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Hybrid Energy Powered Water Pumping System

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Abstract: - Renewable energy resources (solar-wind energies), can be used for water pumping application in rural areas where the availability of grid is not desired. The output of renewable energies will be hybridized after stepping up to the desired voltage using DC-DC (Boost converter). A battery is used to maintain the DC voltage, when there is no minimum irradiation to PV, and wind speeds to wind energy system. Speed control is maintained by v/f method. Input to the three phase induction motor is fed from VSI with the application of SPWM technique. The system is simulated in MATLAB-Simulink environment and results for different irradiation and wind speeds with and without battery are presented.

Keywords: - MPPT control, PV array (Photo voltaic array), SPWM technique, MPPT control, V/F control of induction motor, wind energy system

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I. INTRODUCTION

The depreciation of energy resources is one of the main area of concerns for generation and distribution of power supply in the field of agriculture and domestic applications in rural and remote areas where the demand for water content is not always satisfied. Due to the non-availability of grid and transmission systems. Diesel generator engines were the conventional systems for water pumping applications. However in the last decade the trend of conventional method of water pumping is replaced by alternative source i.e. renewable energy powered water pumps (PV pumps, wind energy powered water pumps). The preference of renewable energy as source over fuel powered pumps is due to some disadvantages namely rise of fuel price , pollution due to emission levels of greenhouse gases. Solar and wind energies are intermittent in nature, to improve the output to be efficient both the energy sources are hybridized and a battery system can be used for backup purpose. In Bush land Texas, off grid wind turbine and PV array for water pumping systems were analysed individually and combined as hybrid system. To verify the merits and demerits of hybrid system over using wind or PV system alone [1]. PV water pumping system using PMDC motor is discussed in [2] , which does not need any speed control mechanism due to technological advancement of Power electronics . Since induction motors are rugged in nature and works efficiently the IM was preferred in most pumping applications [3] [4]. Various Maximum power point tracking algorithm (MPPT) are discussed in [5]. Stability improvement of V/F controlled large capacity VSI fed induction motor is discussed in [6]. Performance improvement of V/F induction motor control in low frequency range is discussed in [7] .Digital signal processing based v/f controlled induction motor drive is discussed in [8].

II. PROPOSED HYBRID ENERGY POWERED WATER PUMPING SYSTEM BLOCK DIAGRAM

Fig 1.shows the configuration of proposed hybrid (solar-wind) energy powered water pumping system. From left to right, the proposed system consists of PV system, boost converter, and MPPT control system for generating corresponding duty cycle to boost converter.

A wind energy system consists of wind turbine coupled to permanent magnet synchronous generator, the output of WES is rectified and MPPT is used for generating duty cycle for boost converter, boost converter is used step to the required DC voltage. Battery system is used to provide backup. Due to the intermittent nature of renewable energy sources. DC voltage from battery is fed to three phase voltage source inverter with gating pulse from SPWM technique. Output of VSI is fed to three phase induction motor.

