International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue-17
December 2017

Model Reference Controller based Shunt Active Power Filter

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Abstract- *In this paper the execution of a three-phase shunt active power filter (APF) utilizing Model Reference Controller (MRC) has been contrasted and that utilizing prompt dynamic and responsive (p-q) hypothesis. The curiosity of this exploration lies in the use of MRC to create the amplitude of the reference supply current required by the APF circuit and the effective execution of the APF framework for harmonic disposal. The whole system has been displayed utilizing MATLAB 6.1 tool environment. Simulation results show the appropriateness of MRC for the control of APF.*

I. INTRODUCTION

The significant reasons for power quality issues are because of the across the board utilization of static power electronic converters, saturable systems, fluorescent lights and arch heaters. A portion of the adverse impacts of poor power quality are diminished motor life, expanded losses, mal-operation, electromagnetic interference, more heating, and defective timing signals. Despite the fact that there are no standard waveforms to specify control quality issues, IEEE standard, American national standard guides (ANSI), British standards (BS), European norms (EN), and so on are broadly taken after to keep up electrical power quality. The IEEE standard 519 is a prescribed practice for control factor adjustment and harmonic effect confinement at static power converters. IEEE-519 standard restrains the total harmonic distortion (THD) of voltage and current beneath 5 %. Dynamic electrical cable conditioners have been proposed for harmonic disposal and power factor change [1] , cancelation of negative and zero arrangement segments [2] , voltage sag and swell [3] . Numerous regular control methodologies have been proposed and executed for the effective control of APF framework. Late research demonstrates the adequacy of artificial intelligence (AI) based controllers, for example, fluffy logic controller and neural system controllers for the control of APF framework [4] . This examination proposes MRC for the control of APF framework. The curiosity of this exploration lies in the utilization of MRC for the assurance of abundancy of reference supply current required in an APF framework. This examination additionally talks about the control of APF framework utilizing p-q hypothesis. The control methodologies of APF framework are mentioned in the second part of this paper. Simulation brings about the third part exhibit the adequacy of MRC for the control of APF system [5].

This undertaking to wipe out the harmonics and enhancing the power factor MRAC is utilized. MRAC is the best controlling procedure for plants and any electrical systems. It is having more future in prior days. It is exceptionally straightforward and solid strategy contrast with different methods.

MRAC is not having lengthy calculations and equations it is easily understandable to everyone it is having simple calculations and small equations [6]. When compare to the other techniques it is cheap. It can be provided any electrical systems, power plants, industries, electric power lines..Etc. by considering the above factors the project is having bright scope.

II. METHODOLOGY

Two methods are used for developing this project one is PQ theory and another one is MRC (model reference control) in both the cases shunt active power filter is used [7]. Shunt active power filters are used for cancellation of negative and zero sequence currents, voltage sag and swell many control strategies have been proposed for the successful controlling.

The heart of the shunt active power filter is IGBT based voltage source inverter (VSI).a dc capacitor is used for delivering the power to VSI. By using both the methods we are getting unity power factor and improving power quality of the system

Design of Active Filters:

To configure filters, the particulars that should be built up include:

- The scope of wanted frequencies (the pass band) together with the state of the recurrence reaction. This shows the assortment of channel (see above) and the middle or corner frequencies.
- Input and output impedance prerequisites. These point of confinement the circuit topologies accessible; for instance, most, yet not all dynamic channel topologies give a cradled (low impedance) output. In any case, recollect that the inner output impedance of operational speakers, if utilized, may rise especially at high frequencies and decrease the constriction from that normal. Know that some high-pass filter topologies give the info very nearly a short out to high frequencies.
- The degree to which undesirable signs ought to be rejected.

On account of limited band pass filters, the Q decides the - 3dB data transfer capacity yet in addition the level of dismissal of frequencies far expelled from the middle recurrence; if these two prerequisites are in strife then a stunned tuning band pass filter might be required.

For notched filters, how much undesirable signs at the indent recurrence must be rejected decides the exactness of the segments, however not the Q, which is represented by wanted

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steepness of the indent, i.e. the data transfer capacity around the notch before lessening turns out to be little.

For high-pass and low-go (and in addition band-pass channels a long way from the middle recurrence), the required dismissal may decide the slope of attenuation required, and therefore the "request" of the filter [8]. A moment arrange all-shaft channel gives an extreme slope of around 12 dB for each octave (40dB/decade), however the incline near the corner much recurrence is less, once in a while requiring an indent be added to the filter.

