SELECTIVE HARMONIC ELIMINATION FOR VSI FED DRIVES

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Abstract - Voltage Source Inverter (VSI) fed drives plays a vital role in energy savings. The problem with these drives is the presence of harmonics which produces unnecessary heating, reduced power factor and other effects. So it becomes a major concern to eliminate the harmonics present. Various techniques are used to solve the problem of harmonics but each one has its own limitation. The technique Selective Harmonic Elimination (SHE) is analyzed for a single phase full bridge inverter to eliminate dominant harmonics present in the system. A suitable design of filter also helps to eliminate the higher order harmonics, which as a result reduces Total Harmonic Distortion (THD) level. Results are obtained using MATLAB software.

Keywords — Selective Harmonic Elimination, Unipolar Pulse Width Modulation, Pattern Search Method, Total Harmonic Distortion.

I. INTRODUCTION

Inverter is a circuit used to convert DC supply to AC supply. The advancement in the field of power semiconductor devices rooted the application of inverter in various applications. The application includes HVDC links, Electrical drives fed through voltage source inverter and current source inverter, UPS, and other industrial and domestic applications. Developing country like India whose future for electricity is mainly dependent on renewable energy resources. Wind energy and solar energy contributes more power in this sector. The energy developed through these resources can be connected to the grid and utilized only with the help of inverter system.

Though these circuits have a large extent of applications they also have few limitations that can be rectified and many researches is going on based on this. The major limitation is the presence of harmonics. With the presence of harmonics the application suffers from low power factor, electromagnetic interference, overheating, etc. Therefore it is always necessary to keep an eye over harmonics during the energy conversion process. The harmonics are mainly classified as Dominant harmonics (lower order harmonics) and less dominant harmonics (Higher order harmonics). The word dominant is used to mean the magnitude of these harmonics will be high. Hence it is required to eliminate these harmonics and to satisfy the load. Many techniques are used to eliminate such as elimination through transformer connection, Pulse Width Modulation techniques, filter designs, etc. In this paper Selective Harmonic Elimination (SHE) is used to eliminate 5th, 7th and 11th order harmonics.

The main aim of selective harmonic elimination is to produce the fundamental component while not generating specifically chosen harmonics [18]. To achieve this it is required to solve the transcendental equation obtained from Fourier series of the single phase inverter. The inverter circuit is triggered with the obtained switching angles to eliminate particular order harmonics. This transcendental equation is solved using Pattern Search (PS) Method.

II. HARMONICS

Voltage or current waveform having frequency other than fundamental are said to be harmonics. The waveform that has harmonics not only has the fundamental frequency but also the multiples of the fundamental frequency. If 50Hz is the fundamental frequency then multiples of 50 i.e. 100Hz (2nd order), 150Hz (3rd order), 200Hz (4th order), 250Hz (5th order), etc. 150Hz, 250Hz are said to be odd harmonics and 100Hz, 200Hz are said to be even harmonics. For a symmetrical waveform there will be only odd harmonics whereas the even harmonics will be zero.

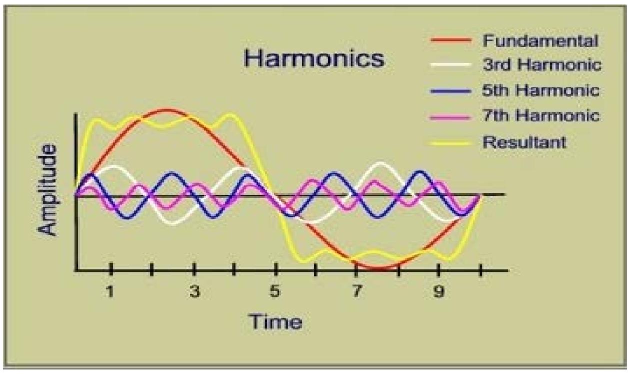


Fig 1. - Fundamental with 3, 5, 7 harmonics and resultant

III. SINGLE PHASE FULL BRIDGE INVERTER

Voltage Source Inverters are inverters in which input voltage is constant; output voltage waveform does not vary with load whereas the load current waveform varies with load. The application of these inverters includes adjustable speed drives, Flexible AC transmission system, etc.

.The circuit has a DC voltage source, four semiconductor switches connected in two legs, load (R or RL or RLE) and freewheeling diodes connected across each semiconductor switches in case of inductive loads.

