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Review on Sustainable Energy Source Based Hybrid Power System

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ABSTRACT
Currently, multi-days reality is moving toward green and clean energy sustainable energy for example, (wind, solar, biomass, hydro and tidal), these are able to defeat the voltage list and low voltage defect ride according to standard counterfeit code. For a particular PV, irradiation and temperature, wind velocity (for WECS) and water flow rate (for hydro), there is always a point at which maximum power out of these systems can be extracted. This paper first reviews sustainable energy the wind power and photovoltaic (PV) power generation techniques and their maximum-power-point tracking (MPPT) methods are described. Then, a new Grid tied sustainable energy based power generating system is proposed. For the wind power generation permanent-magnet synchronous machine is used to capture the maximum wind power by using optimum speed control. For the PV power generation boost converter is adopted to harness the maximum solar power by tuning the duty cycle. Simulation validations are providing to fiancée of proposed system.

Keywords: *Boost converter, controller, fossil fuel, MPPT, solar power system, wind energy, utility grid, voltage source inverter*

INTRODUCTION

With the advantages of being abundant in nature and nearly no pollutant, renewable energy sources have attracted wide attention. Wind power is one of the utmost likely clean energy sources as it can easily be caught by wind generators with high power capacity. Photovoltaic (PV) power is one more promising clean energy source as it is worldwide and can be tie together without using rotational generators. In fact, wind power and PV power are balancing to some extent ever since strong winds are frequently to occur all through the night and cloudy days however sunny days are often calm with weak winds [1].

In order to convert the wind energy to electrical energy, two types of wind turbines are employed; fixed speed and variable speed wind turbines installed onshore or offshore [4]. In the static speed wind turbine, electrical generator is linked straight to the power grid. Thus, the generator runs at persistent frequency and speed. Active and reactive power control of these turbines is described in [5, 6]. The variable speed wind turbine (VSWT) is used for more attraction of energy from the wind. The VSWT, which attracts10–15% more energy, has lesser mechanical stress and less power variation in contrast with the fixed speed ones. Furthermore, the wind turbine is divided into two large categories: horizontal and vertical axis wind turbines. Savonius and Sherbious are the furthermost well-known vertical axis wind turbines (VAWT). The aerodynamic efficiency of the VAWT is lower than the horizontal type but complexity and price of these types are lower [7].

One of the most important studies in the VSWT is the application of various control

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schemes for several purposes in the plant. There are some methods to control VSWT. These methods are used to track the maximum power, to control the voltage and frequency of the load and reduce power fluctuation [8–10]. Pitch control is a method to control power extracted from the VSWT [11]. Maximum power attraction from the VSWT is achieved using linear control; fuzzy logic control and hill climb searching (HCS) method [12–15].

Due to efficient and economical utilization of renewable energies, some of renewable energy resources such as wind turbine and solar array are integrated [16]. Because of dependency on wind speed and sun irradiance in such systems, their reliability in satisfying the load demands decreases under all conditions. Hence, some studies propose the combination of a diesel generator as a backup and wind/solar power generation systems [17,18].

This efficiency maximization of the PV power processing system is useless if the MPPT control does not ensure that the maximum power is extracted from the PV array, both at a steady state and under varying climatic conditions.

In fact, the total efficiency of the power processing system is almost the product of the conversion efficiencies, which must be maximized by taking into account the extremely variable operating conditions throughout the day [19] as well as the MPPT efficiency.

There are multiple MPPT techniques [20] that could be compared using different criteria (Table 1). The main techniques are dP/dV or dP/dI feedback control, incremental conductance (IncCond), and hill climbing {or perturbation–observation (P&O)}.

Table.1: *MPPT Comparision for Photovoltaic System.*

S. No	MPPT Technique	PV Array Dependent	True MPPT	Convergence Speed	Implementation Complexity	Sensed Parameters
1	P&O	No	Yes	Varies	Low	Voltage, current
2	IncCond	No	Yes	Varies	Medium	Voltage, current
3	Fractional *Voc*	Yes	No	Medium	Low	Voltage,
4	Fractional *Isc*	Yes	No	Medium	Medium	current
5	Fuzzy logic	Yes	Yes	Fast	High	Varies
6	Neural network	Yes	Yes	Fast	High	Varies
7	*dP*/*dV* control	No	Yes	Fast	Medium	Voltage, current

In photovoltaic system a front-end boost converter is generally required at the input of inverter to match the load requirements. In such DC-AC or DC-DCAC power converters, there is a possibility of simultaneous switching of switches (IGBTs/MOSFETs) of the same leg(s) of inverter due to EMI effect, improper firing of switches, nuisance circuit breaking and absence of cross-conduction protection within the gate-drivers itself etc. This leads to shorting of source or DC link capacitor through the shorted leg(s) of inverter, causing a large current flow and damage to the system. A voltage source inverter is one of the examples.