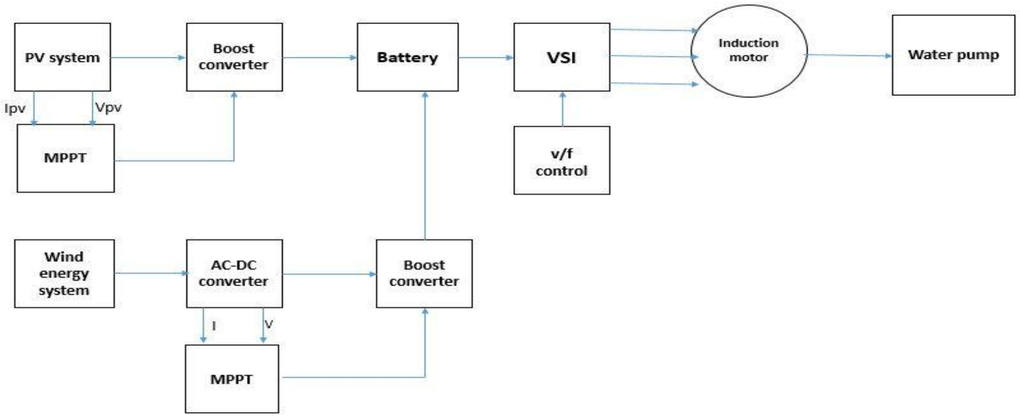


Fig 1: Schematic diagram of Hybrid energy powered water pumping system

Photovoltaic system

The PV system is designed to generate power of 4.028kW of rated power at standard temperature of 25 degree Celsius and irradiation of 1000W/m^2. On a cloudy day the irradiation can reach a minimum value, without producing an output voltage which is not suitable to drive the motor. During such situations, Battery with stored energy can be utilized to drive the motor. To track the maximum power point available with respect to a particular irradiation and temperature, incremental conductance algorithm technique is used .This method of MPPT compares the present instant of power, with the power tracked in the previous instant , the difference between the power instant P(k) – P(k-1) = ΔP [5] . The difference in this power value is used to adjust the duty cycle for DC- DC boost converter.

Id = Isat [exp(Vd / VT)] (1)

Id = Diode current (A)

Isat = Saturation current of diode. (A)

Vd = Diode voltage (V)p

VT = Temperature voltage.

VT = (k.T) / (q.Qd.Ncell.Nser) (2)

T= cell temperature(K)
K= Boltzman constant= 1.3806J.K^-1 q= Electron charge= 1.6022e-19 C Qd= Diode quality factor
Ncell= Number of series connected cells per module Nser= Number of series connected modules per string

Wind turbine system

The PMSG based wind turbine is used, it is a variable speed wind turbine. The variable speed wind turbine gives 10% - 15% more efficient than fixed speed wind turbine. The wind energy system is connected to an uncontrolled rectifier bridge to obtain DC voltage .The DC obtained from rectifier is stepped up DC-DC converter. Table 1 gives the parameters of wind energy system.

The mechanical power Pmech delivered by wind turbine can be expressed as in (3)

$$Pmech = C(\lambda w, \beta w)\, \rho A v^3 / 2 \quad (3)$$

Where Cp is power coefficient of the wind turbine, ρ is the air density (kg/m3), A is turbine swept area (m^2), v is wind speed (m/s), βw is blade pitch angle (degree) and λw is tip speed ratio given by (3).

$$\lambda = \omega R / v \quad (4)$$

SPWM technique

In a three phase sinusoidal pulse width modulation, a triangular voltage waveform ($V_{triangular}$) is compared with three sinusoidal control voltages (V_aVb,Vc) which are 120 degree out of phase with each other and relative level of waveforms are used to control the SPWM. Fig 2 gives the control signal generator for SPWM.

