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Performance And Analysis Of Z-Source Inverter Based Grid Connected Solar Power System

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Abstract

Photovoltaic energy is a renewable energy with high potential, easy installation, simple maintenance, reliability and long lifetime. Photovoltaic system output is non-linear and is affected by weather conditions, so maximum Power Point Tracker (MPPT) was implemented to draw out the maximum power from solar energy. In edict to increase the efficiency of stand-alone photovoltaic (PV) system, it is most important an efficient Maximum Power Point Tracker (MPPT) is required. A comparative work is held out for the performances of solar powered Z source inverter with Perturb & Observe (P&O) and Incremental Conductance (INC) algorithms and found the strength of the MPPT algorithms in this theme. To test the strength and performance of ZSI is evaluated using MATLAB/Simulink software.

Keywords: Incremental Conductance, PI Controller, Perturb & Observe, SPWM, Z-source inverter.

INTRODUCTION

The origin of PV energy conversion technology goes back in 1839, when becquerel first discovered the PV effect. PV energy conversion is the direct conversion of radioactive energy, in the form of sunlight, into electrical energy. In the past decades, there was a huge development in the field of renewable-energy sources. Photovoltaic system (PV) is unrivaled of the sources of high cost and low conversion efficiency have limited use such endless energy source. It is a clean energy technology and is expected to have a substantial donation to the world energy production towards the end of this country. PV systems have exceptional features that offer some added value as an arrangement of the output force of a PV system is nonlinear and it is moved by environmental conditions, such as irradiation and temperature.

So Maximum Power Point Tracking (MPPT) method was devised to describe out the maximum power from each PV array [1]. In fact, that the rise of PV as a formula to obtain electricity is one of the highest recorded in the area of renewable-energy. On the other hand, the cost and low conversion energy are considered to be a main obstacle in the use of this energy system. The process that extracts additional power from the PV array, under certain conditions by tracking is called max power point tracking (MMPT). Today, a large number of techniques are proposed for maximum power point tracking concept such as constant voltage tracking [2].

A DC-DC converter is typically needed to change its buck and boost operation in front of the VSI. However, the DC-DC converter makes this inverter costly and inefficient, and the two stage topologies also cause difficulties in control strategy. Recently, a Z-source inverter [3] which possesses both voltage-buck and boost capabilities in one single stage has been used in distributed generation (DG) systems. The ZSI can boost the DC voltage and converts a DC source to grid-compatible AC power.

In addition, it can greatly reduce the output distortion and improve the reliability since dead time is no longer needed and a short circuit across any phase leg is allowed. So, Z-source inverters have been built up in different directions [3-10]. Authors in [4] presented the Z-source inverters decrease voltage suppress of the condensers, and authors in [5-6] improve the potential boost in version's ability of the Z-source.

In this paper, a Z-source inverter topology is shown based on the singular feature of the Z-source. The feasibility of the proposed topology sinusoidal pulse width modulation strategy with the solar power conditioning system is examined in detail and verified by simulation.

MAXIMUM POWER POINT TRACKING (MPPT)

The PV modules have maximum operating points corresponding to the surrounding conditions such as the strength of the sun, the temperature of the PV modules, cell area, and load. When solar energy is utilized as a power source, the output power has to be maximized by improving the efficiency of the power conditioning equipment used and implementing an adaptive power controller that automatically traverses the system to the level of maximum power delivered from the solar panel under all conditions. The instantaneous current and voltage is sampled and multiplied to obtain the power [11].

The control objective is to track and extract maximum power from the PV arrays for a given solar insolation level. The maximum power corresponding to the optimum operating level is set for different solar insolation level. Fig.1 shows the typical current, voltage relationships of a PV panel as well as the comparable output power shown in Fig.2.

