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HARMONIC ANALYSIS AND THD CALCULATION OF TRAPEZOIDAL PWM TECHNIQUE BY FFT TOOLS

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Abstract

Pulse Width Modulation is a powerful technique for controlling analog circuits with a power sent to a load. PWM is a way of digitally encoding analog signal levels. There are a several PWM techniques which are being employed for diverse applications, a few of them being sinusoidal, square wave, trapezoidal, stair-case, delta, delta-sigma, space vector, harmonic injection, third harmonic PWM technique etc. PWM techniques aim at providing better controllable output voltage along with reduction of harmonics. This paper deals with harmonic analysis performed by trapezoidal PWM techniques using FFT tool of simulink in MATLAB.

Keywords:- FFT Tools, Pulse with modulation, Total Harmonic Distortion, Trapezoidal

NOMENCLATURE

α	Duty cycle
T_{on}	Turn-on time
T_{off}	Turn-off time
T	Chopping period
V_s	Supply voltage
V_{avg}	Average DC voltage
I_{avg}	Average load current
P_o	Output power
R	Resistance
σ	Triangular factor

1.INTRODUCTION

1.1 Principle of PWM

Pulse width modulation (PWM) is a powerful technique for controlling analog circuits with a processor's digital outputs.PWM of a signal or power source involves the modulation of its duty cycle, to either convey information over a communications channel or control the amount of power sent to a load[1].

1.2 Duty Cycle

It is defined as the fraction of time during which the switch remains on. Mathematically, duty cycle can be representated as follows [2]:

$$\alpha = T_{on} / (T_{on} + T_{off}) \quad (1)$$

$$\text{Or, } \alpha = T_{on} / T \quad (2)$$

where, T_{on} is the on-time, which is the time during which the DC supply is applied to the load, T_{off} is the off-time, which is the period during which that supply is switched off. Duty cycle can be varied from 0 to 100 % as shown in figure (1).

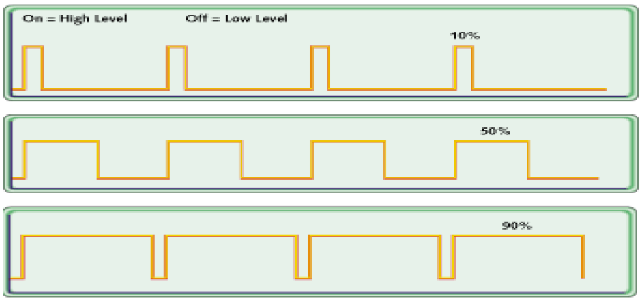

Figure 1 Duty cycle modulation

When a switch is closed for T_{on} seconds, the input voltage appears across the load; if switch is off for T_{off} seconds, then the voltage across the load is zero.

a. Governing Equations

- Average DC voltage

$$V_{avg} = 1/T \int_0^{Ton} Vs\, dt = (T_{on}/T)V_{in} = \alpha\, V_{in} \quad (3)$$

- Average DC current

$$I_{avg} = (V_{avg}/R) = \alpha V_{in}/R \quad (4)$$

- RMS value of o/p voltage

$$V_{rm} = [1/T\int_0^{Ton} Vs^2\, dt]^{1/2} = \alpha^{1/2} V_{in} \quad (5)$$

- Output power (P_o) = $(V_{rms}^2)/R = (\alpha V_{in}^2)/R$ (6)

The duty cycle can be varied from 0 to 1 by varying T_{on} and T. Therefore, the output voltage V_o can be varied from 0 to V_s by controlling α, and the power flow can thus be controlled. Basically, the width of the pulse is varied in this technique and is called Pulse Width Modulation (PWM) control.

b. Trapezoidal PWM Technique

Comparing a triangular carrier wave with the modulating one, the gating signals are generated by trapezoidal wave as shown in the figure below.

- The trapezoidal wave can be obtained from a triangular wave by limiting its magnitude to $\pm$ A_r which is related to the peak value A_r (max) by

$$A_r = \sigma\, A_r\,(max) \quad (7)$$

Where, σ is the triangular factor.

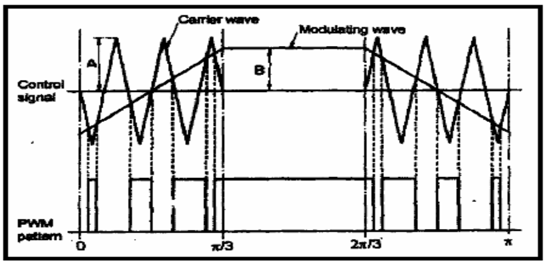

Figure 2 Trapezoidal PWM Technique

- To limit switching losses it is necessary to control the device switching frequency, irrespective of the fundamental frequency of the current waveform. This can be achieved by making the parameter *m*, the pulse number in half cycle of the inverter operation, constant in many segments of the fundamental frequency

