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Modeling, Design and Analysis of Multi Pulse Converter Using MATLAB Simulation

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ABSTRACT

This paper presents modeling and simulation of multi-pulse converter topologies. In this paper multi-pulse converter are developed for improving power quality, to reduce harmonics in ac main, and ripple in dc output. The simulation of 12 pulses, 18 pulses, 24 pulses and 48 pulses MPC is performed on MATLAB Simulink. The ripple factor and form factor are calculated for all the above mentioned multi pulse converters. The primary winding of the transformers are connected in zigzag, while the secondary windings of the transformer are connected in series to the converter. By choosing appropriate phase shift between the primary and secondary sides of the transformer and synchronously switching the three-phase bridges at specified phase relations, lower order harmonica can be eliminated in pair. Thus a very high power quality voltage waveform can be synthesized using low switching frequencies

Keywords: Multi-pulse, Total Harmonics Distortion, 12 pulse, 18 pulse, 24pulse, 48 pulse converter.

1. INTRODUCTION

In the last years, increasing attention has been paid to the reduces of current harmonics present at the input side of the rectifiers, Harmonic current and voltage are created by nonlinear loads connected on the power distribution system. All power electronic converters used in different types of electronic systems can increase harmonic disturbances by injecting harmonic currents directly into the supply network. Common non-linear loads include motor starters, variable speed drives, computers and other electronic devices such as electronic lighting welding supplies and uninterruptible power supplies. Harmonics may cause cables to overheat, damaging their insulation. Motor may also overheat or become noisy and torque oscillations in the rotor can lead to mechanical resonance and vibration. Three phase ac-dc conversion of electric power is widely employed in HVDC system, adjustable speed drives, uninterruptible power supply and utility interfaces with non-conventional energy sources such as solar photovoltaic systems (PVs).AC-DC converter, which are also known as rectifiers, are basically contained diodes and rectifiers

2. MULTI-PULSE CONVERTER TOPOLOGY

The multi-pulse converter can be obtained from the combination of several converter modules switching at the fundamental frequency. Three-phase converter switching at the fundamental frequency is known as 6-pulse converter. Generally the pulse number is a multiple of 6(assuming 3-phase system),so 12, 18,24,48- pulse circuit etc. are possible. A 12 – pulse

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converter, consists of two 6-pulse converters fed from a 6 –phase supply and connected in series or parallel on the DC side. Since a 6 phase supply is not normally available, it is generated from the 3- phase supply using a phase shifting transformer (6-phase source is equivalent to two 3- sources with 30 degree phase shift between them).

2.1 Phase Shift Transformer

The phase-shifting transformer is an indispensable device in multi-pulse diode/ SCR rectifiers. It provides three main function: (a) a required phase displacement between the primary and secondary line-to-line voltage for harmonica cancellation (b) a proper secondary voltage, and (c) an electric isolation between the rectifier and the utility supply. According to the winding arrangements, the transformers can be classified into star/zigzag and delta/zigzag configuration, where the primary winding can be connected in wye or delta while the secondary winding is normally in zigzag connection. Both configurations can be equally used into rectifiers.

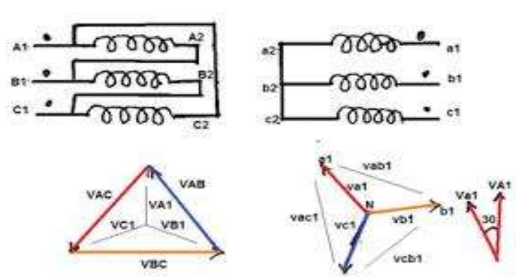

Fig 1: Delta Star + 300 connections (Dy11)

3. SIMULINK MODEL OF MULTI-PULSE CONVERTER

3.1 Simulation of 12-Pulse Converter

An enhancement of the six-pulse bridge arrangement uses 12 valve in a twelve-pulse bridge. A twelve Pulse Bridge is effectively two six pulse bridge connected in series on the DC side and arranged with a phase displacement between their respective AC supplies so that same of the harmonic voltages and current are cancelled. The phase displacement between the two AC supplies is usually 30˚ and is realized by using converter transformer with two different secondary winding usually one of the valve windings is star(wye) connected and the other is delta connected. With twelve valves connecting each of the two sets of three phase to the two DC rails, there is a phase shift with 30˚ and harmonics are considerable reduced. In fig.2 shows the simulation model of 12 pulse converter.

