CHAPTER THREE

ACTIVE FILTER

3.1 Introduction

Active filtering is a new technology that uses intelligent circuits to measure harmonics and take corrective actions. Either active filters use the phase cancellation principle by injecting equal, but opposite harmonics, or they inject/absorb current bursts to hold the waveform within an acceptable tolerance of sinusoidal.

They are much more expensive than passive filters, but they have some great advantages. For example, they do not resonate with the system. Because of this advantage, they can be used in very difficult parallel resonance spots where passive filters cannot operate successfully.

They are very useful for large distorting loads fed from somewhere weak points on the power system. Also, they can be used for more than one harmonics at a time and are useful against other power quality problems such as flickers.

The main idea is to replace missing since wave portion in a nonlinear load. In an active filter, an electronic control monitors the line voltage and/or current, switching the power electronics very precisely to track the load current or voltage and force it to be sinusoidal. Either an inductor is used to store up current to be injected into the system at the appropriate instant or a capacitor is used instead. As a result, the load current is distorted as demanded by the nonlinear load but the current seen by the system is much more sinusoidal. Active filters correct both harmonics and PF of the load [1].

3.2 Active Filter Configuration

The active filter uses power electronic switching to generate harmonic currents that cancel the harmonic currents from a nonlinear load. The active filter configuration investigated is based on a pulse-width modulated (PWM) voltage source inverter that interfaces to the system through a system interface filter as shown in Figure 3.1 in this configuration; the filter is connected in parallel with the load being compensated. Therefore, the configuration is often referred to as an active parallel filter. The dc capacitors and the filter components must be rated based on the reactive power associated with the harmonics to be canceled and on the actual current waveform (RMS and peak current magnitude) that must be generated to achieve the cancellation.

The current waveform for canceling harmonics is achieved with the voltage source inverter and an interfacing filter. The filter consists of a relatively large isolation inductance to convert the voltage signal created by the inverter to a current signal for canceling harmonics. The rest of the filter provides smoothing and isolation for high frequency components. The desired current waveform is obtained by accurately controlling the switching of the insulated gate bipolar transistors (IGBTs) in the inverter. Control of the current wave shape is limited by the switching frequency of the inverter and by the available driving voltage across the interfacing inductance.

