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Modelling and Simulation of Multi Pulse AC to DC Converter Feeding To Different Reactive Power Loads and their THD Analysis

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Abstract: This paper presents a navel approach for developing method to improve power quality by enhancing number of pulses at the output of multi pulse AC to DC converter by using zigzag transformer and by the use of phase shift provided by zigzag transformer. The approach is to start with normal 6 pulse AC to DC rectifier and increasing number of pulses at the output to 24, 48 and then 96 pulses. The model for 24 48 and 96 pulse multi pulse converter is developed in MATLAB Simulink and their effect in harmonic reduction is observed by connecting it to different reactive power loads. The result shows that there is considerable decrease in harmonics drawn from the supply mains.

Keywords: MPC, GRID, THD.

I. INTRODUCTION

The advent of thyristor has revolutionised the art of power generation, conversion and control to a very large extent. Semiconductors played a key role in various engineering applications of electrical, electronics, instrumentation, telecommunication and control engineering.

A common concern has been keeping THD (Total Harmonic Distortion) below 10%. Power sources act as non-linear loads and draw a distorted waveform that contains harmonics. These harmonics can cause interference in the working of other electronic systems. Therefore it‘s important to measure the total effect of such harmonics. Total Harmonic Distortion gives us the information about the harmonic content in a signal w.r.t. fundamental component. Higher THD means higher distortion present on the input mains or lower power quality.

The nonlinear characteristics of many industrial and commercial loads such as power converters, fluorescent lamps, computers, light dimmers, and variable speed motor drives (VSDs) used in conjunction with industrial pumps, fans, and compressors and also in air-conditioning equipment have made the harmonic distortion a common occurrence in electrical power networks. These Harmonics injected by these loads are too small to cause a significant distortion in distribution networks. However, when operating in large numbers, the cumulative effect has the capability of causing serious harmonic distortion levels. These do not usually upset the end-user electronic equipment as much as they overload neutral conductors and transformers and, in general, cause additional losses and reduced power factor [1-4]. Large industrial converters and variable speed drives on the other hand are capable of generating significant levels of distortion at the point of common coupling (PCC), where other users are connected to the network[5,6].

To withstand with these harmonic standards, installations utilizing power electronic and nonlinear loads often use one of the growing numbers of harmonic mitigation techniques. Because of the number and variety of available methods, the selection of the best-suited technique for a particular application is not always an easy or straight forward process. Many options are available, including active and passive methods. Some of the most technically advanced solutions offer guaranteed results and have little or no adverse effect on the isolated power system, while the performance of other simple methods may be largely dependent on system conditions.

II. HARMONIC MITIGATION TECHNIQUES

There are three main techniques namely, passive techniques, active techniques, and hybrid harmonic reduction techniques using a combination of active and passive methods. A brief description of the electrical characteristics of each method is presented with the aim of providing the designer and site engineer with a more informed choice regarding their available options when dealing with the effects and consequences of the presence of these harmonics in the distribution network.

Passive Techniques:

Many passive techniques are available to reduce the level of harmonic pollution in an electrical network, including the connection of series line reactors , tuned harmonic filters ,and the use of higher pulse number converter circuits such as 12-pulse,18-pulse,and24-pulserectifiers.Inthesemethods, the undesirable harmonic currents may be prevented from flowing into the system by either installing a high series impedance to block their flow or diverting the flow of harmonic currents by means of a low-impedance parallel path[7].

Harmonic mitigation techniques used for supply power factor correction and harmonics mitigation in two ways to qualify the products performance. One is to put a limit on the PF for loads above a specified minimum power. Utility companies often place limits on acceptable power factors for loads (e.g., <0.8 leading and >0.75 lagging). A second way to measure or specify a product is to define absolute maximum limits for current harmonic distortion. This is usually expressed as limits for odd harmonics (e.g., 1st, 3rd, 5th, 7th, etc.). This approach does not need any qualifying minimum percentage load and is more relevant to the electric utility. Harmonic regulations or guidelines are currently applied to keep current and voltage harmonic levels in check. Certain techniques, such as the use of tuned filters, require extensive system analysis to prevent resonance problems and capacitor failures, while others, such as the use of 12-pulseor24-pulse converters, can be applied virtually with no system analysis.

