International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 14
October2016

Fast Energy Storage with Bi-Directional Converter Controlled Super Capacitor Based UPQC

Kasarla Sandeep
M-tech Scholar
Department of Electrical & Electronics Engineering,
Aurora's Scientific Technological and Research Academy;
Bandlaguda
Hyderabad (Dt); Telangana, India.
Email:ksandeep9308@gmail.com

Manoj Nethala
Assistant Professor
Department of Electrical & Electronics Engineering,
Aurora's Scientific Technological and Research Academy;
Bandlaguda
Hyderabad (Dt); Telangana, India.
Email: manojnethala@gmail.com

Abstract- In the proposed concept UPQC with Super Capacitor for fast energy storage super capacitor can be used. Modern power grids must be highly reliable and provide power with a high quality. Power quality issues like voltage sags or current harmonics must be minimized, in order to achieve high levels of reliability in the system. One possible way to overcome such problems is through the utilization of active power filters like a Unified Power Quality Conditioner (UPQC). On the other hand, Superconducting Magnetic Energy Storage (SMES) is one of the most promising superconducting devices, considering its possible applications in power systems. This concept contains a combination of a SMES with a UPQC for power quality improvement in an electric grid. Through the utilization of a SMES unit, it is possible to increase the stored energy in the DC link of the UPQC, thus improving the system capacity to overcome power quality issues. Voltage sags and current harmonics are simulated and the system behavior is demonstrated.

Keywords: UPQC; SMES; Power Quality.

I. INTRODUCTION

The modern equipment's that are used in home are very sensitive and prone to harmonics as well as voltage disturbances with poor power factor. The power quality problem is also due to the different faults conditions occurring on the power system network. These conditions cause voltage sag or swell in the system and malfunctioning of devices which damages the sensitive loads [1]. The mitigation of these on the source and load sides is most important for improving the reliability as well as performance on the system. Unified Power Quality Conditioner (UPQC) is expected to be one of the most powerful solutions to large capacity loads that are sensitive to the changes in supply voltage, flicker or imbalance. The UPQC has a single topology that combines series active power filter and shunt active power filter with a common DC link. These two are connected in a back to back configuration [2]. Shunt active power filter compensates all current related distortions and series active power filter compensates all voltage related distortions. The compensation can be done effectively, if there is an effective DC link. The operation of both series active power filter and shunt active power filter are based on voltage source converter technique. The shunt compensator takes care of reactive power compensation, current harmonic compensation, load unbalance compensation and power factor improvement. The series compensator acts for voltage harmonics, voltage sag or swells, flickering etc., with the harmonic isolation between load and supply [3-4].

The super capacitor is used as a battery storage device across the DC link for short time duration. The energy can be stored in the form of batteries, flywheels, compressed air, hydraulic systems and super conducting energy storage systems [5]. A configuration with STATCOM-super capacitor energy storage system is used to enhance power system stability and quality [6]. Super capacitors are also find applications in metro vehicles and hybrid electric vehicles [7], also in traction [8]. The battery has a high storage capacity but unreliable and flywheels requires a lot of maintenance. The discharge rate is slower in batteries because of slower chemical process. But now the future is turned to higher rate of charging and discharging the energy which is possible with the super capacitors. The super capacitors stores less energy however the power transfer capability is high compared to the conventional batteries. The rate of discharge while compensation is fast and it takes only a small current for charging [9]. Use of super capacitor is proposed in UPQC scheme as it is characterized by less weight, faster charge/discharge cycle time, higher power density, higher efficiency and almost maintenance free. The paper [10-11] explains the power circuit modelled as a 3-phase 4- wire system with a non-linear load that is composed of 3- phase diode-bridge rectifier with RC load in the DC side [12-13].

II.SYSTEM OVERVIEW

The designed system is depicted in Fig.1. The simulated grid contains a power source, which was simulated using a three phase programmable power source in Simulink, a pure resistive load and the hybrid system consisting of the UPQC+SMES. The series active filter that builds the UPQC is placed close to the power source and the shunt filter is placed close to the load. Although it is possible to choose a reverse configuration (shunt filter close to the source and series filter close to the load) this arrangement was chosen because it allows a better controllability of the DC bus voltage. This is a fundamental characteristic in this hybrid system because the SMES is connected to this DC bus.

