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REVIEW PAPER ON THE GRID CONNECTED PV SYSTEM AND RELATED PROBLEMS

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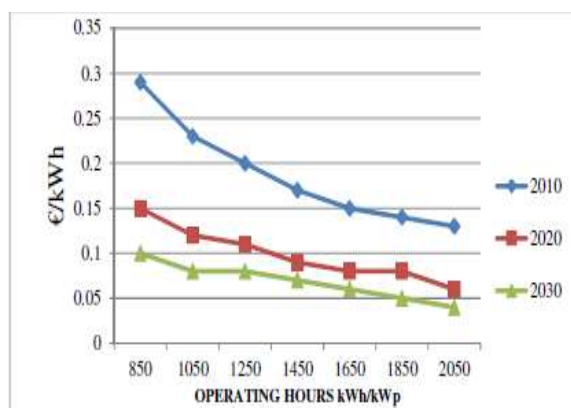
ABSTRACT
As the increasing installation of grid-connected PV systems, especially large systems in the order of megawatts, might lead to some operational problems in the electric network. Such negative impacts include power and voltage fluctuation problems harmonic distortion, malfunctioning of protective devices and so on. This may still prevent further share of grid-connected PV system in electricity market. Therefore, studying the possible impacts of PV systems on the electric network is and will be becoming an important issue and receiving a lot of attention from both researchers and electric utilities. For example, different algorithms are developed to mitigate the harmonics injected into the electric network. Active power filter is one of the most used methods.
KEYWORDS: grid, PV system, harmonic distortion,algorithm.

INTRODUCTION
In the last few years, the demand for renewable energy has increased significantly due to the disadvantages of conventional fossil fuels and greenhouse gas effect. Among various types of renewable energy resources, solar energy and wind energy have become the most promising and attractive because of advancement in power electronic technique for production of electricity. Photovoltaic (PV) sources are used nowadays in many applications because they have the advantage of being maintenance free and pollution free. In the past few years, solarenergy demand has grown consistently due to the following facts:
1) Increasing efficiency of solar cells.
2) Manufacturing technology improvement.
3) Economies ofscale.
Usually reliability of a PV system is associated with inverter topology and the main components.

The high uses of PV technology was induced by continuous increase of energy price generated in coal,diesel and gas power plant. PV system have been required to reduce costs in order to complete the demand of population and compete on energy market but on the same time to provide reliability. At the same time, more PV modules have been attached in series and will be connected to utility grid in many countries. The largest PV power plant is more than 100MW all over the world. But, the output of PV arrays is significantly influenced by solar irradiation and weather. More importantly, high initial cost and limited life time of PV panels make it more hard to extract as much power from them as possible.



Operating Hours kWh/kWp Vs e/kWh

The fast expansion and development of PV system into the lower parts of grid raised several concerns for grid reinforcement. This is the reason, grid operators had to impose strict operational rules in order to keep the LV grid under control and to harmonize the behavior of all distributed generators connected to it in terms of accuracy, efficiency and prices.PV array can be use as a standalone system but in this type power system suffers from the effect of complete and partial shading, which is usually caused by clouds, forests and commercial and domestic buildings. Under partially shaded condition, the IV characteristics of the PV array become complex with multiple peaks. These multiple peaks are generated due to non-uniform insolation level that receives on a partially shaded PV array surface or PV modules surface. The PV array efficiency is decreased due to these non uniform insolation level.

As the efficiency of PV system is growing significantly, the effect of PV modules on power grid can't be ignored. They can create problems on the grid like flicker, increase of harmonics, and aggravated stability of the power system. To both increase the capacity of PV arrays and maintain power quality, it's necessary to meet with the technique requirements of the PV system, such as fault ride through proficiency and harmonic current increment. Especially when a large scale PV module is connected to the grid, the effects on the grid may be quite severe. Therefore, the system activity and system stability under fault conditions should be checked when PV modules are connected with power grid.

