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Multi Level Converters for Medium Voltage Applications

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Abstract - This paper focuses on basic introduction to the three configuration of multilevel inverter and the fabrication of one of the configuration .Three topologies are proposed for voltage balance in multilevel converters i.e 1) diode-clamp, 2) flying capacitors or capacitor clamped, and 3) cascaded-inverters with separate dc sources. The circuit topologies, advantages ,disadvantages of all the three configurations and the circuit diagram for hardware fabrication of diode clamped three level single phase inverter is discussed.

Keywords **- Three level voltage source inverter.**

1. Introduction

In today's era, high power equipment of Megawatt level is used in industries. To work with the higher voltage levels, a family of multilevel inverters has come up as a solution. Multilevel converters are better than two level converters due to improved efficiency, lower voltage and current on the switching devices, extremely low *dv/dt* and audible noise resulted from small voltage steps and low switching frequency per device. Hence it is found that, multilevel converters are more suitable for medium and high voltage applications.

2. Multilevel Inverters

An array of power semiconductors and capacitors voltage sources are used in multilevel inverters, the output voltage of which is in the form of stepped waveform. An output voltage with two values (levels) with respect to negative terminal of the capacitor is generated by two level inverters. Similarly three level inverters generate three levels and so on. The output voltage in the form of staircase waveform with reduced harmonic distortion is generated by increasing the number of levels in the inverters. Several modulation and control strategies have been developed or adopted for multilevel inverters including the following: multilevel sinusoidal pulse width modulation (PWM), multilevel selective harmonic elimination, and space-vector modulation (SVM). Major limitations of multilevel converters are the voltage unbalance between different levels. The technique to balance the voltage between different levels normally involves voltage clamping or capacitor charge control. Three topologies to implement voltage balance in multilevel inverters are:

1. Diode clamped (Neutral clamped)
2. Capacitor clamped (flying capacitor)
3. Cascaded inverters with separate DC sources.

2.1 Diode clamped inverter

With diodes blocking the sources, the diode clamped multilevel inverters are derived. As mid voltage level was defined as the neutral point in three level inverter, hence the diode clamped inverters are also called as neutral point clamped inverters (NPC). Device voltage level can be effectively doubled by using NPC inverters.

Advantages and disadvantages of diode clamp multilevel voltage source converter are as follows:

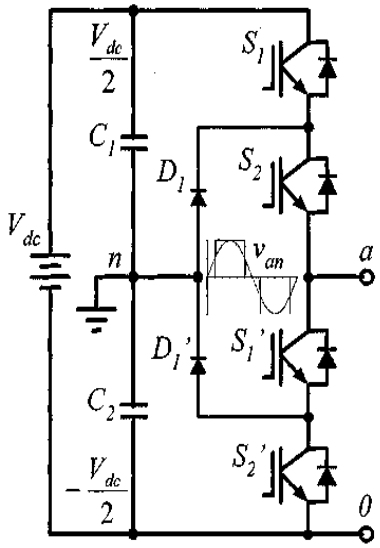


Figure 1

(a) Diode-clamped multilevel inverter circuit topologies : Three level [1]

Advantages:

- The need of filter is avoided when the number of levels is high enough and hence the harmonic contents will be low.
- As all the devices are switched at the fundamental frequency, efficiency is high.
- Reactive power flow can be controlled.
- For back to back intertie system the control method is simple.

Disadvantages:

- When the number of levels is high then excessive clamping diodes are required.
- For individual converter the real power flow control is difficult.

2.2. Capacitor Clamped (flying capacitor):

In capacitor clamped inverters, independent capacitors clamp the device voltage to one capacitor voltage level. Advantages and disadvantages of capacitor clamped multilevel voltage source converter are as follows:

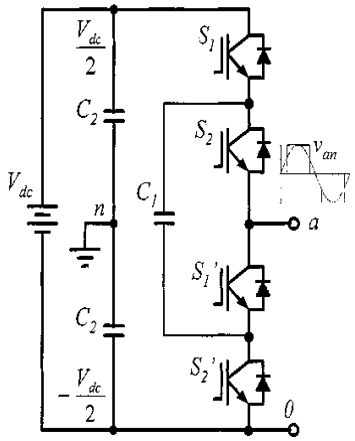


Figure 2

(b) Capacitor-clamped multilevel inverter circuit topologies : Three level [1]

Advantages:

- During power outage large amount of storage capacitors provides extra ride through capabilities.
- For balancing different voltage levels switch combination redundancy is provided.
- Both real and reactive power flow can be controlled.

Disadvantages:

- It is difficult to package high level systems and it is more expensive with required bulky capacitors.
- For real power transmission the switching frequency and switching losses will be high and the inverter control will be very complicated.

