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Two and Three Level Converters for Power Quality Improvement: a Comparison

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ABSTRACT : The blocking voltage stresses with higher harmonic distortion are the main limitations of conventional two level converters in high power & voltage applications for power quality improvement. The multilevel converters have come up as solutions to above problems with basic concept of cascaded connections for power semiconductor switches with several lower voltages of dc sources to obtain waveform more close to sinusoidal. In this article a three level converter of NPC topology along with SVPWM has been simulated and the results have been compared with two level converter. Although the NPC structure can be extended to higher number of levels, these are less attractive, because of higher losses and uneven distribution of losses in the outer and inner devices [1].

Keywords :Neutral Point Clamped (NPC), Shunt Active Power Filter (SAPF), Space Vector Pulse Width Modulation (SVPWM), Total harmonic Distortion (THD) , Voltage Source Converter (VSC)

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I. INTRODUCTION

The two level conventional voltage source Converter (VSC) has been used widely so far in active power filters but with the increase in demand of high power and voltage applications, these converters exhibit many problems related to power quality issues and losses. A significant improvement in the output voltage quality and converter losses has been noticed by increasing the voltage levels. A multi-level converter is a power electronic circuit, where more numbers of switches are used in cascade to produce a desired voltage from several levels of dc voltage as inputs. In this way the blocking voltage stress level per switching device is greatly reduced. With the increase in number of levels, the output waveform of a multi-level converter becomes smoother and closer to a sinusoidal form; however the cost and complexity of firing circuit also increases. This will be always a challenge for researchers to suggest the selection of converter level for various applications. Mainly three topologies are used in multi-level converters. In this paper a three-level Neutral Point-
Clamped topology has been considered based on its own advantages [2].

This papers aims to compare the two level converter with three level being used as shunt active filters to reduce Total Harmonic Distortion (THD) in the power distribution line.

II. TWO LEVEL CONVERTER

These converters produced two level of output voltage ie; +Vdc or -Vdc. There are two switches per-phase in a conventional, two-level converter as shown in figure 1. There are three legs for three phase converter and under no condition the two switches of any leg is switched on simultaneously.

Although these converters have some advantages, such as simplicity in circuitry design, lesser number of switches and capacitors requirements, but generated output contains lots of harmonics, polluting the power supply lines along with limited power handling capabilities.

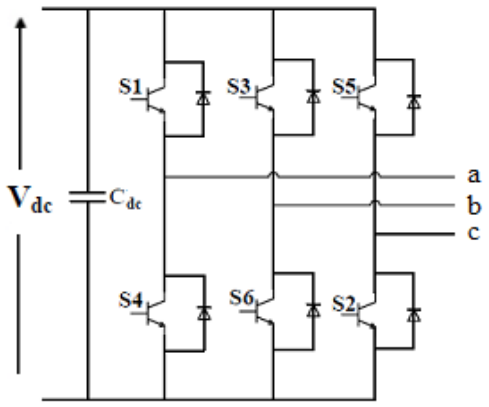

figure 1 : Three Phase two-level converter

III. THREE LEVEL CONVERTER [3]

There are three basic multilevel topologies in use (i) H bridge Cascaded multilevel converters (ii) Diode or Neutral point clamped multilevel converters (iii) Capacitor clamped or Flying capacitors multilevel converters.

The three-level Neutral Point-Clamped converter is shown as in figure 2.

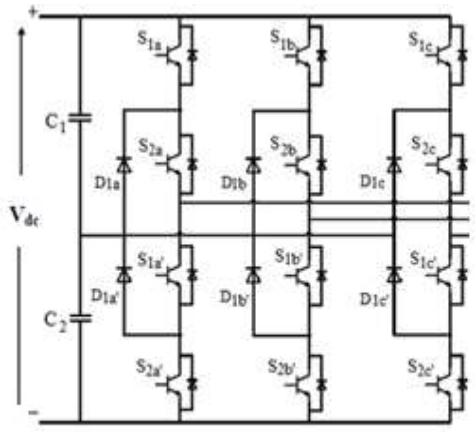

figure 2 : Three Level converter with NPC topology

There are four switching devices, per phase in a three-level Neutral Point-Clamped (NPC) converter and the blocking voltage per switch required in case of a three-level inverter is halved when compared to a two-level inverter. Each phase has a pair of clamping diodes by virtue of which the DC-bus voltage can be increased beyond the voltage rating of each switch. [4]

IV. CONTROL SCHEME

A carrier-based SVPWM modulation technique [4] is used in order to provide an appropriate switching pattern for better output sinusoidal voltage waveform. However, this technique is collaborated with the d-q synchronous reference frame control scheme in order to the generate reference current for control. The algorithm of overall control scheme is as following.

