Modeling and Control of MPPT Based Grid Connected Wind-PV Hybrid Generation System

S.Chandra Shekar
Ph.D Scholor Electrical and Electronics Engineering
Koneru Laxmaih University
Vijayawada,India
chandueeehod@gmail.com

K.Raghu Ram
Professor
Laqshya Institute of Technology and Sciences
Khammam,India
dr_k_raghuram@yahoo.com

***Abstract*—** Renewable energy sources such as the solar & wind offer clean, abundant energy. As the power demand increases power failure also increases so the renewable energy can be used to provide constant loads. To convert the basic circuit equation of solar cell into simplified form a model developed including the effects of changing solar irradiation and temperature. Power control strategy is used to extract the maximum power. Maximum power point tracker (MPPT) control is essential to ensure the output of photovoltaic power generation system at the maximum power output as possible. This system consists of PMSG as a wind generator, solar array, dc-dc converter and grid interface inverter. In this paper perturbation & observation (P&O) method and incremental conductance method are used and simulated in Matlab/Simulink. The voltage source inverter interface with grid transfers the energy drawn from the wind turbine and PV array to the grid by keeping common dc voltage constant. The simulation results show the control performance and dynamic behavior of the hybrid wind-PV system.

Keywords- *Wind power generation system, solar PV system, grid interface inverter, MPPT*

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I. INTRODUCTION

Wind and PV systems rely on highly transient energy sources and exhibit strong short-term and seasonal variations in their energy outputs. They need to store the energy produced in periods of low demand, in order to stabilize the output, when the demand is high. While batteries are most commonly used for this purpose, they typically lose 1–5% of their energy content per hour and thus can only store energy for short periods of time. There are presently no practical means available for long-term storage of excess electrical energy produced by the renewable energy sources.

Over recent years several research and investment has been carried out in hybrid power system, such as Yang [1], who recommended an optimal design model for hybrid solar–wind system, which employs battery banks to calculate the system's optimum configurations in China. Reichling [2], modeled a hybrid solar wind power plant in south western Minnesota for a two year period, using hourly solar irradiation and wind speed data. Ekren [3], showed an optimum sizing procedure of PV/wind hybrid system in Turkey. Several modeling studies on PV/WT power system have been conducted. Among them, Kim [4], developed a grid-connected photovoltaic model using PSCAD/EMTDC for electromagnetic transient analysis. Tsai [5], implemented an insulation-oriented PV model using MATLAB/SIMULINK software package. J.A. Gow et.al [6] discussed in Development of a photovoltaic array model for use in power-electronics simulation studies Khan [7], presented the model of a small wind-fuel cell hybrid energy system and analyzed life cycle of a wind-fuel cell integrated system. Chayawatto [8], developed a mathematical model of a dc/ac full-bridge switching converter with current control for PV grid connected system under islanding phenomena; these phenomena occur when the grid system is disconnected for any reason and the distributed generation still supplies to any section of local loads. Onara [9], modeled a hybrid wind/FC/

ultra-capacitor (UC) power system for a grid-independent user with appropriate power flow controllers.

The wind generation aspect of the system. Modeling and analysis of the power circuit of the system will be proposed. Based on that, a control algorithm will be developed and implemented. The transient response and stability analysis of the control method will also be analyzed. At the end, dynamic simulation and experimental verification results will be presented.

The PV generation aspect of the system. Modeling and transient analysis of the PV generator and power circuit will be developed. According to this, a direct switching duty control using a variable step incremental conductance algorithm will be proposed with guidelines to optimize the controller parameters. These guidelines will improve the controller tracking efficiency and speed. The proposed controller may have to work in a reduced power mode according to the supervisory controller signal. The controller will also be verified by dynamic simulation and experimental results.

In this paper study, a detailed dynamic model, control and simulation of a smart grid-connected PV/WT hybrid power generation system is proposed. Modeling and simulation are implemented using MATLAB/SIMULINK and Sim Power System software packages to verify the effectiveness of the proposed system.