Proposed system is designed for maximum energy captured from the wind turbine / solar array and deliver to utility grid. This paper is organized as follows: description of the proposed system and modeling is illustrated in Section 3. Section 4 describes the control system design. Simulation results and discussion are presented in Section 5. Section 6 is the conclusions.

PROPOSED SYSTEM DESCRIPTION

The proposed hybrid energy generation system is depicted in Figure 1. This system consists of a horizontal axis and variable

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speed wind turbine, a solar array, permanent magnet synchronous generators, sinusoidal pulse width modulation (SPWM) converters, DC/DC converters, an adaptive feedback linearization controller.

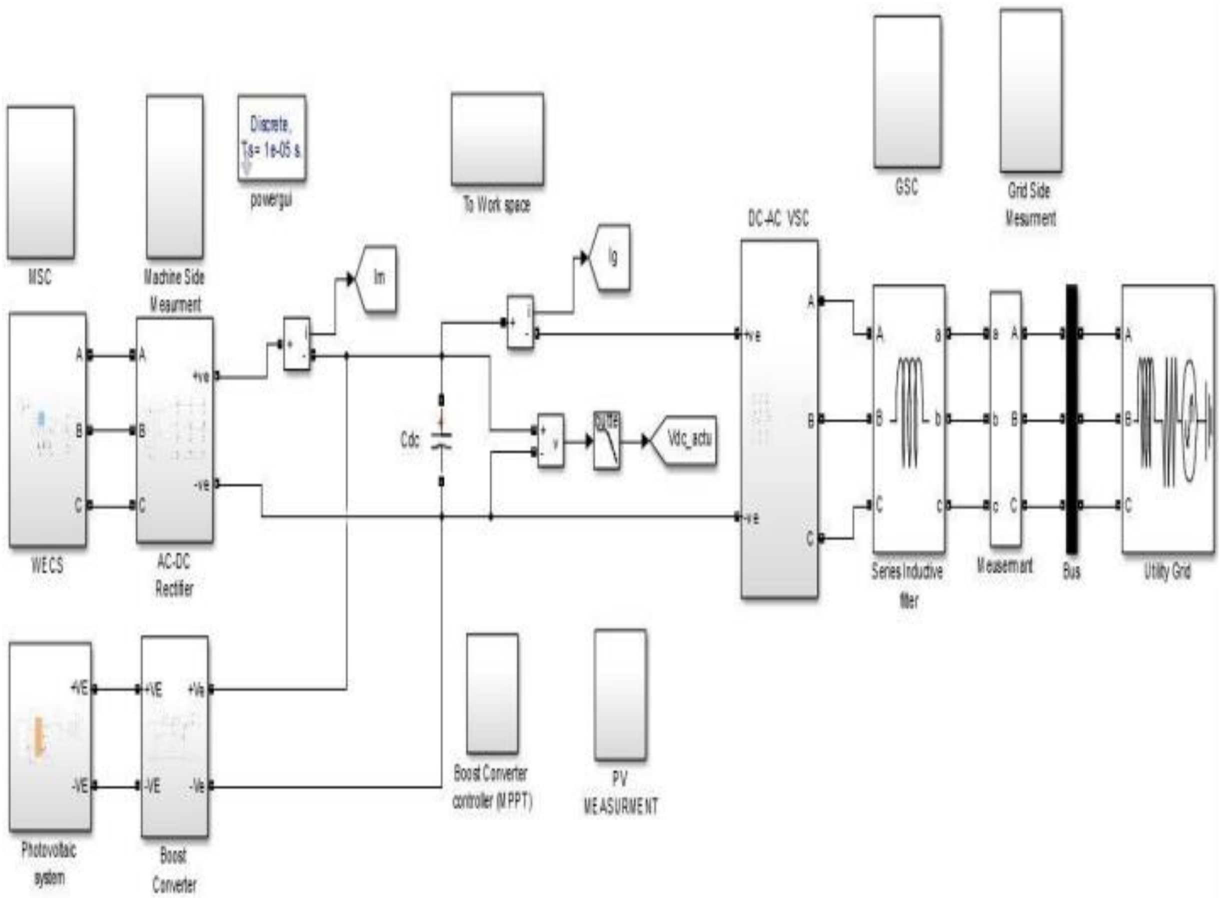

Fig.1: *Proposed System modeling*

Modeling of Wind Energy Conversion System

In wind energy conversion system (WECS) wind potential energy is converted into electrical energy with the help of wind turbine and generator, in proposed paper permanent magnet synchronous generator is used to convert mechanical energy to electrical energy. In modeling of WECS following key equations are used,

