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RESEARCH ARTICLE

OPTIMISATION OF SOLAR PHOTOVOLTAIC SYSTEM EMPLOYING DISTRIBUTED MPPT CONTROL

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Abstract

This paper presents simulation and modeling with optimization and analysis in solar photovoltaic systems, as well as the role and potential of maximum power extraction with controller. Matrix calculations for grid inverters with data graphing, their functions, MPPT algorithm applications, user interface design for monitoring PV modules, and interaction with inverter and converter are all aided by simulations of renewable energy systems. It looks at how well they work on a single-phase grid with a PV system. Simulink model for solar energy conversion systems allows you to examine the performance of Photovoltaic cells, modules, arrays, Maximum Power Points and inverters. Controllers are being tracked when the environment and physical variables change. A distributed MPPT scheme, which allows adjustment of each DC-link voltage, may be adopted for PV systems to achieve maximum PV module usage and solar energy extraction. The pattern that has been developed allows for independent management of each DC-link voltage in order to track the MPP for each string of PV panels. For various operating circumstances, simulation results are provided.

Introduction:-

Solar power is now the foremost prominent renewable resources in recent decades. In comparison to other energy sources, it is both easily available and environmentally friendly. The demand for new energy sources is dramatically growing as the world's population continues to expand. Fossil fuels are currently the most widely used energy sources for power generation. Petroleum, natural gas, coal, and other fossil fuels are examples of these resources, all of which hurt the environment by releasing toxic carbon dioxide into the atmosphere, contributing to global warming. Furthermore, such sources are non - renewable, finite sources of energy that cannot meet the world's rising energy demand. Due to their dependability and proximity towards the source, solar PV systems have garnered significantly so much consideration than other renewable sources of energy.Photovoltaic systems have more benefits than drawbacks. Long life, low maintenance, easy installation, without fuel requirement are some of the benefits; drawbacks are poor performance on cloudy season and initial expensive setup costs. Due to the low voltage provided by a PV cell, a PV panel must be built up of numerous cells (approximately 0.5 to 0.7 V). It can also be connected in parallel and series to produce a greater voltage with high current on same voltage, or the same current with the same voltage.

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A PV system's smallest component is the PV cell. A photovoltaic cell is a unique model P-N junction, usually made of Si-based semiconductor that allows electricity to be input via the photoelectric effect. In 1839, French physicist Edmund Bequerel developed the photoelectric phenomenon, demonstrating that when certain materials are exposed to sunlight, they generate electricity. As a result of charge transfer, the substance absorbs photons from the light, which frees electrons, resulting in current and an electric field. During the last century, several scientists, including Albert Einstein, investigated physics of the photoelectric effect and light, it results invention of solar cell.

Thepower generated from the solar PV source is nonlinear in nature. System changes with varying radiation and temperature, on the other hand, can strive to maximize power. To achieve high operating efficiency, the PV system terminal voltage must be continuously adjusted to match changing atmospheric conditions, ensuring that power transmission is constantly at its maximum. This method is called as MPPT (Maximum Power Point Technique). The Perturb and Observe (P&O) Algorithm is a basic methodology for voltage control that is widely utilized.Maximum power production may be attained in a photovoltaic system by continuously changing the PV array operating point for specific conditions. In order to generate maximum power in a PV system, several MPPT algorithms are employed to accomplish this goal.

The suggested design maximizes the overall capacity of the photovoltaic module while enhancing power quality and efficiency at the same time. The converter can split the grid from the PV string to achieve distinct control purposes.Controlling the intrinsic power disparities that occur not only in the cells of one phase, but also throughout the three phases of the converter, is a major issue in this arrangement.The major disadvantage of photovoltaic systems is that their power output is greatly dependent on climatic variables such as solar radiation power and climate temperature, both of which have non-linear P-I and V-I characteristics.As a result, PV systems have a low conversion efficiency and can't effectively use solar energy in diverse climates. The MPPT pattern is primarily used to optimize PV cell performance and produce high-power output based on current climatic conditions.

System description

PV systems provide a number of advantages; however they are susceptible to system output unpredictability due to climatic fluctuations (solar irradiance, heat), high infrastructure costs, and low module performance of less than 20%. As a result, PV system modelling has been a common topic of discussion when analyzing PV system performance.

A mathematical term that defines the individual, series, or parallel operation of PV modules as part of a PV system. It's made-up collection of modules that are coupled in both. The number of series and parallel resistances is affected by collection of modules. The PV system's series and parallel resistances are calculated by using the equation below:

$$R_s = \frac{N_s}{N_p} R_s \quad (1)$$

$$R_{sh} = \frac{N_s}{N_p} R_{sh} \quad (2)$$

Where,

For each subsystem,

N_s counts the set of series PV modules and N_p counts set of parallel PV modules.

The module's series resistance is R_s (Ω).

The module's Shunt resistance is R_{sh} (Ω).

