ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 3, Issue 2, pp: (8-18), Month: April 2016 - June 2016, Available at: www.paperpublications.org

The Harmonic Mitigation in Induction Furnace Using Hybrid Filter

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Abstract: **In the induction furnace most concern issue are related to power quality, In the system nonlinear load causes current harmonics and induction furnace cause voltage harmonic. The harmonics produced in the system they distorts the fundamental sinusoidal waveform So harmonics must be mitigate. One of the best solutions to mitigate harmonics problems is the use of Hybrid filters. Shunt passive filter is to eliminate harmonics currents. Passive filter has some disadvantages mainly related to the filter frequencies they were previously tuned, fixed compensation, resonance can occur because of the interaction between the passive filter and other load, with undesired results. So to overcome this problems development of active filter is required. Series active filter is suitable for the mitigation of voltage harmonics in this paper we discussed the hybrid scheme having passive filter with tunable element which mitigate current harmonic in between sub order harmonic frequency to particular design order frequency which maintain desired power factor, series active filter with direct control strategies which mitigate voltage harmonic and maintain desired reactive power.**

Keywords: **Induction furnace, Active filter, Passive filter, System simulation, THD.**

I. INTRODUCTION

The most common ways of producing steel is made by using the induction furnaces. The problem with this type of furnaces is the creation of a harmonic distortion. The cause of the distortion is within the induction furnace design and operation. An induction furnace works melting the scrap using a medium frequency magnetic field created by a coil. The coil is fed by the medium frequency AC current supplied by an inverter which is fed by a DC current converter connected to the AC distribution network supply. The created distortion is very high and affects the voltage supplied by the distribution system it is possible that other loads supplied from the same system will be affected [1].

An Induction furnace is an unbalanced, nonlinear and time varying load, which can create much problems to the power system quality. Harmonics, inter-harmonics, voltage flicker & unbalance are the power quality problems The nonlinear voltage-current characteristic of the arc can create harmonic currents. The evolution of two aspects concerning power systems has created conditions for a more extended use of active filters. A first aspect is related to power semiconductor device development. The other aspect is the gradual application of regulations limiting the generation of harmonic currents. Active filters are suitable for filtering harmonic currents[1]. Active filters allows to eliminate some problems of passive filters such as poor tuning due to dispersion of their characteristic parameters and resonances with the impedance of the surrounding electrical network which may appear[4]. The different methods for controlling active filters, by using of pq-theory (active and imaginary power) .It are used for separating the residual harmonics and thus eliminating (as theory indicates) or reducing the harmonic distortion.

The previous solutions adopted for harmonic mitigation are as follows:

a) Delta-Delta and Delta-Wye Transformers: This system uses two separate feed transformers with equal non-linear loads. This shifts the phase relationship to various six-pulse converters through cancellation techniques[2].

b) Isolation Transformers: An isolation transformer provides a better solution in many cases to mitigate harmonics generated by nonlinear loads. The advantage is the “voltage match” by stepping up or stepping down the system voltage, and by providing a neutral ground reference for ground faults. This is the best solution when using AC or DC drives that use SCRs as bridge rectifiers[2].

c) Use of Reactors: Use of reactor is a simple and economical method to eliminate the harmonics created by nonlinear loads. This method is the best solution for harmonic reduction than an isolation transformer. When the current through a reactor changes, a voltage is induced across its terminals in the opposite direction of the applied voltage which opposes the rate of change of current.

The Recent solutions adopted for harmonic mitigation are as follows:

a) Passive Harmonic Filters:

Passive filter are also known as harmonic trap filters. This is used for harmonic mitigation or control more dominant lower order harmonics specifically 5th, 7th, 11th and 13th. Passive filter is of a passive L-C circuit which is tuned to a specific harmonic frequency which needs to be mitigated. Their operation works on the “resonance phenomenon” which form due to variations in frequency in inductors and capacitors.

b) Active filters:

The active filter is combination of the IGBT bridge and DC bus structure. The active filter measures the “distortion current” wave shape by filtering out the fundamental current from the nonlinear load current waveform, which fed to the controller to generate pulse to fire IGBT & generate compensation current for harmonic current.

II. SYSTEM CONFIGURATION

A) Passive filter:

The passive filters are used in order to protect the system by reducing the harmonic current. The most common type of shunt passive filters used in harmonic reduction is the single tuned filter(STF) which is either a low pass or band pass filter. This is the simplest form of filter to design and less expensive.

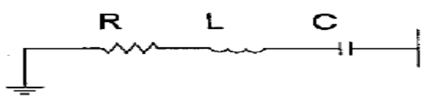

Fig 2.1 Single Tuned Filter

The double tuned filter (DTF) can be used to filter two harmonic source simultaneously. DTF has a advantages such as only one reactor is subjected to full line voltage and smaller space needed.

