ANALYSIS, DESIGN AND DEVELOPMENT OF SOME CUSTOM POWER DEVICES FOR POWER QUALITY ENHANCEMENT

By

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CERTIFICATE

This is to certify that the thesis entitled "Analysis, Design and Development of Some Custom Power Devices for Power Quality Enhancement", being submitted by Mr. Jayaprakash P for the award of degree of Doctor of Philosophy, is a record of bona fide research work carried out by him in the Centre for Energy Studies of Indian Institute of Technology, Delhi.

Mr. Jayprakash P has worked under our supervision and has fulfilled the requirement for the submission of this thesis, which to our knowledge has reached the requisite standard. The results obtained here in have not been submitted in part or full to any other university or institute for award of any degree.

Dated: Signature of supervisors

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ABSTRACT

The upcoming use of sensitive and critical equipments in the distribution system has resulted in the awareness of the *power quality* (PQ) issues. The PQ problems are the concern for both the electric utilities and end users of the electric power. The PQ problems in the ac current include high reactive power burden, harmonics currents, poor voltage regulation, unbalanced loads and excessive neutral current. The PQ problems in the voltage are sag, swell, unbalance and harmonic distortion in the supply voltages. The group of devices used for power quality enhancement is called by the generic name *Custom Power Devices* (CPDs). The CPD includes shunt connected *Distribution Static Synchronous Compensator* (DSTATCOM) for improving the power quality of the current, series connected *Dynamic Voltage Restorer* (DVR) for mitigating the power quality problems in the voltage and the *Unified Power Quality Conditioner* (UPQC) is a combination of series and shunt active devices. The UPQC is used to reduce both current and voltage based power quality problems. The custom power devices enhance the quality and reliability of the power that is delivered to customers.

The unplanned expansion of distribution system and the increase of non-linear loads drawing non-sinusoidal currents have resulted in excessive neutral current in the distribution system. The neutral conductor is overloaded resulting in busting of it. The passive devices such as a zig-zag transformer and a star/ delta transformer are reported in the literature to mitigate the neutral current in the source neutral conductor. Some new methods for the neutral current compensation are developed based on transformer magnetics such as a T-connected transformer, a star/hexagon transformer and a star/polygon transformer. These methods are designed, modelled and their performance is simulated and then tested with hardware prototypes in the laboratory environment and a comparison is carried out with the existing techniques of the neutral current compensation.

The various control algorithms and topologies of three-phase three-wire and three-phase four-wire DSTATCOM are investigated for load compensation. The control strategies such as *synchronous reference frame theory* (SRFT) and Adaline based *neural network* (NN) are studied by simulation as well as by hardware implementation in the laboratory environment using dSPACE processor and *insulated gate bipolar transistor* (IGBT) based *voltage source converter* (VSC). The three-phase four-wire DSTATCOM is tested for reactive power compensation, harmonics elimination, load balancing and neutral current compensation. The proposed new topologies of three-phase four-wire DSTATCOM include configurations of isolated and non-isolated 3-leg VSC with transformers such as a zig-zag transformer, a star-delta transformer, a T-connected transformer, and a star-hexagon transformer. Similarly, another set of topologies of DSTATCOM are with isolated and non-isolated two-leg VSC with transformers such as a zig-zag transformer, a star-delta transformer, a T-connected transformer and a star-hexagon transformer. A comparison of the above topologies is carried out to identify the suitable topology of DSTATCOM considering reduced complexity and the cost for a given application.

An active series compensator such as *series active filter* (SAF) and a *dynamic voltage restorer* (DVR) are investigated for the desired performance with different control algorithms. The SAF is to compensate the harmonics in the source current thereby reducing the harmonic distortion of voltage at PCC at non-linear loads. Similarly, the performance of the battery supported and the capacitor supported DVR are studied for enhancement of power quality during various power quality disturbances like sag, swell, unbalance and harmonics in the PCC voltage. The operation of a DVR is demonstrated under different voltage injection schemes and a comparison of the performance with different schemes is performed for voltage quality improvement. The capacitor supported DVR is controlled by implementing the algorithm with the SRF theory and the Adaline based NN theory.

The UPQC is used for multiple power quality solutions both in the current and voltage. Some new configurations of three-phase four- wire UPQC are proposed for mitigating multiple power quality problems. An isolated reduced rating three-leg VSC with a T-connected transformer and another one with an isolated reduced rating two-leg VSC with a zig-zag transformer are proposed as a shunt controller of UPQC along with an isolated three-leg VSC based series controller for three-phase four-wire systems. The transformer of a shunt controller is used as a neutral current compensator and it provides the functions such as isolation and an optimum voltage selection for the shunt VSC. The shunt controller of UPQC supports the common dc link under various disturbances. The series compensator of UPQC is used to regulate the amplitude at the load voltage when the PCC voltage is affected by the sag, swell or harmonics.

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