ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Mitigation of Sag in Single and Double Phases Using STATCOM and Ultra capacitor

M.Deepak
M.Tech Student (PS&PE),
Department of EEE,
NOVA College of Engg and Technology.

A Surya Narayana Babu
Assistant Professor,
Department of EEE,
NOVA College Of Engg and Technology.

Abstract:

The STATCOM (Synchronous Static Compensator) based on Voltage Source Converter (VSC) is used for voltage regulation in transmission and distribution systems. The STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control. However, STATCOMs are limited in their ability to improve the system stability margin due to their restricted capability for delivering real power.

The integration of Ultracapacitor energy storage system (UCESS) into STATCOMs can provide independent real and reactive power absorption/injection into/from the grid, leading to a more economical and/or flexible transmission controller. The aim of this work is to investigate how ultracapacitor based energy storage technology can be used to enhance the capability of STATCOM units to maintain a high quality of distribution voltage, performance voltage sagging in the system and improve the system stability.

Keywords:

MATLAB/Simulink, STATCOM, Ultracapacitors, Voltage Source Converter (VSC).

I.INTRODUCTION:

Quality power supply is essential for proper operation of industrial processes which contain critical and sensitive loads. These loads include low-power electronics devices such as process control equipment, computers as well as power electronics-controlled motor drives. Disturbances such as voltage sags and swells, short duration interruptions, harmonics and transients may disrupt the processes and lead to considerable economic loss. Among the disturbances, voltage sags are considered to be the most significant and critical. Voltage sag is a momentary decrease of the voltage RMS value with the duration of half a cycle up to many cycles. Voltage sag can cause serious problem to sensitive loads that use voltage sensitive components such as adjustable speed drives, process control equipment, and computers.

STATCOMs [1],[2] by their own can exchange reactive power with the power system, but they are limited in their ability to improve the system stability margin due to their restricted capability for delivering real power because they don't include energy storage devices. Recent developments and advances in energy storage and power electronics technologies are making the application of energy storage technologies a viable solution for modern power applications. Viable storage technologies include batteries, flywheels, ultracapacitors, and superconducting energy storage systems. Some of these energy storage systems have been used with STATCOMs for steady-state voltage control and to enhance the performance of power system

The recent development of ultracapacitors provides a new range of devices which can store significant amounts of energy. Their main application is for short term "power boost" type applications where they can release a large amount of energy quickly, and then recharge, with a smaller current if necessary.The aim of this work is to investigate how ultracapacitor based energy storage technology can be used to enhance the capability of STATCOM units to maintain a high quality of distribution voltage, performance voltage sagging in the system and improve the system stability.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

II.ULTRACAPACITOR ENERGY STORAGE SYSTEM:

Ultracapacitors (also known as electrochemical capacitors, supercapacitors or double layer capacitors) are becoming one of the most interesting solutions due to their electrical nature, which is characterized by high power density, good efficiency and an increasing energy density. Besides, they offer better endurance, reliability, high cycling capability, long lifetime and small dimension. Furthermore, operation in a wide temperature range is possible, they are more environment-friendly when compared to batteries, and maintenance is not required.

These exhibit high energy density in comparison with conventional capacitors (even when compared to electrolytic capacitors) reaching values of thousands of Farads. Nevertheless, their nominal voltage is very low and series connection is required to handle high voltage levels. Ultracapacitors are constructed similarly to a battery in the sense that two electrodes are immersed in an electrolyte with an ion-permeable separator between the electrodes in order to prevent the electrical contact, but still allow ions from electrolyte to pass through.

The electrodes are made with high effective surface materials, such as porous carbon or carbon aerogel, usually carbon, in order to achieve a larger surface. Charge is stored in those micropores near the interface between the electrode and the electrolyte. The mechanism of energy storage is more complex in ultracapacitors due to their structure and as a consequence their dynamic response differs in several ways when compared to a conventional capacitor.

