A HYBRID MICROGRID WITH FLC FUEL CELL INTEGRATION

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ABSTRACT

The growing popularity of wind energy for autonomous operation requires the system to be robust and efficient at the same time. The hybrid system displayed a stable response for load sharing between all the constituent generators without compromising the power quality..

Keywords: SOFC (Solid Oxide Fuel Cell; WECS (Wind Energy Conversion System) and FLC (Fuzzy Logic Control).

I. INTRODUCTİON

There is an increasing awareness about power quality along with environmental concerns. Hence in order to address the power needs of remote and non-grid connected areas autonomous hybrid power offers credible solution. Small isolated control of Distributed generation with fuel cell and diesel was investigated. Fuzzy Logic Control is used to interface the SOFC at the DC link and the system dynamics greatly improved as compared to the conventional PI controllers. The intermittency of the wind poses a hurdle as the fluctuations are transmitted to the load side compromising on the power quality. The load and generation balancing and reactive power generation are some of the key issues that need to be addressed. Energy storage system is indispensable to Intermittent Renewable Energy sources such as wind power, solar power and wave power which have highly variable output Variable speed wind turbines are preferable as they offer many advantages over fixed speed wind turbines such as increased energy capture, operation at maximum power point better efficiency and power quality.

However, the operation and control of variable speed wind turbines are more complicated than fixed speed. PMSG's felicitates gearless operation and hence, the features of lightweight and low maintenance can be obtained in this type of wind generation system. In addition, output power smoothening is a major issue as the DC link voltage fluctuation affects the performance of the system besides decreasing the life of the components used in the Wind energy conversion systems. Especially the electrical stresses on the DC-Link choke inductor and the DC-Link electrolytic capacitors, potentially shortening the lifetime of the capacitor. In this paper efficient control and co-ordination strategy is proposed among the various components of hybrid wind–diesel

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system under different wind and load conditions. The proposed wind-diesel-SOFC hybrid generation feeding isolated loads can be properly operated to achieve system power-frequency balanced condition The proposed hybrid structure adopts the widely used AC-DC-AC converter topology with fully controlled PWM voltage-source converters (VSC). Different coupling schemes find their own appropriate applications. Different renewable energy sources can complement each other when used in hybrid mode, multi-source hybrid alternative energy systems with new and effective control strategies have great potential to provide higher quality and more reliable power to customers than a system based on a single resource. DC coupling is the simplest and the oldest type of integration. It saves on the wiring and transmission losses are also avoided. In the system, the renewable wind is taken as the primary source, diesel as the secondary while fuel cell is used as a backup. The DC-link voltage command is determined according to output power fluctuations of the PMSG. In the proposed system the voltage and frequency of the system is stabilized by the load side inverter. Bidirectional buck-boost converter is interfaced between the SOFC and the DC bus. The paper is arranged in the following way. The power balance is achieved by the generator side controller and the load side converter side. The paper is detailed as follows: The system is described in section 2. The proposed strategy for generator side FLC of SOFC and load side controller is discussed in the next section. The simulation results are displayed and explained in section 4. The results are concluded in section 5.