II. SYSTEM DESCRIPTION AND MODELING

In this section, the dynamic simulation model is described for photovoltaic/wind turbine hybrid generation system. The developed system consists of two 100KW photovoltaic array, dc/dc converter with an isolated transformer, designed for achieving the maximum power point with a current reference control (I_{ref}) produced by P&O algorithm, wind turbine, asynchronous induction generator, and ac/dc thyristor controlled double-bridge rectifier. The proposed block diagram and simulation representation is shown in figure1 and figure 2

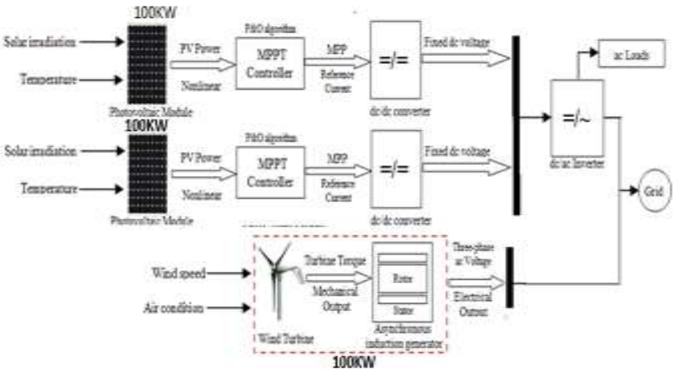

Fig. 1. Block diagram of the proposed system

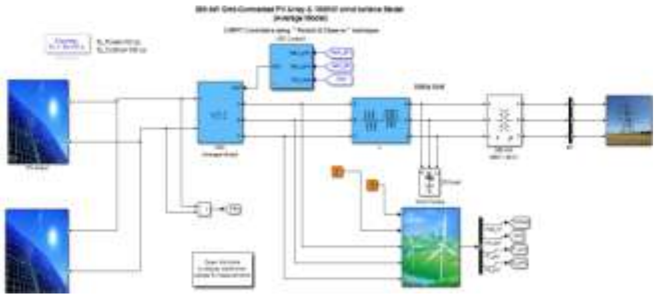

Fig 2. Simulation representation of Proposed System

III. MODELLING OF PHOTOVOLTAIC CELL

In PV panels solar cells are the basic components and it is made of silicon. A solar cell is generally a p-n junction which is made of silicon. It is made up of two different layers when a smaller quantity of impurity atoms added to it. A PV system convert's sunlight in to electricity and the PV cell is basic device of the photovoltaic system. Number of Cells are combined and grouped to form PV panels or modules and form large photovoltaic arrays. The solar arrays are combination of number of cells connected in series or in parallel group of panels to get required power generation.

There are many stages are used in grid connected PV system like PV array, DC to DC converter, DC to AC converter. In this paper a model is developed through converting common circuit equation of solar cell in to simplified form including the effects of changing solar irradiation and changing temperature. In this paper a control approach for interfacing the PV array with DC-DC converter. The power injected into the grid from the PV panel through two stages. In first stage in order to enhance the DC voltage level of PV panel the PV array is connected to the DC-DC converter. The MPPT is used to track the maximum power point in order to achieve the maximum power point. In second stage through grid connected inverter control dc power is converted into ac power. Also this control the current and power injected from the grid.

The Voltage vs Power characteristics and Voltage vs Current characteristics of a solar cell are mainly dependents upon the solar irradiation shown in fig 3, 4. If there is change in the environmental condition then the solar irradiation level change which results different maximum power. So maximum power point tracking algorithm are used to maintain the maximum power constant if there is any change in the solar irradiation level. If the solar irradiation level is higher, then the input to the solar cell is more which results more magnitude of the power with the same voltage value. Also when there is increase in the solar irradiation the open circuit voltage increases. Because, when there is more solar light fall on the solar cell, with higher excitation energy the electrons are supplied, they increase the mobility level of electron and more power is generated.

