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Design and Implementation of MPPT Technique Applied to Solar Wind Hybrid System

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Abstract: A hybrid power control system is being proposed in this paper contain solar power and wind power generation systems. Today demand for electricity is increasing rapidly whether yield of energy from fossil fuels is dwindling and therefore the choice of the clean energy source is required. The proposed method of MPPT control system is compared with the conventional perturbation and observation (P&O) method.

Keywords: MPPT, Boost Converter, Hybrid System, Renewable Energy.

I. INTRODUCTION

Wind and solar energy has been used since the earliest civilization to grind grain, pump water from deep wells. In past recent decades, the industry has been perfecting the wind turbine to convert the power of the wind into electricity [1]. The wind turbine has many advantages that make it an attractive energy source, especially in parts of the world where the transmission infrastructure is not fully developed. It is modular and can be installed relatively quickly, so it is easy to match electricity supply and demand. The wind and solar energy is free and plentiful, and store expensive fuels [2, 3]. It reduces pollution as generator does not produce any harmful emissions in the process of generating the electricity, unlike many other generation sources. In order to regulate the output power of the photovoltaic system a DC/DC converter is used.

The wind turbine being operated at its maximum aerodynamic efficiency. It has become imperative for the power and energy engineers to look out for the renewable energy sources such as solar, wind energy, geothermal, ocean and biomass as sustainable, cost-effective and environment friendly alternatives for conventional energy resources. However, the non-availability of these renewable energy resources all the time throughout the year has led to research in the area of Hybrid Renewable Energy Systems (HRES). A hybrid wind-solar electric system demands a higher initial investment than single larger systems. Large wind and solar PV systems are proportionally cheaper than two smaller systems. The paper provides a combined setup for Supplying individual and common load both.

II. PROPOSED HYBRID SYSTEM BLOCK DIAGRAM

The solar PV module out pit is converted to dc-dc boost converter to get higher output and given to load. Permanent magnet synchronous generator is used as wind energy source .power from both the system is combined together.

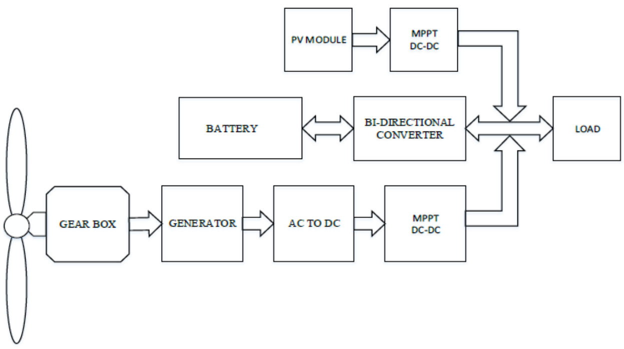

Fig.1 Hybrid System Block Diagram

III. PHOTOVOLTAIC CELL EQUIVALENT MODEL

The equivalent circuit of a PV cell is shown in Fig.1.The Solar cell can be modelled by a current source and a diode in parallel with it.

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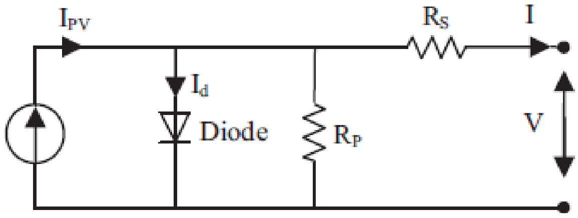

Fig.2 equivalent circuit of solar cell

Here R_s represents series resistance the internal resistance to the current flow, and depends on the PN junction depth and contact resistance. The shunt resistance R_{sh} is inversely related to the leakage current to ground. In an ideal PV cell, R_s = 0Ω (no series loss), and R_{sh} =∞ (no leakage to ground). Value of Rs taken from 0.04 to 0.10 Ω and R_{sh} from 199 to 299Ω.

$$V_{oc}=V+IR_{sh} \quad (1)$$

$$I=I_{ph}-I_D-I_{sh} \quad (2)$$

$$I=I_{ph}-I_0\left[\exp\left(\frac{q(V+R_s I)}{NKT}\right)-1\right]-\frac{V+R_s I}{R_{sh}} \quad (3)$$