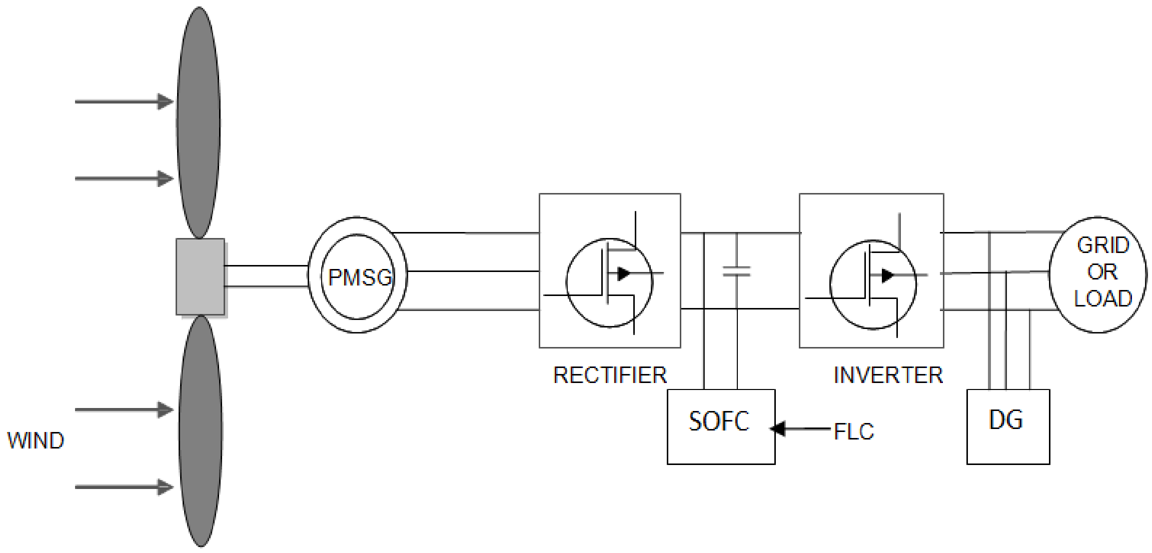

Fig 1:- Schematic of The Proposed Hybrid System

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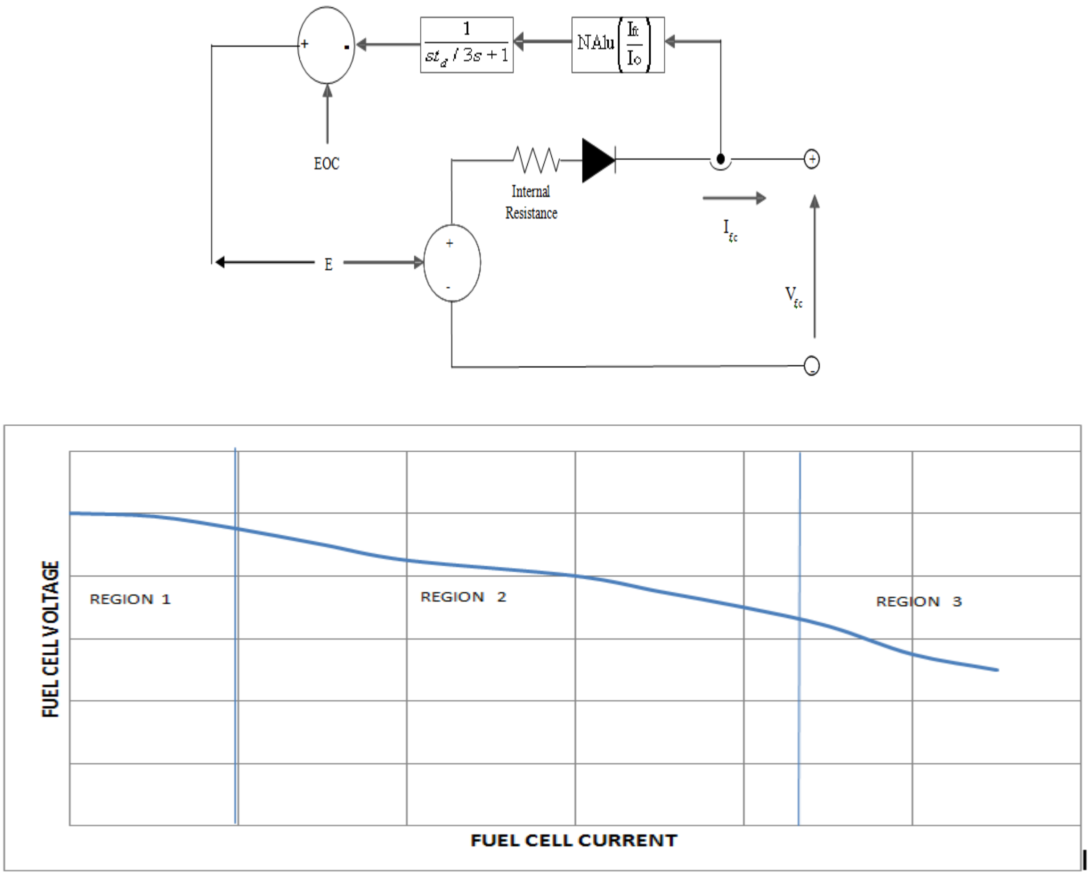


