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# Power Quality Improvement in Induction Motor Drive using 24-Pulse AC-DC Converter Employing Pulse Multiplication Technique

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**Abstract**: The term multipulse is characterized as any number of six n-pulse bridge rectifiers connected in series or parallel, where n is greater than one. The two fundamental points of interest to utilizing multi-pulse rectifier topologies are a decrease in the ac input line current harmonic and a reduction in the dc output voltage ripple. One of the outline objectives in multipulse converters is to increase the pulse number so as to wipe out more harmonics in the input line current. Numerous multipulse converters are acquainted with accomplish clean power, for example, an ordinary 12-pulse converters, 18- pulse converter and 24- pulse system. These multi pulse converters are shaped by a blend of 6-pulse bridge rectifiers, isolation transformers and so on which result in extensive size and cost. Moreover, in multipulse system careful attention topractical aspects, for example, leakage reactance in series witheach diode rectifier bridge interphase reactor windingdesign and pre-existing utility voltage distortion isimportant for equal current sharing and elimination ofharmonics in the input line currents.

**Keywords**: Phase shifting transformer, multipulse ac–dc converter (MPCs), pulse multiplication, VSI, Induction Motor drive.

## I. INTRODUCTION

In the modern era ac motors, especially squirrel cage induction motors are widely used in industries due to their less maintenance and rugged construction. Because of the absence of slip rings, brushes, maintenance duration and cost associated with the wear and tear of brushes are minimized. Apart from this squirrel cage motors are reliable, economical, high efficiency, good power factor etc. The power supply interface feeding voltage source inverter (VSI) of an induction motor drive consists of diode bridge rectifiers. This arrangement results in the injection of harmonics in ac mains, thereby decreasing the power quality at the point of common coupling (PCC).The standard IEEE 519-1992 [1]is instigate to limit this harmonic contents and by that increasing the power quality of the system. There are numerous mitigating methods have been proposed by various researchers around the world. Various harmonic mitigating strategies are accessible including active and passive techniques. Numerous aloof procedures are accessible, for example, association of arrangement series line reactors harmonics filters, and multipulse converters etc. In these strategies multipulse converters [2] are famous as a result of their effortlessness. In light of these worries, a 24-pulse rectifier system is designed by utilizing a phase shifting transformer, zero sequence blockingtransformer (ZSBT) in the dc link and an interphase reactor. By using this the system extends the 12-pulse operation to 24-pulse operation. The yield of 24-pulse rectifier is given to a VSI fed induction motor. Simulink model of induction motor with 24-pulse converter is generated and the simulation results are analysed. Different multipulse converters are compared by simulating in matlab software and the THD values are compared.MPCs can be classified based on power flow, number of pulses, and the isolated and nonisolated topologies.

### A. Unidirectional ac–dc converters

The unidirectional ac–dc converters have only unidirectional power flow i.e. ac input to dc output and are used in variable frequency ac drives for fans, compressors, pumps, waste water treatment plants, electroplating, telecommunication power supplies etc.

### B. Twelve-Pulse ac-dc Converters

These 12-pulse unidirectional converters are extensively used in both isolated and nonisolated circuit topologies depending upon voltage levels on the input ac mains and dc output. If there is much lower dc output voltage required such as electroplating then isolated topologies are preferred from the protection point of view, andisolated multiwinding transformer is used before feeding it to the diode rectifier. However, if the voltage difference between

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input and output is not much, then nonisolated topologies are used through different types of autotransformers to reduce the size, cost, weight, and losses in the magnetics before it is fed to uncontrolled diode rectifiers.

