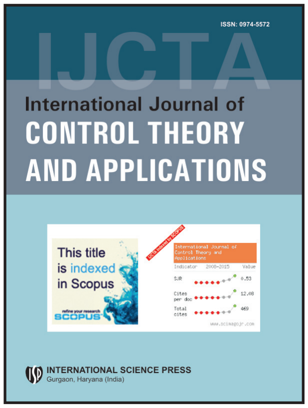

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Design and Simulation of Stand Alone Closed Loop IRES for Remote Areas

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Abstract: Un-electrified remote areas and rural households are still present in India where the electrification using conventional grid is not possible and uneconomical. These areas can be electrified using integrated renewable energy resources. In this paper, design and simulation of a stand-alone closed loop integrated renewable energy system consisting of solar and wind energy sources integrated through a DC bus has been presented using MATLAB and the results are analysed.

Keywords: Solar system, wind system, Inverter, closed loop operation, IRES.

1. INTRODUCTION

The conventional systems of power generation using fossil fuels are widely used across the globe. By reasons of global environmental and economic concerns, the consumption of conventional fuels for electric power generation has to be reduced. To meet the energy demand and to provide access to electricity to remote areas, renewable energy sources like wind, solar, biogas, biomass, hydro, geothermal etc., can used[1,2]. But the disadvantages of these renewable energy sources are unavailability and uncertainty of the resources because of the seasonal effects. A single renewable energy source supplying load will never ensure uninterrupted power supply[3]. To provide uninterrupted power supply to the consumers, integration of renewable energy sources (IRES) is a viable option for remote area electrification. Hence the electrification of remote areas can be achieved using IRES, which is more preferred due to its economic viability. A system consisting of solar energy and wind energy integrated to DC bus supplying a load of 5000 watts is presented in this paper.

Sun light is the major source of photons, which is known to mankind. In photovoltaic system, this photo energy is converted into useful form of electric energy[4]. The other renewable energy source used for integrated system in this study is wind energy. The conversion of kinetic energy present in wind into rotation for low torque shaft which is connected to high torque shaft through a gear box to produce electrical energy is known as wind energy conversion system[5]. Solar and wind sources are accessible in several places. Integration of renewable energy system with these two sources for power generation is beneficial. In this paper, the design of integrated renewable energy system consisting of solar and wind systems is discussed.

2. MODELLING OF IRES

The solar and wind energies are converted into electrical energy. The obtained voltage from the solar and the wind are boosted to acquire the desired DC voltage levels 715V. The integrated system is designed to supply 5000 watts with voltage value of 600V and current value of 8.5A.

2.1. Solar System

The solar system is modelled for two stage conversion. In the first stage, the solar energy is converted into the electrical energy and the second stage is to boost the voltage obtained by PV array as per load requirement. Solar cell is basically a *p*-*n* junction fabricated in a thin layer of semiconductor. Sun light consists of photons which have energy required to excite an electron into conduction band of the semiconductor are absorbed and creates some electron-hole pairs. A photo current is created which is directly proportional to solar insolation[6]. The conversion process of solar energy into electrical energy is implemented in MATLAB/SIMULINK by using the V-I characteristic equations of PV cell[7]. The characteristic equations of PV cell are given by are

$$I_{ph} = (I_{Scr} + K_i \times (T - T_r)) \times (S/1000) \quad (1)$$

$$I_{rs} = I_{rr}((T/T_r)^3)e^{(q \times Eq/(k \times A) \times ((1/T_r) - (1/T))} \quad (2)$$

$$I_o = N_p \times I_{ph} - N_p \times I_{rs}(e^{(q/(k \times T \times A) \times V_0/N_s} - 1) \quad (3)$$

$$I = I_{ph} - I_d \quad (4)$$

At temperature (T) of 35°C and variable irradiance the output voltage and current obtained from this PV array is 200V and 8.251A and the power output is 1650W. The output obtained from the first stage has to be transformed into the required form. This task is done in the second stage. In this stage, the voltage value is boosted and controlled according to the desired value by using closed loop controlled operation of a boost converter. In order to reduce voltage ripple a capacitor is added at load side. Closed loop operation of boost converter is obtained using suitable control strategy. The controller operation is as shown in Figure 1. The designed closed loop solar system with boost converter is as shown in Figure 2. The output of the boost converter is 15V and 2.2A. Thereby the power obtained is 1500W.