III.SYSTEM OVERVIEW:

Fig.1 summarizes the proposed detailed model of the STATCOM-UCES for dynamic performance studies. This model consists mainly of the STATCOM, the ultracapacitor unit and the DC/DC converter to interface both devices. The STATCOM basically consists of a three-phase voltage source inverter (VSI) shunt-connected to the distribution network by means of a step-up Δ–Y coupling transformer and the corresponding line sinusoidal filter.

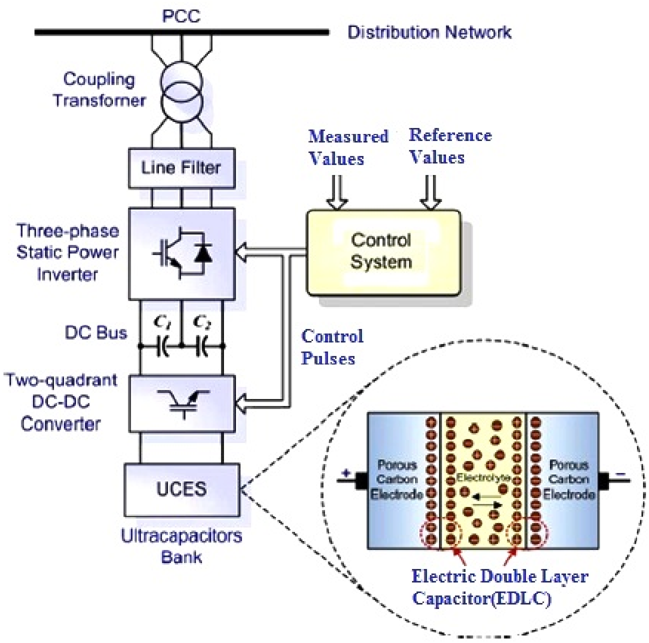


Fig.1. General structure of the STATCOM-UCESS.

The VSI presented corresponds to a DC-AC switching power converter using Insulated Gate Bipolar Transistors (IGBT). As the power rating of the inverter is intermediate to small, the output voltage control [3],[4],[5] of the VSI can be achieved through pulse width modulation (PWM) techniques by using high power fast-switched IGBTs.The integration of the UCES system into the DC bus of the STATCOM device requires a rapid and robust bidirectional interface to adapt the wide range of variation in voltage and current levels between both devices, especially because of the ultracapacitor fast dynamic behaviour. Controlling the UCES system rate of charge/discharge requires varying the voltage magnitude according to the UC state-of-operation, while keeping essentially constant the DC bus voltage of the STATCOM VSI.

Hence, a buck/boost DC/DC converter topology by using high power fast-switched IGBTs is proposed. This step-down and step-up converter allows decreasing the ratings of the overall power devices by regulating the current flowing from the UCES to the inverter of the STATCOM and vice versa. The power circuit for the UCESS is shown in Fig.2. The specified current and voltage ripple are used to derive the inductance (L), and nominal DC link voltage respectively. The UCESS and STATCOM both connect to the DC link capacitor, a conventional electrolytic capacitor C. Csc is the supercapacitor module, D is a diode, and IGBT is an Insulated Gate Bipolar Transistor.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

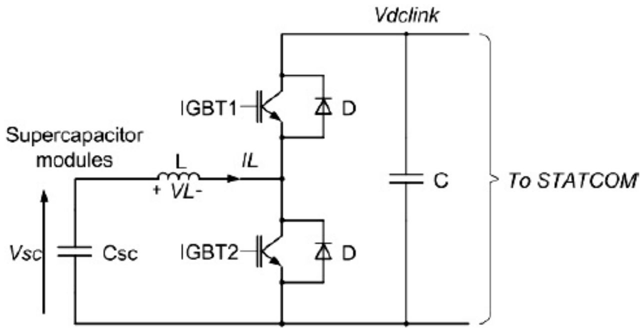


Fig.2. Circuit diagram of UCESS

The DC-to-DC converter operates in "Buck Mode" [6] to recharge the Ultracapacitors, whereas "Boost Mode" transfers the stored energy to the DC link maintaining the DC link voltage constant during real power delivery.

