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Performance Analysis of Standalone Hybrid PV-SOFC- BATTERY Generation System

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Abstract-- Due to the increasing future energy demands and global warming, the renewable alternative energy sources and the efficient power systems have been getting importance over the last few decades. Renewable energy sources are newer alternatives in electric power generation. The main challenge in replacing legacy systems with the newer alternatives is to capture maximum energy and deliver maximum power at minimum cost for the given load such as induction motor. Solar energy which is free and abundant in most parts of the world has proven to be an economical source of energy in many applications. Among the renewable energy technologies, the solar energy coupling with fuel cell technology will be the promising possibilities for the future green energy solutions. The new efficient photovoltaic array (PVA) has emerged as an alternative measure of renewable green power, energy conservation and demand-side management. However in photovoltaic power generation system the control problems arise due to large variances of output under different insulation. This problem can be overcome by hybrid photovoltaic generation system i.e. use of photovoltaic arrays with fuel cells and power storage such as battery bank. In this work performance analysis of standalone hybrid PV-SOFC-Battery generation system is done.

Index Terms: MPPT, PV System, Induction Motor, Delta transformer.

I. INTRODUCTION

Solar power is a renewable energy source and a bright prospect to replace fossil fuel dependent energy sources. However, solar power cost per kilowatt-hour has to be competitive with fossil fuel energy sources. Currently, solar panels are not very efficient, now a day's these have only about 12 - 20% conversion efficiency from sunlight to electrical power. The efficiency may drop further due to other factors such as solar panel temperature and load conditions. The main objective of this paper is to simulate and optimize PV system. The Maximum Power Point Tracker (MPPT) compensates for the varying voltage v/s current characteristics of the solar cell. It is important to operate the panel at its optimal power point. This paper presents a design of charge controller called a Maximum Power Point Tracker (MPPT) in order to maximize the power derive optimal power point.

A mathematical model of the co-generation system is developed. To illustrate the performance, the system is considered in a solar-solid oxide fuel cell (SOFC) mode, which is low solar radiation time when the solar photovoltaic (PV) and SOFC are used for electric and heat load supply; and a SOFC mode, which is the power and heat generation mode of reversible SOFC using the storage H2 at night time. This study is also revealed the combined heat and power (CHP) efficiency of the system.

Solar hybrid systems generate power using a solar power generator like photovoltaic (PV) module and additional renewable source of energy. The analysis and modeling of the PV/SOFC hybrid generation system and sub-systems. Mathematical and circuit models of the PV and SOFC systems are established based on basic circuit equations of the photovoltaic (PV) solar cells including the effects of solar irradiation and temperature changes. The new model results for a directly coupled AC load via an inverter and 3-phase induction motor are also presented.

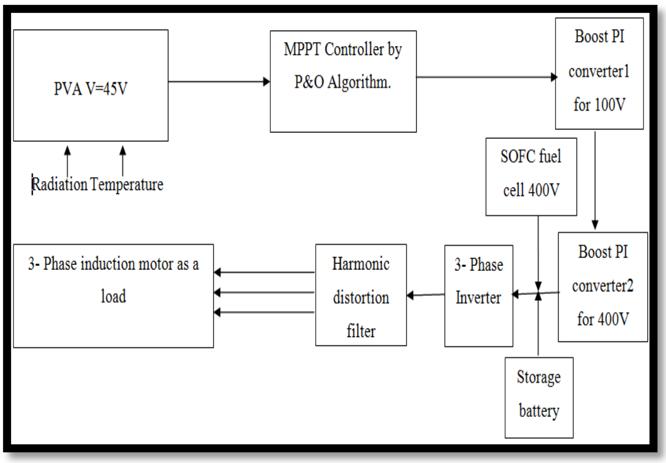

Fig.1 basic block of proposed system

II. MATHEMATICAL MODELING OF PV ARRAY

Mathematical modeling of PV system is based on following equations:

