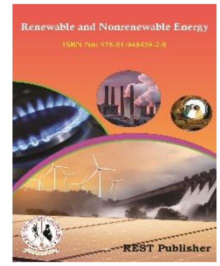
**Renewable and Nonrenewable Energy**

**Vol: 5(1), 2026**

**REST Publisher; ISBN: 978-81-948459-2-8**

**Website: https://restpublisher.com/book-series/ese/**

**DOI: https://doi.org/10.46632/rne/5/1/10**




# Modelling And Simulation of Grid Connected Photovoltaic System with Advanced Controlling Technique

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***Abstract:*** *Solar energy is clean, inexhaustible and environment friendly resource among all the renewable energy sources. But neither a standalone solar PV system nor a wind energy system can provide a continuous supply of energy due to periodic weather changes. Therefore, in order to satisfy the load demand, grid connected energy systems are now being implemented, that combines renewable energy power and utility grid. In this paper, a grid tied photovoltaic system was developed by omitting the storage device like large capacity battery bank. It will not only reduce the internal losses incurred in charging and discharging of battery but also cost of the system. Here we proposed a new approach to design a photovoltaic grid connected system, which can be operated by feeding the surplus power to the utility grid. Again, there is an extra power demand for residential load along with the solar power then this system can also provide an opportunity to consume the power from the grid. If the power consumption by the residential user is zero watts, then the entire generated solar power is fed to theutility grid only. This system provides anti islanding protection to the system. Also, an overview of Indian net metering mechanism for renewable energy sources for power generation systems was carried out in this paper. By the proposed design and control mechanism, the efficiency of the photovoltaic system was increased.*

***Keywords***: *Boost converter, Maximum power point (MPP), Inverter, Net metering, Perturb & Observe (P & O), Pulse width modulation (PWM)*

## 1. INTRODUCTION

Among the renewable energy resources, the energy due to the photovoltaic effect can be considered the most essential and prerequisite sustainable resource because of the ubiquity and sustainability of solar radiant energy. Regardless of the intermittency of sunlight, solar energy is freeand widely available. Recently, solar photovoltaic system is recognized to be in the forefront in renewable electric power generation. It can generate direct current electricity without environmental impact and contamination when exposed to sun. Being a semiconductor device, the photovoltaic system is static, quiet, free of moving parts, and has little operation and maintenance costs. Application of photovoltaic as electrical energy source shows increasing trend, both in implementation on spread area over the world and in capacity of plant. This trend is triggered by many factors such as the increasing of fossil fuels cost and declination of production cost per kW electric from photovoltaics and also technology development that cause the photovoltaic power conversion more and more efficient. PV module represents the fundamental power conversion unit of a solar photovoltaic generator system. The output characteristics of a photovoltaic module depend on the solar insolation, the cell temperature and the output voltage of the module. Owing to changes in the solar radiation energy and the cell operating temperature, the output power of a solar array is not constant at all the times. Photovoltaic generation system can either be operated in isolated system or be connected to the grid to form integrated system, and with other electrical renewable energy source can form distributed renewable energy generation as shown in figure 1.