Where, I_{ph} is photo current, I_D is diode current,I_0 is saturation current, A is ideality factor, T is cell temperature, I is cell current and V is cell voltage. Electronic charge q is $1.6x10^{-9}$ and k is Boltzmann's constant having value $1.38x10^{-23}$.The power output of a solar cell is given by equation (4).

$$P_{PV} = V_{PV} * I_{PV} \quad (4)$$

IV. MODELLING OF SOLAR PV SYSTEM

When cell working temperature increases, the output current of PV module also increases, while the maximum power output decreases [4]. The total power decreases at high temperatures because the increase in the output current is much less than the decrease in the voltage.

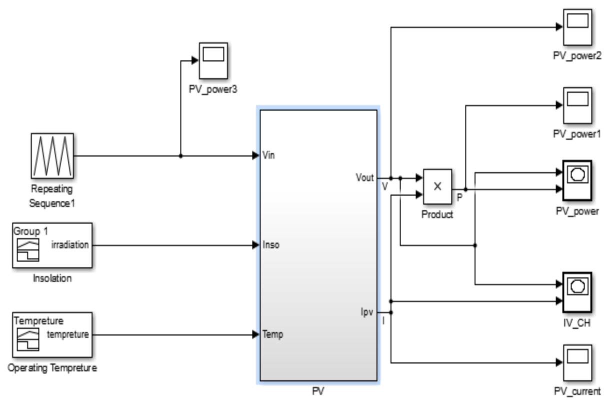

Fig.3 SIMULINK model of PV system

At different irradiation the I V and P V characteristics are shown in fig. 4(a) and 4(b) respectively.

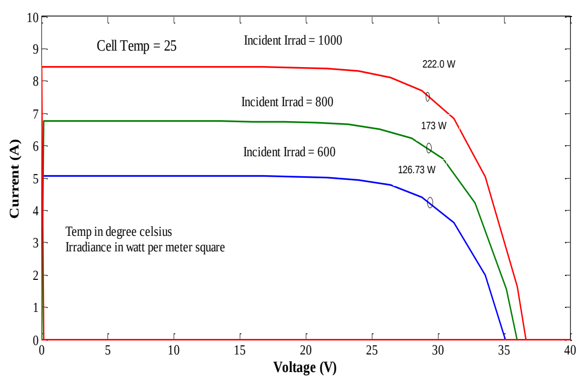

Fig .4(a) I-V characteristics with Varying Irradiation

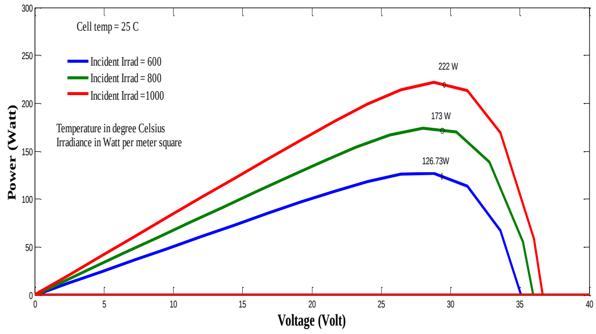

Fig. 4(b) P-V Characteristics with Varying Irradiation

A. DC- DC boost converter

This is a dc to dc voltage converter giving output dc voltage greater than input dc voltage [5]. An IGBT based boost converter is used to increase the voltage level. To change the voltage up to desired level firing pulses are generated by Perturb and Observe (P&O) MPPT technique [6, 7]. In ON state, switch is closed, inductor current increase. In OFF state, switch is open, the inductor current decrease.

V. MPPT TECHNIQUE FOR SOLAR PANEL

A. Maximum power point theorem

According to the concept of Maximum Power Transfer theorem, the output power of any circuit will be maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance [8]. Therefore problem of tracking the maximum power point reduces to an impedance matching problem. By changing the duty cycle of the boost converter appropriately [9].

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic modules in a manner such that it allows them to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun [10, 11]. MPPT is a completely electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power to the load.

