COST EFFECTIVE RETROFITTING OF 12 PULSE AC-DC CONVERTER USING 24 PULSE AC-DC CONVERTER

R.Suguna*

S.Navadeep*

D.Banupriya**

Abstract:

This paper proposes a new topology of multipulse converter which results in cost effective replacement of 12 pulse AC-DC converter by 24 pulse AC-DC converter, where 12 pulse converter is being used in industries. The proposed 24 pulse converter can reduce content of harmonics upto 21st level. The technique of pulse doubling is used to achieve 24 pulse from 12 pulse converter circuit. The pulse number is increased in order to decrease the harmonic content to meet the IEEE standard. According to IEEE, the permitted percentage of total harmonic distortion (THD) is below 5%. The topology proposed in this paper reduces THD upto 1%. The simulations are done in MATLAB simulink and comparative results of THD for different firing angles are recorded.

Keyword: Converter, Harmonics, Pulse doubling ,THD

* Department of Electrical and Electronics, Muthayammal College of Engineering, Namakkal

** Department of Electrical and Electronics, Aadhithiya Institute of Technology, Coimbature.

I. Introduction

In the past few decades, researches are going on to increase the quality of power supplied by utility. Due to improvements in the field of power electronics, effective conversion of AC to DC can be done by semiconductor devices like diode, thyristors, IGBT etc. Six pulse converter has been used widely for AC-DC/DC-AC conversion. Six pulse converter can eliminate harmonics content in input current only upto 3rd level, i.e , the harmonic distortion is more in six pulse converter. Researchers found that as the pulse number is increased, the harmonic distortion is decreased. Thus a method of increasing pulse number was found out by increasing the number of converter circuit. The cost of semiconductor devices is high and therefore the cost of converter circuit also increases as the number of pulses increase. Thus 12 pulse converter is being used in industries as it cancels harmonic upto 11th level and the distortion is satisfactory. But the percentage of total harmonic distortion does not meet the IEEE standard of 5%. In order to achieve this, the pulse number is to be increased. The method of increasing number of converter circuit will lead to high cost of converter circuit and therefore researches are going on to find an alternative method.

Multipulse converters have various applications like hydroelectric, gas turbine, diesel, biomass and wind system based power plants. The renewable energy systems need converter system to control the power output as the source for power plant is not continuous and steady. The use of semiconductor switches in the converter produce harmonic distortions. But the power produced is desired to have less harmonic content as possible. The use of 24 pulse converter can eliminate harmonics upto 21st level in the input line current, which can meet the IEEE standard.

The proposed 24 pulse converter is developed through pulse doubling technique in 12 pulse converter circuit. Thus, the existing 12 pulse converter can be easily replaced by the proposed circuit without much alterations. 12 pulse converter is achieved by cascading two six pulse converters in series or parallel. The converters should be 30 ^{0} phase shifted from each other to attain 12 pulse output. 24 pulse can be achieved in the same method by cascading four 6 pulse converters which are 15^{0} phase shifted to each other. In the proposed 24 pulse converter only 2 set of six pulse converter is required. Figure 1 shows the schematic diagram of the existing 12 pulse converter. ZSBT (zero sequence blocking transformer) and interphase reactor is used for attaining pulse doubling characteristics in the circuit.

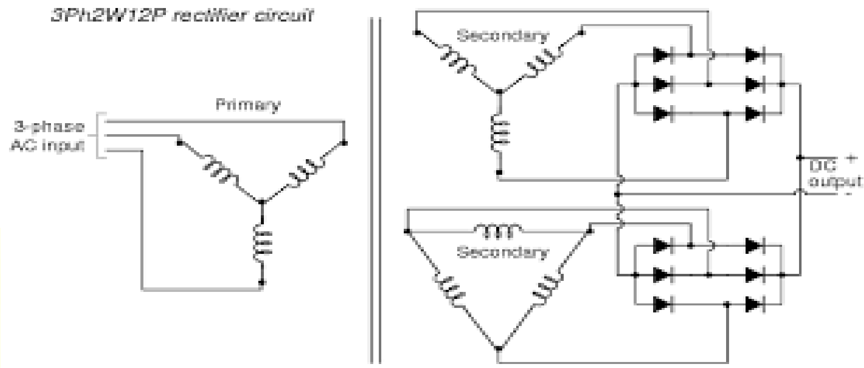

Figure 1: Image showing existing 12 pulse converter

II. Multi Pulse Converters

A converter whose pulse number is greater than six is categorized as multipulse converters. Assuming three phase supply, the minimum pulse number under this category is twelve and that converter is named as 12 pulse converter. The number of pulses can be increased as multiple of 6 like 12, 18, 24, 30, 36, 48 etc. The harmonic content in the input current mains corresponding to pulse number of converter is given in table 1.The minimum phase shift between each converter circuit is calculated as,

Phase shift = 60^0 / number of converter circuit used.

