International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-6, April 2019

PV-Wind Integrated Grid with P&O and PSO MPPT Techniques

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***Abstract*: Hybrid grid is a new novel model developed in order to satisfy the demand of electricity required by various utilities. Mainly the characteristics of any smart grid depends on the performance optimization, reliability and efficiency. PV alone can't generate the power continuously over a period of time such constraint can be overcome by integrating Wind to form a hybrid grid. In the proposed paper it consists of PV array, Wind turbine, doubly fed induction generator, converters and controlling parameters. Optimization techniques like P&O and PSO MPPT are used to maximize the generated power and its comparative results are proposed through MATLAB/SIMULINK**

Index Terms: ***Hybrid Grid, PV array, Wind system, Power electronics devices, control systems, MPPT techniques***

1. INTRODUCTION

Conventional Sources are the major sources utilized to generate electrical energy and supplied to the utilities. Due to certain limitations like its availability, effect to the environment, global warming etc. We are in search of alternative energy sources like Non-conventional energy sources. Due to the increase in demand of electricity day by day it is becoming a difficult task to generate electricity from fossil fuels keeping in view of effects caused to the environment and to overcome from such certain issues by not only maintaining supply with respect to demand to the utilities but also continuity is also important. Non-conventional energy sources like Solar and Wind are capable to generate energy to meet the demand. [1-4]

Energy sources like Solar and wind are intermittent at various climatic conditions so to generate maximum output from them all the time as they vary time to time and depends on the environmental conditions. Such constraints can be overcome by adopting optimization techniques like MPPT controllers. These techniques are used to track maximum at various climatic conditions. Many MPPT techniques are studied and in this paper Perturb and observation and Particle swarm optimization are implemented to track the maximum power. DC to DC converter is employed with MPPT which generates the duty cycles required to operate and gives some fixed dc as output. The input to the Wind is in form of kinetic energy and this energy is converted into mechanical energy by using wind turbine and then fed to squirrel cage induction generator to convert into electrical output.[5-7]

Revised Manuscript Received on April 18, 2019.

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In this paper modeling and control strategy of PV and wind integrated hybrid grid system is proposed.MATLAB/Simulink software is used to check the operation of system proposed.

II. MODELING AND SYSTEM DESCRIPTION

A Design of Photo Voltaic System:

The equivalent circuit of solar cell is being studied since many years. It generally consists of photo current, diode, series and shunt resistor. General PV model is built in MATLAB/SIMULINK and verified the characteristics

Photo voltaic current expression is as follows:

$$I_{PV} = I_L - I_O\left\{\exp\left[\frac{V + I_{RS}}{nV_T}\right] - 1\right\} - \frac{V_J}{R_{SH}}$$

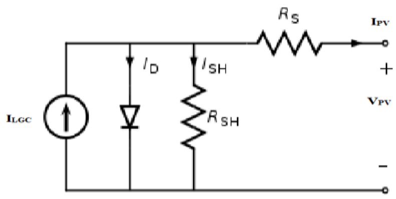

Figure 1. Solar cell equivalent circuit

$$I_{PV} = I_{LGC} - I_D - I_{SH} \quad (1)$$

Where

$I_{LGC} = light\ generated\ current$

$I_D = diode\ current$

$I_{PV} = photo\ voltaic\ curret$

$I_{SH} = shunt\ current$

$$V_j = V + I_{PV}R_S \quad (2)$$

$V_{PV} = voltage\ across\ output\ terminals$

$V_J = voltage\ across\ both\ diode\ and\ resistor\ Rsh\ (V)$

$I_{PH} = output\ current(A)$

$R_S = seires\ resistance$

$$I_D = I_O\{\exp\left[\frac{V_J}{nV_T}\right] - 1\} \quad (3)$$

$I_O = reverse\ saturation\ current$

$n = diode\ density\ factor$

$K = Boltzman's\ constant$

$T = absolute\ temperature$

$$V_T = KT/q \quad (4)$$

By Ohm's Law

$$I_{SH} = \frac{V_J}{R_{SH}}$$

$$I_{PV} = I_{LGC} - I_O\left\{\exp\left[\frac{V + I_{RS}}{nV_T}\right] - 1\right\} - \frac{V_J}{R_{SH}}$$

$$I_{PV} = I_{LGC} - I_O\left\{\exp\left[\frac{V+I_{RS}}{nV_T}\right] - 1\right\} - \frac{V+I_{RS}}{R_{SH}} \quad (5)$$

