Sag and Swell mitigation in Distributed Generation with the help of DSTATCOM

REPORT OF PROJECT SUBMITTED FOR PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF
BACHELOR OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

By

Name	Class roll no.	Univ. roll no.
Tanujit Pramanik	EE2016/003	11701616013
Anshu Shikha	EE2016/051	11701616067
Ajay Kumar Singh	EE2016/053	11701616069

UNDER THE SUPERVISION OF
MR.SUBHASISH BANERJEE
[GUIDE]

AT
RCC INSTITUTE OF INFORMATION TECHNOLOGY
[Affiliated to Maulana Abul Kalam Azad University of Technology]
CANAL SOUTH ROAD, BELIAGHATA, KOLKATA – 700015

RCC INSTITUTE OF INFORMATION TECHNOLOGY

KOLKATA – 700015, INDIA

CERTIFICATE

The report of the Project titled ***SAG AND SWELL MITIGATION IN DISTRIBUTED GENERATION WITH THE HELP OF DSTATCOM*** *submitted by Tanujit Pramanik(11701616013),Anshu Shikha(11701616067),Ajay Kumar Singh(11701616069) (of B. Tech. (EE) 8th Semester of 2020) has been prepared under supervision of Mr.Subhasish Banerjee for the partial fulfillment of the requirements for B Tech (EE) degree in MAKAUT. The report is hereby forwarded.*

OPTIONAL IN CASE

[Name of Guide]	*[Name of Guide]*
Designation	*Dept. of*
Institute Name	*RCCIIT, Kolkata*
(External Supervisor)	*(Internal Supervisor)*

Countersigned by

…………………………………………..

Name of Head

Department EE

RCC Institute of Information Technology, Kolkata – 700 015, India

ACKNOWLEDGEMENT

It is our great fortune that we have got opportunity to carry out this project on topic "SAG AND SWELL MITIGATION IN DISTRIBUTED GENERATION WITH THE HELP OF DSATCOM" work under the supervision of Mr.SUBHASISH BANERJEE in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India. We express our sincere thanks and deepest sense of gratitude to my guide for his constant support, unparalleled guidance and limitless encouragement.

We wish to convey my gratitude to Prof. DEBASHISH MONDAL HOD, Department of Electrical Engineering, RCCIIT and to the authority of RCCIIT for providing all kinds of infrastructural facility towards the research work.

We would also like to convey our gratitude to all the faculty members and staffs of the Department of Electrical Engineering, RCCIIT for their whole hearted cooperation to make this work turn into reality.

RCC INSTITUTE OF INFORMATION TECHNOLOGY

KOLKATA – 700015, INDIA

CONTENT

INTRODUCTION

Power quality determines the fitness of electric power to consumer devices. The term is used to describe electric power that drives an electrical load and load's ability to function properly. Without the proper power, an electrical device may malfunction, fail prematurely or not operate at all.

There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. Power quality is certainly a major concern in the present era. It becomes especially important with the insertion of sophisticated devices ,whose performance is very sensitive to the quality of power supply.

A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Modern industrial processes are mainly based on electronic devices such as PLC's, power electronic devices, drives etc., and since their controls are sensitive to disturbances such as voltage sag, swell and harmonics, voltage sag is most important power quality problems. It contributes more than 80% of power quality (PQ) problems that exist in power systems, and more concern problems faced by many industries and utilities.

By definition, voltage sag is an rms (root mean square) reduction in the AC voltage at the power frequency, for duration from a half- cycle to a few seconds. Voltage sag is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single- phase or multiple- phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. Voltage sags are not tolerated by sensitive equipment's used in modern industrial plants such as process controllers, programmable logic controllers (PLC), adjustable speed drive (ASD) and robotics. Various methods have been applied to reduce or mitigate voltage sags. The conventional methods are by using capacitor banks, introduction of new parallel feeders and by installing uninterruptible power supplies (UPS). However, the PQ problems are not solved completely due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to *provide not only for voltage sags mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control. One of the most common power quality problems today is voltage dips. A voltage dip is a short time(10 milliseconds to 1 minute) event during which a reduction in rms (root mean square) voltage magnitude occurs. It is often set only by two parameters, depth/magnitude and duration. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration from half a cycle to 1 min. In a three-phase system a voltage dip is by nature a three-phase phenomenon, which affects both the phase-to-ground and phase-to-phase voltages. A voltage dip is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance.*

OBJECTIVES OF PROJECT

- *Study of major source of power quality problems*
- *Impact on other equipment and on the power system*
- ***Measurement techniques***
- ***Mitigation Method***

LITERATURE REVIEW

1.MITIGATION OF VOLTAGE SAGS/SWELLS UNBALANCED IN LOW VOLTAGE DISTRIBUTION SYSTEMS

The main problems of the power quality like voltage sags/swells in low voltage distribution systems and on the transmission side due to sensitive loads, the terminology used for the compensation devices is different. Dynamic Voltage Restorer(DVR) is one of the equipment's for voltage disturbance mitigation in power systems. It is installed between the incoming supply and the sensitive loads to maintain the voltage at the sensitive load from balance. It proposes a mitigation of voltage sags/swells in low voltage distribution system using an effective series compensator (DVR). The compensator should protect sensitive loads against of voltage sags/swells. Performance of the proposed method is investigated under different types of fault in both single phase and three phases for various sensitive load conditions. The simulation was carried out with the help of SIMULINK & MATLAB and the results show appropriate operation of the proposed control system.

