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# Multi-level Inverters Technology using Photovoltaic System

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**ABSTRACT**: In this paper three main types of multi-level inverters are reviewed (diode-clamped, flying capacitor, and cascaded H-Bridge inverters). Different multi-level inverter topologies which are currently available on the market as far as components for the electrical integration of PV systems are also concerned. The new trends of all of these topologies are seeking to reduce the cost, the size of the inverter and the losses by reducing the number of the switches and capacitors and keeping the output voltage steps high enough at least to be similar to the previous topologies.

**KEYWORDS**: Photovoltaic, Multi-level inverter, Diode clamped, flying capacitor, cascaded H-Bridge inverters.

## I. INTRODUCTION

Since the 1990s switching devices such as GTO thyristors and IGBT transistors have been widely used in Power Electronic Converters. These Converters are currently classified into:
a) Rectifiers — Converters that convert an input alternating voltage and current into output direct voltage and current;
b) Inverters — Converters that convert input direct voltage and current into output alternating voltage and current;
c) DC voltage Converters (Choppers) — Converters that convert input direct voltage and current of one value into output direct voltage and current of other values;
d) AC Converters — Converters that convert input energy with one parameters (alternating voltage, current, number of phases, frequency) into alternating output energy with other parameters.
This paper investigates the realization of a Multilevel Inverter (MI) that belongs to category (b) —Inverters. The conventional single-phase Inverter generates ordinary rectangular voltage on its output. Power Electronic switchers are switched to two input voltages— positive and negative. This type of Inverter is called a two-level Inverter. Electronic Switchers are stressed by full input DC voltage in this case. The Electronic Switcher voltage stress can be reduced using a series connection or a Multilevel Inverter. Conventional Inverters are used in low-voltage electrical equipment up to 1 kV.
For medium and high voltage equipment over 1 kV, a series connection of GTO/IGBT or a Multilevel Inverter is applied. The three-level Inverter is the Multilevel Inverter with the smallest number of levels. The advantages of three-level Inverter topology over conventional two-level topology are:
• The voltage across the switches is only one half of the DC source voltage;
• The switching frequency can be reduced for the same switching losses;
• The higher output current harmonics are reduced by the same switching frequency.

Multilevel Inverters find applications in new areas of medium- and high- voltage applications,
e.g. frequency Inverters for high voltage adjustable speed drives, Inverters for high- voltage compensators, high-voltage Unified Power Flow Controllers (UPFC), and high- voltage Active Power filters, etc. Voltage sources of the next levels can be realized as separated sources or as voltage capacitor dividers. Separated sources require further Power Hardware. The chief problem in Multilevel Inverters with capacitor dividers is the proper control strategy for voltage stabilization without additional Power Hardware. The most popular types of MI are Diode Clamped Multilevel Inverters (DCMI) and Flying Capacitor Multilevel Inverters (FCMI). For a three-level topology, only both types of MI can be designed without any separated voltage sources or auxiliary Power circuits. Papers [6] and [7] compare these two types of Multilevel Inverters from various points of view. The comparison was realized for the same output Powers. The mathematical models for both types of In-verters were investigated in the Simulink program. This comparison showed that three-level DCMI requires the total capacity of all capacitors to be at least two times lower

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than three-level FCMI in order to achieve the same capacitor voltage swinging. Hence the DCMI solution is considered more effective for three-level MI.

However, for a higher number of levels than 3 in DCMI, the capacitor voltage cannot be balanced using only the control strategy. Additional circuits or independent sources are required. For example, paper[3] describes the stabilization of capacitor voltage in five-level DCMI using the advanced strategy together with auxiliary circuits. On the contrary the voltage can be stabilized using only the control strategy in FCMI for all levels. Multilevel Inverters with more than three levels are mainly used in high-voltage applications for the voltage greater than 10 kV.The purpose of this paper is to present the results of a theoretical study and the practical realization of a five-level FCMI. After a brief description of five-level FCMI topology, we present the simulation and experimental results. The simulation and experimental results of five-level FCMI are carried out on a model, supplied with 200 V DC source. Both of these results show that a five-level output voltage is generated and the capacitor voltage is stabilized using only the control strategy. Five-level FCMI is investigated here because only this strategy is able to balance the capacitor voltage using only the control strategy.
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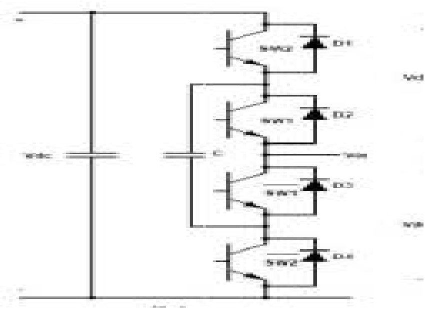
## II. PHOTOVOLTAIC SYSTEM MULTI-LEVEL INVERTERS

Multi-level inverters are able to synthesize a higher output voltage compared to the voltage rating of each incorporated switching device and allow for a much smoother output wave.Also the harmonic distortion is reduced. Different types of multi-level inverters are available these days. There are three main multi-level inverters; diode-clamped inverter, flying capacitor inverter and cascade H- Bridge inverters.