When the PLL has detected the frequency and phase from grid system, the phase angle is used to be a reference for the two-phase transformation (abc-dq). These independent parts of signal are being controlled via the PI controller, which are act as current and voltage control, respectively. The controlled signals are re-transformed into 3 phase control signals (dq-abc), and then transformed into controlling signals using a Park's transformation. These control signals are suitable to use as a reference signal for the carrier-based SVPWM technique. [5]

The reference signal for such technique utilized in this paper is shown in Figure 4.

The mathematical relation between 3 phase control signals (abc) to d-q axis and α-β axis can be expresses by the following equations.

$$\begin{bmatrix} Vd \\ Vq \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad \text{——— (1)}$$

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad \text{——— (2)}$$

The above relation can be realized through simulation model as shown in figure 4

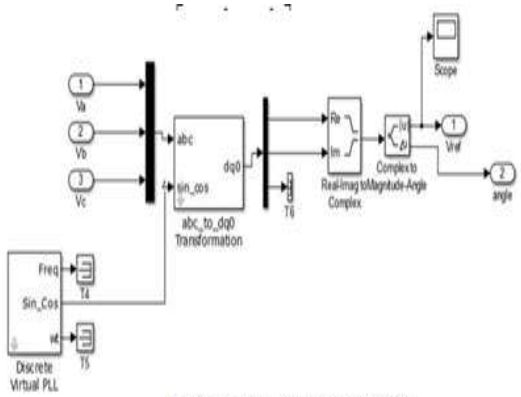

figure 3 : Magnitude - Angle conversion Scheme

V. SPACE VECTOR PULSE WIDTH MODULATION

The space vector pulse width modulation technique SVPWM is used to generate switching pulses so as to generate sinusoidal voltage and current due to its facility and efficiency with low harmonics distortion.

This technique is employed very conveniently in power electronics applications especially in multilevel converters.

The basic concept behind SVPWM [3], [4] is to divide the two dimensional plane into six equal areas each of them is called sector as shown in figure 4.

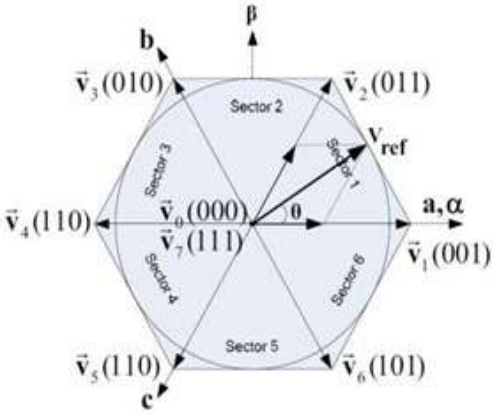

Figure 4 : SVPWM Six switching Sectors

There are eight possible switching vectors for the converter, V_0 to V_7.

V_1 to V_6 are the six active switching vectors whereas V_0 and V_7 are two zero vectors. [6]

VI. SIMULATION MODELS

The simulations on two and three level converters are used as shunt active filters for same non linear loads have been performed on MATLAB/Simulink R2015a.

The simulation models of both SAPF of two and three level have been shown by figure 4 and 5 respectively.

The non linearity on load side has been generated by using three phase bridge rectifiers.

