A Review Paper On Simulation and Analysis of Solid Oxide Fuel Cell Based Three Phase Electrical Power System with Instantaneous Reactive Power Control Method

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Abstract*—This work explains the basic characteristics of a designed fuel cell system, here also it is introduced the different types of fuel cells and their current state of research findings opportunities. The electrical characteristics of the fuel cell are emphasised and implies that it is a relatively stiff power source. Advance power electronic systems are necessary for designing the fuel cell electrical output power suitable for different loads, either it is linear or non-linear. Controlling of converters is an important issue concerns with the power quality. The hysteresis band current controller (HBCC) technique to the three-phase pulse width modulation (PWM) AC chopper used to control the magnitude of the sinusoidal currents and voltages applied to the AC loads. The converters play a dominating role on shaping the electrical power and meeting the load requirement. The interconnection between a fuel cell and a three-phase ac inverter is modelled because of the widespread applicability of this universal combination. The MATLAB simulation results have validated the effectiveness of the proposed scheme and confirmed the developments of SOFC based Electrical power system.

I. INTRODUCTION

Since the middle of the 20th century, traditional energy was consumed in large quantities, fossil fuels are growing shortage and the environment has been deteriorated. Nowadays, the society is facing an extremely serious energy and environmental crisis. It is imminent to develop a safe, efficient and clean energy [1]. Fuel cell is an energy tool which uses hydrogen as a raw material and converts its chemical energy directly into electric energy by a certain device. And it has many advantages such as high energy density, low pollution emission, strong ability of adaptation, therefore, fuel cell is becoming a promising substitute for conventional fossil fuel [2–4]. Moreover, fuel cell electricity generation is regarded as the core of the future hydrogen production and utilization industry [5]. Among a variety of fuel cells, solid oxide fuel cell (SOFC) has been a focus in order to implement large-scale power generation because it has simple principle, high efficiency, long-term stability and excellent load flexibility [6–8]. SOFC attracts increasing attention, especially in sustainable generation and power supply field, it is widely considered as one of the effective ways to solve the current energy problems [9–16]. Load flexibility of SOFC is capable of adjusting the power output to meet the requirements from power grid balance. However, there still exist many difficulties which should be conquered to promote practical application and commercialization of SOFC, especially, it is crucial to implement an effective control for SOFC system to maintain output voltage as constant and fuel utilization rate kept within a safe range, so that extends the life of the electric pile, improves the operating efficiency and the power quality of SOFC [17–19]. But it’s precisely effective control is completely difficult because SOFC features the multivariable coupling and nonlinearity within a wide-range operation caused by its electrochemical properties.

1.1 Fuel Cell Generally, SOFC is composed of cathode, anode and electrolyte between them. The anode gas channel is injected with the certain amount of fuel gas and the cathode is supplied with the appropriate amount of oxidant gas. The two gases continuously pass through the bipolar gas channels severally sat both sides of the electrolyte to react to generate electricity. Usually, hydrogen is as fuel gas and cheap air is as oxidant gas. Based on constant output voltage mode of SOFC, in the practical operation, the outside resistance load demand is met by the use of providing the proper amount of hydrogen and air, meanwhile, it is necessary to keep SOFC constant output voltage [20] and fuel utilization rate within a safe range. The fuel utilization rate is to be the ratio of the amount of hydrogen that generates electrochemical reaction in the SOFC to the amount of hydrogen that is fed into the SOFC, it is an important parameter influencing the performance of SOFC system. The fuel utilization rate is usually required between 0.7~0.9, too large or too small, respectively, indicate the amount of hydrogen overused and underused, which may result in SOFC performance

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drop or permanent damage [21]. Simplified working process of SOFC is shown in figure(1.1)

