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The Comparative Study of Voltage Source Inverter using Sinusoidal PWM and Third Harmonic Injection PWM Techniques for Mitigation of Harmonics

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***Abstract*: The sinusoidal Pulse Width Modulation (SPWM) technique is one of the most popular PWM technique for controlling output and harmonic reduction of inverter. Advancement in power electronics and semiconductor technology have led to use of higher carrier frequency in PWM modulation techniques. In the presented work voltage source inverter is connected to the RL load with LC filter of three phase inverter. Two PWM techniques have been used to operate voltage source inverter are sinusoidal(SPWM) PWM and third harmonic injection(THIPWM) PWM. Both techniques are studied and compared in terms of harmonics distortion.**

***Keywords*: SPWM, THD, Voltage source inverter, carrier frequency, Modulation index, third harmonic injection PWM.**

1. Introduction

Inverter converts input DC voltage into a.c. output voltage. Three phase inverters are normally used for high power applications. The applications of inverters include uninterrupted power supply (UPS), adjustable speed drives, a.c. motor speed controllers etc.

These considered parameters are varied to get desired low harmonics output. In this paper sinusoidal PWM and third harmonic injection PWM techniques are considered to operate VSI. They are compared in terms of THD is simplest of all the above PWM techniques. The required signals for gates of inverter are generated by comparing reference sine wave and triangular wave.

Various PWM control strategies have been developed in the past decades [2]. To obtain variation of output voltage and modulation PWM control strategies such as Sinusoidal pulse width modulation (SPWM), Third harmonic pulse width (THPWM), Space vector pulse width modulation(SVPWM) and 60° PWM are most commonly used for three phase inverters. SPWM are compared with a high frequency triangular carrier signal (V_r). The resulting switching signals from each comparator are used to drive the inverter respective switches. The harmonic content in the converter output waveform is chosen as the performance criterion and it is desired to minimize for proper operation. The frequency of reference signal determines the inverter output frequency & amplitude of reference signal controls the modulation index. The harmonic distortion of SPWM is higher than other switching schemes especially at high modulating index. Switching losses are also high in SPWM. This technique is based carrier frequency variation and modulation index variation. At low to high carrier frequency harmonics decreases at output of three phase inverter with LC filter. Power MOSFET and insulated-gate bipolar transistor (IGBT) are largely used power semiconductor devices for inverters.

The voltage source inverter (VSI) gives controlled AC output voltage waveform and behaves as a voltage source for many industrial applications [10]. The output voltage waveform of VSI is unaffected by the load.

SPWM technique is characterized by constant amplitude pulses with different duty cycles for each period. The width of these pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content [12].

2. PWN techniques

PWM is most efficient control technique used within the inverter itself. In the PWM method, a constant input DC voltage is applied to the inverter and AC output voltage with desired frequency is obtained. It is accomplished by controlling turn on and turns off periods of the inverter switching devices. The main aim of these modulation techniques is to enhance the output of the inverters [1], [4]. The advantages of PWM techniques are that they are easy to implement and control, reduces lower order harmonics [5]. SPWM and THPWM techniques are analyzed and compared in terms of THD.

A. Sinusoidal PWM

Three sinusoidal modulating signals (V_m) at low frequency but displaced from each other by 120°.

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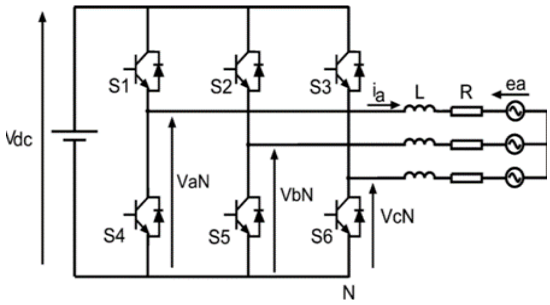

