GAS FLOW MEASURMENT AND CONTROLLER

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Abstract: At present gas flow measurement and control are the key parts in the fuel cell and solar energy equipment. The percent of mixture gas would be calculated theoretically to achieve the high efficiency. Thus a new gas flow measurement and controller are presented for energy industry in this paper. Based on the thermal sensor and low pressure drop solenoid valve, the new gas flow measurement controller is integrated by temperature compensation. Experiment and customer testing results demonstrate the better performance of the new gas flow measurement and controller.

Keywords: Mass Flow Controller, Fuel Cell, Temperature Compensation

1. Introduction

At Present, the energy problem attracts more and more attention. The fuel cell, which is a device that generates electricity by a chemical reaction, became one of solutions. Compared with Solar cell, wind energy and nuclear power, the fuel cell could provide the continued, safe and high efficient and high concentrated power [1].

A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate virtually continuously as long as the necessary flows are maintained.

In the fuel cell system, the efficiency is a very important specification to be evaluated. The efficiency could be impacted by many factors. The flow accuracy and stable will be the bottle-neck of the fuel cell system. Thus the fuel cell system is a typical application for the mass flow controller.

2. Gas Flow Controller Used in the Fuel Cell System

Considering the principle applicability, pressure applicability, installation applicability and cost requirement, the thermal-based gas flow controller is dominant in the fuel cell system. The thermal-based gas flow controller had been developed forty years since it was invented for the Apollo moon landing program. The construction of the thermal gas flow controller could be summarized in the Fig.1. A bypass, a sensor, an electronic board and a regulating valve are constructed to be a whole system. The measurement and control function are operated inside of the system. And it was well-known in the semiconductor, vacuum industry [1,2]. However, in the fuel cell application the gas flow controller need different characteristic, which has not been attended widely.
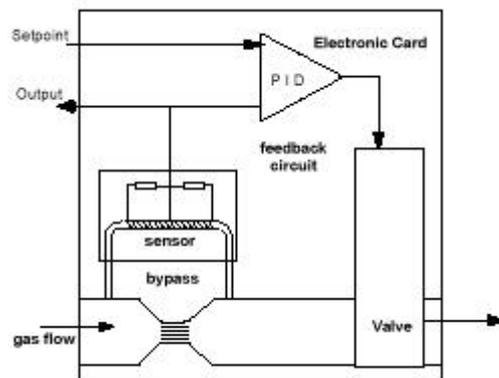
Fig.1 Construction of the mass flow controller

In the semiconductor or industrial application, the most critical specification for the mass flow controller is the repeatability. The equipment engineer could adjust the setpoint according to the process testing results. The absolute accuracy is not very critical for the procedure. And most of time, the equipment will be installed in the cleaning room. The temperature and humidity will be kept in the constant range. Moreover, the semiconductor wants high metal surface quality because of hundreds of danger and corrosion gases used in the process. Multi-gas and multi-range should be available for less inventory and easy configuration.

Normally, when a fuel system was design, the percentage of mixture gas had been calculated theoretically. The maximum of gas flow is limited for high efficiency. The less gas flow could increase the efficiency but will decrease the life of the fuel cell. Thus the absolute accuracy should be more critical. Moreover, the environment of the fuel cell system will be different in thousands ways. The gas flow controller should meet the high absolute accuracy specification with fighting the atrocious weather. Compared with the semiconductor, less than 10 gases would be used in the fuel cell system. And high quality surface and multi-gas and multi-range are not necessary.

3. Design of the gas flow controller of the fuel cell

A gas flow controller designed for the fuel cell is presented in this paper. The construction is shown in the Fig.2
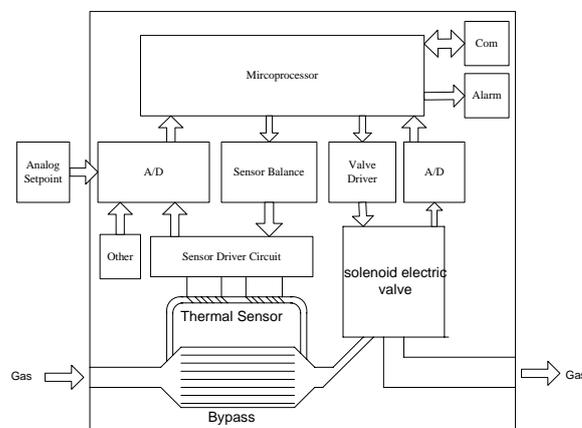