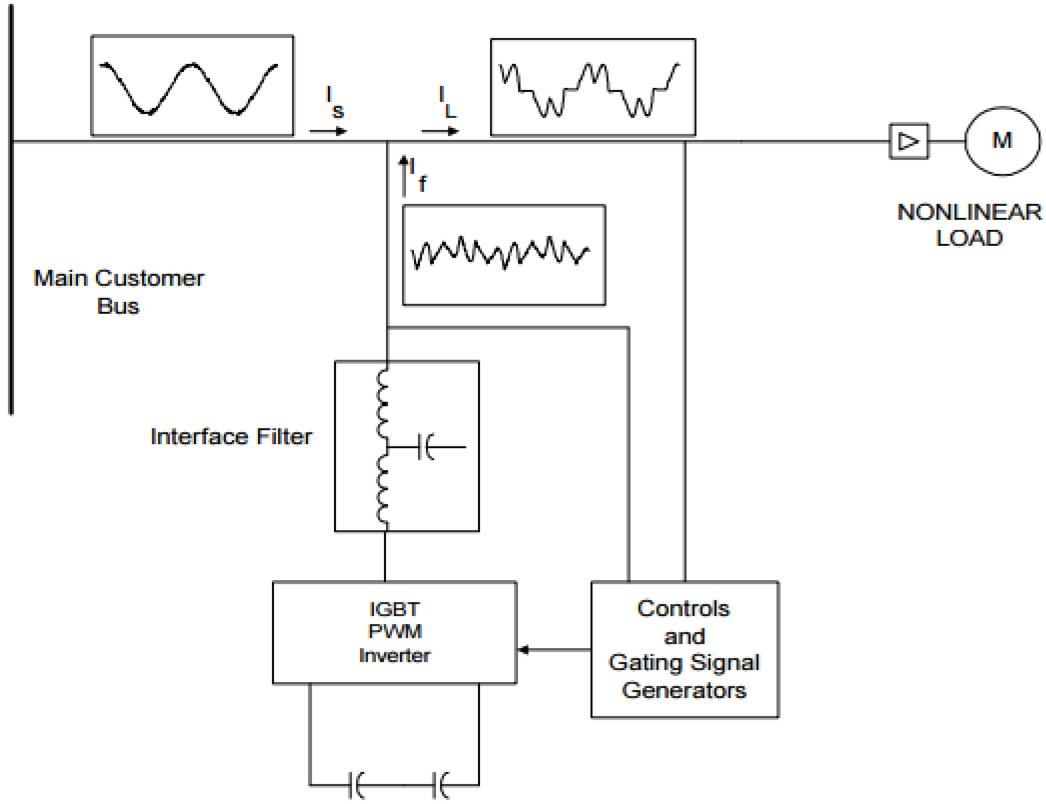

Figure 3.1: Illustrating components of the shunt connected active filter

The voltage source inverter used in the active filter makes the harmonic control possible. This inverter uses dc capacitors as the supply and can switch at a high frequency to generate a signal which will cancel the harmonics from the nonlinear load. One leg of the inverter is shown in Figure3.2 to illustrate the configuration.

The active filter does not need to provide any real power to cancel harmonic currents from the load.

The harmonic currents to be canceled show up as reactive power. Reduction in the harmonic voltage distortion occurs because the harmonic currents flowing through the source impedance are reduced [6].

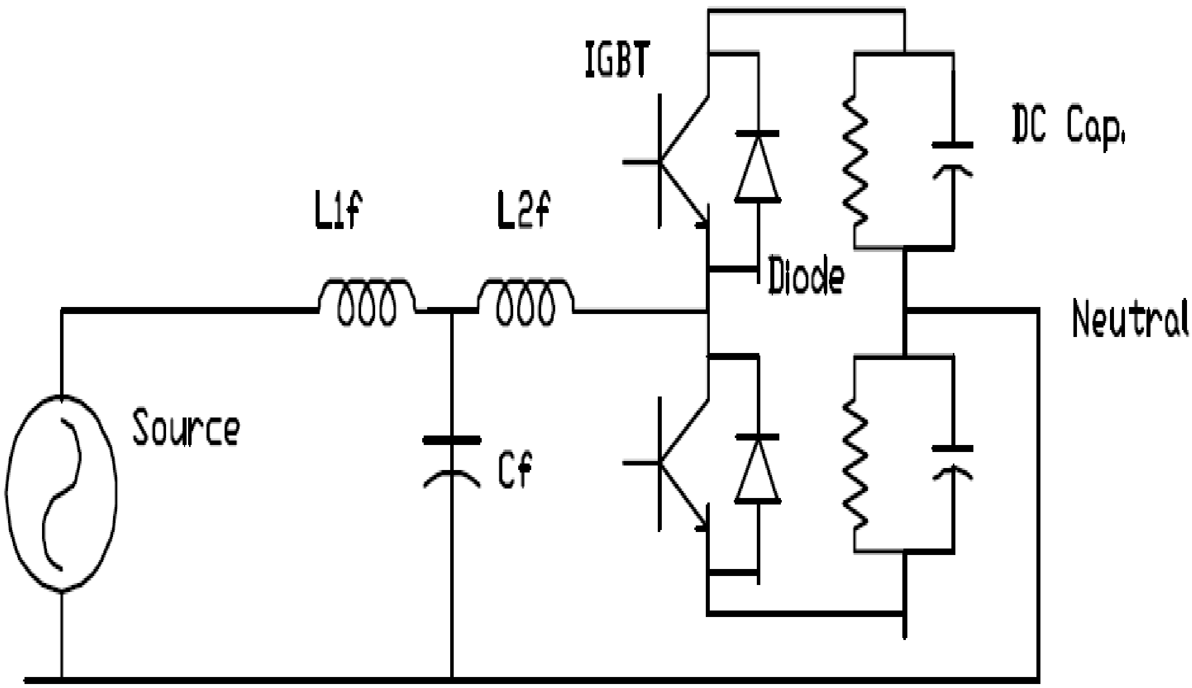

Figure 3.2: One line diagram for one leg of the active filter

3.3 Comparison of passive filter and active filter

Active and passive power filters are differentiated by the passivity of the components used in the filter circuit. If a component consumes power or incapable of power gain then it is known as a passive component. Components that are not passive are known as active components. Active filter can be used in very difficult circumstances where passive filters cannot operate successfully because of parallel resonance problems, they can also address more than one harmonic at a time and combat other power quality problems such as flicker. They are particularly useful for large, distorting loads fed from relatively weak points on the power system, the table below shown the main differences between active and passive power filter:

Table 3.1: Comparison of passive filter and active filter

	Passive filter	Active filter
Harmonic control by order	Very difficult	Possible via parameters
Harmonic current control	Requires filter for each frequency	Simultaneously monitors many frequencies
Dimension	Large	Small
Weight	high	Low
Influences of a frequency variation	Reduced effectiveness	No effect

3.3.1 Advantages of active filter over passive filter:

1. Active filter do not resonate with the system where as passive filters resonate with system.
2. They can work independently of the system impedance characteristics and therefore they can be used in very difficult circumstances where passive filters cannot operate successfully because of parallel resonance problems.
3. They can address more than one harmonic at a time and fight with other power quality problems also.
4. They can be programmed to correct harmonics as well as power factor.

3.4 Active filter Types

Active filters are relatively new types of devices for eliminating harmonics. They are based on sophisticated power electronics and are much more expensive than passive filters. However, they have the distinct advantage that they do not resonate with the system. Active filters can work independently of the system impedance characteristics. Thus, they can be used in very difficult circumstances where passive filters cannot operate successfully because of parallel resonance problems [7].

3.4.1 Shunt active filters

It is the most widely used and dominant form of APFs to compensate the load current harmonics and reactive power as well. It is connected in parallel to the distribution supply at PCC and it injects harmonic current that is equal in magnitude to the load harmonic current but having 180 degree phase shift to cancel out the load current harmonics and the source current becomes sinusoidal. Figure 3.3shows the system configuration of shunt active filter design. For an increased range of power ratings, several shunt active filters can be combined together to withstand higher currents. This configuration consists of four distinct categories of circuit, namely inverter configurations, switched capacitor circuits, lattice structured filter and voltage regulator [8].

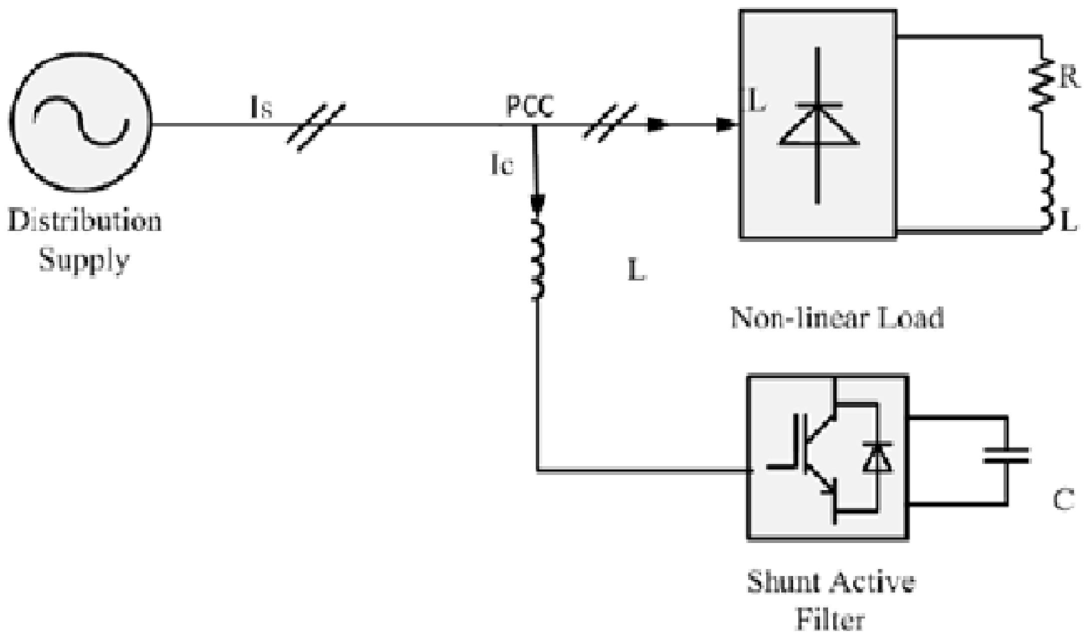

Figure 3.3: Shunt active filter connection to the network

3.4.2 Series active filter

The series active power filter is connected in series with the utility by a matching transformer. Normally, the series active power filter is suitable for harmonic compensation of a voltage harmonic source such as diode rectifier with a DC link capacitor. In general, series active filters are less commonly used against the shunt design. Unlike the shunt filter mainly carries compensation current, the series circuit has to handle high load currents. This causes an increased rating of the filter suitable to carry the increased current. Figure 3.4 shows the system configuration of series active filter design [8].

