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A 0.8 KW Programmable Electronic power Load for Fuel Cell Dynamic Test System

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Abstract

In order to investigate the output characteristic of a fuel cell based on the electrical empirical model, A 40A/0.8KW/100V, high performance dynamic Fuel Cell load system with total protection circuits is presented using with parallel power MOSFETs ,Analog and digital Isolation technique. This efficient dynamic load utilizes current and voltage Feedback to realize protections. The safety is increased due to employing both control commands and feedback signals. This programmable dynamic load will be very useful to optimize the Fuel cell design, improve the operation performance, and develop the real-time control system of fuel cells. A good match is found between simulation results and experimental data. The electronic load remotely programmed via an RS-232 serial port.

Keyword: fuel cell- tester – power transistor – electric load

Introduction

Fuel cells are considered clean and efficient power generators for various applications. The Polymer Electrolyte Membrane (PEM) fuel cell is particularly well suited for electrical vehicle and other mobile applications because of its high power density, low operating temperature, and fast response times [1].

One of the important cases of the fuel-cell power systems is proper monitoring, instrumentation and data acquisition of system parameters such as load voltage, current, fuel cell output power, etc.

Development of the Fuel cell test system technologies is critical for the growth of the fuel cell industry and Power electronics plays an increasingly important role in improving performance and safety of fuel cells. Active Power semiconductor devices such as metal oxide transistors (MOSFET) and Isolated Gate Bipolar Transistors (IGBT) are widely used in power electronic loads for fuel cell test system.

The Fuel Cell Test System incorporates a freely programmable electronic load required to simulate a wide range of potential fuel cell applications.

Fuel cell test systems must precisely monitor and control aforementioned system parameters. It is necessary to have an instrumentation system which is able to monitor and control fuel cell operation under varying conditions.

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Instrumentation and interface systems must also provide flexible data acquisition, monitoring, and control capability to precisely control fuel cell operation Therefore a typical fuel cell test system requires high-resolution, high voltage input, isolation, and waveform acquisition capability. [3].

From the hardware and operation point of view, Most of bipolar transistors (BJT) or MOSFETs can be operate in linear region and the energy taken is converted into heat. Designers need Dynamic features of system consist of input current ripple and harmonics and should be considered when choosing the appropriate load to be connected to the Fuel cell. IGBT is a combination of FET and BJTs, IGBT technology provides high dynamic load at high voltage and high current, but IGBT is well suit to switching operation, so in fuel sell test load power linear operation MOSFET is proper than IGBT[3].

However, obtaining an appropriate dynamic fast response power load for testing and find electrical models of fuel cells remains as a major hot active research[4-6].

In this paper, technique based on W9N80Z Power MOSFETs operation and fully control current, voltage and power with differential amplifiers and overall feedbacks is proposed. First operation described. Then, the printed circuit board prototype laboratory and control software of system is discussed.

The main objective of this paper is design and implementation of a high-resolution data Acquisition and interface module for an 800 W fuel cell power station under computer control with using C++ and LABVIEW software.

Principles of proposed tester

In this part operation of the Fuel Cell Electronic Load will be describe. Fuel cell data acquisition and monitoring system is designed and implemented. This load is a DC Electronic Load Mainframe used for evaluation of fuel-cell test.

Figure .1 shows overall system bloc diagram and operation, as A conventional method for regulation and control is based on negative feedback. This feedback forces the load current and power to follow the input reference.

Figure . 2 illustrate the Principles of proposed programmable fast response dynamic electronic Load structure, obtained by interposing in-parallel W9N80Z power MOSFETs. In this programmable Electronic Load, fuel cell output voltage and current of the R_{Sense} is used for current measuring and short circuit protection state of the system.

As shown in Figure .2, when the current, voltage and power of fuel cell tracking begin, feedbacks regulate desired parameters. When any parameters exceeds from control values, the analog signal of A and B points, which digitized and transferred in to computer, will be change and regulate in the proper value of parameters.