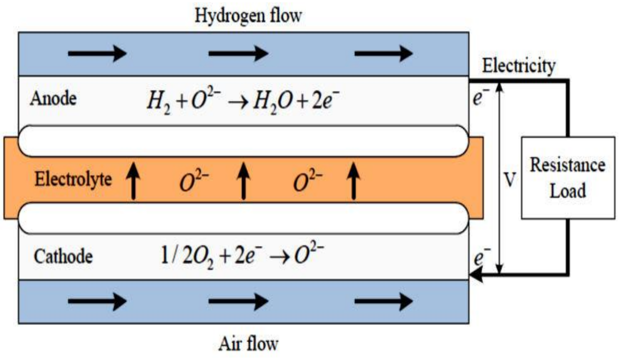


Figure 1.1. Schematic of the SOFC

SOFC has strong nonlinearity due to its complicated electrochemical properties, especially when outside resistance load changes in a wide-range, therefore, a single controller is difficult to satisfy the control requirements. And the hydrogen flow rate and air flow rate fed into SOFC are usually constrained in working process, for instance, the limit caused by the performance of fuel blower. To deal with nonlinear problems, multiple model control method is extremely suitable, meanwhile, model predictive control (MPC) can be used to deal with multivariable coupling and constraint problems skilfully.

A dynamic model of SOFC proposed and is taken account of as the control plant in this paper. The one-dimensional mathematical model of an SOFC is presented, which considers

electrochemical, thermodynamic and fluidic characteristics inside SOFC and presents detailed explanations of operating mechanisms and model parameters of SOFC and verifies its dynamic model in MATLAB SIMULINK. The dynamic model of SOFC developed and is widely accepted and cited in research field [23–28]. The dynamic model consists of the diffusion, material conservation parts and the electrochemical, thermodynamic parts, the simplified diagram of the dynamic model of SOFC is illustrated in Figure 1.2.

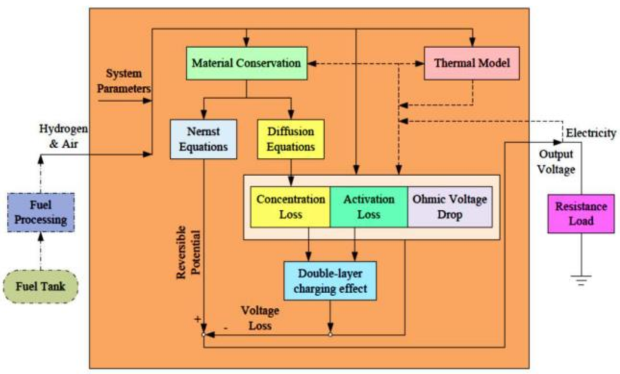


Figure 1.2. Diagram of the dynamic model of SOFC

1.3 Fuel Cell based power system:

Fuel cell systems are similar to other energy storage or generating devices such as batteries and photovoltaic (PV) cells in the sense that they can generally be described as a voltage source with internal impedance. However, in contrast to batteries, fuel cells can produce continuous power as long as fuel and oxidant are supplied. Further, while battery internal impedance is passive, the fuel cell internal impedance is a controlled variable that is a function of its operating condition including reactant concentration, temperature, and humidity levels. In contrast, while the PV cell is a generating device like the fuel cell, it is essentially a passive device with an output that is primarily controlled by the solar irradiance, not by the balance of plant operation. Thus, the fuel cell is a controllable source that produces power when needed as long as fuels are available, making it a promising candidate for portable power, transportation, uninterruptible power systems (UPSs), and distributed generation applications.

Proper application of fuel cells requires a basic understanding of fuel cell system components, their steady state and dynamic behaviour, and their interaction with the load. Furthermore, fuel cells have regulatory requirements, including grounding requirements that are unique as compared to those of other energy generation and storage devices. The design of power electronics circuits and controls for fuel cell systems must address the overall operation of the fuel cell system while complying with the unique electrical demands associated with the particular application. The purpose of this paper is to provide an Fig. 1.3

