IMPACT OF VARIABLE FREQUENCY DRIVES ON ELECTRICAL SYSTEM

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ABSTRACT

This paper present the impacts of power quality issues namely harmonic distortion, transient in electrical system due to Variable Frequency Drives (VFD) known as Power Drive system (PDS) and its elimination techniques is investigated both side at the Point of Common Coupling (PCC) and input side of motor. The Harmonic measurements of electrical supply system and motor drive are done, with the help of Matlab software to determine whether a significant amount of harmonic in currents or voltages is presented. From these measurements and analysis, the impact of harmonics is analyzed and found that the harmonic content of electrical power system & motor drives to be minimized by suitable strategies like Multi pulse converter or Active front end converter, within the limits of international harmonic standards like IEEE 519 and IEC. In recently, multi pulse and multilevel drive solution gained an increased attention due to their effective harmonic elimination which is implemented in Matlab/Simulink. Sinusoidal Pulse width modulation (SPWM) and Space Vector Pulse Width Modulation (SVPWM) techniques are used to generate switching sequence for the multilevel inverter and a detailed harmonic study has been carried out.

KEYWORDS— *Variable Frequency Drives (VFD); Pulse Width Modulation (PWM); Sinusoidal pulse width modulation (SPWM); Space vector pulse width modulation (SVPWM); Induction Motor (IM); Point of common coupling (PCC); Power Drive System (PDS).*

I. INTRODUCTION

In modern electrical system, due to increase controlling technology, power quality has become a great concern. Non-linear loads, which were only 15 % of total loads in 1987, have increased to 75 % in 2012.These non-linear loads introduce harmonics into the electrical supply system and draw non-sinusoidal currents from ac mains and cause reactive power load ,extreme neutral current, Low power factor, Low energy efficiency, interference by EMI and distortion of the line voltage, etc. The variable frequency drives comes under non-linear loads and they are one of the main source of harmonics generation and power quality problems.

The harmonic distortion depends on the network parameter mainly impedance, the technology used in the VFD, incoming rectifier and the impedance values of the components used in the VFD power circuit. The most commonly used variable frequency converter is of a type called pulse width modulation (PWM). This uses a 6-pulse diode rectifier at the input. Many firms are using inductive reactor to reduce the harmonic distortion level. With the inductive reactor, the typical THD (total harmonic distortion in current) value is around 30%. Without the inductive reactor, it can be 70% to 120%. Industries with heavy motor load and VFDs generate harmonics and thus pollute the supply power which also affects other consumers. Therefore consumers are needed to evaluate the impact of their plants on the electrical power system. For this reason, it is essential to measure harmonics at the Point of Common Coupling (PCC).

Also in Draft standard IEC 52.800-x (1st edition) introduced the term power drive system (PDS). It composed an electric motor connected with electronic variable speed drive without restrictions to specific technologies.

II. CONVENTIONAL HARMONIC MITIGATION TECHNIQUES

There are many ways to reduce harmonics, ranging from variable frequency drive signs to the addition of auxiliary equipment. The primary methods used today to reduce harmonics are:

A. Power System Design:

Harmonics can be reduced by restrictive the non-linear load upto to 30% or less of the maximum transformer's capacity. However, with Power factor correction capacitors installed, resonating conditions can occur that could efficiently limit the percentage of non-linear loads to 15% of the transformer's capacity.

B. 12-pulse converter front end:

In this configuration, the front end of the bridge rectifier circuit uses twelve diodes instead of six pulse rectifier. The advantages are the elimination of the 5th and 7th harmonics to a higher order where the 11 and 13th become the predominate harmonics. This will minimize the magnitude of harmonics, but will not eliminate them.

C. Delta-Delta and Delta-Wye Transformers:

This transformer configuration uses two separate utility feed transformers with equal non-linear loads. This shifts the phase relationship to various six-pulse converters through cancellation techniques. It is similar to the twelve-pulse converter configuration.

D. Isolation Transformers:

An isolation transformer provides a good solution in many cases of harmonics elimination. The advantage isolation transformer is the potential to "voltage match" by stepping up or stepping down the system voltage, and by providing a neutral ground reference for nuisance ground faults.

E. Line Reactors:

The line reactor is More commonly used for harmonic elimiantion, also small size and less cost, when compared to an isolation transformer. So the line reacor is best suited for AC drives that use diode bridge rectifier at front end.

F. Harmonic Trap Filters:

Used in applications with a high non-linear ratio system to eliminate harmonic from currents. Filters are tuned to a specific harmonic such as the 5th, 7th, 11th, etc. In addition, harmonic trap filters pro-vide true distortion power factor correction.

G. Active front end converter:

"Active front ends converter" (AFEC), also known as "PWM controlled input rectifiers". Many manufacurer are used AFEC for AC drive and UPS system in order to eliminate a low input harmonic footprint.

III. POWER DRIVE SYSTEM

Power Drive System (PDS) such as VFDs and electronically commutated (EC) motors require power electronic units, either actually separate from the motor or connected to the motor casing. Such unit converts AC power from suppy line source to DC power that is temporarily stored in the so-called DC link circuit. The DC link voltage is then inverted to variable a frequency- and amplitude-modulated 3-phase AC output voltage that then finally excites the motor windings. The inverter output frequency and voltage amplitude determine the resulting motor shaft speed. *Figure 1* shows the flow of power in a PDS motor electronics unit.