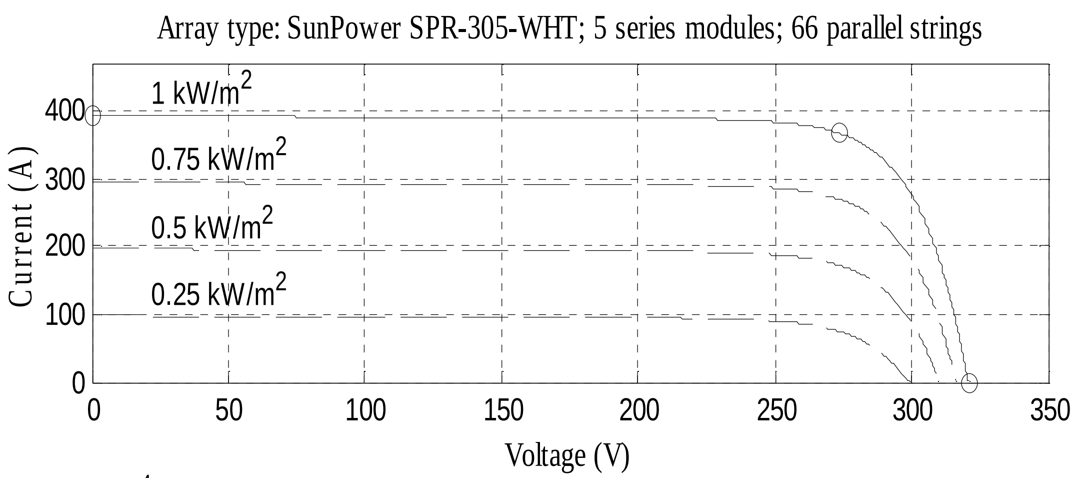

Fig. 1. V-I characteristics for four different irradiation levels

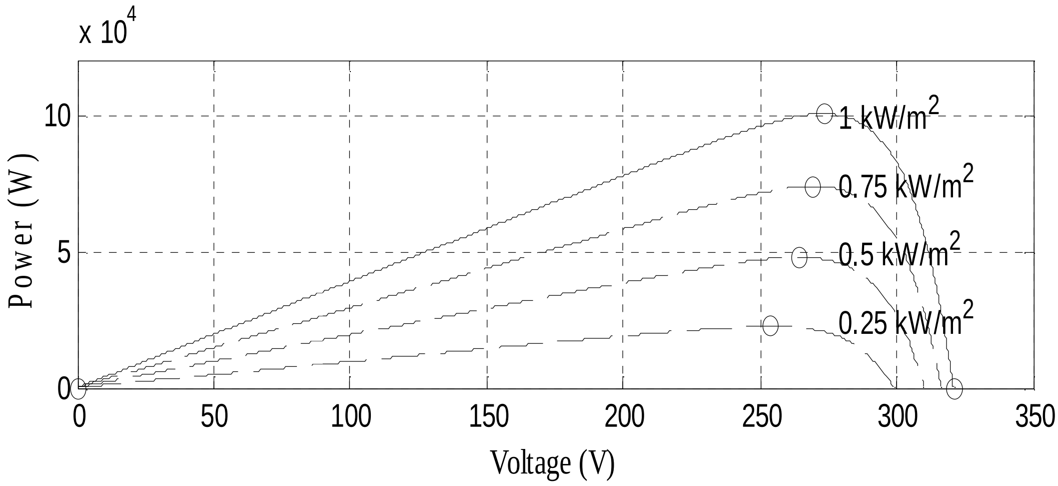

Fig. 2. P-V Characteristics for four different irradiation levels

Normally a DC-DC converter is applied between the input source and the load for the purpose of MPPT. The stage of solar irradiance, inspection of the PV array characteristic reveals that the period of maximum force is approximately achieved with an output voltage V_{mp} which is proportional to the open-circuit voltage V_{oc} of the PV array. Thus, sensing of the open-circuit voltage in a single PV cell kept in the same environment as the force-producing cells provide information along the actual solar radiation and calculates a reference value V_{PV} ref for the input voltage of the PV array converter for MPPT of PV system. The operating voltage of the power producing array is then set to the required values, which equate to maximum power [12].

PROPOSED SYSTEM DESCRIPTION

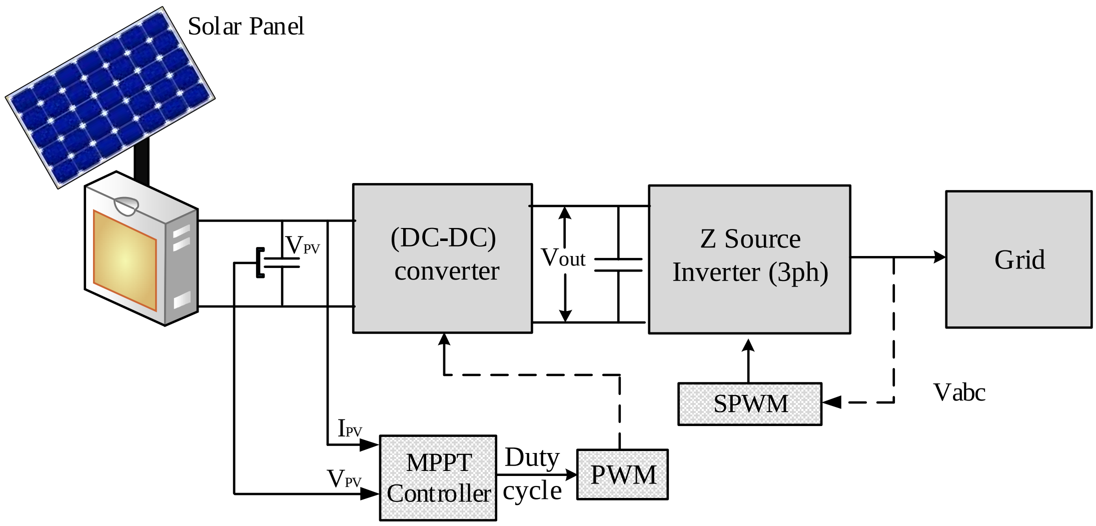

Fig.3. Block diagram representation of Grid connected solar power system

The Fig.3 shows the block diagram representation of Grid connected solar power scheme. The asset of the PV system is accompanied with the total operating efficiency of the system demarcated in the equations as follows [13].

$$\eta_{Total} = \eta_{PV} \cdot \eta_{MPPT} \cdot \eta_{Inverter} \quad (1)$$

$$= \frac{P_{PV}[W]}{G\left[\frac{W}{m^2}\right].A\left[m^2\right]} \cdot \frac{P_{MPPT}[W]}{P_{PV}[W]} \cdot \frac{P_{OUT}[W]}{P_{MPPT}[W]} \quad (2)$$

Where

η_{Total} -Total efficiency of the PV system

η_{MPPT} -Efficiency of the MPPT algorithm

$\eta_{Inverter}$ -Efficiency of the PV inverter

η_{PV} -Efficiency of the PV array

P_{PV} -Maximum power from the PV array

P_{MPPT} -PV power tracked by MPPT

P_{OUT} -Output power to the utility grid

G -The solar irradiance

A -The PV array area.

Fig.3 consists of three divisions such as, DC source, Z-source inverter and grid. A DC power source (solar panel) connected in series with the DC-DC converter. The converter (DC/DC) which regulates the output voltage of the solar panel and helps to attain the maximum power using two different algorithms such as Perturb & Observe and Incremental Conductance algorithms. PWM Z-source Source Inverter (DC-AC) shall enable to convert solar power to the utility grid.

