*Journal of Electronicsl and Communication Engineering (IOSR-JECE)*
*ISSN: 2278-2834-, ISBN: 2278-8735, PP: 44-54*
*www.iosrjournals.org*

# Mitigation of harmonics using shunt active filter

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***Abstract***— *Power Quality issues are becoming a major concern of today's power system engineers. Harmonics play significant role in deteriorating power quality, called harmonic distortion. Harmonic distortion in electric distribution system is increasingly growing due to the widespread use of nonlinear loads. Large considerations of these loads have the potential to raise harmonic voltage and currents in an electrical distribution system to unacceptable high levels that can adversely affect the system. IEEE standards have defined limits for harmonic voltages and harmonic currents. Active power filters have been considered a potential candidate to bring these harmonic distortions within the IEEE limit. A voltage source inverter with pulse width modulation (PWM) is employed to form the APF. A diode rectifier feeding capacitive-resistive load is considered as nonlinear load on ac mains for the elimination of harmonics by the proposed APF. MATLAB model of the scheme is simulated and obtained results are studied.[1]*

## I. INTRODUCTION

The term ''power quality'' means different things to different people. To utility suppliers, power quality initially referred to the quality of the service delivered as ''measured'' by the consumer's ability to use the energy delivered in the desired manner. This conceptual definition included such conventional utility planning topics as voltage and frequency regulation and reliability. The end-user's definition of power quality also centers around their ability to use the delivered energy in the desired manner, but the topics considered can be much more specific and include magnitude and duration of different events as well as wave shape concerns. Fortunately, a good working definition of power quality has not been a point of contention, and most parties involved consider ''quality power'' to be that which allows the user to meet their end use goals. The working definition is not complicated by particular issues; engineers are well aware that topics from many aspects of power engineering may be important.[1]

Power quality can be roughly broken into categories as follows:

1. steady-state voltage magnitude and frequency,
2. Voltage sags,
3. Grounding,
4. Harmonics,
5. Voltage fluctuations and flicker,
6. Transients, and
7. Monitoring and measurement

## II. POWER QUALITY AND HARMONIC

### 2.1 Power Quality

Can be defined as: "Any power problem manifested in voltage, current or frequency deviations that result in failure or improper operation of customer equipment".

The ideal power distribution system delivers, 100% continuous, real power at a constant voltage described by the following equation:

$$p(t) = v(t) * i(t) = VIsin^2(\omega t)$$

Where $v(t) = V \sin(o\, t)$; $i(t) = I \sin(\boldsymbol{\omega} t)$

In the real world this will never happen. Why? Factors which influence Power quality:

-Outages
-Voltage drop
-Power factor
-Transients (lightning and switching surges)
-Non-linear steady-state load conditions (harmonics).

Power system engineers have been dealing with outages, voltage drop, power factor, and Transient conditions since the invention of the first AC distribution system back in the early 1900's. Adverse power system harmonics caused by the installation of non-linear devices loads on the distribution system has become an increasing concern to utilities in the 1970's and 1980's.

### 2.2 Harmonics

Any steady-state periodic time domain waveform can be expressed by an infinite summation of sinusoidal waveforms at integer multiples of a fundamental frequency.

$$\boldsymbol{f(t)} = \frac{a0}{2} + \sum_{a=0}^{\infty} an\ \cos\left(n\pi\,\frac{t}{L}\right) + bn\ \sin\left(n\pi\,\frac{t}{L}\right)$$

$$\boldsymbol{an} = \frac{1}{L}\int_{-L}^{L} f(t)\cos\left(n\pi\,\frac{t}{L}\right)dt$$

$$\boldsymbol{bn} = \frac{1}{L}\int_{-L}^{L} f(t)\sin\left(n\pi\,\frac{t}{L}\right)dt$$

Where,
f ( t ) = Time Domain Function
L = Length of one Cycle in Seconds.
n = Harmonic Index
INDIAN fundamental frequency is 50 Hz
3rd Harmonic is 3 x 50Hz or 150Hz
5th Harmonic is 5 x 50Hz or 250Hz, etc

### 2.3 Each harmonic whether current or voltage is characterized by its

1. Order
2. Magnitude- expressed as % of magnitude at fundamental frequency
3. Phase angle
4. Sequence

### 2.4 Common sources of power system harmonics

- Transformer saturation
- Transformer inrush
- Transformer neutral connections
- MMF distributions in AC rotating machines
- Electric arc furnaces
- Computer switch mode power supplies
- Battery chargers
- Imperfect AC sources
- Static VAR compensators
- Variable frequency motor drives (VFD)
- DC converter[2]

## III.Harmonic measurement and reduction

### 3.1Harmonics to be measured and eliminated

The most frequently encountered harmonics in three-phase distribution networks are the odd orders. Harmonic amplitudes normally decrease as the frequency increases. Above order 50, harmonics are negligible and measurements are no longer meaningful. Sufficiently accurate measurements are obtained by measuring harmonics up to order 30.