Power contains in the undisturbed wind is in form of kinetic energy then the power is,

$$P = \frac{1}{2}\dot{m}v_a^2 \quad (1)$$

Where $\dot{m}$ and v_a are rate of flow of wind and speed of undisturbed wind respectively, and the rate of flow of wind is the function of air density, area through wind is passing and speed of wind then the power contains in undisturbed wind can be also written as,

$$P = \frac{1}{2}\rho A v_a^3 \quad (2)$$

Where ρ and A are the density of wind and swept area of wind turbine respectively Power output from the wind turbine is given as,

$$P = \frac{1}{2}\rho A V_a^3 C_P \quad (3)$$

$$P = \frac{1}{2}\rho\pi R^2\left(\frac{\omega^3 R^3}{\lambda^3}\right)C_P \quad (4)$$

Where λ is tip speed ratio it is depends on wind speed length of blade and generator angular speed in the case of direct driven wind turbine. And C_p is the betz limit its optimums value is 0.49. Characteristic of wind turbine is shown in Figure 2

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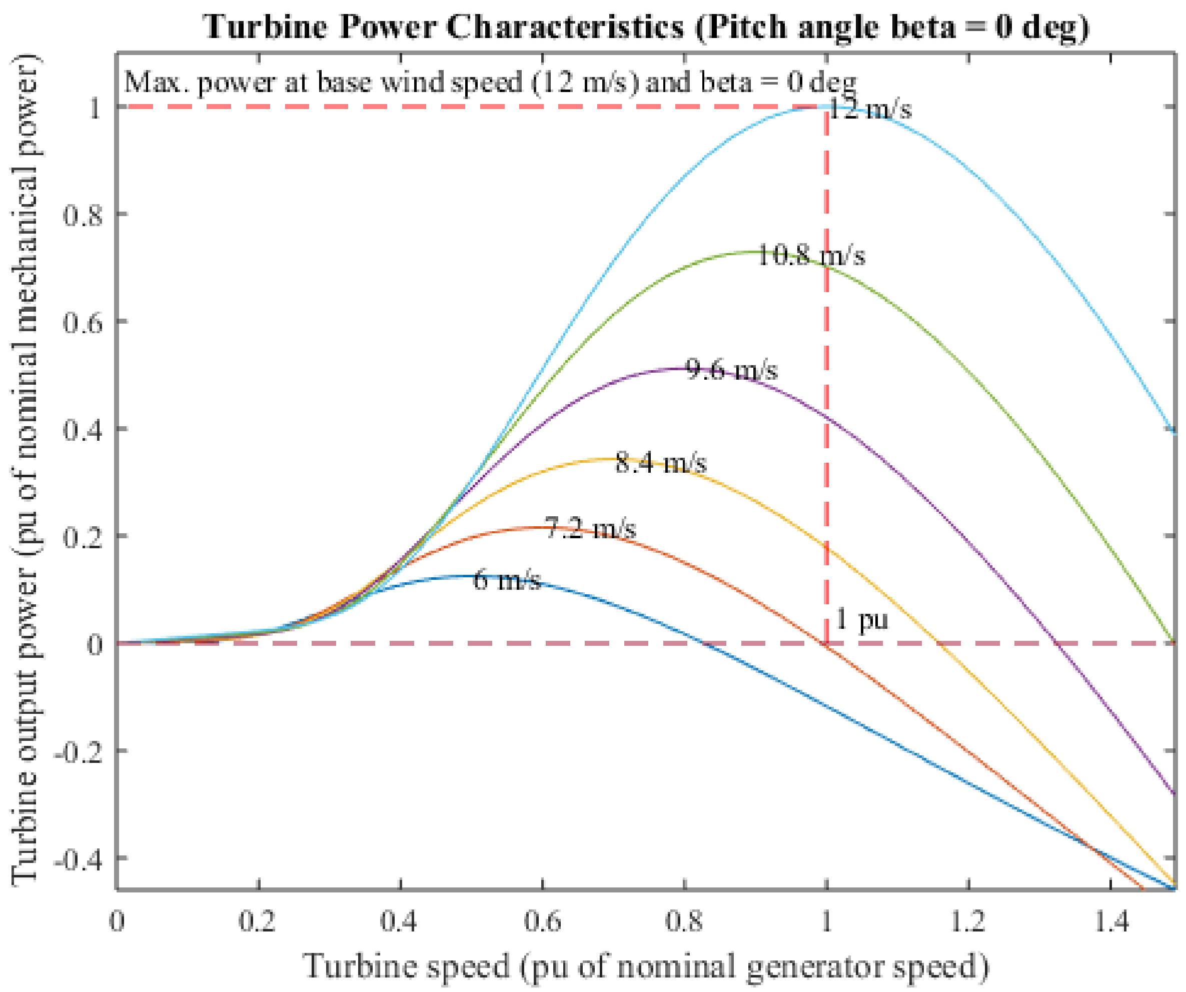