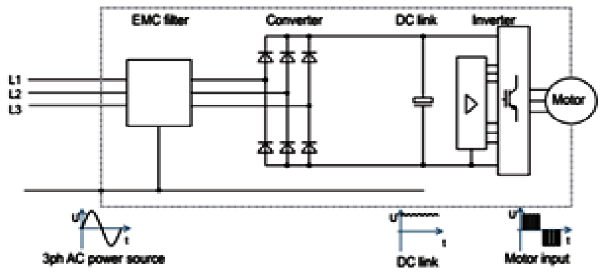

Figure 1: Topology of a 3ph PDS

The converter with a passive rectifier bridge and its highly capacitive DC link circuit draws non-sinusoidal, non-linear power line input current.

Active from end converters have become available recently. As essential parts of the electronic power units these can satisfy the most sever specifications, reaching THD of 2% or less. *Figure 2* shows the flow of power in PDS through front end Active converter.

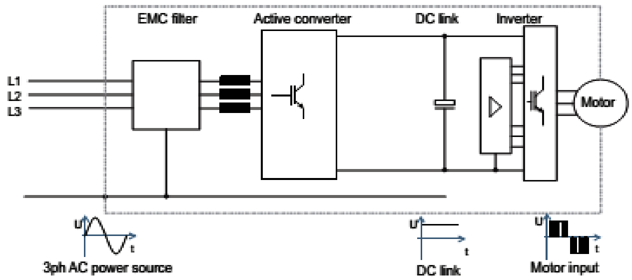

Figure 2: 3ph PDS with active front converter

IV. HARMONIC ANALYSIS OF POWER DRIVE SYSTEM

PDS such as VFDs and motors need a power electronic units. VFD's are the power electronic control devices that provide unique and beneficial opportunities for AC induction motors (IM) control. VFD's offer process control through speed variation and starting control for motors. VFD's convert/rectify voltage from a constant frequency alternating current (AC) power system to create a direct current (DC) voltage link, and then electronically invert the DC voltage link to create a variable voltage variable frequency output. While doing this conversion, the supply is rectified and inverted using power semiconductor devices. As the power semiconductor devices are non linear generates harmonics in the line current waveform and electrical power gets polluted.

The harmonic distortion depends on the network impedance, the technology used in the VFD incoming rectifier configuration and the impedance values of the components used in the VFD power circuit.

Different configurations of Power Drive system are:

1. 6 Pulse-3 level SPWM VFD
2. 6 Pulse-3 level SVPWM VFD
3. 12 Pulse-3 level SPWM VFD
4. 12 Pulse-3 level SVPWM VFD

A. 6 Pulse-3 level SPWM VFD

In *figure 3* shows block diagram of simulated 6 pulse-3 level SPWM VFD in which the 6 pulse uncontrolled rectifier as a front end converter and SPWM controlled 3 level inverter used for supply of IM.

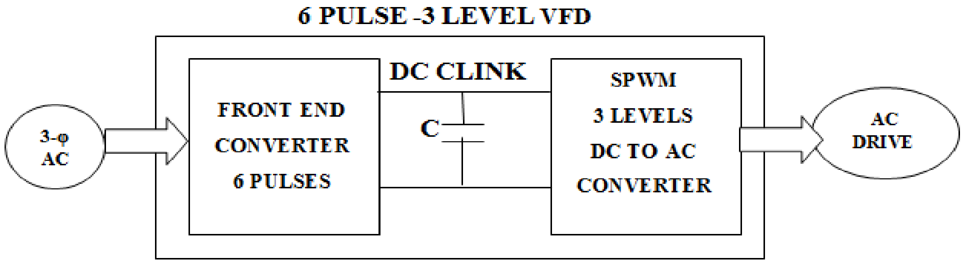

Figure 3: 6 Pulse-3 levels SPWM VFD

In above simulated system observe that Supply system voltage sinusoidal figure 6 but supply current figure 4 is non sinusoidal because of non linear load and contains dominant harmonics. So because of non linear harmonic current electrical system power quality is poor, which affect the other load connected to system. The result of simulate system as shown below and Analysis results of above model mention in Table 1.