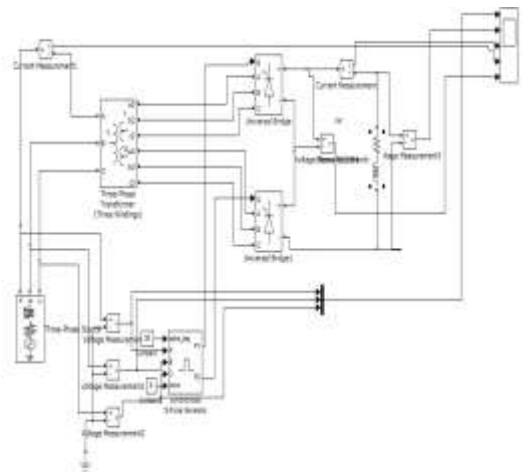

Fig 2: Simulation Model of 12 Pulse converter

3.2 Simulation of Eighteen Pulse Converter

The eighteen pulse transformer is designed to provide one third the normal input voltage to each of the three rectifiers at a 20 degree phase displacement from each other. The 20-degree phase shift isobtained by phase shifting the transformers secondary windings.Theoretical input current harmonics for rectifier circuits are a function of pulse.

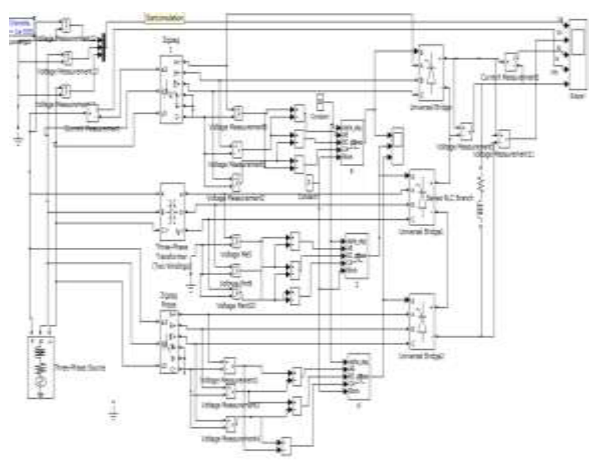

Fig 3: Simulation Model of 18-Pulse converter

3.3 Simulation of Twenty Four Pulse Converter

The Simulation model of a 24-pulse series-type rectifier is shown in Fig.4, Where a phase-shifting transformer is used to power four sets of six-pulse rectifiers. To eliminate six dominant current harmonics (the 5th, 7th, 11th, 13th, 17th, and 19th), the transformer should be arranged such that there is a 15° phase displacement between the voltages of any two adjacent secondary windings. The line-to-line voltage of each secondary winding is usually one fourth that of the primary winding. In Fig 4 shows the simulation model of 24 pulse converter.

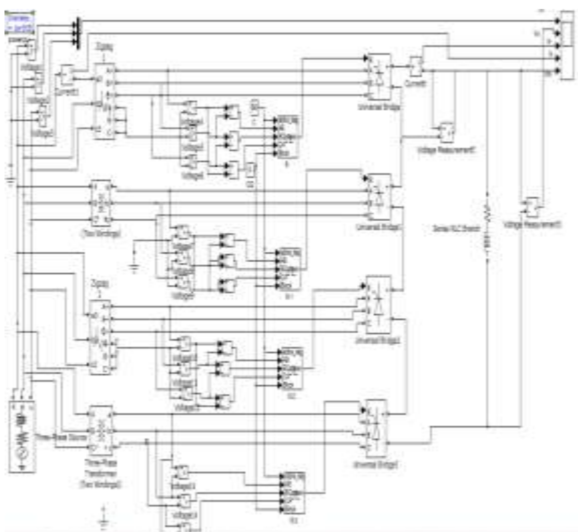

Fig4: Simulation Model of 24-Pulse Converter

3.4 Simulation of Forty-Eight Pulse Converter

Four 12 pulse converter, Phase shift by 7.5 degree from each other, can provide a 48- pulse converter, obviously with much lower harmonics on ac side. Its ac output voltage would have 48n± 1 order harmonics, i.e. 47th, 49th, 95th, 97th ….. Harmonics, with magnitudes of 1/47th, 1/49th, 1/95th, 1/97th ……., respectively, of the fundamental ac voltage. 48-pulse operation with eight six-pulse groups, with one set of transformers of one 24-pulse converter phase-shifted from the other by 7.5 degree, or one set shifted by +3.75 degree and the other by -3.75 degree. Logically, all eight transformer primaries may be connected in series, but because of small phase shift (7.5 degrees), the primaries of the two 24-pulse converters may be connected in parallel if the consequent circulating current is acceptable. This should not be much of the problem because the higher the order of harmonics, the lower would be the circulating current. For 0.1 per unit transformer impedance and the 23rd harmonics, the circulating current would be 1.9% only. The circulating current can be further limited by higher transformer inductances or by inter-phase reactors at the point parallel connections of the two 24-pulse converters. With 48-pulse operation, ac filters should not be necessary. In Fig 5 shows the simulation model of 48 pulse converter.