2.HARMONIC ANALYSIS USING FFT ANALYSIS TOOL IN MATLAB-SIMULINK

2.1 Harmonic Limits

- According to IEEE 519, harmonic voltage distortion on power systems of 69 kV and below is limited to 5.0% of total harmonic distortion (THD) with each individual harmonic limited to 3%.
- The current harmonic limits vary based on the short circuit strength of the system they are being injected into [3]. Essentially, the more the system is able to handle harmonic currents, the more the customer is allowed to inject.
- The harmonic current limits specify the maximum amount of harmonic current that the customer can inject into the utility system.
- The utility is responsible for providing a clean (low distortion) voltage to the customer. The utility can only be fairly judged, however, when the customer meets the harmonic current limits. Otherwise, the customer may be guilty of causing the voltage distortion himself.
- The intent of IEEE 519 is that this recommended practice recognizes the responsibility that the users have not to degrade the voltage of the utility serving other users by requiring nonlinear currents from the utility.
- It also recognizes the responsibility of the utilities to provide users with close to a sine wave of voltage.
- Using PWM control per cycle reduces the load current distortion induced in phase controlled circuits [3]. Synchronization with the supply mains is not required.
- The THD can be reduced employing specified controlled PWM pattern. At high switching frequency, the largest harmonic can be reduced using simple capacitive filtering.

2.2 FFT Analysis Tool

- The Fast Fourier Transform (FFT) tool in MATLAB-Simulink allows the computation of the fundamental component of voltage and current while simulation is running.
- This FFT tool of Powergui is used to display the frequency spectrum of voltage and current waveforms.
- The fundamental component and total harmonic distortion (THD) of the line voltages are displayed above the spectrum window.
- Harmonics are displayed in percent of the fundamental component.

3. RESULTS AND DISCUSSION

3.1 Simulink Model

The SIMULINK of MATLAB was used and the simulation and corresponding FFT analysis of trapezoidal PWM techniques applied to inverters were carried out and the following waveforms were obtained[4]-[6].

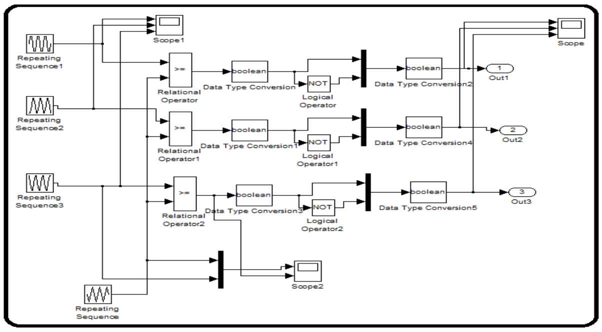

Figure 3 Components used in the simulink model of trapezoidal PWM

3.2 Output Waveforms

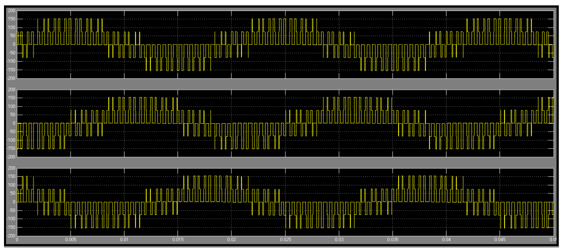

Figure 4 Voltage Waveform using Resistive Load

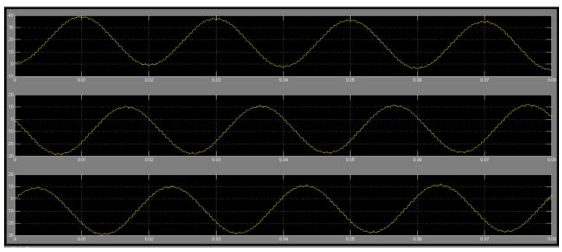

Figure 5 Current Waveform using Resistive Load

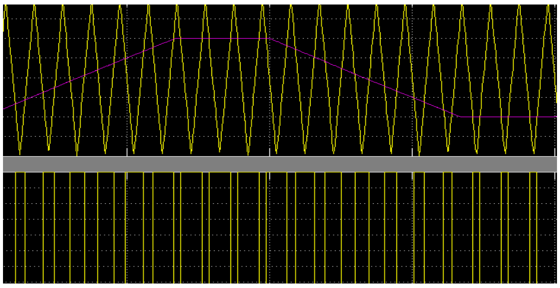

Figure 6 Generation of PWM Signal

3.3 FFT Analysis

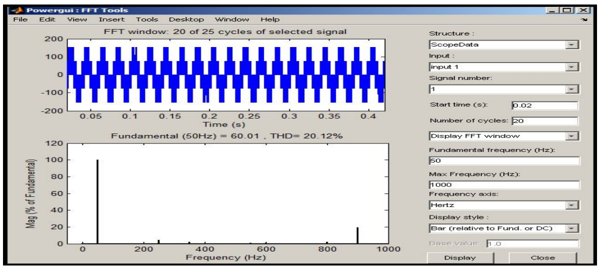

Figure 7 FFT Analysis of Trapezoidal PWM

4. SUMMARY AND CONCLUSION

In many industrial applications, the control of the output voltage of inverters is often necessary for the following reasons:

- To cope with the variations of dc input voltage.
- To regulate the voltage of the inverters.
- To satisfy the constant volts and frequency control requirement.

Among the various other methods to vary the inverter gain, the most efficient one is to incorporate PWM control within inverters.PWM technique is very useful in improving the power quality. The value of THD in trapezoidal PWM technique is found to be 20.12.

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