International Journal of Science, Environment
and Technology, Vol. 2, No 5, 2013, 969 – 980

ISSN 2278-3687 (O)

A NOVAL APPROACH FOR AMELIORATION OF QUALITY POWER MANAGEMENT BY A CUSTOM POWER DEVICE

P.G.L. Mandakini[1], Dr. K. Ravichandrudu[2], Mr. P. Yohan Babu[3]
and Mr. G.V.P. Anjaneyulu[4]
[1,2,3]Krishnaveni Engineering College for Women, Narasarao pet, A.P, India
[4]Reaserch Scholar, SV University College of Engineering, S.V.U, Thirupathi

Abstract: According to the analysis, results suggest that maximum part of interruptions at industrial facilities is power quality related. This paper presents a new unified power-quality conditioning system (UPQC), capable of simultaneous compensation for voltage and current in multi bus / multi feeder systems. Power quality (PQ) is a service and many customers are ready to pay for it. In the future, distribution system operators could decide, or could be obliged by authorities, to supply their customers with different PQ levels and at different prices. A new device that can fulfill this role is the OPEN unified power quality conditioner (UPQC), composed of a power-electronic series main unit installed in the medium-voltage/low-voltage (LV) substation, along with several power-electronic shunt units connected close to the end users. The series and parallel units do not have a common dc link, so their control strategies are different than traditional UPQC control techniques. When voltage sags happen, the transformers, which are often installed in front of critical loads for electrical isolation, are exposed to the disfigured voltages and a dc offset will occur in its flux linkage. When the compensator restores the load voltage, the flux linkage will be driven to the level of magnetic saturation and severe inrush current occurs.

Index Terms: Active power conditioner, custom power, unified power-quality conditioner (UPQC), power quality (PQ), Flux linkage, inrush current, voltage sag /swell, voltage sag/swell compensator.

INTRODUCTION

Power Quality (PQ) is very important to certain customers. For this reason, many utilities could sell electrical energy at different prices to their customers, depending on the quality of the delivered electric power. With increasing applications of nonlinear and electronically switched devices in distribution systems and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation. In order to

*Received July 27, 2013 * Published October 2, 2013 * www.ijset.net*

meet PQ standard limits, it may be necessary to include some sort of compensation. Modern solutions can be found in the form of active rectification or active filtering.

A shunt active power filter is suitable for the suppression of negative load influence on the supply network, but if there are supply voltage imperfections, a series active power filter may be needed to provide full compensation. In this paper, a new configuration of a UPQC called the unified power-quality conditioner (UPQC) is presented. The system is extended by adding a series-VSC in an adjacent feeder. 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. Various transformer inrush reduction techniques have been presented, like controlling power-on angle and the voltage magnitude, or actively controlling the transformer current.

These methods could easily alter the output voltage waveforms of the converter, and thus, is not suitable for voltage sag compensators, which demand precise point-on wave restoration of the load voltages. In this paper, the inrush issue of load transformers under the operation of the sag compensator is presented. An inrush mitigation technique is proposed and implemented in a synchronous reference frame voltage sag compensator controller. The proposed technique can be integrated with the conventional closed-loop control on the load voltages. The new integrated control can successfully reduce inrush current of load transformers and improve the disturbance rejection capability and the robustness of the sag compensator system. Laboratory test results are presented to validate the proposed technique.

MAIN SOURCES, CAUSES AND EFFECTS OF ELECTRICAL POWER QUALITY PROBLEMS

Power Quality is “Any power problem manifested in voltage, current, or frequency deviations that result in failure or miss operation of customer equipments”. Power systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the isolated systems, some of the primary source of distortion can be identified as below.

