Abstract---This review provides a survey of shunt active power filter based on inverter in three phase four wire system. These topologies are applied to solve problem due to non linear load in power system network such as a power quality issue, reactive power compensation and harmonic current suppression. In making a review it should be noted that this paper will not attempt to give an all encompassing review of most of the published references. It will rather make an attempt to survey some promising directions and point to the references that can be used as a comprehensive description of those conditions. In order to accomplish its goal this survey will start with a brief overview of the shunt active power filter and how to increase stability of three phase wire system of the survey. Also mention various types of control strategies. Last but not least, the time span covered by this survey should be noticed for the sake of future updates and future references.

I. INTRODUCTION

The widespread increase of non-linear loads nowadays, significant amounts of harmonic currents are being injected into power systems. Harmonic currents flow through the power system impedance, causing voltage distortion at the harmonic currents' frequencies. The distorted voltage waveform causes harmonic currents to be drawn by other loads connected at the point of common coupling (PCC). The existence of current and voltage harmonics in power systems increases losses in the lines, decreases the power factor and can cause timing errors in sensitive electronic equipments. An alternative method to solve or minimize these problems is the use of shunt active power filters (APFs), applied in single-phase and three-phase three-wire and four-wire systems. APFs are used to inject in the line, compensation currents in order to cancel harmonics and/or reactive components of the load currents. For three-phase four-wire systems, depending on the control strategies adopted, the APF can control each phase independently. Thus, it is possible to compensate all the harmonic and reactive current components. In this case, the compensation of the unbalanced load is not taken into account [1] [2] [3] [7].

Use of nonlinear load such as a switching power supplies, inverters, single phase and three phase power supplied, among other, being used in industrial, commercial and residential applications. This load has contributed for the generation of a great content of harmonic and reactive power, which are responsible to contributing power quality degradation. Power quality (PQ) problem arise when non linear load are connected to three phase four wire system. Power system transient, power frequency disturbances, grounding and bounding, electro-magnetic interference (EMI), electro-static discharge (ESD), power factor are also issue of power quality.

Passive LC filter are used current harmonic reduction, which are its simplicity and low cost. However, passive filter have several drawbacks such as large size, tuning and risk of resonance problems. So, four legs active power filter system can solve problems of current harmonics, reactive power, load current balancing and excessive neutral current simultaneously, and can be a much better solution than conventional approach [11].

Figure.1 shows the basic compensation principal of shunt active power filter. It is designed to be connected to be connected in parallel with the non linear load to detect its harmonic and reactive current and to inject into the system a compensating current, identical with the load harmonic current [3].

II. TYPES OF FILTERS

A. Passive Filter
   - Single tuned filter
   - First order high pass filter
   - Second order high pass filter

B. Active Power Filter
   1) Converter-Based Classification
      - VSI (Voltage Source Inverter) bridge structure
      - CSI (Current Source Inverter) bridge structure
   2) Topology-Based Classification
      - Shunt APF
      - Series APF
      - UPQC: Shunt APF + Series APF
      - Hybrid APF: Shunt or series APF + passive filter
   3) Supply-System-Based Classification
      - Two-wire APF
      - Three-wire APF
      - Four-wire APF

Fig. 1: Shunt active power filter
Compensati on
For specific application

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<tr>
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<th>Active power filter topology</th>
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<td></td>
<td>Shunt APF</td>
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<tr>
<td>Current Harmonic</td>
<td>Mode-rate</td>
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<tr>
<td>Reactive power</td>
<td>Fast</td>
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<tr>
<td>Load Balancing</td>
<td>Low</td>
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<tr>
<td>Neutral current</td>
<td>Mode-rate</td>
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<tr>
<td>Voltage Harmonic</td>
<td>Fast</td>
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<td>Voltage Regulation</td>
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<td>Voltage Balancing</td>
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Table: 1 Compensation for application

III. APF CONTROL STRATEGIES

A. First Stage: Signal Conditioning
- Sensing System Information by PT, CT, Isolation Amplifiers
- Monitor, Measure, Record: THD, Power Factor, Active/Reactive Power, Crest Factor.

B. Second Stage: Derivation of Compensating Signal
1) Current level and/or voltage level
2) Frequency domain:
   - Based on Fourier transformation
   - Cumbrous computation, large response time
3) Time domain:
   - Based on instantaneous derivation
   - P-q theory, synchronous d-q reference frames method,
     Synchronous detection method, flux-based controller,
     and Notch filters method.