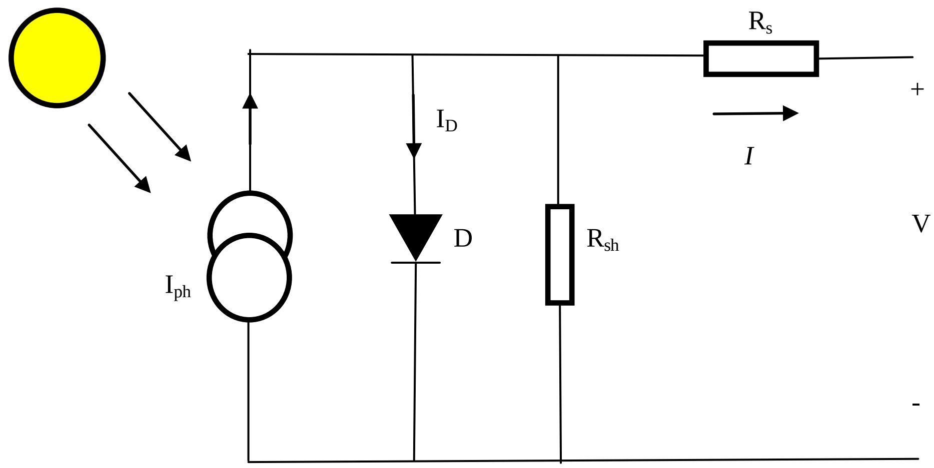

Figure 1:- PV module's equivalence circuit

In this article, the following equations are often used to simulate a solar photovoltaic cell.

Current of solar photovoltaic module is given by,

$$I_{ph} = [I_{sc} + K_i(T - 298)] * \lambda/100 \quad (3)$$

Reverse saturation current is calculated by,

$$I_{rs} = \frac{I_{sc}}{\exp\left(\frac{qV_{oc}}{N_s kAT}\right)} - 1 \quad (4)$$

Saturation current of the solar PV module is calculated by,

$$I_0 = I_{rs}\left[\frac{T}{T_r}\right]^3 \exp\left[\frac{q * E_{go}}{Bk} * \left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \quad (5)$$

Output current of the solar PV module is given by,

$$I_{pv} = N_p * I_{ph} - N_p * I_0\left[\exp\left(q * \frac{V_{pv} + I_{pv} * R_s}{N_s kAT}\right) - 1\right] \quad (6)$$

Here V_{pv} is equal to V_{oc}

Solar cells, like many other semiconductor instruments, are temperature sensitive. The semiconductor band gap shrinks as temperature rises, affecting most of the parameters of it's material. A reduction in a semiconductor's band gap as temperature rises can be interpreted as an increase in the energy of the material's electrons. Reduced bond energy decreases the band gap in the bond model of a semiconductor. As a result, raising the temperature lowers the band difference. The open-circuit voltage is the parameter in a solar cell that is most influenced by temperature changes.

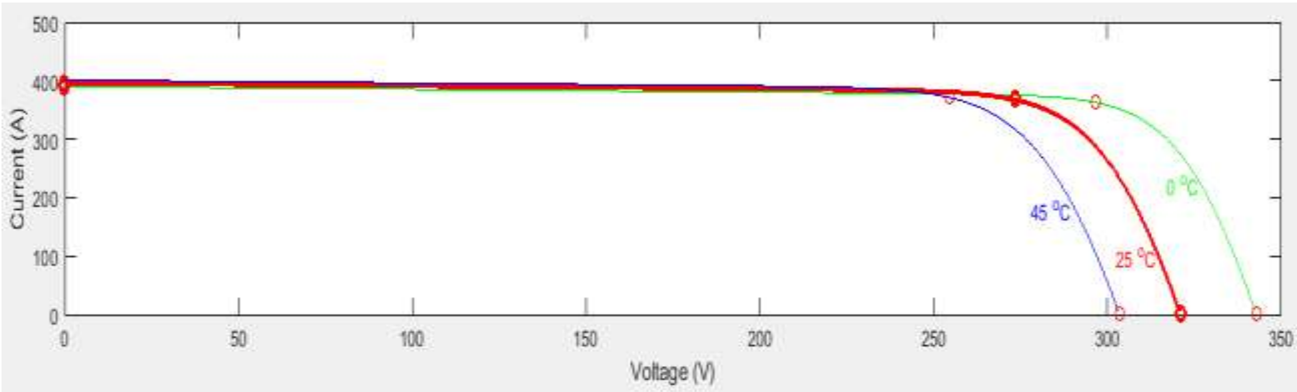

Figure 2:- Effect of temperature on Current.