Fig 2. SOFC Modeling

The simplified model shown in fig. 2 represents a particular fuel cell stack operating at nominal conditions of temperature and pressure. The parameters of the equivalent circuit can be modified based on the polarization curve obtained from the manufacturer datasheet. It requires input in the mask the value of the voltage at 0 and 1 A, the nominal and the maximum operating points, for the parameters to be calculated. A diode is used to prevent the flow of negative current into the stack. A typical polarization curve consists of three regions: the first region represents the activation voltage drop due to the slowness of the chemical reactions taking place at electrode surfaces. Depending on the temperature and operating pressure, type of electrode, and catalyst used, this region is more or less wide. The second region represents the resistive losses due the internal resistance of the fuel cell stack. Finally, the third region represents the mass transport losses resulting from the change in concentration of reactants as the fuel is used.

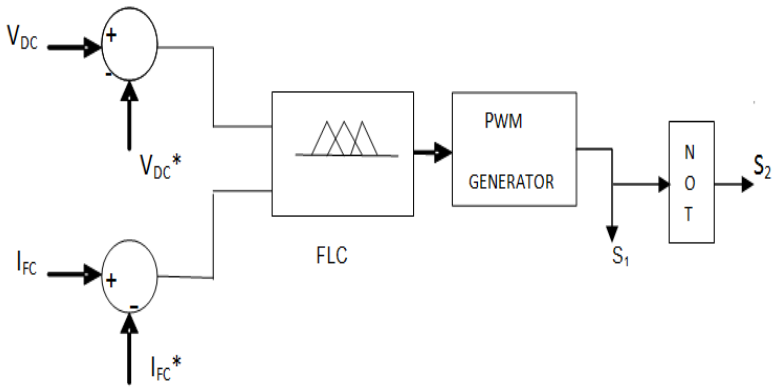


Fig 3 FLC Based Control

A FLC controller shown in fig.3 was designed to make the system more effective and increase the speed of the response. The difference between the DC link and the reference as well as the difference in the SOFC reference current and the measured current is treated as the input to the controller. The output obtained is then given to a triangular pulse wave modulator which generates pulses for the IGBT buck–boost converter switches. The fuzzy rules are so designed that based on the voltage at the DC link and the current of the SOFC the pulses are regulated. Fuzzy logic controllers apply intuitive reasoning, similar to how human beings make decisions, and thus the controller rules contain expert knowledge of the system.

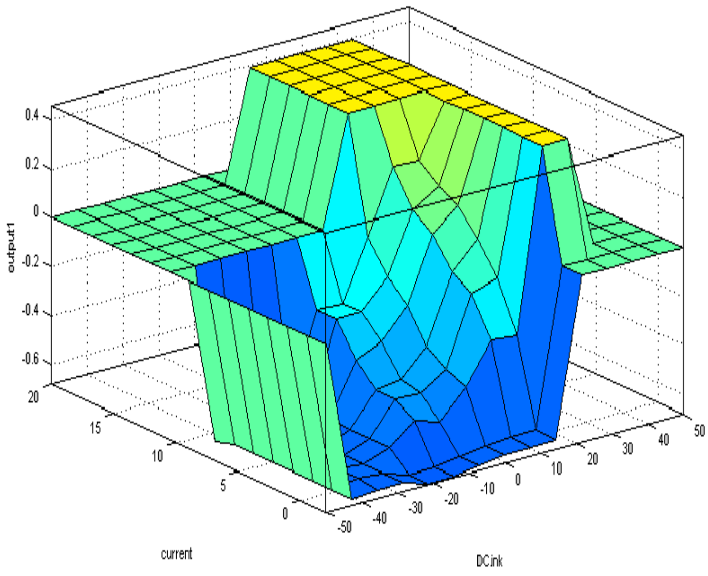


Fig 4. FLC Rule Base

II. WIND TURBINE DYNAMICS

Beca Power in the wind turbine varies as the cubic function of the wind speed.