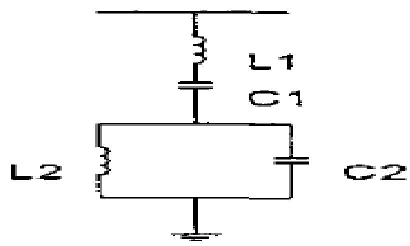

Fig 2.2 Double Tuned Filter

B) Active Filters:

It is made up of OP-Amps, resistors and capacitors. Active filters are easy to adjust over a wide frequency range without altering the desired response. High input impedance prevents excessive loading of the driving source, and low output impedance prevents the filter from being affected by the load. The active filters are used in a condition where the harmonic orders change in terms of magnitudes and the phase angles. In such conditions, it is feasible to use the active elements instead of passive ones in order to provide dynamic compensation.

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There are three types of configurations; they are series active filter, shunt active filter and hybrid filter.

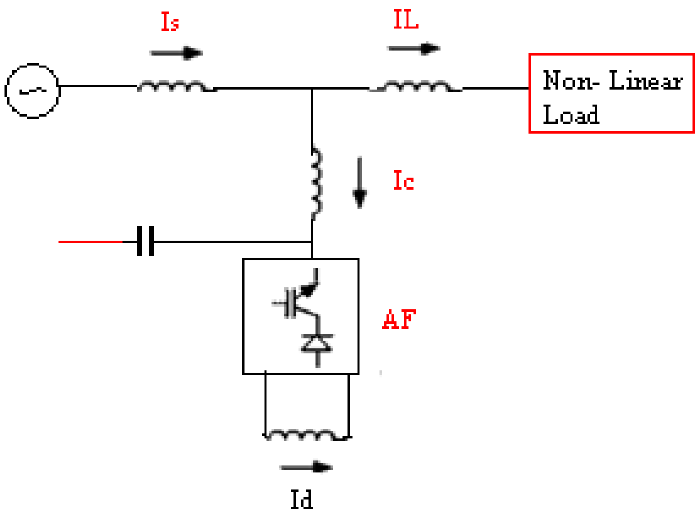

Fig 2.3 Current fed type AF

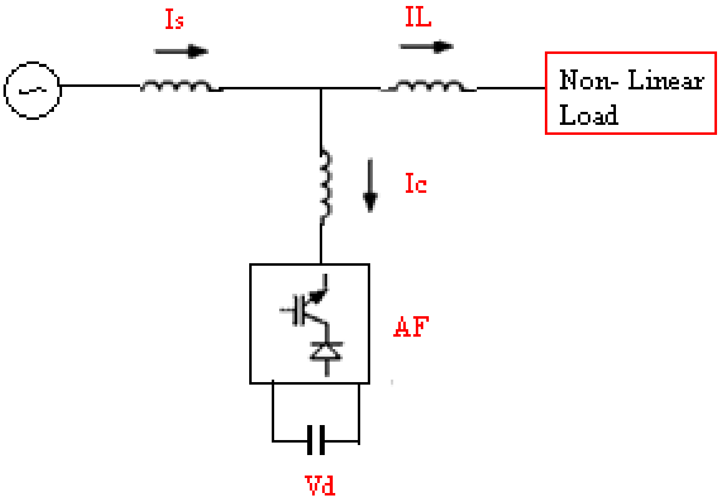

Fig 2.4Voltage fed type AF

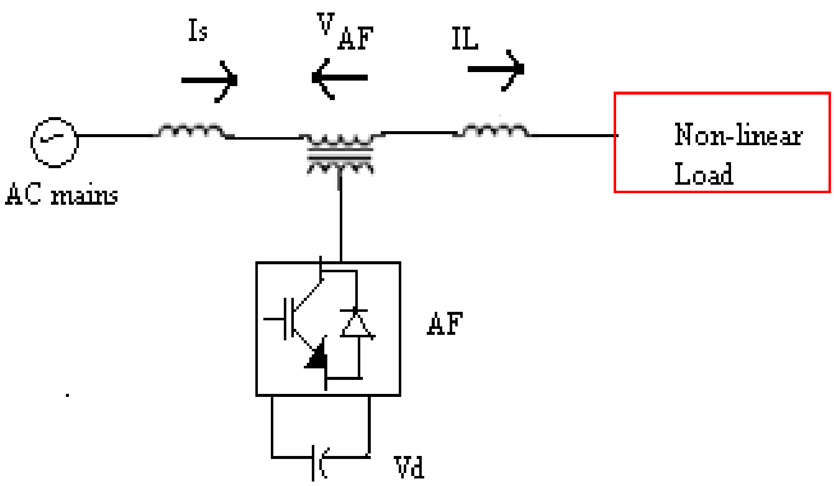

Fig2.5 Series Type AF

Active filters can be used with passive filters for improving compensation characteristics of the passive filter and avoiding the possibility of the generation of series or parallel resonance in the power system. The combination of both active and passive filter is known as a hybrid filter [2].

III. SELECTION OF FILTERS

Table.1 gives a proper selection of active filter for all power quality disturbances. Since nowadays many industries are manufacturing active filters.