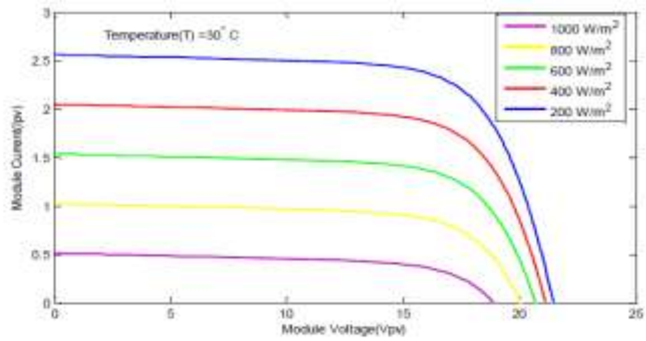

Fig.3 V-I characteristics with different irradiance

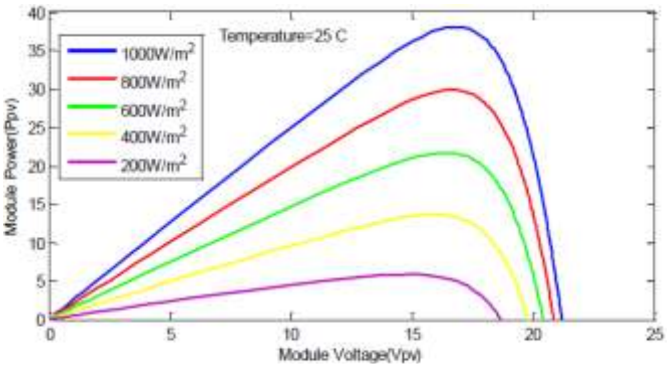

Fig.4 P-V characteristics with different irradiance

According to the variation of temperature also the output of the PV cell. When the temperature of the solar cell increases the power generation capability also change which is an undesirable feature. As fig.5 illustrates P-V characteristics with different temperature and the increase in temperature the open circuit voltage decreases which results increase in the band gap so more energy is required to cross the barrier. As a result the solar cell decreases its efficiency.

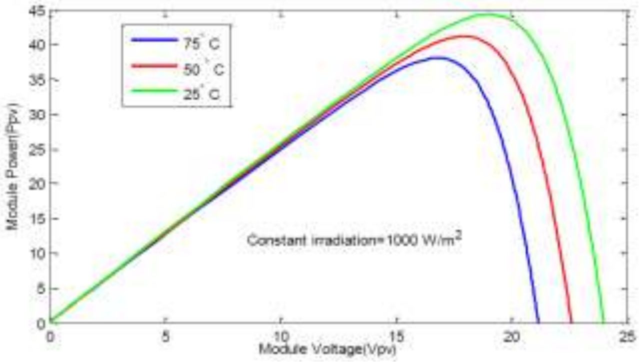

Fig.5 P-V characteristics with different temperature

IV. Maximum Power Point Tracking (MPPT)

In solar panel peak power is archived with the help of a DC-DC boost converter and it is used in between the PV generator and the load by adjusting the duty cycle. Maximum Power Point of a solar module varies with the variation of irradiation and temperature So MPPT algorithms are necessary in PV applications because by the use of MPPT algorithms it obtain the peak power from the solar panel. Previously there are different methods to find the MPP have been published and developed. According many aspects these techniques differ such as required sensors, complexity, range of effectiveness, according to speed, cost, if there is change in irradiation and temperature than also the effectiveness of tracking, requirement of hardware and its implementation. 19 different MPPT algorithms are there among these techniques, the Incremental conductance algorithms and the P&O algorithms are generally used. This is easy to use and simple in operation and required less hardware as compare to other. When there is more than one MPP other MPPT technique are used and it appeared generally when the PV array is partially shaded. The circuit arrangement of maximum power point tracking shown in fig 6

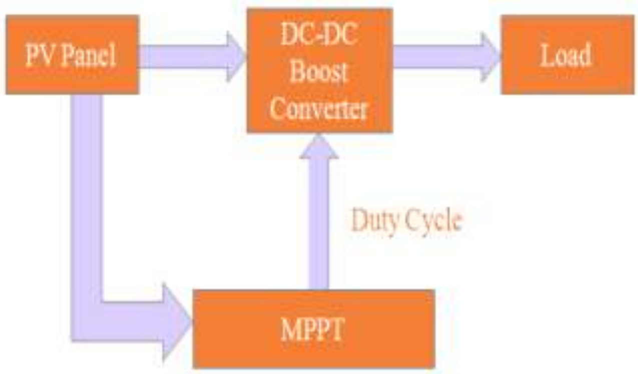

Fig.6 Circuit Arrangement of MPPT

V. Perturbation and Observation Method

According to the change in power the perturbation direction is taken into account. Fig 7 illustrates the flow chart of perturbation and observation method.If there is change in power which is positive than the voltage will increase in the right hand side direction similarly if it is negative or decreases than the voltage perturbation will in the opposite that is left ward direction. So the direction of the perturbation is decided whether the voltage at present is higher than voltage at previous one, accordingly due to this change in power control signal of the PWM can be calculated. According to this algorithm, overshoot appear in the starting and slowly decrease till it reaches a stable steady state. The control action will stop only when the output power reach its maximum values. From the flowchart it is summarized that:

When $dP > 0$ and $dv > 0$, that's means power is in the left side of the maximum power point therefore increase the voltage, similarly when $dP > 0$ and $dv > 0$ power is right side of the maximum power point and therefore decrease the voltage. At that is the maximum power point.

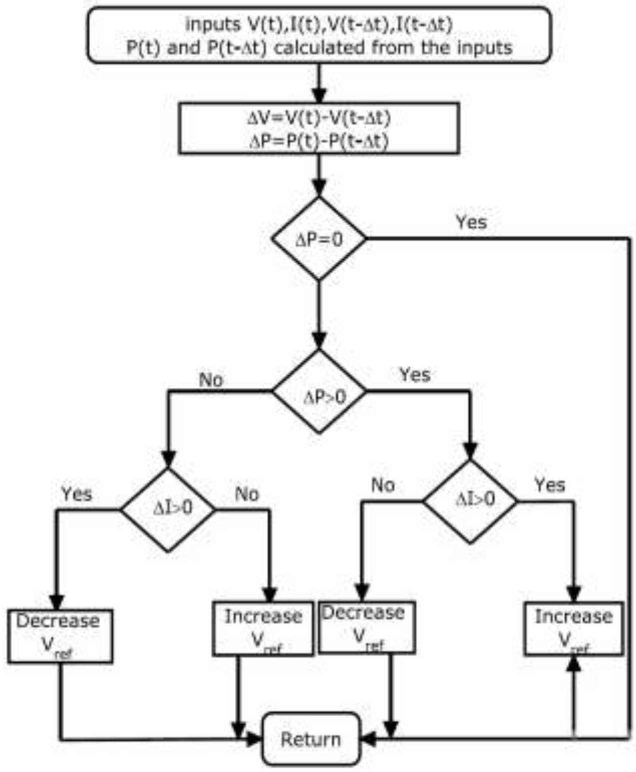

Fig. 7 Flow Chart of perturbation and observation algorithm

In this study, a general PV model is built and implemented using MATLAB/SIMULINK to verify the nonlinear output characteristics for the PV module. The proposed model is represented MPPT Controller using perturbation and observation technique shown in Fig 8 and implementation of the PV Array model illustrated in Fig.9. In this model, whereas the inputs are the solar irradiation and cell temperature, the outputs are the photovoltaic voltage and current

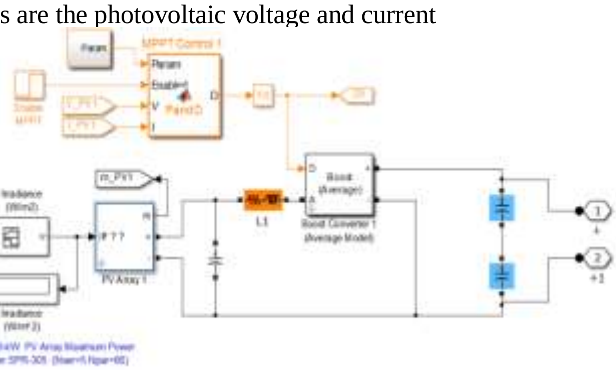

Fig. 8. MPPT Controllers using Perturb & Observe technique

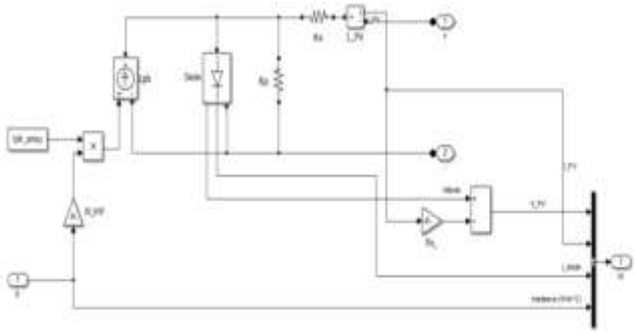

Fig. 9 Subsystem implementation of the PV Array model

VI. WIND TURBINE

Wind energy is capable of supplying large amount of power and the total amount of obtainable power available from the wind is considerably more than the present human power used from all the sources. Wind power is an alternative of fossil fuels, is plenteous, widely expanded, clean, and renewable and during operation no greenhouse gas produced. Wind power is the fast growing source of energy.