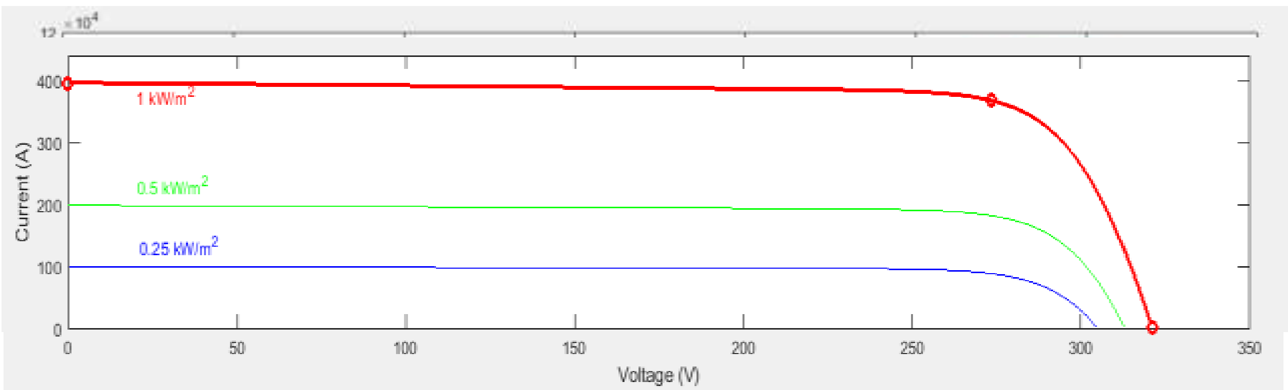

Figure 3:- Effect of temperature on Power.

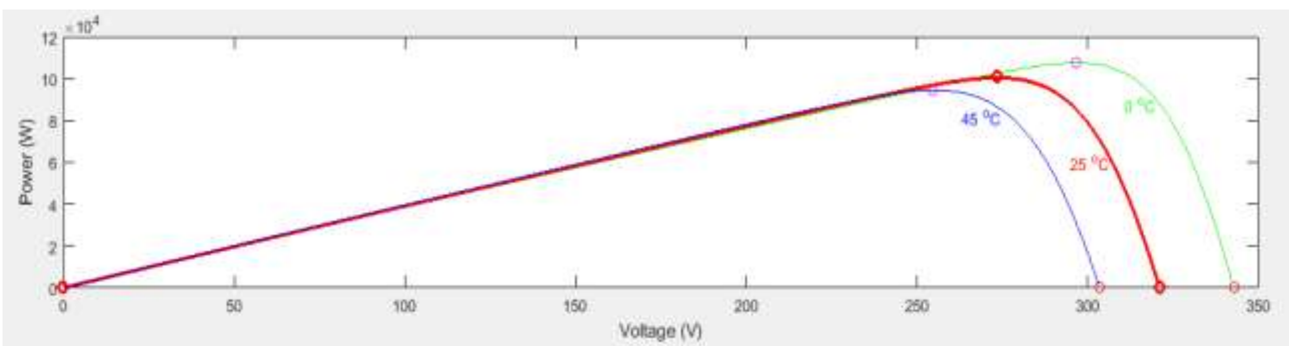

Figure 4:- Effect of Isolation on Current.

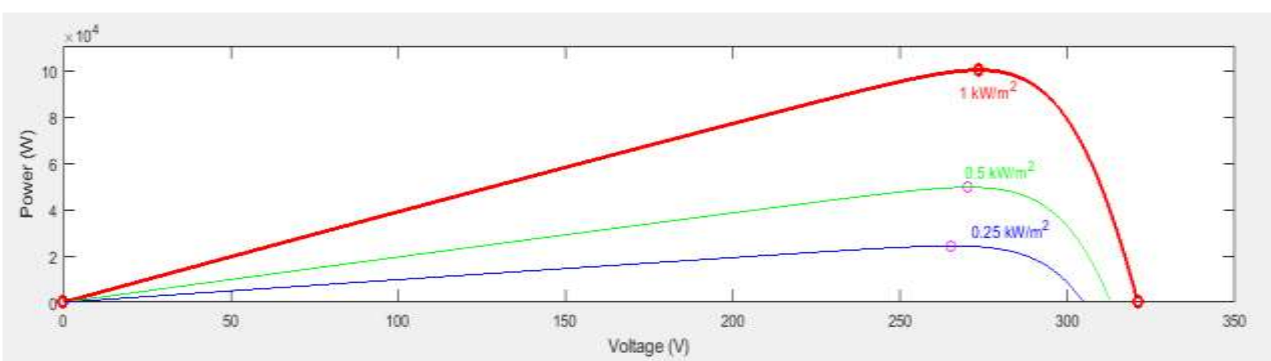

Figure 5:- Effect of Isolation on Power.

On a typical, solar cell Current V/s Voltage characteristics curve, the major electrical features of a Photovoltaic module are described in the waveform between the voltage and current generated. The quantity of solar radiation (insolation) that reaches the solar cell handles the current (I), whereas the voltage (V) is lowered as the temperature of the solar cell rises.Current and Power characteristics versus voltage of solar PV module on varying temperature and isolation are as shown in the above figures.

