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Design and Implementation of Shunt Active Filter for Harmonics Reduction in Distribution Grid

Mr. Harshal Yashwant Thakur[1]
(Student at SRK University Bhopal)

Mr.Vivek Kumar Yadav[2]
(Professor at SRK University Bhopal)

Abstract— This paper explores the modeling of a Simulation primarily based, shunt active power filter (SAPF) for a distribution network to scale back current harmonics fed to a nonlinear load. Nonlinear load draw non sinusoidal current and voltage from the utility. These non-sinusoidal current and voltages created thanks to nonlinear load are known as harmonics. The harmonic voltage and current have a nasty impact on the system and creates larger power quality downside. Thus, to mitigate harmonic issues totally different techniques are used. During this work as introduction totally different power quality issues, harmonics and their reduction techniques or filters are bestowed. Between the various ways that to eliminate harmonics active power filters are most distinguished one. This paper works represent active shunt filter exploitation MATLAB simulation.

I. INTRODUCTION

In recent years, the developments of power physical science parts have nice advantage in energy conversion and utilization. Because of increase in use of power physical science device like variable frequency drive, switch mode power offer, thyristors, arc furnaces, fluorescent lamps, rectifiers etc. used to extend potency of grid however these are main supply of harmonic. This load attracts non- curved currents attributable to high switch potency. Therefore, generation of harmonics that causes power quality disturbances has become a big drawback for the distributors and shoppers of electrical power moreover. Power physical science instrumentation attracts distorted current from the system. Because the current distortion is conducted through line, it creates voltage distortion in numerous components of the ability system. As a result of these non-linear load the availability system result in warming of cables and conductors, magnetic attraction interference to near communication facilities etc. By considering the results of harmonics in numerous equipment's in grid, it's necessary to eliminate these harmonics. To eradicate such problems and enhance the standard of power offer, active power filters (APFs) are planned. Historically, passive filter and electrical condenser bank are wont to filter the harmonics and compensate the reactive current parts because of non-linear load. They're straightforward management however terribly complicated below resonant conditions. The traditional filters have some disadvantages like the fastened compensation, massive size and resonance. To beat these issues active filters are introduced. To boot its activity the reactive-power management to attain power-factor improvement and voltage regulation, reducing the voltage-flicker. The shunt active filter has varied management algorithms, topologies, and reference generation techniques. The instant PQ theory had attracted the eye of researchers because of their straightforward principle and high potency.

II. Model of Shunt Active Power Filter

The Shunt Active Power Filter (SAPF) wont to eliminate the harmonic currents. The essential building diagram for the compensation techniques during a SAPF is illustrated in Fig 1. The SAPF is controlled for generating compensating currents Ic specified it not solely cancels this harmonics that square measure predominant within the AC mains, however conjointly adjusts the availability current to be in-phase and sinusoidal in nature.

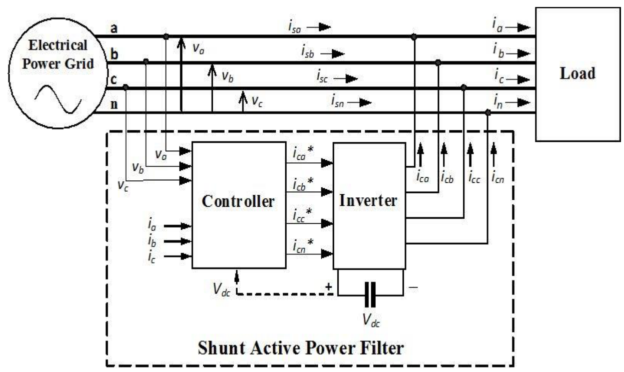

Fig.no.1. Grid system with shunt active filter

APF is functioning within the method by generating the compensating current equal within the magnitude and opposite to the harmonic made within the system. The Active Power Filter (APF) consists of DC bus electrical condenser with Voltage supply electrical converter with the dominant device and inductors. Acting because the current supply device and compensating the harmonic current at completely different nonlinear load conditions. P-Q theory is to derive the compensating signal. The important and reactive power p and Q provides the compensating current for the nonlinear load. The VSI switches management the shape forms of current this. IGBT device is employed for the electrical converter circuit because it is with high change frequency. Triggering the electrical converter circuit rely upon the feedback loop system output. The active power filtering is to compensating the harmonic currents that is occurred as a result of non-linear masses and check that for manufacturing the curved style of supply currents and voltages.