In this paper mainly two MPPT methods are used first is perturb and observe and second one is fuzzy logic control. The results are compared also to identify the better one.

B .Perturb and observe method

This is the main idea that is used in the P&O algorithm to track the MPP. The voltage and current are measured using sensors and then power is calculated. This calculated power is compared with previous value and accordingly increase or decrease the voltage is performed to locate the Maximum Power Point by altering the duty cycle of dc-dc converter [12].

P&O method SIMULINK diagram is shown in Fig.5

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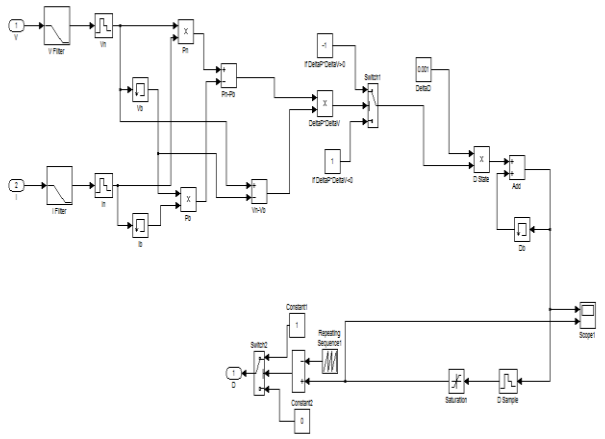


Fig.5 Perturb and Observe MPPT Tracking MATLAB Model

C. SIMULINK Model of solar with Perturb and Observe

In fig.6 Simulation Model of Solar with Perturb and Observe Control is shown. The output can be taken by at different temperature and irradiance level. The standard test values of temperature and irradiance are 25°C and 1000W/m^2 respectively [13].

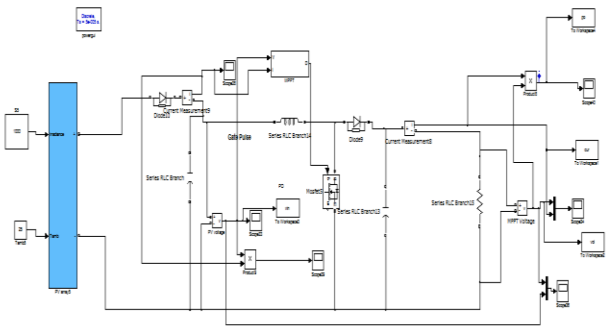


Fig.6 Simulation Model of Solar With Perturb and Observe Control

D. Modelling of Solar using Fuzzy MPPT

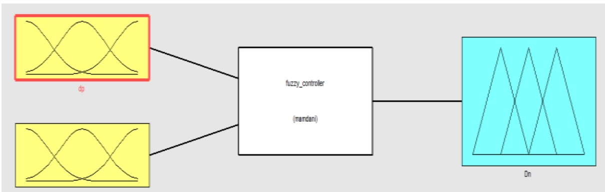
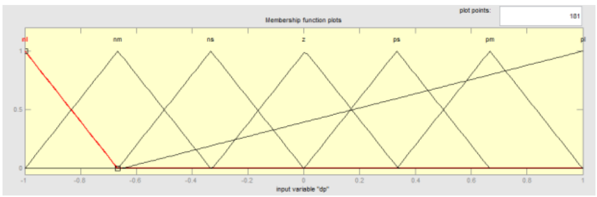


Fig.7 FIS Structural Characteristics used in Simulation

Inputs and their membership functions appear to left of FIS Structural Characteristics whether output and their membership functions to the right side of FIS [14].



