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# Modeling, Simulation and Design of Prototype Three Phase 6, 12, 18 and 24 pulse converters with Phase Shifting Transformer for Power Quality Improvement

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**Abstract:** This research paper presents the, 6,12,18 and 24 pulse converters with Phase Shifting Transformer Configuration for power quality improvement, as it highly reduces the Total Harmonics Distortions current in main ac supply. Interconnection of conventional transformers are used to make Four 3-φ systems to obtain different phase shifts is presented and obtained performance is compared between of a 6,12,18 and 24 -pulse Transformer Rectifier Configuration. Such multi pulse topologies consist on the various 6-pulse converter units connected either in parallel or series on the DC side. Each units phase shifted by the auto transformer or individual designed isolated transformers to compensate the harmonics content in the order of (nP±1), n = 1,2, 3, and P = Pulses. This proposed work is mainly based on the two objectives (1) to simulate the various multi pulse transformer (up to 24 pulse) with R-Load, using the matlab software. (2) Prototype hardware model. In both cases analysis the Total Harmonic Distortions current in main ac supply by FFT Analysis and FLUKE 43 Power Quality Analyzer. Finally, Simulation based results have been validate with Gutor and IEEE 519-1992 Standard. Experimental results compared with IEEE Standard and additionally improves the THDs voltage, Crest Factor and K Factors.

**Keywords**: Multi-pulse Transformer, Converters, Harmonics, Total Harmonic Distortion (THD)

## 1. Introduction

Many technique of power quality improvement has been developed in recent, multipulse converter is one of them with help of transformer arrangement and configuration to improve PQ, PF, THD, Crest factor, k-factor etc. As demand grows of non linear equipments day by day, mostly system shifted to Power electronics due to several advantages like as energy saving, reliability, and properly utilization, increases efficiency, reduces the weight , size and overall cost[1-4]. Three phase AC–DC converters are widely employed in several practical applications, from low power rectifiers to high voltage system and application, used for controlled power supplies, many types of DC motors drives, electro-chemical processes and UPS, CVCF, VFD, VSD, SMPS etc [5-8]. In modern power electronics, three phase rectifiers used as utility interface across the renewable energy source [9-12]. Many researchers have been used Passive filters in with different configurations [10]. Such circuits suffer from resonance effects due to heavy filters elements and become bulky. The Active filters have been preferred in most researches, but this technique suffers from high cost and circuit complexity [12-13]. In this situation, A Hybrid filter seem to be the best option and improves the performances of passive filters. Especially used in high power applications [6]. However, this method used for high voltage application because multi pulse transformer converters are much heavy, larger in size so occupied more space. Having high cost, manufactures rarely construct it due to complex circuitry [7]. A single 6–Pulse rectifier is capable to contribute several periodic harmonics spectrum like as 5 th, 7th, 9th, 11th… harmonics, defined by H=np ±1.

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Here, n is an integer, P is the number of pulses in rectifier DC side equal to the one complete cycle of ac input current or voltage. Power quality in this technique improves gradually by increases number of pulse. In this paper, discuss the reductions in THDs current using multipulse transformer rectifier / converter configurations. First simulates the performance improvement based various multipulse models across the R-Load using the Simulink Matlab software, secondly Experimental prototype hardware model is developed for analysis. Finally, both measured results validates with the IEEE / IEC Standards. Lot of techniques has been used from few decades to reduce the Harmonics distortions across the utility line current [9].

## 2. Multi-Pulse Converters

Pulse number can be define as, the amount of pulses comes out at the DC output Voltage, equal to the one time period of input ac source voltage [1]. It is usually preferred for high voltage and power applications purpose. The multi-pulse transformer rectifier converters, which follows the concepts of multi pulse, namely as 6, 12, 18, 24, 30, 48 pulses and extensity reduces the harmonic distortions across the main ac supply current known as the multi pulse converters. These converters need the special designed zig-zag transformers. Which are connected with the proper configuration and arrangements across each of Diode Bridge or thyristor , SCR bridge [11]. In multi pulse converters respectively harmonics are reduced as shown in Table.1.