While solar PV voltage output is impacted by ambient conditions and useable irradiance, a boost converter is utilized to provide a constant input voltage to the converter, irrespective of solar PV voltage output fluctuations. Using DC-DC converter solar energy is fed into a common DC connection. This type of converter often known as a DC-DC step-up converter. The following equations are used in the modeling and simulation of the boost converter.

Duty cycle of the boost converter can be calculated using the equation

$$V_0 = \frac{V_s}{1-D} \quad (7)$$

Where, V_s-Input voltage
V_0-Output voltage required
D-Duty cycle

The minimum and maximum inductor currents can now be calculated using

$$I_{Lmin} = I_L - \frac{\Delta I_L}{2} \quad (8)$$

And

$$I_{Lmax} = I_L + \frac{\Delta I_L}{2} \quad (9)$$

Where $\Delta I_L = (0.2\ to\ 0.4) * I_0 * \frac{V_0}{V_s}$

The inductor value is obtained from

$$L = \frac{V_s D}{\Delta I_L f} \quad (10)$$

Where, f- Switching frequency
D- Duty cycle
L- Inductance

The capacitor value is obtained from

$$\mathrm{C} = \frac{\mathrm{D}}{\mathrm{R}\left(\frac{\Delta \mathrm{V}_0}{\mathrm{V}_0}\right)\mathrm{f}} \quad (11)$$

Where ΔV_0- Output voltage ripple.

MPPT:-

A solar cell's efficiency is low. Routines must be carried out in order to match the source and load appropriately, with the explicit purpose of increasing efficiency. MPPT is one such approach. This method is used to obtain the greatest extreme force possible from a fluctuating source. The I-V curve in photovoltaic frameworks is indirect, making it complicated to use. This is accomplished by using a help converter with a duty cycle that is varied using an MPPT algorithm.

The MPPT Algorithms are designed for the Photovoltaic systems which can generate maximum power at any instant of varying conditions. There are basically two sensors used at the input side of MPPT for voltage and currentmeasurement. The current, voltages established in the MPPT do have mathematical relations to justify operation. The most regularly utilized MPPT strategy is Perturb and Observe because of its simplicity of execution.The operating voltage has been increased The length of (dP)/dV is certain, i.e. the voltage is higher. In the event that (dP)/dV is found to be negative, the working voltage is reduced. (dP)/dV is close to zero, the voltage is held constant. The complex nature of this computation takes less time, but when it gets close to the MPP, it continues to bother. When there is a lot of variation in the sun-oriented illumination, this computation isn't appropriate. The voltage never quite reaches a careful esteem, but it irritates around the most extreme force point (MPPT).If there is a variation in irradiance, temperature, or ageing of PV panels, the MPPs (maximum power points) of PV panels might fluctuate. Because of this mismatch, there's a good chance that PV panels' total efficiency may suffer. To prevent the negative effects of mismatch circumstances and to achieve highly optimal efficiency, all PV panels must be operated at separate voltages in order to get the maximum amount of energy.

Another significant factor to consider is the efficiency of the power stage. In reality, one disadvantage of DMPPT applications is that, in the presence of mismatching events, DMPPT can only lead to better energy extraction than CMPPT provided the power stage efficiency of the SCPVMs is sufficiently high.Furthermore, because of the extra MPPT DC/DC conversion stages, the total efficiency of a PV system using CMPPT is projected to be higher than that of a PV system using DMPPT under uniform operating circumstances. Indeed, DMPPT does not always necessitate energy flow across two DC/DC stages.The fact that the DMPPT method does not always lead to each PV module in the field operating in its MPP is a significant disadvantage of DMPPT PV applications. This is owing to the finite voltage and current ratings of the devices used in the power stage of SCPVMs, as well as the restricted voltage conversion ratio of the MPPT DC/DC converters utilized.

