# Novel High Accurate Senseless Duel Axis Solar Tracking System by MPPT for Microgrid Application

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## ABSTRACT

*In this study, a novel high accurate sensorless dual-axis solar tracker controlled by the maximum power point tracking unit available in almost all photovoltaic systems is proposed. The maximum power point tracking controller continuously calculates the maximum output power of the photovoltaic module/panel/array, and uses the altitude and azimuth angles deviations to track the sun direction where the greatest value of the maximum output power is extracted. Unlike all other sensorless solar trackers, the proposed solar tracking system is a closed loop system which means it uses the actual direction of the sun at any time to track the sun direction, and this is the contribution of this work. The proposed solar tracker has the advantages of both sensor based and sensorless dual-axis solar trackers, but it does not have their disadvantages. Other sensorless solar trackers all are open loop, i.e., they use offline estimated data about the sun path in the sky obtained from solar map equations, so low exactness, cloudy sky, and requiring new data for new location are their problems. A photovoltaic system has been built, and it is experimentally verified that the proposed solar tracking system tracks the sun direction with the tracking error of 0.11° which is less than the tracking errors of other both sensor based and sensorless solar trackers. An increase of 28.8-43.6% depending on the seasons in the energy efficiency is the main advantage of utilizing the proposed solar tracking system.*

**Keyword :** *Solar energy, Diesel generator, maximum power point tracking, efficiency***.**

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## 1. INTRODUCTION

PV systems are generally used for isolated loads or household purposes [1]. The increase in power demand in the utility side with less harmonics and fluctuation are the major issues .The conventional sources of energy have the probability to last for limited time but renewable sources of energy like solar energy is infinite and also eco-friendly. With the increased efficiency of power electronics devices we can use this solar energy to provide the power to the consumers. The only aw of solar energy is that the set-up required is quite expensive. The output power of PV depends on many criterias like insolation and temperature. With variation in these two parameters the output is also varied, which will thereby lead to fluctuation in the utility side, which is totally undesirable. So it is important to have a control which will make our SOLAR-PANELs output totally independent of weather conditions. Currently there are many algorithms like incremental inductance, perturbation and observation, fuzzy logic etc. [2]-[7]. In this paper we totally concentrate on the method of PERTURBATION and OBSERVATION. This algorithm controls the duty cycle of boost converter and it is given as gate pulse to the converter then. The boost converter used here are for getting higher efficiency. A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load).. A standalone PV system has many practical applications. For household purposes it can be used for any type of loads { linear or nonlinear. The simulation results and the hardware design shows that STANDLONE-PV system can be efficiently used for isolated loads.

In this study, a novel high accurate sensorless dual-axis solar tracking system controlled by the internal MPPT unit is proposed. The MPPT controller continuously calculates the maximum output power of the PV module at any time, and then, it uses the deviations of the altitude and azimuth angles to find the correct direction of the sun where the greatest value of the maximum output power is obtained. In fact, the PV module itself plays the role of a sensor, so the proposed sensorless dual-axis solar tracker operates as a closed loop system which uses the online data indicating the actual position of the sun in the sky at the moment. Thus, it has the advantages of both sensor based and sensorless dual-axis solar, but it does not have their disadvantages. In other words, on the one hand, it is a very high accurate solar tracker, so that, its tracking error is about $0.11^o$ which is even less than that in sensor based trackers because it uses only one dual-axis mechanical system rather than the two independent mechanical systems used in sensor based trackers. On the other hand, similar to sensorless trackers, its cost and complication are less than the sensor based type because it does not need any sensors and extra dual-axis mechanical system for orienting the sensors

## 1.1Requirement of Renewable Energy

Renewable energy is the energy which can be naturally replenished. It is derived from natural resources such as sunlight, wind, tides, waves, biomass and geothermal heat. Such resources are inexhaustible unlike fossil fuels which are getting exhausted at an alarming rate. REN21s 2014 report states that contribution of renewable energy sources was 19 percent in energy consumption and 22 percent in electricity generation. Organisations all over the globe are adopting Clean Development Mechanisms (CDMs). Fossil fuels cause pollution too which has an adverse effect on the atmosphere. Renewable energy sources however do not cause any emissions, which results in clean energy; one that is not associated with effects of pollution.

