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Power Quality Improvement by Using Phase Shifting Transformer

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ABSTRACT- Non-linear loads like direct current loads and induction motor drives are a major source of harmonics in the power system. Multipulse converters are widely used to overcome the problem of harmonics. This thesis highlights the performance comparison of different multipulse converters which are simulated in MATLAB/SIMULINK. Performance comparison of the 6-pulse, 12-pulse, 24-pulse and 48-pulse converters feeding RL-load is performed. The phase shift in the converters is achieved by using ziz-zag phase shifting transformers. The Total Harmonic Distortion (THD) in input current and input voltage along with ripple content in the output voltage and output current are measured and their corresponding waveforms are observed. Also, performance comparison of 6-pulse, 12-pulse, 24-pulse and 48-pulse converters is performed. The results obtained with a multipulse converter are compared with those obtained with the six pulse converter. It is observed that multipulse converters provide better results in terms of THD in input voltage and input current. It is found that as the pulse number of a converter increases, THD in input voltage and input current along with ripple content in the output voltage and output current is decreased.

KEYWORDS- Phase Shifting, Multipurpose Converters, Power Quality, Harmonic Mitigation, Line Current Distortion.

I. INTRODUCTION

Electricity was discovered about 400 years ago. There has been a continuous development in generation, distribution and use of electricity. During the industrial revolution, stress was given on novel and advanced methods of electricity generation and its usage. Earlier, the electrical machines and devices required significant amount of power for their operation but showed good performance. Priority was given to performance rather than the cost of the machine. However, the industrial age put emphasis on the products to be cost effective as well. With time, the demand for electricity increased in the industrial sector as well as in the residential sector. This increase in demand was met by extensive power generation and distribution grids. Electrical utilities do not operate independently but function in a large network of utilities tied together. The use of non-linear devices became dominant during 1950's. These devices also contributed to power quality problems. All these factors contributed to the need of systems requiring clean and reliable power. Power quality affects the cost and reliability of any electrical system. Consequences of poor power quality may include malfunction, accelerated wear and tear, overheating and false tripping of circuit breakers. [1]

II. MULTIPULSE CONVERTERS

With the advancement in technology, more focus was put on the use of power electronic devices so as to provide most efficient energy conversion. The major objective of using power electronic devices is that they are lower in cost, lesser size, and lesser weight and have reduced power loss. They also have high energy efficiency due to which removal of heat produced because of dissipated energy is reduced. However, technology of power electronics has some disadvantages. One major problem is the generation of harmonics. A rectifier is a power electronic circuit that should provide dc output voltage with lesser harmonic component. Multipulse converters provide a simple and effective technique for harmonic elimination. The phase shifting transformers have an important part in the working of multipulse converters. Multipulse converters are useful in waste water industries where lower harmonic distortion is required. They are also required in applications where a high percentage of motor drive loads is present as compared with the total facility load. [2]

III. POWER QUALITY

The major issue these days in our power system is to provide good quality of power. Power quality concerns with end users, utilities, engineers and manufacturers. The presence of non-linear devices and the complexities involved with industrial processes are the major factors for the increased interest in power quality. Our system is subjected to various power quality events which include short duration variations, long duration variations, transients, and voltage imbalance and waveform distortion. It is very important to provide good quality of power. Non-linear devices like rectifiers, drives etc have increased the problem of harmonics. They affect the supply voltage and supply current. These days, multipulse converters are preferred for harmonic mitigation as they have many advantages. They are usually formed by a number of

converters connected together either in series or in parallel connection. These converters should be at appropriate phase shift from each other. The phase shift can be provided by using star/delta transformers, star/polygon transformers etc. However, each one of the transformers has their own advantages. Various parameters have to be considered before selecting the type of transformer for a particular application. Some of these parameters are size, weight, mechanical characteristics, electrical indicators etc. Zigzag phase shifting transformers can also be used for providing the required phase shift. Multipulse converters are based on the principle of harmonic cancellation such that the harmonics produced by one converter are cancelled by the harmonics produced by the other converter. [10]

To meet the strict harmonic requirements set by North American and European standards such as the IEEE Standard 519-1992, leading high power drive manufacturers around the world are increasingly using multiplex diode rectifiers in their drives as front-end converters. 12-, 18- and 24-pulse rectifiers can be configured using rectifiers, supplied with a phase shifting transformer having a number of secondary windings. A six-pulse diode rectifier is fed by an each secondary winding. The output of these rectifiers is connected to a voltage source inverter.

