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A Short Review Paper on Active Filters

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Abstract:

Quality of power is related to voltage quality of supply. Voltage quality of supply must be clean i.e. pure sinusoidal waveform of constant frequency 50 Hz in our country. But harmonics are introduced in the system because of non-linear loads. It distorts pure waveform, which affects different equipments differently. This paper presents a review on active filters and its classification. It also explains the effects of harmonics. It gives a little information about components of active filters & control strategy. It concludes with some additional features of using active filter for improvement in power quality.

Keywords — **Active filter, Semiconductor Devices, Non-Linear Loads, Harmonics, Power quality improvement.**

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I. INTRODUCTION

Semiconductor devices are one of the most important discoveries. It makes the different operations easily & smoothly controllable and reduces the size of the systems [1, 2]. By proper switching of these semiconductor devices, the transfer of electrical power to loads can be controlled for the desired performance of loads [3-6]. This concept is applied in various places e.g. operations of electric motors in an industry or in electrical power generation plants based on renewable energy sources.

With many advantages of semiconductor devices, it is the main cause of harmonics [7-8]. It is a type of non-linear load. Non-linear loads are responsible for harmonic injection in system and draws reactive power components of current from ac supply mains. Ultimately, the overall system has low efficiency and poor power factor. Traditionally, passive L-C filters were used to eliminate or mitigate the harmonics with limitations of large size, fixed compensation and resonance problem.

The most popular and modern solution is Active filters [9-12]. It provides dynamic and adjustable solutions to power quality problems. This paper gives complete and compact information related to Active filters e.g. Classifications of active filters based on converter, topology used and supply system, control strategies, components of active filter

II. METHODOLOGY

Active filters may be classified based on type of converter used, topology and supply system. There are two types based on converter i.e. VSI and CSI. Series and shunt topology are discussed here. Based on supply system, there are three types i.e. single line-neutral wire (single phase), three wire system (three phases without neutral) and four wire system (three phases with neutral).

A. Converter Based

The CSI (see figure 1) is the current fed PWM inverter. To cancel the harmonic currents due to non-linear load, it works as source of non-sinusoidal current wave. Due to high losses and requirement of high values of parallel ac power capacitors, it can't be used in multilevel modes.

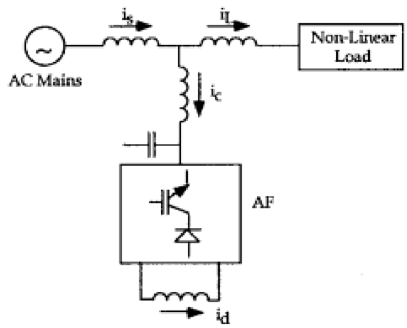

Figure 1: Current fed Active filter

The VSI is the voltage fed PWM inverter given in figure 2. It is lighter, cheaper in cost and has ability to expand to multilevel versions. In the presence of supply mains, this inverter bridge acts as active filter to mitigate/compensate harmonics of critical non-linear loads.

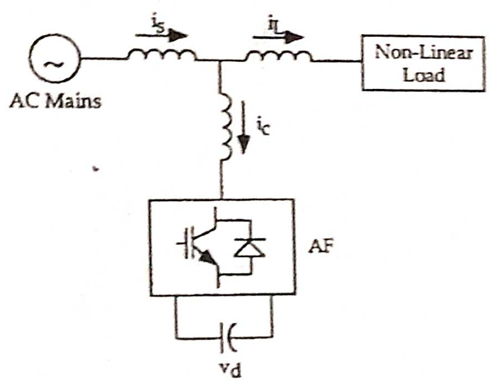

Figure 2: Voltage fed Active filter

B. Topology Based

Series Active filters are connected in series with the mains just before the loads as shown in figure 3. It is responsible for elimination of voltage harmonics and balances & regulates the terminal end voltage of load. It filters out propagation of harmonics due to occurrence of resonance problem.

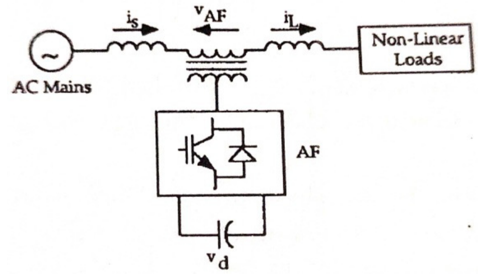

Figure 3: Series type Active filter

Active Shunt filter is connected at the load end. It is applied to remove current harmonics, compensate reactive power and to balance unbalanced currents. It injects current, equal in magnitude but opposite in phase to cancel out harmonics and reactive components of non-linear load current at POC.