$P=0.5\rho AV_W^3$ (1)

wind turbine can only extract part of the power from the wind, which is limited by the Betz limit (maximum 59%). This fraction is described by the power coefficient of the turbine, *Cp*, which is a function of the blade pitch angle and the tip speed ratio[6],[7]. Therefore the mechanical power of the wind turbine extracted from the wind is where *Cp* is the power coefficient of the wind turbine, β is the blade pitch angle and λ is the tip speed ratio.

$$P_w = 0.5Cp(\beta,\lambda)\rho A V_W^3 \quad (2)$$

The tip speed ratio λ is defined as the ratio between the blade tip speed and the wind speed V_W where Ω is the turbine rotor speed and *R* is the radius of the wind turbine blade

$$\lambda = \Omega R / V_W \quad (3)$$

Thus, any change in the rotor speed or the wind speed induces change in the tip speed ratio leading to power coefficient variation. In this way, the generated power is affected. A pitch controller decreases the dynamics of the system and β can be assumed to be zero for low to medium speed range.

III. MODELLİNG OF PMSG AND BACK TO BACK PWM CONVERTER CONTROL

The PMSG is modelled in the dq frame of reference. The voltage and torque equations of the PMSG are given with the following equations.

$$V_d = R_a i_d + L di_d / dt - \omega_e L_q i_q \quad (7)$$

$$V_q = \omega_e L_q i_d + R_a i_q + L iq / dt \quad (8)$$

$$T_e = P\{K i_q + (L_d - L_q) i_d i_q\} \quad (9)$$

V_d and V_q are the d and q axis voltages respectively and i_d and i_q are the dq axis currents. R_a is the stator resistance, L_d and L_q are the direct and quadrature axis inductances. ω_e is the generator rotational speed, K is the permanent magnetic flux and P is the number of pole pairs.

PID controller is used to control the gate pulse of the IGBT-Diode universal bridge rectifier. The reference speed is obtained by measuring P_{dc} at the DC link capacitor. Since, $P_{out}=\omega^3$, hence variable speed operation is obtained. Considering the converter losses to be negligible $P_{gen}=P_{dc}$. For this purpose, the power at dc-link is used to obtain reference speed by using the power-speed curve of the generator. The error of this reference speed and actual speed is then given to the proportional-integral (PI) regulator to obtain reference torque of the generator expressed as the q axis reference current is obtained by first obtaining the reference torque (Te*)[3]. The d-axis reference current component can be set to zero in order to obtain maximum torque at minimum current and therefore to minimise the resistive losses in the generator. The WECS adopts an AC-DC-AC converter system. The PMSG is connected to the grid through two PWM-VSCs: a generator-side converter and a grid-side inverter. The generator-side converter achieves variable-speed operation by controlling the rotational speed of the PMSG [4], [5],[6]. On the other hand, the load-side inverter supplies the electrical power, which is synchronized with the grid frequency (diesel).The generator-side converter controls the rotational speed of the PMSG to achieve variable-speed operation with the MPPT control[7], [8], [9]. Vector control scheme is used in the control methodology [10]. The speed control of the PMSG is realized on a rotating reference frame, where the rotational speed error is used as the input to a speed controller, which produces *q*-axis stator current command i_q . The dq axis voltages are transformed to phasor (v_{abc}) and fed to the pulse generator.

The load side converter management is realized by using a synchronous reference frame , the DC-link voltage (V_{DC}) is controlled by the grid-side inverter. The V_{DC}*(ref) is set to 1000V for UPF operation, iq*= 0, [10]. The active power exchange is directly proportional to the i_d and this direct-axis current i_d is also responsible for regulating the dc-link voltage.

IV. SIMULATION RESULTS AND DISCUSSION

The simulation results show that the system is stable for a range of wind speed, the stack voltage is 65V and the DC link voltage is 1000V in fig.5 and fig. 6 We can see that the DC link voltage remains constant and the stack is well integrated to the DC link by means of buck- boost converter which is fuzzy logic controlled. Moreover the diesel operation is restricted to a minimum in case of medium wind speeds and hence maximum energy is tapped from the renewable resources. This system can also be integrated with grid in addition to autonomous operation.

