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A REVIEW ON INVERTER CONTROL TECHNIQUE FOR UPQC

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Abstract: For power quality improvement various devices are used. But we use UPQC to get accurate power quality. UPQC is best device to compensate both load and source side problem but to control this UPQC various control strategies are used. Various control strategies for nine switch UPQC are presented in this paper. And these control strategies have capability to mitigate voltage unbalanced related problems also this mitigate current harmonics. Most of the control strategies are easy for calculation but most of are difficult for calculation here we discuss all this easy and difficult control methods.

Index Terms - **Unified Power Quality Conditioner (UPQC), Series Active Filter (SAF), Shunt Active Filter (PAF), Synchronous Reference Frame (SRF), Active Power Filter (APF), Fast Fourier Transform (FFT), Low Pass Filter (LPF), Phase Locked Loop(PLL).**

I. INTRODUCTION

UPQC consist of APF (Active Power Filter) .it has two type I) series APF II) shunt APF UPQC is the combination of series APF and shunt APF. series APF compensate voltage distortion problems shunt APF compensate current distortion problems [1]. There are many control strategies are used to control shunt APF and series APF. these control strategies are classified into time domain and frequency domain and also combination of time and frequency domain. Time domain techniques such as Synchronous Reference Frame technique (D-Q technique) [2], instantaneous power technique (P-Q technique) [3], wavelet based technique [4], Enhanced phase locked loop [5], Discrete adaptive notch filter [6], Sinusoidal tracking algorithm [7]. frequency domain technique is FFT or DFT based technique [8] and combination of time domain and frequency domain techniques are SRF with FFT technique, P-Q with FFT technique [9].

These are all reference calculation techniques. These time domain methods such as D-Q, P-Q based method are discussed in [10]. But time domain method allows fast tackle time variant disturbances but it make more complex their selective compensation and frequency domain methods are more flexible but their dynamical response is slower.

In this paper a control strategy which is combination of SRF and FFT, P-Q and FFT technique for power quality compensation as well as power flow control. For all these techniques separate measurement devices for measurement of input signal .so we also use control strategy combination such as D-Q and P-Q theory to calculate improved reference signals for operation of PAF.

In this paper we discuss all these control strategies used for SAF and PAF for their best results control strategies plays vital role.in performance of the power conditioner.so we have to know all these time domain and frequency domain method for better result of UPQC.

II. TYPES OF CONTROL TECHNIQUES

A. Time domain method

1.Synchronous Reference Frame technique (D-Q technique)

2. Instantaneous power technique (P-Q technique)
3. wavelet based technique
4. Enhanced phase locked loop (EPLL)
5. Discrete adaptive notch filter (DANF)
6. Sinusoidal tracking algorithm (STA)

B. Frequency domain method
1. FFT or DFT based technique

C. Combination of time and frequency domain
1.SRF with FFT technique
2. P-Q with FFT technique

A. Time domain method

1.Synchronous Reference Frame technique (D-Q technique)

