Multi Converter-Unified Power Quality Conditioner using Generalized Fryze Control Strategy

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Abstract

This paper presents a fryze control strategy for a Multi converter unified power quality conditioner. This control strategy is used in three-phase three-wire systems The MCUPQC device is a combination of two series-active filters with one shunt-active filter. The active power filter controller is based on the instantaneous power theory. And it can be classified in two groups. The first one is based on the transformation from abc phase to three-orthogonal axes, and other is based on directly from abc. In first method abc phases are converted into $\alpha\beta0$ transformation and is called as p-q theory In second method it deals with directly abc phase, so it is called as abc theory. In second theory current minimization method is used to apply in real time application. The second method is proposed as control strategy in this paper because it has some advantages over p-q theory. The shunt active power filter is used for current compensation and series active power filter is used for voltage compensation. The MATLAB\SIMULINK software with P-Q and fryze control strategy is compared in this paper.

Index Terms—Active filters, Generalized fryze theory, power quality, Instantaneous active and reactive power

1. INTRODUCTION

The present power distribution system is usually configured as a three-phase three-wire or four-wire structure featuring a power-limit voltage source with significant source impedance, and an aggregation of various types of loads. Ideally, the system should provide a balanced and pure sinusoidal three-phase voltage of constant amplitude to the loads; and the loads should draw a current from the line with unity power factor, zero harmonics, and balanced phases.

In Four-wire systems, no excessive neutral current should exist. As a result, the maximum power capacity and efficiency of the energy delivery are achieved, minimum perturbation to other appliances is ensured, and safe operation is warranted. However, with a fast increasing number of applications of industry electronics connected to the distribution systems today, including nonlinear, switching, reactive, single-phase and unbalanced three-phase loads, a complex problem of power quality evolved characterized by the voltage and current harmonics, unbalances, low Power Factor (PF). In recent years active methods for power quality control have become more attractive compared with passive ones due to their fast response, smaller size,

and higher performance. For example, Static VAR Compensator (SVC) have been reported to improve the power factor; Power Factor Corrector (PFC) and Active Power Filters (APF) have the ability of current harmonics suppression and power factor correction; some active circuits were developed to compensate unbalanced currents as well as limit the neutral current.

In general, parallel-connected converters have the ability to improve the current quality while the series-connected regulators inserted between the load and the supply, improve the voltage quality. The active filter which have ability to compensate nonlinear load current and unbalance supply voltage and they are used as shunt active filter and series active filter respectively. If we use two or more series active filters and one shunt active filter then it is called as Multi Converter Unified Power Quality Conditioner (MC-UPQC), which has ability to solved problem related to current and voltage harmonics simultaneously.

2. MC-UPQC System Circuit Configuration

The single-line diagram of a distribution system with an MC-UPQC is shown in Fig. 5.1. As shown in this figure, two feeders connected to two different substations supply the loads L1 and L2. The MC-UPQC is connected to two buses BUS1 and BUS2 with voltages of u_{t1} and u_{t2} respectively. The shunt part of the MC-UPQC is also connected to load L1 with a current of i_{t1} . Supply voltages are denoted by u_{s1} and u_{s2} while load voltages are u_{L1} and u_{L2} . Finally, feeder currents are denoted by i_{s1} and i_{s2} load currentsarei_{t1} and i_{t2} . Bus voltages u_{t1} and u_{t2} are distorted and may be subjected to sag/swell. The load L1 is a nonlinear/sensitive load which needs a pure sinusoidal voltage for proper operation while its current is non sinusoidal and contains harmonics. The load L2 is a sensitive/critical load which needs a purely sinusoidal voltage and must be fully protected against distortion, sag/swell, and interruption. These types of loads primarily include production industries and critical service providers, such as medical centers, airports, or broadcasting centers where voltage interruption can result in severe economical losses or human damages.



Fig.1.Single Line Diagram of MC-UPQC

2.1 MC–UPQC Structure

The internal structure of the MC–UPQC is shown in Fig.5.2. It consists of three VSCs (VSC1,VSC2, and VSC3) which are connected back to back through a common dc-link capacitor. In the proposed configuration, VSC1 is connected in series with BUS1 and VSC2 is connected in parallel with load L1 at the end of Feeder1. VSC3 is connected in series with BUS2 at the Feeder2.

2.2 Typical MC-UPQC used in a distribution system

As shown in Fig.2, all converters are supplied from a common dc-link capacitor and connected to the distribution system through a transformer. Secondary (distribution) sides of the series-connected transformers are directly connected in series with BUS1 and BUS2, and the secondary (distribution) side of the shunt-connected transformer is connected in parallel with load L1.

The aims of the MC-UPQC shown in Fig.2 are:

- 1. To regulate the load voltage against sag/swell and disturbances in the system to protect the nonlinear/sensitive load L1;
- 2. To regulate the load voltage against sag/swell, interruption, and disturbances in the system to protect the sensitive/ critical load L2;
- 3. To compensate for the reactive and harmonic components of nonlinear load current.
- 4. In order to achieve these goals, series VSCs (i.e., VSC1 and VSC3) operate as voltage controllers while the shunt VSC (i.e., VSC2) operates as a current controller.



Fig.2.Typical MC-UPQC Used In Distribution System

2.3 Control Strategy

As shown in Fig.2, the MC-UPQC consists of two series VSCs and one shunt VSC which are controlled independently. The switching control strategy for series VSCs and shunt VSC are Generalized Fryze Control Strategy.