A.STATCOM-UCESS controller:

The control system designed in this research for the UCESS is similar to the one used in[7]. The control system consists of two parts; namely boost mode control and buck mode control.

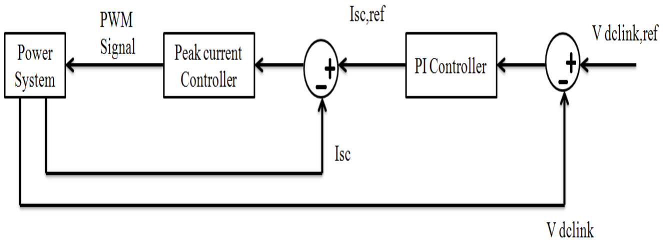


Fig.3. UCESS boost mode control

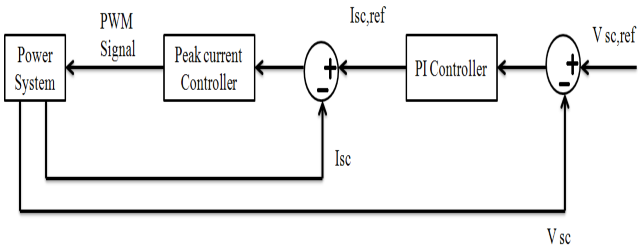


Fig.4. UCESS buck mode control

In the UCESS boost mode control, the controller consists of one control loop which controls the discharge current inside another control loop that controls the DC link voltage. (Fig.3) shows the control block diagram for the UCESS in boost mode.

In the UCESS buck mode control, the controller consists of one control loop which controls the charging current inside another control loop that controls the Ultracapacitor voltage. (Fig.4) shows the control block diagram for the UCESS in buck mode. In both modes, the inner current loop current control is based on peak current control mode. The details of the peak current control mode are well explained in. The outer voltage controllers are conventional PI controllers.

IV.SIMULATION OF STATCOM-UCESS:

The basic theme of connecting UCESS with STATCOM formulates the compensation of both active and reactive Power. STATCOM contribution in case of elimination of sag occurred in the power system has been concentrated in this paper. The system in Fig 5 consists of Power System Network of ratings as VL=400V (Phase), IL=5A. Then Single phase Sag from 0.15 to 0.25sec and a Double phase Sag from 0.1 to 0.2sec has been introduced in the System.

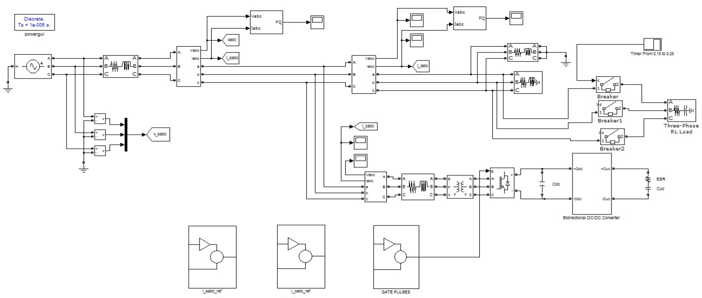


Fig.5. (a) Matlab simulink for Single Phase Sag From 0.15 to 0.25Sec of STATCOM-UCESS.

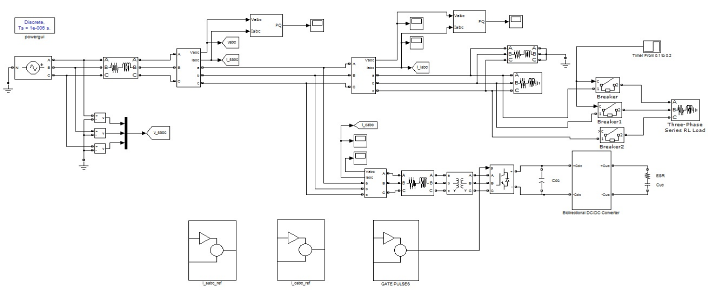


Fig.5. (b) Matlab simulink for Double Phase Sag From 0.1 to 0.2Sec of STATCOM-UCESS

