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Review of Different PWM Techniques

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***Abstract*: -- In AC power the quality of sinusoidal waveform is more important than the quantity.In order to improve the quality, the harmonic content in the output must be reduced. To achieve this, different pulse width modulation techniques are used for different applications. This paper presents the overview of carrier based pulse width modulation techniques as a single pulse width modulation, multiple pulse width modulation, sinusoidal pulse width modulation and also deals with hysteresis current control technique.**

***Keywords*: PWM, SPWM, VSI**

I. INTRODUCTION

Prolong distance electrical transmission prefers AC power, as it is facile to vary the voltage levels by using the transformers. By enhancing the voltage, less current is required to dispatch a given quantity of power deliver to a load, minimizing the resistive loss through conductors. The preference of AC Power has created a trend where most devices adapt AC power from an external into DC power for use of the device. However, AC power is not eternally available and the need for portability and simplicity has given batteries preference in portable power. Thus, for mobile AC power, inverters are needed. Inverters are known as DC to AC power converters. In other words, an inverter is a circuitry that transforms a DC power into an AC power at required output voltage and frequency. The conversion is obtained by controlling the turn-on and turn-off of switching devices like IGBT's BJT's, MOSFET's, etc or by forced commutated thyristors depending on required output the switching devices are used.

The function of an inverter is to convert the DC input voltage to a symmetrical AC output voltage of the required amplitude and frequency.

The different methods of controlling the output voltage are

1. Controlling of the ac output voltage externally.
2. Controlling of the dc input voltage externally.
3. Controlling of inverter internally.

In external type of control, circuit becomes bulky, costly and complicated as chopper comes into action enlarging the losses so internal control of inverter is of better convenience. In internal control inverter output voltage can be adjusted by exercising the control within the inverter itself. The two possible ways of doing this are:

1. Series inverter control.
2. Pulse Width Modulation techniques.

Pulse-width modulation (PWM) employs a rectangular pulse wave whose pulse width is modulated leading the variation of the average value of the waveforms. The easiest way to produce a PWM signal is the interceptive method, which requires only a saw tooth or a triangle waveform and a control wave. When the value of the reference signal is greater than the modulation waveform, the PWM signal is at the maximum state; else it is at the minimum state.

II. TYPES OF PULSE WIDTH MODULATION

There are many PWM control techniques available for different applications of inverter. This paper includes following PWM techniques such as:

- Single-pulse width modulation (PWM)
- Multiple-pulse width modulation (MPWM)
- Sinusoidal pulse width modulation (SPWM)
- Hysteresis band pulse width modulation

A. SINGLE-PULSE WIDTH MODULATION

In Single-pulse width modulation, by comparing a rectangular reference signal of amplitude (Ar) with a triangular carrier wave (A_C) the signals are generated., There is only one pulse per half cycle of the output voltage in Single-pulse width modulation. The pulse width can be varied to control the output voltage of inverter.

The r.m.s value of the output voltage is given by:

$$V_0 = V_S\sqrt{\frac{2t_{on}}{T}}$$

$$\frac{t_{on}}{T} = \delta$$

Where,
Vs is the input DC voltage.
δ is the duty cycle.

Duty cycle is the ratio of the ON period to the OFF period ofthe output voltage wave. The fundamental frequency of the output voltage is obtained by the frequency of the reference signal. For this technique the amplitude modulation index (M) is be defined as

$$M = \frac{A_r}{A_c}$$

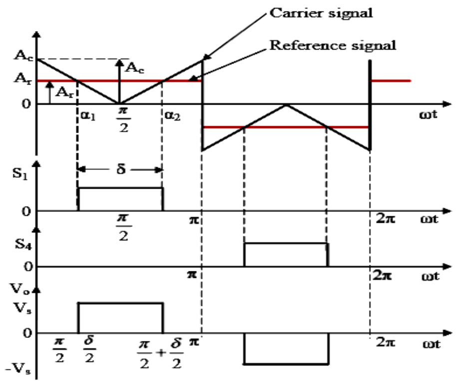

Fig.1: Generation of Single pulse width modulation

A. MULTIPLE-PULSE WIDTH MODULATION

In Multiple-pulse width modulation, there are multiple number of pulses per half cycle of output voltage. The widthof each pulse is similar and can be altered by varying the carrier signal. The frequency of the triangular carrier wave is greater than that used in Single-pulse width modulation. The frequency of the carrier wave decide the number of gating signals per half cycle. By using several pulses in each half cycle of output voltage, the harmonic content can be reduced. The formation of gating signals for turning ON and OFF transistors by comparing a reference signal with a triangular carrier wave. The frequency (Fc), decides the number of pulses per half cycle. By controlling the modulation index the output voltage can be controlled. Such type of modulation is also known as uniform pulse width modulation (UPWM).