**Table 1** –Harmonics Orders by respective multi pulse

| No. of Pulses | Harmonic Order |
|---|---|
| 6 | 5,7,11,13,17,19……. |
| 12 | 11,13,23,25,35,37…….. |
| 18 | 17,19,35,37,53,57…… |
| 24 | 23,25,47,49,71,73…….. |
| 30 | 29,31,59,61,89,91 |
| - | |
| 48 | 47,49,95,97,143,147 |
| **No. of Pulses** | **Harmonic Order** |
| 6 | 5,7,11,13,17,19……. |
| 12 | 11,13,23,25,35,37…….. |
| 18 | 17,19,35,37,53,57…… |
| 24 | 23,25,47,49,71,73…….. |
| 30 | 29,31,59,61,89,91 |
| - | |
| 48 | 47,49,95,97,143,147 |

## 3. Multi-Pulse Converter Configurations and Different Techniques

Figure I shows classification of different harmonic reduction techniques such as Passive, Active, HAPF and EMI Filters and Multipulse converters which are further classified in 6,12,24,48 multipulse converters.

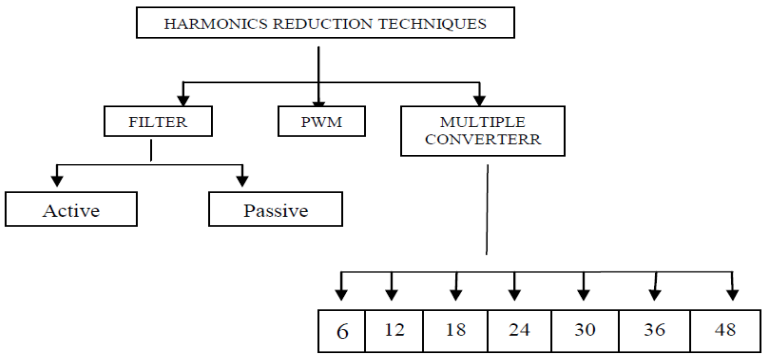


**Fig. 1 –** Various Harmonics Reduction Techniques

In this paper, different models & simulations and experimental results of multipulse transformer rectifier/ converters are presented. In this only uncontrolled method has been used in all cases, diode rectifiers bridges are used like as (6-Pulse, 12 Pulse, 18 Pulse and 24 Pulse rectifier bridges), zigzag transformer was used in the simulating model and in the performing experimental works single phase transformer used with different configuration to obtain simulated model. In last validates the main THDs current results with some standards as explain above. The 3–Φ Six Pulse Transformer Converter AC–DC conversion schemes are involved to creating some troubles in main ac supply. So, it can be eliminated by multi pulse conversion schemes. In this method various 6-Pulse rectifiers are connected with different configurations, as in series or parallel on the bus. The harmonics generated by one converter is easily cancelled by other converters. In this way less distorted power to be supplied across the load [2]. Figure.2 illustrated for AC-DC converter classification which may controlled and uncontrolled further divided into isolated and non-isolated type.

