Analysis of Harmonic Distortion Impact on Grid Connected Solar Power Inverter

A. Sindhuja and A. Rathinam

Abstract--- The Power Quality Analysis impacts of the grid-connected photovoltaic power plant on the harmonic current in the power quality aspect of the distribution network, Summaries the requirement of harmonic current injecting in grid caused by photovoltaic power plant which connected in user side. The grid-connected photovoltaic generation and then analyzes it by build models of photovoltaic generation and the power grid. At the same time, it can cause harmonics which result in waveform distortion and affect electronic devices that receive power. Then, it could make electronic device malfunction. This paper studies the characteristics of harmonics on the grid, PV system, and load. The result shows that most grids' harmonics are affected from PV system and load when the inverter power up to almost the rated power, meanwhile, percentages of harmonics are reduced and harmonics of load depend on the type of load. Next, comparing harmonics on three sides, and found that harmonics of PV system hardly affect to load and harmonics of the grid are more affected by load than PV system.

Keywords--- Distributed Generation (DG), Harmonic Distortion, Photovoltaic Energy (PV), Power Quality, Solar Inverter.

I. INTRODUCTION

Renewable energy technology has undergone a substantial development in the last three decades. Photovoltaic (PV) system is promising and one of the fastest growing renewable energy sources. The worldwide cumulative installed capacity of PV systems has been increasing exponentially in the last decade and recently has reached a level of 178GW at the end of 2014 due to the decreasing price per PV panel and government policies in many countries. The photovoltaic generation technology which based on utilizing solar energy is growing rapidly according to the medium and long-term renewable energy. A large amount of photovoltaic generation integrated with grid promotes the utilization of solar resources; on the other hand, the photovoltaic generation brings new challenges on the planning and designing, power quality, operation, protection etc. The output power of PV generation is affected greatly by light illumination with the characteristics of volatility, intermittent and periodicity which would cause the voltage fluctuation and voltage flickering of the grid. With the proportion of PV generation in power resources becoming larger, the influence of the characteristics of volatility, intermittent and periodicity on peak shaving of the grid will be greater which would cause the frequency of grid variation. And, there are voltage pulses, surge, voltage sag and momentary interruption dynamic power quality problems caused by PV generation.

There are many hazards of harmonic in power system, mainly are causing protection fault, resonance, over-voltage, over-current and increasing loss of transmission lines and motors. The purpose of adjusting reactive power and voltage is to guarantee the voltage level and power quality on the point of common coupling (PCC) of photovoltaic (PV) plant. The capability of voltage adjustment and reactive power providing is varied with the development of technology. A harmonics from PV system and the effect of inverter have been reviewed. The Harmonic interactions between the grid and a certain number of DG inverters can be preliminarily estimated. The

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fourth-order bandpass filter, the proposed harmonic detector can effectively.

II. LITERATURE SURVEY

Jiang Nan (2010) presented the solar energy photovoltaic (PV) generation will play an important role in future power energy structure all over the world. The inverter is an important facility of a PV system. To ensure its safety and quality is a necessary link in developing this technology. The status and prospect of PV power generation especially detection and certification are introduced. Secondly, a detection platform is designed for the grid-connected inverter according to an industry standard of China, in which basic structure and working mode are analyzed. Also, testing method, testing item, and testing instruments are described, including electrical performance, electromagnetic compatibility, protection function and environment test primarily. At last, a conclusion is presented the next step of the platform is given. As a promising low-carbon technology, solar energy photovoltaic (PV) generation will play an important role in future energy structure. Compared with other kinds of energy, it is no pollution, easy to install, without restriction of the region, high reliability and so on. For this reason, many countries in the world take solar power system as a crucial development direction. According to the forecast of European Joint Research Center (JRC), electricity generated by solar will account for more than 60% at the end of this century. From then on, solar power becomes a leading energy. An inverter is a key unit of the solar power system which can convert the DC power produced by PV module to AC power provided to consumer and Power Company conveniently.

Experimentation

For the experiment, we used a PV Simulator to generate the direct current of solar energy. Then, an on-grid inverter transformed direct current to alternating current for sending to grid-connected and/or electrical loads. There are 5 types of loads, which are herein incandescent, ballast, incandescent and ballast, Light Emitting Diode (LED), and motor. In this system, we connected solar energy from PV simulator to on-grid inverter, grid system, and loads at the connecting point. The testing results were recorded using an oscilloscope to keep current and voltage waveforms of the system at the connecting point, and using Power Quality Analyzer to keep electrical parameters and harmonics. Solar energy was sent to each load according to the load power.