Utilities monitor harmonic orders 3, 5, 7, 11 and 13. Generally speaking, harmonic conditioning of the lowest orders (up to 13) is sufficient. More comprehensive conditioning takes into account harmonic orders up to 25

### 3.2 Total Harmonic Distortion:-

Harmonics in the electric power system combine with the fundamental frequency to create distortion. The level of distortion is directly related to the frequencies and amplitudes of the harmonic current. The contribution of all harmonic frequency currents to the fundamental current is known as “Total Harmonic Distortion” or THD. This THD value is expressed as a percentage of the fundamental current. THD values of over 10% are reason for concern. THD is calculated as the square root of the sum of the squares of all the harmonics divided by the fundamental Composite Waveform signal (50 or 60Hz). This calculation arrives at the value of distortion as a percentage of the fundamental. Mathematically, %THD is the ratio of the sum of the root-mean-square (RMS) of the harmonic content to the root-mean square (RMS) value of the fundamental 50 or 60Hz signal, and expressed as a percentage.

$$\%THD = \sqrt{\frac{Sumofsquareofamplitudeof allHarmonics}{Squareofamplitudeof fundamental}} \times 100$$

$$\%THD(voltage) = \sqrt{\frac{V_2^2 + V_3^2 + V_4^2 + V_5^2 + \cdots + V_n^2}{V_1^2}} \times 100$$

$$\%THD(current) = \sqrt{\frac{I_2^2 + I_3^2\ + I_4^2 + I_5^2 + \cdots\quad + I_n^2}{I_1^2}} \times 100$$

Another useful parameter is the Distortion Factor, or %DF. Distortion Factor is the Total Harmonic Distortion referenced to the total RMS signal. The T H D is expressed as a percentage and may not be greater than the fundamental. The %DF never exceeds 100%. We provide this term because of the market need and the requirement of this value under the international standard IEC-555. Mathematically, it is the ratio of the sum of the root-mean-square (RMS) of the harmonic content to the root-mean square (RMS) value of the total signal, and expressed as a percentage

$$\%DF = \sqrt{\frac{Sum\ of\ square\ of\ amplitude\ of\ all\ Harmonics}{Square\ of\ total\ RMS}} \times 100$$

$$\%DF(voltage) = \sqrt{\frac{V_2^2 + V_3^2\ + V_4^2 + V_5^2 + \cdots\quad + V_n^2}{V_{rms}^2}} \times 100$$

$$\%DF(current) = \sqrt{\frac{I_2^2 + I_3^2\ + I_4^2 + I_5^2 + \cdots\quad + I_n^2}{I_{rms}^2}} \times 100$$

## IV.How harmonics can be reduced?

### 4.1 Harmonic reduction by filters

### 4.1.1 Passive LC Harmonic Filters

In diode or thyristor rectifier loads, a dc choke can be added for harmonic reduction. When the dc choke value is increased to a sufficient amount, the current eventually becomes square. One of the big drawbacks of dc choke is that it will cause dc bus voltage drop, so to degrade the ride-through capability. For PWM converter loads, an ac side second-order LC filter can effectively reduce the harmonics flowing into ac mains. In the design of the filter, we should consider the position of the resonant frequency to meet the harmonic attenuation, requirements, and introduce damping at the resonant frequency to avoid amplification of residual harmonics. The problem is further complicated by considerations related to power factor, voltage attenuation, and filter parameter variation. The most commonly used passive filter is shunt connected tuned filter or high-pass damped filter, which are shown in Fig

Fig:1 Circuit diagram of tuned or high-pass damped filter for harmonic mitigationFigure 5.8 Circuit diagram of tuned or high-pass damped filter for harmonic mitigation

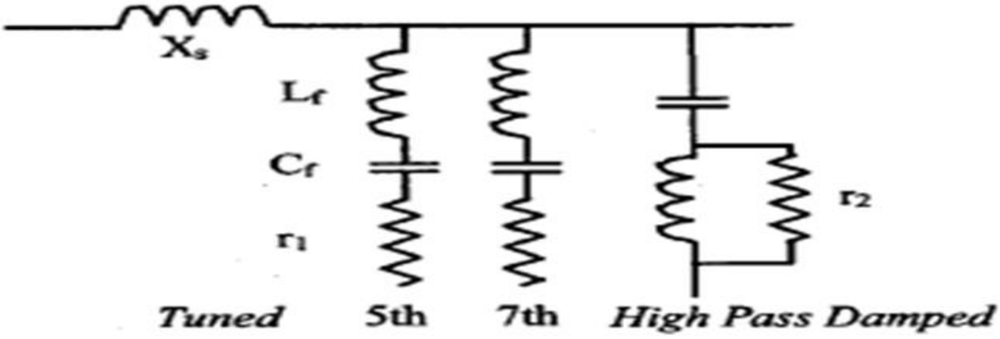


Fig:1Circuit diagram of tuned or high-pass damped filter for harmonic mitigation

### 4.1.2 Active filter

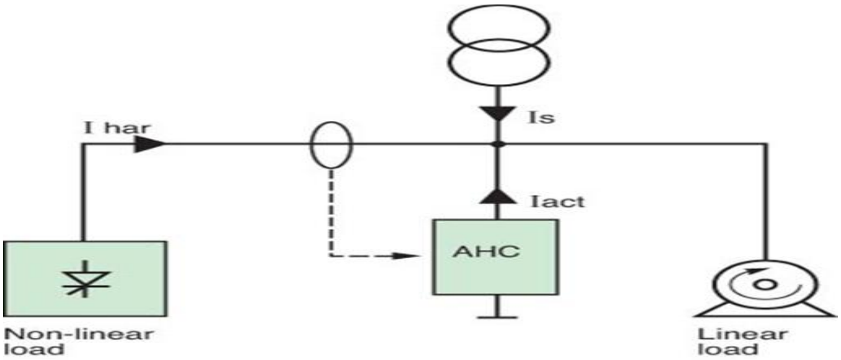


Fig:2 active Harmonic filters

An active harmonic filter is something like a boost regulator. The concept used in an active filter is the introduction of current components using power electronics to remove the harmonic distortions produced by the non-linear load. Active harmonic filters are mostly used for low-voltage networks.