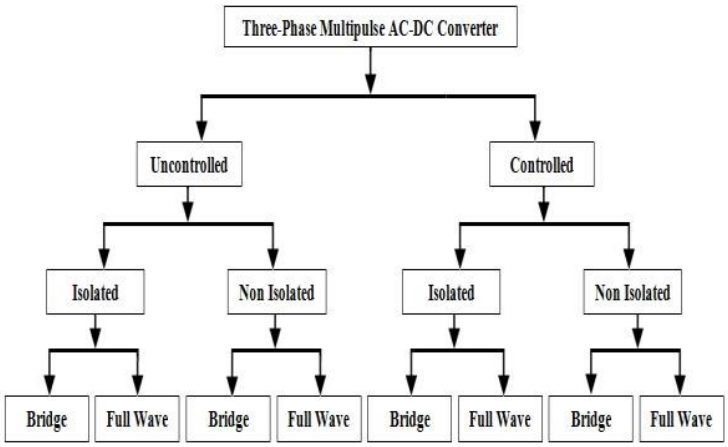


**Fig. 2-** Multi-Pulse Converter Configurations

# 4. Simulation of multi-pulse transformer converters

All the models have been simulated using the matlab tool Sim Power System. In this setup for multipulse topologies , every component is rated with the similar rating. The zig-zag transformer phase shifted according to the formula given below in Equation-1.

$$Phase\ Shifted\ Angle = \frac{60^{\circ}}{no\ of\ 6\text{-}Pulse\ converters} \quad (1)$$

In all simulations, input and output of converters are parallel coupled with sources and R–Load. The THDs current in main ac supply with improved wave form which is observed by FFT analysis.

### 4.1 Six Pulse Converters

The 6-Pulse converter is the basic multi-pulse converter unit as shown in Figure.3. In which six diodes are connected in a bridge manner, usually used as rectifier for HVDC transmission system, UPS, Inverters, CVCF, SMPS System. The three phase supply fed to single 3–Φ zig-zag transformer having zig-zag – Delta connections and 60° phase shifted. The current harmonics are generated in main ac supply in order of $6(1) \pm 1$, dominating harmonics orders are 5th and 7th.

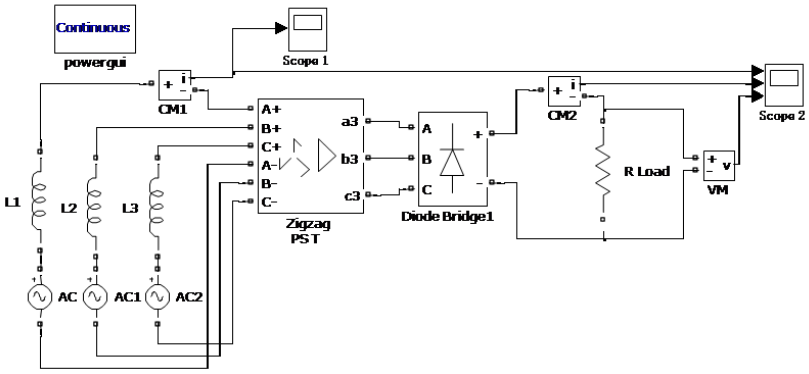


**Fig. 3-** 6- Pulse Converter Model

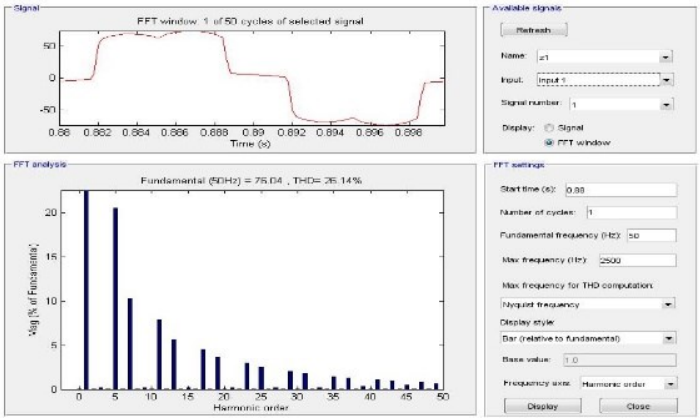


**Fig. 4 –** Waveform and THD Results

### 4.2 Twelve Pulse Converters

The two 6-Pulse rectifier bridges are coupled in parallel with two individual three phase supply system, having phase shifted angle 30° means 30 electrical degrees a part from each other as setup shown in Figure.5. The harmonics generated by one 6-pulse converter eliminated by other 6-pulse converter. The current harmonics generated in main ac supply in order of $6(2) \pm 1$, dominating harmonics are 11th and 13th.

