ISSN (Print) : 2319-8613
ISSN (Online) : 0975-4024

Simulation Research on Integrated Hybrid PV- Wind Driven Generator Supplying AC/DC Micro-grid

Arjun Kumar GB[#1], Dr. Shivashankar*[2], Dr. Bhagwan Shree Ram[#3]
[#]Research Scholar, Dept. of E&CE, SVCE, Bengaluru, Karnataka, India
[1]arjungb@gmail.com
*Professor & Head, Dept. of E&CE, SVCE, Bengaluru, Karnataka, India.
[2]Chenduss123@gmail.com
[#]Power System Domain, LPU, Jalandhar, Punjab, India.
[3]bhagwan.24828@lpu.co.in

Abstract- Electricity demand in the current days is more compared to the power generated, the scarcity of power requirement is more for the day to day needs. In this paper, the modeling and simulation of a Permanent Magnet Synchronous Generator (PMSG) based wind power generation system under power system dynamic conditions are presented and also shows a simple method for converting wind energy and solar power hybrid system for AC/DC Micro-Grid application is introduced. Wind driven generator is coupled to tail vane by that energy is generated in all the directions which increases the total power and improves the efficiency of the system. A 3Ø bridge rectifier is used to supply AC micro-grid and Buck-Boost DC-DC converter is used to supply the DC micro-grid. This algorithm is implemented using simple microcontroller to generate gate pulses to the converters and track the power generation and consumption. A simple control algorithm is used to supply power for the DC/AC micro-grid from the small/large scale power. The simulation is supported by using MATLAB/SIMULINK tool under different grid and load conditions and the corresponding simulated results are encouraged. The working model of the proposed methodology has been implemented with hardware and results are shown.

Keywords — DC/AC, Micro-Grid, Induction generator, Wind Energy, Solar Energy, Power Converter.

I. INTRODUCTION

Today dominate energy source are primarily fossil based, like petroleum, coal, natural gas and atomic energy. But by the growth of populations and advancement of economies maybe in future these fossil based sources will be exhausted rapidly and other energies such as solar energy and wind [1].

Among all these renewable energy resources, power generation is most preferable from solar and wind energy. Power production from the Photovoltaic (PV) system and Wind Turbine, PV system is made by a semiconductor material which will become a PV cell, it has a silent working nature, low maintenance and pollution free behaviour, each cell transforms the solar irradiance directly into the electrical energy [2]. Similarly wind technology is also one of most popular source of energy. It can be classified into two categories such as horizontal axis wind turbine and vertical axis wind turbine. In the horizontal axis wind turbine, shaft of the rotor are coupled with generator which is arranged horizontally and located at the top of the tower. In the vertical axis wind turbine, shaft of the rotor are coupled with generator which is arranged vertically, and it can be placed near the ground. The wind turbine can be used to operate on either fixed or variable speed. The variable speed operation is mostly preferred to extract the maximum available wind power and high-power quality [3].

In present scenario, many of the remote areas are suffered due to lack of electricity. To meet the electricity demand the micro grids are operated for remote areas. These micro-grids are operated with the non-conventional energy sources like solar and wind turbines. It can be connected to the utility grid or can be operate separately off grid. The off-grid system is mostly used for the remote areas because in the some of the remote areas there is a lack of electricity due to problem in transmission lines. From this off-grid system it has the continue power supply with less losses and it is environmental friendly. It can also reduce the cost of the system [4].

The challenge is to build wind turbine with tail which runs the induction generator accurately with 360° rotation to produce maximum power. To extract maximum power from grid connected photovoltaic systems, DC-DC step up or step down chopper converter which is connected with the line commutated voltage source inverter. The fluctuating DC voltage from the photovoltaic panel is given as input to the voltage source inverter and the output voltage of the DC-DC Boost converter is always same with a conduction angle where the inverter is fixed at a suitable value ⋗90°. The value of grid voltage should be less than the constant DC-link voltage. It consists of full order model of the mechanical and electrical system of Permeant Magnet Synchronous Generator (PMSG) based wind power generation model Three-blade Horizontal Axis Wind Turbine (HAWT) with PMSG is used as the wind power generation unit. The turbine blade starts to rotate when the wind passes over the blade. The wind turbine produces the mechanical power by taking the input as wind speed. The shaft of the PMSG is connected with the Wind Turbine (WT) through the gearbox. The generated mechanical power is given as input to the PMSG, and it produces the electrical power with the help of permanent magnets. The generator terminal voltage is stepped-up to the suitable grid level using the step-up transformer, and it is connected to the power grid.

II. PROPSED WORKING DIAGRAM OF THE SYSTEM

The induction generator is operated in self-rotor excited system, the system can be operated over a wide range of speed for extracting Maximum Power available in the wind by rotating 360° as per the wind blows. Solar power is connected to the DC micro grid and battery is used to work in bidirectional to charge /discharge the power. The DC micro-grid supplies the power to the AC/DC loads depending on the requirement of the load with suitable converters to maintain constant voltage and frequency as shown in figure 1.

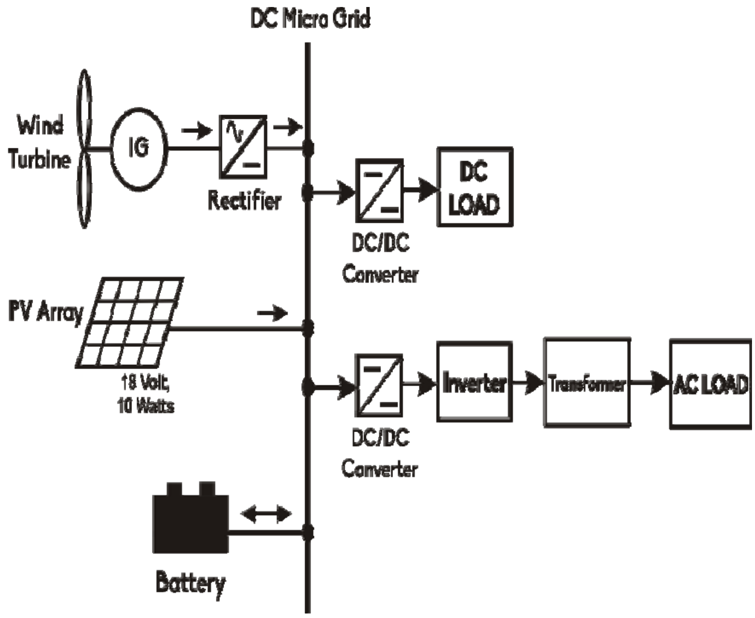


Figure 1:Propsed Working Diagram of the system

Performance of the DC micro-grid system is presented to some researcher with different set of voltage and suitable electrical subsystem interface with grid, the voltage drop, based on efficiency, cost, thermal limits and protection issues. Considering various parameter, they came to conclusion the system which as low voltage (24V) will give maximum performance for the application which has low power.

