Analysis of Harmonic Stability In A Microgrid In Accordance With IEEE-519 Standard

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Abstract- *Microgrid system is a primary source for distribution system which is used to supply the electrical power to the local loads. In distribution system power quality is an important element. In this paper, the harmonic distortion levels are observed and also reduction methods are applied at a point where there is an increased penetration level of Photo Voltaic Generators (PVGs) in the distribution network. The maximum IHD and THD of both voltage and current of the system do not exceed the IEEE-519 limit. Another objective of this paper is to analyse the reactive power control of the microgrid system using Photo Voltaic Generators (PVG) and battery as a source. To achieve the Maximum Power, microgrid system with Perturb and Observe algorithm and Maximum Power Point Tracking (MPPT) have been proposed. This paper proposes several control algorithms through which the capability of PV generators for active and reactive power (P-Q) connected in microgrid could be harnessed and enhanced. A closed loop is implemented to improve the voltage. In this closed loop system PI controller is used which maintains the stability of the system. The chosen control parameters in the proposed control methodologies can seamlessly control inverter P-Q in grid connected system. The proposed technique is designed by MATLAB/Simulink version 8.3.0.532 (R2014a). The simulation of PQ control is analysed and also harmonic distortion level is observed and reduced.*

Keywords- Photo Voltaic generators, MPPT technique, battery, Total Harmonic Distortion (THD), Individual Harmonic Distortion (IHD), Proportional Integral Derivative (PID) controller, Sine Wave Pulse Width Modulation (SPWM)

I. INTRODUCTION

Microgrid3is a power supply network in which a cluster of small on-site generators provide power to a small community. The increasing3interest in microgrid is changing the dependency on3the conventional centralized power system. Modern microgrids are regarded as small power systems that confine electric energy generating facilities from renewable energy sources, conventional synchronous generators, and customer loads with respect to produced electric energy [1]. They can be connected to the main grids or operated as isolated power systems, hence are more efficient and initiate less environmental issues. Control and3loss reduction problems of volt/var are significant issues for microgrid planning and operation. Microgrid reactive power needs to be compensated and managed in such a way that it ensures sufficient amount of power is being produced in order to meet demand and regulate voltage within specified limits, so that the microgrid can run efficiently. The proposed system shown in this work subsidizes the power quality problems faced in microgrid.

The array of a photovoltaic power system produces direct current (DC) which fluctuates with the intensity of sunlight. For practical use this usually requires conversion to certain desired voltage level using DC-DC conversion. DC-DC converter is a major part of the system, which is commonly used in photo voltaic generators to improve the output voltage. Buck Boost converter is used in the proposed system as DC-DC converter whose output voltage is typically of the same1polarity of the input and can be lower or higher than the input voltage magnitude. This supplies power to the microgrid which reduces the power loss and improves the power quality of the system. Multiple PV generators are used in the system and this paper involves analysis of IHD and THD. All the PV panels are connected at a common point, which is known as Point of Common Connection (PCC).

This system proposes the3MPPT technique in which PID controller is used for photovoltaic systems to maximize power output. Perturb and observe technique is used in MPPT due to its ease of implementation. This method provides top-level efficiency, proper predictive and hill climbing strategy. To minimize the error values PID controller is used, which makes a closed loop feedback path. A PID controller continuously calculates error values as the difference between measured values and desired values.

This paper presents a PV system in MATLAB/Simulink and the maximum power tracking by using the P&O algorithm. SPWM technique reduces reactive power requirement and corresponding waveforms are shown in the simulation output.

II. OBJECTIVES

The prime agenda behind this project is to meet the following objectives:

1) to improve output voltage and stability of the microgrid system,
2) control the reactive power,
3) eliminate higher order harmonics and to maximize power output,
4) to obtain pollution free power generation and to increase the overall efficiency of microgrid,
5) power quality improvement by enhancing active power and compensating reactive power and
6) to minimize the installation and operational costs when compared to conventional grid system.

