Simulation of Wind Solar Hybrid Systems Using PSIM

Akhilesh P. Patil, Rambabu A. Vatti and Anuja S. Morankar

Abstract— **The renewable energy sources like wind and solar energies are combined to increase the total power generation and thereby increase the efficiency of the system. The combination also provides a means to overcome the intermittent nature of the solar and wind renewable energy sources, since one source can be used for power generation when other is not available. AC-DC converters are used convert the Alternating voltage of the wind generator to a constant DC value which can be used to charge the batteries or later converted to AC voltage to drive AC loads. A Maximum Power Point Tracking (MPPT) system using boost converter is designed to extract maximum possible power from the sun when it is available. An inverter stage is implemented using Sinusoidal Pulse width Modulation (SPWM).This method provides better harmonic reduction since Harmonic content is detrimental for the generator lifespan, heating issues, and efficiency. Simulations are carried out in PSIM software and results in the form of graphs are provided to highlight the merits of the system under consideration.**

Key words— **AC-DC converters, Maximum Power PointTracking(MPPT),Sinusoidal Pulse Width Modulation(SPWM), Powersim(PSIM).**

I. INTRODUCTION

Continue use of non renewable sources like coal, petrol, natural gas raises environmental issues like global warming, green house effect etc. so to cope up the rising energy demand and to reduce the the environmental issues an optimistic view for the renewable energy sources over the past few years. The renewable sources like solar, wind, hydro have the substantial capabilities to compensate for the increasing energy demands. Commercial Wind turbine Generators located in wind-farms are alone capable of producing large amount of power in MW's, but the presence of wind is a highly unreliable factor since at some time it can be very high beyond the safe operating point ,particularly in situations like tornadoes ,or some time it can be very less ,probably lesser than the cut-off wind speeds require to start a wind mill. Same is the case for the solar energy .Though it is present in diffused form throughout the day ,but the irradiation levels keep on varying depending on the natural conditions such as shadows cast by clouds, objects, trees etc. The intermittent natures of the wind and solar energy make them unreliable sources of energy. However, by combining these two intermittent sources and by implementing maximum power point tracking (MPPT) algorithm, the system's power transfer efficiency and reliability can be improved significantly. When one source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the power difference. [1].In order to perform the MPPT control for the PV panel the boost converter topology is used. This DC-DC converter has very high efficiency which is greater than ninety percent.

In this paper the complete Wind Solar hybrid system is simulated in PSIM software[2][3]. Powersim (PSIM) is a fast simulation software used at circuit level or system level with a friendly user interface [2]. It is especially used in simulation of power converters and control circuits.

Wind Solar Hybrid system is shown in figure 1, the wind generation part consists of Wind Turbine block, the AC generator for the wind turbine which is Permanent Magnet Synchronous Generator and the rectifier stage which consists of voltage feed backed Three-Phase Fully-Controlled Bridge Converter using SCR's (Silicon Controlled Rectifiers).The solar generation part consists of Solar module(PV) and the maximum power point tracking controller implemented using boost converter. The outputs from both these individual sources (which is DC after the rectification of wind generator output) is combined and can be used to charge DC batteries at a constant voltage or can be converted into AC voltage to drive AC loads. For this purpose single phase transistorized Inverter is used and the Pulse width Modulation technique used for the inverters is Sinusoidal Pulse Width Modulation(SPWM). For the purpose of simulation the load to the inverter is simple R-L load is taken under consideration.

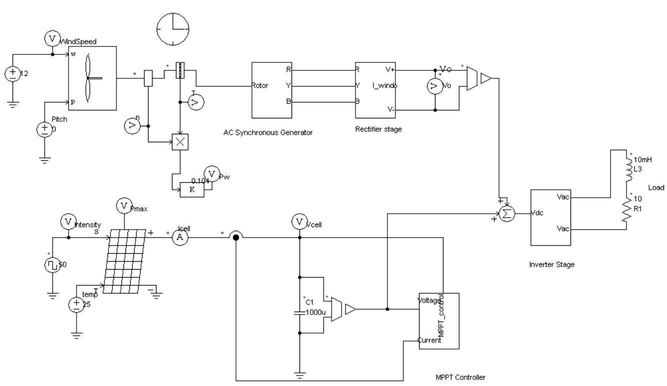

Fig 1: Block diagram of Wind solar hybrid system

Akhilesh P. Patil , Rambabu A. Vatti and Anuja S. Morankar are with Dept. of Electronics, Vishwakarma Institute of Technology, Pune, India, Emails: patil.akh@gmail.com, rambabu.vatti@vit.edu, anuja.morankar@yahoo.com

II .VARIOUS COMPONENTS USED IN HYBRID SYSTEMS

1)Solar Module Block:

In this paper we have used the Physical model of the Solar Module as can simulate the behavior of the solar module more accurately, and can take into account the light intensity and temperature variation. The various attributes for this block are as follows.
For the purpose of simulation the MSX-60 photovoltaic module was taken as reference [4].