- Non – Linear Loads
- Power Electronic Devices

- IT and Office Equipments
- Arcing Devices
- Load Switching
- Large Motor Starting
- Larger capacitor bank energies
- Embedded Generation
- Electromagnetic radiations and Cables
- Storm and Environment Related Causes

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power quality encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

METHODS TO IMPROVE POWER QUALITY ISSUES

A traditional method to achieve improve power quality is to use passive filters connected at the sensitive load terminals. However, this practice has some shortcomings: the effectiveness of the scheme could deteriorate as the source impedance or load condition changes; it can lead to resonance between the filter and the source impedance. Essentially an active filter, connected at the sensitive load terminal, injects harmonic currents of the same magnitude but of opposite polarity to cancel the harmonics present there. However harmonics distortions are only part of the problem, the variations in the drive load would result in voltage sag. Thus, the challenge is to regulate the sensitive load terminal voltage so that its magnitude remains constant and any harmonic distortion and voltage sags are reduced to an acceptable level. This paper introduces series compensator and its operating principle. Then a simple control based PWM method is used to compensate Harmonics, Voltage sags. At the end MATLAB SIMULINK model based simulated results were presented to validate the effectiveness of the proposed control method of Series Compensation.

I. SYSTEM CONFIGURATION OF THE COVENTONAL COMPENSATOR

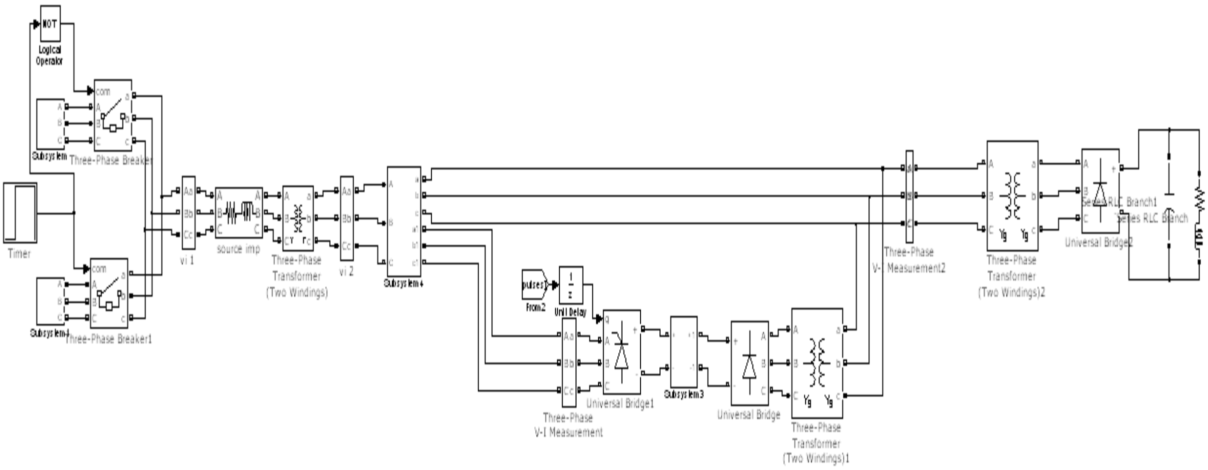


Fig.1. A conventional single line diagram of the off-line series voltage sag/swell compensator.

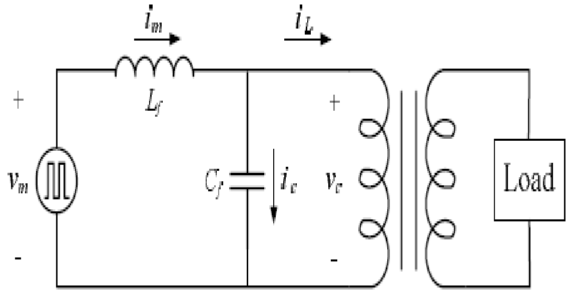


Fig 2. The basic conventional structure for Series Compensator.

The simple power system model shown in Figure 2 is used to explain the principle of the proposed mitigation method. The upstream generators are aggregated and represented as an ideal voltage source. Zs represents the equivalent source impedance. The main drives or machinery loads are modeled as a lumped resistive-inductive load connected to the source through a power converter, assumed to be a six-pulse rectifier. The much smaller capacity sensitive loads are assumed to be supplied through point of common coupling and are modeled by the resistor R in parallel with the capacitor C. It is series connected with the sensitive load. The function of the C is to ensure that the voltage across the sensitive load terminals is of high quality VSI where a PWM switching scheme is often used. Because of the switching, harmonics are generated, and filtering is required. The function of each component of Series Compensator is as follows.