C. Third Stage: Generation of Gating Signal
Hysteresis, PWM, SVPWM, sliding mode, fuzzy-logic.

IV. RELATED WORK

In paper [1] work describe on the shunt active power filter on both topology, one of the four leg full bridge voltage source inverter and other is three full bridge voltage source inverter for compensation of reactive power and harmonic current. The synchronous reference frame theory is to generate compensation reference current. PI controller use to control current. In three phase full bridge topology two strategies adopted on SRF based. In first strategy the only load harmonic suppression and the load unbalanced current compensation is not in the account. In second strategy load unbalanced current compensation is not in the account. Simulation results are present in order to evaluate the performance of the APFs approaches.

Paper [2] describes causes related to poor power quality. In this paper a control scheme based on PI controller has been proposed for generation of reference current to mitigate the harmonics and neutral current for two different topologies. This methodology offer to implement and increases reliability of the system. Three phase four wire active power filter based on three-leg IGBT inverter, adopted with the dc-link composed by two capacitors connected in split. A disadvantage of this topology is the fact that the size of the dc-link capacitors has to be overdimensioned. The Other topology with four switching-legs was fourth leg provided to return path for neutral conductor. This paper also included significance of D.C. Capacitor. The capacitors are designed to limit the dc voltage ripple to a specified value, typically 1 or 2 %. But in this paper capacitor should be designed for the worst case.

Metin Kesler and Engin Ozdemir in [3] take the performance of Shunt Active Power Filter under Unbalanced and Distorted Load Conditions. LC filter have been use to eliminated harmonic but disadvantage of LC filter are bulky, load dependent, inflexible also resonance problem of the system. Due to above problem of LC filter, Active power filter comes in the structure. Shunt active are connected in parallel with non linear load to detect harmonic and reactive power which is produce into compensating current system.

The control method is based on Instantaneous Reactive Power theory (IRP) or P-q theory. This requires only measuring the source currents to reduce the number of Current Sensors (CSs) needed in the conventional control approach. In the conventional p-q theory based control approach for the shunt APF, the compensation current references are generated based on the measurement of load currents. However, the current feedback from the SAPF output is also required and therefore, minimum six CSs are desired in an unbalanced system. To compensates power quality problem and can also interface renewable energy sources with electric grid with 3-phase 4-wire shunt active power filter present in [4].

The Instantaneous Reactive Power theory is use to control. This paper suggests a new method compensating problem like power factor, current imbalance and current harmonic. A dc-dc converter can be use to adjust the output voltage of renewable energy source then available energy maintain by controller of shunt active power filter. The simulation take in three cases: - Case 1: Active power filter injecting energy in the electric grid. Case 2: Active power filter compensating harmonics, power factor, and injecting energy in the electric grid. Case 3: Active power filter compensating harmonics, power factor, and unbalance and injecting energy in the electric grid.

In paper [5] Lonnie Stitt and Jake Chambers describe shunt active power filter with a control algorithm of unit vector template method. Power synchronous detection for reference current generation is compared. The active power filter designed in PSIM software and control algorithm done in simulink environment. PSIM and MATLAB software is linked by Sim coupler. The capacitor voltage maintained constant by using PI controller.

References [6] of this paper describe the purpose of the shunt active filter is to provide compensation currents such that the source needs to supply balanced (positive-sequence) fundamental source current at unity power factor even though the load consumes harmonic currents as well as positive, negative, and zero-sequence currents. The instantaneous active and reactive power theory introduced by Akagi has been used very successfully to design and control active power filters. Aredes presents general equations that relate the concept of instantaneous active and
reactive power theory and the well-known theory of symmetrical components for the case of three-phase four-wire systems. In the paper novel control approach is the instantaneous power in a three-phase four-wire system is made, design of shunt active filters using the symmetrical component method is described. A major feature of the proposed approach is that symmetrical component transformation is not needed in the control of the active filter. In addition, the power factor of the positive-sequence fundamental component is close to unity and only positive-sequence power is supplied by the source.

Paper [7] include multilevel inverter based shunt active power filter in three phase three wire and four wire system. This paper presents a direct current-space-vector control of an active power filter (APF) based on a three-level neutral-point-clamped (NPC) voltage-source inverter. The proposed control can selectively choose harmonic current components by real-time fast Fourier transform to generate the compensation current. The advantages of three-level VSIs include lower harmonic distortion, lower switching frequency, and lower power loss.