PROBLEMS ASSOCIATED WITH GRID CONNECTED PV SYSTEMS

The increased number of grid connected PV system with the use of inverters gave rise a lot of problems concerning the stability ,efficiency and safety of grids. The main problems are:

Voltage Rise Problem

The integration of large amounts of PV system in the LV network increases generation of active power leading to increase in the rise of voltage along the feeders. At the moment the voltage rise does not exceed the 2% limit imposed by old grid code but now a days this limit has been increased by 3%.

50.2 Hz Problem

When the grid frequency reaches and exceeds 50.2 Hz an immediate shutdown is required from the grid connected generators to avoid risks which can appear in operation of network. If power deviation is higher than the predefined power of primary control, the system will not be able to stabilize and control the grid frequency. To overcome this problem we should use the frequency dependent active power control.

Increased Harmonics

As the number of grids in PV system increased than it also leads to an increase in harmonic content at the connection point. Each PV system connected to utility grid injects harmonics. More PV systems are connected the more harmonic content will increase. If one or more non linear loads are present, the total harmonic distortion can increase above allowable limit.

Increased Voltage Unbalance

The features of installed PV system such as their location and power generation capacity can lead to an increase in the voltage unbalance. This effect most the power quality in the LV residential networks due to random location of PV installation and their single phase grid connection. The voltage of three phases is different because the PV systems are installed randomly along the feeders and with various ratings. When the difference in amplitude between these phases is high then voltage unbalance increases.

Anti-islanding

Islanding happens when the PV generator is disconnected from the grid, but continues to supply power locally. The islanding problem mainly occurs in Low Voltage (LV) Networks, Therefore it is recommended for the generation units to disconnect the power supply within a narrow frequency band such as 49 to 51 Hz.

REVIEW ON GRID TECHNOLOGY

Development and improvement in PV technology in balance of system components, as well as experience gained from thousands of grid connected PV system installation, the cost of PV Energy and performance have improved to the point where a large off-grid market is flourishing and the on-grid market is nearly economic. More integration of PV modules with utility grid may lead to some operational problems in the electric network.

Many previous works deal with high penetration of PV system into power grid. Status in identifying and reviewing photovoltaic (PV) codes and standards (C&S) was reported in. Related electrical activities for grid-connected, high-penetration PV systems with utility distribution grid interconnection were also explored. It included identifying topics and concerns not yet in the scope of existing Codes & Standard documents, identifying Codes & Standard-related ongoing work and approaches, and providing recommendations related to Codes & Standard needs.

Currently, interconnection Codes & Standard in the US had been developed based on passive participation of PV systems in the grid. As higher

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levels of PV systems were integrated into the electric power system, these PV systems could play an active role in both the technical and business operations of the utility grid and in the customer facility and loads management. Therefore, addressing grid-integration technical and analytical issues was a necessary prerequisite for the long-term viability of the distributed PV industry, and in particular, that was paramount for high penetration.

The main technical impacts of large scale PV generations on power grid were: electricity quality, power flow control, voltage and frequency stability, new requirements to simulation technologies and test of power system environment, codes and standards revising or supplementing of grid operation and dispatching. Several fields were proposed to meet the practical and research requirements:

1) Modeling methods of PV systems
2) Control technology of grid-connected PV systems

Various models and algorithms were examined, simulated and tested for the objective of analyzing the grid-connected PV system performance. In a 3 MW PV system with the distribution system was modeled in Matlab/Simulink. The modeled PV system based on the equivalent circuits of the PV cell considered the number of series and parallel connections of PV cells and the changes in the temperature and irradiation level. The oscillation of voltage and current occurred after the initiation of the fault. In all fault types, the PV array was not operating at maximum power point (MPP). The output power of the PV array in the case of the three-phase fault was the smallest, while the output power of the PV array in the case of the single line-to-ground fault was the largest.

