Evaluation Performance of Multi-Array Grid coupled Solar Photovoltaic Systems

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Abstract- **Developed and developing countries consider employing renewable energy sources like solar photovoltaic (PV), wind, and biomass to interest up their potential for more clean and sustainable development and to realize revenues by export. Increasing interest and investment in renewable energy produce to early development of high penetration solar power. There are frequent ways to incorporate PV arrays with the power grid. The topology of a multiarray one-stage PV module with a unified inverter is developed in the paper, which is very much suitable for small and medium power applications. Though, the output of solar arrays varies due to change of solar irradiation and climate conditions which are intermittent in nature. Hence, the maximum power point tracking algorithm is employed in DC/DC converter (boost) allow PV arrays to operate at maximum power point. Then the central inverter is controlled by feedback current control algorithm and interfaced with the utility grid through the distribution network. Also, the current control of the inverter is independent of maximum power point control of the DC/DC converter.**

Index Terms: **DC (Direct current), PV (Photo-voltaic), MPPT (maximum power point tracking).**

I. INTRODUCTION

Soon, the interest for electric energy is relied upon to increment quickly because of the wide-reaching populace development and mechanization. This expansion in the energy request requires electric utilities to build their age. Recent studies predict that the world's net electricity generation is expected to rise from 17.3 trillion kilowatt-hours in 2005 to 24.4 trillion kilowatt-hours (an increase of 41%) in 2015 and 33.3 trillion kilowatt-hours (an increase of 92.5%) in 2030. At present, an enormous portion of power is created from petroleum products, particularly coal because of its low costs. Be that as it may, the expanding utilization of petroleum byproducts represents a critical part of natural contamination and ozone harming substance outflows, which are viewed as the principle purpose for the hazardous atmospheric deviation. For example, the emissions of carbon dioxide and mercury are expected to increase by 35% and 8%, respectively, by the year 2020 due to the expected increase in 2 electricity generation. Moreover, possible depletion of fossil fuel reserves and unstable price of oil are two main concerns for industrialized countries.

1.1 GRID – CONNECTED PV SYSTEMS: OVERVIEW

In a grid connected PV system, also known as a "grid-tied", or "on-grid" solar system, the PV solar panels or array are electrically connected or "tied" to the local mains electricity grid which feeds electrical energy back into the grid. The main advantage of a grid connected PV system is its simplicity, relatively low operating and preservation costs as well as reduced electricity bills. The hindrance however is that a sufficient number of solar panels need to be installed to generate the required amount of excess power.

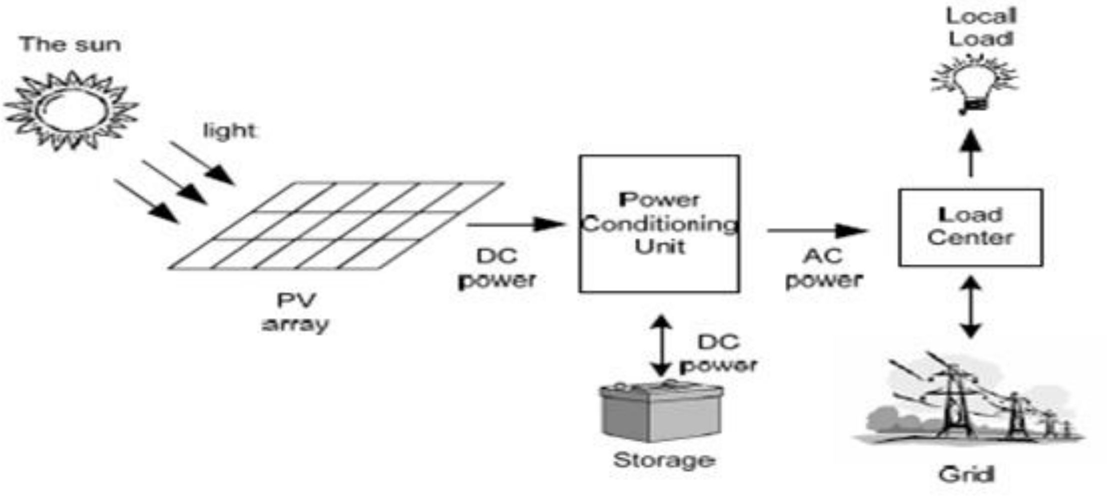


Fig. 1.1 Main Components of grid-connected photovoltaic system.

1.2 THE LIGHT FROM THE SUN

Irradiance or insolation is the instantaneous solar power received on a unit surface area and is normally given in W/m2. The *global irradiance*, *Gg*, that reaches a horizontal surface on the earth is the sum of two components:

a) *direct (beam) irradiance, Gb*, that directly reaches the horizontal surface without being scattered by the atmosphere and;
b) *diffuse irradiance*, *Gd*, that reaches the horizontal surface after being scattered by clouds.

Weather stations usually measure the global horizontal irradiance by a Pyranometer placed horizontally at the required location. On the other hand, a Pyrheliometer is used to measure the direct normal irradiance, which is the irradiance received by a surface that is perpendicular to the sun rays. Accordingly, the direct irradiance on the horizontal surface can be calculated.

Fig. 1.2 Irradiance observation use in Pyranometer.

1.3 PV ARRAYS: TECHNOLOGIES AND MODELLING

The electric characteristics of the PV cell depend mainly on the irradiance received by the cell and the cell temperature. Figure 2-5 displays the electrical characteristics of the cell at different levels of the irradiance and constant temperature. It is clear that the change in irradiance has a strong effect on the short-circuit current and output power of the cell, but negligible effect on the open-circuit voltage. On the other hand, Figure 2-6 shows that the change in temperature at constant irradiance has a strong effect on the open-circuit voltage and output power of the cell, but negligible effect on the short-circuit current.