The power levels which are more than 3KW the level of dc voltage is 120V and it gives maximum operating efficiency as per the proposed windmill system and photovoltaic arrays generates 24V at DC grid and 230V at AC grid. By using suitable inverters, it changes the level of voltage along with energy storing system, like battery set. The whole control system has been implemented by using microcontroller.

III. Model-Based development of the system

A. Photovoltaic Cell

The silicon photocell is fabricated by forming a junction between two different materials in a single crystal of silicon, the silicon material by itself a poor conductor of electricity. By adding of a trace of another element, like arsenic or phosphorous, this contributes one electron to the silicon and makes it conducting. In this material, designated as n-type silicon, conduction is obtained by positive and the negative free electrons. The p-type silicon is formed by the addition of an element such as boron, or gallium that contains one less electron than silicon. The absence of electrons in p-type material creates positive charges or holes that also cause the silicon to become conductive. The boundary between the two regions, n-type and p-type in the single silicon crystal, establishes p-n junction.

B. Mathematical modeling of PV array.

The output current of the PV array is modeled by the following mathematical equations.

$$I_m = I_{pv}N_{pp} - I_0 N_{pp}\left[\exp\left(\frac{V + R_s\left(\frac{N_{ss}}{N_{pp}}\right)X\, I}{V_t\, \alpha N_{ss}}\right) - 1\right] \quad (1)$$

ISSN (Print) : 2319-8613
ISSN (Online) : 0975-4024

Where,

$I_{pv} = (I_{pv,n} + K_i \Delta T)\frac{G}{G_n}$

$I_{pv,n} = Photo\ current\ (A)$

$I_0 = Saturation\ Current\ of\ the\ array\ (A)$

$N_{pp} = Number\ of\ parallel\ cell$

$N_{ss} = Number\ of\ series\ cells$

$$V_t = \frac{KTN_s}{q} \quad (2)$$

Where,

$q = Electron\ charge\ 1.60217646 8 * 10^{-19} C$

$K = Boltzmann's constant\ 1.3806503 * 10^{-23}\ \frac{J}{K}$

N_s = Represent series connected cells

V_t = Thermal voltage (V)

$$I_{pv,n} = (R_p + R_s)\frac{I_{sc,n}}{R_p} \quad (3)$$

Where,

R_s and R_p $= series\ and\ parallel\ inherent\ resistance of\ the\ cell$

$I_{sc,n}$ = Short circuit current [A]

$$\Delta T = (T - T_{ref}) \quad (4)$$

Where,

T_{ref} = reference temperature = 298.15 K

$$I_o = \frac{I_{sc} + K_i \Delta T}{\exp\left(\frac{V_{oc,n} + K_v \Delta T}{\alpha V_t}\right) - 1} \quad (5)$$

I_0 are the photovoltaic, thermal voltage, photo generated current and saturation currents of the array

C. *Wind Energy*

Wind energy is one of the auspicious alternatives sources of energy. In the present crisis, the wind energy though not successful in large scale, will play a vital role in the rural areas, wind power can be successfully used for irrigation, lighting and running small scale industries. Winds on earth's surface are caused principally by unequal warming of the land and water by sun the variation in the thermal limits induce the course of air from one region to another region. Nearly 10 million MWs of wind energy are available in countries like USA, Netherlands and Denmark, strong and steady blow is there, and it can be successfully utilized through various mechanical conversions for power generation. Wind energy can supply economically a part of the power requirement.

The mechanical power developed by the wind turbine is,

$$P_m = \frac{1}{2}\rho A v^3 C_p(\theta, \lambda) \quad (6)$$

where ρ is the density of air, A is the swept area of the rotor in m^2, v is wind speed in m/s, C_p is the power coefficient, and it depends on the pitch angle of the rotor blades (θ) and tip speed ratio (λ). It can be calculated using the following relations,

$$C_p = 0.73\left(\frac{151}{\lambda_i} - 0.58\theta - 0.003\theta^{2.14} - 13.2\right)e^{-\frac{18.4}{\lambda_i}} \quad (7)$$

Where,

$$\frac{1}{\lambda_i} = \frac{1}{\lambda - 0.02\theta} - \frac{0.003}{\theta^3 + 1} \quad (8)$$

Tip speed ratio,

$$\lambda = \frac{\omega_r R}{v} \quad (9)$$

Where ω_r is the rotor rotational speed in rad/sec, and R is the radius of the rotor blade in m. Fig. 2 shows the C_p vs λ curve. The power coefficient can be calculated with the help of tip speed ratio.

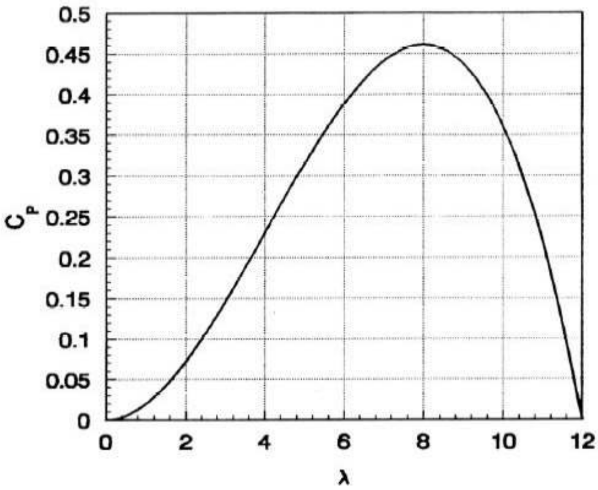


Figure 2: C_p vs λ curve

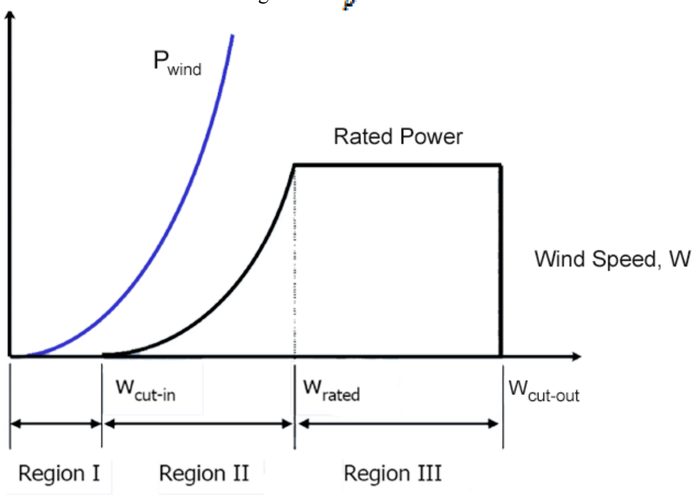


Figure 3. The power curve of WT.