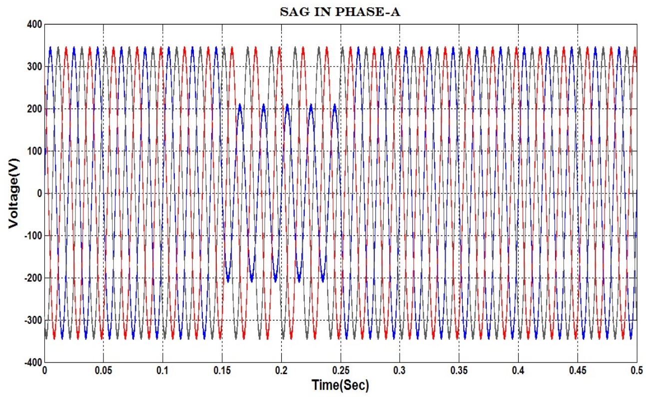
V. SIMULATION RESULTS:

The obtained simulation results have been shown in Fig.6, Fig.7 and Fig.8 which represents the mitigation of sag with the help of STATCOM and UCESS.

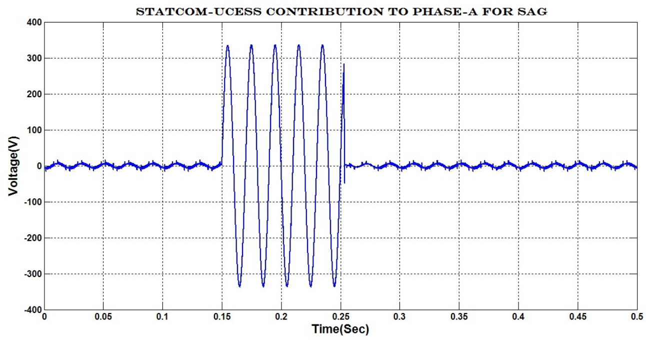
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The voltage of the ultracapacitors rise rapidly in the initial stage of charging, When the external system had failure, the voltage of the ultracapacitors stop rising but began to decline with the discharging process. And the voltage of the ultracapacitors slowly decreased. When the external system restored, the voltage of the ultracapacitors maintain constant.

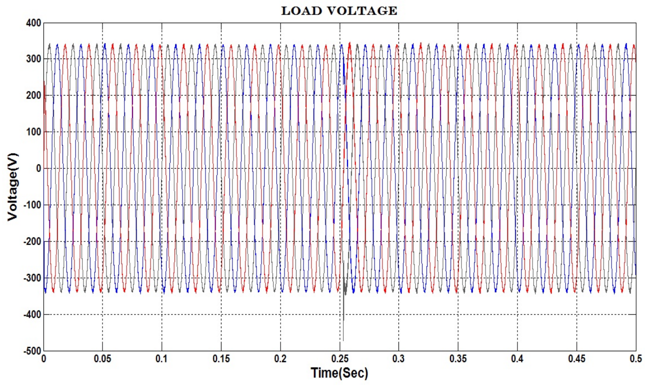
Fig.6 (a) shows the voltage waveform under abnormal condition i.e., when a Single Phase Sag between 0.15 to 0.25 sec occurred in the external system, Fig.6 (b) shows the contribution waveform of STATCOM-UCESS, Fig.6 (c),(d) shows the voltage and current waveforms after Mitigation the Single Phase Sag by STATCOM and UCESS



