A Review on Power Quality Improvement of Off-grid Connected Solar Photovoltaic Power Plant

Ajay A. Toraskar, Nayan J. Kotmire, Mahesh M. Wagh

Abstract— The limited fossil fuel resources and continuously increasing energy demand are the main reason for use of Renewable Energy sources. Renewable energy systems are playing an important role in sustainable development. This paper focuses on power quality development for an Off-grid connected solar PV power plant which comprises PV array, power quality improvement of harmonics distortion, correcting power factor and protection of solar PV plant by over voltage and over current using Matlab/Simulink. In this paper, different techniques for an analysis of different parts of solar PV plant power quality improvement and protection are reviewed.

Index Terms— renewable energy, solar photovoltaics, power quality improvement, photovoltaic (PV), MATLAB, simulink, off-grid solar power plant,

1 Introduction

Now a day, energy-related aspects are becoming extremely important. They involve, for instance, a rational use of resources, the environmental impact related to the pollutants emission and the consumption of non-renewable resources. For these reasons, there is an increasing worldwide interest in sustainable energy production and energy saving. Among the technologies that could play a role in the generation of sustainable and widespread energy, interesting solutions are represented by photovoltaic (PV) cells, wind generators, biomass plants and fuel cells. The research activity and development in PV field have usually been focused on solar radiation analysis, efficient operating strategies, design, and sizing of these systems. Solar cell efficiency is an important input parameter in PV-powered product design. Often, only limited space is available for the solar cells to be integrated. Effect of dust on the power reduction and efficient reduction of PV module was quantified [1].

When considering only modern renewables, Solar Photovoltaic technology is getting the most attention, due to its feasibility in most parts of the world unlike the wind and tidal projects which are practically feasible only at certain geographical locations in the world.

The solar energy system has many advantages like; it is free of cost and unlimited source of energy, eco-friendly and sustainable to the environment, But even with these advantages over conventional resources, its growth is limited, mainly due to high investment costs per unit generation which are a result of higher manufacturing costs and improper awareness about its design, installation, and behavior leading to lower yield than expected [19]. In some cases, PV faults may remain undetected and result in more severe damages. Although the milestone of 100GW PV installation capacity throughout the world was achieved in 2012, any PV installation is susceptible to faults, and these faults may remain undetected. Most of the PV-related published articles are based on improved cell level efficiency, electrical circuit modeling, maximum power point tracking (MPPT), panel architecture, circuit level optimization, and there have been comparatively few articles based on different faults in PV systems. This article will investigate different faults in PV systems including power quality improvement of harmonics distortion, correcting power factor and protection of solar PV plant by over voltage and over current prevention and detection techniques [3].

2 Power Quality Improvement of Solar PV Plant

Renukadevi V and Dr. B Jayanand have proposed a two part of the circuits, one of the circuit is detecting harmonic and reactive component, and other circuit generating the compensation current of grid-connected PV system. Here the load current is having three components – active, reactive and harmonic. It tracks the actual compensation current that the command current aroused, and compensate Harmonic and reactive component of the grid current, and offset harmonics and reactive component of load current and compensate the active component of grid current, and provide the active power the load and power grid.

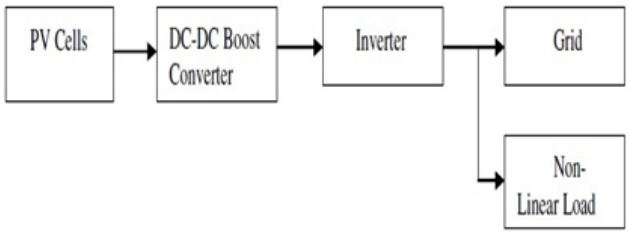

Fig. 1. Block diagram representation of the proposed system [3]

Albert Alexander S has explained a detailed analysis of employing different switching techniques and observing its performance. MATLAB/Simulink is used to perform the simulation studies in which a separate model is developed for

- *Ajay A. Toraskar, Mtech. Student, EnergyTechnology, Shivaji University, Kolhapur, India.*
- *Nayan J. Kotmire, Assistance Professor, Department of Technology, Shivaji University, Kolhapur, India.*
- *Mahesh M. Wagh, Co-ordinator, Energy Technology, Shivaji University, Kolhapur, India.*

solar PV which serves as the input to the inverter. In addition, the past works by the author including intelligent control strategy and switches reduction topology are also included. This ensures the consumers to make an optimal choice of the photovoltaic inverter which upholds the better improvement in performance parameter [4].