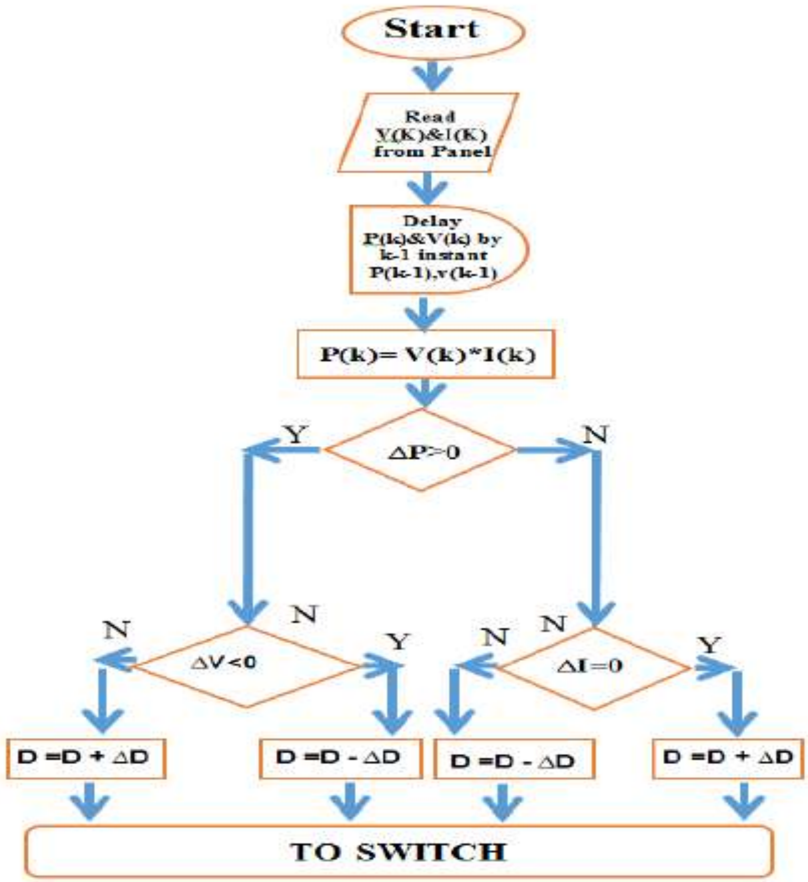

Figure 6:- Flow chart of P&O.

Figure 6 illustrates that in this technique, the operational PV voltage and current are examined (perturbed), and then the resulting power is monitored to determine whether the reference voltage or current should be decreased or increased.If the power increases as the perturbation step increases, the system is approaching MPP; if the power decreases as the perturbation step increases, the system has achieved steady state, and the perturbation step should be reversed. Instead of using reference voltage or current, the system can be constructed and configured to be controlled by the duty ratio.The perturbation step, on the other hand, has been conducted in the duty ratio, as indicated in the P&O block diagram.

A photovoltaic panel matrix converts sunlight into DC power, while a PCU is a device that transforms power DC to AC. The obtained AC power is either utilized by local loads or fed into UG. PV systems are occasionally supplemented with storage devices to improve power availability. A battery storage bank is not essential for grid-connected PV system, which considerably reduces the initial and ongoing expenditures. On the other perspective, the grid acts as a bank in the PV system, enabling for the deposit and withdrawal of additional electric power as needed. PV modules are often built on roof, when a PV system is installed in a residence, which reduces the size of the mounting structure and the quantity of land required.

A vector Control is use to control the dq components of the inverter currents, this controller is using two PI regulators (PIid and PIiq). For better transient behaviour, the equations incorporate the cross-coupling factors Lid and Liq, and a decouple technique is advised. After applying the inverse Park's transformation, Vd and Vq are sent to the PWM module. Finally, the PWM module's output is the state of the power switches of the three-phase inverter's power electronics devices (e.g., Insulated Gate Bipolar Transistors (IGBTs)). Predictive, hysteresis band PWM, and sinusoidal pulse width modulation control are typical output control approaches for a three phase VSI (SPWM).

Predictive control employs a calculation based on probable voltage values, followed by a switching state which generates predictive current that is closest to set reference current. This sort of control strategy can be defined as any optimization technique a system model to predict future behaviour and selects the best control action based on a set of criteria. It generates a quick dynamic reaction, as well as the ability to easily include nonlinearities and limitations into the system. The proposed a grid-connected inverter with LCL filter that has a robust predictive current control.

Hysteresis band current controllers use a variable switching frequency control approach to generate an output current at the inverter, in which the carrier frequency varies with the output waveform. This control approach has good accuracy, quick response, and unconditioned stability, but it may have drawbacks such as noise-causing uneven switching frequency and complicated input filter design.

