ANTI-Islanding in Grid Connected Solar Photovoltaic System

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Abstract- Introducing distributed generations (DGs) into distribution systems, leading to a bi-directional power flow. Several benefits of embedding DGs into distribution systems, such as increased reliability and reduced system losses, can be achieved.Photovoltaic (PV) is one of the popular choice among the DGs, which typically establishes in grid-connected systems. However, for grid-connected systems, the issue of islanding remains as a great challenge. Islanding is the condition in which a zone of the distribution system remains energized after being disconnected from the grid. It leads to troubles in voltage and frequency control and power quality issues. Therefore there is a need for appropriate anti-islanding measures for grid-connected PV systems. PV gridconnected Distributed generators must detect islanding and immediately disconnect from the circuit this is referred to as Anti-islanding.Anti-islanding methods generally can be classified into four major groups, which include passive methods, active methods, hybrid methods and communication based methods.
The proposed system uses passive anti-islanding detection technique in which islanding shall be detected by continuously observing voltage and current across the load. The presence of an island and the detection time of the islanding condition are monitored through different methods.The protection was tested in case of complete disconnection of the PV system from the electric power grid and also in case of various grid faults.To achieve this photovoltaic inverter is equipped with voltage source converter and LC filter, which is able to reduce the Total Harmonic Distortion of the output waveform.

Keywords- Distribution Generation (DGs), Anti-islanding, photovoltaic, OVP/UVP, OFP/UFPTHD

I. INTRODUCTION

Global environmental concerns and the escalating demand for energy, coupled with steady progress in renewable energy technologies, are opening up new opportunities for utilization of renewable energy resources[1]. Solar energy is the most abundant, inexhaustible and clean of all the renewable energy resources till date. Solar energy is the most efficient renewable energy source if it is efficiently harnessed by the modern technology. In solar PV system, the sunlight is directly converted into the electrical energy. The energy that can be produced by a solar cell basically depends on the intrinsic properties of the cells and the amount of solar radiation which falls on the panel .The typical size of the solar array as well as AC inverter required for solar PV applications depends on the type of loads connected [16]. The energy from the panel can also be stored by using battery storage for later use.To increase the system efficiency and to extract maximum power from the panels MPPT (Maximum Power Point Tracking) techniques are used.One important requirement for distributed generators is anti-islandingcapability. It is the capability of a distributed generator to detect if it operates in an islanded system and to disconnect itself from the system in a timely fashion. Islanding occurs when a portion of the distribution system becomes electrically isolated from the remainder of the power system, yet continues to be energized by distributed generators [4]-[6]. The incapability to trip islanded DGs can lead to many problems for the PV inverter and the connected loads.

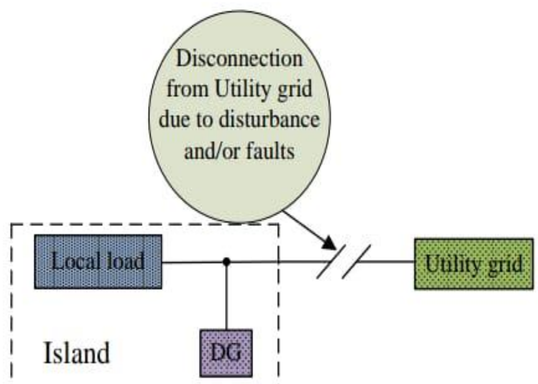

Fig.1: Schematic diagram of a utility network illustrating the concept of DG islanding

Islanding can be either intentional (preplanned) or unintentional (accidental) based on their occurrence. Unintentional islanding issues are worth focusing on since they distort the power quality of the utility grid to a large extent if found negligent. An electricalisland is the result of disconnection of DGs and local loads from the utility grid with the DGs still energized and remain to be operative supplying power.IEEE 929-1988 standard requires the disconnection of DG once it is islanded. IEEE 1547-2003 standard stipulates a maximum delay of 2 seconds for detection of an unintentional island and all DGs ceasing to energize the distribution system.Islanding detection methods are evaluated based on attributes such as detection time, size of Non Detection Zone, Power Quality issues and System cost. A non-sensitive operating condition with varying degrees of power quality corruption called the non-detection zone (NDZ). Islanding has to be removed as soon as possible as it may result in frequency instability and higher proportion of harmonics.As large numbers of DG are continuously adding to the power grid, there is increasedrisk in the safety of the personnel and harm to the power system[8]. Consequently there is a requirement fordetection of islanding and adopting the corrective measures to minimize the risk. If the high speed re-closure is done on the islanding part of the utility grid, then the forced connection results not only affects the PVs, but also the grid and the load.Detecting an islanding condition is an important aspect, which includes threelargely defined methods.These three categories are:

• Passive methods resident in the grid tied inverter.
• Active methods resident in the grid tied inverter.
• Methods not resident in the DG but communicating the DG and the utility.