Solar Module (Physical Model)	
Number of cells	36
Standard Light Intensity	1000lux
Ref. Temperature Tref	25 degree centigrade
Series Resistance Rs	0.008 ohm
Shunt Resistance Rsh	1000 ohm
Short Circuit Current Isc0	3.8 A
Saturation Current Is0	2.16e-8 A
Band Energy Eg	1.12 eV
Ideality Factor A	1.2
Temperature Coefficient Ct	0.0024 A/degree C or A/degree K
Coefficient Ks	0

Table 1: Parameters for Solar Module[2].

2)Wind Turbine Block:

The Wind turbine block gives the power of the turbine shaft as a function of wind speed and pitch angle. The power generated by a wind turbine can be expressed as:

$$P = \frac{1}{2} \cdot A \cdot v_{wind}^{3} \cdot \rho \cdot C_p \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where, A = area of the rotor blade (m^2)
v = wind speed (m/s)
ρ = air density (kg/m^3)
Cp = power coefficient.

The power coefficient Cp is a function of the tip speed ratio λ and the blade pitch angle β. The various attributes for this block are as follows. For the purpose of simulation the Aeolos Wind Turbine 5kw model was taken as reference[5] .

Wind Turbine	
Nominal Output Power	5kW
Base Wind Speed	12 m/s
Base Rotational Speed	10m/s
Initial Rotational Speed	0.8 rpm
Moment of Inertia	1m kg.m^2
Torque Flag	0
Master/Slave Flag	1

Table 2 : Parameters for the Wind Turbine[2]

3)AC Synchronous Generator:

The Generator Used in the wind turbine generator is Permanent Magnet Synchronous Generator. A 3-phase permanent magnet synchronous machine has 3-phase windings on the stator, and permanent magnet on the rotor.

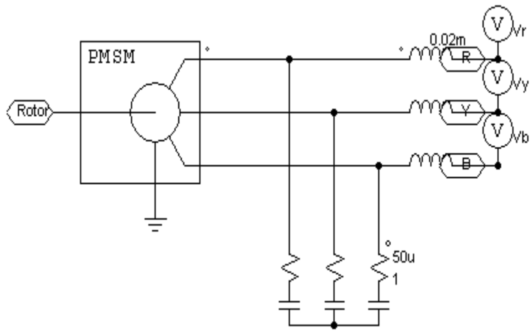

Fig 2: The Generator sub-circuit

The various attributes for this block are as follows.

Permanent Magnet Synchronous Machine	
Rs (stator resistance)	1m ohm
Ld (d-axis ind.)	1m H
Lq (q-axis ind.)	1mH. The d-q coordinate is defined such that the d-axis passes through the center of the magnet, and the q-axis is in the middle between two magnets. The q-axis is leading the d-axis.
Vpk / krpm (Peak line-to-line back emf constant, in V/krpm (mechanical speed)).	7112
No. of Poles *P*	30
Moment of Inertia	100m kg.m^2
Master/slave Flag	0

Table 3:Parameters for Permanent Magnet Synchronous Machine[2]

4)Rectifier Stage:

The rectifier stage consists of a Three –phase fully controlled bridge with voltage feedback. The output voltage is compared with the reference voltage and feedback is given to the firing angle controller of the SCR's.

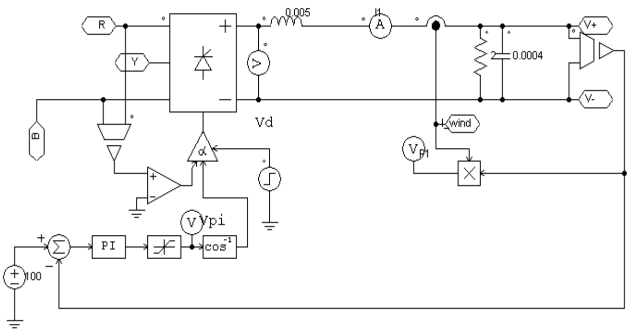

Fig 3: The rectifier sub-circuit

$$E_{dc} = \frac{3\sqrt{3}E_{mph}}{\pi}\cos(\alpha + \mu) + \frac{3\omega L_s}{\pi} I_d \quad ....(2)$$