Fig.2: *Wind Turbine Characteristic.*

Modeling of Solar Energy Conversion System

Solar energy conversion system is manly depends on PV module which is consist with PV cell equivalent circuit of PV cell is given in Figure 3.

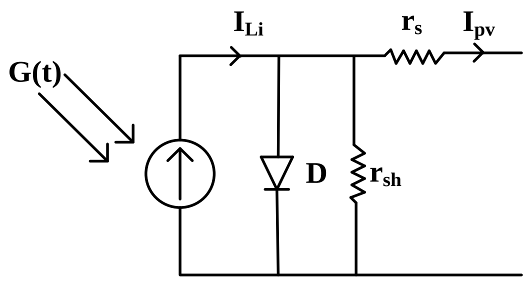

Fig.3: *The equivalent circuit of PV cell*

Current equation of PV module are given as,

$$I_{pv} = I_{Li} - I_0\left[e^{\frac{q(V_{pv}+r_s)}{\eta A_i \Theta}} - 1\right] - \frac{V_{pv}+I_{pv}r_s}{r_{sh}} \quad (5)$$

Where Ipv output current of PV panel, I_{Li} light induced current, Io is the reverse saturation current q is the electron charge, Vpv is the voltage of PV, η is the Boltzmann constant, Ai is the semiconductor material ideality factor and Θ is the cell temperature Light induced current is given as

$$I_{Li} = G(t)[I_{sc} + \beta_i(\Theta - \Theta_r)] \quad (6)$$

Where G(t) solar irradiation in (w/m2) I_{sc} is short circuit current, β_i temperature coefficient in (per °C) and Θ_r is reference cell temperature and reverse saturation current is given as

$$I_0 = I_{rs}\left(\frac{\Theta}{\Theta_r}\right)^3 . e^{\left[\frac{E_b}{\eta A_i}\left(\frac{1}{\Theta_r} - \frac{1}{\Theta}\right)\right]} \quad (7)$$

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Where I_{rs} reverse saturation current at standard testing condition and E_b is energy band gap. Power provided by PV array is written as

$$P_{PV} = N_p N_s P_{module} \eta_{mppt} \eta_{oth} \quad (8)$$

Where Np and Ns are Number of PV module connected in parallel and series respectively, Pmodule power developed by single module, ηmppt and ηoth are efficiency at maximum power point and other existing losses.

Characteristic of PV module is shown in Figure 4.