Table 1. Selection of Filters for Harmonic

Sr.no	Compensation for particular Application	Active Series	Active Shunt	Hybrid of Active Series and Passive Shunt	Hybrid of Active Shunt and Active Series
1	Voltage Harmonics	XXX		XX	X
2	Current Harmonics		XX	XXX	X
3	Current Harmonics & Reactive Power		XXX	XX	X
4	Current Harmonics Reactive Power & Load Balancing		XX		X

XXX:
XX:
X:

IV. DESIGN OF FILTER

a). Passive Shunt Filter :

In design of the filter, the proper selection of the capacitor size is very essential from power factor point of view. A series-tuned filters is a capacitor designed to trap a certain harmonic by adding a reactor such that $Xl = Xc$ at the frequency fn.

To design series-tuned following step are followed:

Determine the capacitor size Qc in MVAR, say the reactive power requirement of the source.

The capacitor reactance is

$$Xc = \frac{KV^2}{Qc} \qquad (3.1)$$

Capacitance for filters is calculated by

$$C = \frac{1}{2*\Pi*f*Xc*n} \qquad (3.2)$$

Where n = number of filter

The resonance condition will occur when capacitive reactance is equal to inductive reactance as:

$$Xl = Xc \qquad (3.3)$$

To trap the harmonics of order h, the reactance should be of size

$$L = \frac{1}{(2\Pi hf)^2 \times C} \qquad (3.4)$$

The resistance of filter depends on the quality factor (Q) by which sharpness of the tuning is measured.

$$R = \frac{Xl - Xc}{Q} \qquad (3.5)$$

Where Q is the quality factor and for series tuned is $30 < Q \leq 100$.

b) Active Filter:

There are basically two types of active filters the shunt type and the series type.

ISSN 2349-7815

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i). Shunt active filter:

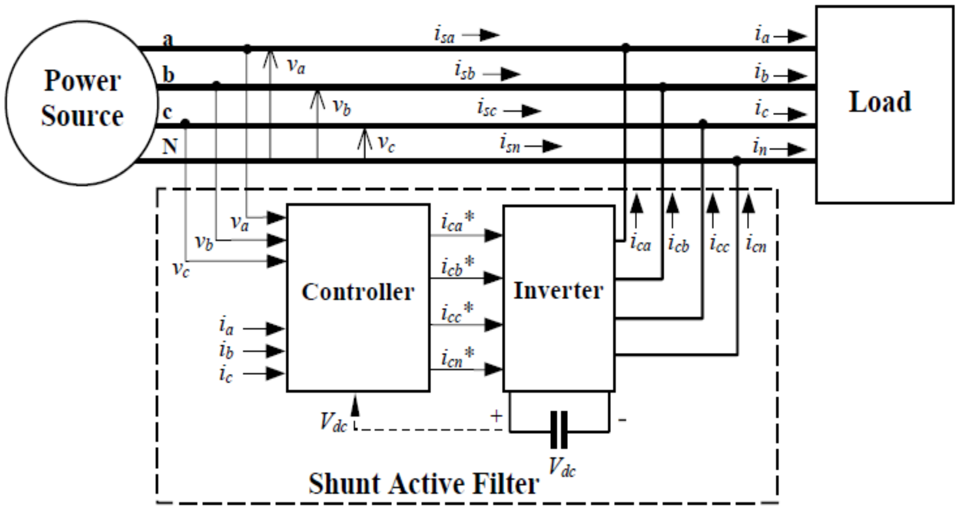

Fig 4.1 configuration of shunt active filter

Above fig. shows a shunt active filter for a three-phase power system with neutral wire, which is able to compensate for both current harmonics and power factor & it allows load balancing, eliminating the current in the neutral wire. The power stage is, basically, a voltage-source inverter with only a single capacitor in the DC side. Controlled in a way that it actsnlike a current-source. From the measured values of the phase voltages (*va*, *vb*, *vc*) and load currents (*ia*, *ib*, *ic*), the controller calculates the reference currents (*ica**, *icb**, *icc**, *icn**) used by the inverter to produce the compensation currents (*ica*, *icb*, *icc*, *icn*).

ii).Seris active filter:

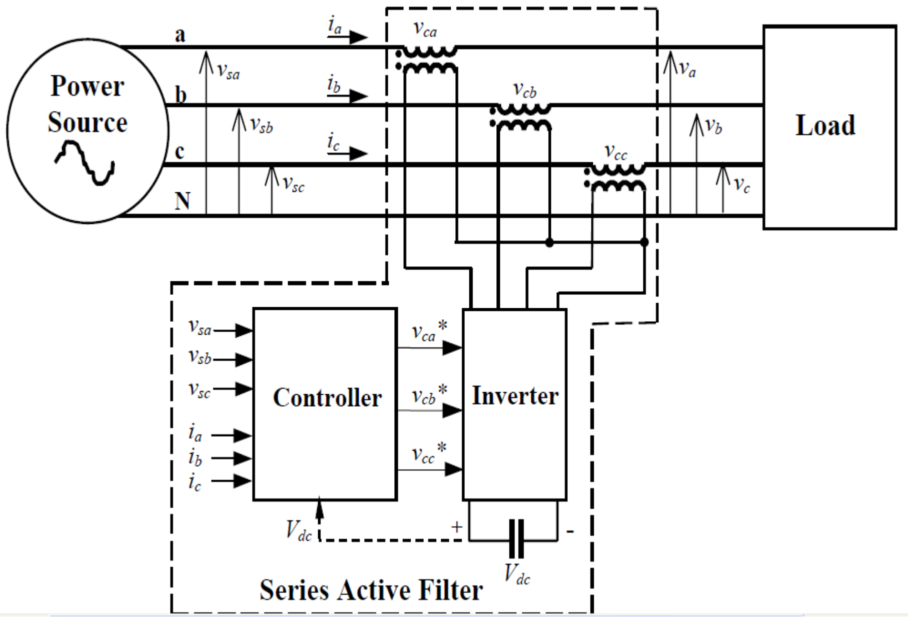

Fig 4.2 configuration of series active filter

Above fig. shows a series active filter for a three-phase power system. It is able to compensate for distortion in the power line voltages, making the voltages applied to the load Sinusoidal. The filter consists of a voltage-source inverter and requires 3 single-phase transformers to interface with the power system. The series active filter does not compensate the load current harmonics but it acts as high-impedance to the current harmonics coming from the source side.

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V. CONTROL STRATEGIES

I).shunt current compensation by p-q theory:

In the shunt current compensation Basic concept is compensation of unwanted current that is compensator inject the current such that it cancel the unwanted current in system Figure2 show the simplest form of shunt compensator. Is, abc show the source current. Il, qbc Show the load current and Ic, abc show the compensator current. Shunt compensator behaves as three-phase controller current source. It generates compensator current as per requirement of system.

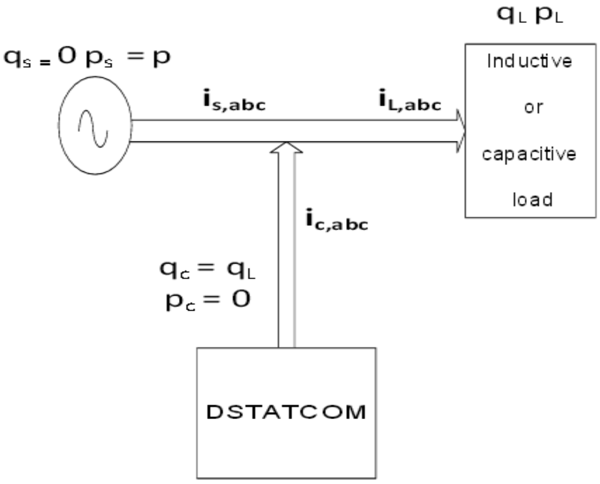

Fig 5.1 control strategies for shunt filter

Figure 5.2 Show the basic control scheme used in controller of shunt compensator. In this firstly calculate the real and reactive power then both divided into overage (and oscillating part from these powers calculate the reference current. There is no any exchange of real power in compensator there for compensator does not required any power source or energy storage system.

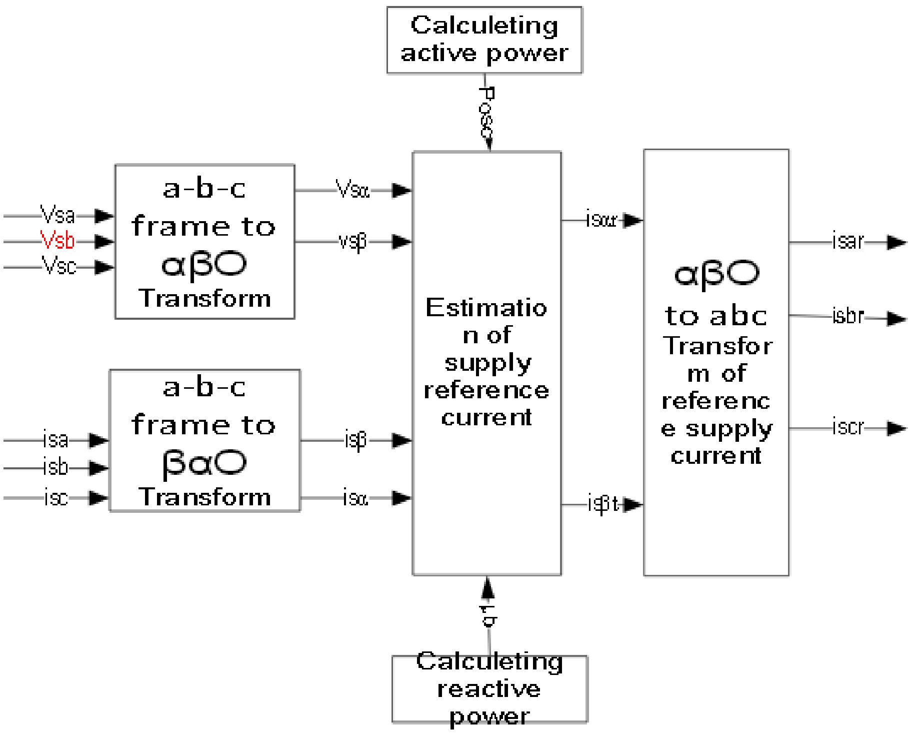

Fig 5.2 generation of reference current for shunt compensation

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ii).series voltage compensation using p-q theory:

Fig 5.3 show the basic configuration of series voltage compensation. Where Vsa, Vsb, Vsc, are the source voltage Vca, Vcb, Vcc, are the compensator voltage and Vla, Vlb, Vlc, are the load voltage. Series compensator behaves as control voltage source In shunt current compensation current component calculate as function of the voltage, active and reactive power but in the series voltage compensation voltage component calculate as a function of current and reactive power.

