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"ACTIVE HARMONIC FILTER DESIGN FOR PROCESS INDUSTRY"

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Abstract : Industrial electronic devices and non linear loads are the major cause of harmonic generation. As the current drawn from the supply no longer remains sinusoidal, thus the resultant waveform is made up of a number of different waveforms of different frequencies, harmonics are a major cause of power supply pollution lowering the power factor and increasing the electrical losses, which may causes a premature equipment failure and higher rating requirement for equipment .A different type of load draws non-sinusoidal current from the mains, degrading the power quality by causing harmonic distortion. These nonlinear loads appear to be prime sources of harmonic distortion in a power system. In addition, the harmonic currents produced by nonlinear loads can interact adversely with a wide range of power system equipment, most notably capacitors, transformers, and motors, causing additional losses, overheating, and overloading and interferences. In this dissertation, active harmonic filter by using MATLAB/Simulink is designed . An active harmonic filter is designed in Simulink to mitigate the harmonics produced in process industry Also origin of total harmonics distortion and it's consequences into the load. Active filter's harmonic reduction techniques to improve the quality of power, by injecting equal current or voltage distortion into the network but in opposite magnitude, which automatically cancels the actual distortion presented in the circuit is studied in this paper.

***IndexTerms* - Shunt active power filter (APF), 2nd harmonic, control methods, proportional integral control (PI), Proportional resonant control (PR), unbalanced and nonlinear load**

I. INTRODUCTION

Harmonic in power systems shortens the life expectancy of equipment and can interfere with communication lines and sensitive equipment. Increasing concern over this problem stems from the growing numbers and power ratings of the highly nonlinear power electronic devices used in controlling power apparatuses in industrial power systems. The filter design has become essential for industrial power systems. The problem of designing a harmonic filter has been conventionally by trial-and-error approach, In the recent decade, various formulations for a more systematic approach to harmonic filters design have been developed, although effective in eliminating the harmonic.Active harmonic filter are used to compensate for harmonics from nonlinear loads, for reactive power compensation and or balancing mains currents. This paper will investigate the effect of using an APF to improve the output power quality. Using an APF, simulation and experimental results show significant improvements in output current and reduced the THD in the system.

In this paper, fuzzy model is proposed for APF, it has the advantages of without using prior knowledge of the structure and parameters of the controlled system and can be considered as a powerful tool for the control of complex system. T-S fuzzy models are suitable to model a large class of non-linear systems, it has the ability to achieve complicated mappings and therefore can be used to predict harmonic compensating current at various conditions. During fuzzy modeling, fuzzy model is derived from input-output measured data by means of fuzzy clustering, similarity driven rule base simplification is applied to detect and merges compatible fuzzy sets in the model and a novel method is proposed to determine the number of clusters. All these techniques ensure the fuzzy model compact and accurate. Based on the predictive model, the value of control variable is acquired by means of optimization technique. Iterative optimization techniques are mostly slow due to computational complexity, this hampers its application to fast system. In order to solve the problem, branch-and-bound optimization method is adopted. The fuzzy model predictive algorithm is used in internal model control scheme to compensate for process disturbances, measurement noise and modeling errors. Simulation test under various conditions is implemented, the effectiveness of the control scheme is effective.

II. POWER SYSTEM AND POLLUTION

2.1 Harmonic

Power systems are designed to operate at frequencies of 50 or 60 Hz. However, certain types of load produces currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. These frequencies components are a form of 9 electrical pollution known as harmonic distortion.

2.1.1 Total Harmonic Distortion (THD)

The total harmonic distortion of a signal is a measurement of the harmonic distortion present in current or voltage. It is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Harmonic distortion is caused by the introduction of waveforms at frequencies in multiplies of the fundamental.

2.1.2 Effects of Harmonics

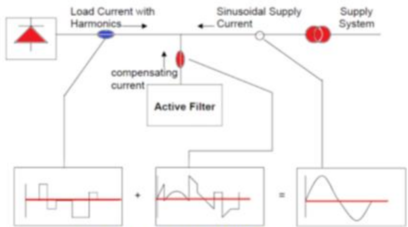
The voltage or current distortion limit is determined by the sensitivity of loads (also of power sources), which are influenced by the distorted quantities. The least sensitive is heating equipment of any kind. The most sensitive kind of equipments is those electronic devices which have been designed assuming an ideal (almost) sinusoidal fundamental frequency voltage or current waveforms.