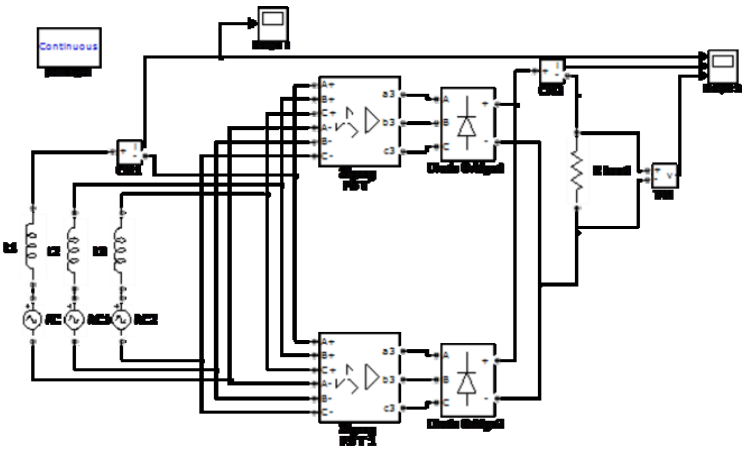


**Fig. 5:** 12- Pulse Converter Model

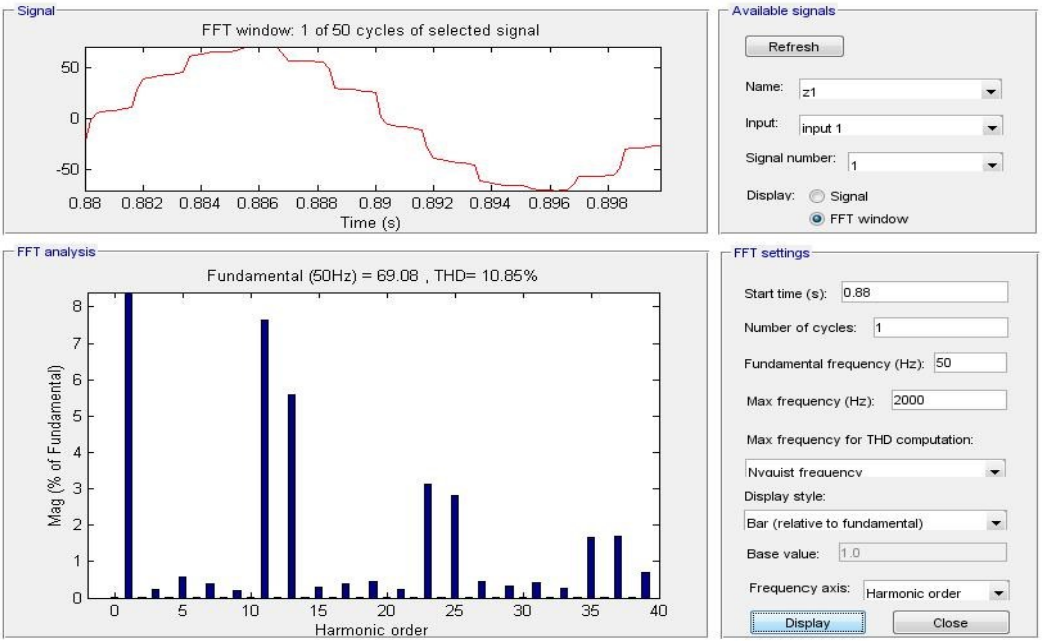


**Fig. 6**: Waveform and THD Results

### 4.3 Eighteen Pulse Converters

In 18-Pulse converters scheme, the three six pulse rectifier bridges are connected parallel with R–Load, feds from three individual three phase supply sources as setup shown in Figure7. Three six pulse converters are 20 electrical degrees a part from each other. The current harmonics generated in main ac supply in order of 6(3) ±1, dominating harmonics are $17^{th}$ and $19^{th}$.