3. Generalized Fryze Current Compensation

Fig.3 shows the generalized fryze current control strategy for shunt active filter. This block diagram is used to calculate the compensating current. The first block is used to calculate the instantaneous fryze conductance by the use of load current and load voltage. This conductance is passed through the low pass filter and average value will be calculated, which is used to calculate the active current. In that calculation load voltage is also used. Now at last these active currents will be subtracted from the load current to calculate the compensating current.



Fig.3. Generalized Fryze Current Compensation

4. Generalized Fryze Voltage Compensation

Fig.4 shows the generalized fryze voltage control strategy for series active filter. This block diagram is used to calculate the compensating voltage. The first block is used to calculate the instantaneous fryze resistance by the use of load current and load voltage. This resistance is passed through the low pass filter and average value will be calculated, which is used to calculate the active voltage. In that calculation load current is also used. Now at last this active voltage will be subtracted from the load voltage to calculate the compensating voltage.



Fig.4.Generalized Fryze Voltage Compensation

5. Simulation Studies

The proposed MC-UPQC and its control schemes have been tested through extensive case study simulations using MATLAB/SIMULINK. In this section, simulation block diagram, simulation results and FFT analysis are presented, and the performance of the proposed MC-UPQC system is shown



Fig.5.Simulation diagram of MC-UPQC

5.1 Distortion and Sag/Swell on the bus voltage:

The MC–UPQC is switched on at 0.02 s. The BUS1 voltage, the corresponding compensation voltage injected by VSC1, and finally load L1 voltage are shown in Fig.6. In all figures, only the phase waveform is shown for simplicity. Similarly, the BUS2 voltage, the corresponding compensation voltage injected by VSC3, and finally, the load L2 voltage are shown in Fig.6. As shown in these figures, distorted voltages of BUS1 and BUS2 are satisfactorily compensated for across the loads L1 and L2 with very good dynamic response.



Fig.6. Distortion and Sag/Swell on the bus voltage

The nonlinear load current, its corresponding compensation current injected by VSC2, compensated Feeder1 current, and, finally, the dc-link capacitor voltage are shown in Fig. 10. The distorted nonlinear load current is compensated very well, and the total harmonic distortion (THD) of the feeder current is reduced from 28.5% to less than 5%. Also, the dc voltage regulation loop has functioned properly under all disturbances, such as sag/swell in both feeders

5.2. Upstream Fault on Feeder2

When a fault occurs in Feeder2 (in any form of L-G,L-L-G and L-L-L-G faults),the voltage across the sensitive/critical. Simulation results for an upstream fault on Feeder2: BUS2 voltage, compensating voltage, and loads L1 and L2 voltages.



Fig.7.Upstream Fault on Feeder

Load L2 is involved in sag/swell or interruption. This voltage imperfection can be compensated for by VSC2. In this case, the power required by load L2 is supplied through VSC2 and VSC3. This implies that the power semiconductor switches of VSC2 and VSC3 must be rated such that total power transfer is possible. This may increase the cost of the device, but the benefit that may be obtained can offset the expense. In the proposed configuration, the sensitive/critical load on Feeder2 is fully protected against distortion, sag/swell, and interruption. Furthermore, the regulated voltage across the sensitive load on Feeder1 can supply several customers who are also protected against distortion, sag/swell, and momentary interruption

5.3 Load Change

To evaluate the system behavior during a load change, the nonlinear load L1 is doubled by reducing its resistance to half at 0.5 s. The other load, however, is kept unchanged. The system response is shown in Fig. It can be seen that as load L1 changes, the load voltages and remain undisturbed, the dc bus voltage is regulated, and the nonlinear load current is compensated.



Fig.8.Load Change

5.4 Unbalance Voltages and current

The control strategies for shunt and series VSCs, which are introduced in above Section , are based on the method. They are capable of compensating for the unbalanced source voltage and unbalanced load current. To evaluate the control system capability for unbalanced voltage compensation, a new simulation is performed. In this new simulation, the BUS2 voltage and the harmonic components of BUS1 voltage are similar to those given in Section IV. However, the fundamental component of the BUS1 voltage is an unbalanced three-phase voltage with an unbalance factor of 40%.



Fig.9.Unbalance Voltages and current

5. 5 Reduction of Harmonic Current



Fig.10.Reduction of Harmonic Current



5.6 FFT Analysis of MC-UPQC Without Using Fryze Control Strategy

Fig.11.FFT analysis of load voltage without series filter



Fig.12.FFT analysis of load current without shunt filter **5.7 FFT Analysis Of P-Q Theory**



Fig.13.FFT analysis of load voltage with series filter



Fig.14.FFT analysis of load current with shunt filter



5.8 FFT Analysis of MC-UPQC Using Fryze Control Strategy





Fig.16.FFT analysis of load current with shunt filter

6. Conclusion and Future Scope

By the use of generalized fryze theory in shunt and series active filter, it gave effective result of compensation. It took less computation time than p-q theory. Its fundamental is based on the p-q theory but it is not used the Clark transformation to calculate instantaneous active and reactive power for calculation of compensating current. But it used the current minimization technique to calculate compensating current. So, it takes less time than p-q theory. It is observed that less THD values for Fryze control strategy when compared with p-q theory

Further investigation can be done on shunt active power filter and robust control can be studied by designing a prototype model to demonstrate the simulation results for both balanced and unbalanced non-linear loads under distorted source voltage conditions.

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