Where ,
E_{dc}= DC output voltage of the Rectifier,
E_{mph}= phase peak voltage ,
α= firing angle of the SCR,
μ=overlap angle or the commutation angle,
ω = angular frequency in rad/sec,
L_s= source Inductance,
I_d= load current.[6]

5) MPPT Controller:

MPPT devices are used in the electric power systems so it will give sufficient voltage and current, its regulation and filtering for driving various loads like motor, including power grids,
batteries, or home appliances. The controller consists of boost converter.

There are total 4 types of methods by which we can implement maximum power point tracking:

- Perturb and observe method
- Incremental conductance method
- Current sweep method
- Constant voltage method

Out of which we are using perturb and observe (P&O) method. In this method, the voltage is adjusted in steps by small amounts using a controller and power is calculated; if the power increases, voltage is increased in the same direction. If power decreases the direction of voltage increment is reversed. The tracker oscillates about the MPP which may lead to oscillations in power output. It is also referred to as a *hill climbing* method.
The algorithm of this method is as follows:

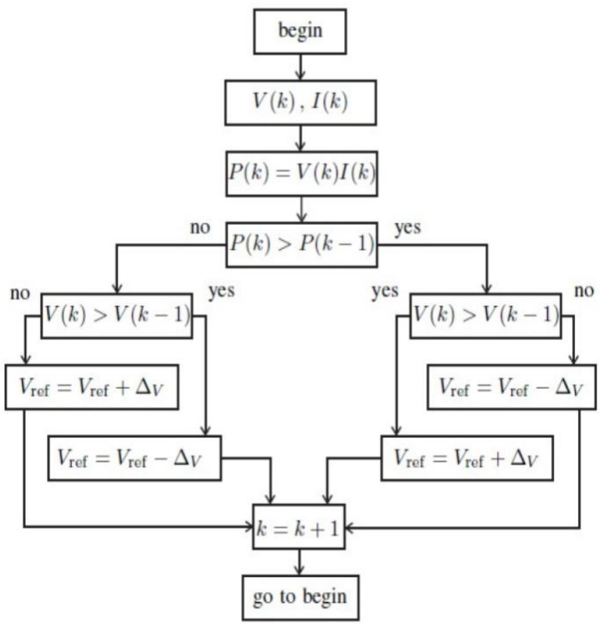

Fig 4: Flowchart of Perturb and Observe method

As the flowchart shows, first of all voltage and current of the system are measured. Thereby power is calculated. The instantaneous calculated power is compared with the power calculated at (k-1)st instant. If the instantaneous power p(k) > p(k-1) then the corresponding voltages are compared. If v(k)>v(k-1) the Δv is subtracted from the corresponding voltage so as to make the maximum power point stable. Similarly there are other 3 cases according to comparison.

At the same time there is trade of between the value of Δv and the time required to get the stable output. The lesser the value of Δv, more time we require to get the stable output. These ultimately reduce the perturbations around the maximum power point.

