Identification of Harmonics in AC Drives and Design of Harmonic Filter using SIMULINK

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ABSTRACT

Generally the harmonics are not presents in a supply which is given to the drives but the harmonics are generated by the load itself. Harmonic distortion is form of electrical noise that can cause a problem such as, motor may overheat or become noisy and torque oscillations in the rotor can lead to mechanical resonance and vibration, capacitors overheat. All power electronic converters used in different types of electronic systems can increase harmonic disturbances by injecting harmonic currents directly into the grid. Common non-linear loads include motor starters, variable speed drives, computers and other electronic device. After the identification of the harmonics, it can be reduced either by modifications to the drive system or by using external filtering. The current harmonics depend on the drive construction and load. Factors that increase current harmonics include large motor compared to the supply transformer higher motor load Factors that decrease current harmonics include Greater DC or AC inductance, Higher number of pulses in the rectifier. By using simulation with mat lab software we can reduce the harmonics for AC drives to overcome the above mentioned problems and to get smooth performance.

Keywords: Point of common coupling (PCC), short circuit safe. Adjustable Speed Drives (ASD)

1. INTRODUCTION

The application of cost effective power converter circuits which enhance the overall performance, efficiency, and reliability of industrial processes is common in all industry. The industrial applications of AC/DC and DC/AC power converter have increased gradually since the advent of silicon controlled rectifiers (SCR) in 1957. However, the wide use of single and three phase diode/thyristor rectifiers, for DC power supplies, Adjustable Speed Drives (ASD), Uninterruptible Power Supplies (UPS), and for household and industrial appliances, took place in the last two decades. With an estimated 65% of industrial electrical energy used by electric motors, the major users in industry increasingly see energy reduction as a key to improve their profitability and competitiveness [1]. Because variable speed drives reduce energy consumption (20-30% savings) and decrease pollutant emission levels to environment while increasing productivity, their proliferation is inevitable. For variable speed applications, ASDs are widely employed in driving induction and permanent magnet motors due to the high static and dynamic performance obtained in such systems[1][2][3]. High energy efficiency and high motion quality, low starting torque, etc. are the positive attributes of the ASDs. ASDs, consists of AC/DC converter connected to DC/AC inverter. Of all the modern power electronics converters, the Voltage Source Inverter (VSI) is perhaps the most widely utilized DC/AC conversion device with commonly used Pulse Width Modulation (PWM) methods. The PWM-VSI consists of six power semiconductor switches with anti-parallel feedback diodes. It converts a fixed DC voltage to three phase AC voltages with controllable frequency and magnitude. In AC motor drive applications, typically a rectifier device converts the AC three phase line voltages to DC voltage. Following the rectifier voltage passive filtering stage (typically capacitive filtering with/without DC link reactor), the VSI interfaces the DC source with the AC motor to control the shaft speed/position/torque[4][5][6][7]. The most used frontend topology for ASDs is still the 6-pulse diode/thyristor rectifier, due to well-known advantages such as, high efficiency, low cost, robustness and reliability. The main structure of PWM-VSI drive with a 6-pulse diode rectifier front end of some of the conventional wireless networking problems, such as medium access control, routing, self-organization, so as to prolong the network lifetime. In most of the applications events are estimated. The cost of transmitting information is higher than computation

2. THEORY OF DRIVES AND CAUSES OF HARMONIC GENERATIONS

In three phase systems, the actual current flows in two pulses that are 60o apart. For line 1, one pulse occurs when the voltage difference between L1 and L2 is at its maximum and a second pulse occurs when the voltage difference between L1 and L3 is at its maximum. The actual input current to a basic drive is shown in figure 3.1