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$$V_c = \frac{AKT_c}{e} ln\left(\frac{I_{ph}+I_0-I_c}{I_0}\right) - R_s I_c \ldots\ldots (1)$$

$$C_{TV} = 1 + B_T(T_a - T_x) \ldots\ldots (2)$$

$$C_{TI} = 1 + \frac{Y_T}{S_c}(T_x - T_a) \ldots\ldots (3)$$

$$C_{SV} = 1 + \beta_T \alpha_s (S_x - S_c) \ldots\ldots (4)$$

$$C_{SI} = 1 + \frac{1}{S_c}(S_x - S_c) \ldots\ldots (5)$$

$$\Delta T_c = \alpha_s (S_x - S_c) \ldots\ldots (6)$$

$$V_{CX} = C_{TV} C_{SV} V_c \ldots\ldots (7)$$

$$I_{phX} = C_{TI} C_{SI} I_{ph} \ldots\ldots (8)$$

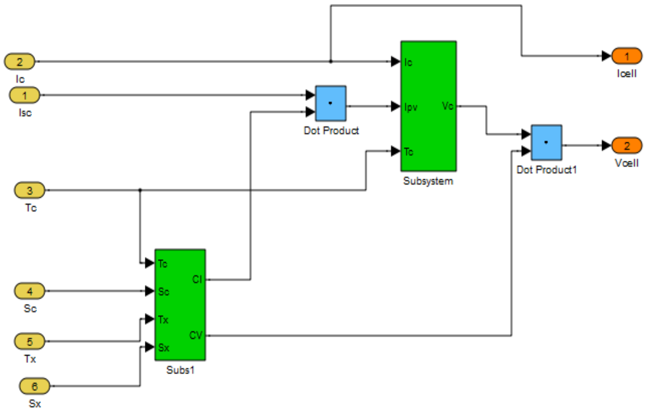

Fig. 2 PVA Subsystem1 model developed in MATLAB–SIMULINK

$$V_{CX} = C_V V_c \ldots\ldots (9)$$

$$I_{phX} = C_I I_{ph} \ldots\ldots (10)$$

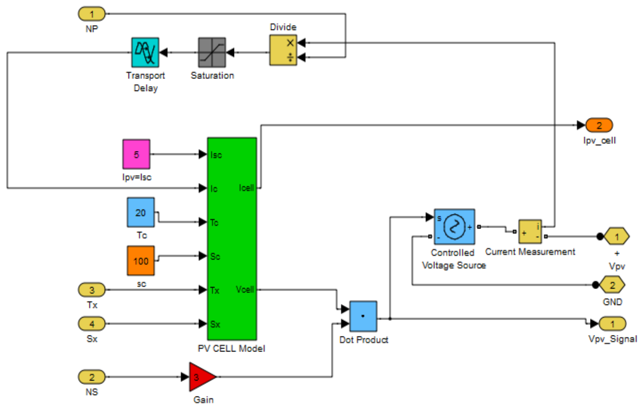

Fig. 3 PVA Subsystem2 model developed in MATLAB - SIMULINK

Solid Oxide Fuel Cell

A solid oxide fuel cell is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. Fuel cells are characterized by their electrolyte material; the SOFC has a solid oxide or ceramic, electrolyte. Advantages of this class of fuel cells include high efficiency, long-term stability, fuel flexibility, low emissions, and relatively low cost .Fuel Cell (FC) generates electricity from hydrogen by a chemical process and their emissions are water, the operation of all fuel cells is based on the reaction of hydrogen with oxygen to produce water:

$$2H_2 + O_2 = H_2O$$

In order to extract current and thus electric power, from a fuel cell, the above reaction must be separated into two half reactions. In an SOFC, these half-reactions take the form:

$$H_2 + O^- = H_2O + 2e^-$$

$$O_2 + 4e^- = 2O^-$$

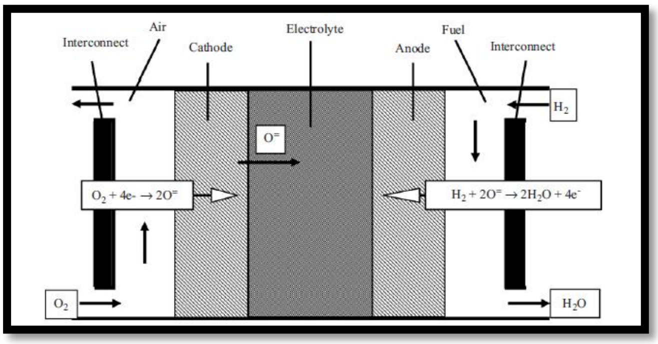

Fig: 4 Schematic diagram of a planar SOFC single cell structure

III. MPPT SYSTEM SIMULINK SETUP

The proposed algorithm reads the value of current and voltage from the solar PV module. Power is calculated from the measured voltage and current. The value of voltage and power at Kth instant are stored. Then next values at (k+1)th instant are measured again and power is calculated from the measured values. The power and voltage at (k+1)th instant are subtracted from the values from kth instant. In the power voltage curve of the solar PV module in the right hand side curve where the voltage is almost constant the slope of power voltage is negative (dP/dV < 0) whereas in the left hand side the slope is positive (dP/dV > 0) . The right side curve is for the lower duty cycle (nearer to zero) whereas the left side curve is for higher duty cycle (nearer to unity). Depending on the sign of dP(P(k+1) - P(k)) and dV(V(k+1) - V(k)) after subtraction the algorithm decides whether to increase the duty cycle or to reduce the duty cycle. The SIMULINK setup of the MPPT system is shown in the Fig.3. The MPPT block takes the module voltage and current through the multimeter. The irradiation and the temperature are kept fixed and are not varied.