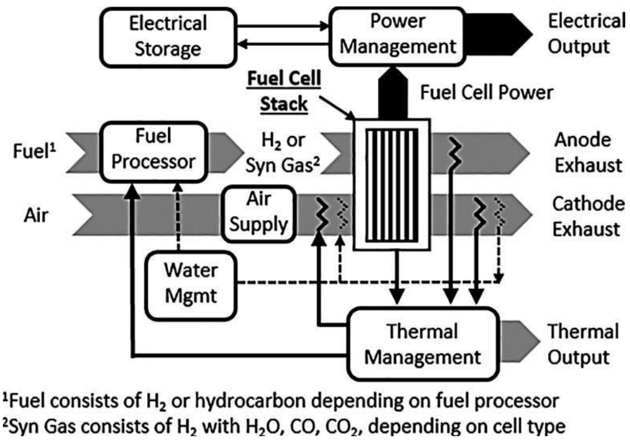


Fig. 1.3 A fuel cell system is composed of subsystems

II. LITERATURE REVIEW

Among a variety of fuel cells, solid oxide fuel cell (SOFC) has been a focus in order to implement large-scale power generation because it has simple principle, high efficiency, long-term stability and excellent load flexibility. SOFC attracts increasing attention, especially in sustainable generation and power supply field, it is widely considered as one of the effective ways to solve the current energy problems Load flexibility of SOFC is capable of adjusting the power output to meet the requirements from power grid balance. However, there still exist many difficulties which should be conquered to promote practical application and commercialization of SOFC, especially, it is crucial to implement an effective control for SOFC system to maintain output voltage as constant and fuel utilization rate kept within a safe range, so that extends the life of the electric pile, improves the operating efficiency and the power quality of SOFC.

[1] Ashik Ahmed, Md. Shahid Ullah.et.al (2019)

The proposed proportional–integral (PI) controllers are incorporated in the feedback loops of hydrogen and oxygen partial pressures, grid current d–q components and dc voltage with an aim to improve the small signal dynamic responses. The controller design problem is formulated as the minimization of an eigenvalue-based objective function where the target is to find out the optimal gains of the PI controllers in such a way that the discrepancy between the obtained and desired eigenvalues is minimized. Eigenvalue and time domain simulations are presented for both open-loop and closed-loop systems. To test the efficacy of DE over other optimization tools, the results obtained with DE are compared with those obtained by particle swarm optimization (PSO) algorithm and invasive weed optimization (IWO) algorithm. Three different types of load disturbances are considered for the time domainbased results to investigate the performances of different optimizers under different sorts of load variations.

[2] Esmaeil Zangeneh Bighasha, Seyed Mohammad Sadeghzadeha.et.al (2018) Recently, the model-predictive control algorithm for single-phase inverter has been presented, where the algorithm implementation is straight forward. In the proposed approach, all switching states are tested in each switching period to achieve the control objectives. However, since the number of the switching states in single-phase inverter is low, the inverter output current has a high total harmonic distortion. In order to reduce the total harmonic distortions of the injected current, this paper presents a high-quality model-predictive control for one of the newest structures of the grid connected photovoltaic inverter, i.e., HERIC inverter with LCL filter. In the proposed approach, the switching algorithm is changed and the number of the switching states is increased by some virtual vectors. Simulation results show that the proposed approach lead to a lower total harmonic distortion in the injected current along with a fast-dynamic response. The proposed predictive control has been simulated and implemented in a 1 kW single-phase HERIC inverter with LCL filter at the output.

[3] Niancheng Zhou, Chunyan Li, Fangqing Sun.et.al (2017) The weakness of SOFC lies in its slow response speed when grid disturbance occurs. This paper presents a control strategy that can promote the response speed and limit the fault current impulse for SOFC systems integrated into microgrids. First, the hysteretic control of the bidirectional DC-DC converter, which joins the SOFC and DC bus together, is explored. In addition, an improved droop control with limited current protection is applied in the DCAC inverter, and the active synchronization control is applied to ensure a smooth transition of the microgrid between the grid-connected mode and the islanded mode. To validate the effectiveness of this control strategy, the control model was built and simulated in PSCAD/EMTDC.

[2.1] Jih-Sheng Lai and Michael W. Ell is .et.al (2017) Fuel cell power systems offer a unique combination of high efficiency, wide size range, modularity, and compatibility with cogeneration. The development of complete energy systems that realize the benefits offered by fuel cell technology requires a basic understanding of fuel cell system components as well as the associated power electronics for different applications. This paper explains the basic characteristics of a fuel cell system, describes the different types of fuel cells and their current state of development, and discusses the potential application of these systems to transportation and stationary power. Particular emphasis is given to the electrical characteristics of the fuel cell, which is a relatively stiff power source. Power electronic systems are essential for making the fuel cell electrical output compatible with most loads. Options for dc-dc and dc-ac power conversion circuits are given with a discussion of the distinct features of each circuit that can be used for system planning purposes. The interaction between a fuel cell and a single phase ac inverter load is highlighted because of the widespread applicability of this particular combination.