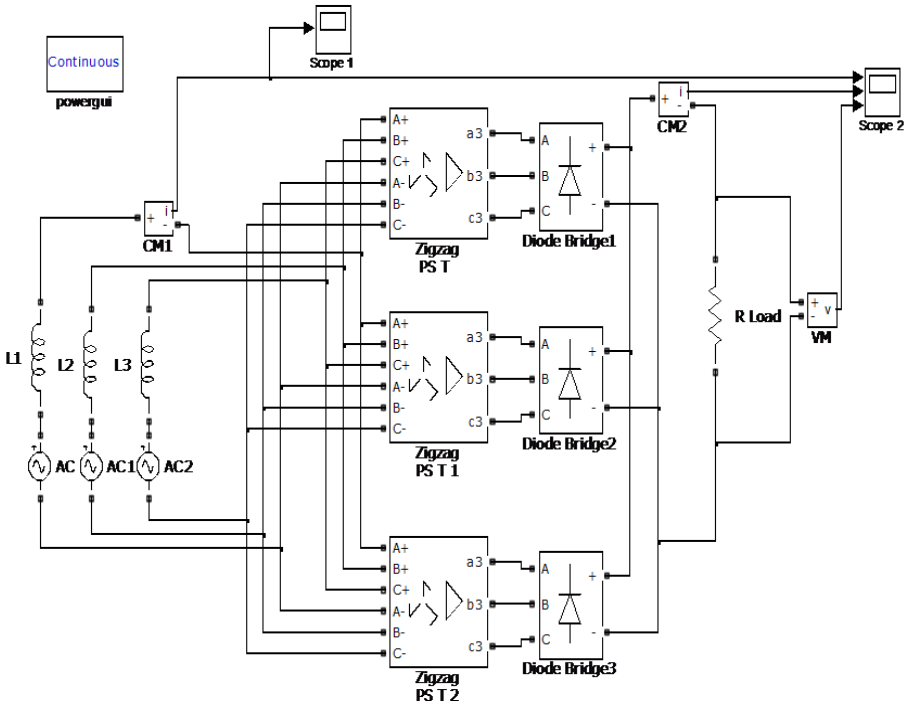


**Fig. 7:** 18- Pulse Converter Model

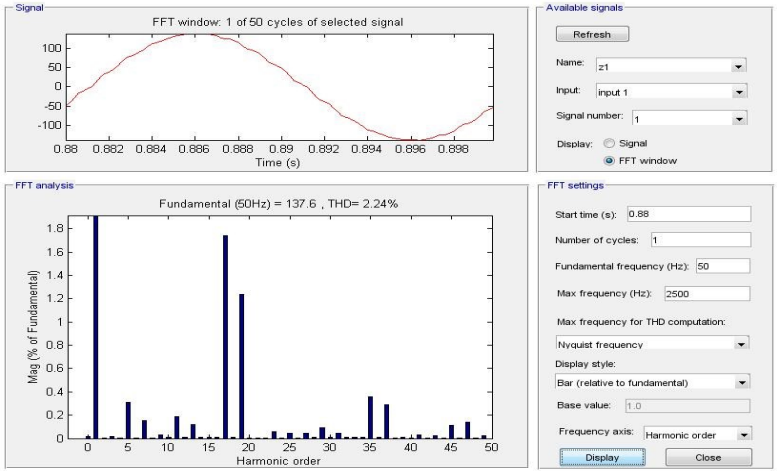


**Fig. 8:** Waveform and THD Results

### 4.4 Twenty Four Pulse Converters

The 24–Pulse system is a combination of four six pulse converter units. Which are 15° phase shifted to each other and provides 24 pulse rectification with much reduced harmonics contents. The current harmonics generated in main ac supply in order of 6(4)±1, dominating harmonics are $23^{th}$ and $25^{th}$.

