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A Literature Review and Industrial Survey on Active Power Filter

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***Abstract*— In recent years research in active filter is increased .this paper gives a literature review on active filter. Types of active power and reference current generation technique are classified in time domain and frequency domain method. Then gating pulse generation techniques are described as a linear control technique and hysteresis control technique.**

Keywords—harmonics; active filter; passive filter, PWM control;hyaterisis control.

I. INTRODUCTION

Power quality problem in distribution system is major concern due to increasing use of nonlinear load like adjustable speed drive (ASD), furnaces, computer, fluorescent light, battery chargers etc. this nonlinear loads are sources of harmonic distortion in voltage or current. Due to this distorted voltage a power quality issue like sag ,swell, harmonics, flicker is occur in the power. To mitigate this harmonic content from the ac power supply voltage a traditional passive filter is used but there are some limitation and drawbacks of passive filter. So to overcome this limitation and draw backs of passive filter a power electronics switch based active filter is used with suitable algorithm. An active filter is also known as active power line conditioner, instantaneous reactive power compensator, active power filters

II. COMPARISON OF PASSIVE FILTER AND ACTIVE FILTER

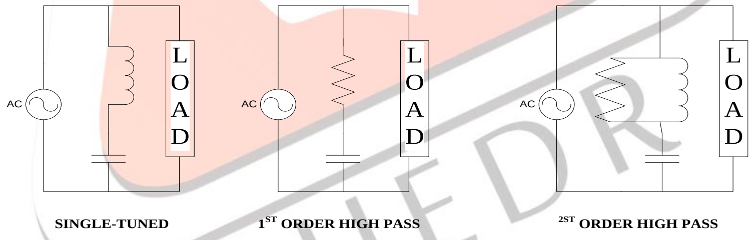

Fig1.common type of passive filter

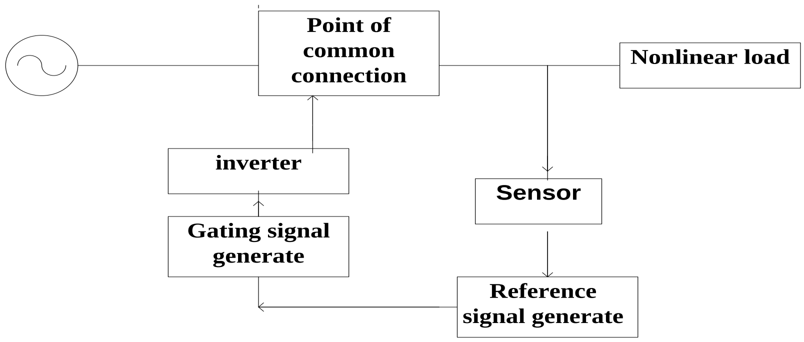

Fig2.general block diagram of active filter

The harmonic filter connected to ac power system must have two objectives:
1) To reduce harmonic current and voltage from the distorted voltage or current a 5% as per IEEE 519 standard.
2) To compensate reactive power absorbed by the converter system.

Table I : Comparison between passive and active filter [4]

Type of influence	Passive filter	Active filter
Influence of an increase in current	Risk of overload and damage	No risk of overload
Added equipment	In certain cases requires modification to the filter	No problem if harmonic current greater than load current
Harmonic control by filter order	Very difficult	Possible via parameters
Harmonic current control	Require filter for each frequency	Simultaneous monitor many frequencies
Influence of a frequency variation	Reduced effectiveness	No effect
Influence of a modification in the impedance	Risk of resonance	No effect
Modification in the fundamental frequency	Cannot be modified	possible via reconfiguration
weight	high	Low

From above table it is shown that active filter has a more advantage compared to conventional passive filter so active filter is better for the mitigation of the harmonics from the distorted waveform.