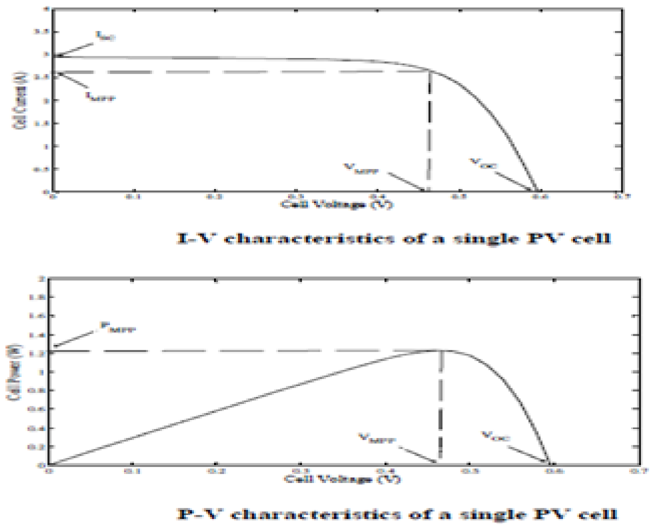


Fig. 1.3 Characteristics of PV Cell

Usually, solar cells are connected in series to form a solar module and modules are then connected in series to form a string. Finally, the strings are connected in parallel to form a PV array. The number of modules in each string is specified according to the required voltage level of the array. On the other hand, the number of strings is specified according to the required current rating of the array. Most PV arrays have a power diode, called bypass diode, connected in parallel with each individual module or a number of modules.

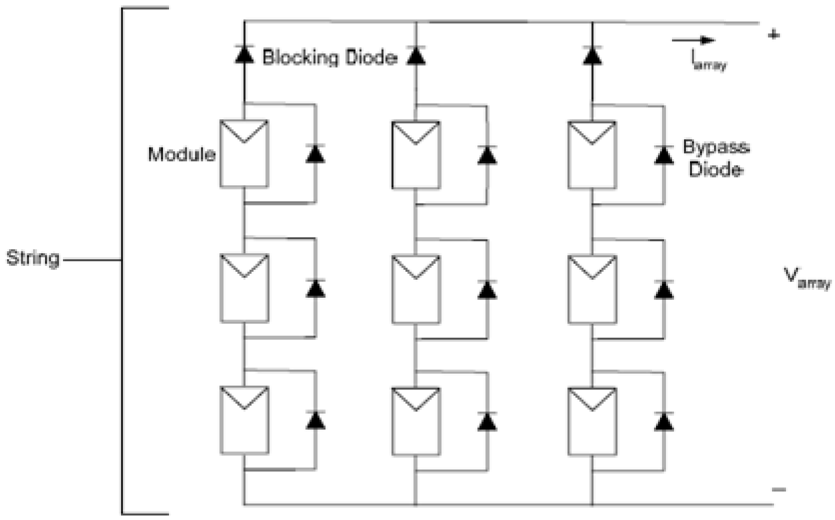


Fig. 1.4 Layout of a PV Array

Most studies related to the performance of PV systems require the use of a model to convert the irradiance received by the PV array and ambient temperature into the corresponding maximum DC power output of the PV array, *PMPP*. The models recorded in the literature vary in accuracy and complexity, and thus, appropriateness for different studies.

i) a current source, *Iph*, representing the light-induced current generated in the cell due to the separation and drift of the electron-hole pairs produced by incident photons from the sun,

ii) a shunt diode representing the p-n junction of the PV cell,

iii) a shunt resistance, *Rsh*, accounting for the leakage currents due to the impurities of the p-n junction (the value of this resistance should be made as high as possible), and

iv) a series resistance, *Rs*, representing all the distributed ohmic resistances in the semiconductor and the resistances of the metallic contacts (ideally, the value of this resistance should be zero).

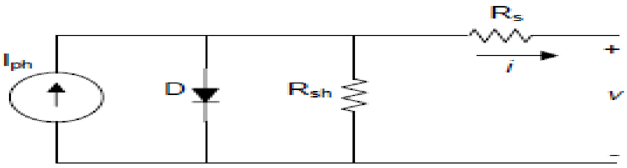


Fig. 1.5 Single Diode model of a PV cell

1.4 CONNECTION TOPOLOGIES OF PV SYSTEMS

PV systems have different topologies according to the connection of the PV modules with the PCU. Some of the common topologies are shown in figure and comparison between these topologies.

a) Centralized topology

This is one of the grounded geographies. It is normally utilized for huge PV frameworks with high force yield of up to a few megawatts. In this geography, a solitary inverter is associated with the PV cluster.

b) Master-slave topology

This geography plans to work on the unwavering quality of the concentrated geography. For this situation, a number of equal inverters are associated with the exhibit and the quantity of working inverters is picked with the end goal that in the event that one inverter comes up short, different inverters can convey the entire PV power.

c) String topology

In the string topology, each string is associated with one inverter; henceforth, the unwavering quality of the framework is improved. Additionally, the misfortunes because of incomplete concealing are decreased on the grounds that each string can work at its own most extreme force point.

d) *Team Concept topology*

This topology is utilized for huge PV frameworks; it joins the string innovation with the ace slave idea. At low irradiance levels, the total PV exhibit is associated with one inverter as it were. As the irradiance level builds, the PV cluster is partitioned into more modest string units until each string inverter works at near its evaluated power.

e) Multi-String topology

In this topology, each string is associated with a DC-DC converter for following the most extreme force point and voltage enhancement. All the DC-DC converters are then, at that point associated with a solitary inverter by means of a DC transport.

f) Modular topology

This is the latest geography. It is likewise alluded to as "AC modules", on the grounds that an inverter is installed in every module. It enjoys many benefits, for example, decrease of misfortunes because of fractional concealing, better checking for module disappointment, and adaptability of cluster plan. Notwithstanding, this geography is appropriate just for low force applications (up to 500W) and its expense is generally high.