The output power of the WT can be varied with the help of wind speed as shown in Fig. 3. The WT output power is zero when the wind speed is lower than the cut-in speed (W_{cut-in}). The turbine starts to operate once the wind speed goes more than the W_{cut-in}. The power output of the WT is a cubic relationship with the wind speed (it can be varied using the C_p) until the rated wind speed (W_{rated}) is reached. Then, the power output remains constant up to the cut-out wind speed ($W_{cut-out}$). The WT will go to shut down once the wind speed exceeds the cut-out wind speed. The WT designer sets the cut-in, rated and cut-out wind speed limits.

The dynamic model of the WT is given by,

$$J\frac{\omega_r}{dt} + B\,\omega_r = T_m - T_e \tag{10}$$

where J is the inertia coefficient, B is the friction coefficient, T_m is the turbine mechanical torque, and T_e is the electromagnetic torque.

D. Mathematical model of Permanent Magnet Synchronous Generator Wind Turbine.

The dynamic model of the PMSG is established by using the voltage and flux equations and it does not depend on the equations related to the rotor windings due to its permanent magnets. The voltage (V_s^{abc}) and magnetic flux (λ_s^{abc}) in the stator windings are given by (abc-3-axis),

$$V_s^{abc} = r_s i_s^{abc} + d\lambda_s^{abc} \tag{11}$$

$$\lambda_s^{abc} = L_s i_s^{abc} + \lambda_m \tag{12}$$

Where,

i_s^{abc} = 3 phase Stator winding current

r_s and L_s = Stator winding resistance and inductance

λ_m= Permanent magnet flux linkage

The dynamic model of the PMSG can be defined using the rotor reference frame.

The voltage on the d and q axis are given by,

$$V_{qs} = r_s i_{qs} + \omega_r \lambda_{ds} + \frac{d\lambda_{qs}}{dt} \quad (13)$$

$$V_{ds} = r_s i_{ds} - \omega_r \lambda_{qs} + \frac{d\lambda_{ds}}{dt} \quad (14)$$

λ_{ds} and λ_{qs} are the flux linkages of the d and q axis

Then,

$$\lambda_{ds} = L_d i_{ds} + \lambda_m \quad (15)$$

$$\lambda_{qs} = L_q i_{qs} \quad (16)$$

where L_d and $L_q$are the inductance of the d and q axis. i_{ds} and i_{qs} are the d and q axis stator currents. Substitute (15) and (16) in (13) and (14), we get,

$$V_{qs} = r_s i_{qs} + \omega_r L_d i_{ds} + \omega_r \lambda_m + L_q \frac{di_{qs}}{dt} \quad (17)$$

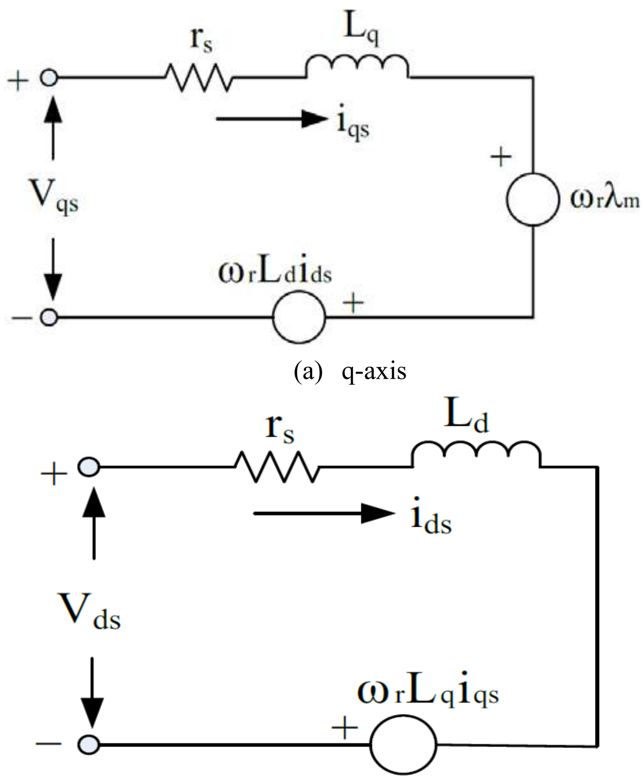
$$V_{ds} = r_s i_{ds} - \omega_r L_q i_{qs} + L_d \frac{di_{ds}}{dt} \quad (18)$$

The electromagnetic torque is given by,

$$T_e = \frac{3}{2} * \frac{P}{2} (\lambda_m i_{qs} + (L_d - L_q) i_{qs} i_{ds} \quad (19)$$

Where,

P= number of poles. The equivalent circuit of the PMSG which consists of the q and d axis circuit is shown in Fig. 4



(b) d-axis

Figure. 4. Equivalent circuit of the PMSG, (a) q-axis, (b) d-axis.

E. Simulation Results

The model calculation for the 5 MW systems

Given data:

Diameter of the Rotor blade (D) = 128 m

Radius of the rotor blade (R) = 64 m

$Swept\ area\ (A) = \pi R^2 = 12868\ m^2$

Blade length = 62.5 m

Average wind speed = 11-12 m/s

$W_{cut-in} = 3 - 5m/s$

$W_{cut-out} = 25m/s$s

Air density (ρ) = 1.225 kg/m3

Rotor rotational speed in rpm, $N_r = 5 - 11.7\ rpm$

Generator rotational speed in rpm, $N_g = 490\ rpm$

$Gearbox\ ratio = \frac{490}{11.7} = 41.83$

$Tip\ speed\ ratio\ (\lambda) = \frac{\omega_r R}{v} = \frac{\frac{2\pi N_r}{60} R}{v} = 6.5$

Pitch angle of the rotor blade (θ) = 2.4°

λ_i can be calculated by using the equation (8)