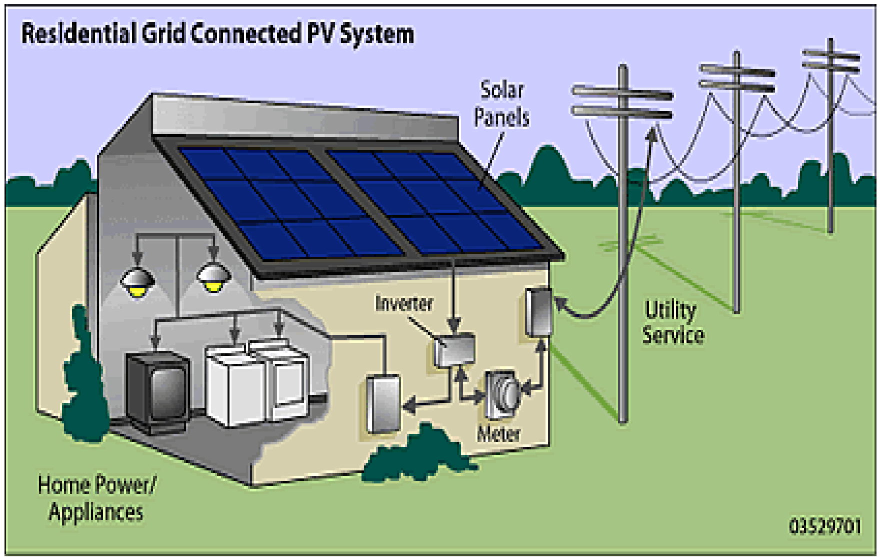


**FIGURE 1**. Residential Grid tied PV System

## 2. LITERATURE SURVEY

K. Agbossou, M. Kolhe, J. Hamelin, and T. K. Bose, proposed a paper on an AC-linked hybrid wind/photovoltaic (PV)/fuel cell (FC) alternative energy system for stand-alone applications. Wind and PV are the primary power sources of the system, and an FC-electrolyzer combination is used as a backup and a long-term storage system. P. Denholma and R. M. Margolis, in this paper they evaluate technologies that will enable solar photovoltaic (PV) to overcome the limits of traditional electric power systems. We performed simulations of a large utility system using hourly solar insolation and load data and attempted to provide up to 50% of this system's energy from PV. We considered several methods to avoid the limits of unusable PV that result at high penetration due to the use of inflexible base load generators. The enabling technologies considered in this work are increased system flexibility, load shifting via demand responsive appliances, and energy storage. C. Wang and M. H. Nehrir, proposed a paper on an AC-linked hybrid wind/photovoltaic (PV)/fuel cell (FC) alternative energy system for stand-alone applications. Wind and PV are the primary power sources of the system, and a fuel cell electrolyzer combination is used as a backup and a long-term storage system. An overall power management strategy is designed for the proposed system to manage power flows among the different energy sources and the storage unit in the system. A simulation model for the hybrid energy system has been developed using MATLAB/Simulink. The system performance under different scenarios has been verified by carrying out simulation studies using a practical load demand profile and real weather data.

## 3. MODELLING OF IDEAL PV CELL

The solar PV cells are made with P-N junction fabricated in a thin wafer or layer of semi-conductors. When they exposed to light, a photo current proportional to the solar radiation is generated. I-V characteristics of solar cells have an exponential characteristic similar to that of a diode. The ideal equivalent circuit of a solar PV cell is a current source in parallel with a single diode.

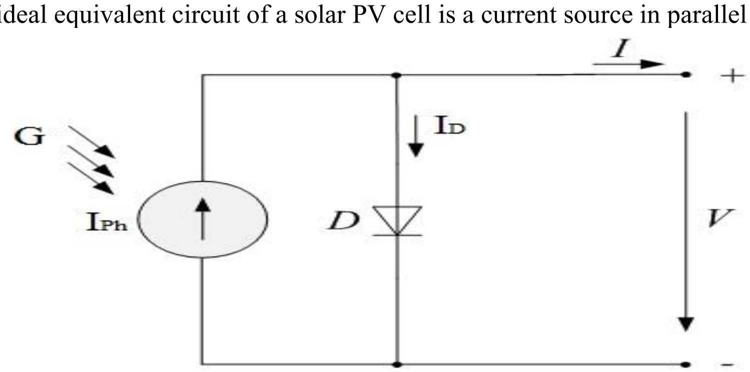


**FIGURE 2.** Equivalent circuit of ideal solar cell

In Fig. 2, G is the solar radiance, $I_{Ph}$ is the photo generated current, $I_D$ is the diode current, I is the output current and V is the output voltage.
According to Kirchhoff's current law,

$$I = I_{Ph} - I_D$$
$$I = I_{Ph} - I_o\left(exp\left(\frac{qV}{AKT}\right) - 1\right)$$

In this equation, $I_o$ is the diode reverse bias saturation current, q is the electron charge, A is the diode ideality factor, K is the Boltzman's constant, and T is the temperature.