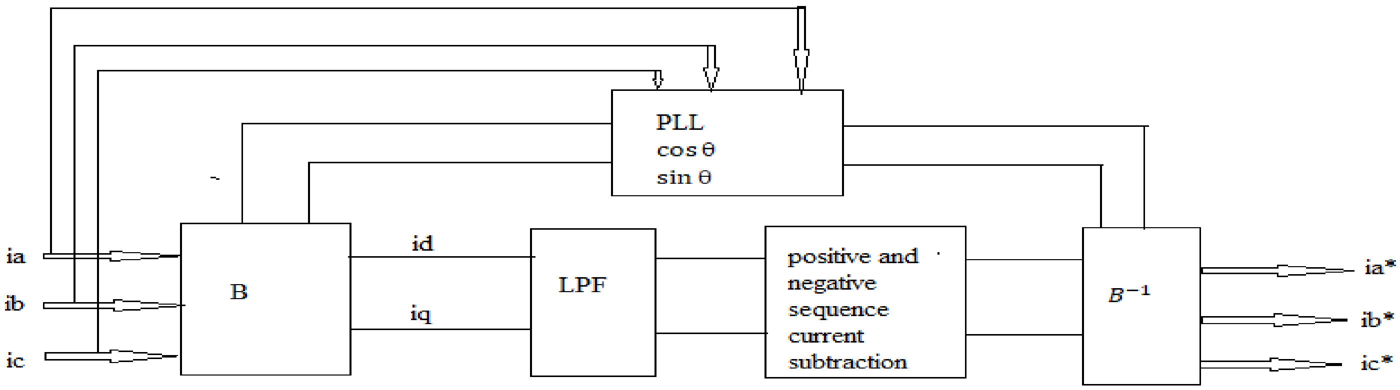

fig1.block diagram of srf technique

Is a most common method for harmonic extraction to extract three phase reference currents used by active power filter. In this method load currents are converted from abc stationary reference frame to the dq synchronous reference frame to separate positive and negative sequence components of instantaneous currents.in this SRF technique makes use of park transformation ia*ib*ic*are the reference currents.

$$B= \begin{bmatrix} iq \\ id \\ i0 \end{bmatrix} = \frac{2}{3}[A] \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \quad ..(1)$$

where A matrix denotes,

$$A= \begin{bmatrix} \cos\theta & \cos(\theta-120) & \cos(\theta+120) \\ \sin\theta & \sin(\theta-120) & \sin(\theta+120) \\ ½ & ½ & ½ \end{bmatrix}$$

In SRF technique because of this transformation fundamental components are low pass filtered to extract high frequency components .in this method firstly convert load current from three phase currents to dq reference frame because LPF it comprises harmonic component.in inverse park transformation transfers the currents from the dq frame to the abc frame is given by,

$$B^{-1} = \begin{bmatrix} ia* \\ ib* \\ ic* \end{bmatrix} - \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120) & \sin(\theta-120) & 1 \\ \cos(\theta+120) & \sin(\theta+120) & 1 \end{bmatrix} \begin{bmatrix} iq \\ id \\ i0 \end{bmatrix} \quad ..(2)$$

In this block diagram PLL block is used to detect θ angle between 3 reference frame this angle is used to transfer load currents to dq frame using equation 1 and transfer from LPF and finally this component transfer from dq to abc rotating frame .if the θ is negative resulting current is negative sequence .the frequency of negative and positive is same but direction is opposite of positive sequence the harmonic current is determined by subtracting fundamental positive and negative from total currents.

$$\begin{bmatrix} harmonic \\ current \end{bmatrix} = \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} - \begin{bmatrix} positive\ sequence \\ current \end{bmatrix} - \begin{bmatrix} negative\ sequence \\ current \end{bmatrix}$$

2. Instantaneous Power Technique (P-Q Technique)

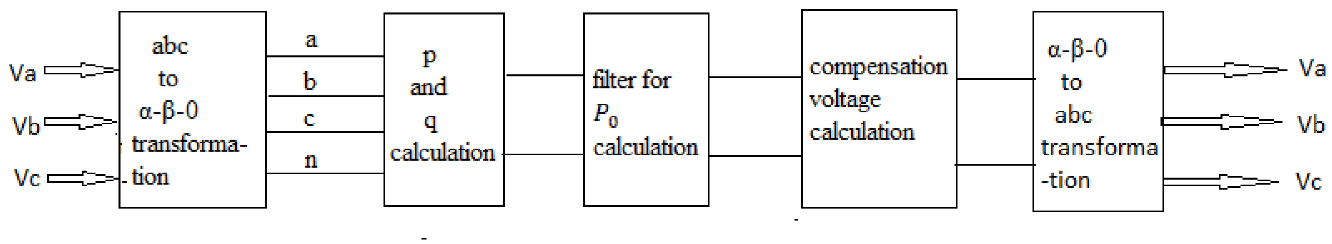

fig2. block diagram of pq technique with system 3phase with neutral wire

In this method load currents or load voltages are converted from abc stationary reference frame to α-β-0 reference frame. This method also used for harmonic extraction used by active power filter.in pq theory makes use of Clarke transformation where α-β co-ordinates are orthogonal to each other and 0 co-ordinate denote zero sequence component. The voltage and current are calculated in α-β-0 coordinates by using following equation

$$\begin{bmatrix} io \\ i\alpha \\ i\beta \end{bmatrix} = T_1 \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \text{or} \begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = T_1 \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \text{.....(3)}$$

$$\text{Where T=Transformation matrix ,T=} \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}$$

