Simulation of Hybrid Energy System Comprising of PV and Wind and for Grid Connected System

AP. ANIL KUMAR and DR. NARESH KUMAR

Abstract – This paper deals with power control of a wind and solar hybrid generation system for interconnection operation with electric distribution system. The proposed system consists of a variable-speed direct-drive wind generator, wind-side converter, solar array, dc-dc converter and grid interface inverter. Power control strategy is to extract the maximum energy available from varying condition of wind speed and solar irradiance while maintaining power quality at a satisfactory level. Hence the need of non-conventional resources with good technology at lower cost is the utmost requirement of today's generation.
Renewable energy systems especially dealing with PV and Wind are in research with past few years. MATLAB stimulations provide verified and effective results of the proposed models .

***Index Terms*— Wind energy, PV, hybrid system, Grid synchronized, MATLAB modeling.**

I. INTRODUCTION

A fast reduction of the fossil fuels worldwide has created an alarming condition for the energy requirement of tomorrow. The alternate energy resources taken into consideration like solar, wind, are clean i.e. environment friendly and of great potential. PV power can be easily harnessed in the countries with good amount of sunny days. [1] The non-renewable energy resources provide a continuous and stable power to the grid whereas considering the climatic conditions there may be variations in the generation by PV, Wind and hybrid of both, which may cause problems like extreme frequency variation to the grid. For attaining the reliability of a system it is required to associate it with some other power source for getting continuous power generation. Photovoltaic (PV) solar energy is a source of clean and renewable energy that is attracting attention both as a research topic and industrial application. With the futile disputes regarding numerous aspects of fossil fuels, more and more people are looking for cleaner, more sustainable alternative energy source. Solar energy, in general, tops other prospective sources of renewable energy in terms of long service life and high reliability. Nevertheless, photovoltaic solar energy suffers from a few drawbacks, including high cost of implementation and low efficiency. Due to the shortcomings of the photovoltaic solar energy, it contributes less than other energy sources. Therefore, it is a necessity to increase the efficiency of photovoltaic in order to increase the market penetration and the commercial acceptance of PV cells. The simulation results show the control performance and dynamic behavior of the wind/PV system .

II. Wind energy

When the wind strikes the rotor blades, blades start rotating. The rotor is directly connected to a high-speed gearbox. Gearbox converts the rotor rotation into high speed which rotates the electrical generator. An exciter is needed to give the required excitation to the coil so that it can generate required voltage. The exciter current is controlled by a turbine controller which senses the wind speed based on that it calculates the power what we can achieve at that particular wind speed. Then output voltage of electrical generator is given to a rectifier and rectifier output is given to line converter unit to stabilize the output AC that is feed to the grid by a high voltage transformer. An extra units is used to give the power to internal auxiliaries of wind turbine (like motor, battery etc.), this is called Internal Supply unit. ISU can take power from the grid as well as from wind. Chopper is used to dissipate extra energy from the RU for safety purpose .

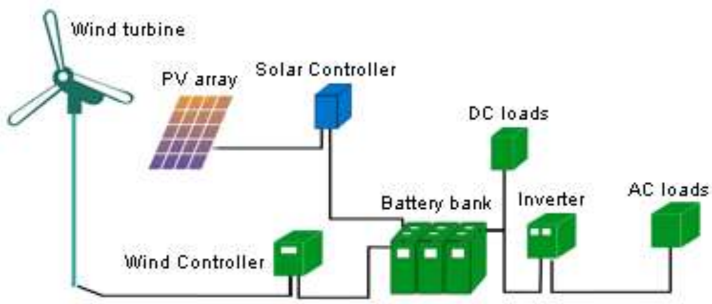

Figure 1: Block diagram of wind generating system

Although wind turbine technology appears simple but there are many mechanical complication in modern wind turbine. Wind rotates turbine's blade around a central hub, which turns a gearbox shaft at low speed, this in turn rotates a high speed generator in order to produce electricity. Hence the generator converts kinetic energy
Into electrical energy which is carries via cables to electrical sub stations for distribution.