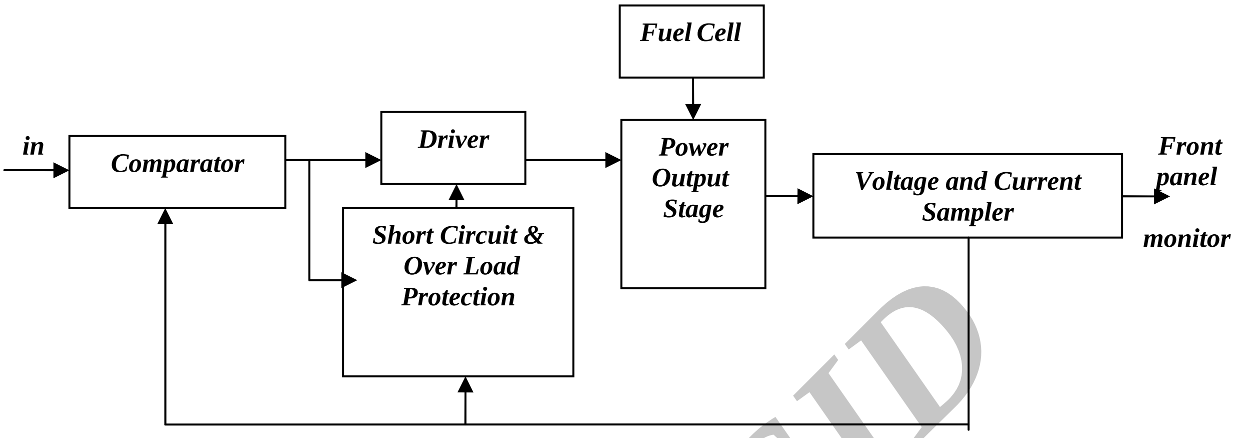


Figure .1: system block diagram

The tester Specification summarized in table (1-2). Tester can operate independently in constant current (CC) mode, constant power (CP) mode, or constant resistance (CR) mode and, inputs of load can be turned on or off (open-circuited), or short-circuited. A load's input can be toggled on/off via the RS-232. Note that the Input On/Off command supersedes the mode commands and Short On/Off command.

Programming is done with very similar SCPI (Standard Commands for Programmable Instruments) commands, which make the electronic load programs compatible with those of other loads that are also SCPI compatible. Automatic Control is in effect immediately after program is applied. In the Constant Current Mode, the module will sink a current in accordance with the programmed value regardless of the input voltage. The Constant Current Mode and The current level can be set via RS-232. If the Constant Current Mode is the active, the new setting immediately changes the input at a rate determined by the software setting.

A current level can be preset (stored in the electronic load) allowing the input to be updated when a trigger is received instead of immediately. By the way, The electronic load includes both hardware and software over current protection features. As shown in Figure . 3, hardware protect unit is designed with U4 comparator.

The electronic load allows the user to set a current limit via the RS232 which will shut down the input if the current limit is exceeded beyond a programmable time delay. Note that the software current limit not only is in effect for the Constant Current Mode, but also in any other mode of operation. Load includes the following protection features: Over voltage and over current (hardware and software), over power, over temperature reverse voltage protection. All of the protections features latch when they are tripped, except for the hardware-over current and reverse- voltage protections.

The short circuit protection operates by sensing the fuel cell output current with resistor of R_{Sense} ,it is a 0.05 ohm/20Wat power resistor.

The voltage developed across R_{Sense}, control the power dissipation and current regulation command, which is normally less than the maximum current set with u4 as a Hardware setting. When the current through R_{Sense} reaches about Isc (the maximum safe level),out put of u4 being high and simultaneously send a alarm to software and lath in digital FPGA logics, to reject gate drive signal and away from the gate of power transistors.

The operation of this circuit in current regulation can be seen by calculating the transfer characteristic of u1 and u3 when driving gates of power transistors.

This can be done using in Figure .2.

$$V_A = K_1.I_{sense} \qquad (1)$$

Also

$$V_B = K_2.V_{sense} \qquad (2)$$

In normal operation, When

$$V_c = 0 \qquad (3)$$

And gate drive voltage is:

$$V_G = K_3.V_D \qquad (4)$$

Where V_d is updated set-point value, which computer is assigned in a software PID controller loop. From equation of (1) :

$$V_D(s) = H_{PID}(s).V_A \qquad (5)$$

Substituation of (1) and (3) in (4) gives:

$$V_G(s) = K_3.K_1.H_{PID}(s).I_{sense}(s) \qquad (6)$$

To protect the electronic load from possible damage, the input voltage must not exceed the Maximum input voltage rating and Never apply the ac line voltage to tester input connectors.

The Fault output signal used to trip an external circuit breaker and control a relay for disconnecting the electronic load inputs from the fuel cell. It is need to testing when an overvoltage or a reverse Voltage condition occurs.