The reasonable "swell" (variety from a level reaction, in decibels) inside the pass band of high-pass and low-pass channels, alongside the state of the recurrence reaction bend close to the corner recurrence, decide the damping factor (corresponding of Q). This additionally influences the stage reaction, and the time reaction to a square-wave input. A few critical reaction shapes (damping factors) have understood names:

Chebyshev filter – slight topping/swell in the pass band before the corner;
Q>0.7071 for second request channels
Butterworth filter – flattest sufficiency reaction; Q=0.7071 for second request channels
Pointer or transitional Thompson-Butterworth or compromise filter – quicker tumble off than Bessel; Q=0.639 for second request channels.
Bessel filter – best time-delay, best overshoot reaction; Q=0.577 for second request channels.
Elliptic filter or Causer filter – include an indent (or "zero") simply outside the pass band, to give a considerably more noteworthy incline in this district than the mix of request and damping factor without the score.

Shunt Active Filter:

The technology of active power filter has been developed during the past two decades reaching maturity for harmonics compensation, reactive power, and voltage balance in ac power networks. All active power filters are produced with PWM converters (current source or voltage source inverters). The present nourished PWM inverter connect structure acts as a non-sinusoidal current source to meet the harmonic current necessity of the nonlinear load. It has a self-dependent dc reactor that guarantees the contiguous flow of the dc current. They display great dependability, yet have vital misfortunes and require higher estimations of parallel capacitor channels at the AC terminals to expel undesirable current harmonics. In addition, they can't be utilized as a part of multilevel or multistep modes arrangements to permit remuneration in higher power ratings. The other converter utilized as a part of active power filter topologies is the voltage-source PWM inverter. This converter is more advantageous for dynamic power separating applications since it is lighter, less expensive, and expandable to multilevel and multistep forms, to enhance its execution for high power rating pay with bring down exchanging frequencies. The PWM voltage source inverter must be associated with the AC mains through coupling reactors. An electrolytic capacitor keeps a dc voltage steady and swell free.

Active power filters can be arranged in light of the sort of converter, topology, control plan, and remuneration qualities. The most well known characterization depends on the topology, for example, shunt, arrangement or hybrid. The hybrid setup is a blend of detached and dynamic remuneration. Shunt active power channels are broadly used to remunerate current harmonic, receptive power and load current unbalanced. It can likewise be utilized as a static var generator in control framework systems for settling and enhancing voltage profile. Arrangement dynamic power filters is associated before the load in arrangement with the AC mains, through a coupling transformer to dispense with voltage harmonics and to adjust and direct the terminal voltage of the load or line.

Shunt Active Power Filters:

These filters remunerate current harmonic by infusing parallel yet inverse harmonic repaying current. For this situation, the shunt active power filters works as a present source infusing the harmonic segments created by the load yet stage moved by 180. Therefore, segments of harmonic streams contained in the load current are crossed out by the impact of the dynamic channel, and the source current stays sinusoidal and in stage with the particular stage to unbiased voltage. This standard is pertinent to a load considered as a harmonic source. Additionally, with a fitting control plot, the dynamic power filter can likewise repay the load control factor.

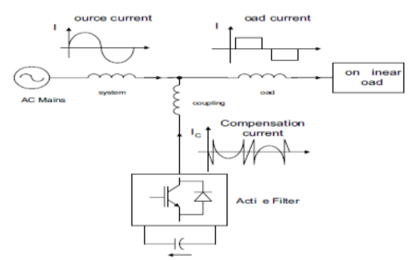

Fig.1: Compensation characteristics of a shunt active power filter

Model Reference Adaptive Control:

The control parameters are updated in view of this error. The objective is for the parameters to join to perfect esteems that reason the plant reaction to coordinate the reaction of the reference show. For instance, you might endeavor to control the position of a robot arm normally vibrates. You really need the robot arm to make brisk movements with practically no vibration. Utilizing MRAC, you could pick a reference show that could react rapidly to a stage contribution with a short settling time. You could then form a controller that would adjust to influence the robot to arm move simply like the model.

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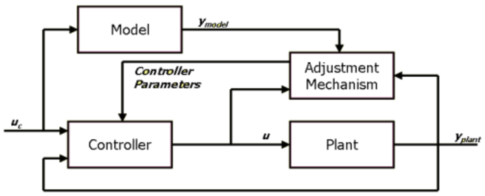

Fig.2: Block diagram of MRAC

MRAC is a broad subject area with many different applications and methods. The purpose of this tutorial is to introduce the design of an MRAC using the MIT rule. The theory is explained and examples are used to illustrate the concepts. The MIT rule is then applied to control the motion of a pendulum. The remainder of the tutorial demonstrates the simulation and experimental implementation of MRAC on the pendulum system. Oriel is to introduce the design of an MRAC using the MIT rule. To see how the MIT rule can be used to form an adaptive controller, consider a system with an adaptive feed word gain. The block diagram is given below

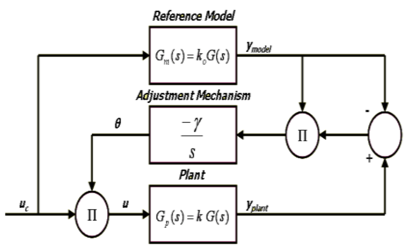

Fig.3: Block diagram of adaptive feed word gain

III. SIMULINK MODELS AND RESULTS

An APF system based on MRC has been successfully modeled and tested using MATLAB/Simlink 6.1 toolbox. The effectiveness of the system has been tested for various firing angles (a) in the range of 0° and 180°. The performance of the developed system is illustrated with the one using p-q theory for a = 165°.