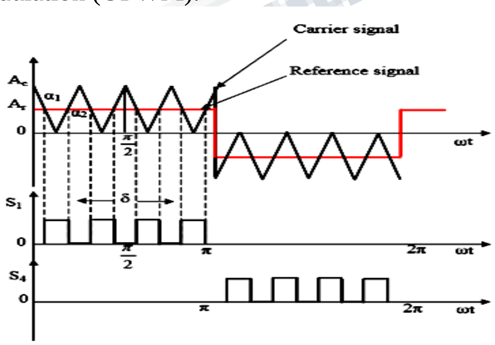

Fig.2: Generation of Multiple pulse width modulation

B. SINUSOIDAL PULSE WIDTH MODULATION

Sinusoidal PWM refers to the generation of PWM outputs with sine wave as the modulating signal. The OFF and ON time of a PWM signal in this case can be obtained by comparing a reference sinusoidal wave (modulating wave) with a triangular wave of high frequency (the carrier wave) as shown in Fig. 3. Sinusoidal PWM technique is widely used in industrial applications and is abbreviated here as SPWM. The frequency of the modulating wave decides the frequency of the output voltage. The peak amplitude of modulating wave decides the modulation index and controls the RMS value of output voltage. By changing the modulation index, the RMS value of the output voltage can be varied.

As compared to other ways of multi-phase modulation This technique improves distortion factor more significantly and also it eliminates all harmonics less than or equal to 2p-1, where "p" is defined as the number of pulses per half cycle of the sine wave. The output voltage of the inverter is not fully filtered it contains some harmonics. The higher order harmonics can be removed easily by using filter.

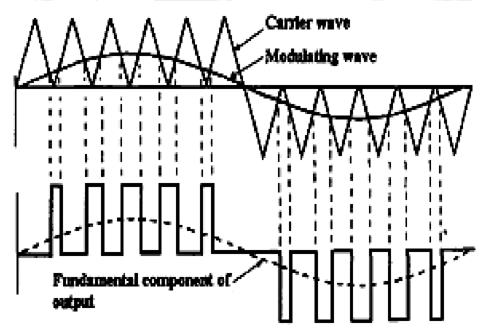

Fig.3: Sinusoidal pulse width modulation

In order to implement Sinusoidal PWM using analog circuits, one has to use the given building blocks (1) Triangular wave generator (2) Sinusoidal wave generator (3) Comparator (4) Inverter circuits.

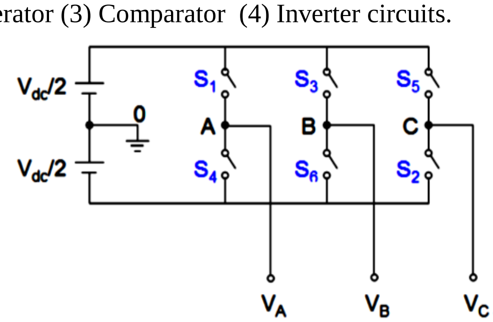

Fig.4: Three-Phase Sinusoidal PWM Inverter

SWITCHING STRATEGY

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The peak of the sinusoidal modulating waveform is less than the peak of the triangle carrier voltage waveform. When the sinusoidal waveform is higher
than the triangular waveform, the upper switch is turned ON and the lower switch is turned OFF. Similarly, when the sinusoidal waveform is lower than the triangular waveform, the upper switch is OFF and the lower switch is ON. According to the switching states, either positive or negative half DC bus voltage is applied to each phase. The switches are controlled in pairs ((S1; S4), (S3; S6), and (S5; S2)) and the logic for the switch control signals is:-

Sr.No.	Conducting Switches	Condition
1	S_1	Va>VT
2	S_4	Va<VT
3	S_3	Vb>VT
4	S_6	Vb<VT
5	S_5	Vc>VT
6	S_2	Vc<VT

Table1: switch control signals

The pulse widths depend on the intersection of the triangular and sinusoidal waveforms. The inverter output voltages are determined as follows
The inverter line-to-line voltages are obtained from the pole voltages as:
Vab = Vao-Vbo
Vbc = Vbo-Vco
Vca = Vco-Vao
The inverter line-to-line voltages are obtained from the pole voltages as:
Van= 2Vao-Vbo-Vco/3 >Vtri Then Vco = 0.5Vdc

C. HYSTERESIS BAND PULSE WIDTH MODULATION

Hysteresis PWM refers to the technique where the output is free to oscillate within a predefined error band, known as "hysteresis band". The switching instants in this case are generated from the vertices of the triangular wave shown in Fig.5. Hysteresis PWM techniques does not rely on any information about the inverter load characteristics. As far as the reference signal is known and the inverter output voltage does not saturated, the inverter output will always follow the path of reference band. For this technique the switching frequency of power devices is not fixed and will change depending upon the magnitude and frequency of the reference. Hence, switching losses for this technique can be greater to other techniques.

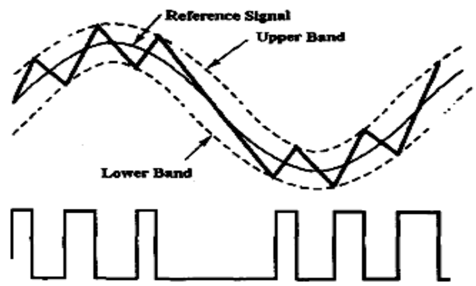

Fig.5: Hysteresis pulse width modulation

The Hysteresis Band PWM is described as an instantaneous feedback current control method of PWM where the actual current continuously follows the command current within a specified hysteresis band.

III. CONCLUSIONS

This paper gives overview of different techniques for simulation of different inverters. To study different PWM techniques for inverters. The hysteresis current control technique is last technique.

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