Alexander S. Albert and Manigandan T. has presented the section analyses of possible resonance phenomenon in electrical networks which concentrated on DP inverters. For the home connection, the equivalent capacitance of connected appliances also has a large influence. This equivalent capacitance can vary over a wide range from around 0.6 to 6 F. The typical values for the inverter input capacitance change also over a wide range as discussed in the previous paragraph. Commercial inverters in the 1–3 kW power range typical use values of 0.5 to 10 F for the output capacitance.

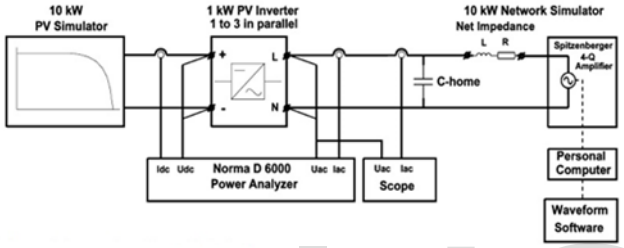

Fig. 2 Block diagram of the power electronic network simulator [5]

The simulation results with the Dutch national average background distortion (THD=3%) are presented in Fig. 2. For this case, the nominal effective voltage at Vmain was reduced by 2% in order to keep the voltage within the regulation limits at all the different household connections. Under conditions of maximum distortion, several inverters tripped. This was mainly because the maximum voltage levels were exceeded. These increased voltages were due to the increased voltage distortion and double zero crossings in the voltage waveforms. The effects of the tripped inverters are clearly seen at the different connection points. From these results, it is clear that the inverters in the network, with the average background distortion, should operate well, but at increased levels of distortion currents. This is mainly due to the series resonance initiated by the background supply harmonics and the network components. In the results with the maximum levels of voltage distortion, some inverters tripped and furthermore large levels of voltage distortion are visible [5].

Rahim Nasrudin A and Selvaraj Jeyraj have developed the design and implementation of a solar PV fed cascaded fifteen level inverter with various modulation and strategies in order to reduce the harmonic distortions. This includes the multiple carrier PWM techniques such as APOD, PD, and POD along with the SPWM techniques. The modifications, they remade in both carrier and reference arrangements to provide the best-suited strategy for solar PV applications in spite of variations in the solar PV input. Appropriate modulation technique with the choice of various parameters such as modulation index, switching frequency, and signal arrangement will certainly improve the power quality by reducing the harmonics in the system [6].

Johan H. R. Enslin and Peter J. M. Heskes have explained the penetration of PV systems in the distribution network, the becoming an important issue of harmonic distortion of current and voltage waveforms. It is due to conversion of dc current in order to synchronize with the AC main supply by utilizing inverter. The author said that the current harmonic Ih, reduced to 30%, with the possibility of better filtering. The PV harmonic behavior of a 20 kW inverter as a function of the solar radiation in different weather condition is considered in. The measurement results which have captured the harmonic impact of the 20 kW PV plant in several weather conditions is presented in this research too. The harmonic profile of the current and fundamental current is captured at the PCC [8].

M. Karimi et al; has presented a comprehensive overview of important issues affecting the distribution system as a result presented on PV penetration. Pertinent issues such as voltage fluctuation, voltage rise, voltage balance, and harmonics and their effect on the system [11].