Renewable energy is being rapidly adopted by countries which has resulted in significant energy security and limiting magnitude of long-term climate changes mitigating deterioration of environment. Market for renewable energy technologies has been growing at a steady rate and projects based on renewable energy being undertaken by developing countries also help in poverty reduction. Renewable energy technologies are getting cheaper because of mass production and market competition as well as mass acceptance.

**Types of Renewable Energy**

There are different types of renewable energy resources such as

1.Solar energy
2.Wind energy
3.Hydro energy
4.Geothermal energy
5.Biomass.

## 1.2 Solar energy

Solar energy is an important source of renewable energy. It is harnessed as heat and radiant light from the sun. Solar thermal energy, used in space heating can be harnessed from solar energy. Solar energy can also be converted to electrical energy which then can be used in a wide variety of applications. Even though it has an additional cost of initial installation, the long term benefits are rewarding. Implementation of solar energy is the huge step in mitigation of global warming. Solar energy in particular has accelerated in its adoption by countries as a source of energy generation. It is increasingly being adopted in order to balance climate changes.

## 1.3 Recent Trends in Renewable Energy

Currently renewable energy resources are being adopted at a steady rate. Renewable energy has provided an estimated 19 percent of the total energy consumption of the world in the year of 2012 and has only grown since. Solar PV has expanded at a rapid rate with a growth capacity of 55 percent annually for the past 4-5 years. However it is to be noted that the use of renewable resources is still limited in comparison to the vast potential that they hold.

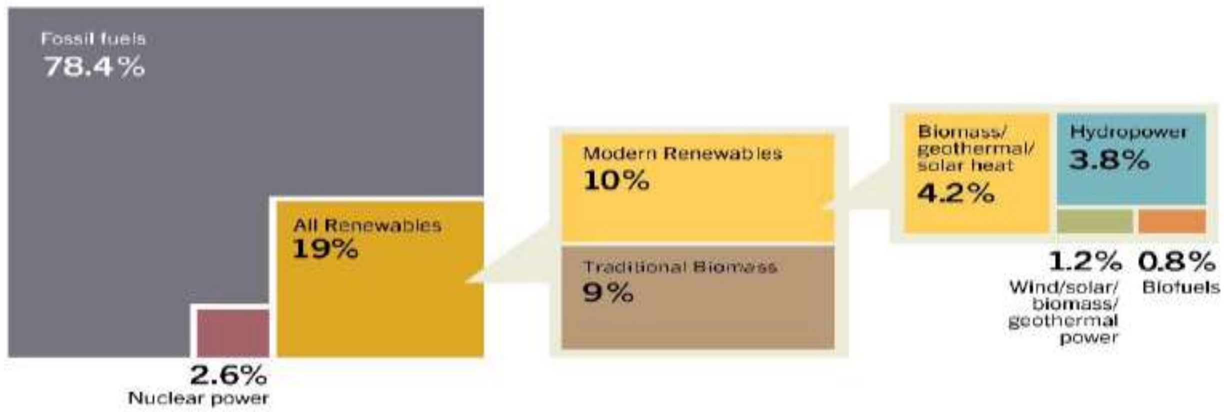



Figure: Estimated Renewable energy share of global final energy consumption in 2012

## 1.4 Solar Cell

A solar cell is an electrical device which converts incident light rays into electricity on the basis of photovoltaic effect. Solar cells are used in building solar panels. Solar cells are considered as photovoltaic even though the incident light may be sunlight or an artificial source. Solar modules are made of semiconductor material. Silicon crystals are the mostly used semiconductor crystal. Manufacturing of solar cells is done by the help of high purity silicon. Using melt and cast method silicon crystals are processed into cells and then the cast is sliced into wafers from the ingots. PV cell absorbs incident sunlight and creates electron hole pairs. Then separation of charge carriers takes place and the carriers are separately extracted to external circuit. A solar array generates solar power on the principle of photovoltaic effect. Solar cells can be connected in series or in parallel decided by the voltage and current requirements. The photovoltaic modules have a sheet of glass on the side that faces the sun so as to protect the wafers even while allowing light to pass through. The electrical energy produced from a solar panel is DC and can be used for DC loads or stored in a battery to be used later. For homes that are connected to a utility grid, inverters can be used to convert the DC to AC thereby running AC loads. Modules can be connected or stringed together to make an array with a specific DC voltage and current capacity, but MPPTs are preferred in order to obtain a higher value of efficiency.

