ANALYSIS OF CAPACITOR VOLTAGE BALANCE IN MULTILEVEL INVERTER

VNSR.Murthy¹
Research Scholar, EEE Dept
KL University
Vijayawada
vnsrmurthy@gmail.com

Dr.A.Pandian²
Professor, EEE Dept
KL University
Vijayawada

Abstract - A redundancy balancing technique for the five-level diode-clamped inverter is presented, which balances the four dc-link capacitor voltages at high modulation index and high power factor. The technique is based on dividing the vector space of the five-level inverter into six two-level vector spaces. Dwell times are calculated as for conventional two-level space vector modulation, and the switching sequence is determined depending on the four capacitor voltages, using a redundant state method. The proposed technique maintains link capacitor balance for high modulation indices, including over modulation, irrespective of the power factor. The proposed algorithm is validated by simulation and practically. The results obtained from the MATLAB/SIMULINK is tabulated to compare the total Harmonic Distortion (THD) for different modulation techniques.

Key words - Five level Diode Clamped Inverter, Capacitor Voltage balancing, Three level boost converter, Modulation Index, Total Harmonic Distortion (THD).

I. INTRODUCTION

Multilevel inverters suffer from dc-link capacitor voltage imbalance problems at high modulation indices. Many techniques have been proposed to solve this problem one of these techniques is the redundant state method. This method has power factor and modulation index limitations when used on a five-level inverter. The proposed SVM technique offers capacitor voltage balance at high power factor and high modulation index by using a state redundancy method. To address the above mentioned issue multilevel inverters is emerged as an important alternative in high power and medium voltage control. There are three multi level inverter topologies among them diode clamped inverter is extensively used by many researchers. The main advantage of multilevel inverter is to increase the power rating, lower harmonics and synthesized sinusoidal output waveform. To address the above mentioned issue multilevel inverters is emerged as an important alternative in high power and medium voltage control.

399
There are three multi level inverter topologies among them diode clamped inverter is extensively used by many researchers. The main advantage of multilevel inverter is to increase the power rating, lower harmonics and synthesized sinusoidal output waveform. The advantage of this technique is balancing of the five-level inverter at high modulation index and high power factor without any auxiliary circuits therefore energy losses are reduced and hardware costs are decreased.

The output voltage quality of some of the single-phase multilevel inverters can be improved when their dc-link voltages are regulated asymmetrically. Symmetrical and asymmetrical multilevel diode-clamped inverters have the problem of dc-link capacitor voltage balancing, especially when power factor of the load is close to unity. In [1], the effectiveness of various algorithms applied to a five level diode clamped inverter is discussed in terms of Total Harmonic Distortion (THD). Nabae and Takahashi [2] introduce design analysis and control of a neutral point clamped Pulse Width modulation inverter. He also discusses that the main problem in Diode Clamped Inverter is to balance the inner dc link capacitor voltage.

Yuan and Barbi [3] propose a new diode clamped multilevel inverter in this new topology not only the main switches are clamped by the clamping diodes, the clamping diodes are also clamped mutually by themselves. In this paper, a new single-inductor multi-output dc/dc converter is proposed that can control the dc-link voltages of a single-phase diode-clamped inverter asymmetrically to achieve voltage quality enhancement. The circuit of the presented converter is explained and the main equations are developed.
II. DIODE CLAMPED INVERTER

The multilevel voltage-source diode-clamped converter (DCC) has attracted significant interest for high power/voltage applications since, as compared with a two-level converter, it has the following advantages:

1) provides higher power quality at the ac side;
2) Can operate at higher ac-voltage levels and minimize or even eliminate the interface transformer;
3) Reduce switching losses.

The first approach uses separate dc sources, one per capacitor, to maintain the capacitor voltages. The dc sources are usually provided by phase-shifting transformers through diode bridge rectifiers. Such a source is large, heavy, inefficient, expensive, and potentially with adverse impacts on the power quality of the primary power supply.

The second approach is based on an auxiliary converter to inject current components in the dc-side intermediate points of the DCC to balance the dc-side voltages. The main shortcoming of this approach is the need for additional power hardware, which adds to the system cost and complexity, particularly at high-voltage/power levels.