APFs based on three-level inverters are generally more expensive but can be compensated by using smaller filter inductors, assuming the same switching frequency. However, the control of a three-level inverter is more complicated than a two-level inverter because of the large number of inverter switching states. Therefore, there is greater difficulty in synthesizing the voltage reference vector. In this paper, a new current control, based on SV current control, is compared with the stationary αβ-coordinates based control.

Maria Isabel Milanes Montero, Enrique Romero Cadaval and Fermin Barrero Gonzalez are comparing of various control strategies for shunt active power filters in three-phase four-wire Systems in paper [8]. This paper first presents a review of four control strategies p–q method, d–q method, unity power factor (UPF) method, and perfect harmonic cancellation (PHC) method for the extraction of the reference currents for a shunt active power filter connected to a three-phase four-wire source that supplies a nonlinear load. Then a comparison of the methods is made by simulations under both ideal and distorted mains voltage conditions and various load conditions. Also experimental results are presented.

In paper [9] the synchronous reference frame (SRF) strategy is used to generate current reference for compensation and conventional PI controllers can be used as the controller. 2-Level PWM-VSI has been used to implement in this paper. Space Vector modulation (SVM) technique was originally developed as a vector approach to use pulse-width modulation (PWM) for three-phase inverters. SVM technique used to utilize DC bus voltage more efficiently and generates less harmonic distortion in a three phase voltage source inverter.

In paper [10] also describe synchronous reference frame (SRF) strategy is used to generate current reference for compensation of unbalanced non-linear load and neutral current. It can also compensate reactive current and power factor nearly unity power factor.

Finally in [11] Mehmet Ucar and Engin Ozdemir implement control of 3-phase 4-leg APF under non-ideal mains voltage condition. P–q theory base control algorithm is proposed for SAPF. The APF is composed from 4-leg voltage source inverter (VSI) with a common DC-link capacitor and hysteresis–band PWM current controller. In order to show validity of the proposed control algorithm, compared conventional p–q and p–q–r theory, four different cases such as ideal and unbalanced and balanced-distorted and unbalanced-distorted mains voltage conditions are considered and then simulated.

V. OCC OF CONSTANT FREQUENCY SWITCH

For a constant frequency switch, Ts is constant. The object of One-Cycle Control is to adjust the switch ON-time TON in each cycle, such that the integrated value of the chopped waveform is exactly equal to the control reference.

![](image)

Fig. 2: one-cycle constant frequency switch

The implementation circuit for One-Cycle Control of a constant frequency switch is shown in Fig. 2 the key component of the One-Cycle Control technique is the real-time integrator. The real-time integration is started the moment the switch is turned ON by the fixed frequency clock pulse. The integration value,

\[
\psi_{\text{inst}} = \frac{1}{T_s} \int_0^T x(t) dt, \]

is compared with the control signal \(v_{\text{ref},0}\) in real time. At the instant when the integration value \(v_{\text{inst}}\) reaches the control signal \(v_{\text{ref},0}\), the controller sends a command to the switch to change it from the ON state to the OFF state.

At the same time, the controller resets the real-time integrator to zero to prepare for the next cycle. The duty-ratio \(d\) of the present cycle is determined by the following equation:

\[
\frac{1}{T_s} \int_0^{T_{\text{ON}}} x(t) dt = v_{\text{ref}}(t) \]

Since the switch period \(Ts\) is constant and the duty-ratio is controlled, the average value of the waveform at the switch output \(y(t)\) is guaranteed to be

\[
y(t) = \frac{1}{T_s} \int_0^{T_{\text{ON}}} x(t) dt = v_{\text{ref}}(t) \]
VI. EFFECT OF NON-LINEAR LOAD

A. Effect of Non Linear With R-C Load on Source Current ($I_s$)

![Fig. 3:](image)

B. Effect of Non Linear With R-L Load on Source Current ($I_s$)

![Fig. 5:](image)

VII. CONCLUSION

In this paper describe various types of passive filter and active filter. Also studied various control strategies which are control output of shunt active power filter. How the effect of harmonic on power quality and solution given by shunt active power filter for three phase four wire systems. A method will be simulated any software of electrical.

REFERENCES