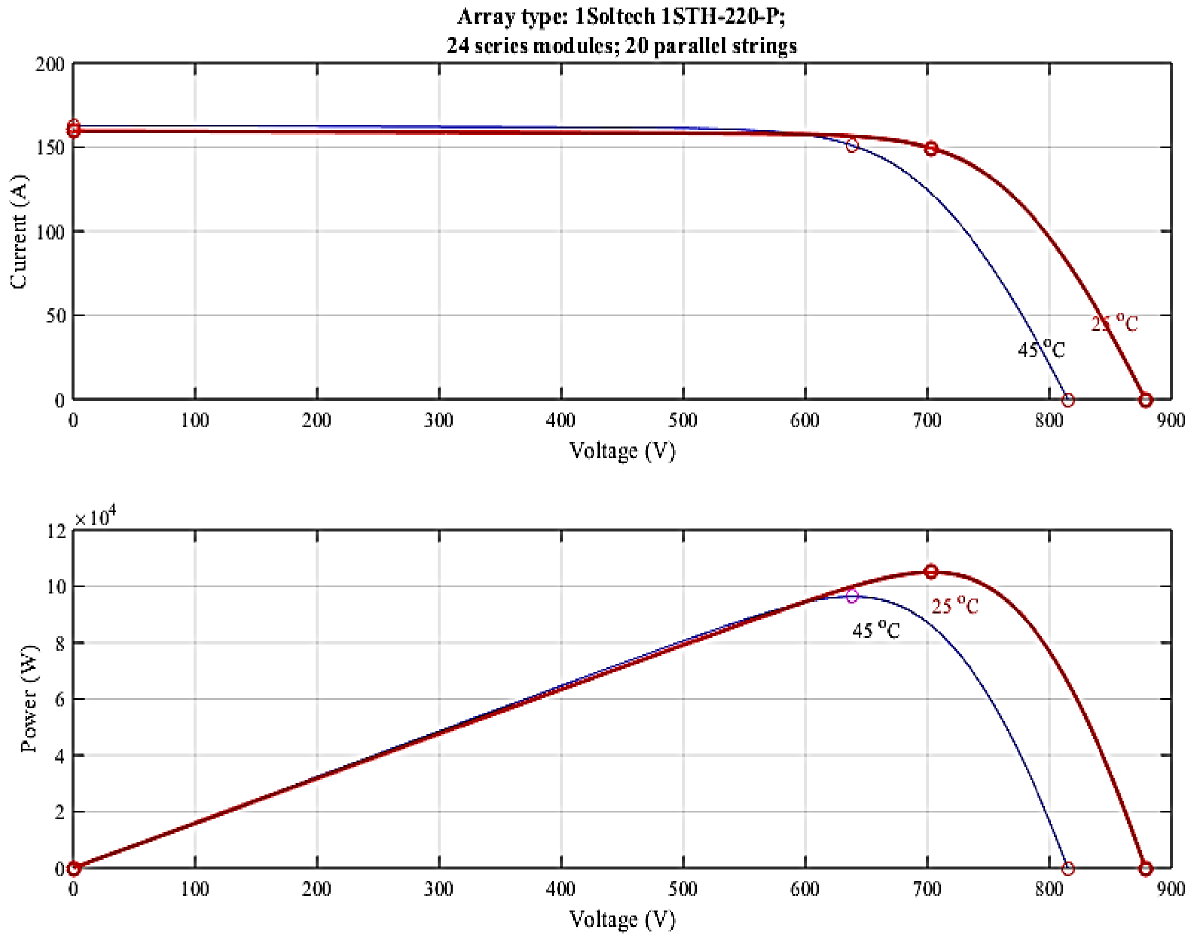

Fig.4: *Characteristic of PV Module.*

MPPT CONTROL FOR SOLAR ENERGY CONVERSION SYSTEM

To enhancing the efficiency of the photovoltaic panel MPPT is utilized. According to the maximum power point theorem, the output power of any circuit will be maximum whenever source impedance equivalent to the load impedance, so the MPPT algorithm is utilized to the problem of impedance coordination. In this paper work, the Boost Converter is utilized as impedance coordination device between input and output by changing the duty cycle of the converter circuit. Favorable position of the Boost is that low to high voltage is acquired from the accessible voltage. Control algorithm, the PV voltage and current are sensed and then estimate the power, after that find the change in power and voltage by comparing the previous power and voltage; if change in power is zero then duty cycle will be same as previous otherwise duty cycle will change according to the fallowed condition which is shown in Figure 5.

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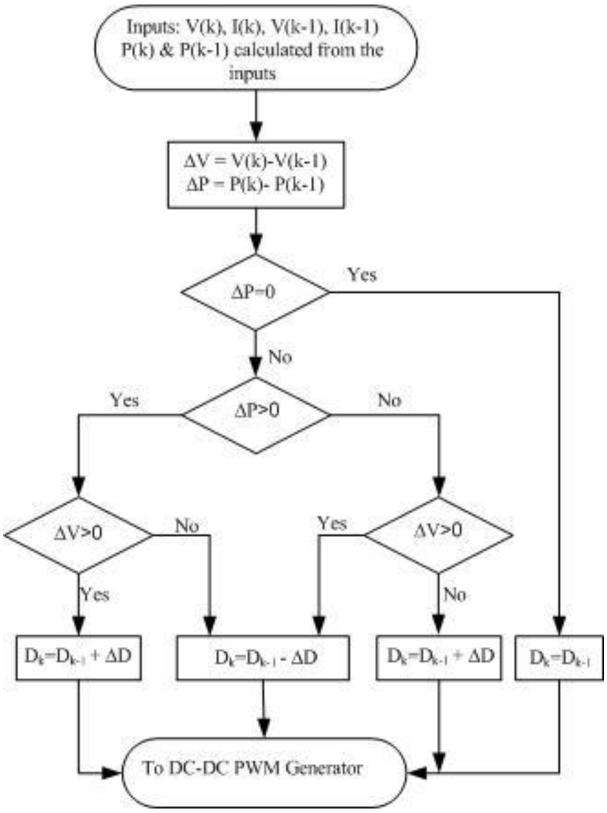

***Fig.5:** Perturb and Observe Control Algorithm.*

GRID CONVERTER CONTROL

Furthermost inverters function as present sources inserting a current that is sinusoidal and in phase with the grid voltage, with a power factor identical or very nearby to unity. It is required that the inverter synchronizes with the fundamental component of the grid voltage, even in the cases when the grid voltage is distorted or unbalanced or when the grid frequency varies. An example of synchronization in steady state for a three-phase system is shown in Figure 6, in which three phase wind photovoltaic co generation system with load.