The zero sequence power (P_0), the real power (p) and the imaginary power (q) are the three instantaneous powers which are calculated by using phase voltages and line currents in α-β-0 coordinates. The inverse transformation is given by,

$$\begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} io \\ i\alpha \\ i\beta \end{bmatrix} \text{..... (4) Similarly for voltage}$$

We can easily do separation of zero sequence components into the zero sequence axis by using α-β-0 transformation.in fact α-axis and β-axis do not have any contribution from zero sequence components. if the 3phase system has three wires with no neutral. Zero sequence current components do not exist and io is eliminated i) if we assume the system is 3phase wire system zero sequence voltage or current is not present in this situation power is given by,

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ V_\beta & -V_\alpha \end{bmatrix} \cdot \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \text{.... (5)}$$

ii) If we assume the system is 3phase system with neutral wire zero sequence current and voltages are present in this situation power is given by,

a) The instantaneous real power (p) = $V_\alpha . i_\alpha + V_{\beta} . i_\beta$

b) The instantaneous imaginary power (q) = $V_\beta . i_\alpha - V_{\alpha} . i_\beta$

c) The instantaneous zero sequence power $(P_0) = v_0 . i_0$

3. wavelet based technique

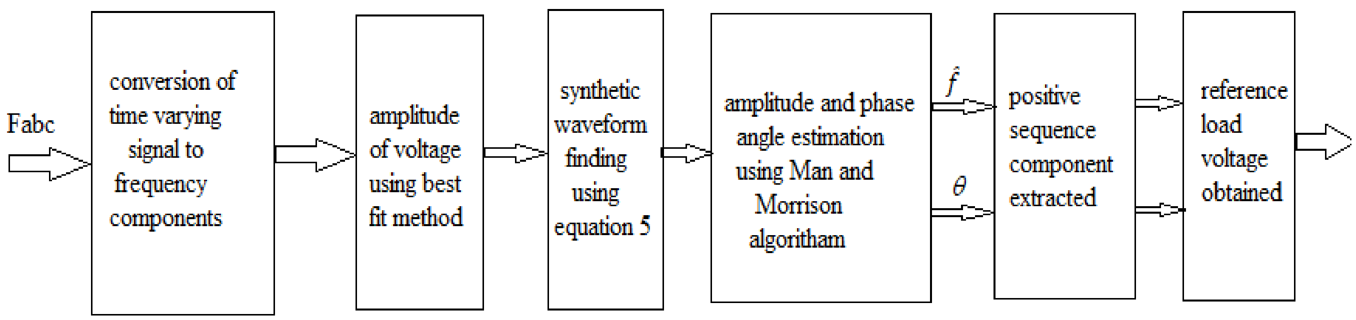

fig3.block diagram of wavelet based technique

This is time domain method which is used to estimates the phase angle and amplitude of system voltages because use the large phase angle jump because of fault.in this technique use discrete wavelet transform and MRA (Multiresolution Analysis) to extract fundamental component of current and voltage from unbalanced load current and source voltage this technique has 2 steps i)Fundamental component extraction ii) Amplitude and phase angle estimation these 2 steps can be obtained by using Man and Morrison algorithm.in fundamental component extraction firstly time varying signal represented in terms of frequently component using MRA represent complicated signal terms of scaling and wavelet function.

$$f'(t) = f(t) \times \left| \frac{f_1^0(t)}{f_1^{-1}(t)} \right| \text{....... (5)}$$

f(t) =symmetric waveform of the last period of original waveform, $f'(t)$is its modification $|f_1^0(t)|, |f_1^{-1}(t)|$ are amplitudes of fundamental component of the waveform in the last cycle and previous cycle. Best fit method is used to extract amplitude of voltage by using equation (5) synthetic waveform can be found which is used to extract fundamental component because synthetic waveform cannot produce error in algorithm response so response cannot have disrupted. Then amplitude and phase angle can be estimate using man and Morrison algorithm. Man and Morrison method is very fast for sinusoidal waveform.in this Man and Morrison method phase angle and amplitude of waveform can be obtained mathematically using last three samples. Above block diagram $\hat{f}$ is a amplitude and θ is phase angle by using $\hat{f}$ *and* θ positive sequence component are extracted and then reference load voltage are obtained .then compensating voltages are obtained by subtracting load voltages from reference voltages.

