Performance analysis of PI controller based grid connected renewable energy system

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Abstract - *At the present time, electricity is most required facility for the human being. The role of renewable energy sources is becoming very necessary due to the limited reserves of fossil fuels and global environmental concerns for the production of electrical power generation and utilization. In this paper, on and off grid connected integrated renewable energy system (IRES) is designed in MATLAB/Simulink. The integrated renewable energy system is composed of solar PV, wind system and fuel cell. The synchronous d-q reference frame controller is used to control the voltage source inverter (VSI), therefore controlled current added to the grid. The Integrated renewable energy system is modelled and simulated in MATLAB/SIMULINK and the simulation results are presented.*

Key Words: **integrated renewable energy system (IRES), voltage source inverter (VSI), synchronous d-q reference frame controller.**

1. INTRODUCTION

The need of electrical power is increasing continuously used for numerous consumptions because of its efficiency and flexibility. Electricity accessibility is needed for improvement in quality of life of rural, semi-urban population and economic growth. The usage of conventional energy sources are reducing day by day and the cost of power generation is increases. It is well known that the utilization of conventional energy sources like coal, crude oil and natural gas has several drawbacks including limited availability, increasing cost of these fuels, cost of generation of energy in addition to the higher level of pollution caused to the environment. The use of renewable energy sources (RES) is the best path to promise that human energy demands are satisfied while solving the previously stated problem to renewable energy sources. The role of renewable energy sources (RES) is the best path to promise that human energy demands are satisfied while solving the previously stated problem. The use of renewable energy sources is increases due to the installation cost are less, abundant nature, pollution free and inexhaustible [1]. Locally available non-conventional and renewable power resources can meet localized rural energy needs with minimum transportional cost.

System employing two or more locally available renewable energy resources for instance solar, wind, biomass and small hydro etc.in order to supply electricity in local villages is known as Integrated Renewable Energy System (IRES). The individual renewable energy systems cannot provide continuous power supply as a result of variations in weather conditions like wind speed variations and non-sunny days[2]. Therefore, the combination of two or more renewable power generation technologies to use of their operating characteristics and to obtain efficiencies higher than that can be achieved from a single power source. The integration of distributed energy sources such as solar panels, Wind turbine system and fuel cell are the most suitable renewable energy technologies for the production of effective electrical energy from past few years and have important impact on the power system nowadays. In present years, PV and wind power generation ensure advancing prospects for operating the renewable energy sources for electricity generation because they are having high potential ,zero emission of pollution gases, easy availability and both these sources are used as primary energy sources. This energy is available in abundance, but is intermittent in nature and site specific. To overcome this drawback, back up energy devices (secondary sources) are introduced into the system to supply the shortage of power and to take care of transient load demands [3]. Therefore, using this type of system provide reliable supply to the distributed load. This type of systems are improves system efficiency and reliability Integrated renewable energy system (IRES) delivers the most favorable

solution for rural electrification to the remote areas without of power grid contact [4].

In this paper, an integrated renewable energy system is considered to provide uninterrupted power supply to grid system and has been modeled in MATLAB/Simulink. These IRES having solar PV, variable speed wind turbine and fuel cell are used for power generation. The solar cell is designed using the static equations of a PV cell. Six solar panels are connected in series in this solar system to increase the output voltage of the solar panel. Variable speed wind energy conversion system and proton exchange membrane type fuel cell is used to design in MATLAB/Simulink. These sources are connected three phase voltage source inverter, which converts DC supply to AC supply. The voltage source inverter supply power to the load, at the same time satisfying the grid interconnection standards. The synchronous DQ reference frame control structure is used to control the grid connected inverter and controlled current supply to the grid.

