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Enhancement of PV-MIC Performance by Controlling PV-Panel Temperature

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ABSTRACT: India has so far focused on thermal, gas, hydro and nuclear power. Now efforts should shift to solar, wind and biogas. Country has set an ambitious target of adding 175,000 Mega Watt (MW) of renewable energy by the year 2022, which includes 100,000 MW of solar power and 75,000 MW from other sources comprising of wind, mini-hydel and bio-gas based power plants. This thrust towards renewable energy product is all set to user in a new energy revolution in India.

The rising consumer demand and government incentives are motivating the quick growth of renewable energy generation. In mostly, the number of distributed photovoltaic (PV) system installations is increasing quickly. However, the high cost of the PV systems and safe operation of utility grid could become barriers to their future expansion. Large use of PV-system is necessary to bring down the PV system cost but it is not possible to reduce payback period. With installing large PV-Panel it gives appreciable output but it increase the cost of system as well as installation area. But it is not optimum solution of enhancing performance of renewable energy generation. For enhancing performance of renewable energy generation here a converter is selected for obtaining optimum performance and further increase in output power by maintain various environmental parameters of panel surface like temperature, dust & humidity. The PV panel temperature is brought down by force cooling technique. The appraisable & remarkable results are obtained such as increase in power output performance. Here simulation results with realistic results data are compared with aid of MATLAB/Simulink. Attempt has been taken by force cooling technique and observed 10% increase in power output & 0.4 % in specific generation as compared to regular system.

KEYWORDS: ZSI, Boost Factor, qZSI.

I.INTRODUCTION

There exist two conventional converters: voltage source and current-source converters Fig. 1shows the conventional single-phase voltage-source inverter structure. A dc voltage source supported by a relatively huge capacitor feeds the main converter circuit, to a bridge. The dc voltage source like battery or PV-Panel, resistive load stack, diode rectifier, and/or capacitor. Six switches are used in the main circuit; each is traditionally composed of a power transistor and an Anti parallel (or freewheeling) diode to provide bidirectional current flow and unidirectional voltage blocking capability. The V-source converter is widely used.

It, however, has the following conceptual and theoretical barriers and limitations. The ac output voltage is limited below and cannot exceed the dc-rail voltage or the dc-rail voltage has to be greater than the ac input voltage. Therefore, the V-source inverter is a buck (step-down) inverter for dc-to-ac power conversion. Fig.1.Shows the Single Phase VSI Supply to load.

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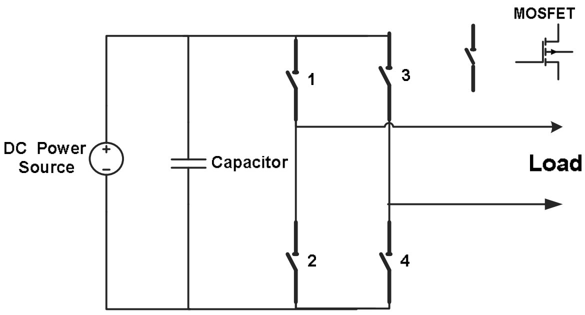

Fig.1. Single Phase VSI

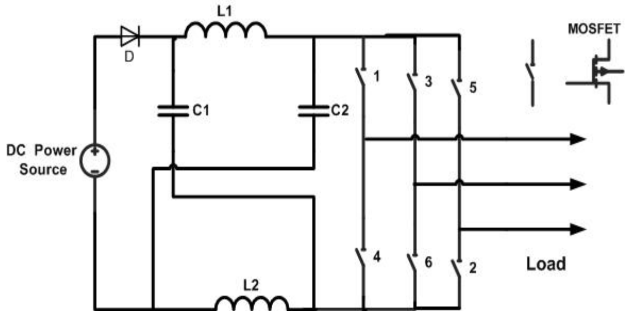

Fig .2. Z-source inverter

In Fig 2, a two-port network that consists of a split inductor L1and L2 and capacitors C1and C2 connected in X shape is employed to provide an impedance source (Z-source) blend the converter (or inverter) to the dc source, load, or another converter. The dc source can be either a voltage or a current source. Therefore, the dc source can be a battery, PV-Panel, converter, fuel cell, an inductor, a capacitor, or a combination of those. Switches used in the converter can be a combination of switching devices and diodes such as the anti-parallel combination as shown in the series combination figure. As examples, two three-phase Z-source inverter configurations. The inductance L1andL2 can be provided through a split inductor or two separate inductors.Table.1.gives comparison of ZSI, CSI & VSI.