4. Enhanced Phase Locked Loop Technique (EPLL)

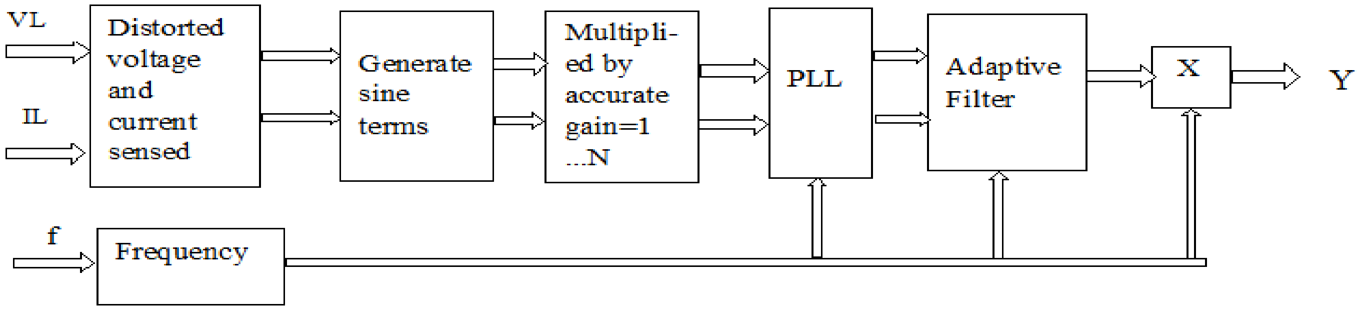

fig4.block diagram of epll

This control strategy is the way to generate reference signal for the both shunt and series APFs of UPQC. We calculate the reference signal to compensate the error, distortions in voltages and currents. This method is relatively used to achieve sinusoidal and balanced voltage. the most critical problem in UPQC to find out which algorithm obtain an accurate harmonic reference signal. this method is based on the noise cancelling theory to measure harmonic component of nonlinear load current and voltages.

Let's the frequency, load voltage and load currents are the inputs to the PLL. the three unbalanced distorted supply voltage is sensed and given to the PLL which generates sine terms. this sensed distorted voltage is multiplied by a suitable gain value before given to an input to the PLL. gain values are 1…N. V_L and $I_L$is the load voltage and load current X is the output signal of adaptive detecting circuit and Y is the output signal of adaptive detecting circuit f is the reference frequency which is in phase with AC voltage.

In this system DC component of the output of integrator will tune, simultaneously until they are equal in magnitude because the input reference signal which is sinusoidal i.e. the fundamental component of system voltage and currents has same frequency and in phase with the fundamental component of load voltage and current.

5. Discrete Adaptive Notch Filter Technique (DANF)

DANF is a method used for extraction of fundamental active current amplitude and fundamental grid voltage template. This method also used in the phase detector of PLL. This method DANF method is also used for extraction of fundamental grid voltage and magnitude of fundamental active load current.

X is the input signal which contains both fundamental and harmonics. The λ and μ are two adjustment parameters they are adjusted based on balance between accuracy and speed of convergence. There are three discrete integrators are used in the DANF. the output of DANF are fundamental component. the frequency is implemented in backward Euler implementation and remaining other integrator is in forward Euler.

The output of DANF are fundamental component X_{FD}, fundamental quadrature component X_{FQ},fundamental frequency ω and the amplitude x. fundamental template $\sin\emptyset$ and quadrature template $\cos\emptyset$ can obtained by mathematical operation on the fundamental and quadrature output of DANF.