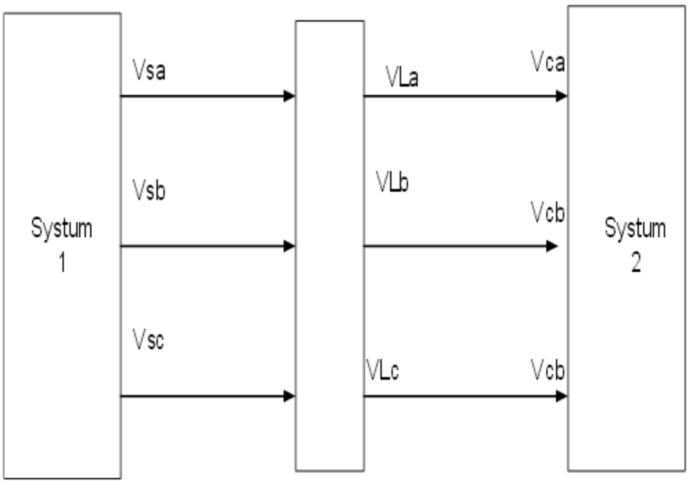

Fig 5.3 control strategies for series filter

Fig 5.4 shows the control sachem for series voltage compensation base on the pq theory the compensating reference voltage are directly calculate from load terminal and connected from abc to α-β-0 frame and calculate the active and reactive power and estimate the reference current, then convert these current from α-β-0 frame to abc frame.

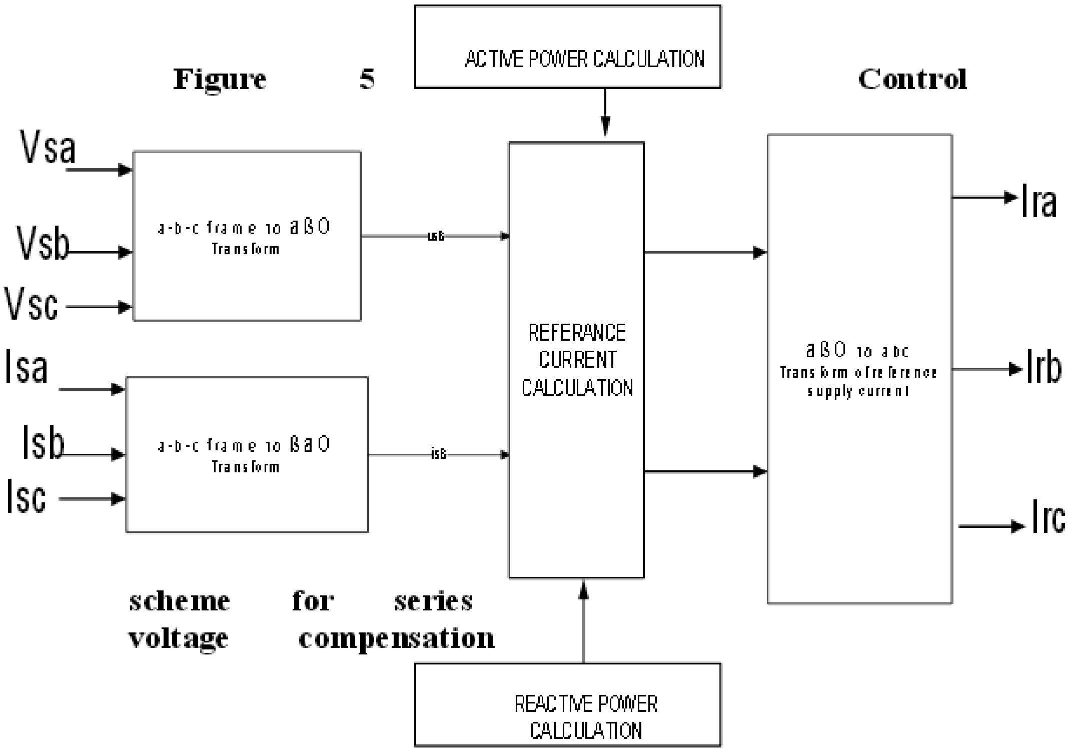

Fig 5.4 generation of reference current for series compensation

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VI. SIMULATION OF INDUCTION FURNACE WITH CONSIDERING AC DRIVE AND D.C. DRIVE