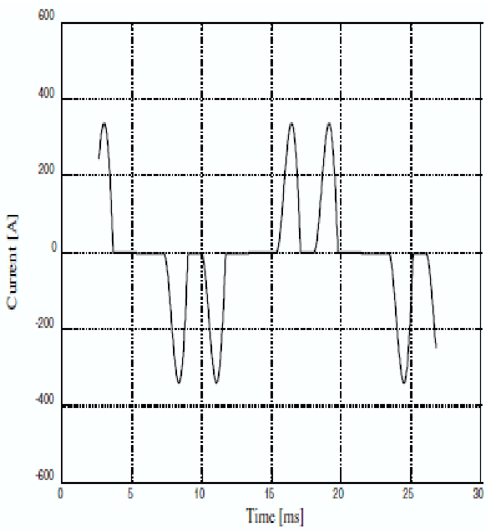

Fig 1: Actual input current

2.1 Input Current To A Basic Variable Frequency Drive

This short duration, high peak current pulses can cause a number of problems to the rest of the building's electrical systems.

One concern relates to the power transformers that feed the drive. Transformers are designed to handle smooth, sinusoidal current. Short current pulses like the ones shown above cause additional heating in the transformer. If the transformer is not designed to safely deal with such currents, it may overheat and fail. Where no filtering is applied, it may be necessary to double the current carrying capacity of a transformer.

In the test performed for this note, the rms input current for the drive with no harmonic filtering was 107% of the fundamental current for the drive with harmonic filtering. These tests were made using a moderately high impedance power line. If the power line's impedance was lower, this difference could approach 175%. Clearly, this additional current could require an increase in the size of all of the devices supplying current to the drive: the wires, switch gear and transformers. This increased installation cost penalty for harmonic current distortion is often overlooked.[8]

Nomenclature

AC = Alternating Current [A]

DC = Direct Current [A]

eX = Transformer Impedance [%]

HC = Harmonic Constant [%]

IFL = Full Load Current on Transformer [A]

ISC = Short Circuit Current of Transformer [A]

PE = Iron Loss Factor of Transformer

PVFD = Active Power of Drive Load [kW]

PWHD = Partial Weighted Harmonic Distortion

SNOM = Transformer Nominal Apparent Power [kVA]

SSC = Short Circuit Apparent Power of Transformer [MVA]

SVFD = Drive Apparent Power [kVA]

THCD = Total Harmonic Current Distortion [%]

THD = Total Harmonic Distortion [%]

THVD = Total Harmonic Voltage Distortion [%]

System Data

All data in this note are based on the following

system data.

Transformer Apparant Power	1.5 kVA
Primary voltage	11 kV
Secondary voltage	400 V
Impedance	5.1%
Short circuit power, secondary	25 MVA
Short circuit power, primary	350 MVA
Short circuit ratio	250
Drive input power	100 kW
HC of Drive without filter	745%
HC of Drive with filter	319%

The voltage is assumed to be 100% balanced. It is also assumed that before adding drives to the system, no harmonic distortion was present.

2.2 Distribution Of Linear Load And Drive Load

How much linear load a transformer can be loaded with depends on the drive load on the same transformer. This shows that the transformer can only be loaded to 44% of its nominal power if the drives use no harmonic filtering. This means that the transformer has to be almost twice the size.

A second concern is interference with other equipment. The strength of the magnetic field around a wire is proportional to the rate of changes in the direction of the current in the wire. These fast changing current pulses transmit a stronger electrical noise signal than normal sinusoidal currents. This can result in an audible hum in the other equipment in the system, unstable displays on monitors, unreliable data transmission, or interference with the operation of sensitive electronic equipment. Thirdly such current pulses cause a more widespread and therefore more critical problem[9]. The current is pulsating and the voltage equals current x system impedance, therefore the voltage wave form will not be sinusoidal. It will be similar to figure which looks more like a trapezoid. This phenomenon is often referred to as "flat topping". Remote lighting control systems, clock synchronization systems and other similar systems, which rely on the building's electrical power distribution system to transmit information, may operate erratically because of the clipping of the voltage peaks. The voltage regulators on emergency power generators may cause unstable generator operation as they attempt to compensate for the missing voltage peaks[10][11][12]. Other equipment, which relies on a "clean" source of power to operate reliably, may also be affected. The same voltage is used by all of the electrical equipment connected to the circuit; therefore its effects can be quite widespread. Voltage distortion is therefore a major concern.