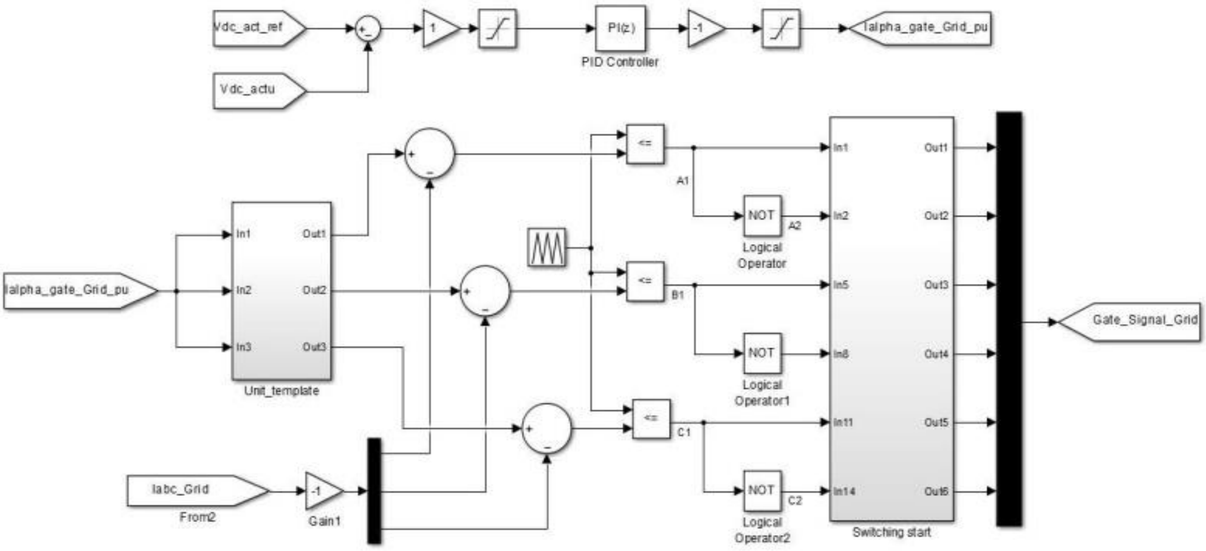

***Fig.6:** Grid Side Converter Control.*

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RESULTS AND DECEPTIONS

MATLAB Simulink™ 15a is used to evaluate the performance of the proposed co generation system and controllers. For the energy conversion system utilized in this paper, pitch angle is assumed zero and yaw control mechanism is not considered. It consists of an aerodynamic system based on wind speed model, wind power versus wind speed model and etc., permanent magnet synchronous generator (PMSG), a SPWM AC/DC converter, a DC/DC boost converter, a DC/AC inverter and AC filters, PID controllers.

Performance of PV System

Figure 7 shows the performance of PV system with time 0 to 4 second of 100kW rating solar irradiation increases and decreases to perform the system. This section is divided into five section in which first section represent to solar irradiation profile, second section present to PV voltage, third waveform represent to PV current which is depends on solar irradiations profile if irradiation is increases then PV current is increases and whenever irradiations decreases then current is decreases. Fourth wave shows the dc link voltage which is constant of magnitude 1400V. Fifth one represents to PV power generated.