The Wind power is measured in watts, it is determined by the size of rotor blades the wind velocity and the density of air. Theoretically the power in moving air is proportional to rate of flow of kinetic energy per second through a wind turbine. The equation of wind power is given by

$$P = 0.5 \times \rho \times A \times V^3 \times Cp \text{ (Watts)} \quad (1)$$

Where
P = Wind power (watts)
ρ(rho) = Air density (kg/m3)
A = circular region in (m2) swept by rotors
V = air velocity in m/s or mph
Cp = power coefficient efficiency (0.35-0.45%)

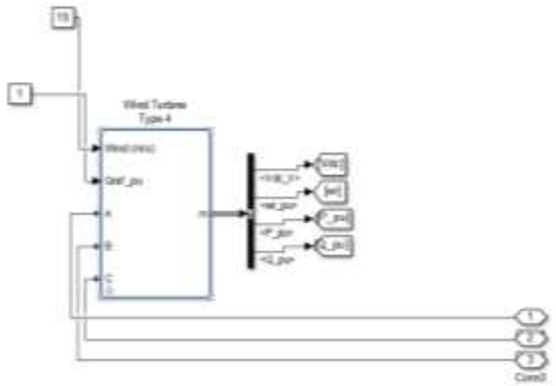

Figure 2: Model of Wind Energy System

The mathematical equations of above model are demonstrated using MATLAB as Simulink model shown in figure 2. The system is designed for 5 KW and the output profile of the system is as shown in figure 3.

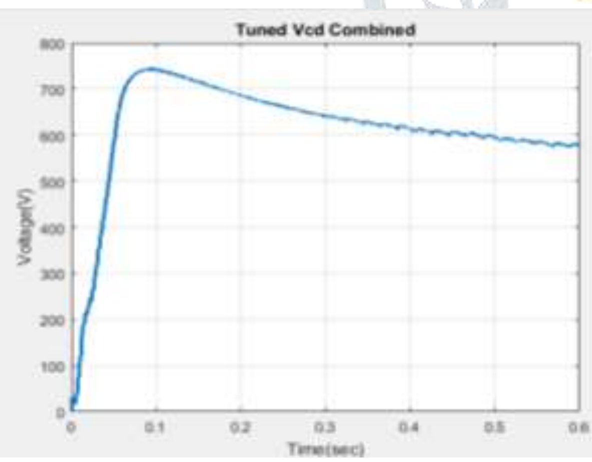

Figure 3: Output of Wind Energy System

II. PV Energy System

PV cells are semi-conductor device used in the conversion of solar energy into electrical energy directly. Most of the PV cells produced today are made up of crystalline silicon as a semiconductor material. A typical PV cell has an efficiency of about 15 % that means it converts 1/6 of the solar energy into electricity. PV cells have life expectancy of about 30 years and are made up of silicon which is a non-toxic material. They require minimal maintenance and can be almost completely recycled .

Figure 4: PV cells

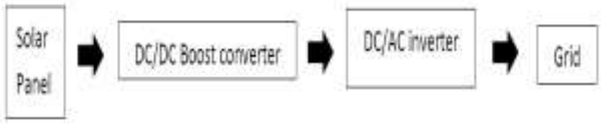

Figure-:5 Solar block diagram

A PV panel produces a DC voltage which needs to be elevated to the appropriate level. Therefore, a boost converter is needed to increase the DC voltage. A DC/AC inverter is the power electronics converter which converts the DC voltage to 3-phase AC voltage that can be connected to the grid.
The primary focus of research in such systems is the DC-DC boost converter. A closed loop system has to be used to track the change of the output current or voltage of the PV panels and change the switching rate of the boost converter to maximize the power output of the solar panels.
According to quantum physics light has a dual character i.e. it is a particle as well as wave. The elements of the light are termed photons that are mass less and move with the speed of light. The energy of a photon can be considered by the Einstein's rule given by :

$$E=HV \quad (2)$$

Where:
E= Photons energy
H= Plank's constant (6.626×10^{-34}Js)
V = Frequency of the photon

In the metals electrons exists as valance and free electron. The order for a valance electron to become a free electron it must be supplied with an energy that which is more than or equal to the binding energy. In Photo electric effects the electrons acquire this energy by their collision with photons. The free electrons so obtained are called photo electrons. The energy required to release these valance electrons is called "workout" and lasting energy is altered into kinetic energy of the free electrons .

$$HV = w_i + e_{Kin} \quad (3)$$

Where-

HV= Energy of the photons
w_i = Work out
e_{Kin} = Emitted electron kinetic energy

The effectiveness of PV solar cell is termed as percentage of electric power output to the solar radiation power. Mathematically it can be written as:

$$\eta = \frac{P^*_{el}}{p_{sol}} = \frac{u.i}{e.a} \qquad (4)$$

Where:
P^*_{el}= Electric power output
p_{sol}= Radiation power
u= Value of output voltage
i= Value of electricity output
e= Precise radiation power
a= Region

These equations are modeled using MATLAB as Simulink model shown in figure 5 and the corresponding output graphs are shown in figure 6.