From the above equation we get the output as I_{PV} which is shown in the following figure 2

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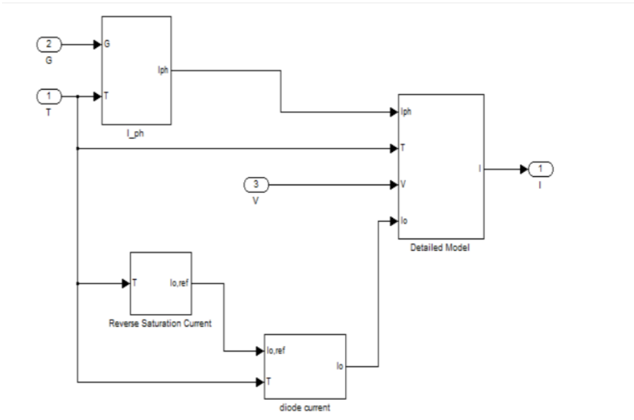

Figure 2.General PV model is built in MATLAB/SIMULINK

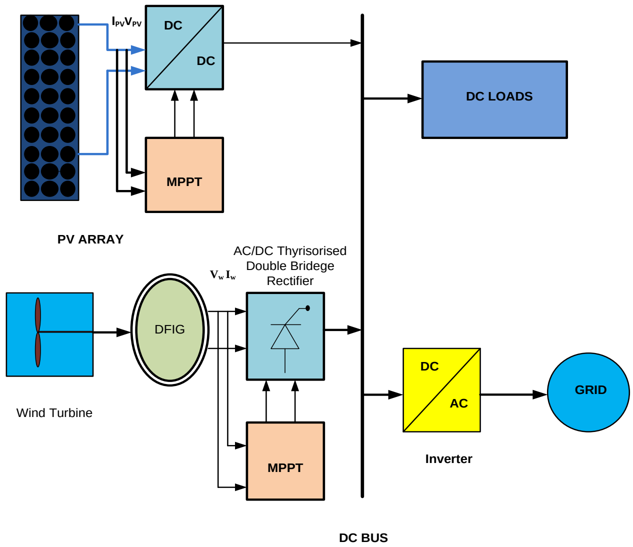

Figure 4 Block diagram of Proposed

B. Photovoltaic Control Diagram:

The inputs to the photovoltaic panel are solar irradiance and temperature which are nonlinear because they are intermittent in nature which changes due to climatic conditions all the time which make the output power to change continuously. To overcome such problems we need to use MPPT technique to operate the PV module. In the proposed model we used Perturb and observe and Particle Swarm optimization Techniques to achieve maximum power as the output and its comparative results are tabulated. The control structure is designed in MATLAB. The outputs are I_{pv} and V_{pv} which ae given to the proposed MPPT's which periodically functions by raising or decaying the operating current of a PV array and compares previous value output and if the condition is satisfied the control system moves the PV operating point in the same direction or else in the reverse direction. It generates the duty pulses if the condition is satisfied and gives it to the dc/dc converter which further increases its output voltage to higher voltages by using boot converters.[7-8]

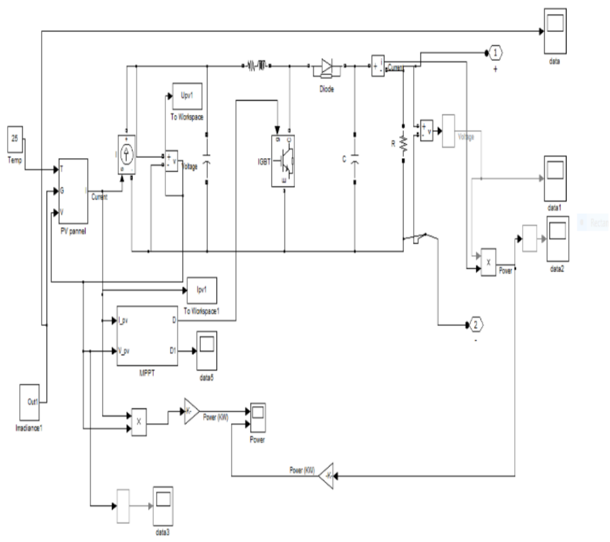

Figure 3. SIMULINK Diagram of PV

C. Design of Wind Turbine System:

Wind is also a form of solar energy which is produced due to fast moving airs. The input to the wind turbine is Wind speed, generator speed as feedback and pitch angle. The output of wind turbine is mechanical toque which is given to the DFIG which consists of stator and rotor windings. Winding of stator are grid connected and wind turbine drives rotor thus converts the mechanical torques into electrical power which is transferred to the grid through windings of stator [15]. The output power of wind turbine is given by

$$P_m = \rho A \frac{1}{2} V_{wind}{}^3 C_P(\lambda, \beta) \quad (6)$$

Where P_m= mechanical power

C_p= coefficient of turbine

λ = tip speed ratio

β = pitch angle

A= turbine swept area

ρ =air density

Coefficient of $C_p(\lambda, \beta)$ used is considered from[16] and given by

$$C_P(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4\right)e^{\left(\frac{-c_5}{\lambda_1}\right)} + C_6\lambda \quad (7)$$