There are three types of active harmonic filters based on the way they are connected to the AC distribution network.

i) The series filter is connected in series with the AC distribution network. It serves to offset harmonic distortions caused by the load as well as that present in the AC system.

ii) The parallel filter is connected in parallel with the AC distribution network. Parallel filters are also known as shunt filters and offset the harmonic distortions caused by the non-linear load.

iii) The hybrid filter is a combination of an active and a passive filter and could be of a series or a parallel configuration.

Function of single phase active power filter compensation principle, which is controlled in a closed loop manner to actively shape the source current into sinusoidal Single phase active filter concept uses power electronics to produce harmonic current components with 180° phase shift to the harmonic current components generated from non-linear loads. The shunt connected single phase active power filter is based on the principle of injection of harmonic currents into the ac system of the same amplitude but opposite in phase to that of the load harmonic currents.

4.1.3Based on the components used to build the passive filter and active filter, there are the following types

A Band-pass filter is a common passive filter that is built using a capacitor connected in series with a resistor.

A High-pass filter has a resistor connected in parallel with a reactor. This helps in reducing the q value of the filter, which will in turn help reduce the higher frequencies.

A High-pass filter when used in combination with a band-pass filter will provide a solution for medium voltage and sub-transmission voltage networks, which have moderate harmonic distortions.

A C-type filter is used for complex loads, cyclo-converters and electric arc furnaces and is a special variation of the high pass filter. This filter will provide the load with reactive power and avoid forming parallel resonance circuits with the load.[1,8]

4.1.4Comparison between active and passive filter

| **Influences of parameters** | **LC** | **Active Filter** |
|---|---|---|
| Influences of increase in current | Risk of over load damage | No risk of over load damage |
| Added equipment | Requires modification to the filter | No problems if harmonic current is greater than load current |
| Harmonic control by filter order | Very difficult | Possible via parameters |
| Harmonic current control | Requires filter for each frequency | Simultaneously monitors many frequencies |
| Influence of frequency variation | Reduced effectiveness | No effect |
| Influence of modification in the impedance | Risk of resonance | No effect |
| Modification in fundamental frequency | Cannot be modified | Possible via reconfiguration |
| Dimensions | Large | Small |
| Weight | High | Low |

## V. Designing of shunt active power filter

5.11 Shunt active power filter topology

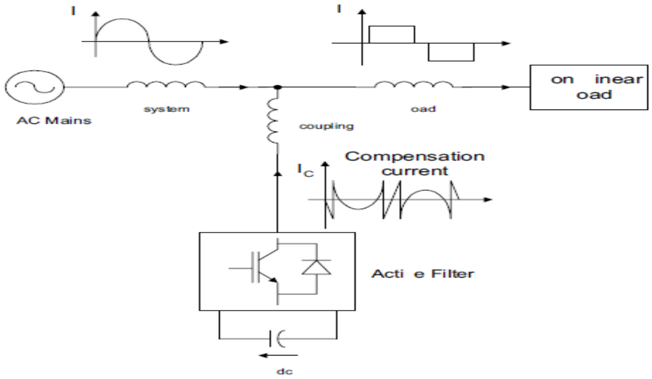


Fig:3Active filter topology

which is controlled in a closed loop manner to actively shape the source current into sinusoidal. Single phase active filter concept uses power electronics to produce harmonic current components with 180 degree phase shift to the harmonic current components generated from non-linear loads. The shunt connected single phase active power filter is based on the principle of injection of harmonic currents into the ac system of the same amplitude but opposite in phase to that of the load harmonic currents. The operation of the SPAPF, shown in Fig.3, is investigated for the general case. It is assumed that the supply feeds single phase non-linear load, connected between the line and neutral. Also the current drawn by the load is non-sinusoidal and have all odd harmonics.

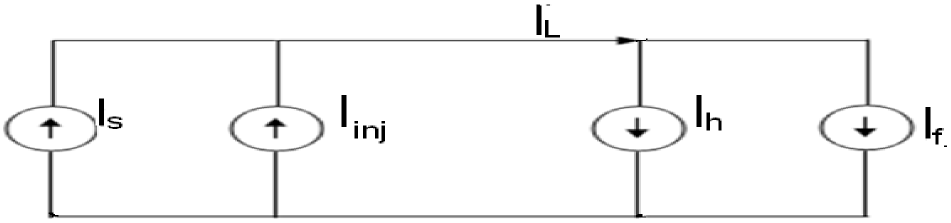


Fig:4 Basic Operating Principle of SAPF

The nonlinear load is modeled by two current sources Ih (harmonic current) and If (fundamental current). Current sources Is and Iinj are used to model the supply current and injection current of the shunt active filter, respectively.