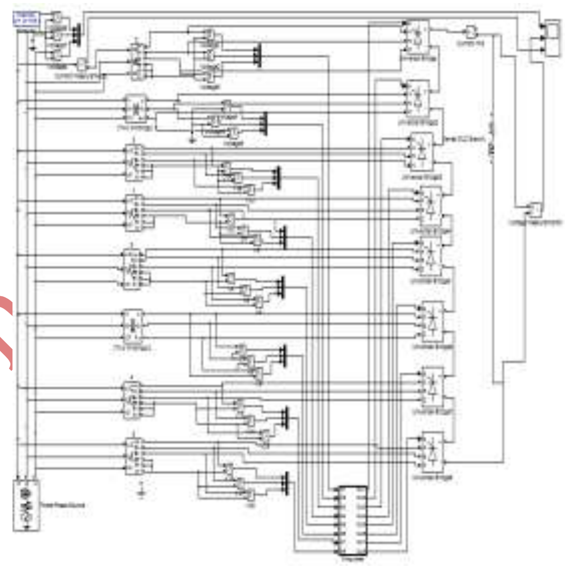

Fig 5: Simulation Model of 48-Pulse Converter

4. RESULT AND DISCUSSION

4.1 Waveform and FFT of Twelve Pulse Converter

Fig 6 shows the waveform of 12 pulse Simulink model. The first axis represents the input AC voltage of the 12 pulse converter. Second axis represents the output voltage of the 12 pulse converter, which gives 12 pulses in one cycle of input AC supply. Third waveform represents the output current, the fourth one is the input current waveform. Fig 7 shows the FFT of the input AC current supply, which is 11.39% of 12 pulse converter.