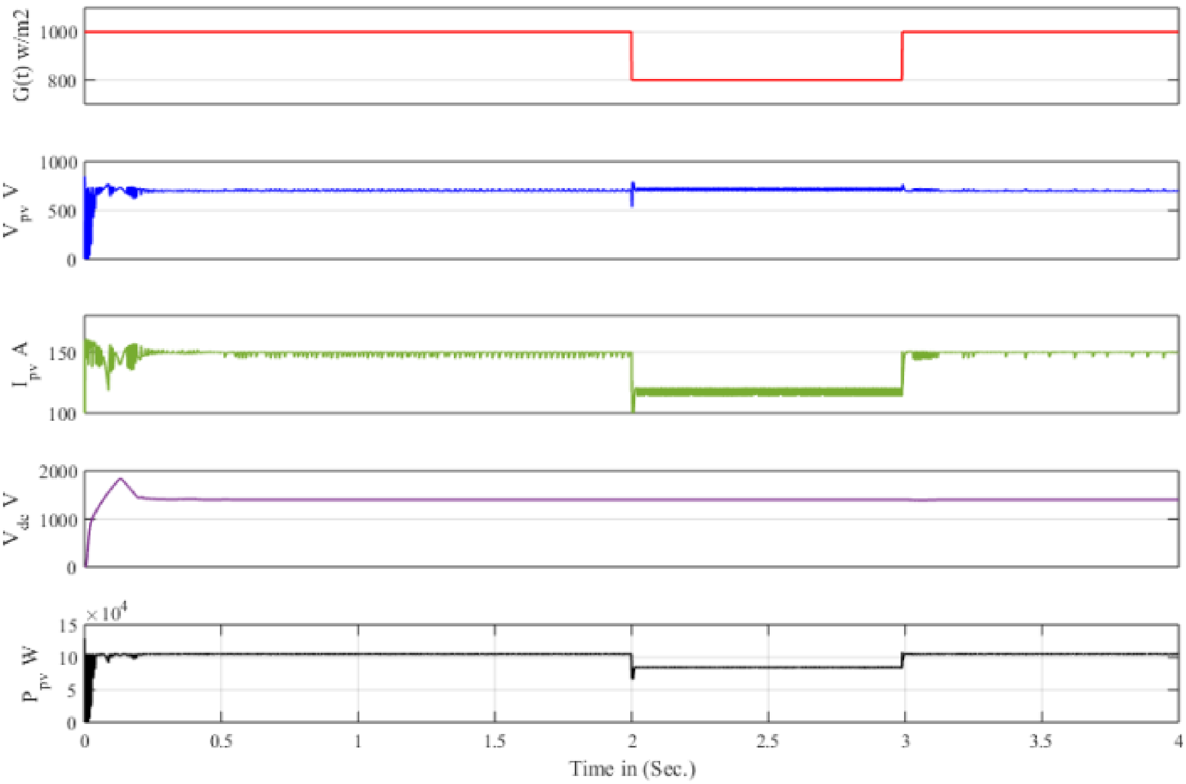

Fig.7: *Performance of PV System.*

Performance of Wind Energy Conversion System

Demonstrating the performance of proposed system under normal conditions when wind speed is fixed at 12 m / s with disturbance depicted in Figure 8. When PMSG operated near rated speed at 2.72 rad/s, active power generated from wind turbine is 2 MW and electromagnetic torque of generator is -0.68 MN-m (negative sign indicate that machine operated as generator). Machine side converter maintained DC link voltage at 1400V.

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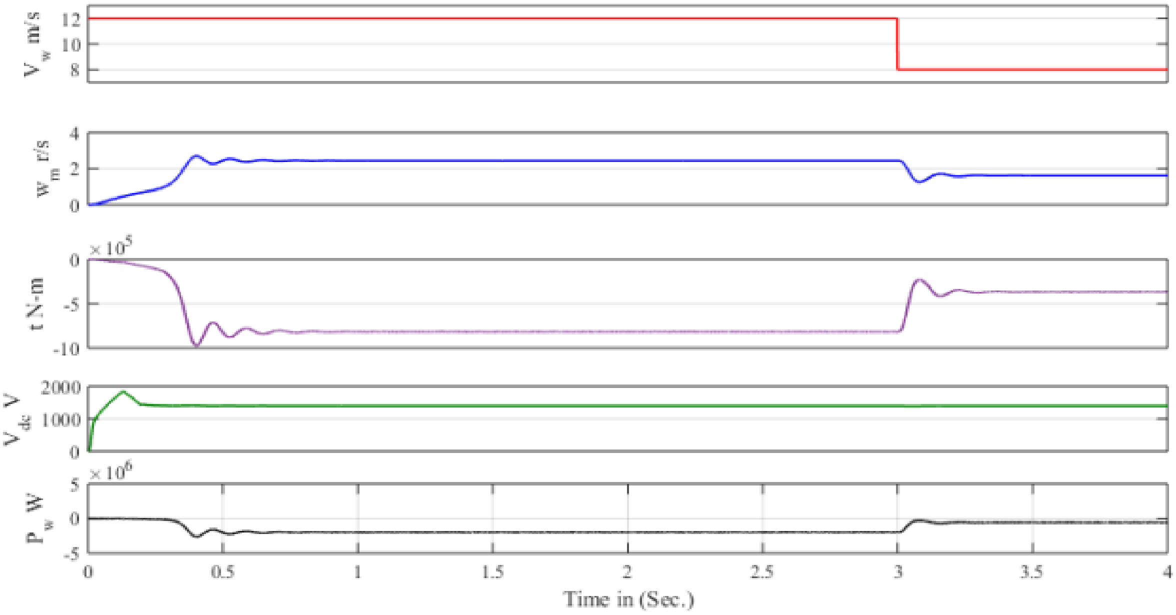