A. PASSIVE METHODS

This kind of methods lies in the inverter. They are based on the monitoring of certain characteristic parameters inthe point of common coupling (PCC). The anti-islanding method causes the disconnection of the inverter from theutility grid under fault conditions when the parameter monitored, different for each method, gets out of thecontrol range considered as usual during the normal operation. The basic principal of this procedure easily understand by this flow-chart-

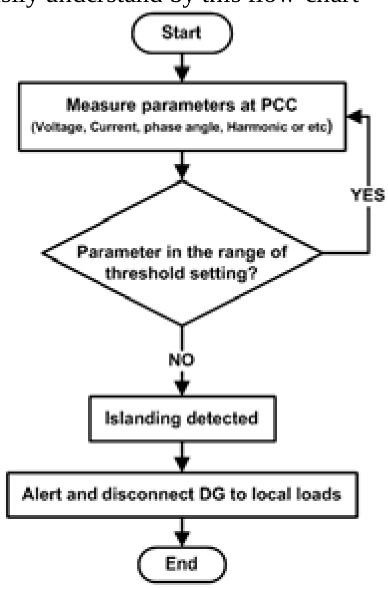

Fig.2: The flow chart of passive islanding detection procedure

- **The Over Voltage Protection / Under Voltage Protection(OVP/UVP)**

This method controls the PCC voltage value and compares it with certain established limits. When the control system registers an rms voltage higher or lower than that permitted at the PCC, it produces the STOP signal.

- **The Over Frequency/Under Frequency Protection(OFP/UFP)**

This methodcontrols the frequency of the voltage signal at the PCCevery zero crossing, comparing its value with theregulated limits to check it is always kept in between. Inthe case the calculated frequency fall out of the acceptedrange the control system would generate the STOP signalto produce the interruption of the generation.

- **THD Detection.**

The harmonic distortion detection method checks thevoltage Total Harmonic Distortion at the PCC and compares it withthe established limits as acceptable in the utility. Whenthe utility is connected this distortion is fixed at a very lowlevel. But just after disconnection it increasesquite a lot going beyond the accepted level. Thisproduces the disconnection signal of the DG in this anti-islandingmethod failure of the main utility. The level of harmonic distortionincremented and quickly uncontrolled, due to resonancesbetween induction coils and capacitors of the local load.

B. ACTIVE METHODS

Active methods residing in the inverter to detect theisland operation mode introduce deliberated changes ordisturbances to the AC output.Certain parameters are monitored at the PCC in order todetect if the generator is functioning in island-mode orgrid-connected mode. If the perturbation introduced bythe inverter affects to the AC output characteristicsfurther than the established limits, considered as normalutility fluctuations, the control circuit, or even the voltageand frequency protections in case of getting out of range,disconnects the power generator. On the other hand, ifthe perturbation leads to no changes in the PCC, the DGcan assume the main supply is still on.By means of the perturbation the response of activemethods is faster and more effective than that of thepassive methods, reducing the non-detection zone where the DG keeps on working once the utility grid hasbeen disconnected. This NDZ dependmainly on the localloads connected to the DG [8]. The closer the activepower consumed by these loads is to the active powersupplied by the DG, the higher the probability to form anisland. In the same way, as the resonant frequency of thelocal load approaches the EPS frequency (50Hz) thepotential formation of islands increases.The main active methods used for preventing the islanding operation are represented as-

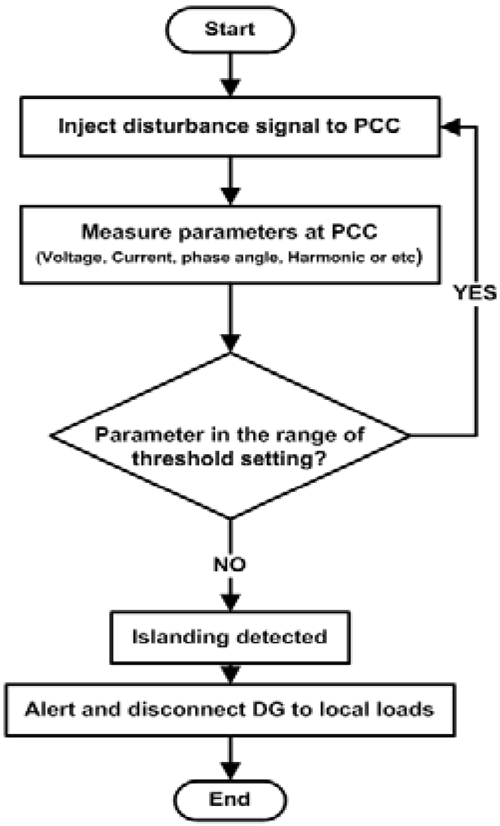

Fig.3: The flow chart of active islanding detection procedure.