When variable frequency drives are applied to HVAC systems, it is important to limit the harmonic voltage distortion that they cause. When a basic variable frequency drive is used in an HVAC application, this important caution is frequently overlooked. As a result, the entire building's electrical system may suffer.

The key to controlling harmonic distortion is limiting the current pulses. This is generally accomplished through the use of coils which may also be called reactors, inductors or chokes. The inductance of a coil creates a back electromotive force (emf, or voltage) as the current pulse passes through it. This reduces the current pulsation. The input current for a drive, which includes coils in the DC bus as standard, is shown in figure . A comparison between this and the larger input current pulses of the basic drive, shown in figure, shows a large improvement in the wave form, although it is still not sinusoidal[13-17].

The table 2.1 in figure No: 2.5 compare the total harmonic distortion and the true power factor measured in these tests.

Table 2.1. Comparison between readings of a drive with and without harmonic filters.

	Drive with no Harmonic Filtering	Drive with DC reactors
THCD	107%	42%
True Power Factor	0.68	0.91

The graph in figure No.2.2 shows the amplitude of each harmonic current.

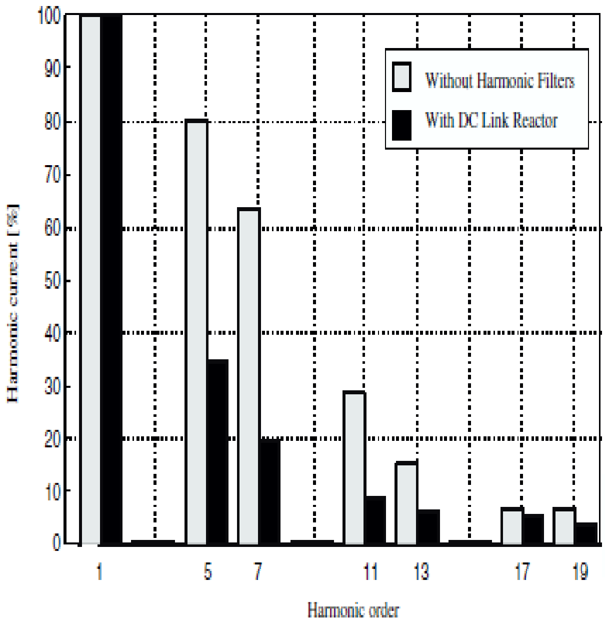

Fig. 2.5: Comparison between the harmonic current spectrum caused by a drive with and without harmonic filters.

The important concern is of course the voltage distortion.

The total harmonic voltage distortion for the basic drive was measured to be 4 % which would be unacceptable for critical applications. For the drive in figure using DC reactors, it was measured to be 2% which meets even the most stringent IEEE standard. The true power factor was found to be 0.68 when using the basic drive and 0.91 when using the drive with DC rector[18-24].

3. MODELING AND SIMULATION

3.1 Data Type

In MATLAB simulation we design the system which generate the harmonics. In power system many cause the generation of harmonics but we are here take the drive load which vary continuously the load torque .that change of torque drive always change the voltage and frequency this change is the cause of generation of harmonics .

Now we take a source of three phase supply and the transformer detail given to rectifier and PWM IGBT Inverter for controlling the speed & torque of the drive.

1) Three – Phase Voltage Source
   a)phase to phase rms voltage (v)-33KV
   b)50 Hz
   c) Star connected ground

2) Three Phase Transformer
a) Configuration winding 1 –star
b)winding 2 –delta
c)5 MVA
` d) 50 Hz
e) 33KV / 600V
f) Resistance in ohms
0.4356 (33KV side)/0.000432(600V side)
g) Inductance in Henry
0.055462(33KVside)/5.5004e-005(600vside)
h) Magnetization resistance Rm(ohm)
1.089e+005
i) Magnetization reactance Lm(H)
346.64
3) Filter LC branch a) L= 1e-3
b) C =60e-3

In the cause of converter or inverter the mechanism change the voltage and frequency with respect to total impedance & capacitance.
(Impedance=motor winding + cable length)
(Capacitance=Transmission line + capacitor for DC Filtration)
So we add the impedance and capacitance in the system to equalize the system and filter the harmonics. It's called the Harmonics Filter.
In simulation we design the two same system by using the harmonics filter and without harmonics filter. Take the both system waveform of the voltage and current from different location like Vin,V out ,Iabc.

