Boost Converter fed PV Interfaced AC Distribution System Incorporating Islanding Detection Technique

Indu M[1] Soumya A V[2]
[1]P.G. Student [2]Assistant Professor
[1,2]Department of Electrical & Electronic Engineering
[1,2]Mar Baselios College of Engineering and Technology, Trivandrum

Abstract— The increased penetration of inverter connected Distributed Generation (DG) in the utility systems demands an appropriate level of monitoring and detection mainly under islanding conditions. This paper proposes a photovoltaic (PV) system interfaced with AC distribution system incorporating islanding detection technique. The maximum power of the PV system is tracked using Maximum Power Point Tracking(MPPT) technique called Beta MPPT technique. The MPPT is achieved by varying the duty cycle of the boost converter. A three phase grid-tie inverter is used for interfacing with the grid. Under unscheduled islanding operation, the photovoltaic source will continue supplying power which causes potential risk to the line workers and user equipments. This necessitates the enforcement of a rapid and accurate islanding detection method. Inorder to detect the moment of islanding, a passive anti-islanding technique is proposed here. The feasibility of the system were verified in MATLAB/Simulink.

Key words: Islanding, Beta-Maximum Power Point Traking (MPPT), Boost converter, Inverter, Distributed generation(DG), Photovoltaic system(PV)

I. INTRODUCTION

The intensification of global environmental pollution due to industrialisation, fast growing population etc and the depletion of conventional energy sources have lead to the rapid increase in the penetration rate of distributed generation (DG). Among the renewable energy sources photovoltaic and wind energy are receiving wide attention. Recently, Photovoltaics (PVs) are commonly used as renewable source due to its ease of installation and static operation. Inorder to achieve maximum power from the PV system MPPT techniques are used. Some of the commonly used MPPT techniques are Perturb and Observe, Hill climbing , Incremental conductance etc.Various DC-DC converters can be used for interfacing PV array and inverter. The MPPT is achieved by varying the duty cycle of the DC-DC converter. DC-AC converters are used to feed the power to grid.

The major issue faced in interfacing a DG with the utility is islanding condition. Islanding is a condition in which a portion of the utility system that contains both load and distributed resources remains energized while isolated from the remainder of utility system [1]. Islanding can occur due to power quality issues, equipment damages and interference with grid protection devices. This condition can be dangerous to utility workers, who may not realise that the circuit is still energized. Therefore islanding protection is a major concern in DG applications.

In this paper, a PV interfaced AC distribution system incorporating islanding detection technique. Fig.1 shows a block diagram of the PV interfaced AC distribution system. The suggested system consists of Photovoltaic with Beta MPPT, Boost converter, Inverter and islanding protection circuit. Simulations are carried out by MATLAB Simulink software.

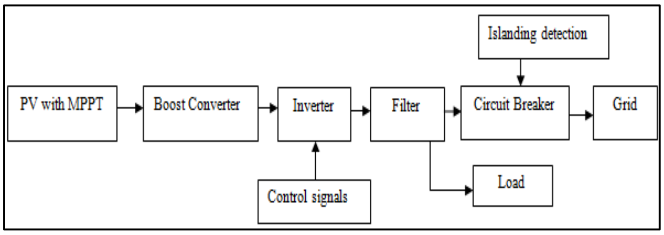

Fig. 1: Block Diagram of DG interfaced Grid system

II. MODELLING OF PV WITH MPPT

A solar cell is fundamentally a p-n junction fabricated in a thin wafer of semiconductor. In this, solar energy is directly converted to electricity through photovoltaic effect. PV cells are grouped in larger units called PV modules which are arranged in parallel and series configurations to form PV arrays. This arrangement helps in achieving various power ratings as per the load demands. Fig.2 shows single diode model of PV cell. It can be modelled as a current source with a diode in antiparallel. For an ideal solar cell, Series resistance (R_s) is zero and parallel resistance (R_p) is infinity.