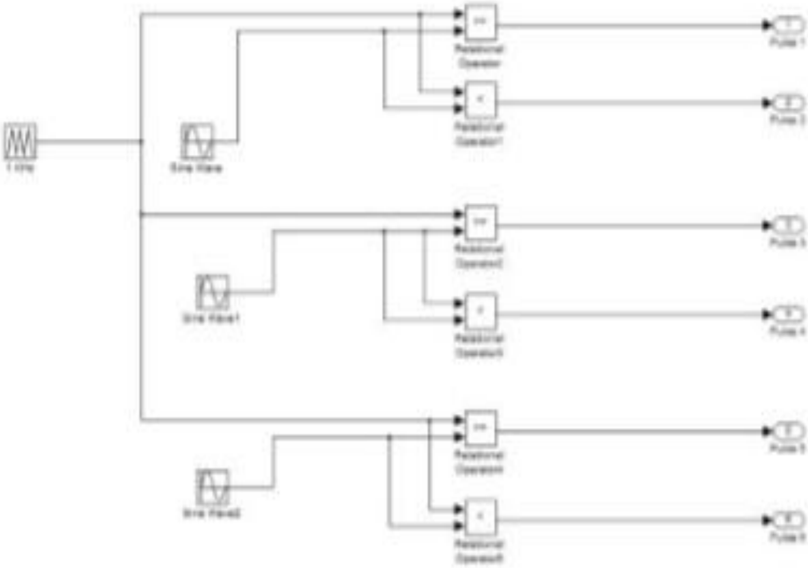


Fig 2 : Control Signal Generation for SPWM

III. V/F SPEED CONTROL OF INDUCTION MOTOR

Synchronous speed of the induction motor can be controlled by varying the frequency of supply. Voltage induced in the stator is 1 proportional to Φ1 re where Φ1 is the flux (air-gap flux) and f is the supply frequency. If we ignore the stator voltage drop then we arrive at terminal voltage 1 proportional to Φ1 re. Therefore decreasing the frequency without any change in supply voltage, will in turn lead to a higher value of air-gap flux which is not expected. Therefore when frequency is changed to control speed, the terminal voltage is changed as well to maintain the ratio of voltage/frequency constant. Hence by maintaining the ratio V/f constant, because of the constant V/f ratio, maximum torque of the motor becomes constant for varying speed. Fig 2a gives the V/f control of induction motor.

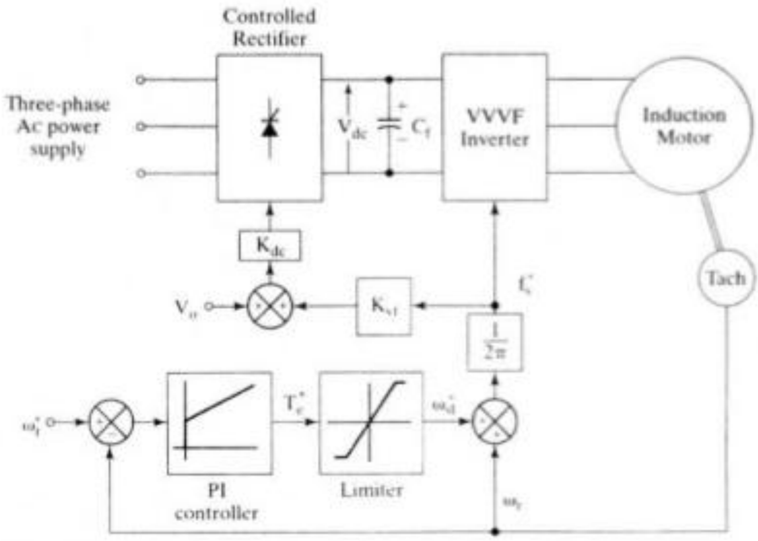


Fig 3. V/f control of induction motor

IV. SIMULATION CIRCUIT

Case 1: PV system boost converter simulation with irradiation of 500 W/m^2 is shown below the output of PV system is connected to the input terminals of boost converter. Fig 3. gives the PV system with boost and MPPT.

