Comparative Analysis of Cascaded Multilevel Inverter with Different Switching Techniques

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Abstract— Multilevel inverters can provide an AC staircase output waveform without the use of a hefty passive filter. As a result, multilayer inverters are gaining favour for solar applications among various types of inverters. The total harmonic distortion (THD) of the voltage output waveform may become unsatisfactory if the switching angle configuration approach is not properly chosen. In this paper the algorithms based on space vector pulse width modulation for neutral point clamped multilevel inverter fed induction motor are suggested and implemented. These space vector-based algorithms produce the necessary basic frequency voltages, but they also remove harmonics to the full extent and thus reduce the overall harmonic distortion (THD). The objective is to discuss the various topologies of inverters along with the design of the multi-stage inverter circuit at the desired frequency with regulated amplitude and to decrease the harmonic distortion through harmonic elimination. For single and cascaded output voltages, a PSIM based model is developed. With the suggested circuit, the THD of the output voltage is decreased. Furthermore, the specifications of diodes and capacitors are also reduced for cascaded inverters.

Keywords — *Cascaded Multilevel Inverter, Switching Angle, Power Quality, THD.*

I. INTRODUCTION

Concerns about global warming and rising oil costs have accelerated the development of renewable energy sources such as solar, wind, and geothermal energy. Solar energy is one of the most important renewable energy sources accessible today. Solar radiation is converted to energy using photovoltaic panels in a photovoltaic system[1]. Inverters are the components that convert DC electricity to AC power at the specified output voltage. It also has other advantages, such as higher power quality, fewer order harmonics, lower switching losses, and lower electromagnetic interference and frequency [5]. The conversion of the input DC supply into the AC supply takes place at the desired frequency and voltage in ordinary two-level inverters with the help of semiconductor power switches. Depending on the setup, four or six switches are used. A group of switches provides the positive half cycle at the output, referred to as positive group switches, while another group provides the negative half cycle, referred to as negative group switches [2] – [4]. A full comparison of the traditional inverter and the multilayer inverter is presented in Table 1.

TABLE 1. COMPARISON OF CONVENTIONAL TWO LEVEL INVERTER AND MULTILEVEL INVERTER

Conventional inverter	Multilevel inverter
Higher THD in output voltage	Low THD in output voltage
Switching stresses are more on the device	Switching stresses reduces on the device
High voltage application is not available	It is applicable for high voltage applications
Higher voltage level of ouput are not produced	Higher voltage level of output are produced
Since dv/dt is high ,EMI for the system is high	Since dv/dt is low ,EMI for the system is low
Higher switching frequency is used hence switching losses are high	Lower switching frequency can be used hence reduction in switching losses
Power bus structure ,control scheme are simple	Control scheme become complex as number of level increases
Relaibility is high	Relaibility can be improved, rack swapping of level is possible

II. PROBLEM IDENTIFICATION

The power inverter's output voltage should be a pure sinusoidal waveform with minimal distortion. But the

output voltage for practical inverters is a sequence of rectangular waveforms. The key problems for power inverter control are having sufficient modulation methods to control the rectangular waveform output to synthesize the desired waveforms. Owing to the increased number of dc voltages, the multilevel inverters result in a better approximation of a sinusoidal waveform. This increased number of dc voltages offers an opportunity for more harmonic material to be removed. The residual harmonic material can be easily removed by smaller filters that are less costly. Several switches are needed in multilevel inverters, because of the large number of dc voltages. Since switch tension is decreased and lower switch grades are used.

Because of reduced harmonic distortion, lower electromagnetic interference, and higher DC voltages, their output is greatly superior to that of traditional two-level inverters.

III. METHODOLOGY

A. Conventional Two Level and Three Level Voltage Source Inverter

The Switched Inverter mode generates a sinusoidal AC output voltage whose magnitude and frequency can be controlled. They are widely employed in the field of AC induction motor drives. The Half Bridge Inverter is the most basic and simplest structure for generating the two-level square wave output voltage waveform. Figure 4.1 depicts the half bridge inverter's circuit operation. To avoid a shoot through fault, either switch S1 or S2 is turned on at the same time to provide a load voltage, VAO of $\frac{+V_s}{2}$ .To complete one cycle, S1 is turned OFF and S2 is turned ON to give a load voltage, VAO of $\frac{-V_s}{2}$.