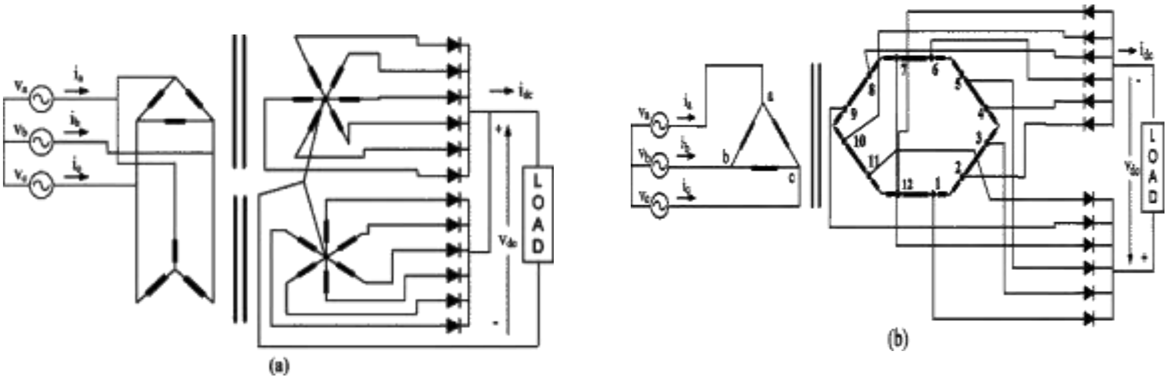


Fig.1 (a) three-phase unidirectional 12-pulse full-wave ac–dc converter using isolated two transformers (delta/double-star and star/double-star). (b) three-phase unidirectional 12-pulse ac–dc converter using isolated single-polygon transformer.

Fig.1(a) shows a circuit with a two-winding transformer to feed one bridge with a phase shift of $30^0$As shown in Fig.1 (a) and (b), these types of full-wave MPCs can also be further classified whether it uses double star or tapped polygon transformer secondaries to create twelve phases to feed full-wave diode rectifiers. Both types of MPCs have relative merits and demerits in terms of device utilization, transformer utilization etc. However, these two types of converters offer almost the same level of performance in input ac mains in terms of THD of current and power factor and ripples in dc output.

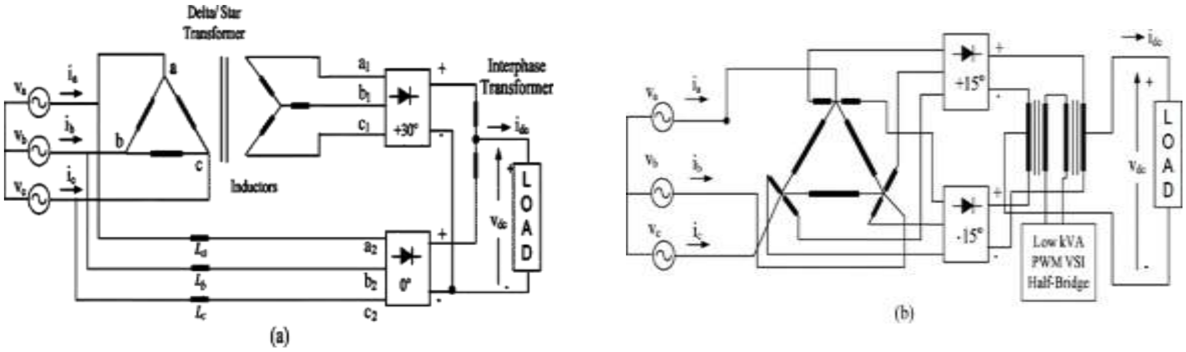


Fig.2 (a) Three-phase unidirectional 12-pulse bridge ac–dc converter using delta-star connected transformer.(b) Three-phase 12-pulse bridge ac–dc converter with active interphase reactor.

and other bridge is fed directly through small ac reactors to adjust input ac inductances in both bridges with an interphase transformer on dc side to realize 12-pulse in the dc output.Fig.2 (b) shows a 12-pulse ac–dc converter in which a set of phase shift of $\pm 15^0$ is achieved using an extended delta connection to feed two sets of three-phase diode rectifiers with interphase transformers on the dc side with small (2%) rating active PWM current source to improve its performance in terms of THD of less than one percent of ac mains current. These are also called active interphase reactors and use a half bridge with two self-commutating devices along with its self-supporting dc bus voltage source converter.