Where C_1 and C_6 depends on the WTR and design of blade and λ_1 is given by the following equation

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (8)$$

Further equation (6) can be written for specific values of A and ρ as shown below

$$P_{m-pu} = K_p C_{p-pu} V^3{}_{wind-pu} \quad (9)$$

Wind turbine is implemented whose inputs are wind speed, generators speed as feedback and pitch angle.

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The output of the turbine T_m is applied to the shaft of generator based on generated speed and Power. The developed output electrical power is grid connected (stator side). Thus the electrical power developed experiences change in frequency and amplitude which is due to change in wind speed to mitigate such constraints and maintain controllable dc voltage we used three phase two winding transformer with six input ports with appropriate phase angles for the double bridge ac/dc rectifier whose firing angle is controlled by PI controller.[8-9]

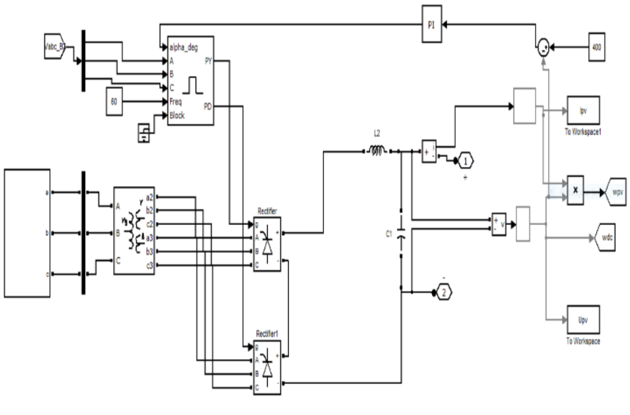

Figure 5. SIMULINK Diagram of Wind system

III MPPT'S TECHNIQUES EMPLOYED

A.Perturb and observe

At different conditions of irradiance and temperature maximum power is tracked and delivered to load. It calculates Power(P(t)) by measuring I and V and continuously it compares with the previous power once if there is an increment in step size then the output voltage is varied and the duty pulses are generated which is given to the controlled switch IGBT of DC/DC boost converter[10-13]

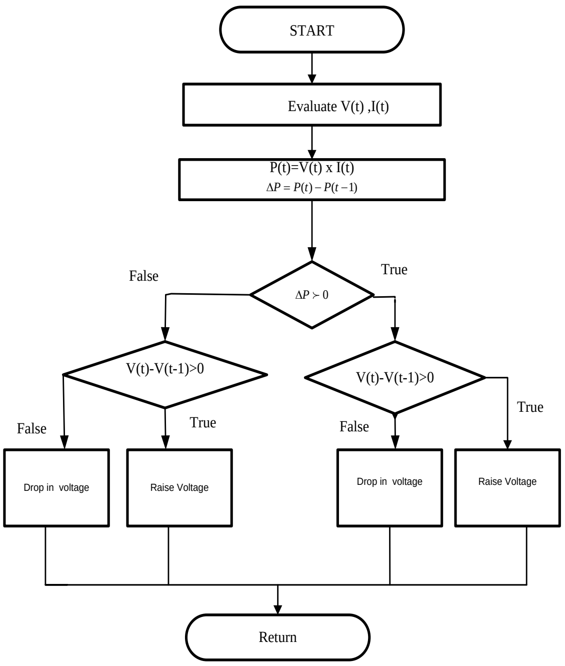

Figure 6. P&O flow chart

B. Particle Swarm Optimization:

PSO is widely used optimization technique which works on intelligent movement of swarms. In search space it contains number of swarm particles moving around to track the best solution. All the particles tacks towards neighboring particle to produce the P_{best} . Same process is repeated in such a way that a global best value is tracked among the best particles called global best ($G_{best)}$ and these both values are stored and derived by the velocity function.[14]