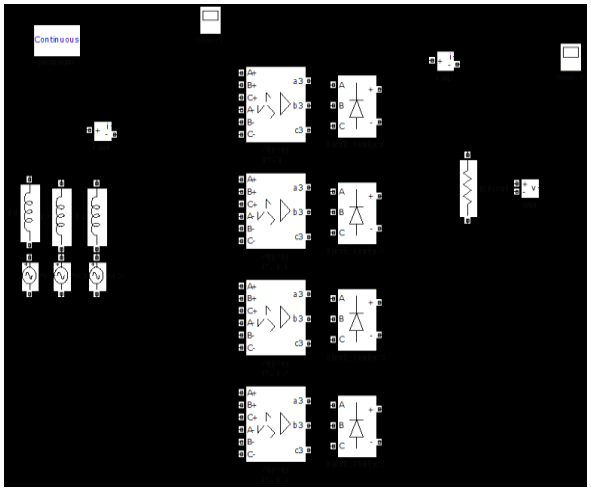


**Fig. 9:** 24- Pulse Converter Model

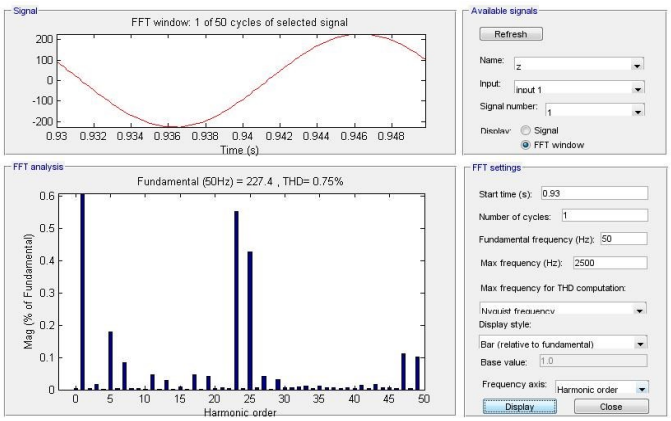


**Fig .10:** Waveform and THD Results

# 5. Experimental Prototype Model of 6, 12, 24 Multipulse Converters

Due to enormous applications and benefits in HVDC System of multipulse converters, many researchers has started work in this area and most of them have done researches in the simulation sides using matlab software, also founds the successful results, such as reduces the THDs currents and improved the P.F & Ripple factor. This mitigation technique offers the superior performance as compare to otehr. Currently, it is the necessary to implement such converter in prototype hardware and validates their results.

## 5.1 Prototype Hardware Model of 6, 12, 24 Multipulse Converters

Experimental Prototype Model Hardware Implementation of Multipulse Converters require the components, such as multiple transformer of different rating (380/220 Volt, 250 VA), circuit breaker, diode bridges rectified, resistive load (two bulbs 100 W), phase shifting transformers etc. All of these components are arranged and configured in a single model according to their simulations. The 3–Φ phase shifted transformer is made using the various single phase transformers as shown in figure. 11 below.

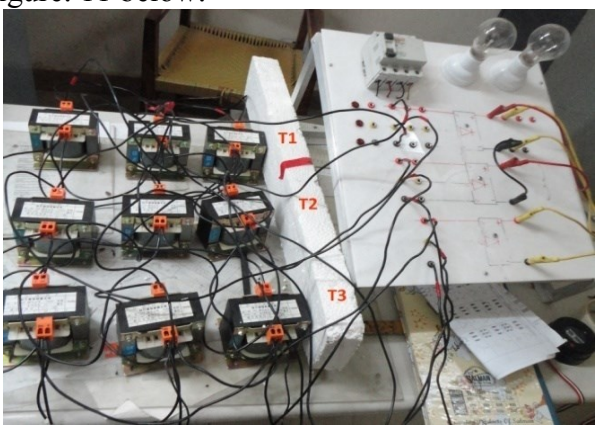


**Fig .11:** 18- Pulse Hardware Model

Every three pair of transformer (T1, T2, T3 & T4) act as an individual 3–Φ Phase shifting transformer, different three pin points are left for manually connections purpose such as Y– Y, Y–Δ, Δ–Y, and Δ–Δ. The best results obtained at the Δ–Δ. R–Load parallel coupled with DC output.