For the same irradiance and PN junction temperature conditions, the short circuit current $I_{sc}$ is the greatest value of current generated by the cell. The short circuit current $I_{sc}$ is given by

$$I_{sc} = I = I_{ph} for V = 0$$

For the same irradiance and P-N junction temperature conditions, the open circuit voltage $V_{oc}$ is the greatest value of the voltage at the cell terminals. The open circuit voltage $V_{oc}$ is given by,

$$V = V_{oc} = \frac{AKT}{q}\ln\left(1 + \frac{I_{sc}}{I_o}\right) for I = 0$$

The output power is given by,

$$P = V\left[I_{sc} - I_o\left(exp\left(\frac{qV}{AKT}\right) - 1\right)\right]$$
$$I_o = I_o^*\left(\frac{T_c}{T^*}\right)^3 exp\left(\frac{qE_g}{AK}\left(\frac{1}{T^*} - \frac{1}{T_c}\right)\right)$$

In this equation, $I_o^*$ is the diode saturation current at reference condition, $T_c$ is the PN junction cell temperature, $T^*$ is the PN junction cell temperature at reference condition, and $E_g$ is the band gap energy of the semiconductor.

## 4. GRID CONNECTED SYSTEM

**Existing System:** In existing system power is stored in battery using charge controller and when utility power fails, load runs on the battery power. A typical grid connected system is shown in fig. 3,. In this, photovoltaic system generated power is stored in the battery and when needed it supplied to the loads by using the inverter.

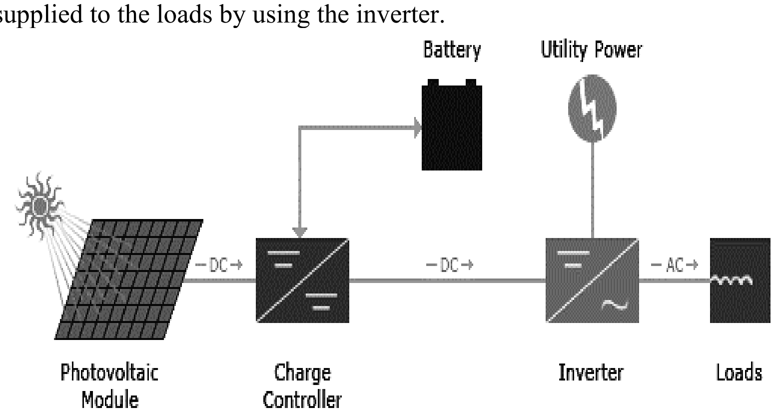


**FIGURE 3.** Grid connected Photovoltaic system with storage

**Proposed System**: There are losses present in charging and discharging of the batteries. For that reason, here we proposed a system that does not have storage equipment shown in Fig. 4, and a new controlling technique was proposed to control the photovoltaic generated power and utility supply. We designed a controlling technique by tacking four conditions into account. Those conditions are: a) Load value is less than the photovoltaic system (day time), b) Load value is equal to the photovoltaic system (night time),c) Load Value is more than the photovoltaic system (day time), and d) Load value is almost equal to zero (day time).

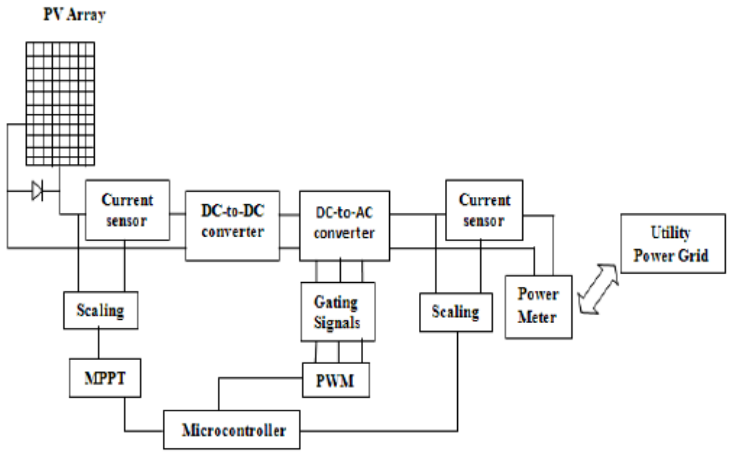


**FIGURE 4.** Grid connected Photovoltaic system without storage

## 5. SYSTEM DESCRIPTION

For any renewable energy plant, storage system costs nearly 30 percent in the total cost of the system. So, cost of the renewable energy power generation plant is high. Here we proposed a PV system that works without storage system, by that we can able to reduce cost of the system. Relay circuit is used to control which device to operate and which not to operate. Here we designed a relay circuit by using three relays. The voltage obtained by the photovoltaic system is boosted by using a DC-DC boost circuit. The booster circuit boosts the output voltage to 20Volts. The output of booster circuit is connected to inverter. Here we designed an inverter that is having best islanding effect. Relay control circuit is shown in Fig. 5, and which is used to control the total system. Islanding is defined as the condition in which a distributed generator continues to power a location even though electrical utility is no longer present.