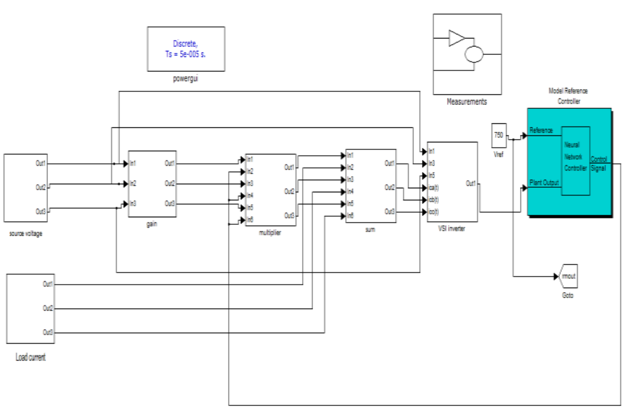

Fig.4: Simulink model of APF using MRC

Fig.4 shows the simulink modeling of APF system by using Model Reference Controller developed sub system successfully modeled and tested in the Matlab simulink. The sub systems are modeled source voltage, gain, multiplier, sum, VSI Inverter and load currents represents in the each subsystem.

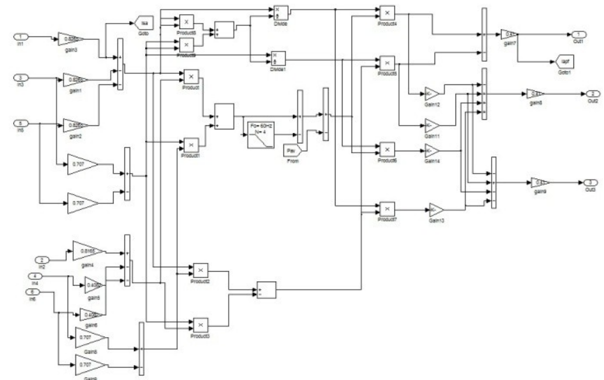

Fig.5: Simulink model of APF using P-Q theory sub system

Fig.5 shows the sub system represent sum in the MRC source currents and load currents are multiplied in simulink modeling of the APF using P-Q theory sub system. The Reference compensation currents could be evaluated using parks backward transformation and the required currents are obtained $i_{ca(t)}$, $i_{cb(t)}$, $i_{cc(t)}$ these currents gives input to the VSI Inverter sub system.

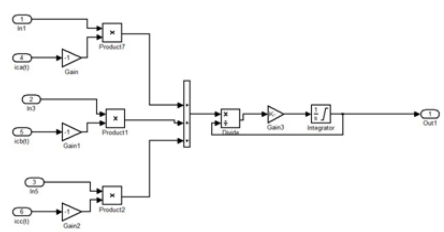

Fig.6: Inverter sub-system

Fig.6 shows simulink model of the inverter sub system modeled as a current amplifier with unity gain. Load currents and supply voltages are multiplied in product and to decrease reactive power with the integrator then obtained the active power. This power given as a input to the MRC.

In the control of APF system MRC is used in the simulink modeling. One may observe that in MRC based APF system, reference source currents are obtained by multiplying the required amplitude of the source currents with the unit amplitude waveform in-phase with the supply voltages. MRC checks the desired capacitor voltage and the actual capacitor voltage and the control input is adjusted to achieve the reference value.

It has two neural networks, the first one is plant model network and second one is controller network. To train controller, first of all neural network plant model identified and trained training data has generated input and output data.

Input and Output Data for NN MRC:

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue-17
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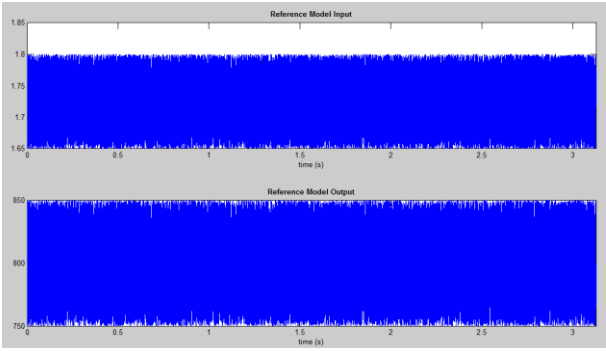

Fig.7: Input and Output Data for NN MRC

By accepting the given data in the plant model network and controller network, they generate Testing data, validation data, and Training data in model reference controller. These can be shows plant input, plant output, error and NN output.