III. METHODOLOGY

The proposed method has been built considering the conventional PV array being the source of a microgrid as shown in the Figure 1.1.

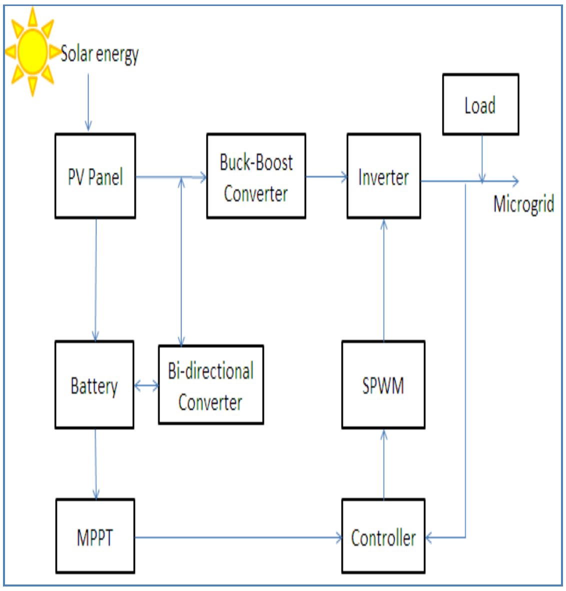

Fig.1 General Block diagram of the proposed system

The voltage output produced in the Photovoltaic Generators is fed into DC to DC converter which increases the voltage at its output. A battery is used across a bi-directional converter to store electrical energy when it is produced by the PV array and to supply energy to electrical loads as needed or on demand. The Buck Boost converter is a type of DC-DC converter which is used, whose output voltage is typically of the same polarity of the input, and can be made to lower or higher the input voltage magnitude. The3further generated output3is incorporated3into the3inverter, whose purpose is for3the conversion of3DC to AC. Low pass filter is used in order to reduce higher order harmonics which is produced during the current conversion in the inverter stage. The inverted output, after filtering is given to microgrid. Another output of the inverter3is given to the equipment where the Clarke transformation occurs. The SPWM is used to give switching voltage to the inverter with the help of PID controller and in order to get maximize power Perturb and Observe MPPT algorithm is used. The P and Q control technique facilitates compensation of reactive power.

IV. PROPOSED SYSTEM

The proposed system as shown in figure 2 is constructed for two PV systems each 1KW which is connected with microgrid. The PV panel is interfaced with Buck- Boost converter using MPPT technique. This is in turn connected via inverter to microgrid to feed linear and non-linear loads. . The battery energy storage system is3connected with the3input of inverter3so that3the battery supplies the load in the absence3of sunlight. Low pass filter is used in order to reduce higher order harmonics which is produced during the current conversion in the inverter. The inverted output is given to microgrid. Another output of the inverter is given to the equipment where the Clarke transformation occurs.

The IHD & THD is measured to ensure PV system is properly designed to ensure IEEE recommendations. This paper proposes several control algorithms through which the capability of PV generators for active and reactive power (P-Q) control in grid connected microgrids could be harnessed. The major contribution of the proposed control methods lie in the coordination among individual proposed control methods. MPPT controls P-Q control algorithm at the inverter side. The chosen control parameters in the proposed methodologies are dependent on the PV, battery and external power grid.