2.1.3 Solutions for the Harmonics

The electric companies, from its side, use different filtering equipment's and encourage the researches toward finding new efficient solutions for the power quality problems. The clients install also sometimes reactive power and harmonic compensation batteries to ameliorate the power factor and reduce the energy consumption bill. Many traditional and modern solutions for harmonics mitigation and power quality improvement were proposed in literary. Some of these solutions investigate in the load to minimize the harmonic emission while the others propose the use of external filtering equipment's that prevent the spread of harmonics into the grid.

III. THREE PHASE ACTIVE HARMONIC FILTER

Shunt active power filter compensates current harmonics by injecting equal-butopposite harmonic compensating currents into the grid. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180° This principle is applicable to any type of load considered as harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non linear load and the active power filter as an ideal resistor. The current compensation characteristics of the shunt active power filter is shown in Figure Harmonics come from the nonlinear load. Active harmonic filters, also called harmonic correction units, are parallel devices that act like a noise cancellation system and inject equal and opposite frequencies to mitigate harmonics. The filters can also provide additional current to correct the power factor. So, what's left coming from the source flowing back to the utility is only a nice, clean current that is in phase.



Block Diagram of Active Filter

3.1 Basic Operation Of APF

The harmonic filter working principle is to decrease distortion through deflecting harmonic currents within less-impedance lanes. These filters are capacitive at the basic frequency, so used to generate the reactive power necessary through converters & also for correction of power factor. The Active filter uses a CPU for detecting the order and magnitude of the harmonics present in the network and generates a harmonic current spectrum in phase opposition to the measured spectrum. The control system of the Active Harmonic Filter is designed to operate in real time. The Active filter is IGBT based harmonics generator. The active harmonic filter is connected in parallel to the load to be compensated. The harmonics present in the system is measured by the CPU of active filter unit. The CPU controls the IGBT unit of the active filter. The CPU commands to the IGBT control unit to generate the harmonics spectrum in just phase opposition to the measured harmonic spectrum in a real time basis to nullify the load harmonics. The active filter provides very fast response to compensate the harmonic current.

IV. REFERENCE CURRENT EXTRACTION METHOD

The reference current extraction method is classified into time-domain and frequency-domain. The time-domain method is used to extract the reference current from the harmonic line current with simple algebraic computation. The frequency domain based on Fast Fourier Transformation (FFT) method provides accurate individual and multiple harmonic load current detection. The merit of time-domain method has fast response compared to frequency-domain. The following time-domain methods are carried out for the active power line conditioner. Several techniques are available. we have carried out a comprehensive investigation including our proposed methods for the sake of comparison.

4.1.1 Fuzzy Logic Controller

Fuzzy logic control is deduced from fuzzy set theory; which was introduced by Zadeh in 1965. In the fuzzy set theory concept, the transition is between membership and non-membership function. Therefore, limits or boundaries of fuzzy sets are undefined and ambiguous but useful in approximating systems design. In order to implement the fuzzy logic control algorithm of an active power line conditioner in a closed loop, the dc-link capacitor voltage is sensed and compared with the desired reference value. The error signal (e(v) = Vdc-ref – Vdc) passes through a Butterworth low pass filter that allows only the fundamental component. The voltage error signal e(n) and change of error signal ce n( ) are used as inputs for fuzzy processing as shown in fig

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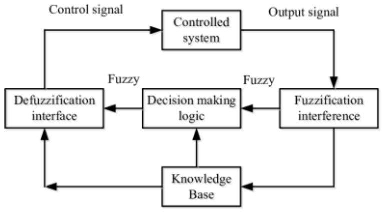


4.2.2 Steps for Computing the Output of fuzzy logic controller

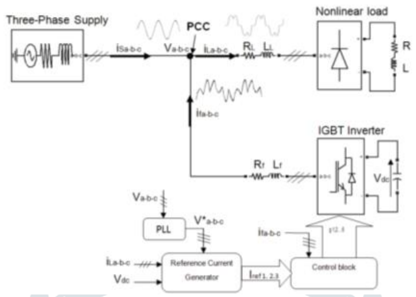
Following steps need to be followed to compute the output from this FIS –

- Step 1 − Set of fuzzy rules need to be determined in this step.
- Step 2 − In this step, by using input membership function, the input would be made fuzzy.
- Step 3 − Now establish the rule strength by combining the fuzzified inputs according to fuzzy rules.
- Step 4 − In this step, determine the consequent of rule by combining the rule strength and the output membership function
- Step 5 − For getting output distribution combine all the consequents.
- Step 6 − Finally, a defuzzified output distribution is obtained.

