

Micro Energy Resources can be integrated with Power Grid

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ABSTRACT: Renewable energy sources have been taken the place of the traditional energy sources and especially rapidly developments of photovoltaic (PV) technology and fuel cell (FC) technology have been put forward these renewable energy sources (RES) in all other RES. PV systems have been started to be used widely in domestic applications connected to electrical grid and grid connected PV power generating systems have become widespread all around the world. On the other hand, fuel cell power generating systems have been used to support the PV generating so hybrid generation systems consist of PV and fuel cell technology are investigated for power generating. In this study, a grid connected fuel cell and PV hybrid power generating system was developed with Matlab Simulink. Output current and voltage of PV system was used for input of DC/DC boost converter and its output was used for the input of the inverter. 100kw PV array system was connected to the grid and designed 25 kW solid oxide fuel cell (SOFC) system was used for supporting the DC bus of the hybrid power generating system. All results obtained from the simulated hybrid power system were explained in the paper. Proposed model was designed as modular so designing and simulating grid connected SOFC and PV systems can be developed easily

I. INTRODUCTION

As energy generation and distribution companies compete in the market place we have seen an increasing interest in renewable and alternative energy sources. In addition to this competition, companies are seeing demands from customers for higher quality and cleaner electricity [1]. Also, considering the worlds coal stocks are reducing and the creation of legislation which is pushing for greener energy solutions [2], we are led to seek new energy generation methods. One solution which is currently attracting attention are micro-grid systems. Micro-grid systems are comprised of several alternative energy sources. They can include solar cells, wind turbines, micro-turbines (natural gas), fuel cells and storage batteries [3, 4]. They are connected in addition to the main power grid and are placed on the site that is to use the system. That is it is connected to the low voltage distribution network through power electronics. There are several reasons why micro-grids are so interesting [5, 6]. First, because they involve alternative energy sources, and most alternative sources offer far higher

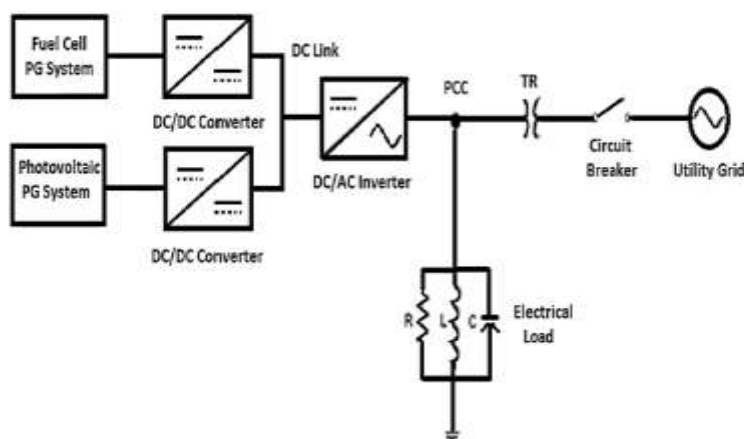


FIG-1

efficiency and less environmental issues than standard power generation. Furthermore, since they are to be on the site which they are to supply, losses due to transmitting electricity is proportionally eliminated, which makes micro-grids even more efficient and cleaner than their standard counterpart. Finally, it is possible to tailor a micro-grid to suit the needs of the area it will be servicing [7e9]. Currently a lot of research is being undertaken into micro grids. Although the components of a micro-grid are somewhat understood the system as a whole is not. When several sources are connected to form a micro-grid the systems behavior is unpredictable [10]. This being the case, modeling the system and investigating it in order to evolve an appropriate control system is the heart of micro-grid research [11]. Currently several research groups around the world are investigating the feasibility and benefits that micro-grids may provide. One model which has been proposed is The Consortium for Electric Reliability Technology Solutions (CERTS) model [12]. This model is based on minimum control. CERTS are funded in part by the US government in association with several private companies. The crux of the CERTS concept is the notion of a flexible, controllable interface between the micro-grid and the wider power system. The CERTS group this year intends to build a micro-grid both for use and testing. To date no results or evidence that it has occurred is available. Another American company, Northern Power Systems is also investing in micro-grid technology. In 2003 they announced that they would be engineering and building a micro-grid in Waitsfield, Vermont [13]. They have not released many details about their plan. They hope it will service five commercial and industrial facilities, and up to 12 residences. They are currently in the engineering phase. The research group of most interest to this project is the CSIRO Energy Centre in Newcastle, Australia. Onsite they have a micro-system setup, the system has a photovoltaic array, several wind turbines, several micro-turbines, a fuel cell and batteries [14]. They are currently in the process of researching the micro-grid system and modeling its features. This project aims to lay the ground work for the development of such a model.