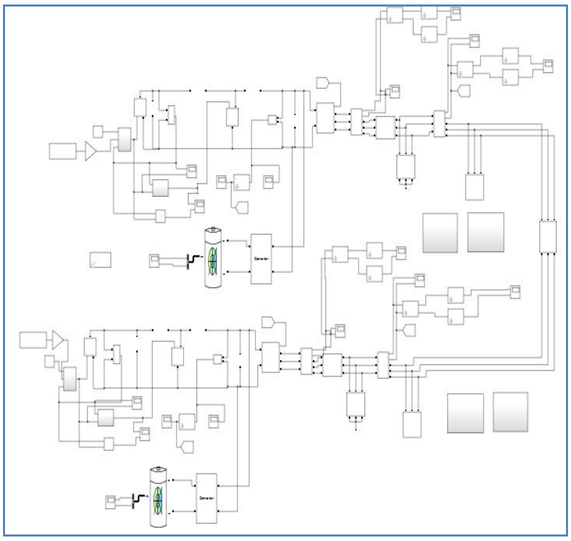

Fig.2 Simulation diagram of proposed method

The Clarke or a/3D transform is mathematical representation of space vector transformation specially for time-domain signals (e.g. voltage, current, flux, etc.) from a very natural three-phase coordinating system (ABC) into the required stationary two-phase reference frame (d,q).The coordinated output is given to the microgrid, previously to the injection of voltage profile, one more process occurs, the corresponding voltage enters into the special device referred to as the (SPLL) shift phase locked loop whose necessity is for the separation of a particular signal into phase angle and magnitude over any system. Shift phase locked loop convert the phase angle of voltage into 90°. It is connected to Clarke transformer for the calculation of direct and quadrature current and voltage for making quadrature voltage as zero. This output is combined to enter into the Clarke transformation device. Currents and voltages are splatted into the direct and the quadrature currents and voltages. The voltages are collectively fed into the power calculation representation and the currents are injected into the current controller division. The Clarke transformation generates four parameters I_d, I_q, V_d, V_q and the power is calculated. The calculated power is given to the power control and they are compared with the reference signal. In turn the corresponding details are referred and compared for the signal modulation in the (SPWM) sine wave pulse width modulation, the further technical results are sent into the filter for harmonic distortion removal, and the respective result is given to the microgrid for the real power requirement. Thus, the reactive power is compensated efficiently. Figure 3 represents the operation of reactive power compensation using Clarke's transformation in MATLAB.

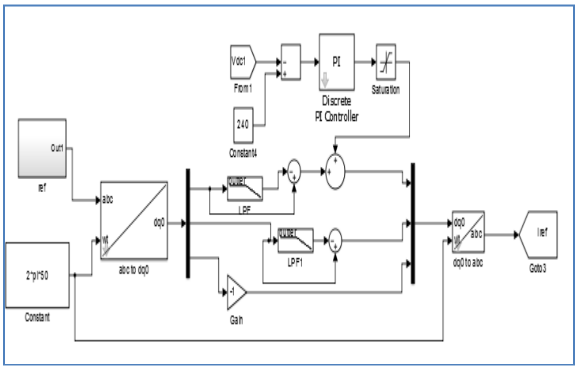

Fig.3 Operation of reactive power compensation using Clarke's transformation

V. MAXIMUM POWER POINT TRACKING ALGORITHM

MPPT algorithm is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. The MPPT controller which is used in this proposed system is more sophisticated (and more expensive): it will adjust its input voltage to harvest the maximum power from the solar array and then transform this power to supply the varying voltage requirement of the battery plus load. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin's impedance of the circuit (source impedance) matches with the load impedance. Hence the problem of tracking1the maximum power1point reduces to an impedance matching problem. In the source side, a boost1convertor is connected to solar panel in order to enhance the output voltage, so that it1can be used for different applications like motor load, etc. By changing the duty cycle of the boost converter appropriately, the source impedance can be matched with that of the load impedance.

A. PERTURB AND OBSERVE ALGORITHM

In this method, as shown in figure 4, a slight perturbation is introduced in the system which changes the module power. If power increases due to perturbation it is continued in the same direction. When peak power is reached the next perturbation will give decrement in the power and perturbation reverses. When steady state is reached, the algorithm oscillates around peak point. Perturbation size is generally kept small in order to keep the variation in power as small as possible. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller, then, acts moving the operating point of the module to that particular voltage level. It is also observed that some power loss due to this perturbation fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple. Fig.4 represents the hill-climbing technique in P&O method.