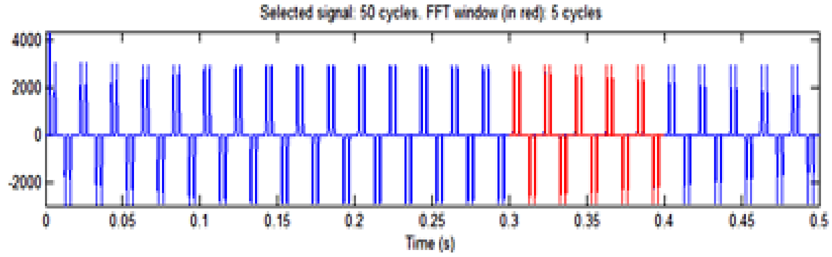

Figure 4: Supply Current

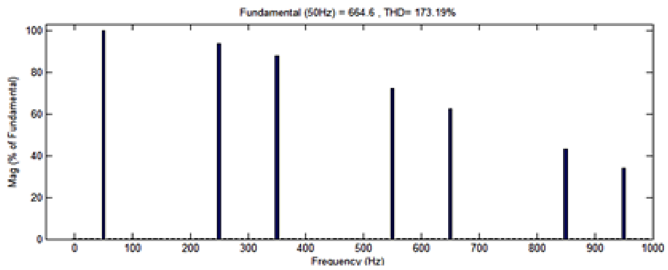

Figure 5: Supply Current FFT

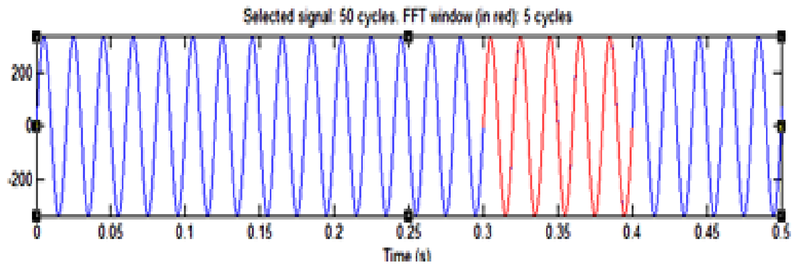

Figure 6 : Supply Voltage

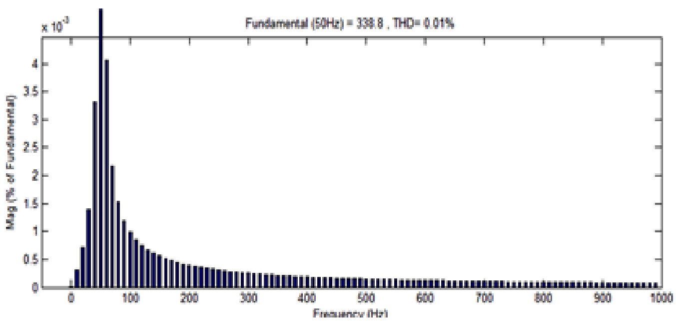

Figure 7 : Supply Voltage FFT

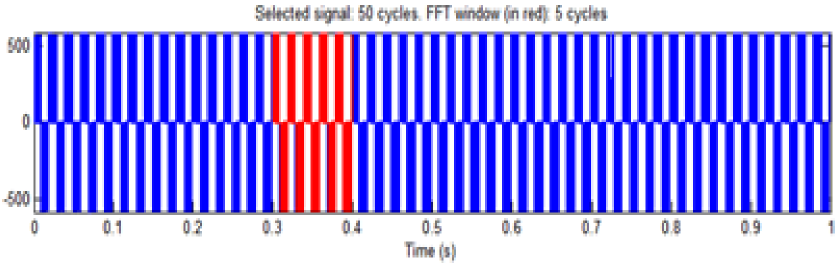

Figure 8 : Inverter output Voltage

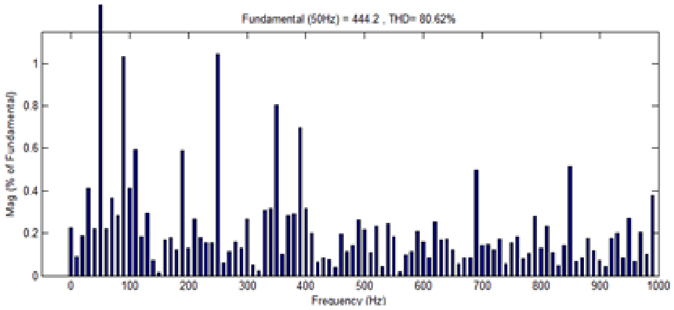

Figure 9: Inverter output Voltage FFT

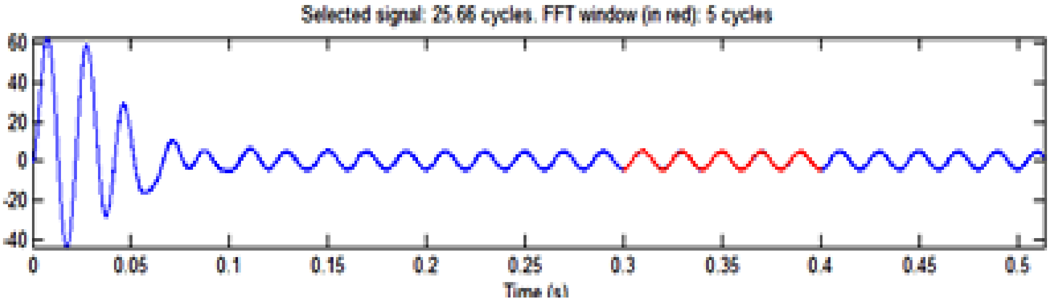

Figure 10: Motor Supply Current

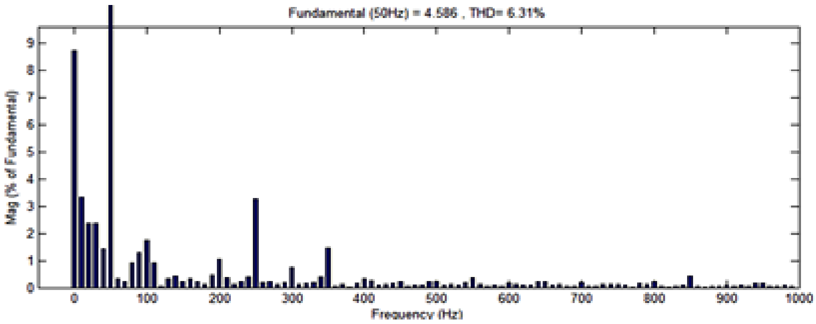

Figure 11: Motor Supply Current FFT

B. 6 Pulse-3 level SVPWM VFD

In *figure 12* shows block diagram of simulated 6 pulse-3 level SVPWM VFD in which the 6 pulse uncontrolled rectifier as a front end converter and SVPWM controlled 3 level inverter used for supply of IM.