II. INVERTERS

Inverter is a device which converts DC power into AC power.

Inversion Inversion is the conversion of dc power to ac power. Inversion can be accomplished using SCRs or IGBTs. In high power applications, IGBTs have been used. Inverters for static UPS systems can be single-phase or three-phase. Single-phase inverters are used in ratings up to approximately 75 kVA; at higher ratings three-phase inverters are used.

2.1 Inverter Voltage Control

The common methods of inverter output voltage control are pulse width control, PWM, and use of a ferroresonant transformer. Any of these methods may be used for output voltage control. In some designs a combination of pulse width control and modulation is used. However, a ferroresonant transformer is never used in combination with either of the other two methods. The pulse width control technique has become less common than the PWM technique and the use of ferroresonant transformers. Also, some manufacturers advocate the use of PWM while others favor the use of ferroresonant transformers. Although each method may have some advantages over the others, the voltage control method is normally not specified when specifying UPS systems. Either type may be used provided it meets the performance requirements.

6 step SCR similar to 6 pulse rectifiers, low cost, largest filter required.

12 step SCR similar to 12 pulse rectifier, low cost, still filtered

IGBT similar to, often identical to, IGBT rectifier, no filter required.

In the early 1980's most UPS were 12 pulse rectifiers and 12 step inverters.

2.2 The IGBT rectifiers with IGBT inverters have the following benefits,

- I.** Rectifier speed matches with inverter needs
- II.** Handles high step loading without using battery or bypass
- III.** Maximizes battery life as battery is not required to support inverter for harmonic and step load needs
- IV.** Eliminates transfers to bypass for step loading
- V.** Rectifier puts out low ripple which maximizes battery life
- VI.** Well suited for high performance in parallel UPS design
- VII.** Only design that should be selected for isolated redundant designs

2.3 Use of A Ferroresonant Transformer

A ferroresonant transformer connected across the inverter's output can be used to regulate the output voltage and reduce its harmonic content. The ferroresonant transformer is basically a two-winding transformer with an additional small secondary compensating winding and a series low pass filter connected across part of the main secondary winding. The filter presents low impedance to the lower order harmonics and reduces their amplitude in the output to a low acceptable value. The compensating winding voltage is added to the secondary

output voltage 180° out-of-phase thus maintaining the output voltage within a narrow regulation band. However, with the use of a ferroresonant transformer, the output voltage is not continuously adjustable as in the previous techniques

2.4 Three-Phase Inverters

Three-phase inverters are commonly made up of three single-phase inverters connected to the same dc supply. The secondaries of the three single-phase inverter output transformers are connected in wye configuration. To generate a three-phase output, the firing signals for phase B inverter SCRs are delayed 120° from those of phase A inverter. Similarly the firing signals for phase C inverter SCRs are delayed 120° from those of phase B inverter. The resulting phase-to-neutral voltages for 180° pulses and the line-to-line secondary voltages

$$EA-B = EA-N - EB-N \quad , \quad EB-C = EB-N - EC-N \quad , \quad EC-A = EC-N - EA-N$$

In this case as with the single-phase inverter, the output wave shape is a square wave and means for conditioning the output to a sinusoidal waveform is required. The three phase inverter output voltage control can be accomplished by the same techniques used for single-phase inverters. However, the use of ferroresonant transformers is not feasible in many three-phase applications. This is due to the fact that a slight load current unbalance can cause substantial phase shifts in the ferroresonant transformers output voltages. With substantial voltage phase shift, the three line to neutral voltages may have the same magnitude but the line-to-line voltages may be extremely unbalanced. However, PWM technique can also be used as in the case of single-phase inverters.