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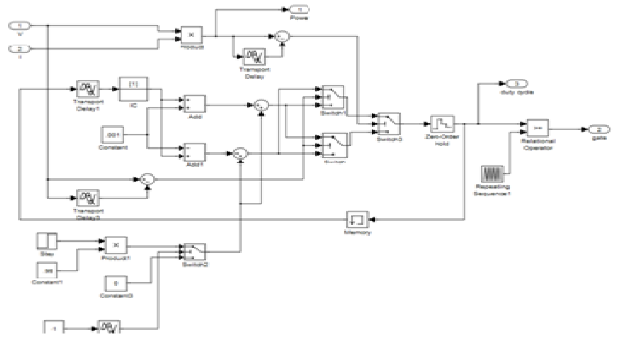

Fig. 5: Implementation of algorithm in SIMULINK

IV. DC/DC CONVERTER

(IV. a) Buck Converter: A DC converter forms an integral part of any MPPT system. Without DC/ DC converter no MPPT system are designed. The step down DC/ DC converter as shown in Fig. 6 in which output voltage is less than input (VO < Vi).

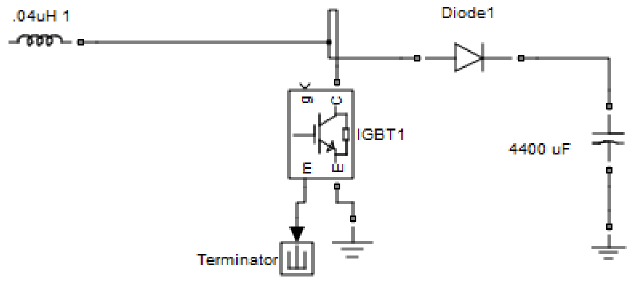

Fig. 6 Buck converter (Vo < Vi)

(IV. b) Boost Converter: The received output voltage 25 V of PV array is boosted up by two cascade connected boost up converters. Boost up converter is designed using PI controller. Converter 1 has reference voltage 100 Volt, converter 2 has reference voltage 400 Volt. Converter designed in MATLAB SIMULINK is shown in the following figure 7.

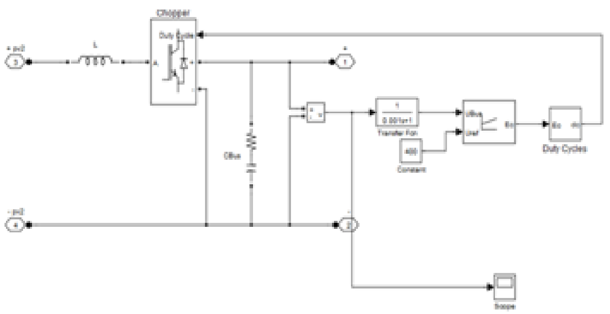

Fig. 7 Boost converter

V. Standalone hybrid PV-SOFC-Battery generation system developed in MATLAB-SIMULINK

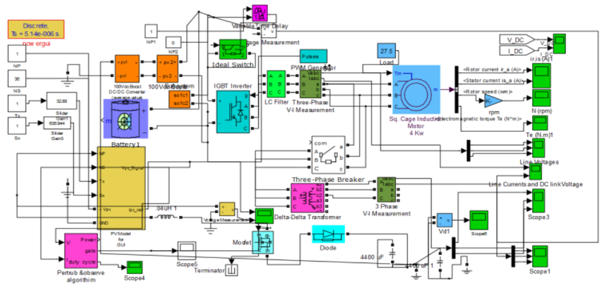

FIG 8 MATLAB SIMULINK MODEL OF PV-SOFC - BATTARY HYBRID GENERATION SYSTEM

VI. SIMULATION RESULTS

The developed PV-SOFC-Battery based standalone hybrid system during this work .The analysis of the developed model is done PV ARRAY (PVA) & SOFC BOTH.