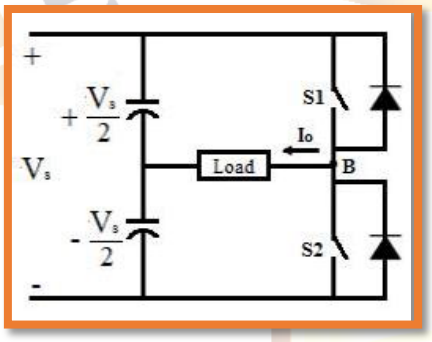

Fig. 1 Half Wave Inverter Circuit

The full wave bridge topology's circuit construction is shown in Figure 4.3. A three-level square wave output voltage waveform was achieved using this topology. The three possible levels are listed in Table 2. S1, S3, or S2 and S4 do not have to be closed at the same time. If this is the case, there will be a short circuit through the DC source.

TABLE 2. SWITCH OPERATION AND OUTPUT VOLTAGE LEVEL

Operated switch	Output Voltage
S1 & S4	+Vs
S2 & S3	- Vs
S1&S2 or S3 &S4	0

B. Multilevel Inverter

Three levels are the starting point or level for being called a multilevel inverter. Ideally, the number of levels increases to infinity to obtain zero THD on the output voltage. The limit is set by the problems of voltage unbalance, voltage clamping requirement, circuit layout and packaging restrictions for the number of voltage levels that can be achieved [6] – [10]. Electromagnetic compatibility issues have been reduced in multilevel inverters because it produces output at very low distortion and decreases stresses of dv/dt as well.

By producing low CM voltage, the multilevel inverter will reduce the stress on the bearings of a motor connected to it. In addition, by using advanced modulation techniques, CM voltage can be eliminated.

Simple switching frequency and high switching frequency PWM, the design of multilevel inverters is performed in such a way that they can easily work. It is obvious that the lower frequency of switching means lower loss of switching and greater performance. For that three distinct large multilevel inverter structures are used [11].

- Diode clamped /Neutral clamped Multilevel Inverter.
- Flying capacitors /Capacitor clamped Multilevel Inverter.
- Cascaded H-bridge Multilevel Inverter.

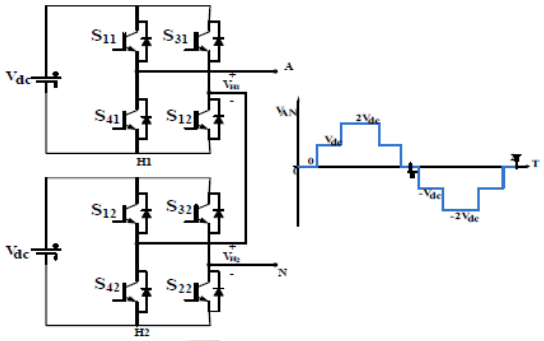

Fig. 2 Cascade H-Bridge Inverter

IV. CONFIGURATION OF PROPOSED MULTILEVEL INVERTER

In the proposed inverter, each transformer will create three voltage levels: zero, $+V_{dc}$, and $-V_{dc}$. The secondary sides of the transformers are connected in

series. $+nV_{dc}$ can thus provide the maximum voltage from the setup indicated in Figure 4.8, where n is the number of transformers. Different switching states and their corresponding output voltages will be established for the suggested, turn ratios of the transformers will be determined to be the same for the symmetric operation of the inverter. The proposed multilayer inverter has the following key goals:

1. A cascaded multilevel inverter transformer with a reduced number of switching components will be added.
2. The suggested topology utilizes single-phase low-frequency transformers and a source of DC voltage.
3. In contrast with traditional cascaded transformer multilevel inverters, this design will minimize the number of switches.
4. To minimize the low order harmonic elements, the selective harmonic elimination technique is applied.