$\lambda_i = 6.4642$

Power coefficient (C_p) is calculated by using equation (9),

C_p= 0.37

Total power in the wind stream:

$$P_{total} = 0.5Av^3C_p \quad (20)$$

$P_{total} = 5MW$

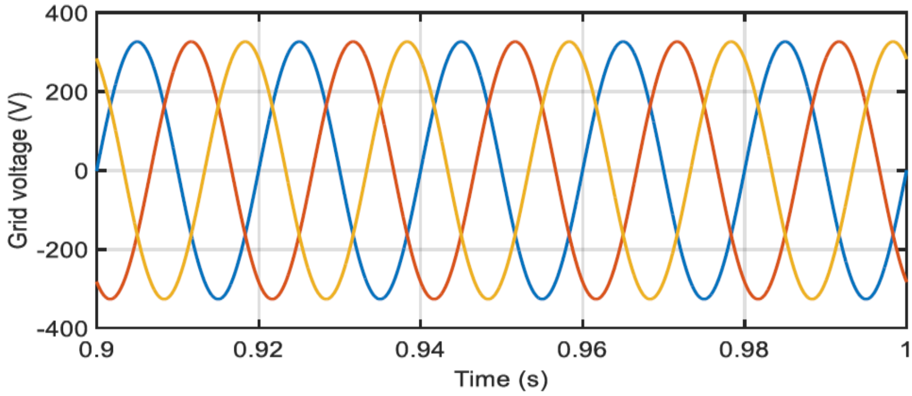
Table I. Grid simulation parameters

Parameter	Value
$Grid\ Voltage$	$V = 400\ V$
$Grid\ Frequency$	$f = 50\ H_z$
$Grid\ Resistance$	$R_g = 0.1\ \Omega$
$Grid\ Inductance$	$L_g = 0.01\ mH$
$DC\ link\ Capacitor$	$C_{dc} = 700\ \mu F$
$DC\ link\ Voltage$	$V_{dc} = 800\ V$
$Diode\ Rectifier$	$R_{sf} = 500\ \Omega, C_s = 250\ nF$
$3-phase\ linear\ RL\ load$	$P_{linear\ load} = 10\ to\ 20KW$
$Non-linear\ RL\ load$	$3-phase, R_L = 10\ \Omega, L_L = 60\ mH$ $1-phase, R_L = 20\ \Omega, L_L = 20\ mH$

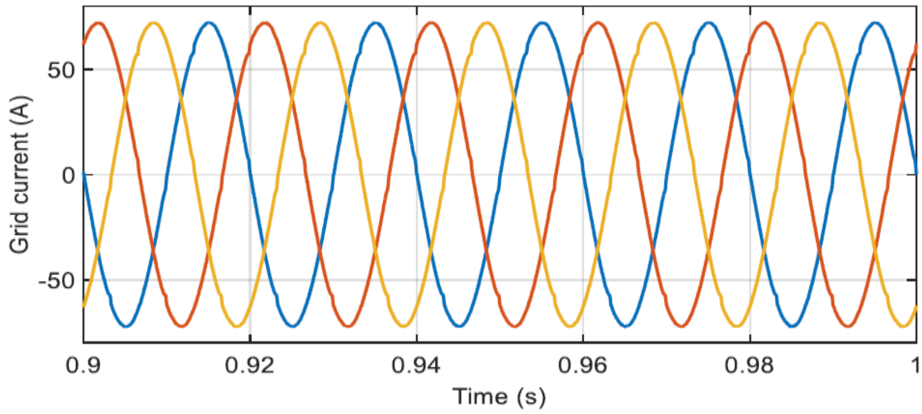
Simulated using MATLAB/SIMULINK tool under different grid & non-linear load conditions and the parameters used for simulation is tabulated in Table. I.

i. Power generation from PV & wind ($P_{pv} + P_{wind}$) is greater than the load demand.

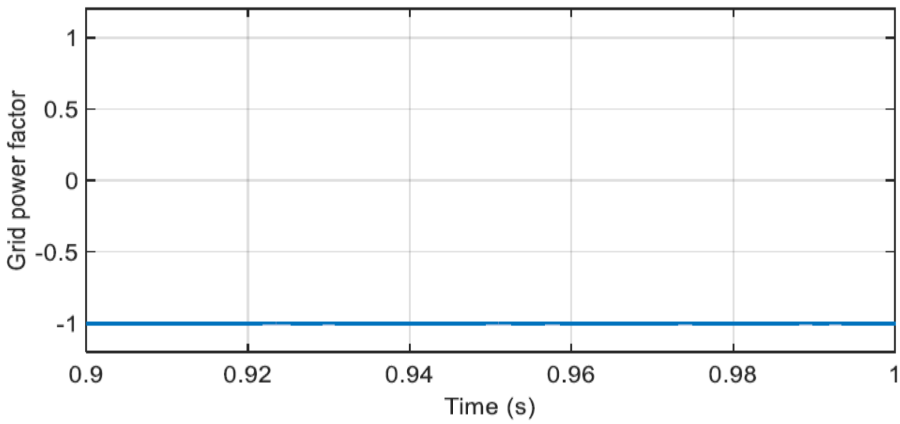
In this case, the hybrid PV/wind energy sources are interconnected with three phase bridge rectifiers in order to supply the power to the balanced linear & non-linear loads, the load current and load voltage is shown in Fig. 5(a) & 5(b). The output voltage of both PV and wind is boosted through DC-DC booster to the 800V at DC grid which is maintained constant by Interfacing Voltage Source Inverter (IVSI) control in order to control the real power is shown in Fig. 5(d). The total amount of power generated from both PV at 200W/m^2 & wind at 10m/s meets the total load demand and further the surplus power is injected to the grid as shown in Fig. 5(e) and the corresponding grid power factor is shown in Fig. 5(c).



