CHAPTER 3

UNIVERSAL ECONOMIC HYBRID POWER QUALITY CONDITIONER

3.1 INTRODUCTION

A tuned passive filter will be designed to improve the power factor and to reduce the harmonic content in industries conventionally. The passive filters do not give effective solutions because these filters result in resonance. Also, the passive filter is not suitable for the industries in which the load keeps varying. The active filters are more effective, but the cost is relatively high. The hybrid filters are more effective for high–power, non–linear loads. These filters compensate harmonic distortion, unbalanced and reactive power and are cost effective because of the reduction in kilovolt ampere rating of power electronic devices.

Various combinations of shunt passive and series active filters are proposed to improve the power quality on the source side. But these types of filters may be very costly for the high rated industries.

Proposing power quality conditioner for each equipment may lead to high cost for the whole industrial sector.
Hence, a Universal Economic Hybrid Power Quality Conditioner is proposed which is the modified version of the power quality conditioner having the combination of Active filter, Thyristor Controlled Reactor and Passive Filter as a common solution for the commercial and the industrial sector. The passive filter used is tuned for 5\textsuperscript{th} harmonic filtration. The reactive power compensation is done by the Thyristor Controlled Reactor and it is connected in parallel with the tuned passive filter. The active filter's rating decreases due to use of Thyristor Controlled Reactor and passive filter. The active filter is used to improve the filtering characteristics and reduce the harmonic content.

3.2 UNIVERSAL ECONOMIC HYBRID POWER QUALITY CONDITIONER

The proposed Universal Economic Hybrid Power Quality Conditioner has an Active filter and a parallel combination of a Passive filter and a Thyristor Controlled Reactor. The proposed system is represented through a block diagram and is shown in Figure 3.1. The 5\textsuperscript{th} order harmonics is compensated through the passive filter. The reactive power compensation is achieved through the Thyristor Controlled Reactor. The Active filter improves the filtering performances. The usage of TCR in the proposed system reduces the rating of the Active filter. On reducing the Active filter’s rating, the overall cost of the compensation is remarkably reduced even when used for very high rated loads.
In order to derive the triggering pulses for the TCR, the power factor is calculated from the source voltage and source current. With the calculated power factor, the source current and the reference value of the power factor, the values for the triggering pulses are calculated and the triggering pulses are generated using the PWM generator. In order to drive triggering for the active filter, the active power and the reactive power are calculated from the source voltage and load current. The power loss is calculated from the value of DC voltage at the active filter. Using the calculated active, reactive power, power loss and the present active filter current, the triggering pulses are calculated. Triggering pulses for active filter are generated through PWM generator. The schematic diagram of the Unified Economic Hybrid Power Quality Conditioner is shown in Figure 3.2.
Figure 3.2 Schematic Circuit of UEHPQC
Figure 3.3 Control circuit of the proposed Power quality Conditioner
The proposed control circuit for the proposed power quality conditioner is shown in Figure 3.3. The triggering pulses for active filter and TCR are derived through the PI controller along with the PWM generator. The power loss is calculated through the controller. Active power and reactive power are calculated from the source voltage and source current using PQ Calculator. The active power is passed through the low pass filter and is summed with the calculated power loss. Using the calculated power loss, source voltage and load current, computed reference current for compensation is calculated through the compensation current calculator. The calculated reference current is compared with the existing compensation current and the source current. The triggering pulses for the TCR and Active filter are generated.

3.3 MATHEMATICAL MODELLING OF THE PROPOSED CONDITIONER

The mathematical modeling equations of the shunt hybrid filter and the Thyristor controlled reactor used in the proposed conditioner are discussed.

3.3.1 Shunt Hybrid Filter

The equations using Kirrchoff’s voltage law in reference frame are

\[ V_1 = V_{CP1} + V_{LP1} + V_{RP1} + V_{C1} \]  
\[ V_2 = V_{CP2} + V_{LP2} + V_{RP2} + V_{C2} \]  
\[ V_3 = V_{CP3} + V_{LP3} + V_{RP3} + V_{C3} \]  
\[ V_{CP1} = V_{LT1} - C_{P1} L_{T1} \frac{\partial^2 V_{CP1}}{\partial t^2} \]
\[ V_{CP2} = V_{LT}^2 - C_{P2}L_{T2} \frac{\partial^2 V_{CP2}}{\partial t^2} \] (3.5)

\[ V_{CP3} = V_{LT3} - C_{P3}L_{T3} \frac{\partial^2 V_{CP3}}{\partial t^2} \] (3.6)

The switching sequence of the converter \( C_n \) is 1 when \( S_n \) is on and \( S_{6-n} \) is off and is 0 when \( S_n \) is off and \( S_{6-n} \) is on.

\( V_{CK} \) is depends on the switching state \( K_{SP} \) and can be defined as

\[ = \left( C_n - \frac{1}{3} \sum_{p=1}^{3} C_P \right) S \] (3.7)

In ac current and voltages, if zero sequence is absent, the equations are transformed to

\[ V_{LP1} = -V_{RP1} - K_{n1}V_{dc} - V_{CP1} + V_1 \] (3.8)

\[ V_{LP2} = -V_{RP2} - K_{n2}V_{dc} - V_{CP2} + V_2 \] (3.9)

\[ V_{LP3} = -V_{RP3} - K_{n3}V_{dc} - V_{CP3} + V_3 \] (3.10)

\[ i_{dc} + \frac{V_{dc}}{R_{dc}} = \sum_{i=1}^{3} K_{ni}i_i \] (3.11)

3.3.2 TCR

\[ V_1 = V_{LT1} + V_{LP1} + V_{RP1} + K_{n1}V_{dc} \] (3.12)

\[ V_2 = V_{LT2} + V_{LP2} + V_{RP2} + K_{n2}V_{dc} \] (3.13)

\[ V_3 = V_{LT3} + V_{LP3} + V_{RP3} + K_{n3}V_{dc} \] (3.14)

On Park’s theorem

\[ V_{LT}(\theta) = V_{LTq}(\theta) + V_{LPq} - V_{LPd} - V_{RPd} + K_nV_{dc} + V_q \] (3.15)
To control the reactive current

\[ V_{LTq} = \frac{di_{LTq}}{dt} = S(\theta)\omega \left[ -V_{LPd} - V_{LPq} - V_{RPq} - K_n v_{dc} \right] \]  \hspace{1cm} (3.16)

where \( S(\theta) \) is susceptance

The Susceptance is given by

\[ S(\theta) = S \frac{2\pi - 2\theta + \sin(2\theta)}{\pi} \]  \hspace{1cm} (3.17)

Where \( S = \frac{1}{L_P \omega_0} \) \hspace{1cm} (3.18)

3.4 SUMMARY

The Universal Economic Hybrid Power Quality Conditioner is proposed by combining an Active filter, a Thyristor Controlled Reactor and a Passive Filter as a common solution for the commercial and industrial sectors. This Universal Economic Hybrid Power Quality Conditioner has been analysed and studied. Also, the mathematical modelling of the proposed UPHPQC has been discussed.