3.2 Circuit Model Description

A 50 Hz, voltage source feeds a 50 Hz, 500 kW load through an AC-DC-AC converter. The 600V, 50 Hz voltage obtained at secondary of the Wye/Delta transformer is first rectified by a six pulse diode bridge. The filtered DC voltage is applied to an IGBT two-level inverter generating 50 Hz. The IGBT inverter uses Pulse Width Modulation (PWM) at a 2 kHz carrier frequency. The circuit is discretized at a sample time of 2 us. The load voltage is regulated at 1 pu (380 V rms) by a PI voltage regulator using abc_to_dq and dq_to_abc transfomations. The first output of the voltage regulator is a vector containing the three modulating signals used by the PMW Generator to generate the 6 IGBT pulses. The second output returns the modulation index.

The Discrete 3-Phase PWM Pulse Generator is available in the Extras/Discrete Control Blocks library. The voltage regulator has been built from blocks of the Extras/Measurements and Extras/ Discrete Control libraries.

The Multimeter block is used to observe diode and IGBT currents. In order to allow further signal processing, signals displayed on Scope block (sampled at simulation sampling rate of 2us) are stored in a variable named Scope for filter and scope 1 for without filter .

3.3 Demonstration

Start the simulation. After a transient period of approximately 50 ms, the system reaches a steady state. Observe voltage waveforms at DC bus, inverter output and load on Scope1. The harmonics generated by the inverter around around multiples of 2 kHz are filtered by the LC filter.

As expected the peak value of the load voltage is 537 V (380 Vrms). In steady state, the mean value of the modulation index is m = 0.80 and the mean value of the DC voltage is 778 V. The fundamental component of 50 Hz voltage burried in the chopped inverter voltage is therefore: Vab = 778 V * 0.612 * 0.80 = 381 V rms.

Once simulation is completed, open the Powergui and select 'FFT Analysis' to display the 0 - 1000 Hz frequency spectrum of signals saved in the scope structure. The FFT will be performed on a 5-cycle window starting at t=0.1-2/50 (last 5 cycles of recording). Select input labeled 'Vab Load'. Click on Display and observe the frequency spectrum of last 5 cycles. Notice harmonics around multiples of the 2 kHz carrier frequency. Maximum harmonic is 1.4 % of fundamental and THD is 5.35 %.

Now the same system design with all the same parameter but without filter the compare the result of the THDv and THDi and FFT Analysis .

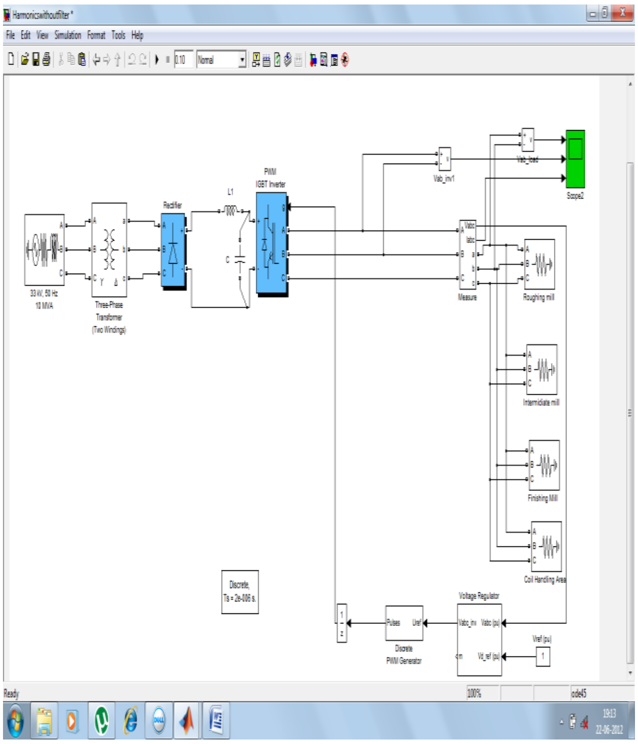

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Fig 3.1(a): MATLAB Simulation model of Power System Without Filter