The ability to reduce the line current harmonic distortion the main feature of the multipulse rectifier. The cancellation of some of the low-order harmonic currents generated by the six-pulse rectifiers is achieved by the phase shifting transformer. In general, the line current distortion decreases with the increase in the number of rectifier pulses. Rectifiers with a pulse of more than thirty pulses are generally used in practice, mainly due to the increased cost of transformers and limited improvements in performance [3].

IV. OBJECTIVES

The major objectives of the research are summarized as follows:

• Reduction of total harmonic distortion by using multipulse rectifiers along with phase shifting transformers.

• A comparative analysis of 6- pulse, 12-pulse, 24-pulse and 48-pulse converter feeding RL-load has to be achieved so as to improve the power quality by mitigating the effect of harmonics.

V. LITERATURE REVIEW

A. Introduction

The quality of power is very important to ensure that the loads are operating at their optimal capacity. Sometimes, the major reasons for the deterioration in power quality are the loads themselves. Computers, communication equipment, and process controls are some of the electronic devices are sensitive to the power system's disturbances. Power quality disturbance can be considered in terms of susceptibility and vulnerability on the equipment. The malfunction of a device due to disturbances in the system refers to susceptibility [2]. This phenomenon can be observed in computing devices where if transients exceed a threshold, error occurs. A device that is said to fail when the voltage is above its alarming level. This condition can be observed in an unsuccessful correction when it comes to transient volumes exceeding a certain level. IEEE Standard IEEE1100 defines power efficiency "as the concept of regulating and establishing sensitive electronic devices in a manner consistent with the use of those devices". . [10]

B. Perspectives of Power Quality

Perspectives of power quality are as follows:

- The first perspective concerns with the customer's side of the meter. In this, it focuses on electrical disturbances affecting equipment.
- The second perspective also concerns with the customer's side of the meter. In this case, the tool manufacturer must be aware of the level of emergency and their timing of occurrence in order to determine the tolerance limitations of the equipment.
- The third perspective comes from the utility. They are interested in power disturbances on both sides of the meter. They are concerned with how the power disturbances that have originated on the utility side will affect the customer equipments. They also take into consideration, the affect of user generated disturbances on the equipment of other customers or utility [5].

C. Importance of Power Quality

Recently, a lot of focus has been put on improving the power quality. The issue of power quality concerns the utility as well as the consumers. Power quality is gaining importance due to the following reasons:

- The dependency of our society on electrical supply has increased. Even a small power outage can cause heavy losses for traders. It is a long -term crisis that affects all functions of society.
- Towards power quality problems, the new equipment are having higher sensitivity.
- With the advent of power electronic devices like variable speed drives, new disturbances have been introduced into the supply system.[2]

D. Symptoms of Power Quality Problems

Some of the symptoms of power quality problems are as follows:

- Electronic testing equipment is needed to investigate energy efficiency.
- Disoperation of a piece of equipment at the same time of day.
- Circuit breakers trip without getting overloaded.
- During thunderstorms the equipment may fail.
- Frequent failure of electronic systems to operate.
- Electronic systems work in one place but do not work in another. [1]