By using the power of the wind turbines produce electricity by drive an electrical generator. A moving force is exerted and generates lift when wind is passing over the blades. The rotating blades rotate the shaft which is connected with the gearbox. The gearbox adjusts the rotational speed which is convenient for the generator to get a desired output. The output of the wind generator is fed to the transformer which converts the electricity of the generator up to 33 kv Which is the appropriate voltage for power system. Mechanical power transfer to the shaft is equal to

$$P_m = 0.5\rho A c_p V_w{}^3$$

Where power coefficient (C_p). The characteristics curve show the detail behavior of mechanical power extract from the wind and the rotor speed at different wind speed. The proposed wind turbine model as shown from fig.10 and fig.11and also implementation of DC-DC Boost converter is shown in Fig 12.

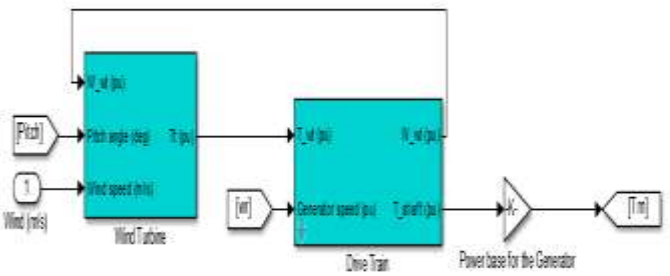

Fig. 10. Implementation of the Turbine and Drive model

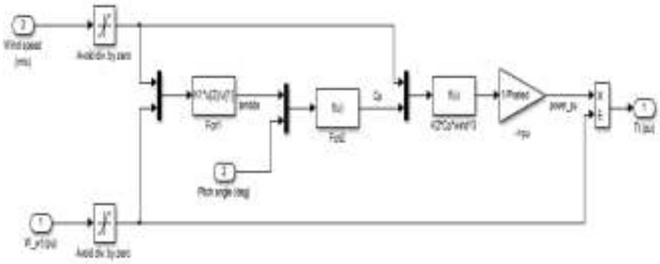

Fig.11 Subsystem implementation of the WT model

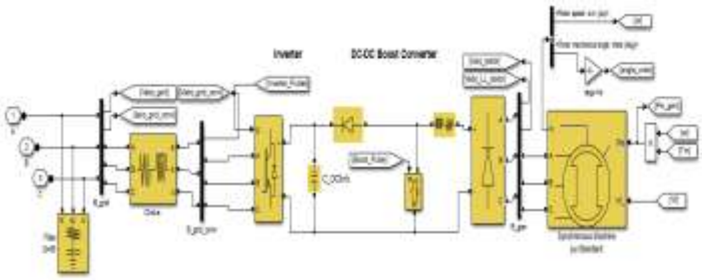

Fig. 12.Subsystem implementation of DC-DC Boost converter

Power Control Systems

1) Photovoltaic Control System

The output characteristics of the PV model with different solar irradiance and cell temperature are nonlinear. Furthermore, the solar irradiation is unpredictable, which makes the maximum power point (MPP) of the PV module changes continuously. Therefore, a maximum power point tracker (MPPT) technique is needed to operate the PV module at its maximum power point (MPP). Perturb and observe (P&O) algorithm is the maximum power point tracker (MPPT) control algorithm that will be adapted in this model. The P&O algorithm operates by periodically incrementing or decrementing the PV array operating current, and comparing the PV output power with the previous one. If it's positive the control system moves the PV array operating point in the same direction, otherwise, it's moved in the opposite direction. A MPPT controller model is built and implemented using MATLAB, to operate the PV module at its maximum power point. The P&O algorithm requires two measurements: measurement of the current (*Ipv*) and measurement of the voltage (*Vpv*). The proposed model is implementation as shown in Fig.13.