Active methods are based upon Impedance measurement,Active Frequency Drift (AFD), Sandia Frequency Shift (SFS), Sandia Voltage Shift (SVS), Automatic Phase-Shift (APS), Reactive Power Variation (RPV)

II. PROPOSED METHOD

A.PV INVERTER CONFIGURATION

The solar PV system consists of mainly two power electronic components: boost converter and inverter. The close loop solar PV system having interconnected power electronic components where boost converter will convert the fluctuating dc obtained from PV panel into constant dc value and the inverter will convert this constant dc value into ac value which is compatible for the connected ac loads. The system parameters like dc link voltage and inverter output voltage will change, as the output parameters (loads) as well as input parameters (solar radiation and temperature) are changed. To obtain the controlled system the switching of power electronic devices are changed and PI controllers are used.The MATLAB/Simulink model of proposed Anti-Islanding control scheme for grid-tied PV inverter system is shown in fig. 4. A control unit shall be developed in such a way that MPPT (extraction of maximum) power from PV module easily be done. It will monitor the parameters like voltage, current and frequency and control the islanding in the inverter system.

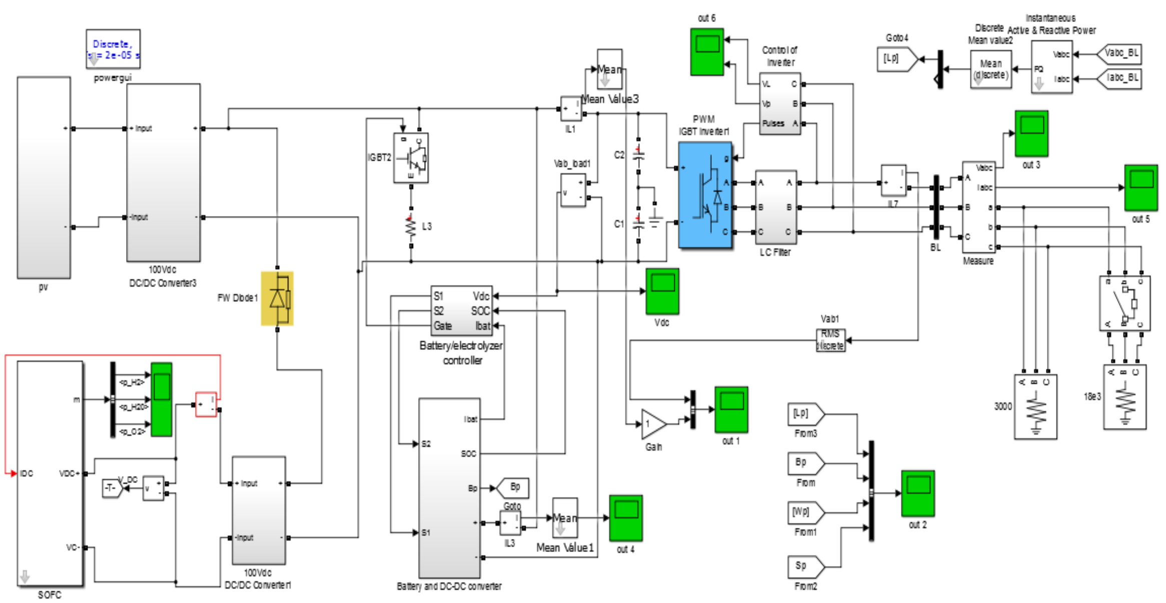

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Fig.4: Balanced DG without islanding System.

B.VOLTAGE SOURCE CONVERTER

The changing input parameters tends to change the changeof dc link voltage as shown in Fig. 5 and the inverter outputvoltage. The voltage across the dc link should remain constantfor having controlled system and better result at the outputside. The input side controlling of the system is done by usingPI controller in the input loop by tuning the value of controllerto maintain the dc link constant throughout the operation. Thus,other than the MPPT technique, the input loop can also becontrolled by simply using PI controller at the input side. Thecontrol scheme of VSC is shown in the Fig.5

