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Solar Converters Power Quality Issues- A Review

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Abstract

The main objective of this paper is to identify the problems associated with solar converters in the solar power system due to the involvement in more number of power electronics components. The main objective of this work is to study of the behaviors of the solar PV systems and the power quality issues in converters. Harmonics are created by the switching system of the power electronic circuit and can cause damage to power equipment on the utility side and sensitive loads on the customer side.

Keywords: Converters, Inverters, PV, Power quality

1. Introduction

Government promotion of renewable energy sources has led to several large scale solar power plants in India. India receives solar energy in the region of 5 to 7 kWh/m2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant per square kilometer land area. With about 300 clear, sunny days in a year, India's theoretical solar power reception, on only its land area, is about 5 Petawatt-hours per year (PWh/yr) (i.e. 5 trillion kWh/yr or about 600 TW). The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 1500–2000 sunshine hours per year (depending upon location), which is far more than current total energy consumption. For example, assuming the efficiency of PV modules were as low as 10%, this would still be a thousand times greater than the domestic electricity demand(in India) projected for 2020. The amount of solar energy produced in India is less than 1% of the total energy demand. The grid interactive solar power as of December 2018 was merely 10 MW. Government-funded solar energy in India only accounted for approximately 6.4 MW-yr of power as of 2005. However, as of October 2019, India is currently ranked number one along with the United States in terms of installed solar power generation capacity.

In those installations, a large amount of relatively low power inverters is connected to a common AC low voltage bus and high voltage distortion levels have been reported although the single inverters comply to the harmonic emission standard.

2. Role of Power Electronic Components in Solar Power System

Grid-connected PV systems are currently being widely installed in many of the developed countries [1]. In addition to their environmental benefits, PV systems have a number of technical and economical benefits. They can be operated to decrease the losses and improve the voltage profile of the feeder to which they are connected [2], [3]. One of the main characteristics of PV systems is the high variability of their output power. The variability stems from the fact that these systems are static, and thus, any instantaneous change in the irradiance reaching the PV arrays leads to a corresponding change in their output power. The time frame for the short-term fluctuations in irradiance is in the order of seconds to few minutes [4], [5]; thus, some studies have considered the fluctuations in the PV power to be within the same time frame [6], [7]. However, other studies have recommended the use of 10-min irradiance data when studying the power fluctuations generated from PV systems [8], [9].

This is especially suitable for systems with ratings in the order of tens of megawatts that extend over a large land area, such as the 10-MW PV plant in Pocking, Germany [10]. A recent report published by the North American Electric Reliability Corporation showed that the output power of existing large PV systems, with ratings in the order of tens of megawatts, can change by 70% in a five to ten-min time frame [11]. It should be noted that for a number of small systems that are distributed over a large land area, the resulting combined fluctuations are much less due to the smoothing effect [12], [13]. Also, the fluctuation in the power of these systems can lead to unstable operation of the electric network prior to the fault conditions, high power swings in the feeders [14]. However, PV power fluctuates depending on weather conditions, season, and geographic location and may cause problems like voltage fluctuation and large frequency deviation in electric power system operation [15],[16],[17]. To date, it has not been necessary for small PV generators to provide frequency regulation services to the power system. In the future, with an increasing penetration of PV generation, their impact upon the overall control of the power system will become significant [18]. This will lead a situation where the PV generators will be required to share some of the duties, such as load frequency control.

The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality. The power-electronic technology plays an important role in distributed generation and in integration of renewable energy sources into the electrical grid, and it is widely used and rapidly expanding as these applications become more integrated with the grid-based systems. During the last few years, power electronics has undergone a fast evolution, which is mainly due to two factors. The first one is the development of fast semiconductor switches that are capable of switching quickly and handling high powers. The second factor is the introduction of real-time computer controllers that can implement advanced and complex control algorithms. These factors together have led to the development of cost-effective and grid-friendly converters. Regardless of the power ratings of the alternative energy generation unit, it has to be converted to a suitable form by utilizing power electronic converters. In this paper[19], new trends in power-electronic technology for the integration of renewable energy sources and energy-storage systems are presented. Therefore, power electronics is vital to the future energy systems and process of green industrialization.