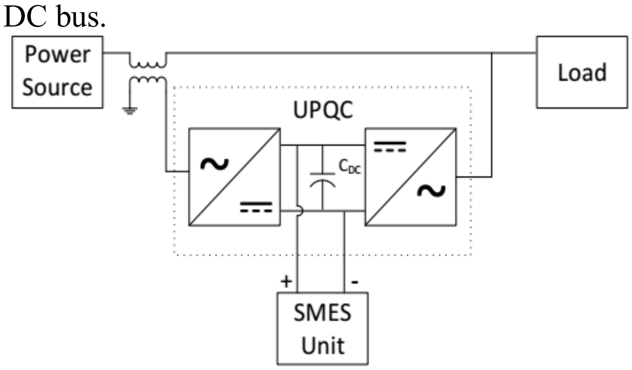

Fig 1: Implemented system

A.UPQC

The UPQC is the main component of the designed system. Fig.2 shows a schematic of the implemented active power filter. The UPQC flexibility allows a full control of voltage and current. The series power active filter is responsible for voltage control and the shunt filter for current control. This control is possible by measuring the different values of voltages and currents in the grid and comparing them to reference values. The two filters are controlled using PWM generators and follow two different control strategies: the reference signal for the PWM generator of the series filter follows a "feedforward" control method, comparing the voltage of the filter to a well-defined reference value; on the other hand, the reference signal for the PWM generator of the shunt filter is obtained following a Synchronous Reference Frame Method [5]. A major responsibility of the UPQC controller is to maintain the DC bus voltage always above a required level. On this particular case, the chosen value is 700 V, which is higher than the minimum voltage necessary to have full controllability of both active filters at all time. The minimum value in this case is 648V, calculated following the formulation presented. The capacitor used in the DC bus has a value of 50 µF.

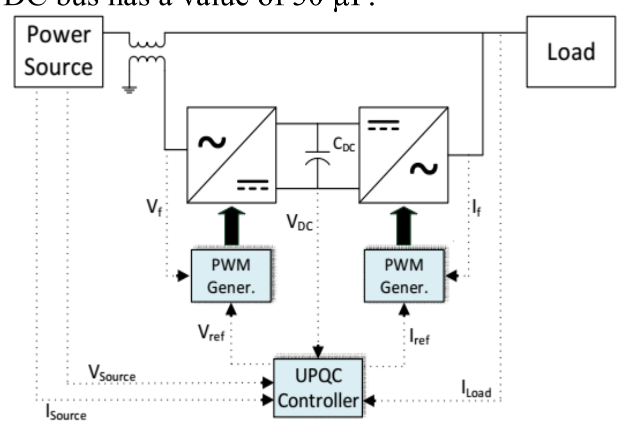

Fig 2: Implemented UPQC

B.SMES

An SMES is a very complex system, composed by three main components: a superconducting (SC) coil (placed inside a cryostat) where energy is stored; a Power Converter System (PCS), which is a power electronics bidirectional converter, responsible for the exchange of energy with the grid to which the SMES is connected, and a Control System (CS) responsible for controlling all

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 14
October2016

energy exchanges with the grid and also for overviewing and protecting the conditions of the SC coil. Fig.3 depicts a typical configuration of the systems