UPQC or universal active filter is the combination of series and shunt AF. The DC-link storage element (L or C) is shared between two current source or voltage source bridges operating as active series and active shunt compensators as shown in figure 4. It eliminates the negative sequence currents. It can provide clean power to critical & harmonic-prone loads.

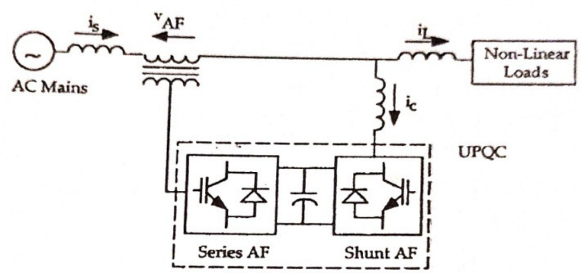

Figure 4: Universal Active filter

Hybrid filters are the combination of series AF and passive shunt filters. It is comparably popular due to reduced size and reasonable cost. (See figure 5)

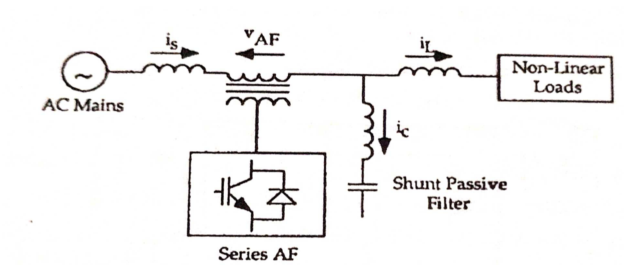

Figure 5: Hybrid filter

C. Supply System Based

Single line - neutral AFs are used in three modes as series, shunt and UPQC. Current source PWM Bridge with inductive energy storage and voltage source PWM Bridge with capacitive dc bus energy storage elements are used to form Single line - neutral AFs circuits. (See figure 6)

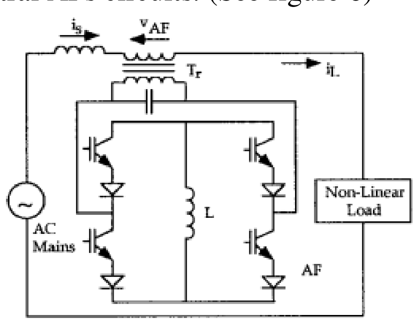

Figure 6: Single line - neutral AFs with CSI converter

Active shunt AF is designed with three single phase AF with isolation transformers for proper voltage matching, independent phase control and reliable compensation with unbalanced systems.

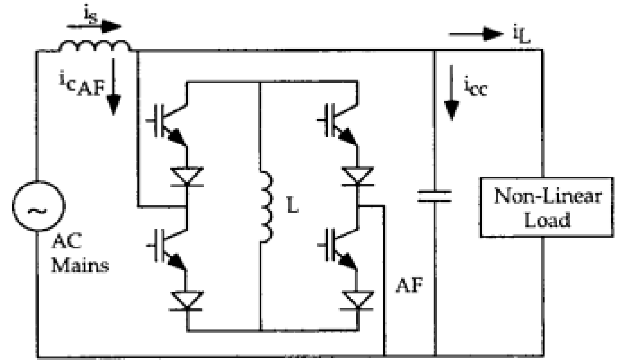

Figure 7: Two-Wire shunt AF with CSI converter.

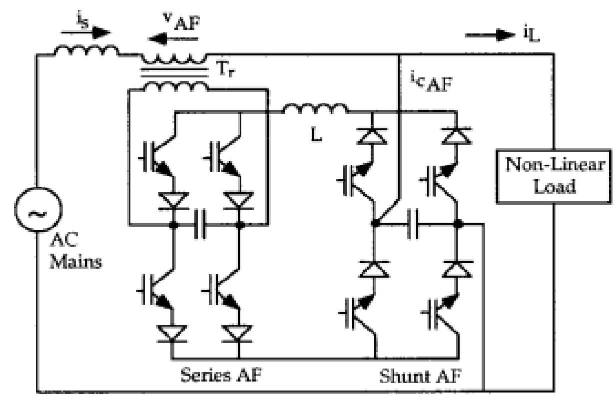

Figure 8: Two-wire UPQC with CSI converter.