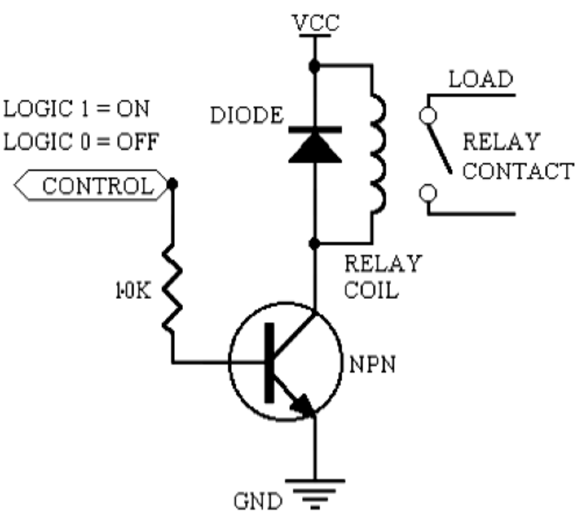


**FIGURE 5.** Relay Control Circuit

Solar irradiation is typically provided as kWh/m$^2$.However, it can be stated as daily peak Sun hours. Thisis the equivalent number of hours of solar irradiance of1kW/m$^2$. The grid interactive roof top solar PV system comprises the following equipment.a) Solar PV Power Source, b) DC-DC converter, c) Inverter, d) Mounting Structure, e) Power and control Cables,f) Earthing equipment /material,g) Junction Boxes or combiners, andh) Instruments and protection equipments.

**Solar PV Power source:** Solar photovoltaic system use the light available from the sun to generate electricity and feed this into the utility electricity grid or load as the case may be. The photovoltaic (PV) panels convert the light reaching them into DC power. The amount of power they produce is roughly proportional to the intensity and the angle of the light reaching those. They are therefore positioned to take maximum advantage of available sunlight within the siting constraints. Maximum power is obtained when the PV panels are able to 'track' the sun's movements during the day and the various seasons. However, these tracking mechanisms tend

to add a fair bit to the cost of the system, so a most of installations either have fixed PV panels or compromise by incorporating some limited manual adjustments, which take into account the different 'elevations' of the sun at various times of the year. The best elevations vary with the latitude of the load location.
Current and voltage relationship of a PV cell is given by

$$j_i = j_o \left[exp\left(\frac{V_e}{KT}\right) - 1\right]$$

Were,

$j_o$ is the saturation current also called the dark current
v is the voltage across junction
e is the electronic charge
k is Boltzmenn's constant
T is the absolute temperature

**DC-DC converter:** This converts the lower 10V voltage to 20V DC voltage. For this purpose, boost converter is used. Fig. 6, shows the simulink model of the boost converter.

