SIMULATION AND COMPARATIVE ANALYSIS OF NPC AND QUASI Z-SOURCE INVERTER TOPLOGIES

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Abstract: Applying multilevel inverters to photovoltaic (PV) power systems is gaining more and more attention. Among the typical multilevel inverter topologies, cascade multilevel inverter (CMI) is more widely used due to its attractive features, such as achieving the distributed maximum power point tracking (MPPT) and high voltage/ high power grid-tie without transformer. This paper also proposes a control scheme for the energy stored qZS-CMI and NPC based PV system. The proposed system can achieve the distributed maximum power point track for PV panels, balance the power between different modules, and provide the desired power to the grid. The simulation of proposed system has been carried out in Matlab-Simulink.

1. INTRODUCTION

Quasi-Z-source inverter (qZSI) is a new topology derived from the traditional Z-source inverter (ZSI). The qZSI inherits all the advantages of the ZSI, which can realize buck/boost, inversion and power conditioning in a single stage with improved reliability.

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In addition, the proposed qZSI has the unique advantages of lower component ratings and constant dc current from the source. All of the boost control methods that have been developed for the ZSI can be used by the qZSI. The qZSI features a wide range of voltage gain which is suitable for applications in photovoltaic (PV) systems, due to the fact that the PV cell's output varies widely with temperature and solar irradiation.

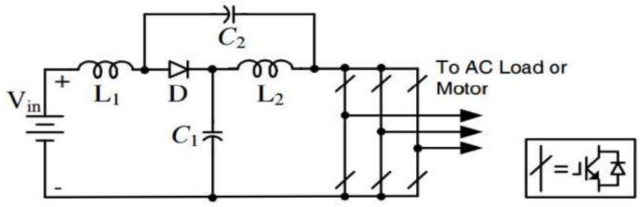

Figure 1 Quasi-Z-Source Inverter

If the switching period is T and the shoot through time is to, is the voltage across capacitor C1, is the voltage across capacitor C2, and are the voltage across inductor L1 and L2, is output voltage of PV module, is the input voltage of inverter.

$$V_{C1} = v_{L1}, \quad V_{C2} + V_{pv} = v_{L2}, \quad v_i = 0 \tag{1}$$

During any non-zero state as shown in Figure 1.7, the equations are as follow

$$v_{L1} = V_{C1} - v_i = -V_{C2}, \quad v_{L2} = V_{pv} - V_{C1}, \quad v_i = V_{C1} + V_{C2} \tag{2}$$

The average voltage across the DC link is given by:

$$v_i = \frac{T_1(V_{C1} + V_{C2})}{T} = \frac{T_1}{T_1 - T_o} V_{pv} = B.V_{pv} \tag{3}$$

Where B is the boost factor obtained from zero state and is given by

$$B = \frac{T_1}{T_1 - T_o} = \frac{1}{1 - \frac{T_o}{T_1}} \geq 1 \tag{4}$$

The output ac voltage from the inverter is given by

$$v_{ac} = M.B.\frac{V_i}{2} \tag{5}$$

2. MULTI-LEVEL INVERTER

Mostly a two-level inverter is used in order to generate the AC voltage from DC voltage.

A two-level Inverter creates two different voltages for the load If Input Voltage is Vdc. Then it produces output as +Vdc/2 AND –Vdc/2 based on switching of power devices. This method of generating AC output seems to be Effective but possess following drawbacks

1. High Harmonic Distortion in Output Voltage
2. High dv/dt.

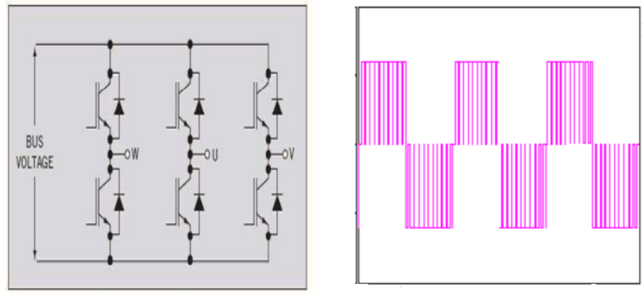

Figure 2Multi-level inverter

In order to create a smoother stepped output waveform, more than two voltage levels are combined together and the output waveform obtained in this case has lower dv/dt and also lower harmonic distortions. Smoothness of the waveform is proportional to the voltage levels, as we increase the voltage level the waveform becomes smoother but the complexity of controller circuit and components also increase.