Is+Iinj=Ih+If

To achieve the supply current Is to be the fundamental current If, from equation.

Iinj = Ih

To illustrate that in order to obtain a clean sinusoidal supply current Is the shunt active filter has to keep on injecting compensating harmonic currents to cancel the current harmonics present in the nonlinear load.

Is=If this equation shows that with SPAF the supply current harmonics can be compensated completely

5.2Basic block diagram of model

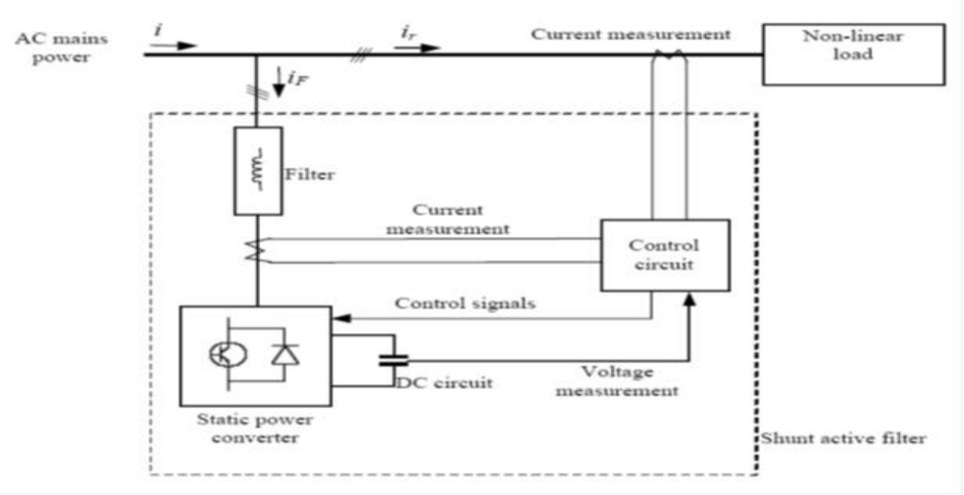


Fig:5 Block diagram of voltage fed inverter with SAPF

5.3Implemented Control Scheme

As shown in Fig. the sensed dc voltage of the APF is compared with its set reference value in the error detector. The voltage error is processed in the P-I voltage controller. Its output is limited to the maximum permitted value. This output of the voltage controller is taken as peak value of supply current

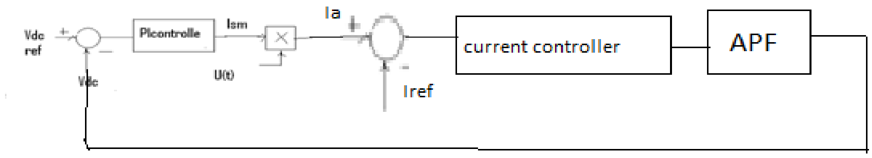


Fig:6 PI with APF

Operation of controller loop:-

Being connected to the PCC (Point of Common Coupling), during non-switching operation, APF charges dc capacitor via diodes to the maximum value of system voltage. Voltage of the dc capacitor experiences the second harmonic ripple of the ac mains fundamental frequency. Thus dc storage capacitor voltage is symmetric about half the period of the ac cycle under steady state operating condition. This voltage is averaged over the half cycle of ac mains for the use in P-I voltage controller. This P-I voltage controller will try to maintain constant dc capacitor voltage to a reference value. For that, it will draw the necessary power from ac source to meet the losses in the APF such as switching loss, capacitor leakage current, etc. in addition to the real power the load.

Under any disturbance in the load (either increase or decrease), the load will try to draw new increased or decreased value of current. This increased load current will be supplied immediately from the APF resulting in decreased energy storage on dc capacitor. It reduces the average voltage across dc capacitor. This reduction in dc capacitor voltage of the APF will activate the P-I controller and increases the supply current. This increased source current tries to restore the stored energy of the capacitor in addition to increased load active power. Supply current settles to new steady state value within few cycles. Vice-versa operation will be performed for load current decrease.

Since the corrective action of the P-I voltage controller is taken within the half cycle of the ac mains it results in fast response.

### 5.4Modeling of Single Phase APF and PI

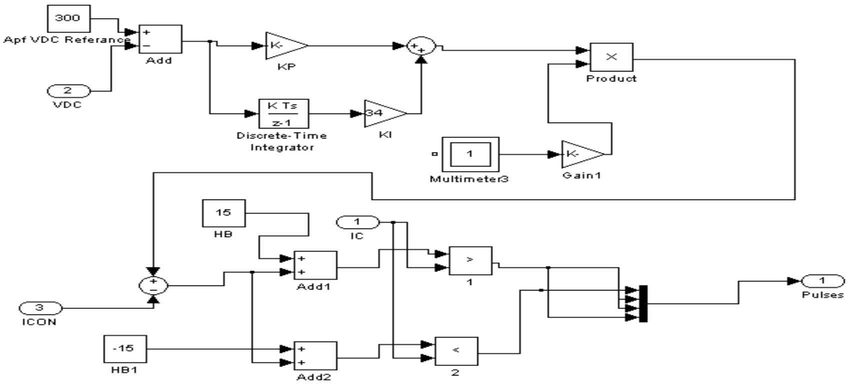


Fig:7Modeling of Single Phase APF and PI

Explanation:-

-Instantaneous dc bus voltage (Vdcc), supply voltage (Vin) and converter current (icon) are sensed to obtain the switching signals to control the switching devices of APF.