HYBRID SOLAR SOFC

The SOFC is not working in this case so the SOFC current and voltage are zero. SOFC pressure for hydrogen (PH2), water vapor (PH2O) and oxygen (O2) are displayed. It is seen that for SOFC off case the pressure of hydrogen (PH2) and oxygen (O2) is increase while the pressure of water vapor (PH2O) is decrease. This is obvious that during SOFC off it stores the energy so that during on situation energy can be released.

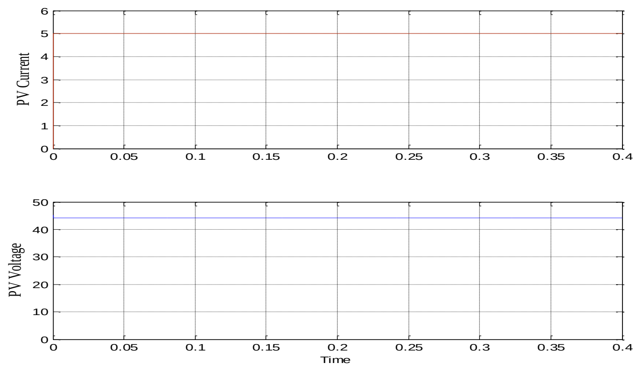

Fig. 9 PV array current and voltage for PV-SOFC both

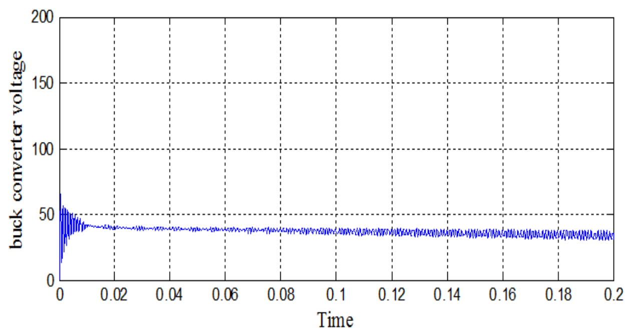

Fig. 10 MPPT buck converter output voltage for PV-SOFC both

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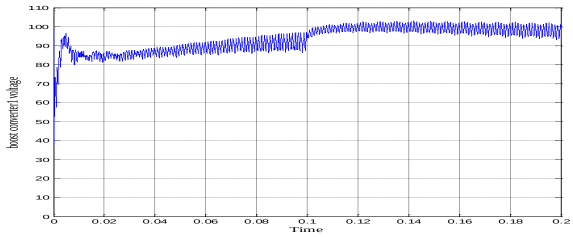