[2.2] Jimin Zhu, Hai Liu, Linlin Zhuang, Shulin Wang and Yong Song .et.al (2016). Utilization of hydrogen in the intermediate temperature solid oxide fuel cell (IT-SOFC) and micro gas turbine (MGT) hybrid system has the advantages of low costs, non-pollution, and wide range of sources. In this paper, the detailed model of SOFC/MGT hybrid system fueled by hydrogen was implemented to investigate the system operating performance as well as the influence of fuel inlet temperature and flow rate. At the beginning, the framework and functions of the SOFC/MGT hybrid system were introduced, and the topping cycle was arrested. Then, the numerical analysis was performed by using MATLAB software. The result of the simulation was generated to explain the performance and the electrical efficiency which can reach up to 75.61% at the design point. With an increasing fuel inlet temperature, both the output power and efficiency of the SOFC, MGT and hybrid system rose slightly. The rising fuel flow rate increased the output power of SOFC, MGT and the whole system, but made the system efficiency decrease.

[2.3] B Dziurdzia and Z Magonski and H Jankowski .et.al (2015). The paper presents the analysis of commercialisation possibilities of the SOFC stack designed at AGH. The paper reminds the final design of the stack, presented earlier at IMAPS-Poland conferences, its recent modifications and measurements. The stack consists of planar double-sided ceramic fuel cells which characterize by the special anode construction with embedded fuel channels. The stack features by a simple construction without metallic interconnectors and frames, lowered thermal capacity and quick start-up time. Predictions for the possible applications of the stack include portable generators for luxurious caravans, yachts, ships at berth. The SOFC stack operating as clean, quiet and efficient power source could replace on-board diesel generators. Market forecasts shows that there is also some room on a market for the SOFC stack as a standalone generator in rural areas far away from the grid. The paper presents also the survey of SOFC market in Europe USA, Australia and other countries.

[2.4] Murat Kale, Engin Ozdemir .et.al (2005). In this paper, an adaptive hysteresis band current controller is proposed for active power filter to eliminate harmonics and to compensate the reactive power of three-phase rectifier. The adaptive hysteresis band current controller, proposed by Bose [An adaptive hysteresis band current control technique of a voltage feed PWM inverter for machine drive system, IEEE Trans. Ind. Electron. 37 (5) (1990) 402–406] for electrical machine drives, is adapted to active power filter (APF). The adaptive hysteresis band current controller changes the hysteresis bandwidth according to modulation frequency, supply voltage, dc capacitor voltage and slope of the ic reference compensator current wave. The hysteresis band current controller determines the switching signals of the APF, and the algorithm based on an extension of synchronous reference frame theory (d-q-0) is used to determine the suitable current reference signals. The results of simulation study of new APF control technique presented in this paper is found quite satisfactory to eliminate harmonics and reactive power components from utility current. All of the studies have been carried out through detail digital dynamic simulation using the MATLAB Simulink Power System Toolbox. The APF is found effective to meet IEEE 519 standard recommendations on harmonics levels.

[2.5] Murat Kale, Murat Karabacak , Bilal Saracoglu .et.al (2013) This paper presents the application of the hysteresis band current controller (HBCC) technique to the three phase pulse width modulation (PWM) AC chopper used for the purpose of controlling the magnitude of the sinusoidal currents and voltages applied to an AC load. If the HBCC technique used in the inverters is directly employed in the three phase PWM AC chopper, it causes the AC chopper to fail to provide balanced three phase sinusoidal currents for a three phase AC load. In return, this situation leads some unavoidable and serious faults to occur in the hardware of the three phase PWM AC chopper. In respect to this case, the detailed analysis expressing the related faults is presented. Consequently, for the first time, a novel HBCC technique overcoming these faults is proposed for the three phase PWM AC chopper. The proposed method is tested under various operating conditions and a very precise control performance is achieved. Simulation results prove the feasibility and validity of the proposed method.