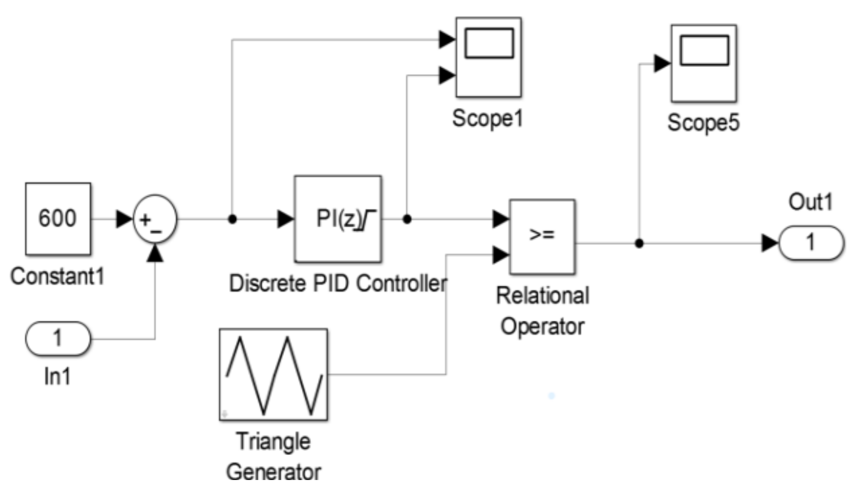

Figure 1: Controller operation

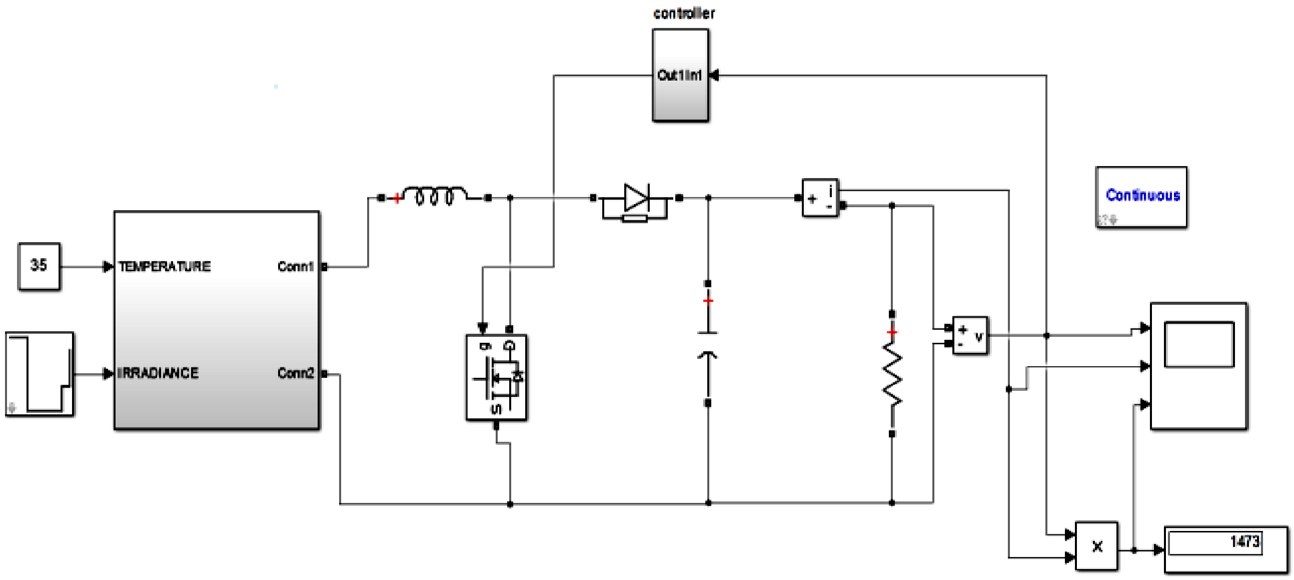

Figure 2: Closed loop solar system with boost converter

2.2. Wind System

This wind system is of two stage system. In the first stage the wind energy is converted into the electrical energy and in the second stage the voltage value is boosted and controlled according to the desired value. The kinetic energy present in the wind is converted into load torque by the turbine blades of wind turbine and its shaft is connected to the generator rotor thus mechanical energy of turbine is converted into electrical power. The power available in the wind is given by the Eq. (5).

$$P_{air} = \frac{1}{2}\rho A v^3 \tag{5}$$

where, ρ is the air density (approximately 1.225 kgm^{-3}), A is the swept area rotor (m^2), V is the wind speed (ms^{-1}). Power transferred to the wind turbine rotor is given by the Eq. (6).

$$C_P = \frac{P_{windturbine}}{P_{air}} \tag{6}$$

where, C_p is the power coefficient,

$$P_{windturbine} = C_p P_{air} = C_P \frac{1}{2}\rho A v^3 \tag{7}$$

The C_p value is defined by Betz limit, C_p is the ratio of mechanical power at shaft to the power available in the wind and given as the function of tip-speed-ratio λ.

$$\lambda = \frac{\omega R}{v} \tag{8}$$

The wind is variable with respect to time so, a variable speed wind in m/s is given as input there by the output voltage is also variable with respect to wind variations[8]. Thus this output obtained from the first stage has to be altered up to the required value. This task is done in the second stage. In the second stage the voltage value is boosted and controlled according to the desired value by using closed loop controlled operation of a boost converter. In order to reduce voltage ripple a capacitor is added at load side. Closed loop operation of boost converter is obtained using suitable control strategy. The controller operation is as shown in Figure 1. The designed closed loop wind system with boost converter is as shown in Figure 3. After boosting, the voltage is increased to 700V with a current of 2.2A with power capability of 1500W.