Multipulse converters are categorized as improved power quality AC-DC converters (IPQC) which are used in high power applications involving high voltage and low current. Multipulse converter reduces current harmonic content, improves power factor, increases efficiency, elimination/reduction of DC filters, reduced voltage distortion and well regulated DC output resulting in improvement in power quality.

TABLE 1: Table showing Variation Of Harmonics With Pulse Number

Pulse number	AC harmonics
1	1,2,3…..
2	1,3,5……
3	2,4,5…..
6	5,7,11…..
12	11,13,23…..
18	17,19,35……
24	23,25,47……

III. 12 Pulse AC-DC Converters

12 pulse rectifier is the combination of two 6 pulse rectifier in cascaded form.The phase shift of 30^0 is required to produce 12 pulse rectification. It is achieved through three winding transformer. The primary of the transformer is in star connenction wheareas one of the secondary is star connected and the other secondary is delta connected. Thus the delta connected winding produces a 30^0 phase shift. The converter 1 is connected to star connected secondary and converter 2 is connected to delta connected secondary. Figure 2 shows the simulation diagram of 12 pulse converter. The output of the rectifier contains 12 pulses which is shown in figure 3. The THD analysis of 12 pulse converter is shown in figure 4. The magnitude of output voltage,

$V_0 = V_{01} + V_{02}$

Where V_{01} and V_{02} are output voltages of converter 1 and converter 2 respectively.