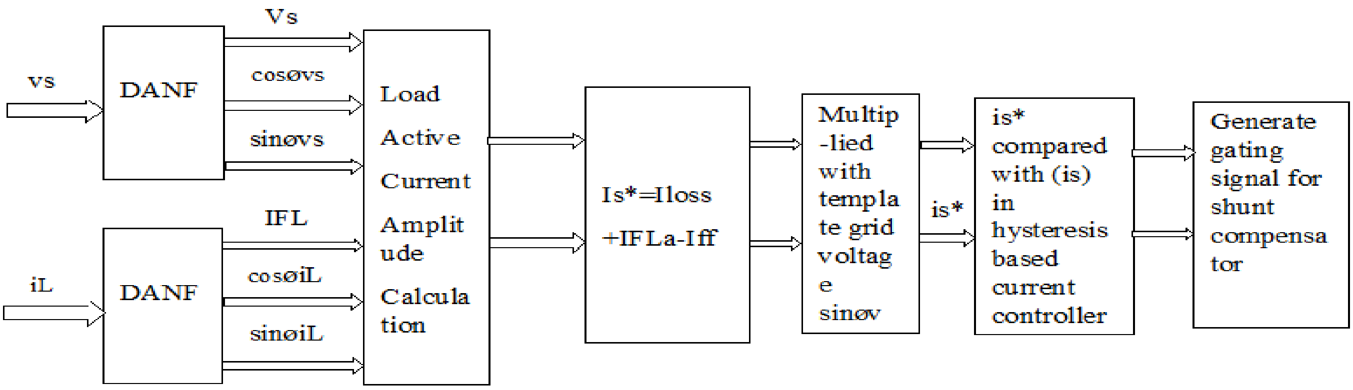

fig5.block diagram of danf for shunt compensator

There are two DANFs are used for extracting fundamental component phase and amplitude of grid voltage and current. The load current (i_L) DANF gives fundamental component peak (I_{FL}) in phase template sin($\emptyset i$) and quadrature template $\cos\emptyset\, i$.the grid voltage (vs) DANF gives fundamental component peak(Vs), in phase sin(Øv) and quadrature template cos Øv.

The output of the DC-link PI controller gives the equivalent current which represent the loss component of power needed to maintain the DC-link voltage. the losses include losses in inductors, snubber circuit, switching losses in shunt and series compensator. The feed forward component (I_{ff}) is subtracted from the sum of loss component (I_{loss}) and load active fundamental peak (I_{FLa}) to form the magnitude for fundamental peak grid voltage (Is*).then this multiplied with the template of grid voltage $\sin\emptyset\, v$ give the grid reference (is*). The reference grid current compared with sensed grid current (is) in a hysteresis based current controller to generate gating signal for shunt compensator.

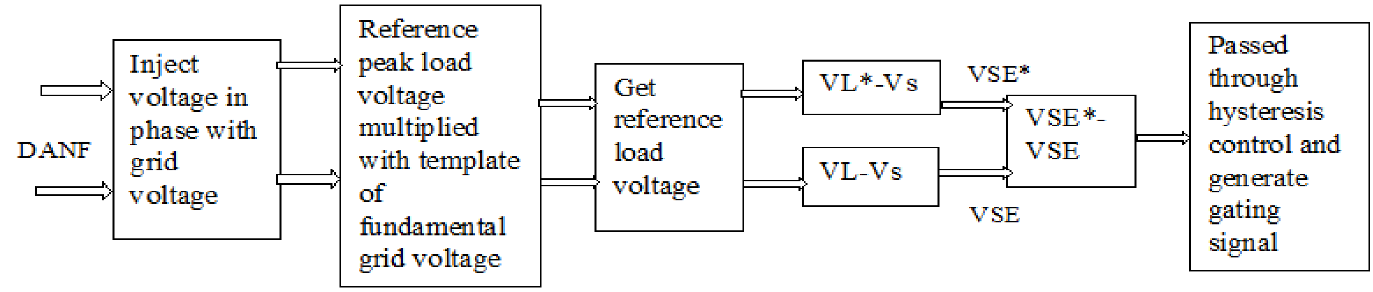

fig6.block diagram of danf for series compensator

The series compensator is used when voltage sag and swell occur. series compensator inject voltage in phase with grid voltage during voltage sag. And opposite phase with grid voltage during voltage swell.

Grid voltage Vs, the load voltage after compensation is also in phase with grid voltage Vs. The reference peak load voltage VLp* is multiplied with fundamental grid voltage and we get reference load voltage VL*. The difference between VL* and Vs gives reference series compensator voltage VSE * then we take difference between load voltage VL and Vs then we get actual series compensator voltage VSE then the difference between VSE* and VSE is passed through hysteresis controller and generate required gating signal for series compensator.