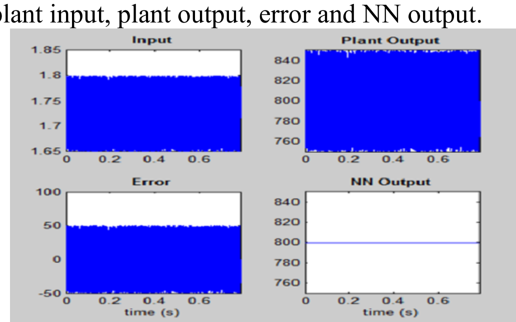

Fig.8: Testing Data for NN MRC

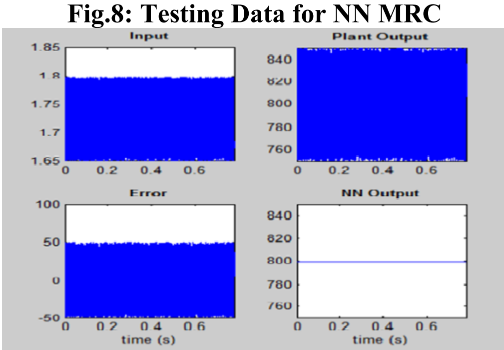

Fig.9: Validation data for Neural Network MRC

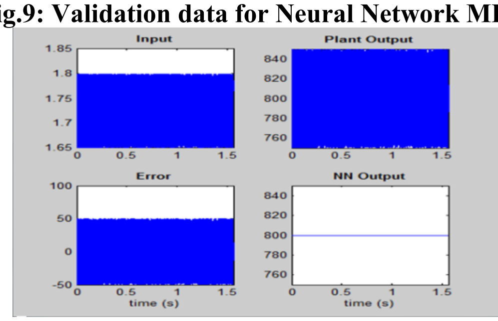

Fig.10: Training data for Neural Network MRC

Simulink Results of MRC:

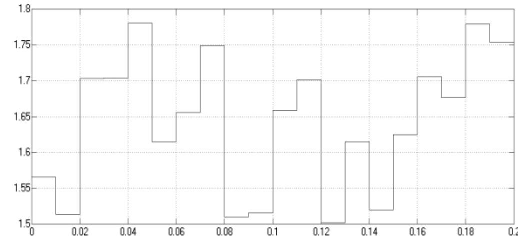

Fig.11: NN plant model Reference input

Fig.11 shows plant model reference input current which is defined in neural network plant in the MRC. Reference Input(I_{ref}) NN Plantmodel Time(sec)

Fig.12 shows the output of the neural network signal to obtain a given parameters in MRC to reach the signal up to the reference value.

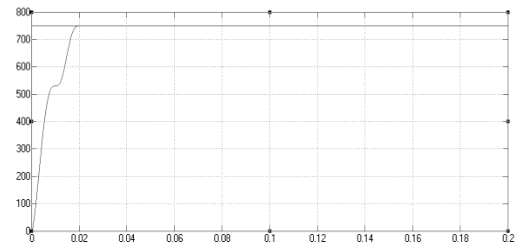

Fig.12: Reference model and NN outputs in MRC

Fig.13 shows when load is on inverter mode, source current is in phase with supply voltage, by using MRC base APF system. So by observing this figure power factor is improved.

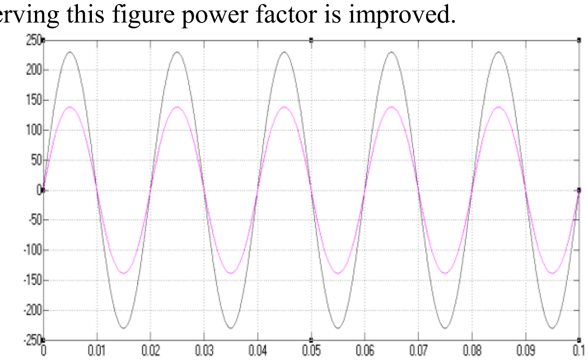

Fig.13: Power factor in MRC

Fig.14 and Fig.15 shows compensation currents. The Reference compensation currents could be evaluated using park backward transformation and the required currents are obtained $I_{ca\ (t)}$, $i_{cb\ (t)}$, $i_{cc\ (t)}$ these currents gives input to the VSI Inverter sub system. However by using MRC source currents are in-phase with the supply voltages. One may observe that in MRC based APF system, reference source currents are obtained by multiplying the required amplitude of the source currents with the unit amplitude waveform in-phase with the supply voltages. MRC checks the desired capacitor voltage and the actual capacitor voltage and the control input is adjusted to achieve the reference value.