An experimental setup was created using an off-the-shelf grid-connected inverter to emulate the event of a fault occurred on a distribution feeder. The experimental results had shown that, without violating the specified criteria in the standard, the grid-connected inverter took time to detect an islanding condition and stop energizing. It also showed that higher penetration level of the PV grid-connected systems resulted in higher fault current which unavoidably had effects on the protective devices. To effectively detect islanding, feed forward compensation was proposed. This detection scheme came into operation when frequency, voltage, total harmonic distortion (THD), or impedance at the point of common coupling (PCC) exceeded the set thresholds due to opening of the breaker on the grid-side. The islanding detection capability was enhanced if any of these quantities were used as a feed-forward signal in the control scheme. And the detection was based on the measurement of voltage.

A new control strategy of inner current-control loop and an outer dc-link voltage control loop was adopted. The current-control strategy permitted dc-link voltage regulation and enabled power-factor control. Moreover, the current-control significantly decoupled dynamics of the PV system from those of the distribution network and the loads. The dc-link voltage-control scheme enabled the control and maximization of the real-power output of the PV system. And the influence of the control strategy was verified through digital time-domain simulation studies conducted on a detailed switched model of the whole system. In addition, a model analysis or sensitivity analysis was conducted on a linearized model of the system to characterize the dynamic properties of the PV system, to evaluate robustness of the controllers, and to recognize the nature of interactions between the PV system and the network. DC bus model was introduced in multistring PV system, and distribution network was also presented on grid side. Decoupled current control was employed in the voltage source inverter (VSI) to control the power injected into the network. The transient responses of the system were studied under disturbance conditions such as sudden change of solar irradiation, fault in the distribution network and fault in the DC bus. To reduce the huge increase in DC link voltage under fault condition, the storage system was introduced. The storage system comprise of a storage capacitor, resistor and inductor in series. And the storage system controller was designed to absorb the solar power under fault conditions. Then a multi level inverter was proposed since it offered great advantages such as lower total harmonic distortion (THD), improved output waveform, lower Electromagnetic Interference (EMI) and others, compared with two-level inverter for the same switching frequency. Two symmetrical triangular carriers were employed to generate the switching decisions for the nine-switch three-level inverter.

More and more nonlinear loads like rectifier circuits and switched mode power supplies result in injection of harmonic currents into electric power distribution network. Installation of active filter could be one of the solutions to mitigate the harmonic. On the other hand, photovoltaic (PV) systems can be controlled to operate as an active power filter (APF), as well as supplying power to grid. A high performance harmonic current reduction control scheme had been presented. Its

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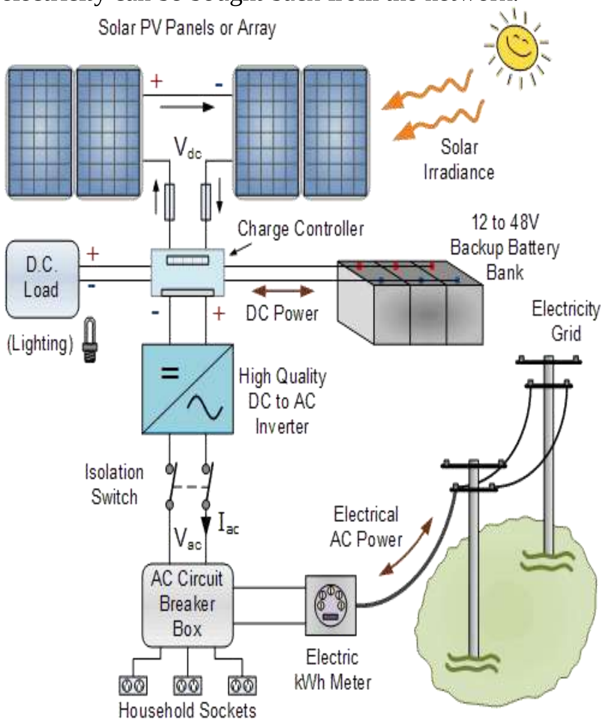
purpose was to reduce the harmonic current that flew through a power conditioning system (PCS) by outputting harmonic voltage equal to the one that contained in the grid. The control scheme did not use grid current and had low interference with the existing current control and fault-ride through capability. Extraction algorithm for the harmonic voltages enabled the voltage source inverter (VSI) in the PV generation system to output harmonic voltages that were very close to the harmonic voltage of the grid.

