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Modeling and Controlling of MC-UPQC to Enhance Power Quality

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Abstract

This paper presents a new Unified Power-Quality Conditioning System (MC-UPQC), capable of simultaneous compensation for voltage and current in multi-bus/multi-feeder systems. By using one shunt Voltage-Source Converter (VSC) and two or more series VSCs the configuration is made. The system can be applied to adjacent feeders to compensate for supply-voltage and load current imperfections on the main feeder and full compensation of supply voltage imperfections on the other feeders. The configuration will be designed as all converters are connected back to back on the dc side and share a common dc-link capacitor. Therefore, power can be transferred from one feeder to adjacent feeders to compensate for sag/swell and interruption. The proposed topology can be used for simultaneous compensation of voltage and current imperfections in both feeders by sharing power compensation capabilities between two adjacent feeders which are not connected. The system is also capable of compensating for interruptions without the need for a battery storage system and consequently without storage capacity limitations. By the simulation the performance of MC-UPQC as well as the adopted control algorithm will be illustrated. The performance of the proposed configuration has been verified through simulation studies using MATLAB/SIMULATION on a two-bus/two-feeder system and results are presented. Ultimately, I conclude with an outlook and recommendations for companies and cloud providers.

Keywords: Power quality (PQ), unified power-quality conditioner (UPQC), voltage-source converter (VSC).

Introduction

Power quality is the quality of the electrical power supplied to electrical equipment. Poor power quality can result in mal-operation o f the equipment .The electrical utility may define power quality as reliability and state that the system is 99.5% reliable. MCUPQC is a new connection for a unified power quality conditioner (UPQC), capable of simultaneous compensation for voltage and current in multi bus/ Multi Feeder systems. A MCUPQC consists of a one shunt voltage-source converter (shunt VSC) and two or more series VSCs, all converters are connected back to back on the dc side and share a common dc-link capacitor. Therefore, power can be transferred one feeder to adjacent feeders to compensate for sag/swell and interruption. The aims of the MCUPQC are:

A. To regulate the load voltage (u*l**1***) against sag/swell, interruption, and disturbances in the system to protect the Non-Linear/sensitive load L1.

B. To regulate the load voltage (u*l**2***) against sag/swell, interruption, and disturbances in the system to protect the sensitive/critical load L2.

C. To compensate for the reactive and harmonic components of nonlinear load current (i*l**1***). As shown in this figure 1 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 ut1 and ut2, respectively. The shunt part of the MC-UPQC is also connected to load L1 with a current of il1.Supply voltages are denoted by us1 and us2 while load voltages are ul1 and ul2. Finally, feeder currents are denoted by is1 and is2 and load currents are il1 and il2. Bus voltages ut1 and ut2 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.

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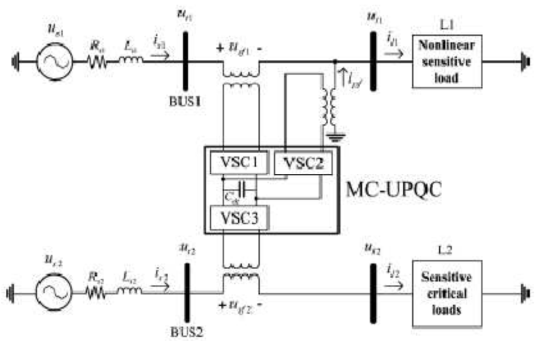

Fig1 Distribution system of MC-UPQC

A Unified Power Quality Conditioner (UPQC) can perform the functions of both D-STATCOM and DVR. The UPQC consists of two voltage source converters (VSCs) that are connected to a common dc bus. One of the VSCs is connected in series with a distribution feeder, while the other one is connected in shunt with the same feeder. The dc- links of both VSCs are supplied through a common dc capacitor. It is also possible to connect two VSCs to two different feeders in a distribution system is called Interline Unified Power Quality Conditioner (IUPQC). This paper presents a new Unified Power Quality Conditioning system called Multi Converter Unified Power Quality Conditioner (MC-UPQC).

Proposed MC-UPQC System

A. Circuit Configuration

The single-line diagram of a distribution system with an MC-UPQC is shown in Fig.2

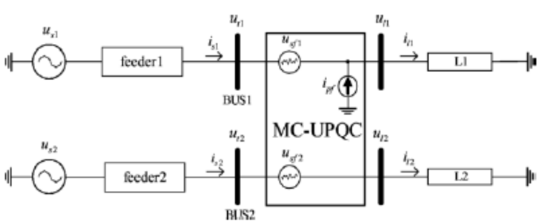

Fig 2 Distribution system of single line with an MC_UPQC.