2. Modelling of Integrated renewable energy system (IRES) in MATLAB/Simulink:

2.1 System Description:

Rural electrification is one of the major problems in developing countries like India because delay and connection of conventional grid or main grids through high voltage is impossible in small villages and remote areas due to economical considerations and power quality problems are presented. Therefore to overcome above mentioned problems using integrated renewable energy systems are feasible solution to supply electricity to the rural areas and remote areas[5]. Integrated renewable energy sources are producing continuous supply than single renewable system due to its intermittent nature. In this paper, the proposed IRES includes solar PV panel, variable speed wind energy convertion system, PEM fuel cell, three phase voltage source inverter, synchronous DQ reference frame controller and LC filter and then all the sources are connected to the load as well as grid. Integrated solar PV, variable speed wind energy system and fuel cell is designed. Solar and fuel cell are connected to dc-dc converter to increase the voltage individually as well as rectified wind energy system also connects to the boost converter which regulates the DC bus voltage in 1000V are connected in parallel and then connects to the inverter which converts dc supply into ac supply to the desired load demands[6]. SPWM technique is used to generate pulses to the inverter is connected to the LC filter to reduce the harmonics of the output voltage and current.

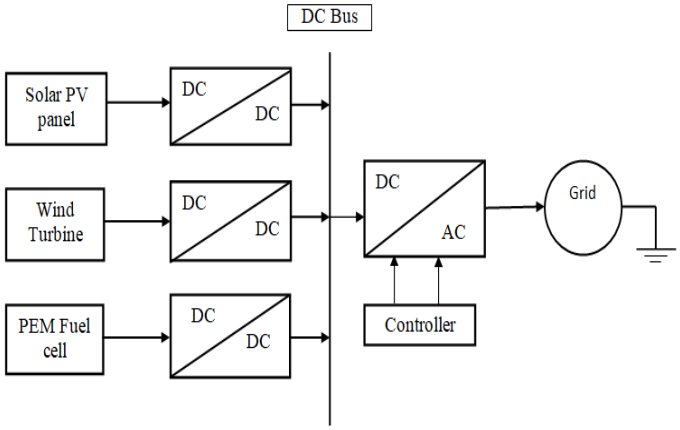

Fig – 1: Block Diagram of Integrated Renewable Energy System

2.1.1 Solar photovoltaic system:

Solar PV panel, which absorb and converts sun light into electrical energy by using photovoltaic effect. Solar photovoltaic system basically semiconductor material which is made up of using silicon material are specially treated to form an electric field which is positive on one side and negative on other. Electric current is developed when solar radiation hits the the region in barrier of a semiconductor P-N junction. The produced current from solar panel is essentially depend on irradiation, temperature, material and age of solar cell. The generated voltage from solar cell is low, hence number of cells are connected in series and parallel to form solar module to increase the current and voltage respectively [7]. In this paper,boost converter is used to increase the output voltage of the system instead of number of sPV panels because the PV panels are very costly. The output load current of the PV is as given in Eq.(1)

$$I_o = N_p * I_{ph} - N_p * I_{rs} * \left(\exp\left[\frac{qv_o}{KTAN_s} \right] - 1 \right) \quad (1)$$

2.1.2 Wind energy conversion system:

The utilization of wind energy for power generation increase nowadays to deliver a sustainable power supply to the consumers due to its advantages like no pollution, cost free and no fuel is required. The wind energy conversion system consists of aerodynamics, mechanical and electrical systems. The main part of aerodynamic system is wind turbine, which converts kinetic energy of wind energy into mechanical energy [8]. Mechanical energy is of high torque and low speed which has to be converted into low torque high speed suitable for generator using gearbox. This gearbox is the interfacing component between aerodynamic system and electrical system. The mechanical energy from gear box connected to generator converts into electrical energy. This electrical energy is variable in nature. Hence to stabilize the output, it is connected to back to back converter. The back to back converter composed of rectifier and inverter connected through DC link capacitor. This DC link capacitor filter out the switching harmonics.

2.1.3 PEM fuel cell:

The fuel cell is one of the most promising sources of renewable energy. These are commonly classified according to temperature and/or the type of electrolyte. Among others, includes proton exchange membrane (PEM) is widely used due to its low-temperature, its simplicity and high power density. A fuel cell is an electrochemical energy conversion system, where chemical energy is converted directly into electrical energy and heat and it uses hydrogen as its fuel to produce protons, electrons. The fuel cell consists of three main parts. They are the anode, cathode and the electrolyte. Hydrogen is injected across the anode side where a catalyst decomposed into positive ions (protons) and negative ions(electrons). These electrons are pass through the external circuit of the cell to produce electricity. At cathode side oxygen is combined with protons and electrons to produce heat and water as byproducts [9].