BASIC PSO FUNCTION

Velocity function

$$Vi(k+1) = Vi(k) + t1i(Pi – Xi(k)) + t2i(G – Xi(k))$$

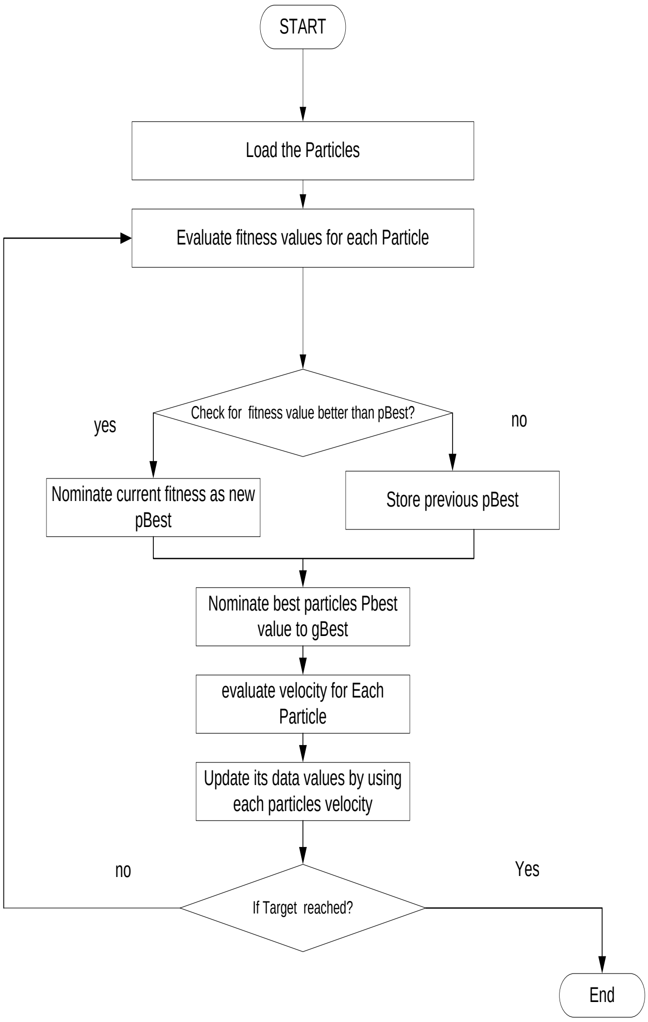

Figure 7 PSO flow chart

IV SIMULATION RESULTS AND DISCUSSIONS:

The I-V and P-V curves are shown in figure 8(a),8(b) the obtained power and current of PV model depends on its inputs and operating voltage.

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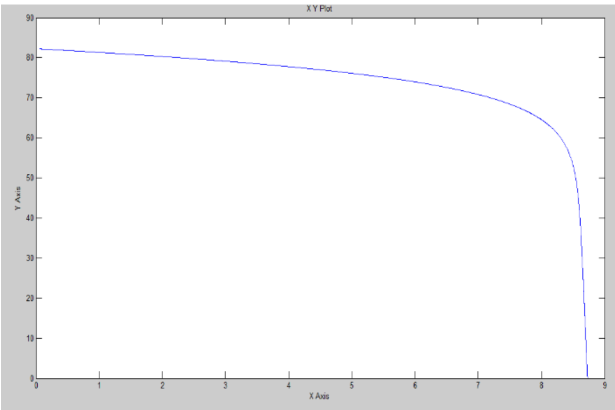

Figure 8(a) Solar System I-V Curves

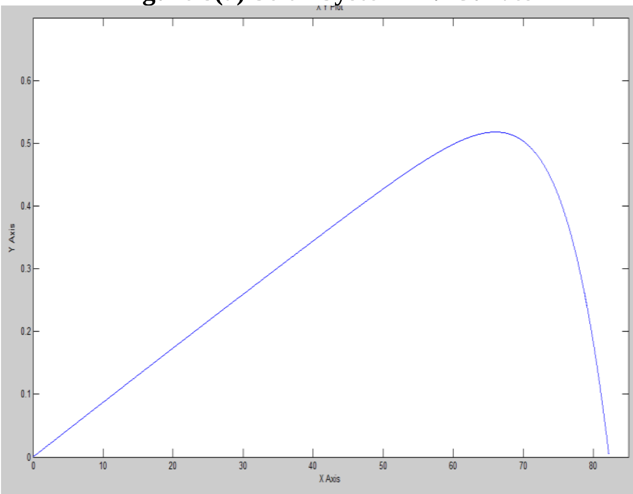

Figure 8(b) Solar System P-V Curves

Table I PV panel specifications

Name	Range
No.of cells and connections	60
Maximum power (P_m)	225 W
Voltage at P_m	29.76 V
Current at P_m	7.55 A
Short circuit current (I_{sc})	8.27 A
Open circuit voltage	36.88 V