Results:-

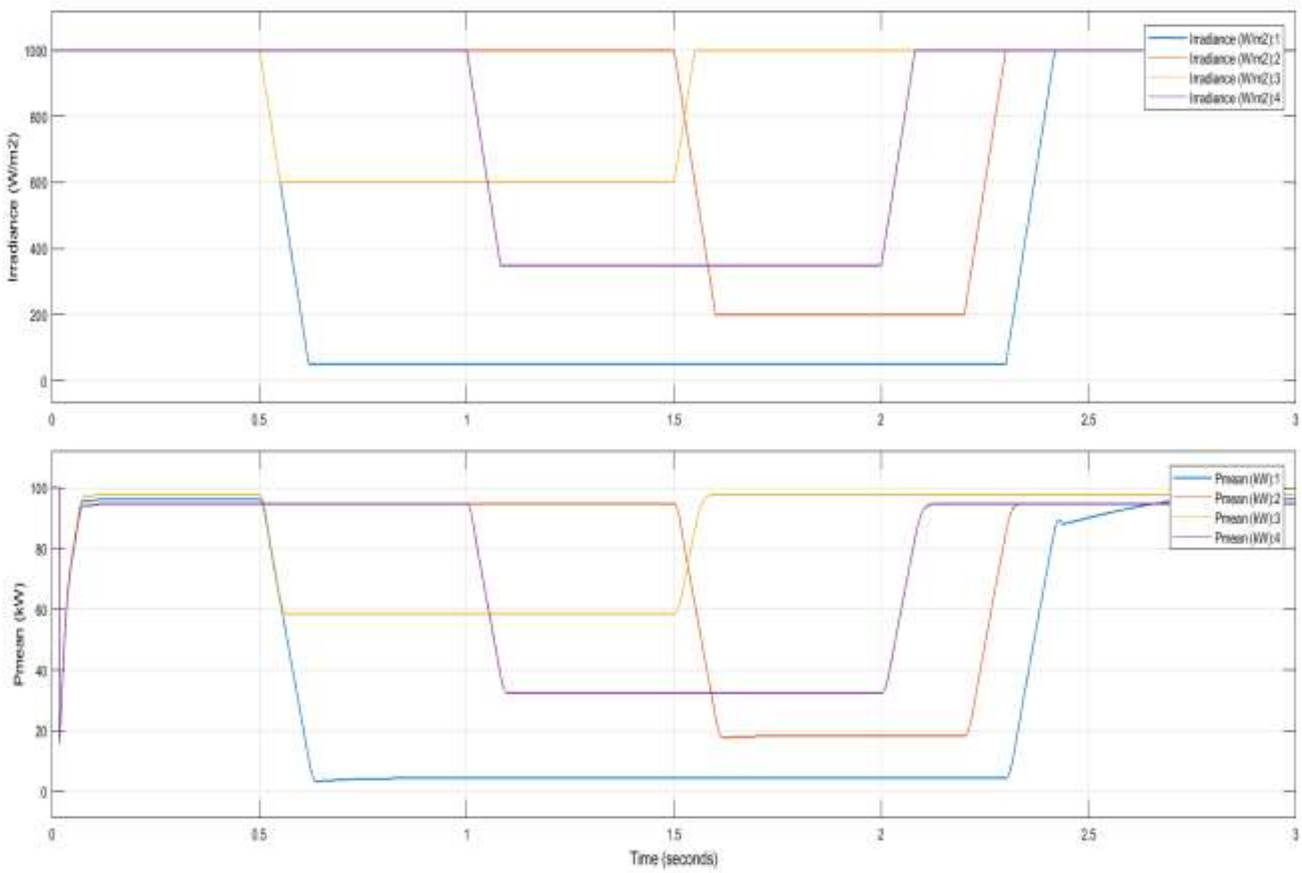

Figure 7:- Output waveform of solar mean power according to irradiance changes.

As shown in fig. 7the output waveform of mean power changes according to the solar irradiance of different solar module changes which is demonstrated in the above output waveform.

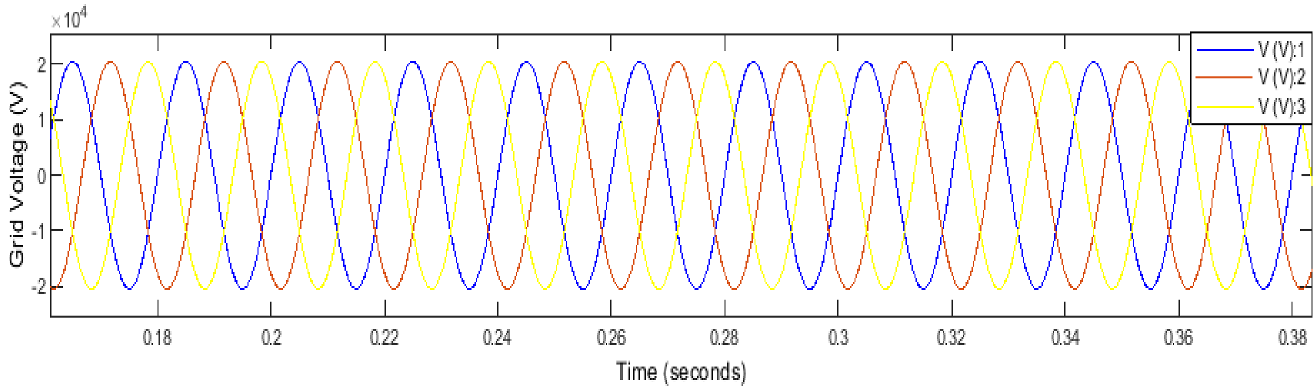

Fig. 8:- Grid side voltage.

Grid side voltage waveform is shown in figure 8. The voltage is generated from solar PV using distributed MPPT technique. To integrate the solar power to grid the grid side voltage should be sinusoidal and power factor should be unity.