### C. Eighteen-Pulse ac–dc Converters

Eighteen-pulse ac–dc converters are developed to achieve improved performance in terms of low THD of ac mains current and have low value of output voltage ripples. These are also used both in isolated and nonisolatedtopologies depending upon the requirements of specific applications [3].

Fig.3.shows one typical circuit of bridge-type 18-pulse isolated ac–dc converter in which a multiwinding transformer with primary in delta and three secondaries using one in delta with zero-phase shift and two polygon windings having a phase shift of $\pm 20^0$ are used to feed three sets of three-phase diode bridge rectifiers connected in series for dc output. It has the advantage of avoiding interphase components and insensitive ac mains voltage harmonics.

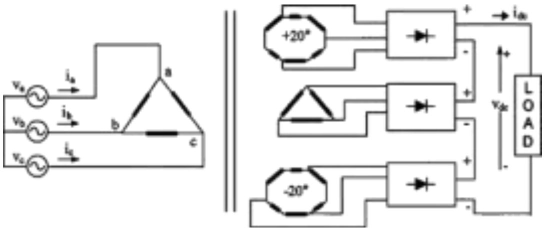
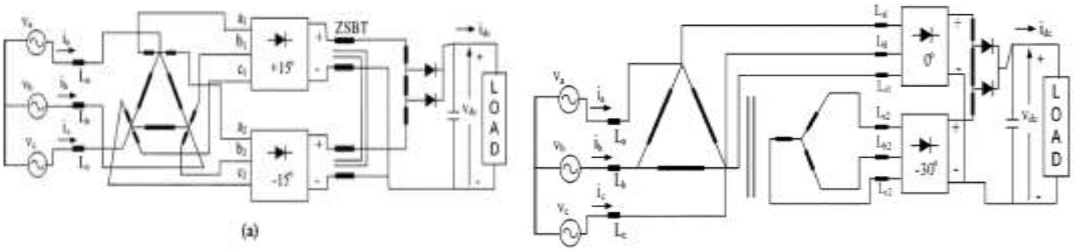


Fig.3 Three-phase unidirectional 18-pulse bridge ac–dc converter using isolated delta/delta/double polygon transformer.

### D.Twentyfour-Pulseac–dcConverters

Twenty-four-pulse ac–dc converters are used in high power rating applications where the use of a large number of devices is acceptable. It provides ripple-free dc output and almost sinusoidal ac current in the ac mains.Fig.4(a) shows the circuit with a delta fork autotransformer and two three-phase diode bridge rectifiers with two zero sequence blocking transformers (ZSBT) and one interphase transformer with two additional diodes for pulse doubling [4].



(b)

Fig.4 (a) Three-phase unidirectional 24-pulse bridge ac–dc converter using delta fork autotransformer with zero sequence blocking transformer (ZSBT) and two diodes. (b) Three-phase unidirectional 24-pulse bridge ac–dc converter using two winding transformer, two diodes and interphase transformers.

However Fig.4 (b) shows two windings with a delta and star connection for $30^0$ phase shift and with a pulse doubling circuit which reduces the number of diodes and associated input transformer.

### E.Bidirectional ac–dc converters

The bidirectional ac–dc converters have the power flow from ac mains to dc output or vice versa and normally use thyristors with phase angle control to obtain wide varying dc output voltages. In these converters, harmonic reduction is made with pulse multiplication using magnetics. The use of a higher number of phases through the input of a multiple winding transformer and pulse multiplication using tapped reactors, interphase, and injection transformer with additional components and optimum value of interphase reactors reduces THD of ac mains currentand ripples in the output dc voltages [5]. These MPCs are used to feed dc motor drives, synchronous motor drives, and to realize an ideal dc current source to feed the current source inverter fed ac motor drives. These MPCs are also used in HVDC transmission systems and power supplies for magnets, plasma, and a number of other applications.