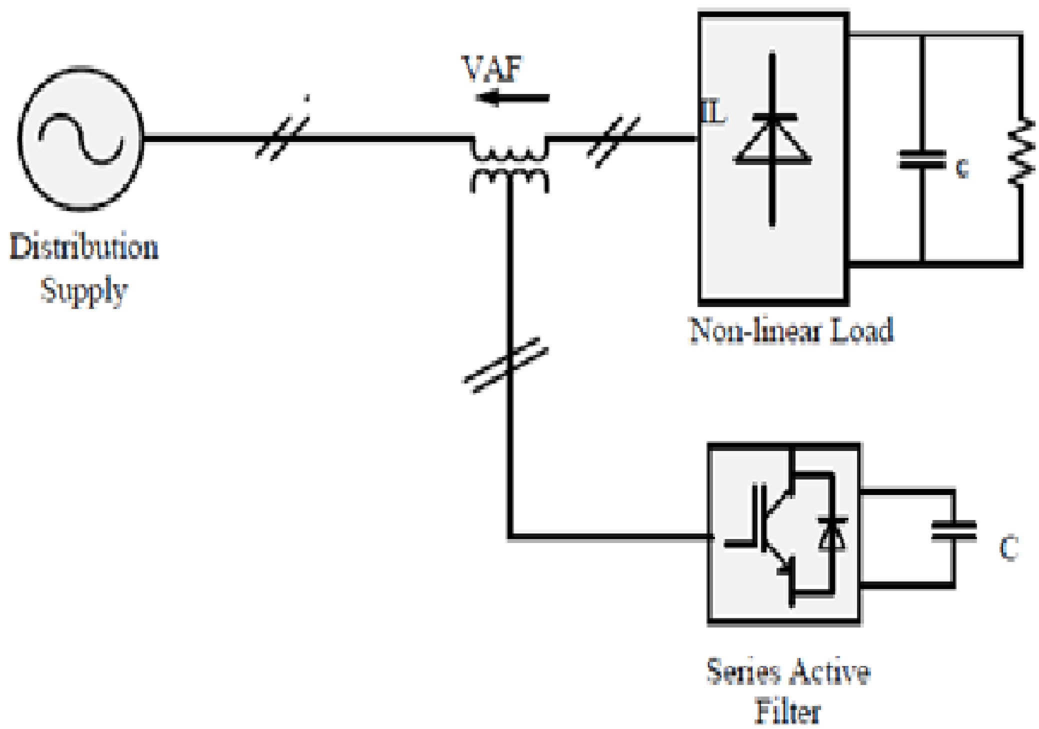

Figure 3.4: Series active filter connection to the network

3.4.3 Hybrid Active-Passive Filters

The application of hybrid passive-active filters may be considered as an alternative to the use of shunt active filters as shown in Figure 3.5. For example: on installations needing large amounts of harmonic cancellation. The use of passive filter elements is often seen as a means to reduce the current rating of the active filter while still retaining the benefits. In return, the connection of an active filter to a passive filter can eliminate the disadvantages of conventional passive filters (i.e., the possibility of resonance in a power system and the effects on the performance of a passive filter should the load characteristic or source impedance change).