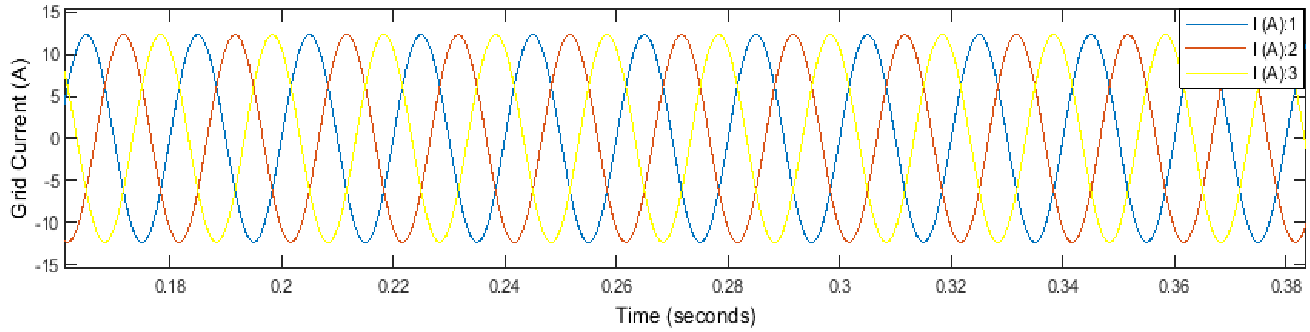

Fig. 9:- Grid side current.

The grid side current with changes in solar PV characteristics is shown in the simulation result above. The current will rise or fall in proportion to the solar irradiance and temperature.

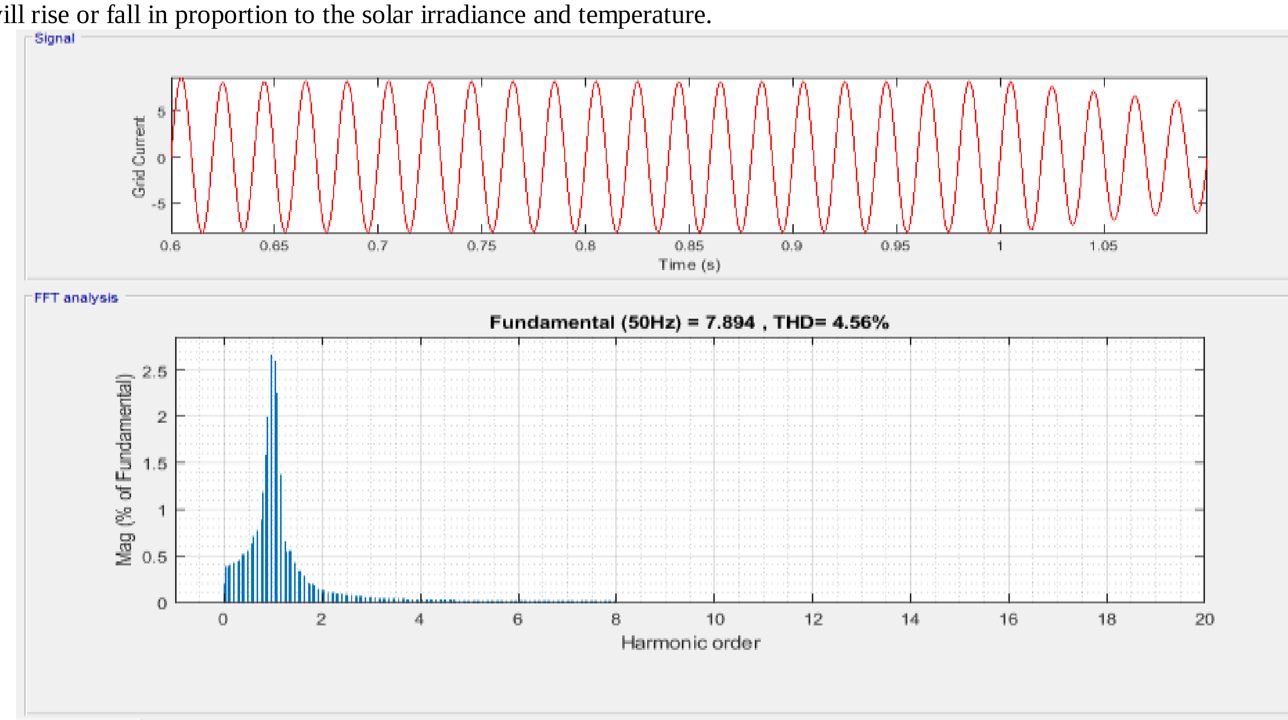

Fig. 10:- THD Analysis of Grid Current.

The distortion of a voltage or current is due to harmonics in the signalis describe by Total harmonic distortion (THD). Figure 10 shows the THD analysis of grid side current. THD should be less than 5%, according to IEEE standards and the determined THD value is 4.56%.