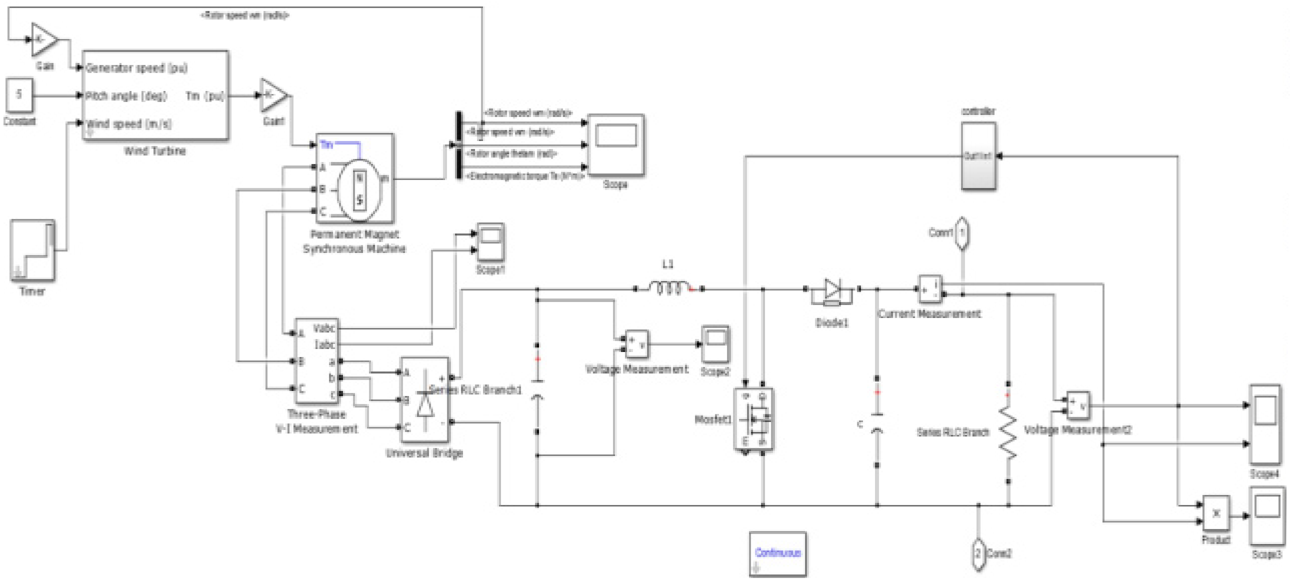

Figure 3: Closed loop wind system with boost converter

3. CLOSED LOOP OPERATION OF INTEGRATED RENEWABLE ENERGY SYSTEM

The designed solar and wind systems are integrated to a DC bus. By using the inverter we convert the DC to AC and then it is supplied to load[9]. If the supply is more than load then the excess power then it is supplied to dump loads. The block diagram representation of this system is as shown in Figure 4.

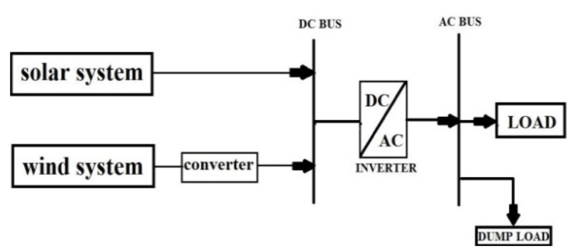

Figure 4: Block diagram of Integrated solar and wind power systems

The open loop operation of Integrated renewable energy system, the solar and wind systems are integrated to a DC bus and then the DC supply is converted into AC using power electronic devices thereby the AC power is supplied to the load[10].

For closed loop operation of renewable energy system the output is controlled using a PI controller and load voltage V_{abcL} is taken as feed back to the system. The inverter used in this system is a SPWM inverter. The three phase load voltage V_{abcL} is compared with a three phase sine V_{abcR1} as reference signal for implementation of sinusoidal PWM technique. This will reduce the harmonic content in the output and as well will control the DC link voltage. The relational operator generates the gating pulses for the IGBTs in inverter using triangle wave and output from PI controller. The controlling operation of closed loop IRES as shown in Figure 5.