Table.1. Comparison between VSI , CSI and ZSI

Z- Source Inverter	**Current Source Inverter**	**Voltage Source Inverter**
Used in only buck and boost operation of inverter.	Used in only buck or boost operation of inverter.	Used in only buck or boost operation of inverter.
In ZSI miss firing of the switches are also acceptable	Momentary short circuit on load and misfiring of switches are acceptable.	miss firing of the switches form more dangerous situation
Capacitor and Inductor is used in dc link, It acts as a High impedance voltage source.	Inductor is used in dc link, the source impedance is high, and It acts as a const, current source.	Capacitor is used in dc link; It acts as a low impedance voltage source.
Less affected by EMI noise.	Affected by EMI noise.	Affected by EMI noise.
It has low harmonics distortion.	Considerable amount of harmonics distortion.	Considerable amount of harmonics distortion.
Power loss should be low.	Power loss should be high	Power loss is high.
Efficiency is high.	Efficiency Low.	Efficiency should be low.

II.SYSTEM MODEL AND ASSUMPTIONS

In renewable energy conversion devices achieved optimum efficiency by implementing inverter of ZSI-Source family with MPPT & PWM technique, *e.g.* efficiency of grid tie Quasi Z-Source inverter up to 97.5%. But for further enhance performance (or output) of the system it required to increase no. of PV-Panel but it is not optimum solution for getting maximum power output. So in this paper increase the power output of PV-Panel by decreasing its temperature & increasing humidity. Experimentally presents water cooling (spraying) technique is improve photovoltaic (PV) array specific generation ratio and enhance the net power output. In cooling technique water is flow over the surface of PV array at constant rate it decreasing panel surface temperature & directly increase the power output of PV-panel. Simultaneously, the output hot water is very beneficial for houses, buildings & hospitals as a water heating system specifically in the remote areas. The greater economical results were achieved midday with increase the power output & specific generation of the day. Table 2 gives factor affecting on PV-Panel performance.

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Dependent Factor of Solar-Photovoltaic (PV) System Performance

Table.2. Affecting Factor on PV-Panel Performance

Sr. No.	Factor which effects positively are given below	Factor which effects negatively are given below
1	Maximum power (Pmax)	Ambient temperature
2	Tolerance rated value %	Relative humidity
3	Maximum power voltage (Vmax)	Dust storms and suspension in air
4	Maximum power current (Imax)	Shading
5	Open-circuit voltage (Voc)	Global solar radiation intensity
6	Short-circuit current (Isc)	Spectrum and angle of irradiance

The electrical performance of a PV module which involves both the electrical efficiency as well as the power output, both are inversely proportional the operating temperature of PV-panel.

$$\text{Electrical efficiency or Power output of PV} - \text{System} = \frac{1}{\text{Operating Temperature of PV Panel.}}$$

Temperature affects how electricity flows through an electrical circuit by varying the speed at which the electrons pass through. This is due to an increase in resistance of the circuit by increase in temperature and the efficiency of photovoltaic cells decreases as temperature increases. Similarly, resistance is decreased with decreasing temperatures. Cooling technique use for PV panels allows higher efficiency and yield additional power output. Panels' temperature can be droop down actively or passively, an active system requires some external power source to run the cooling system. *E.g.* use of electrical water pump to spread water forcefully over the panel surface. Passive cooling system use only nature source for cooling like air, greenery of surrounding area etc…In this paper, to improve the electrical efficiency of solar panels that work in optimal conditions, an active water cooling system has been built on crown of PV array to spray (pump) a cool water on front of the panel surface, to pull away heat, keep the panel cool and clean within certain temperatures limits, *i.e.* within ambient temperature range or below the ambient temperature. Figure 3 illustrated the characteristics of PV-panel; they show the dependency voltage, current, power and effect different temperature, radiation on Voltage, current & power.