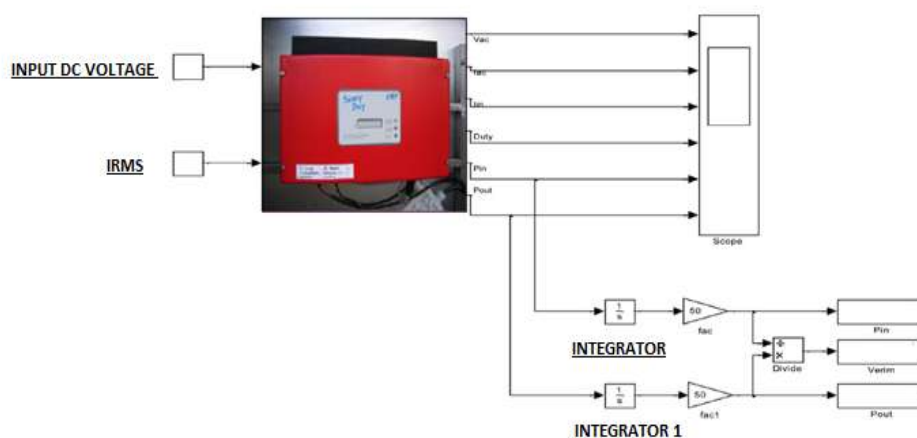


Fig-2 Inverter

III. GRID CONNECTED PV CELL & FUEL CELL GENERATING MODEL

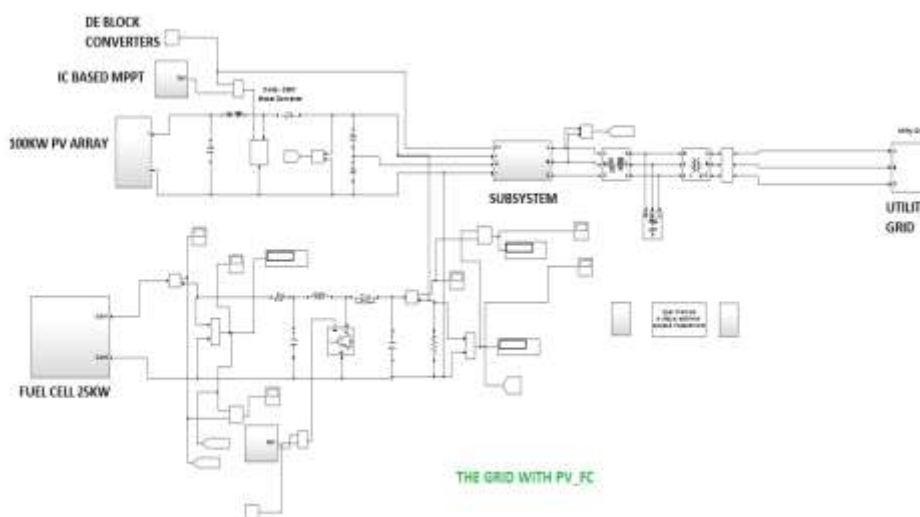


Fig-3 The Grid Connected Pv_Fc

The technical details of a micro-grid are specified in the details of the individual sources (here a photovoltaic array and SOFC) . Fig. 1 shows the general structure of the developed model. A possible inverter configuration for the systems will be set out. Connecting them to a load and to the mains supply was discussed. Finally, a possible format for connecting them as a micro-grid was considered and discussed in terms of the physical reality of such systems. Developed Matlab/Simulink model is shown in Fig. 3. SOFC and PV system are connected to the inverter and the grid via DC/DC converters in this system.

3.1 Grid Connected Fuel Cell Model:-

25 kW SOFC model was developed in Matlab/Simulink and the main structure of the model can be seen in Fig. 4. Constant parameters of the SOFC system are the inputs of the model and voltage, current and power determined from the proposed model. Main structure of the SOFC model is shown in Fig. 4. All input parameters are evaluated in these blocks and outputs parameters are generated according to these parameters. SOFC model output voltage is shown in Fig. 5 & 6. Input parameters of the developed SOFC model will change the output voltage of the SOFC. SOFC generates the desired power and it is used input of a DC/DC converter. Then this power converted to an AC signal and system is connected to the grid.