III. PROBLEM FORMULATION

The power provided by the cell is simply the product of voltage and current and, as shown for the PEM fuel cell in Fig. 3, reaches a maximum at a current density roughly corresponding to the onset of significant concentration over potential. The ideal electrical efficiency η ideal of the cell can be expressed as the ratio of the work available from the reaction [given by the change in Gibbs energy ΔG (J/g) for the reaction] to the heating value of the fuel, HV (J/g)

$$\eta_{\text{ideal}} = \frac{\Delta G}{HV}$$

Multiplying the numerator and denominator by the mass flow rate of fuel, ṁ (g/s), and recognizing that the product of the mass flow and ΔG is the ideal power, Ẇ i deal (W), yields.

$$\eta_{\text{ideal}} = \frac{\dot{m}\Delta G}{\dot{m}HV} = \frac{\dot{W}_{\text{ideal}}}{\dot{m}HV} = \frac{V_{\text{ideal}} I}{\dot{m}HV}$$

Where V ideal is the ideal or reversible voltage and I (A) is the current. For fuel cells operating on hydrogen with minimal fuel crossover, the difference between V ideal , and the operating cell voltage V cell , reflects the sum of the over potentials and thus the main inefficiencies associated with the cell1. The effect of these inefficiencies is captured in the voltage efficiency ηV.

$$\eta_V \stackrel{\text{def}}{=} \frac{V_{\text{cell}}}{V_{\text{ideal}}}$$

The fuel cell electrical efficiency η fc is the ratio of the fuel cell stack power W˙ fc (W) to the flow of chemical energy into the stack and can be related to the ideal efficiency and the voltage efficiency

$$\eta_{fc} = \frac{W_{fc}}{\dot{m} \cdot HV} = \frac{V_{oc} I}{\dot{m} HV} \times \frac{V_{cell}}{V_{oc}} = \eta_{ideal} \times \eta_V .$$

Equation (4) implies that that the polarizations curve also provides a good representation of the variation of fuel cell efficiency with current. At high current, the cell efficiency suffers, while at part load, the cell becomes more efficient as Vcell approaches Videal.

IV. METHODOLOGY

The architecture of a typical fuel cell and its associated power management system consists of fuel cell stack, which consists of tens or even hundreds of cells connected in series. Associated with the balance of plant controls flow rate, pressure, temperature and humidity using heat exchangers, humidifiers, compressors, and blowers. In addition to controlling the balance of plant, the control and power management system must provide stable voltage for the associated load. To stabilize the output voltage and to limit the effect of voltage fluctuations imposed by the load on the fuel cell, a large capacitor bank can be added across the fuel cell output, but the life expectancy of such a capacitor bank can be a concern, especially with the use of electrolytic capacitors.

It is possible to add a dc–dc boost converter at the cell level, which not only can stabilize the stack voltage, but also help voltage balancing and provide boost functions. However, the cost is proportionally increased as the number of cells increases. Therefore, instead of adding dc–dc converters at the cell level, most high-voltage grid interconnect systems adopt a dc–dc nconverter as the buffer stage in between the load side converter.

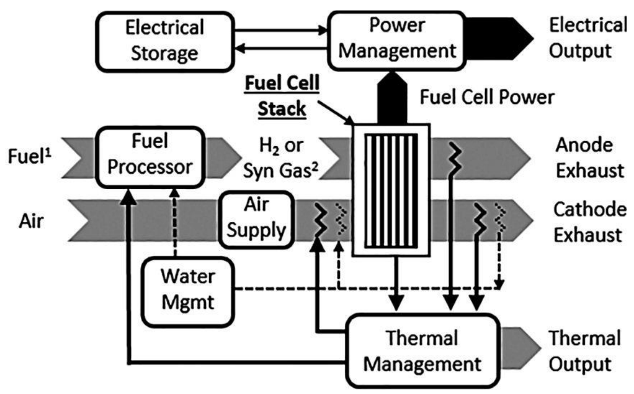


Figure-1: A fuel cell system based power system

In addition to controlling the balance of plant, the control and power management system must provide stable voltage for the associated load. To stabilize the output voltage and to limit the effect of voltage fluctuations imposed by the load on the fuel cell, a large capacitor bank can be added across the fuel cell output.

