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Inverter for Grid Connected PV System A Review

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ABSTRACT*:* Grid connected photovoltaic power systems energised by photovoltaic panels which are connected to the utility grid. Grid connected power systems comprise of PV panels, Power conditioning units, controllers, MPPT, Solar inverters, filter, and Grid connection equipments. Solar PV generation depend upon weather condition and require storage system during night. However, with the use of MPPT technology, the PV system can generate maximum power at different weather condition and feed to utility grid without using any storage system. The multilevel inverter has gained much attention in recent years due to its advantages in lower switching loss, better electromagnetic compatibility, higher voltage capability, and lower harmonics. Solar Energy is one of the favorable renewable energy resources and the multilevel inverter has been proven to be one of the important enabling technologies in photovoltaic (PV) utilization. Photovoltaic (PV) power systems are getting more and more widespread with the increase in the energy demand and the concern for the environmental pollution around the world.

KEYWORDS: MPPT, Controllers, Solar Inverters, Filter, MATLAB/Simulink

I. INTRODUCTION

The direct current to alternating current inverter concepts for photovoltaic applications. The PV module is capable of generating electric DC power, when exposed to sunlight. Inverter where the load is the low-voltage AC public utility network and the source is a single PV module. The photovoltaic effect is the basic physical process through which a PV cell converts sunlight directly into electricity. PV technology works any time the sun is shining, but more electricity is produced when the light is more intense and when it is striking the PV modules directly when the rays of sunlight are perpendicular to the PV modules. Sunlight is composed of photons, or bundles of radiant energy. When photons strike a PV cell, they may be reflected, absorbed, or transmitted through the cell. PV cells come in many shapes and sizes. The most common shapes are circles, rectangles, and squares. The size and the shape of a PV cell, and the number of PV cells required for one PV module, depend on the material of which the PV cell is made. Due to low voltage of the individual solar cell (mainly 0.5V) several cells are wired in series for manufacture of a laminate. Then the laminate is assembled into a protective weather proof enclosure thus making a photovoltaic module or solar panel. Modules are then strung together into a photovoltaic array. A photovoltaic array is a linked assembly of PV modules. Most PV array use an inverter to convert the dc power produced by the modules into alternating current. The modules in a PV array are connected in series to obtain the desired the voltage, the individual string are then connected in parallel to allow the system to produce more current. A solar or PV inverter converts variable direct current (DC) output of the photovoltaic solar panel into a utility frequency alternating current that can be fed into a commercial electrical grid or it is used by the local or off grid electrical network. It is a critical component in the photovoltaic system allowing the use of ordinary commercial appliances. Solar inverters have special functions adapted for use with the photovoltaic arrays including maximum power point tracking and anti islanding protection.

II. GENERAL DESCRIPTION OF PHOTOVOLTAIC SYSTEM

The solar cell is the basic unit of a photovoltaic module and it is the element in charge of transforming the sun rays or photons directly into electric power. The solar cell used is the P-N junction, whose electrical characteristics differ very little from a diode. Major advantages of the photovoltaic power are-

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1- Short lead time to design it, install, and start up a new plant.
2- Highly modular, hence, the plant economy is not a strong function of size.
3- Power output matches very well with peak load demands.
4-Static structure, no moving parts, hence, no noise.
5- High power capability per unit of weight.
6- Longer life with little maintenance because of no moving parts.

Main applications of photovoltaic are-
Domestic Buildings Lighting and general power, Industrial Buildings Lighting, general power and process equipment, General Alarms for remote buildings, Area lighting CCTV Advertising, Leisure Boats, Electric boat, Battery charging (lighting & TV) Camping & Remote Homes, Commercial Buildings Lighting and general power.

Fig. 1 shows the block diagram of a photovoltaic system, which includes solar photovoltaic panel with DC to DC converter, single phase inverter and load. The solar photovoltaic panel produces electricity when the photons of the sun light strike on the photovoltaic cell array. The output of the photovoltaic panel is directly connected to the DC to DC boost converter to step up the DC output of photovoltaic panel. Then it is fed to an inverter which converts DC into AC power at the desired voltage and frequency. A current controller is normally preferred due to its advantages like flexibility and modify easily through of software, simplicity possible implementation in fixed point computation etc.

The mechanism behind the photon-to-electron conversion inside the PV module is described. This ended up a model of the PV module, taking into account the inherent PN junction and the current generated by the incoming sunlight. The model was used to investigate the role of partial-shadow and voltage/current ripple at the PV module terminals, in respect to power degradation. Based on the analysis of the PV module, the present and expected future standards for the grid-interface, the specifications for the inverter to be designed.