THE CONVENTIONAL CONTROL METHOD

Figure 3 shows the block diagram of the proposed control method. Note that the d-axis controller is not shown for simplicity. The block diagram consists of the full state feedback controller and the proposed inrush current mitigation tech. Detailed explanations are given in the following sections.

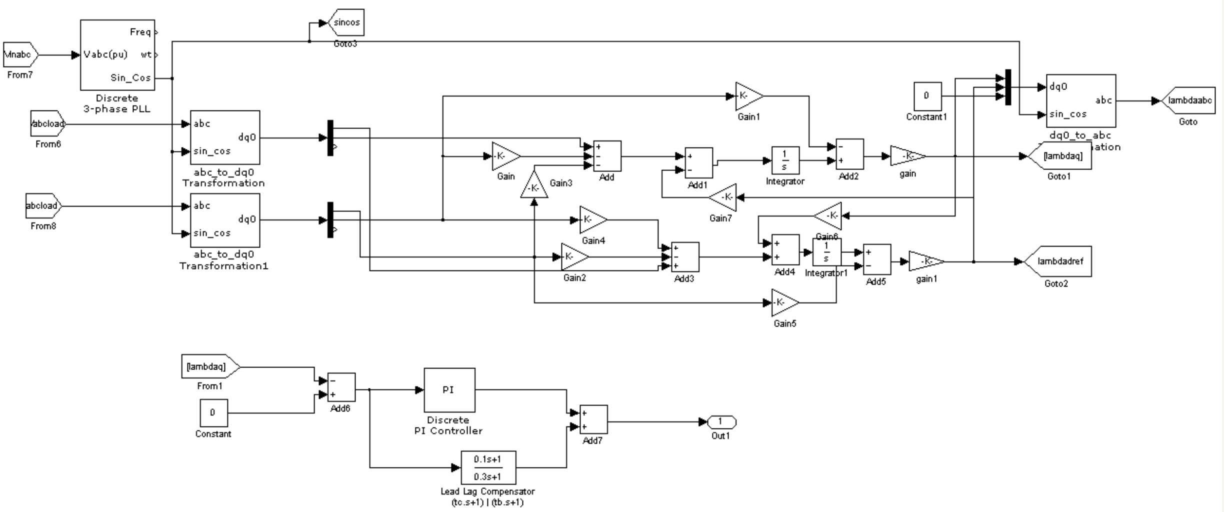


Fig. 3. Block diagram of the proposed inrush current mitigation technique with the sate feedback control.

II. SYSTEM CONFIGURATION OF PROPOSED CUSTOM POWER DEVICE (UPQC)

This concept can be extended to design multi converter configurations for PQ improvement in adjacent feeders. For example, the unified power-quality conditioner (UPQC), which is the extension of the IPFC concept at the distribution level, has been proposed in. The UPQC consists of one series and one shunt converter. It is connected between two feeders to regulate the bus voltage of one of the feeders, while regulating the voltage across a sensitive load in the other feeder. In this configuration, the voltage regulation in one of the feeders is performed by the shunt-VSC. However, since the source impedance is very low, a high amount of current would be needed to boost the bus voltage in case of a voltage sag/swell which is not feasible. It also has low dynamic performance because the dc-link capacitor voltage is not regulated.