Higher Pulse Converters:

Three phases, 6-pulse static power converters, such as those found in VSD, generate low frequency current harmonics. Predominantly, these are the 5th, 7th, 11th, and 13th with other higher orders harmonics also present but at lower levels. With a 6-pulse converter circuit, harmonics of the order $6k \pm 1$, where$k = 1, 2, 3, 4$, and so forth, will be present in the supply current waveform. In high-power applications, AC-DC converters based on the concept of multi pulse, namely, 12, 18, or 24 pulses, are used to reduce the harmonics in AC supply currents. They are referred to as a multi pulse converters. They use either a diode bridge or thyristor bridge and a special arrangement of phase shifting magnetic circuit such as transformers and inductors to produce the required supply current waveforms [8] high levels of voltage distortion at the supply‘s PCC because of the presence of an LC resonance circuit[9,10].

Harmonic Mitigation Using Pulse Converters:

Harmonic distortion at the input side of source ac supply can be reduced by using a pulse converter at the input side before connecting to input of any dc machine like direct control torque.

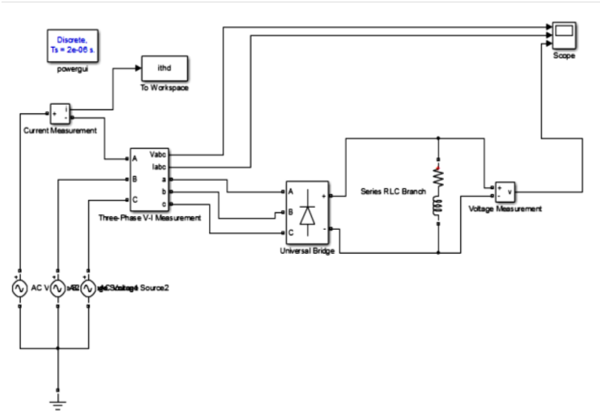

Fig. 2.1 Six Pulse Converter Circuit Diagram Made Using MATLAB

A six pulse converter circuit basically consist of six diodes in the following arrangement as shown below to form a circuit. This circuit is connected to a three phase ac source. The output will be a R L load to study the non linear variation of output voltage waveform.

III. Modelling And Simulation

Diode Rectifier Circuit - 12 Pulse Generation:

n large converter installations, where harmonics generated by a three-phase converter can reach unacceptable levels, it is possible to connect two6-pulse converter sin series with star/delta phase-shifting transformers to generate a 12-pulse waveform and reduce the harmonics on the supply and load sides, as shown in Fig3.1 This could be beneficial despite the considerable extra cost of the transformers. Twelve-pulse rectifier is frequently specified by consulting engineers for heating, ventilating, and air conditioning applications because of their theoretical ability to reduce harmonic current distortion. Instead of connecting the two converter bridge sin series, they could also be connected in parallel to give 12-pulse operation. A parallel 12-pulse arrangement is shown in Fig 3.1 Parallel connections require special care to ensure adequate balance between the currents drawn by each bridge. Secondary leakage reactance must be carefully matched, and extra reactors are needed on the DC side to absorb the instantaneous differences between the two DC voltage waveforms. When using a 12-pulse system, the 5th and 7th harmonics disappear from line current waveforms leaving the 11th as the first to appear. Only harmonics of the order $12k \pm 1$,where k =1,2,3,4, and so forth, will be present in the supply current waveform, thus resulting in a high power factor, low THD at input AC mains, and ripple-free DC output of high quality.

A 12 pulse diode rectifier consists of two 6 pulse diode rectifiers in series configuration six peaks of output voltage.