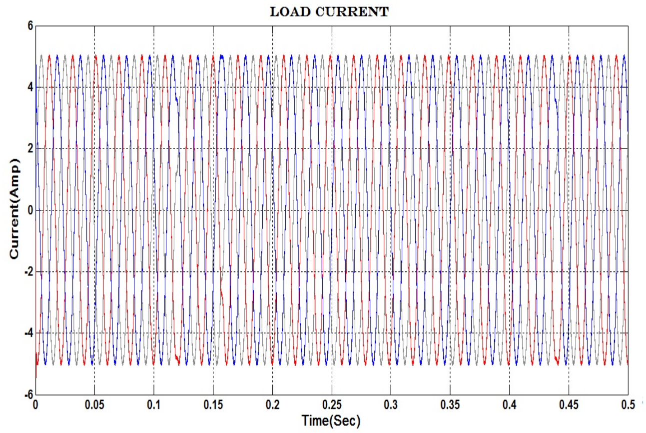
(a)



(b)



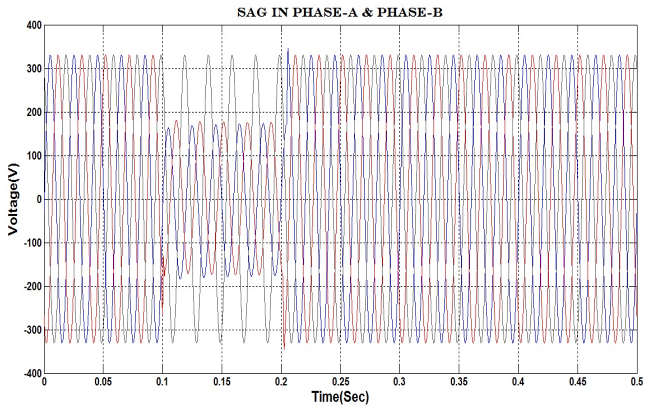
(c)



(d)

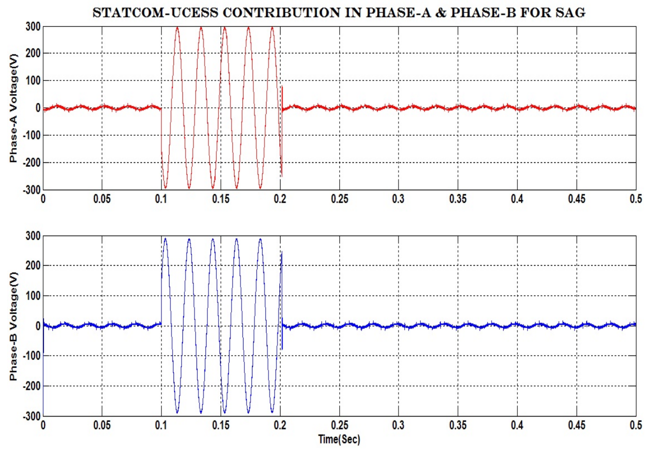
Fig.6.(a) System operating under abnormal condition, Occurrence of a Single Phase Sag between 0.15 to 0.25 sec (b)Contribution Of Statcom-UCESS (c),(d) Bus Voltage and current at PCC after Mitigation of the Single Phase Sag

Fig.7 (a) shows the voltage waveform under abnormal condition i.e., when a Double Phase Sag between 0.1 to 0.2 sec occurred in the external system, Fig.7 (b) shows the contribution waveform of STATCOM-UCESS, Fig 7 (c),(d) shows the voltage and current waveforms after Mitigation the Single Phase Sag by STATCOM and UCESS.

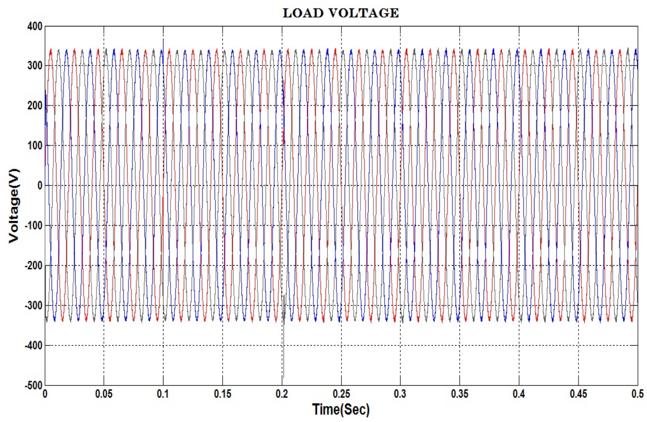


(a)