3. Power Quality Issues in Converters

Typical power electronic converters arrangements for PV systems are shown [20].Authors [21] discussed the many sources of nonlinearity in power electronics systems. Authors demonstrated with an analytical and experimental result and proved that complex nonlinear phenomena such as sub harmonics, quasi periodicity and chaos can arise in even the simplest power electronic systems. Switched mode dc-dc converters inherently produce ripple at the switching frequency and its harmonics. The unwanted signal which appears at both the input and the output is undesirable for electromagnetic compatibility. Filtering must generally be employed to reduce it to an acceptable level [22].Switched-mode DC-DC converters are nonlinear and time-varying systems. In unsteady nonlinear systems a variety of strange effects are observed, including sub harmonics, quasi periodic oscillation, intermittency, and chaotic behavior, apparently random motion. Because closed loop buck converters are strongly nonlinear system, plenty of nonlinear phenomena may occur at operation, which will result in the instability of the system [23]. Lupco V. Karadzino and David C. Hamill [21] highlighted that all switching converters have some stray inductance in series with their diodes, so we expect the phenomena to be widespread, especially as switching frequencies are pushed ever higher. The various power qualities such as voltage and frequency profiles, THD in voltages and currents and voltage and current unbalance factors have been measured for renewable energy using a power quality analyzer [25].

4. Power Quality Issues in Inverters

With the increase of the renewable energy penetration to the grid, power quality (PQ) of the medium to the low voltage power transmission system is becoming a major area of interest. Most of the integration of renewable energy system to the grid takes place with the aid of power electronics converters. The main purpose of the power electronic converters is to integrate the distributed generation (DG) to the grid in compliance with power quality standards. However, high frequency switching of inverters can inject additional harmonics to the system, creating major PQ problems if not implemented properly [26]. Bosman[27] experimentally showed that a distorted grid voltage can significantly influence the harmonic content of the current injected by the inverter. In this paper, Photovoltaic connected to grid is used as power supply to the load [28]. A laboratory setup was established to perform the measurement. Approximately 70-80% of all power quality related problems can be attributed to faulty connections and/or wiring [29]. Power frequency disturbances, electromagnetic interference, transients, harmonics and low power factor are the other categories of PQ problems that are related to source of supply and types load [30].

Though the output of a PV panel depends on the solar intensity and cloud covers, the PQ problems not only depends on irradiance but also are based on the overall performance of solar photovoltaic system including PV modules, inverter, filters controlling mechanism etc. Studies presented in [31], show that the short fluctuation of irradiance and cloud cover play an important role for low voltage distribution grids with high penetration of PV. Therefore special attention should be paid to the voltage profile and the power flow on the line. It also suggests that voltage and power mitigation can be achieved in super capacitors which result in an increase of about 20% in the cost of the PV system. Voltage swell may also occur when heavy load is removed from the connection. Concerning DG, voltage disturbance can cause the disconnection of inverters from the grid and therefore result in loss of energy. Also long term performance of grid connected PV system shows a remarkable degradation of efficiency due to the variation of source and performance of inverter [32]. The PV array can be single or a string of PV panels either in series or parallel mode connection. Centralized or decentralized mode of PV systems can also be used and the overview of these PV Inverter-Grid connection topologies along with their advantages and disadvantages are discussed in [33]. These power electronic converters, together with the operation of non-linear appliances, inject harmonics to the grid. In addition to the voltage fluctuation due to irradiation, cloud cover or shading effects could make PV system unstable in terms of grid connection. Therefore this needs to be considered in the controller design for the inverter [34], [35]. In general grid connected PV inverter is not able to control the reactive and harmonic currents drawn from non-linear loads. An interesting controlling mechanism has been presented in [36] where a PV system is used as an active filter to compensate the reactive and harmonic as well as injecting power to the grid. This system can also operate in standalone mode.

5. Power Quality Issues in Grid Connected Solar Power System

The general solar power system is shown in figure.1. The major components include boost converters and inverters.