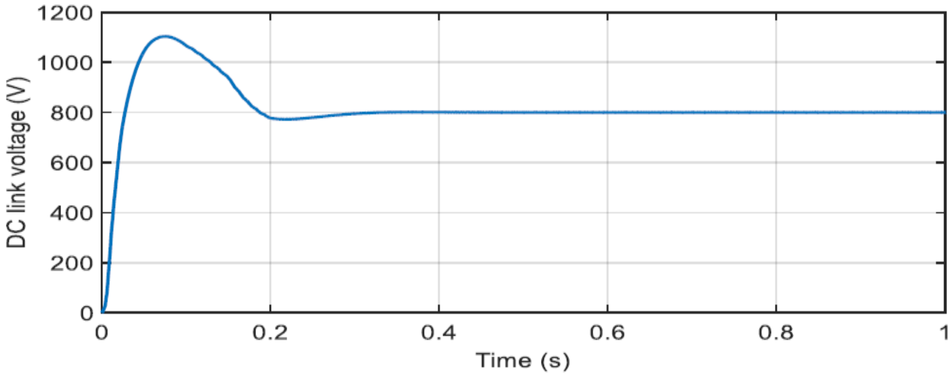
(a) Grid voltage



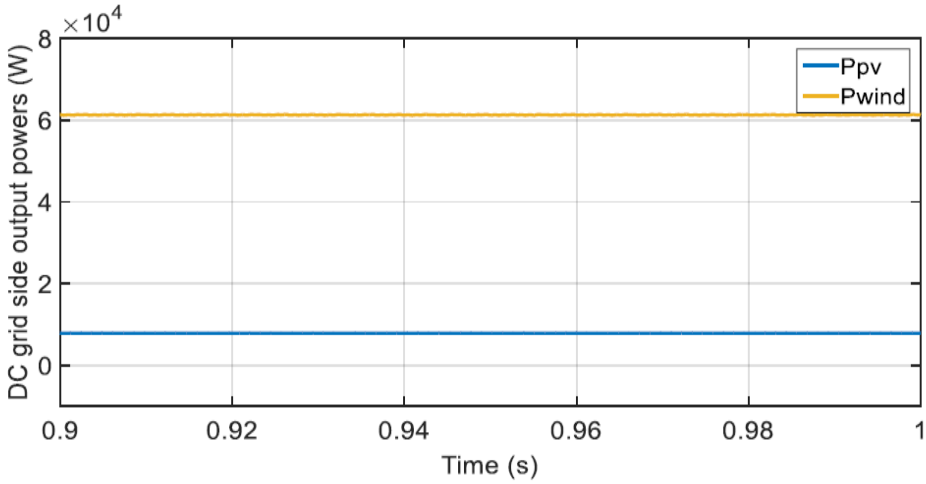
(b) Grid current



(c) Grid power actor



(d) DC link voltage

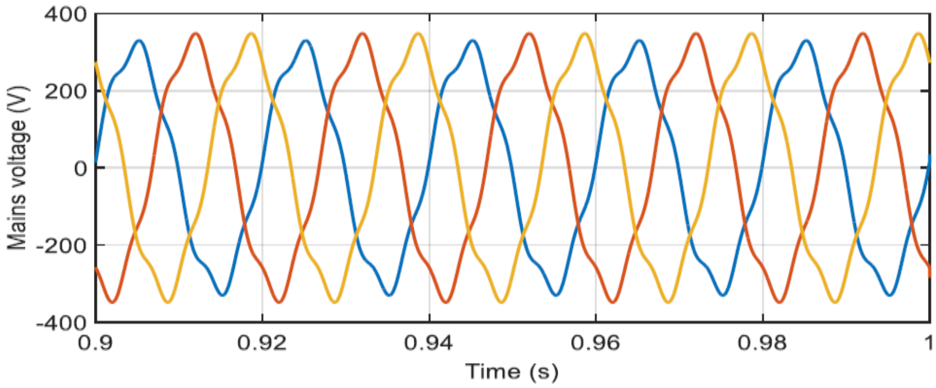


(e) DC grid side output powers

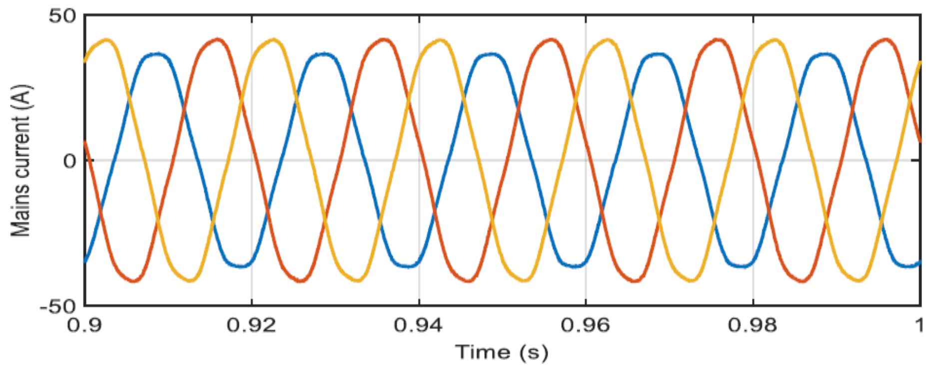
Figure 5. (a) Grid voltage, (b) Grid current, (c) Grid power factor, (d) DC link voltage, (e) DC grid side output powers

ii. B. Power generation from PV & wind ($P_{pv} + P_{wind}$) is less than the load demand

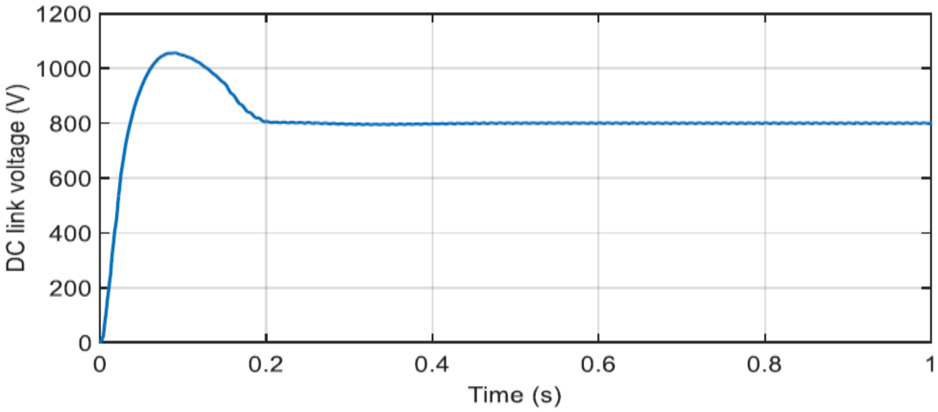
In this case, the hybrid PV/wind energy sources are interconnected with three phase bridge rectifiers in order to supply the power to the unbalanced linear & non-linear loads, the load current and load voltage is shown in Fig. 5(a) & 5(b). The output voltage of both PV and wind is boosted through DC-DC booster to the 800V at DC grid which is maintained constant by IVSI control in order to control the real power is shown in Fig. 5(c). The total amount of power generated from both PV at 800W/m^2 & wind at 5m/s is less than the total load demand and hence the remaining power received from the grid to fulfil the total load demand as shown in Fig. 5(e) and the corresponding grid power factor is shown in Fig. 5(d).