Fig. 11 Boost conveter1 output voltage for PV-SOFC both

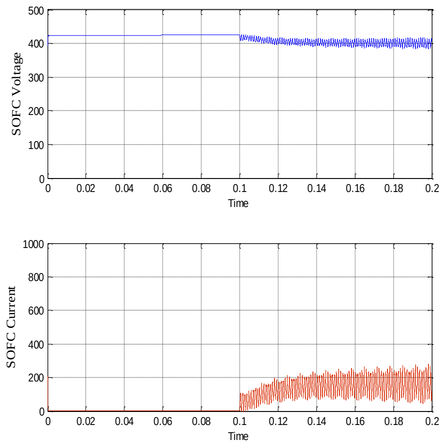

Fig. 12 SOFC current and voltage for PV-SOFC both

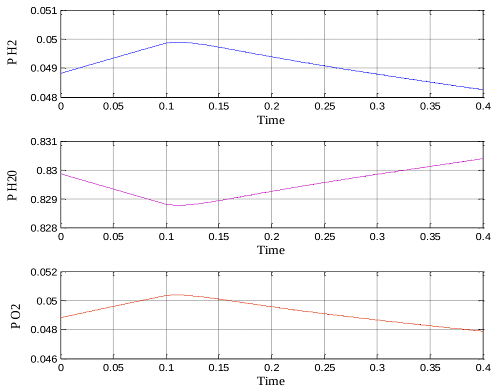

Fig. 13 H2, H2O and O2 pressure curves of SOFC for PV-SOFC both

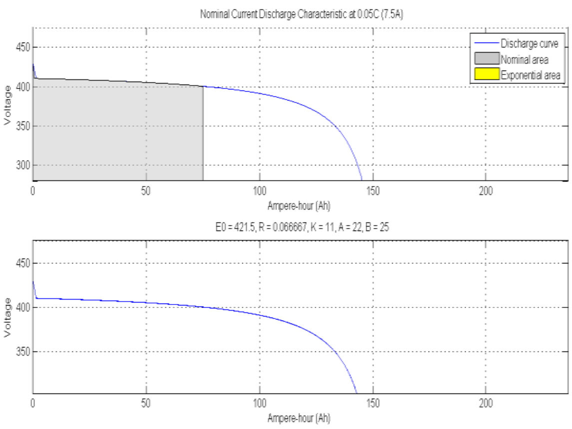

Fig. 14 Battery discharge characteristic for PV-SOFC both

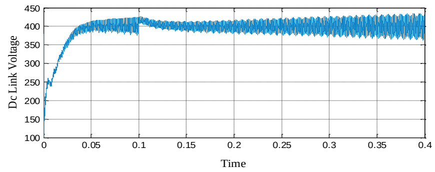

Fig. 15. DC link voltage for PV-SOFC both

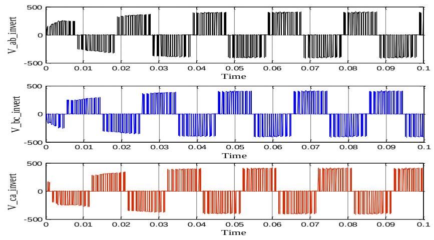

Fig. 16 3-Phase inverter output voltage waveforms for PV-SOFC both

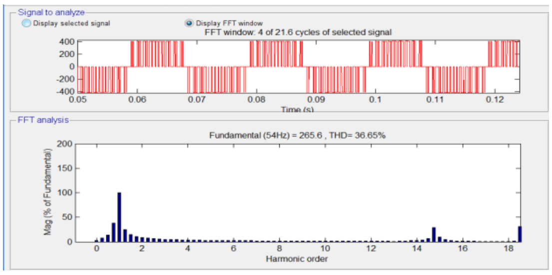

Fig. 17. FFT analysis of inverter output voltage (Vab invert) for PV-SOFC both

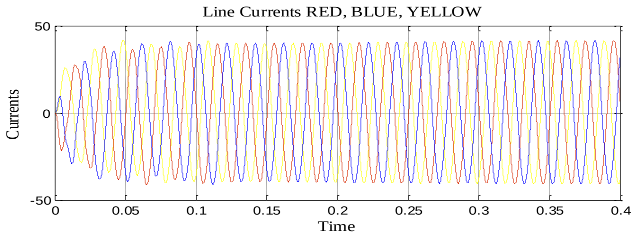

Fig. 18. Line currents for PV-SOFC both

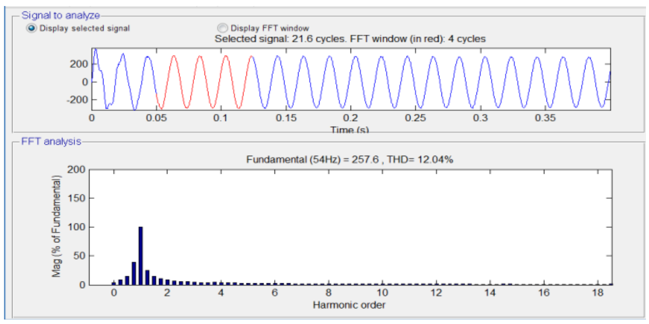

Fig. 19. FFT analysis of line voltage (V_ABL) for PV-SOFC both

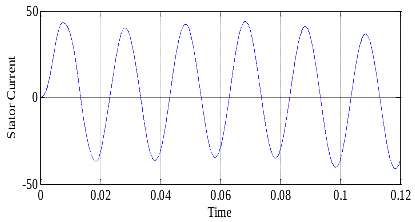

Fig. 20. Stator current of induction motor for PV-SOFC both

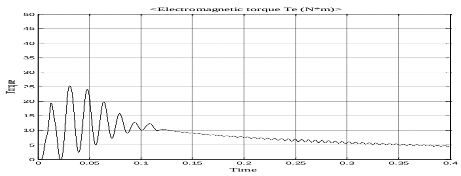

Fig. 21. Electromagnetic torque characteristic of induction motor for PV-SOFC both

CONCLUSION

In this paper a PVA model is designed in a MATLAB/ SIMULINK GUI environment for maximum power point search and a dynamic Perturb & Observe algorithm is used to detect the maximum power point output of the module. The results showing this are presented in this paper. Delta connected Transformer provides the path to third harmonics and thus they do not flow through induction motor. The improvement is observed with the MPPT system as compared to that without the MPPT system.

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BIOGRAPHIES

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