As shown in this fig.2, 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 ut1 and ut2, respectively. The shunt part of the MC-UPQC is also connected to load L1 with a current of il1. Supply voltages are denoted by us1 and us2 while load voltages are ul1 and ul2 finally, feeder currents are denoted by is1 and is2 load currents are il1 and il2 Bus voltages ut1 and ut2 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.

Power-Rating Analysis of the MC-UPQC

The power rating of the MC-UPQC is an important factor in terms of cost. Before calculation of the power rating of each VSC in the MC UPQC structure, two models of a UPQC are analyzed and the best model which requires the minimum power rating is considered. All voltage and current phasors used in this section are phase quantities at the fundamental frequency. There are two models for a UPQC - quadrature compensation (UPQC-Q) and inphase compensation (UPQC-P). In the quadrature compensation scheme, the injected voltage by the series-VSC maintains a quadrature advance relationship with the supply current so that no real power is consumed by the series VSC at steady state. This is a significant advantage when UPQC mitigates sag conditions. The series VSC also shares the volt ampere reactive (VAR) of the load along with the shunt-VSC, reducing the power rating of the shunt-VSC. Fig. shows the phasor diagram of this scheme under a typical load power factor condition with and without a voltage sag. When the bus voltage is at the desired value , the series-injected voltage is zero Fig.(a).

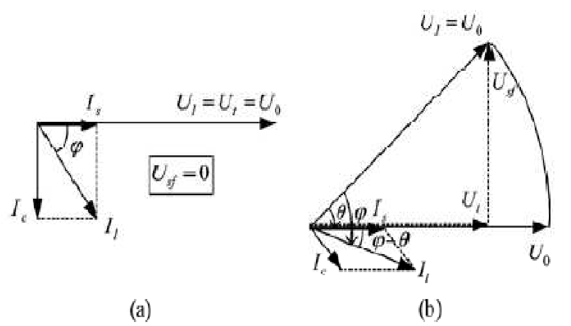

Fig 3 Phasor diagrams (a) without voltage sag (b) with voltage sag

Analysis of UPQC

MC-UPQC consists of three voltage source converters (VSCs) that are connected to a common DC bus.VSC1 is connected in series with BUS1 and VSC3 is connected in series with BUS 2at the end of feeder 2. VSC2 is connected in shunt with the induction motor load at the end of feeder 1. The converters consisting of

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IGBTs are used as they are fast acting switches. IGBTs are efficient for medium power and low switching frequency applications. Commutation reactor is used to limit the increase of current on the mains side and also prevents the flow of switching harmonics into the power supply, along with the high pass filter.

A Series VSCs:

The function of series VSC is to mitigate voltage sag and swell, voltage harmonics and current compensation during interruption. The control algorithm used is based on d-q method. The control block of series VSC is shown in fig.4. It consists of abc to dq0 transformation block which computes the three phase quantities to the direct axes, quadrature axes and zero sequence voltages, in the rotating reference frame using Park's transformation.

$$u_{t\_dq0} = T_{abc}^{dq0} u_{t\_abc} = u_{t1p} + u_{t1n} + u_{t10} + u_{th}$$

Where

$$T_{abc}^{dq0} = \frac{2}{3}\begin{bmatrix} \cos(\omega t) & \cos(\omega t - 120^\circ) & \cos(\omega t + 120^\circ) \\ -\sin(\omega t) & -\sin(\omega t - 120^\circ) & -\sin(\omega t + 120^\circ) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

The controlling is based on comparison of a voltage reference and measured terminal voltage ***ut-abc***. The PLL block is used to synchronise three phase terminal voltages on a set of frequency. The resultant signals are again transformed back to three phase quantities. This will be a vectorised signal consisting of three phase sinusoidal quantities.

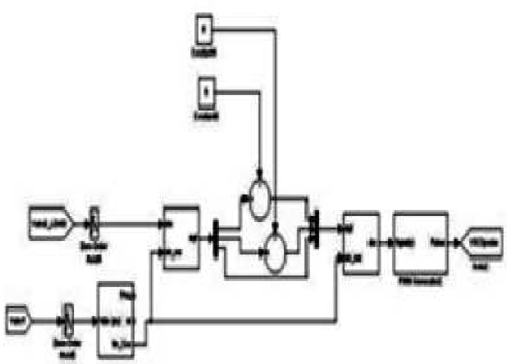


Fig 4 Control block of series VCS

B Shunt VSC:

The function of shunt VSC is to compensate for the reactive and the harmonic components of the load currents of non-linear load. It should also regulate the voltage of common DC-link capacitor. Here the three phase load currents are converted to dq0 quantities and harmonics are eliminated to obtain three phase vectorised currents. These currents are used as carrier signals in the PWM hysteresis current control method to generate pulses for the shunt converter which produces distortions less currents for the load. PI controller is used maintain the DC-link voltage at the reference value ***udc-ref***.