III. TYPES OF ACTIVE FILTER

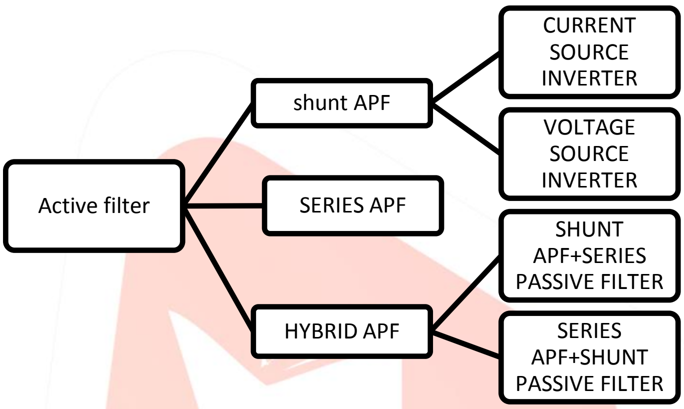

Fig3.types of active filter

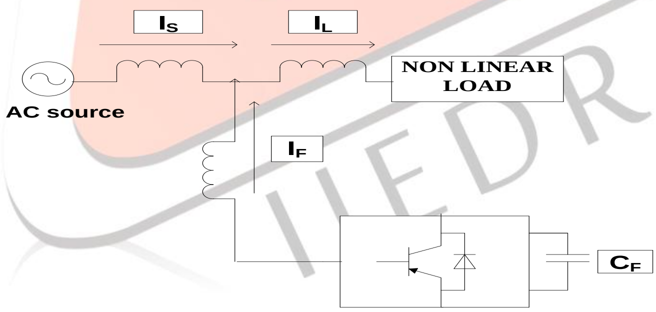

Fig4.shunt active filter

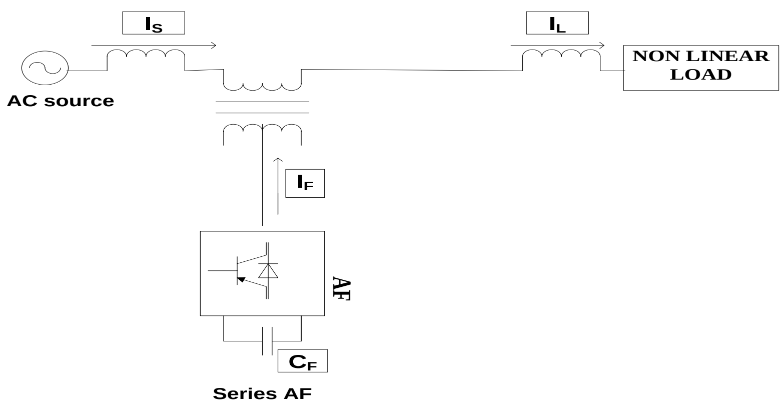

Fig5. Series active filter

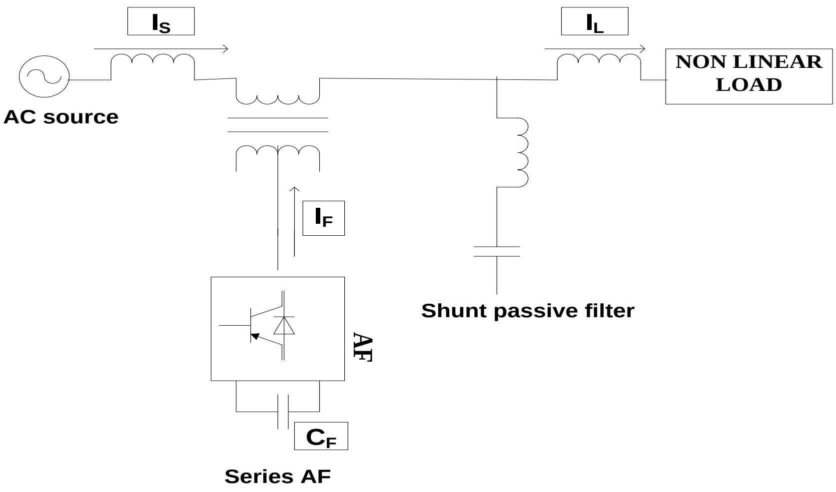

Fig6.hybrid active filter arrangement of series AF and shunt Passive filter

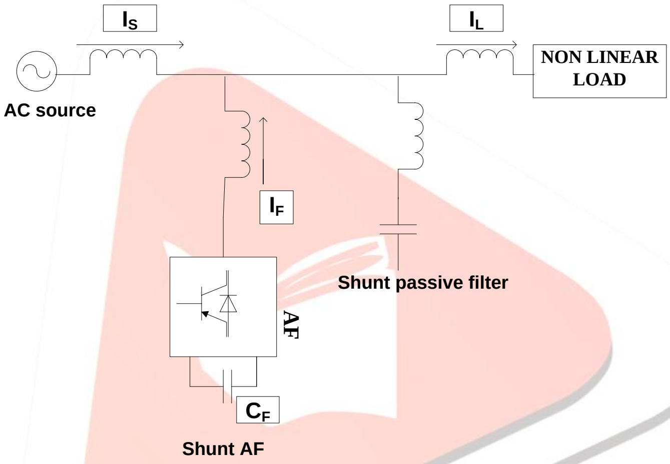

Fig7.hybrid active filter arrangement of shunt AF and shunt Passive filter.

An active filter is generally classified in a main three type shunt, series and, hybrid active filter. In shunt active filter A filter is connected in shunt with the supply system and mostly it is connected in load side. A series active filter is connected in series with the supply system using a current transformer it is mostly used to mitigate source side generated harmonic. Hybrid active filter use a component of active filter and passive filter is mostly used for a particular where it is required.fig 3 shows the briefly classification of the types of Active filter.

Fig 4 shows the topology of the shunt active filter in which active filter is connected in a shunt with the supply voltage shunt active filter is used a controllable voltage or current source. It is used a PWM switching technique and mostly voltage source inverter based active filter is used.

Fig5 shows the topology of the series active filter. It is connected in series with the supply system using an identical transformer to mitigate harmonics from the voltage. It is installed by electric utility to mitigate harmonics from the voltage and to overcome resonance problem occur in the line. Voltage source inverter is used as a control source.