Types of Photovoltaic systems

PV technology was first inserted in space, by providing electricity to satellites. On the basis working operation PV systems operate in four basic forms.

Grid connected PV systems

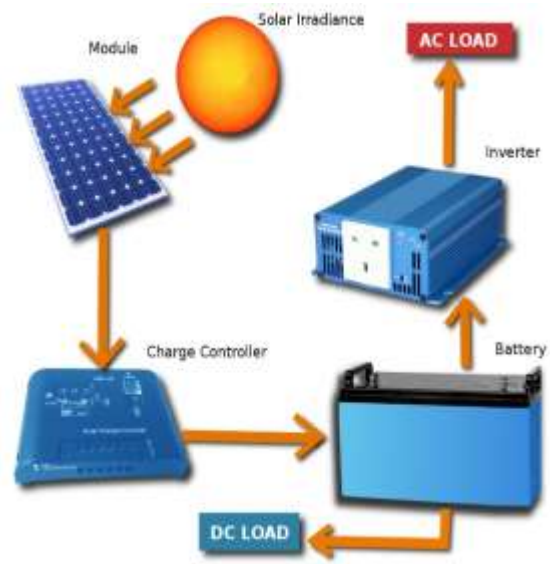
These systems are connected to broader electricity network. The PV system is attached to the utility grid using a high quality inverter, which changes DC power from the solar array into AC power that conforms to the electrical requirements of grid. During the day, the solar electricity produced by the system is either used immediately or sold off to electricity supply companies. In the evening, when the system is unable to supply immediate power, electricity can be bought back from the network.



Grid connected PV System

Standalone systems

PV systems not connected to the electric utility grid are known as off grid PV systems and also called ‘stand-alone systems’. Direct systems use the PV power immediately as it is generated, while battery storage systems can keep energy to be used at a later time, either at night or during cloudy weather. These systems are used in isolation of electricity grids, and may be used to power radio repeater stations, telephone booths and street lighting. PV systems also give invaluable and acceptable electricity in developing countries like India, where conventional electricity grids are unreliable or non-existent.



Stand-alone PV systems

Hybrid system

A hybrid system combines PV with other forms of power generation usually a diesel generator. Biogas is also used. The other form of power generation is usually a type which is able to modulate power output as a function of requirement. However more than one form of renewable energy may be used like wind or solar. The photovoltaic power generation is able to reduce the consumption of non renewable fuel.

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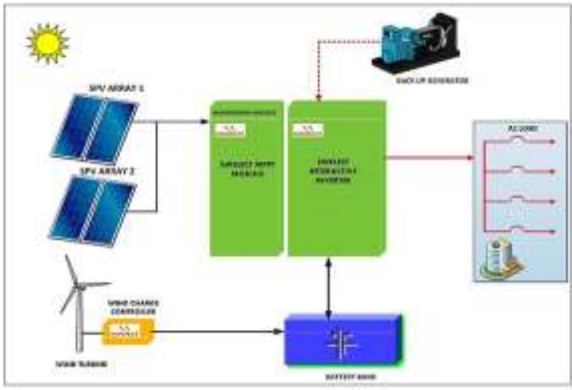

Hybrid system

Grid tied with battery backup PV system

Solar energy stored in batteries can be used at night time. By the use of net metering, unused solar power can be sold back to the grid. With this type of system, we can have power even if our neighborhood has lost the power.