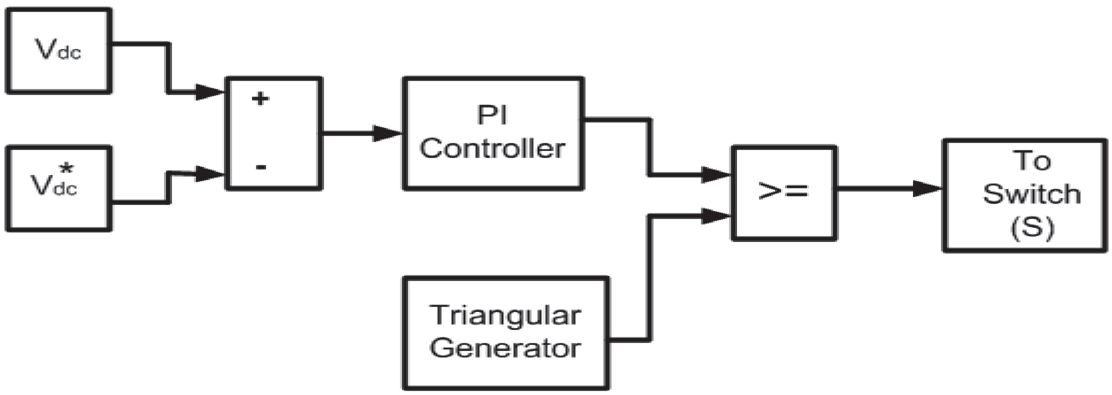

Fig.5: VSC with PI controller control scheme

C.INVERTER CONTROL SCHEME

The inverter output voltage is also affected by the variation in system parameters. Thus, the inverter output is alsomaintained to a constant value. Fig. 6 shows the control scheme for one inverter to control the output side of the system. The voltage across the dc link is sensed and compared with the reference value. The error produced is sent to PI controller. The PI output obtained will be a dc quantity. This dc quantity is multiplied by the sinusoidalvalue to convert it into ac value which is then compared with the triangular wave for producing pulses for inverter switches.

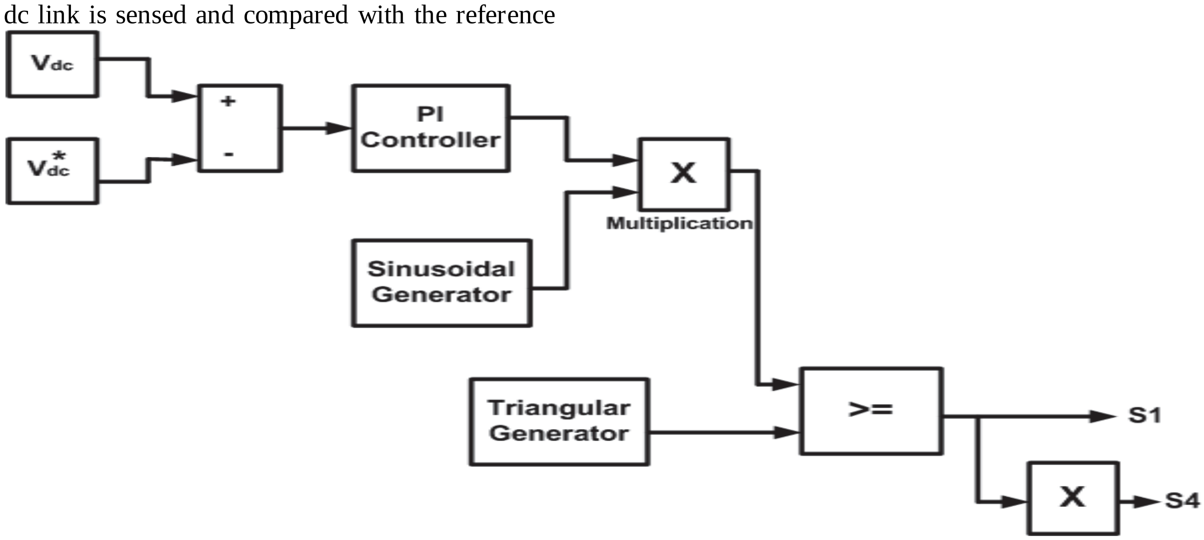

Fig.6: Inverter control scheme

Now, the case is consider when islanding occurs. The Simulink Model of Fig.7 is shown that the opening the circuit breaker would form an island consisting of the inverter and the load.

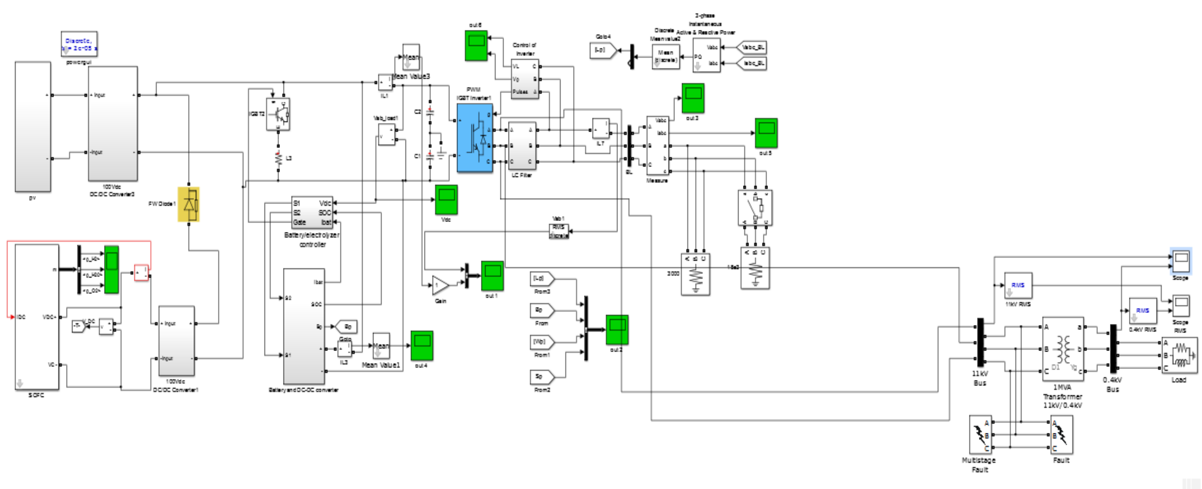

Fig.7: Simulink model of grid connected photovoltaic system

The model consists of three parts; the grid and the circuit breaker side, the RLC load and the three phase inverter representing the DG side. The Switching of inverter switches is done by using PWM scheme. To remove harmonics and THD in the AC output of an inverter LC filter is used Loop controlling technique is used in which PI- Controller in both the input and output control loops gives utmost stability. The IGBT's are used as switches. In this paper, the gate pulses given to the inverter switch are generated by using switching technique.Voltage Source Converter (VSC) isused for applications of Switched Mode Power Supply connection and the load is an RLC load.