The power electronic interface for PV-grid systems has following main tasks:
1- To amplify and invert the generated DC power into a suitable AC current for the grid. A standard PV module generates approximately 100 W to 150 W at a voltage around 23 V to 38 V, whereas the grid mostly requires 110V at 60 Hz or 230 V at 50 Hz.
2-To control the PV module so as to track the Maximum Power Point (MPP) for maximizing the energy capture. Both tasks must be made at the highest possible efficiency, over a wide power range, due to the morning-noon-evening and winter-summer variations. The MPP is tracked by means of a MPP Tracker (MPPT) device.
3- The inverter to inject a sinusoidal current into the grid, and to optimize the operating point of the PV modules, to capture the maximum amount of energy.
4- The inverter has been optimized in respect to cost, reliability, efficiency, and a prototype has been build and tested.
Control of grid-connected pv system
1-The MPPT Control, which the main property is to extract the maximum power from the PV generator.
2-Control the active and regulate the reactive power injected into the grid.
3-Control the DC bus voltage.
4-Ensure high quality of the injected power.

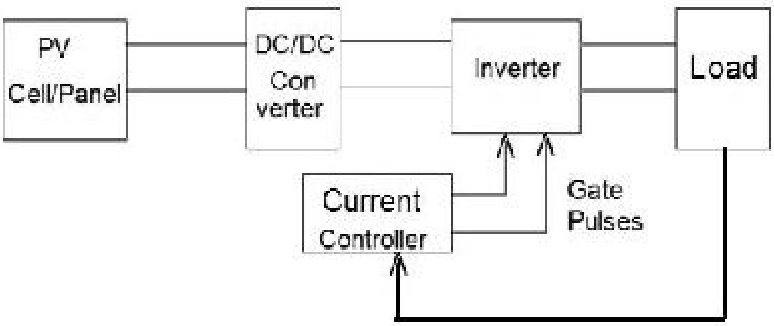

Fig.1. Block diagram of photovoltaic system.

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III. MULTILEVEL INVERTER

Multilevel inverters, in case of n-level, can increase the power by (n-1) times than that of two-level inverter through the series connection of power semi conductor devices without additional circuit to have uniform voltage sharing. The general structure of the multilevel converters is to synthesize a near sinusoidal voltage from several levels of dc voltages, typically obtained from capacitor voltage sources. As the number of levels increases, the synthesized output waveform has more steps, which produce a staircase wave that approaches a desired waveform. Also, as more steps are added to the waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases. The multilevel inverters can be classified into three categories:

Diode-Clamped Multilevel Inverter-The diode clamped inverter uses half bridge version in each level. The diode clamped multilevel inverter is most commonly used. However, it is difficult to control voltage of each capacitor constituted DC-link beyond four levels. It is hard to be expanded to high level systems structurally due to large number of clamping diodes. The diode clamped inverter is most suitable for the back-to-back inertia system operating as a unified power controller.

Flying Capacitor Multilevel Inverter-The flying capacitor multilevel inverter does not require separately isolated dc sides and additional clamping diode. The FCMLI offers a great advantage with respect to the availability of voltage redundancies. They are defined as different combinations of capacitors allowing preferential charging or discharging of the individual flying capacitor in producing the same phase lag voltage.

Cascaded Multilevel Inverter-A cascaded multilevel inverter consists of a series of H-bridge (single-phase, full bridge) inverter units. The cascaded multilevel has no voltage sharing problem except for series connected devices and capacitors but it has separately isolated dc power supplies, which requires special input transformer.

The key features of a multilevel structure follows:
1-He output voltage and power increase with the number of levels.
2- The harmonic content decreases as the number of levels increases and filtering requirements are reduced.
3- In the absence of any techniques, the switching losses can be avoided.
4- Static and dynamic voltage sharing among the switching devices is built into the structure through either clamping diodes or capacitors.
5- Multilevel inverters can easily be applied for high power applications such as large motor drives and utility supplies.
6- Multilevel converters usually utilize a large number of dc sources; switches are required to block smaller voltages. Since switch stresses are reduced, required switch ratings are lowered. As a result, cost is reduced.
7- One distinct benefit is the idea that no transformers are needed to produce these high voltages, whereas traditional pulse inverters require transformers.
8- Increasing the number of voltages levels in the inverter without requiring higher ratings on individual devices can increase the power rating.
9-By using multilevel structure, the stress on each switching device can be reduce in proportional to the number of levels and thus the inverter can handle higher voltages.
10- MLI led to a better and more sinusoidal output voltage waveform. As a result, lower Total Harmonic Distortion (THD) is obtained.

Applications of multilevel inverters are follows:
1-Multilevel inverters can be implemented using distributed energy resources such as photo-voltaic and fuel cells.
2- Using a multilevel inverter as a reactive power compensator can help to improve the power factor of a load.
3- If the dc sources of the multilevel inverter are banks of batteries or capacitors, the multilevel inverter can also be used to provide ride-through capability under emergency conditions.
4- Multilevel inverters can also be used to construct a high voltage dc back-to-back inertia so it can be used as a frequency changer, it would seem reasonable that a multilevel inverter can also be used as an Adjustable Speed Drive.
5-Multilevel inverters are used in Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs). Multilevel inverters generally allow for smaller components, thus reducing weight.