Above figures 5 and 6 shows the configuration of the hybrid active filter in which active filter and passive filter is used to develop hybrid active filter fig 5. Show the configuration of hybrid active filter using series active filter and shunt passive filter.fig6. Show the configuration of hybrid active filter using shunt active filter and passive filter. The task of eliminating harmonics is divided in two filters. An active filter mitigates the lower order harmonics and passive filters eliminate the higher order harmonics. [2]

Table II. Active filter for specific application [2]

Compensation for specific application	Active filters			
	Active series	Active shunt	Hybrid of active series and passive shunt	Hybrid of active shunt and active series
A. current harmonics		**	***	*
B. reactive power		***	**	*
C. load balancing		*		
D. neutral current		**	*	
E.voltage harmonics	***		**	*
F.voltage regulation	***	*	**	*
G.voltage balancing	***		**	*
H.Voltage flicker	**	***		*
I.voltage sag dips	***	*	**	*
J.(A+B)		***	**	*
K.(A+B+C)		**		*
L.(A+B+C+D)		*		*
M.(E+F)	**			*
N.(E+F+H+I)	**			*
O.(A+E)			**	*
P.(A+B+E+F)			*	**
Q.(F+G)	**		*	
R.(B+C)		*		
S.(B+C+D)		*		
T.(A+B+G)		**	*	
U.(A+C)		*		
V.(A+D+G)		*	**	

NOTE: AF configuration with high number of * is more ideal.

IV. TECHNIQUES TO GENERATE REFERENCE SIGNAL FOR ACTIVE POWER FILTER

Extraction of reference signal is an important part of the active filter there are several methods in time domain and frequency domain to extract a reference compensating current or voltage from the distorted waveform. The reference signal is generated through the detection of necessary system voltage or current information. Typical current variable are AC source current, load current, compensating current, DC link current of the active filter and voltage variables to be sensed are DC bus voltage of the APF, and voltage across interfacing transformer.

