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Modeling and analysis of a quasi-linear multilevel inverter for photovoltaic application

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Abstract

A quasi-linear Cascaded H-Bridge multilevel inverter is introduced for solar application. In this paper, a separate solar panel with boost converter is placed instead of DC sources in the proposed configuration. The Incremental and Conductance maximum power point algorithm method is implemented for tracking maximum power with a fast response. Sinusoidal reference with triangular carriers is utilized in pulse width modulation for generating the switching pulses for proposed inverter. The proposed inverter can generate a 19-level output voltage with total harmonic distortion of 6.10% which is simulated using MATLAB/Simulink. Cost analysis of power switches is discussed.

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Keywords: Grid connected MLI; boost converter; hybrid multilevel iinverter; pulse width modulation;single phase grid.

1. Introduction

Renewable Energy Sources (RES) such as the wind, solar, biomass are employed to avoid the ecological problems such as global warming and air pollution caused by fossil fuels [1]. The cost of photovoltaic modules has reduced over the last decades. So, Solar energy is the cheapest energy source when compared to other RES also nowadays solar plant with Megawatt range are becoming a standard in many countries [1,2]. Multilevel inverter (MLI) proved as substantial global attention by the researchers and industries in the applications of renewable energy system integration, AC motor drives and grid power quality [2]. The features of MLI are developed to other applications such as electric ship propulsion, aircraft, hybrid electric vehicle, multiphase drives and traction systems.

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Single phase MLIs are becoming more popular in medium power microgrid applications because it can able directly connected to the grid without any transformers [3]. Different types of PV based grid connected inverters are the central inverter, string inverter, multi-string inverter, AC module inverter, and cascaded H-Bridge (CHB) inverters [4]. CHBMLI is being investigated as an interesting topology in grid connected solar application. Different types of reduced switch topologies for grid connected solar application are developed and presented in [5]. The main disadvantage of these reduced switch inverter topologies is not possible to generate all additive and subtractive combinations of the input DC sources. In CHBMLI is the appropriate choice for generating output voltage levels in all the combination and also utilized for high voltage applications. Asymmetric MLI provides getter better output voltage level when compared to symmetric MLI [5].

In this paper, PV based grid connected CHBMLI is developed and it is operated at quasi-linear ratio (asymmetric). Incremental and Conductance method is used for tracking the maximum power. Sinusoidal reference with triangular carriers is used for generating the switching pulses. Three boost converters are designed based on the quasi-linear ratio and PV panel input voltage. Simulation results are shown to prove the effectiveness of grid connected quasi-linear multilevel inverter.

2. Modeling of PV System

A mathematical model for PV cell with the single diode and two resistors (series & parallel) combination is discussed in this section. The equivalent circuit of PV cell is shown in Fig. 1. Table 1 shows the 80 W PV panel rating. The mathematical formula for PV cell using the below formula [6]

$$I = I_{PV,cell} - I_{o,cell}\left[exp\left(\frac{qv}{akT}\right) - 1\right] \tag{1}$$

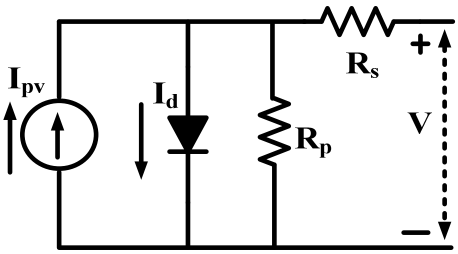

Fig. 1. Equivalent circuit diagram of PV cell

Table 1. Rating of 80 W PV Panel

Parameter	Values
Short circuit current	4.71 A
Open circuit voltage	22.24 V
Maximum power point voltage	18.33 V
Maximum power point current	4.37 A

A PV module is formed by connecting several PV cells are connected in series and parallel. Fig. 2 shows the I-V curve and P-V curve. The mathematical formula for PV arrays using the below formulas

$$I = I_{PV} - I_o\left[exp\left(\frac{V + R_sI}{V_ta}\right) - 1\right] - \frac{v + R_sI}{R_p} \tag{2}$$

$$I_{PV} = \left[I_{PV,n} + K_I\Delta_T\right]\frac{G}{G_n} \tag{3}$$

$$I_o = \frac{I_{SC,n}K_I\Delta_T}{\exp\left[\left(V_{oc,n} + K_I\Delta_T\right)/av_t\right] - 1} \tag{4}$$

The PV panel is designed and tested at Standard Test Condition (STC). The detailed explanation of modeling the solar panel is discussed in [6]. To track the maximum point of voltage and current in IV-curve and PV-curve, Incremental and Conductance MPPT is used. This MPPT technique provides a fast response when compared to the P&O technique. The design of MPPT technique is explained in [6].