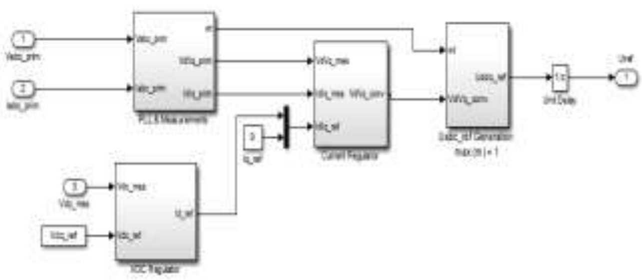

Fig..13 Implementation of the PV control system model

2) Wind Turbine Control System

Due to the variations in wind speed, the output power of the wind turbine induction generator experiences variations in frequency and amplitude. Therefore, a controllable ac/dc converter is used to smooth the wind turbine output power before being supplied to other electronic devices. The subsystem implementation of excitation, speed and pitch control illustrated in Fig.14 and fig.15

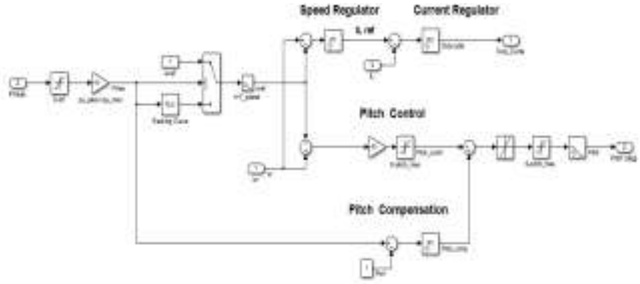

Fig. 14. Subsystem implementation of speed and Pitch control

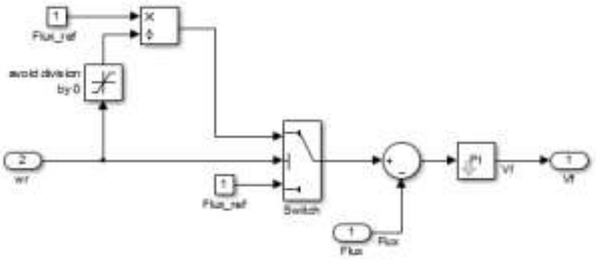

Fig .15 Sub systems for excitation control

VII. SIMULATION RESULTS AND DISCUSSION

The major inputs for the proposed PV model were solar irradiation, PV panel temperature and PV manufacturing data sheet information’s and wind system specifications are listed in Table I and Table II.

Table 1 : Solar Module (100KW) Specification	
Rating	37.06V
Current at Peak	7.71A
Voltage at Peak	26.6V
Short circuit current	8.36A
Open circuit voltage	33.2V
Number of Cells per Module	54
Number of series connected modules per string	8
Number of parallel strings	61

Table II: Wind generation Specification	
Rating	100KW
Diameter	8 m
Number of blades	3
Cut in speed of wind	11m/s
Cut out speed of wind	25 m/s
Generator Rating	50Kw
Nominal Voltage	260V
Generator frequency	50Hz

The total power generation of PV-wind shown in figure 16and PV Generation irradiance, mean power and generated voltage of Panel-1 and Panel-2 are shown in fig 17.