### F.Power quality considerations

One of the major objectives to increase the number of pulses in ac–dc converters is to improve the power quality at input ac mains and output dc load in a wide variety of applications. The main drawbacks of conventional ac–dc converters have been harmonicinjection into ac mains which results in a number of problems such as poor power factor, poor utilization of the distribution system, increased losses, EMI and RFI, increased noise, distortion in voltage wave forms at the point of common coupling (PCC), disturbance to neighbouring consumers, etc. Similarly ripples in dc output voltage causes derating of loading equipment, additional losses in the load, etc. These power quality problems are increasing at a fast rate due to the enhanced use of solid-state converters. There are a number of options for power quality improvement, and multipulse ac–dc converters is one of among others,such as PWM converters, filters (passive, active, and hybrid), etc. MPCs are quite effective to improve power quality at input ac mains and output dc loads [6].

Three-phase unidirectional multipulse ac–dc converters are capable of reducing THD of ac mains current well below the limits specified in the several standards. For example, unidirectional 18-pulse ac–dc converters are able to reduce THD of ac mains current below 2% with proper design and without any control. Similarly active interphase transformer in the dc bus is able to reduce THD below 1% of ac mains current in 12-pulse ac–dc converters. The concept of improved magnetics with novel configurations of ac–dc converters is capable of providing a high level of power quality in terms of reduced THD of ac mains current well below 5% or around and almost ideal ripple-free dc output voltage to feed variety of loads. The bidirectional ac–dc converters are capable of reducing THD of ac mains current below 1% in 12-pulse converters. It does not improve only the power quality but reduces the cost, size, weight, and losses in the converters. Novel concepts of pulse multiplication are able to increase many times the pulses without increasing the size of magnetics to result in a high level of power quality.

### G .Latest trends and future developments in MPCs technology

MPCs technology has been developed to a mature level and is finding wide-spread applications in variable-speed drives using variable frequency ac motor controllers and dc motors, power supplies, electrochemical, and HVDC transmission systems. However, there are consistent new developments in MPCs for further improving their performance through cost, size, weight, loss reduction, and enhancement of reliability by reducing the number of component counts. Newer configurations of MPCs are on the way to reduce the size of magnetics, number of components, and energy storage elements. A breed of transformer connections for the use in MPCs is being developed to improve the overall performance of these converters. The numbers of increased configurations of these converters are able to provide a good choice for the design engineers to meet exact requirements of a particular application [7]. The concept of pulse multiplication in these converters has given a real boost to increasing the number of pulses for improving power quality without increasing much hardware. Similarly, the concept of the active interphase reactor has also made a drastic improvement in power quality by reducing THD of ac currents less than 1% even in 12-pulse converters. It is expected that such new inventions in MPCs will further improve the power quality in ac–dc conversion without increasing their costs, and they will find their use more and more common in the near future.

## II. PULSE MULTIPLICATION MODEL

The most direct way of controlling voltage distortion, the main subject of harmonic legislation, is to limit the current harmonic injections, which for static convertor plant requires the use of high pulse configurations [8]. Although this can be achieved by increasing the number of transformers and convertor groups, economic designs make extensive use of current harmonic filters instead. The high cost of filters are encouraging alternative designs, based on active harmonic cancellation [9]. For large power ratings, however, the useof line commutated high-pulseconfigurations is still preferred and a technique producing the same effect as transformer phase-shifting, and referred to as DC ripple re-injection[10]. A generalisation of the DC ripple re-injection technique is explained here. The Twelve pulse fed drive's input circuit consists of two six-pulse rectifiers, displaced by 30 electrical degrees. The 30-degree phase shift is obtained by using a phase shifting transformer.Theoretical input current harmonics for rectifier circuits are a function of pulse number and can be expressed as: $h = (np + 1)$ where n= 1, 2, 3, 4……. and p = pulse number.
A typical block diagram of a proposed twenty four-pulse drive appears in Fig.5.