Fig. 8: *Performance of Wind Energy.*

Performance of Grid of Proposed System

Figure 9 shows the performance of grid of cogeneration unit. Here performance of proposed system analyzed, in which first wave represents to grid voltage second one to grid injected current third one is grid injected active power while fourth one reactive power wave. It is observed that whenever power generation by wind and PV increases then grid injected current is increases and therefore active power is increases.

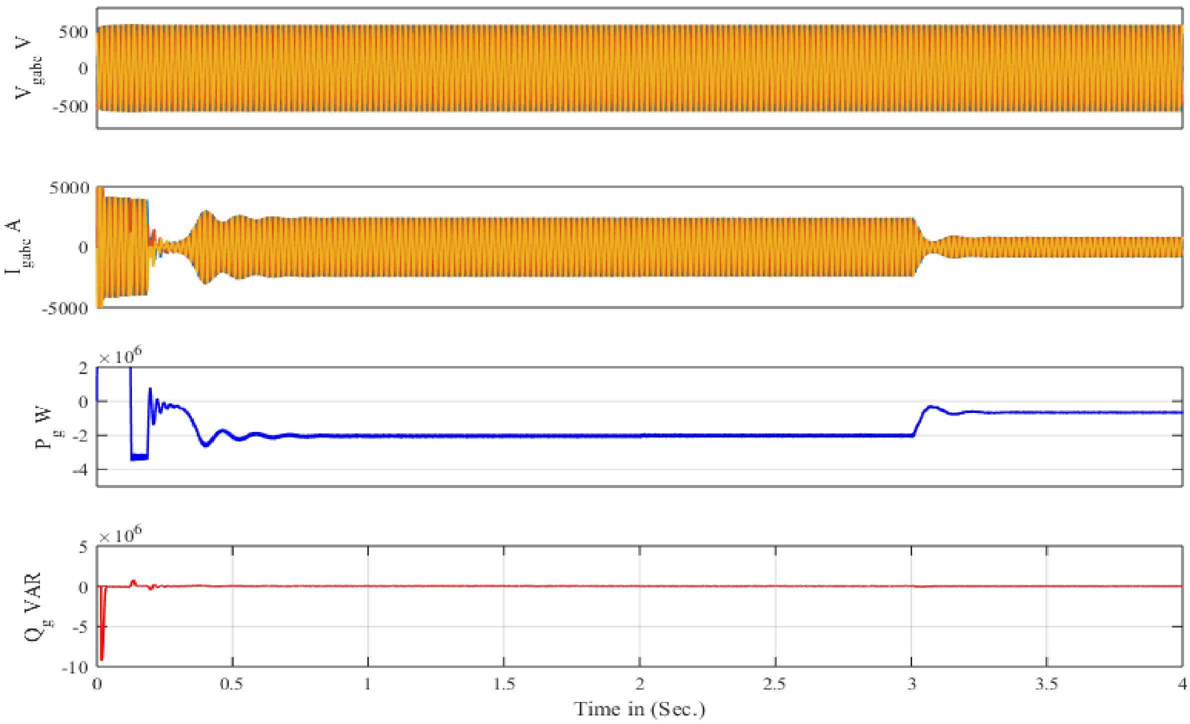

Fig.9: *Performance of Grid of Proposed System.*

CONCLUSION

Wind-PV sustainable energy based system with grid tied are increasing both in the number of installations and also in the rated power of each plant, and will cover a significant percentage of the electric generation mix. In this article, a comprehensive overview of grid-connected wind PV systems is presented. Different control techniques for proposed system such as PV mppt, WECS MPPT control. And Inverter control and it performance is validated through the MATLAB Simulink version 2015a. Grid side converter control is done to grid synchronization with power (active and reactive) control.

Appendix

Table.2: *PV Specifications.*

Variable	Description	Value
P_{PV}	Rated power	218W
V_{OC}	Open circuit voltage	36.6V
I_{SC}	Short circuit current	7.97A
V_{PVM}	MPPT voltage	29.3V
I_{PVM}	MPPT current	7.47A
N_s	Number of series module	20
N_P	Number of parallel module	24

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