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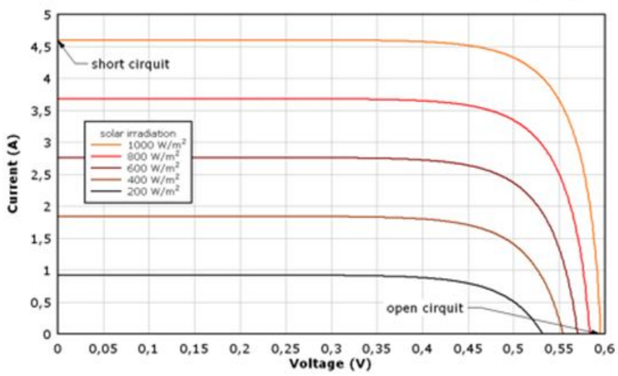

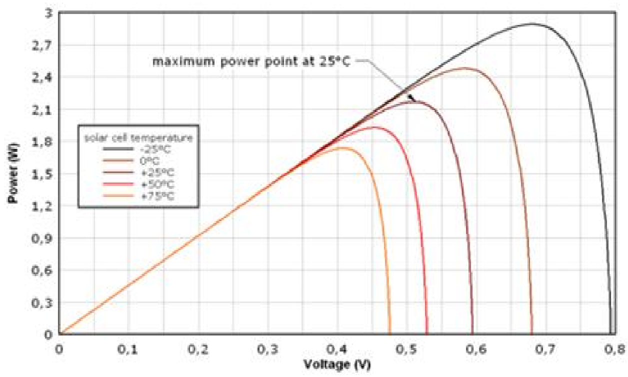

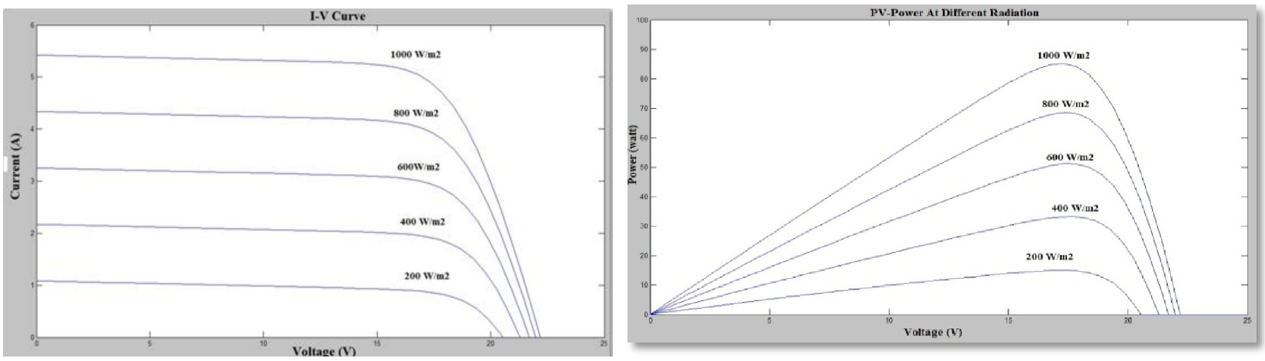

Fig.3 Solar cell (PV-panel) characteristics

In order to predict the energy Generation of PV modules, it is necessary to predict the module temperature as a function of ambient temperature (T ambient), wind speed and total irradiance. The cell temperature can be determined by the following relationship.

T module (˚C) = A x T ambient + B x Irradiance – C x Wind Speed + D

Where a, b, c and d are system-specific regression coefficients, T ambient is given in (°C), irradiance in (W/m2) and wind speed in m/s. (A =0.943 ,B = 0.0195, C = 1.528, D = 0.3529)

III. EXPERIMENTAL METHODOLOGY

For observing effect of temperature on PV-panel surface, perform one experiment at Jalgaon, Maharashtra. In this experimental PV-array cooled by a thin but continues water flowing on the front of the panels. Cooling technique was utilized spray water on the PV-array front surface by fogger system .Fogger is the device mostly used in agriculture or gardening for water feeding to plant. Due to the rapid flow of the water over the panel there should be slight increase in water temperature. PV panels which are connected in series to increase the electric current flow. Moreover, the evaporating water should further decrease the panel surface temperature with increase in voltage, gaining better electrical efficiency due to decreasing the reflection loss (refractive index of water is 1.3, which is intermediate between glass, with 1.5, and air, with 1.0) .So in result increased power output.

A. System Configuration

Experimental setup of cooling technique for PV system illustrated in fig.7 System consist tow 3–phase grids tie inverter each having capacity of 10 kW. PV system installation classified into two categories which are given below.
1) PV-panel with water spray and 2) PV-panel without water spray.

One inverter is connected to PV-panel with water spray and another one connecting to PV-panel without water spray; it is fixed at 21° south facing. The dc-power produced from the PV array is sent to inverter system and ac-power of inverter directly fed to grid. Technical specifications of PV modules with PV-panel configuration are given in table3.