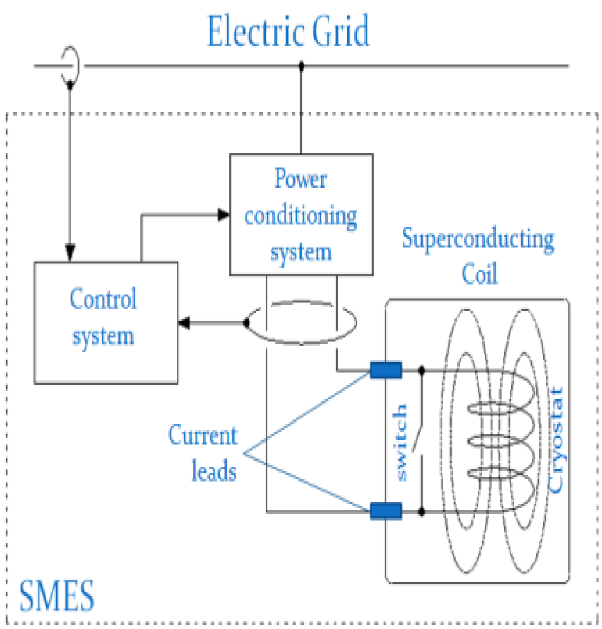

Fig 3 SMES system constitution

In this particular case, because it is a simulation work and because the SMES is connected to a DC bus, several simplifications are possible. The PCS becomes simpler than the used one when the SMES is connected to an AC grid. In this case, it is necessary to use only a DC/DC converter. The typical choice is a chopper converter, due to its simplicity. The control strategy used in the PCS also becomes simpler due to this fact, which will also decrease the complexity of the CS. Other simulations are performed on the controller of the SMES: all variables related to the cryogenic system and protection of the SC coil are not considered. However, since the hybrid system is supposed to be able to overcome voltage swells, it is necessary to add a resistor in parallel with the SC coil, so that the excess energy (in case of a voltage swell) can be dissipated. This dissipation of energy will only occur if the SMES is already fully charged. The model used for simulation of the SMES is represented in Fig.4. To simulate the chopper two IGBTs (S_1 and S_2) were used.

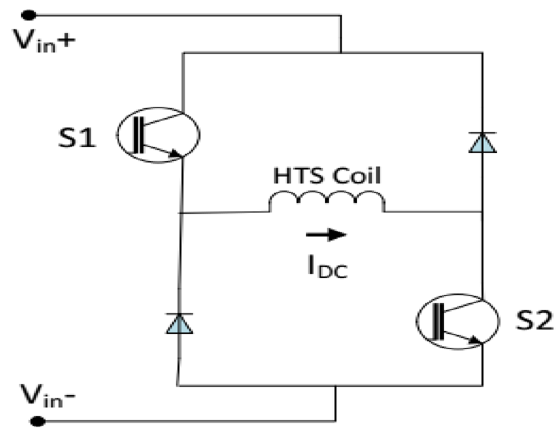

Fig 4 SMES model

The control of these two switches allows the SMES to work in three different modes:

• S1 and S2 closed – Charging Mode: the coil is charging;

• S1 S2 closed – Discharging Mode: the coil is discharging, due to the occurrence of some fault in the grid;

• S1 open and S2 closed – Persistent Mode: the coil is already full charged and its nominal current value is kept using this mode.

When the SMES is operating alone, the charging process is straightforward. The energy can be extracted from the DC link without any special care. However, in this particular case, since the SMES is connected to the DC bus of an UPQC, its the charging process must take into account the fact that the DC voltage cannot decrease below a certain level. Thus, it is only possible to charge the SMES when the DC voltage is above 700 V (the chosen value for the DC bus voltage). The controller of the SMES (which controls the IGBTs S1 and S2) must consider this aspect.

The main characteristics from the SMES unit simulated in this work are presented in table I such characteristics were obtained following the method presented. The implemented model also considers a resistor (with 0.1 Ω) in series with the coil, to simulate the existence of connectors in the superconducting tape and a capacitor (with 1nF) in parallel, to simulate capacitance between the single pancake coils.

TABLE I
Characteristics Of The Simulated SMES Unit.

Characteristic	Value
Number of pancake coils	4
Number of turns (each coil)	130
Total inductance (H)	0.28
Nominal current value (A)	70
Critical current of SC tape considered (A)	120
Total length of SC tape necessary to implement this SMES (m)	800

In an UPQC operating alone, in the same conditions as in this case, i.e., the same DC voltage (700 V) and the same capacitor in the DC bus (50 μF), the stored energy is 12.25J.This is a small value, which strongly limits the range of applications of such system, namely when used for voltage sags compensation. In this case, with an SMES with these characteristics connected to the DC link of the UPQC, the stored energy increases to 698.25J. This represents an increase of 5700% in stored energy, which greatly expands the range of application of the hybrid system, when comparing to the UPQC alone.

C.FAULT DETECTION

To be able to overcome faults, it is first necessary to correctly and rapidly identify those events in the grid. Voltage sags and swells are detected following a method presented. Briefly, this method detects a voltage sag or swell by comparing the grid voltage value with a reference value. This reference value has the same phase and amplitude as the nominal voltage of the grid, which is very convenient because this is also used as a reference for the series active power filter.

III SUPERCAPACITOR

A super capacitor (SC) (sometimes ultra capacitor, formerly electric double-layer capacitor (EDLC)) is a high-capacity electrochemical capacitor with capacitance values much higher than other capacitors (but lower voltage limits) that bridge the gap between electrolytic capacitors and rechargeable batteries. They typically store 10 to 100 times more energy per unit volume or mass than electrolytic capacitors, can accept and deliver charge much faster than batteries, and tolerate many more charge and discharge cycles than rechargeable. They are however 10 times larger than conventional batteries for a given charge.