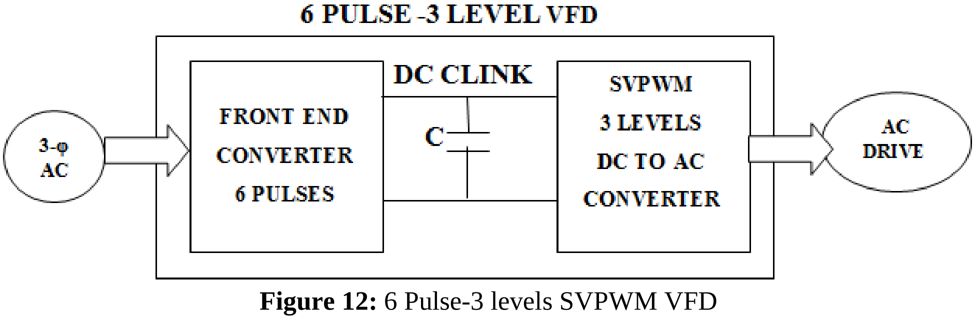

Figure 12: 6 Pulse-3 levels SVPWM VFD

In above simulated system observe that Supply system voltage sinusoidal figure 15 but supply current figure 13 is non sinusoidal because of non linear load and contains dominant harmonics. Also on load side because of SVPWM techniques power quality improved. So because of non linear harmonic current electrical system power quality is poor, which affect the other load connected to system. The result of simulate system as shown below and Analysis results of above model mention in Table 1