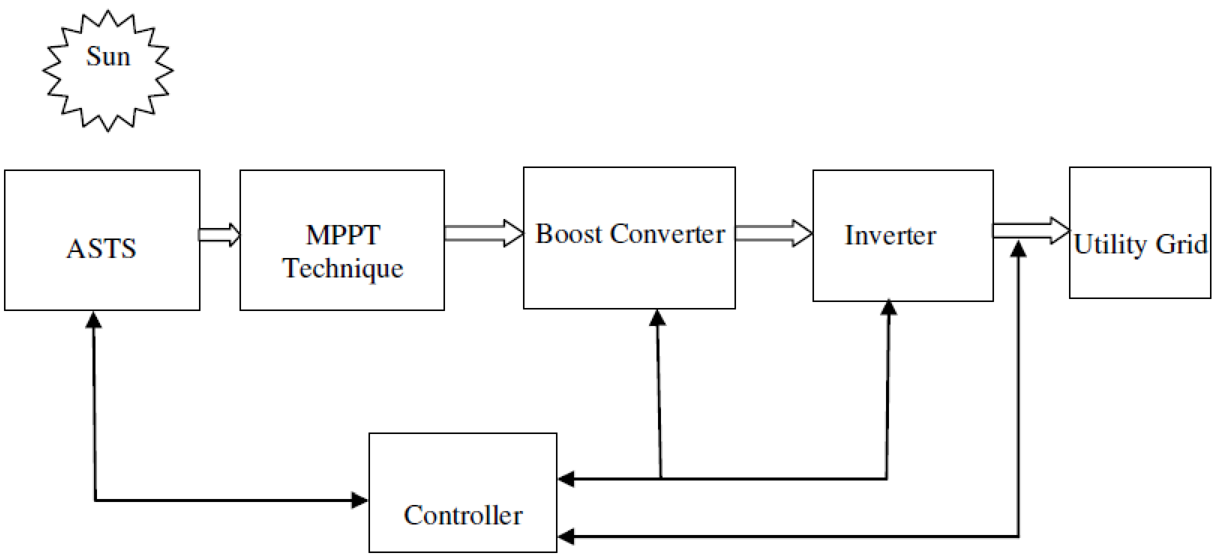

Figure 1: Basic Block Diagram

Converter – A boost converter is a DC-DC converter with an output voltage greater than the source voltage. The aim is to analyze and design the high efficient modified converters to extract maximum power from solar PV panels.

Inverter – Multilevel inverters offer high power capability, associated with lower output harmonics and lower commutation losses. The new topology has a significant reduction in the number of power devices and capacitors required to implement a multilevel output. Additionally, the dedicated modulator circuit required for multilevel inverter operation will be implemented using a control circuit, reducing overall system cost and complexity.

Controller – The embedded controller will fetch the input from the sensor and give command to the motor to run in order to tackle the change in the position of the sun. And also controller monitors the various electrical parameters and generates the control signal to solve the power quality issues.

Power quality is certainly a major concern in the present era; it becomes especially important with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Modern industrial processes are based a large amount of electronic devices such as programmable logic controllers and adjustable speed drives. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage swells, and harmonics. The distortion in the quality of supply power can be introduced /enhanced at various stages; however, some of the primary sources of distortion [24] can be identified as Power Electronic Devices, IT and Office Equipments, Arcing Devices, Load Switching, Large Motor Starting, Embedded Generation Electromagnetic Radiations and Cables Storm and Environment Related Causes etc. Authors presented [38] a survey of the techniques for reduction of harmonics. Fundamental ways are given to reduce harmonics by means of active and passive methods. Especially active ways are focused on, because they can be integrated into power electronic converters. Beside their prime task of converting power, these converters have thus the potential to deliver an ancillary service, namely: active harmonic reduction. Authors proposed [39] a hybrid active filter for the damping of harmonic resonance in industrial power systems. The hybrid filter consists of a small rated active filter and a 5th-tuned passive filter. The active filter is characterized by detecting the 5th harmonic current flowing into the passive filter. Experimental results obtained from a 20-kW laboratory model verify the viability and effectiveness of the hybrid active filter proposed. Walid and Kazerani investigated the methods that can be used to reduce the fluctuations in the power generated from large PV systems. The authors suggested to use the of battery storage systems , use of dump load and curtailment of the generated power by operating the power-conditioning unit of the PV system below the maximum power point to reduce the fluctuations in large PV system. And also authors examined the economic aspects of using different methods for smoothing the output power of large PV systems. Authors presented a grid-connected photovoltaic (PV) system with direct coupled power quality controller (PQC). The proposed PV system used an inner current control loop and outer feedback control loops to improve grid power quality and maximum power point tracking (MPPT) of PV arrays.

6. Conclusion

This paper has provided a brief summary of solar PV systems and power quality issues in grid connected power system. This paper has also presents a summary of converts and inverters in solar power system and its power quality issues. Suitable control techniques are also discussed briefly. The intention of the authors was simply to provide groundwork to readers interested in looking back on the evolution of power quality issues in PV systems, and to consider where to go from here.

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