## III. FLYING CAPACITOR INVERTER

The flying capacitor inverter configuration is an alternative to the diode-clamped variety. However, in the case of the flying capacitor configuration, voltage across an open switch is constrained by means of clamping capacitors rather than diodes shows the single leg of a three level of flying capacitor inverter. If the input DC link is Vdc and theflying capacitor works in a state of balance, in order to attain equal step voltages at output voltage, the clamped capacitor must be regulated at VC1 = Vdc/2 in the case of a three-level inverter. The clamped capacitor for a four level inverter should be regulated to VC2 = 2VC1 = 2Vdc/3. It should be noted thatalong with the increase in quality achieved with a four level inverter, voltage stresses on the switching components are reduced by a factor of Vdc/6. Although the output voltage levels in the flying capacitor inverter configuration are quite similar to the diode-clamped inverter; there are several switching states available to attain the same level. These are referred to as redundant switching states. Such redundancy provides the flexibility to balance the clamped capacitor voltages such that they may provide alternate current loops through the capacitors .Table II is describing the switching states of the flying capacitor inverter.



The possible switching states of flying capacitor inverter

| On- State switches | Vo |
|---|---|
| $\overline{SW1}$ and $\overline{SW2}$ | 0 |
| Sw2 and $\overline{SW1}$ | $0.5V_{dc}$ |
| Sw1 and $\overline{SW2}$ | $0.5V_{dc}$ |
| Sw1 and Sw2 | $V_{dc}$ |

Fig.1. Flying Capacitor Inverter Operation

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## IV. BASIC FEATURES

The topology consists of diodes, capacitors and **switching devices**.

- Although theoretically this topology has been designed to give infinite levels, but due to practical limitations this only gives up to six levels of voltage.
- Each leg consists of switching devices which are generally transistors.
- Every inverter limb consists of cells connected in inward nested series.
- Every cell has a single capacitor and two power switches. Power switch is a combination of a transistor connected with an anti-parallel diode.
- Unlike diode clamped inverter, this topology uses capacitors for clamping.
- An inverter with N cell will have 2N switches and N+1 different voltage levels including zero.
- We can also have negative voltage levels, and so all in all we can say that N cell multilevel inverter can give 2N+1 voltage levels.
- Capacitors nearer to the load have lower voltage.
- Capacitors nearer to the source voltage (Vdc) have higher voltage.
- The number of level depends upon the number of conducting switches in each limb.
- It is also known as Imprecated Cell Inverter.
- They are called Flying Capacitor Multilevel Inverter, because the capacitors float with respect to earth's potential.

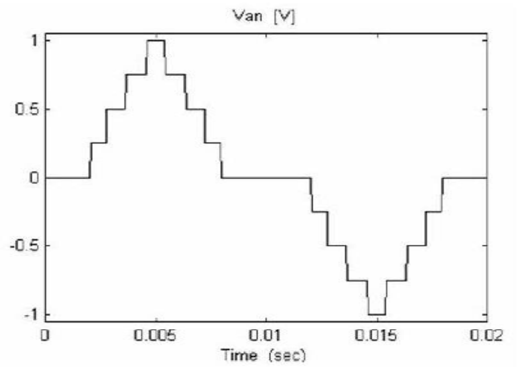


Fig.2. Converter Output

## V. VOLTAGE BALANCING OF CAPACITORS

One of the major advantages of using a Flying Capacitor Multilevel Inverter is its ability to operate at voltages higher than the blocking capacity of each power cell consisting of diode and switching element.
Current co-efficient of each limb is equal and opposite in polarity. That is why there is no net change in the charge of capacitors.
The cell and capacitor voltage difference is maintained within a safe band and hence there is no chance of unbalancing the capacitor voltages.

## VI. SWITCHING STRATEGY

To synthesize a sinusoidal waveform at the output, switching strategy needs to be defined. It is quite simple. Every voltage is applied at output with a certain electrical angle. Careful application of the angle gives low harmonic distortion and required amplitude at the output.
More than one switching strategies are available for a single voltage level. Three conditions should be followed for the right choice: For every change in the state, only one switch shift should be allowed. Capacitor's voltage balance should

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be maintained. All the switching devices should be used equally. Here the advantages is Each branch can be analyzed separately and individually and disadvantage is Pre charging of capacitors is necessary and difficult.

## VII. CONCLUSIONS

All in all flying capacitor multilevel inverter topology is famous topology which has its own benefits. The number of devices used in the circuitry is quite sufficient and is also economically controlled. This multilevel inverter gives good power quality performance.

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