A multiyear research plan has been undertaken to reduce such ancillary power to 8 and 14 kW with and without the expander. However, even with these improvements, maintaining the pressure and humidity of the stack reactants to support efficient cell operation will still require an additional 10%–18% of the stack net power.

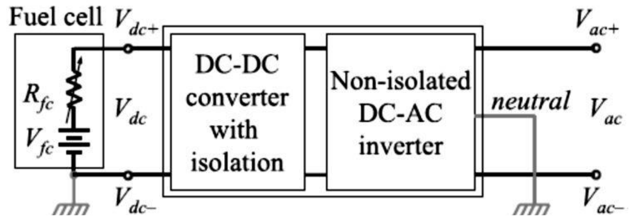


Figure-2: fuel cell system with dc source and ac output.

Control strategies and algorithms

In power system, control algorithms has major role for deciding the performance of harmonic compensation. The gate pulses provided are provided using the control algorithms to the voltage source inverter used in filtering system. It makes a closed loop control on the harmonic current present in the line and compares with ac sinusoidal source to get an error. This error is passed through some controllers and control algorithms to generate pulses for VSI. The reliability and performance of power system filtering largely depend on control algorithms used in the system, there are many number of control algorithms proposed in the last decade some of which work good under balanced and unbalanced conditions also. Input to the control block is source current, load current and the DC link voltage.

Synchronous Detection Method

Under balanced and unbalanced condition the working of this theory is very much satisfactory. It is considered taking into account the magnitude of per phase voltage because the compensating current. Then synchronous detection concept is uses the equal current spreading method of current to determine the three phase compensating current to be given by the active filter. Hysteresis Band Controller In the vector control scheme, the current controller has direct influence on the power system performance and its design requires special considerations. The basic requirements for the current controllers are to reduce losses, and fast response in order to provide high dynamic performance [4-5]. Due to the inherent nature of the HBCC, the switching signals of each phase are exactly independent of each other [4]. This implies that all the switching states given in Table 1 are

possible to be performed at any moment in time according to the dynamics of the load driven. Moreover, including all the initial conditions of the load currents, the continuity of the load currents are provided on account of the inverse parallel diodes of the IGBTs. In this context, there is no possible fault to be able to occur as regards the switching sequence. In this technique, the DC-bus voltage of the inverter and the phase angle of the load are not required to be measured and/or calculated.

V. MODELING & SIMULATION

This section presents the simulation results of hysteresis band controlled SOFC based power system which maintain sinusoidal AC current and ripple free constant dc-link voltage. The fuel cell is modelled for better results. The parameters used for the simulation study is given in Table-I. The SIMULINK model is shown in Fig. 5.6. TABLE -I: Simulation Parameters

SOFC		
Sr. No.	**Parameters**	**Value**
1	Number of Fuel Cells in Series	450
2	Initial Current	50 A
3	Initial Voltage	422 V
4	Maximum and Minimum Fuel Utilization	[.9 .8]
5	Value of Molar Const.	.83x10-4, 2.52x10-3, 2.18x10-4
6	Response Time for H, O2 & H2O	[26.1, 2.91, 78.3]
	Ohmic Loss	3.28x10-4
	Fuel Processor Response Time	5 Sec.
	H2 & O2 Ratio	1.145
VSI (Voltage Source Inverter)		
1	Inverter	Universal Bridge Inverter
2	Switching Devices	IGBT
3	Ron	$1x10^{3}$ ohms
4	Hysteresis Band	.3 A
5	Snubber Resistance	$1x10^{5}$ ohms
6	Reference DC Link Capacitor	3.0 µF

5.1 Solid Oxide Fuel Cell (SOFC)

The complete model is divided into different parts like compensation block, inverse Clark, Hysteresis Controller, main controller and complete model. In figure 4.1 the compensation block is shown in which the current components are calculated by the math function from the power and voltage signals to generate reference current. Here real power loss, real power, reactive power and voltage components are responsible to calculate the current components.