Z SOURCE INVERTER (ZSI)

Fig.4 shows the schematic of a Z-source network, it has a DC source, Z impedance with the switch 'S' and diode 'D'. As shown, the Z source network is made of an X shape LC structure that can boost or buck the DC input voltage depending upon the interval of shoot-through zero state during a switching cycle [14-17].

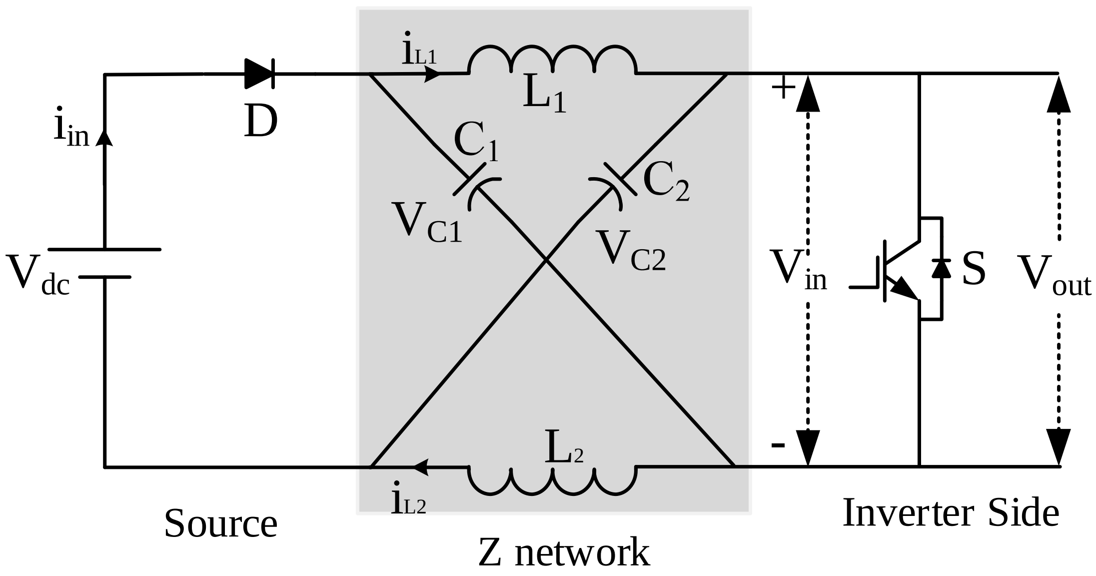

Fig.4: Schematic representation of a Z-source network

During the shoot-through mode, switch 'S' is ON and diode 'D' is OFF, in non-shoot through mode, switch 'S' is OFF and the diode 'D' is ON vice versa. The circuit of shoot-through mode is shown in Table. 1,

$$V_L = V_C \tag{3}$$

$$V_{in} = 0 \tag{4}$$

The circuit of a non-shoot through mode the output of LC network can be [16-17],

$$V_L = V_{dc} - V_C \tag{5}$$

$$V_{in} = V_C - V_L \tag{6}$$

$$V_{in} = 2V_C - V_{dc} \tag{7}$$

Let, the average voltage of the inductor is zero, so the relationship between capacitor and output voltage is found at [3],

$$\frac{V_C}{V_{in}} = \frac{T_{ns}}{T_{ns} - T_{sh}} \tag{8}$$

Where, T_{sh} is the total period of shoot-through mode and T_{ns} is the total period of non-shoot through mode

By substituting equation (8) in (7), then,

$$V_{in} = \left(\frac{1}{1 - 2\left(\frac{T_{sh}}{T} \right)} \right) V_{dc} \tag{9}$$

$$B = \frac{1}{1 - 2\left(\frac{T_{sh}}{T} \right)} \tag{10}$$

Where T is the switching period and B is boost factor.

Table.1. Switching states of Z-source network

Mode of operation	**State**
Shoot-through mode	‘S’ ON, ‘D’ OFF
Non shoot-through mode	‘S’ OFF, ‘D’ ON

All the mentioned explanations and analysis of the Z source system is focused around presumption that the inductance of the inductor in the impedance system is sufficiently incredible to keep up the inductor current very nearly consistent. While, when the inductance is little and inductor current ripple is high or broken these suppositions are not fulfilled [16].

PERTURBATION AND OBSERVATION METHOD (P&O)

The P & O method is widely used in MPPT, because it has a fewer measured parameters. It can track the maximum power point quite accurately through variations in radiation and temperature. It operates by perturbing the system by increasing or decreasing the panel operating voltage and observing the impact of this change in the panel output power.