MAXIMUM POWER POINT TRACKING (MPPT) TECHNIQUE

Maximum Power Point Tracking, frequently point to as MPPT, is an electronic system that starts the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are adaptable of. MPPT is not a mechanical tracking system that "physically moves" the modules to point them more openly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Extra power harvested from the modules is then made available as increased battery charge current. MPPT can be used as a mediator with a mechanical tracking system, but the two systems are completely differ from each other.

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel.

According to Maximum Power Transfer theorem, the output power of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our difficulty of tracking the maximum power point reduces to an impedance matching problem.

In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By correcting the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

Different MPPT techniques

There are various techniques used to track the maximum power point. Most popular techniques of MPP are:

1) Perturb and observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks

The choice of the algorithms rely on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation.

Perturb & Observe

Perturb& Observe (P&O) is the very easy method. In this we utilize only one sensor, that is the voltage sensor, to get the PV array voltage and so the cost of implementation is less and hence easy to apply. The time difficulty of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When perturbing happens on both the directions the algorithm has stretched very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.

However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To escape from this problem we can use incremental conductance method.

Incremental Conductance

Incremental conductance method utilizes two voltage and current sensors to sense the output voltage and current of the PV array.

At MPP the slope of the PV curve is 0.

$$(dP / dV)_{MPP} = d(VI) / Dv \qquad (1)$$

$$0 = I + VdI / dV_{MPP} \qquad (2)$$

$$dI / dV_{MPP} = - I/V \qquad (3)$$

The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance is equal to the conductance of the solar then MPP is reached. Here we are getting both the voltage and current together. Hence the mistake due to change in irradiance is deleted. However the complexity and the cost of implementation increase. As we go down the list of algorithms the problem & the cost of utilization goes on increasing which may be suitable for a highly difficult system. This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms.

Fractional open circuit voltage

The non linear relationship between V_{MPP} and V_{OC} of the PV array, under varying irradiance and temperature levels, has given rise to the fractional VOC method.

$$V_{MPP} = k_1 Voc \quad (4)$$

Where:
k_1 is a constant of proportionality.
Since k_1 depends upon the characteristics of the PV array, it usually has to be calculated before by empirically determining V_{MPP} and V_{OC} for the specific PV array at different irradiance and temperature levels. The factor k_1 has been measured between 0.71 and 0.78. Once k_1 is known, V_{MPP} can be calculated with V_{OC} measured periodically by momentarily shutting down the power converter. However, this reveals some disadvantages, including temporary loss of electricity.

Fractional short circuit current

Fractional short circuit current shows the conclusion from the fact that, under varying atmospheric circumstances, I_{MPP} is approximately linearly related to the I_{SC} of the PV array.

$$I_{MPP} = k_2 I_{sc} \quad (5)$$

Where:
K_2 is proportionality constant.
In the fractional VOC technique, k_2 has to be explained according to the PV array in use. The constant k_2 is generally appeared between 0.78 and 0.92.Measuring I_{SC} during operation causes problems. Generally an additional switch has to be added to the power converter to periodically short the PV array so that I_{SC} can be measured using a current sensor.

Neural Network

Another technique of implementing MPPT which are also well adapted for microcontrollers is neural networks. Neural networks mainly have three layers: input layer, output layers, hidden layers.
The number of nodes in every layer vary and are user-dependent. The input variables in input layer can be PV array parameters like V_{OC} and I_{SC}, atmosphere data or whether condition like irradiance and temperature, or any union of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPP.

CONCLUSION

After observational study various characteristics of diiferenr MPPT Techniques are concluded as shown in table.

Table 1. Characteristics of diff. MPPT techniques

MPPT Technique	**Convergence speed**	**Implementation Complexity**	**Periodic tuning**	**Sensed parameters**
Perturb Observe	Varies	Low	No	Voltage
Incr. Conductance	Varies	Medium	No	Voltage, Current
Fractional VOC	Medium	Low	Yes	Voltage
Fractional ISC	Medium	Medium	Yes	Current
Fuzzy logic Control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

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