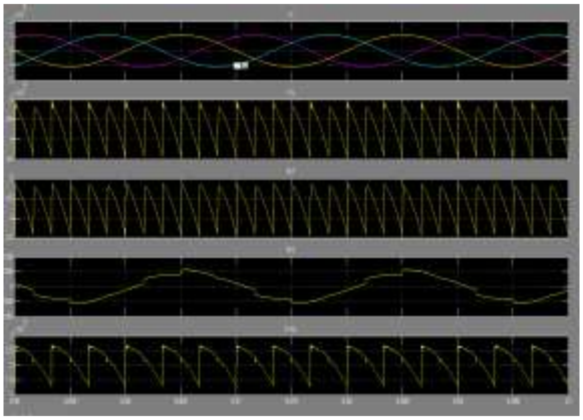

Fig 6: Waveform of 12-Pulse converter

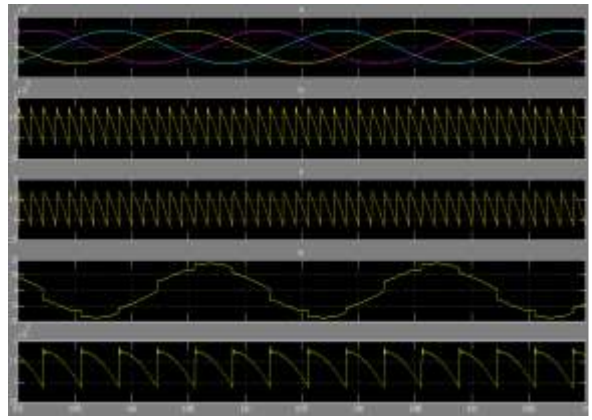

Fig 8: Waveform of 18-Pulse converter

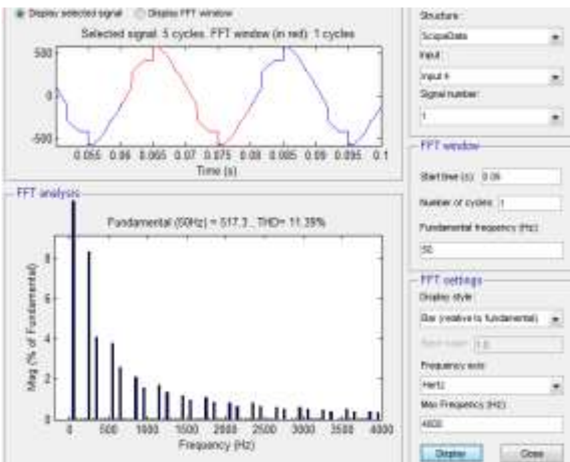

Fig 7: FFT of 18-Pulse Converter

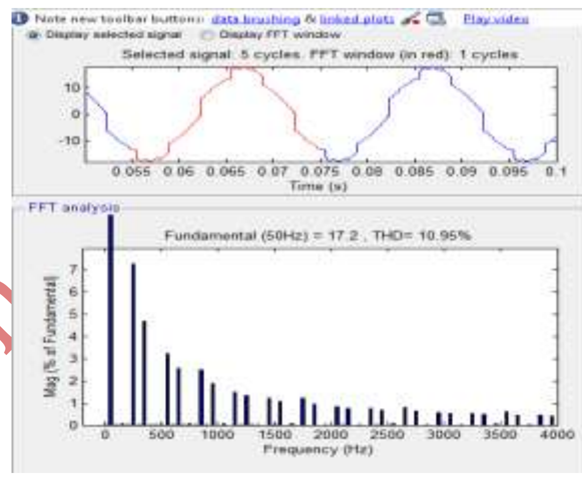

Fig9: FFT of 18-Pulse Converter

4.2 Waveform and FFT of Eighteen Pulse Converter

Fig 8 shows the waveform of the 18 pulse converter, in the waveform, axis first represents the input of the supply voltage, and second waveform is the output of the 18 pulse converter, which gives the 18 pulses in one cycle of input voltage. And axisfour shows the input current of the converter. In this waveform observe that the input current is improved and in more smooth comparison 12-pulse converter, so the THD of the Input current show in Fig 9, it is 10.95% is less than to 12 pulse converter.

4.3 Waveform and FFT of Twenty-four Pulse Converter

Fig 10 shows the waveform of the 24 pulse converter, in the waveform, axis first represents the input of the supply voltage, and second waveform is the output of the 24 pulse converter, which gives the 24 pulses in one cycle of input voltage. And axis third and four shows the output and input current of the converter respectively. In this waveform observe that the input current is improved and is more sinusoidal comparison 18 -pulse converter, so the THD of the Input current show in fig.11, it is 4.29% is less than to 18 pulse converter.

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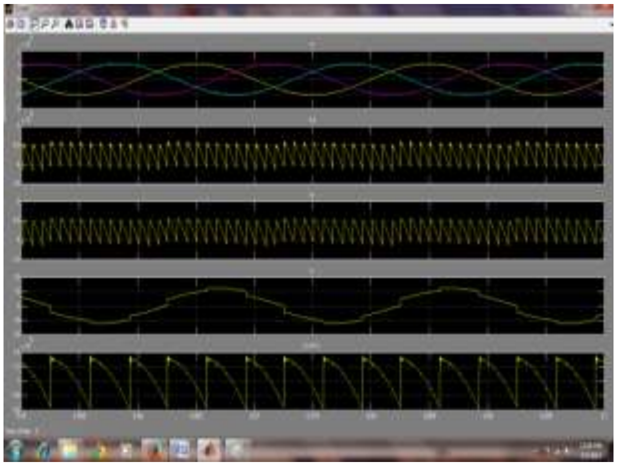