Simulation Results

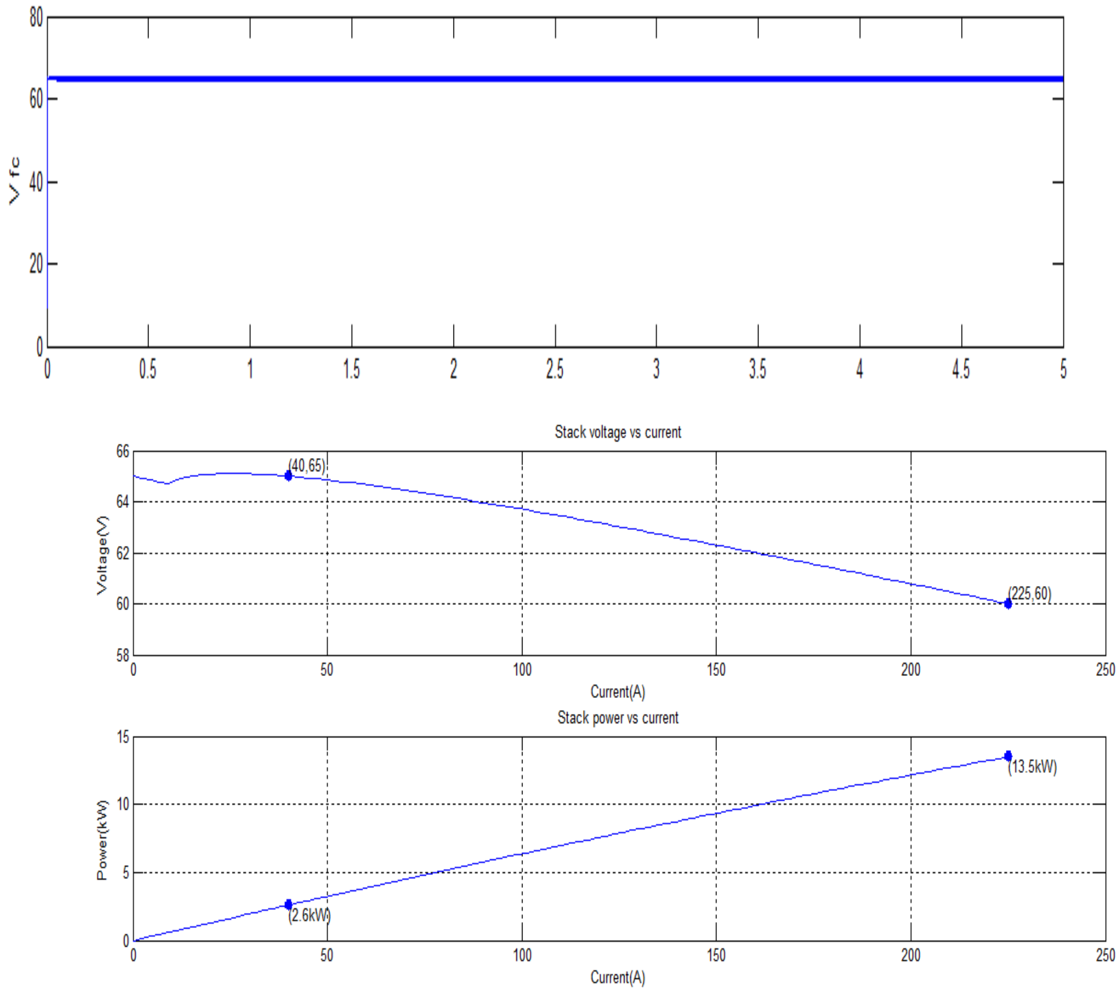
