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Electrolytic Capacitor-Less Zeta Converter Based PV Interfaced DC Distribution System Incorporating Anti-Islanding Technique

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ABSTRACT:This paper proposes a electrolytic capacitor-less zeta converter based photovoltaic (PV) generation system interfaced with a DC Distribution system. In this proposed system the short lifetime of electrolytic capacitors can be eliminated by using film capacitors which guarantees full lifetime and improves efficiency. Zeta Converter is a fourth order DC-DC converter which is capable of operating either in step-up or step-down mode. The MPPT technique used here is ripple correlation control (RCC) technique which utilises the available ripples and correlates it with the switching function thereby controlling the operating point of PV. In addition, the system also incorporates an islanding detection technique for protecting the DC distribution system. The system is simulated in MATLAB R2013a and the simulation results verify that the proposed system gives high efficiency and faster response to detect islanding.

KEYWORDS: Zeta Converter, MPPT, RCC, Anti-islanding , Electrolytic capacitor , DC distribution , Photovoltaic.

I.INTRODUCTION

Due to the increased demand for electrical energy and increase in energy cost , the penetration of renewable energy sources such as photovoltaic and wind energy are taking a lot of attention nowadays. Compared to AC distribution system, the DC interface is more energy efficient as the power generated from dc sources like photovoltaics can be supplied directly to the loads thereby eliminating the dc-ac and ac-dc conversion stages allowing the reduction of conversion losses [1]. By 2040 PV is expected to be the biggest portion among the renewable energy sources for its ease of installation and infinite utilization [2],[3].Applying DC distribution system, the lifetime of PV converter module can be guaranteed by eliminating the electrolytic capacitors which also reduces the system cost [4] .The factors affecting the output power of the PV modules are temperature, solar irradiation etc. Due to the variation in load, temperature and radiation the efficiency of the system is highly decreased. Therefore to improve the efficiency of the system a circuitry called maximum power point tracking is used here [5].

The operation of MPPT techniques are based on the maximum power transfer theorem, where the maximum power is transferred when the load impedance matches the source impedance. For tracking the maximum power point, there are various techniques such as Perturb and Observe , Hill Climbing, Incremental Conductance etc. Perturb and Observe , Incremental Conductance have disadvantages such as (i) reduction in tracking performance during sudden change in solar irradiance (ii) an effective perturbation size need to be found[6].The above disadvantages are overcome by the use of ripple correlation control technique.

Various DC-DC converters such as buck, boost, buck-boost, Sepic converters can be used for interfacing with the DC Distribution. The MPPT is usually achieved by varying the duty cycle of the DC-DC converters. In this proposed system, Zeta Converter is used. Zeta Converter is a fourth order DC-DC Converter which is capable of operating either in step-down or step-up mode.

This paper mainly focuses on PV interfaced DC distribution system with a Zeta converter. The interfacing with DC distribution system not only improves the system lifetime by eliminating theelectrolytic capacitors but also eradicates various issues utilizing the advantages of DC distribution. Islanding detection methods are important for system

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protection, safety of line workers etc. A new anti-islanding method for DC distribution system has been proposed in this paper [1].The block diagram of the system is given in Fig.1.

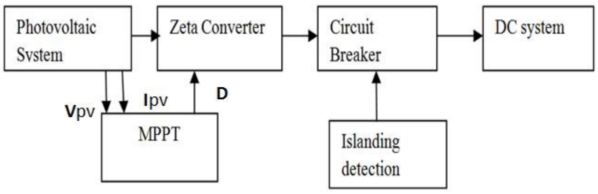

Fig.1. Block diagram of the system

II.DC DISTRIBUTION SYSTEM WITH PV INTERFACE

In the conventional ac distribution system, the power produced by sources such as fuel cells, photovoltaics need to be first converted in AC which adds complexity and reduces the efficiency of power system [7]. However, the use of computers, televisions, monitors and other DC power consuming devices in our buildings have lead to the need to convert the AC power again to DC. This dc-ac and ac-dc conversion stages further adds to complexity and losses in the power system. The use of DC distribution system is a solution to this problem as it eliminates the intermediate conversion stages thereby increasing the reliability and efficiency of the system.