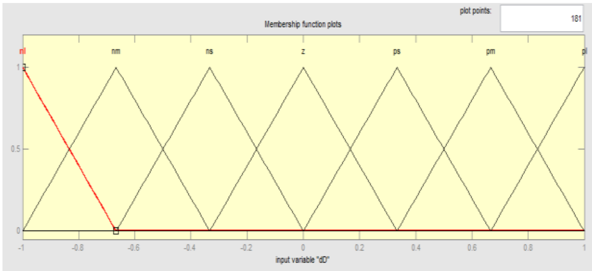


Fig.8 Input Membership Functions (Dp_n ,Dd_n)

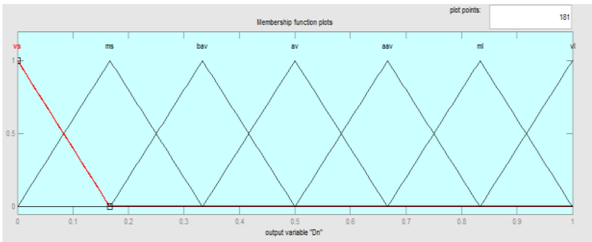


Fig.9 Output Membership Functions (D_n)

E. Rule Base

Table.1 shows rule base where linguistic variables nl ,ml, nl, ms , vs, av,aav,bav are notations for output fuzzy set. Here notation nl is for negative large ,nm is for negative medium, ns is for negative small , z is for zero, pm is for positive medium and pl is for positive large. In same way vl is for very large , ml is for medium large , nl is for negative large ,vs is for very very small av is for average aav is for above average bav is for below average.

The rule base contains two dimensions corresponding to fuzzy controller having two inputs and one output. Every row provides the resultant output fuzzy set for each combination of input fuzzy set. The entire rule base can be written in terms of IF-THEN rules, these are AND and OR combinations.

Table 1 Rule for a Fuzzy MPPT Controller

dD_{n-1}	dP_n						
	nl	nm	ns	z	ps	pm	pl
nl	vl	vl	mv	bav	ms	vs	vs
nm	vl	ml	aav	bav	bav	ms	vs
ns	ml	aav	aav	av	bav	bav	vs
z	vs	ms	aav	av	aav	ml	vl
ps	ms	bav	aav	av	aav	aav	ml
pm	vs	ms	aav	aav	aav	ml	vl
pl	vs	vs	ms	ml	ml	vl	vl

VI. WIND POWER GENERATION

A .Mathematics of Wind Power

The amount of mechanical power captured from wind by a wind turbine can be formulated as:

$$Pm= (1/2)\rho AC_pv^3 \qquad (5)$$

ρ= Air density (Kg/m^3)
A = Swept area (m^2)
C_P = Power coefficient of the wind turbine
V = Wind speed (m/s)

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In addition, the wind turbine is normally characterized by its CP-λ curve; where the tip speed ratio, λ, is given by

$$\lambda=(\omega R)/v \quad (6)$$

Fig.10 shows a typical "C_p- λ" curve for a wind turbine. It shows that CP has its maximum value at λ_{opt}, which results in optimum efficiency; therefore, maximum power is captured from wind by the turbine [15-17].

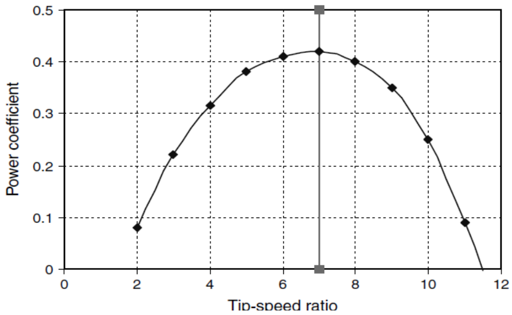

Fig.10 Power Coefficient vs. Tip-Speed Ratio

The optimum speed of rotor can be estimated as follows

$$\omega_{opt} = \frac{v\lambda_{opt}}{R} \quad (7)$$

$$v=\frac{R\omega_{opt}}{\lambda_{opt}} \quad (8)$$

Unfortunately, measuring the wind speed in the rotor of turbine is very difficult, thus to avoid using wind speed, (8) needs to be revised. By substituting the wind speed equivalent from (7) into (5), the output power of the turbine is given as:

$$P_m = \frac{1}{2}\rho ACp\left(\frac{R\omega_{opt}}{\lambda_{opt}}\right)^3 \quad (9)$$

Finally, the target torque can be written as:

$$T_{target} = k_{opt}\,\omega_{opt}^2 \quad (10)$$

Where,

$$k_{opt} =\frac{1}{2}\rho AC_{p_{max}}\left(\frac{R}{\lambda opt}\right)^3$$

To extract maximum power ω_r should vary with the wind speed such as to maintain λ at its optimumλ_{opt}.