Load currents in MRC:

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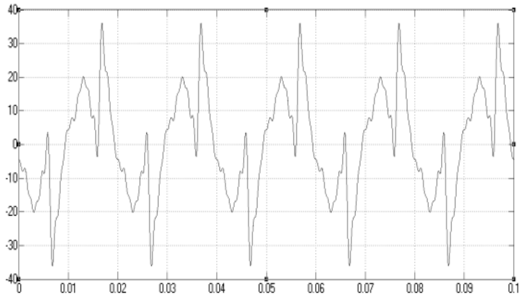

Fig.14: Load current without compensation in MRC

Fig.14 Shows load current without compensation harmonics are produced non sinusoidal wave form the harmonic components are produced.

Fig.15 Shows load current with compensation harmonics are produced sinusoidal wave farm the harmonic components are reduced.

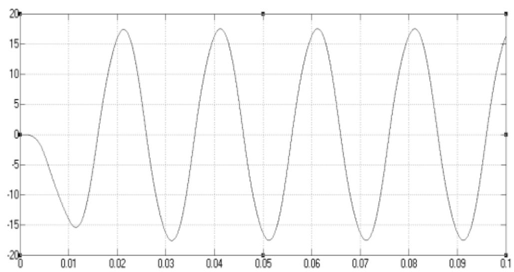

Fig.15: Load current with compensation in MRC

Fig.16 Observe compensation currents. Load current is affected by source current. Components of harmonic currents contained in the load current are cancelled by the effect of the active filter.

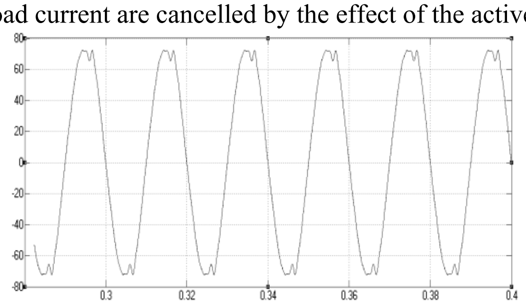

Fig.16: Compensation current(Ic) in MRC

Fig.17 Observe that in MRC based APF system. Reference source current (i_{sa}), load current (i_{la}), compensation current (i_{ca}), and source voltage (v_{sa}) these results are shown in the matlab/simulink. However by using MRC source currents are in-phase with the supply voltages. One may observe that in MRC based APF system, reference source currents are obtained by multiplying the required amplitude of the source currents with the unit amplitude waveform in-phase with the supply voltages.

However by using MRC source currents are in-phase with the supply voltages. One may observe that in MRC based APF system, reference source currents are obtained by multiplying the required amplitude of the source currents with the unit amplitude waveform in-phase with the supply voltages. By using MRC base APF system. Whereas the detailed control structure of APF system using MRC is illustrated observing this figure power factor is improved.

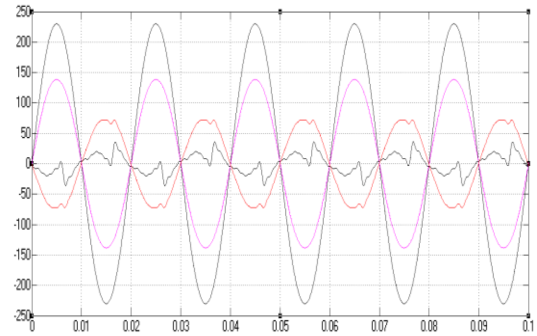

Fig.17: Plots of $v_{sa}(t)$, $i_{sa}(t)$, $i_{la}(t)$, $i_{ca}(t)$ using MRC

Fig.18 THD of source current and load current after compensation using MRC. The source current (I_s)is in the shown above the 0.5 and the settling time more then the load current(I_l) load current settling time less than the source current after compensation.