III. Methods of Harmonic Current Extraction

Based on the compensating commands by frequency and time domain techniques the management strategies area unit used for harmonic reduction. Within the active filtering the harmonic current extraction is to be injected into the harmonic manufacturing load. The most effective extraction of harmonics will be achieved by the economic power filtering. The Fast Fourier rework (FFT) within the frequency domain is employed to extract the present harmonics. Among management strategies in time domain, instant power (p-q) theory is one and bestowed during this work. The p-q theory calculations area unit applied within the shunt active power filter. From phase voltages (va, vb, vc), and cargo currents (ia, ib, ic) and DC voltage, the controller calculates the reference currents, The electrical converter circuit uses reference currents to supply the compensation currents.

$$\begin{bmatrix} I_{co} \\ I_{cb} \\ I_{cc} \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{c\alpha} \\ I_{c\beta} \\ I_{co} \end{bmatrix} \quad \text{..... (1)}$$

$$\begin{bmatrix} V_{co} \\ V_{cb} \\ V_{cc} \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_{c\alpha} \\ V_{c\beta} \\ V_{co} \end{bmatrix} \quad \text{...... (2)}$$

Above shows the compensating currents and voltages in three phases are calculated from the two phase reference currents and voltages using inverse Clarke transformation. In fig.2 IEEE Std 519 establishes harmonic limits on voltage as 5% for total harmonic distortion and 3% of the fundamental voltage for any single harmonic see in fig 2.

Table 10.2, p77
Low-Voltage System Classification and Distortion Limits

	Special Applications[1]	General System	Dedicated System[2]
Notch Depth	10%	20%	50%
THD (voltage)	**3%**	**5%**	10%
Notch Area (A_N)[3]	16 400	22 800	36 500

NOTE: The Value A_N for other than 480 V systems should be multiplied by V/480

1 **Special applications include hospitals and airports**
2 A dedicated system is exclusively dedicated to the converter load
3 In volt-microseconds at rated voltage and current

Fig.2. Table of voltage distortion limits in IEEE Std 519

To outline current distortion limits, IEEE Std. 519 uses a short circuit magnitude relation to ascertain a customer's size and potential influence on the voltage distortion of the system. The short circuit ratio (Isc/IL) is that the magnitude relation of contact current (Is) at the purpose of common coupling with the utility. To the customer's most load or demand current (IL). Lower ratios or higher resistivity systems have lower current distortion limits to stay voltage distortion at affordable levels. For power systems with voltage levels between 120V and 69000V the bounds is found shown in fig.3.

Table 10.3, p78
Current Distortion Limits for General Distribution Systems
(120 V Through 69,000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Where:
I_{SC} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at PCC.

Fig.3. Table of Current distortion limits in IEEE Std 519

The table defines Total Demand Distortion (current) limits moreover as individual harmonic current limits. The bounds square measure most severe for short circuit magnitude relations of but twenty as a result of this lower ratio indicates a high impedance facility or an outsized client or each. The relevance medical instrumentality sensitivity provides some indication on why the bounds square measure evens a lot of severe for special applications like hospitals and airports. For applications within the business the overall system limits square measure most applicable. This suggests that we tend to should style our systems for c 5% VWD and with no single harmonic larger than 3%.

IV. Problems and Data Analysis in Industry

The major concerns were the effect of harmonics mainly in the induction and synchronous machines. In earlier days, the harmonic problem in power system created by magnetic saturation of transformers, and because of industrial loads like arc furnace, arc welding machine. Additional methods for dealing with harmonics are necessary because of nonlinear loads grow exponentially in recent years in industrial, commercial and residential areas. Generally the power system equipment's and the system loads are sensitive to the harmonics. The main objective of this study is to reducing harmonic distortion, improving system capacity and reliability, energy efficiency using active harmonic filter. The industry chosen for the data collection is Power Line Engineering Work.

Above said industry receives 11KV power from substation feeder and after converting from 11/0.44 KV fed to welding shop and furnace shop. Harmonic analyzer measured all necessary data like single phase and three phase of voltage, current, active power, reactive power, apparent power, power factor. Here calculations are used to be performed as because the different components and the units are rated in different format. Below show the name plate data of transformer.

Table 1: Transformer name plate data.