In the ac distribution system, an electrolytic capacitor of large capacitance is connected to the dc input bus in order to decouple the power pulsations [8]. The lifetime of the electrolytic capacitor depends on environmental conditions such as temperature and during summer season its lifetime is shortened due to the high temperature. By the use of DC distribution, the dc voltage is tightly regulated such that there are no ac fluctuations. So a film capacitor can be used in the place of electrolytic capacitor thereby increasing the lifetime of the system.

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 modeled 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.

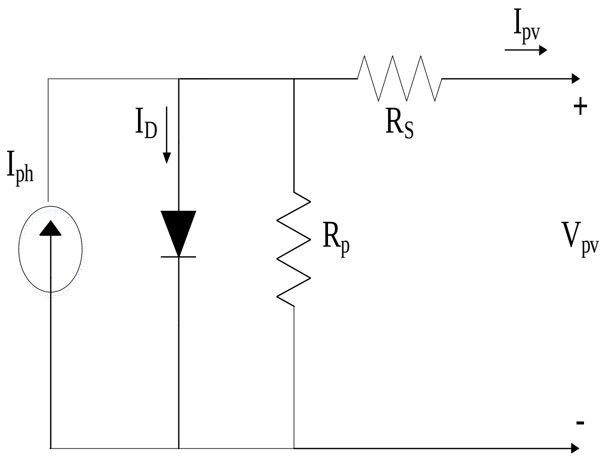

Fig.2. Single diode equivalent circuit of PV cell

The output current of a PV module is given by,

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

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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 of cells 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,

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

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/m²), G is the present irradiance level [9].

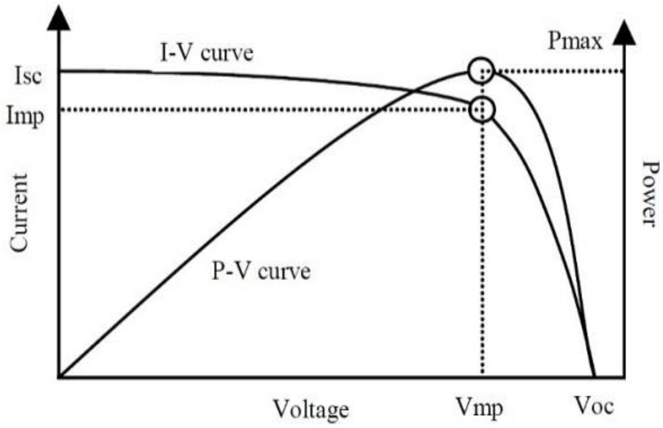

Fig.3. I-V and PV characteristics of solar cell

The PV module parameters are shown in Table 1 [1]. 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

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 [10]. Among the existing MPPT techniques, Ripple correlation control (RCC) is selected for achieving the maximum power from the module. When a PV array is connected to a converter, it imposes voltage and current ripple on the PV array as a result of its switching action. The RCC make use of this ripple to perform MPPT. It correlates the time derivative of time-varying PV array current or voltage to drive the power gradient to zero thereby reaching the MPP.

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The duty ratio control input is :

$$d(t) = - k3 \int pv dt \quad (1.3)$$

k3 is a positive constant, controlling the duty ratio in this way assures that the MPP will be continuously tracked, making RCC a true MPP tracker. The Simulink model of RCC technique is shown in Fig. 4.