VI. METHODOLOGY

Multipulse converters can be defined as diode/thyristor converters that provide more than 6 pulses of dc per cycle. Usually, it consists of a combination of a number of 6-pulse rectifiers connected either in parallel or in series. Each rectifier is powered by a process that drives a second voltage of the transformer so that the first voltage is installed close to the sinusoidal. One rectifier is present at each of the secondary windings. As the number of rectifiers is increased, the number of steps in the primary current waveform is also increased. Thereby producing a

sinusoidal shaped supply current which then flows into the transformer winding. The multipulse converters that consist of diodes as switching elements are referred to as uncontrolled converters whereas the multipulse converters that consists of thyristors as switching elements are referred to as controlled converters. For harmonic mitigation, the use of uncontrolled converters is very popular. This is due to the fact that they do not require any control system for the diodes. However, output voltage /cannot be controlled. In case of controlled converters, a control circuit is required for switch/ing of the thyristors. Due to the modular control concept, the overall design and circuit realization becomes easier. Multipulse converter provides a simple and effective technique for harmonic elimination. They are based on the principle of harmonic cancellation. It involves multiple converters so that harmonics generated by one converter are cancelled by harmonics produced by the other converters. [4]

VII. SYSTEM ARCHITECTURE

A. Configuration of A Multipulse Converter

The major components of multipulse converters are as follows:

B. Zigzag Phase Shifting Transformer

Zigzag phase shifting transformer is used to achieve the desired phase shift in-between the converter voltages. It consists of three single-phase, three-winding transformers. Primary winding is connected in zigzag manner. Each of the core leg consists of two coils i.e. the inner coil and the outer coil. Both the coils consist of same winding turns but their direction of rotation is opposite in nature. Figure 1 and Figure 2 depicts zig-zag coupling for positive phase shift and negative phase shift, respectively. [6]

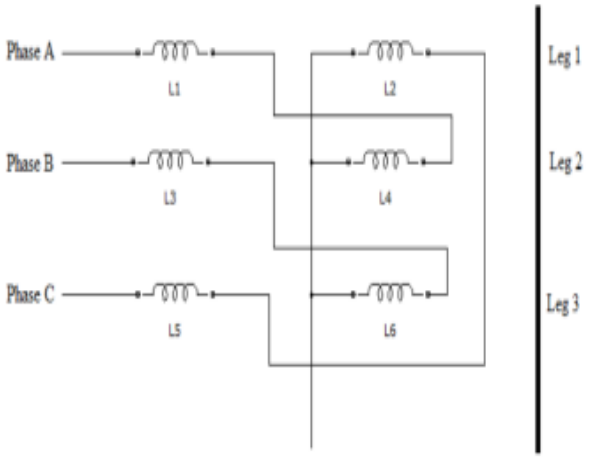

Figure 1: Zig-Zag Coupling for Positive Phase Shift

The secondary winding of the zig-zag phase shifting transformer is configurable in the following ways:

- Star: In case of star connected secondary winding, the secondary phase voltages will lead or lag the primary voltages by a phase angle.
- Star with accessible neutral
- Grounded star
- Delta (D11): If the secondary winding is connected in delta (D11) then an additional phase shift of +30° is provided to the phase angle.
- Delta (D1): If the secondary winding is connected in delta (D1) then an additional phase shift of -30° is provided to the phase angle. [7]

C. Three phase rectifier

Three-phase rectifiers are commonly used in industries to produce a dc voltage and dc current for large loads. Figure-3 and Figure 4 shows the diagram and corresponding waveforms of a three phase rectifier, respectively. The three phase voltage source considered is balanced in nature.

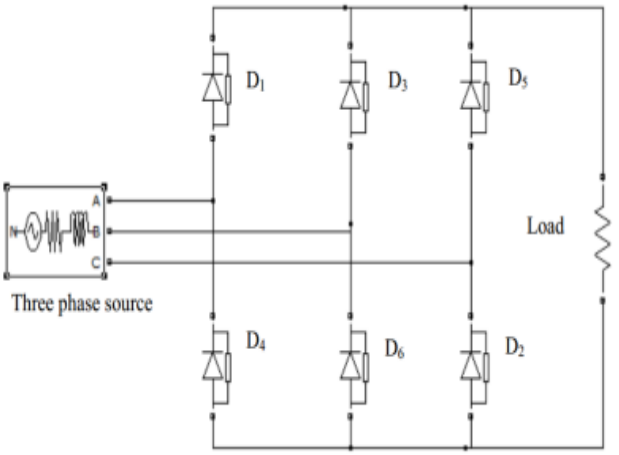

Figure 2: Circuit Diagram of a Three Phase Rectifier
Working of a three phase rectifier is described as follows:

- Only one diode in the top half of the bridge i.e. D1, D3, or D5 will conduct at a time.
- Only one diode in the bottom half of the bridge i.e. D2, D4, or D6 will conduct at a time.
- No two diodes in the same leg would conduct simultaneously else a short circuit can occur.
- Diode pairs (D1, D4), (D3, D6) and (D5, D2) cannot conduct simultaneously.
- The output load voltage is one among the line to line voltages of the source. For example, when D1 and D2 would conduct then the corresponding output voltage is Vac.
- The diodes that would conduct are determined by which line to line voltage is the maximum at that instant.
- There are six combinations of line to line voltages. Each combination exists for an interval of 60°.
- As six transitions occur in line to line voltages for each period of the source voltage, the circuit is also referred to as a 6-pulse rectifier.
- Therefore, fundamental frequency of the output voltage is 6*grid frequency. Whenever a diode conducts, voltage across it becomes equal to zero. [8]

VIII. RESULTS

A. Results Using A Six Pulse Rectifier

B.

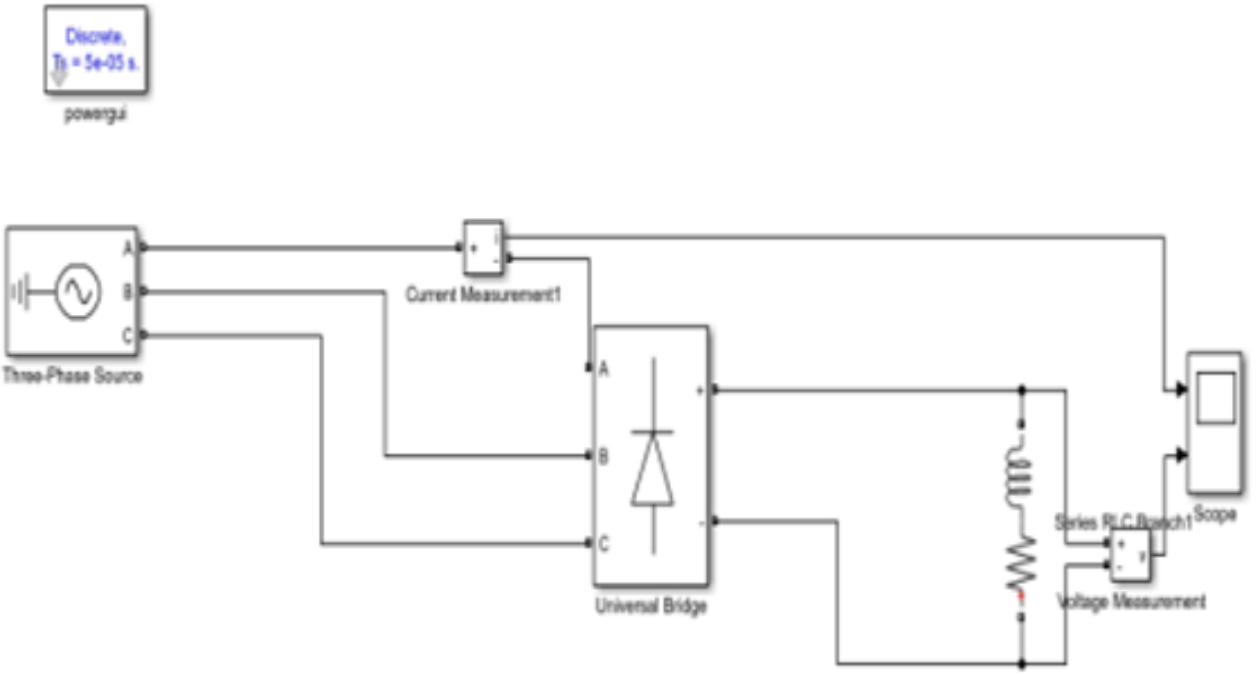

Figure 3: Simulation diagram of six pulse rectifier

Above is the simulation diagram of six pulse rectifier. We designed it using RL Figure 3 shows the simulation of 6-pulse rectifier in MATLAB. Figure 4 gives us results of a 6-pulse rectifier. One can see the input grid current isa is distorted and it becomes a quasi-square wave. FFT analysis of this current shows a total harmonic distortion of 30.89 per cent as shown in figure 5.

Whenever we have a non linear load like a dc load, the current from grid side gets distorted and to reduce these distortion multipulse rectifiers along with phase shifting transformers are used.