Table.3. Technical specifications of PV modules

Parameter	Values
Vmax (Volt)	26.07
Imax (Ampere	7.61
Voc (Volt)	32.9
Isc (Ampere)	8.21
Rated capacity of each PV array (Watt)	200.14
Module Efficiency	15%
Rated capacity of each PV array connected to Inverter (Watt)(parallel) 25*2= 50 to each inverter.	10000
Total installed capacity (Watt) 25*4=100	20000

The measurements were recorded during a clear and cloudy day at Jalgaon, in between13th to 20th of May. Water were spraying and circulated by one hp solar pump connected to 235 watt solar panels, which is produce sufficient power to run the pumping system. The power required for water pumping should be less than the obtained extra gain power from PV by using the spraying technique. Fig.4. show Experimental setup of PV-panel cooling system

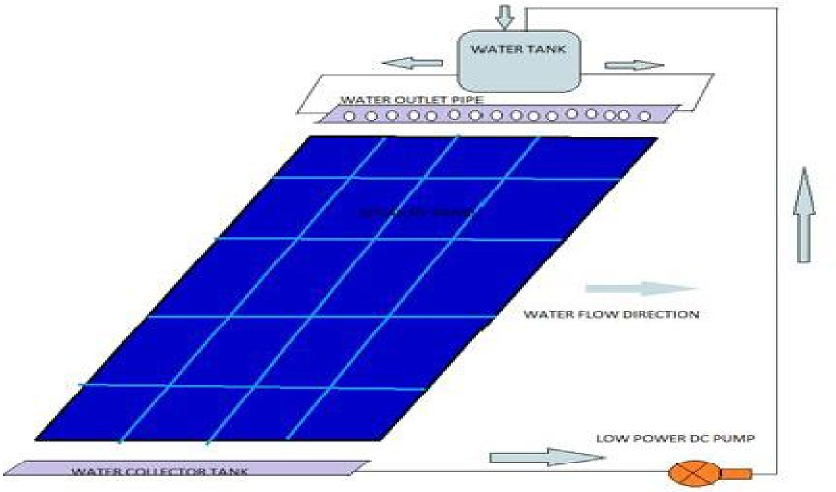

Fig.4. Experimental setup of PV-panel cooling system

The flow rate of water is measured by an analog flow meter, the solar irradiance was measured by a pyranometer at one reference incident plane of the modules and ambient temperature was measured by thermal imager. Input voltage, current, dc-power, output voltage, current, ac-power & frequency were measured by in built meters in inverter. The power output from each of the PV array was recorded in every 10 min and the spraying system was continuously on for specific duration of day. More than one reading is taken at the fewer intervals in order to get smoothing curves and this is eliminating difficulties in getting such smooth curves during fluctuation in solar irradiance at the experimental site. The testing was done at clear day in order to get a maximum sun radiation with highest temperature on the PV surfaces.

IV. RESULT & DISCUSSION

A. Realistic Data Collection

Measurements on Clear Day of MAY 2015

May 16th was clear day of this month; Figure 8 shows the difference in peak power output of both inverters at same time. From figure it is cleared that, the solar irradiance increases from 9:30am to 12:30pm, where it has a maximum value at 12:10 pm is 850 W/m2, this is high value of solar irradiance causes the higher output power of PV system indicated in Table.2. The surface temperature PV-panel increases from 25 ^{0}C at 7:30 am to 70 ^{0}C at 12:00 pm. The reduction of temperature due to applying the spraying technique is near about 40^{0}C to 50^{0}Cat 12:10 pm, where the panels' surface temperature is 25^{0}C & cooling rate of PV-panel surface was7 to 9^{0}C per minute.

Table.4. Actual value of voltage, current& DC – power at 12:10 (16 may 2015)

Inv. No	Panel Temp (^{0}C)	Current (Amp)	Voltage (Volt)	Power (Watt)	Specific Generation
1	70	14.30	513.7	7286.4	4.5
2	25	14.30	586.1	8349.8	4.9

The total obtained power during the testing period is shown in table 4. So, the obtained gain for the whole period of test in one day is given in table 4. Here we assume working hour is 10hr's and calculate Specific generation of the day .formula of specific generation is given below.

$$\text{Specific Gneration of the day} = \frac{\text{Total Output (kw)}}{\text{Total Installed capacity (kW)}}$$

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From table 2 it is cleared that practically increase output of system by 1000 watt (i.e. 8349.8-7286.4) at peak radiation .Also increase specific generation by 0.4 %.