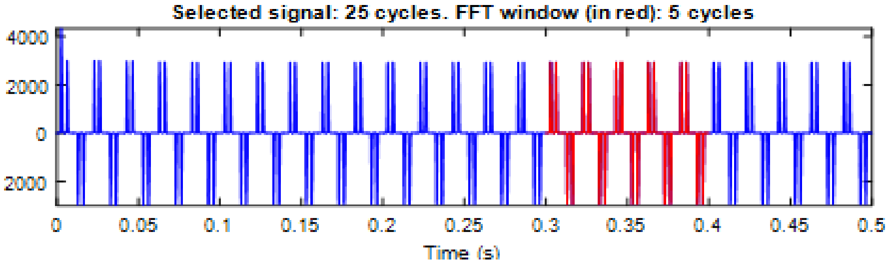

Figure 13: Supply Current

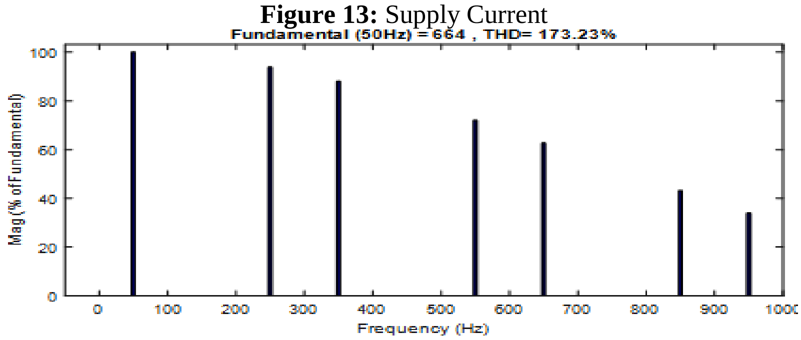

Figure 14: Supply Current FFT

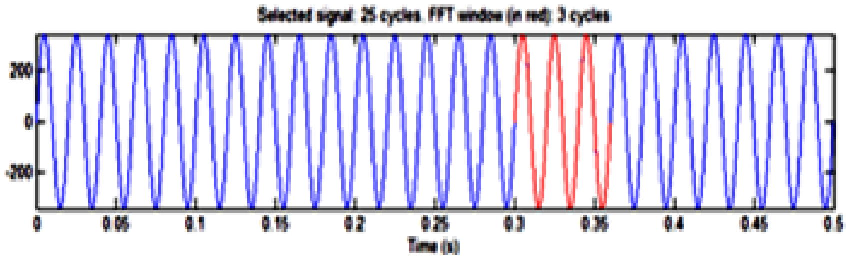

Figure 15 : Supply Voltage

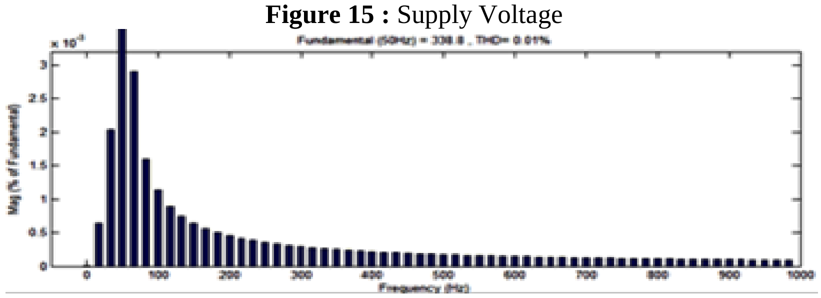

Figure 16 : Supply Voltage FFT

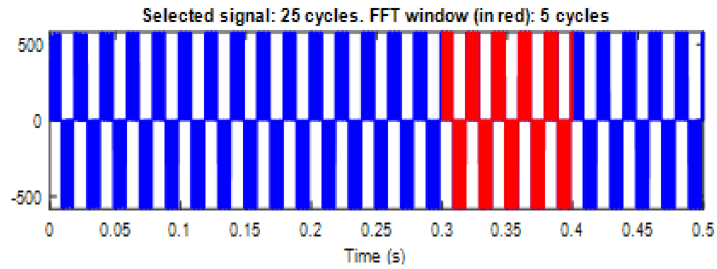

Figure 17 : Inverter output Voltage

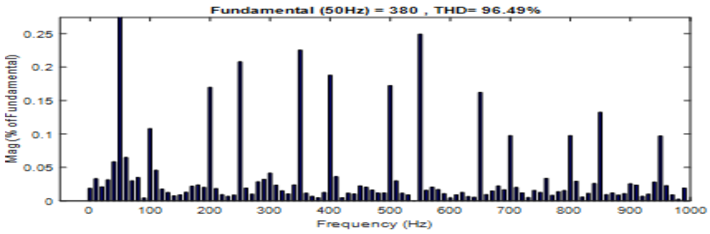

Figure 18 : Inverter output Voltage FFT

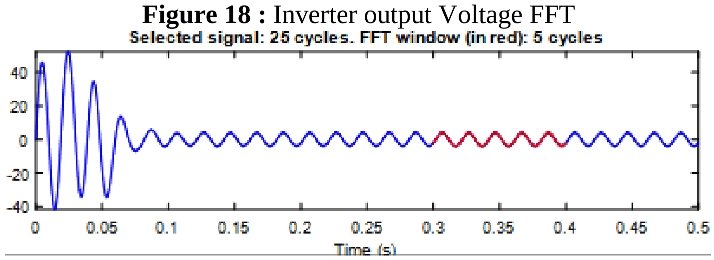

Figure 19: Motor Supply Current

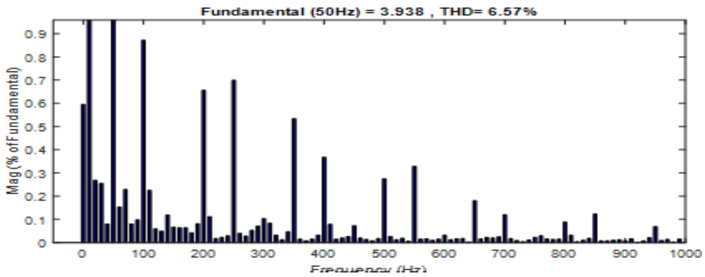

Figure 20: Motor Supply Current FFT

C. 12 Pulse-3 level SPWM VFD

In *figure* 21 shows block diagram of simulated 12 pulse-3 level SPWM VFD in which the 12 pulse uncontrolled rectifier as a front end converter and SPWM controlled 3 level inverter used for supply of IM.

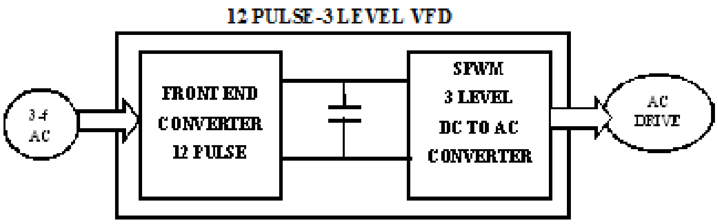

Figure 21:12 Pulse-3 levels SPWM VFD

In above simulated system observe that Supply system voltage sinusoidal figure 24 but supply current figure 22 quality improved because of 12 pulse converter at front end, still supply current is non sinusoidal because of non linear load and contains dominant harmonics. So because of non linear harmonic current electrical system power quality is poor, which affect the other load connected to system. The result of simulate system as shown below and Analysis results of above model mention in Table 1.