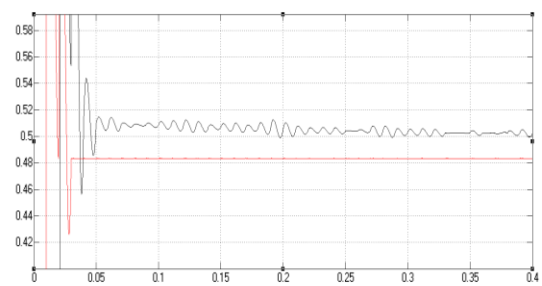

Fig.18: THD of source and load currents after compensation using MRC

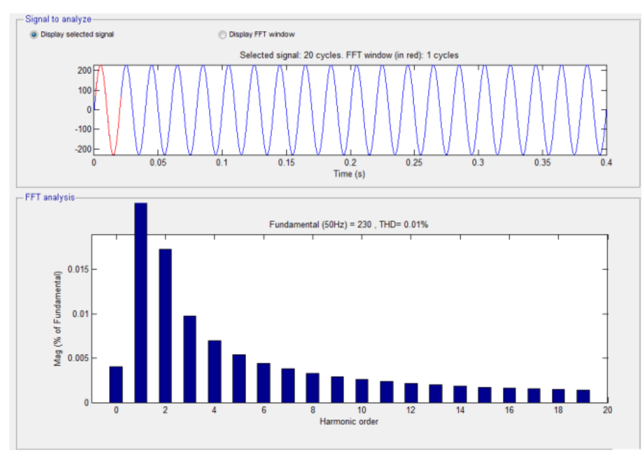

Fig.19: THD of MRC source in voltage FFT Analysis

Fig.19 Show THD is in the FFT analysis in MRC the source voltage is about 0.01% because of there is no harmonic effect.

Fig.20 Shows the THD of source current in FFT analysis in the MRC about THD is 1.27% because the harmonics are eliminated in the source current after the compensation.

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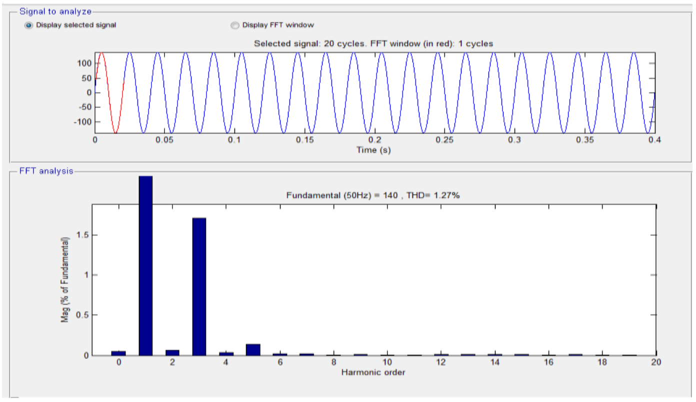

Fig.20: THD of MRC source current in FFT analysis

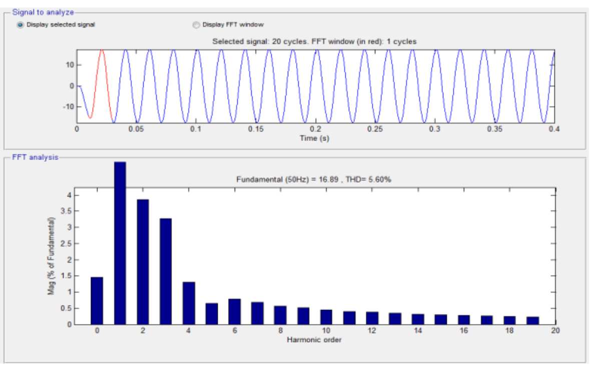

Fig.21: THD of MRC load current with compensation in FFT analysis

Fig.21 Shows the THD of load load current in FFT Analysis in the MRC harmonics are eliminated in the source current after the compensation. For harmonic elimination and reactive power could be eliminated. In FFT analysis load current THD is about 5.60% of the fundamental frequency after the compensation it is the purely sine wave.

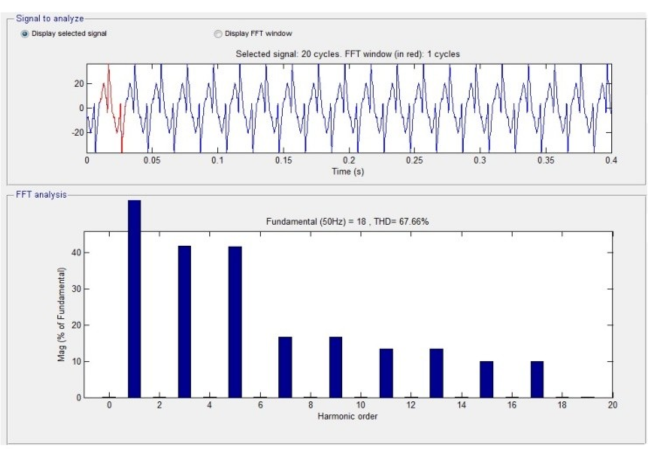

Fig.22: THD of MRC load current without in FFT analysis

Fig.22 THD of MRC load current in FFT analysis is about 67.66% of the fundamental frequency before the compensation it is generates harmonics the wave is non sinusoidal.

Simulink Model of APF using PQ Theory:

Fig.23 is complete structure of Control APF system using p-q theory by the simulink model of APF system PQ theory is successfully modeled and tested proposed to determine the compensation current could be injected by the APF system.

The sub systems are modeled source voltage, gain, multiplier, sum, VSI Inverter and load currents represents in the each subsystem. In PQ theory PID controller is used for the improve the power factor. In the simulink modeling the outputs are obtained.