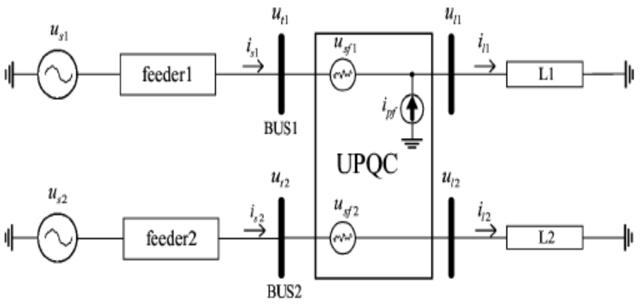


Fig. 1. Single-line diagram of a distribution system with an MC-UPQC

The single-line diagram of a distribution system with an UPQC is shown in Fig. 1. As shown in this figure, two feeders connected to two different substations supply the loads L1 and L2. The UPQC is connected to two buses BUS1 and BUS2 with voltages of $\mathbf{U_{t1}}$, and $\mathbf{U_{t2}}$ respectively. The shunt part of the UPQC is also connected to load L1 with a current of. Supply voltages are $\mathbf{U_{si}}$, and $\mathbf{U_{s2}}$ denoted by and while load voltages are. Finally, feeder currents are denoted by and load currents are. Bus voltages $\mathbf{U_{t1}}$, and $\mathbf{U_{t2}}$ 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.

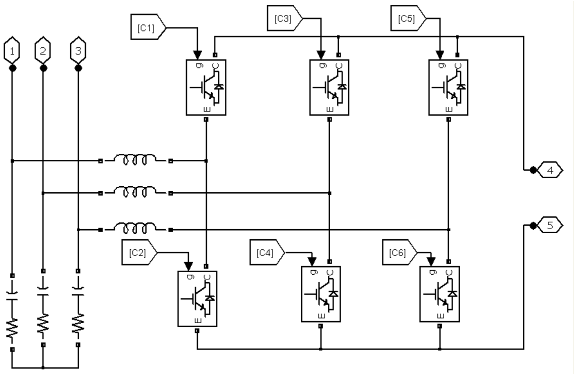


Fig. 3. Schematic structure of a VSC

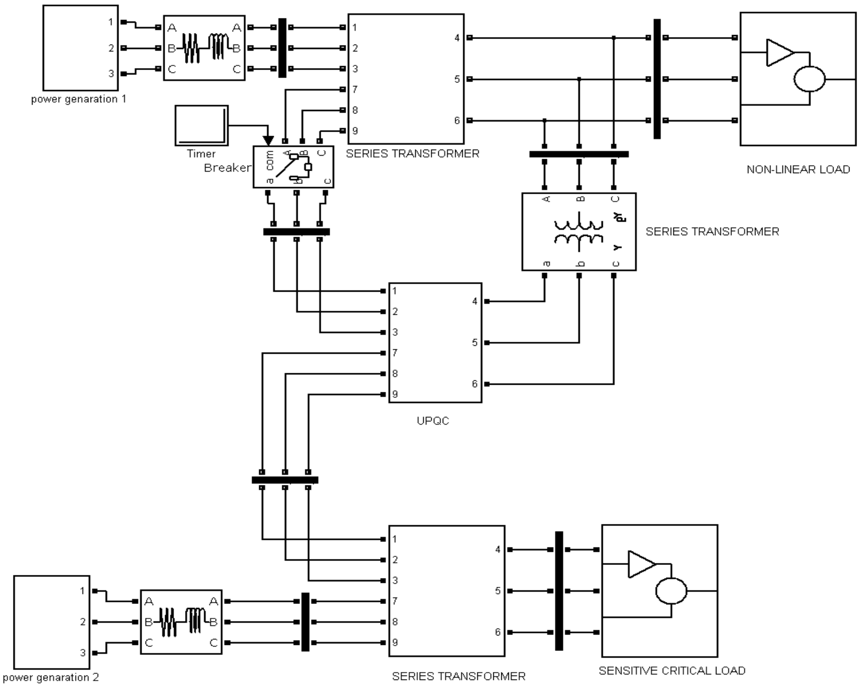


Fig. 3. Typical proposed UPQC used in a distribution system

THE PROPOSED CONTROL METHOD

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 the shunt VSC are selected to be sinusoidal pulse width-modulation (SPWM) voltage control and hysteresis current control, respectively. Details of the control algorithm, which are based on the – method, will be discussed later. *Shunt-VSC:* Functions of the shunt-VSC are:

1) to compensate for the reactive component of load L1 current;
2) to compensate for the harmonic components of load L1 current;
3) to regulate the voltage of the common dc-link capacitor.