The third approach modifies the converter-switching pattern according to a control strategy to balance and maintain the dc-capacitor voltages. Although this approach requires a more elaborate control strategy/algoritham as compared with the previous methods, it provides an economically viable approach to address the main technical issue of the DCC. However, it is viable only under special conditions, which practically may not be achievable or enforced.

III. IMPORTANCE OF BALANCED VOLTAGE SHARING

The importance of multilevel inverters has been increased since last few decades. These new types of inverters are suitable for high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum and with less Total Harmonic Distortion (THD). Numerous topologies have been introduced and widely studied for utility of non-conventional sources and also for drive applications. Amongst these topologies, the multilevel cascaded inverter was introduced in Static VAR compensation and in drive systems.
Diode-clamped multilevel inverters use \((m-1)\) clamped diodes and dc capacitors in order to generate ac voltage. This inverter is manufactured in 3, 4 and 5-level structures[1]. A typical five level inverter topology is shown in Figure 1. Here for each leg there are four positive thyristors and four negative thyristors. These positive and negative thyristors are controlled using a opposite polarity PWM signal.
A multilevel voltage-source converter system is proposed for high-voltage, high-power applications such as back-to-back interconnection of power systems, large induction motor drives, and electrical traction drives. Multilevel voltage-source converters have a voltage unbalance problem in the dc capacitors. The problem may be solved by use of additional voltage regulators or separate dc sources. However, these solutions are found not to be practicable for most applications. The proposed converter system can solve the voltage unbalance problem of the conventional multilevel voltage-source converters, without using any additional voltage balance circuits or separate voltage sources. Mechanism of the voltage unbalance problem is analyzed theoretically in this paper. The validity of the new converter system is demonstrated by simulation and experiment.

Table 1 lists the output voltage levels possible for one phase of the inverter with the negative dc rail voltage $V_0$ as a reference. State condition 1 means the switch is on, and 0 means the switch is off [2]. Each phase has five complementary switch pairs such that turning on one of the switches of the pair require that the other complementary switch be turned off. The complementary switch pairs for phase leg A are (Sa1, Sa’1), (Sa2, Sa’2), (Sa3, Sa’3), and (Sa4, Sa’4). Table 1 also shows that in a diode-clamped inverter, the switches that are on for a particular phase leg is always adjacent and in series.
However, the development of large VA rated converters with low harmonic distortion and fast dynamic response has been limited by the use of bulky transformers for multiple connections, the device ratings, and problems of series connections of devices. On the other hand, a multilevel voltage-source converter has been attracting many researchers, because it has the following features compared with a conventional 5-level pulse width modulation converter:

- It is much more suitable to high voltage, large VA rated applications. The efficiency is much higher and can be more than 99%.
- It generates an M-step staircase waveform of output voltage with the line frequency switching and without converter transformers for an M-level converter, thus reaching almost pure sinusoidal output voltage by increasing the number of levels.
- Since the multilevel converter itself consists of series connection of switching devices and each device is clamped to the dc capacitors through the diodes, it does not require special considerations to balance voltages of the switching devices.
- Electromagnetic interference level is much lower because \( \frac{dv}{dt} \) at switching is one of that of the conventional 5-level converters.

**IV. MATLAB/SIMULINK RESULTS AND DISCUSSION**

In this paper a five level diode clamped inverter is modeled using MATLAB/ Simulink along with the three level boost converter to balance the dc link capacitors. Here a separate technique is employed to control the inner dc link capacitors and outer dc link capacitors.
The inner two capacitors are controlled using a three level boost converter and the outer two capacitors are controlled using generalized method by taking the voltage across inner capacitors as reference.

![MATLAB/Simulink model Capacitor Balancing using three level boost circuit](image)

**Figure 7:** MATLAB/Simulink model Capacitor Balancing using three level boost circuit

**V. CONCLUSION**

In this paper, two control schemes for the active regulation of flying capacitors in FCCs are proposed. They are based on the converter equations and involve implementing simple rules. In this method, the modulation index is manipulated to regulate the capacitor voltages. The implementation of the proposed control methods is very straightforward. Moreover, both of these control schemes can be generalized and expanded to FCCs with any desired number of levels. The simulation and experimental results clearly show the effectiveness of both methods in maintaining balanced capacitor voltages.

**VI. REFERENCES**