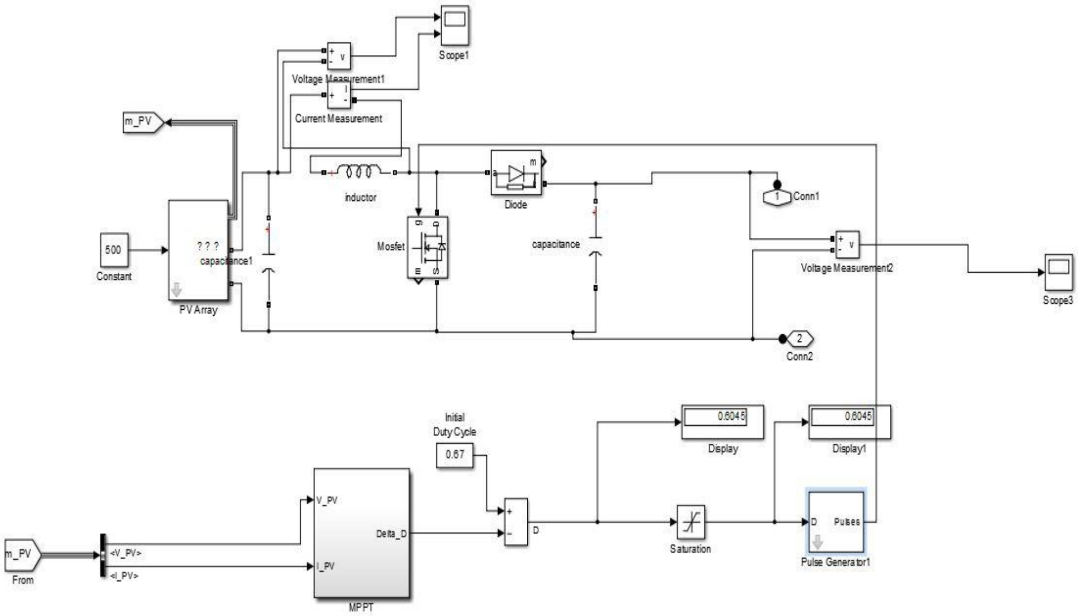


Fig 4. PV system with boost and MPPT

A wind turbine is coupled to PMSG, where the output of wind energy is converted to DC by the application of a diode rectifier. The DC output from the rectifier is stepped up by the boost converter, for wind speed of 7m/s. Fig 4 gives the wind system with MPPT.

