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Comparitive Performance Analysis of Total Harmonic Distortion in Power System Using Two Different Filters: Active Filter & Passive Filter

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***Abstract*–Now a day's numbers of power system equipment contain power electronic based controller to get smooth operation, better reliability & efficiency in the operation. These controllers contain Non-Linear components which is responsible to produce harmonics in the source current & hence in the source voltage at the point of common coupling (PCC). These harmonics creates the disturbance in normal operation, excessive heating in the equipments etc. so it is necessary to abate these harmonic problems.Filters are the good choice in reducing harmonics.Both passive and active filters are find suitable in mitigating harmonics.For the calculation of reference currents in active power filter d-q theory is used since the number of voltage equations are reduced and performance of power can be analysed without complexity in voltage equation.Synchronous Reference Frame(SRF) algorithm is used to compensate the harmonic current of a three phase non-linear load. By considering both the filters this paper presents a comparative analysis in reducing the harmonics current generated by non-linear loads using Shunt Active Power Filter (SAPF) and Passive filter.MATLAB Simulation powersystem toolbox is used as the software platform to evaluate the simulation results of the proposed system.**

***Index Terms*—** Active Filter,Passive Filter, Synchronous Reference Frame Algorithm, harmonics etc.

1.INTRODUCTION

In recent years most of the power system equipments are using power electronic devices. The best example is the micro grid which is a localized grouping of electricity sources and loads that normallyoperates connected to and synchronous with the traditional centralized grid (macro grid), but can disconnect and function seperately.Distributed generation is a approach which employs small scale technologies to produce power. It is also on-site generation or decentralized energy is generated or stored by a variety of small ,grid-connected devices referred to as distributed energy resources.[1]Nowadays, power quality and custom power have been hot topics because of the widespread use of nonlinear electronic equipment such as diode/thyristor, rectifiers, switched mode power supply (SMPS), welding equipment, incandescent lighting, and motor drives are degrading power quality in micro grid systems. These non-linear loads result in harmonic or distortion current and create reactive power problems. Harmonic suppression and reactive power compensation are essential for the construction of smart grid, which gathers, distributes, and acts on the behaviour of suppliers and consumers in order to improve the efficiency and sustainability of electric services.[2] Power quality determines the fitness of the electric power to consumer devices. "Any power problems discovered in voltage, current, or frequency deviations which results in failure or mal-functioning of customer equipment". The power quality issues are Power Factor, Harmonic Distortions,Disturbances, Unbalance,Frequency.[3]

In the past years passive filters are used for reactive power compensation because of its advantages that it can handle large currents and high voltages,it doesn't require power supply and it is very reliable. But, the disadvantage is bulky in size, resonance problem & it compensate only tuned harmonics frequencies.(4)Active filters may contain passive as well as active components.InActivefilter,the advantages are it is easier to design,no need of inductors and they are small in size and weight..Disadvantages in this filter are it require many components and power supply. In this paper active filter and Passive filter analysed with synchronous reference frame algorithm to compensate the harmonic current of a three phase Non- Linear load. [5] This method relies on the performance of the Proportional-Integral (PI) controller for obtaining the best control performance of the SAPF. Many theories have been developed for instantaneous current harmonics detection in active power filter such as FFT (fast Fourier technique) technique, neural network, instantaneous p-q theory(instantaneous reactive power theory), synchronous d-q reference frame theory or by using

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suitable analog or digital electronic filters separating successive harmonic components.

Among this d-q theory is meant to be efficient .since,it reduces the voltage equations.Using Reference Frame Transformation, reference signals are transformed from a–b–c stationery frame to 0 –d –q rotating frame. Using the PI controller, the reference signals in the 0 –d –q rotating frame are controlled to get the desired reference signals for the Pulse Width Modulation[6].The next section contains a brief description on shunt active power filter.

The remaining part of the paper is organised as follows:Section 2 presents about the shunt active filter concept.Section 3 describes about the passive filter.Section 4 discuss about the reference frame theory that helps to calculate reference current.The mathematical modelling of filter is also induced in this part.Section 5 explains about the simulation model under study.The simulation results are evaluated and analysed in section 6.Finally the conclusions are specified in section 7.