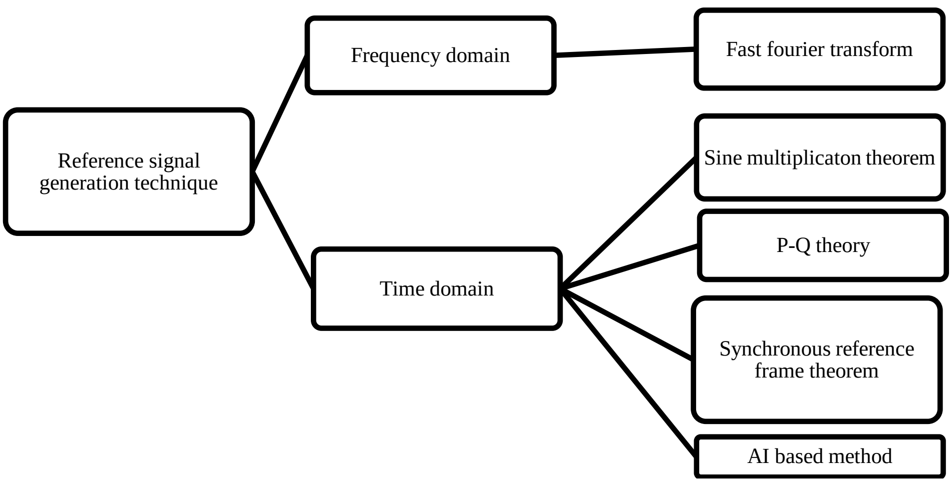

Fig8 types of reference signal generation method

A. Frequency domain method

Reference signal generation in the frequency-domain is suitable for both single phase and three phase systems. They mainly derived from principle of Fourier analysis.

1) FAST FOURIER TRANSFORM TECHNIQUE

In this method amplitude and the phase angle of the distorted waveform is calculated using a Fourier analysis. The harmonic component of the current and voltage is sensed then fundamental component of the waveform is extracted from this wave form. Inverse Fourier transform is then apply to estimate the compensating signal. This technique is suitable for slow varying loads because it requires a time delay to calculate system variable and to convert then Fourier co-efficient modified FFT is given in the[10,12]

An amplitude and phase angle is calculated using equation [10]

$$\bar{x}_h = \sum_{n=0}^{N-1} x(n).\cos\left(\frac{2\pi hn}{N}\right) - j\sum_{n=0}^{N-1} x(n).\sin\left(\frac{2\pi hn}{N}\right)$$

$$\bar{x}_h = x_{hr} + j.x_{hi};$$

$$|\bar{x}_h| = \sqrt{x_{hr}^2 + x_{hi}^2}; \qquad \varphi_h = arctan\left(\frac{x_{hi}}{x_{hr}}\right)$$

Where; N=no. of samples per fundamental period

X (n) = input signal at point n

X_h = complex Fourier vector of h^{th} harmonic of the input signal.

X_{hr} = real part of X_h.

X_{hi} = imaginary part of X_h.

$|\bar{x}_h|$ = amplitude of the vector.

φ_h = phase of the vector.

B.Time domain method

In time domain method an instantaneous estimation of reference signal is adopted either in the form of voltage or current signal from distorted voltage or current waveform .this method is applicable for both single phase and three phase system.