- Incandescent of 500 W
- Ballast of 850 W
- Incandescent and Ballast of 1000 W
- LED lamp of 300 W
- Motor of 200 W

III. PROPOSED APPROACH

The Power Quality Analysis of Photovoltaic to produce electricity from solar energy, it would be required an inverter to convert the direct current into alternating current. The inverter is the cause of problems that affect the stability of the power system because it is a switching device served to adjust the frequency of the AC power as needed. At the same time, it can cause harmonics which result in waveform distortion and affect electronic devices that receive power. The grid-connected photovoltaic power generation on power quality of harmonic current and reactive-power/ voltage in the distribution network, gives the summary of the requirement of power quality caused by photovoltaic power plant which connected in the user side.

3.1. Proposed Block Diagram

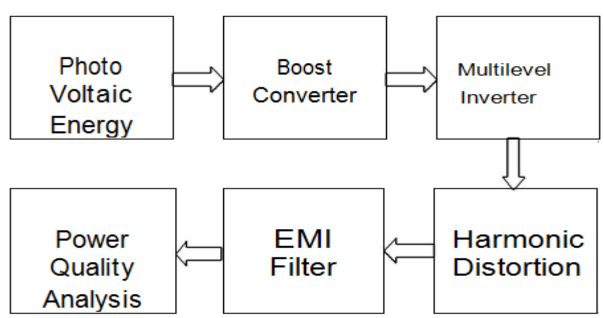

Fig. 3.1: Proposed Block Diagram

3.2. Photovoltaic Energy (PV)

The name photovoltaic connects two terms–photo suggests light and voltaic means energy. A photovoltaic operation in this discussion uses photovoltaic cells to convert sunlight into electricity directly.

A photovoltaic energy (PV) is a functional semiconductor diode that changes noticeable light into direct current (DC). Some PV cells can also transform infrared (IR) or ultraviolet (UV) radiation into DC electricity. Photovoltaic cells are an essential part of solar-electric energy systems, which are growing increasingly relevant as alternative sources of service power.

3.3. Boost Converter

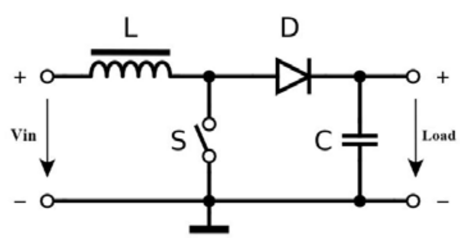

Fig. 3.3: Boost Converter Circuit

3.3.1. Boost Converter Circuit

A Boost converter is a switch mode DC to DC converter in which the output voltage is higher than the input voltage. It is also called as a step up converter. The name steps up converter comes from the fact that analogous to step up transformer the input voltage is stepped up to a level higher than the input voltage. By law of conservation of energy the input power has to be equal to output power

The central working principle of the boost converter is that the inductor in the input circuit resists sudden variations in input current. When the switch is in the inductor stores power in the form of powerful electricity and releases it when the switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The critical time constant compared to switching period ensures a constant output voltage VO(t) = VO (steady).

3.4. Inverter

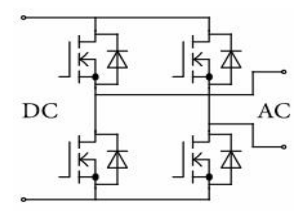

Fig. 3.4: Inverter Circuit

3.4.1. Multilevel Inverter

An inverter converts the DC energy to an AC voltage. In most cases, the input DC voltage is usually lower while the output AC is equal to the grid supply voltage of either 120 volts, or 240 Volts depending on the country. The inverter may be built as standalone equipment for applications such as solar power, or to work as a backup power supply from batteries which are charged separately. The other configuration is when it is a part of a more significant circuit such as a power supply unit, or a UPS. In this case, the inverter input DC is from the rectified mains AC in the PSU, while from either the rectified AC in the in the UPS when there is power, and from the batteries whenever there is a power failure.

There are different types of inverters based on the shape of the switching waveform. These have various circuit configurations, efficiencies, advantages, and disadvantages. An inverter provides an ac voltage from dc power sources and is useful in power electronics and electrical equipment rated at the ac mains voltage. In addition, they are widely used in the switched mode power supplies inverting stages.

This is an entirely straightforward DC to AC inverter that provides 220VAC when a 12VDC power reference is given. It can be used to power very light loads like night lights and cordless phones but can be transformed into a powerful inverter by adding extra MOSFETs. It practices 2 power IRFZ44 MOSFETs for driving the output power and the 4047 IC as an as multi-table vibrator operating at a frequency of around 50 Hz. The 10 and 11 pin outputs of the IC directly drive power MOSFETs that are used in the push-pull arrangement. This output transformer has a 9V-0-

9V, 2 Amps on the developed and 230V in the primary. Use suitable heat-sinks for MOSFETs. Remember that this is not a sine-wave inverter, not even a modified one. It's just a square-wave one so you can power only light bulbs, and small power tools that do not require a frequency.