Advantages

1. Increased whole day power output of system by 9 to 12 % also increase the specific generation of the day by 0.4%.
2. It is also reduced Co2 emission.
3. We are able to harvest more power output from existing system by implementing this concept which is supported by statistic included in report.
4. It required monthly cleaning .where as conventional system required to clean within 3 to 5 day cleaning schedules i.e. 6 to 10 time per month.
5. It is beneficial in all-weather condition .Specially it is beneficial in winter and rainy season because in those day humidity is high so evaporation rate also decrease.
6.

Disadvantages

1. It required dedicated pumping system for maintaining pressure & flow in spray system.
2. Due to water spraying on solar panel scaling is collected. So it required special cleaning process after some time.
3.

B. MATLAB/Simulink Model & Data Collection

As discuses effect of maintaining panel temperature give tremendous output difference compared to normal (without cooling) system. During simulation it is develop system of 100watt input power connected to single phase 230 Vac grid. Practical system consists of 10000 watt input power connected to three phase 440Vac grid. As per discussion grid connected qZSI having higher efficiency so there is no issue of efficiency. Technical Specifications of PV modules use in MATLAB/simulink Model given in table 5.

Table.5. Technical Specifications of PV modules use in MATLAB/simulink Model

Parameter	Values
Vmax (Volt)	16.3
Imax (Ampere	3.1
Voc (Volt)	20.1
Isc (Ampere)	3.5
Rated capacity of each PV array (Watt)	50
Rated capacity of each PV array connected to Inverter (Watt)(parallel) 1*5= 5 each inverter	1000
Total installed capacity (Watt) 5*2=10	2000

1. Output of PV-panel at 70 °C

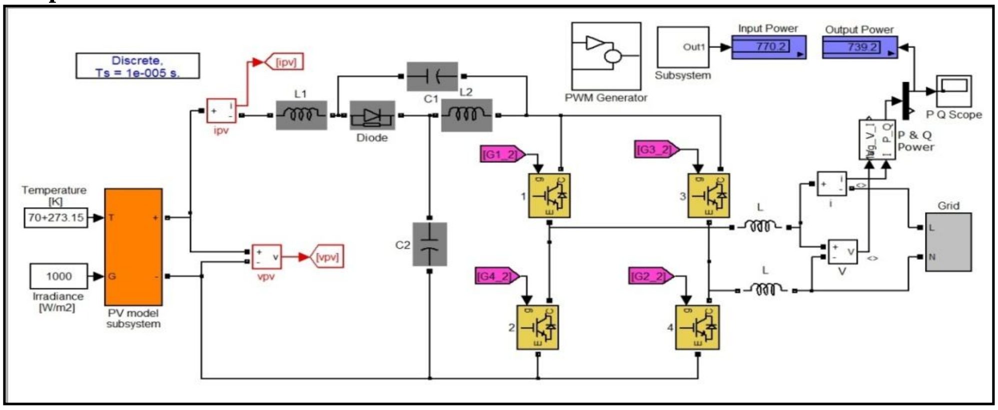

Fig.5. MATLAB/Simulink model of grid tie qzsi

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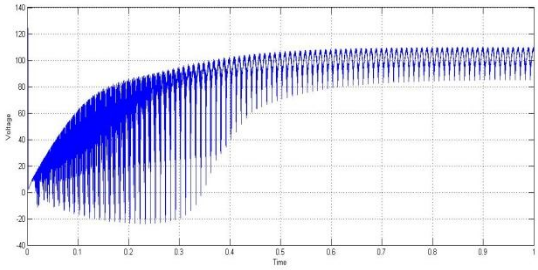
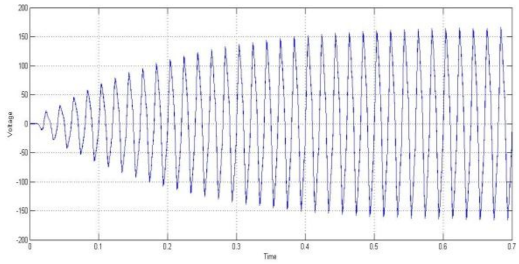
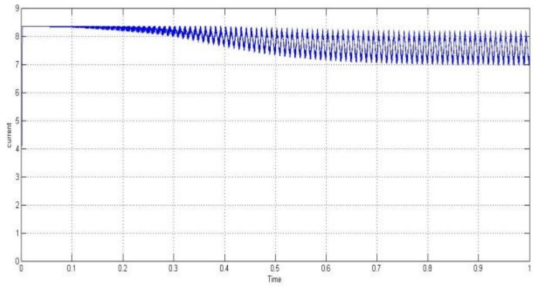
During maximum temperature panel output is low due to decreases in output voltage. Fig.5. Shows the MATLAB/Simulink model of qZSI with grid connection at panel temperature 70 ^{o}C.