The SOFC is able to convert fuel chemical energy directly into electricity, skipping the limitation of the Carnot cycle and the mechanical loss. The output voltage of a single SOFC is limited, therefore the SOFC stack is considered to be piled up with numerous single cells all behaving in the same way. The typical schematic of planar SOFC is illustrated in Fig. 2. A SOFC module is composed of electrode, electrolyte and interconnect. The flow paths formed by interconnect allow the fuel pass over the anode and the air pass over the cathode. And

electrons created in the electrochemical reactions can be transmitted through interconnect. In the cathode, oxygen combines with electrons from the anode and turns into free divalent negative oxygen ions. These ions from the cathode can be transported by the electrolyte to the anode and react with hydrogen, resulting in water and releasing electrons. For each mole of reacting hydrogen, two moles of electrons are generated. Free electrons removed by interconnects constitute an electric current. In this paper, the process uses H2 as fuel O2 from

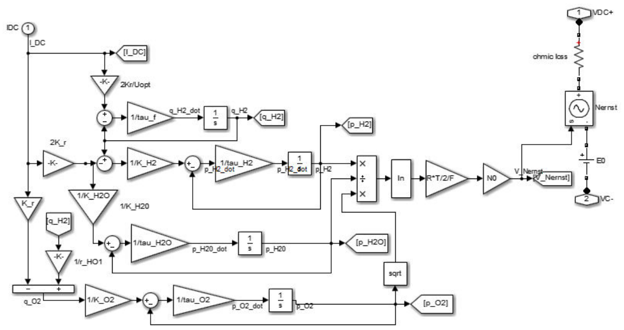


Figure 4.1 SOFC model

5.2 Inverse Clark

The three phase current reference signal is generated with the help of the current componentsobtained in the compensation block, this current is use full to calculate the switching sequence for the inverter, which is the result of the control action of hysteresis controller. The complete block is shown in the inverse Clark block in figure 4.2

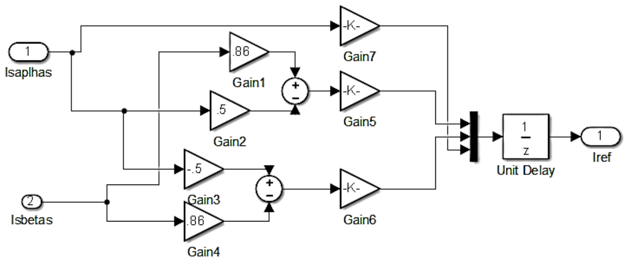


Figure 4.2 Inverse Clark

5.3 PI Controller

The main control action is defined by the PI controller which is used to control band limit of

the hysteresis controller to get appropriate switching sequence. Here Kp=.2 and Ki=1.5

5.4 Hysteresis controller

The hysteresis controller is the versatile arrangement which used to generate the switching pulses, in this the relays are used in such a way that these can work in between positive and negative sequences shown in figure 4.4. The comparison of reference current and the existing current takes place and the signal is followed by the relay to get switching pulses. This whole arrangement shown in figure 4.4 is part of pulse generation sub-system.

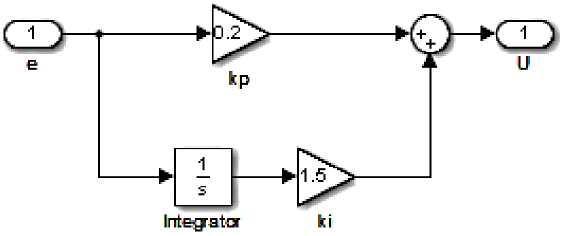
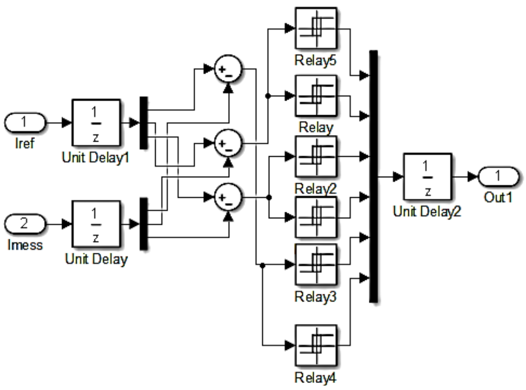


Figure 4.3 PI Controller



4.5 Series Inductor between Inverter and Grid

VI. RESULT & DISCUSSION

The SOFC based power system responses after switching can be easily distinguished from the waveform and THD values given in the table II. This section presents the MATLABSIMULINK based simulation results of above discussed control scheme for SOFC-PS system. The load current (Fig. 5.7) remains independent of operation of inverter, it can be observed from the source current waveform.