2.3. Multilevel Converter using Cascaded Inverters with Separate DC Sources:

Cascaded inverters are used in areas where there is a great demand of medium voltage high power inverters. Cascaded inverters are more suitable for motor drives and utility applications.

Advantages and disadvantages of cascaded inverter based multilevel voltage source converter are as follows:

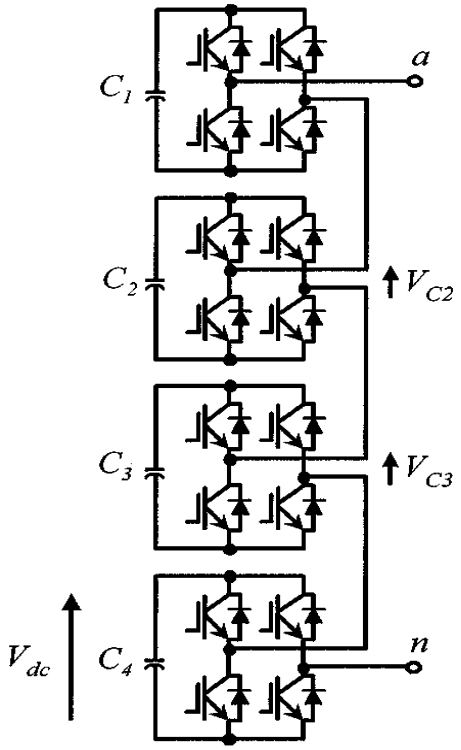


Figure 3

(C) Cascaded inverter circuit topology and its associated Waveform [1]

Advantages:

- Among all multilevel converters, it requires the least number of components to achieve the same number of voltage levels.
- No extra clamping diodes or voltage balancing capacitors are there.
- Soft switching can be used in this structure.

Disadvantages:

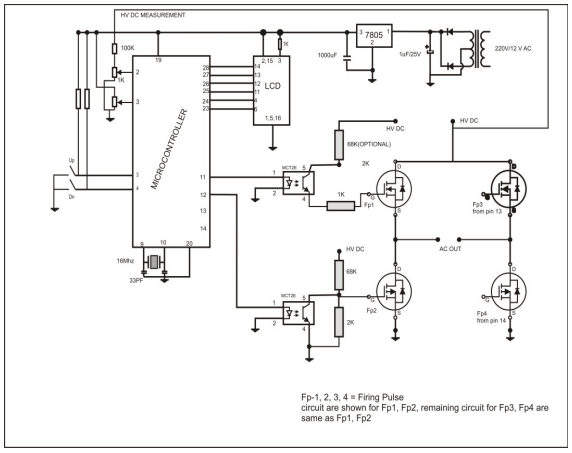
- For real power conversions, separate DC sources are needed and thus the applications are limited.

3. Applications

- All three multilevel converters can be used in reactive power compensation without having the voltage unbalance problem.
- Back to back intertie.
- Utility compatible adjustable speed drives.
- Multi pulse rectifiers have been used for the reduction of harmonics in the line current by using transformers for phase shifting in order to eliminate harmonics, to eliminate the phase shift transformers, multilevel rectifiers have been proposed.

Components	Ratings
Microcontroller	PIC (8 bit)
LCD	16 charac/2line
Voltage regulator	7805
Opto coupler	MCT2E
MOSFET : P type N type	 Z944 Z540
Capacitors	1000µf,470µf
Step down transformer	220v/12v AC
Diodes	IN 5407

4. Circuit Diagram for Hardware Fabrication of Diode Clamped Three Level Voltage Source Inverter



Components:

1. Step down transformer
2. Rectifier
3. Voltage regulator
4. LCD display
5. PIC Microcontroller
6. Opto Coupler
7. MOSFET
8. Diodes
9. Resistors and Capacitors

5. Working

Continuous power supply is given to the step down transformer which steps down the 220V ac to 12V ac. Rectifier rectifies the output of step down transformer .The rectified voltage is filtered by the capacitor .The filtered 12V dc is converted to constant 5V dc by voltage regulator .This constant 5V dc is supplied to microcontroller and LCD. Gates of MOSFETs are triggered by microcontroller through Opto couplers to get the desired output .Complementary pairs of MOSFETs are triggered at a time.

Desired result would be a approximate sine wave.

6. Conclusion

All the three converters can be used as a static Var generator. Diode clamp type multilevel inverter is more suitable as compared to other two types of converters for back to back intertie. The other two types of converters requires more switching per cycle and more complex control to balance the voltage for back to back intertie. The comparison among all the three converters assumes that all the devices have same voltage rating but not necessarily the current rating. Cascaded inverters are most promising for utility interface applications.Hardware fabrication using above circuit of three level inverter can generate desired output.

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