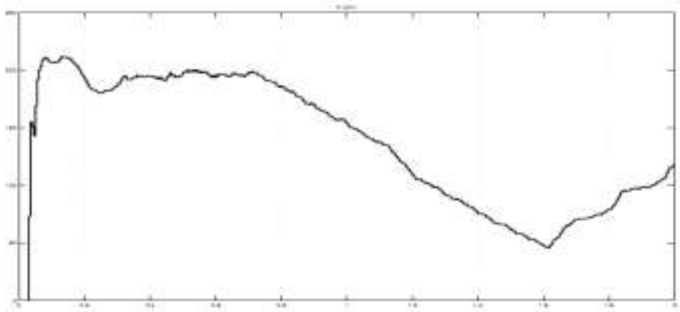

Fig.16 Total Power generation of PV-Wind generating system

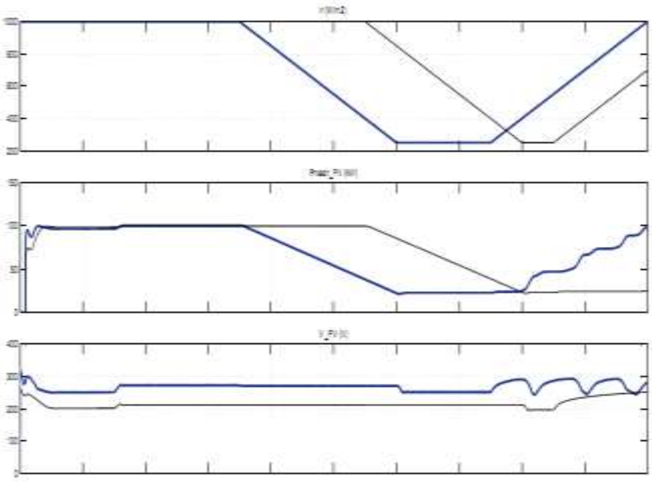

Fig 17: PV Generation irradiance, mean power and generated voltage of Panel-1 and Panel-2.

The wind turbine output voltage, mechanical power, active and reactive power represented from fig 19 to fig 22.