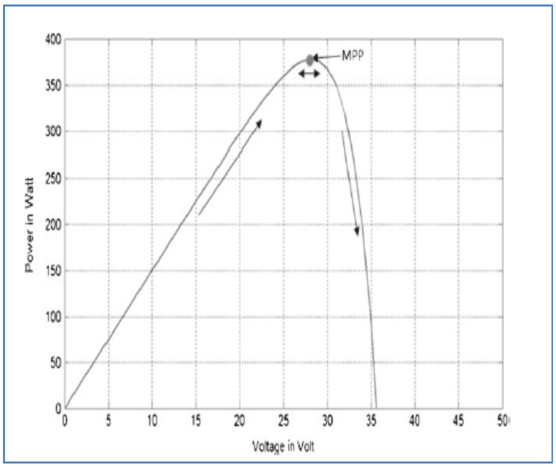

Fig.4 P&O method

The Perturb and Observe algorithm is also known as "hill climbing" method. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O involves a perturbation in the operating voltage of the DC link between the PV array and the converter.

VI. RESULTS

A. OUTPUT VOLTAGE FROM PVGs

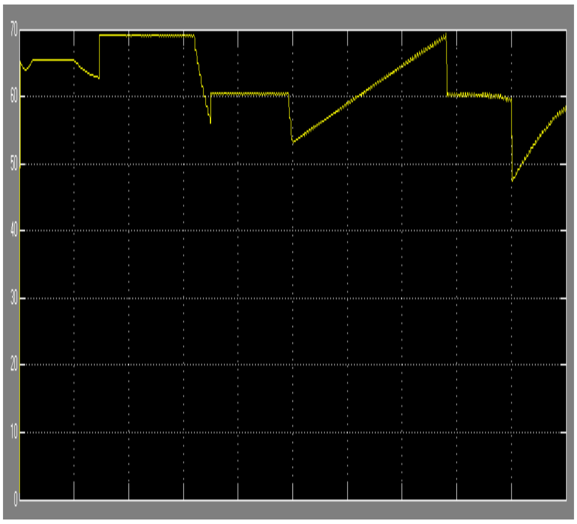

Fig.5 PV output voltage

PV panel is used as a source. The PV output voltage magnitude is about 66V. In Figure 5, graph of voltage and time is shown.

B. OUTPUT VOLTAGE OF BUCK-BOOST CONVERTER

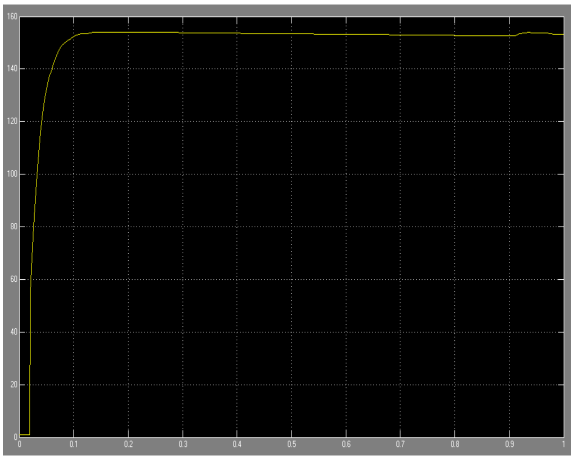

Fig.6 Output Voltage Waveform of Buck Boost Converter

Figure 6 shows the output of boost converter and which is about 150V by taking 66V as an input from the PV system.

C. OUTPUT OF THE INVERTERS

Figure 7 shows the output voltage and current of voltage source inverter whose values are about 100V and 20A respectively, before filtering, which contains distortion.