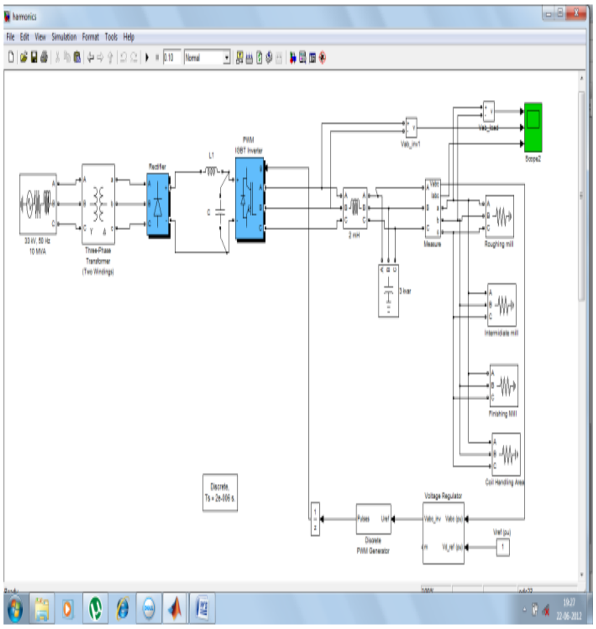

Fig 3.1(b): MATLAB Simulation model of Power System With Filter

SIMULATION RESULT AND DISCUSSION

3.2 Wave form Output

As per the waveform we get the result of system .In the system when we not use the filter the inverter output waveform of the current and voltage is not sinusoidal and with filter we get the proper sinusoidal waveform of the current and voltage.

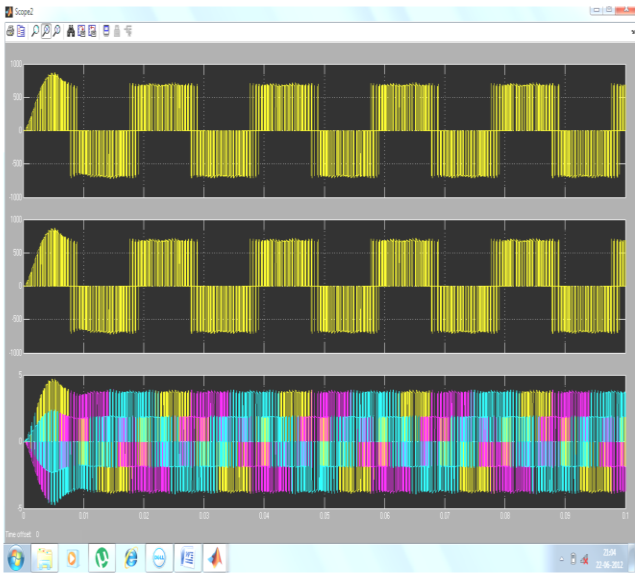

Fig 3.2: Waveform of Vinv, Vab load, Iabc (without Harmonics Filter Power system)