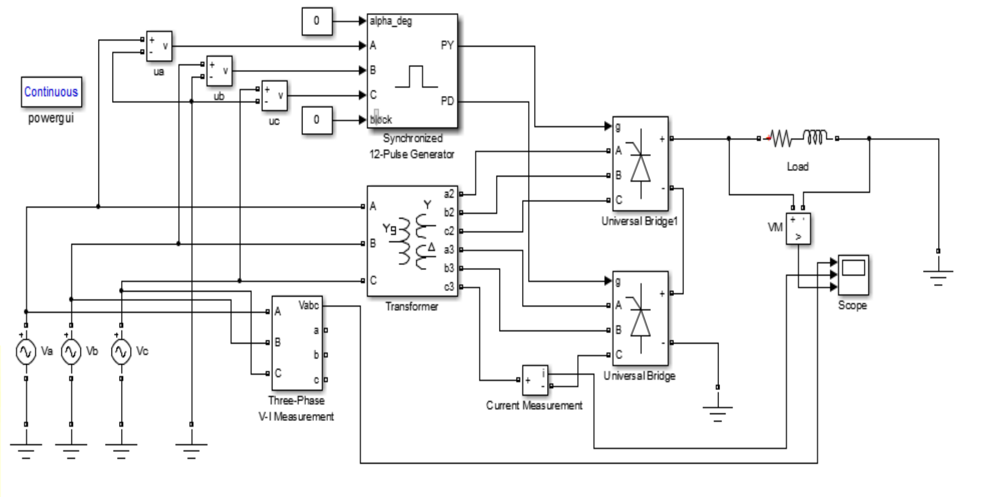

Figure 2: Image showing simulation of 12 pulse converter

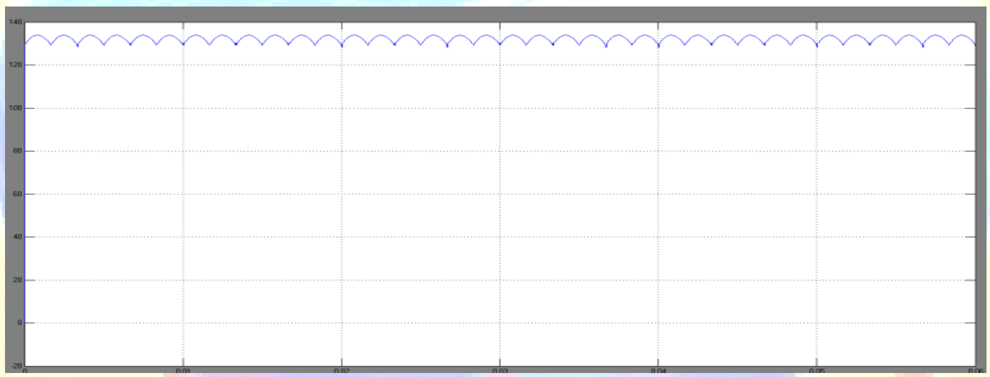

Figure 3: Image showing Output Waveform Of 12 Pulse Converter

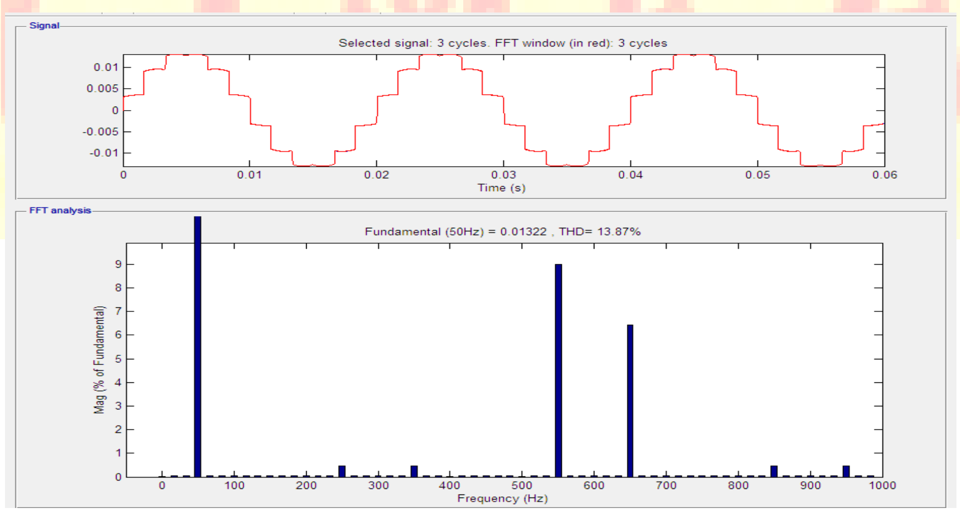

Figure 4: Image showing THD analysis of 12 pulse converter

IV. Proposed 24 Pulse Converter

Figure 5 shows the block diagram of proposed 24 pulse converter. In the existing 12 pulse converter, if inter phase reactor (IPR) of proper design is added then the output will be 24 pulse converter. Inter phase reactor is being used in industries so as to draw near sinusoidal current from utility. By proper design of IPR, the THD value can be brought nearly 1 %.

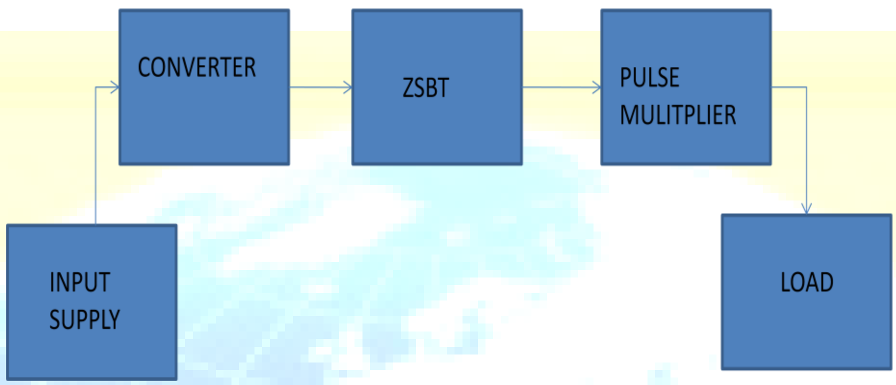

Figure 5: Image showing Block Diagram of Proposed 24 Pulse Converter

Figure 6 shows the schematic diagram of proposed 24 pulse converter. Zero sequence blocking transformer is used to attain the following :

(a) Independent working of the two converter circuit.

(b) To block zero sequence current as it does not cancelled out as it is in phase in the output of two converters.

The two diodes tapped from IPR will on/off according to the voltage difference to produce 24 pulse output.