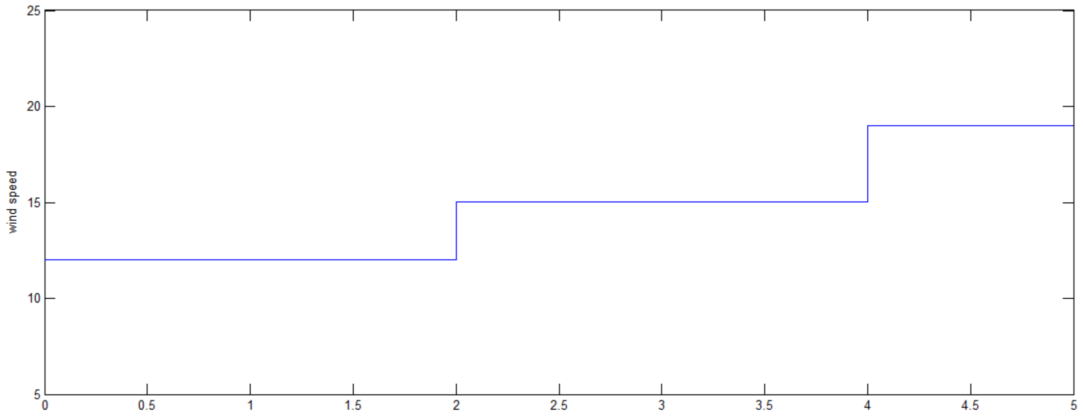
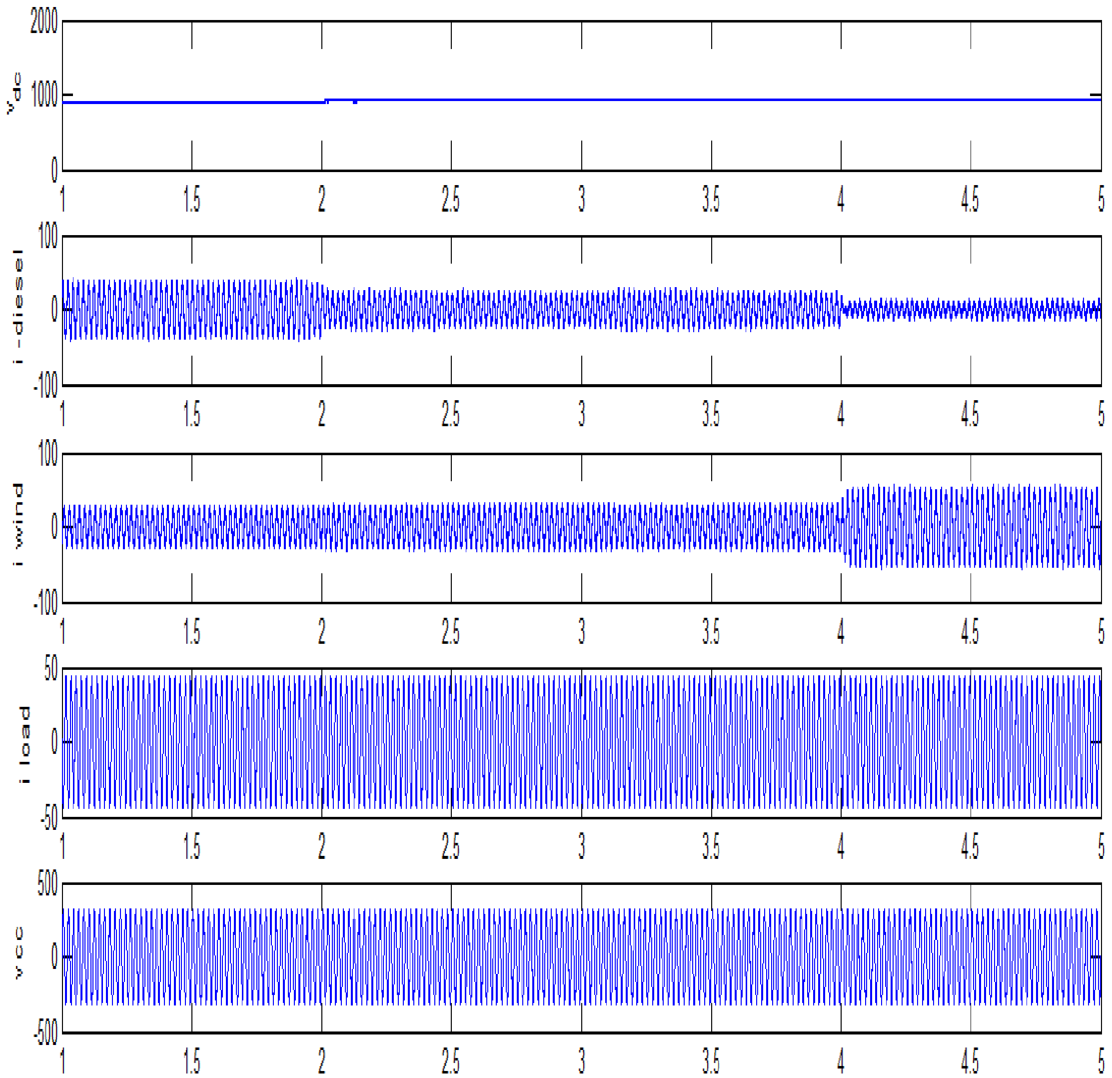