II. LITERATURE REVIEW

Modelling of PV systems as distributed energy resources for steady-state power flow studies

Luis M. Castro, et.al. (2020), proposed that PV system model useful for steady-state power flow studies of practical electrical networks. This multi-array PV system model features a comprehensive representation of the three main stages taking part in solar energy conversion systems: (i) PV arrays for the solar-to-electrical energy conversion, (ii) the DC boost converter useful for establishing the MPPT strategy and for stepping up the output voltage of the PV arrays, and (iii) the DC-to-AC power conversion by the voltage source converter (VSC) used to link the PV system with the AC grid. For validation purposes, a 1.5-MW PV system coupled to a 3-bus AC network was simulated.

PV fed Hybrid Energy Storage System Supported DC Microgrid

J. Kumar, et.al. (2019) proposed that DC Microgrid has been a key research area from the last few decades. Most of the renewable
energy sources are intermittent in nature. Power management for the system is essential to guarantee high utilization of renewable
sources and stable operation of MG. This paper presents an Islanded DCMG in which PV connects with the DC bus through the unidirectional boost converter and its duty cycle is controlled by the P&O MPPT algorithm. Its power is fed to a variable DC load.

Analysis and mitigation of power quality issues in distributed generation systems using custom power devices
Hossain, E. et.al (2018) discussed that the power quality issues for distributed generation systems based on renewable energy sources, such as solar and wind energy. A thorough discussion about the power quality issues is conducted here. The power quality issues, followed by discussions of basic standards. A comprehensive study of power quality in power systems, including the systems with dc and renewable sources is done in this paper. Power quality monitoring techniques and possible solutions of the power quality issues for the power systems are elaborately studied. Then, we analyse the methods of mitigation of these problems using custom power devices, such as D-STATCOM, UPQC, UPS, TVSS, DVR, etc., for micro grid systems. For renewable energy systems, STATCOM can be a potential choice due to its several advantages, whereas spinning reserve can enhance the power quality in traditional systems. At Last, the study of power quality in dc systems. Simpler arrangement and higher reliability are two main advantages of the dc systems though it faces other power quality issues, such as instability and poor detection of faults.

Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems
Gandoman, F.H. et. al. (2018) says that in last two decades, emerging use of renewable and distributed energy sources in electricity grid has created new challenges for the utility regarding the power quality, voltage stabilization and efficient energy utilization. Power electronic converters are extensively utilized to interface the emerging energy systems (without and with energy storage) and smart buildings with the transmission and distribution systems. Flexible ac transmission systems (FACTSs) and voltage-source converters, with smart dynamic controllers, are emerging as a stabilization and power filtering equipment to improve the power quality.

III. PROBLEM IDENTIFICATION

3.1 PROBLEM IDENTIFIED

There are certain challenges in the integration of wind and solar systems with grid directly. For grid connection of renewable energy sources, we use Grid Integration – Grid-tie Inverter. The use of Inverter is to take energy from grid when renewable energy is insufficient.

1. Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency. Electrical appliances and generators all produce harmonics and in large volumes (e.g. computers and compact fluorescent lamps), can cause interference that results in a number of power quality problems. Most grid-lattice associated inverters for DG applications put out exceptionally low degrees of symphonious current, and in view of their circulation on the organization are probably not going to cause consonant issues, even at high infiltration levels.

2. Frequency and voltage fluctuation which are again classified as:

a) Grid-derived voltage fluctuations

Inverters are by and large designed to work in network 'voltage-following' mode and to detach DG when the lattice voltage moves outside set boundaries. This is both to assist with guaranteeing they contribute appropriate force quality just as help to secure against unexpected islanding. Where there are huge quantities of DG frameworks or huge DG frameworks on a specific feeder, their programmed disengagement because of the lattice voltage being out of reach can be dangerous in light of the fact that different generators on the organization will out of nowhere need to give extra force.

b) Voltage imbalance

Voltage imbalances is the point at which the sufficiency of each stage voltage is distinctive in a three-stage framework or the stage contrast isn't actually 120°. Single stage frameworks introduced excessively on a solitary stage might cause seriously unequal organizations prompting harm to controls, transformers, DG, engines and force electronic gadgets.

c) Voltage rises and Reverse power flow

Conventional centralized power network includes power stream one way in particular: from power plant to transmission organization, to dissemination organization, to stack. To oblige line misfortunes, voltage is generally provided at 5-10% higher than the ostensible end use voltage. Voltage controllers are additionally used to make up for voltage drop and keep up with the voltage in the assigned reach along the line.

d) Power factor Correction

In view of helpless force factor line losses increments and voltage regulation become troublesome. Poor power factor on the grid expands line misfortunes and makes voltage guideline more troublesome. Inverters designed to be voltage-following have solidarity power factor, while inverters in voltage-managing mode give current that is out of stage with the network voltage thus give power factor adjustment.

3.2 IMPACTS OF CONNECTING PV SYSTEM TO THE GRID

If the PV penetration is really high Photovoltaic systems can subject the grid to several negative impacts. They are:

1. Reverse power flow,
2. Overvoltage along Distribution feeders,
3. Voltage control difficulty,

4. Phase unbalance,
5. Power Quality problems,
6. Increased Reactive power and
7. Islanding detection difficulty.

These impacts are dependent on the size and location of the installed PV systems. According to the Solar America Board for Codes and Standards (Solar ABCs) PV systems are classified into three categories, based on the ratings of the system. Small-scale systems are rated at 10kW or less; Medium-scale systems are rated between 10kW and 500kW; and large-scale systems are rated above 500 kW.

3.3 PROBLEM IN CONVENTIONAL INVERTERS USED IN PV SYSTEMS

1. A traditional inverter used in PV systems cannot overcome the intermittent nature of the produced power by RESs remains one of the major issues in grid-connected RES. It is believed that the contribution of RESs to the global energy market will increase in the future; hence, this problem of power fluctuations in grid-connected RESs demands to be addressed.

2. The normal Inverters with SPV system are unsuitable for large-scale RES application. The conventions inverter doesn't have multiterminal direct current (MTDC) and DC grids due to their constructional features. The inverters embedded with PV systems into the present power system are not able to significantly enhance system reliability and efficiency, support renewable energy integration, and improve the economy and flexibility of power transmission.