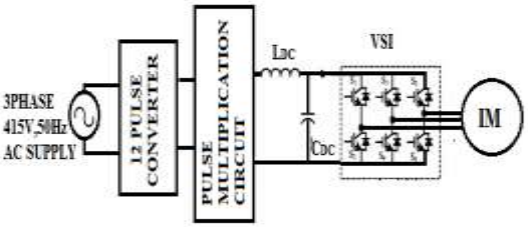


Fig.5 Twenty-four pulse converter fed induction motor drive

### A. DC ripple reinjection technique

The 24-pulse converter has been designed below. Fig. 6 shows the block diagram of the 24-pulse converter.

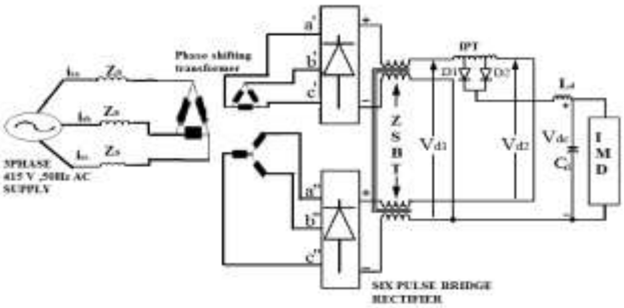


Fig.6 Twenty-four pulse converter

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### B. Interphase transformer

Usually the output voltage of paralleled rectifier bridges is not equal. In this case there will be a current flow from the converter with higher voltage output towards the other ones and reduce the efficiency of rectifier with current losses and lowering the average output voltage of both bridges. This is caused by the little differences in the characteristics of the semiconductor devices with same model and producer. The solution is to use a centertapped reactor [11] to have the same DC output voltage. This reactor is called interphase transformer. In DC ripple technique the tapping of the interphase reactor is changed to two taps so with two additional diodes connected to them, a configuration is made that doubles the number of pulses in the ripple of DC voltage. The output voltage of the 24-pulse ac–dc converter is given by:

$$Vdc = 0.5(Vd1+Vd2)$$

The rectifier's output voltage Vd1 and Vd2 are the same with a 30° phase shift (which is required for achieving 12-pulse operation). These voltages have a ripple of six times the source frequency. The ac voltage across interphase transformer Vm also has a frequency six times the source frequency and is given by:

$$Vm = Vd1 - Vd2$$

Fig.7 shows the tapped interphase transformer and two additional diodes which are needed to multiply the number of pulses.

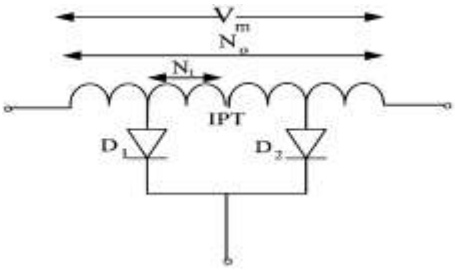

Fig.7 Interphase reactor.

The voltage across the interphase transformer is an ac voltage with six times the frequency of the supply making it compact in volume. Depending on the polarity of this voltage, one of the diodes conducts. Like a half wave rectifier, each diode conducts when its anode has higher potential in a half cycle and blokes in the other half cycle. For proper pulse multiplication the ratio of the interphase transformer must be:

$$Nt/N_0 = 0.2457$$

The voltage across the whole windings (Vm) and the current through the middle winding are AC, but current in the other parts of the windings are DC currents saturating the transformer core. The solution is to use air gaps in the transformer magnetic circuit to heighten the overall reluctance and to change the saturation point at the desired current magnitude.

### C. Zero Sequence Block Transformer (ZSBT)

In the converter system the transformer input voltage and 2 resulting output voltages are interconnected so there are routes for harmonic currents to flow from one phase shifted output towards the other one, creating a current loop or flow towards AC mains. In case of current loop, harmonic currents,especially triplen harmonic currents will affect the conduction of diodes in bridge rectifiers, decreasing their conduction period and increases current losses. In order to prevent these unwanted routes and to ensure independent operation of the two diode bridge rectifiers and the 120° conduction of each diode, a zero sequence block transformer must be used to block triplen harmonic currents and show higher impedances to other harmonic currents (because of their higher frequencies). It also helps in equal current sharing in the bridges outputs. The voltage across ZSBT which has a frequency three times the supply frequency will be calculated as:

$$V_{ZSBT} = Vd1 - Vd2 - Vm$$

## III.SIMULATION STUDY

The performance of a twelve pulse converter is compared with a conventional six pulse converter. Fast Fourier Transform (FFT) analysis was carried out on both 6-pulse and 12-pulse converters. The current waveform and THD plot of six pulse converter is shown in Fig.8