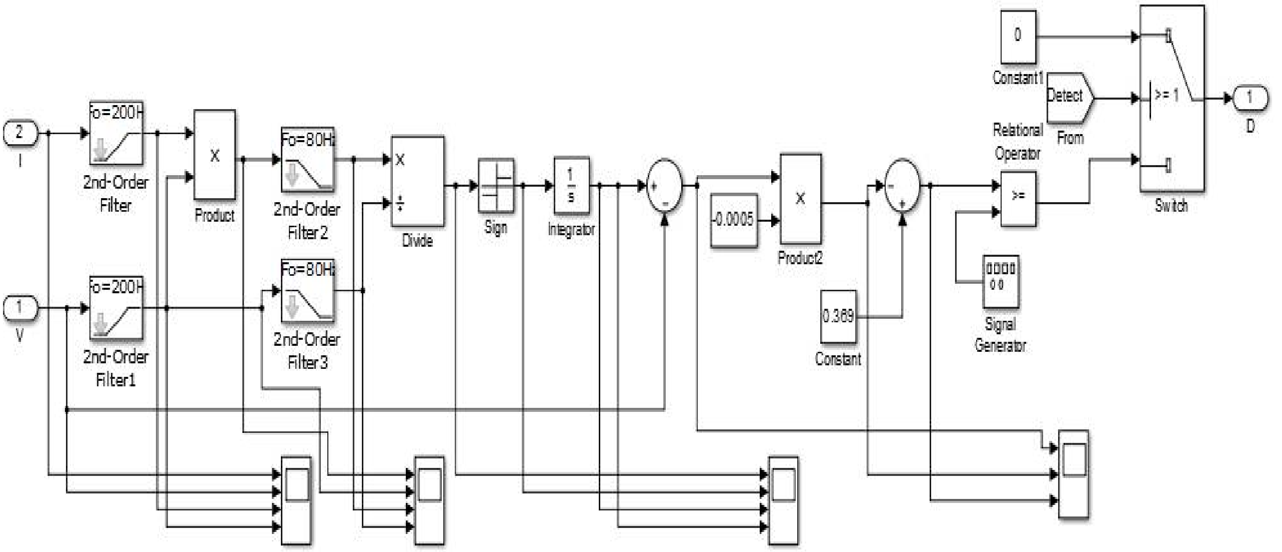

Fig.4. Simulink model of RCC technique.

III.ZETA CONVERTER

A Zeta Converter is a fourth order non linear system which can with regard to the energy input , it can act as a buck-boost-buck converter and with regard to the output it can be seen as boost-buck-boost converter. It does so without inverting the polarities. The basic circuit of Zeta converter is shown in Fig.5[5].

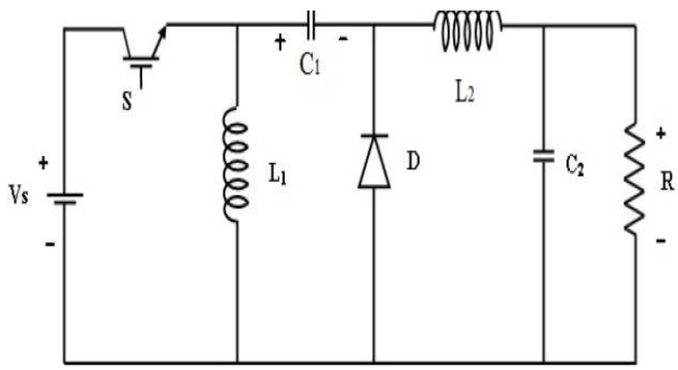

Fig.5. Basic circuit of Zeta converter

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It exhibits two modes of operation. In the first mode, the switch is ON (closed) and the diode D is OFF. During this period, the current through the L_1 and L_2 are drawn from the voltage source V_s and this mode is called charging mode. In the second mode of operation, the switch is OFF and the diode D is ON position. Here all the energy stored in the L_2 is transferred to the load R and this mode is the discharging mode. The waveforms of the Zeta converter is shown in Fig.6.