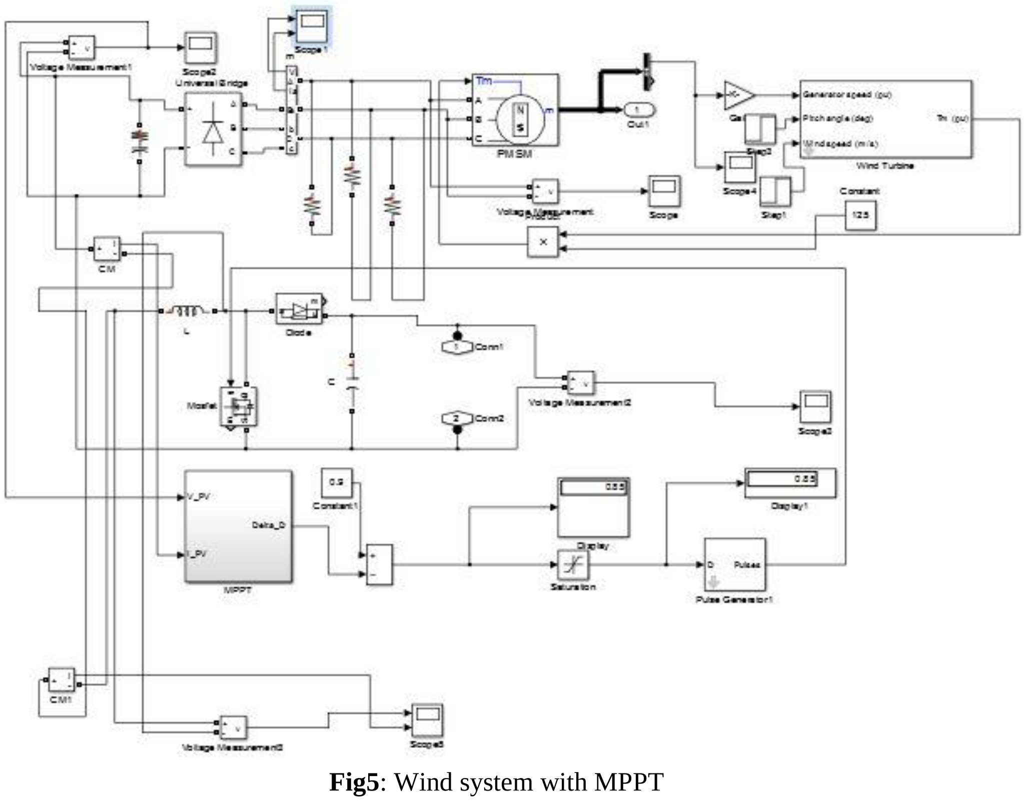


Fig5: Wind system with MPPT

The simulation circuit representation for V/f control is shown in figure 5, the above circuit PV system (subsystem consisting of PV array, boost converter MPPT control), and a wind system (subsystem consisting of PMSG, rectifier to convert AC to DC and a boost converter with MPPT control) with irradiation of $500 w/m^2$ wind speed of 7 m/s power up the battery to maintain a constant DC voltage before being inverter to AC. Three phase induction motor is powered by SPWM driven two level inverter circuits. Fig 5 gives the V/f control of IM with PV and wind system

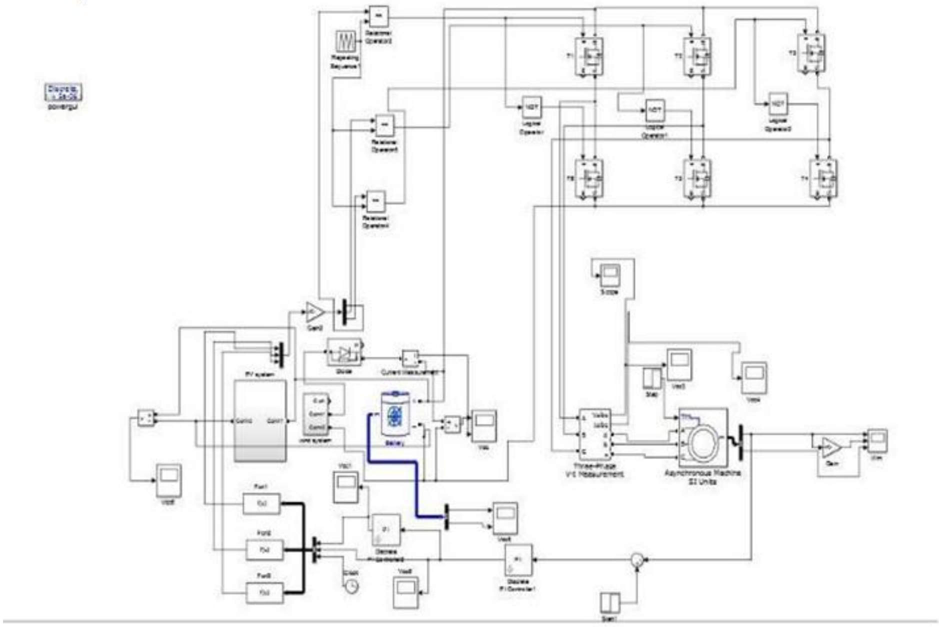


Fig 6 V/f control of IM with PV and Wind as source

Case 2: PV system boost converter simulation with irradiation of $1000 w/m^2$ is shown below the output of PV system is connected to the input terminals of boost converter. Fig 6 gives PV system with boost and MPPT.