3. The integration of renewable energy systems to grids using suitable traditional Inverters in consideration cannot reduce the total standing voltage (TSV), in order to increase the suitability for the integration of both PV and wind energy systems.

These are severe problems in classical inverter and its control integration with PV systems with conjunction to grid which are mentioned above, so I have to introduce BESS in RES systems instead traditional topology, because it has many evolutionary tuning techniques for giving optimal output which are best suited in industrial and commercial applications for satisfying the demanding load

IV. METHODOLOGY

4.1 LAYOUT OF PROPOSED TOPOLOGY

In grid-connected inverters for PV applications, a number of different approaches have been developed and used over the last 20 years. An excellent review of such systems available in many Literature reviews. Only the two or more common approaches used in smaller residential scale installations.

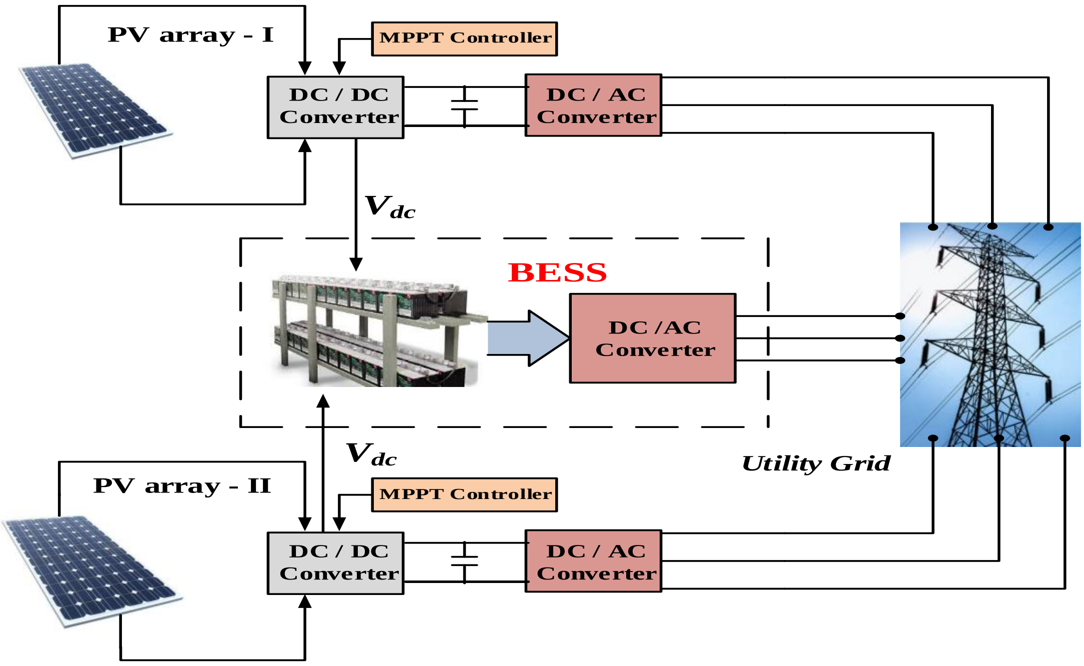


Fig. 4.1 Proposed multi-array PV connected grid system.

4.2 PV ARRAY MODELLING

Photovoltaic cell is the most basic generation part in PV system. Single-diode mathematic model is applicable to simulate silicon photovoltaic cells, which consists of a photocurrent source I_{ph} a nonlinear diode, internal resistances R_s and R_{sh}. as shown in below Figure

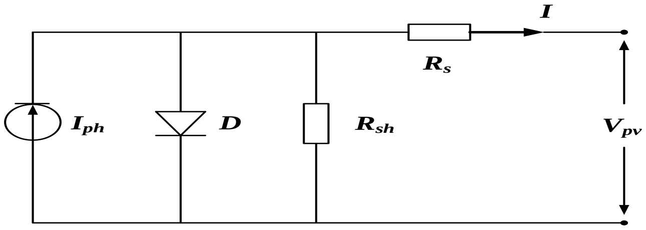


Fig. 4.2 Single-diode mathematical PV model

The mathematic relationship for the current and voltage in the single-diode equivalent circuit can be described as:

$$I = I_{ph} - I_s\left(e^{\frac{q(V+IR_S)}{AkT}} - 1\right) - \frac{V+IR_S}{R_{sh}} \quad (1)$$

where, I_{ph} is photocurrent; I, is diode saturation current; q is coulomb constant (1.602e·19C); k is Boltzman's constant (1.38Ie-23 J/K); T is cell temperature (K); A is P-N junction ideality factor; R and R_{sh} are intrinsic series and shunt resistances.

Photocurrent is the function of solar radiation and cell temperature, described as:

$$I_{ph} = \left(\frac{S}{S_{ref}}\right)\left[I_{ph,ref} + C_T\left(T - T_{ref}\right)\right] \quad (2)$$

where, S is the real solar radiation (W/m^2); S_{ref} ,T_{ref}, $I_{ph,ref}$ is the solar radiation, cell absolute temperature, photo current in standard test conditions respectively; C_T is the temperature coefficient (A/K).

Diode saturation current varies with the cell temperature;

$$I_s = I_{s,ref}\left(\frac{T}{T_{ref}}\right)^3 e^{\left[\frac{qE_g}{Ak}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]} \quad (3)$$

where $I_{s,ref}$ is the diode saturation current in standard test conditions; E_g is the band-gap energy of the cell semiconductor (eV), depending on the cell material.