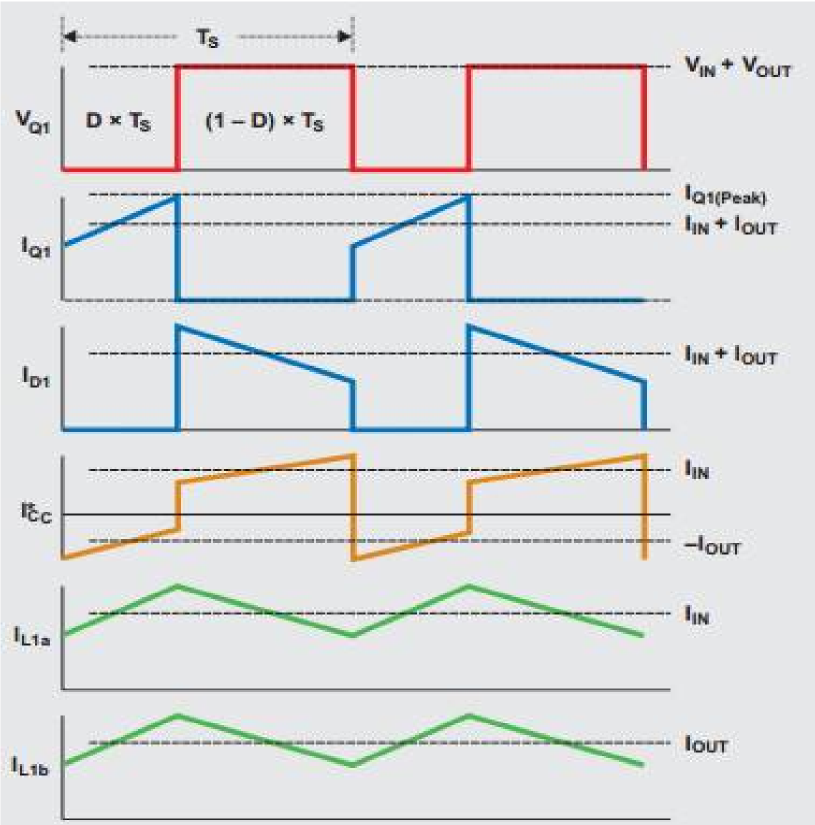

Fig.6. Waveforms of Zeta converter

The design equation is given as,

$$V_0 = \frac{V_{in}}{(1-D)} \qquad 1.4)$$

IV.ANTI-ISLANDING DETECTION

The islanding detection is very important for safety of equipments and utility workers. Like in the AC distribution system, islanding detection is important in the DC distribution also. Here the islanding detection is done by comparing the voltage V_d with the standard IEEE values and the pulse to the switch of Zeta converter is made zero thereby turning off the Zeta converter in case of islanding .Therefore an event of islanding is quickly detected by this detection method and system safety can be achieved easily. The Simulink model of the islanding detection circuit is shown in Fig.7.

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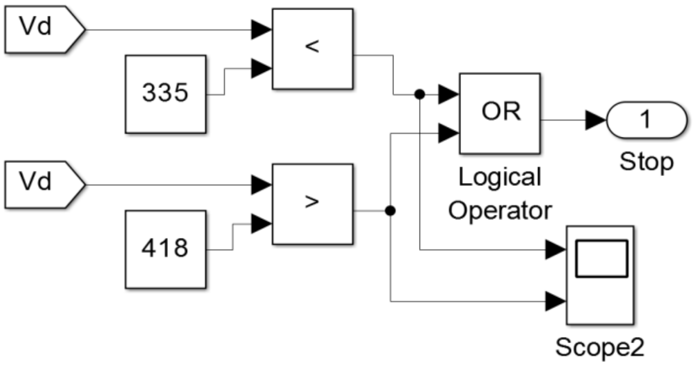

Fig.7. Simulink model of islanding detection

V. RESULT AND DISCUSSION

Simulation of proposed System is done in MATLAB/Simulink. Fig.8. shows the Simulink model of the proposed PV interfaced DC system with anti-islanding protection.