3.5. Harmonic Distortion

The harmonic distortion or THD is a standard measurement of the level of harmonic distortion present in power systems. THD can be related to either current harmonics or voltage harmonics, and it is defined as the ratio of total harmonics to the value at fundamental frequency times. Harmonics are a distortion of the standard electrical current waveform, generally transmitted by nonlinear loads. Switch-mode power supplies (SMPS), variable speed motors and drives, photocopiers, personal computers, laser printers, fax machines, battery chargers and UPSs are examples of nonlinear loads.

A harmonic filter is used to eliminate the harmonic distortion caused by appliances. Harmonics are flows and charges that are constant multiples of the fundamental frequency of 60 Hz such as 120 Hz (2nd harmonic) and 300 Hz (5th harmonic). When two transformers with a delta-zigzag connection (-30° and 0°) are used for phase-shifting, the 3rd harmonic currents are canceled due to the secondary. The 5th and 7th harmonic currents are aborted in the electrical supply common to both transformers and the voltage distortion is reduced.

3.6. EMI Filter

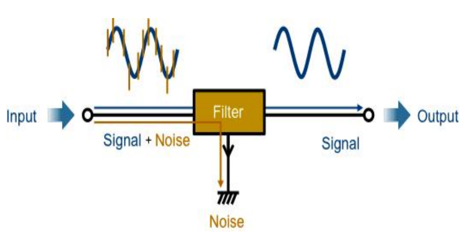

Fig.3.6: EMI Filter

3.6.1. Sampling Filtration Waveform

An EMI filter, or an electromagnetic interference filter, is an electronic passive device which is used in order to suppress conducted interference that is present on a signal or power line. EMI filters can be used to suppress interference that is generated by the device or by other equipment in order make a device more immune to electromagnetic interference signals present in the environment.

Most EMI filters consist of components that suppress differential and common mode interference.Electromagnetic interference (EMI), also called radio frequency interference (RFI) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction. The disturbance may degrade the performance of the circuit or even stop it from functioning. In the case of a data path, these effects can range from an increase in error rate to a total loss of the data. Both man-made and natural sources generate changing electrical currents and voltages that can cause EMI: automobile ignition systems, mobile phones, thunderstorms, the Sun, and the Northern Lights. EMI frequently affects AM radios. It can also affect mobile phones, FM radios, and televisions, as well as observations for radio astronomy. EMI can be used intentionally for radio jamming, as in electronic warfare.

3.7. Power Quality Analysis

The Advanced metering system (AMI) is a new venerable metering system for the two-way measurement and communication operation in Smart Grid single-phase power quality parameters measurement has grown one of the several attractive analysis topics in recent years. A CS approach based on two-dimensional model compression for power quality analysis is proposed. Since the sampling message of strength quality (PQ) has outstanding frequency-domain sparse characteristics; it can be applied to the study of a theoretical model with two-dimensional image compression algorithm using compressed sensing (CS). According to the single-phase, power quality measurement using compressed sensing, a two-dimensional sparse measurement model on voltage, current and power signals is established.

Only a few amounts of points of electrical state power signal are sampled. Using these samples, the power signal is recovered in order to efficiently detect the operating status of the power quality parameters involving harmonic, instantaneous power disturbance, etc.

The performance of the proposed approach and other different schemes are compared through numerical experiments and analysis of compression sampling ratio (CSR), signal to noise ratio (SNR), mean squared error (MSE), energy recovery percentage (ERP). Numerical results have shown that CS based power quality analysis approach behaves exceptionally well in practice.

3.7.1. Overview of DG System

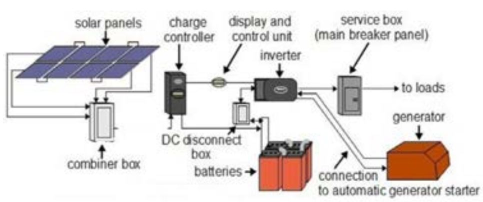

Fig. 3.7.1: DG System

3.8. Distributed Generation

The Distributed generation (also known as distributed energy) refers to power generation at the point of consumption. Generating power on-site, rather than centrally,eliminates the cost, complexity, interdependencies, and inefficiencies associated with transmission and distribution.