1) INSTANTANEOUS REACTIVE POWER THEORY

In single phase p-q theory, voltage and current waveform articulated in terms of their real and imaginary axis components, which could be corresponding to ∝β variable in IRPT. Using a high pass filter a fundamental component is extracted on real and imaginary parts of the complex power. This method is applied to single-phase application by creating two virtual voltages that have the same magnitude as measured voltage and current and displayed by 120^0 phase shift. [10]

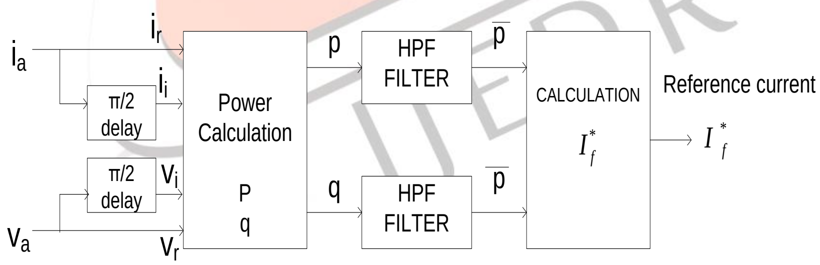

Fig.9 block diagram of single phase instantaneous reactive power theory

2) SINE MULTIPLICATION THEOREM.

Here indirect current control technique is considered. The current reference extracting method is based on the determination of the amplitude of the fundamental active current i_{Lf}, which is done with the help of the classic demodulation technique. The current of the non-linear load I_L is expressed by:

$$i_l(\theta_s) = \sum_{h=1}^{\infty} i_{lh}\sin(h\theta_s - \phi_h) = i_{l1}\sin(\theta_s - \phi_1) + \sum_{h=2}^{\infty} i_{lh}\sin(h\theta_s - \phi_h)$$

The fundamental component i_{Lf} and the harmonic components i_{Lh} of the load current I_L are given by:

$$i_{LF} = I_{L1}\sin(\theta_s - \phi_1) \text{ (Fundamental component)}$$

$$i_{Lh} = \sum_{h=2}^{\infty} i_{Lh}\sin(h\theta_s - \phi_1) \text{ (Harmonic component)}$$

Where,

$\O_1$ =Phase angle of fundamental current

I_{L1} =Magnitude of fundamental component
$Ø_h$ = angle of the h^{th} harmonic load current
I_{Lh} = magnitude of the h^{th} harmonic load current
θs = ωt(ω Is angular frequency of network)

Now fundamental current is divided into two currents:
The Fundamental Active Current:

$$I_{Lfa} = I_{L1}\cos\phi_1 \sin\theta_s$$

The fundamental reactive current:

$$I_{Lfr} = I_{L1}\sin\phi_1 \cos\theta_s$$

Therefore the reference current for the active filter i_s^* is given by:

$$i_s^* = i_{Lfa} = i_L - (I_{Lh} + i_{Lfr})$$

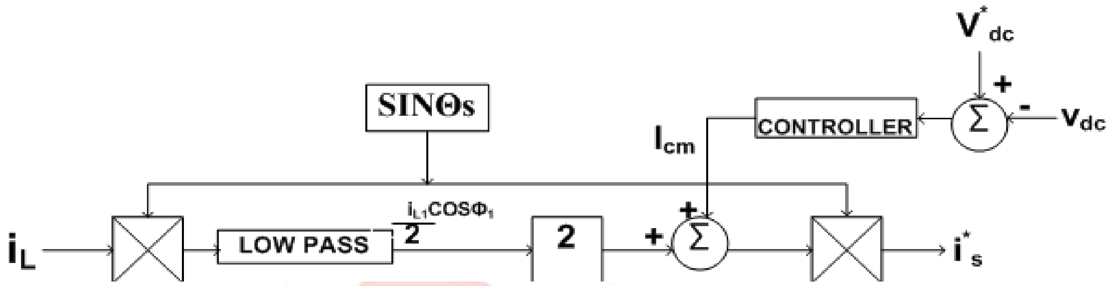

Fig.12 indirect current control algorithm of SPSAPF algorithm

A low pass filter, with a relatively low cut-off frequency is used to prevent the high frequency component entering the output. The error between v_{dc}^* and the sensed feedback value V_{DC} is processed towards a PI controller giving I_{cm} signal. This current is added to $2i_{Lf}$, leading the peak value of the reference current. In order to reconstitute the fundamental active reference current, peak value is multiplied by $\sin\theta_s$. The block diagram of the proposed control algorithm of the active filter with indirect current control is shown in fig.12. [5]