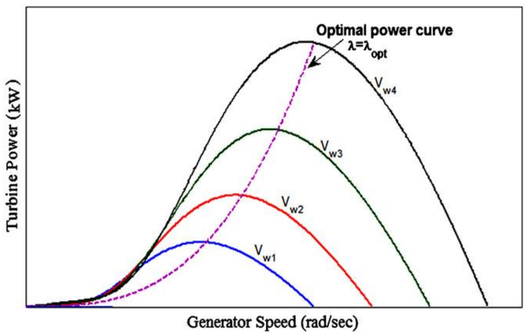

Fig.11 Wind Turbine Torque vs. Shaft Speed for Different Wind Velocities

B. Wind Energy Conversion System (WECS)

Wind Energy Conversion System contains Wind Turbine, Permanent Magnet synchronous Generator (PMSG), and two masse Drive train Pitch angle controller [18-20].

C. Wind Turbine linked with Synchronous Generator

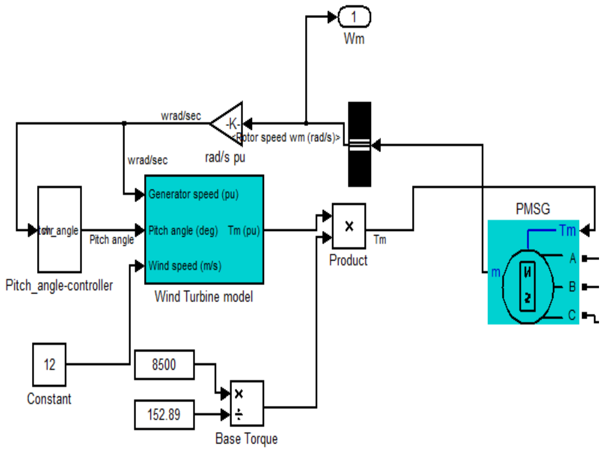

Fig.12 Wind Turbine linked with Synchronous Generator

VII. HYBRID SYSTEM

Here In this paper Solar Photo voltaic and WECS is combined for establishing a hybrid system which is delivering power to load simultaneously [21,22].
After modelling all building blocks of wind energy conversion system and solar energy developed SIMULINK block of hybrid system with MPPT is shown below in Fig.13.

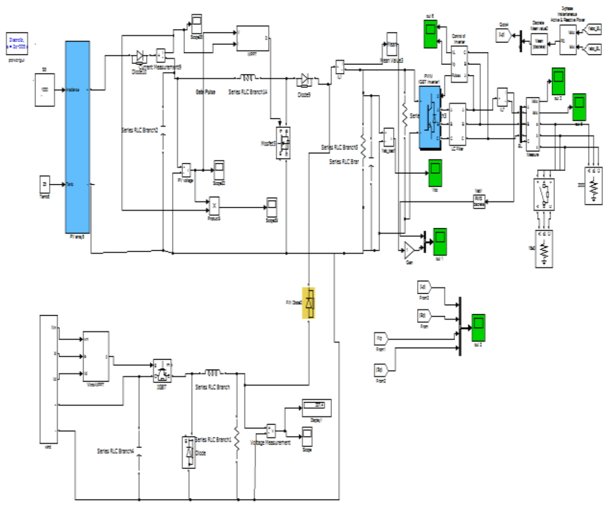
Fig. 13 Simulation Model of Proposed Hybrid System SIMULATION

VIII. RESULTS

The conventional MPPT method for solar is shown here. Without MPPT the solar output voltage is 48 Volts and after using MPPT this output is approximately goes to 160 Volts.