2.1.4 Synchronous DQ reference frame controller:

The generated power from the renewable energy sources is DC, before connecting this supply to the grid need to convert it into AC supply, therefore using three phase voltage source inverter The output of grid connected inverter can be controlled as a voltage or current source and pulse width modulated (PWM) voltage source inverters (VSI) are most widely used. In this paper, current controlled voltage source is used to supply continuous power to the grid. A constant 1000V dc voltage is supplied by the integrated renewable energy system. Synchronous DQ reference frame controller is used to control the three phase voltage source inverter connected to grid. The main purpose of control strategy of 3-phase grid connected inverter is to control the active and reactive power flow independently [10]. The grid voltage and currents are transformed from their three phase component (abc) into a two phase DC component (dq) using park's transformation; thus controlling becomes easier to achieve. Proportional–integral (PI) controllers have an acceptable behavior when dealing with dc variables hence PI compensators are used for the control. The PI controller tuning is done by Ziegler-Nichols method [12]. Phase locked loops are used for achieving grid synchronization. Synchronous DQ reference frame controller having two control loops namely voltage control loop and inner current loop. Outer loop controller is used to to control the DC link voltage and inner current loop Control variable The active and reactive powers are regulated by a reference value of d and q current components. In this controller PI controller is used to reduce the error. The application of PI based Synchronous DQ reference frame controller is it regulates the DC quantities and allows minimizing the steady state error. .The phase angle required for abc-dq transformation is obtained using PLL method. Phase Locked Loops is also used for grid synchronization. Then convert two phase quantities into three phases. The pulse generated from the controller is fed to the three phase SPWM inverter. The advantage of this system is that continuous power supply is provided to the load by the active conversion of dc to ac. The controller implementation is simple and effective. The simulation diagram of grid connected renewable energy system as shown in Fig. 2.

3. Simulation Results:

The integrated renewable energy system formed by Solar PV system, Wind System and PEM fuel cell stack has its simulation diagram as shown in Fig. 2

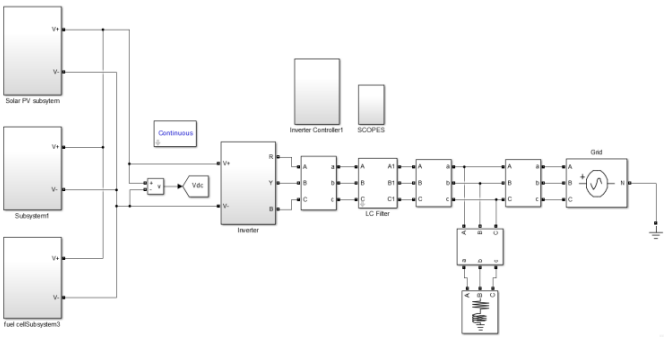

Fig – 2: Simulink model of grid connected solar PV, wind and fuel cell in MATLAB

In Fig. 2, 1.5 KW solar PV, 1.5 KW PMSG based wind energy conversion system and 1.5 KW PEM based fuel cell are modelled in MATLAB/Simulink. The individual boost converters are used to increase the output voltage as well as to control the power flow to the load and grid. All these three sources are connected in parallel to common DC link bus. The integrated renewable energy system DC-link voltage is 1000V. The voltage from DC-link is fed to the inverter to convert DC supply to AC supply. The inverter output is given to the load as well as grid. The total output power of the IRE system is 4500W.

The Voltage and current outputs of the system is shown in Fig. 3 and Fig. 4. The voltage and current from the inverter is 600V and 22A. The voltage and current to the load is 600V and 12A and grid voltage and current is 600V and 10A as shown in Fig. 3 and Fig. 4.