Super capacitors are used in applications requiring many rapid charge/discharge cycles rather than long term compact energy storage: within cars, buses, trains, cranes and elevators, where they are used for regenerative braking, short-term energy storage or burst-mode power delivery. Smaller units are used as memory backup for static random-access memory (SRAM). Super capacitors do not use the conventional solid dielectric of ordinary capacitors. They use electrostatic double-layer capacitance or electrochemical pseudo capacitance or a combination of both instead:

- Electrostatic double-layer capacitor use carbon electrodes or derivatives with much higher electrostatic double-layer capacitance than electrochemical pseudo capacitance, achieving separation of charge in a Helmholtz double layer at the interface between the surface of a conductive electrode and an electrolyte.
- The separation of charge is of the order of a few angstroms (0.3 0.8 nm), much smaller than in a conventional capacitor.
- Electrochemical pseudo capacitors use metal oxide or conducting polymer electrodes with a high amount of electrochemical pseudo capacitance. Pseudo capacitance is achieved by Faradic electron charge transfer with redo, intercalation or electro sorption.
- Hybrid capacitors, such as the lithium-ion capacitor, use electrodes with differing

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 14
October2016

characteristics: one exhibiting mostly electrostatic capacitance and the other mostly electrochemical capacitance

III.MATLAB/SIMULATION RESULTS

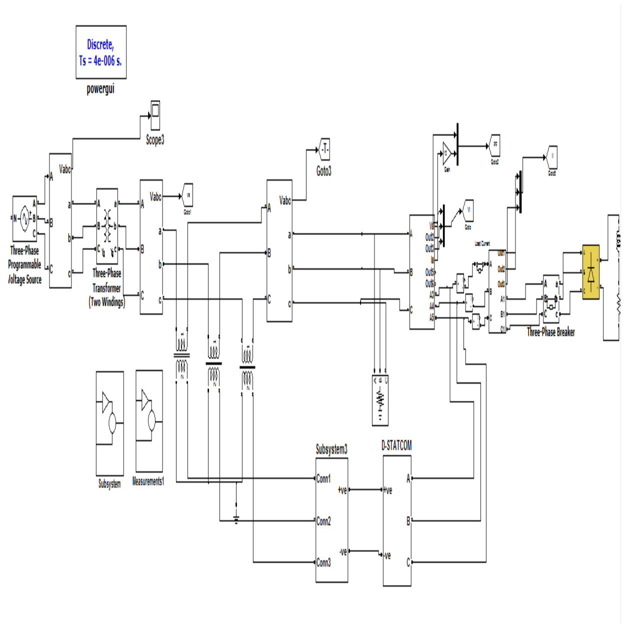

Fig 5: Simulation model of superconducting magnetic energy system of UPQC

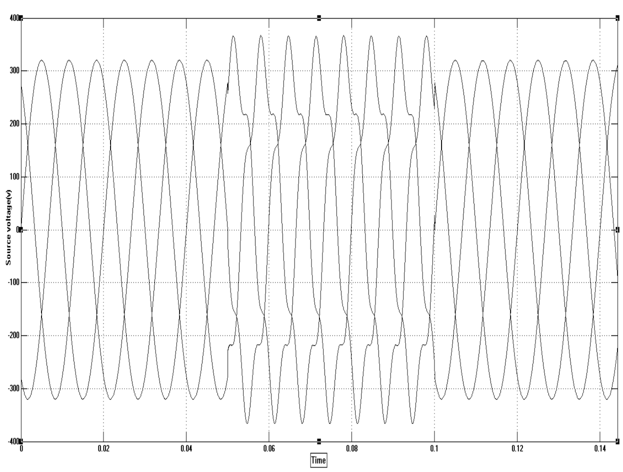

Fig 6: Harmonic Distortion Compensation of Source Voltages

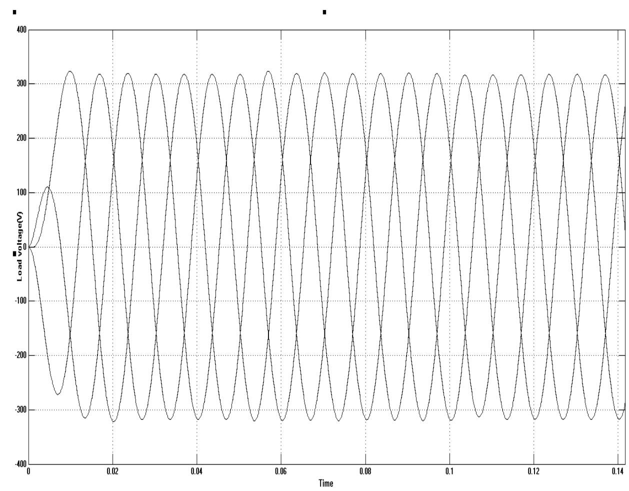

Fig 7: Harmonic Distortion Compensation of Load Voltages

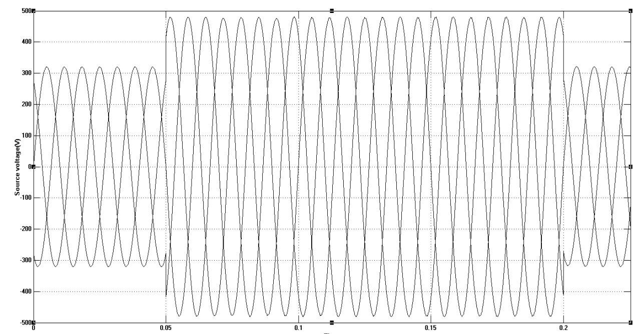

Fig 8: Voltage Swell Elimination of Source Voltages

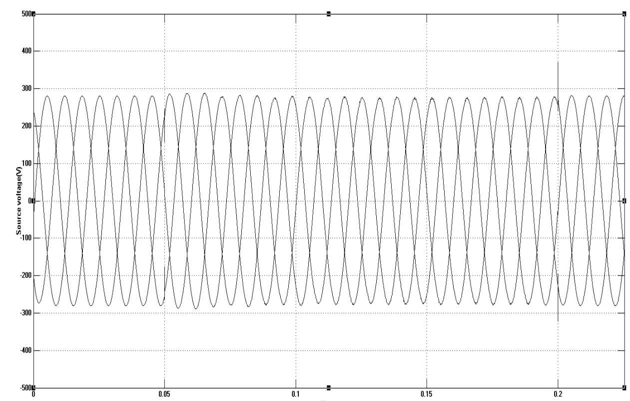

Fig 9: Voltage Swell Elimination of Load Voltages

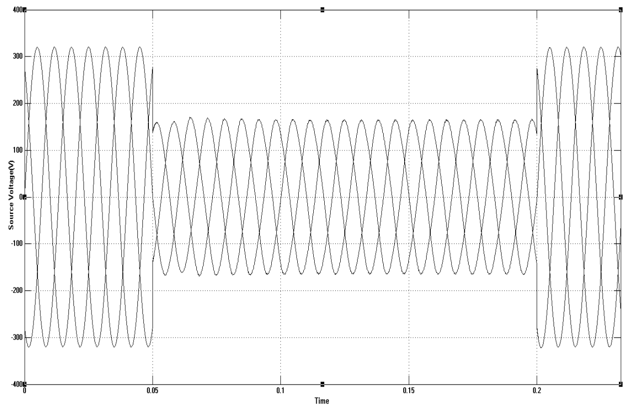

Fig 10: Voltage Sag Elimination: Source Voltages during the Fault.

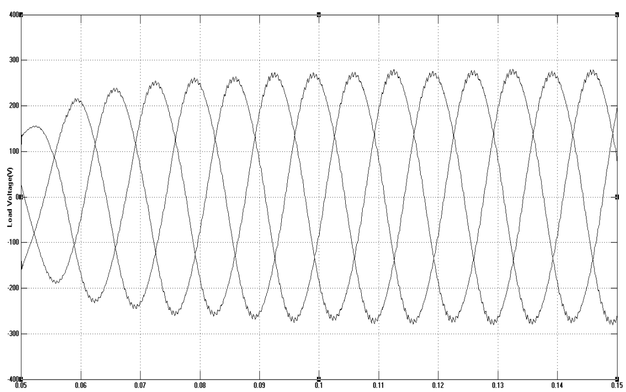

Fig 11: Voltage Sag Elimination: Load Voltages during the Fault.