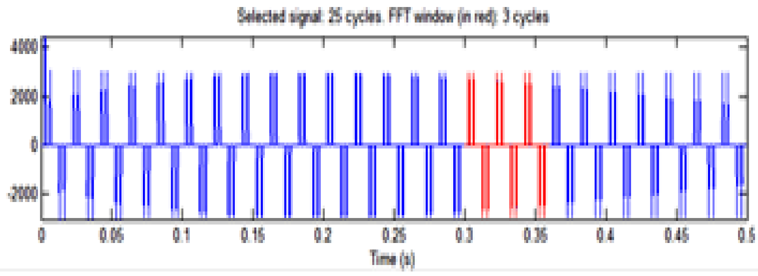

Figure 22: Supply Current

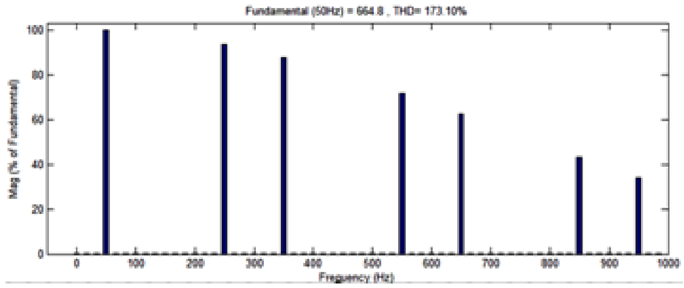

Figure 23 : Supply Current FFT

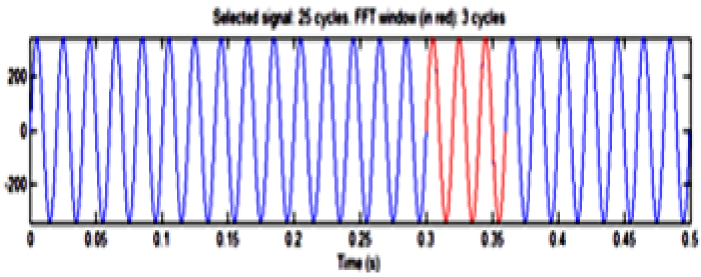

Figure 24 : Supply Voltage

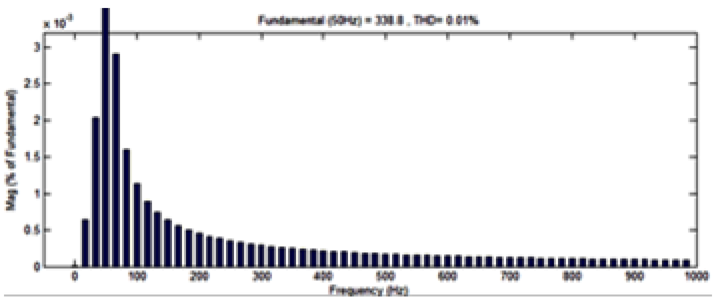

Figure 25 : Supply Voltage FFT

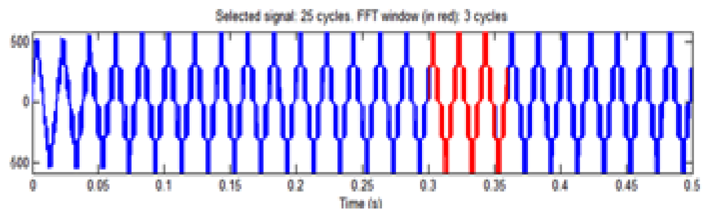

Figure 26 : Inverter output Voltage

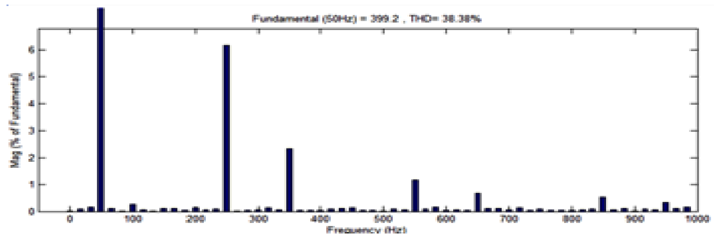

Figure 27 : Inverter output Voltage FFT

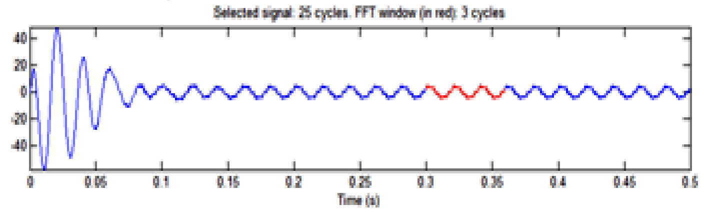

Figure 28: Motor Supply Current

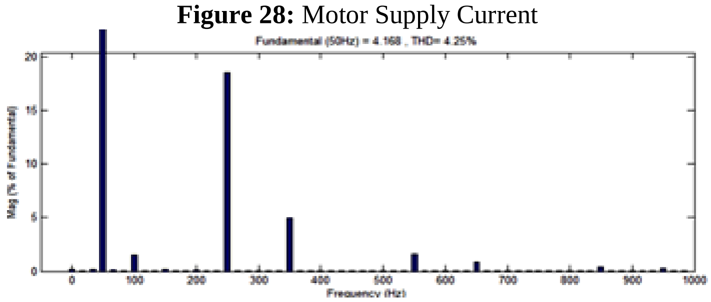

Figure 29: Motor Supply Current FFT

D. 12 Pulse-3 level SVPWM VFD

In *figure 30* shows block diagram of simulated 12 pulse-3 level SVPWM VFD in which the 12 pulse uncontrolled rectifier as a front end converter and SVPWM controlled 3 level inverter used for supply of IM.

