Comparative Study of Different Firing Scheme for three Phase Voltage Source Inverter

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ABSTRACT

Inverters are used to create single or polyphase AC voltages from a DC supply. In the class of polyphase inverters, three-phase inverters are by far the largest group. A very large number of inverters are used for adjustable speed motor drives. The typical inverter for this application is a “hard-switched” voltage source inverter producing pulse-width modulated (PWM) signals with a sinusoidal fundamental. Recently research has shown detrimental effects on the windings and the bearings resulting from unfiltered PWM waveforms and recommends the use of filters.

According to the type of ac output waveform, these topologies can be considered as voltage source inverters (VSIs), where the independently controlled ac output is a voltage waveform. These structures are the most widely used because they naturally behave as voltage sources as required by many industrial applications.

The vital role of voltage source inverters for the high power AC motor drives has been described. The concept of pulse width modulation and different PWM Techniques has been emphasized. The proposed switched mode PWM inverter has been discussed in detail, which is one among the various types of VSIs. The concept of PWM current ripples in the output current, its variation due to change in high frequency clearly shows that the use of filters becomes mandatory in order to reduce it.

Keyword---- BOS, APOD, DSPs, MATLAB

I. INTRODUCTION

Inverters are used to create single or poly phase AC voltages from a DC supply. In the class of the poly phase inverters and three phase inverters are by far the largest group. A very large number of the inverters are used for adjustable speed motor drives. The typical inverter for this application is a “hard switched” voltage source inverter producing pulse width modulated (PWM) signals with a sinusoidal fundamental. Recently research has shown detrimental effects on the windings and the bearings resulting from unfiltered PWM waveforms and recommend the use of the filters. A very common application for single phase inverters are so called “uninterruptable power supplies” (UPS) for computers and other critical loads. Here and the output waveforms range from square wave to almost ideal sinusoids. UPS designs are classified as either “of-line” or “online”. An of line UPS is connect the load to the utility for most of the time and quickly switch over to the inverter if the utility fails. An online UPS is always feed the load from the inverter and switch the supply of the DC bus instead. Since the DC bus is heavily buffered with capacitors and the load sees virtually no disturbance if the power fails.

Modern inverters use insulated gate bipolar transistors (IGBTs) as the main power control devices and Besides IGBTs and power MOSFETs are also used especially for lower voltages and power ratings and applications that require high efficiency and high switching frequency. In recent years and IGBTs and MOSFETs and their control and protection circuitries have made remarkable progress. IGBTs are now available with voltage ratings of the up to 3300 V and current ratings up to 1200 A. MOSFETs have achieved on-state resistances approaching a few milliohms. In addition to the devices and manufacturers today of the customized control circuitry that provides for electrical isolation and proper operation of the devices under normal operating conditions and protection from a variety of the fault conditions. In addition and the industry provides good support for specialized passive devices such as capacitors and mechanical components such as low inductance bus-bar assemblies to facilitate the design of the reliable inverters. In addition to the aforementioned inverters and a large number of the special topologies are used.
II. TYPES OF THE INVERTER

1. Single Phase Inverters

Figure 2.1 shows the basic topology of a full bridge inverter with single phase output. This configuration is of their called an H bridge and due to the arrangement of the power switches and the load. The inverter can deliver and accept both real and reactive power.

The controller is hereby control the duty cycle of the conduction phase of the switches. The average potential of the centre-point of each leg is be given by the DC bus voltage multiplied by the duty cycle of the upper switch and if the negative side of the DC bus is used as a reference. If this duty cycle is modulated with a sinusoidal signal with a frequency that is much smaller than the switching frequency and the short term average of the centre-point potential is follow the modulation signal. “Short term” in this context means a small fraction of the period of the fundamental output frequency to be produced by the inverter. For the single phase inverter and the modulation of the two legs are inverse of each other such that if the left leg has a large duty cycle for the upper switch and the right leg has a small one and etc. The output voltage is then given by Eq. (5.1) in which $m_a$ is the modulation factor. The boundaries for $m_a$ are for linear modulation. Values greater than 1 cause over modulation and a noticeable increase in output voltage distortion.