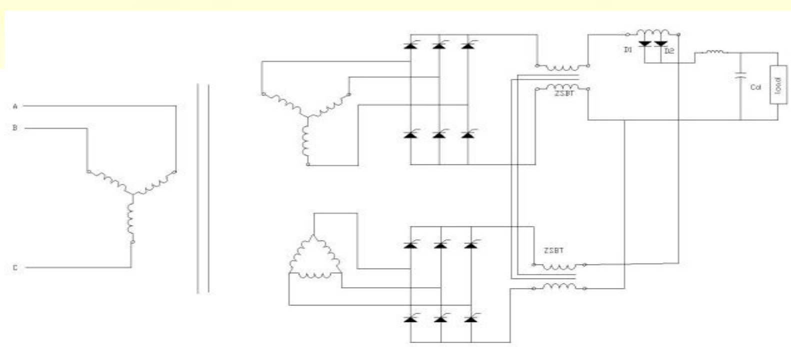

Figure 6: Image showing Schematic of Proposed 24 Pulse Converter

A. Design Of Inter Phase Reactor

Inter phase reactor (IPR) not only ensures smooth current flow, if properly designed produces pulse doubling. Here 3 winding reactor is used in which the end most windings have turns equal to half the number of turns of the middle winding. The diodes connected get on/ off respective to the voltage across the windings of reactor to produce pulse doubling from where the diodes are tapped.. The frequency of the voltage appearing across the IPR is 6 times the source frequency. The diodes conducts according to the polarity of the voltage across the reactor windings. The turns ratio os the reactor windings is given by

$N_A / N_0 = 0.2457$

B. Design Of ZSBT

Zero sequence blocking transformer is connected at the output of the two rectifiers in order to achieve independent operation of the converter circuits. The zero sequence component of the voltage and current present in the output of the two converters will not cancel out with each other as they are in phase. ZSBT blocks the zero sequence component present in the DC output. The voltage appearing across the ZSBT contains triplen frequency components and therefore ZSBT can be of small size, weight and volume. Thus the retrofitting application of 24 pulse converter can be done cost effectively. The design of ZSBT can be calculated in the same way as IPR.

V. Matlab Simulations And Results

The proposed 24 pulse converter and the existing 12 pulse converter is simulated in MATLAB simulink using PSB toolboxes. Figure 7 shows the simulation circuit of 24 pulse converter. Figure 8 shows the output waveform and THD analysis of 0^0 firing angle. Figure 10 shows output waveform and THD analysis for 0^0 firing angle. Table 2 shows the variation of THD with different firing angles.