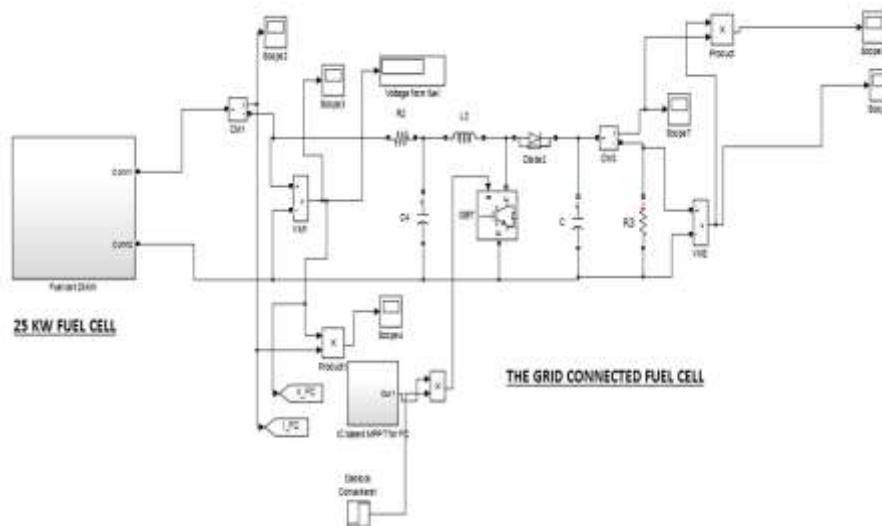


Fig -4 Grids Connected Fuel Cell Model

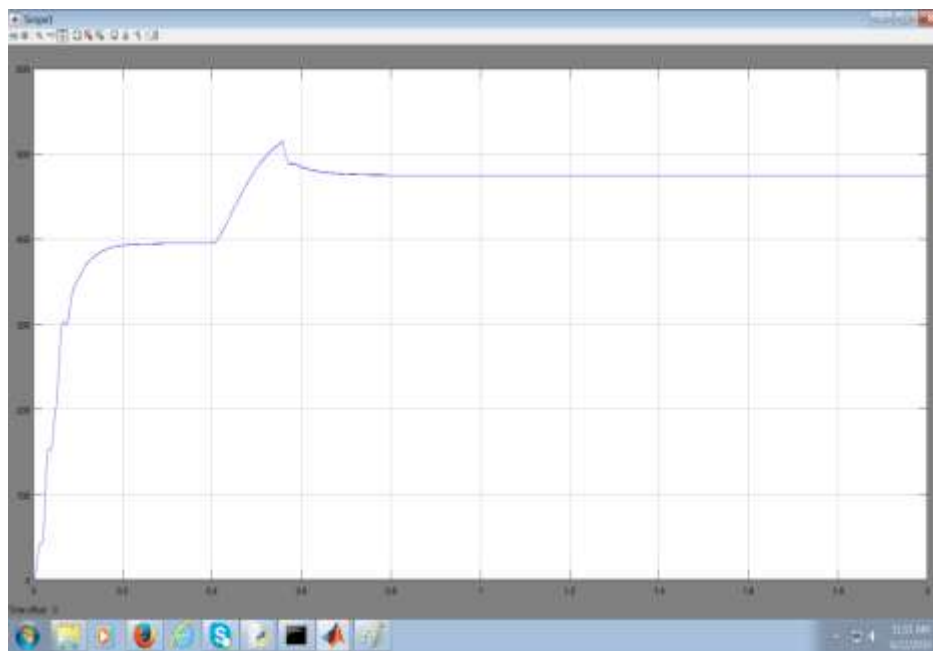


Fig -5 Dc Voltage

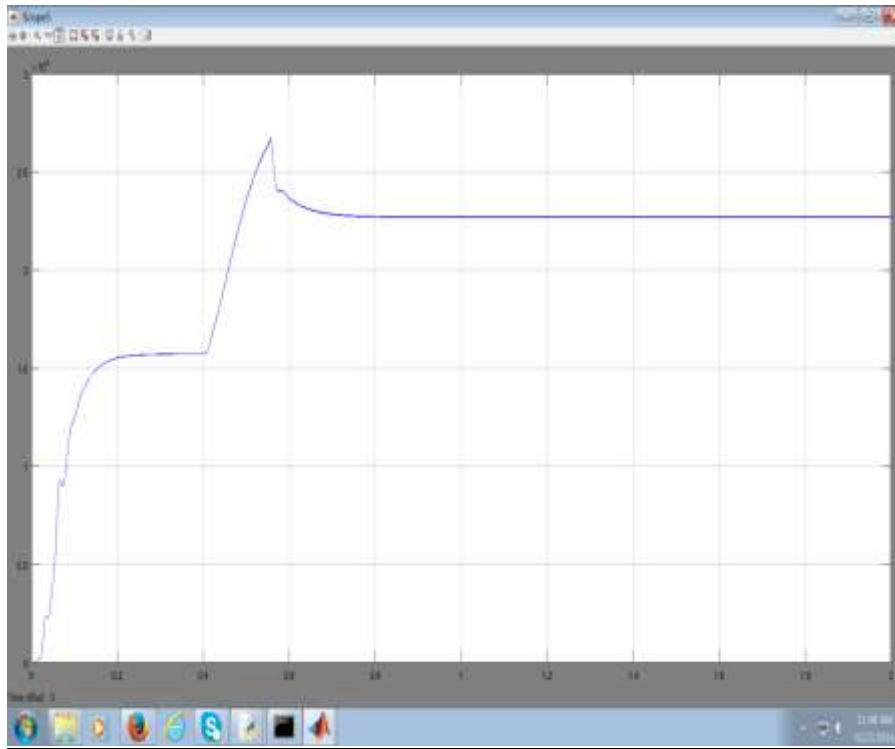


Fig -6 Dc Power

Fuel Cell is Micro Energy resources and environmental friendly. The above Power O/P and voltage O/P shows in figure 5 & 6 that it draws the constant voltage and constant active power on grid side so that can be easily integrated with grid by using inverter and it can be understood by