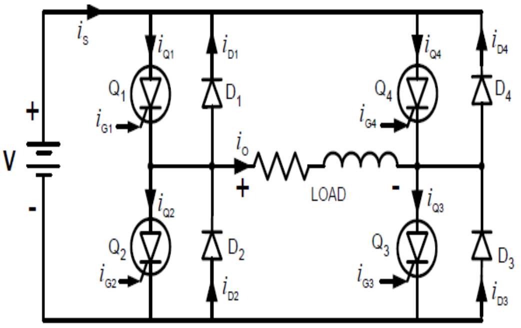


Fig 2. Single Phase Full Bridge Inverter

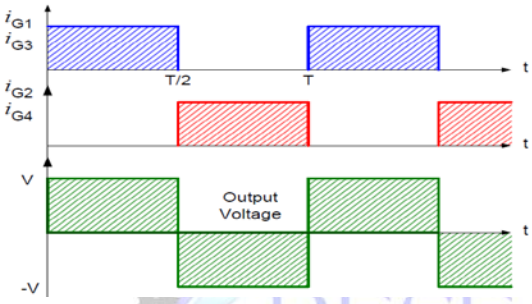


Fig 3. Gating signal and output waveform

The above Fig shows the gating signal applied to the gates of semiconductor switches and the output voltage waveform of the inverter. It is clear that the output voltage waveform is not a pure sine wave and it is a square wave. This means that the output waveform has not only the fundamental frequency but also frequencies other than fundamental (harmonics). So it is necessary to eliminate these harmonics to satisfy the load requirement. From the Fast Fourier Transform (FFT) analysis of the inverter output voltage waveform, the dominant and less dominant harmonics can be obtained. To eliminate the dominant harmonics selective harmonic elimination is used.

IV. SELECTIVE HARMONIC ELIMINATION

The harmonics whose magnitude is high can be eliminated using Selective Harmonic Elimination. To find the triggering angle to eliminate the dominant harmonics, it is required to solve the transcendental equation formed from the Fourier series expansion of single phase inverter. To eliminate two harmonics (say 3rd and 5th) it is required to solve three equations having unknown angles.

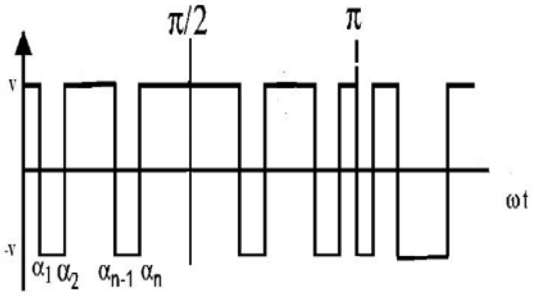


Fig 4. SPWM wave with odd and half wave symmetry

V. PROBLEM FORMULATION

In this section, the mathematical formulation of the problem is presented for unipolar case [9].

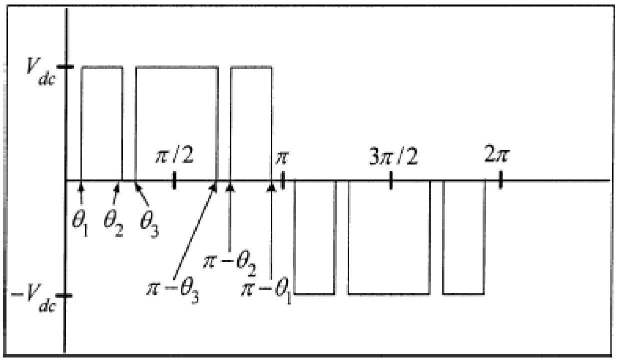


Fig 5. Unipolar PWM waveform

The Fourier series expansion of unipolar waveform is given by:

$$v(\omega t) = (4V_{dc} / \pi) \left\{ \sum_{n=1,3,5}^{\infty} \sin(n\omega t)/n \; [(\cos n\theta_1 - \cos n\theta_2 + \cos n\theta_3 - \cos n\theta_4)] \right\} \quad (1)$$

The problem is to find the unknown angles with transcendental equations as follows:

$$\cos\theta_1 - \cos\theta_2 + \cos\theta_3 - \cos\theta_4 = m \quad (2)$$
$$\cos 5\theta_1 - \cos\theta_2 + \cos 5\theta_3 - \cos 5\theta_4 = 0 \quad (3)$$
$$\cos 7\theta_1 - \cos 7\theta_2 + \cos 7\theta_3 - \cos 7\theta_4 = 0 \quad (4)$$
$$\cos 11\theta_1 - \cos 11\theta_2 + \cos 11\theta_3 - \cos 11\theta_4 = 0 \quad (5)$$

This formulated problem will be solved using PS method, whose objective function aims to minimize the harmonic equations subject to the constraints,

$$0^{\circ} < \theta_1 < \theta_2 < \theta_3 < \theta_4 < 90^{\circ} \quad (6)$$

VI. OPTIMIZATION RESULTS

To obtain the best and optimum solution for the given non-linear transcendental equations, the following PS parameters were used.