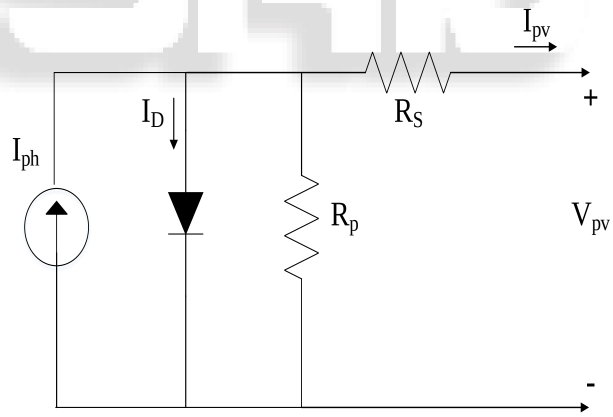

Fig. 2: Single diode equivalent circuit of PV cell

The output current of a PV module is given by

$$I = N_p I_{ph} - N_p I_o \left(exp\left[\frac{q(V/Ns + IRs/Np)}{AkT} \right] - 1 \right) - \frac{V + IR_s}{R_p} \quad (1.1) \quad (1)$$

where, I is the current, V is the voltage of the PV module, I_{ph} is the photo-current, I_0 is the reverse saturation current, N_p is the number of cells connected in parallel, N_s is the number ofcells connected in series, q is the charge of an electron (1.6*10^{-19}C), k is Boltzmann's constant (1.38*10-23J/K), A is p-n junction ideality factor and T is the PV module temperature.

For a solar cell, the only generated current is by means of a photo current, is given by

$$I_{ph} = [I_{sc} + k_1(T - T_{ref})]G \quad (1.2)$$

where Isc is the short circuit current of the PV cell, K_1 is the short-circuit current/temperature coefficient, T is the present atmospheric temperature and Tref is the temperature at nominal condition (25°C and 1000W/m^2), G is the present irradiance level [2].

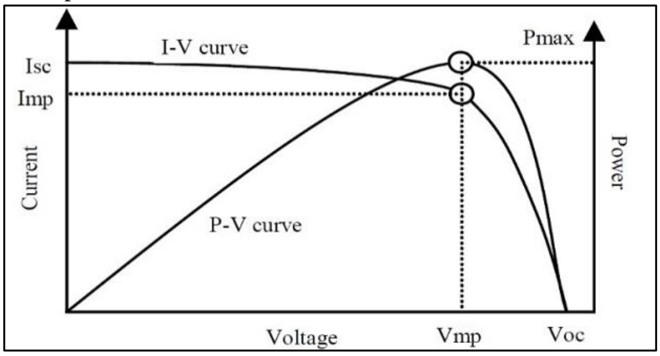

Fig. 3: I-V and PV characteristics of solar cell

The PV module parameters are shown in Table 1 [3]. From the open circuit voltage and short circuit current, the PV module of required power rating is modelled.

Electrical Parameters	Value
Open Circuit voltage	146 V
Short Circuit current	1.261 A
Voltage at MPP	118 V
Current at MPP	0.935 A
Maximum Power	110 W

Table 1: PV Module Parameters

A. *MPPT Technique*

For tracking the maximum power from PV modules MPPT techniques are used. Fig.3 shows the I-V and P-V characteristics of solar cell [4]. Among the existing MPPT techniques, Beta method is selected for achieving the maximum power from the module. Here an intermediate variable β is approximated through an equation to find the maximum power point.

$$\beta = ln\left(\frac{I_{pv}}{V_{pv}}\right) - c * V_{pv} \qquad (1.3)$$

$$c = \left(\frac{q}{(\eta K T N_s)}\right) \qquad (1.4)$$

Here c is a constant which depends on electron charge(q), Temperature(T), Number of series cells(N_s), Boltzmann constant(K) and panel quality factor(η).