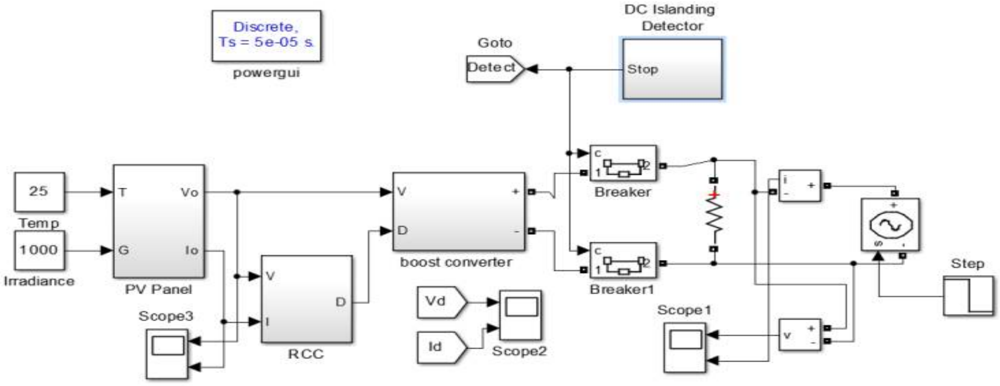

Fig.8. Simulink model of entire system

The PV system is modelled to get the rated power. The MPPT controller provides the pulses for the Zeta converter to obtain the maximum power. The islanding occurs after 1s and the pulses to the Zeta converter is stopped on detection of the islanding condition with the help of islanding detection circuit. The pulses to the switch of Zeta converter is given in Fig.9. The output voltage and current waveform of Zeta converter is given in Fig.10. The output waveform of islanding detection circuit is shown in Fig.11. The final output voltage and current waveforms are analysed in Fig 12 and 13 respectively.

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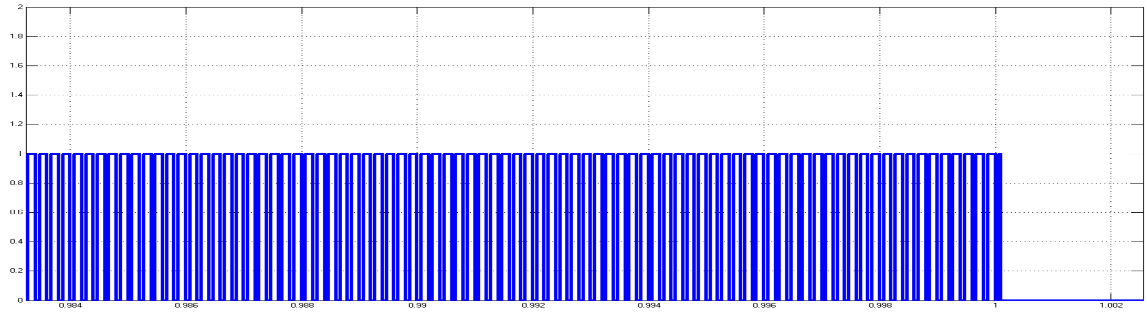

Fig.9. The pulses to the switch of Zeta converter (x axis : sec, y axis : 0.2/ div)