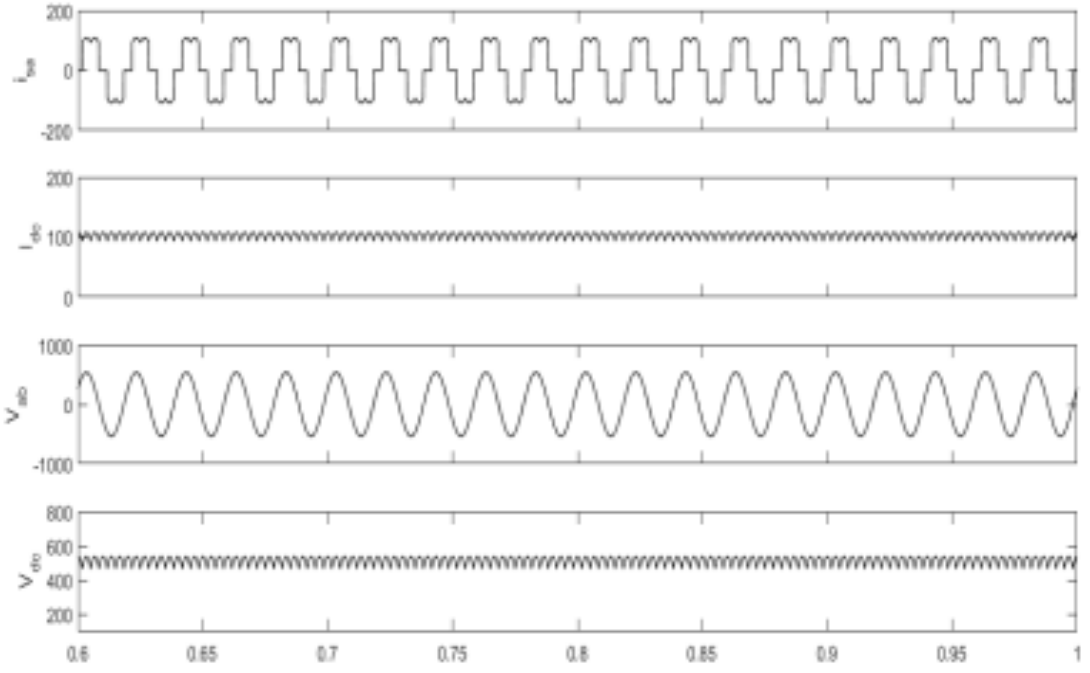

Figure 4: Results of 6-pulse rectifier

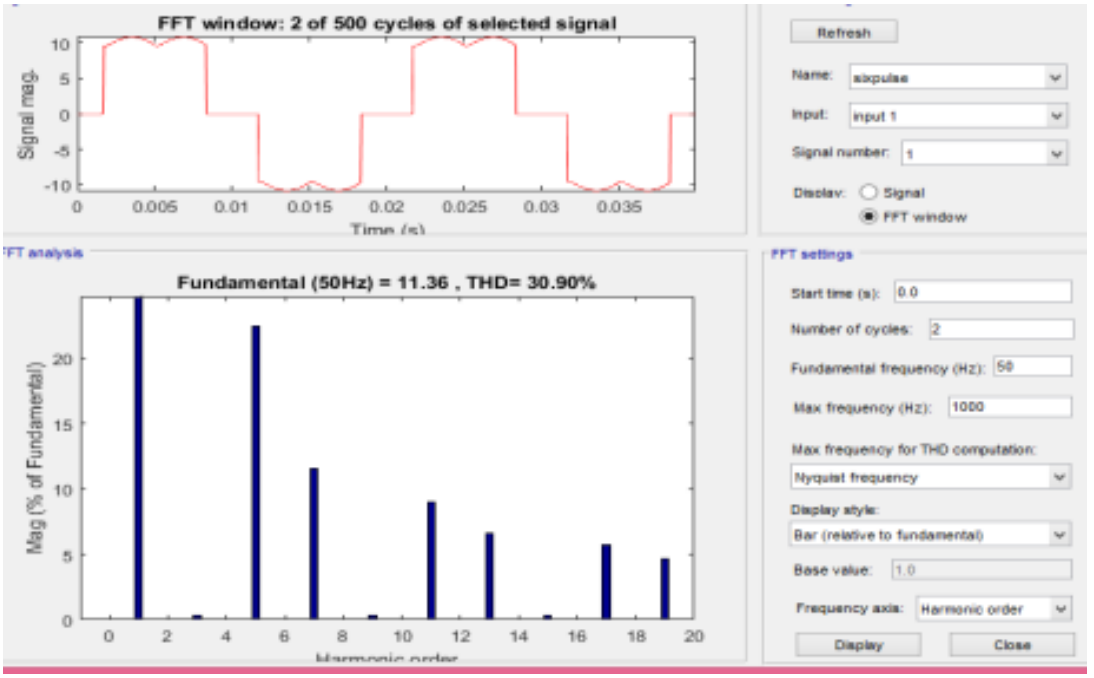

Figure 5: FFT Analysis of 6 pulse rectifier

C. Results Using A 12 Pulse Rectifier Along With Phase Shifting Transformers

In this setup there are two identical six-pulse diode rectifiers powered by a phase-shifting transformer with two secondary windings. The outputs from the six-pulse rectifiers are connected in series. To eliminate low-order harmonics in the input grid side current, the line to-line voltage of the wye-connected secondary winding is in phase with the primary voltage while the delta-connected secondary winding voltage leads Y connected primary winding by 30 degrees. The phase displacement makes it possible for certain harmonic currents generated by a three-phase nonlinear load to cancel out. It suppresses 5th and 7th harmonics. [9]