-The sensed dc bus voltage (Vdcc) is compared with the dc reference voltage (Vdcref). The output of the comparator is error signal e (t).

-This error signal is then processed in a P-I controller and the peak value of reference supply current (Ism*) is obtained.

-The unit vector u (t) of supply voltage is derived from its sensed value. The peak value of reference supply current (Ism*) is multiplied with the unit vector to generate reference sinusoidal unity power factor current (is*) The reference supply current (is*) is compared with the actual converter current (icon) to give reference APF current (ic*).

-The actual APF current (ic) and the reference APF current (ic*) are processed in a hysteresis current controller to derive gating signals of the devices (MOSFETs) of the APF.

P-I controller: $E(t) = V_{dcref} - V_{dcc}$

$$Ism^* = e(t) * K_p + K_i / T_i * \int e(t)\,dt$$

Where, Kp and Ki are the proportionality and integral gain constants of the P-I controller.

The Ism* is the peak value of reference supply current.

Estimation of reference supply current

$I_s^* = u(t).I_{sm}^*$

Where, u (t) is the unit vector for input voltage Vin.

Estimation of reference APF current

$i_c^* = i_s^* - i_{con}$

Where, icon is the input current of the ac-to-dc converter without APF.

5.5 Hysteresis current controller:-

The hysteresis current control scheme used for the control of shunt active filter is shown in Fig. 15 .The reference for compensation current to be injected by the active filter is referred to as ic* and the actual current of the active filter is referred to as ic. The control scheme decides the switching pattern of active filter in such a way to maintain the actual injected current of the filter to remain within a desired hysteresis band (HB) as indicated in Fig.15

The switching logic is formulated as follows:

If (ic>ic* + hb) S1'and S2' OFF, S3 'and S4 ' OFF

If (ic<ic* -hb) S1'and S2' ON, S3'and S4' ON

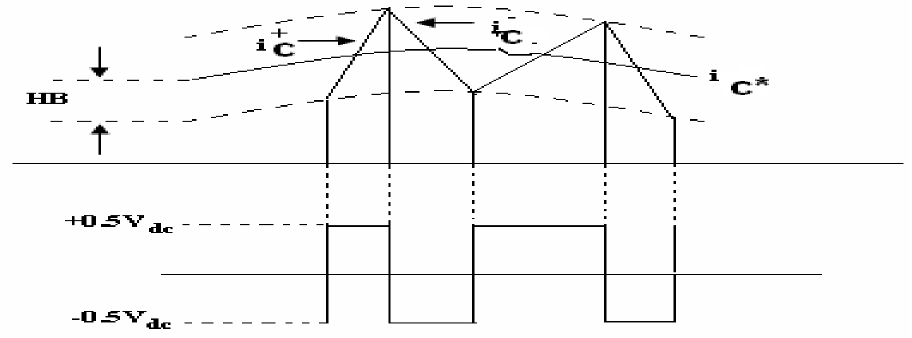


Fig:8 Hysteresis Controller

S1', S2', S3', S4' are the switching devices of the APF and HB is the hysteresis bandwidth in ampere.

The switching frequency of the hysteresis current control method described above depends on how fast the current changes from upper limit to lower limit of the hysteresis band, or vice versa. Therefore the switching frequency does not remain constant throughout the switching operation, but varies along with the current waveform. Furthermore, the filter inductance value of the active filter is the main parameter determining the rate of change of active filter current.[1,3,5,]

6.4.3 Determining Value of KP and KI

The block diagram representation of the DC-link voltage control loop is shown in Figure. The DC-link voltage controller consists of a PI controller, where the integral part reduces the steady state error of the DC-link voltage. The low pass filter introduced in the feed -back loop limits the bandwidth of the DC-link voltage controller. Hence, generation of counter actions due to the DC-link voltage variation caused by the active filter currents is avoided. Furthermore, the low bandwidth is circumvented by the feed forward of the battery current. This implies a faster response to changes in the battery current and thereby reduction of the DC-link voltage deviation during transients.

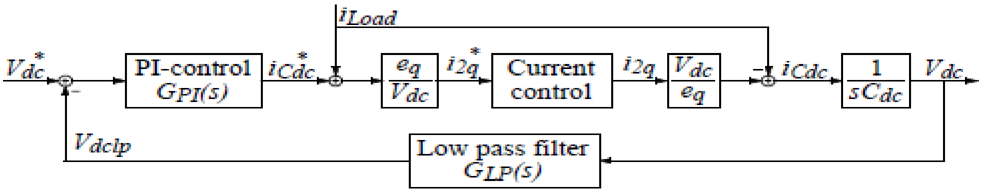


Fig:9 Block diagram representation of DC link voltage controller

The low pass filter further implies that the dynamics of the line current controller can be neglected in the DC-link voltage controller synthesis. From Figure 9 the closed loop transfer function of the DC-link voltage controller is obtained according to

$$G_{PIc}(s) = \frac{\frac{1}{sC_{dc}} G_{pI}(s)}{1 + \frac{1}{sC_{dc}} G_{pI}(s) G_{Lp}(s)} \text{.............}(1)$$