2.SHUNT ACTIVE POWER FILTER:

Active filter is classified as series active filter and Shunt active filters. Series filter is consist capacitor and inductor connected in parallel with each other but in series with the load. This types of filter provides high impedance to the harmonics currentsand allow to pass them reaching the power supply, but allows the fundamental frequency of 60Hz current to pass through. But these types of filters have a drawback of carry of full load current. Shunt active filter consist of capacitor and inductor connected in series but parallel with load. This filter provides low impedance path for harmonics current and divert the harmonics to ground. Shunt filter is common and less expensive because they don't have to carry the full load current.

The three-phase shunt active power filter is a three-phase current controlled "voltage-source inverter" (CC-VSI) with a mid-point earthed, split capacitor in the dc bus and inductors in the ac output (It is essentially three independent single phase inverters with a common dc bus). Christo Ananth et al. [7] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

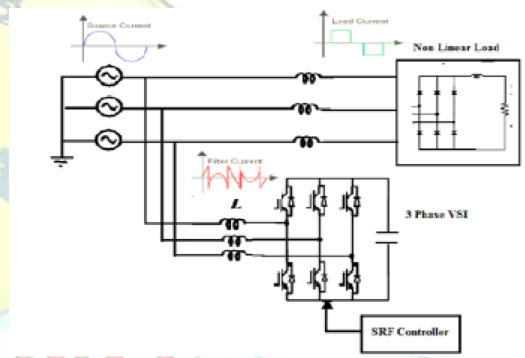

Fig1. Three Phase SRF based SAPF

3. PASSIVE FILTER

The passive filter uses resistors, inductors, and capacitors, and they do not rely upon any type of external power source. In addition, you will find that the passive filters are not going to need to rely on transistors, or other types of active components to work. The inductors and the capacitors work as opposites. The inductors will block high frequency signals and conduct low frequency signals. The capacitors are going to do just the opposite. Because there are been advances in technology and different types of filters on the market, the passive filters might not be in use as much as they were years ago. However, they are still playing a part in many applications . People tend to use them when they want to be able to reduce the amount of harmonic currents, as well as when they need to improve power.Fig.2 shows the circuit of passive filter.

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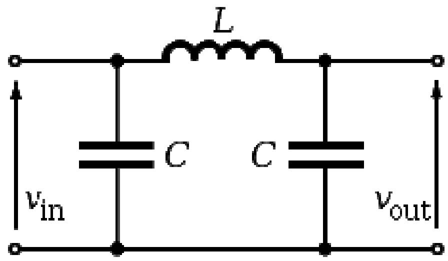

Fig2. passive filter

4. SYNCHRONOUS REFERENCE THEORY:

There are different control strategies being used for the calculation of reference currents in active power filter namely Instantaneous Reactive Power Theory (p-q theory), Unity Power Factor method, One Cycle Control, Fast FourierTechniqueetc .Here, SRF theory is used to extract the three-phase reference currents (ica*, icb*, icc*) used by the active power filters [8]. Figure 1 shows the block which explains three-phase SRF-theory, usefor harmonic component extraction.