Fig 10: Waveform of 24-Pulse Converter

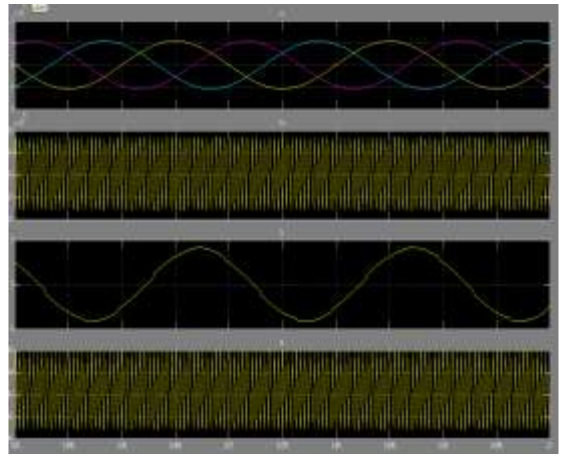

Fig13: Waveform of 48-Pulse Converter

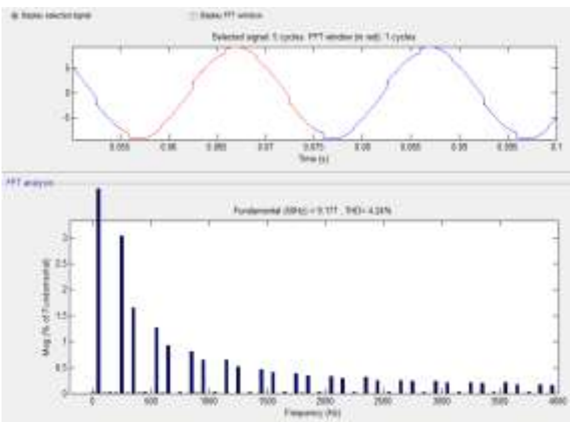

Fig 11: FFT of the 24- Pulse Converter

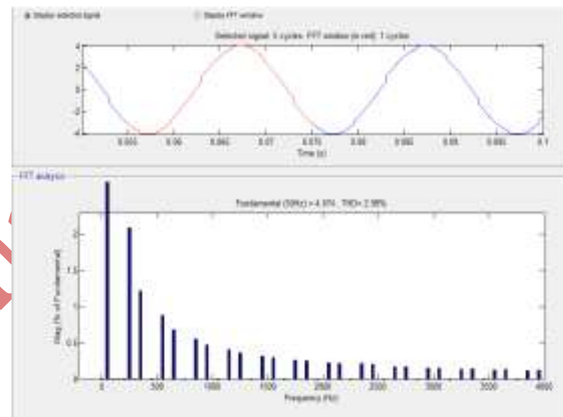

Fig 14: FFT of 48-Pulse converter

4.4 Waveform and FFT of Forty-eight Pulse Converter

Fig 12 shows the waveform of the 48 pulse converter, in the waveform, axis first represents the input of the supply voltage, and second waveform is the output of the 48 pulse converter, which gives the 48 pulses in one cycle of input voltage. Third and four axis shows the input current and output current of the 48pulseconverter. In this waveform observe that the input current is more improved comparison previous cases. It is more smooth comparison 12-pulse,18-pulse,24-pulse converter, so the total harmonics of the input current is reduce ,and overall system is improve as increasing the no. pulses. THD of the Input current shows in fig.14, it is 2.89% is less than to 24 pulse converter.

4.5 Simulink Model for Calculating Form Factor and Ripple

In Fig 15 shows the result of form factor and ripple factor. For calculation of FF and RF, use RMS and Mean value block, by this block find the RMS and average value of output voltage. This values is use for calculating the Form factor andRipple Factor of the output voltage, by the formula given in equations no.1 andno.2

FF= RMS value/ Mean Value (1)

$$RF = \sqrt{FF^2} - 1 \quad (2)$$

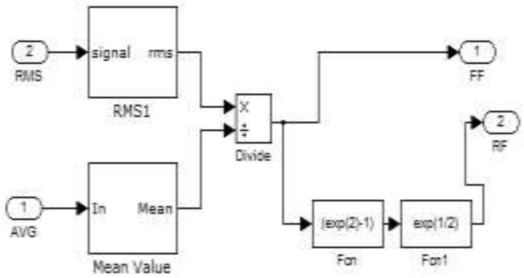

Fig 15:Calculation of Form Factor and Ripple Factor

4.6 Comparison Result of Converter

Table 1 shows the THD of the input current of different pulse converter, in this table shows that the THD of the 48-pulse converter in less than the 12-pulse, 18-pulse, 24-pulse, converter. Table 2 represents the ripple content of the input voltage. Table 3 shows that the Form factor of the output voltage.

Table 1. Analysis of THD

No. of Pulse	THD of RL Load
12	11.39
18	10.95
24	4.5
48	2.98

Table 2. Analysis of Ripple Contents

No. of Pulse	Ripple factor of RL Load
12	1.678
18	1.667
24	1.645
48	1.635

Table 3. Analysis of Form Factor

No. of Pulse	Form Factor of RL Load
12	1.1
18	1
24	1
48	1

5. CONCLUSION

The Various Multi-Pulse configuration is simulated using the software Simulink/MATLAB, and the results are presented in the paper. The main objective of the present work is to investigate the performance of controlled Multi-pulse converter. These converters are studied in terms of harmonic spectrum of AC main current, Output voltage Ripple and Form Factor. It is Conclusion that in general that increases the number of pulse in multi-pulse converter the performance of the converters are significantly improved.

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