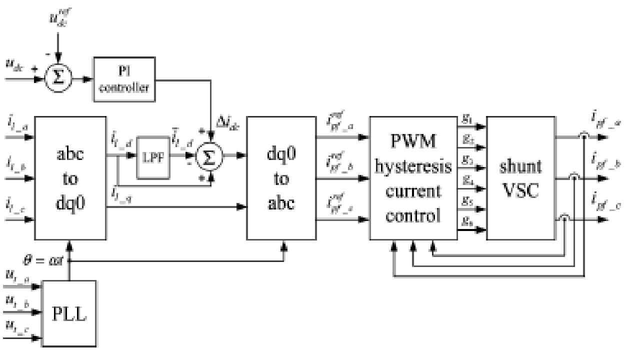


Fig. 4. Control block diagram of the shunt VSC

By this transform, the fundamental positive-sequence component, which is transformed into dc quantities in the and axes, can be easily extracted by low-pass filters (LPFs). Also, all harmonic components are transformed into ac quantities with a fundamental frequency shift.

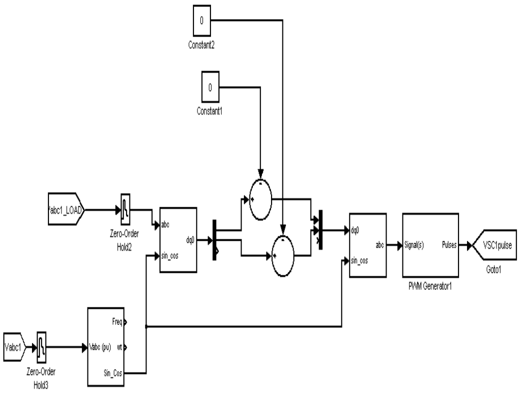


Fig. 5. Control block diagram of the series VSC

LABORATORY TEST RESULTS

A prototype voltage sag compensator with inrush current mitigation technique is implemented in laboratory. The one-line diagram is as given in Fig. The system parameters of test bench and controller are given as follows:

- Source: 220V, 60Hz;
- Loads: non-linear load (R=140Ω, L=2.0mH, C=3300uF);
- Voltage sag compensator: a conventional three phase inverter switching at 10kHz, the leakage inductance of the coupling transformer Lf=0.32mH, and filter capacitor Cf=4.0μF.
- Load transformer: 3kVA, 220V/220V (Delta/Wye connection)

The power rating of the UPQC is an important factor in terms of cost. Before calculation of the power rating of each VSC in the 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 in phase 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.