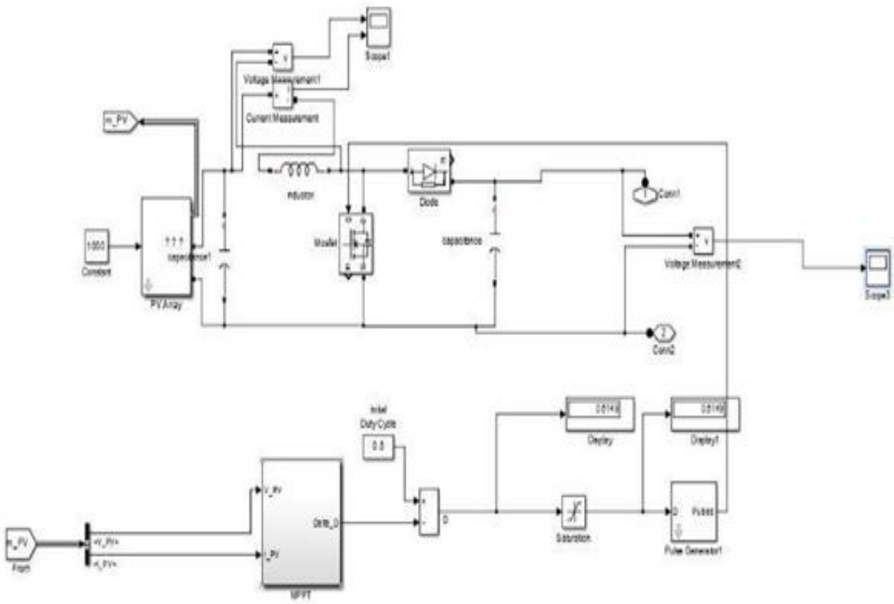


Fig 7 PV system with boost and MPPT

A wind turbine is coupled to PMSG, is shown in fig 7 below , where the output of wind energy is converted to DC by the application of a diode rectifier. The DC output from the rectifier is stepped up by the boost converter, for wind speed of 12m/s. Fig 7 gives wind system with MPPT.

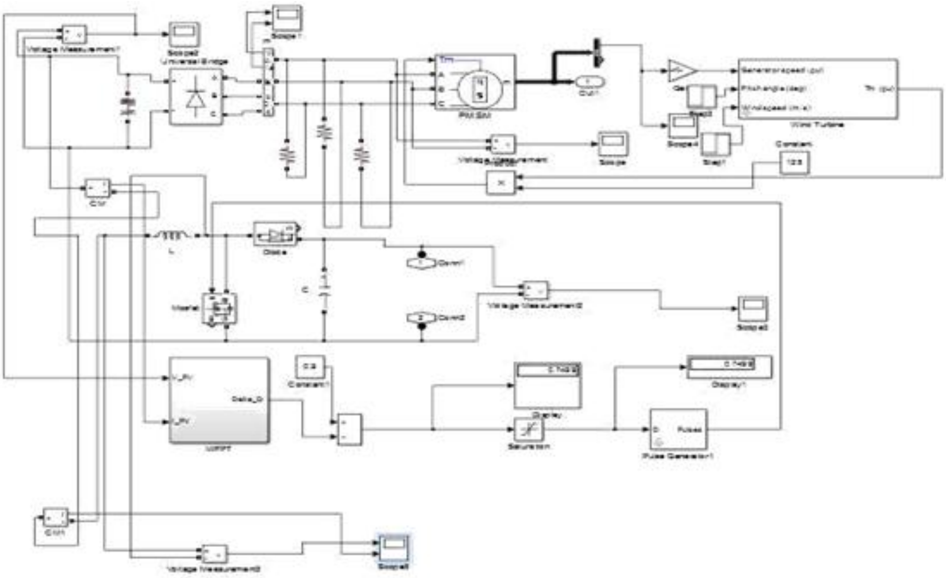
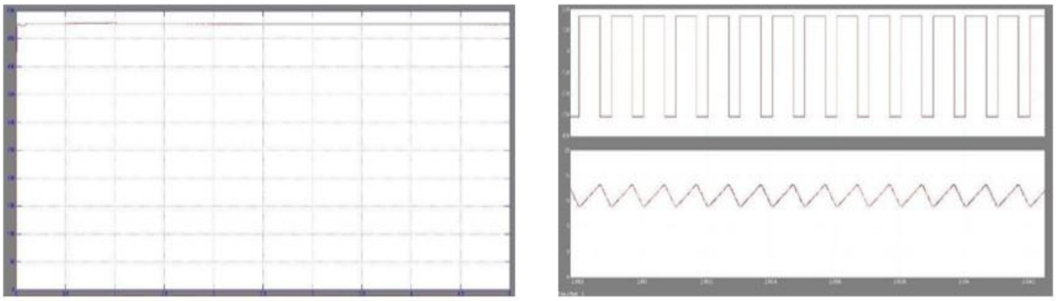