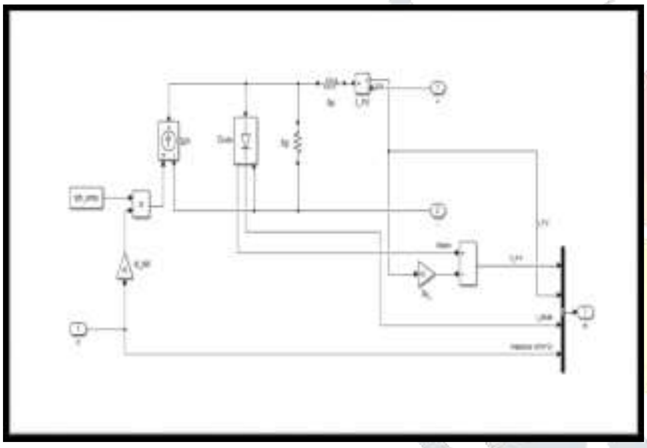

Figure:-6 Simulink model of PV

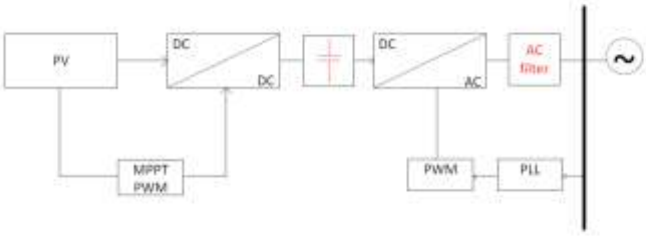

Figure 7: Model of PV Energy System

III DC-DC Boost Converter

For implementing the MPPT, there is need to include the dc-dc converter into the system. The dc-dc converter can be either buck or boost converter. The buck converters are step-down and the boost converters are step-up power converters. They are popular because of their high efficiency and compact size. In this work, the boost converter is chosen which steps up the input voltage magnitude to a required output voltage magnitude where the duty cycle of boost dc-dc converter is controlled by PWM signal from controller implementing the MPPT algorithms. The main components of a boost converter are an inductor, a diode and a high frequency switch .

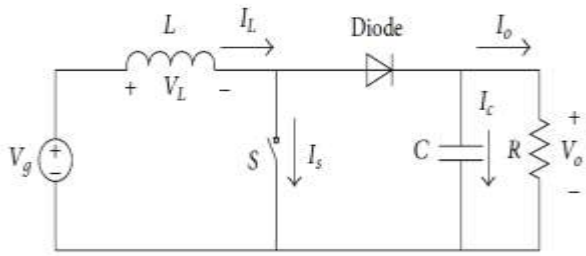

Figure-:8 Model of DC-DC boost converter

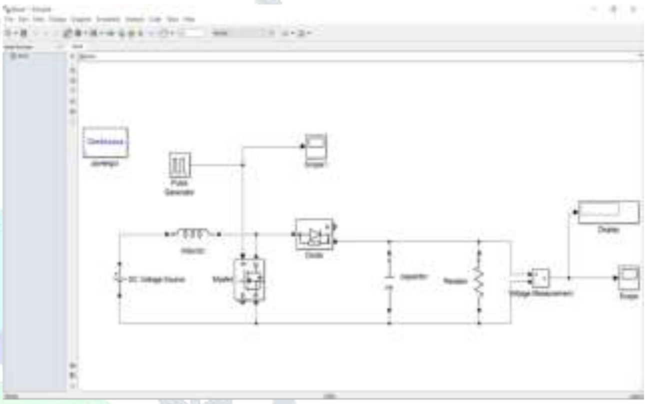

Figure-:9 Simulink model of DC-DC boost converter

The SIMULINK model of the boost converter is which boost voltage from 273.5V to 500V is shown above.
The boost converter plays very important role as it varies the PV array terminal voltage with the change of the duty cycle. The duty cycle will be determined depending on the signal of the maximum power point tracker

IV. Controlling techniques used to synchronize the hybrid system with grid

The combination of PID and PSO is implemented in synchronizing the system with grid. The PSO is used to compute the values of PID controller. The table1 shows the value of PID used in the system synchronization.