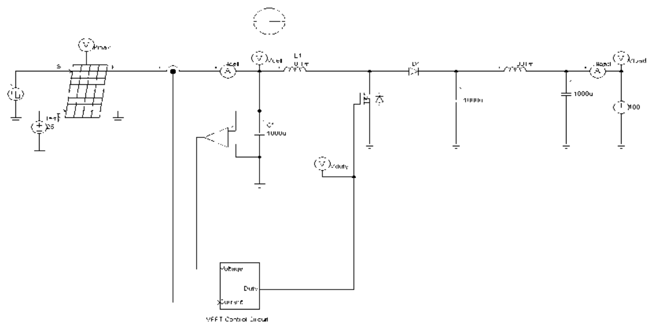

Fig 5:Simulation of MPPT algorithm in PSIM

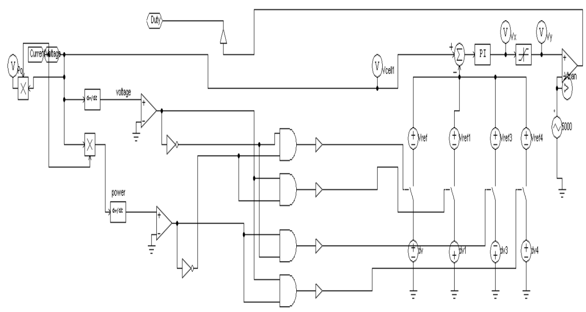

Fig 6: MPPT control circuit

Figure 6 shows the circuit level schematic of MPPT Controller block. This block is the actual hardware implementation of the flowchart shown in Figure 4.The basic aim of the control circuit is to design the PWM signal for driving the MOSFET. The current and voltage values calculated from the sensors are multiplied to obtain the power. The dp/dt slope is calculated and checked if it is greater than 0. Similarly the voltage values are checked. If V(k)>V(k-1) the actual output should reduce. This is done by reducing the PWM width given to the MOSFET drive. This ultimately reduces the output voltage as Vref=Vref-ΔV. Similarly other 3 cases are implemented.

The figure 5 is the actual implementation circuit of the MPPT. Here, the physical model of solar PV cell is used. The figure 7

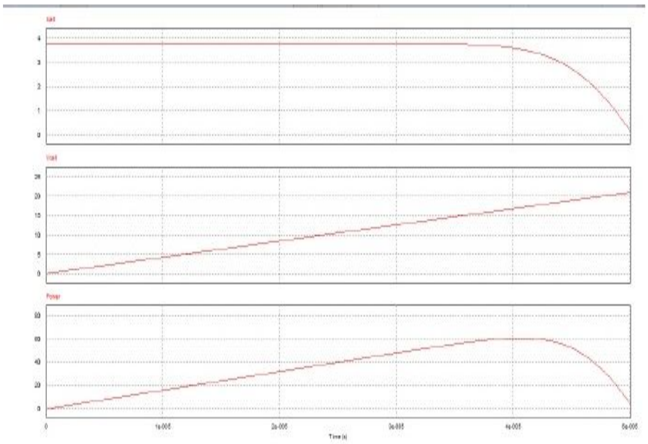

Fig 7: P-V characteristics of solar cell
(a) Icell (b) Vcell (c) Power

shows the P-V characteristics of solar cell taken for the purpose of simulation.

The DC-DC boost converter topology is used for better performance. Boost converter topology is also used in incremental conduction method for higher efficiency[10].

The LC filter is added at the end of boost stage to remove the high frequency ripples from the output voltage waveform.

6) Inverter Stage:

Inverters are the Power electronic circuits that produce variable-frequency ac outputs voltages from dc sources. DC-to-AC inverters (also known as static inverters) use fixed dc sources to produce symmetrical ac output voltages at fixed or variable frequency or magnitude. Inverting circuits are used to deliver power from a dc source to a passive or active ac load employing conventional MOSFETs or other switching devices. Today's inverters can operate in wide ranges of regulated output voltage and frequency with reduced harmonics. DC-to-AC inverters are used in applications where the only source available is a fixed dc source and the system requires an AC load such as an uninterruptible power supply (UPS).

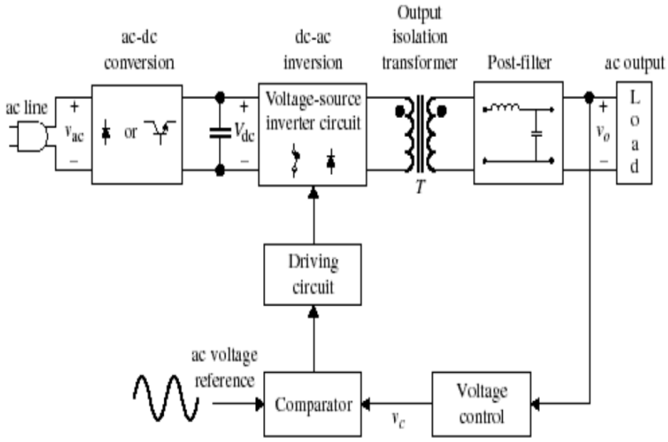

Fig 8: Block diagram of inverter stage

The feedback circuit is used to sense the output voltage and compare it with a sinusoidal reference signal. The control objective is producing a controllable ac output from an uncontrollable dc voltage source. The Pulse width modulation techniques which can be used as the control techniques are

1. Single-Pulse Width Modulation(SPWM)
2. Multiple-Pulse Width Modulation (MPWM)
3. Sinusoidal Pulse Width Modulation (sin PWM)

In this simulation we have used the Sinusoidal pulse width modulation technique because it offers better harmonic reduction. Sinusoidal Pulse-Width-Modulation allows the pulse width to be modulated sinusoidally, i.e. the width of each pulse is proportional to the instantaneous value of a reference sinusoid whose frequency equals the fundamental's as shown in the figure below.