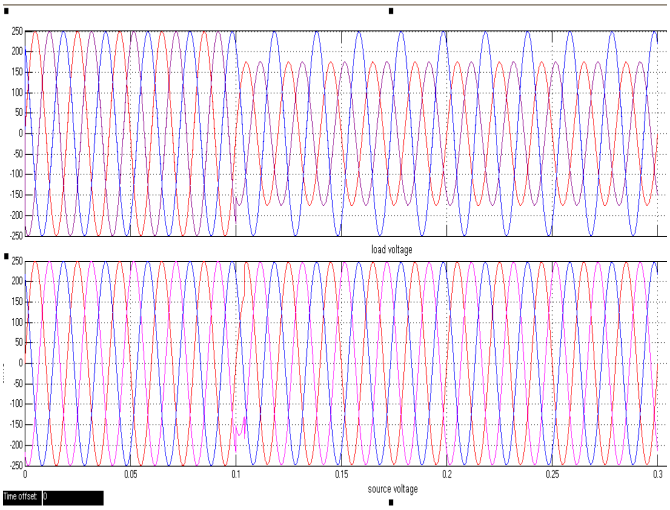


Fig. 9. Experimental voltage waveforms with conventional technique

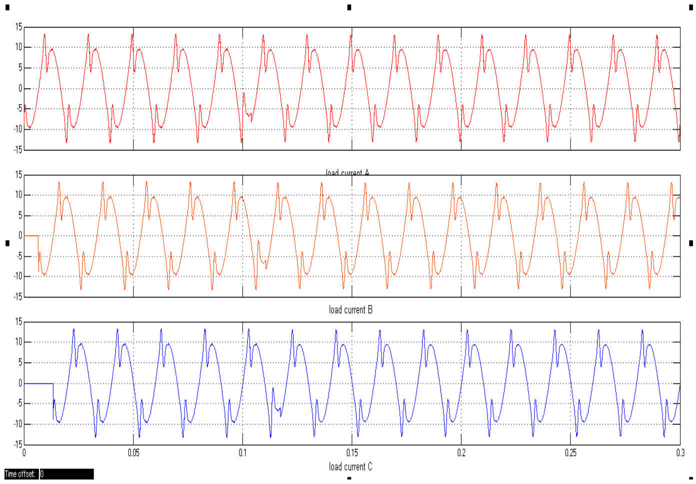
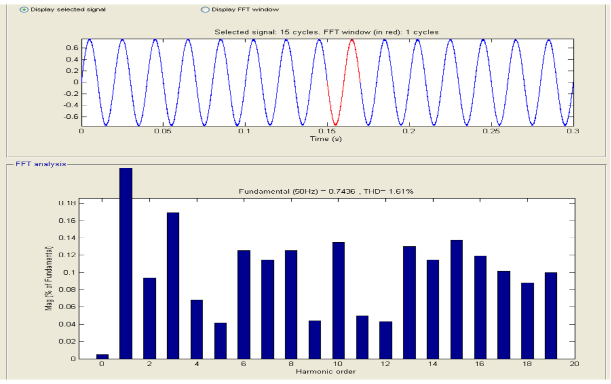


Fig. 10. Experimental waveforms of current with the with conventional technique



Selected signal: 15 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 0.7436 , THD= 1.61%

Fig 11: t.h.d analysis of conventional system (1.61%)

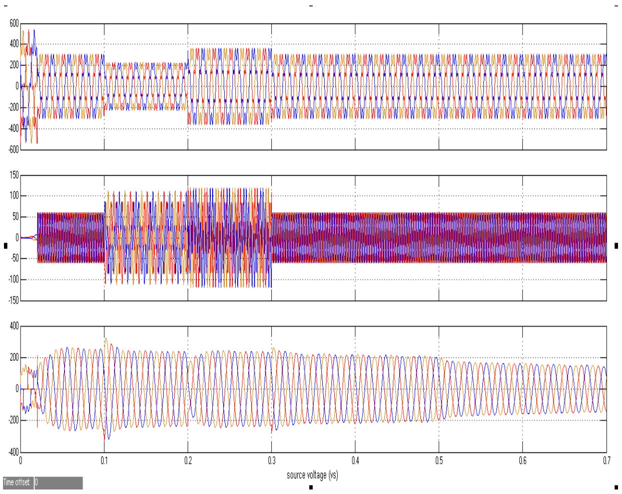


Fig. 12. BUS1 voltage, series compensating voltage, and load voltage in Feeder1 under unbalanced source voltage.

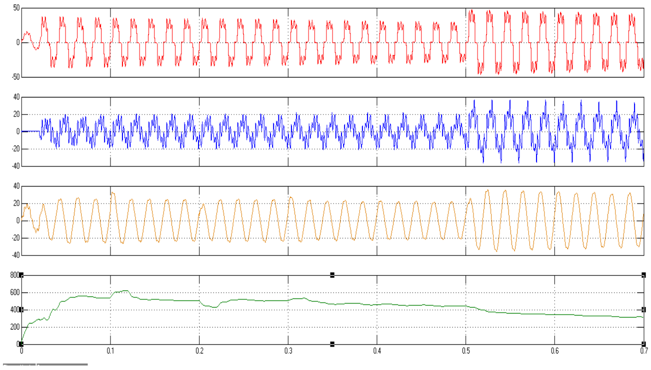
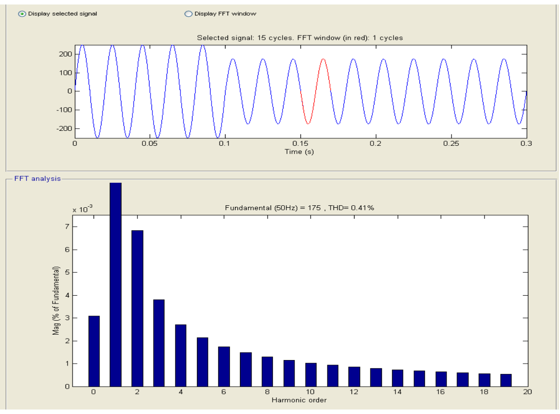


Fig. 13. Simulation results for load change: nonlinear load current, Feeder1 current, load L1 voltage, load L2 voltage, and dc-link capacitor voltage.