Transformer rating	HV (KV)	LV (KV)	HV (A)	LV (A)	Z (%)
200	11	0.44	10.5	278.2	5.21

We know that,
Short circuit current (Isc) is,

$$Isc = \frac{Full\ load\ current\ of\ transformer}{Impedence\ of\ transformer} \quad \ldots\ldots\ldots\ldots (3)$$

From above table rated load current at secondary side is 278.2 Amp. And impedance is 4.21%. From equation number 2 we get,

$$Isc = \frac{278.2}{0.0521} = 5339.73Amp. \quad \ldots\ldots\ldots\ldots\ldots (4)$$

$$\frac{I_{sc}}{I_{load}} = \frac{5339.73}{278.2} = 19.19 \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Table 2: Comparison of measured value with standard value

Distortion limit as per IEEE		Calculation and measurement		Remark
$\frac{I_{sc}}{I_{load}}$	%THD	$\frac{I_{sc}}{I_{load}}$	%THD	
< 20	5.0	19.19	16.8	Mitigation requires.

V. Simulation results and analysis

The system studied has been sculptural victimization Simulink as shown in Fig.4 here Mat-lab simulation responses for the planned system with shunt active filter. From this assessment the harmonic disturbance is known that it's an enormous power downside and causes conductor heating, reduces life time of capacitors false or spurious operations and journeys of fuses AND gate breakers, will increase iron and copper losses or eddy currents in electrical device. So to unravel this downside shunt active filter is intended and simulation has been done.

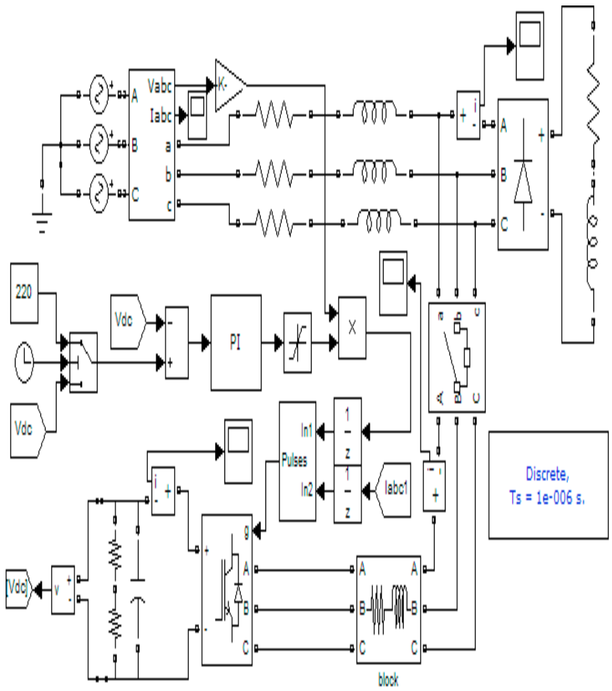

Fig.4 Shunt active power filter

The voltage is considered as a curved and balanced in the Matlab simulation. The load current THD is found to be 29.45% when a switching power electronic load is considered. The system parameter use in simulink is shown in below table.

Table 3: Parameters used in MATLAB Simulink.

Parameters	**Values**
Supply Frequency	50 Hz
Supply Voltage	240V
DC link capacitance	1500μf
DC link Voltage	210V
Snubber resistance	450 Ώ
Load impedance	50 Ώ
Snubber Capacitance	50 μf
Load	Rectifier
Source inductor	0.20 mH
Hysteresis Band	±0.25A

Below shows the supply current of 1 phase while not compensator in fig.5. supported this before shunt active filter connected to the system the simulation showed that THD of current is 17.18% and this is often a lot of bigger than five-hitter the allowable commonplace by IEEE. This affects the facility system and therefore the machines within the business therefore should be slaked.

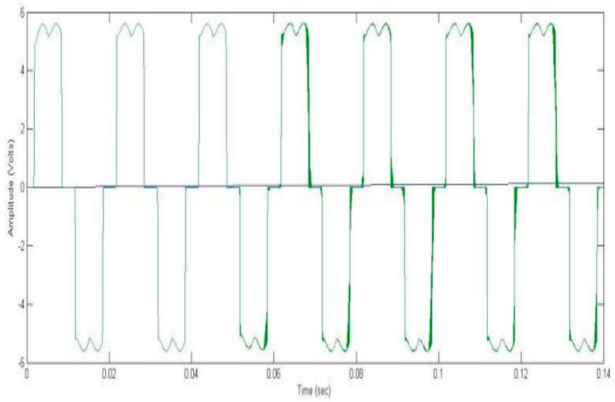

Fig.5.current without compensator

. Based on this shunt active filter is designed and connected to the modeled system. It shows very good result in MATLAB simulation which shown in fig.6 that is current with controlled shunt active power filter.