## 1.5 Types of PV Panels

PV is not only used as standalone-systems but also in microgrids [8]. PV panels can be differentiated on the basis of their efficiency and the amount of space taken by them, i.e. installation size. There are different types of PV panels available in the market such as

1.Monocrystalline Panels
2.Polycrystalline Panels
3.Hybrid Panels

### 1.5.1 Monocrystalline Panels

In this type, the cells are aligned in a particular direction, which means when the sun is incident on the cells at the correct angle; they exhibit high efficiency and work best when sun directly shining on them.

### 1.5.2 Polycrystalline

Panels In these panels, the individual crystals are not all perfectly aligned together which reduces their efficiency as compared to monocrystalline panel. However, this misalignment can be a benefitting factor because the cells work better even when light is incident from other angles.

### 1.5.3 Hybrid Panels

The extra amorphous layer behind the monocrystalline cells is able to extract more energy from the incident sunlight, especially under low light conditions. They have the highest efficiency and take up less space. These, however are more expensive than monocrystalline and polycrystalline panels.

### 1.6 Concept of a microgrid

A micro grid (MG) can be defined as a group of renewable energy sources and energy storage devices controlled by a monitoring system to provide power to the loads for which it is designed (Bouzid et al., 2015). The energy source may or may not include the local utility grid. A microgrid can be seen as a smaller version of the traditional power grids. The consortium of Electric Reliability Technology Solutions (CERT) describes the concept of a microgrid as an aggregation of loads and micro sources operating as a single system providing both power and heat. A microgrid consists of power generators, distribution and control systems for voltage regulation just like a conventional grid. However, the main difference between the conventional grid and the microgrid is the close proximity between the power generation and the end users. In recent years microgrids have gained a lot of attention due to the advancements in renewable energy technologies.

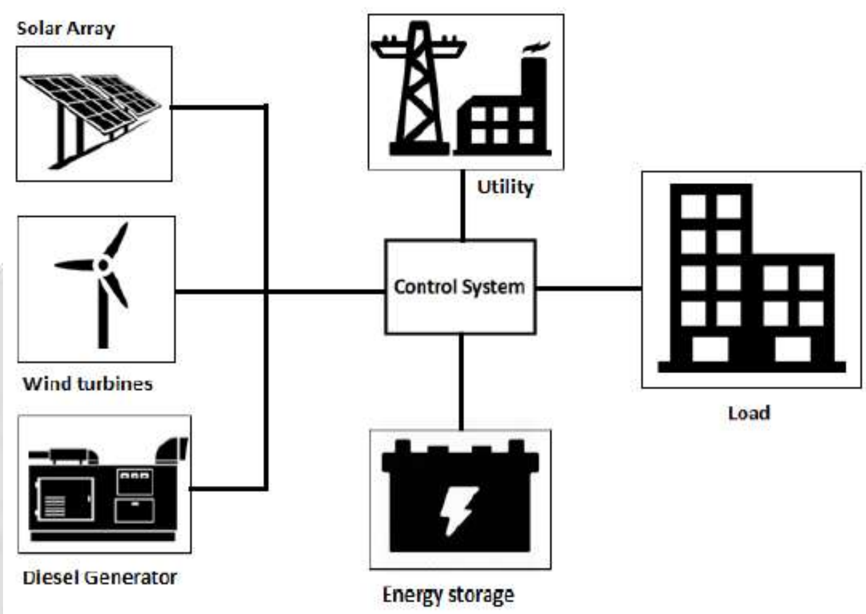



Figure :Concept of a microgrid

The figure describes one of the many concepts of microgrids. The figure contains power sources such as solar PV arrays, wind turbines, utility grid and energy storage devices. The diesel generators can be used as a backup power supply or as a regular power source running parallel to the renewable energy sources (RES). The control system denoted is used as a means to regulate the power from various sources to the load.