Many single-phase loads may be supplied from three phase mains supply with neutral conductor to prevent it from huge neutral current, harmonic & reactive power burden and imbalance.

III. CONTROL STRATEGY

The working operation of active filters is controlled by these strategies. It is implemented in three stages as given in figure 9.

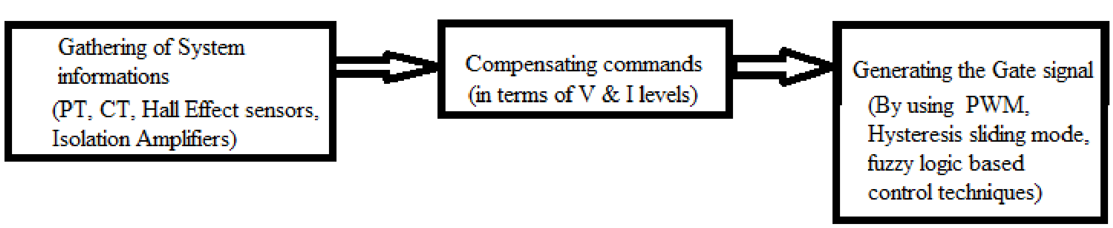

Figure 9: Flow of control strategy

IV. ACTIVE FILTER COMPONENTS

The main component of AF is the solid state device itself. This device starts from diode to BJTs followed by MOSFETs used for small rating applications. For medium ratings, IGBT is used and for higher ratings, GTO (gate turn-off thyristor) is used.

A series inductor is also installed at input between the supply terminal voltage and PWM voltage. The value of series inductor should be optimum to obtain achieve satisfactory performance of the AF. The DC-Bus capacitor value of the AFs is another important parameter in designing of AF.

V. EFFECTS OF HARMONICS

Harmonics affects differently on different equipments and parameters.

Power Factor:

It decreases as harmonics increases in system. The overall reactive power demand increases due to increase in harmonics content. But the effective real power is same. So, equipments with higher ratings are required for protection and distribution network.

Cable\Conductor losses:

Additional reactive current drawn from source is responsible for added cable losses at the conductor.

Skin Effect:

Skin Effect increases with frequency, so, higher order harmonics currents can cause added losses and requires for over-sizing of conductors.

Motors and Generators:

Core losses increase with harmonics as Eddy current losses depend on square of the frequency. Copper losses increases, as it depends proportionally to THD of current value and frequency. Negative sequence harmonics motor vibration, added heat, need for de-rating, etc.

Transformers:

Triplen harmonics in the neutral conductor of a Δ-Y distribution transformer can dangerously overheat them. There is also a potential risk of resonance between transformer inductance and supplied capacitive loads, at the harmonics frequencies. Laminated transformers cores can also vibrate at certain harmonic frequencies, causing audible noise and overheat. Transformer windings can be affected also by Proximity Effect causing the current distribution to the more distant areas of these two conductors. This effect of reduced effective area and is proportional to frequency, so for higher order harmonics the AC resistance of winding conductors will be further increased, i.e. added losses.

Flicker:

Voltage harmonics and inter-harmonics supplying lighting circuits can cause fluctuations of light intensity, affects performance of incandescent and fluorescent lamps.

Circuit breakers and fuses:

Thermal-magnetic tripping mechanism in circuit breakers responds proportionally to RMS current, a highly distorted current signal (Irms much higher than the fundamental I1) can cause unwanted MCB's tripping, or need to oversize them. Also, circuit-breakers, which are designed to interrupt current at zero crossing, can meet in the case of much distorted current premature interruption of the circuit. Similarly for fuses, the higher the RMS current, the higher the heating effect of that current in the fuse, so faster the fuse will act. Then, for the case of non-linear loads, it may be necessary to de-rate fuse selection.

VI. CONCLUSION

With increase in use of semiconductor power control devices (e.g. diodes, transistors, MOSFETs, Thyristors etc.), harmonic pollution increases in system and can cross the tolerable limits. But, using of Active filters improves Power quality (improve the voltage profile) with additional effects of compensation of reactive power, load balancing, regulation of voltage and voltage imbalance compensation. Many configurations of AFs are available to improve power quality. It also helps in compensating harmonic currents, neutral current and unbalance current. It can be observed that, to limit the distortion in system due to non-linear loads, semiconductor devices are needed to be used, which itself is a non-linear load.

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