- **System without filter and Result:**

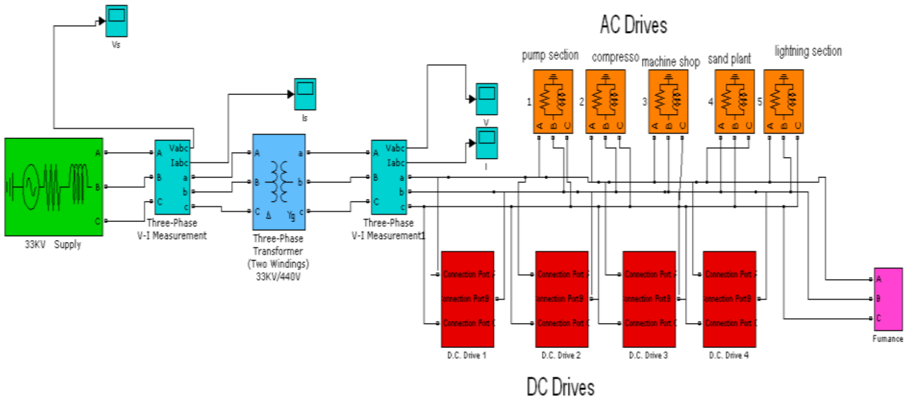

Fig.6.1Simulation Without filter

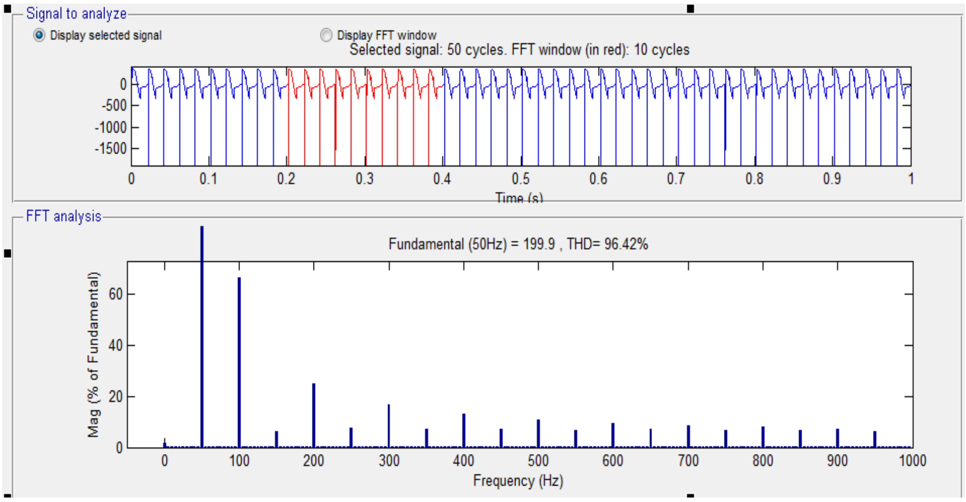

Fig.6.2 voltage THD Analysis

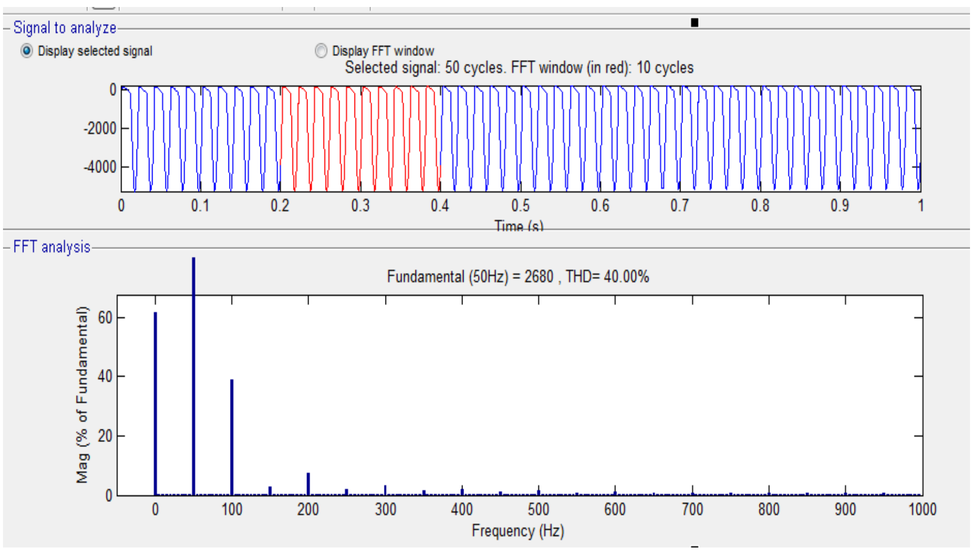

Fig.6.3 current THD Analysis

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- ***System with Passive Filter And Result:***