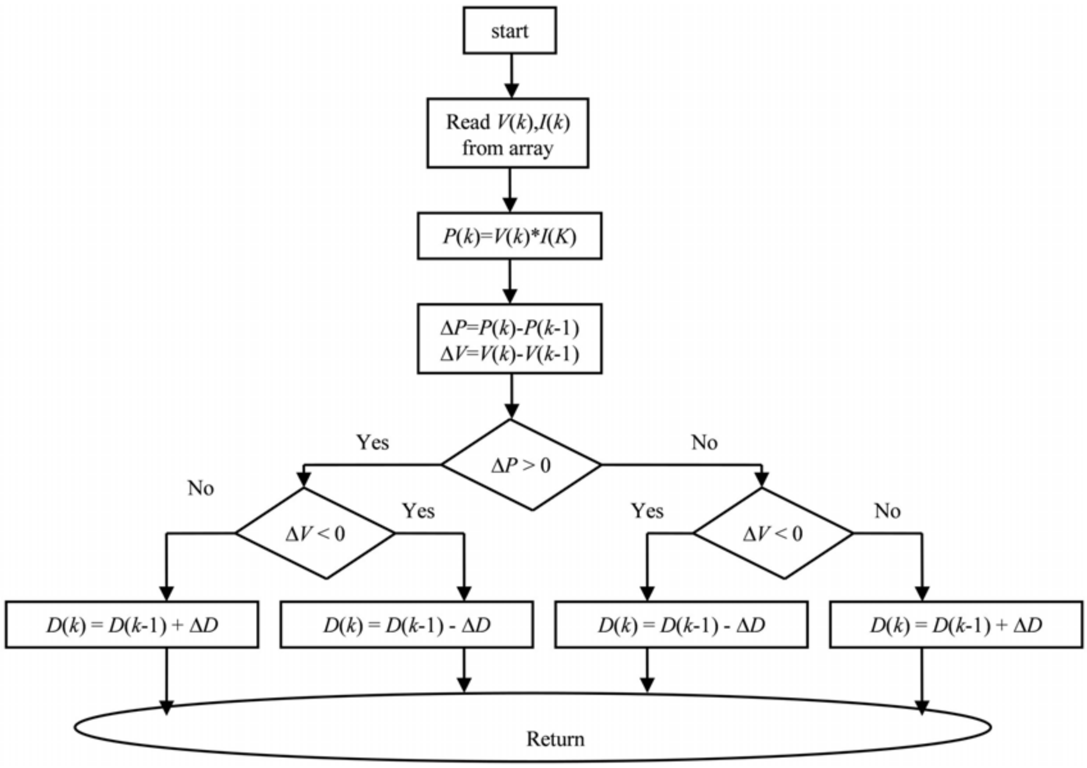

Fig.5: Flow chart of Perturb & Observe Algorithm

Fig.5 shows a flow chart of the P&O algorithm. If the output power had decreased, panel voltage is perturbed in the opposite direction as in the previous cycle. When the maximum power point (MPP) is reached, the output voltage will oscillate around the maximum operating voltage [19-20].

INCREMENTAL CONDUCTANCE ALGORITHM

The Incremental conductance algorithm is an advanced version of P&O algorithm. The Incremental Conductance (IC) method had taken in order to overcome the drawbacks of the PO algorithm when subjected to fast changing environmental conditions. With the help of voltage and current measurements, the conductance I/V and incremental conductance dI/dV are determined so that the decision can be made to increase or decrease the operating voltage according to the operating point on the left or the right of the MPP respectively.

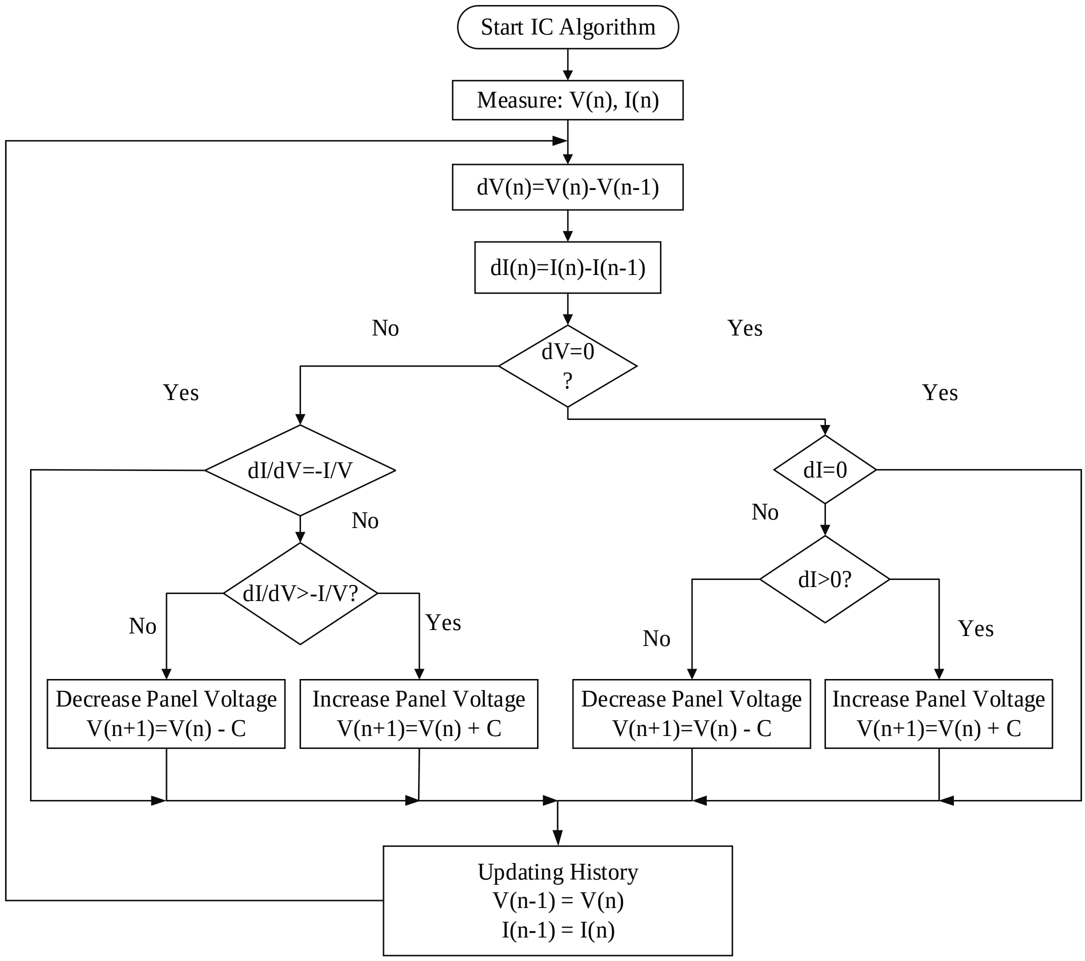

Fig.6: Flow chart of Incremental Conductance Algorithm

Operating principle

The operating principle of the IC method relies on the fact that the gradient of the PV panel power curve is negative on the right of the MPP, zero at the MPP and positive on the left of the MPP as follows:

$$\frac{dP}{dV} > 0 \text{ left of MPP } (V<V_{MPP})$$

$$\frac{dP}{dV} = 0 \text{ at MPP } (V=V_{MPP})$$

$$\frac{dP}{dV} < 0 \text{ right of MPP } (V > V_{MPP}) \tag{11}$$

Since P=VI, the gradient of power curve at MPP as follows,

$$\frac{dP}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV} = 0 \tag{12}$$

Equation 9, can be written as,

$$\frac{dI}{dV} < -\frac{I}{V} \text{ right of MPP}$$

$$\frac{dI}{dV} = -\frac{I}{V} \text{ at MPP} \tag{13}$$

$$\frac{dI}{dV} > -\frac{I}{V} \text{ left of MPP}$$

According to equation 13, the incremental conductance (IC) algorithm provides enough data to locate the MPP. This is made possible by the respective measurement and comparison of, dI/dV and I/V. VMPP is the set point reference voltage corresponding to the MPP at which the PV module is required to operate. The detailed operating principle of the IC algorithm can be seen by the accompanying flow chart [21-22].

According to the IC algorithm given in Fig.6, the current and voltage are to be measured, then a test is conducted to assess on one side if the difference in voltage and current is equal to zero respectively, and on the other side if the variation of voltage is equal to zero and the balancing condition dI/dV + I/V= 0 at MPP is obtained. If so, no changes take place in the operation's process. If not, the IC method acts to increase or decrease the voltage according to the difference in the current or the condition dI/dV + I/V is superior or inferior to zero respectively.

SIMULATION RESULTS OF ZSI BASED GRID CONNECTED PV SYSTEM

Closed loop analysis of a grid connected solar powered Z Source Inverter and their performances have been carried out with P&O and Incremental Conductance algorithms using MATLAB/Simulink software. In this control strategy a PI controller is implemented to generate the PWM signal for three phase inverter in association with sinusoidal pulse width modulation (SPWM) technique. The inverter output voltage monitored and controlled by this technique. The SPWM Simulink control diagram as shown in Fig. 7.

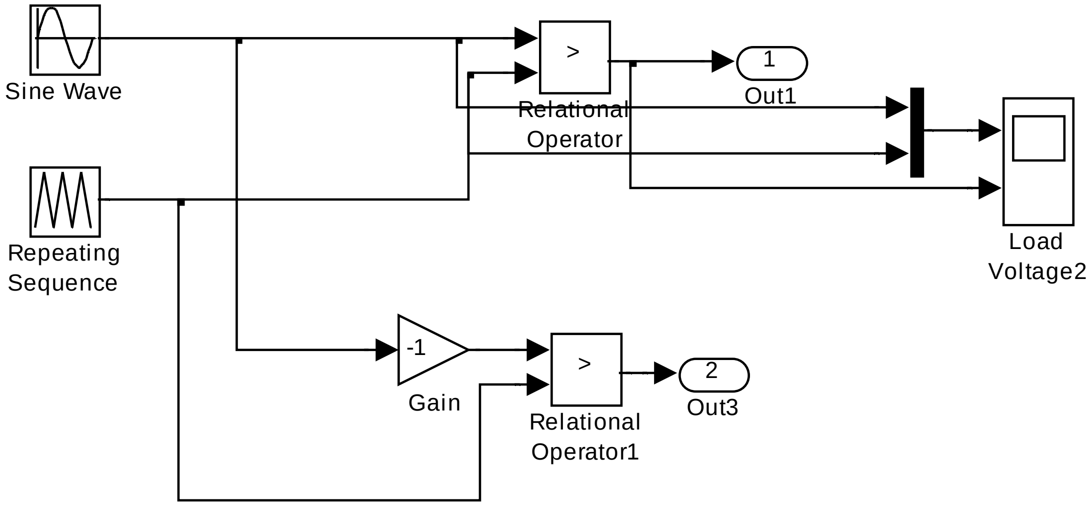

Fig.7: Sinusoidal pulse width modulation for proposed system

Figs.8-13 shows the simulated responses of the proposed z-source inverter based grid connected solar power system using P&O and INC MPPT algorithms. Fig.8 represents the voltage generated by the solar panel and after boosted with a DC-DC converter. It shows nearly 500V boosted using this proposed structure. Fig.9 shows the solar panel voltage, temperature and irradiance responses of with the corresponding duty cycle of P&O and INC MPPT algorithms.

