

## Design of Seven Level Diode Clamped Multi Level Inverter

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**Abstract - This paper proposes three phase Seven level Diode Clamped Multilevel Inverter (DCMLI) to simulate various modulating techniques for induction motor load. These Pulse Width Modulation (PWM) techniques include Carrier Overlapping (CO) strategy, Variable Frequency (VF) strategy, Phase Shift (PSPWM) strategy and Sub-Harmonic Pulse Width Modulation (SHPWM) i.e. Phase Disposition (PD) strategy, Phase Opposition Disposition (POD) strategy and Alternate Phase Opposition Disposition (APOD) strategy. The Total Harmonic Distortion (THD), VRMS (fundamental), crest factor, form factor and distortion factor are evaluated for various modulation indices.**

### I.INTRODUCTION

the elementary concept of a multilevel Inverter to achieve higher power is to use a series of power semiconductor switches with several

lowerVoltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as theMultiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected [1-4].

### II. MULTI LEVEL INVERTER

The Multi-Level inverter has drawn a tremendous interest in power industry. They present an important in reactive power compensation. It may be either to produce a high power, high

voltage inverter with Multi level inverter. Increasing the number of voltage level without requiring higher rating of individual levels can increase the power rating.

The term *Multi-Level* began with the three levels Inverter. Subsequently, several multilevel Inverter topologies have been developed. However, the basic concept of a multilevel Inverter 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 [7-9].

The commutation of the power switches aggregate these multiple dc sources to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only on the rating of the dc voltage sources to which they are connected. Consider a three phase inverter system with DC input voltage. Series connected capacitors constitute the energy tank of the inverter [5-6]. Each capacitor has the same voltage which is given by,

$$E_m = (\text{Voltage input } V_{dc}) / (m-1)$$

Where  $m$  denotes the number of levels, the term  $m$  denotes the number of nodes to which the inverter can be accessible

### III. DIODE CLAMPED MULTI LEVEL INVERTER

In the 1990s, several researchers published articles that have reported experimental results for four-, five-, and six-level diode-clamped converters for uses such as static var compensation, variable speed motor drives, and high voltage system interconnections. A three-phase six level diode-clamped inverter is shown in Fig. Each of the three phases of the inverter shares a common dc bus, which has been subdivided by five capacitors into six levels. The voltage across each capacitor is  $V_{dc}$ , and the voltage stress across each switching device is limited to  $V_{dc}$  through the clamping diodes. Table 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.

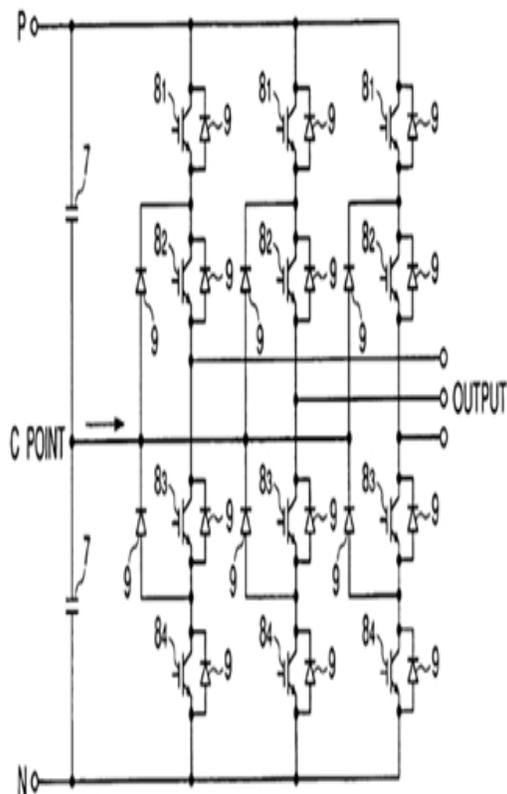
Each phase has five complementary switch pairs such that turning on one of the switches of the pair require the other complementary switch to be turned off.

The complementary switch pairs for phase leg  $a$  are  $(S_{a1}, S_{a\_1})$ ,  $(S_{a2}, S_{a\_2})$ ,  $(S_{a3}, S_{a\_3})$ ,  $(S_{a4}, S_{a\_4})$ , and  $(S_{a5}, S_{a\_5})$ . Table also shows that in a diode-clamped inverter, the switches that are on for a particular phase leg is always adjacent and in series.

For a six-level inverter, a set of five switches should be on at any given time. The line voltage  $V_{ab}$  consists of a phase-leg “a” voltage and a phase-leg “b” voltage. The resulting line voltage is a 11-level staircase waveform. This means that an  $m$ -level diode-clamped inverter has an  $m$ -level output phase voltage and a  $(2m - 1)$ -level output line voltage. Although each active switching device is required to block only a voltage level of  $V_{dc}$ , the clamping diodes require different ratings for reverse voltage blocking. Using phase  $a$  of Fig as an example, when all the lower switches  $S_{a\_1}$  through  $S_{a\_5}$  are turned on,  $D_4$  must block four voltage levels, or  $4V_{dc}$ . Similarly,  $D_3$  must block  $3V_{dc}$ ,  $D_2$  must block  $2V_{dc}$ , and  $D_1$  must block  $V_{dc}$ . If the inverter is designed such that each

blocking diode has the same voltage rating as the active switches,  $D_n$  will require  $n$  diodes in series; consequently, the number of diodes required for each phase would be  $(m - 1) \times (m - 2)$ . Thus, the number of blocking diodes is quadratically related to the number of levels in a diode-clamped converter.