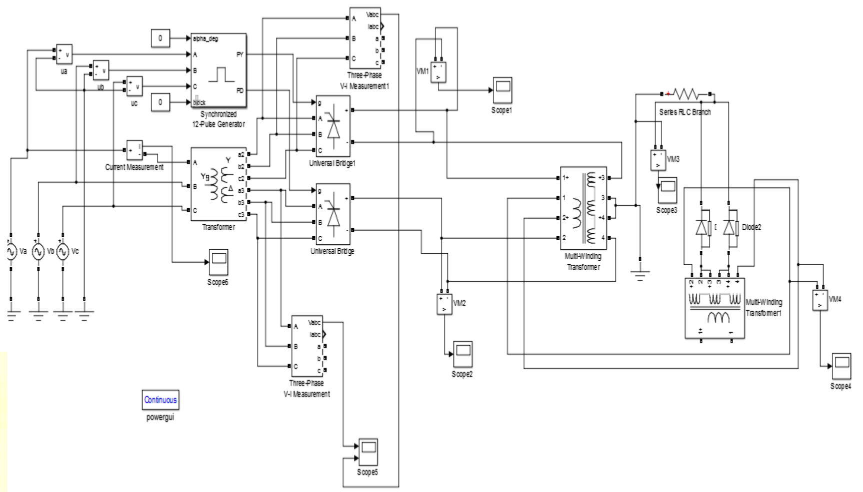

Figure 7: Image showing MATLAB simulation of 24 pulse converter

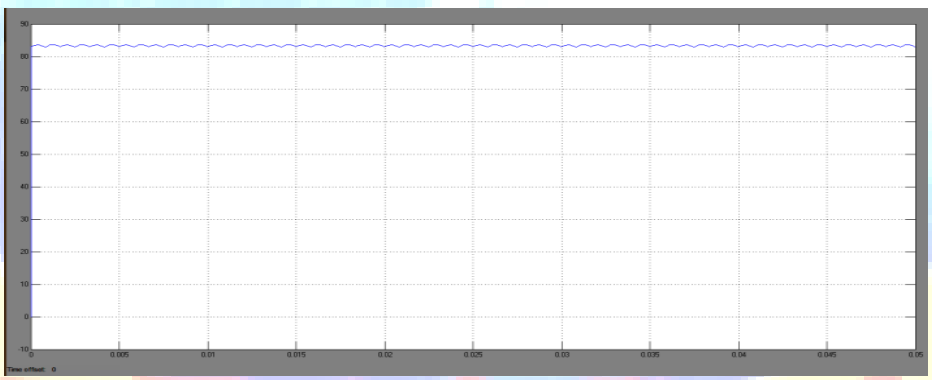

Figure 8: Image showing Output Waveform Of 24 Pulse Converter For Firing Angle 0^0

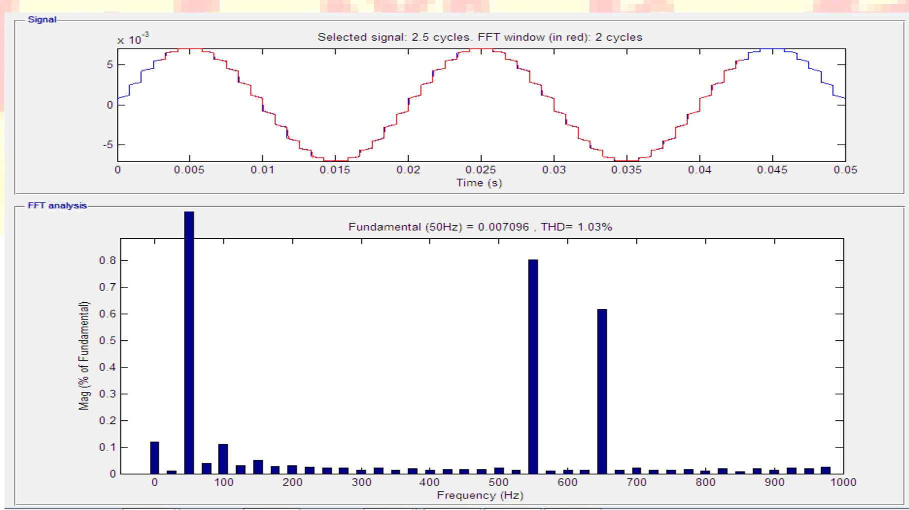

Figure 9: Image showing THD analysis of proposed 24 pulse converter

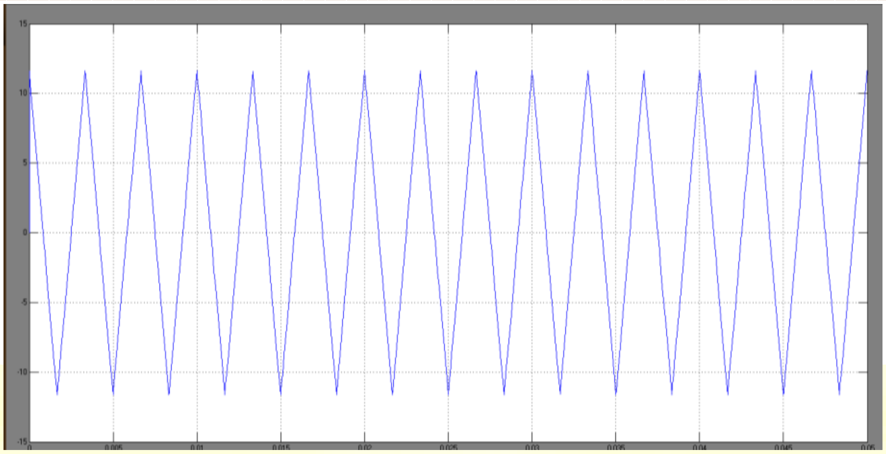

Figure 10: Image showing Voltage waveform across IPR

TABLE 2: Table showing Comparison of THD With Different Firing Angles

Firing angle (degree)	THD (percentage)
0	1.03
20	1.97
40	2.60
90	4.68

VI.Conclusion

The proposed 24 pulse converter is simulated in MATLAB simulink and the ouput for different firing angles has been recorded. Replacement of existing 12 pulse converter can be done cost effectively using the proposed converter as the pulse multiplier circuit used is of small ratings, weight and volume. The proposed circuit can be done using IGBT for high voltage applications.

VII.References

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