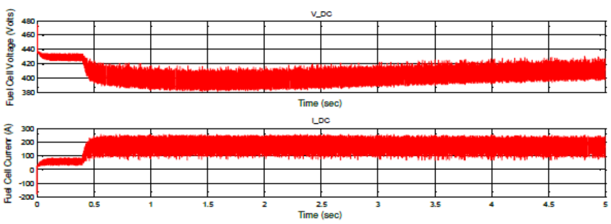


Fig.6.1. SOFC Voltage and Current

6.1 SOFC Voltage and Current

In figure 6.1 SOFC voltage and current waveforms are shown which depend on the rate of flow of H2 and O2 in the fuel cell. Here the output DC voltage is initially about 430 volts, which is further stabilizes at 420 volts and current is initially 50 A, which is stabilizes at 190 A. This is the combined effect of stacked 450 SOFCs.

In figure 6.2 is showing the flow rate and pressure characteristics of H2, H2O and O2 in SOFC. The flow rate control is very important to optimize the power generation and efficiency of the system.

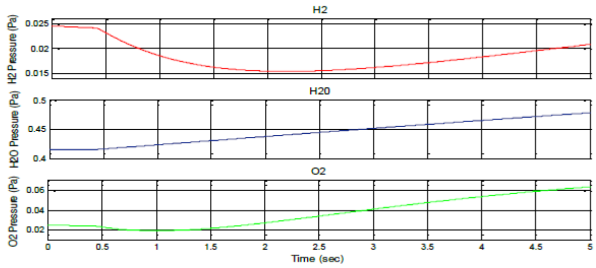


Fig.6.2. H2, H2O and O2 pressure control characteristics of SOFC

The real and reactive power are plotted in figure 5.3, for the fuel cell the real power is not smooth i.e. having some transients while the real power for bus is having less transients. For the fuel cell the reactive power is about 1.80 Kw with significant peak overshoot while the reactive power for bus is having fewer value and peak overshoot.

VI. CONCLUSION & FUTURE WORK

Fuel cell power system has different characteristics that make them appealing in stationary and transportation applications for house hold and electric vehicle. Unlike other uncertain power sources such as PVs, the fuel cell system is reliable and has a control system that manages the balance of plant and determines the static and dynamic characteristics of the power output. As long as the fuel cell system is connected to a reliable source of fuel such as natural gas, it can continuously provide power to the load and making it more acceptable for distributed generation than PVs or wind. Many opted fuel cell technologies can be used to align with the application requirements. Low-temperature fuel cells are best suited for both transportation and stationary applications, provided the stationary application can use lowlevel heat. On the other hand, high-temperature fuel cells are more compatible with natural gas operation and provide heat with high temperature, so making them more reliable, implementable and suitable for stationary applications, where they can used with a thermal power cogeneration efficiency that exceeds more than 90%. For the stationary applications, the major challenge, as the power management system is needed to convert low-voltage dc to high-voltage ac while full filling the grounding requirement for the source. In case of transportation applications, the grounding is not needed by regulations, but the dynamic response is an important and major concern, and also the energy management system with bidirectional chargers is to be needed. The availability of devices and components and the package related parasitic for high-power applications, can impact the power conversion efficiency. The drawback of source supplying energy to a single-phase ac load, the doubleline frequency ripple is flowing from the inverter back to the fuel cell source, which is hazards for fuel cell and may reduce the life expectancy and its efficiency. Proposed approach gives a solution for addressing this concern that is more cost effective than previous approaches. Results are showing that the proposed technique is significantly improving the performance without adding extra components.

The system can be modified further by proper modelling and design of fuel cell and the advance control of converters to achieve better performance and efficiency.

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