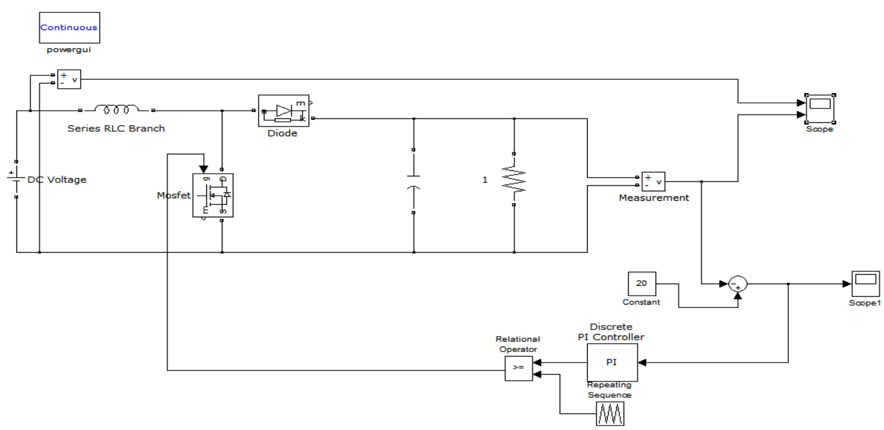


**FIGURE 6.** Boost Converter

Inverter: Output of boost converter is fed to inverter for conversion into alternating current. In a grid interactive system, AC power is fed to the grid at 11 KV three phase systems or to a 415V three phases or to a 220/240 V single phase system line depending on the system installed at commercial establishment or residential complex or single house consumer and load requirement. Power generated from the PV system during the daytime is utilized fully by powering the captive loads and feeding excess power to the grid as long as grid is available. In cases, where the solar power is not sufficient due to cloud cover etc. the captive loads are served by drawing power from the grid. The inverter should always give preference to the Solar Power and will use Grid/DG power only when the PV Power is insufficient to meet the load requirement.

**Mounting structures:** Hot dip galvanized iron mounting structures are used for mounting the modules/ panels/arrays. These mounting structures must be suitable to mount the Solar PV modules/panels/arrays on the roof top, on the ground or on the poles/masts, at an angle of tilt with the horizontal in accordance with the latitude of the place of installation.
**Power and control cables:** The cables shall be 1.1 grade, heavy duty, stranded copper/aluminium conductor, PVC type-A insulated, galvanized steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC type ST-1 outer sheathed. The cables shall be in general conform to IS-1554 P+I & other relevant standards.
**Earthing equipment:** Earthing is essential for the protection of the equipment &manpower. The system earth is earth which is used to ground one leg of the circuit. For example, in the AC circuits the Neutral is earthed while in DC supply positive is earthed.

## 6. CONTROL SECTION

The power measuring block measures the solar power with respect to the time. Fig. 5, shows the relay control circuit. The AC current sensor senses the residential load current which can be converted into power by multiply with the system voltage. The output of the measured solar power and the load demand goes to the controller. The availability of the grid power can be detected by a power transformer. The output of the PT goes to the controller through ADC. With the help of these data controller will send signal to the relay control circuit. Relay is an electrically operated switch. Relays are used to control a circuit by a low power signal (with complete isolation between the circuits), or where several circuits must be controlled by a signal. Normally open (NO) contact connects the circuit when the relay is activated and normally close (NC) contacts disconnect the circuit when the relay is activated.