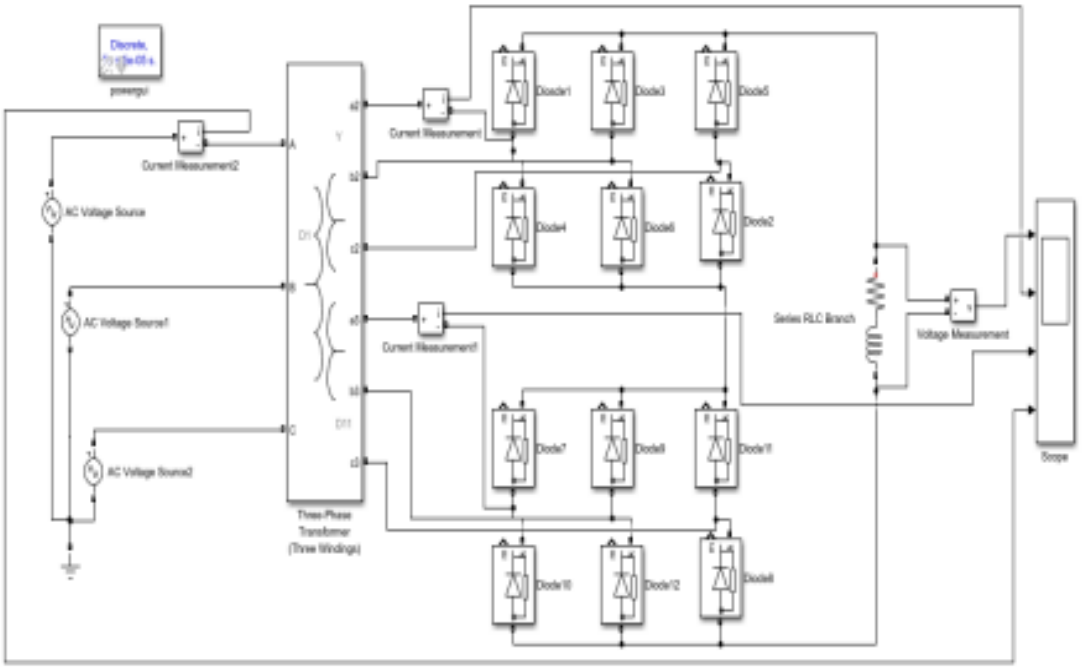

Figure 6: Simulation diagram of 12 pulse rectifier

Figure 6 shows the simulation of 12-pulse rectifier in MATLAB. Figure 7 gives us results of a 12-pulse rectifier. One can see the input grid current isa is less distorted as compared to 6-pulse rectifier. FFT analysis of this current shows a total harmonic distortion of 12.68 per cent as shown in figure 8.