III. RESULT

OVP/UVP, OFP/UFP, THDdetectionfor developing of the process of simulations, thesoftware MATLAB/Simulink has been used. With the help of some predefined modules as well assome new ones and a couple of programmed blocks, aDG connected to the power system can be easily implemented. Forthe case under study, a PV system connected to grid via athree phase connection has been created. The Simulinkmodel of the system resulting from the design can beobserved in Fig.5.The variations have been done to adapting the model to the functioning mode of therespective methods. For simulation procedures, the period analyzed is of 0.02 seconds. Starting the simulation withthe DG connected to the main utility the DG has been disconnected andthe response of the model registered for the differentaspect like stability, voltage regulation and harmonic distortion. The simulation results are shown below-

Case1. Result of photovoltaic system in balanced DG Mode:

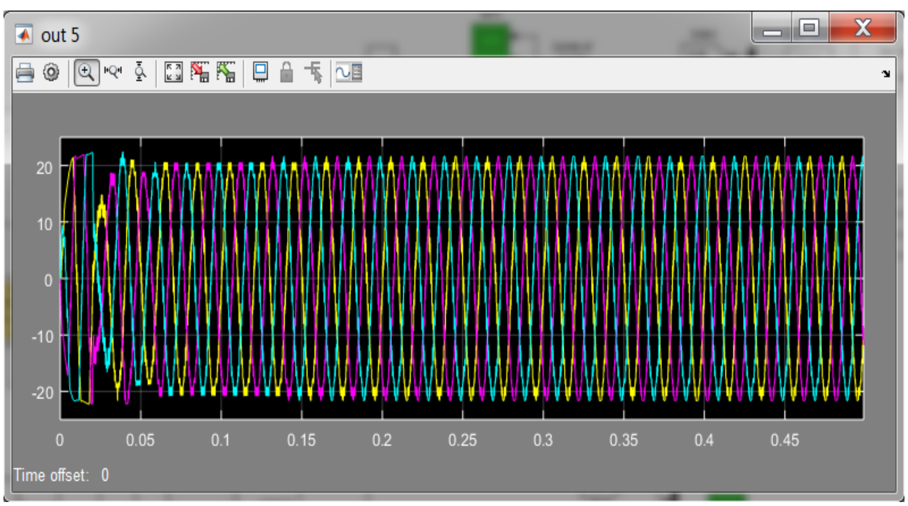

Fig.8: I_{abc} Output.

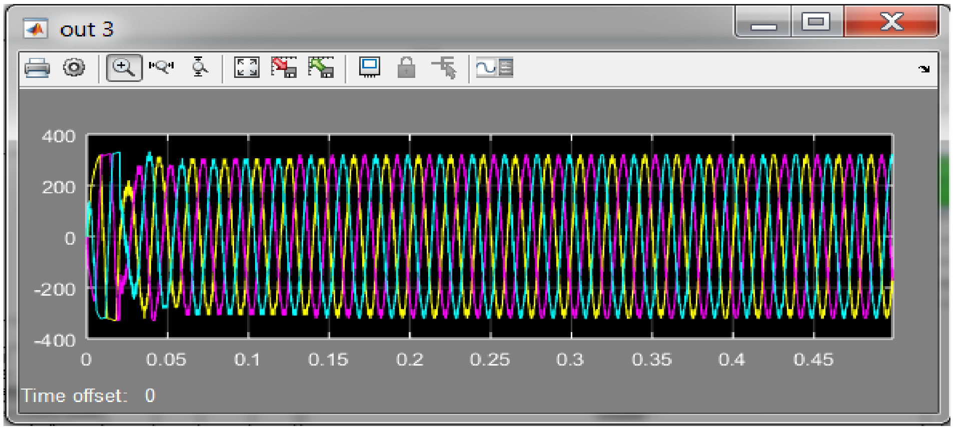

Fig.9: V_{abc} Output.