WTIG Parameters

Table II WTIG parameters

Name	Range
Base wind speed	9 (m/s)
Maximum power at base wind speed	1 (pu)
Coefficient (C_1-C_6)	[0.516,116,0.4,21,0.0068]
Nominal performance coefficient	0.48(pu) for [$\beta=0^0$, $\lambda=8.1$]
Rotor type	Squirrel cage
Nominal voltage (L-L)	460 V
Nominal frequency	60(Hz)
Nominal Power	200 (H.P)
Nominal revolutions per minute	1785 rpm
Stator resistance	0.01282(p.u)
Rotor resistance	0.00702(p.u)
Stator inductance	0.05051(p.u)
Rotor inductance	0.05051(p.u)
Magnetizing inductance	6.77(p.u)
Inertia Constant	0.3096(s)
Friction factor	0.0114(p.u)
Pairs of poles	2

Characteristics of Wind turbine model corresponding to various values for generator speed and generator power in per unit are shown in figure 9.WT output depends on the wind speed and generator speed.

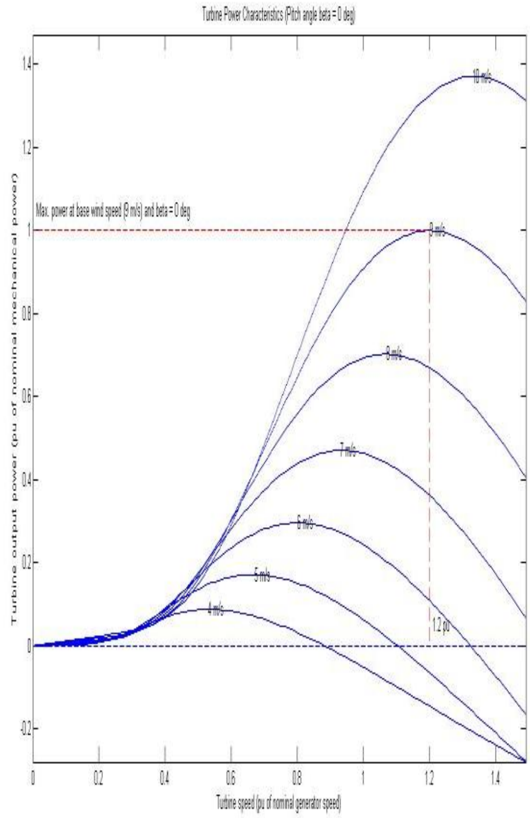

Figure 9. Wind Speed characteristics

Table III Parameters of Boost type dc/dc converter

Name	Range
Initial capacitor voltage	400 V
Capacitance	200 µF
Input port series resistance	0.5
Switching loss current	0.03

Table IV: Parameters for double bridge rectifier

Name	Range
Reference voltage	400 (V)
Snubber resistance of one thyristor	2(kilo ohms)
Snubber capacitance of one thyristor	0.1(µF)

Internal resistance of one thyristor	1 (mH)
Filter inductance	66 (mH)
Filter capacitance	3300(µF)
Pulse width of synchronized 12-pulse generator	80(^{0})
Proportional gain of PI voltage control system	2
Integral gain of PI voltage control system	20

Table V Transformer parameters used in double bridge rectifier

Name	Range
Input winding parameters $(Y_g)[V_1\ R_1\ L_1]$	[460(V) 0.00025(p.u) 0(p.u)
Oput winding parameters $(Y)[V_2\ R_2\ L_2]$	[230(V) 0.00025(p.u) 0.0024(p.u)
Nominal power	120(KW)
Nominal Frequency	60 Hz

Our aim is to check the characteristics of proposed system during simulation process over a period of time. The inputs to the PV and wind are irradiance and wind speed which are gathered from [15] and shown in figure 10(a),10(b) and 7. Even though the inputs fluctuate over a period of time in both the systems they are maintained constant voltage shown in figure 8, 9 by using proper power electronics based converters. The main propose of using P&O and PSO MPPT's is to set the dc/dc and double bridge rectifier reference current (I_{ref}) so that PV array and Wind output operates at maximum power point by sequentially increasing or decreasing the operating currents. From figure 11(c) we could observe that during time period 8.40am and 19.00 pm the power from solar is very less due to nonexistence of radiation. To overcome such constraint we integrated wind system to PV by choosing from wind speed profile as show in figure 10(b) as input to the wind turbine and integrated both together to a common dc bus and maintained at a stable voltages show in figure 11(a),11(b) and by using inverters converted power is transferred to the loads which are maintained at 60 Hz 440V line to line.