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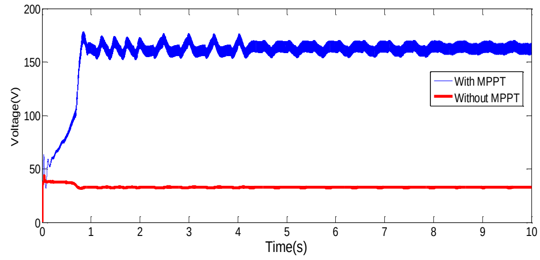

Fig.14 Output Voltage using PO Algorithm

The power output using conventional method is shown in Fig.15

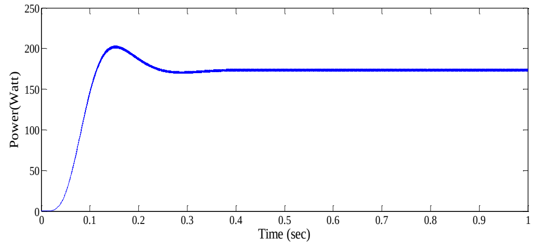

Fig.15 Power Output using PO Algorithm

In fig.16 output voltage is shown using fuzzy MPPT method for solar.

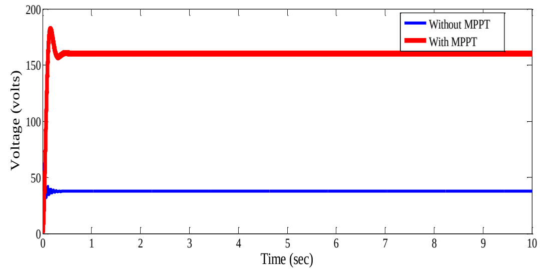

Fig.16 Output Voltage using Fuzzy Method

The duty cycle given to boost converter is shown in fig.17

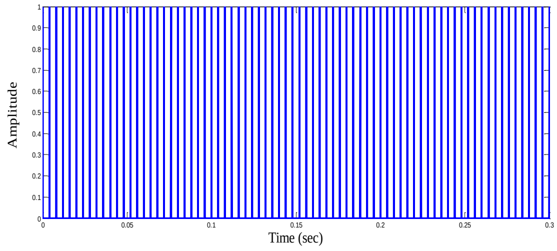

Fig.17 Duty Cycle Fed to DC-DC Converter

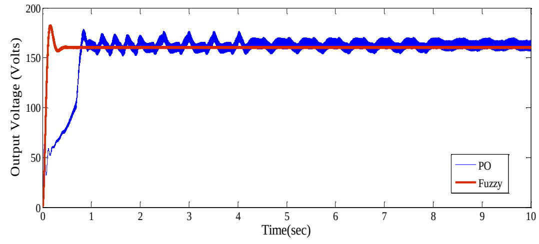

Fig.18 Output Voltage Comparison using PO and Fuzzy

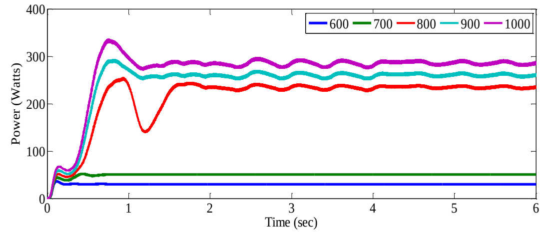

Fig.19 Power Output with P&O at Different Irradiation

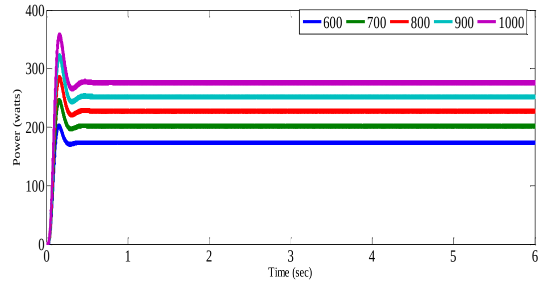

Fig.20 Power Output with FUZZY at Different Irradiation

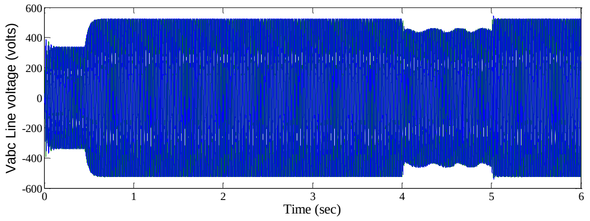

Fig.21 AC Line voltage

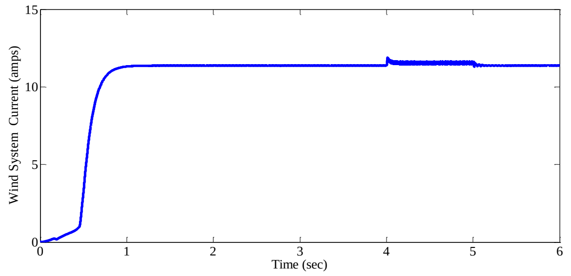

Fig.22 Wind System Current

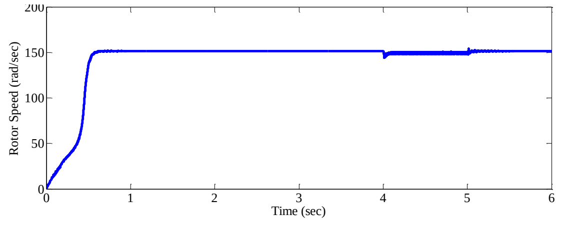

Fig.23 Rotor speed

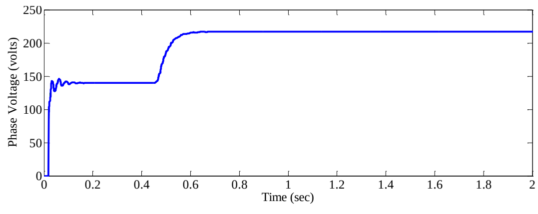

Fig.24 Phase Voltage Given By the Inverter