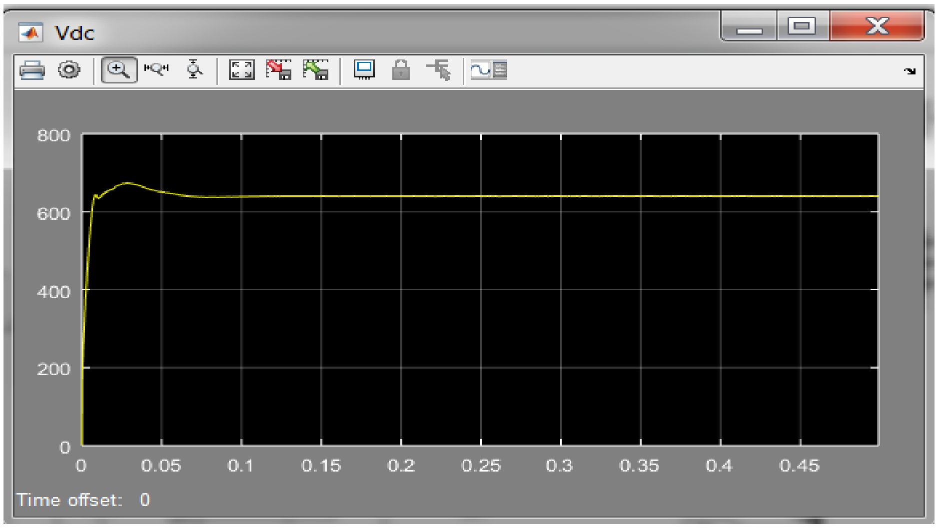

Fig.10: Transient and Steady state analysis.

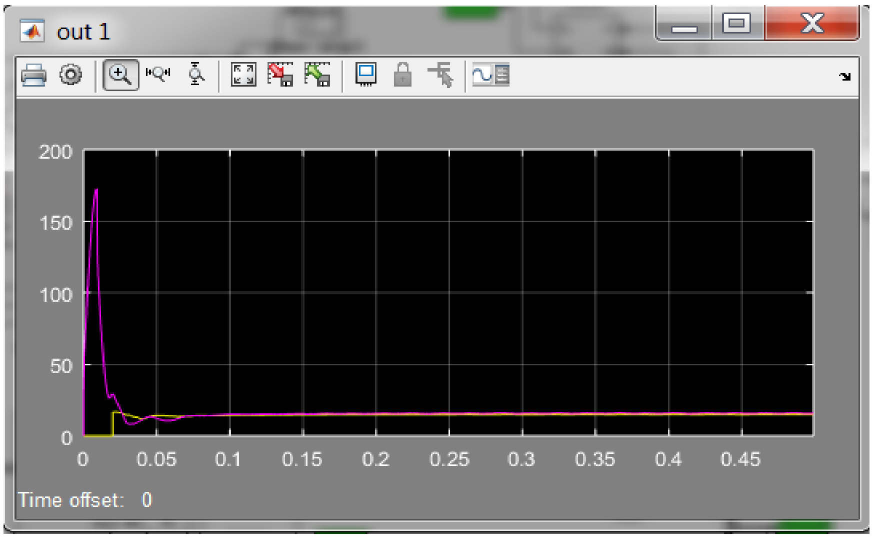

Fig.11: Voltage Regulation.

Case (2) passive method basedislanding detection:

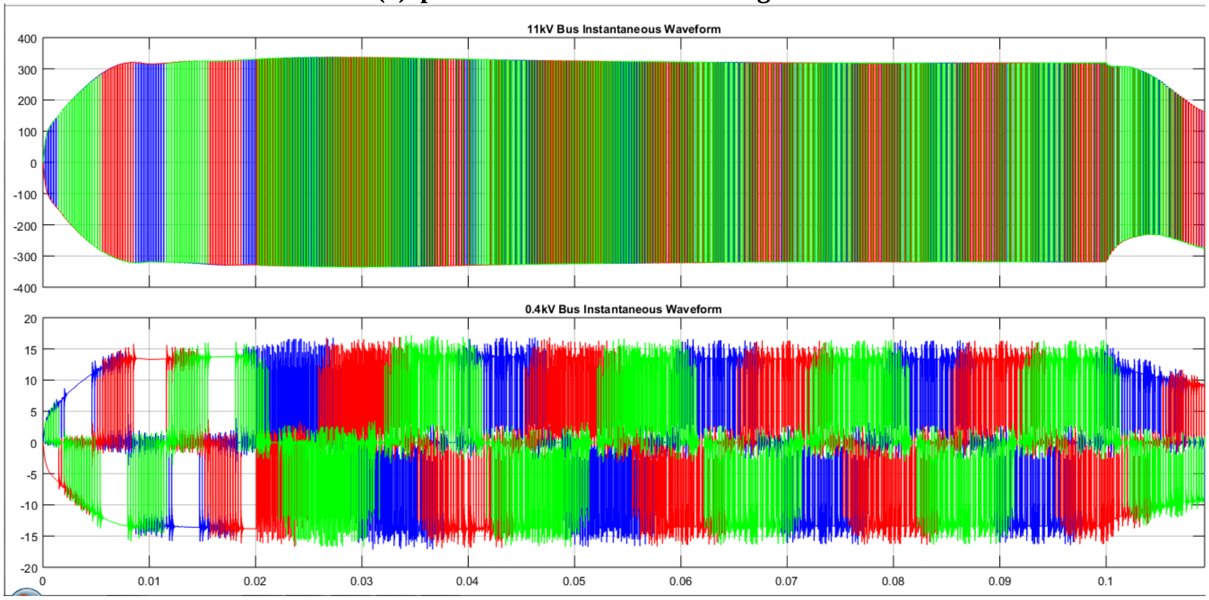

Fig.12: V_{abc} and I_{abc} Output Harmonic distortion.

