seconds cycle again, of course, can be appropriate to make changes, but the refresh rate not less than 30 frames / S. So, because of the persistence of vision, we see is the 4 display in the display at the same time.

C. CPU Alarm Processing Module

When the voltage of the fuel cell is lower than O.2V or above CPU, the 1.5V output control signal controls the peripheral circuit to send an alarm signal, and the program is as follows:

```
Baojing: .Proc
r3=[P_IOB_Data];
r3 =OxOO80;// use B port 8 bit control Light emitting diode
[P_IOB_Data]=r3 ;
r4=0x0001;
[i]=r4:
CALL Xianshi
RETF;
.ENDP
```

VII. SUMMARY

This paper introduces the fuel cell testing system and the hardware design scheme, design based on industrial computer as the core, it greatly saving hardware cost, while improving the automation degree of the system to meet the system of data acquisition and processing fast and accurate requirements. The test system has been verified by practice, and its work is accurate and reliable, and can basically complete the detection of fuel cell parameters.

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