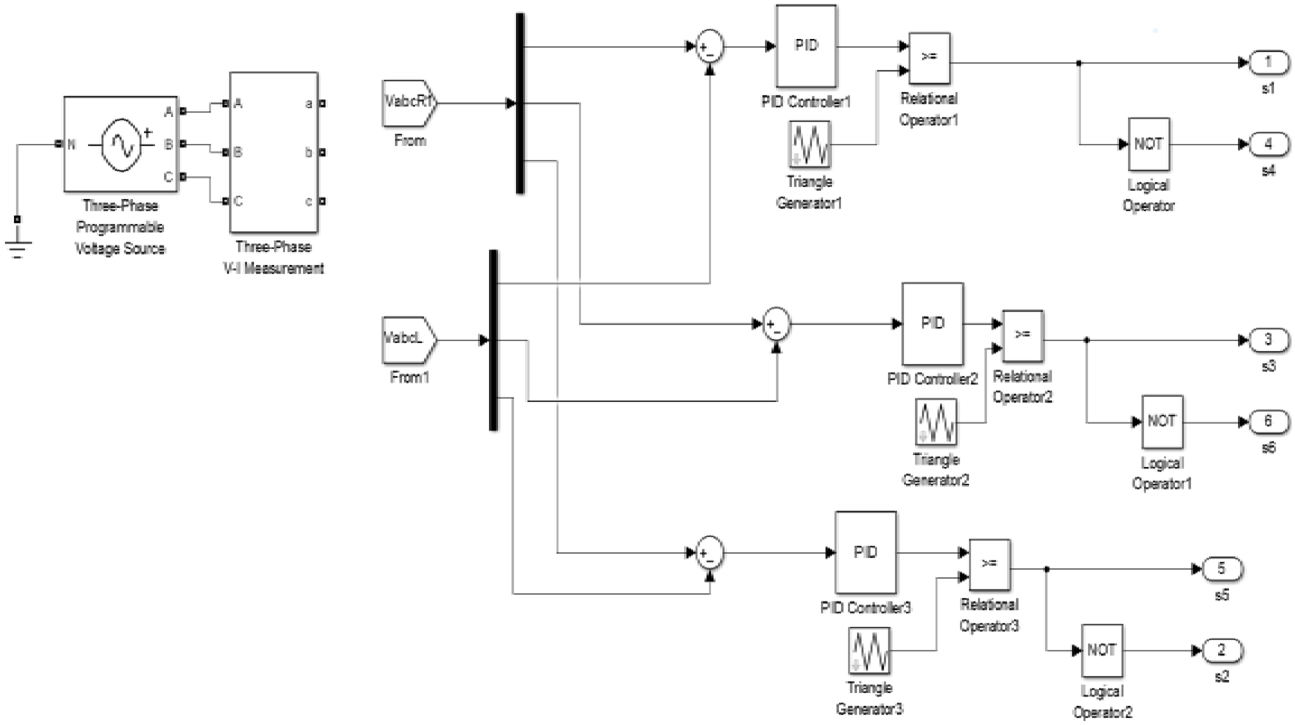

Figure 5: Controlling operation of closed loop IRES

The generated pulses are given as gating switches for IGBTs of the inverter. The stepped two level 3-phase voltage wave form is shown in Figure 6.

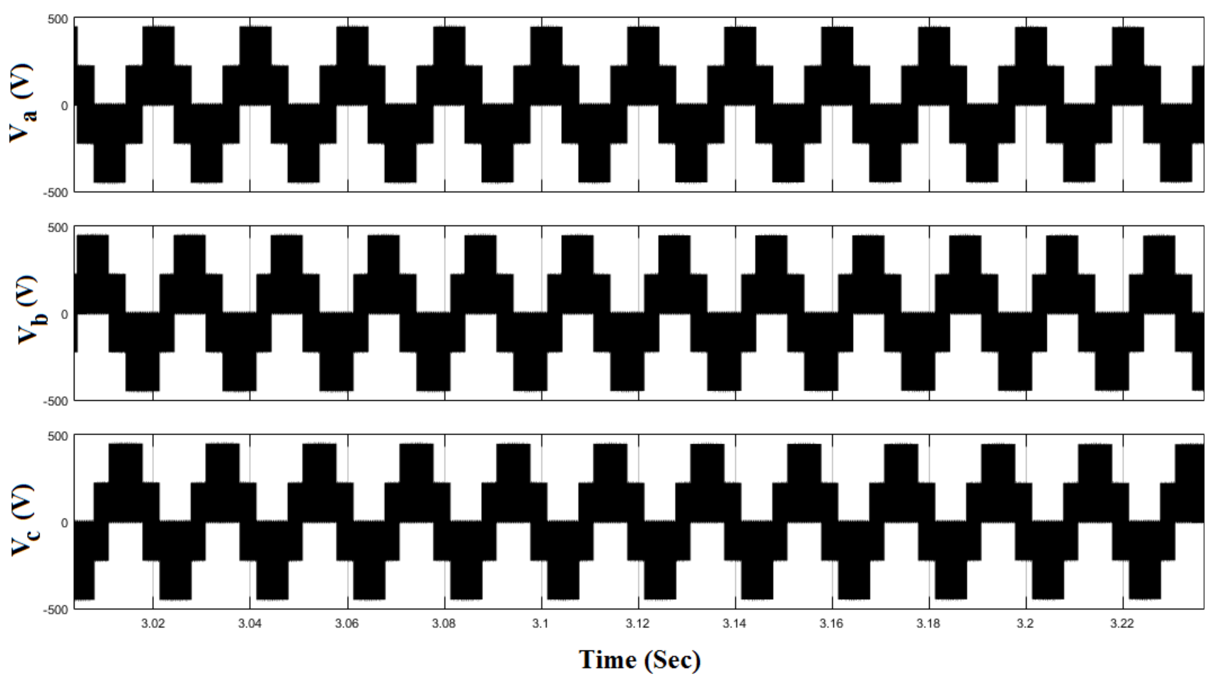

Figure 6: Phase voltages of inverter in closedloop IRES

The closed loop operation of integrated renewable energy system is implemented in MATLAB/SIMULINK as shown in Figure 7.