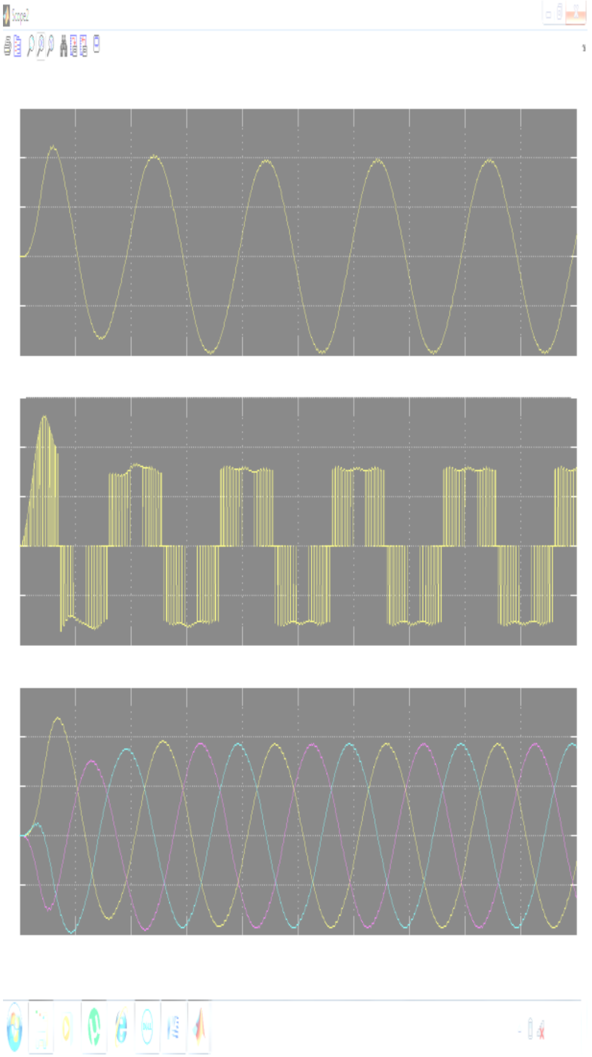

Fig 3.3: Waveform of Vinv, Vab load, Iabc (with Harmonics Filter Power system)

3.2 FFT Analysis

The FFT Analysis of THD also certified the result of harmonics filter power system .

When we take the Bar Graph of the without harmonics filter power system the result is