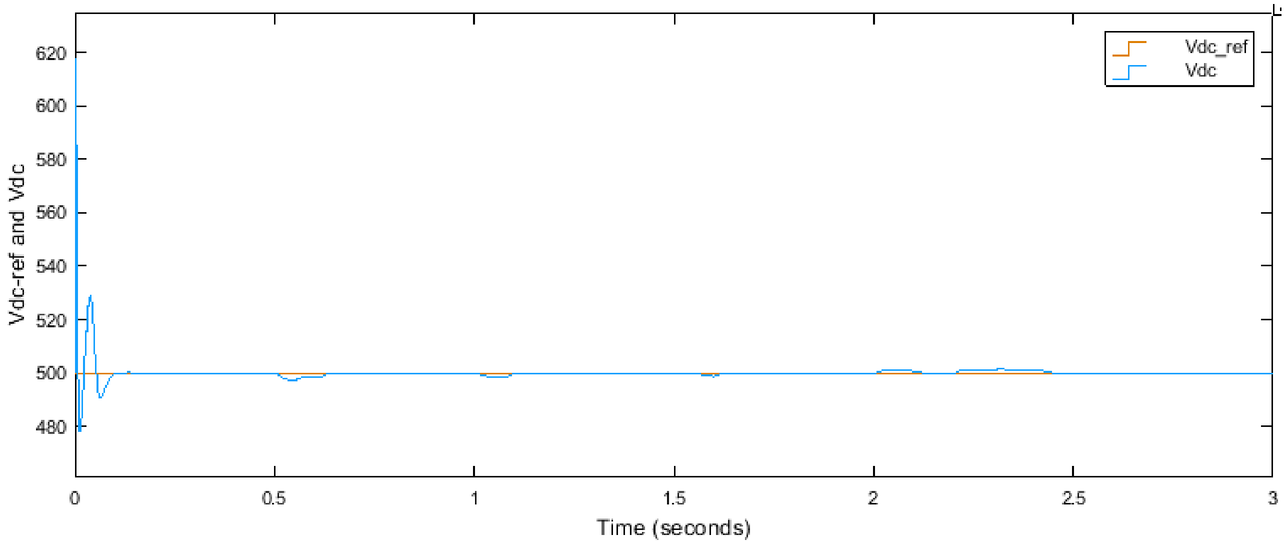

Fig. 11:-Voltage across DC-Link.

DC link voltage across the capacitor follows the reference DC voltage which is 500 volts as shown in above figure the DC link voltage waveform follows the reference value.

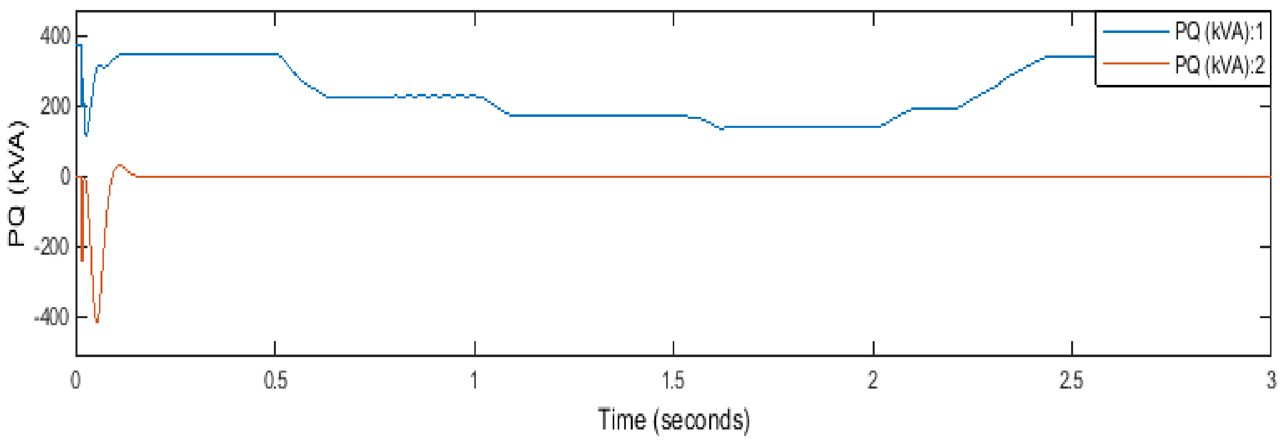

Figure 12:- PQ Across Grid.

The above simulation result shows variations in active power generated according to the irradiance changes. Active power fluctuated in response to variations in solar irradiation and temperature. MPPT is utilized to get the most power out of the solar PV system. Reactive power follows the reference value which is zero as shown in waveform.

Conclusion:-

The Perturb &Observe technique was used to regulate MPPT for PV panel grid linked systems in this research. The MPP of a solar cell varies depending on the amount of radiation and the temperature. With this control method, each PV module is operated at its maximum power point in order to obtain the maximum amount of solar energy. To enhance the total efficiency of PV systems, a distributed MPPT control method for solar PV is demonstrated.

The MATLAB simulations results shows the maximum power output of a PV module is proportional related to insolation and inversely related to temperature. In comparison to temperature, insolation has a greater impact on changes in maximum power production. Also the major parameters that influence DMPPT performance are briefly addressed, and a method for maximising the PV system's energy efficiency is provided.

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