3) SYNCHRONOUS REFERENCE FRAME METHOD

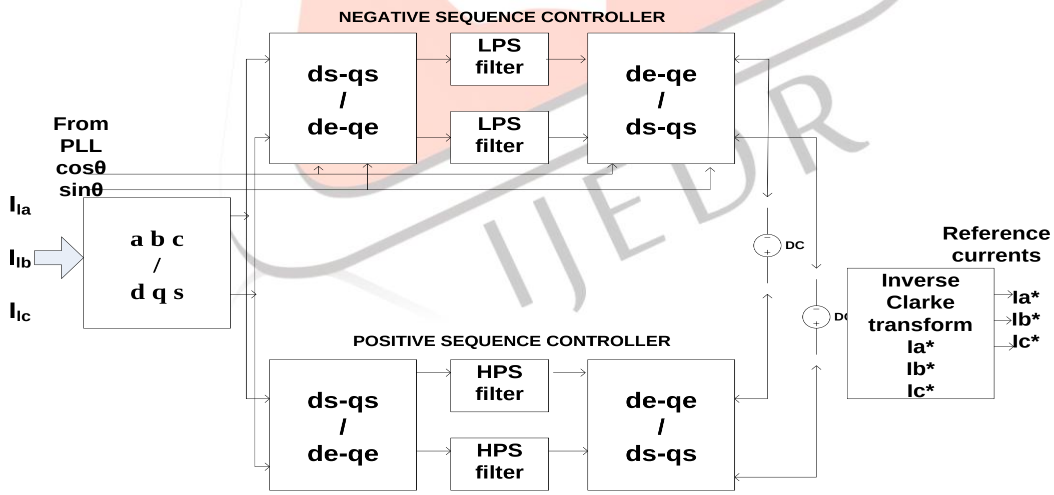

Fig.13 block diagram of synchronous reference frame method

Synchronous reference frame method is based on park transformation is shown in fig.15.there are mainly two blocks positive and negative sequence controller these theorem is applicable for three phase system. The positive sequence component of load current is transformed to de-qe axis by generating positive sequence phase information from PLL circuit.AC quantities in positive sequence waveform include all harmonic components while DC quantity is fundamental component of load current .the negative sequence component of the load current is transformed to de-qe axis by generating negative phase sequence using PLL.if voltage and currents in the three-phase system are balanced, the output of this block will be zero. As long as it is not the aim to compensate current imbalance in the load current , the negative sequence current components are subtracted from the reference current waveform and the active filter only compensate the load current harmonics[10].

IV. GATING SIGNAL GENERATION METHOD

Basically, the aim of the active power filter is to generate suitable gating pulse for the switching transistor founded on the estimated compensation reference signal. The control of active filter is affected by the control technique .therefore the choice of suitable control technique is very important to achieve satisfactory performance of the APF. A variety of control technique like linear control technique, digital dead beat control, hysteresis control etc. are applied to active power filter.

A. Linear control technique

Fig.14 shows the block diagram of linear control technique in which negative feedback of the system is taken and compared with reference signal through compensated error amplifier to produce the control signal. Then this control signal is compared with the triangular waveform using (PWM) controller to generate the suitable gating pulse for switches. [18]