Fig 8 Wind system with MPPT

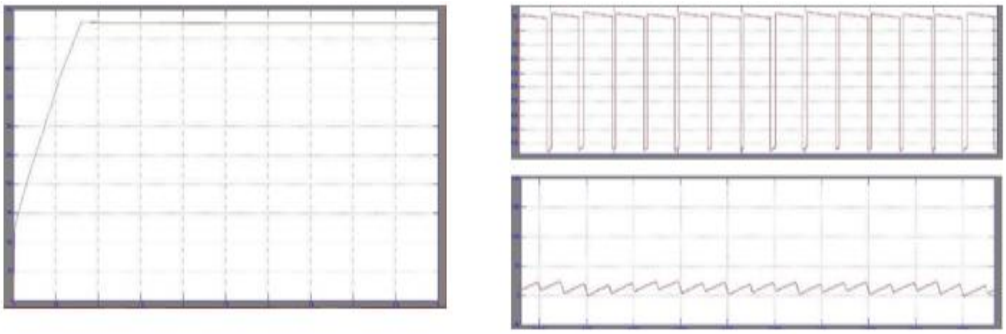
V. SIMULATION RESULTS

Case1: PV irradiation = 500w/m^2 & wind speed = 7w/m^2



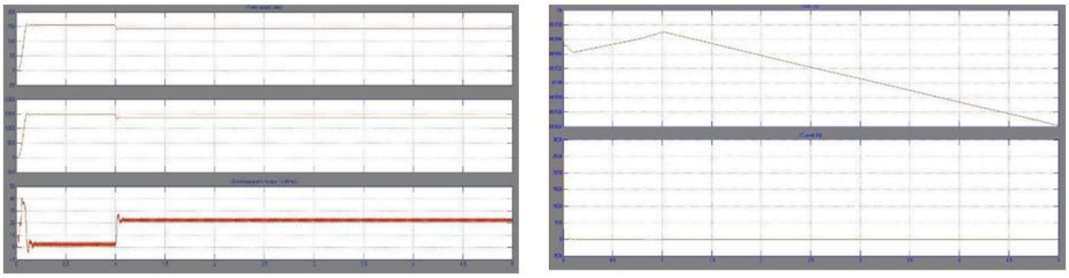
(a) (b)

Fig 9 PV integrated boost output,(b)inductor voltage and



(a) (b)

Fig 10 wind system integrated boost output,(b)inductor voltage and current

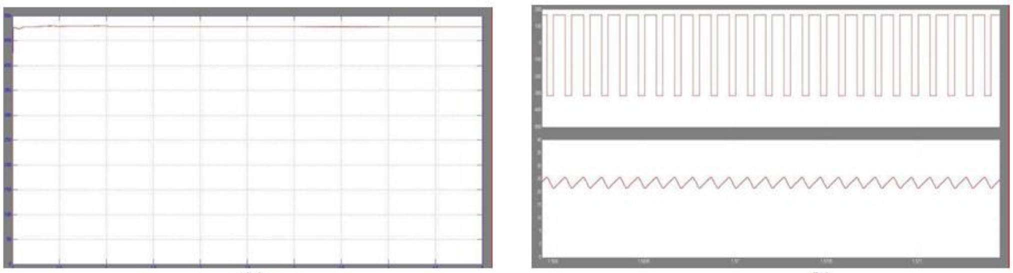


(a) (b)