The Transfer function of Pi controller is

$$G_{pI}(s) = K\left(1 + \frac{1}{sT_i}\right) \text{................}(2)$$

Where the parameters K and Ti are the gain and integral time constant of the PI-controller, respectively. The low pass filter consists of a first order filter with the cut off frequency selected to flp=50 Hz. Hence, the transfer function of the low pass filter is given by

$$G_{Lp}(s) = \frac{\omega_{lp}}{s + \omega_{lp}} \text{..............}(3)$$

The closed loop transfer function of the DC-link voltage controller can then be written

$$GpIc(s) = \frac{\frac{K}{C_{dc}}(sT_i + 1)(s + \omega_{lp})}{S^3 + S^2 + S\frac{K\omega_{lp}}{C_{dc}} + \frac{K\omega_{lp}}{C_{dc}T_i}} \text{.............}(4)$$

Where the denominator of (4) corresponds to the characteristic polynomial of the closed loop system. Since the characteristic polynomial of the closed loop system is known, and thereby also the characteristic equation, the parameters of the PI controller can be determined by pole placement. The poles of the closed loop system are selected as a triple pole, in order to avoid oscillations in the DC-link voltage and also prevent from a large voltage overshoot at system start up. The characteristic polynomial of a triple pole system is given by

(s + x)3 = s3 + 3s 2 x + 3sx 2 + x 3 (5)

Where x corresponds to the location of the poles on the negative real axis in the s-plane, i.e. the angular frequency of the closed loop system. By identification of the coefficients of the characteristic polynomial given by the denominator of (4) with the desired characteristic polynomial in (5), the following equation system with the corresponding solutions is obtained.

$$\begin{aligned} 3x &= \omega_{lp} \rightarrow x = \frac{\omega_{lp}}{3} \\ 3x^2 &= \frac{K\omega_{lp}}{C_{dc}} \rightarrow K = \frac{C_{dc}\omega_{lp}}{3} \text{...............}(6) \\ x^3 &= \frac{K\omega_{lp}}{C_{dc}T_i} \rightarrow T_i = \frac{3^2}{\omega_{lp}} \end{aligned}$$

From (6), it can be concluded that the triple pole placement strategy gives a bandwidth of the closed loop system which is one third of the low pass filter bandwidth.

So, in this model Cdc=3300*10^-6F, wlp=2*pi8*F and F=50Hz

Therefore, KP=CdC* $\frac{\omega_{lp}}{3}$ KI=1/Ti

KP=3300*10-6*2*pi*50/3 KI= $\frac{\omega_{lp}}{3^2}$

KP=0.345 KI=2*pi*50 KI = 34.9

Hysteresis band limit is selected

This limit is selected by taking 10% of Vdc (reference) and it is peak to peak

So, here Vdc (ref) =300V.Therefore, HB=15 and HB=-15[3,6,7]

## 6. Simulation and model

6.1 Simulation of Single phase Shunt Active Filter The simulation study on a single-phase, 50-Hz, and 230 V (peak) distribution systems feeding a single phase diode rectifier with RL load has been carried out in MATLAB. The Simulink model of the distribution network with shunt active filter is shown in Figure

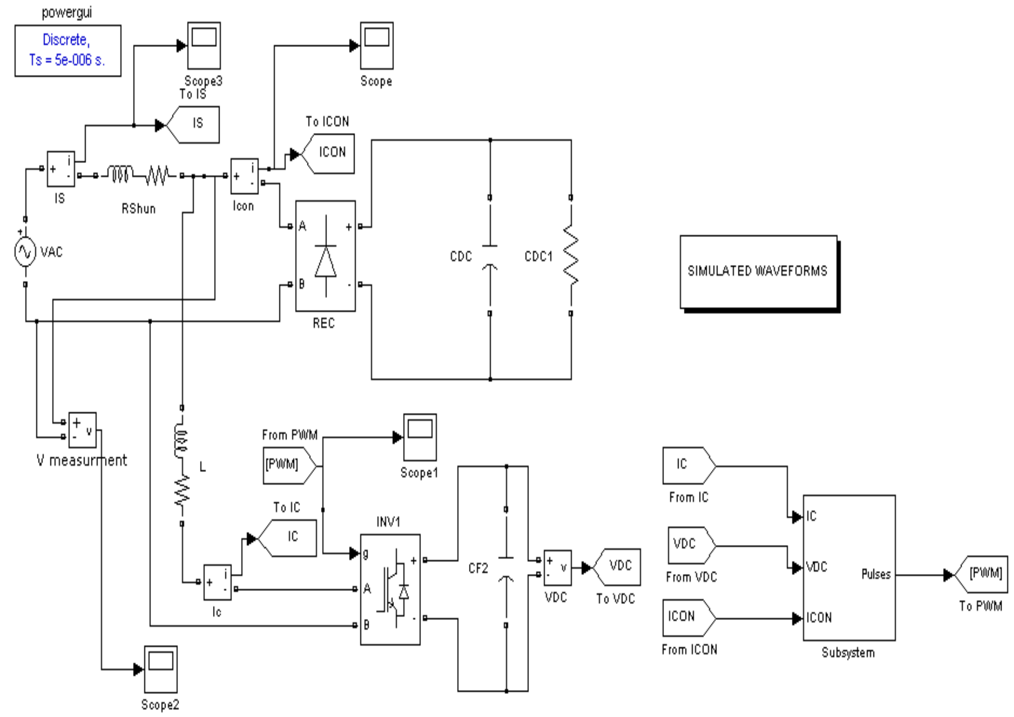


Fig:9Total simulation diagram

The system parameters are furnished in Table I. In the present simulation, harmonic compensation and input power factor improvements are considered.[1,5]