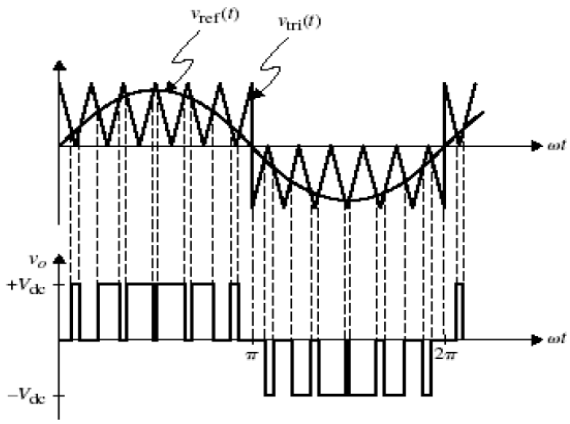

Fig 9: Typical Waveform for Sinusoidal Pulse Width Modulation Technique

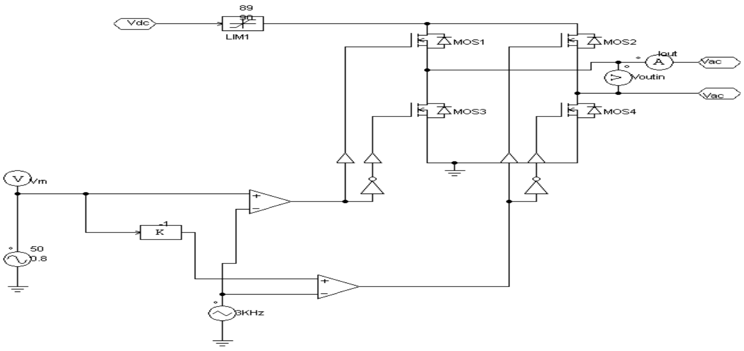

Fig 10: Inverter sub-circuit used in Simulation

III. SIMULATION RESULTS

1) Output of AC Synchronous Generator

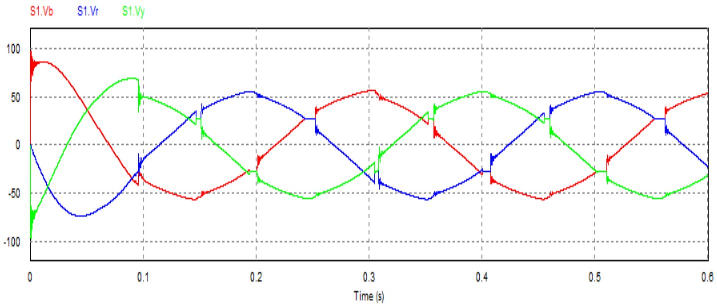

Fig11:Output of AC Synchronous Generator at 12m/s Wind-speed

2) Output of Rectifier stage

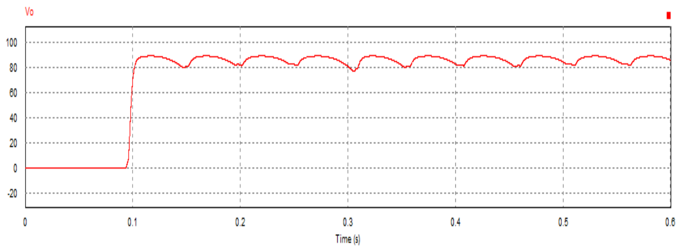

Fig 12 : Output of Rectifier stage

3) Output of inverter stage:

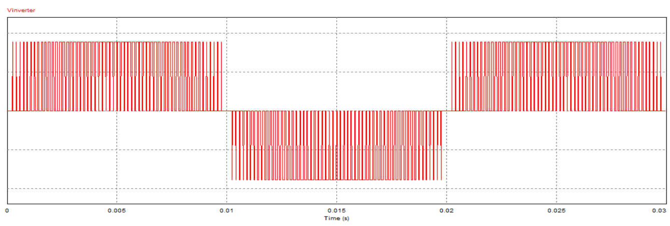

Fig 13(a) :Output of inverter stage (Voltage)