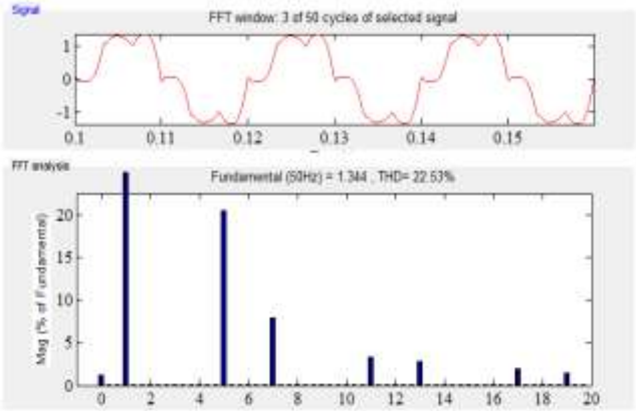

Fig.8 FFT analysis of six pulse converter

From the above Fig.it is observed that the 5th and 7th harmonic components of six pulse converter are very high and the THD value is above 20%. For drive systems the 5th, 7th, and 11th harmonic are the most significant harmonics. Here we can eliminate 5th and 7th harmonic component by using twelve pulse converter. The input waveform of 12pulse converter is not a smooth sinusoidal waveform. To eliminate this distortion and make smooth sinusoidal waveform we use filter at the input.

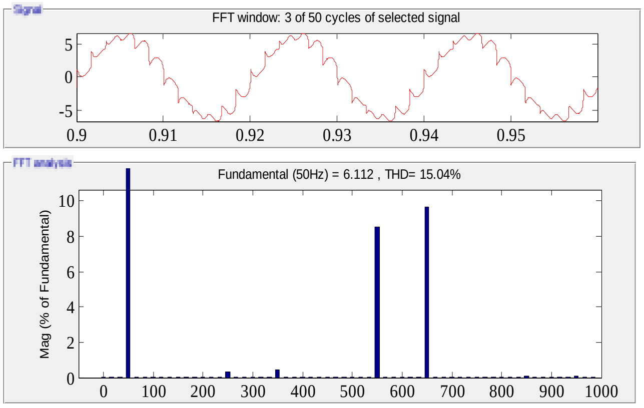

Fig.9 FFT analysis of 12 pulse converter without filter

Here a high pass filter is designed for the circuit. By using passive filter circuit we could able to achieve less distortion and smooth sinusoidal waveform. Also THD is reduced below 5% as shown in Fig.10.

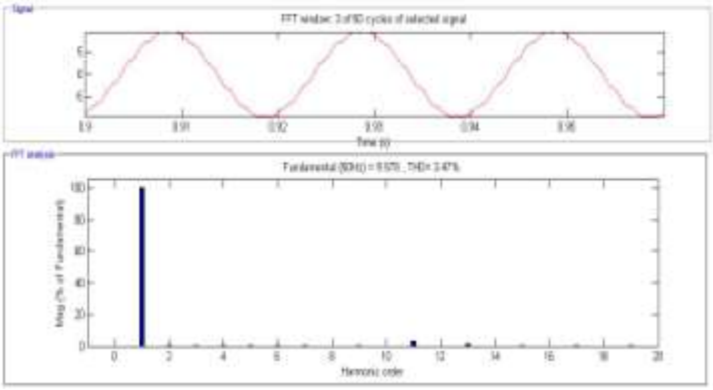

Fig.10 FFT analysis of 12 pulse converter with filter

To improve the power quality indices further, a dc ripple reinjection technique has been incorporated inthe above 12 pulse based ac-dc converters. The supply current and voltage waveform along with its harmonic spectrum is shown in Fig.11.