Table 1: PID controller values

Perimeter	Value
P	-0.9
I	0.15
D	0

a) PID Proportional-Integral-derivative

The controllers have diverse structures. Numerous methodologies are implemented for designing the controller in order to attain preferred performance level, but most dominant among them is (PID) type controller. Mathematical expressions for a PID controller are as :

$$u(t) = K_p[\, e(t) + \tau_d \frac{de(t)}{dt} + \frac{1}{\tau_i}\int_0^t e(\tau)d\tau]$$

The TF of the controller is defined below:

$$C(s) = K_p\left[1 + \tau_d\, s + \frac{1}{\tau_i s}\right]$$

Terms of the controller are defined as:

K_p = Proportional gain

τ_d = Derivative time, and

τ_i = Integral time.

b) Particle Swarm Optimization (PSO)

The PSO is a computational process that enriches a problem by iteratively trying to develop a solution with concern to a given measure of quality.

(c) MPPT Technique

A control block is needed to track the MPP and manipulate the duty cycle of the boost converter. In this section several control mechanisms are explored and implemented.

With the changing weather conditions, the generated power of the PV cell changes. For maximizing the generated power of the cell, tracking the maximum power operating point is necessary .

V. Utility Grid

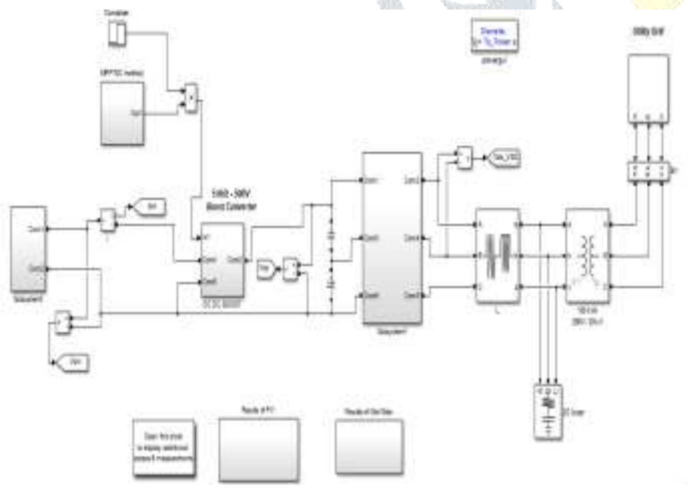

Figure: 10 Hybrid system implementing wind, PV system

Solar PV system integrated with grid which include PV module, MPPT control system 3-ph dc to ac inverter and ac grid. PV module from sim power system Simulink library is used with inbuilt module called as sun Power module (SPR- 305) by also using MATLAB which means one module is of 305 Watt. The results and simulation work are performed and analyze under constant and fast change in irradiation conditions using fuzzy logic and artificial neural network based controller. The most important parameter is used for efficiency and stability analysis of MPPT algorithm are peak overshoot, settling time, oscillation , settling time stability, time tracking and efficiency to reach maximum point .

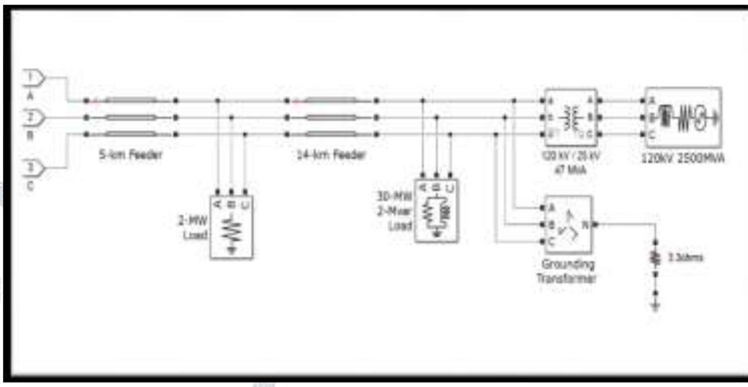

Figure: 11 Grid Model

Power grid includes generation and transmission units. Generator generates at the 120KV voltage and 2500MVA power. This is transmitted through step down transformer 120KV to 25KV down voltage.Distributed parameter line is used to model transmission line. 2-MW load and 30MW, 2-Mvar load is attached between 5km and 14km feeder.