In fixed-power operation against voltage variation, and overpower protection state, the power-limit boundary is set by software. This can be done with monitoring the main current and voltage. If the input power exceeds the power limit, the load module sets the overpower status bit and the load circuit turns off, so the input circuit remains off.

this Tester has an over temperature protection circuit, which will turn off the load. Lm 35 integrated circuit sensor used for sensing temperature. If the internal temperature exceeds from safe limits, the over temperature protection circuit activates, so the LED alarm, Sound Alarm and software status register bits are set.

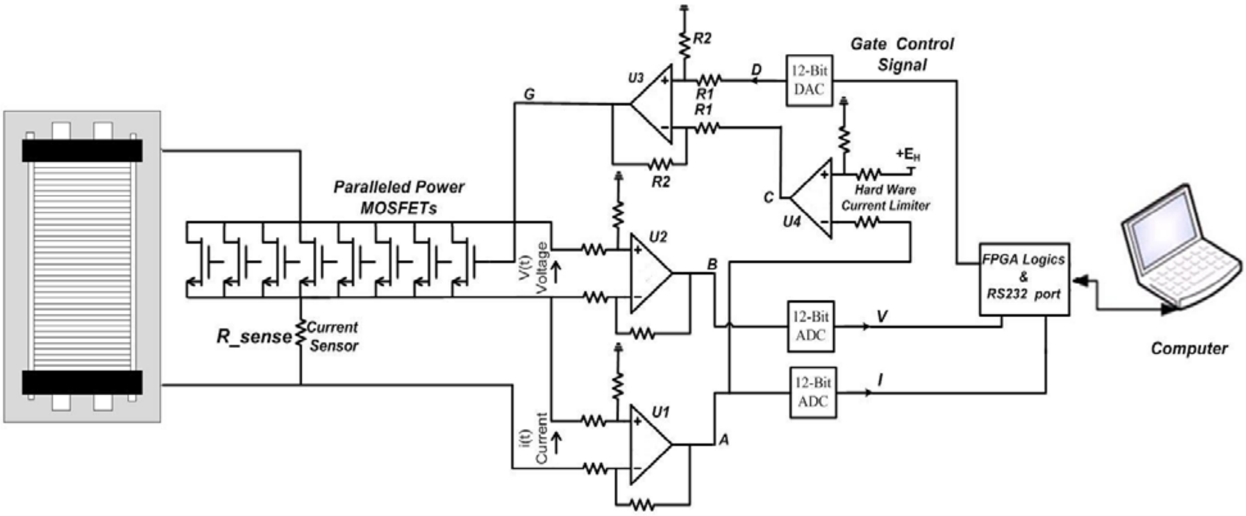


Figure .2: simplified schematic of fuel cell electrical parameters tester

Reverse Voltage protection is an important and essential specification. This feature protects the load in case the input dc voltage lines are connected with the Wrong polarity. If a reverse voltage condition is detected, soft ware turn off system. And the Fault output signal at the control unit tracks the state of the fault. The Fault signal can be used to control an external relay in order to disconnect the module from the source if a Reverse Voltage condition occurs. Inputs Measurements resolution define total system accuracy, load's input current, voltage, and power are continuously measured at the remote control software. The results will be read back when the electronic load software addressed to measuring. Voltage and current measurements are performed with approximately 12-bit resolution of full-scale range with ADCs. Power is computed from product of this information. Voltage and current are measured simultaneously, so that power data is correct in all time. All measurements are performed by digitizing the instantaneous input voltage or current for a defined number of samples and sample interval, storing the results in a buffer, and then calculating the measured result. Parameters of the measurement are programmable. These include the number of samples, the time interval between samples, and the method of triggering. Note that there is a tradeoff between these parameters and the speed, accuracy, and stability of the measurement in the presence of noise or faster response time.

In the Constant Resistance Mode, the module will sink a current linearly proportional to the input voltage in accordance with the programmed resistance. The resistance level can be set via the RS232 If the Constant Resistance mode is active, the new setting immediately changes the input .Resistance slew rates are programmable in ohms per second.

Circuit level description

To measure the RMS of the input voltage or current using the front panel, Ammeter and voltmeter used. The display indicates the present voltage and current reading. For increasing accuracy, the electronic load has variable measurement ranges. The commands that control the measurement ranges of ADCs are Located in the software menu. To change measurement ranges, can be enter a value within the range. The electronic load ADCs will pick the range with the best resolution for that value.