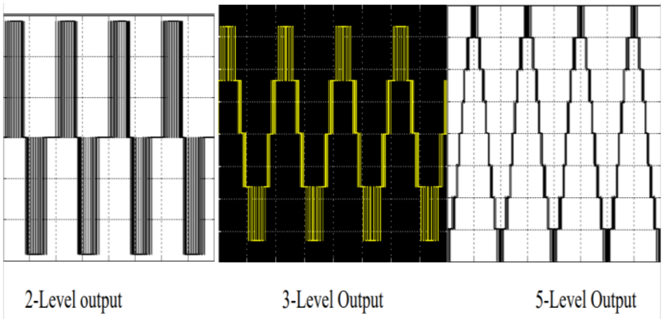

Figure 3 Level of NPC Inverter

The elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. However, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected. There are several topologies of multilevel inverters available. The difference lies in the mechanism of switching and the source of input voltage to the multilevel inverters. Three most commonly used multilevel inverter

THREE LEVEL NPC INVERTER

This topology uses clamping diodes in order to limit the voltage stress of power devices.

A k level diode clamped inverter needs

- (2k – 2) switching devices,
- (k – 1) input voltage source and
- (k – 1) (k – 2) diodes in order to operate.

Vdc is the voltage present across each diode and the switch.

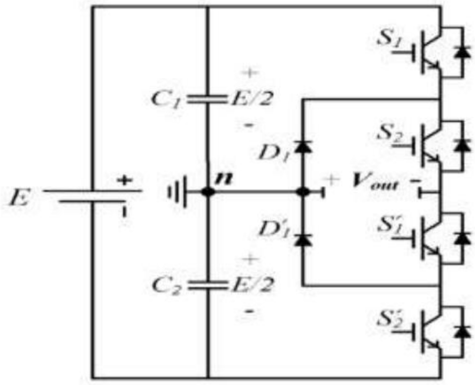

Figure 4 three level diode clamp multi-level inverter

Switch status	State	Pole voltage
$S_1 = ON\ S_2 = ON$ $S_1 = OFF\ S_2 = OFF$	+Ve	$V_{20} = {}^{Vd_c}/_2$
$S_1 = ON\ S_2 = OFF$ $S_1 = OFF\ S_2 = ON$	0	$V_{20} = 0$
$S_1 = OFF\ S_2 = OFF$ $S_1 = ON\ S_2 = ON$	-Ve	$V_{20} = -{}^{Vd_c}/_2$

Table 1 - Switching states in one leg of the three-level diode clamped inverter

FIVE LEVEL INVERTER

The main agent for transferring voltage levels to load in this topology is the capacitor. The switching states in flying multilevel inverter are like that in "Diode clamp inverter" with exemption of clamping diodes in FCMI. In this inverter, the flow of both active and reactive power can be controlled due to the high switching frequency. However, High switching frequency will produce extra losses.

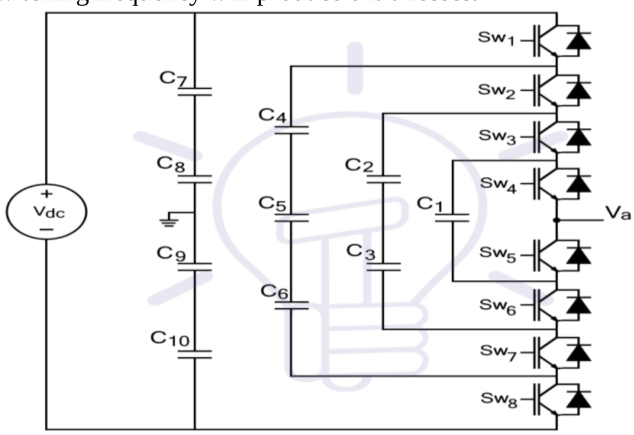

Figure 5 five layer inverter

Flying capacitors provide higher degree of freedom to provide specific output voltage using a smaller number of semiconductor power devices. The aim of this configuration is to keep its output voltage in desired level, avoiding

distortion at its output. There are two techniques to regulate the voltage of capacitor. These two types are: natural balancing and active schemes.
The maximum output voltage of this inverter is the half of the applied input voltage. In other words, the output voltage level cannot increase more than half of the applied voltage. Flying capacitor inverters are further divided into two main categories.

SEVEN LAVEL INVERTER WORKING

In seven-Level Asymmetrical Inverter each leg of a single phase contains 2 DCVS (DC Voltage Source) of 100V and 200V unlike the 3 DCVS of 100V each in 7-Level Symmetrical Inverter. This arrangement thus reduces the number of voltage supplies used. Also the number of IGBTs used is only 24 unlike 36 in the symmetric configuration. Here too the H-Bridge topology is used. Each H-Bridge has 4 IGBTs in it. And each leg has 2 such H-Bridges.