Table 1 Circuit Parameters

| | | | |
|---|---|---|---|
| Supply Voltage ($V_S$) | 230 V | Load Resistance ($R_L$) | 20 Ω |
| Supply Frequency (f) | 50 Hz | Load Capacitance ($C_L$) | 500 μF |
| DC Bus reference Voltage ($V_{dc,\ ref}$) | 300 V | Interface Resistance ($R_{af}$) | 0.25 Ω |
| Source Resistance ($R_S$) | 0.25 Ω | Interface Inductance ($L_{af}$) | 5.12 mH |
| Source Inductance ($L_S$) | 2.5 mH | DC bus Capacitance ($C_{af}$) | 3300 μF |

KP=0.345, KI=34.9 and HB=15

6.2 Calculation of active filter parameters

$I_{load}=I_{Lrms}=9.41$ A

$Is=I_{srms}=63.21$A

$I_h=(I_{srms}{}^2-I_{Lrms}{}^2)^{1/2}$

$I_h=(63.21^2-9.419^2)$A

$I_h=62.50$A

$V_{srms}=110.8$V

$XL=V_{srms}/I_h$

XL=110.8/62.50

XL=1.77Ω

XL=2ΠFL

2ΠFL=1.77

L = 1.77/(2Π*50)

$L=5.6*10^{-3}$ L=5.6mH

$KVA=V_{srms}*I_h$

KVA=110.8*62.50

KVA=6.925 KVA

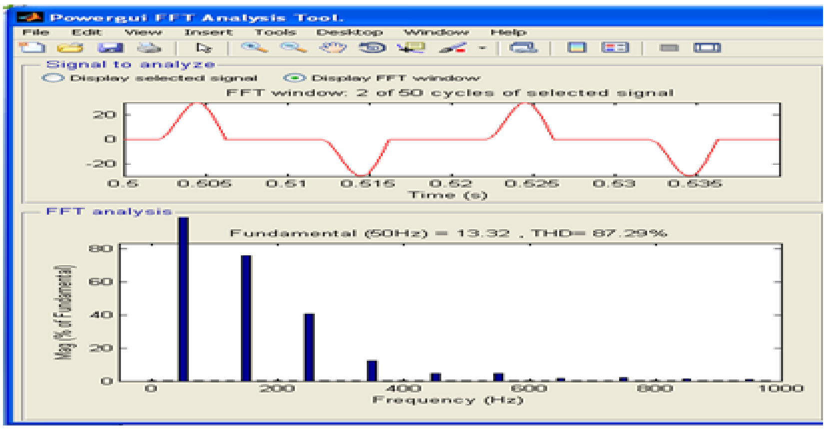
6.3 Simulation Results:-

A standard FFT package is used to compute harmonic spectrum and THD of source current and source voltage for the following conditions