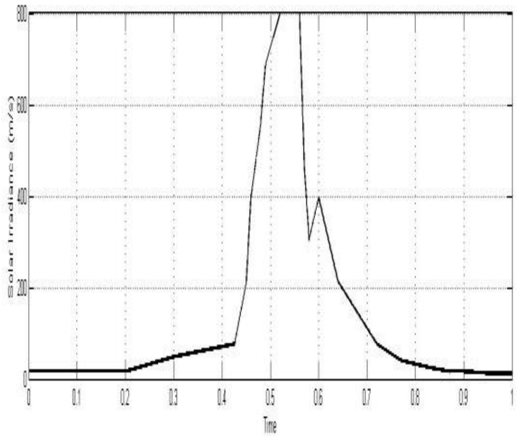

Figure 10(a). Solar Irradiance of PV panel

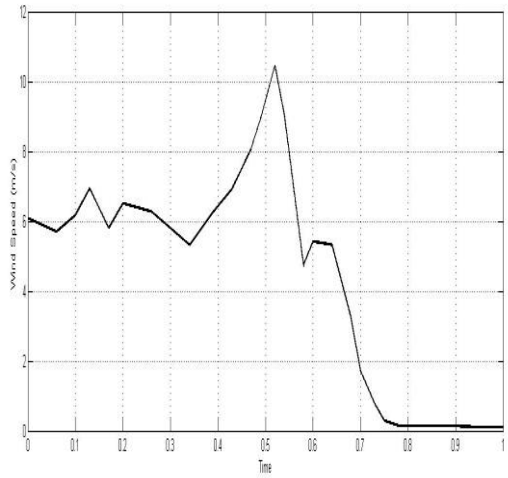

Figure 10(b) wind profile

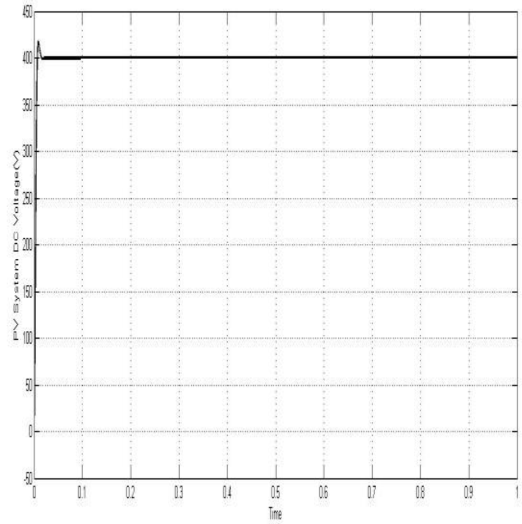

Figure 11(a). DC/DC converter output voltage using P&O

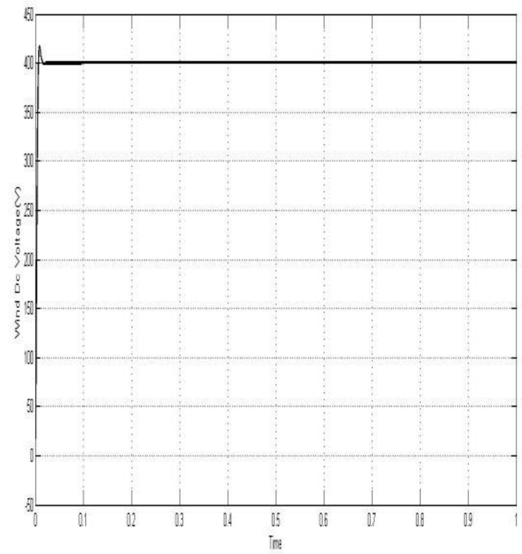

Figure 11(b). wind DC output voltage using P&O

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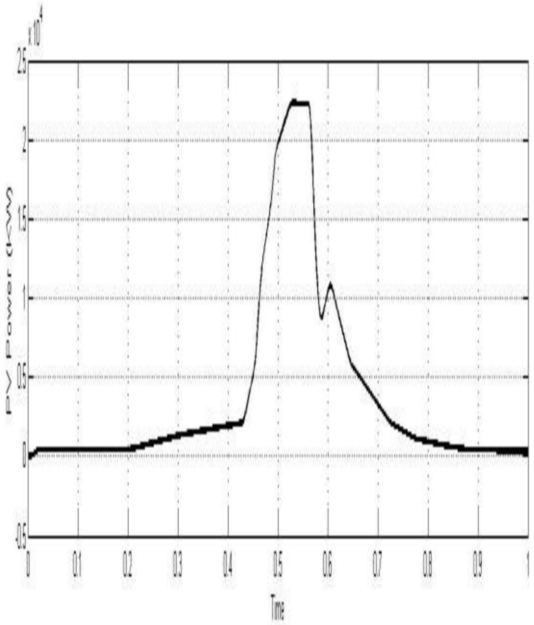