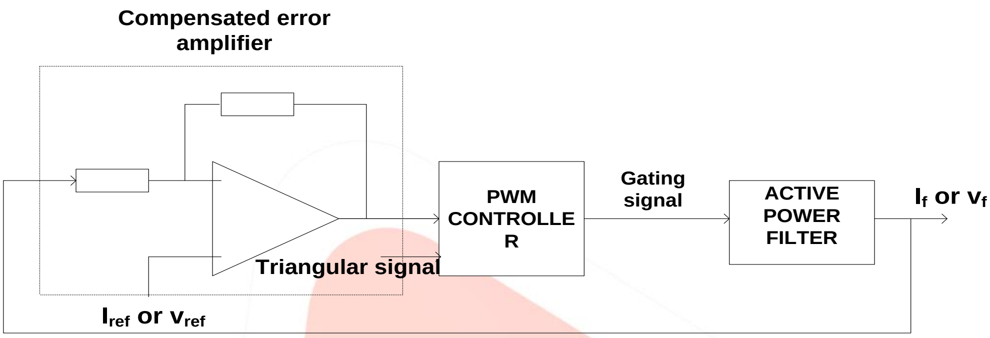

Fig14. Block diagram of the linear control technique

B. Hysteresis control technique

In the hysteresis control method a bang-bang type instantaneous control that forces the APF compensating current (i_f) or voltage (VF) signal to follow its estimated reference signal within a certain tolerance band. This control technique is shown in fig.15.in this method a signal deviation (H) is designed and imposed on i_{ref} or v_{ref} to form the upper and lower limit of hysteresis band. [18]

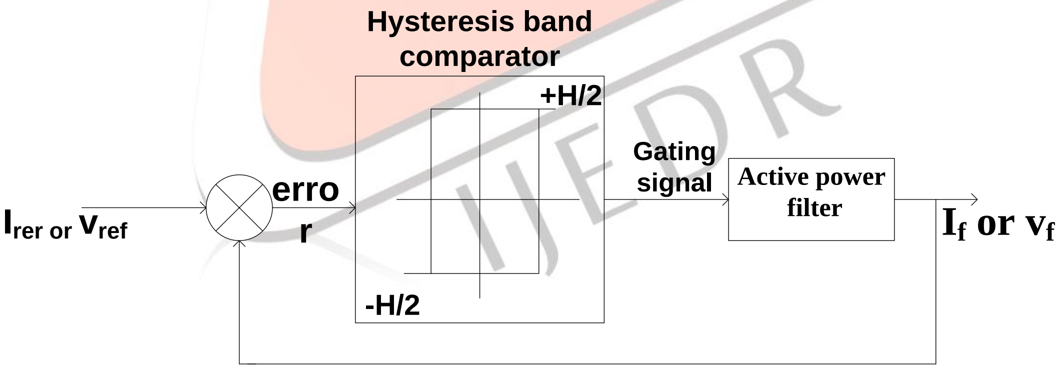

Fig.15 block diagram of hysteresis control technique

V .COMPANY SURVEY ON THREE PHASE ACTIVE POWER FILTER

	ABB	SIEMENS	TOSHIBA	ENERDOOR	COMSYS
MODEL	PQFI PQFM PQFS	SIVACON S8	TOSHIBA	HRMA100 HRMA200 HRMA300	ADFP100
RATED CAPACITY	------	------	50-1000 kva	70-287 kva	49-109 kva
VOLTAGE RATING	208-415V	400V	200-6.6KV	208-690V	208-480V
CURRENT RATING	30-450V	100A	------	80-240A	70-230A

FREQUENCY	50/60Hz +/- 5%	50/60Hz +/- 5%	50/60Hz +/- 2%	50/60Hz +/- 2%	50/60Hz +/- 2%
HARMONIC MITIGATION RANGE	2^{nd} to 50^{th} order	2^{nd} to 50^{th} order	2^{nd} to 25^{th} order	Up to 49^{th} order	Up to 49^{th} order
RESPONSE TIME	2 Cycle	------	Below 1msec	Below 1msec	Below 1msec

V. CONCLUSION:

This paper give an briefly information about active power filter technology. A discussion about harmonic distortion problem and their impact on power quality problem is given. A comparison between active and passive filter is given and then topology of active filters, active filter for specific application is shown in this paper. Reference current generation technique, and control technique is also Described .and finally industrial survey on manufacturer of three phase active power filter is shown in detail.

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