## 5.2 Operation of Multi-Pulse Converters

Experimentally, 6, 12, 18 and 24 pulse converters are operated. The operation of such converters can be easily understand by given figure 12 below.

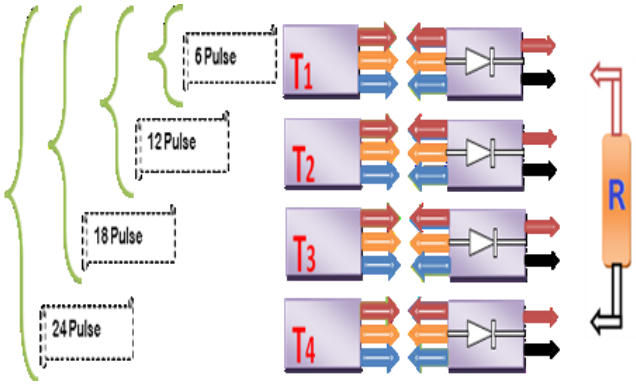


**Fig. 12:** Single Line Model of Hardware

Experiment was performed in to four steps S1, S2, S3 and S4 by manually connected different three phase transformers act as 6– Pulse, 12– Pulse, 18– Pulse and 24– Pulse converters.

### 5.2.1 6-Pulse Converters or S1

In this converter, delta connected three phase transformer T1 directly coupled across their rectifier bridge with resistive load. The power quality parameters have been analysis into the source side. Total harmonics distortions current with waveform is given in figure.13 blow

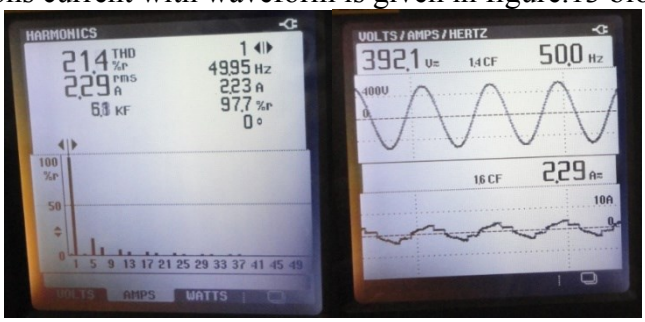


**Fig. 13:** Total harmonics distortions current with wave from

### 5.2.2 12-Pulse Converters or S2

In this converter, two deltas connected three phase transformers T1 & T2 directly coupled across their rectifier bridge with resistive load. The power quality parameters have been analysis into the source side. Total harmonics distortions current with wave form given in figure. 14 blow.

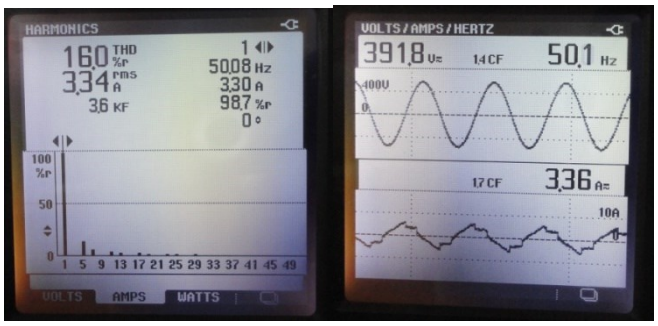


**Fig. 14:** Total harmonics distortions current with waveform

### 5.2.3 18-Pulse Converters or S3

In this converter, three delta connected three phase transformers T1, T2 and T3 directly coupled across their rectifier bridges with resistive load. The power quality parameters have been analysis into the source side. Total harmonics distortions current with wave form given in figure.15 below.