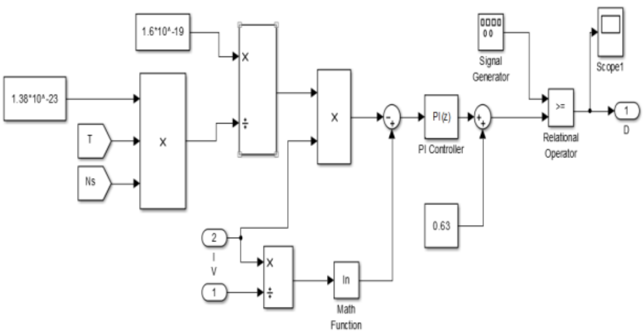

Fig. 4: Simulink model of MPPT

Eventhough the operation conditions changes, the value of β at optimum point remains almost constant. By using voltage and current of the panel the value of β can be continously calculated and then it is inserted on a conventional closed loop with a constant reference. The value of β remains within a narrow band as the array operating point approaches the MPP. Therefore by tracking β , the operating point can be quickly met by large iterative steps. Fig.4 shows the simulink model of MPPT technique.

III. BOOST CONVERTER

A boost converter is a DC-DC converter which steps up voltage from its input to its output. MOSFET and IGBT are used for switching purpose. To reduce voltage ripple, filters made of capacitors are normally added to the converter output. Fig.5 shows the schematic diagram of boost converter with MOSFET as switch.

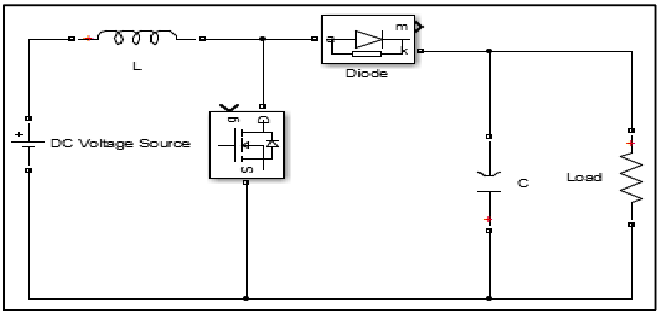

Fig. 5: Schematic diagram of boost converter

A DC-DC Converter in a MPPT system regulates the PV maximum power point and provides load matching for maximum power transfer to occur.The boost converter match the change in source impedance due to varying atmospheric conditions by changing the duty ratio.

The design equation is given by,

$$V_0 = \frac{V_{in}}{(1-D)} \qquad (1.5)$$

$$L = \frac{D(1-D)R}{2f} \qquad (1.6)$$

$$C = \frac{D}{2fR} \qquad (1.7)$$

IV. GRID -TIE PV INVERTER

A. *PV Inverter is the interface between the PV*

array and utility grid. The inverter controls the grid current by means of PWM control. Three major functions are done by grid-tie inverter. The first function is to track the maximum dc power that can be achieved by the PV array. Second is to convert source DC power to AC and to inject it into the grid in a synchronized way with less distortion. Last is to detect a fault in the utility side [5].

V. ANTI-ISLANDING METHOD

UL1741[6] or IEEE1547[7] are the standards to test the anti-islanding method. The islanding condition is detected by monitoring parameters such as voltage imbalance and total harmonic distortion in addition to the conventional parameters [8]. The voltage imbalance varies due to the topology of the network and loads connected in the DG after the loss of mains.

The islanding operation can be found by monitoring the voltage variations in the three phase output voltage of DG . The voltage unbalance at the monitoring time (t) is given by

$$VU_t = \frac{NS_t}{PS_t} * 100 \qquad (1.8)$$

where NS_t and PS_t are the magnitude of negative and positive sequence voltage at time t respectively. This value is compared with standard IEEE threshold value of voltage unbalance and if the VU_t is greater than the standard value then there is a possibility that islanding has occurred. Then the second parameter is monitored to confirm the islanding operation i.e the total harmonic distortion(THD). The THD at monitoring time t is given as

$$THD_t = \frac{\sqrt{\sum_{h=2}^{H} I_h^2}}{I_1} * 100 \qquad (1.9)$$

where I_h is the rms of harmonic components of h and I_1 is the fundamental harmonic component. This value is compared with the standard IEEE and if any violation is monitored then the event of islanding is confirmed and a trip signal is produced for protection[8]. Fig. 6 shows the flowchart of VU and THD method[9].