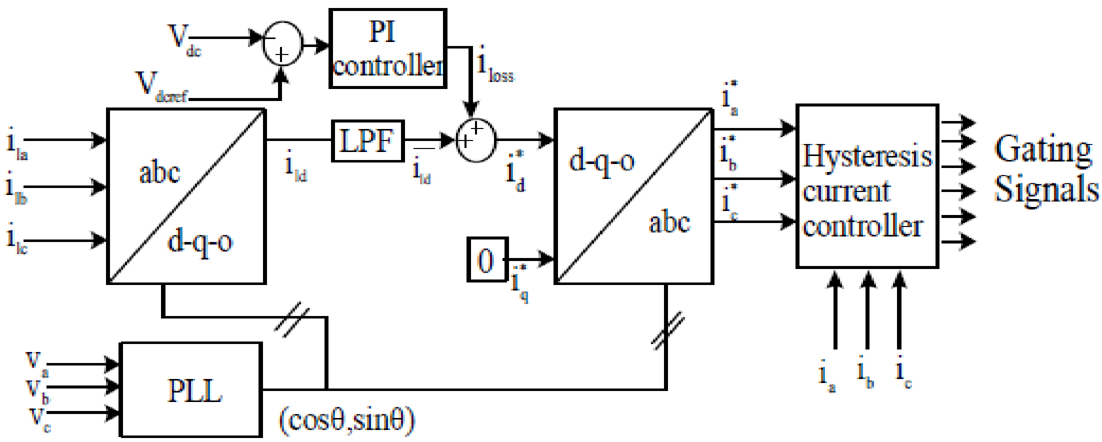

Fig3. Gating signals for PWM current controller

Synchronous Reference Frame theory depends on the transformation of stationary three phase to rotating two phase. In these transformation coordinates from three phase stationary a-b-c coordinates system to 0-d-q rotating coordinates [6]. The following figure shows the transformation of three phase stationary to rotating two phase.Fig 3 shows the gatting signal for current controller.

Here, the source currents (ia, ib, ic) from three phase supply a, b, c are first identified and transformed into stationary two-phase frame (αβ-*0*) from the three-phase stationary frame (a-b-c), as per equation (1).

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \text{-----------(1)}$$

Here two direct and inverse parks transformation is used which allows the evaluation of specific harmonic component of the input signals and a low pass filtering stage LPF. After conversion of stationary three phase to stationary two phase axis the two phase current quantities iα and iβ of stationary αβ-axes are transformed into two-phase rotating synchronous frame (d-q-axes) using equation (2), in this equation Cosθ and Sinθ represents the synchronous unit vectors which can be generated using phase-locked loop system (PLL).

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\vartheta & \sin\vartheta \\ -\sin\vartheta & \cos\vartheta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\alpha \end{bmatrix} \text{-------------(2)}$$

From the above equation , the d-q axis currents (iq and id) are determined which comprises of AC and DC parts. The fixed DC part consist of fundamental component of current and the harmonic components are represented by AC part. This harmonic component can be easily extracted using a high pass filter (HPF). The d-axis current is a combination of active fundamental current (id dc) and the load harmonic current (ih). The fundamental

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component of current rotates in synchronism with the rotating frame and thus can be considered as dc. By filtering id, the current is obtained, which represents the fundamental component of the load current in the synchronous frame. Thus, the AC component idh can be obtained by subtracting id dc part from the total d-axis current (id), which leaves behind the harmonic component present in the load current. In the rotating frame the q-axis current (iq) represents the sum of the fundamental reactive load currents and part of the load harmonic currents. So the q-axis current can be totally used to calculate the reference compensation currents.

After this inverse transformation is used to transform the currents from two phase synchronous frame d-q into two-phase stationary frame α-β as per equation (3),

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\vartheta & -\sin\vartheta \\ \sin\vartheta & \cos\vartheta \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \quad \text{----------(3)}$$

Finally the current from two phase stationary frame αβ0 is transformed back into three-phase stationary frame abc as per equation (4) and the compensation reference currents ica*, icb* and icc* are obtained.

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = [T_{abc}] \begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} \quad \text{-----------(4)}$$

Where,

$$[T_{abc}] = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad \text{-----------(5)}$$

5.SIMULATION MODEL UNDER STUDY:

The simulation model under study with the parameter specification is represented in figure 3 and table 1.In this case system model contain source supplying a non linearload.The rectifier is considered as a load. The shunt active power filter is connected in shunt between source and load.The shunt active filter can be replaced with passive filter by connecting the LC component across the source and load.The simulation results are evaluated with MATLAB SIMULINK software.Parks and clarkes transformation are applied to generate reference current.