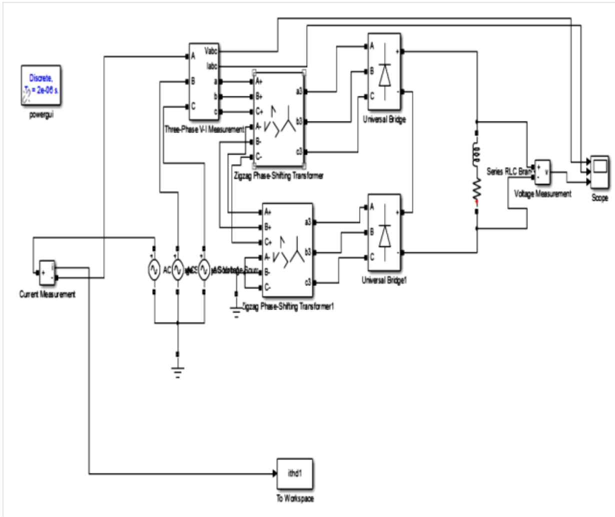

Fig. 3.1 Twelve Pulse Diode Rectifier Circuit with R-L Load

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Circuit consists of a three phase a.c supply connected to zig zag transformers. Consecutive transformers increase their phase shift by a value of 30˚ [11].

Pulse Diode Rectifier - 24 Pulse Generation:

Connecting two 12-pulse circuits with a 15∘ phase shift produces a 24-pulse system. Fig 3.2.1 shows one such system in which the two 12-pulse circuits are connected in parallel to produce the required 24 pulse system. The 11th and 13th harmonics now disappear from the supply current waveform leaving the 23rd as the first to appear. Only harmonics of the order $24k\pm1$, where k=1,2,3,4, and so forth, will be present in a 24-pulse system[12, 13].

The circuit consists of 3 phase ac supply connected in series with 4 Zig Zag transformers each of them in star-wye configuration. Each transformer increases its phase shift value by 15˚. Load consists of resistance and inductance of values 1000Ω and 650µH.

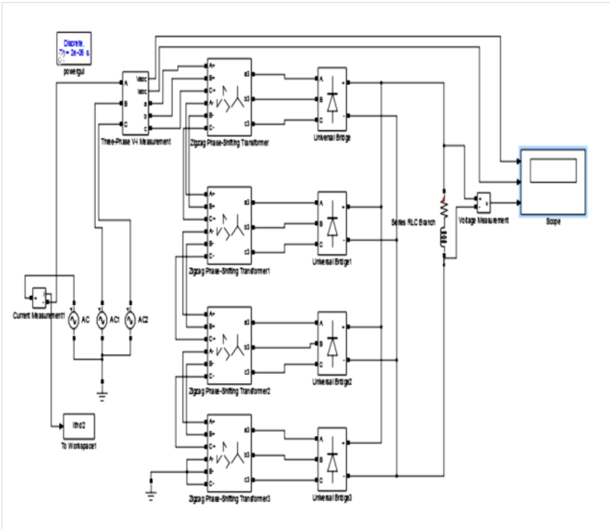

Fig. 3.2 Twenty Four Pulse Generator Circuit with RL Load

Pulse Diode Rectifier - 48 Pulse Generation:

The circuit consists of a 3 phase power supply connected in series with a 8 Zig Zag transformers of phase shift 7.5˚.These transformers are connected to 8 diode rectifiers in series configuration. Load consists of resistance and inductance of values 1000Ω and 650µH

Diode Rectifier - 96 Pulse Generation:

The block diagram of 96 pulse diode rectifier consists of a three phase power supple,3 phase measurement block,16 zig zag transformers,16 six pulse diode rectifiers, RL load, output measurement device scope.

Each transformer increases its phase shift by 3.75˚ starting with 3.75˚ in the first transformer.

Three phase supply of frequency 60 hertz is fed to transformers in series configuration to each other. This transformer output is connected to diode rectifiers and fed to RL load.

The output is connected to a scope to generate voltage and current waveforms across the load.