![Figure 2.1 Topology of a single-phase and full-bridge inverter.](image)

2. Three-Phase Inverters

Figure 2.2 shows a three-phase inverter and which is the most commonly used topology in today’s motor drives. The circuit is basically an extension of the H-bridge-style single-phase inverter and by an additional leg. The control strategy is similar to the control of the single-phase inverter and except that the reference signals for the different legs have a phase shift of 120° instead of the 180° for the single-phase inverter. Due to this phase shift and the odd triple harmonics (3rd, 9th, 15th, and etc.) of the reference waveform for each leg are eliminated from the line-to-line output voltage. The even-numbered harmonics are cancelled as well if the waveforms are pure AC and which is usually the case. For linear modulation and the amplitude of the output voltage is reduced with respect to the input voltage of a three-phase rectifier feeding the DC bus by a factor given by Eq. (5.2). The inverter shown in Fig. 2.2 provides a three-phase voltage without a neutral point. A fourth leg is added to provide a four-wire system with a neutral point. Likewise four-and five-and or n-phase inverters are realized by simply adding the appropriate number of the phase legs.

![Figure 2.2 Topology of the three-phase inverter.](image)

3. Voltage Source Inverters

According to type of the ac output waveform and these topologies is considered as the voltage source inverters (VSIs) and where the independently controlled ac output is the voltage waveform. These structures are used because they naturally behave as voltage sources as required by many industrial applications and such as adjustable speed drives (ASDs) and which is the most popular application of the inverters. Similarly and these topologies is found as current source inverters (CSIs) and where the independently controlled ac output is the current waveform. These structures are used in medium voltage industrial applications and where high quality voltage waveforms are required. Static power converters specifically type inverters are constructed from power switches and ac output waveforms are therefore made up of the discrete values. This leads to the generation of the waveforms that feature fast transitions rather than smooth ones.

3.1 Single Phase Voltage Source Inverters

Single phase voltage source inverters (VSIs) are found as half bridge and full bridge topologies. Although powers range them cover is the low one and they are widely used in power supplies and single phase UP and currently to form elaborate high power static power topologies and such as for instance and the multicell configurations.

3.1.1 Half Bridge VSI

Fig.2 shows the power topology of the half bridge VSI. Where two large capacitors are required to provide a neutral point N and such that each capacitor maintains a constant voltage $(V_i)/2$. Because the current harmonics injected by operation of the inverter are low order harmonics and a set of the large capacitors $(C+ and C−)$ required. It is clear that both the switches $S^+$ and $S^−$ cannot ON simultaneously because a short circuit across the dc link voltage source $V_i$ produced. There are two defined
(states 1 and 2) and one undefined (state 3) switch state. In order to avoid the short circuit across the dc bus and the undefined ac output voltage condition and modulating technique always ensure that at any instant either the top or bottom switch of the inverter leg is on.

### 3.2.2 Full Bridge VSI

Fig. 3 shows the power topology of the full bridge VSI. This inverter is similar to half bridge inverter however and a second leg provides the neutral point to the load. As expected and both switches $S_1^+$ and $S_1^-$ (or $S_2^+$ and $S_2^-$) cannot on simultaneously because a short circuit across the dc link voltage source $V_i$ produced. There are four defined (states 1 2 3 and 4) and one undefined (state 5) switch states. The undefined condition avoided so as always capable of the defining the ac output voltage. Several modulating techniques developed that are applicable to full bridge VSIs. Among them are PWM bipolar and unipolar techniques.

### III. THREE PHASE VSI PWM INVERTER

In the industrial application and VSI is used and because a wide range of the speed control is possible. Three phase VSI is operated at the two modes i) 180 degree mode operation ii) 120 degree mode operation. In 180 degree mode of the operation three switches conduct at one cycle and each IGBT is operated at 60 degree delay angle. In this mode of the operation and easily gets the pure sine wave using a filter. So that it is called as a quasi square wave mode or switched mode. In 120 degree mode of operation is pair of the switch conduct at 120 degree delay angle. In this mode a shoot through fault are occurs.