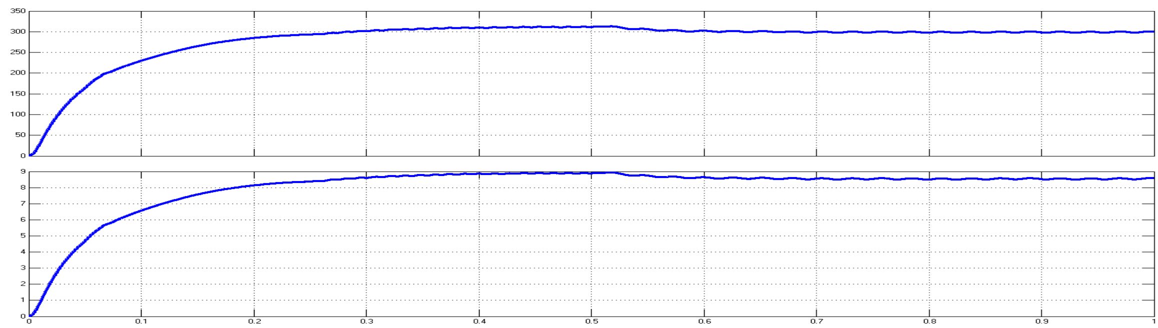

Fig.10. Output voltage and current waveform of Zeta converter (x axis: 0.1 sec/ div, y_1 axis (voltage): 50 V / div, y_2 axis (current): 1 A/div)

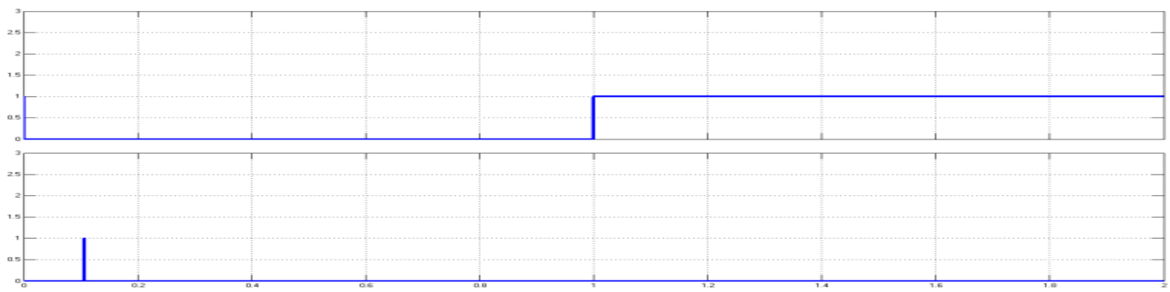

Fig.11. Output waveforms of islanding detection circuit (x axis: 0.2 sec / div, y axis 0.5/ div)

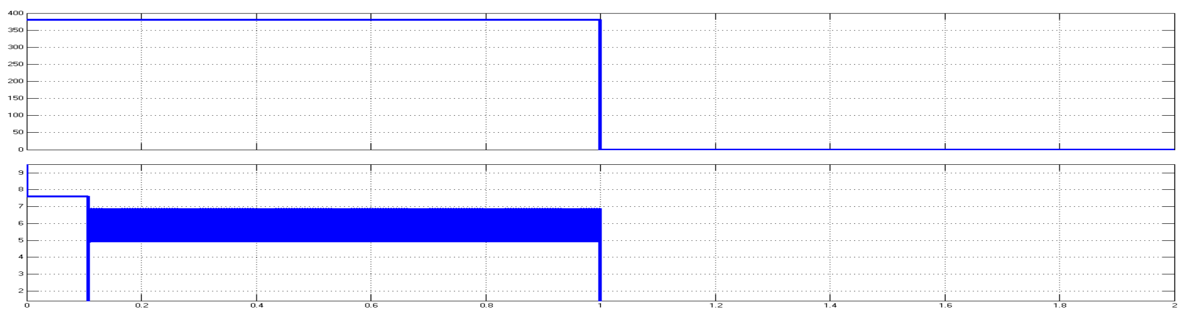

Fig .12. The final output and current waveforms (x axis: 0.2 sec/div, y_1 axis: 50 V/ div, y_2 axis : 1 A/ div)

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VI.CONCLUSION

In this paper, an electrolytic capacitor less zeta converter based PV interfaced DC distribution system incorporating islanding detection technique is proposed. The electrolytic capacitors are replaced by film capacitors utilizing the advantage of dc distribution system. A new anti-islanding is proposed here for system protection. Voltage is the parameter used in islanding detection technique. This technique was modelled on a converter-connected PV system representing a typical DG source. Simulation was done in MATLAB/ Simulink and the results are verified.

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