### 1.7 Components of a microgrid

A microgrid consists of a primary grid source, distributed generators, energy storage devices, power electronics and control system to manage the power supply from the generators. 1. Distributed generators (DG) are the main source of power generation in a microgrid. DGs can be categorized based on their technologies such as renewable energy DG and non-renewable energy DG. Renewable energy sources such as wind and solar are being harnessed quite extensively in microgrids. 2. Energy storage devices have become an inevitable part in a microgrid. Due to the increased implementation of renewable energy technologies and their intermittent nature, Storage devices such as batteries became a must. Examples of storage devices are

## 2. LITERATURE SURVEY

PV system is one of the fuming topics in the research. Many advance level Works have been done. PV has been used to supply to the grid without any energy source or even with energy source [9]. In this case bidirectional is used as we need power ow in both directions, from PV to the grid and even from the grid to the PV. Many PVs are connected in parallel in the form of generators to supply to the load. This paper proposes a fuzzy-based frequency control method for the Photo-voltaic generator in a PV diesel hybrid system without smoothing of PV output power fluctuations [10]. In one of the papers control strategy has been proposed for the distribution network [11]. It is possible that faults (both temporary and permanent faults) or even transient disturbance can occur . At that time a control mechanism is required so that PV output does not have any effect. This paper describes the mechanism. Another paper elaborates power control design of a battery charger for load following applications in a Hybrid Active PV generator [12].

An electricity network consists of two primary systems, which are transmission system and the distribution system. A conventional network comprises a central power station from where the power is being transferred to the distribution center and then to the customers. The problems associated with this are that it is not totally reliable and as the power generation is far from the load it will be difficult to cope with the disturbances occurring at the load end. A micro grid, on the other hand, consisting of distributed generation will be more suitable for these needs. Currently the AC network is predominant in most parts of the world but the DC micro gird network is gaining importance these days due to the higher efficiency when coupled with renewable energy sources and storage systems.

# 3. MAXIMUM POWER POINT TRACKING (MPPT)

Normally a solar panel is able to convert only 30-40 percent of the total incident solar irradiation into electrical energy. Maximum Power Point Tracking (MPPT) is used to improve the efficiency of a particular solar panel. Maximum Power Point Tracking (MPPT) is an algorithm that is used to extract maximum power from PV under specific conditions. Maximum power of a PV panel depends on factors such as solar irradiation, ambient temperature and cell temperature. Normally a PV module produces maximum power voltage at cell temperature of 25C. However depending on outside temperature it can fall or rise. MPPT checks the output of a particular PV panel and after comparing it with battery voltage decides the most efficient voltage i.e. maximum power point voltage. The purpose of a MPPT system is applying proper resistance after sampling output of PV cell in order to obtain maximum power. MPPT is most effective in cooler conditions because PV module works better at cold temperatures. It is also very effective when the battery is deeply discharged because more current can be extracted under low charge conditions. MPPT devices are integrated with power electronics creating an electric power converter system in form of solar inverters which convert DC power to AC power.

## 3.1 MPPT Techniques

There are different techniques used to track the maximum power point such as:
1. Perturb and observe (hill climbing method)
2. Incremental Conductance method
3. Current sweep
4. Constant voltage
5. Fuzzy Logic Control
6. Neural network

### 3.1.1 Perturb and observe (hill climbing method)

Perturb and observe is one of the simplest methods due to its lower value of time complexity. This method uses one voltage sensor which senses the PV voltage and measures power. If power increases, the algorithm is designed to achieve constant power. However, this method can result in oscillations of power output because the algorithm continues to perturb recursively even after reaching MPP. This can be solve by setting an error limit to end the recursion. It is easy to implement and is known as hill climbing method because it depends on the rise and fall of power vs. voltage curve with respect to maximum power point.

### 3.1.2 Incremental conductance

In this particular method, the controller measures incremental changes in voltage and current in the incremental conductance method. Even though it takes more number of computations it is better at tracking changes than perturb and observe method. Maximum power point is calculated by comparing incremental conductance (I / V) with PV array conductance (I / V). The output voltage is the voltage at which both ratios, i.e. conductance are same. The voltage is maintained till there are changes in irradiation levels upon which the process is repeated. Here both

voltage and current are sensed simultaneously, therefore change due to irradiance does not cause in error. This method however is more complicated than perturb and observe
method.

### 3.1.3 Current sweep

This method helps in obtaining I-V characteristics by using a sweep waveform of the PV array current which is updated at fixed intervals of time. MPP is calculated from the curve at the same intervals of time.

### 3.1.4 Constant voltage

In this method the operating point of PV array is maintained near Maximum Power Point. The PV array voltage is matched to a fixed reference voltage which is chosen to give optimal performance.