3.9. Results and Discussion

The result shows that the system is studied include 2 states. First, when the PV system doesn't feed power to a connected point, loads receive power from the grid and generate harmonics that payback to the grid. Therefore, the harmonics in this state are load's harmonics. Next, when the PV system feeds power to a connection point. In this study, it is mainly considered into 2 configurations: with and without PV system, to observe the harmonics generated in the system. In two cases, the voltage harmonics measured at the connecting point are both low whereas the current harmonics are high.

When PV generates more electrical power to the system, the voltage harmonics are still unchanged. But the current harmonics can be more, depending on the supplied power and the type of load; the non-linear load with an active component such as LED with its driver can cause and increase the total harmonics in the system. Therefore, we will mainly pay attention to the current harmonics in a grid system, PV system, and load.

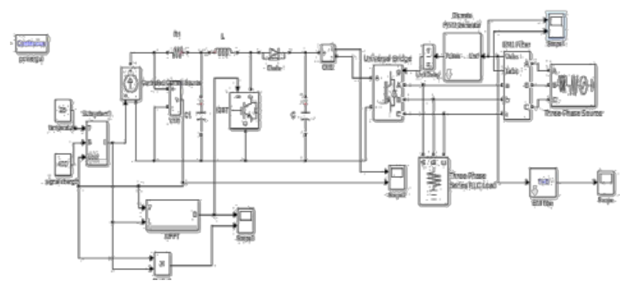

Fig. 3.9: Simulation Diagram for Proposed System

The simulations diagram that respecting, and total harmonics distortion was 4.25% measured at PV system position whereas the grid and load position was relatively small amount because there was more power delivered from the grid to load than the inverter as shown in After the PV generated energy, current harmonics at load side was unchanged. Overall current harmonics of grid and PV system were stepped-up and dramatically increased in 5^{th} and 11^{th} orders.

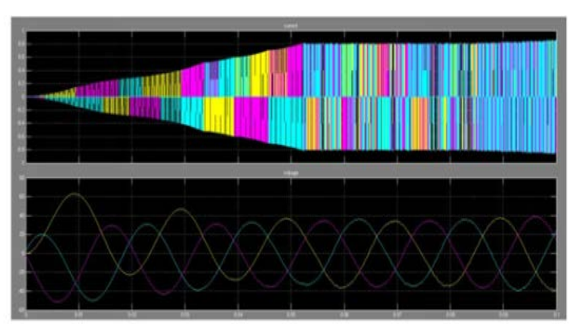

Fig. 3.9.1: Current and Voltage Waveform after the Elimination of Harmonics

The figure 3.9.1 a shows the reimbursing load voltage, load current, real power, reactive power at the three-phase fault state for voltage T=1.0 to 65 v and current T=1.0to 0.9A without Solar Power Inverter in linear load. The waveform calcification occurs in load side voltage due to without Solar Power Inverter.

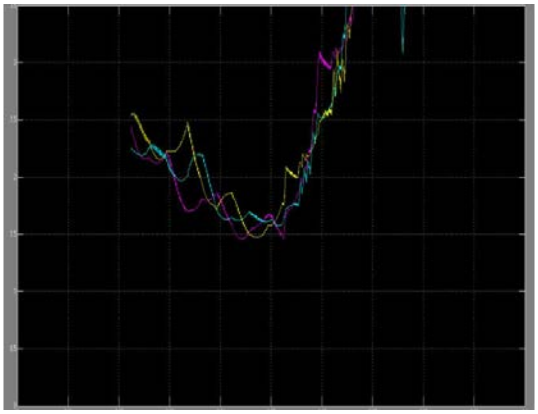

Fig. 3.9.2: Harmonic Distortion of a 3 Phase Sine Wave

Theoretical calculation of voltage (vabc) FFT dimension without Solar Power Inverter in linear load:

The THD value of vh1 to vh19 is taken from the FFT examination of BAR Relative base value is MATLAB simulation

$$THD=\sqrt{\frac{Vh2^2 + Vh3^2 + \ldots + Vhn^2}{Vh1^2}}$$

Assume n=19, FFT analysis value for output voltage (Vabc) for THD =75.26%

IV. Conclusion

The Power Quality Analysis impact of grid-connected photovoltaic power generation on power quality in the distribution network. Summaries the requirement of power quality problems caused by photovoltaic power plant which connected in the user side. This system simulates harmonic current injecting into the grid and reactive power/voltage in one case of grid-connected photovoltaic generation and then analyzes it by developing models of photovoltaic generation and power grid belonged to the user. The harmonic current caused by user side grid-connected photovoltaic generation injecting into the grid the photovoltaic generation system is reactive power regulation capability.

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