circuit Figure 3 Using DC/DC Boost. Here in power o/p is having losses it can be seen very easily with respect to figure-6

3.2 Grid Connected PV Model:-

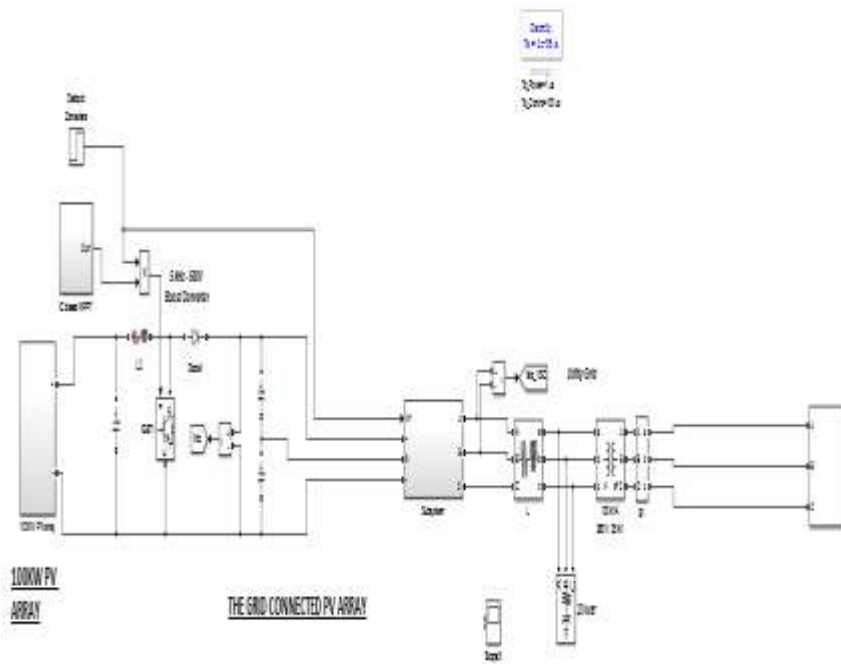


Fig -7 Pv Connected Grid

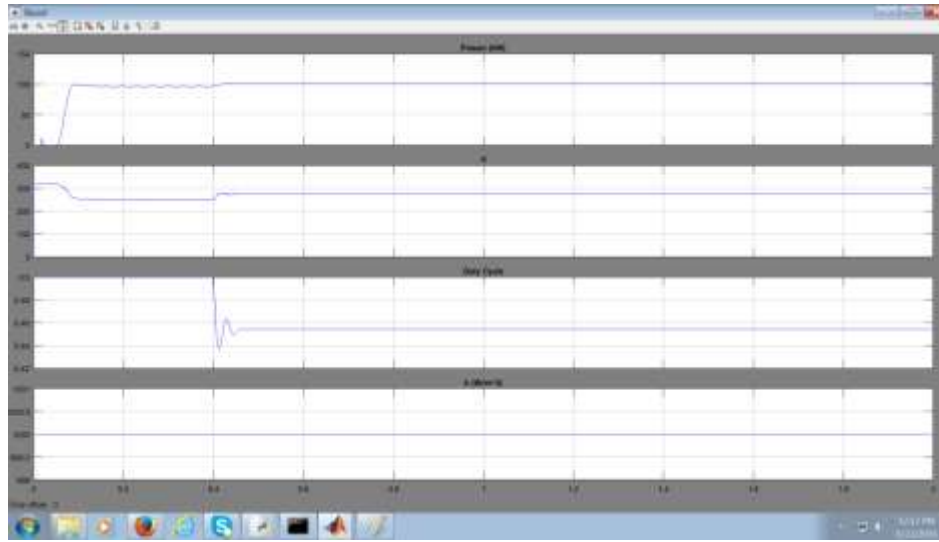


Fig-8 Dc Power O/P & Dc Voltage Voltage O/P

Similarly it can be seen from the figure-7 that the PV connected grid draws in output active power on grid side and it can be easily synchronized with grid by using inverter.