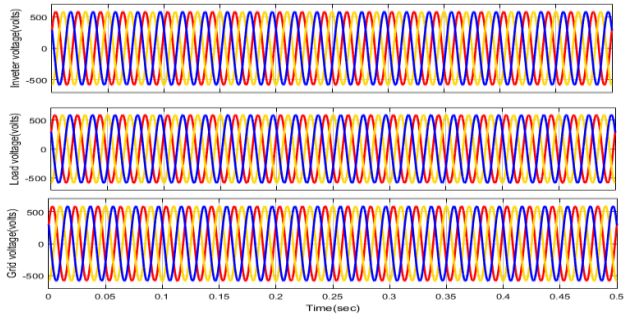

Fig – 3: inverter, load and grid voltages of integrated solar PV, wind and fuel cell

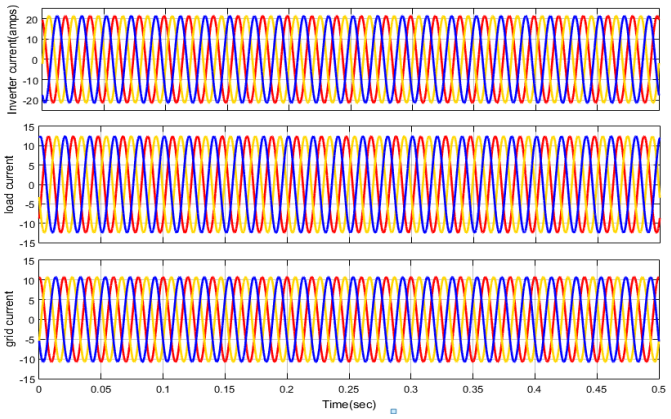

Fig – 4: inverter, load and grid currents of integrated solar PV, wind and fuel cell

The generated power from inverter is consumed by load is 2790W of power and 1710W of power is supplied to the grid system using PI based synchronous DQ reference frame controller to control the three phase voltage source inverter as shown in Fig. 5.

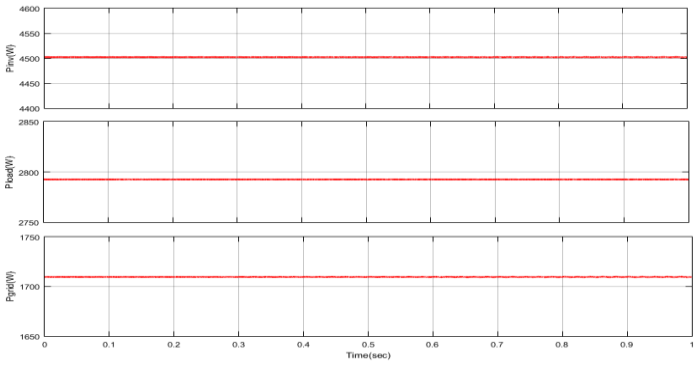

Fig – 5: inverter, load and grid powers of integrated solar PV, wind and fuel cell

The phase angle and frequency of proposed system as shown in Fig. 6.

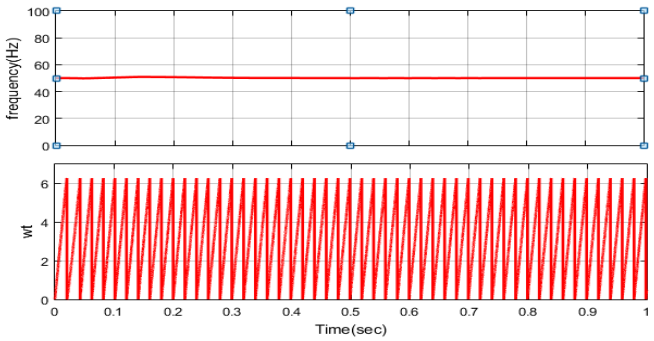

Fig – 6: Phase angle and frequency of the integrated renewable energy system

3. CONCLUSION

In this paper, grid connected integrated renewable energy system has been modelled in MATLAB/Simulink. The PI based synchronous DQ reference frame controller is also designed in MATLAB/Simulink is presented to control the grid connected three phase voltage source inverter. PLL is used to lock grid frequency and phase. The phase detection part of PLL is properly done by using dq transformation in the three phase system. The proposed system improves the system power quality and gives the continuous power supply to the load demands. Integrated renewable energy systems have been recognized as a feasible opportunity for energy supply rural areas and it is also cost effective to the remote areas.

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