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IV. SPECIFICATIONS, STANDARDS, & TEST OF PV INVERTER FOR GRID CONNECTED PV SYSTEMS

Power electronics inverters are necessary to transform into AC current then inject to the grid the energy delivered by the PV systems. Therefore, there are special standards and requirements concerning the connection of the PV to the grid. The rules and regulations set by the utility companies must be obeyed. These standards are to maintain the power quality produced by the photovoltaic distribution system. The grid-connected standards covered the topics about voltage, DC current injection, flicker, frequency, harmonics current, maximum current, total harmonics distortion (THD) and power factor.

Islanding: A condition is which the photovoltaic system and its load remain energized while disconnected from the grid. According to the IEEE Std DG shall detect the islanding for any possible islanding conditions and cease to energize the area within 2 sec for small voltage and frequency signal variation. A large voltage changes below 0.88 pu or above 1.2 pu and for the frequency variations more than 60.5 Hz or less than 59.3Hz at the PCC islanding should be detected within 0.16s.

Distributed resource islanding: An islanding condition is when the photovoltaic sources of energy supply the loads not from the utility system. Grounding: Standard requires the system and interface equipment should be grounded and monitored. It gives more safety and protection in case of ground faults inside the PV system. Voltage disturbances: The utility company set the voltage of grid network. The PV system cannot control the voltage of the grid so the output voltage of the PV has to be within the operating range defined by the standards. The inverters should detect abnormal voltages and prevent islanding of the system.

Dc component injection: the DC current injected should be less than 0.5% of rated inverter output current into the utility AC interface. The DC current could produce inundation of the delivery converters within the grid. Total harmonics distortion**:** The topology has to be chosen along with the modulation scheme of the inverters should give an AC current with low level of harmonic distortion. High current harmonics can cause adverse effects on the diverse equipment connected to the grid.

Voltage flicker**:** The voltage flicker should not exceed the maximum limits.

Islanding protection: The inverters must have a feature that can identify a situation of islanding and respond accordingly to safeguard the people and equipment involved. For instance, the standard stated that the inverter should disconnect from the utility line when there is disturbance from the system. In islanding, the inverters continue to supply local loads even in the case that the grid is no longer connected to the inverter. Inverters that are tied to the grid overlook the utility line and can turn themselves off with great speed if required (in 2 seconds or less) in the event that abnormalities occur on the utility system .The principal concern is that a utility line worker could be exposed to a line that is unexpectedly energized.

Power factor**:** The standard the power factor of the PV system should be 0.85 (lagging or leading).The grid connected PV inverter is designed to have a control current with a power factor unity. Sometimes the inverter is used for reactive power compensation; therefore, the inverter should be capable to control the output power factor.

Reconnect after disturbance: The PV system should not be reconnected until continuous normal voltage and frequency are maintained by the utility for a minimum of five minutes, at which time the inverter can automatically reconnect.

Frequency: The PV systems should have a fixed frequency between 59.3 – 60 Hz. The PV systems should stay synchronized with the grid. For small PV systems, the frequency trip should be 59.2 Hz and 60.6 Hz. A test plan for the developed PV inverter is intended to be a thorough evaluation that can be used for the characterization of the designed inverter. The plan is based on the international standards and the experience in the field of grid connected PV systems. It covers functional tests, protection tests and field tests. These tests are performed in order to evaluate the following characteristics of inverter.
1**-** Static power efficiency: The power efficiency of an inverter is defined as the ratio between the power injected into the grid and the power from the PV module.

2- Power factor**:** The purpose of this test is to determine the power factor of the System and see if it is consistent with the international standards.
3-Current harmonics: In general the operation of the inverter should not cause excessive distortion of the grid voltage or result in excessive injection of harmonic currents into the grid.
4- Standby losses: The standby loss is defined as the consumption of utility power when the inverter is not operating but under standby conditions.
5- Disconnections of ac power line: The purpose of this test is to observe the inverter response under loss of grid connection.
6- Disconnections of dc power line: The purpose of this test is to observe the reaction of the inverter when the DC power line is suddenly disconnected.
7- AC voltage limits: The purpose of this test is to determine the AC voltage limits (over/under voltage) at which the inverter stops operating.
8- Response to abnormal utility conditions: The purpose of this test is to observe and verify the operation of the inverter under abnormal grid conditions.
9- Field test: The purpose of this test is to evaluate the performance of the inverter when connected to normally illuminated modules of different technologies. In this test many parameters such as energy efficiency, start up voltage, start up power, stop voltage and standby losses can be measured.

V. CONCLUSIONS

PV cells are usually connected together to make PV modules, consisting of 72 PV cells, which generates a DC voltage between 23 Volt to 45 Volt and a typical maximum power of 160 Watt, depending on temperature and solar irradiation. The electrical infrastructure around the world is based on AC voltage, with a few exceptions, with a voltage of 120 Volt or 230 Volt in the distribution grid. PV modules can therefore not be connected directly to the grid, but must be connected through an inverter. The two main tasks for the inverter are to load the PV module optimal, in order to harvest the most energy, and to inject a sinusoidal current into the grid.

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BIOGRAPHY

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