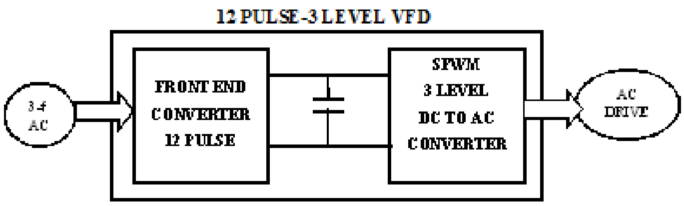

Figure 30 :12 Pulse-3 levels SVPWM VFD

In above simulated system observe that Supply system voltage sinusoidal figure 33 but supply current figure 22 quality improved because of 12 pulse converter at front end, still supply current is non sinusoidal because of non linear load and contains dominant harmonics. So because of non linear harmonic current electrical system power quality is poor, which affect the other load connected to system. The result of simulate system as shown below and Analysis results of above model mention in Table 1.

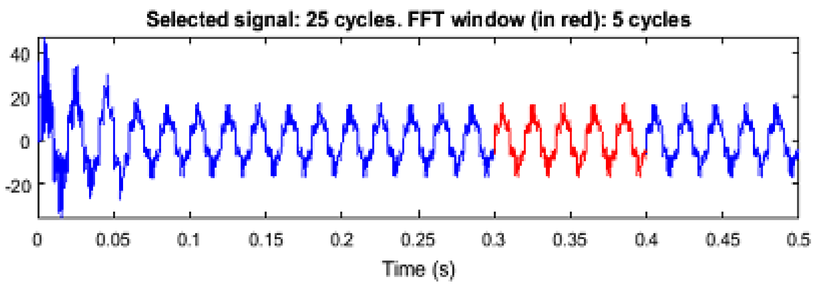

Figure 31: Supply Current

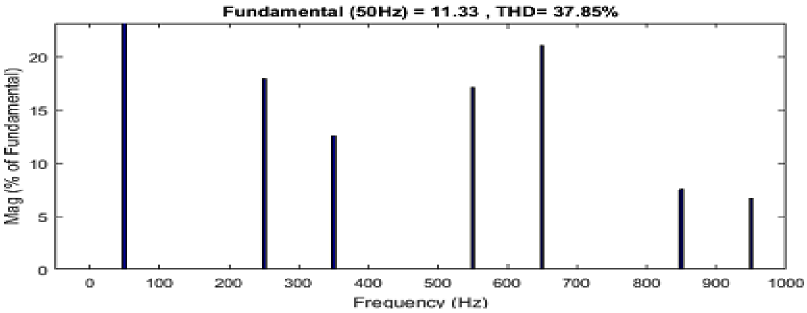

Figure 32: Supply Current FFT

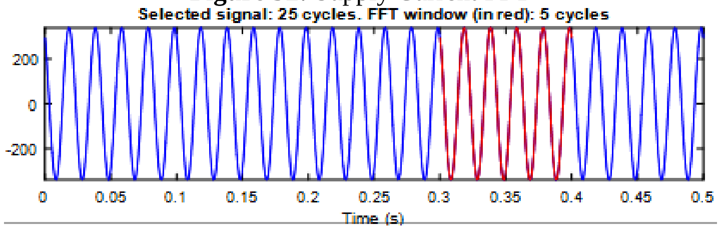

Figure 33 : Supply Voltage

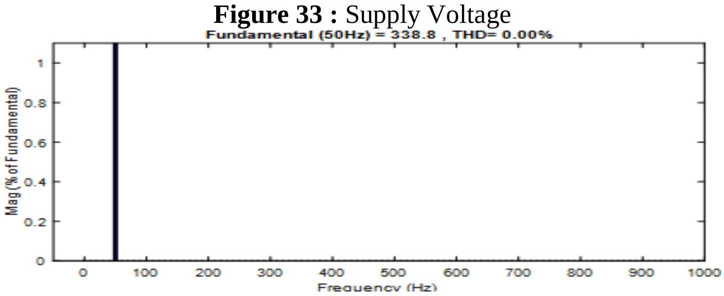

Figure 34 : Supply Voltage FFT

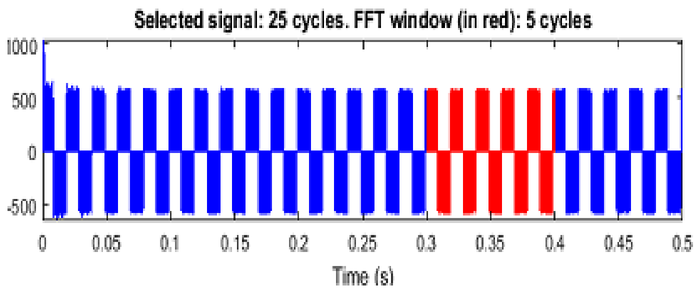

Figure 35 : Inverter output Voltage

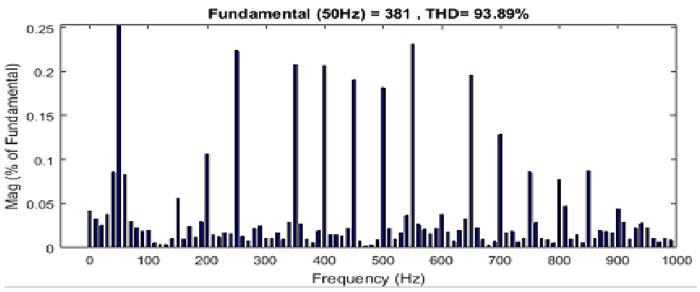

Figure 36 : Inverter output Voltage FFT

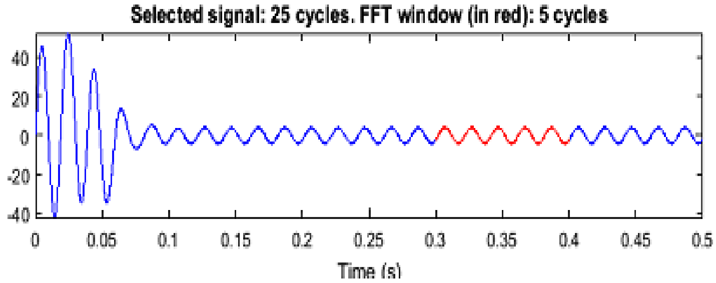

Figure 37: Motor Supply Current

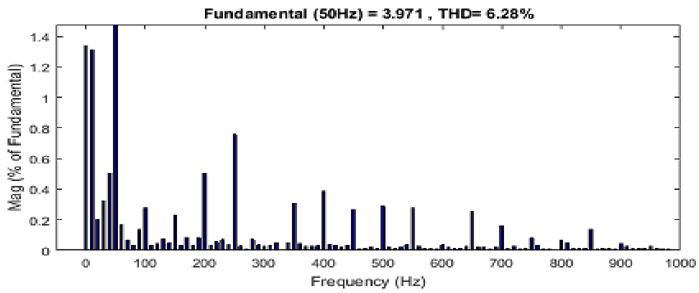

Figure 38: Motor Supply Current FFT

The Analysis results of above model mention in table 1.

TABLE 1. COMPARISON

PWM Techniques	***Total Harmonic Distortions(THD)***				***Voltage***		***Current***
	Vs	Is	Motor input voltage	Stator current	DC link voltage Avg.	Motor input voltage RMS	Stator current RMS
6 Pulse 3 level SPWM VFD	0.01	173.2	80.81	5.80	576	403	3.27
6 Pulse-3 level SVPWM VFD	0.01	173.1	38.38	4.25	577	309	2.982
12 Pulse-3 level SPWM VFD	0.01	173.10	38.38	4.25	586.12	415.30	4.98
12 Pulse-3 level SVPWM VFD	0.00	37.55	93.59	6.28	578.20	414.21	4.88

V. CONCLUSION

All variable frequency drives cause harmonics because of the nonlinear nature of the front end rectifier design. The 6-pulse uncontrolled rectifier is the customary power circuit design for most PWM VFD, but if use 12-pulse configuration still generate a lesser amount of harmonics electrical supply system to some degree by eliminating the 5^{th} and 7^{th} harmonics and expanding the primary characteristic harmonics up to the 11^{th} and 13^{th} .So by using Multi Pulse converter at front end can eliminate dominant lower order harmonics so that the filter cost reduced and supply power quality improved.