6.3.1 FFT analysis of Load Current

1. Load current Without SAPF

FFT window 1 of 50 cycles

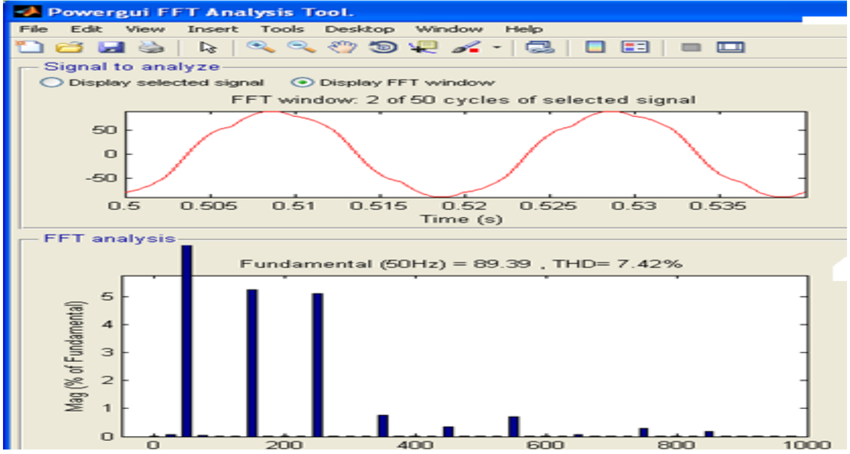


FFT window: 2 of 50 cycles of selected signal

Fundamental (50Hz) = 13.32 , THD= 87.29%

Fig10

2. Load current With SAPF
FFT window 1of 50 cycles



FFT window: 2 of 50 cycles of selected signal

Fundamental (50Hz) = 89.39 , THD= 7.42%

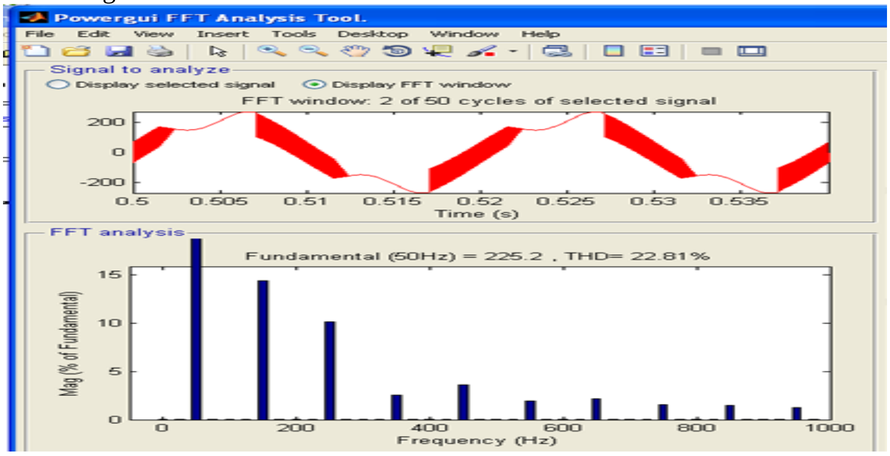
Fig11

Fig. 1 displays typical non-linear load current pattern without APF. Corresponding current harmonic spectrum is obtained after simulation is shown in Fig.7.19. Total current harmonic distortion is found 87.29% of the fundamental

Fig. 2displays corrected non-linear load current with SPAPF, which is sinusoidal after 0.5 seconds. The corresponding current harmonic spectrum is obtained as shown in Fig.7.19. Total current harmonic distortion is found 7.42% of the fundamental

6.3.2 FFT analysis of Load Voltage

1. FFT Analysis of voltage without SAPF

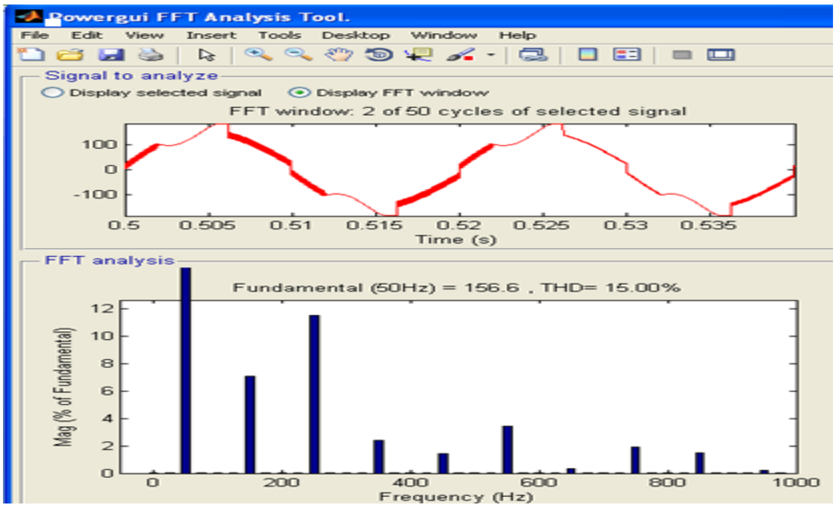


FFT window: 2 of 50 cycles of selected signal

Fundamental (50Hz) = 225.2 , THD= 22.81%

Fig12

2 FFT Analysis of voltage with SAPF



○ Display selected signal ● Display FFT window

FFT window: 2 of 50 cycles of selected signal

Fundamental (50Hz) = 156.6 , THD= 15.00%

Fig13

Fig.1 displays typical non-linear load current pattern without APF. Corresponding current harmonic spectrum is obtained after simulation is shown in Fig.1. Total current harmonic distortion is found 22.81 % of the fundamental.

Fig.2 displays corrected non-linear load current with SPAPF, which is sinusoidal after 0.5seconds. The corresponding current harmonic spectrum is obtained as shown in Fig.2. Total current harmonic distortion is found 15.00% of the Fundamental.

Result with THD %:-

Table for Current and Voltage

Table for current

| Parameters | With APF | Without APF |
|---|---|---|
| Total THD% | 7.42% | 87.29% |
| 3rd Harmonics | 5.24% | 75.82% |
| 5thHarmonics | 5.12% | 40.83% |
| 7th Harmonics | 0.77% | 12.17% |
| 9thHarmonics | 0.35% | 4.42% |

Table for voltage

| Parameters | With APF | Without APF |
|---|---|---|
| Total THD% | 15.00% | 22.81% |
| 3rd Harmonics | 7.08% | 14.34% |
| 5thHarmonics | 10.15% | 10.75% |
| 7th Harmonics | 2.41% | 2.53% |
| 9thHarmonics | 1.42% | 3.60% |

## 7.Conclusion

1.APF improves the power quality and THD and gives us the pure sinusoidal wave.
2.THD in the particular system was to 7.42% from 87.29%.
3.Hysteresis current controller is used to obtain the gate signals for switching devices of APF.
4.Design active power filter of capacity range between 5KVA to 12 KVA suitable for harmonics generating load.

## 8. References

PAPER:[1] Power System Harmonics Causes and Effects of Variable Frequency Drives Relative to the IEEE 519-1992 Standard.
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[4] Advanced Control of Active Filters in a Battery Charger Application
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[5]Implementation of Single Phase Shunt Active Filter for Low Voltage Distribution System
[6] “Single-Phase Resonant Converter with Active Power Filter”