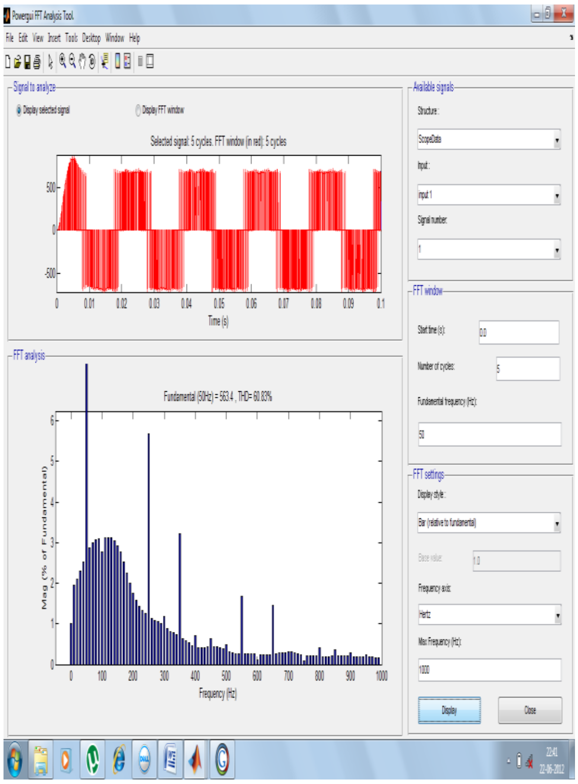

Fig. 3.4: Vinv –THD =60.28%

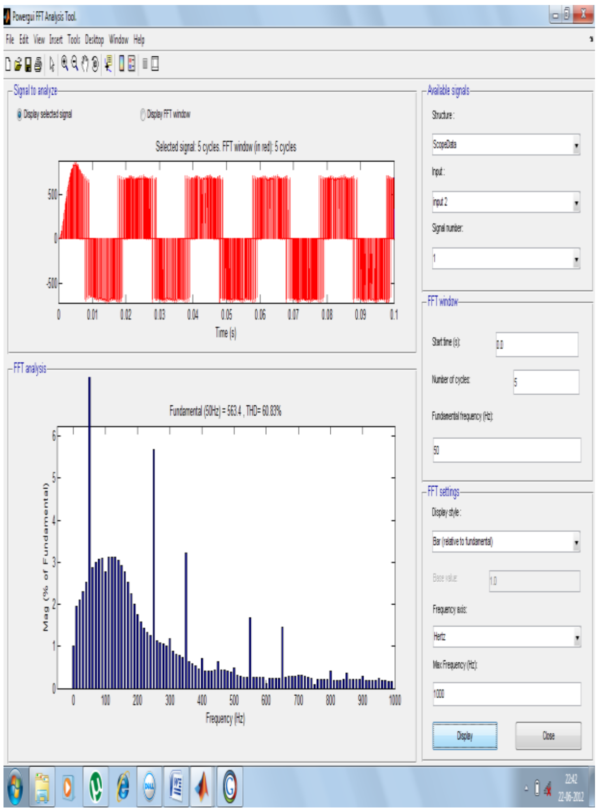

Fig. 3.5: Vabload-THD =60.28%

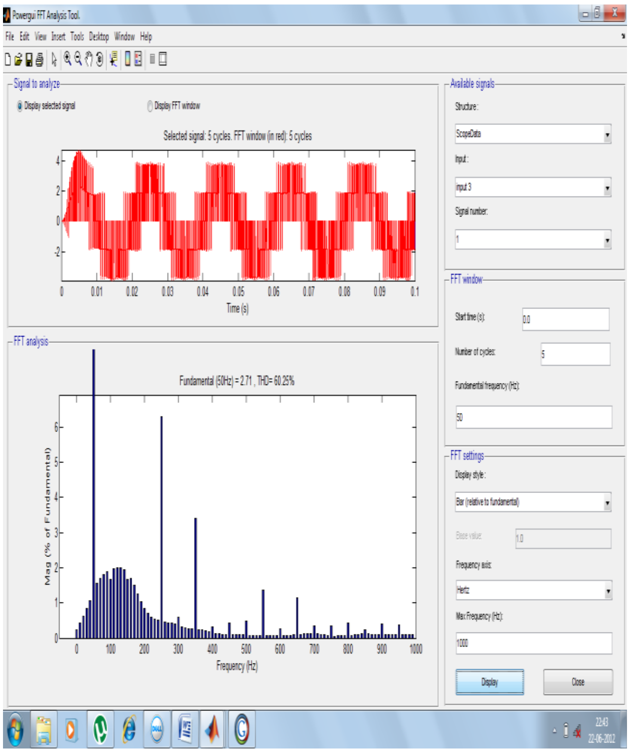

Fig. 3.6: Iabc-THD= 59.86%

When we take the Bar Graph of the with harmonics filter power system the result is