To prevent commutation errors, same switching pulses are provided to IGBT (1, 2), (3, 4), (5, 6), (7, 8) and so on in the other two phases as well. Due to the different input voltages of the cells, high-voltage switches presenting low relative conduction losses are combined with low-voltage switches having low commutation time. Naturally, for most operating points, the switching frequency of low voltage cells is higher. Together with the switch characteristics, one can take advantage of this specificity

3. SIMULATION RESULTS

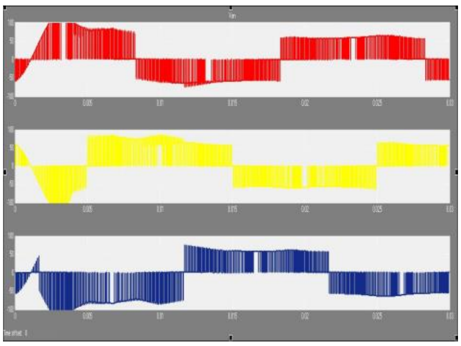

Figure 6- 3-Phase Output voltage of ZSI waveform

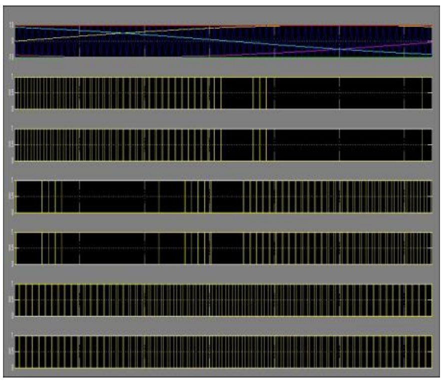

Figure 7 - PWM Controlling pulses waveform

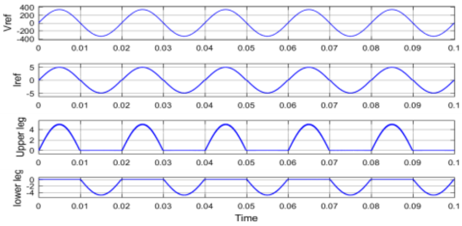

Figure 8: V_{ref}, I_{ref}, Upper and lower leg Current

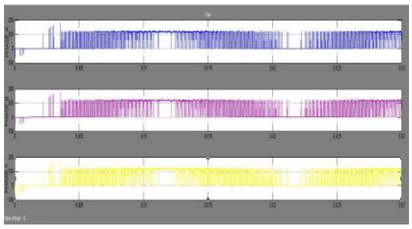

Figure 9 Output voltage of ZSI MLI waveform

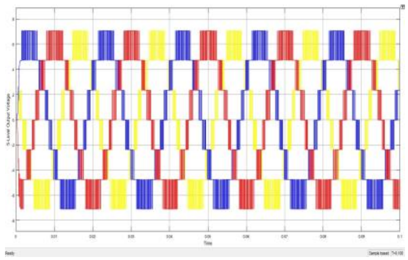

Figure 10 - 5-level output waveforms

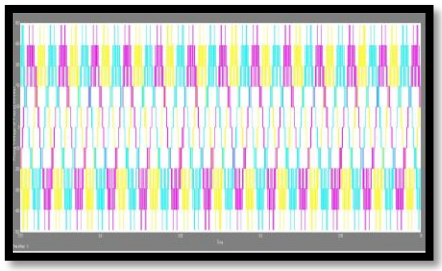

Fig 11 - Phase Voltage Waveform of 7-level inverter output

4. CONCLUSION

As we have studied in this paper the P-V and I-V characteristics of PV system changes as per the change in temperature as well as irradiation. So, the PV Generation is very sensitive to any change in the value of temperature as well as irradiation. So accordingly, the output values of all the components connected will be directly affected to this variation. So, we can conclude that without MPPT boost converter combination it is very difficult to obtain a smooth output and maximum power. To achieve maximum power point, we can control the current or regulate the voltage to maintain the power. Here, MPPT regulates the duty cycle to maintain voltage and achieve maximum power.Multilevel inverter has several advantages compared to two level, as the harmonics and switching losses are reduced. Also, the three phases share a common DC-bus minimizing the capacitance requirements and high efficiency for fundamental switching. Because of all these advantages multilevel inverters instead of two level.

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