TABLE I: PARAMETERS OF A SINGLE PV MODEL

Parameters	***Value***
Solar Irradiance; G_{ref}	1000 W/m^2
Cell temperature; T_{ref}	25^oC
Cell per each module	36
No. of modules connected in Parallel	10
No. of modules connected in Series	10
Open circuit voltage; V_{oc}	64.8 *volts*
Short circuit current; I_{sc}	5.96 A*mps*
Maximum voltage; V_m	54.7 *volts*
Maximum current; I_m	5.58 *mps*
Temperature co-efficient	6.175*%*

With different temperatures and solar radiations, output characteristics of PV array are simulated

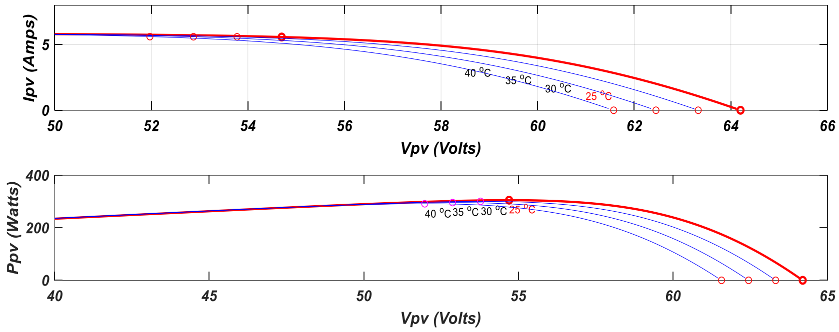


Fig. 4.3 Characteristics curves of a single PV module with different temperature

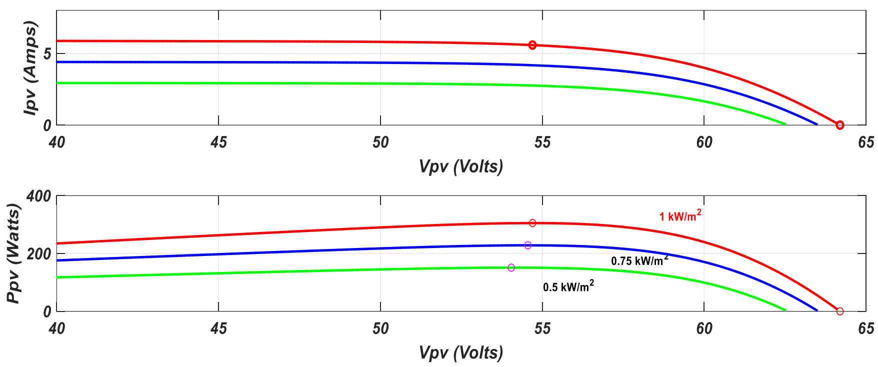


Fig. 4.4 Characteristics curves of a single PV module with different solar irradiation

4.3 BOOST CONVERTER

Boost converter converts variable dc from PV array into stable fixed dc. The boost converter circuit has IGBT switch, inductor, shunt capacitor and diode. Fig. 4.5 shows the circuit diagram of dc–dc boost converter.

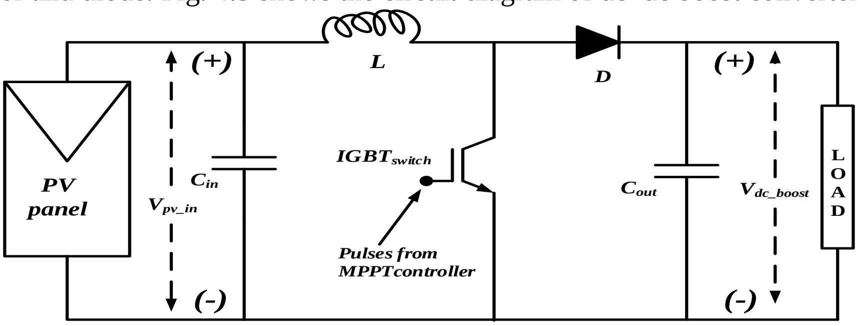


Fig. 4.5 Schematic diagram of DC/DC boost converter

The values of inductance, capacitance, duty ratio and resistive load can be obtained as:

$$L = \frac{V_{i/p} * (V_{o/p} - V_{i/p})}{(\Delta I f_{sw} V_{o/p})}$$

$$\alpha = 1 - \frac{V_{i/p}}{V_{o/p}}$$

$$C = \frac{I_a * \alpha}{(\Delta V f_{sw} V_{o/p})}$$

$$R_{in} = (1-\alpha)^2 R_{internal}$$

Where, $V_{o/p}$ is the output voltage of inductance, α is the duty ratio, ΔI indicates ripple in output current and which is 10% of the input current, f_{sw} is the switching frequency, ΔV indicates ripple in peak voltage, I_a indicates average output current and it is considered as 3% of the output voltage, $V_{i/p}$ is input voltage, R_{in} is the input resistance.

4.4 P&O MPPT ALGORITHM IMPLEMENTATION

The variation of the irradiance level, panel temperature and I–V characteristic of a PV array, led to variation in MPP, (as it is the function of the irradiance level, ambient temperature, efficiency of the heat exchange process and operating point of the panels). It makes necessary to track continuously the MPP to maximize the power output from a PV system, for a given set of operating conditions. The maximum power point tracking (MPPT) can be achieved by different approaches like fuzzy logic, neural networks, pilot cells and DSP based implementations which have been proposed.