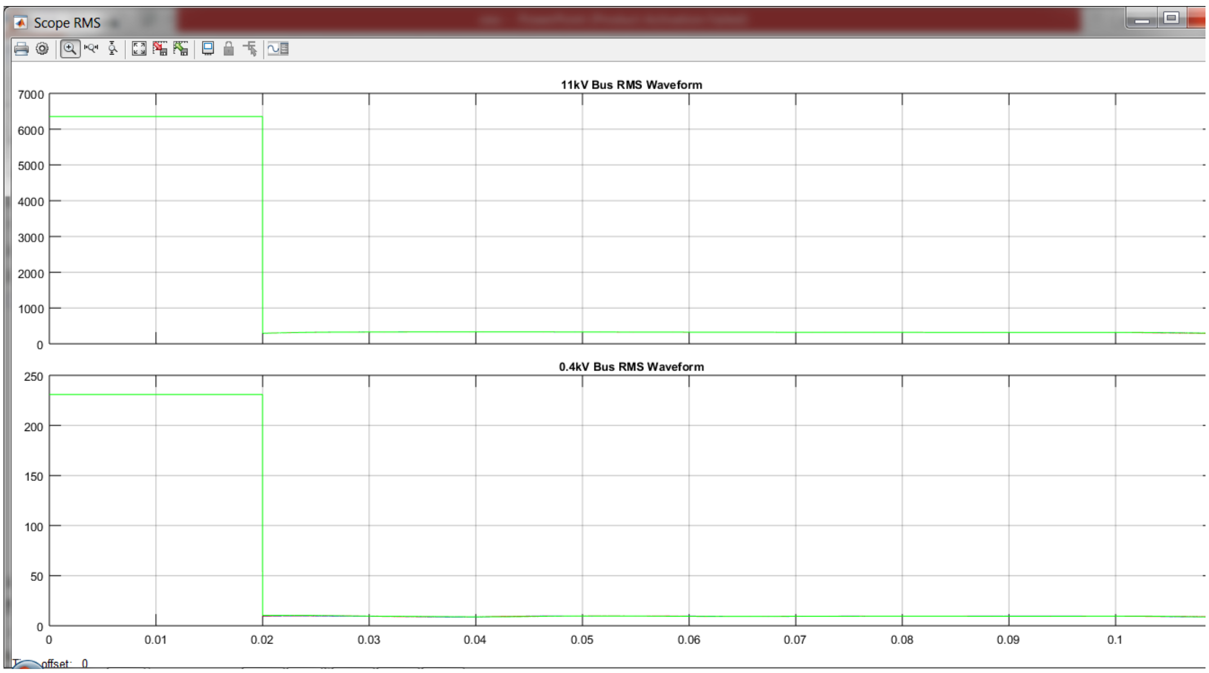

Fig.13: Phase Voltage Magnitude at Circuit breaker open connectivity at (t=0.02s) Frequency response.

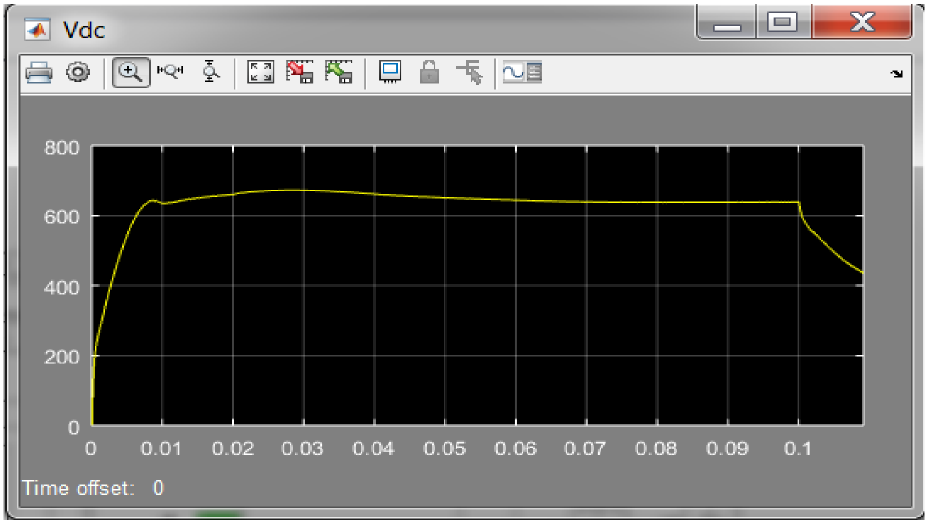

Fig.14:Transient and Steady state analysis.