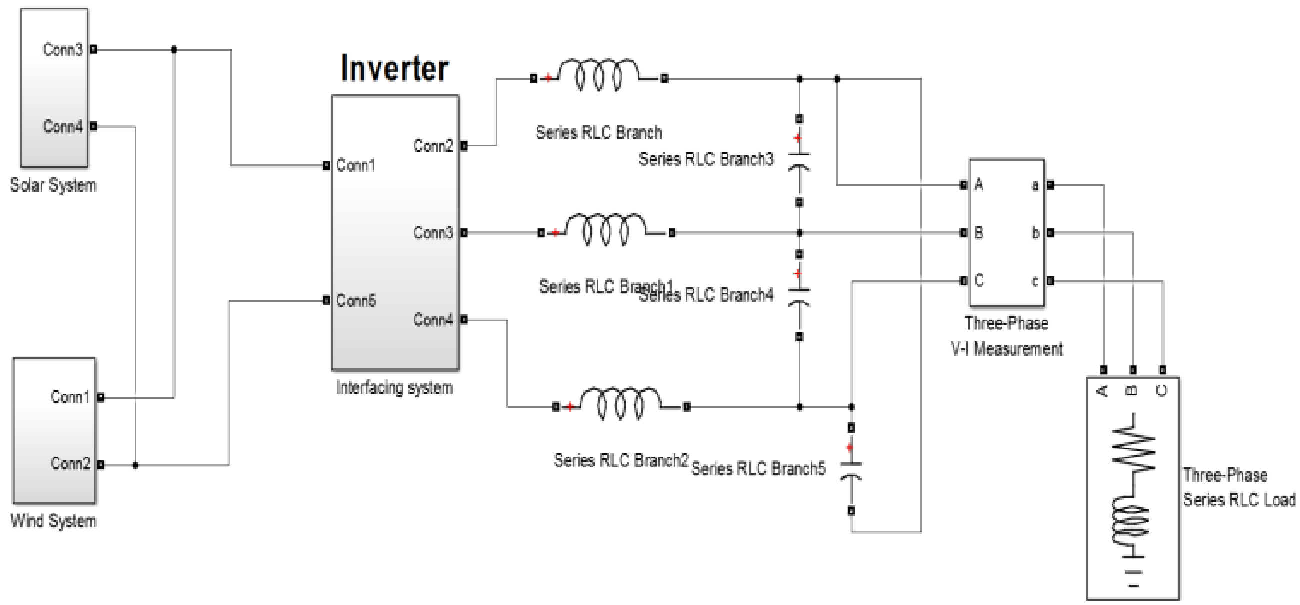

Figure 7: Closed loop IRES with non-linear load

The output power obtained by this closed loop IRES is pure sinusoidal with parametric values voltage (V_{abcL}) of 600V and current (I_{abcL}) of 8.5A generating a power of 5000 watts. The line voltage is 1000V. By observing these output waveforms we can say that the power quality of the IRES has been increased. The output wave forms of voltage and current are as shown in Figure 8, line voltage is as shown in Figure 9, output power is shown in Figure 10. This power is used for supplying stand-alone loads of remote areas. The output side Voltage and Frequency id maintained at 600V peak and 50Hz which as shown in Figure 11 and Figure 12.