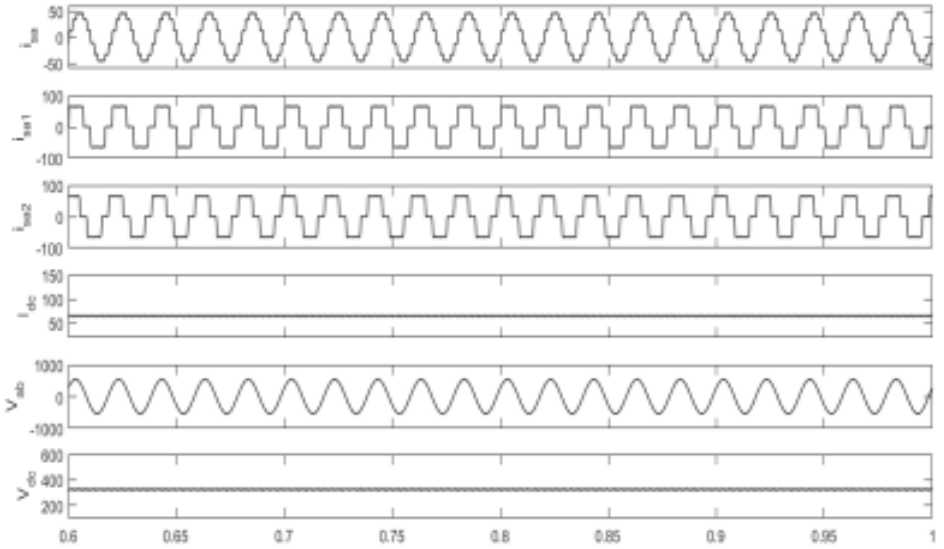

Figure 7: Results of 12 pulse rectifier

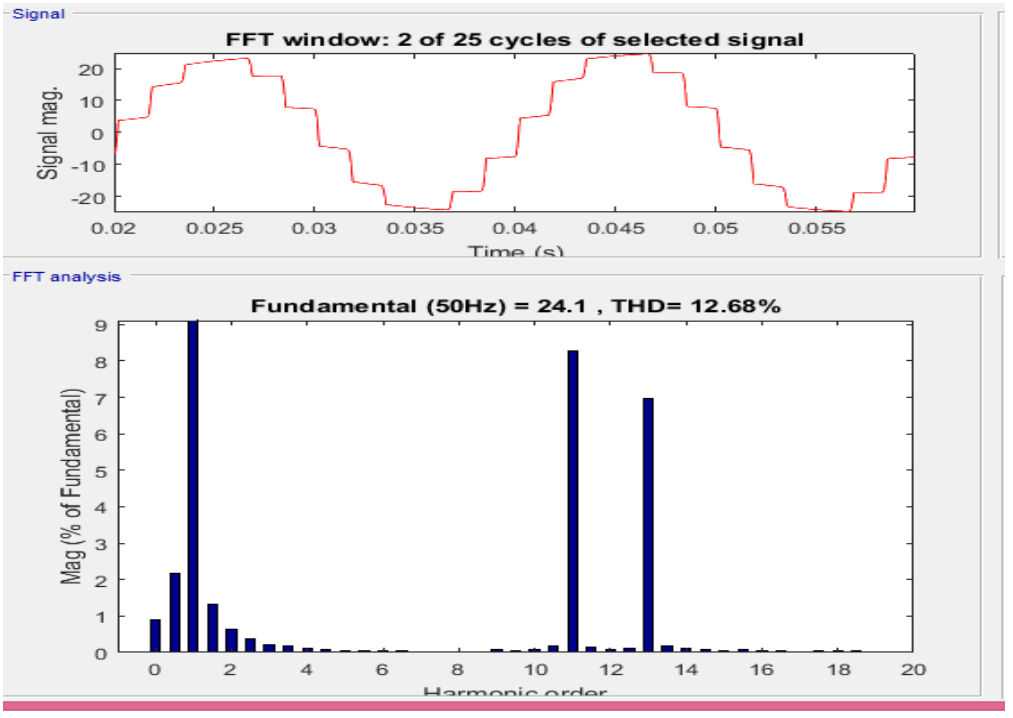

Figure 8: FFT analysis of grid side current (isa) of 12 pulse rectifier

IX. CONCLUSION

- A comprehensive review of phase shifting transformer has been carried out for configurations with ziz-zag connected transformer. It is considered as better alternative because of simple construction, low cost, low THD in source current.
- Higher the number of pulses lower the harmonic distortion.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFRENCES

[1] Bin Wu "High Power Converters and AC Drives" 2006 Ed. A John Wiley & Sons, Inc., Publication.
[2] Muhammad H. Rashid, "Power electronics: Circuits, devices and applications" 3rd Ed. Oxford, UK: Elsevier Inc., 2011.
[3] Jil McIntosh, "How it works: Electric vehicle charging", driving .ca, Oct 27, 2017
[4] Kotubdin, Andrew D Moore, Anup Barai, James Marco, "Effects of high frequency current ripple on vehicle battery performance", Science Direct ,Applied Energy, vol. 178, Sep 15, 2016, pages 142-154.