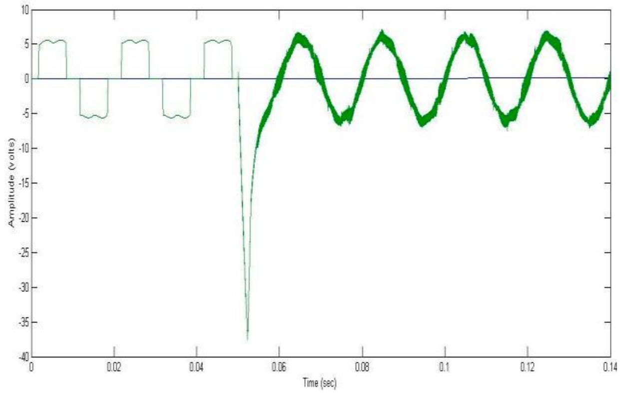

Fig.6 current with Controlled Shunt Active Power Filter.

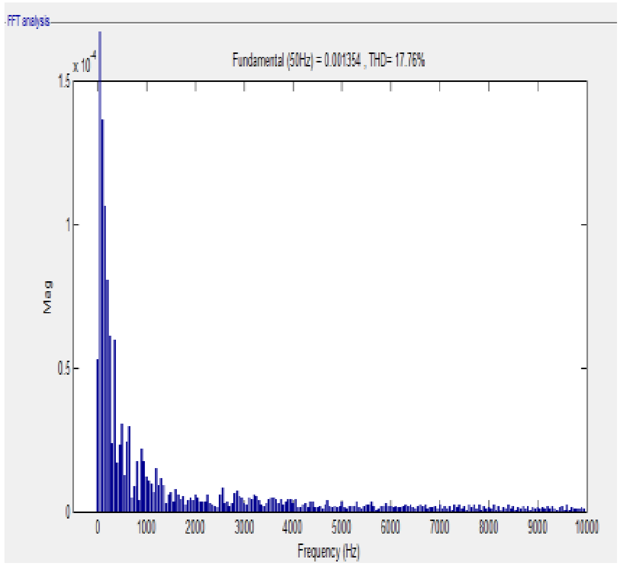

Fig.7 THD before compensating harmonics

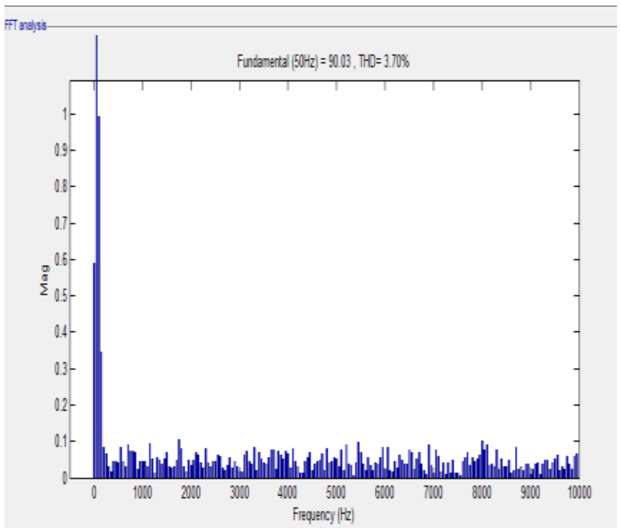

Fig.7 THD after compensating harmonics

The THD of current are reduced from 17.76% to 3.7% that is below the allowable five-hitter declared by

IEEE. The Fig.7 and Fig.8 shows the entire Harmonic Distortion results before the association of filter circuit and once the association of Filter circuit.

VI. Conclusion

This paper bestowed Associate in nursing applicable reference management technique for a 3 phase distribution network connected to switch masses to reinforce the ability quality. The projected system harmonic elimination mistreatment shunt active filter simulated mistreatment MATLAB simulation. The results prove that the projected system enforced within the distribution system eliminates the harmonics effectively. Shunt Active Power Filter matlab-simulink model has been simulated for SAPF so as to eliminate the harmonic components thanks to nonlinear load. The THD Associate in Nursingalysis for the present while not the active filter is manufacturing an output of 17.17%. The enforced controller makes the THD worth for the present to 3.7%. The harmonics elimination share is around 5%. The projected system achieves the goal.

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