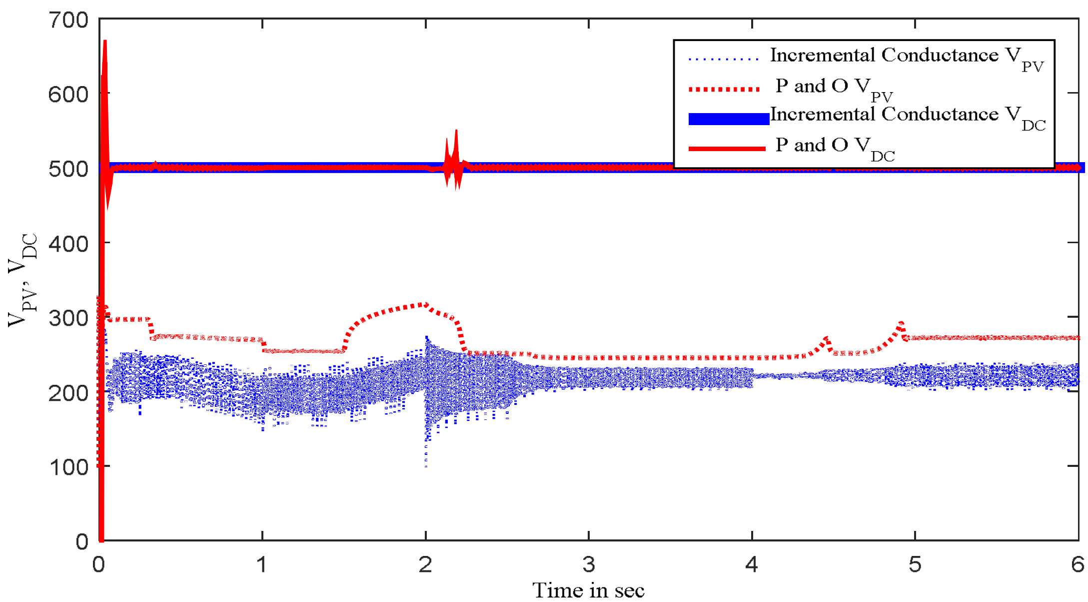

Fig.8: Output voltage generated by solar panel and DC/DC converter

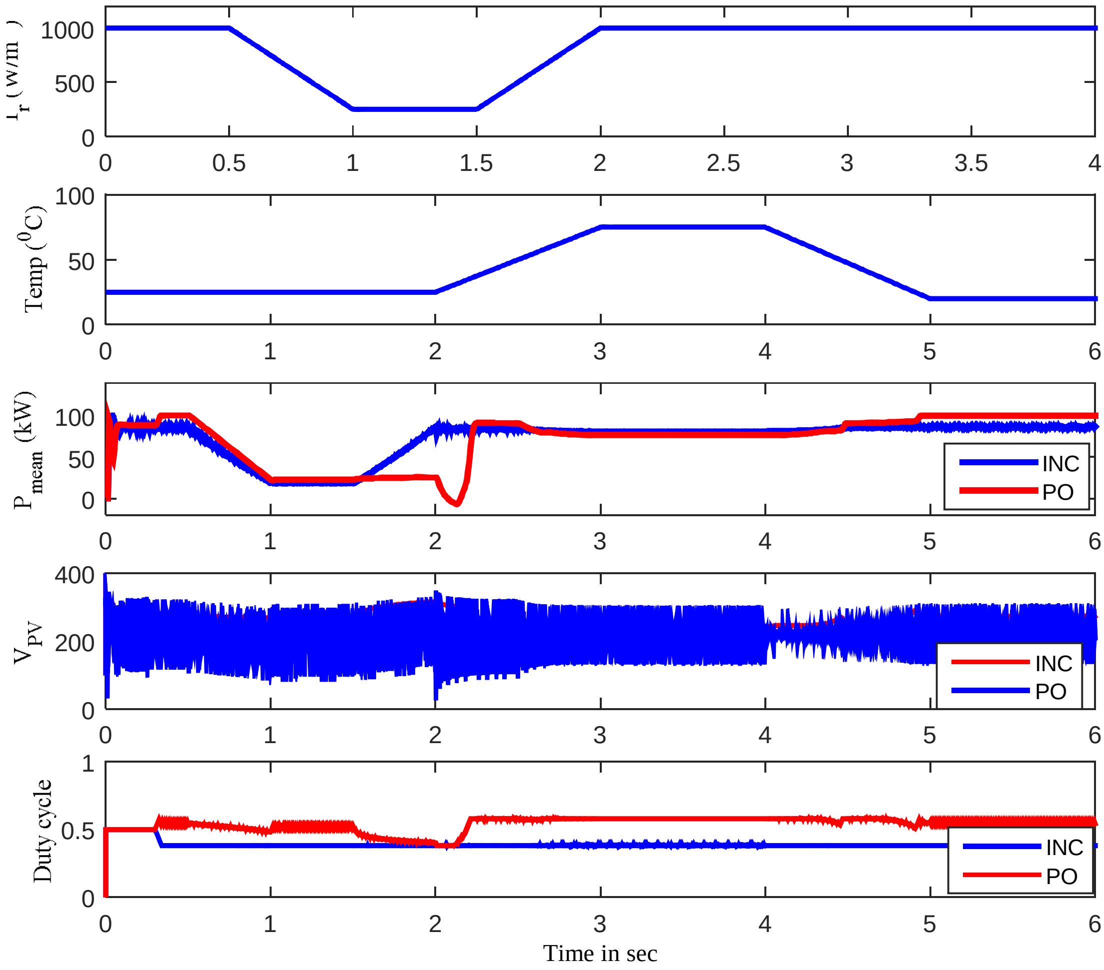

Fig.9: Solar panel voltage and temperature responses with duty cycle

Fig.10 shows the output voltage of the proposed system with P&O and INC algorithms. From the analysis,both the MPPT algorithms are produced nearly same output voltage with use of proposed Z-source inverter with proper switching. Similarly the current responses of the system as shown in Fig.11. Fig.12 shows the grid input voltage and current responses of P&O and INC algorithms of phase ‘a’. The system output power injected in to the grid is measured and displayed in Fig.13.

