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Robust Control of SAG/SWELL Mitigation Using Multi Converter Unified Power Quality Conditioner

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ABSTRACT

The paper proposes a new concept in developing outline and asses strategic business and technology aspects of cloud computing. Theoretical background and overview is presented on the basic underlying principles autonomic and utility computing, Service oriented Architecture**.** This configuration(MC-UPQC), capable of simultaneous compensation for voltage and current in multibus systems. In this configuration, one shunt voltage-source converter (shunt VSC) and two or more series VSCs exist. 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 power can be transferred from one feeder to adjacent feeders to compensate for sag/swell and interruption. 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).

1. 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 multibus/multifeeder 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.

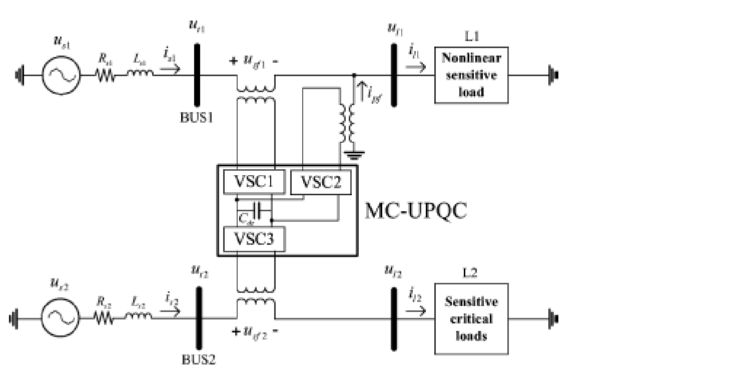

Fig.1: Typical MC-UPQC used in a distribution system.

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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).

2. SAG/SWELL AND DISTORTION ON THE BUS VOLTAGE IN FEEDER-1 AND FEEDEER-2

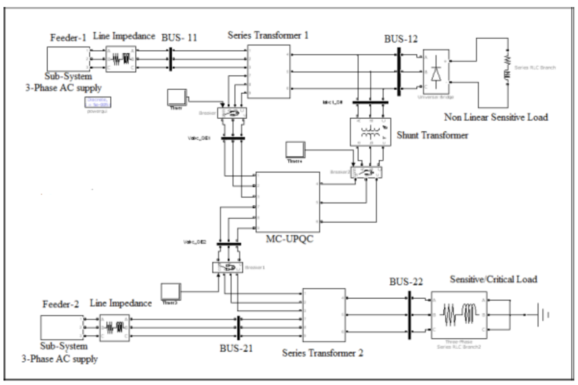

Figure 2: Simulink model of distribution system with MC-UPQC

Let us consider that the power system in Fig. 1 consists of two three-phase three-wire 380(v) (RMS, L-L), 50-Hz utilities. The BUS1 voltage (ut1) contains the seventh-order harmonic with a value of 22%, and the BUS2 voltage (ut2) contains the fifth order harmonic with a value of 35%. The BUS1 voltage contains 25% sag between 0.1s<t<0.2s and 20% swell between 0.2s<t<0.3s. The BUS2 voltage contains 35% sag between 0.15s<t<0.25s and 30% swell between 0.25s<t<0.3s The nonlinear/sensitive load L1 is a three-phase rectifier load which supplies an RL load of 10_ and 30μH. The simulink model for distribution system with MC-UPQC is shown in figure 2.

The critical load L2 contains a balanced RL load of 10Ω and 100mH. The MC–UPQC is switched on at t=0.02s. The BUS1 voltage, the corresponding compensation voltage injected by VSC1, and finally load L1 voltage are shown in Figure 3.

Similarly, the BUS2 voltage, the corresponding compensation voltage injected by VSC3, and finally, the load L2 voltage are shown in figure 4.

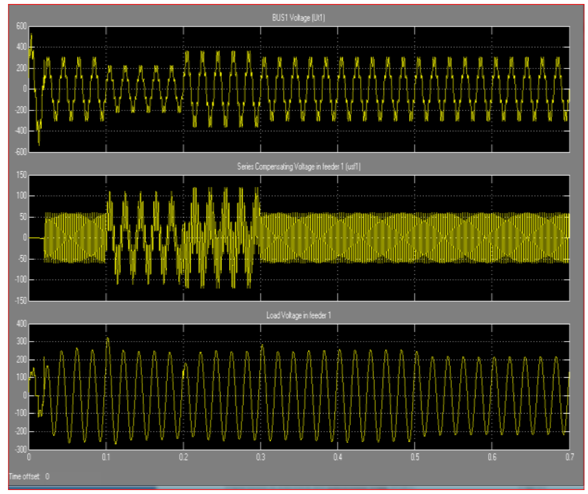

Fig 3.Simulation Result for BUS1 voltage, series compensating voltage, and load voltage in Feeder1

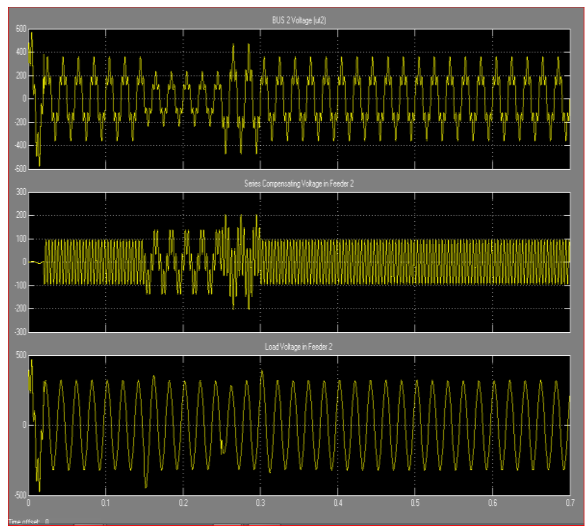

Fig 4.Simulation Result for BUS2 voltage, series compensating voltage, and load voltage in Feeder2.