Mesh tolerance: 1e-006
Maximum iterations: 100 * no. of variables
Maximum function evaluations: 2000 * no. of variables.

Using the proposed PS technique the equations of unipolar case is solved and the four switching angles were found for m = 0.8. The plots obtained using pattern search tool is given below.

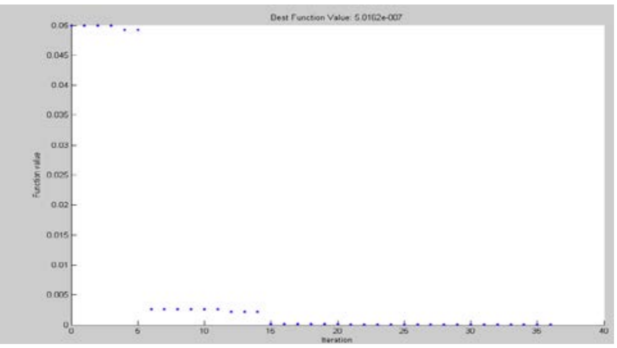


Fig 6. Best function value Vs iteration for m= 0.8

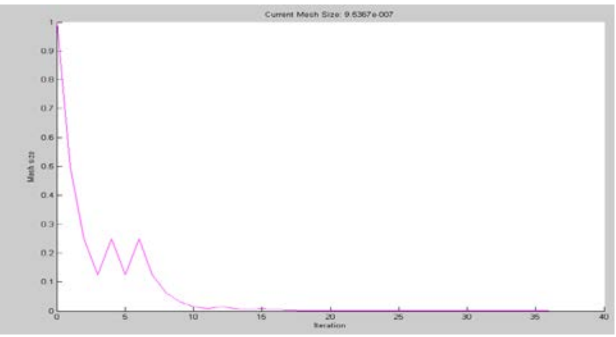
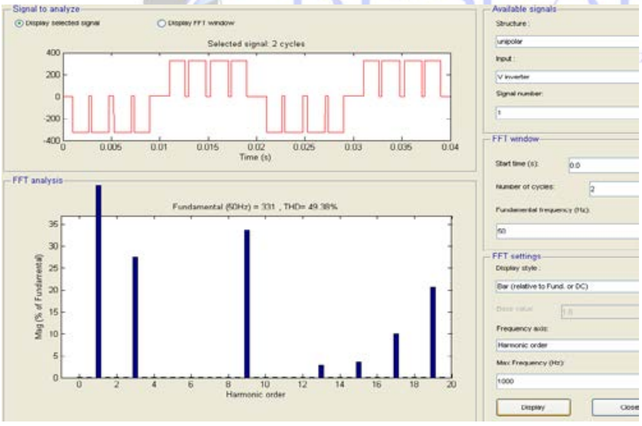


Fig 7. Current mesh size Vs iteration for m= 0.8

This process can be repeated for various modulation indices from 0.1 to 1.3 for both unipolar and bipolar cases.

VII. ELIMINATION OF 5TH, 7TH AND 11TH ORDER HARMONICS BY SHEPWM



Structure: unipolar
Input: V inverter
Signal number: 1
Start time (s): 0.0
Number of cycles: 2
Fundamental frequency (Hz): 50
Display style: Bar (relative to Fund. or DC)
Frequency axis: Harmonic order
Max Frequency (Hz): 1000

Fig 8. FFT after implementation of obtained solution

By solving the equations (2), (3), (4) and (5) subjected to the constraint (6), the required firing angles are obtained to switch the power devices in the circuit and to eliminate 5th, 7th and 11th order harmonics. The transcendental equations are solved using techniques such as iterative numerical techniques, Selective harmonic elimination, Programmed PWM technique, elimination using resultants, etc., to compute the switching angles. Thus by eliminating dominant harmonics the THD value is reduced (49.38%) and hence a suitable filter can be designed to eliminate lower order harmonics.

VIII. CONCLUSION

It is shown that apart from the traditional effects of overheating and pulsating torques, harmonics can lead to malfunctions in control devices due to incorrect or several zero crossings. Poor power factor is another negative effect. Among the mitigation techniques, SHE PWM thus proves to be powerful with the following advantages.

1. Added flexibility in optimizing a particular objective functions such as to obtain selective elimination of harmonics, when compared to the SPWM scheme.
2. Quality of the output can be improved by eliminating number dominant harmonics. But care should to taken the switches won’t be under any stress since it is turned on and off rapidly.

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