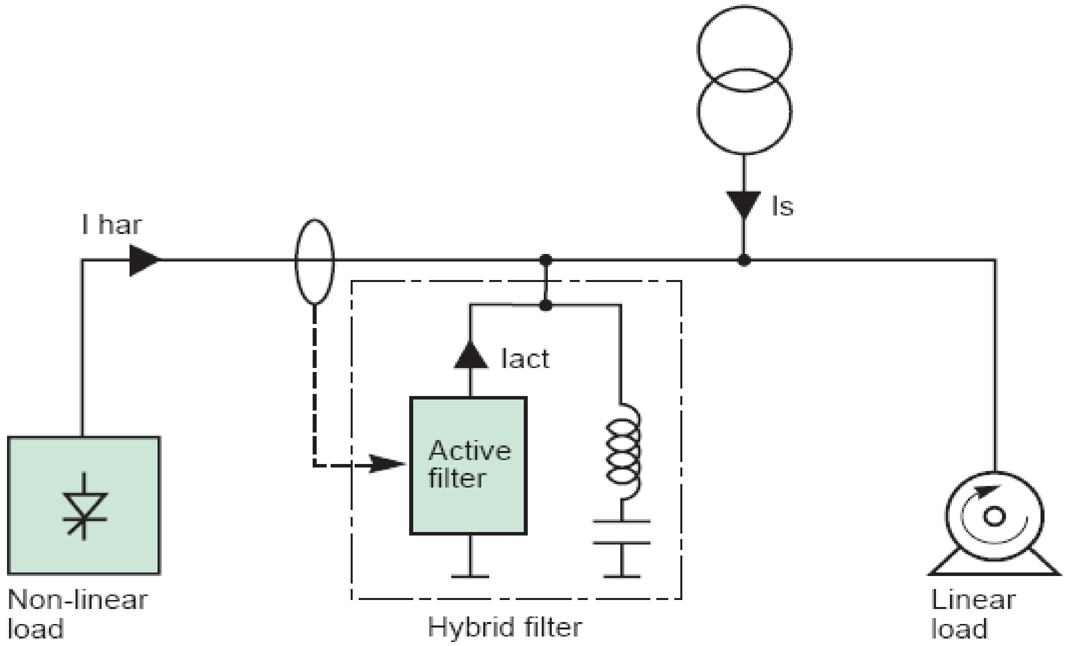

Figure 3.5: Hybrid active-passive filters connection

There is a misconception regarding the operation of hybrid shunt passive-active filters using "standard" industrial active filters. It is assumed that the passive filter, tuned to the 5th and 7th harmonic, removes the majority of those harmonics and, therefore, the active filter only has to be rated, based on the filter's rated current, to provide harmonic cancellation for the 11th harmonic and above. However, it is usually not possible using "standard" shunt active filters due to thermal considerations [8].

3.5 Control Techniques Used for Active Power Filter

The control scheme is based on a cascade control with a current control in the inner loop without mains voltage sensors. The current controller sets the output voltage of the voltage source inverters for each sampling period of the control system so that the line current has a reference value. The voltage controller allows the dc voltage to have an almost constant value. The output signal of the dc-link voltage controller determines the value of the active current of the mains load and losses of the power unit of the restoring system. The reactive current is calculated by the reactive power and flicker estimation module of the control unit [8].

3.5.1 Current control:

The control value of the current control loop is the supply current. This current is a result of the sum of the measured load current and the ac current of voltage inverter. These two three-phase system currents are added together and then are transformed to a signal of the two-phase quantities i_{Sa}, i_{Sb}. In Figure3.6 this current is represented as i_{Sa} and i_{Sb}. The reference value for the current controller i_{ref} d,q (d and q components) is transformed to the stationary reference frame a-b. The transformation of the vector i_{ref} d q, to the vector i1a b, is executed by e^{jw1t}, derived from a phase locked.

The selection of the switching sequence for every switching operation of the both voltage source inverters is achieved through the use of a sliding mode controller.

It is possible to control the active filter without mains voltage sensors. It significantly simplifies the hardware configuration of the active mains compensator, especially for medium and high voltage applications.

The output signals of two P-controllers with saturation represent two components of the mains voltage vector u_{Wa}, u_{Wb} which are used to detect the position of the voltage vector by PLL.

To control harmonic amplitudes in the network, the harmonic calculator is used. The principle of the operation is based on the direct harmonic control method [8].