One application of the multilevel diode-clamped inverter is an interface between a high-voltage dc transmission line and an ac transmission line. Another application would be a variable speed drive for high-power medium-voltage (2.4–13.8 kV) motors as proposed. Several authors have proposed for the diode-clamped converter that static var compensation is an additional function



**Fig 1: Approximated Diode Clamped Inverter**

#### IV. IMPROVED DIODE CLAMPED INVERTER

The power rating of the parallel inverter will now be considered. From Fig the apparent power delivered to the electrical system by the parallel inverter can be expressed as,

$$S_{PI} = S_L - (V_L * I_S) = (P_L + jQ_L) - V_L I_S$$

because the source current  $I_S$  and load voltage  $V_L$  are controlled such that they are in phase with the source voltage [73]. Multiplying and dividing the second term of Eq. (17.32) by  $V_S$  and substituting Eq. (17.27) yields the following,

$$V_L I_S = (V_L / V_S) * V_S I_S = (V_L / V_S) * P_L$$

Substituting Eq.(1) into Eq. (2) and combining like terms yields,

$$S_{PI} = P_L (1 - V_L / V_S) + jQ_L$$

Figure shows the apparent power  $S_{PI}$  in per unit that the parallel inverter must provide as a function of the source voltage  $V_S$  for loads of different power factors. Because the power transferred for voltage declines to less than 50% of nominal is predominantly real power, the parallel inverter would have to have an extraordinarily high rating if the conditioner were designed to compensate for such large voltage sags, just like the series inverter. From Fig. 17.31b, one can see that for voltage sag to 50% of nominal, the parallel inverter has to draw a current  $I_{PI}$  equal to that drawn by the rated load  $I_L$ . However, unlike the series inverter, the

dominant factor in determining the power rating of the parallel inverter is the load power factor if the conditioner is designed to compensate for only marginal voltage sags as shown in Fig. If the design of the universal power conditioner is to compensate for voltage sags to less than 50% of nominal voltage, then Eq. (17.31) should be used to determine the current rating of the parallel inverter. If the design of the conditioner is for marginal voltage sags (to 70% of nominal voltage) and the MUPC will be applied to a customer load that has a power factor of less than 0.9, then the following equation is more suited for calculating the current rating of the parallel inverter's active devices

One common design for the parallel inverter in a universal power conditioner is for the inverter to have a current rating equal to that of the rated load current

#### **V.CHARACTERISTICS OF DIODE CLAMPEDMULTI-LEVEL INVERTER**

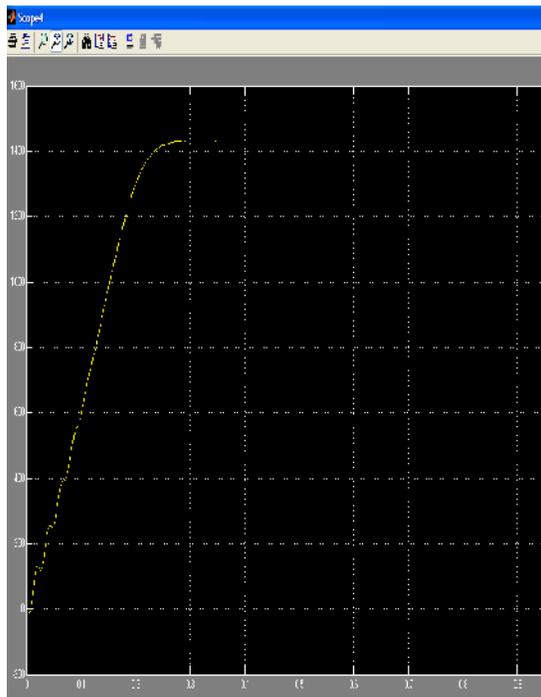
The multilevel inverter performance operation is compared from the phase disposition strategy (PDPWM)

The rules for Phase disposition strategy for a multilevel inverter are

1. The converter is switched to  $+V_{dc}/2$  when the sine wave is greater than both upper carrier.
2. The converter is switched to  $+V_{dc}/4$  when the sine wave is greater than first upper carrier.
3. The converter is switched to zero when sine wave is lower than upper carrier but higher than the lower carrier
4. The converter is switched to  $-V_{dc}/4$  when the sine wave is less than first lower carrier.
5. The converter is switched to  $-V_{dc}/2$  when the sine wave is less than both lower carriers.

The following formula is applicable to sub harmonic PWM strategy i.e. PD, POD and APOD The frequency modulation index  $m_f = f_c/f_m$  The Amplitude modulation index  $m_a = 2A_m/(m-1)A_c$  where  $f_c$  – Frequency of the carrier signal  $f_m$  – Frequency of the reference signal  $A_m$  –Amplitude of the reference signal  $A_c$  – Amplitude of the carrier signal  $m$  – number of levels.

#### **VI. SIMULATION RESULTS**



**Fig 2: Speed vs Rotor Angle**

## VII. CONCLUSION

The above work proposes three phase Seven level Diode Clamped Multilevel Inverter (DCMLI) to simulate various modulating techniques for induction motor load. These Pulse Width Modulation (PWM) techniques include Carrier Overlapping (CO) strategy, Variable Frequency (VF) strategy, Phase Shift (PSPWM) strategy and Sub-Harmonic Pulse Width Modulation (SHPWM) i.e. Phase Disposition (PD) strategy, Phase Opposition Disposition (POD) strategy and Alternate Phase

Opposition Disposition (APOD) strategy. Thus the Total Harmonic Distortion (THD), VRMS (fundamental), crest factor, form factor and distortion factor are evaluated for various modulation indices.

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