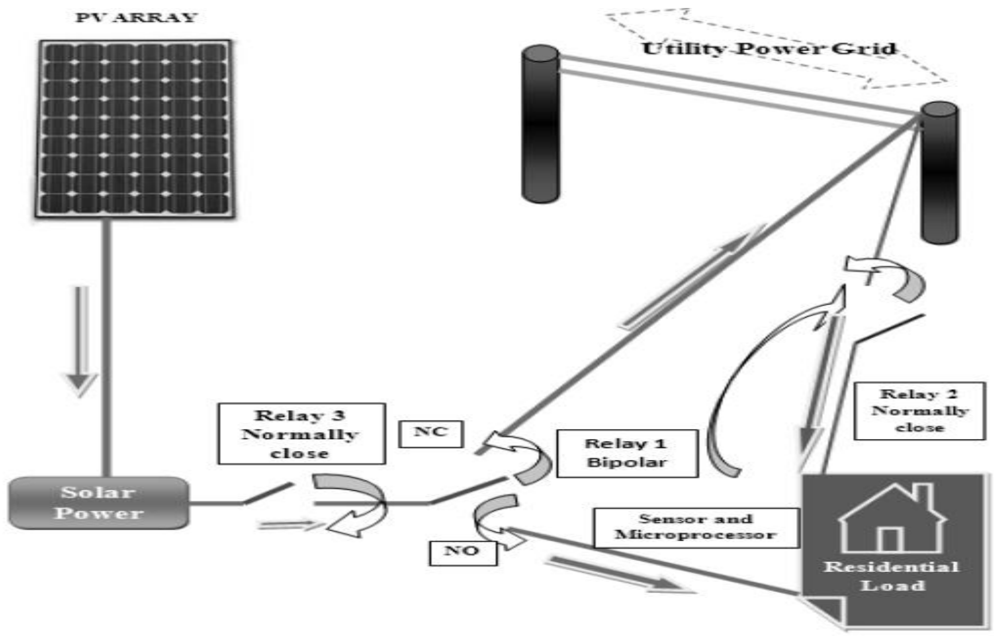


**FIGURE 7.** Relay control circuit

## 7. NET METERING

There are two different types of metering arrangements that can be used for development of rooftop solar photovoltaic (PV) systems: gross and net metering.Net meteringis a service to an electric consumer under which electric energy generated by the electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities, may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period. Government of India launched the Jawaharlal Nehru National Solar Mission (JNNSM) in 2009 to increase share of solar energy. As of June 2015, ten states in India (Gujarat, Andhra Pradesh, Uttarakhand, Tamil Nadu, West Bengal, Karnataka, Kerala, Delhi, Punjab, Telangana) have released a final distributed solar or net metering policy regulatory framework.

Indian Net-metering Guidelines

- Proposed limit for commercial settlement of electricity generation as 90% of the total consumption in a financial year.
- Excess injection (above 90%) at the end of financial year to be considered as free energy.
- No carry forward of energy allowed to next financial year.

## 8. ADVANTAGES OF THE DESIGNED SYSTEM

A typical solar system would require a large battery bank to storage the energy. By removing this storage device the system installation cost can be maintained within an acceptable limit. The grid connected system is more power efficient than a conventional solar system. It ensures full utilization of solar energy whereas battery discharge rate is 65% to 70% in conventional off-grid solar system. As energy storage capacity of these batteries degrade with time, and need replacement, which required extra cost for the system owner. This grid-tied system also represents the consumer as an energy provider to the utility grid. Net metering allows system owners to get credit for any electricity from the system sends to the utility grid. If the grid power is not available, still the system will continue to supply critical on-site loads.

## 9. RESULTS

The residential grid tied solar photovoltaic (PV) system was successful implemented. The boost converter converts input voltage of 10V to 20V and it is given to the inverter.Fig. 8, shows the values of input and output voltages of the boost converter.

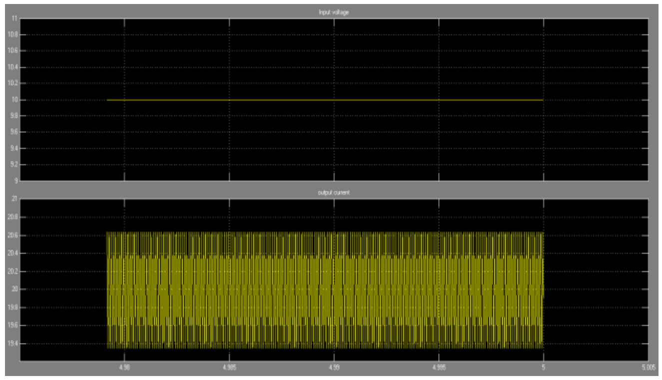

**FIGURE 8.** Input and output voltages of the converter

Relays operation at different load conditions (when grid is available) are shown in table I.

**TABLE I.** Relays Operation At Different Load Conditions

| Solar power (watts) | Grid power (watts) | Load (watts) | Relay-1 | Relay-2 | Relay-3 |
|---|---|---|---|---|---|
| 3 | 0 | 3 | NO | NO | NC |
| 2.9 | 0.1 | 3 | NC | NC | NC |
| 2.5 | 0.5 | 3 | NC | NC | NC |
| 3 | -3 | 0 | NC | NC | NO |
| 2.5 | -1 | 1.5 | NO | NC | NO |

NO – Normally Open     NC – Normally Close

## 10. CONCLUSION

It has been concluded that overall cost of the system was reduced by 30% compared to the cost of existing grid connected photovoltaic system with storage.Losses of the photovoltaic grid tied system were reduced.It is easy to feed the surplus power to the utility grid.By this proposed method, residential user can be able to use power at any time without interruption, and maintenance of the system was also reduced.Best anti-islanding protection is obtained by the designed system.

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