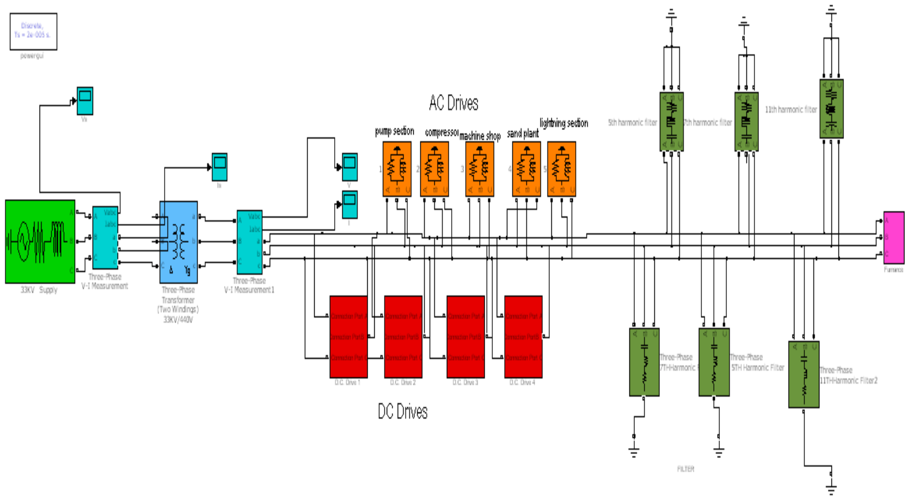

Fig.6.4Simulation With Passive filter

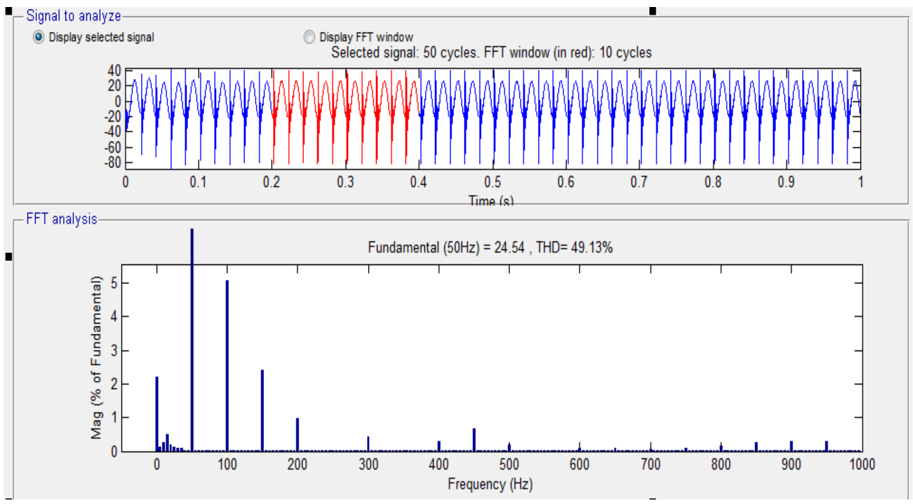

Fig.6.5 voltage THD Analysis

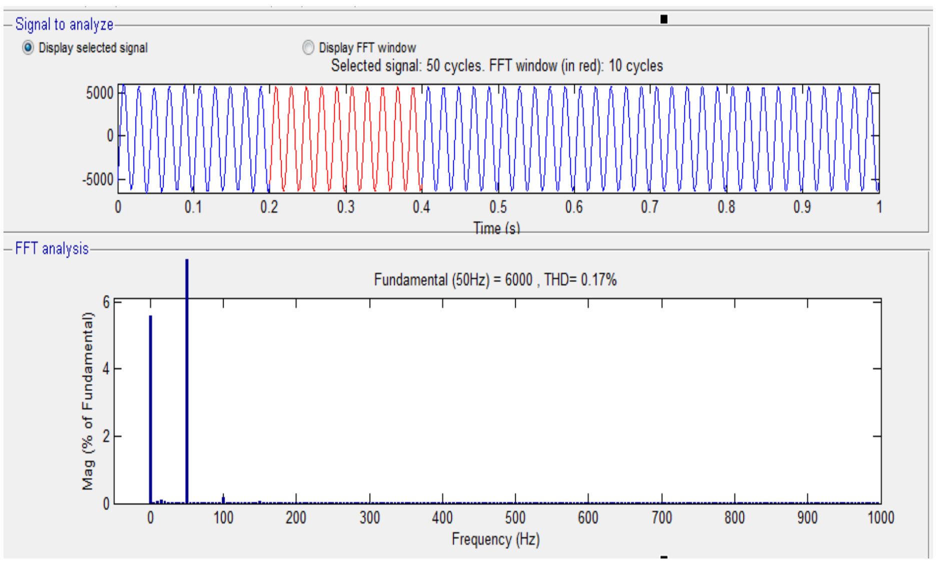

Fig.6.6 current THD Analysis

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- ***System with Hybrid Filter And Result:***