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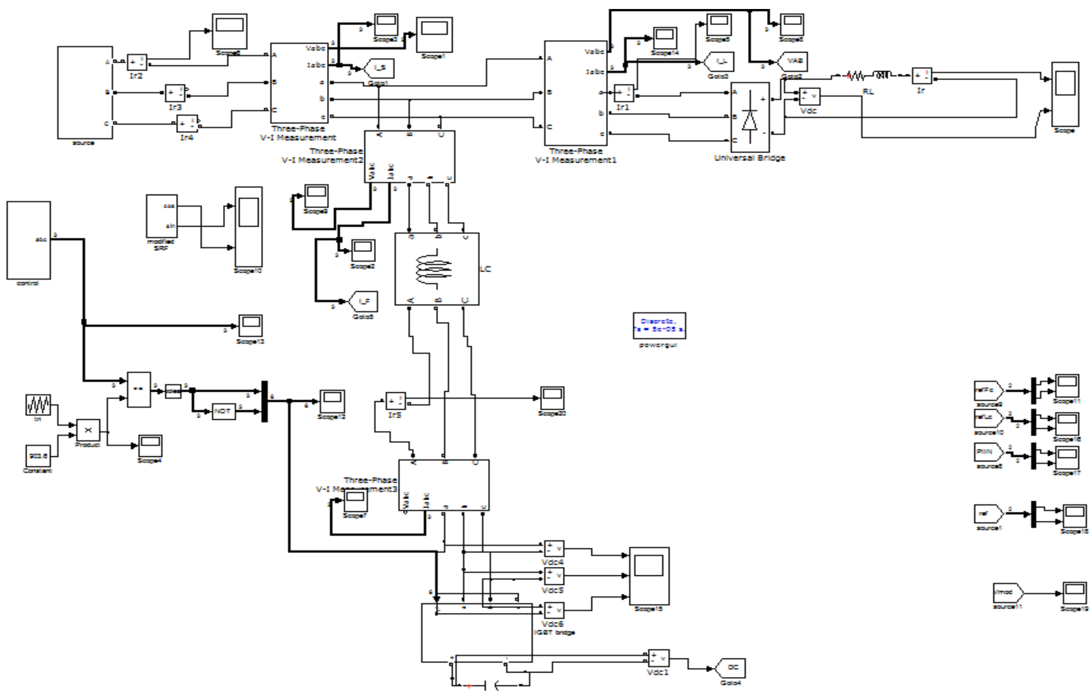

Fig.4simulink model

6.SIMULATION RESULTS:

The harmonic current compensation is implemented in a three-phase power system using a shunt active power filter. The rms value of source voltage of the system is set as 240V and a combination of three-phase universal bridge rectifier with an RLC load across it constitutes the nonlinear load which introduces the harmonics into the system.Table1.shows the various circuit parameters and design specifications used in this simulation.

SYSTEM PARAMETERS	SPECIFICATIONS
Phase voltage	240V
Source Inductance	0.1e-4H
Switching Frequency	50Hz
DC link capacitor voltage	440V
DC link capacitor	2200µF
Coupling inductance	45Mh
Load resistance	1e-3
Load capacitance	1e-6

Table.1 System parameters

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THD WITHOUT FILTER:

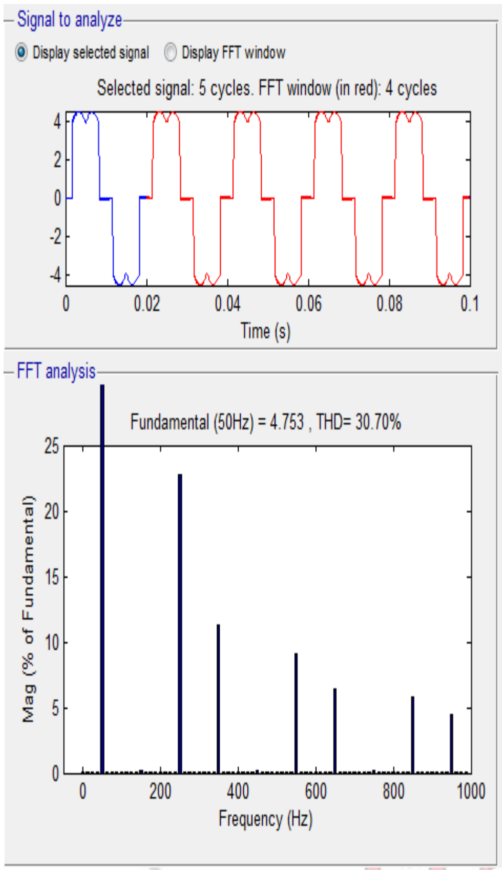

Fig.5 without filter

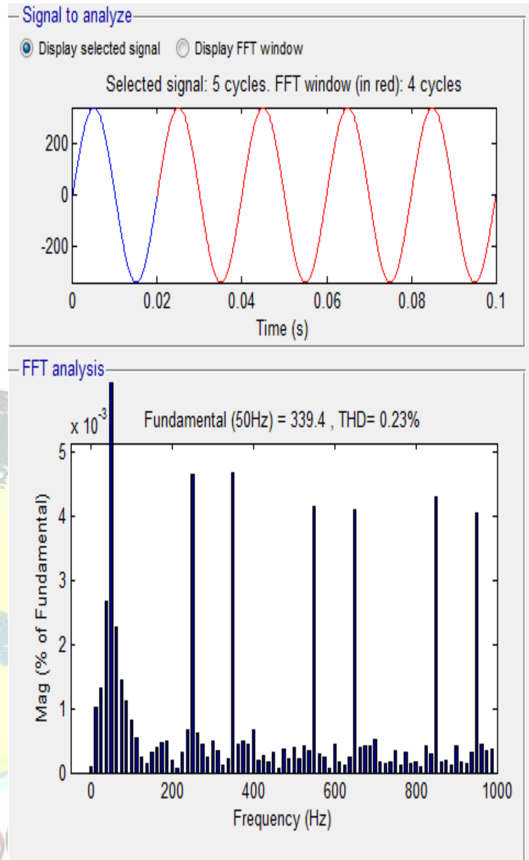

Fig.6 with SAPF

THD WITH PASSIVE FILTER:

THD WITH SAPF:

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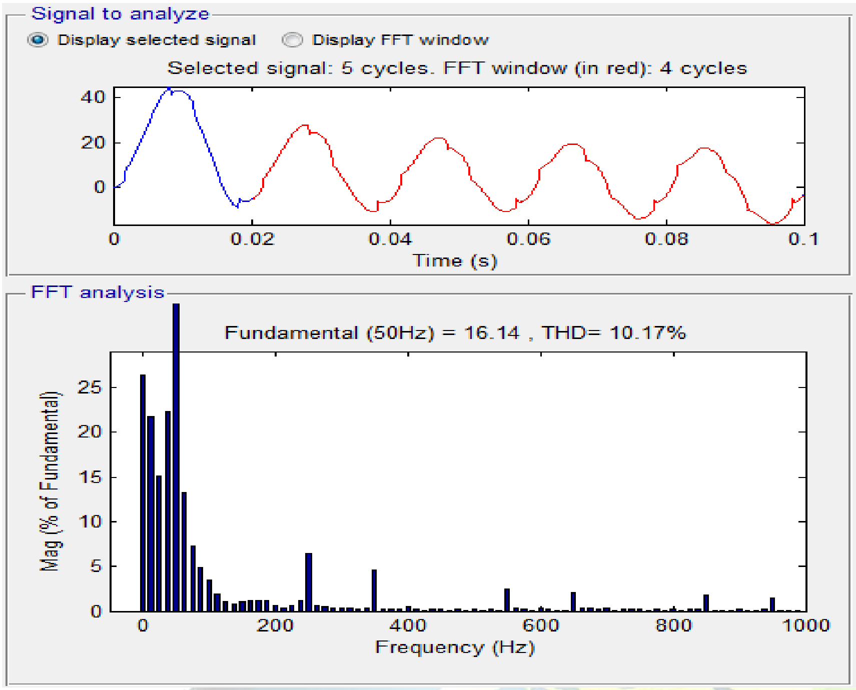

Fig.7 with passive filter

Normally,total harmonic distortion occurs due to the usage of non-linear load.Initially,the harmonic current is introduced in the system,because of the non-linear characteristics of load and so the harmonic power is dissipated to the load.The following figure shows the system simulation with SAPF & with PASSIVE FILTER.The recorded THD of the load is found to be 30.7% without filter.By using passive filter the load current seems to be slightly sinusoidal with a THD of 10.17%.whereas by implementing shunt active filter the load current seems to be pure sinusoidal with a THD of only 0.23%.The traced value of THD uing SAPF is less than the THD allowed in the IEEE standard 1547-2013(THD less than 5%).Hence,the simulation results prove that the current harmonics was effectively compensated with the help of SAPF by applying d-q theory compared with passive filter.

7.CONCLUSION:

Recently,the shunt active power filter have influenced the researchers a lot in reducing current harmonics to the lesser value comparing with passive filter . The reference current is generated with the help of hysteresis current controller by applying d-q theory,the simulation is evaluated by considering a DG supplying a non linear load using both passive and active filter.The harmonic distortion is evaluated in thisarticle.The results prove that shunt active filter offers satisfactory THD comparatively higher than passive filter and therefore helps to enhance the system stability.

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