As shown in Figure .2, Analog feedbacks are provides to adjust the control signal to the Power MOSFETs (W9N80Z) to ensure that each transistor remain within its individually in safe operation area (SOA). This figure also illustrates how transistors can be paralleled for increased power dissipation. Up to eight MOSFET transistors in load can be directly paralleled in all modes. The maximums current, voltage and power are 40A, 100V and, 0.8KW, which can be sink from the source.

The differential Amplifiers are used to amplify the Difference between tow inputs voltages, applied in to plus and mines input of operational amplifier. For describe operation of the differential Amplifiers see the circuit U3 shown in Figure .2. in this structure can suppose the input current of operational amplifier is zero and thus resistors R1 and R2 form a voltage divider. Voltage “Vx” in pulse-input-pin is then given by:

$$V_x = V_C\left(\frac{R_2}{R_1 + R_2}\right) \qquad (7)$$

Voltage “V_y” in minus-input-pin is equal (2) , If the open loop gain is infinite, the summing point constraint that V_i=0 is valid and forces :

$$V_y = V_x \qquad (8)$$

The current I_{R1} ,that sinked from point of “C” is

$$I_{R1} = \left(\frac{V_C - V_y}{R_1}\right) \qquad (9)$$

And

$$I_{R1} = I_{R2} \qquad (10)$$

The output voltage is given by

$$V_G = V_y - I_{R2}.R_2 \qquad (11)$$

Substituting V_y=V_x ,,(6), and (7) into (8) and rearranging gives

$$V_0 = \frac{R_2}{R_1}(V_1 - V_2) \qquad (12)$$

The circuit thus amplifies the difference voltage $(V_D - V_C)$ .These Differential amplifiers are required to detect and amplify small differences between two voltages, and the measurement of the difference voltage between the across of R current sense and main voltage.

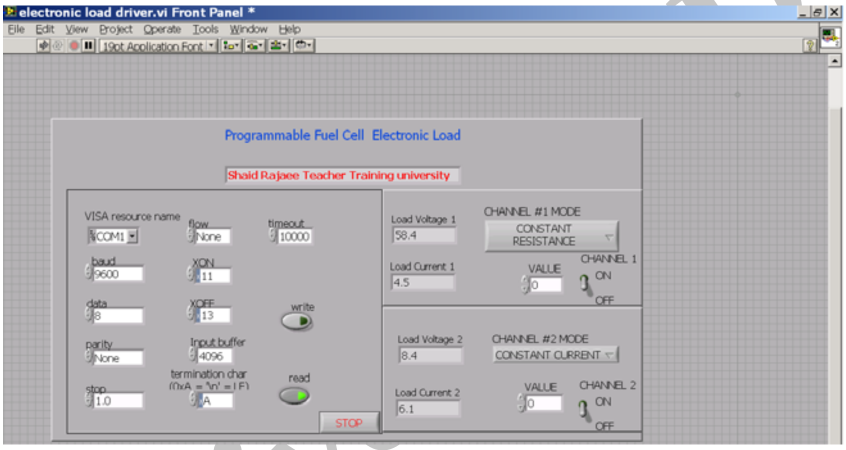
Control Software

System consists of tow main parts, a hardware connected to fuel cell power station and data acquisition boards, and control software based on LabVIEW8.6 and C++, installed in computer controller. The electronic load can be controlled through an RS-232 interface, which is activated and operated by software commands and Software connected to hardware from this serial port. The RS-232 connector is a DB-9, male connector. The RS-232 Standard defines the interconnections between Data Terminal Equipment (DTE) and data Communications Equipment (DCE). The electronic load is designed to be a DTE.

With software commands data acquisition system is capable of measuring voltage, current and consumed power and operation mode to load, in real time.

Lab-VIEW has a proper graphical interface that provides monitoring all variable at the same time numerically and graphically simultaneously.

The requirements of experimental operation require multiple system control modes. Setting values and process data are transferred to and from a PC with Windows operating system. The communication between PC and the load is serial port accomplished via a 4-wire communication line. Profile parameters are also displayed in Graphical User Interface screens (Figure .3).



