HERIC Inverter- A SEPIC based transformer-less converter design and simulation for isolated standalone PV system

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Abstract. Photovoltaic transformer-less inverter due to its high efficiency, low power loss and cost plays an important role in energy market. In this paper solar PV based 1φ transformer-less HERIC converter for standalone isolated PV system has been designed and analysed. To control the solar PV output, a dc-dc SEPIC converter is modelled and designed with the feature of Maximum Power Point Tracking. Contrary to other inverter topologies H5, H6, NPC (neutral point clamping), HERIC inverter comprises low leakage current. The entire proposed system is designed and simulation is carried out in MATLAB environment.

1. Introduction

Due to increasing demand in electricity, energy has been obtained from various sources such as sun, wind, fossil fuels etc., On account of global warming considerations pollution free energy source usage has increased [1]. The availability of solar energy has utilized to draw electricity. In the energy conversion process power electronic components play a vital role [2].

Photovoltaic inverter contributes a major role in the solar Photovoltaic system overall performance. As the number and size of electronic component expand, the system overall cost increases. So, efforts have taken to overcome the above problem. In order to reduce the size of photovoltaic inverter, transformer-less prototype has emerged recently. Various inverter topology such as full bridge, half bridge, H-bridge, H5, H6, H7 topology, HERIC has designed [3-4]. Transformer based inverter topology produce common mode leakage current when integrated with grid[5]. The leakage current must be within the limits otherwise it led to electromagnetic interference and safety problems. Hence transformer-less inverter topology is developing nowadays to eliminate the leakage current problems. A high performance low leakage current HERIC inverter is used [6-7]. To control the solar PV system output, SEPIC converter is chosen among various dc-dc converter topologies such as cuk converter, buck converter, boost and buck-boost converters. Contrary to boost converter, the non-inverting mode of operation is offered by SEPIC converter. In addition, it is common that both input and output current waveforms are fluctuating in the boost converter but the proposed converter has the advantage of drawing continuous input current with lower pulsation [8-10]. As above mentioned, merits make SEPIC converter more suitable for Solar PV system. The well-known R&O Maximum Power Point Tracking method is used to withdraw the possible
maximum power from solar PV panel.

The PV module is designed and simulated in MATLAB/Simulink environment. Figure 1 gives the block diagram of the proposed standalone Photovoltaic system [11-12]. A double frequency SPWM technique is made use for modulation of the inverter with different power converter switching combinations.

![Block diagram of the proposed system](image)

**Figure 1:** Schematic block of proposed system

2. **Proposed system design**

The test system is modeled in such a way that the solar PV array with at most power \( P_{mpp} = 1.5 \text{ kW} \) for feeding a load under STC condition (25 °C) of irradiation 900 W/m². The module specifications are shown in Table 1. It is necessary to determine [13] the number of PV modules is needed for connecting either in parallel combination or series combination is calculated as indicated by equations (1), (2) and (3).

\[
I_{MPP} = \frac{P_{MPP}}{V_{MPP}} = \frac{1500}{120} = 12.5 \text{ A}
\]

Equation (1) represents the input current at MPP.

\[
N_p = \frac{I_{MPP}}{I_M} = \frac{12.5}{8.21} = 1.2 \approx 2
\]

Equation (2) shows the required number of parallel modules

\[
N_s = \frac{V_{MPP}}{V_M} = \frac{120}{26.4} = 4.54 \approx 5
\]

Equation (3) shows the required number of series modules

Thus, a five module series connected and two module parallel connected solar PV array is designed successfully and energy conserved and utilized efficiently [14]

**Table 1:** Specifications of 200W PV panel

| Key Parameters | Numerical Value |
|----------------|-----------------|
| Peak power     | 200 W           |
| \( V_{MPP} \)   | 26.4 V          |
| \( I_{SC} \)     | 8.21 A          |
| \( I_{MPP} \)    | 8.215 A         |
3. SEPIC Converter Design

The SEPIC converter is modeled using MATLAB Simulink software as shown in Figure 2 [15]. For designing of SEPIC converter, the parameters value has been calculated using equations (4), (5), (6) and (7).

The duty cycle can be determined using the equation (4)

\[ D = \frac{V_{OUT}}{V_{OUT} + V_{IN}} = \frac{250}{250 + 120} = 0.676 \]  

\[ I_{OUT} = \frac{P_{MPP}}{V_{OUT}} = \frac{1500}{250} = 6A \]  

\[ L_{1(MIN)} = L_{2(MIN)} = \frac{1 * V_{IN(MIN)} * D}{2 * N_l * f_{sw}} = \frac{1 * 120 * 0.676}{2 * 2 * 8000} \]  

\[ L_{1(MIN)} = L_{2(MIN)} = 2.028mH \]  

If equivalent series resistance is low, then \( C_1 \) & \( C_2 \) can be determined by equation (7).

\[ C_1 = C_2 = \frac{I_{OUT} * D}{\Delta V_{RPL} * f_{sw}} = \frac{6 * 0.676}{0.01 * 250 * 8000} \]  

\[ C_1 = C_2 = 202.8\mu F \]
4. Design of MPPT Algorithm
In this article, the well-known MPPT technique Perturb and observe method is employed. Fig. 3 shows the flow chart of operation of Perturb and Observe method. Power variance and voltage variation shall decide the action needed to increase or decrease the reference voltage. It can be observed by varying the duty ratio of PWM signal given for the purpose of switching the dc-dc converter. The proposed method is simulated and hardware is implemented [16].

Figure 3: Flowchart for Perturb and Observe MPPT technique

5. HERIC Inverter Topology
The simulation diagram of HERIC topology is shown in figure 4. HERIC inverter with additional switches provides isolation between Solar PV array and grid. The reactive power exchange is prevented which increases the efficiency of inverter and performance and reduces complexity problem in inverter [17].

Table 2: Parameters for designing SPWM

| Key Parameters             | Numerical Value |
|---------------------------|-----------------|
| Carrier wave amplitude    | 1V              |
| Carrier frequency         | 8kHz            |
| Reference wave amplitude  | 0.8V            |
| Reference wave frequency  | 50Hz            |

Table 2 gives the parameters value for designing the sinusoidal pulse width modulation technique which generates pulses required for triggering the inverter.
6. Simulation Results

The PV system with battery storage based single-phase transformer-less HERIC inverter with \( R \) Load is designed and simulated by MATLAB Simulink [18]. Fig.5 gives the output values of solar PV voltage as well as current of 120 V and 12.5 A respectively as designed for 1.5KW.

As shown in fig.3, the simulation is done at 67% duty cycle for SEPIC converter and the shape of output waveforms reveal that for the input values from the designed solar panel with MPPT. The output voltage is constant at 250V expected voltage level and does not differ with input variations. In addition, there has been a substantial decrease of overshoot has been noted [19-20].
Fig. 7 shows the output waveforms for the proposed inverter with R load. It shows due to the effects of output voltage drop of SEPIC converter, there is a change in inverter output. The SEPIC converter mainly focuses on extracting maximum power from PV system.

7. Conclusion

The proposed model of solar PV system with HERIC inverter has been designed and simulation result has been obtained. The solar PV array output is regulated using MPPT based SEPI converter for variation in temperature and irradiation. It is observed that the variation in solar radiation and temperature has influence on output of HERIC inverter.

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