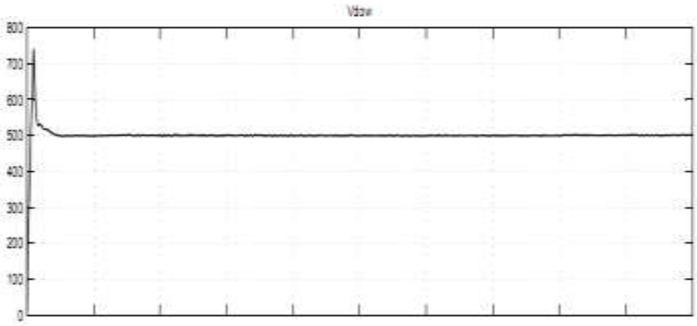

Fig 18: Wind generation output voltage

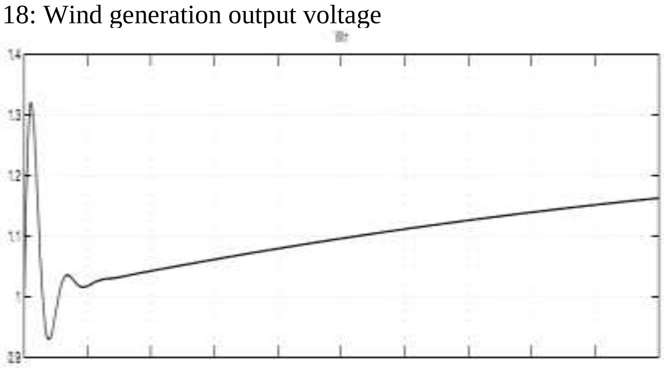

Fig 19: Wind turbine mechanical power in pu

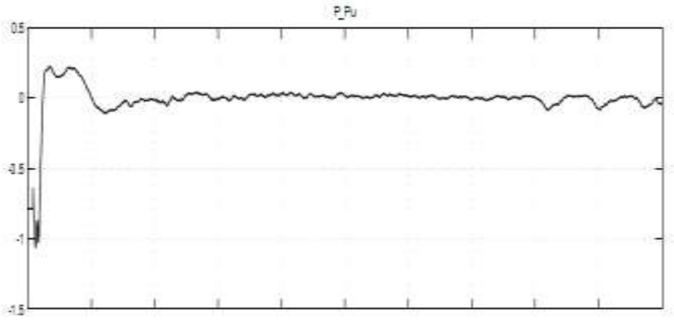

Fig 20: Wind turbine active power generation

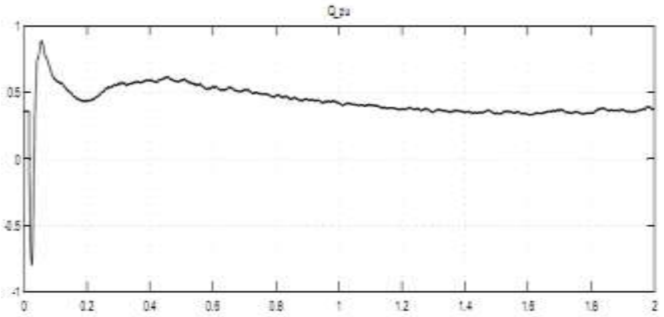

Fig 21: Wind turbine reactive power

CONCLUSIONS

Production and hybridizing solar and wind power sources provide a realistic form of power generation. In this proposed system, Grid Connected Photovoltaic/Wind turbine (GCPW) hybrid system can be used to supply continuous power to the loads. It is observed that the extraction of the maximum power from PV array is obtained using MPPT system. The MPPT algorithm has been implemented. The proposed system has been simulated in MATLAB-SIMULINK environment. The dynamic behavior of the proposed model is examined under different operating conditions. Solar irradiance, temperature and wind speed data is gathered from a 200KW grid connected solar power system and wind power generation. The proposed model offers a proper tool for smart grid performance optimization.

References:

[1]. H. Yang, Z. Wei, and L. Chengzh, "Optimal design and techno economic analysis of a hybrid solar-wind power generation system," Applied Energy, vol. 86, pp. 163-169, Feb. 2009.

[2]. J.P. Reichling, and F.A. Kulacki, "Utility scale hybrid wind-solar thermal electrical generation: a case study for Minnesota," Energy, vol. 33, pp.626-638, Apr. 2008.

[3]. O. Ekren, B.Y. Ekren, and B. Ozerdem, "Break-even analysis and size optimization of a PV/wind hybrid energy conversion system with battery storage – A case study" Applied Energy, vol.86, pp. 1043-1054, July-August 2009.

[4]. S.K. Kim, J.H. Jeon, C.H. Cho, E.S. Kim, and J.B. Ahn, "Modeling and simulation of a grid-connected PV generation system for electromagnetic transient analysis, "Solar Energy, vol.83, pp. 664- 678, May 2009.

[5]. H.L Tsai, "Isolation-oriented model of photovoltaic module using Matlab/Simulink," Solar Energy, vol. 84, pp. 1318-1326, July 2010.

[6]. J.A. Gow, and C.D. Manning, "Development of a photovoltaic array model for use in power-electronics simulation studies," IEE Proceedings- Electric Power Applications, vol. 146, pp. 193-199, Mar. 1999.

[7]. M.J. Khan, and M.T. Iqbal, "Dynamic modeling and simulation of a small wind fuel cell hybrid energy system," Renewable Energy, vol. 30, pp. 421-439, Mar. 2005.

[8]. N. Chayawatto, K. Kirtikara, V. Monyakul, C. Jivacate, and D. Chenvidhya, "DC–AC switching converter modeling of a PV grid-connected system under islanding phenomena," Renewable Energy, vol. 34, pp. 2536-2544, Dec. 2009

[9]. O.C. Onara, M. Uzunoglua, and M.S. Alam, "Dynamic modelling, design and simulation of a wind/fuel cell/ ultra-capacitor-based hybrid power generation system, "Journal of Power Sources, vol. 161, pp. 707-722, Oct. 2006.

S. Chandra Sekhar received his B.Tech Degree in Electrical & Electronics Engineering from RVR&JC college of Engineering, GUNTUR in 2001, M.Tech (High Voltage Engineering) degree in Electrical and Electronics Engineering from University College of Engineering, JNTU, Kakinada in 2004.He is pursuing Ph.D at K L University. Presently he is working as associate professor and Head of the Department. He had publications in Eight international journals. He is guiding both undergraduate and post graduate student projects. His area of interest includes Micro Grids,High voltage transmission and Power Systems.

Dr.K.Raghu Ram received his B.Tech Degree in Electrical & Electronics Engineering from J.N.T.University, Hyderabad, A.P in 1979, M.Tech (Electrical, Power Systems, Engg) degree in Electrical and Electronics Engineering from J.N.T.University, Hyderabad, A.P in 1983.He received his Ph.D from from J.N.T.University, Hyderabad, A.P. Presently he is working professor and Principal at Laqshya Institute of Technology and Sciences, Khammam, A.P. He had Six publications in international journals. He is guiding undergraduate,post graduate and Ph.D student. His area of interest includes 6-phase transmission, Micro Grids, Power Systems Stability etc.