A six step bridge is used for three phase inverter by using six switches and with two switches for each phase. Each step is defined as a change in the time of the operation for each IGBT to the next IGBT in proper sequence. For one cycle of the 360°and each step would be of the 60° intervals for a six step inverter, power circuit diagram of a three phase bridge inverter using six IGBTs. The source voltage $V_s$ fed from three phase uncontrolled rectifier. Large capacitors ($C_1=V_s/2$ and $C_2=V_s/2$) are connected at input terminal to make the DC input constant and also to suppress the harmonics fed back to source. $T_1$ $T_2$ $T_3$ $T_4$ $T_5$ and $T_6$ is the IGBTs switch. In fig. a b and c are the output terminals of the switched mode PWM inverter. This output terminals fed by three phase induction motor and where $n$ is the three phase induction motor neutral terminal.

There are two patterns of the gating the transistors. In one pattern and each transistor conducts for 180 degree and in the other and each transistor conducts for 120 degree. But in both the patterns gating signals are applied and removed at 60 degree intervals of output voltage waveform. Both the modes require a six step bridge inverter.

#### 3.1 Three-Phase 180 Degree Mode VSI

Three switch conduct for 180 degree mode of the operation. The conduction sequence is written as follows $T_6T_1T_2$ and $T_1T_2T_3$ and $T_2T_3T_4$ and $T_3T_4T_5$ and $T_4T_5T_6$. For consider one switching sequence $T_1T_2T_3$ and $T_1T_3$ are upper group and $T_2$ is lower group. $T_1$ operated delay at $t=0^0$ and $T_3$ operated delay at $t=120^0$ and $T_2$ operated delay at $t=60^0$. Transistors in the upper group i.e. $T_1and T_3and and T_5$ conduct at an interval of the 120°. It implies that if $T_1$ is operated delay at $t=0^0$ and then $T_3$ must be operated delay at $t=120^0$ and $T_5$ delay at $t=240^0$ the same thing for lower group of the transistors. Table 3.1 shows the switching states for six switches and also phase to phase $V_{ab}$ and $V_{bc}$ and $V_{ca}$ voltages are obtained.

#### 3.2 Three-Phase 120 Degree Mode VSI

The power circuit diagram of the inverter is the same as shown in Fig. The 120 degree mode VSI and each transistor conduct for 120 degree of the cycle. Like 180 Degree mode and 120 Degree mode inverter also requires six steps and each of the 60 Degree duration and for completing one cycle of the output AC voltage.

During the first 120 degree and $T_1$ conducts with $T_6$ for 60 degree and then conducts with $T_2$ for another 60 degree. The $T_3$ is conduct for 120 degree (from 120 to 240) for 60 (from 120 to 180) with $T_2$ and then Conduct another 60 (from 180 to 240) with $T_4$. The $T_5$ is conducts 120 (from 240 to 360) with $T_4$ for 60 (from 240 to 300) and then conducts for another 60 (from 300 to 360) with $T_6$. The conduction sequence is written as $T_6T_1T_2and T_1T_2and T_3T_4and T_4T_5and T_5T_6and and T_6$. 

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The disadvantage of the 120° mode VSI is shoot through fault is occur during the conduction period.

IV. SWITCH TURN ON AND TURN OFF OF THE TRANSIENTS EFFECTS

The inverter output current ripple at the output and the associated problems are overcome by increasing the PWM switching frequency. This also reduces the filter size and cost and increases control bandwidth. Increasing the switching frequency requires fast turn on and turn off of the switches to minimize the switching losses. The turn on and turn off of the times of the modern IGBTs approach several hundred nanoseconds or less and which correspond to switching transients with frequencies of the MHz range. At these frequencies and the parasitic capacitive elements of the motor drive become effective. For AC motor drives fed by the standard utility grid and the DC bus voltage is approximately 550V and for switching times of the hundreds of the nanoseconds and the rate of the change (dv/dt) of the inverter output voltage is as high as 5kV/μs. Interaction between these voltage pulses and parasitic capacitances of motor drive cause undesired effects in the motor drive.

V. SIMULATION AND RESULTS
VI. CONCLUSION

The main role of voltage source inverters for the high power AC motor drives is described. The concept of pulse width modulation and different PWM Techniques is also emphasized. The proposed switched mode PWM inverter is discussed in detail which is one among the various types of VSI's. Since quasi square wave model VSI is widely used in industrial applications its modes of operation, switching states of the power circuit switches and switching sequence are presented in detail. The concept of PWM current ripples in the output current its variation due to change in high frequency clearly shows that the use of filters becomes mandatory in order to reduce it.

REFERENCES