### 3.1.5 Fuzzy Logic Control

Fuzzy logic is also used for implementing MPPT by the use of microcontrollers. Fuzzy logic controllers are not restricted with the need of accurate models. They have a distinct advantage of handling non linearity and imprecise inputs and have a fast rate of convergence. A fuzzy control system operates on the principle of fuzzy logic. It studies analog input values in context of logical variables having continuous values between zero and one.

### 3.1.6 Neural Network

Neural networks are also used for implementing MPPT and they are also suitable for microcontrollers. They are a family of statistical learning algorithms used in estimation of approximate functions. They have three layers: input, output and hidden layers which have user dependent nodes whose number can be changed. Input variables such as open circuit voltage and short circuit current; temperature and solar irradiation can be used to find outputs such as duty cycle signal which in turn can be used to find maximum power point and make the converter operate around the point.

## 4. Block diagram

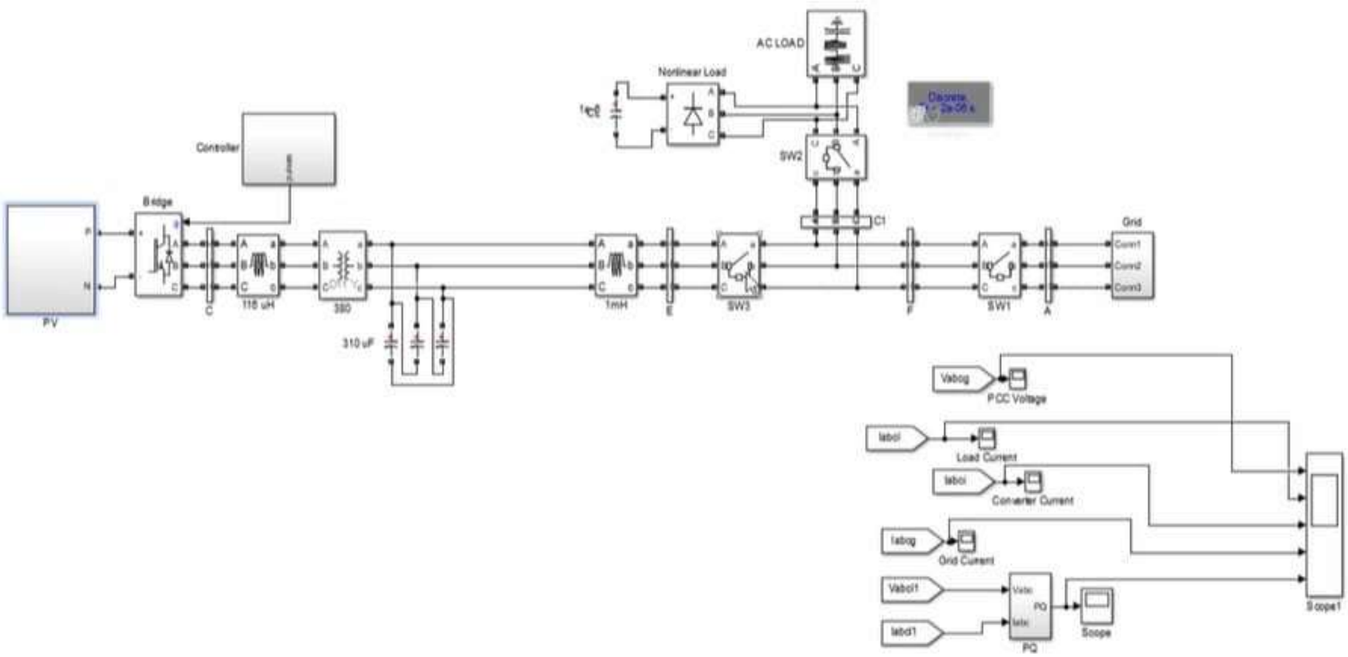
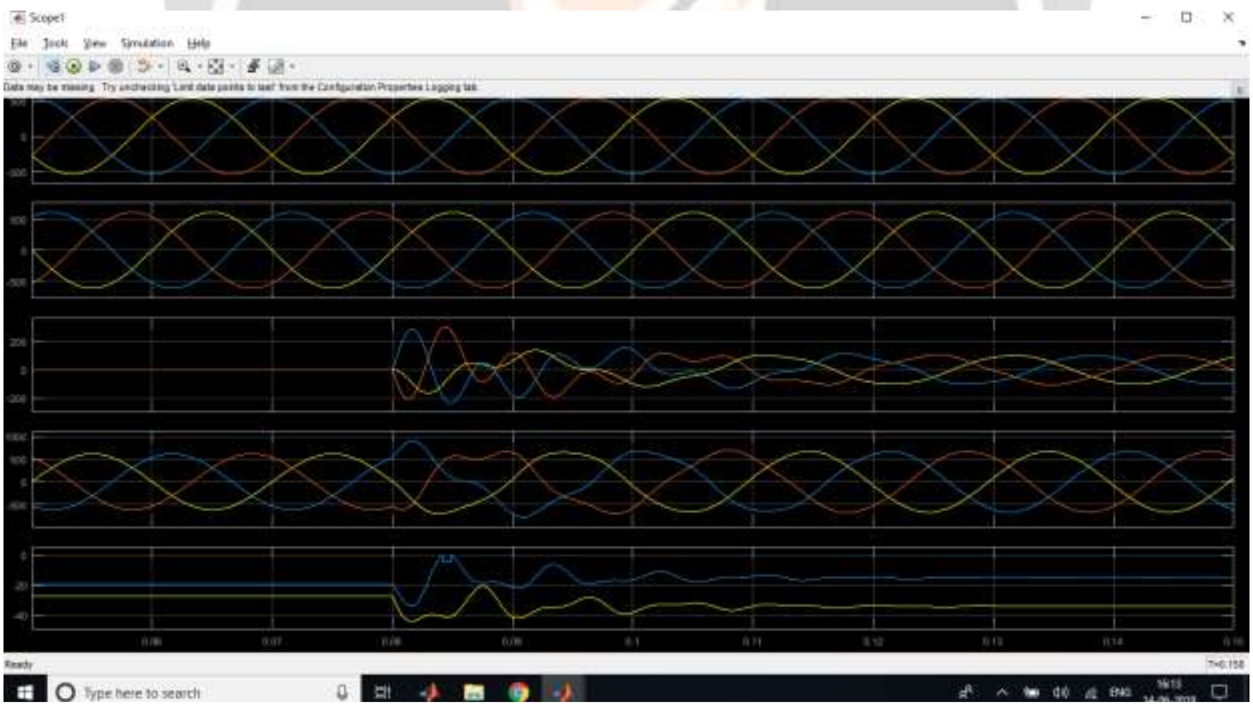
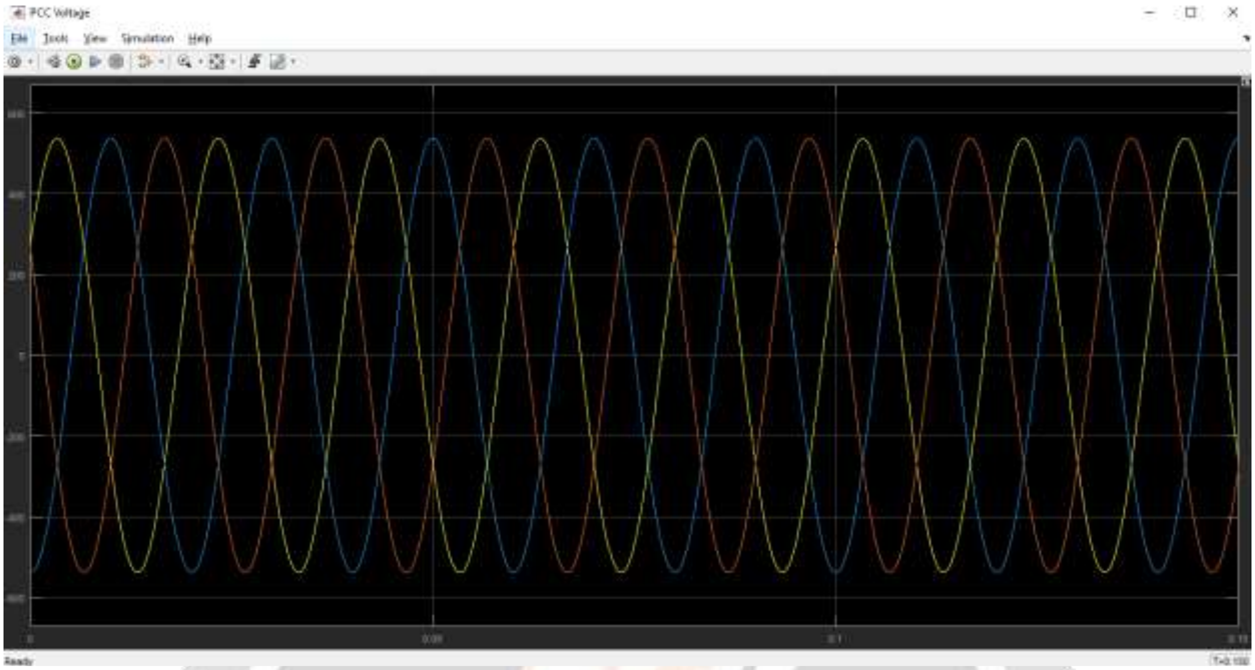