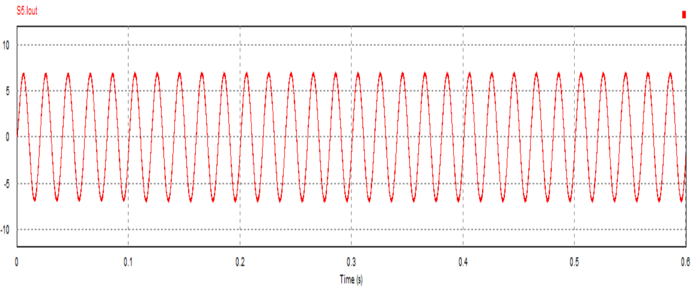

Fig 13 (b) :Output of inverter stage(Current)

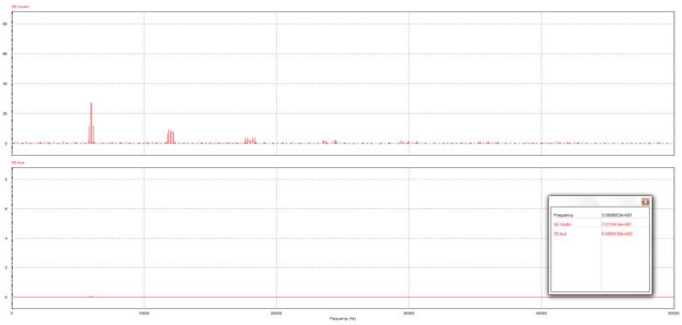

Fig 13 (c) :Fourier analysis of voltage and current waveform

The fundamental component of voltage is present at 50Hz having amplitude 72.1volt and current 6.8amp. The total harmonic distortion is 0.76 for voltage waveform and for current waveform it is 0.018.

4) Output of wind turbine:

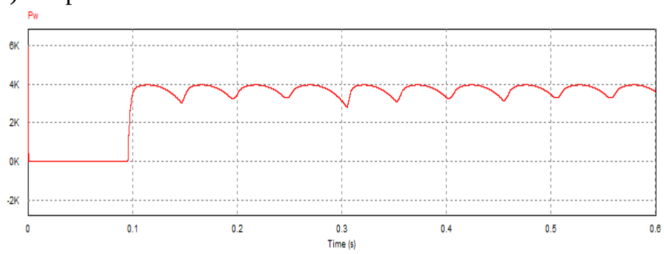

Fig 14 :Output of wind turbine generator

5) Solar MPPT controller Output:

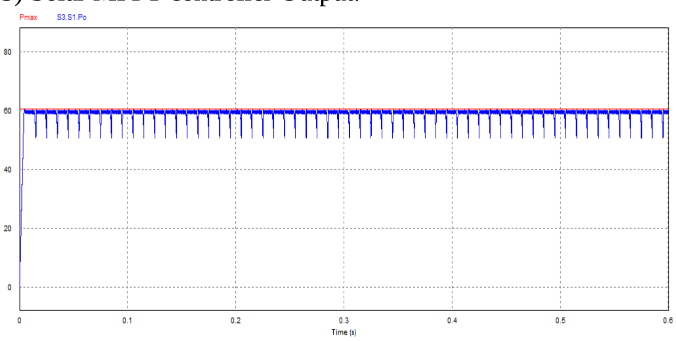

Fig15 : Solar MPPT controller Output

The maximum Power is denoted as Pmax (indicated by red line) and the output of the controller is Po(indicated by blue line).

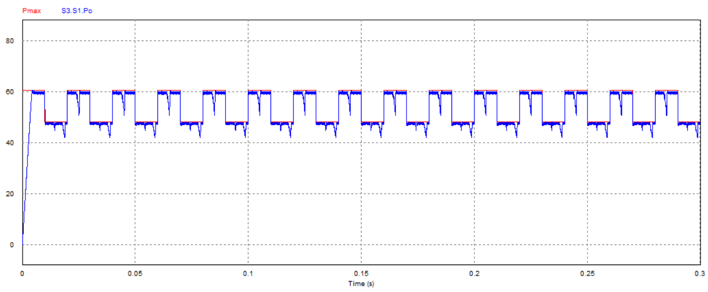

Fig 16 : Controller output with respect to time

The output of the controller under varying light intensities from 800 lux to 1000 lux. The maximum power at 1000lux is 60W and at 800 lux is around 48W .The output of the controller tracks the maximum power at different points of light intensities.

IV. CONCLUSION

simulation model for the wind solar hybrid system is presented in this paper. The generator for the small wind turbine is selected for maximum power of 5 Kw in simulation . The Sine PWM technique presented has better harmonic reduction as compared to single pulse width modulation technique. The with the help of Maximum Power Point Tracking (MPPT) technique and MPPT controller maximum power in Solar system(PV) is detected.

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