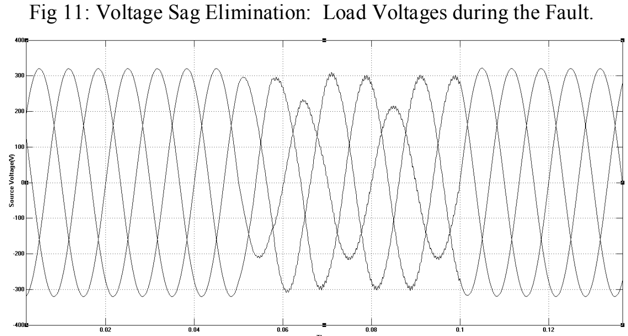

Fig 12: Evolution of Source Voltages during Single Phase Voltage Sag

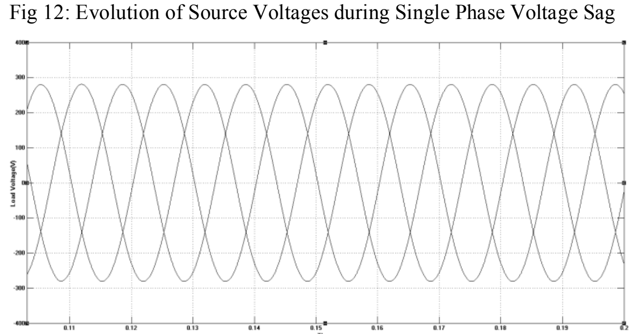

Fig 13: Evolution of Load Voltages during Single Phase Voltage Sag

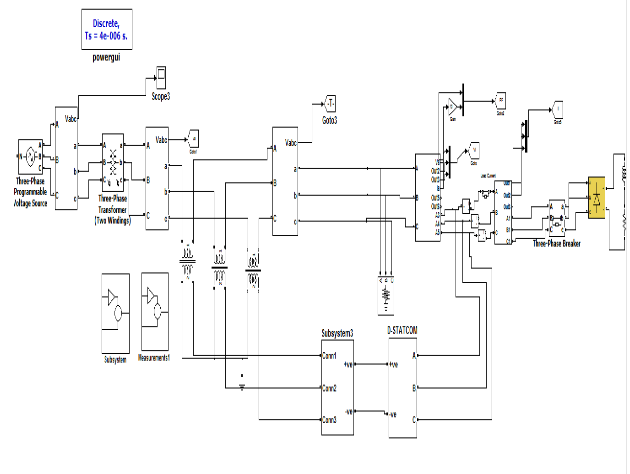

Fig 14: Simulation model of superconducting magnetic energy system of UPQC with super capacitor

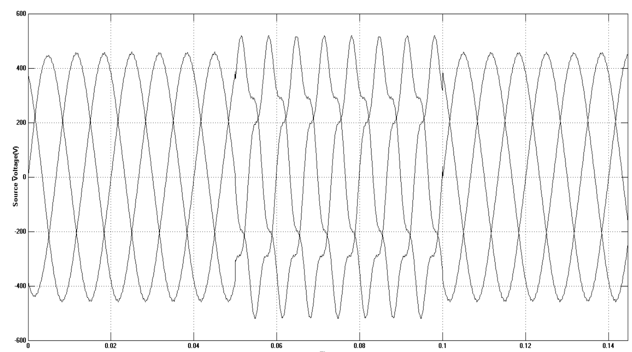

Fig 15: Source Voltages of Super Capacitor based Harmonic Distortion Compensation

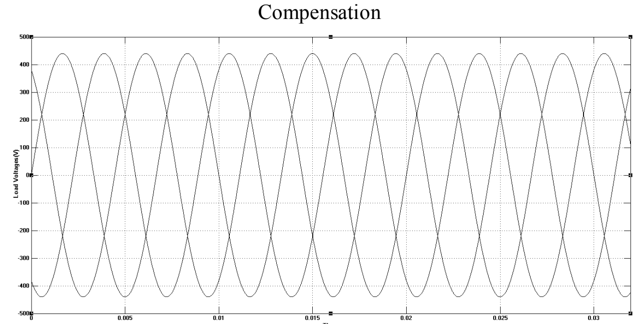

Fig 16: Load Voltages of Super Capacitor based Harmonic Distortion Compensation

IV.CONCLUSION

This paper proposes a new configuration of UPQC that consists of the DC/DC converter and the super capacitor. The proposed UPQC compensated the reactive power, harmonic currents, voltage sag and swell, voltage unbalance, and the voltage interruption. In all the operating conditions the THD of source current has been observed within an IEEE 519-

1992 standard limit of 5%. This paper researches structure principle and the control strategy of UPQC and arrives at the following conclusions: 1) Super capacitor energy storage and DC /DC converter buffer reactive power, exchange and provide energy for voltage compensation. As a result, decoupling series converter and parallel converter is implemented. Moreover, voltage quality problems of power interruption, which beyond the reach of traditional UPQC, can be resolved successfully. With UPQC, power quality problems in distribution network with high penetration of DGs could be improved.