Programmable Fuel Cell Electronic Load

Shaid Rajaee Teacher Training university

VISA resource name COM1
flow None
timeout 10000
baud 9600
XON 11
data 8
XOFF 13
parity None
Input buffer 4096
stop 1.0
termination char (0xA = '\n' = LF) A

Load Voltage 1 58.4
CHANNEL #1 MODE CONSTANT RESISTANCE
Load Current 1 4.5
VALUE 0
CHANNEL 1

Load Voltage 2 8.4
CHANNEL #2 MODE CONSTANT CURRENT
Load Current 2 6.1
VALUE 0
CHANNEL 2

Figure .3: Graphical User Interface

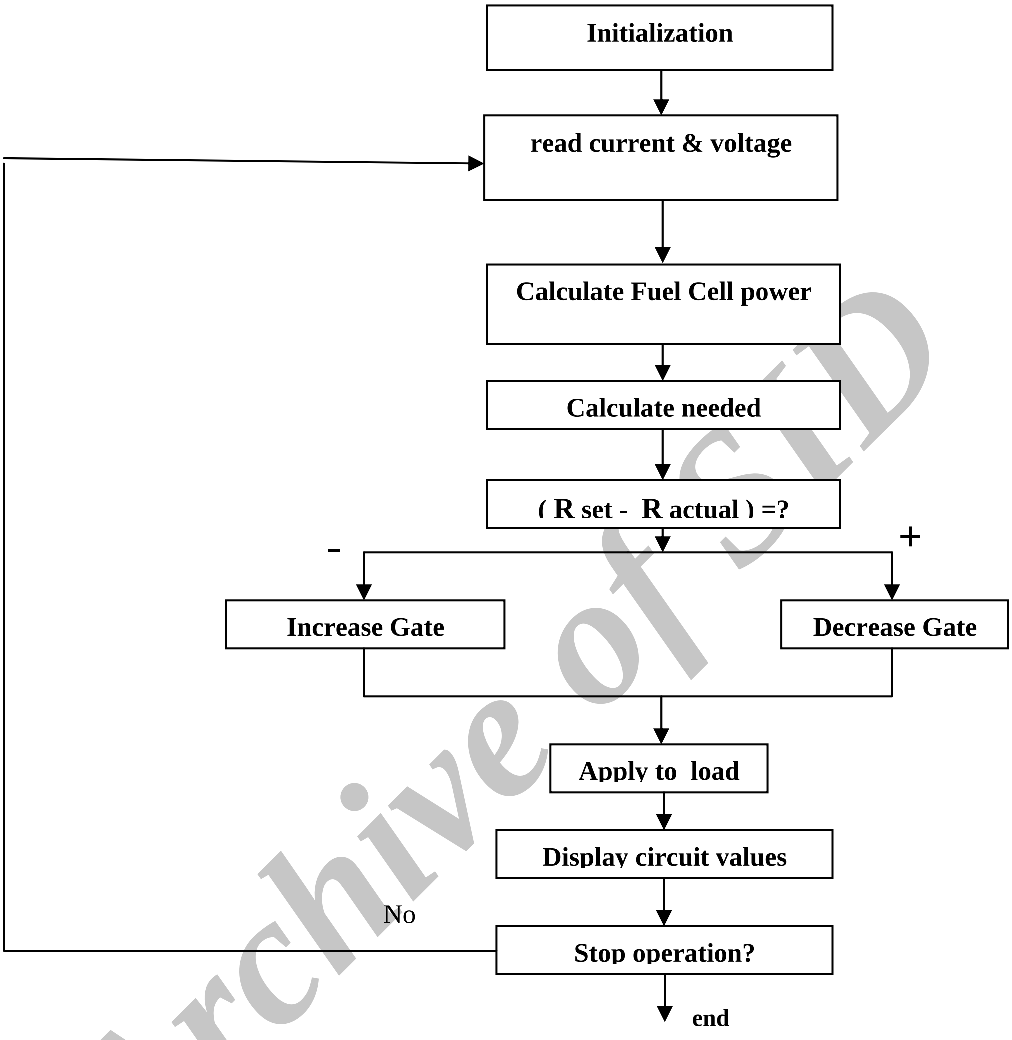


Figure .4: operation flowchart in constant power mode

Hardware implementation

To examine the performance of the proposed tester, a printed circuit board (PCB) prototype, shown in Figure .5, is built.

Figure .5: fuel cell test system a) rear panel B) front panel c) control board

Conclusion

An efficient programmable fast response low distortion dynamic load for fuel cell testing is proposed based on a parallel power MOSFETs analog feedback and computerized control technique. The proposed structure is mathematically analyzed and the equations are given. Although the control is implemented using analog circuitry, it has the advantage of conceptual simplicity. Its operation was verified experimentally with built as PCB.

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