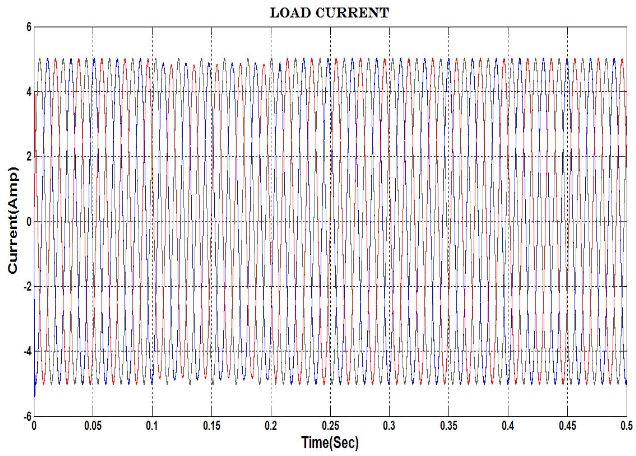
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



(b)



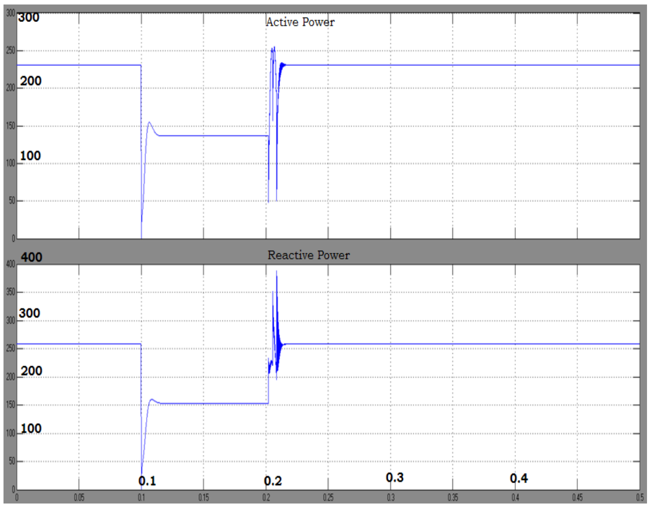
(c)



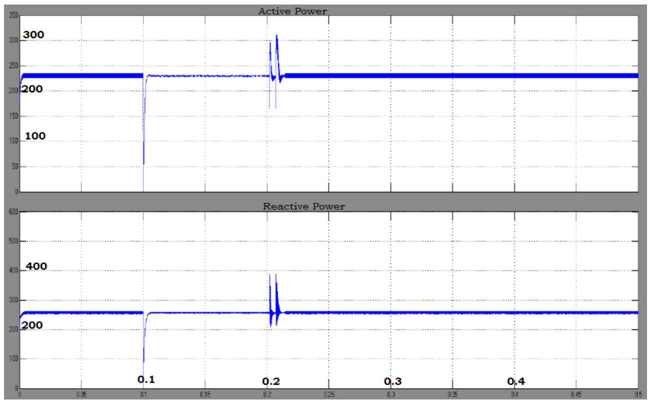
(d)

Fig.7.(a) System operating under abnormal condition, Occurrence of a Double Phase Sag between 0.1 to 0.2sec (b)Contribution Of Statcom-UCESS (c),(d) Bus Voltage and current at PCC after Mitigation of the Single Phase Sag

Fig.8 clearly shows the supply of real and reactive power to the system during the Sag.



(a)



(b)

Fig.8. (a) Active and Reactive power without STATCOM and UCESS (b) Active and Reactive power with STATCOM and UCESS.