6. Sinusoidal Tracking Algorithm Technique (STA)

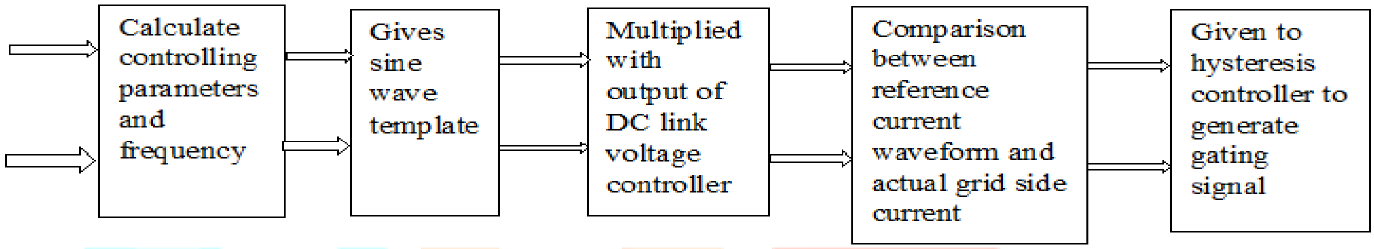

fig7.block diagram of sta

STA means sinusoidal tracking algorithm. STA algorithm is very simple. It is used to extract fundamental components along with amplitude phase and frequency. It gives better current waveform and less harmonic operation and DC- link voltage regulation. STA algorithm gives harmonic compensation and sag/swell compensation. STA algorithm is used to control shunt or series compensator .in this compensators the STA technique calculate pulses and given to the switches (MOSFET, IGBT) terminals and maintain DC-link voltage constant.

In this block diagram first we calculate controlling parameters and frequency it gives sine wave template then this multiplied with output of DC-link voltage controller. After that we take comparison between reference current waveform and actual grid side current. And this difference is given to the hysteresis controller to generate gating signal.

B. Frequency domain method

1. FFT or DFT Based Technique

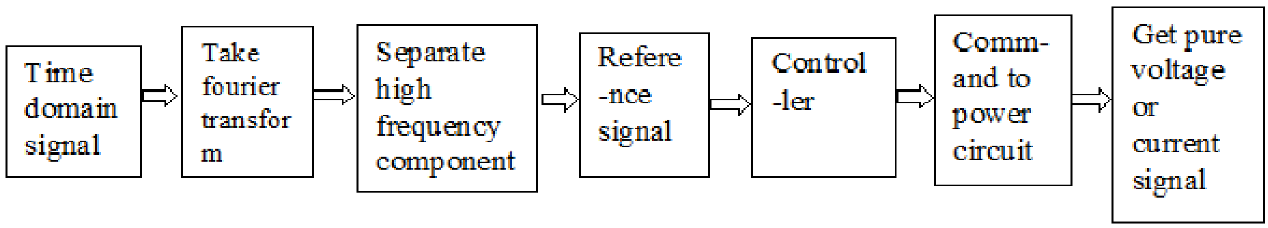

fig8.block diagram of fft

FFT has two types first Continuous Fourier Transform(CFT) and second Discrete Fourier Transform (DFT). FFT is used to convert time domain signal in to frequency domain signal and to get pure voltage or current signal. Signal contains various frequency components. First we take a signal which is analyzed by using Fourier transform and analyze high frequency component and we make a reference signal and this reference signal given to the controllers and controller gives a command to the power circuit switches for proper on off to get pure voltage or current signal.

II. CONCLUSIONS

This paper made comparative study of three main techniques used for shunt series active filters. This paper briefly described how to use these techniques by using some equations step by step. Block diagram explain step by step how these techniques used. This paper did not explain practical problems related with the implementation of digital control system. this paper analyses the different control algorithms for compensation current and solving power quality problems. For reference current calculation D-Q, P-Q, wavelet based technique requires more mathematical calculations. Because of slow PLL it may bring instability problem to grid connected converters. frequency noise distortion increases complexity in PLL. STA technique does not much excellent for harmonic compensation and dc-link voltage regulation. DFT based technique have synchronization problem for calculating reference current.

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