Fig. 1. Three phase voltage source inverter

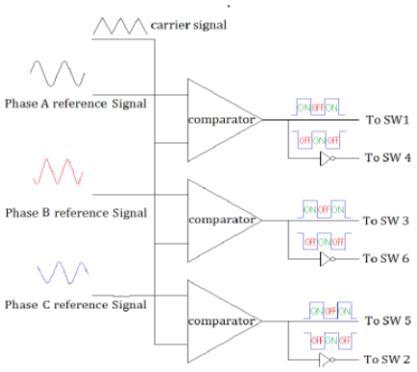

Fig. 2. Sinusoidal pulse width modulation

B. *Third harmonic injection PWM*

In order to improve the inverters performance third harmonic injection PWM (THIPWM) technique was developed. THIPWM is improved sinusoidal PWM technique which adds a third order harmonic content into sinusoidal reference signal (V_r) of fundamental frequency. The resultant waveform is compared with the high frequency triangular carrier waveform. The comparator output generates signal pulses to trigger switches of the inverter exactly as in SPWM inverter. Amplitude of third harmonic signal is 1/6 of sinusoidal reference signal. Addition of third harmonic to sinusoidal reference leads to 15.5% increase in the utilization rate of the DC voltage. The comparator output is used for controlling the inverter switches exactly as in SPWM inverter. The reference signal is composed of fundamental and third harmonic frequency components as following equations.

$$V_{mA} = m.\{\sin(\omega_0 t) + k.\sin(3.\omega_0 t)\}$$
$$V_{mB} = m.\{\sin(\omega_0 + 120^\circ) + k.\sin(3.\omega_0 t)\}$$
$$V_{mC} = m.\{\sin(\omega_0 + 240^\circ) + k.\sin(3.\omega_0 t)\}$$
$$V_{mK} = k.\sin(3.\omega_0 t)$$

C. *Amplitude modulation index*

It is ratio of amplitude of reference signal to the carrier signal.

$$M_a = \frac{A_m}{A_c} \qquad (1)$$

D. *Frequency modulation index*

It is a ratio of carrier frequency signal to reference frequency signal

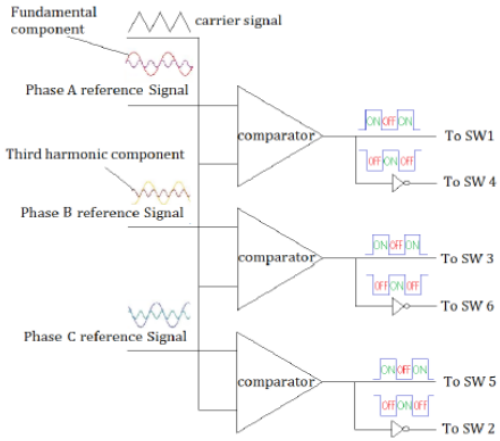

Fig. 3. Third harmonic injection PWM

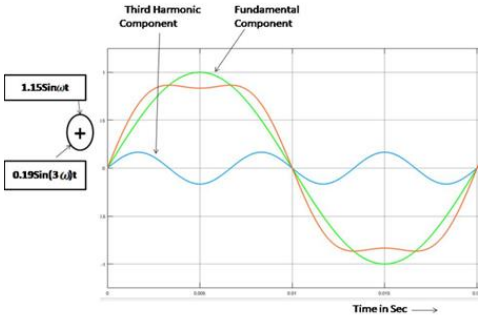

Fig. 4. Third harmonic injection PWM modulating signal

E. *Total harmonic distortion*

THD is defined as the ratio of the equivalent root mean square(RMS) voltage of all the harmonic frequencies (from the 2nd harmonic on) to the RMS voltage of the fundamental frequency signal. It can be defined by a formula given below:

$$\text{THD\%} = \frac{\sqrt{\sum_{n=2}^{\infty} V_{n\_rms}^2}}{V_{fund\_rms}} \text{ x } 100 \qquad (2)$$

It occurs due to non-linear loads which are drawing non-sinusoidal current from input.

3. Conclusion

In this paper, Simulink model for Sinusoidal PWM three-phase VSI with RL load as a load has been developed and tested in the MATLAB/Simulink at different career frequencies. The simulation results proved that THD for the output current decreases with increase in the carrier frequency connecting LC filter at inverter output. Means it has been clearly shown by varying carrier frequency from low to high value. We can minimize the THD of phase currents. So when carrier frequency varied from 2 KHz to 18 KHz and modulation index is 0.5 than THD in output current of inverter decrease.

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