Sarah Rönnberg and Math Bollen have proposed that the advent of new electricity production modes, power electronics, LED lamps and underground cables, new types of disturbances will appear, including an increase in distortion between 2 kHz and 150 kHz that have referred to as supra harmonics. A shift of resonances to lower frequencies may partly compensate for the increased emissions at higher frequencies, but the transfer of disturbances will become less predictable.

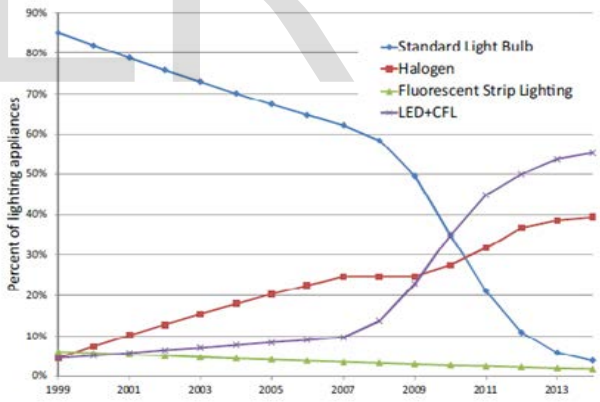

Fig. 3 Graphical representation of Replacement of incandescent lamps by other types of lighting [13]

The development of society is increasing rapidly. Graph easily understands the development. Most of the power electronics equipment has used for the daily routine life of humans life. Therefore these electronics equipment consumptions of electrical energy are less but more amount of harmonics production. Harmonics Distortion is the upcoming important power quality issue [13].

3 Discussions

The above review survey shows that power quality of re-

newable energy technologies is a big issue. The different authors proposed different techniques of simulation in power quality issues in grid connected or micro grid connected power plant. They have not concentrated on off-grid connected or standalone solar PV power plant. Most of the techniques focus on the developing MATLAB simulation of the power quality of the solar plant. Hence, there need of the development of the device to analyze the load affected on the power quality and overcome these losses and increasing the efficiency to equipment.

The current design methodology has some serious issues which are mentioned as follows, in this power system, power supply reliability, and power quality have become important issues for all kind of power electronics systems including photovoltaic systems. Interconnecting a photovoltaic system with utility, it is necessary that the photovoltaic system should meet the harmonics standard and the active power supply requirement.

Most of the PV-related published articles are based on improved cell level efficiency, electrical circuit modeling, maximum power point tracking (MPPT), panel architecture, circuit level optimization, and there have been comparatively few articles based on different faults in PV systems. The review have been present to investigate different faults in PV systems including power quality improvement of harmonics distortion, correcting power factor and protection of solar PV plant by over voltage and over current prevention and detection techniques.

Most of the authors have tried to the development of multilevel or multi-functional inverters using PWM or other some techniques which can maintain power quality of the system. Some authors have developed the grid connected three phase inverter simulation and prototype hardware part. Authors are more concentrated on grid connected solar power plant for power balancing, power factor correction, voltage stability and phase balance of power quality improvement.

Nowadays, the development of society is increasing rapidly. Most of the power electronics equipment has used for the daily routine life of humans life. Therefore these electronics equipment consumptions of electrical energy are less but more amount of harmonics production. Harmonics Distortion is the upcoming important power quality issue. The study shows that the system gives good dynamic performance under varying load conditions. Whereas the reactive current compensation gives highly favorable results, the harmonic performance depends largely on the load. Harmonics may not be completely compensated owing to the limitations posed by the inverter which can produce voltages only in a time-averaged sense.

4 Conclusion

This review has provided brief information on power quality issues for the solar power plant. Most of these authors considered the grid connected issue of three phase system like power stability, phase balancing, voltage stability, harmonics and power factor. Most of the techniques focus on the developing MATLAB simulation of the power quality of the solar plant.

Considering the different existing methods of the solar off-grid connected power plant for power quality improvement as above and advantages and limitations. Also, it is low cost and can be indigenously developed. However, the total power quality improvement for harmonics distortion, power factor correction, over voltage and current protection, economics, durability, reliability, etc. of its components is required to be tested.

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