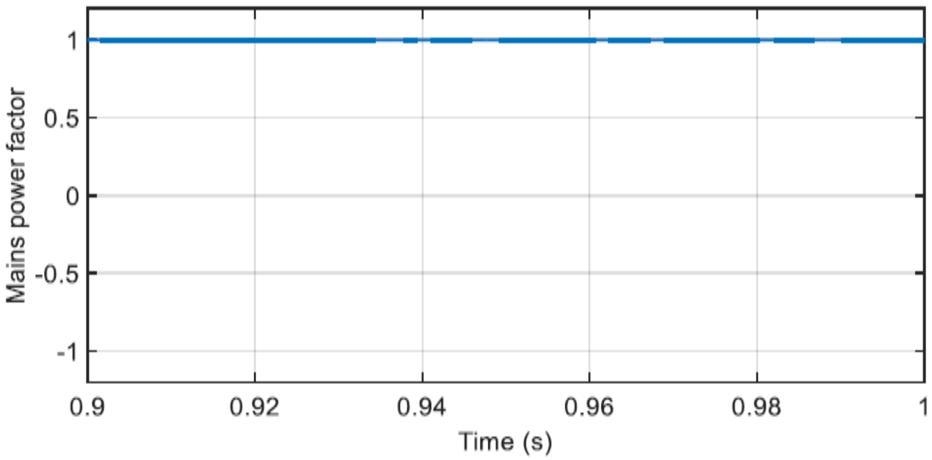
(a) Grid voltage



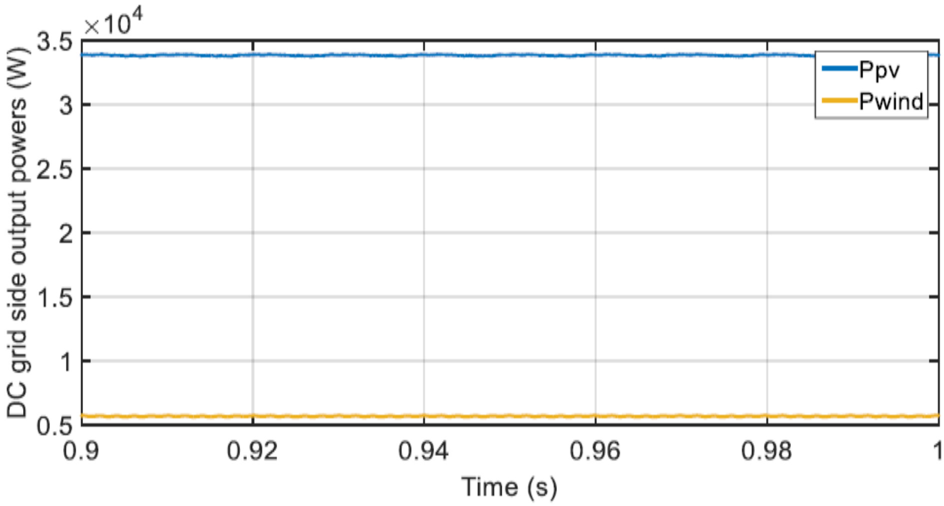
(b) Grid current



(c) DC link voltage



(d) Grid power factor



(e) DC grid side output powers

IV. Complete Assembled Hardware and software of Hybrid Smart DC/AC Power System

Table II: Specifications of the proposed system.

Components/Devices	`Ratings
Induction Generator	0-60V, 3ph AC
Solar PV Array	18V, 10 Watts, 0.83A
Battery	12V, 40Ah
Rectifier	16RA120, 16NA120 IRI
Converter	MOSFET IRF44
Inverter	MOSFET IRF44
Transformer	Step-up 24/230V
Microcontroller	AT89852
PWM	IC 4047

Table III: Specifications of Windmill

Parameters	Specifications
Power	100 Watts
Diameter of rotor	1.2 m
Number of Blades	3
Blade Material	FRP
PMA Capacity	100 – 200W
Rated Wind Speed	8 m/Sec
Start-up or Cut-in Speed	2.5 m/Sec
Survival Wind Speed	30
PMA Output	0-60V, 3ph AC
Mounting	Tubular Fitting type3.5m ht

A. Blade construction and tail construction of the wind turbine.

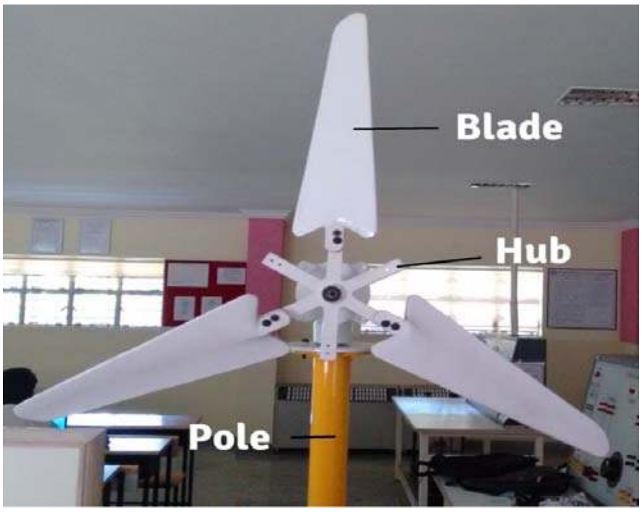


Figure 6: Blade construction of the wind turbine

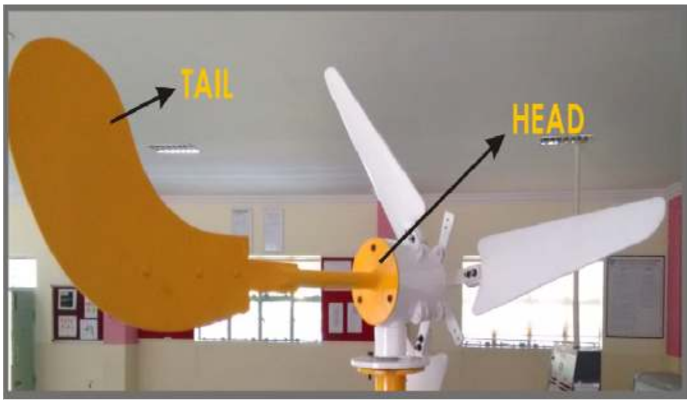


Figure 7: Tail Construction of the wind turbine

The above Figure 6 and 7 shows the Blade construction and tail construction of the wind turbine. The turbine blade is built with suitable composite materials such as carbon fiber and polyepoxide. Epoxy mixtures offer great performance and confirmed reliability in many challenging applications including components for aerospace and wind turbine blades and it has good mechanical properties like corrosion resistance, withstands high temperature and high stiffness and reduced weight on finished parts as shown in Figure 6 and 7.