Fig.2 Construction of the gas flow controller for the fuel cell

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Compared with the normal mass flow controller, the microprocessor will adjust the sensor driver. The temperature will be measured also during the operation. Thus the temperature could be compensated by the microprocessor. In stead of calculating temperature changing on the calibration data, the sensor driver is directly compensated as the hardware. The principle is presented in the Fig.3 [4].
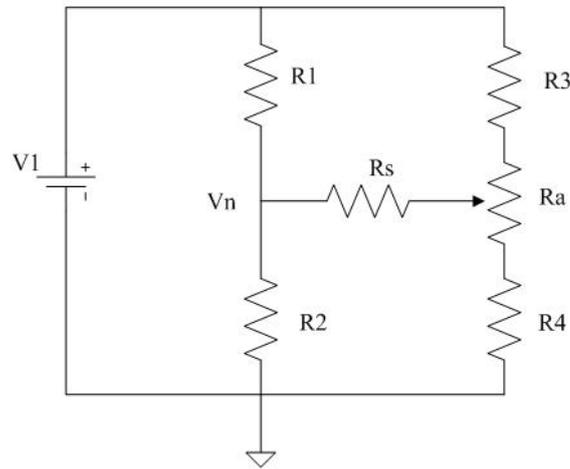

Fig.3 Schematics of temperature compensation

Where

R_1, R_2, R_3, R_4, R_s : Constant resistors

R_a : Adjustable resistor, the adjust ratio w, which range is from 0 to 1

V_1 : Voltage on the power

V_n : Output voltage of the circuit

Thus the relationship between V_1 and V_n should be as follows:

$$V_n = \frac{V_1(r_4 + wR_a)R_1R_2}{(R_3 + R_a + R_4)(R_1 + R_2)(\frac{R_1R_2}{R_1 + R_2} + R_s + \frac{(R_3 + R_a(1-w))(R_4 + wR_a)}{R_3 + R_a + R_4})}$$
$$+ (V_1R_2(R_s + \frac{(R_3 + R_a(1-w))(R_4 + wR_a)}{R_3 + R_a + R_4})) \Big/ ((R_2 + R_s + \cdots$$
$$+ \frac{(R_3 + R_a(1-w))(R_4 + wR_a)}{R_a + R_3 + R_4}) \left(R_1 + \frac{R_2(R_s + \frac{R_3 + R_a(1-w))(R_4 + wR_a)}{R_3 + R_a + R_4})}{R_2 + R_s + \frac{R_3 + R_a(1-w))(R_4 + wR_a)}{R_3 + R_a + R_4}} \right))$$

$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (1)$$

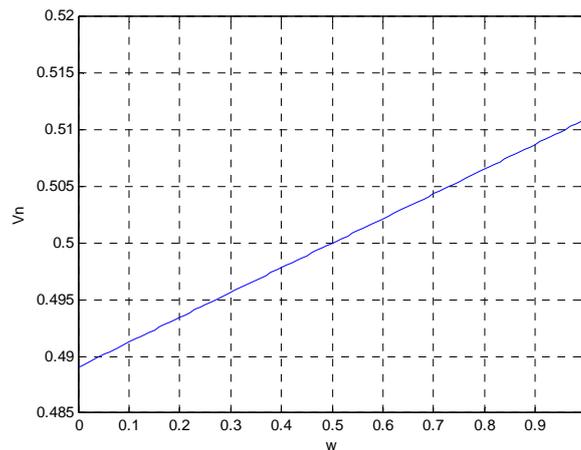If $V_1 = 1$, then the V_n will change with the adjustable resistor ratio w, Fig.4 shows the curve.

Fig.4 Voltage changing with the adjustable resistor

That means the voltage will be adjusted linearly by the ratio w. And the adjustable range would be about $\pm 2\%$ FS.

4. Experimental Results

Based on the new temperature compensation, a new digital gas flow controller for the fuel cell is invented. According to the characteristic of fuel cell system, the CANOPEN interface is included in the gas flow controller.