Figure 11(c) Solar Power output using P&O

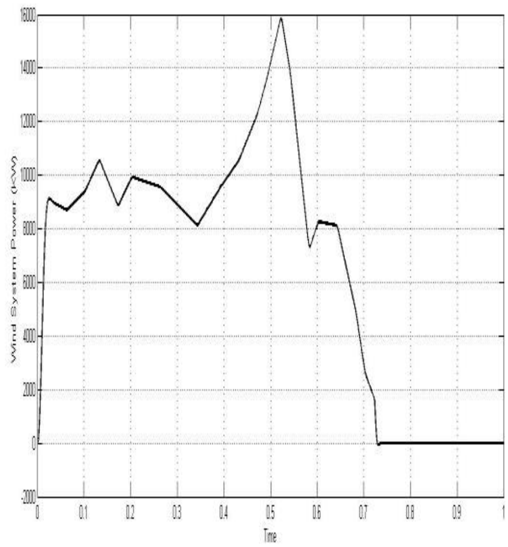

Figure 11(d) Wind output power using P&O

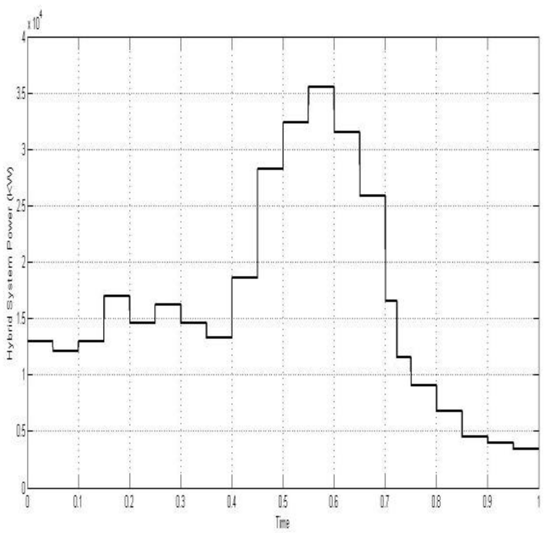

Figure 11(e) Hybrid power Delivered to load using P&O

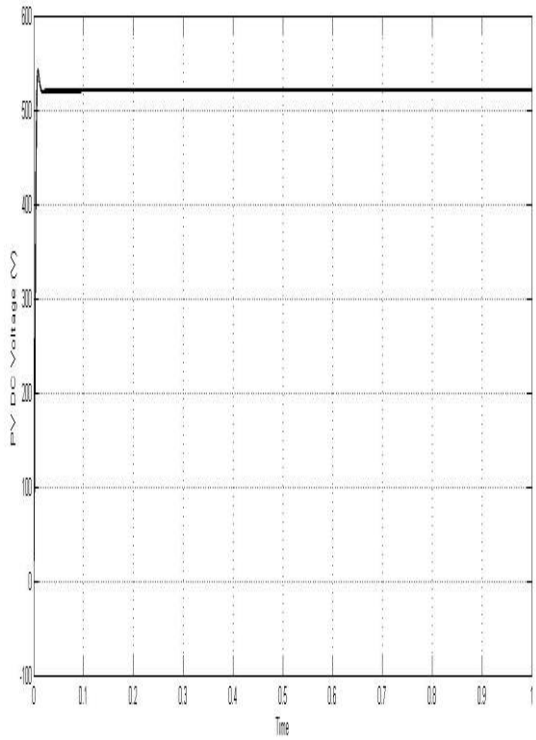

Figure 12(a) DC/DC converter output voltage using PSO

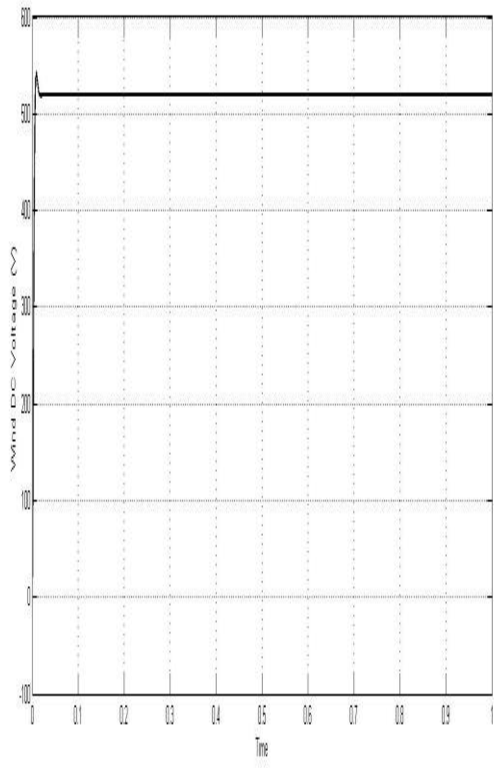

Figure 12(b) wind DC output voltage using PSO

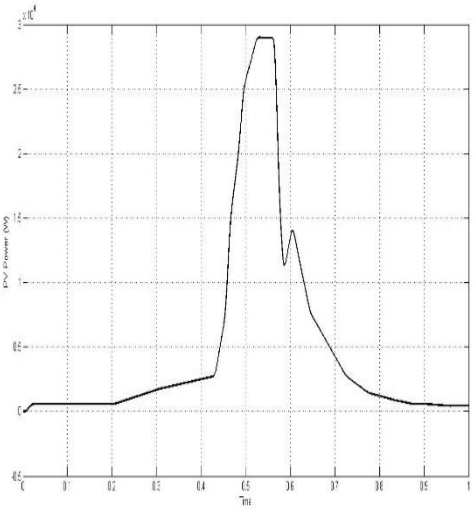

Figure 12(c) Solar Power output using PSO

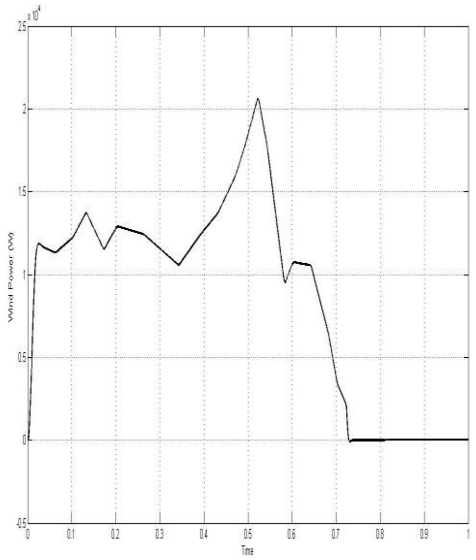

Figure 12(d) Wind output power using PSO

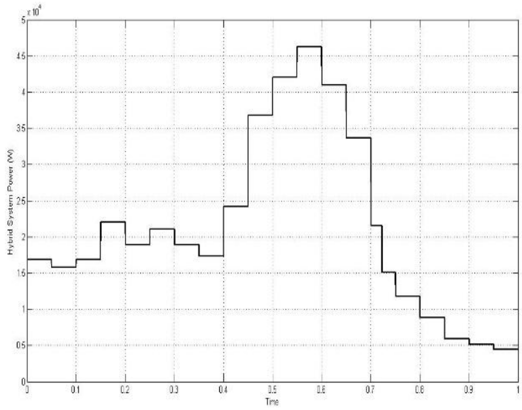

Figure 12(e) Hybrid power Delivered to load using P&O

Comparative Result between P&O and PSO MPPT

S.No	Type of MPPT	PV Power (KW)	Wind Power (KW)	Hybrid System Power (KW)
1	P&O	2.3	1.6	3.58
2	PSO	2.8	2.1	4.63

V. CONCLUSIONS:

In this paper a new method of PV/Wind systems is designed and modelled using MATLAB and its control strategies are studied. Since both the sources are intermittent in nature and we know that solar energy is not existed during certain intervals of time during 24 hours a day. So in order to overcome such constraints Wind system is integrated to the PV plant and thus it becomes an integrated system to continuously supply the load. The total data has been collected from [16] and its performance characteristics were observed by implementing P&O and PSO MPPT's and the comparative results are also obtained.

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