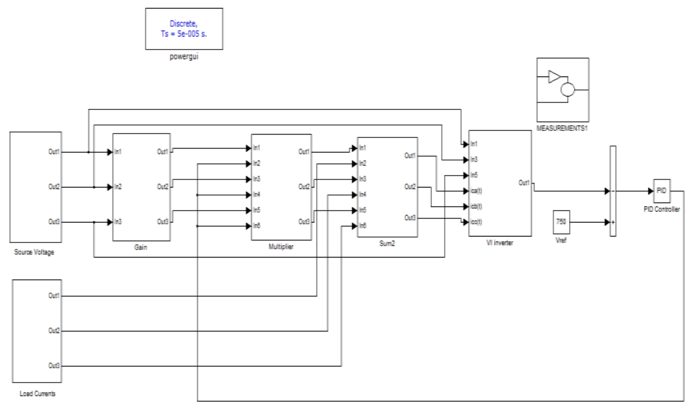

Fig.23: Simulink model of APF using P-Q theory

Simulink Results of PQ Theory:

Fig.24 Shows load is an inverter mode however source current is out of phase with respective supply voltage.

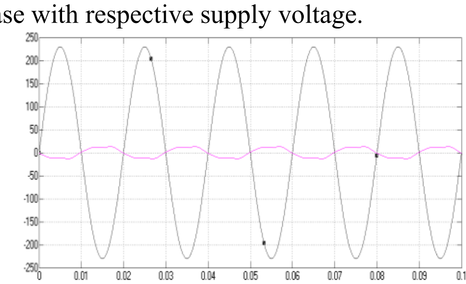

Fig.24: power factor of PQ theory

Load currents in PQ theory:

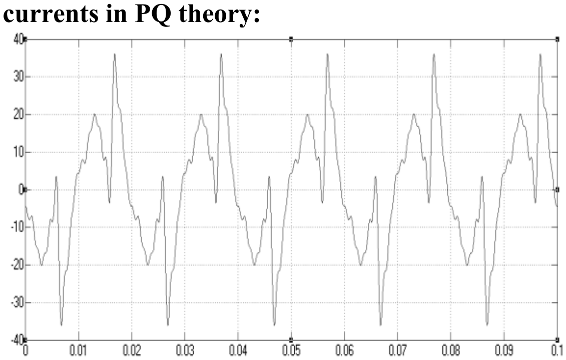

Fig.25: Load current without compensation in PQ theory

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Fig.25 Shows the without compensation load current harmonics are produce in this wave Load current is affected by source current. Components of harmonic currents contained in the load current.

Fig.26 Shows compensation currents. Load current is affected by source current. Components of harmonic currents contained in the load current are cancelled by the effect of the active filter.

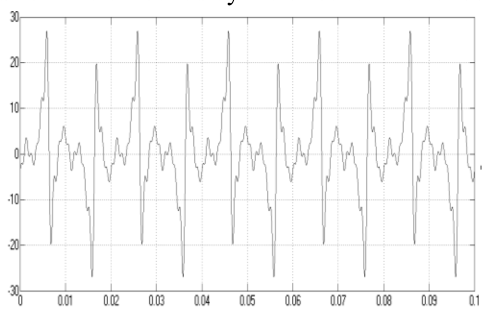

Fig.26: Compensation current(Ic) in PQ theory

Fig.27 Shows load current with compensation harmonics are produced sinusoidal wave farm the harmonic components are reduced.

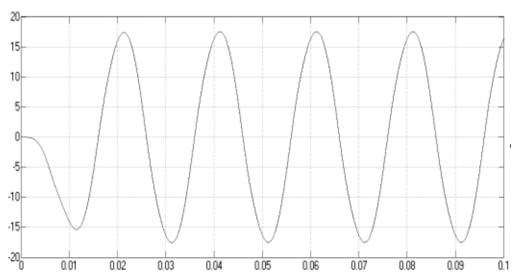

Fig.27: Load current with compensation in PQ theory

Fig.28 Observe that in p-q theory APF based system. Reference source current (i_{sa}), load current (i_{la}), compensation current (i_{ca}), and source voltage (v_{sa}) these results are shown in the matlab/simulink.