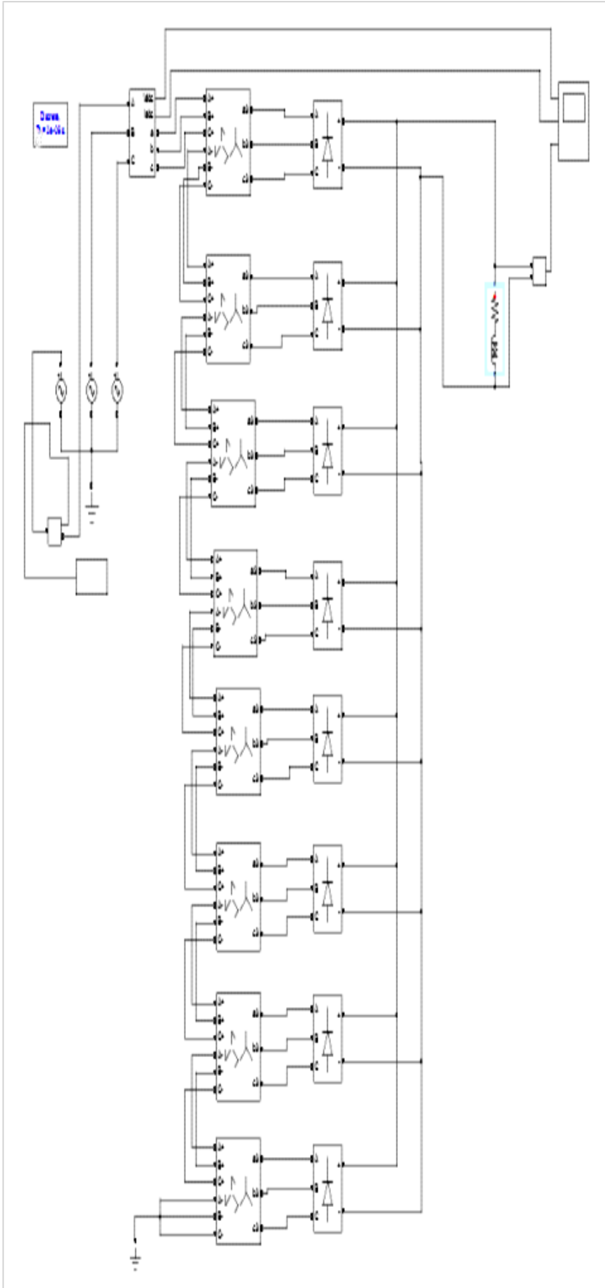

Fig. 3.3. Circuit Design of 48 Pulse Diode Rectifier

IV. Results And Conclusion

We have generated Total Harmonic Distortion for 6,12,24,48 and 96 pulse diode rectifiers with RL load with input frequency of 60Hz and Peak to peak voltage of 312 volts 3-Phase AC supply.