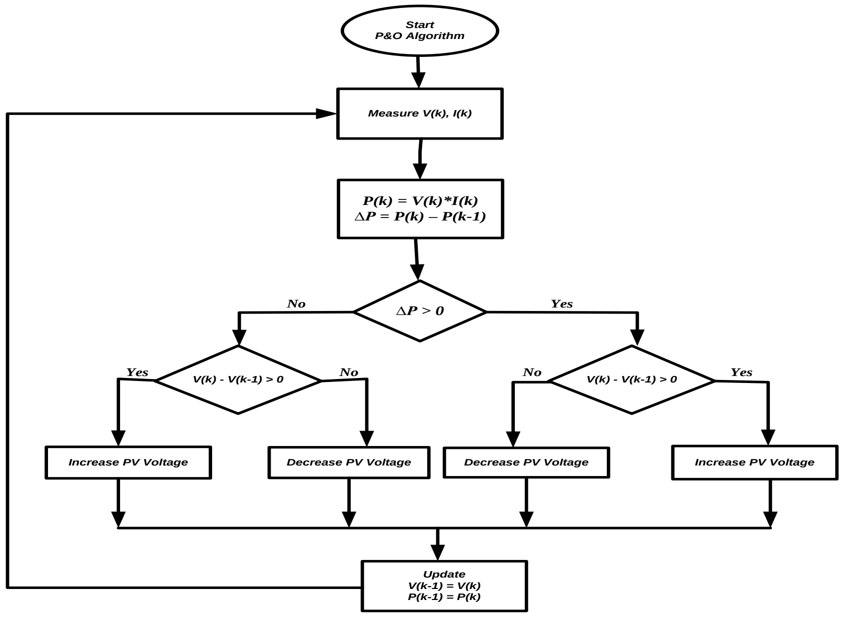


Fig. 4.6 Flowchart of P&O MPPT algorithm

In P&O method, the MPPT algorithm is based on output power the calculation of the PV and change in power by sampling both the PV Array current and voltage. The tracker observes change in voltage (ΔV) and the voltage is incremented or decremented periodically of the PV panel. If the perturbation leads to an increase (decrease) in differential change in power (ΔP) of PV, then the subsequent perturbation is generated in the same (opposite) direction.

4.5 VSI MODELLING

Grid-connected PV generation system is mainly composed of the PV array, the inverter device with the function of maximum power tracking and the control system. The inverter device with the function of maximum power point tracking can inverse the electric power into sinusoidal current, and connect to the grid. The control system mainly controls the maximum power point tracking of photovoltaic, current waveform and power of the output of grid-connected inverter, which makes the output to the grid correspond with the export by PV array.

Voltage Source Inverter control method

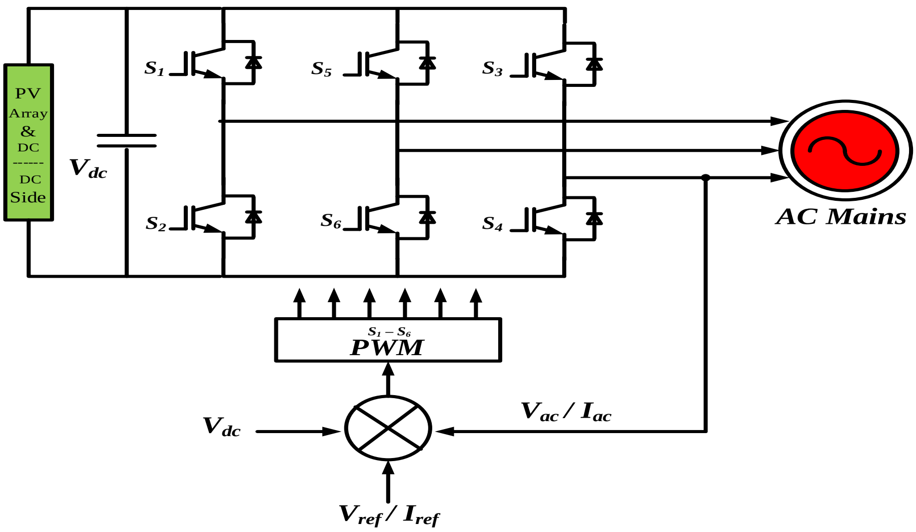


Fig. 4.7 Voltage source inverter and its control method

The PV array's working voltage is set to V_o, the standard voltage V_{ref} should be matched with the working voltage V_o when the PV array is in the maximum power output state. The standard current I_{ref} should be kept to sinusoidal while the power factor should be kept to one which can be realized by PWM control method. S_w is a switch which mainly protects the inverter, and cuts the inverter from the system when the system power off. The voltage source inverter and its control method are shown in above figure.

4.6 ACTIVE & REACTIVE POWER COMPENSATION

The active power pumped by grid tied solar inverter into the grid is a function of solar insolation. This means that the amount of active power pumped into the grid will be lower than the designed rated capacity of solar inverter if the solar irradiance is less (which actually happens as the solar irradiance is not uniformly maximum throughout the day). This leads to underutilization of the inverter resource. If the inverter is programmed to provide reactive power also in addition to active power (based on solar irradiance availability) then the inverter can be operated at its rated capacity even when the solar resource is not fully available. Reactive power compensation through solar inverter is an interesting method to manage network voltages through reactive power injection and absorption.

4.7 Phase-Locked Loop

The phase-locked loop technique has been used as a common way to synthesize the phase and frequency information of the electrical system, especially when it's interfaced with power electronic devices. A simple method of obtaining the phase information is to detect the zero-crossing point of the utility voltages.

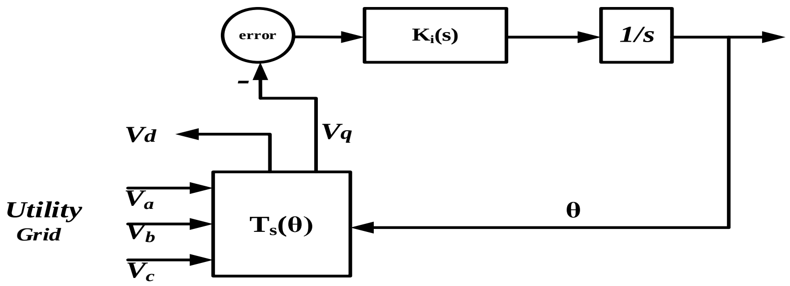


Fig. 4.8 Block diagram of Three phase PLL

However, since the zero-crossing point can be detected only at every half cycle of the utility frequency, the phase tracking is impossible between the detecting points and thus the fast dynamic performance cannot be obtained. An improved method using the integral of the input waveform is proposed in the work. In the three-phase system, the dq transform of the three-phase variables has the same characteristics and the PLL system can be implemented using the dq transform.

$$\begin{bmatrix} v_d \\ v_q \\ v_0 \end{bmatrix} = T_s(\theta)\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin(\theta) & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \qquad (8)$$

As shown in Figure 4.8, the three-phase voltage is transformed into two DC quantities in dq axis. Then the q-axis quantity vsq is compared with the reference value zero and generates the error signal. In steady state, the reference value of q-axis is set to be zero so that only d-axis component exists to represent the AC quantity while the angular frequency becomes equal to the grid frequency. The error passes through a loop filter to derive the angular frequency. The phase shift θ is derived by integral of the angular frequency. By properly designing the loop filter Ki(s), the PLL frequency ω and phase θ can be tracked accurately.