B. Simulation results of DC-DC converter and bridge inverter.

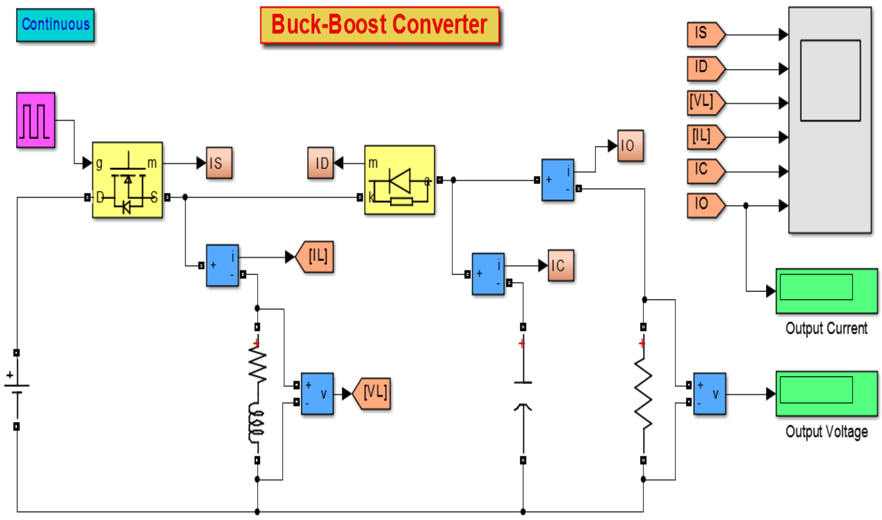


Figure 8: Simulation of buck-boost converter.

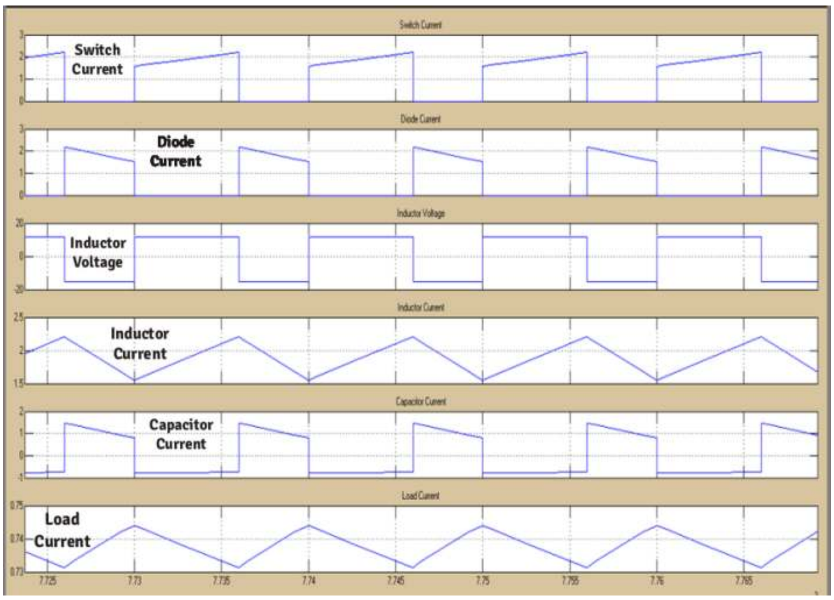


Figure 9: Simulated Results of buck boost converter currents.

Figure 8 and 9 shows the Simulink model and simulated results of DC to DC converter for the DC operated loads. The input is given from dc micro-grid and output is stepped up or steeped down using buck boost converter for the DC load applications.