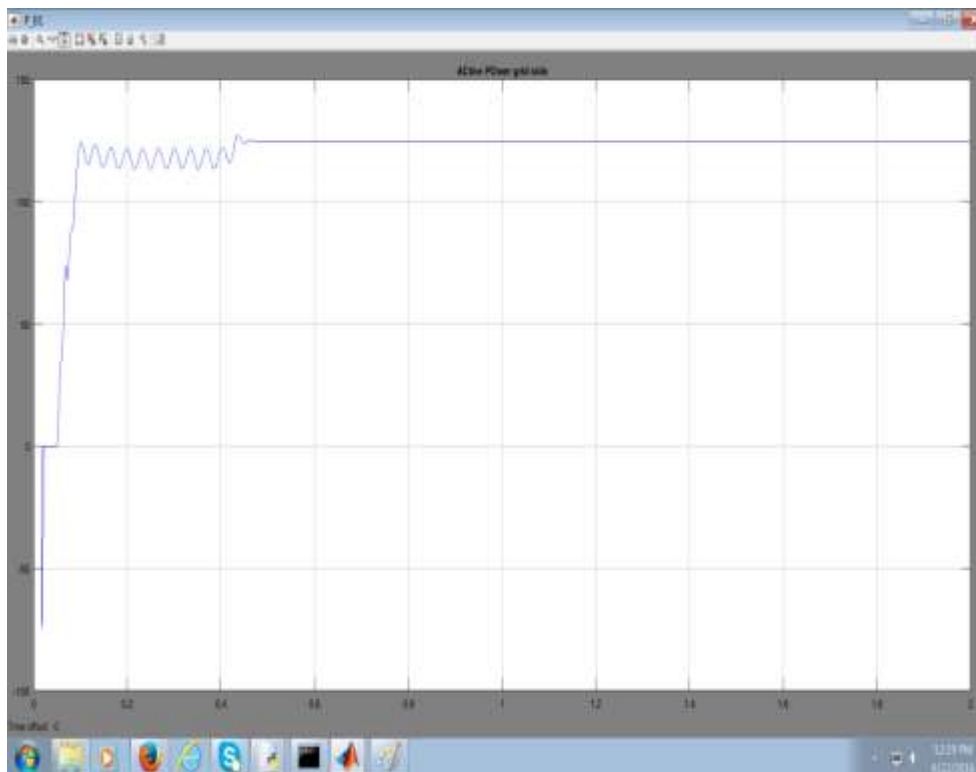


Fig-9 Power O/P Of PV_FC Cell Integrated With Grid

Finally it can be concluded from the power o/p of figure-8 that the integrated system of fuel cell & PV cell gets active power o/p on grid side where integrated systems shows DC Active Power o/p is 125kw . The above Result fig-8 shows the combine energy resources like PV Cell & Fuel Cell integrated with Grid are more efficient than the single system. When the single micro energy resources get more losses than the combine energy resources get integrated with the grid reference to fig-5

IV. CONCLUSIONS

In this study, a grid connected fuel cell and PV hybrid power generating system was developed with Matlab Simulink. Finally it can be concluded from the power o/p of figure-8 that the integrated system of fuel cell & PV cell gets active power o/p on grid side where integrated systems shows DC Active Power o/p is 125kw .Output current and voltage of PV system were used for input of DC/DC boost converter and its output were used for the input of the inverter. 100kw PV system was connected to the grid and designed 25 kW solid oxide fuel cell (SOFC) system was used for supporting the DC bus of the hybrid power generating system. All results obtained from the simulated hybrid power system were explained in the paper. Proposed model was designed as modular so designing and simulating grid connected SOFC and PV systems can be developed.

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- [16]. Bayrak G, Cebeci M. Modelling 3.6 Kw installed power PV generator with Matlab Simulink. J Inst Sci Technol Erciyes Univ 2012;28(2):198e204. Fig. 19 e Duty cycle and input current of the inverter.
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