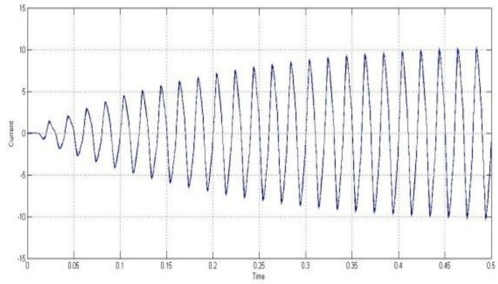
(a) Input Voltage



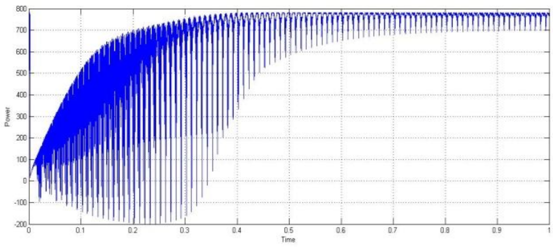
(d) Output Voltage



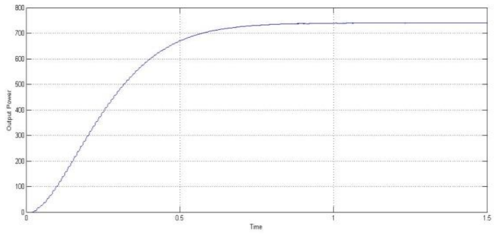
(b) Input Current



(e) Output Current



(c) Input Power



(f) Output Power

Fig.6 Input & output parameter waveforms of grid connected qZSI at 70^{o}C (panel temperature)

Fig.6. show the Input & output parameter waveforms of grid connected qZSI at 70^{o}C (panel temperature) .Which gives magnitude of voltage, current & power

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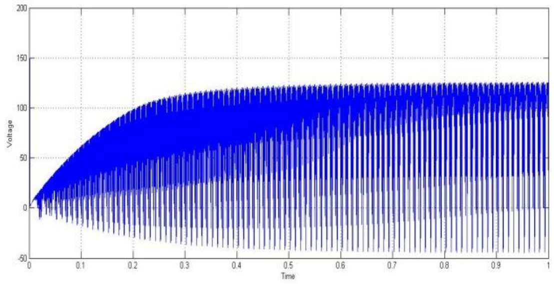
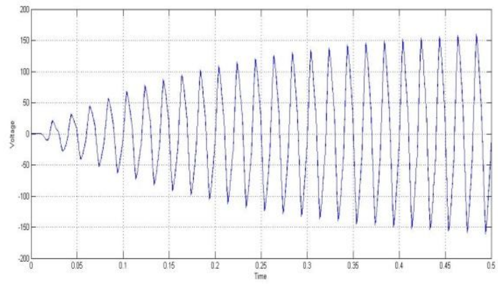
2.Output of PV-Panel at 25 ^{o}C.

Observation of MATLAB/Simulink model getting power output up to 841 watt at 25^{o}C panel temperature.