Fig 11speed of IM in r/s, rpm, torque (N/m),(b)battery SOC,current

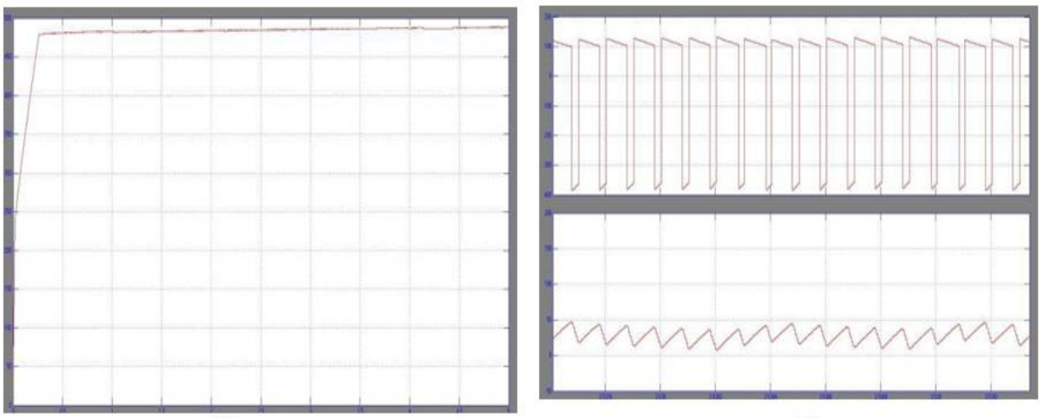
Referring to figure 10 (b) Initially the battery will have 50 % charge, as we can see from figure that the state of charge of the battery reduces as the motor begins to run, and current as well initially when the motor starts to run, it draws high current for a fraction of time period till the motor attains a speed and torque.

Case 2: Case1: PV irradiation = 1000w/m^2 & wind speed = 12w/m^2



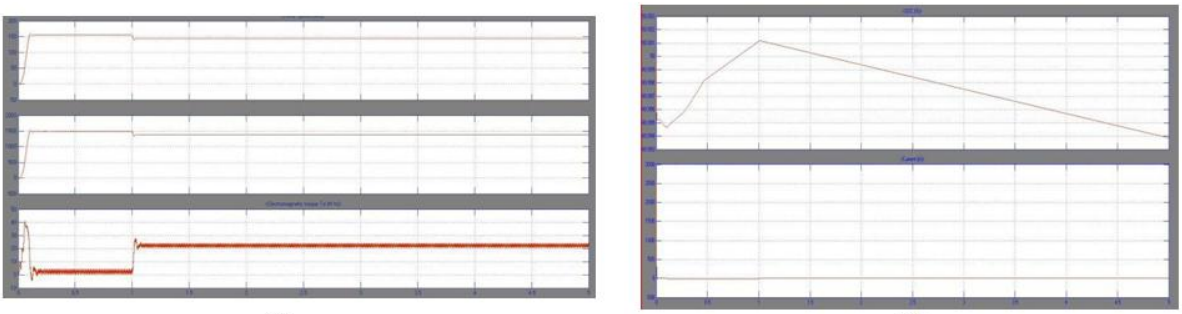
(a) (b)

Fig 12 PV integrated boost output, (b)inductor voltage and current



(a) (b)

Fig 13 wind system integrated boost output,(b)inductor voltage and current



(a) (b)

Fig 14 speed of IM in r/s, rpm, torque (N/m),(b)battery SOC,current

VI. CONCLUSION

In this paper the V/f control technique for inverter has been used in the system to maintain V/f ratio constant. The battery system is used to maintain the DC voltage before being inverted the gating pulse to the inverter is fed by SPWM technique. The selected hybrid energy resources consisting of photovoltaic system, wind system and the battery to maintain the voltage level, is simulated using MATLAB Simulink environment. The simulation result shows that the motor functions at constant speed even after two cases of irradiation and wind speed were simulated and verified.

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