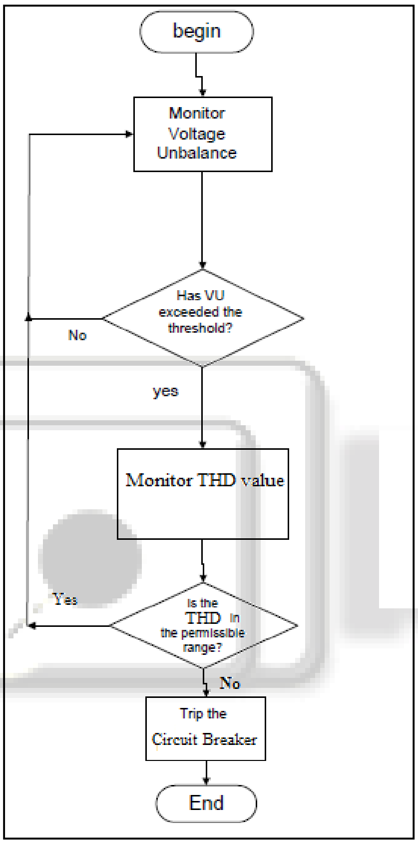

Fig. 6: Flowchart of VU and THD method

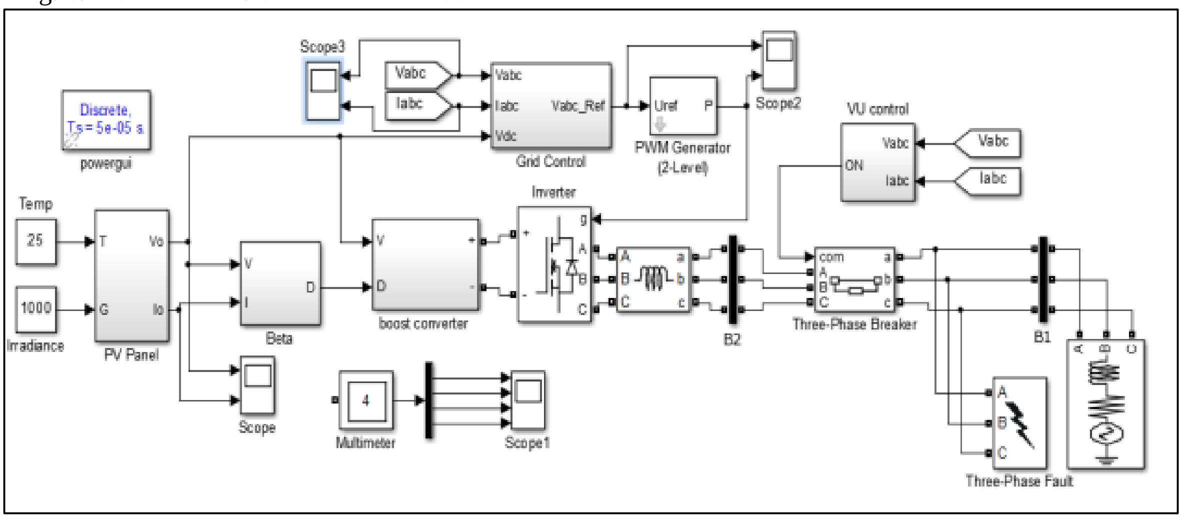

Fig. 7: Simulation model of entire system

VI. SIMULATION RESULTS

Simulation of proposed System is done in MATLAB/Simulink. Fig.7 shows the simulink model of the proposed inverter interfaced DG system with anti-islanding protection. The PV system is modelled to get the rated power. The MPPT controller provides the pulses for the boost converter to obtain the maximum power. The boost converter is connected to a three phase inverter to convert the DC to AC and to synchronize with the grid. The circuit breaker on the utility side is switched open when an islanding condition is detected. A three phase fault is given for a short duration of time from 0.75 s to 1 s during which the islanding condition is detected by voltage unbalance and THD method after which the system