(a) Input Voltage



(d) Output Voltage

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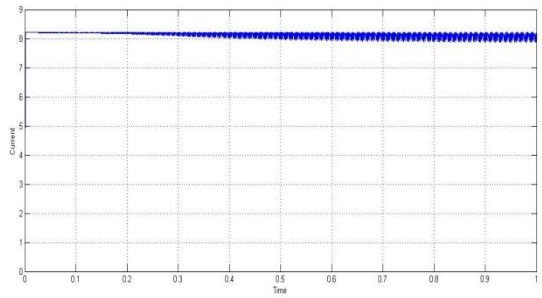
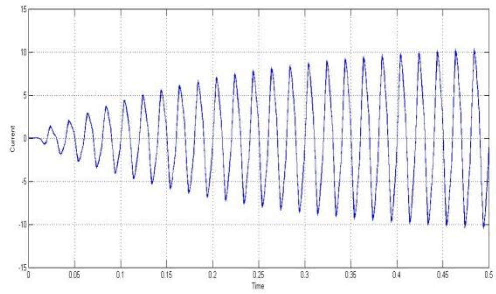
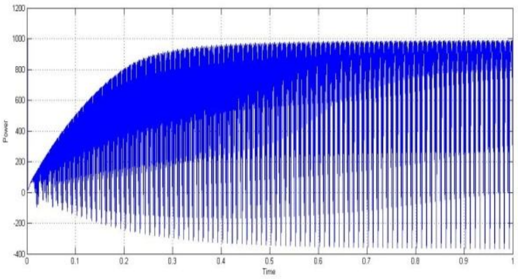


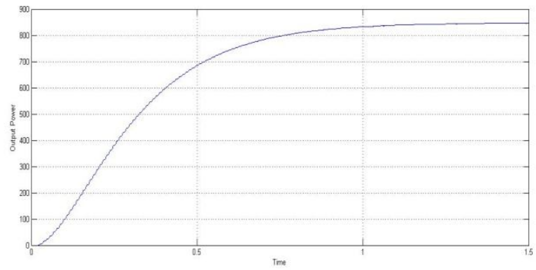
(b) Input Current



(e) Output Current



(c) Input Power



(f) Output Power

Fig.7 Input & output parameter waveforms of grid connected qZSI at 25^{o}C (panel temperature)

Fig.7. show the Input & output parameter waveforms of grid connected qZSI at 25^{o}C (panel temperature), which gives magnitude of voltage, current & power.

3. Final Comparison Summary of Both Temperature Effect

From MATLAB/Simulink result We can observe that output of temperature controlled PV – Panel Increase by near about 100 watt, it also satisfy the practical result. From comparison sheet we can observed that temperature is mostly effect on PV-panel output voltage compared to output current. Voltage difference is near about 8 to 9% and current having 0.8 to 1.5 % only .So both the differences is responsible for increase the overall system output.

V. CONCLUSIONS

Initially optimum Converter (Inverter) system was selected. From entire converters Z-source converter was selected. Z-Source inverter boosted the voltage without considering additional stages. It also increased the system efficiency & reduced system cost. Voltage boost operation was possible because of impedance network present in Z-source inverter and for desired output voltage obtained by corresponding shoot-through state. After selecting optimum converter further enhanced performance of PV-MIC in terms of power output & to maintain various environmental parameters of panel surface like temperature, dust & humidity, force cooling technique was adopted. By reducing temperature of PV-panel it was observed that the power output increased up to 10 % as well as specific generation of system increased by 0.4 %, after comparing with the realistic data. Simulation & experimental result shows the effectiveness & good performance of the proposed method.

Application

1. Cooling system is used for increasing productivity of PV-Power.
2. Use as a PV-Base grid tie inverter.
3. Z-source inverter used for residential photovoltaic system & Induction Motor Drive System for Electric Vehicles.
4. Cooling system used for cleaning of panel & Cooling system is applicable for floating panel (water mount) or surface mount panel.

Benefits	Limitation
Z-source inverter gives single stage power conversion ability.	Inverter required integrated switching arrangement.
It gives less harmonic distortion.	Inverter required proper selection & design of component.
Forced cooling system 9 to 12 % maximum output compared to normal system.	Used of cooling system in dessert area required extra running cost.
Cooling system also reduce effort of frequent PV-panel cleaning.	Without water it is worthless system.

Scope for Future Work

A grid-connected PV power generation system is one of the most gifted applications of renewable energy sources. The proposed qZSI based PV power generation system is projected as a grid connected system and transfers the maximum power from the PV array to the grid by maintaining environmental parameters of PV-Panel Surface. qZSI is best suited interface for photovoltaic power generation system and could prove to be highly efficient when implemented with the improved control techniques and maintaining environmental parameters of PV-Panel Surface.

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BIOGRAPHY

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Mr. Vikas P. Patil received his Bachelor Degree in Electrical Engineering from North Maharashtra University, Jalgaon (MS) India, in 2013. He is currently working toward the Master degree (Electrical Power System) in the Department of Electrical Engineering, North Maharashtra University, Jalgaon . His research interests mainly include renewable energy conversion systems, Energy conservation & management.