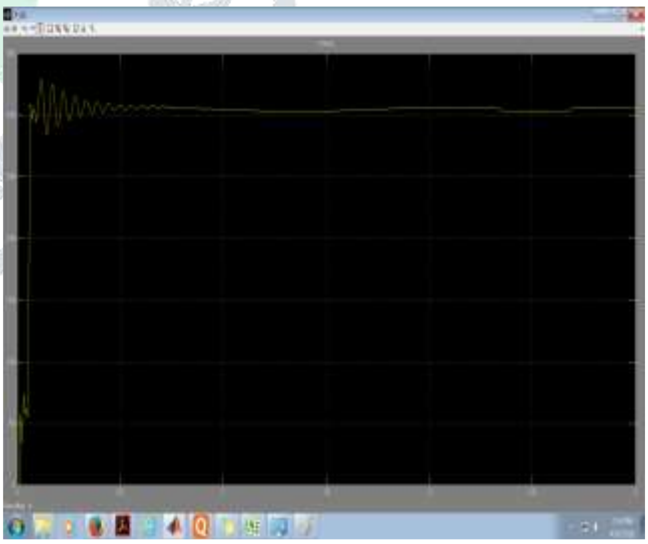

Figure-:12 Grid side active power in KW

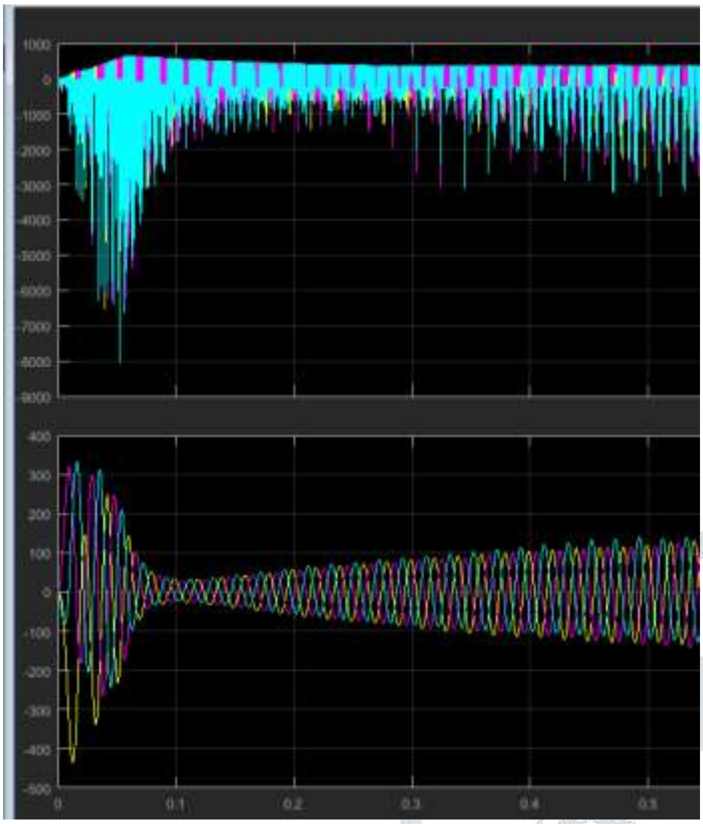

Figure13-: Three phase current waveform

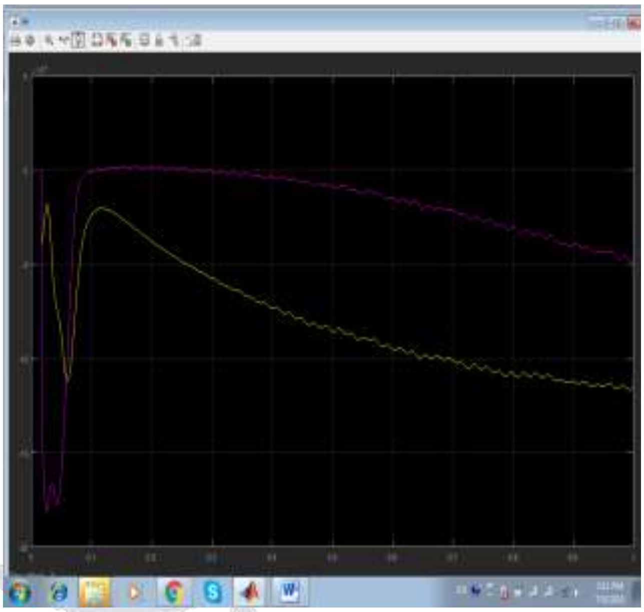

Figure-:14 PQ calculations

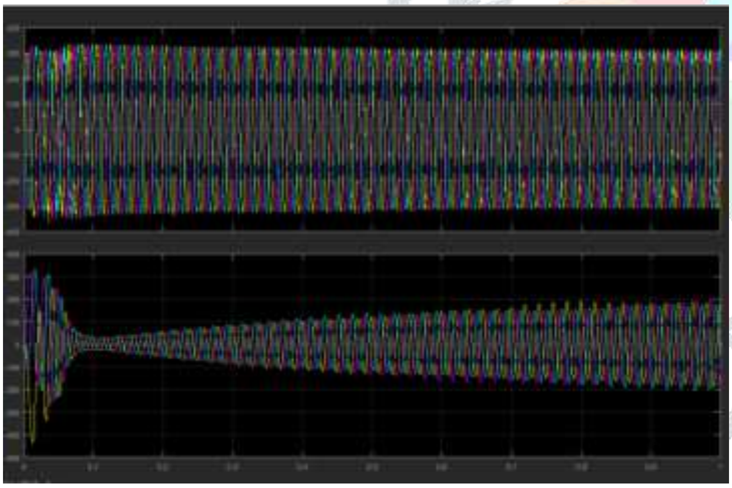

Figure-: 13 3-phase voltage waveform

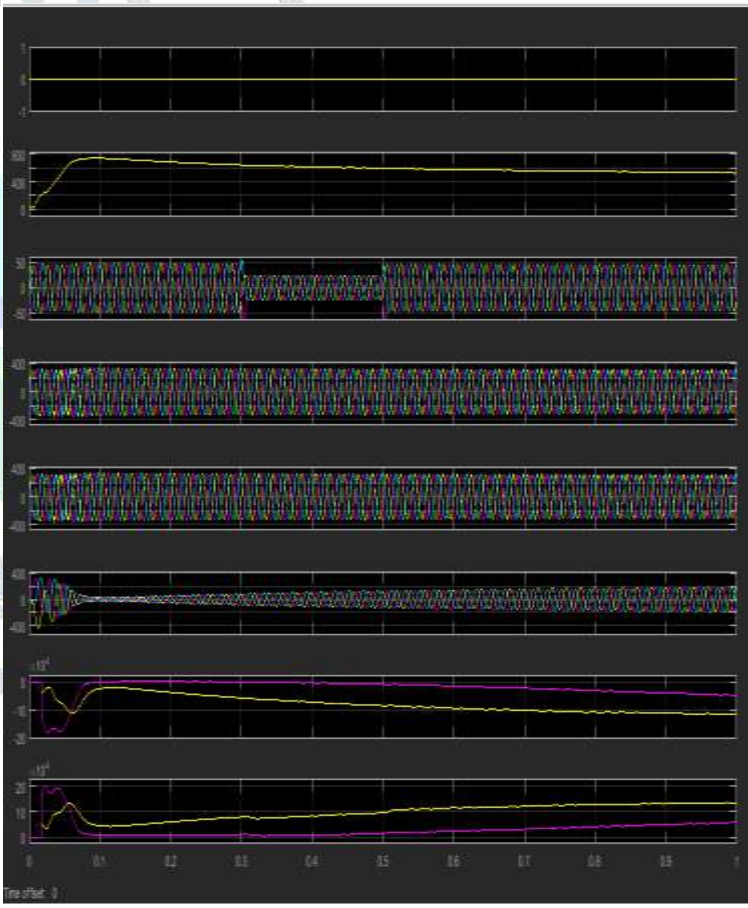

Figure-15 Combined waveforms

VI.Conclusion

Solar energy becomes fruitful over various other renewable resources due to low installation cost, easy installation techniques and less skill maintenance. Research suggests that there are advantages of solar power over any of its competition.

The drive to seek clean, renewable sources of energy is not just driven by a sole environmental factor. Solar power is considered the most sustainable source of energy to be harnessed. Nevertheless, efficiencies are not as high as other generation sources, which put the solar energy generation in an unattractive position industrial, financial and technical wise. Efficiency of a PV generation unit depends on the tracking of the MPP with changing weather conditions.
In this research thesis SIMULINK based model Solar PV system with grid integration is implemented for comparing following MPPT algorithm based Controller.
PSO and PID techniques are used for tuning the voltage and PLL is used for tuning of current .

VII. Reference

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