4.1 Temperature coefficient

One new mass flow controller was tested for temperature coefficient, which could be calculated by Eq.(2)[5]. The test results are presented in the Table1.

$$TCe(\%F.S^0C) = \frac{Q_aY - Q_{a1}X}{Q_{fullscale} \times (T_eY - T_eX)} \times 100 \qquad (2)$$

Where

TCe : Temperature coefficient on the span

$Q_aY - Q_{a1}X$: Flow difference between Temperature T_eX and T_eY on the same set-point.

$Q_{fullscale}$: Full scale of the mass flow controller.

Table. 1 Temperature coefficient test results

30SLM	TCe(12.5℃,0℃)	TCe(25℃,12.5℃)	TCe(37.5℃,25℃)	TCe(50℃,37.5℃)	TCe(37.5℃,50℃)	TCe(25℃,37.5℃)	TCe(12.5℃,25℃)	TCe(0℃,12.5℃)
0% (0SCCM)	-0.000133333	-0.00016	-0.000170667	-0.000973333	-0.000968	-0.00003	-0.000168	0.00001067
25% (7500SCCM)	-0.029306667	-0.020584	-0.022248	-0.010464	-0.005728	-0.01100	-0.023984	-0.03169867
50% (15000SCCM)	-0.029530667	-0.02248	-0.017053333	-0.007589333	-0.002805333	-0.02618	-0.022736	-0.04400267
75% (22500SCCM)	-0.022490667	-0.013272	-0.003293333	0.007957333	0.010077333	-0.02363	-0.008565333	-0.04210400
100% (30000SCCM)	-0.003082667	0.011413333	0.022056	0.035944	0.034258667	0.00242	0.019928	-0.01909333

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4.2 Testing data

The new digital mass flow controller and normal mass flow controller were compared in the real fuel cell system. The data is presented in the Fig.5
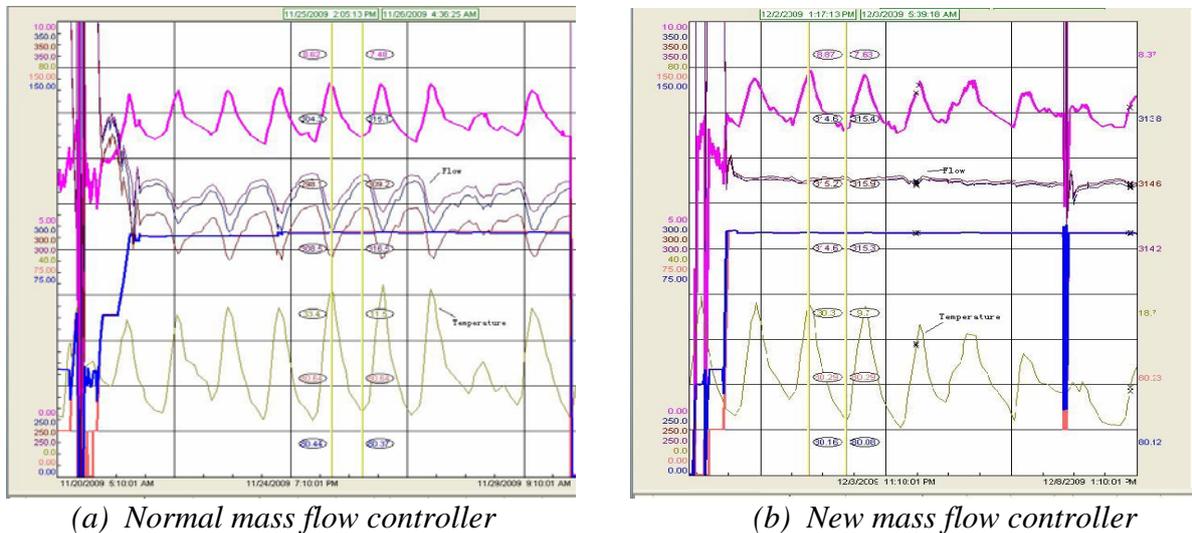

(a) Normal mass flow controller   *(b) New mass flow controller*

Fig.5 The testing data on the fuel cell system

Fig.5 shows that the flow output of new mass flow controller is much stable than the normal mass flow controller.

5. Conclusion

A new digital mass flow controller for the fuel cell is presented in this paper. The hardware circuit for temperature compensation is invented for decreasing the temperature sensitivity. The test data shows the better performance in the fuel cell system.

Acknowledgment

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