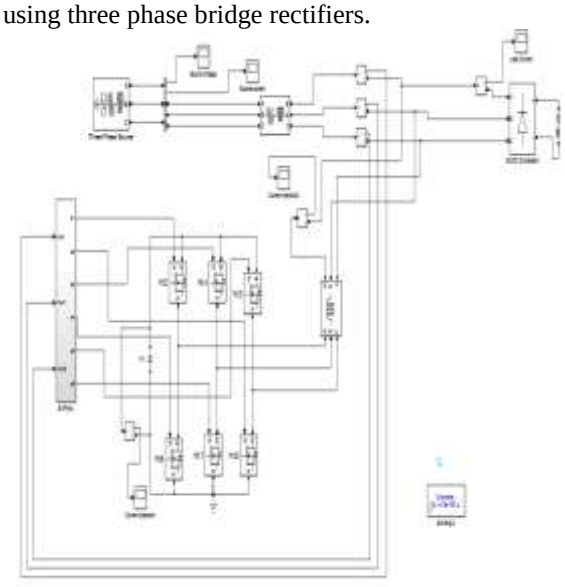

figure 4 : Simulation Model (Two level) SAPF

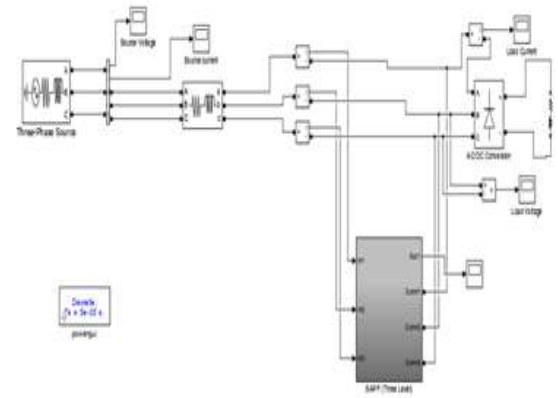

figure 5 : Simulation Model (Three Level) SAPF

VII. RESULTS

The proposed model of two level and three level converter as shunt active filter is simulated on MATLAB R2015 software under static and dynamic non linear load conditions. The dynamic load conditions have been created by using a 1.5 hp dc motor under varying load torque.

The FFT analysis of load current is done before and after compensation. In figure 6 and 7, the THD of load current without compensation is found 22% for static load and 37.43%.

The current distortion is reduced to 3.42% when two level converter as SAPF was employed, whereas the same was reduced to 1.88% when three level converter as SAPF was replaced.

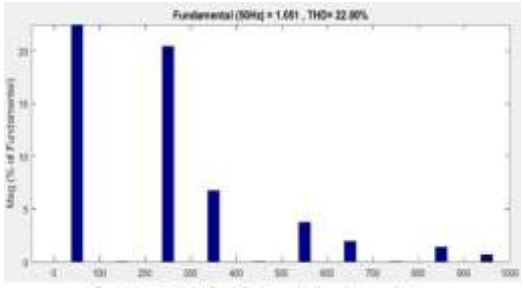

figure 6: FFT analysis of static load current without compensation

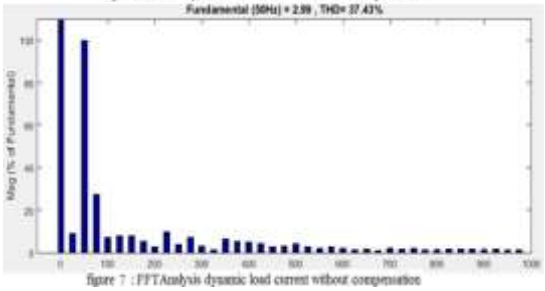

figure 7 : FFTAnalysis dynamic load current without compensation

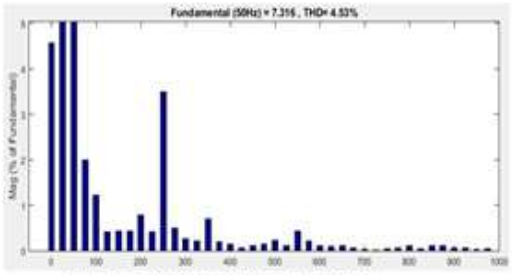

figure 9 : FFT analysis of dynamic load current two level SAPF

Under dynamic load condition the THD is found to be 4.53% with two level SAPF it was reduced to 2.82% when three level SAPF was connected as shown in figure 9 and 10.

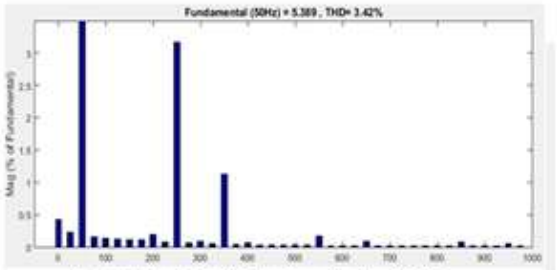

figure 8 : FFT analysis of static load current two level SAPF

figure10 : FFTAnalysis of dynamic load current three level SAPF

VIII. CONCLUSION

The simulation results show that, the THD of load current with three level converter has considerably reduced for static and dynamic load as well.

It is also found that the THD value with two level SAPF for higher power application increases drastically.

It can be concluded that three level converters are more suitable and can be used effectively as harmonic current compensator under static and dynamic load conditions to meet variable reactive power demand and maintain line current profile with lease distortion.

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