VI.CONCLUSION:

In this paper, STATCOM is integrated with the UCESS which allows STATCOM to deliver the real power to the network for short period of time and also it was observed that the PCC bus voltage is very close to the reference value, i.e., 1pu and the voltage sags are minimized completely. Moreover, through simulation results we can judge that the charge/discharge of the capacitor is rapid and hence the response of the STATCOM is fast. It can therefore be seen that the Ultracapacitors with a DC-to-DC converter and proper control can help STATCOMs deliver both active and reactive power instantaneously into grid, which is the key to improving and enhancing the transient stability of the power system.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

ACKNOWLEDGMENT:

Author would like to thank Department of Electrical Engineering, VNIT Nagpur for providing the lab resources.

REFERENCES:

[1]"A Practical Operation Strategy for STATCOM under Single Line to Ground Faults in the Power System" Subhashish Bhattacharya and Zhengping Xi.

[2]Dynamic Performance Of Statcom Under Line To Ground Faults In Power System" Y.Suresh IEEE Student Member, A.Kpanda .

[3]"Control of STATCOM in Wind Power Plants based on Induction Generators during Asymmetrical Grid Faults" P.Rodriguez, A.Luna, G. Medeiros, R. Tedorescu, and F. Blaabjerg, IEEE 2010 International Power Electronics Conference, Pg :2066-2073.

[4]"Instantaneous Phase-Locked Loop for Performance Improvement of Power System with STATCOM under Single-line to Ground Fault" Zhengping Xi, Babak Parkhideh, Subhashish Bhattacharya, IEEE 2011, Pg:3750-3757.

[5]"Analysis and design of a novel fixed-frequency buck-boost zero-current zero-voltage switched converter" G.Ioannidis, E.Xanthoulis, S.N.Manias, IEE Proc.-Electr. Power Appl., Vol. 145, No. 1, January 1998, Pg:33-38 .

[6]"Zero-voltage and zero-current switching buck-boost converter with low voltage and current stresses" B.P. Divakar K.W.E. Cheng D. Sutanto, IET Power Electron., 2008, Vol. 1, No. 3, pp. 297–304 .

[7]P. Srithorn, M. Sumner, and L. Yao, R. Parashar, "A STATCOM with supercapacitors for enhanced power system stability" 4th IET Conference on Power Electronics, Machines and Drives , 2008 , pp.96-100.

[8]B.Singh,R.Saha,A.Chandra,K.Al-Haddad "Static synchronous compensators (STATCOM): a review" www.ietdl.org.

[9]Amin Nazarloo1, Seyed Hossein Hosseini, Ebrahim Babaei and Md Bagher Bannae Sharian"Integrated D-STATCOM with Supercapacitor Used in IEEE Industrial Distribution System" ECTI transactions vol.10, no.1 february 2012.

[10]Bhim Singh,P. Jayaprakash, T.R.Somayajulu and D.P.Kothari "Reduced Rating VSCWith a Zig-Zag Transformer for Current Compensation in a Three-Phase Four-Wire Distribution System" IEEE transactions on power delivery, vol. 24, no. 1, january 2009.

[11]M. Al-Ramadhan and M.A.Abido "Design and Simulation of Supercapacitor Energy Storage System" ICREPQ'12 28th to 30th March, 2012 .

[12]Petar J. Grbovi´c,Philippe Delarue,Philippe Le Moigne and Patrick Bartholomeus "A Bidirectional Three-Level DC–DC Converter for the Ultracapacitor Applications" IEEE trans on industrial electronics, vol. 57, no. 10, october 2010.

[13]Chong Han, Alex Q. Huang, Ding Li, Haresh Mamath, Mike Ingram, Stanley Atcitty "Modeling And Design Of A Transmission Ultracapacitor (TUCAP) Integrating Modular Voltage Source Converter With Ultracapacitor Energy Storage" IEEE 2006 .

[14]Andrew Burke "Ultracapacitors: why, how, and where is the technology" Elsevier Science 2000.

[15]Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems By Narain G. Hingorani & Laszlo Gyugyi .

[16]FACTS: Controllers in Power Transmission and Distribution By K. R. Padiyar