Abstract

In the last few years, the electric utilities have been imposing greater power factor restrictions to their customers in order to achieve better performance in their electric networks. If the limits are violated, the customers are charged for excess reactive power. Use of capacitors for correcting the power factor is well known in the industry but it may cause unwanted resonance with the supply utility. Also, this is unable to exactly compensate the variable fundamental reactive power demand by the load. So thyristor-controlled reactor, thyristor-switched capacitors and combination of both came into picture for reactive power compensation. These equipments generate harmonics by their inherent nature of operation. The increase of harmonic sources in industrial power system is heightening the risk of harmonic pollution and consequently a drastic decrease in electric power quality. So it is important to assess the harmonic pollution prevailing in any industrial plant and to take preventive measures to get rid of it. An *Optimum Harmonic Load Compensator* (OHLC) is suggested to increase the efficiency of industrial facility by improving (i) the power factor, (ii) reducing the voltage and current harmonic distortions within acceptable limits specified by various Standards and (iii) by maintaining the system voltage.

The problem of nonlinear load compensation and harmonic filtering requires the study of the system consisting of source, nonlinear load and compensation circuits. The analysis with an analytical approach would be very complex and impractical. Accepted solution can be obtained by computer simulation. The philosophy and technique adopted in the present research work is to develop a full fledged digital simulator for analyzing an industrial facility for harmonic load compensation. So the digital simulator CAD-OHLC (*Computer-Aided Design of Optimum Harmonic Load Compensator*) is developed which suggests an optimum harmonic load compensator with the help of system formulation and numerical optimization so that optimum performance from the compensating circuit can be achieved.

The suggested optimum harmonic load compensator has two goals, (i) to com-

pensate fundamental non-active power required by the nonlinear variable load with the help of a thyristor-switched reactor, and (ii) to suppress the generated harmonics by load circuit as well as the compensation circuit by allowing them pass through a minimum impedance path offered by harmonic power filter circuit. The first objective is fulfilled with a suitable control algorithm to operate the thyristor-switched reactor for supplying required fundamental non-active power and the second objective is fulfilled with the proper selection of harmonic power filter configuration and its parameters. The selection of filter circuit configuration is done by assessing the harmonic level present in the facility and choosing the corresponding topology. In recognition of the need to simulate different topologies of the filter circuit the digital simulator is made to formulate the complete system automatically from the topological information and simulate it using an efficient and effective numerical method for harmonic analysis. From the system conditions and harmonic information a suitable filter circuit is chosen, the parameters of which are optimized numerically by defining an objective function to fulfill the goals predefined.

During the analysis care has been taken to consider the periodic stability of the system which becomes an important concept in the presence of periodic operation of nonlinear elements like power electronic devices and harmonics. A case study is undertaken to verify the principles and techniques used by the digital simulator. In the present work a Voltage Chopper Controller with a series R-L load is considered for the case study. The back-to-back connected thyristors make the circuit nonlinear in nature and for this circuit an optimum harmonic load compensator is designed and the performance is evaluated. As a first case the single-phase voltage chopper controller is considered in a single-phase supply. It can be seen that the OHLC makes a good compromise between the economy and performance of industrial plant. After successfully designing, simulating and analyzing the Optimum Harmonic Load Compensator in case of single phase, it is incorporated in three phase system where this single phase voltage chopper controller load circuit offers the supply system an unbalanced load structure. The load equalization technique is successfully implemented which brings the system to a balanced condition with the optimized parameters of compensating and filtering subsystems.

A proto-type optimum harmonic load compensator is developed in the laboratory for experimental verification of the designed parameters offered by the digital simulator developed. An Intel Pentium Personal Computer (100MHz) with in-built coprocessor support is used in conjunction with digital control circuits to verify the operational effectiveness as well as the improvement of quality of power. The measuring devices and triggering pulse transmission are implemented by analog hardware

but, all other functions are implemented using the digital circuits and personal computer. Real time control software is written in assembly language for Intel Pentium platform, which is made modular in nature for better portability and re-usability. The sensitivity of supply current with the limited variation of supply impedance and power filter components are also studied. The stability analysis of the whole system is also carried out.

Key words: Harmonics, harmonic load compensation, thyristor-switched reactor (TSR), harmonic power filter (HPF), digital simulation, optimum harmonic load compensator (OHLC), state variable formulation, periodic stability.