Fig5.Fuel Cell Current and Power



Wind speed VS time



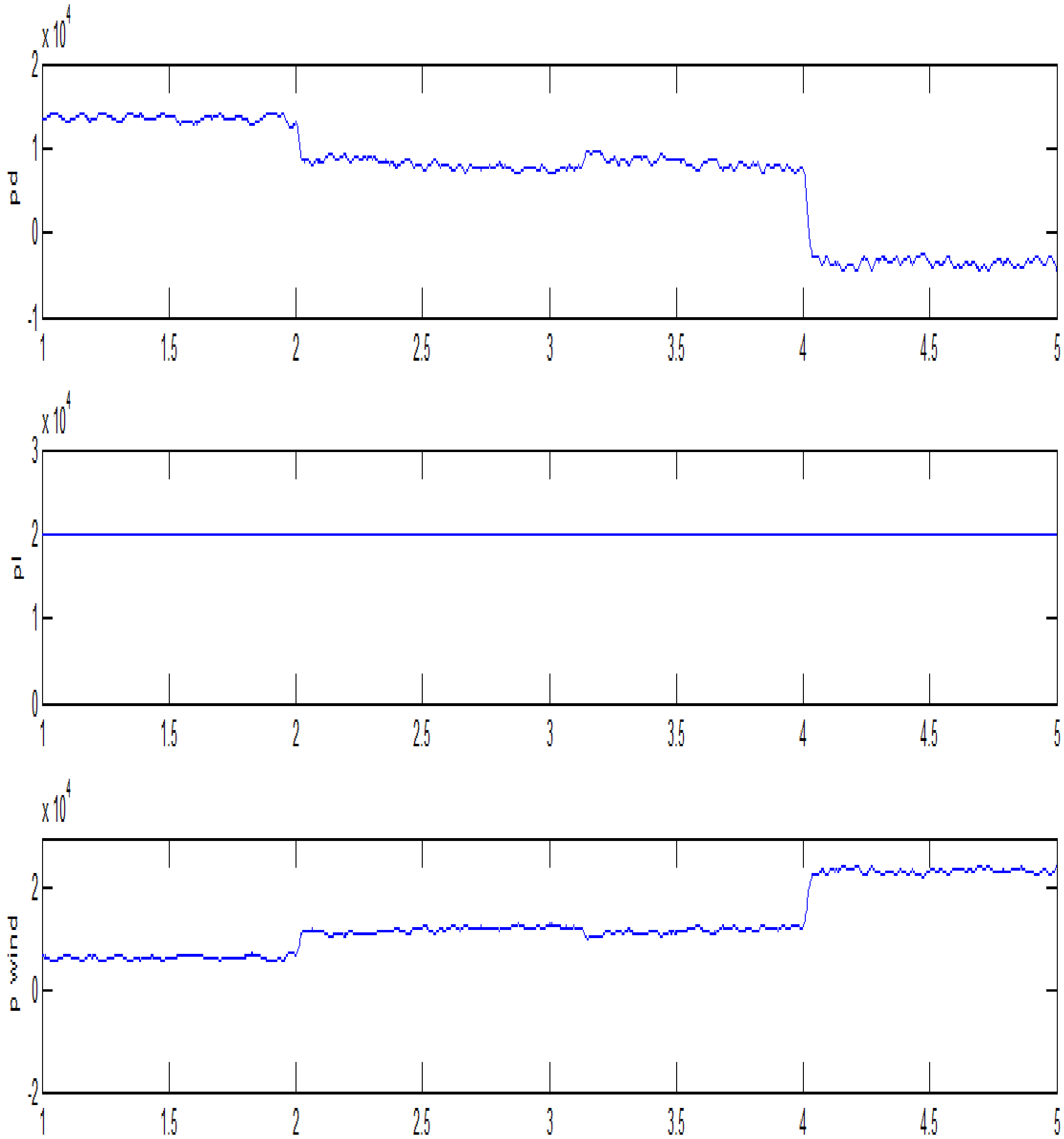


Fig7 Power Balancing

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