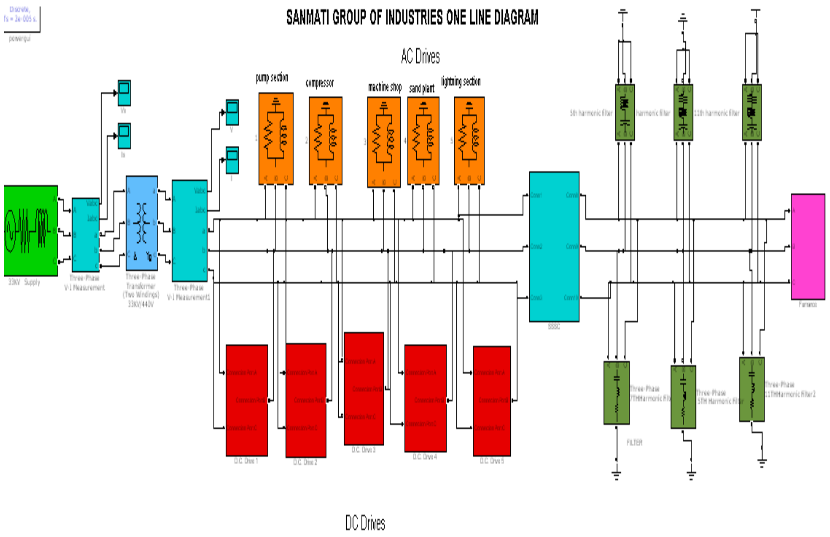

Fig.6.7Simulation With Hybrid filter

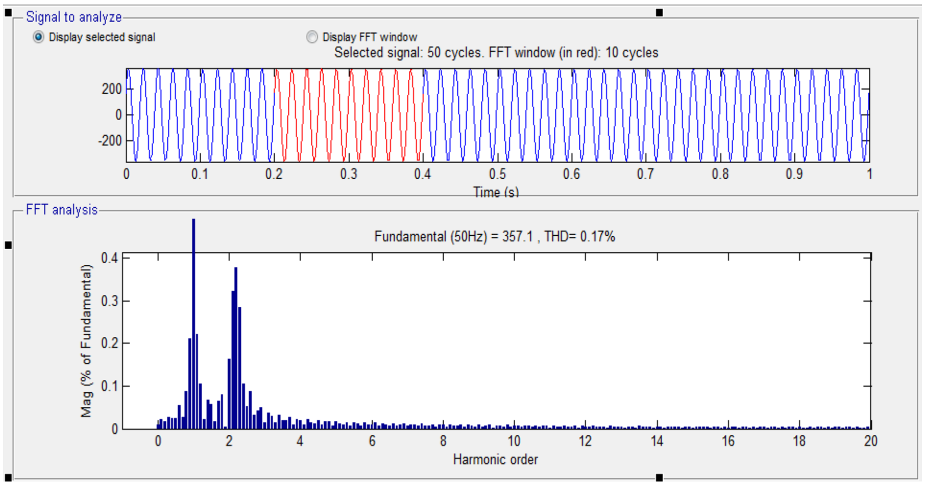

Fig.6.8 voltage THD Analysis

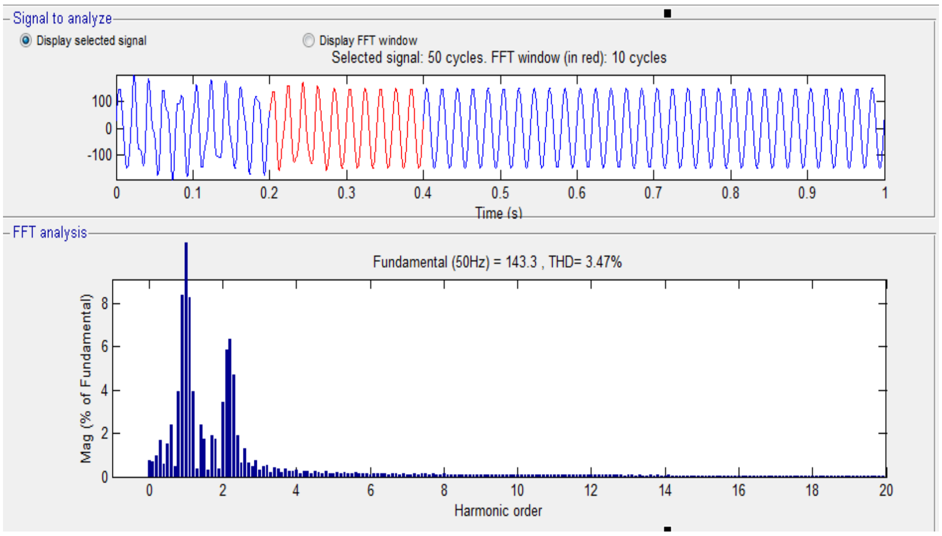

Fig.6.9 current THD Analysis

ISSN 2349-7815

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VII. CONCLUSION

Thus the Hybrid filter is used for reducing the current harmonics and voltage harmonics in the non-linear load.

The active filter is only controlled to inject harmonic voltages through coupling transformers hence advantage of lower VA ratings of the active filter.

As observed from the simulation results the following conclusions are obtained. In the absence of hybrid filter, whenever the non-linear loads are present, voltage harmonics are 96.42% & Current harmonics are 40 %.(Fig. 5.2 & 5.3). In the presences of hybrid filter voltage harmonics are 0.17% &current harmonics are 3.47%. As observed from FFT analysis (Fig.5,8 & 5.9). After Filter injection the THD is reduced .Therefore, the proposed hybrid filter ensures reduction of harmonic content.

ACKNOWLEDGMENT

We want to thank our Department of Electrical Engg. The College. We also thankful to **"Sanmati Indusry, Mangaonwadi"** give us to work on this project. They have been very kind and helpful to us. We also want to thank all teaching and non-teaching staff to support us. Especially we are thankful to our project guide for providing this golden opportunity to work on this project, inspiration during the course of this project and to complete the project within stipulated time duration. We would like to express our sincere gratitude to our guides Tahasildar M.A. for their help during the course of the project right from. We are special thankful for our guide Tahasildar M.A.

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