regains the normal operation.The pulses to the switch of boost converter is given in Fig 8. The output voltage waveform of boost converter is given in Fig.9. The output waveform of voltage unbalance is shown in Fig 10 and the output waveform of THD method in Fig.11. The final output pulse to activate the circuit breaker in case of islanding is given in Fig 12. The output voltage and current waveforms are analysed in Fig 13 and 14 respectively.

The simulation parameters are P_{in} =110W, L= 1 mH, C= 10μH , f = 50 Hz

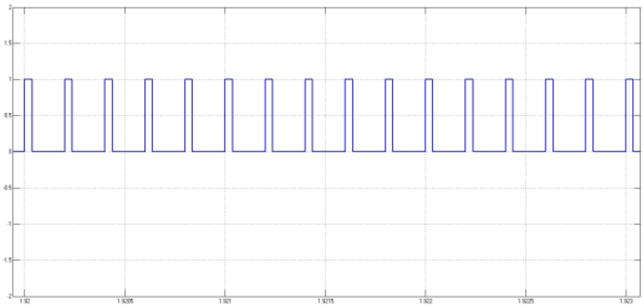

Fig. 8: Pulses to the switch of boost converter (x axis: 0.05 ms/div, y axis: 0.5V/div)

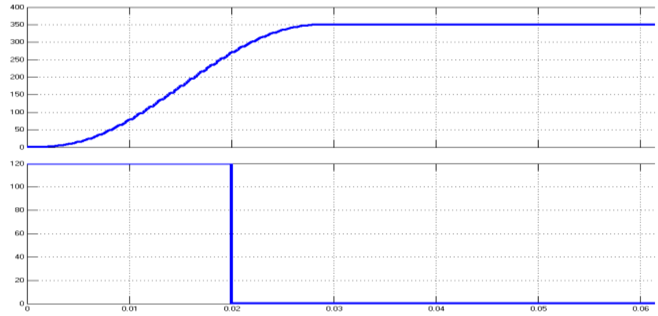

Fig. 9: Output voltage waveform of boost converter with (x axis: 0.01s/div, y axis: 50V/div)

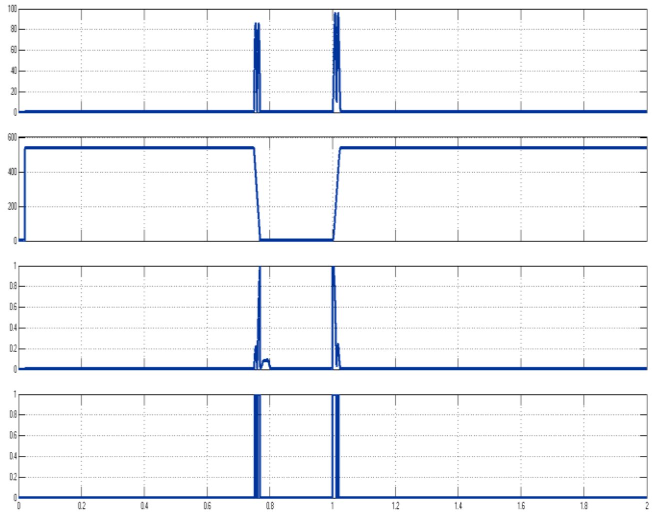

Fig. 10: The Output waveform of Voltage Unbalance (x axis: 0.2s/div)