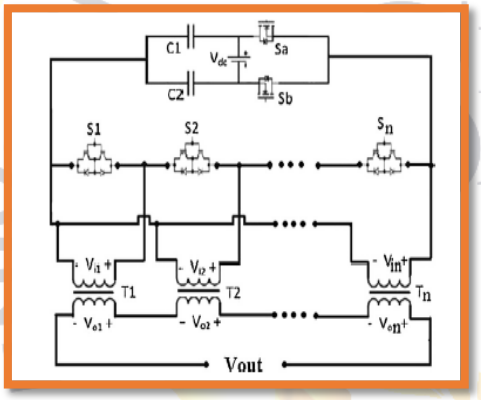

Fig. 3 Proposed Multi-level Inverter

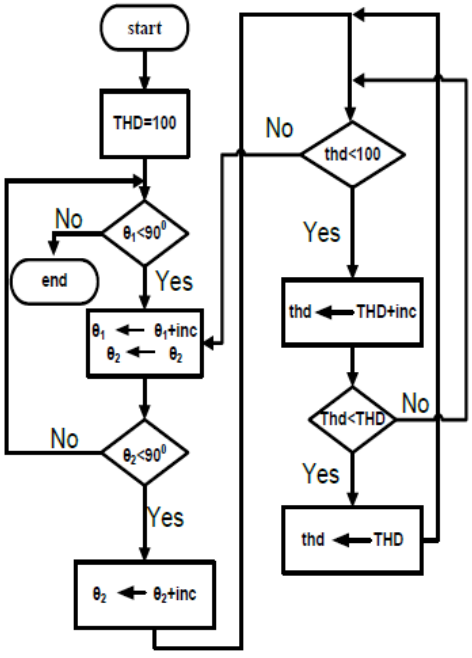

Fig. 4 Proposed control scheme

V. RESULTS AND DISCUSSIONS

A system that converts direct current (DC) to alternating current is an inverter or power inverter (AC). There are three types of inverters, such as square wave, modified-sine wave and pure sine wave, depending on the type of output waveform. A square wave, most commonly used in electronics and signal processing, is a non-sinusoidal waveform. The square wave has two (positive and negative) levels and alternates between these two levels on a regular basis.

The three-level inverters generate voltage in the typical mode, reducing motor stress and not damaging the motor. With low distortion, it can draw the input current. At both fundamental switching frequencies, which are higher switching frequency and lower switching frequency, the inverter will work. It should be remembered that the lower frequency of switching indicates lower loss of switching and greater efficiency is achieved. Together with the multi-level topology, the selective harmonic elimination approach results in the overall harmonic distortion being low in the output waveform without using any filter circuit. The three-level inverter provides many advantages over the two-level inverter, which is more common. For higher voltage converters, the NPC inverter is most commonly used. Since only half of the bus voltage is exposed to the IGBTs, lower voltage IGBT modules can be used.

TABLE 3 SWITCHING SEQUENCES BASED ON CONDUCTION MODE

Switching	Conduction mode	Conduction mode
	ON	OFF
S1	0-180	180-360
S2	0-180	180-360
S3	180-360	0-180
S4	180-360	0-180

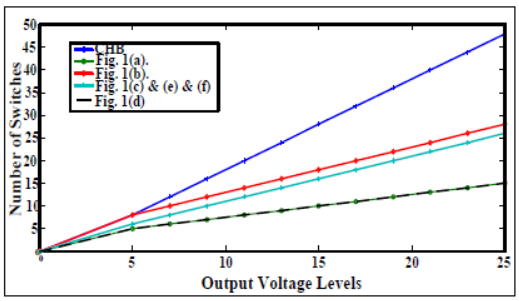

Fig. 5 Comparison of Various Topologies

VI. CONCLUSIONS

Inverters with cascaded H-bridges with different dc sources, clamped (neutral-clamped) diode and flying capacitors (capacitor clamped). In addition, for

multilevel inverters such as sinusoidal pulse width modulation (SPWM), selective harmonic elimination (SHE-PWM), space vector modulation (SVM), and others, abundant modulation techniques and control paradigms have been developed. In addition, many multi-level inverter applications concentrate on medium-voltage industrial motor drives, renewable energy system utility interfaces, Versatile AC Transmission System (FACTS) and traction drive systems. We have considered Square wave as outputs in the paper because this is one of the simplest waveforms an inverter configuration can provide and is most suitable for low-affectability applications, such as lighting and warming. The THD of the 7-level inverter output voltage waveform is found to be 1.5 percent lower than the traditional cascade h bridge multilevel inverter. The proposed inverter eliminates the need for a filter. It is also used along with the single DC sources for all the bridge mix.

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