The output waveform made using this six pulse converter

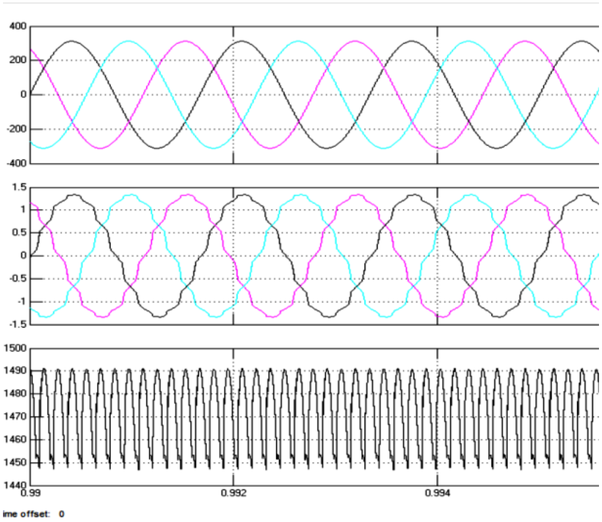

Fig. 4.1. Waveforms of Six Pulse Converter

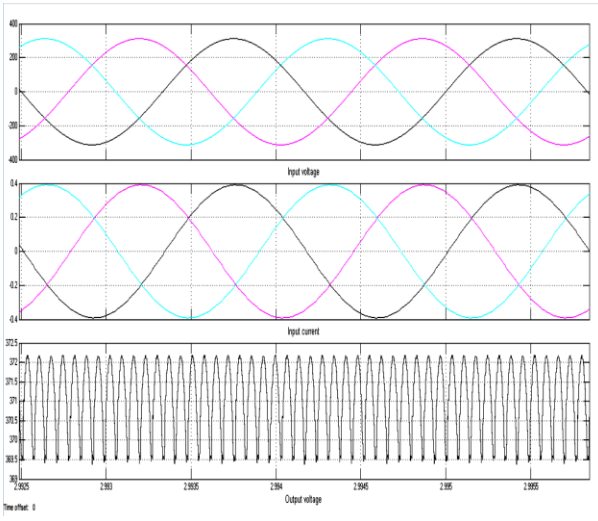

Fig. 4.2. Waveforms of 24 Pulse Converter

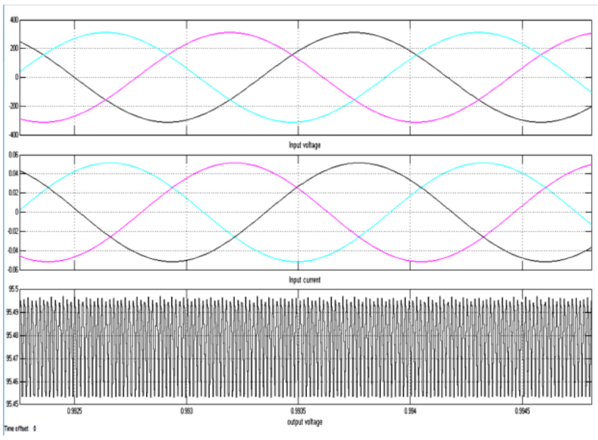

Fig. 4.3. Waveforms of 96 Pulse Converter

THD Observations Using Different Pulse Diode Rectifiers:

We have generated Total Harmonic Distortion for 6, 12, 24, 48 and 96 pulse diode rectifiers with RL load with input frequency of 60Hz and Peak to peak voltage of 312 volts 3-Phase AC supply.

A 12 pulse diode rectifier consists of two 6 pulse diode rectifiers in series configuration six peaks of output voltage.

Circuit consists of a three phase a.c supply connected to zig zag transformers. Consecutive transformers increase their phase shift by a value of 30˚. It suppresses triplet harmonic currents (3,9,15,21 etc) to supply 3 phase power as an autotransformer. It supplies phase shifted 3-phase power[34]. This voltage is fed to a 6 pulse diode rectifiers connected in series configuration with each other.

Connecting two 12-pulse circuits with a 15∘ phase shift produces a 24-pulse system. Fig 3.2.1 shows one such system in which the two 12-pulse circuits are connected in parallel to produce the required 24 pulse system. The 11th and 13th harmonics now disappear from the supply current waveform leaving the 23rd as the first to appear. Only harmonics of the order $24k\pm1$, where k=1,2,3,4, and so forth, will be present in a 24-pulse system.

The circuit consists of 3 phase ac supply connected in series with 4 Zig Zag transformers each of them in star-wye configuration. Each transformer increases its phase shift value by 15˚.

With the similar concept of zigzag transformers and phase difference obtained by them is used with parallel connection of bridge and 48 and 96 pulse AC to DC converters are designed and tested by giving it to various values of RL loads with increasing L for various reactive power and reduction in THD were observed as below.

Resistance (Ω)	Inductance (μH)	6-Pulse (in %)	12-Pulse (in %)	24-Pulse (in %)	48-Pulse (in %)
10000	65	26.78	2.38	0.41	0.12
1000	650	30.12	3.27	1.73	0.92
100	6500	43.84	19.52	13.39	9.55

Table: comparison of THD using different pulse converters.

From the above table it is clearly seen that multipulse converters are very useful way for odd harmonic reduction without affecting the output response.

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