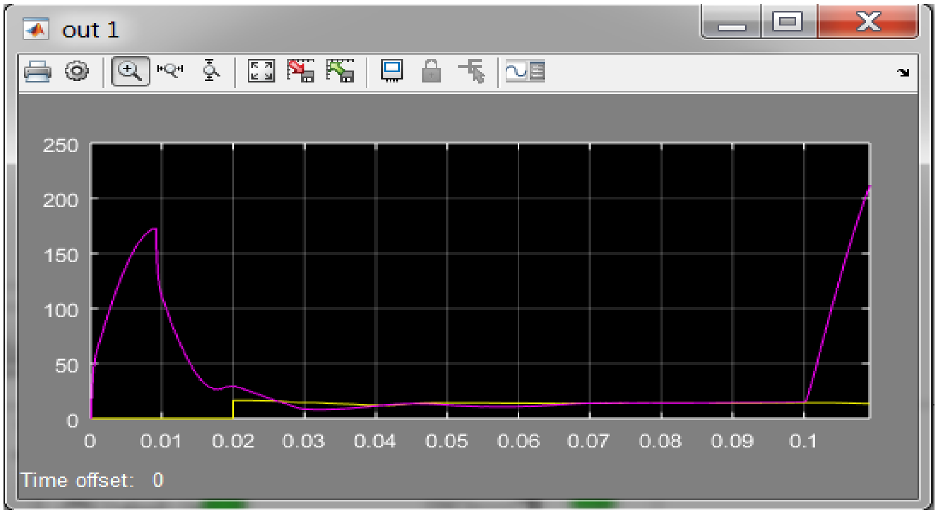

Fig.15: Voltage Regulation.

Case (3) Effect of Anti-Islanding :

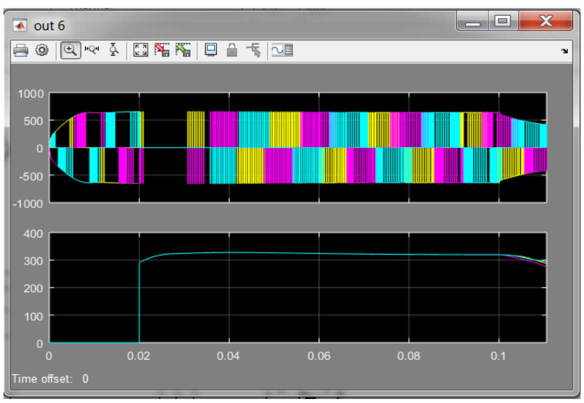

Fig.16A: LC filter based output Harmonic distortion and corresponding islanding detection time(0.02s)

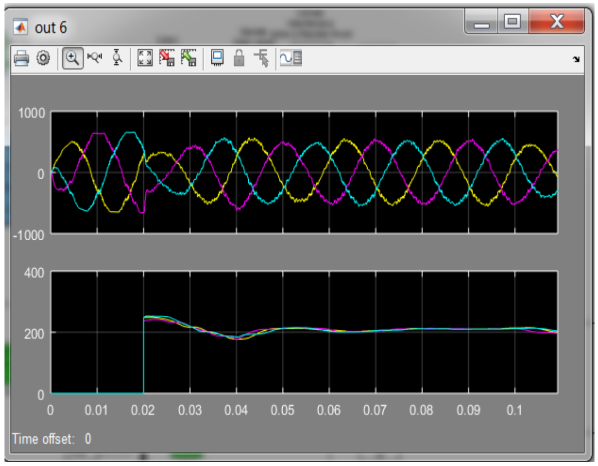

Fig.16.B: LC filter based power compensation and regulation.

Time analysis of islanding mode and Prevention mode

Steady state time islanding mode	t<0.02s
Transient time islanding mode	t>0.02s
Transient state time Prevention mode	t=0.05s (Power breaker OFF)
Steady state time Prevention mode	t=0.05-0.1s (Power breaker ONN)

IV. CONCLUSION

Anti-islanding of grid connected Photovoltaic system is simulated by using MATLAB/ Simulink platform. Islanding is achieved by opening the circuit-breaker at a particular instant. In this work passive islanding detection schemes OUVand OUF relays are equipped with Photovoltaic inverter.Voltage Source Converter(VSC) andLC filter across the output of inverter analyze the result.It is found to be an effective tool in monitoring and analyzing power system disturbance to ensure that control system is reliable including power quality assessment and system protection against fault. LC filter is able to reduce the Total Harmonic Distortion of the output waveform appreciably than the normal combination of controllers. Also loop controlling technique is used in which PI-controller in both the input and output control loops of inverter gives utmost stability. The islanding detection time is 0.02sit means that inverter disconnect from the network grid within 0.02 seconds of a power failure which isstipulated by IEEE 1547-2003 standard.

V. REFERENCE

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