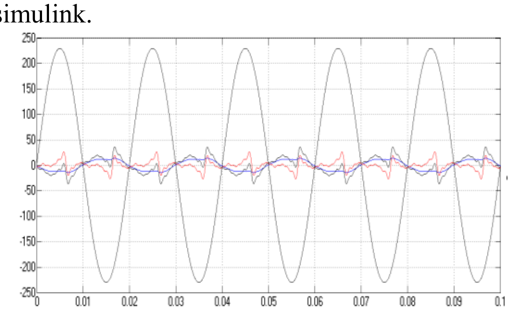

Fig.28: Plots of the $v_{sa}(t)$, $i_{sa}(t)$, $i_{la}(t)$, $i_{ca}(t)$ in p-q Theory

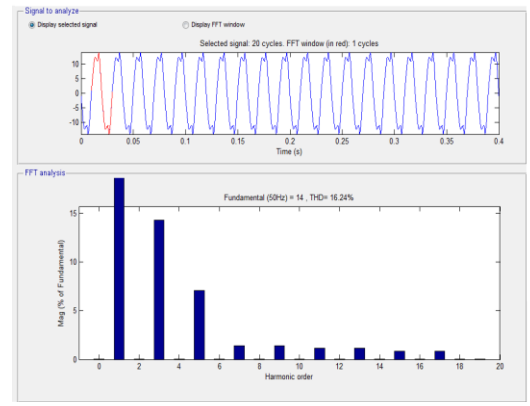

Fig.29: THD of source voltage in FFT analysis in PQ theory

Fig.30 Shows THD of source current is about 16.24% of fundamental component load current is effected by the source current.

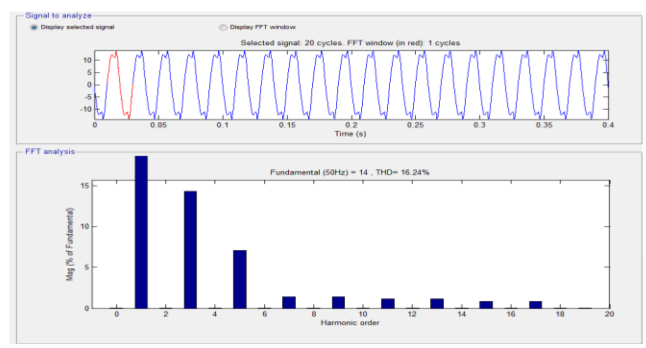

Fig.30: THD of source current in FFT analysis in PQ theory

Fig.31 Shows THD of load current without compensation in FFT analysis in PQ theory .THD of the load current is 67.66% of the fundamental component.

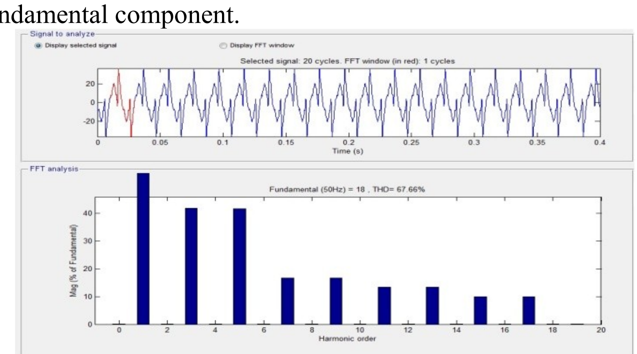

Fig.31: THD of load current without compensation in FFT analysis in PQ theory

Fig.32 Shows THD of load current without compensation in FFT analysis in PQ theory THD of the load current is 5.60% of the fundamental component.

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Volume 04 Issue-17
December 2017

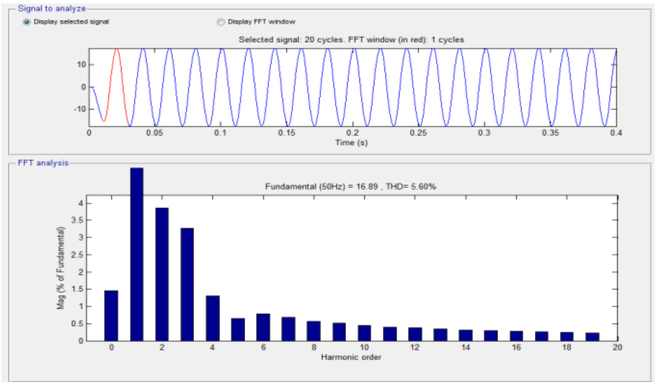

Fig.32 THD of load current with compensation in FFT analysis in PQ theory

IV. CONCLUSION

This task proposes MRC for the control of APF system. The curiosity of this exploration lies in the utilization of MRC for the assurance of amplitude of reference supply current required in an APF system. This exploration additionally examines the control of APF framework utilizing p-q hypothesis. The control techniques of APF system are point by point in the second part of this test. A simulation result brings about the third part exhibit the adequacy of MRC for the control of APF system.

A MRC based APF framework has been displayed and effectively tried for the control of APF. The novelty of this paper lies in the use of MRC to decide the amplitude of the reference source current required in an APF framework. This examination likewise talks about displaying and control of APF system utilizing p-q hypothesis. The execution of the diverse system has been thought about. It has been observed that the convoluted estimations utilized as a part of p-q hypothesis could be eliminated by the utilization of MRC.

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