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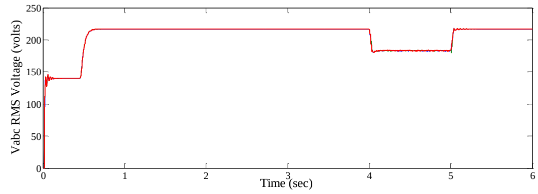

Fig.25 V_{abc} rms voltage

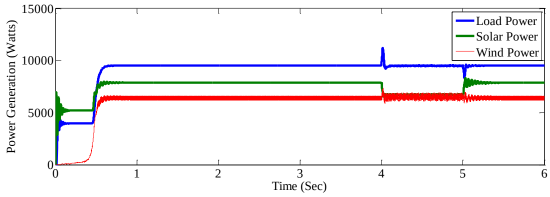

Fig.26 Load Sharing Performance of Hybrid System

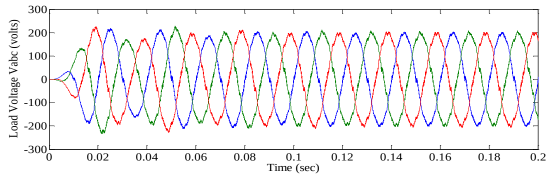

Fig.27 Three Phase Voltage Supplied to the Load

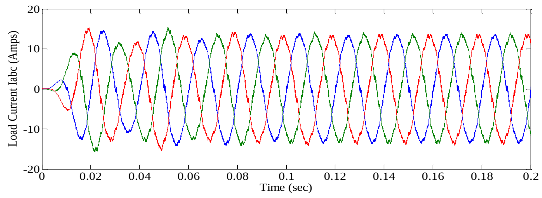

Fig. 28 Load Current Supplied to the Load

IX. CONCLUSION

Here Wind, photovoltaic hybrid energy system, designed to generate a continuous power irrespective of the intermittent power outputs from the wind and photovoltaic energy sources. The wind and photovoltaic systems are controlled to operate at their point of maximum power under all operating conditions. The simulation results show that. The dc-dc converters are very effective in tracking the maximum power of the wind and photovoltaic sources.

• Controller responds efficiently to the deficit power demands.

• With both wind and photovoltaic systems operating at their rated capacity. The system is capable of providing a minimum power of to the load even under worst climatic conditions.

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