V. Proposed System

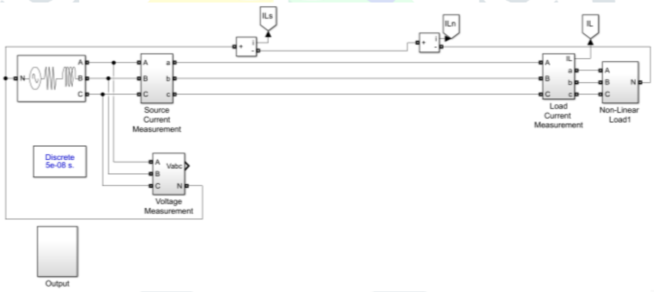
5.1.1 Single Line Diagram For Proposed System

To get instant overview about the proposed system single line diagram for proposed system is shown in below fig.



VI. Results And Simulation

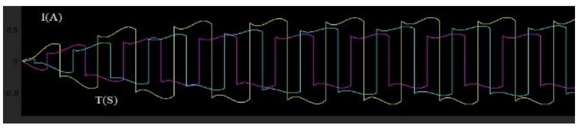
6.1.1 without filter operation



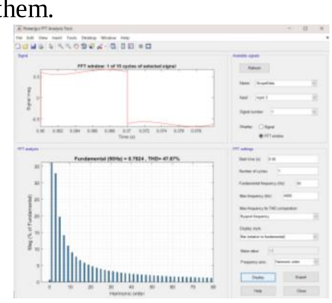
Active harmonic filter is not connected to below system so it obvious particular system contains harmonics. we will discuss comparison of THD % in detail up next in this chapter.

6.1.2 Source current

Fig indicates the source current contains harmonics because of non linear load so we have to mitigate the harmonics by applying harmonic filter in the system also the percentage of harmonics contains in the load current waveform is shown in the next fig.



One thing gets very clear after observation load current and source current contains same amount of harmonics i.e. 47.67 % because there is no harmonic filter is attached in between them.



6.1.3 Load current

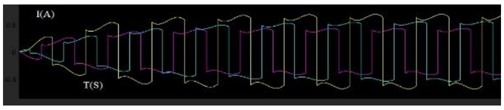
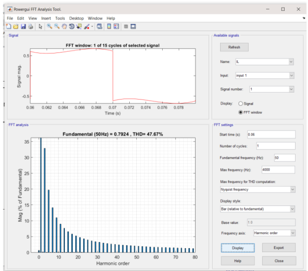
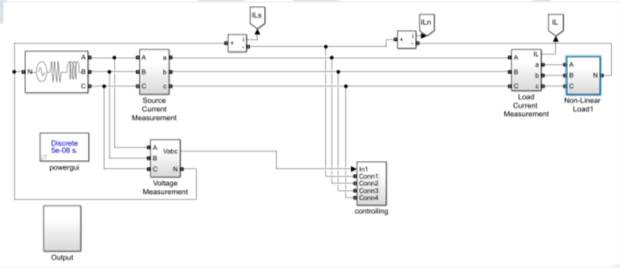


Fig 8.4 indicates the load current contains harmonics because of non linear load so we have to mitigate the harmonics by applying harmonic filter in the system also the percentage of harmonics contains in the load current waveform is shown in the above fig.