Selected signal: 15 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 175 , THD= 0.41%

Fig 14: t.h.d analysis of conventional system (0.41%)

CONCLUSION

The controller includes a voltage control, a current control and a flux linkage control. The conventional control method is based on the synchronous reference frame which enables voltage sag compensator to achieve fast voltage injection and prevent the inrush current. The new configuration is named multi converter unified power-quality conditioner (UPQC). Compared to a conventional UPQC, the proposed topology is capable of fully protecting critical and sensitive loads against distortions, sags/swell, and interruption in two-feeder systems. The idea can be theoretically extended to multi bus/multi feeder systems by adding more series VSCs.

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.

REFERENCES

[1] D.D. Sabin and A. Sundaram, "Quality enhances reliability," *IEEE Spectr.*, vol. 33, no. 2, pp. 34–41, Feb. 1996.

[2] M. Rastogi, R. Naik, and N. Mohan, "A comparative evaluation of harmonic reduction techniques in three-phase utility interface of power electronic loads," *IEEE Trans. Ind. Appl.*, vol. 30, no. 5, pp. 1149–1155, Sep./Oct. 1994.

[3] F. Z. Peng, "Application issues of active power filters," *IEEE Ind. Appl. Mag.*, vol. 4, no. 5, pp. 21–30, Sep../Oct. 1998.

[4] H. Akagi, "New trends in active filters for power conditioning," *IEEE Trans. Ind. Appl.*, vol. 32, no. 6, pp. 1312–1322, Nov./Dec. 1996.

[5] L. Gyugyi, C. D. Schauder, S. L. Williams, T. R. Rietman, D. R. Torjerson, and A. Edris, "The unified power flow controller: A new approach to power transmission control," *IEEE Trans. Power Del.*, vol. 10, no. 2, pp. 1085–1097, Apr. 1995

[6] P.T. Cheng; C. -C. Huang; C. – C. Pan; S. Bhattacharya, "Design and implementation of a series voltage sag compensator under practical utility conditions", IEEE Trans. Ind. Applicat., Vol. 39, pp. 844- 853, May-June 2003.

[7] P. T. Cheng, C. L. Ni, J. M. Chen, "Design of a state feedback controller for series voltage sag compensators," Power Conversion Conference, pp. 398-403, April 2007.

[8] L. Yun Wei, F. Blaabjerg, D. M. Vilathgamuwa, and A. P. C. L. Poh Chiang Loh, "Design and Comparison of High Performance Stationary- Frame Controllers for DVR Implementation," *Power Electronics, IEEE Transactions on,* vol. 22, pp. 602-612, 2007.

[9] L. Gyugyi, K. K. Sen, and C. D. Schauder, “Interline power flow controller concept: A new approach to power flow management in transmission systems,” *IEEE Trans. Power Del.*, vol. 14, no. 3, pp. 1115–1123, Jul. 1999.

[10] B. Fardanesh, B. Shperling, E. Uzunovic, and S. Zelingher, “Multi-converter FACTS Devices: The generalized unified power flow controller (GUPFC),” in *Proc. IEEE Power Eng. Soc. Summer Meeting*, 2000, vol. 4, pp. 2511–2517.

[11] A. K. Jindal, A. Ghosh, and A. Joshi, “Interline unified power quality conditioner,” *IEEE Trans. Power Del.*, vol. 22, no. 1, pp. 364–372, Jan. 2007.

[12] M. Hu and H. Chen, “Modeling and controlling of unified power quality compensator,” in *Proc. 5th Int. Conf. Advances in Power System Control, Operation and Management*, Hong Kong, China, 2000, pp. 431–435.