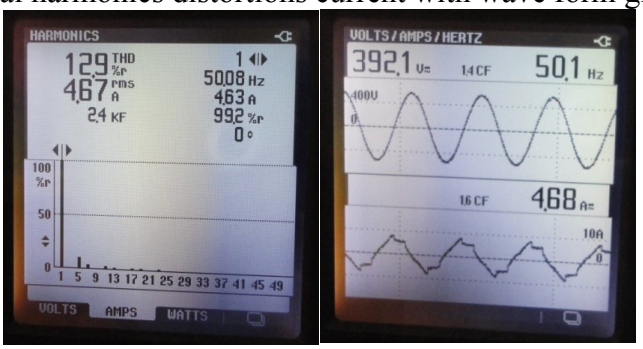


**Fig. 15:** Total harmonics distortions current with wave form

### 5.2.4 24-Pulse Converters or S4

In this converter, four deltas connected three phase transformers T1, T2, T3 and T4 directly coupled with all rectifier bridges with resistive load. The power quality parameters have been analysis into the source side. Total harmonics distortions current with wave form given in figure.16 blow.


**Fig. 16:** Total harmonics distortions current with wave form

### 5.2.5 18 & 24-Pulse Converters

In the 18 & 24 pulse converters, the THDs current in main supply has been reduced to 2.24 % and 0.75%. These values are well within allowable limit defined by IEEE 519-1992 Standard.

## 6. Experimental Results of 6, 12, 18 & 24-Pulse Converters

The experiment performed in to four steps and measured THDs current results 21.4%, 16.00%, 12.9% and 11.7% of 6, 12, 18 and 24 pulse converter respectively as Current Parameters are given in Table no. 2 and Voltage Parameters are given in Table no. 3 against each configuration. Final Total Harmonics Distortions current result 11.7% is well within the IEEE Standard. [1-22].

**Table 2:** Current Parameters

| Configuration | I in | ITHD | C.F(i) | K.F | I % r |
|---|---|---|---|---|---|
| 6-Pulse | 2.29 | 21.4 | 1.6 | 5.3 | 97.8 |
| 12-Pulse | 3.36 | 16.0 | 1.7 | 3.6 | 98.7 |
| 18-Pulse | 4.68 | 12.9 | 1.6 | 2.2 | 99.2 |
| 24-Pulse | 8.12 | 11.7 | 1.6 | 1.6 | 99.3 |

**Table 3:** Voltage Parameters

| Configuration | Vin | VTHD | C.F(v) | V % r |
|---|---|---|---|---|
| 6-Pulse | 392.1 | 0.6 | 1.5 | 100 |
| 12-Pulse | 391.8 | 0.4 | 1.4 | 100 |
| 18-Pulse | 392.1 | 0.3 | 1.4 | 100 |
| 24-Pulse | 388.1 | 0.3 | 1.4 | 100 |

## 7. Conclusion

The proposed harmonics mitigating technique (6, 12, 18 and 24 multipulse converters) has been simulated using Matlab/Simulink and Experimental Prototype Model Hardware Implementation of Multipulse Converters carried out. Step wise operated and analysis the various power quality parameter using FFT Analysis and Power Quality Analyzer. These results have been presented in th paper. Performance improvement Total Harmonics Distortions current in main ac supply has been observed and remarkably reduced in the simulation as well experimentally. These results are founding within the IEEE–519 Standard limit. Consequently, experimentally THDs current in main AC supply has been observed less distorted after applying these multipulse converters. As pulse increased the THDs current reduced accordingly. These multi-pulse configurations practically proved that it reduced the THDs current drastically, additionally improved the Crest Factor and K. Factor without using any filters which act as burden in system. If further number of pulse increases,

then power quality became much better. So it could be considered better substitute because of lower cost, reduced size and higher efficiency of converter specially for HVDC Transmission System, UPS, CVCF System in contrast to various methods for improving power quality.

## 8. Acknowledgement

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