REFERENCES

[1] EURELECTRIC, Power Quality in European Electricity Supply Networks, Second Edi. Brussels, 2003, p. 64.
[2] N. G. Hingorani and L. Gyugyi, Understanding FACTS. IEEE, 1999.
[3] H. Akagi, "New trends in active filters for power conditioning," IEEE Trans. Ind. Appl., vol. 32, no. 6, pp. 1312–1322, 1996.
[4] H. Akagi, E. H. Watanabe, and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2007.
[5] M. H. Rashid, Ed., Power Electronics Handbook. Elsevier, 2011.
[6] W. V. Hassenzahl, D. W. Hazelton, B. K. Johnson, P. Komarek, M. Noe, and C. T. Reis, "Electric power applications of superconductivity," Proc. IEEE, vol. 92, no. 10, pp. 1655–1674, Oct. 2004.
[7] A. P. Malozemoff, J. Maguire, B. Gamble, and S. Kalsi, "Power applications of high-temperature superconductors: status and perspectives," IEEE Trans. Appiled Supercond., vol. 12, no. 1, pp. 778– 781, Mar. 2002.
[8] N. Amaro, J. Murta Pina, J. Martins, and J. M. Ceballos, "SUPERCONDUCTING MAGNETIC ENERGY STORAGE – A Technological Contribute to Smart Grid Concept Implementation," in Proceedings of the 1st International Conference on Smart Grids and Green IT Systems, 2012, pp. 113–120.
[9] K. Shikimachi, H. Moriguchi, N. Hirano, S. Nagaya, T. Ito, J. Inagaki, S. Hanai, M. Takahashi, and T. Kurusu, "Development of MVA Class HTS SMES System for Bridging Instantaneous Voltage Dips," IEEE Trans. Appl. Supercond., vol. 15, no. 2, pp. 1931–1934, Jun. 2005.
[10] A. Friedman, N. Shaked, E. Perel, F. Gartzman, M. Sinvani, Y. Wolfus, D. Kottick, J. Furman, and Y. Yeshurun, "HT-SMES operating at liquid nitrogen temperatures for electric power quality improvement demonstrating," IEEE Trans. Appl. Supercond., vol. 13, no. 2, pp. 1875–1878, Jun. 2003.
[11] A.-R. Kim, S.-Y. Kim, K.-M. Kim, J.-G. Kim, S. Kim, M. Park, I. Yu, S. Lee, M. Sohn, H. Kim, J. Bae, and K. Seong, "Performance Analysis of a Toroid-Type HTS SMES Adopted for Frequency Stabilization," IEEE Trans. Appl. Supercond., vol. 21, no. 3, pp. 1367–1370, Jun. 2011.
[12] Y. Makida, H. Hirabayashi, T. Shintomi, and S. Nomura, "Design ofSMES System With Liquid Hydrogen for Emergency Purpose," IEEETrans. Appl. Supercond., vol. 17, no. 2, pp. 2006–2009, Jun. 2007.
[13] R. Kreutz, H. Salbert, D. Krischel, A. Hobl, C. Radermacher, N. Blacha, P. Behrens, and K. Dutsch, "Design of a 150 kJ high-Tc SMES (HSMES) for a 20 kVa uninterruptible power supply system," IEEE
Trans. Appl. Supercond., vol. 13, no. 2, pp. 1860–1862, Jun. 2003.

I am KASARLA SANDEEP received B-tech from Elenki Engineering College in the year of 2013 and now pursuing M-Tech in the stream of power system control and automation at Aurora's Scientific, Technological and Research Academy; Bandlaguda, Hyderabad.

MANOJ NETHALA Assistant Professor
Department of Electrical & Electronics Engineering, Aurora's Scientific, Technological and Research Academy