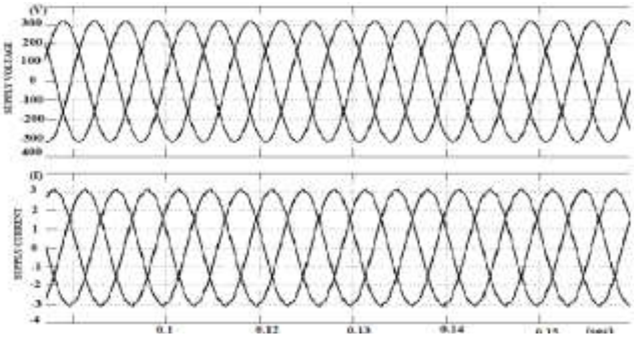

Fig.11 Supply voltage and current waveform

THD of twenty-four pulse converter is reduced up to 1%, and shown in Fig.12.

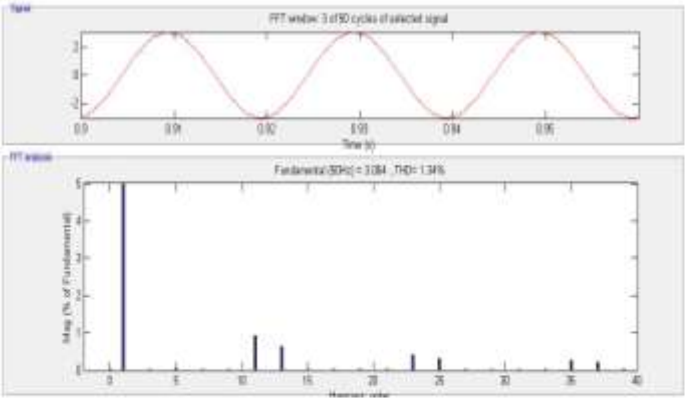

Fig.12 FFT analysis of 24 pulse converter

The output waveform of 12 pulse and 24 pulse converters are compared and shown below.

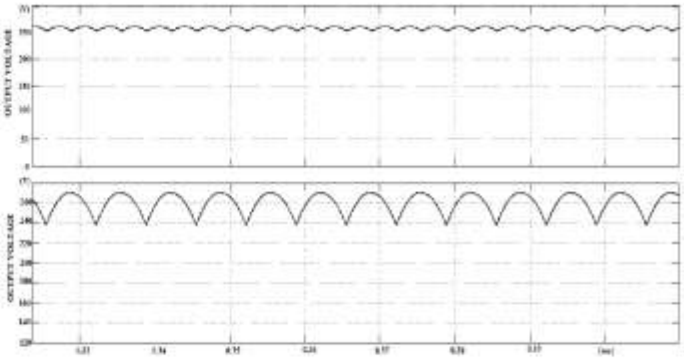

Fig.13 Pulse multiplication waveform

The complete Simulink blockdigram of 24-pulse converter fed induction motor is shown in Fig. 14.

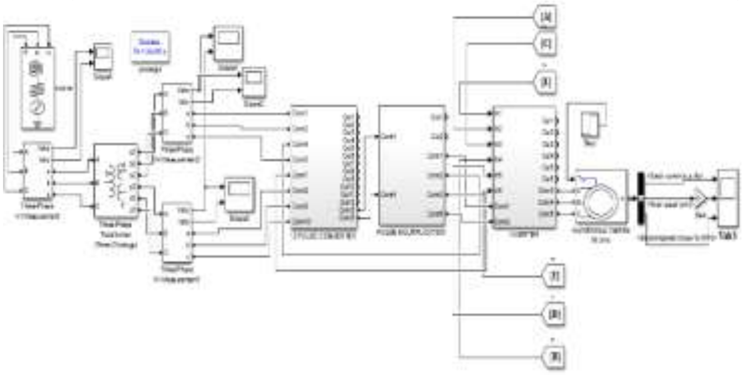

Fig.14Twentyfour pulse converter fed induction motor

The output results of induction motor is shown below.