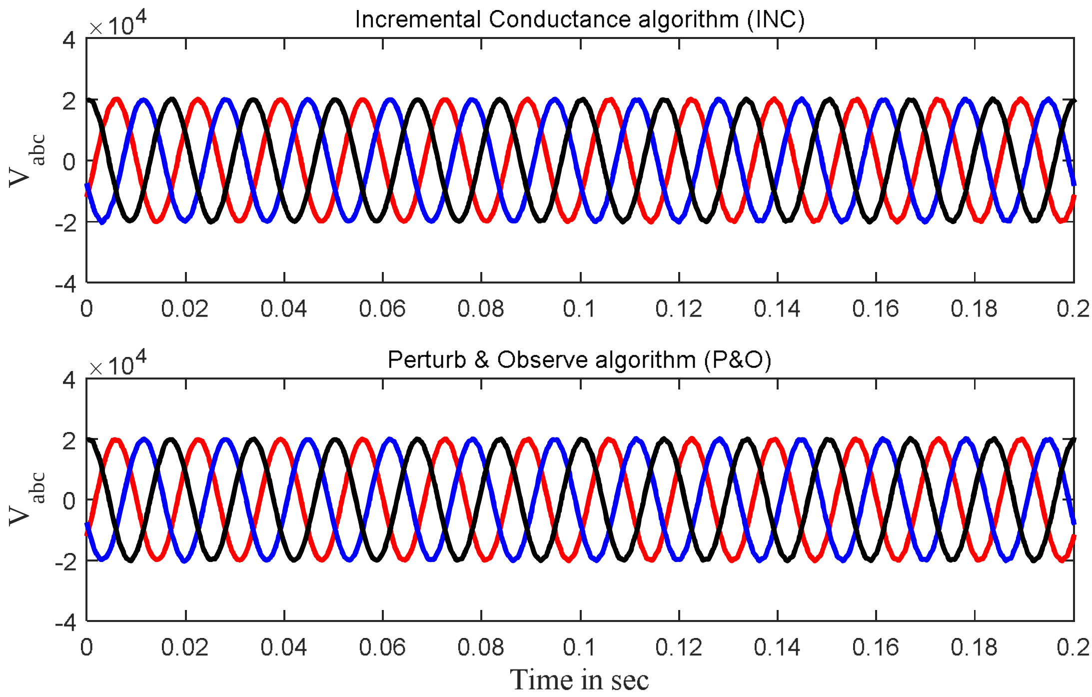

Fig.10: Output voltage injected to the grid using INC and P&O MPPT tracking

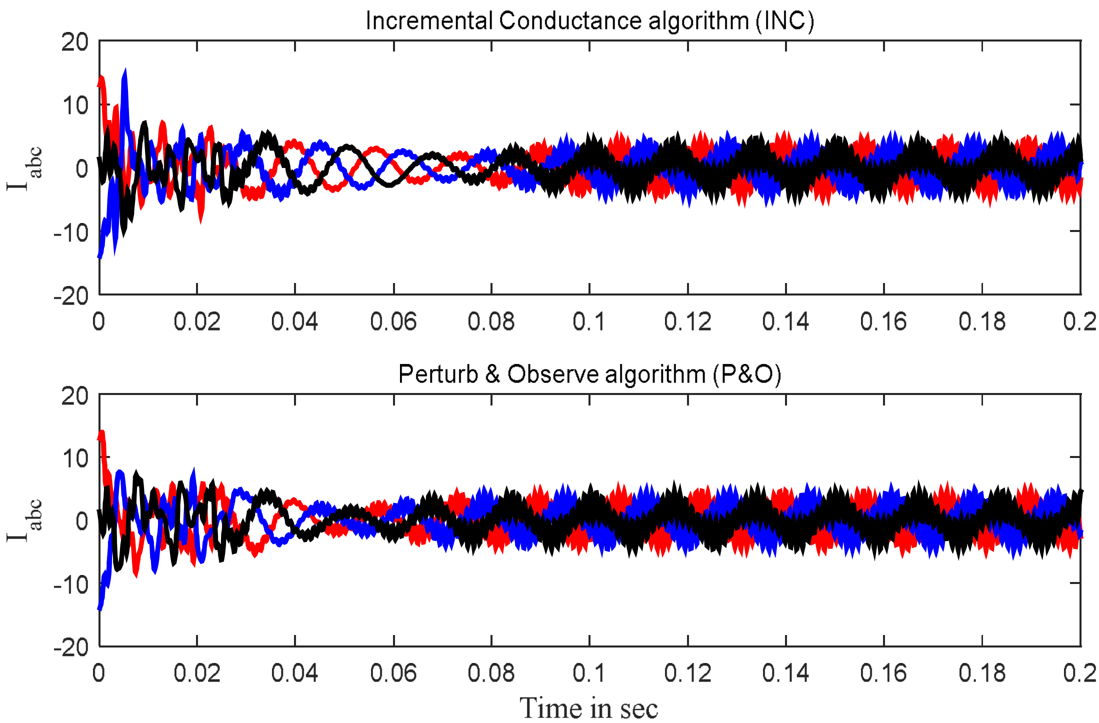

Fig.11: Output current using INC and P&O MPPT tracking

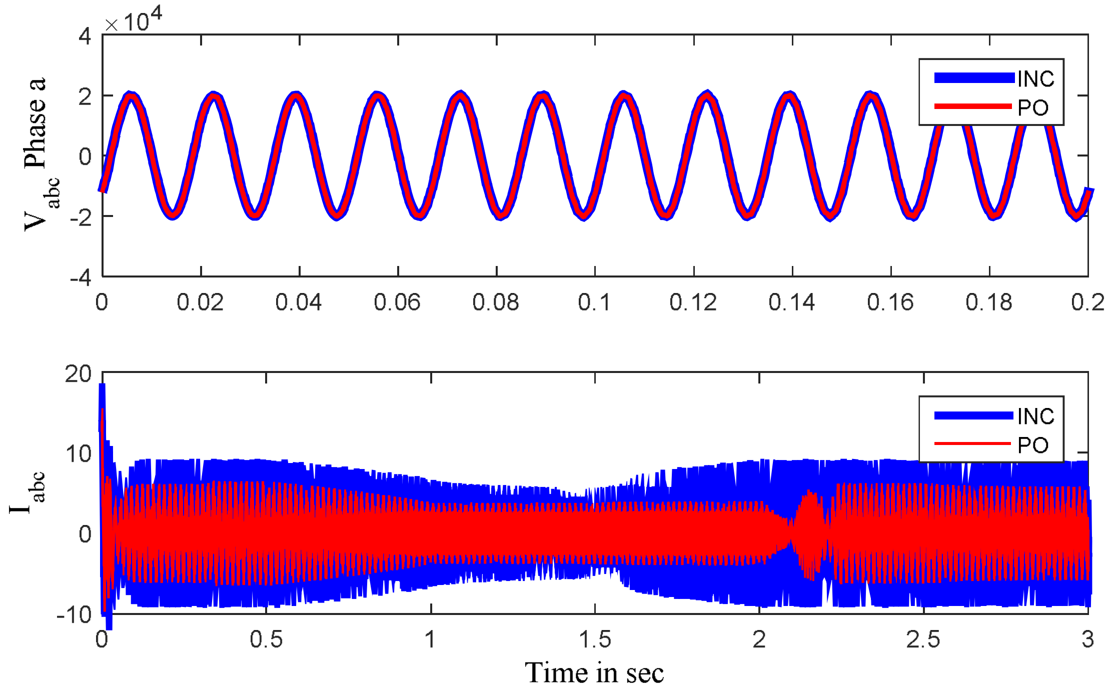

Fig.12: Output voltage and current using INC and P&O MPPT tracking for phase 'a'

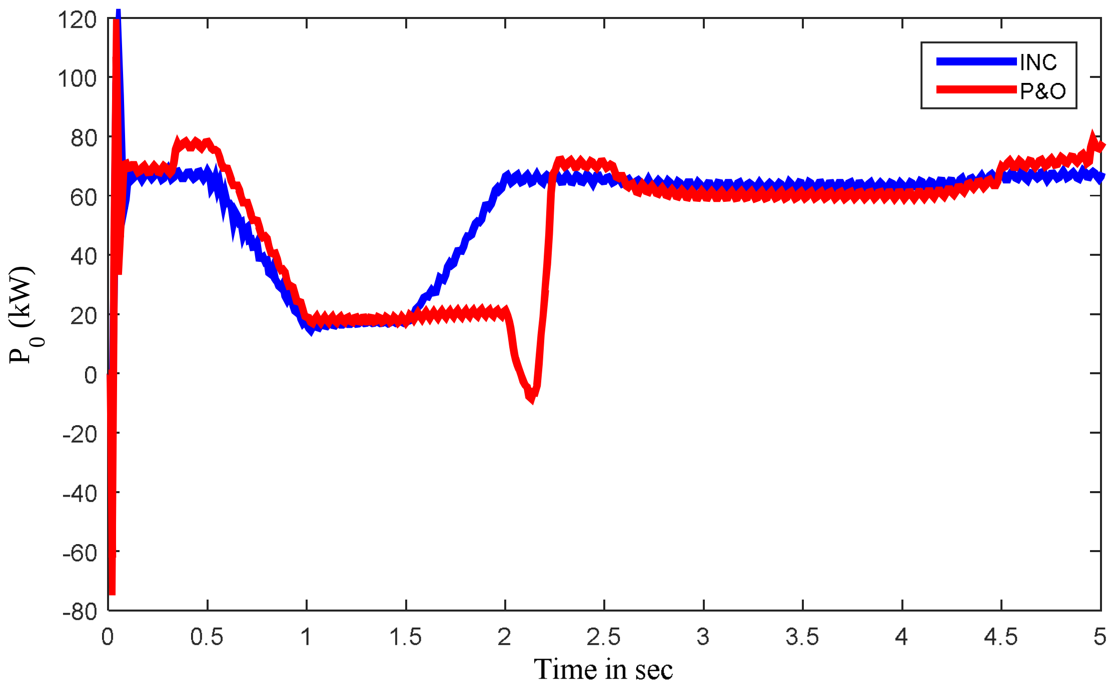

Fig.13: Output power generated by solar power system using INC and P&O algorithm

CONCLUSION

Formal single-phase inverter topologies cannot achieve a common background between the input and output, and then they cannot be applied in conditions where dual grounding is required. To resolve this problem, a Z-source inverter topology has been granted. The performance principle and sinusoidal pulse width modulation control strategy with PI controller are analyzed in detail and verified by simulation results. The effects of the grid connected solar power generation system compared with two different MPPT algorithms such as P&O and INC, and it is noticed that the responses Incremental Conductance algorithm (INC) is superior to P&O method. By changing the conventional Z-source inverter to modified Z-source inverter will get more power output from the PV system with different controllers.

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