**Figure: Block Diagram**

Mainly our system is as shown in figure above. In this the general flow is that the PV is converted to DC to AC. Then that AC power is injected in to the grid. Inject switching time is taken as [0 1] i.e. our SW1 block parameter. Three phase broker (SW3) having switching time 0.8 to 1 at which braker will close. At 0.8 will get harmonics due to load adding. After doing DC to AC whatever fluctuation we are getting due to load variation is given to the controller. In controller, the errors are eliminated and reference signals are generated. The reference signal is given to PWM using integral relay. In PWM we generally one sinusoidal wave signal is generated. But in this we have given the actually feedback i.e. variation changes. Due to which harmonics or disturbance are limit. Now AC signal is filtered using inductor by which step wave is converted to sinusoidal. Then we used transformer after inductor and then we used one capacitor bank. So basically here we used one LTCL topology. For high-power applications, LTCL filters are an attractive solution since the size of inductors can be reduced while maintaining a low switching frequency. However, this type of filter requires additional passive damping elements unless an active damping strategy is included in its control system. The LTCL filter can attenuate the harmonic currents around the multiples of switching frequencies and guarantee –60 dB/decade attenuation in the high-frequency band, leading to a decrease of the total inductance and volume. Furthermore, within half of the switching frequency range, an LTCL -filter-based grid-connected VSC has almost the same frequency-response characteristic as that with the traditional LCL filter. Then the output of active AC load using broker (SW2) is applied. So that the on-off condition of braker is seen. Then the power is injected to grid. Then the disturbance is check in our system. i.e. PCC voltage, load current, converter current, grid current, scope.

## 4. RESULTS AND DISCUSSION






At 0.8 load is changed and harmonics are generated. Before 0.8 the circuit is open i.e not working. As observed from the output wave form during time period of 0.08 to 0.1 the disturbances are cleared and again the stable output waveform is obtained. Here the efficiency is improved and more accuracy is achieved with in small time period the disturbances are cleared.

## 5. CONCLUSIONS

A Photovoltaic System for residential applications is modelled with the help of MATLAB/Simulink. The hardware components of the total system is designed for the purpose of creating the real proposed system to test the results of the simulation and to ensure hardware and software work in tandem.

Control schemes and mathematical models containing MPPT control (method of perturbation and observation) are provided for the boost converter. Control methods are employed and verified for the optimum working of the specified model. Simulation results prove that the boost converter successfully tracks the maximum power point (MPP) of the solar panel and battery is charged accordingly. For the hardware implementation MPPT control is achieved by using a microcontroller. The solar charge controller is no such thing in simulation. This is because the theoretical circuits do not have so simple configuration when we do it practically. We need extra components in addition to what we do in simulation. In the simulation we just used boost converter to track MPPT. This is not so simple in case of hardware. So solar charge controller helps not only in obtaining MPP but also in maintaining state of charge of battery in case of hardware. Microcontroller is needed to maintain MPP and also to generate PWM signal. Battery plays here two roles. One is it acts as a load and other is it acts as an energy storage element. In simulation we took 900 cells in series and 8 cells in parallel but was not feasible for us to use those many number of cells in hardware. So we used one PV cell of 100 W. The results ensure an optimum and efficient model for reliable and high-quality stand-alone PV system.

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