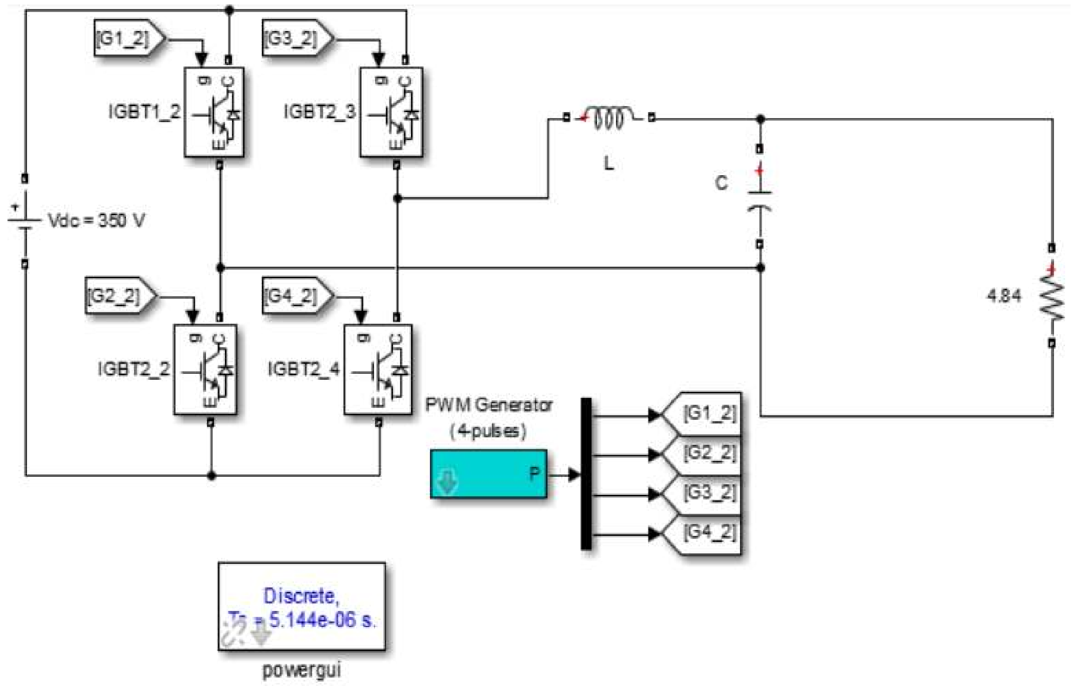


Figure 10: Simulation Model of Bridge Inverter

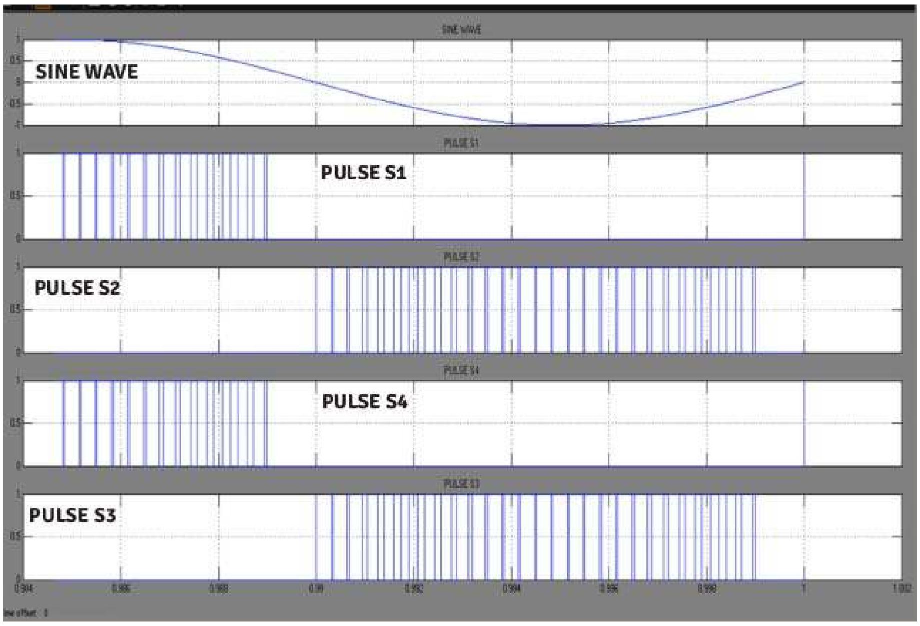


Figure 11: Simulated Results of Gating Pulses

Figure 12: Simulated results of Gating Pulses and input and output voltage.

The above Figure 10, 11 and 12 shows the Simulink model of bridge inverter for the AC operated loads. The input is given from DC micro-grid and output is given to the transformer. Inverter is controlled by Current Source Inverter and it is for the different AC load applications

The charge controller is used to maintain the constant DC output voltage to the inverter and the control of inverter is done by using microcontroller PWM signals the voltage is maintained constant, using transformers to stepped up or down depending on application and solar system which establish the AC/DC off-gird or AC/DC micro-grid.

V. CONCLUSION

In current situation, many nations support the consumers and private organization involved in energy sector, to producing electrical energy from using alternate resource like Non-Conventional Source of energy which moving forward to the establishment of AC/DC off-gird or AC/DC micro-grids. In this view, Dc micro-grid systems attract more focus on low voltage application which is provided from sustainable power sources. Especially, this voltage choice is best fit for domestic utilizations. The distribution network has been verified and validated through simulation studies for different cases. The work has been carried out for 2 cases, one with balanced undistorted grid & balanced non-linear load and the other with unbalanced distorted grid & unbalanced non-linear load. To ease operation and maintenance of DC micro-grid system operated by consumer, a simple circuit configuration and control algorithm are required. Windmill and solar photovoltaic cell produces the maximum power by rotating 360°. Hence, this is implemented by hardware module is presented a simple algorithm and circuit topology for DC/AC micro-grid applications supplied from a minor scale wind energy conversion system.

REFERENCE

[1] D. Committee, I. Power, and E. Society, “IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems," IEEE Power and Energy Society, pp. 1–29, 2014.
[2] B. Singh, K. Al-haddad, and A. Chandra, “A Review of Active Filters for Power Quality Improvement,” IEEE Trans. Ind Electron, vol. 46, no. 5, pp. 960–971, 1999.
[3] V. Soares, P. Verdelho, and G. D. Marques, “An instantaneous active and reactive current component method for active filters,” IEEE Trans. Power Electron., vol. 15, no. 4, pp. 660–669, 2000.
[4] S. Mikkili and A. K. Panda, “Real-time implementation of PI and fuzzy logic controllers based shunt active filter control strategies for power quality improvement,” Int. J. Electric. Power Energy System., vol. 43, no. 1, pp. 1114–1126, 2012.
[5] R. Perveen, N. Kishor, and S. R. Mohanty, “Offshore wind farm development: Present status and challenges,” Renew. Sustain. Energy Rev., vol. 29, pp. 780-792, 2014.
[6] P. M. Anderson, and A. Bose, "Stability simulation of wind turbine systems," IEEE Trans. Power App. sys., vol. 102, pp. 3791-3795, Dec. 1983.
[7] J. G. Slootweg, S. W. H. De Haan, H. Polinder, and W. L. Kling, "General model for representing variable speed wind turbines in power system dynamics simulations," IEEE Trans. power system. vol. 18, no. 1, pp. 144-151, Feb. 2003.
[8] O. Carranza, E. Figueres, G. Garcerá, and R. Gonzalez-Medina, “Analysis of the control structure of wind energy generation systems based on a permanent magnet synchronous generator,” Appl. Energy, vol. 103, pp. 522-538, Mar. 2013.
[9] M. Asadi, A. Jalilian, and H. F. Farahani, “Compensation of Unbalanced Non Linear Load and Neutral Currents Using Stationary Reference Frame in Shunt Active Filters,” Proceedings, 14th IEEE Int. Conf. Harmonics and Quality of Power , pp. 1–5, 2010.
[10] T. A. Youssef, A. T. Elsayed, A. Berzoy, and O. A. Mohammed, “Power quality enhancement for nonlinear unbalanced loads through improved active power filter control,” Proceedings, IECON 2014 - 40th Annu. Conf. IEEE Ind. Electron. Soc., pp. 5202–5207, 2014.
[11] E. Pouresmaeil, M. F. Akorede, D. Montesinos-Miracle, O. Gomis- Bellmunt, and J. C. Trujillo Caballero, “Hysteresis current control technique of VSI for compensation of grid-connected unbalanced loads,” Electr. Eng., vol. 96, no. 1, pp. 27–35, 2014.
[12] Y.-M. Chen, C.-S. Cheng, and H.-C. Wu, “Grid-Connected Hybrid PV/Wind Power Generation System with Improved DC Bus

Voltage Regulation Strategy," Twenty-First Annu. IEEE Appl. Power Electron. Conf. Expo. 2006. APEC '06., no. c, pp. 1088–1094, 2006.
[13] P. G. Arul, V. K. Ramachandaramurthy, and R. K. Rajkumar, "Control strategies for a hybrid renewable energy system: A review," Renew. Sustain. Energy Rev., vol. 42, pp. 597–608, 2015.
[14] M. Singh, V. Khadkikar, A. Chandra, and R.K. Varma, "Grid Interconnection of Renewable Energy Sources at the Distribution Level with Power- Quality Improvement Features," IEEE Trans. Power Del., vol. 26, no. 1, pp. 307–315, 2011.
[15] M. G. Villalva, J. R. Gazoli, and E. R. Filho, "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays," IEEE Trans. Power Electron., vol. 24, no. 5, pp. 1198–1208, 2009.
[16] N. S. Jayalakshmi, D. N. Gaonkar, and K. S. K. Kumar, "Dynamic modeling and performance analysis of grid connected PMSG based variable speed wind turbines with simple power conditioning system," 2012 IEEE Int. Conf. Power Electron. Drives Energy Syst., pp. 1–5, 2012.