We can observe in fig .that the 47.67% of THD present in the load current

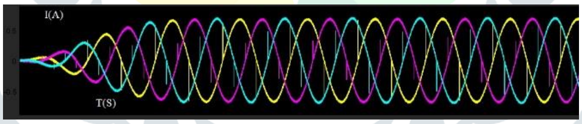
6.2 WITH FILTER OPERATION



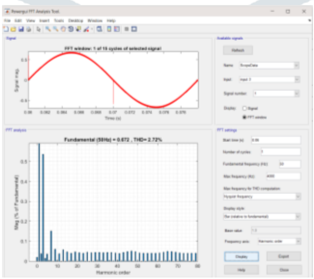
Active harmonic filter is connected to below system so it mitigate the harmonics in the particular system which contains harmonics previously . we will discuss less in THD % after applying active harmonic filter into the system

6.2.1 Source current

Fig 8.7 indicates the source current which is free from harmonics because active harmonic filter is connected in the system also the percentage of harmonics contains in the source current waveform is shown in the below fig.



After applying active harmonic filter THD % get reduced because active harmonic filter injecting compensating current to the system.while the THD in source current is just only 2.72 %.



6.2.2 Load current

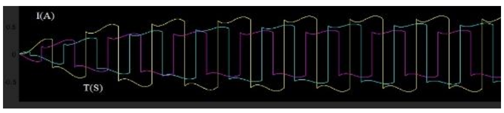
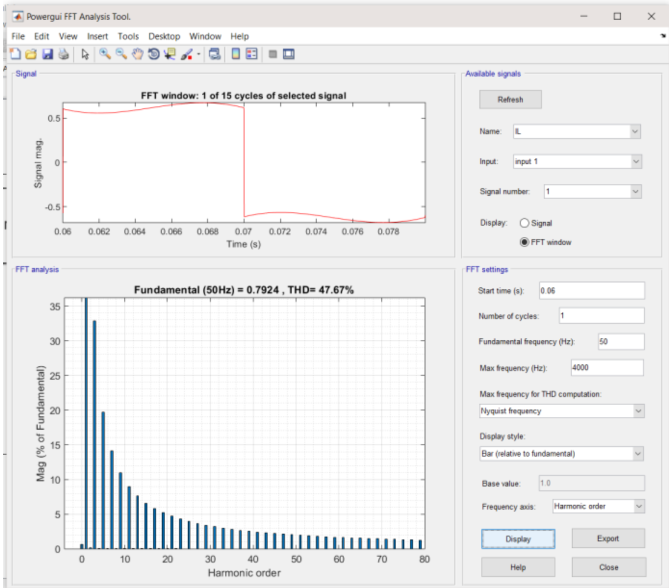


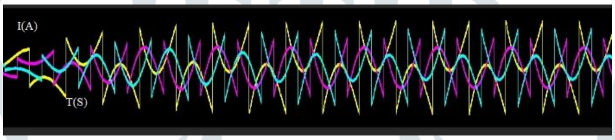
Fig 8.9 indicates the load current contains harmonics because of non linear load but we going to mitigate the harmonics by applying harmonic filter in the system. load current waveform is shown above.



We can observe in aboves figure that the 47.67% of THD present in the load current

6.3 Compensating current

Active harmonic filter detects and measures the harmonic frequencies generated by the drives and injects equal amounts of harmonic current in anti-phase to the



generated harmonics. These cancel out resulting in an acceptable level of harmonics. Compensating current waveform is shown in the waveform.

7. COMPARISON OF TOTAL HARMONIC DISTORTION

7.1. Comparison between with and without APF

Harmonics	Without filter Mag (% of fundamental)	With filter Mag (% of fundamental)
3rd order	32.91	0.54
5th order	19.92	0.04
7th order	14.1	0.15
9th order	11	0.06
11th order	9	0.04
13th order	7.92	0.06
15th order	6.52	0.05

From above observation it is observed that as harmonic order increases THD decreases and vice-versa.

8. COMPARISON OF THD AFTER CHANGE IN LOAD

Load	Without filter THD %		With filter THD %	
	IL (Load current)	IS (Source current)	IL (Load current)	IS (Source current)
Diode	47.67 %	47.67 %	47.67 %	2.74 %
IGBT	47.89 %	47.89 %	47.89 %	2.79 %
Mosfet	47.89 %	47.89 %	47.89 %	2.79 %

From above observation it is observed that change in load i.e.Diode,IGBT and MOSFET gives small changes in THD

9.FUTURE SCOPE

1.More number of non-linear loads can be taken as aload to generate harmonics and the suggested scheme be tested for mitigation of the harmonics, which can be the future scope

2. Other Artificial technique can be used for the generation of harmonics in realtime for mitigating the harmonics present in the load

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