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.

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. 5. 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.

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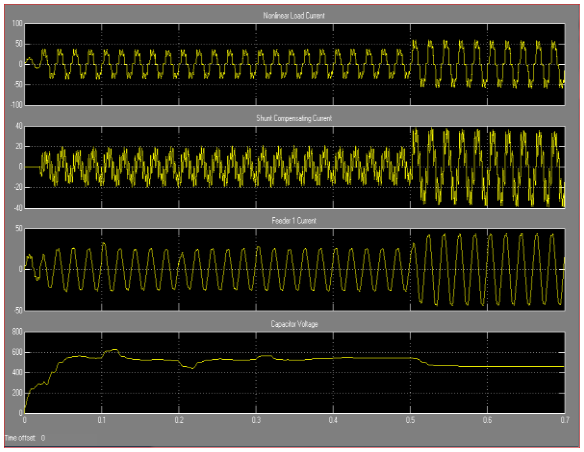

Fig 5.Simulation Result for Nonlinear load current, compensating current, Feeder1 current, and capacitor voltage.

3. UPSTREAM FAULT ON FEEDER2

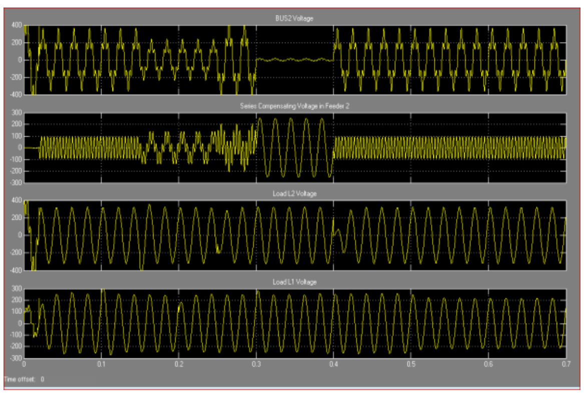

Fig 6.simulation results for an upstream fault on Feeder2: BUS2 voltage, compensating voltage, and loads L1 and L2 voltages.

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 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.

The performance of the MC-UPQC under a fault condition on Feeder2 is tested by applying a three- phase fault to ground on Feeder2 between 0.3s<t<0.4 s. Simulation results are shown in Fig.6

4. 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. In this case load current and source currents are suddenly increased to double and produce distorted load voltages (*Ul1* and U*l2*) as shown in Fig 7.

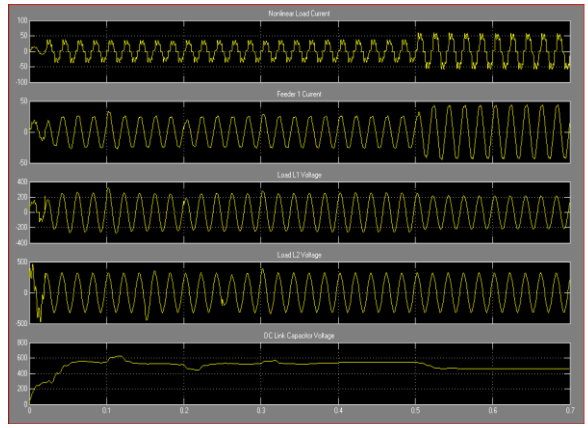

Fig 7.Simulation results for load change: nonlinear load current, Feeder1 current, load L1 voltage, load L2 voltage, and dc-link capacitor voltage.

5. SYSTEM WITH UNBALANCED SOURCE VOLTAGE IN FEEDER-1.

The performance of the MC-UPQC is tested when unbalance source voltage occurs in feeder-1 at nonlinear/sensitive load without and with MC-UPQC.

The control strategies for shunt and series VSCs,
Which are introduced and 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. However, the fundamental component of the BUS1 voltage (Ut1fundamental) is an unbalanced three-phase voltage with an unbalance factor (U- /U+) of 40%.

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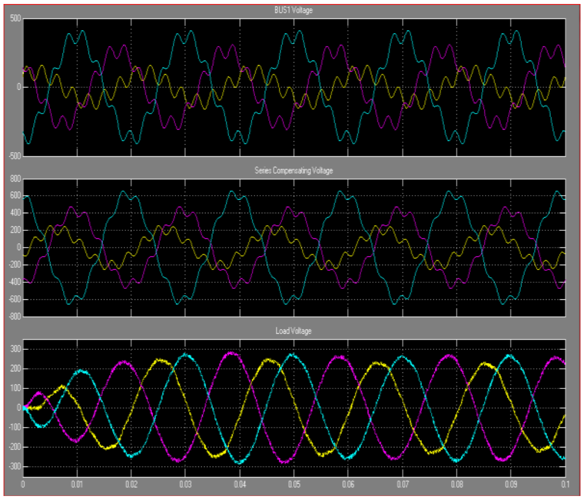

Fig 8.BUS1 voltage, series compensating voltage, and load voltage in Feeder1 under unbalanced source voltage.

The simulation results show that the harmonic components and unbalance of BUS1 voltage are compensated for by injecting the proper series voltage. In this figure, the load voltage is a three-phase sinusoidal balance voltage with regulated amplitude. The simulation results for the three-phase BUS1 voltage series compensation voltage, and load voltage in feeder 1 are shown in Fig.8.

6. 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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