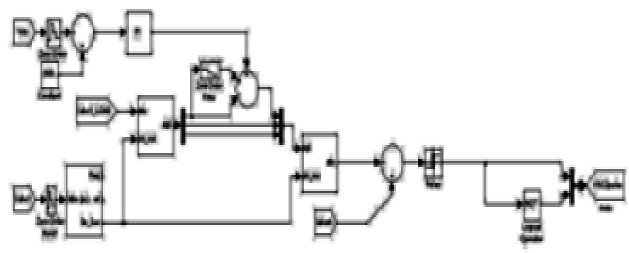
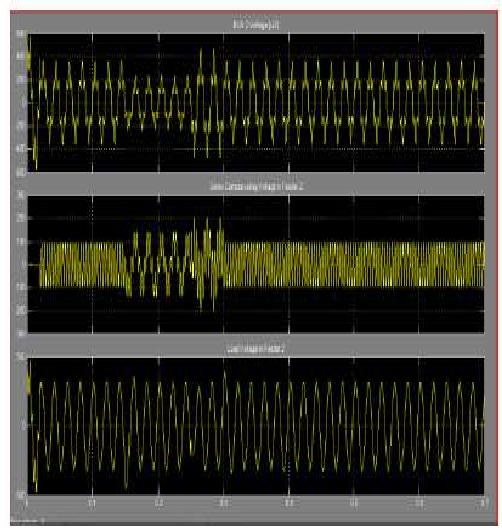
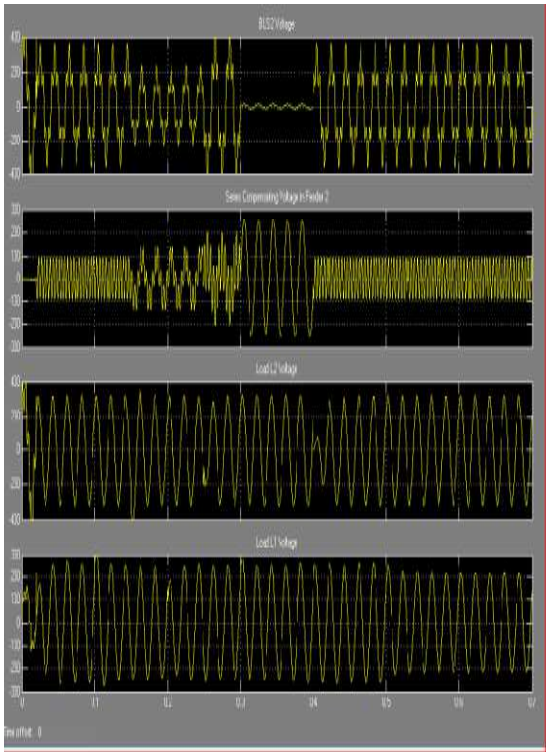


Fig 4.1 Control block of shunt VCS

Simulation Results





Conclusion

The present topology illustrates the operation and control of Multi Converter Unified Power Quality Conditioner (MC-UPQC). The system is extended by adding a series VSC in an adjacent feeder. The device is connected between two or more feeders coming from different substations. A non-linear/sensitive load L-1 is supplied by Feeder-1 while a sensitive/critical load L-2 is supplied through Feeder-2. The performance of the MC-UPQC has been evaluated under various disturbance conditions such as voltage sag/swell in either feeder, fault and load change in one of the feeders. In case of voltage sag, the phase angle of the bus voltage in which the shunt VSC (VSC2) is connected plays an important role as it gives the measure of the real power required by the load. The MC-UPQC can mitigate voltage sag in Feeder-1 and in Feeder-2 for long duration. The performance of the MC-UPQC is evaluated under sag/swell conditions and it is shown that the proposed MCUPQC offers the following advantages: 1. Power transfer between two adjacent feeders for sag/swell and interruption compensation; 2. Compensation for interruptions without the need for a battery storage system and, consequently, without storage capacity limitation; 3. Sharing power compensation capabilities between two adjacent feeders which are not connected.

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