As the regulation of V_{sc} has the effect that the expression for the PV system real power output is simplified to:

$$P_s = \frac{3}{2} v_{sd} i_d \qquad (9)$$

Equation (9) indicates that Ps is proportional to id and can be controlled by id. Ps is controlled to regulate the real power extracted from the PV array. Similarly, the reactive power is regulated by controlling iq.

$$Q_s = -\frac{3}{2} v_{sd} i_q \qquad (10)$$

The voltage and current from the PV module are measured and used to calculate the active power output of PV module generated. For the two string PV system, the real power can be calculated as follows:

$$P_{ref} = V_{pv\_1} I_{pv\_1} + V_{pv\_2} V_{pv\_2} \quad (11)$$

The reactive power Q_{ref} pumped into the distribution network is set to zero so that the power factor of the distribution network can be adjusted. The current references in *d-q* axis can be derived according to:

$$\begin{bmatrix} I_{d\_ref} \\ I_{q\_ref} \end{bmatrix} = \frac{2}{3} \frac{1}{V_{sd}^2 + V_{sq}^2} \begin{bmatrix} V_{sd} & V_{sq} \\ V_{sq} & -V_{sd} \end{bmatrix} \begin{bmatrix} P_{ref} \\ Q_{ref} \end{bmatrix} \quad (12)$$

where Vsd, Vsq represent the voltage in dq axis at the point of common coupling (PCC).

V. RESULTS AND DISCUSSIONS

Detailed simulation studies are carried out on MATLAB/Simulink platform, and the results obtained for various operating conditions are presented in this section. The values of parameters used in the model for simulation are listed in Table I. The steady-state response of the system during the MPPT mode of operation is shown in Fig. 5.1 during slow and drastic changes in input to system. To verify the feasibility of the control strategies, the simulation of three phase, 50 kW solar multi-array PV inverter is presented in this section. MATLAB Simulink platform is used for this simulation

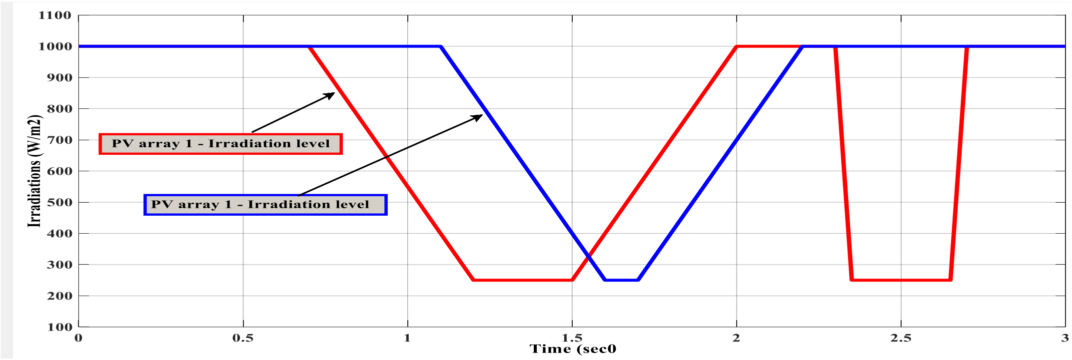


Fig. 5.1 Varying insolation levels to multi-array PV systems

It can easily depict from Fig. that the simulation results of the output power of the multi-array PV array (input power of the DC/DC converter) and the output power of the DC/DC converter for different solar irradiances can easily trace the for power without hard injection of reactive power.

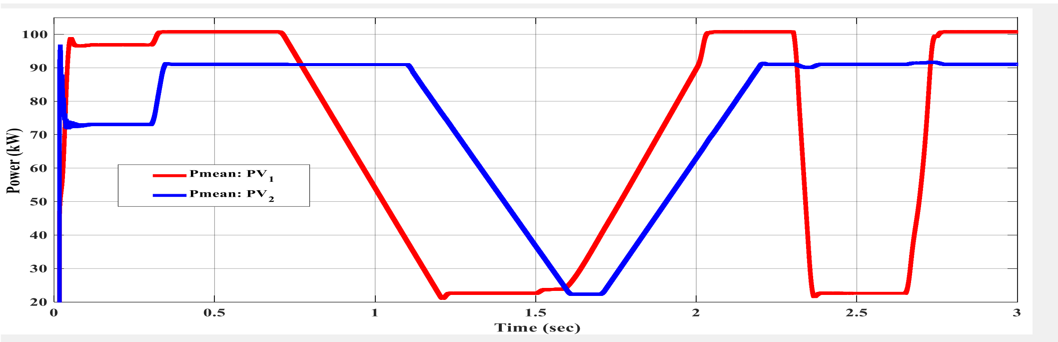
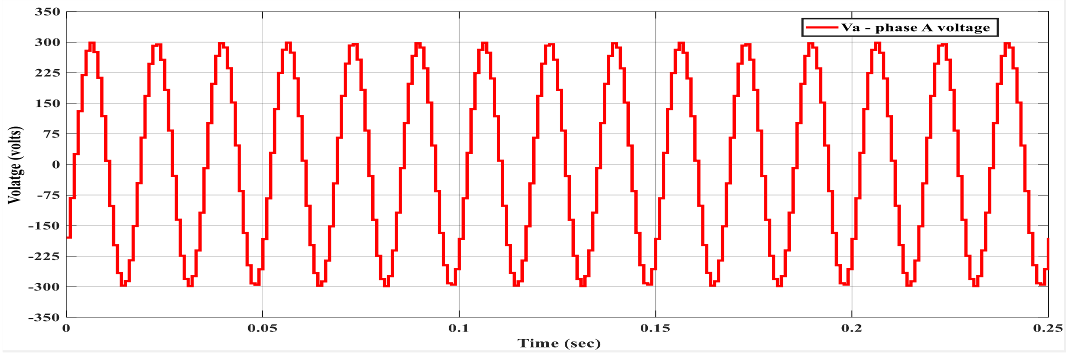


Fig. 5.2 DC output power from multi-array PV systems

Fig. shows a one of single phase (A-phase) out of 3-ph voltage from the output VSC Inverter feeding the grid. The output of VSC Inverter shows 7-lelvel sinusoidal waveform with less harmonic rejections in the grid.