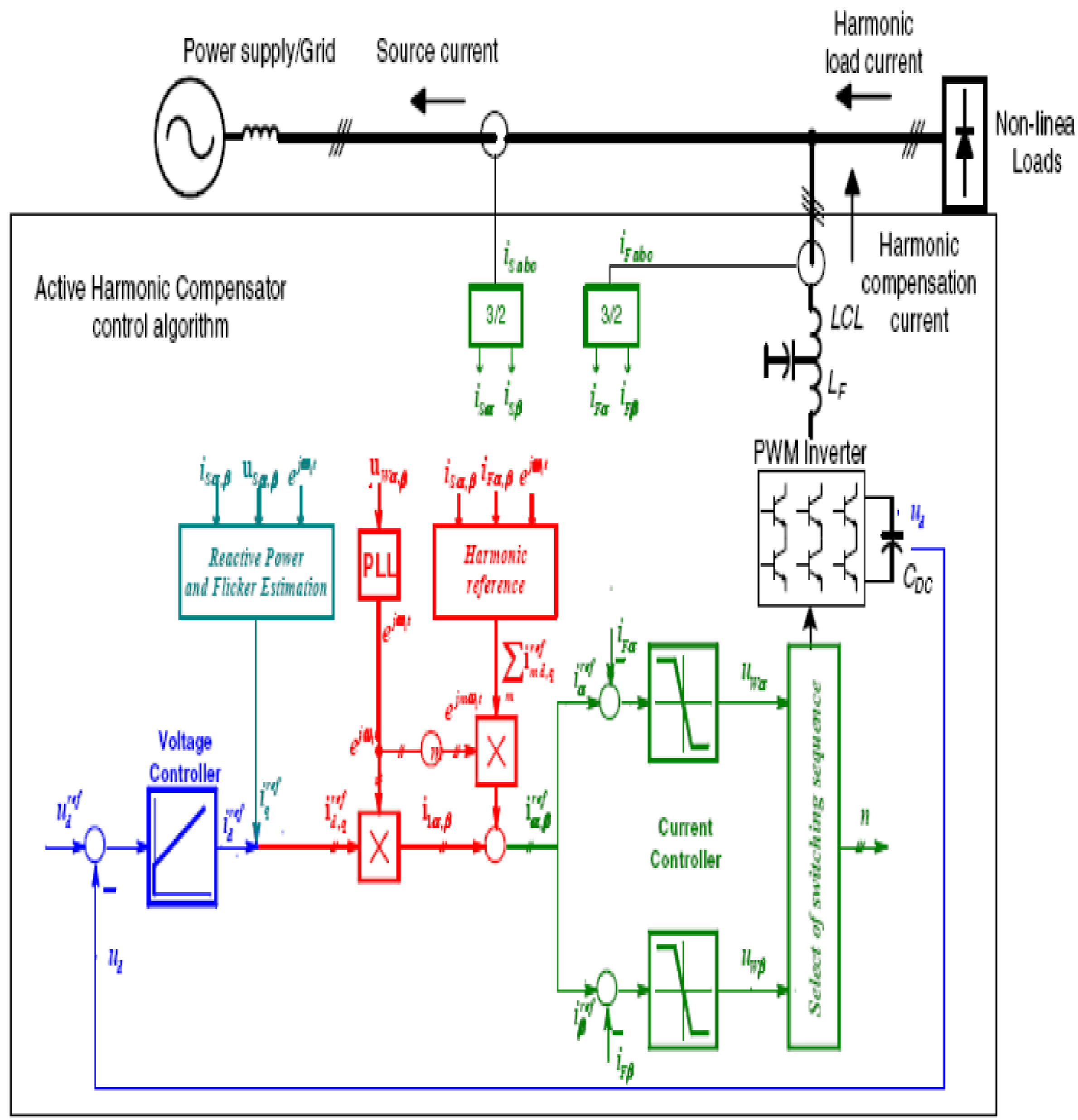

Figure 3.6: Block diagram of the control unit

3.5.2 DC-link Control:

With non-sinusoidal mains current of the voltage inverter, the dc-link voltage contains not only a ripple from transistor switching operations, but also a low frequency voltage ripple like the dc voltage at the dc link of the diode rectifier with capacitor. This low frequency voltage ripple must be filtered in the control loop by feeding back the dc voltage otherwise this voltage ripple would be increased by the proportional part of the voltage controller and it would be passed on to the line current control loop. Therefore the line currents would be distorted.

To decrease the influence of the dc-link voltage ripple on the current control loop, the cut-off frequency of the feedback low-pass filter must be $f0=50\div75$Hz. The low cut-off frequency of the feedback filter causes the large [8].