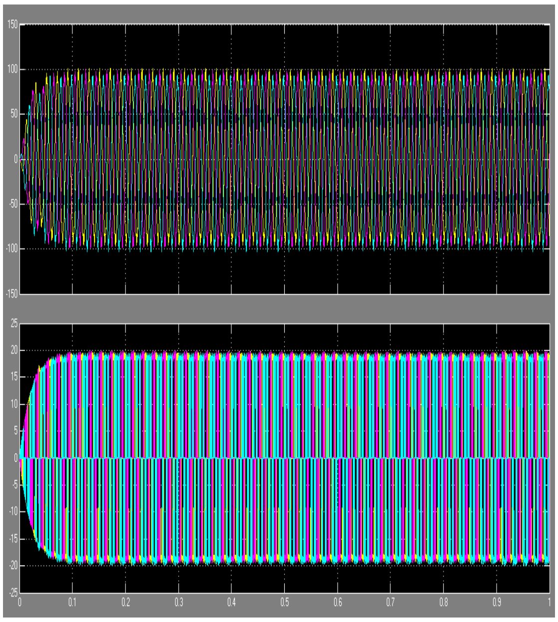

Fig.7 Voltage and current output of Inverter before filtering

Figure 8 shows the output voltage and current of voltage source inverter after passing through the low pass filter whose values are about 260V and 7.5A, which are also pure sine waves without any distortion.

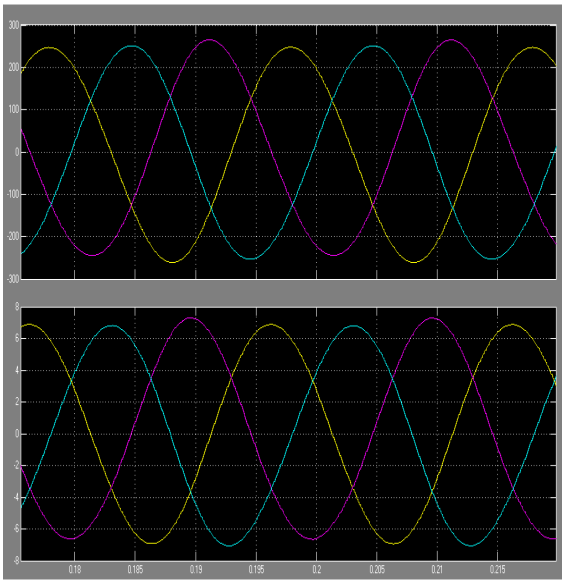

Fig.8 Voltage and current output of inverter after filtering

D. OUTPUT OF REAL AND REACTIVE POWER

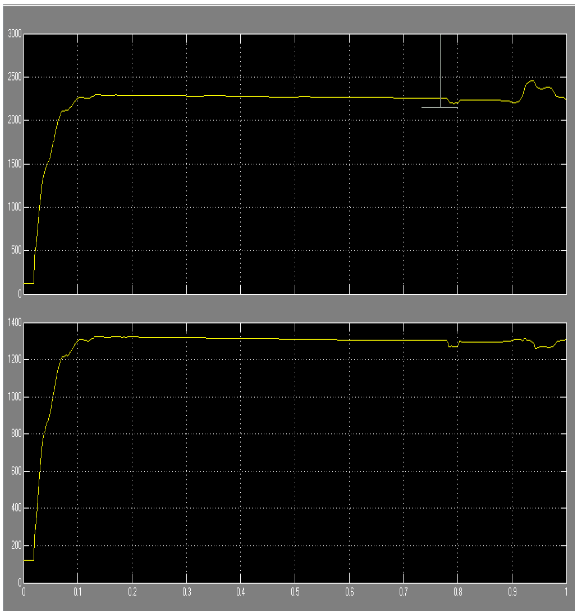

Fig.9 RMS Active and reactive power after filtering

Figure 9 shows the RMS value of Active and Reactive power at the DG (PV system) after being filtered, where the value of active power has increased to 2400W and reactive power has reduced to 1300var.