VI. FUTURE WORK

Sımulate and implement PSD with Active front end converter.

REFERENCES

[1] K. Vinoth kumar, Prawin angel michael, Joseph p. John and dr. S Suresh Kumar,"Simulation & comparison of SPWM & SVPWM control for three phase inverter," School of electrical Science, Karunya

university, Coimbatore ,Tamilnadu, India, ARPN journal of engineering & applied sciences,ISSN 1819-6608 vol. 5,No.7, July2010.
[2] Atif Iqbal, Imtiaz Ashraf and Mohibullah, "Matlab/Simulink model of space vector PWM for three- phase voltage source inverter, Aligarh Muslim University (AMU), India.
[3] Osama A. Al-Naseem and Mohamed A. El-Sayed,"Analysis of Electrical and Non-Electrical Causes of Variable Frequency Drive Failures," Electrical Engineering Department, Kuwait University.
[4] Khaliqur Rahman, Abu Tariq, and Farhad I1ahi Bakhsh," Modelling and Analysis of Multilevel Inverters Using Unipolar and Bipolar Switching Schemes," IEEE Department of Electrical Engineering, Aligarh Muslim University (AMU), Aligarh, India, IEEE-International Conference on Advances in Engineering, Science and Management (lCAESM -2012), March 30, 31, 2012
[5] Sonika Raghuvanshi and Nagendra.Singh," Multipulse Converter for Analysing Total Harmonics Distortion and Its Mitigation," International Journal of Engineering and Technical Research (IJETR), ISSN: 2321-0869, Vol. 2, Issue-7, July 2014.
[6] Mr. Prafulla J. Kale, Dr. Vandana Deodhar-Kulkarni & Miss. Shital Bhad, Modelling & Simulation of Five Level Diode Clamped Inverter for Reduction of Common Mode Voltage in Induction Motor Drive,'' Dept. of Electrical Engineering, Govt. College of Engineering, Aurangabad(M.S),India, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 4, Issue 11, November-2015.
[7] H.P.A.P. Amarajeewa, L.H.P.N Gunawardena, B.C.Harshani, M.A.S.N.Madurawala, D.P. Chandima, "Effective Current Harmonics Mitigation at Point of Common Coupling Using Multilevel Active Front End Converter", Department of Electrical Engineering, University of Moratuwa Katubedda, Sri Lanka.

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