9

Fig. 5.3 Phase "A" of output voltage from *3-ϕ* VSC Inverter

In Fig. it is shown that the converter three-phase output voltages are under varying full insolation throughout the system. The multi-array converter produces a smooth near-sinusoid output voltage which makes it a low distortion system.

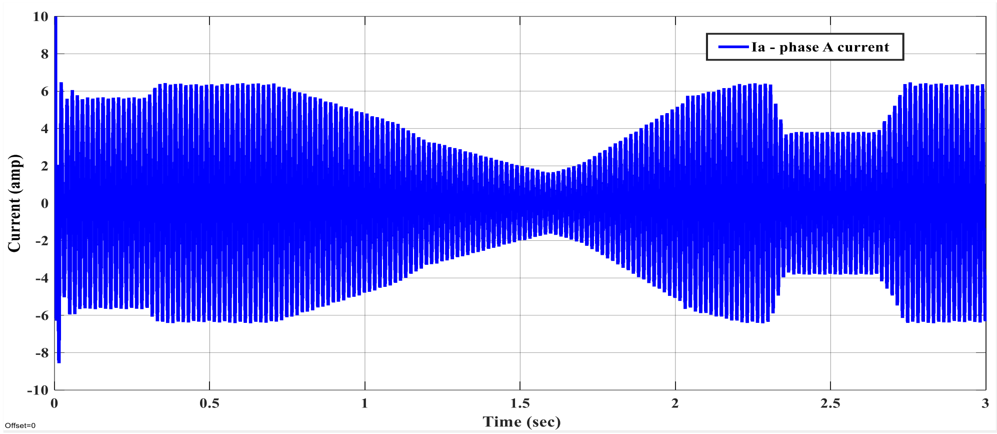


Fig. 5.4 Phase "A" output current waveform of 3-ph VSC Inverter

Fig. 5.4 depicts three phase output current. At time 1.5 sec and 2.5 sec, when insolation's levels fall drastically there is no distortion seen in the wave form

VI. CONCLUSION

In this thesis, the report on a multi-array grid-connected photovoltaic (PV) system with efficient tracking and best active and reactive power scheme in presence of utility grid was presented. For the general configuration, a novel topology of central inverter with individual DC/DC converter was introduced to model the grid interface of solar multi-arrays. Then DC transmission lines were also proposed to emulate the short distance between solar arrays and the central inverter. The system performance and transient response under disturbance conditions were analyzed in MATLAB^{TM}. Later on, small signal analysis was also carried out to validate the simulation model. The results showed that the system remained stable under the disturbance and the performance was acceptable. The active and reactive compensation was tested on Simulink bed which was configured with MATLAB^{TM} to achieve current control algorithm.

Two dynamic insolation levels were introduced in multi-array to study controllable DC output from boost converter to fed inverter was selected to represent the characteristics of the output of solar PV arrays. The VSC inverter was used to convert DC to AC, which was controlled by analog signal firing board. Though the LC filter had limitation for the degree of harmonic compensated, it always existed with the voltage source inverter to improve the voltage waveform on the AC side. The inverter was controlled to generate the lower value of reactive power current needed for the nonlinear load so that the current on the grid side could be approximately sinusoidal, at least within the standard set by the IEEE standard. Experimental results simulated in MATLAB environment corelates with operation needed to be performed by the system for better corresponds with real time working conditions. Finally, it's found out that the system performance of reactive power compensation was satisfied and applicable.

REFERENCES:

1. Luis M. Castro, J.R. Rodríguez-Rodríguez and Cecilia Martin-del-Campo, in "Modelling of PV systems as distributed energy resources for steady-state power flow studies", International Journal of Electrical Power & Energy Systems, Volume 115, 2020, 105505, ISSN 0142-0615.

2. J. Kumar, A. Agarwal and N. Singh, "PV fed Hybrid Energy Storage System Supported DC Microgrid," 2019 IEEE 1st International Conference on Energy, Systems and Information Processing (ICESIP), 2019, pp. 1-6, doi: 10.1109/ICESIP46348.2019.8938295.
3. Narasimha Prasad Tulasi and Lakshmi Devi Aithepalli, "Droop Control of Bi-Directional DC-DC Converter for Improved Voltage Regulation and Load Sharing in DC Microgrid", in International Journal of Intelligent Engineering and Systems, Vol.12, No.3, 2019, pp. 228 - 243. DOI: 10.22266/ijies2019.0630.23
4. Yogesh Tiwar and Gokul Kumar Dewangan, "A Review on Grid Connected Multi Array PV Battery Based Bi-Directional DC – DC Converter", International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 06 | June 2019.
5. Ameerul A. J. Jeman1, Naeem M S Hannoon2, Nabil Hidayat3, Mohamed M. H. Adam4, Ismail Musirin5, Vijayakumar, "Active and reactive power management of grid connected photovoltaic system", Indonesian Journal of Electrical Engineering and Computer Science", Vol. 13, No. 3, March 2019, pp. 1324~1331 ISSN: 2502-4752.
6. Biel, D., & Scherpen, J. M. A. (2018), "Active and Reactive Power Regulation in Single-Phase PV Inverters", in Proceedings of the European Control Conference 2018 IEEE Xplore, https://doi.org/10.23919/ECC.2018.8550507
7. Hirsch, A., Parag, Y. and Guerrero, J., 2018. "Microgrids: A review of technologies, key drivers, and outstanding issues." Renewable and sustainable Energy reviews, 90, pp.402-411.