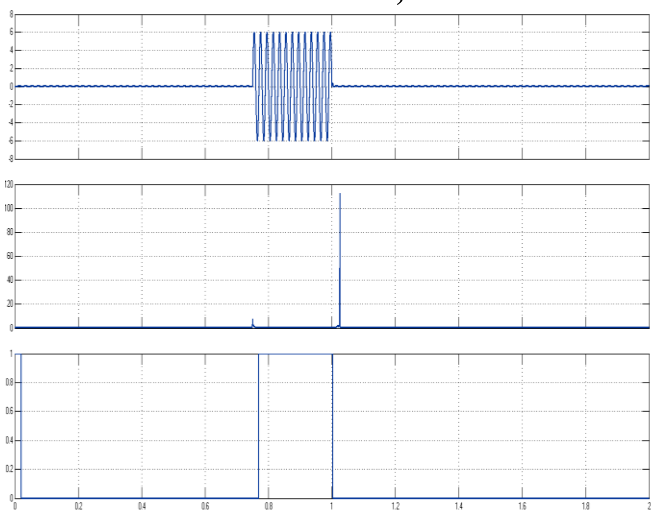

Fig. 11: The Output waveform of THD method (x axis: 0.2s/div)

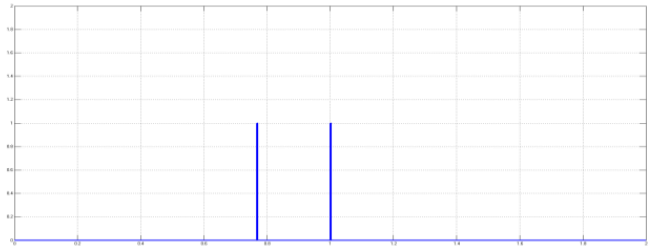

Fig. 12: Final output pulse to initiate circuit breaker (x axis: 0.2s/div, y axis: 0.5V/div)

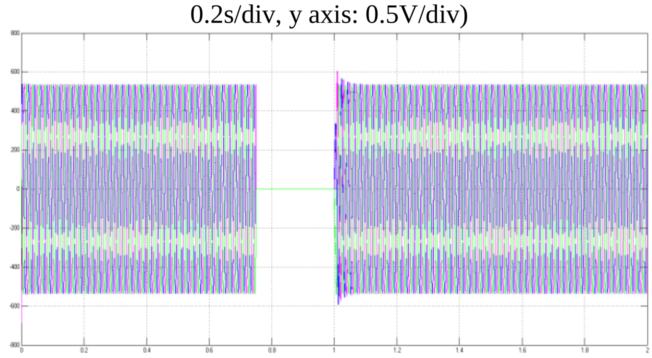

Fig. 13: Output voltage waveform (x axis: 0.2 s/div, y axis: 200V/div)

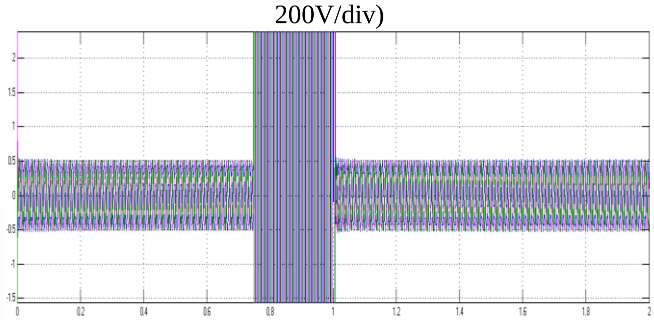

Fig. 14: Output current waveform(x axis: 0.2 s/div, y axis: 0.5A/div)

VII. Conclusion

In this paper, a passive anti-islanding technique for a PV interfaced AC distribution system is presented. The parameters such as voltage unbalance and total harmonic distortion inaddition to the conventional parameters were used for anti-islanding detection. This method merges the advantages of both voltage unbalance and total harmonic distortion technique. The proposed method monitors the time domain change in voltage and THD and detects islanding when there is a deviation from the standard threshold value. This technique was modelled on a grid-connected PV system representing a typical DG source. Simulation was done in MATLAB/ Simulink and the results are verified.

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