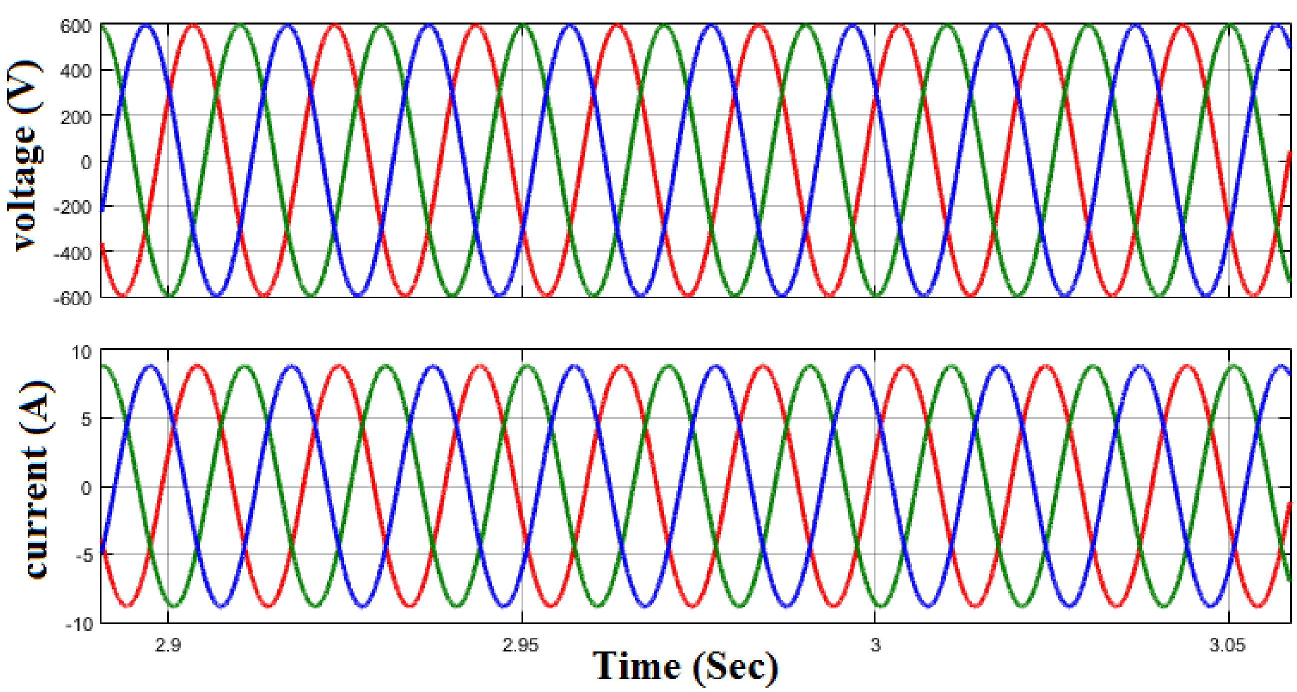

Figure 8: Output voltage and current of IRES in closed loop

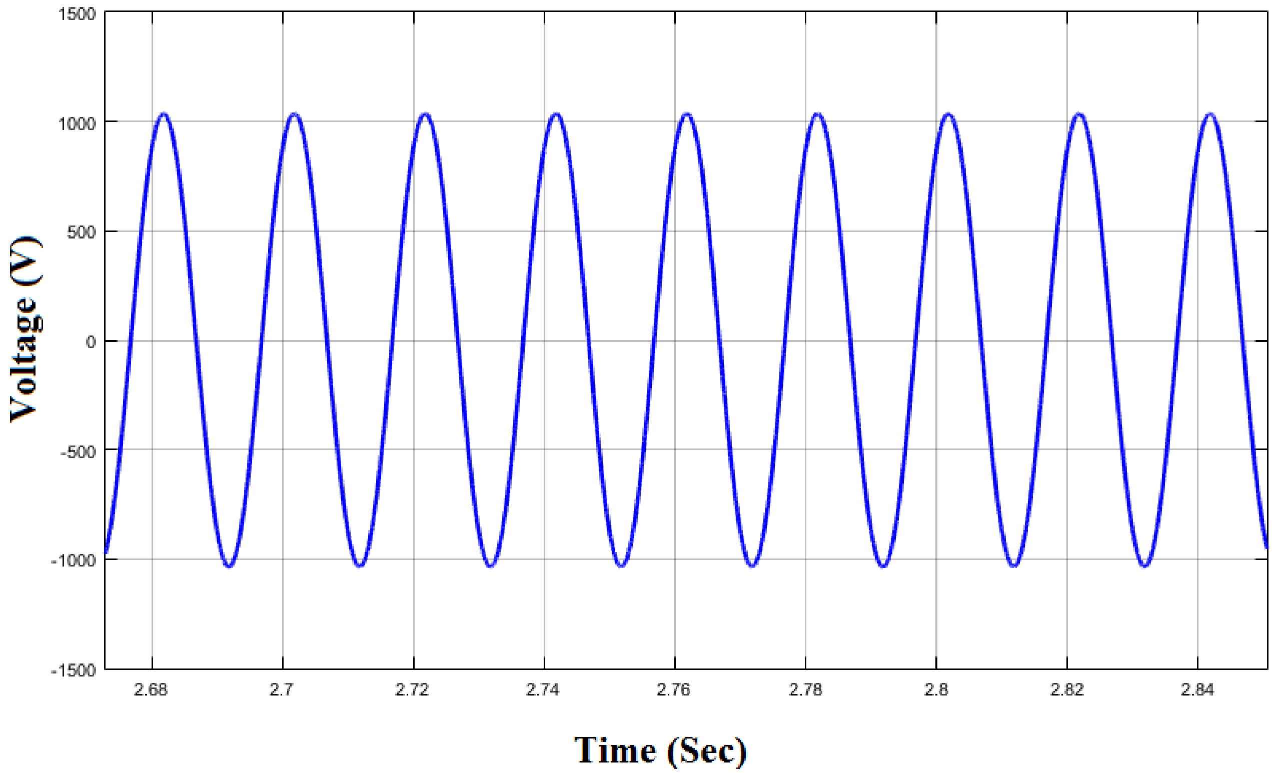

Figure 9: Line voltage of IRES in closed loop operation

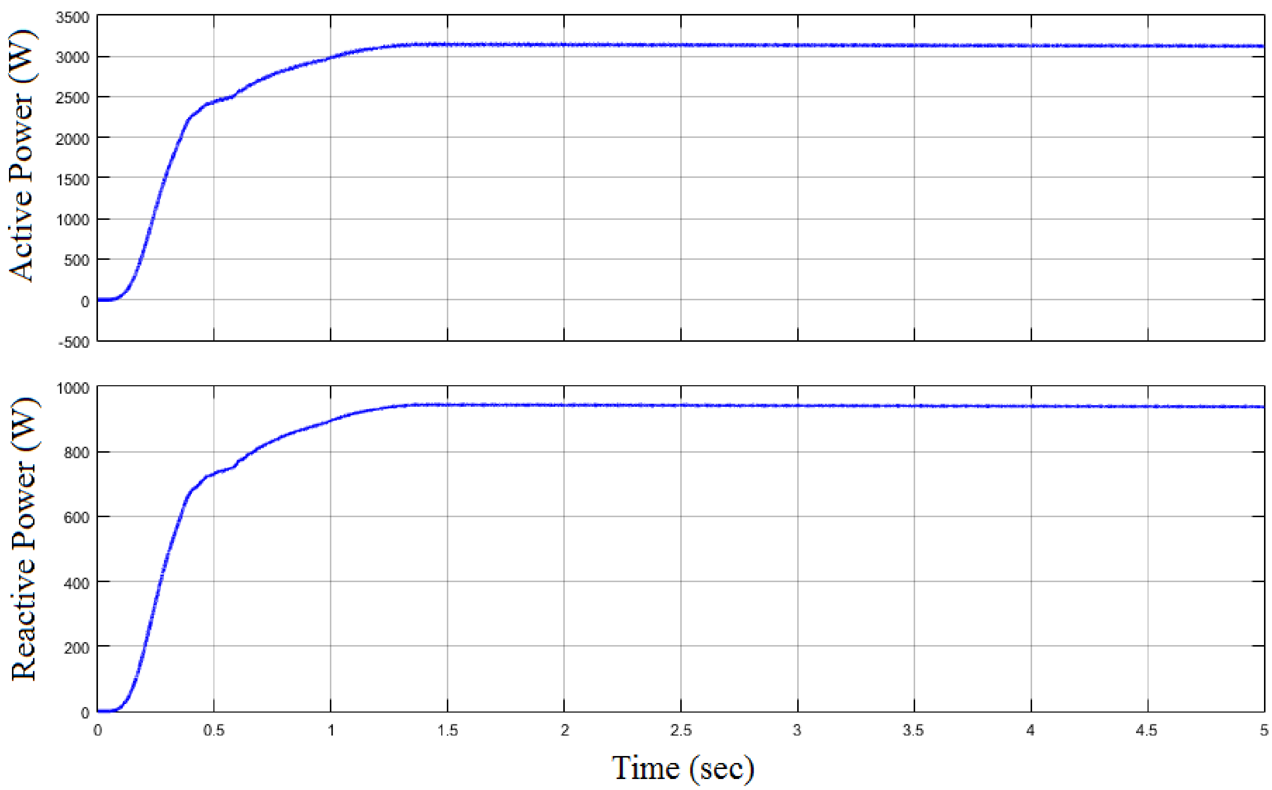

Figure 10: Closed loop Integrated system power output

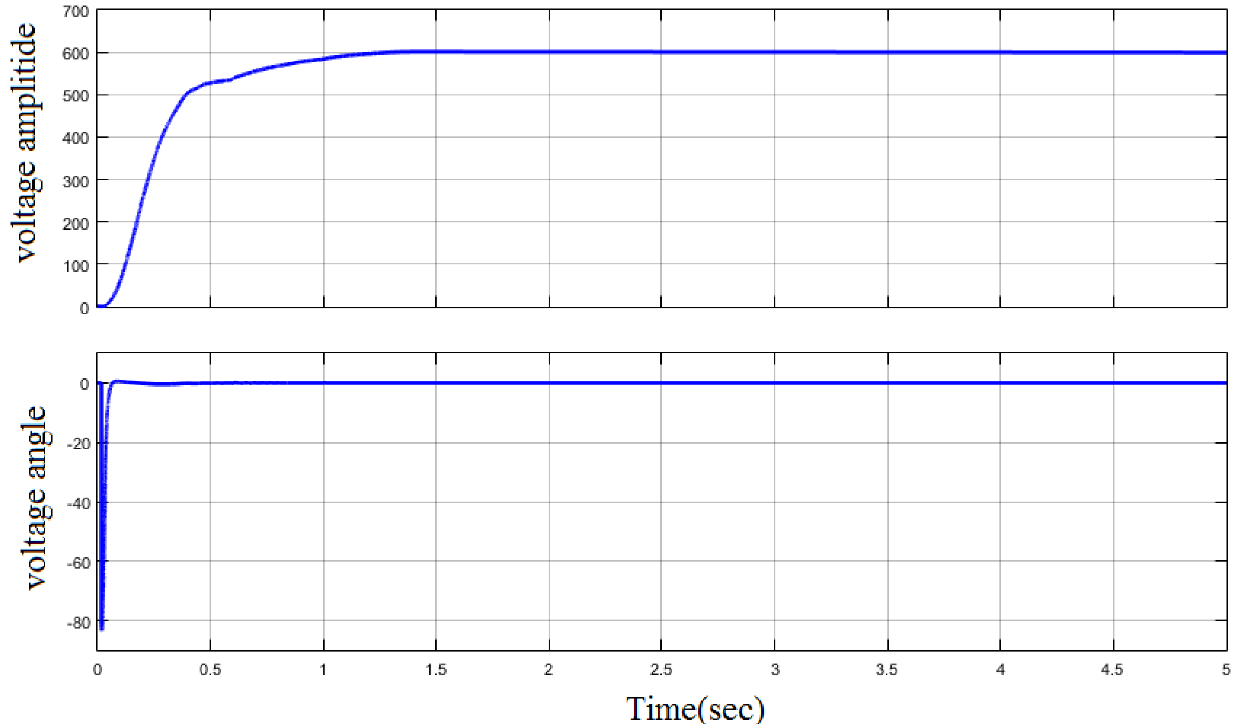

Figure 11: Voltage Magnitude at Load end

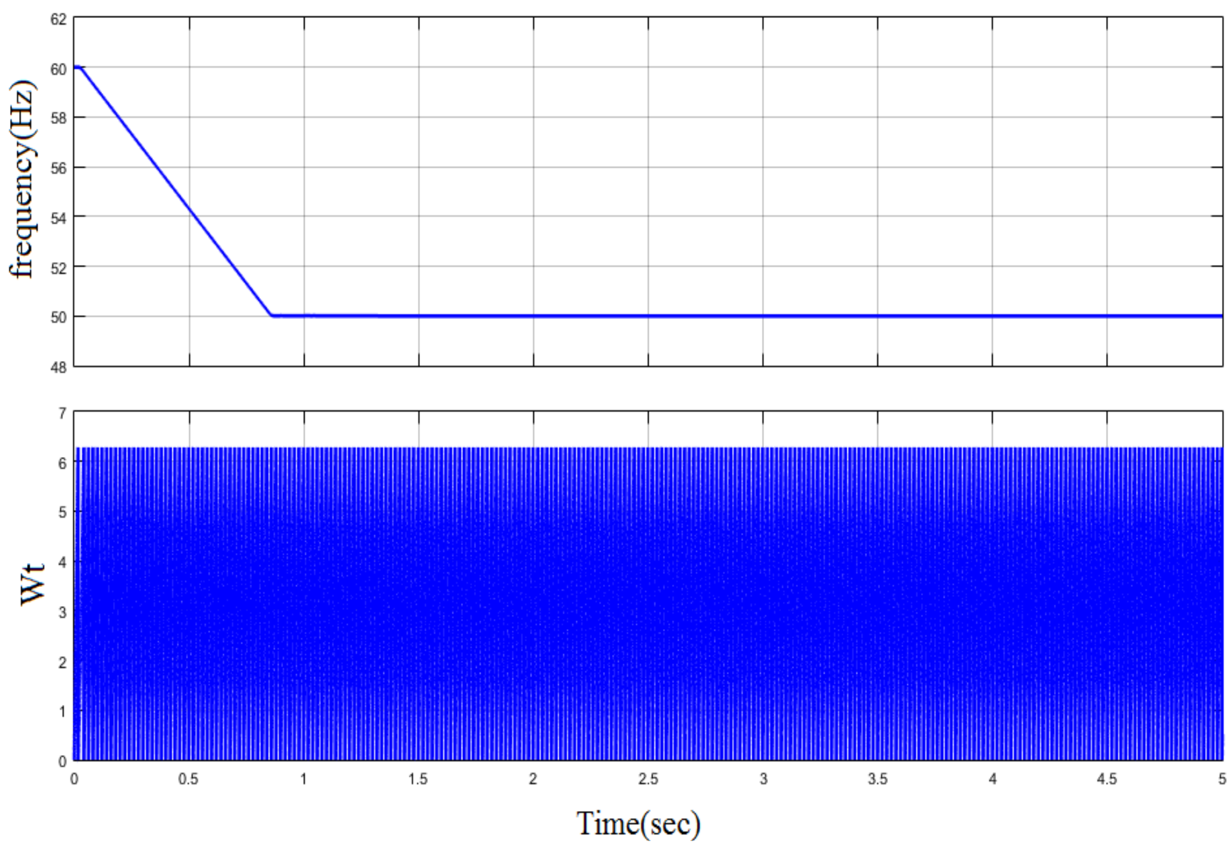

Figure 12: Frequency at the Load end

4. CONCLUSION

Uneconomical extension of the grid has led to the generation of electric power at the user end. Integrated renewable energy systems have been recognized as a feasible option for energy supply in stand-alone applications and it is also cost effective. With developed technologies the use of renewable energy sources such as micro-hydro, wind, solar, biomass and biogas is being explored. IRES electrify the remote areas using renewable energy sources available in that area. In this paper solar and wind energies are considered and integrated.

This paper provides design of solar and wind system and integrated solar and wind system for an isolated load of 4500watts. The two stage solar and wind system of a common DC voltage of 715V is achieved at the end of second stage, i.e. the Boost converter end. The voltage is maintained constant irrespective of the variable output from both the sources using a suitable control strategy of Voltage control technique. These two individual systems with common DC voltage of 715V is integrated to a common DC bus. This DC power is coupled to the AC loads of with the help interfacing system of Inverter. To supply less harmonic content to the load, uninterruptedly, Sinusoidal Pulse Width Modulation Technique with DC link voltage control is employed. Hence 625Vp (440V rms value) with a system frequency of 50Hz is obtained from the inverter end with minimal harmonic content in the output voltage and current in regards with IEEE regulations. By using IRES for isolated loads the social and economic status of people will be improved.

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