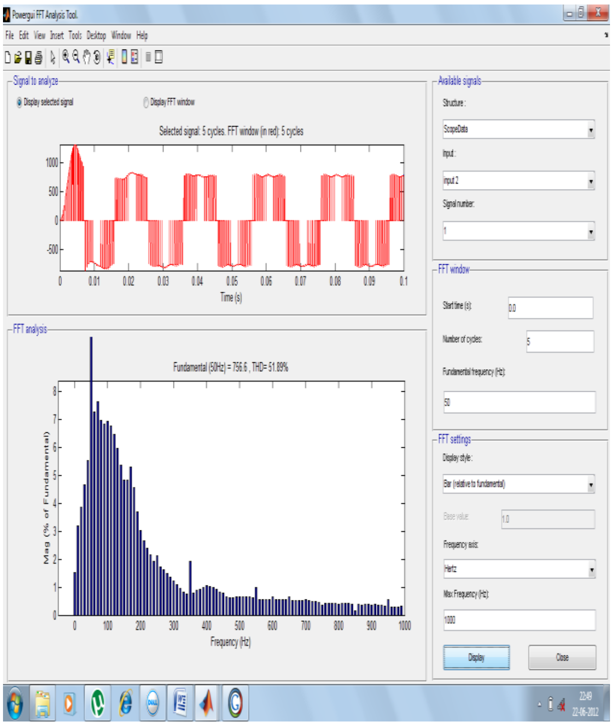

Fig. 3.7: Vinv-THD =51.72%

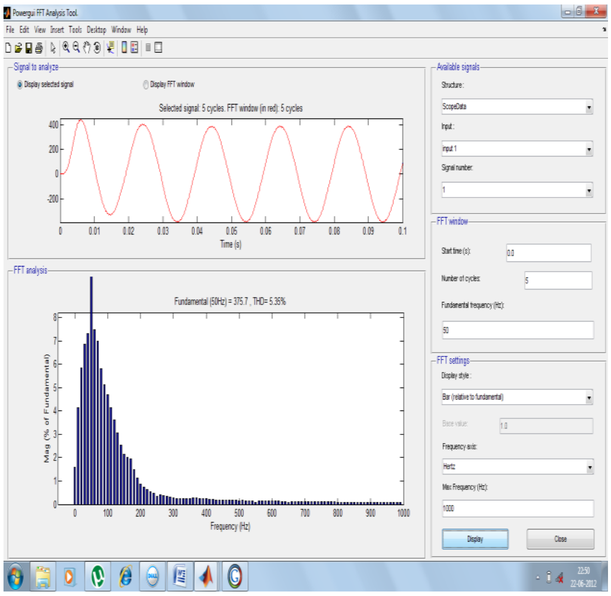

Fig. 3.8: Vabload-THD=5.15%

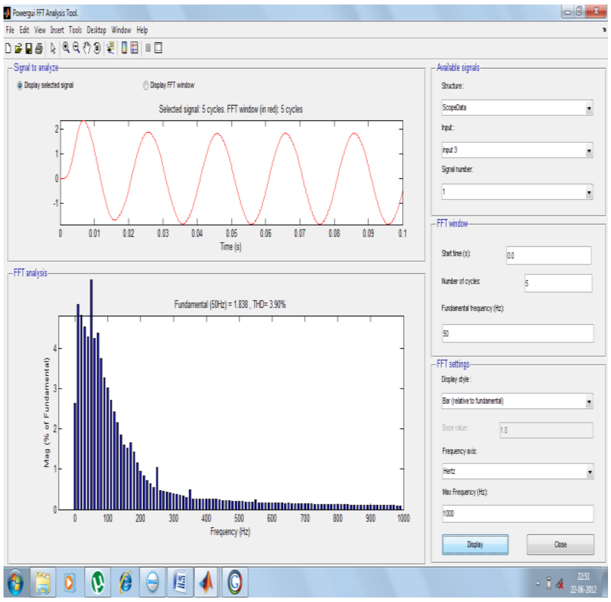

Fig. 3.9: Iabc-THD = 3.86%

The result is Without Harmonics Filter power system
Vinv- THD = 60.28%
Vabload-THD = 60.28%
Iabc- THD = 59.86%

.
The result is With Harmonics Filter power system

Vinv- THD = 51.72%
Vabload-THD = **5.15%**
Iabc- THD = **3.86%**

4.1 CONCLUSION

The use of simulation tools as MATLAB/ Simulink, allows reproducing the behaviour of the power systems in different situations, analysing how the system answers in these situations and choosing the solution that better fit with the particular problem without additional costs. Besides, active filters with different rated values can be simulated in order to analyse different reductions of the harmonic distortion. By means of the simulation carried out, the voltage and current harmonic distortions created by an underground traction system and a steel plant have been obtained. Moreover, the reduction of the distortion by an active filter has been simulated for both systems.

Ø Harmonic pollution is a major contributor to power quality degradation and must be kept under **IEEE 519** standard.

Ø Harmonic Filters not onl y reduce the effects of harmonics but al so provide reactive power for power factor improvement.

Ø Designing of component parameters for a harmonic filter can be made quick and easy with the help of **MATLAB**.

Ø Using a Harmonic Analyzer circuit harmonic analysis is done and data is fed to **MATLAB** program.

Ø **MATLAB GUI** provides user friendly approach and can be u sed for any input data again and again.

Ø **MATLAB** can regenerate graphical analysis for the given case using the data from harmonic analyzer.

Ø The design values thus obtained are tested using **SIMULINK** to check whether the
filter design will work or not.

Ø Hence the whole process o f analysis, design and verification only takes a few minutes using a few keystrokes and mouse clicks as compared to conventional methods which can take hours.

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