E. FFT ANALYSIS

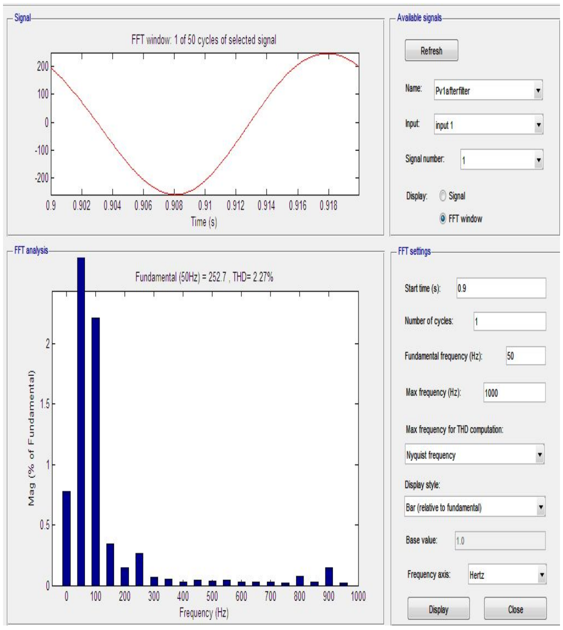

Fig. 10 FFT signal waveform and total harmonic distortion (THD)

The THD of output voltage after filtering is as shown in the Figure 10. The value of THD is about 2.27%, which clearly indicates that the THD of output voltage obtained falls within the IEEE519 standard limit and hence meets the requirement.

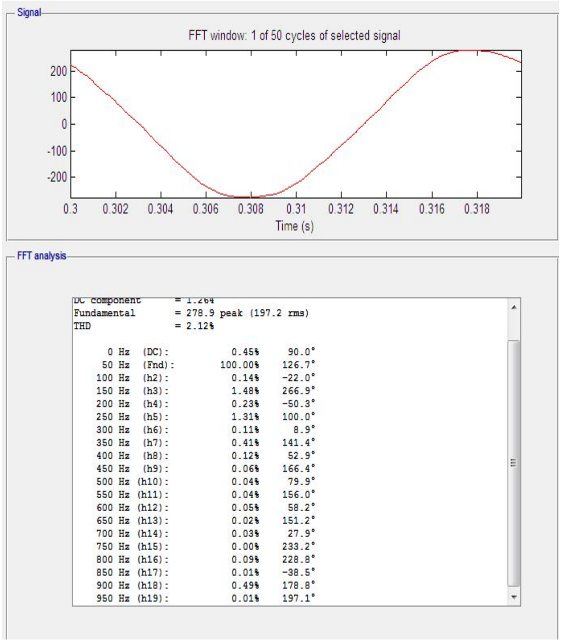

Fig.11 FFT signal waveform and individual harmonic distortion (IHD)

The IHD of output voltage after filtering is shown in the Figure 11. The IHD value obtained falls below 3% for all the multiples of fundamental frequency, which clearly indicates that IHD of output voltage lies within the IEEE519 standard limit. Hence, this proves the analysis of harmonic stability of the proposed system.

VII. CONCLUSION

Microgrid system is a primary source for distribution system which is used to supply the electrical power to the local loads. To reduce the burden on the centralized power system, microgrid or decentralized generating system concept has been brought out in this project. A system is proposed where the PV source (and also battery) is connected to buck-boost converter to boost the output voltage of PV source. In regard to this the following works done and conclusions drawn from them are presented:

1. MPPT is a technique that is used to obtain maximum power point on the PV array in order to get maximum output voltage.
2. P and Q control technique is applied in order to compensate reactive power.
3. Elimination of higher order harmonics present in the system is achieved by using LC filter which makes the system more stable.

4. The harmonic distortion levels and reduction techniques of Photovoltaic Generators (PVGs) in the distribution network are studied.
5. For proposed system, both IHD and THD of current and voltage are computed using MATLAB/Simulink. It is found and ensured that these values (IHDi, IHDv, THDi, THDv) are well within the limits as per IEEE-519 standard.

The system developed in this project provides a source of power which is environmental friendly and cost effective. Implementation of this system will help to set up a decentralized power generating system in places where supply of power from conventional grid is expensive and not suitable.

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