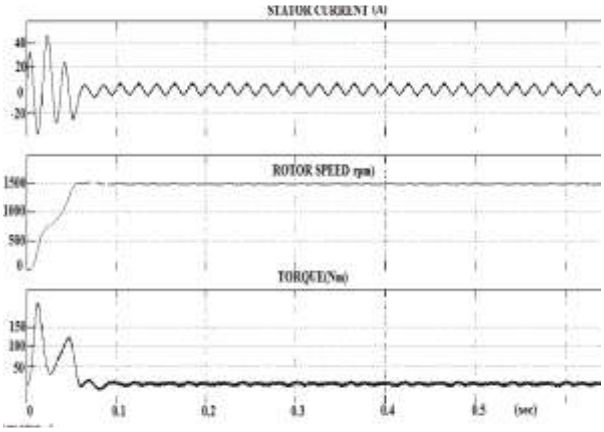

Fig. 15 Induction motors stator current, rotor speed, torque

## IV. CONCLUSION

A 12-pulse and a 24-pulse diode rectifier system employing low kVA components suitable for ac motor drives have been proposed here. Using pulse doubling technique, the 12-pulse ac–dc converter has convertedinto a 24-pulse rectifier which resulted in more improvements in power quality indices. For 24-pulse system the input current THD is reduced to 1.4% exhibiting clean input characteristics. The proposedsystem is suitable to retrofit applications as well as fornew PWM motor drive system

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## REFERENCES

[1] IEEERecommendedPracticesandRequirementsforHarmonicControlinElectricalPowerSystems, IEEEStandard.519-1992, 2014.
[2] Singh. B, Bhuvaneswari. G, Garg. V and Gairola. S. ‘Pulse multiplication in AC-DC converters for harmonic mitigation in vector-controlled induction motor drives’, IEEETransactions on Energy Conversion, June 2006, Vol. 21, No. 2, pp.342–352.
[3] B. Singh, V. Garg, and G. Bhubaneswari “A novel T-connected autotransformer based 18-pulse AC–DC converter for harmonic mitigation in adjustable speed induction motor drives” IEEE Transaction on IndustrialElectronics, volume 54, no. 5, pp. 2500–2511, October 2007.
[4] B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari “A review of three-phase improved power quality AC–DC converters” IEEE Transaction on Industrial Electronics, volume 51, no. 3, pp. 641–660, June 2004.
[5] A.I.MaswoodandFangruiLiu,“AnovelunitypowerfactorinputstageforACdriveapplications”IEEETransactions onPowerElectronics,volume20,no.4,pp.839–846,July2005.
[6] D. A. Paice “Transformers for multi pulse AC/DC converters” U.S. Patent 6 101 113, August 8, 2000.
[7] G. L. Skibinski, N. Guskov, and D. Zhou “Cost effective multi pulse transformer solutions for harmonic mitigation in AC drives” in Conferance Rec.IAS Annual Meeting, October 2003, volume 3, pp. 1488–1497.
[8] S.Choi,“Athree-phaseunity-power-factordioderectifierwithactiveinputcurrentshaping”IEEE Transactions onIndustrialElectronics.Volume 52, no.6,pp.1711–1714,December2005.
[9] Singh. B, and Gairola.S, ‘A novel 40-pulse AC-DC converter for vector controlled induction motor drive’, IEEETransactions on Energy Conversion, June 2008, Vol. 23, No. pp.403–411.
[10] Singh, B., Bhuvaneswari, G. and Garg, V. ‘Multipulse improved-power-quality AC–DC convertors for vectorcontrolled induction-motor drives’, IEEE Process Electronics Power Applications, January 2006, Vol. 153, No. 1, pp.88–96.
[11] M. E. Villablanca “Pulse multiplication in parallel converters by multi tap control of interphase reactor” Industrial Electronics Engineering, volume 139, No. 1, pp. 13–20, January 1992.