[5] Gang Zhao, Yunfie Yue, "Harmonic analysis and suppression of electrical vehicle charging station", Proceedings of 2017IEEE International Conference on Mechatronics and Automation (ICMA), Aug 6-9, 2017, Takamatsu, Japan.

[6] Wajahat Khan, Furkan Ahmad, Mohammad Saad Alam (AMU), " Fast EV charging station integration with grid ensuring optimal and quality power exchange", Science Direct, Aug 16, 2018.
[7] D. A. Paice, "Transformers for Multipulse AC/DC Converters," U.S. Patent 6 101 113, Aug. 8, 2000.
[8] D. A. Paice, Power Electronic Converter Harmonics: Multipulse Methods for Clean Power. New York: IEEE Press, 1996.
[9] S. Hansen, U. Borup, and F. Blaabjerg, "Quasi 12-pulse rectifier for adjustable speed drives," in Proc. 2001 IEEE APEC1 Conf., vol. 2, Mar. 4–8, 2001, pp. 806–812.
[10] Bhim Singh, Senior Member, IEEE, G. Bhuvaneswari, Senior Member, IEEE, Vipin Garg, Member, IEEE, and Sanjay Gairola, "Pulse Multiplication in AC–DC Converters for Harmonic Mitigation in Vector-Controlled Induction Motor Drives", IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 21, NO. 2, JUNE 2006