2. OPTIMAL PLACEMENT OF DSTATCOM FOR VOLTAGE SAG MITIGATION USING AN ANFIS BASED APPROACH FOR POWER QUALITY ENHANCEMENT

DSTATCOM is one of the equipment's for voltage sag mitigation in power systems. Voltage sag has been considered as one of the most harmful power quality problem as it may significantly affect industrial production. This paper presents an Artificial Neuro fuzzy inference system (ANFIS) based approach for optimal placement of Distribution Static Compensator (DSTATCOM) to mitigate voltage sag under faults. Voltage sag under different type of short circuits has been estimated using MATLAB/SIMULINK software. Optimal location of DSTATCOM has been obtained using a feed forward neural network trained by post-fault voltage magnitude of three phases at different buses. Case studies have been performed on IEEE 30-bus system and effectiveness of proposed approach of DSTATCOM placement has been established.

3. PERFORMANCE EVALUATION OF D-STATCOM FOR VOLTAGE FLUCTUATIONS IN POWER DISTRIBUTION SYSTEM

As demand of quality and reliability of electric power is continuously increasing, Power Quality has now become a important aspect in the current power scenario. Power quality determines quality and ability of electric power available at the consumer end. Maintaining voltage, frequency and phase to desired level allows electrical systems to provide quality and reliability of
power without considerable loss of performance or life. poor power quality can be caused due to failure of loads and sudden switching of heavy electrical loads in the network, which mainly result in voltage sag and swell , disturbances in loads may also results in voltage fluctuation.
However voltage flicker and interruptions are the most common problem which effects power quality.

4. MITIGATION OF VOLTAGE SAG AND VOLTAGE SWELL BY USING D-STATCOM AND PWM SWITCHED AUTOTRANSFORMER

This proposes a novel distribution-level voltage control scheme that can compensate voltage Sag and Swell conditions in three-phase power systems. Faults occurring in power distribution systems or facilities in plants generally cause the voltage sag or swell. Sensitivity to voltage sags and swells varies within different applications. For sensitive loads, even the slightest voltage sag for short duration can cause serious problems. Normally, a voltage interruption trigger protection device, which causes shut down the entire load. In order to mitigate power interruptions, this paper proposes a voltage sag support based on a pulse width modulated autotransformer and D -STATCOM. The proposed devices quickly recognize the voltage sag and voltage swell conditions and correct the voltage by either boosting the input voltage during voltage sag events or reducing the voltage during swell events. Simulation analysis of these devices is performed in PSCAD/EMTDC and performance analysis of the system is presented for various levels of sag and swell. Simulation results are presented for various conditions of sag and swell disturbances in the supply voltage to show the compensation effectiveness.

5. COMPARATIVE STUDY ON VOLTAGE SAG/SWELL MITIGATION BY MODELLING AND SIMULATION OF DVR AND DSTATCOM

The electrical energy is one of the easily used forms of energy. It can be easily converted to other forms of energy. With the advancement of technology, the dependency on the electrical energy has been increased greatly. Computer and telecommunication networks, railway network banking, post office, life support system are few application that just cannot function without electricity. At the same time these applications demand qualitative energy. However, the quality of power supplied is affected by various internal and external factors of the power system. The presence of harmonics, voltage and frequency variations deteriorate the performance of the system. In this paper the frequently occurring power quality problem- voltage variation is discussed. The voltage sag/dip is the most frequently occurring problem. There are many methods to overcome this problem. Among

them the use of FACT devices is an efficient one. This paper presents an overview of the FACT devices like- DVR, D-STATCOM, in mitigating voltage sag. Each one of the above device is studied and analyzed. And also the control strategies to control these devices are presented in this project. The proposed control strategies are simulated in MATLABSIMULINK environment and the results are presented in this paper. A
comparative study based on the performance of these devices in mitigating voltage sag is also presented.

6. DESIGN AND SIMULATION STUDIES OF D-STATCOM FOR VOLTAGE SAG, SWELL MITIGATION

This presents the design of a prototype distribution static compensator (D-STATCOM) for voltage sag mitigation in an unbalanced distribution system. The D-STATCOM is intended to replace the widely used static Var compensator (SVC). The model is based on the Voltage Source Converter (VSC) principle. A new PWM based control scheme has been implemented to control the electronic valves in two level of VSC. The D-STATCOM injects a current into the system to mitigate the voltage sags. In this work, the 6-pulse D-STATCOM configuration with IGBT has been designed using MATLAB SIMULINK. Accordingly, simulations are first carried out to illustrate the use of DSTATCOM in mitigating voltage sag in a distribution system. Simulation results prove that the D-STATCOM is capable of mitigating voltage sag as well as improving power quality of a system

7. NEURAL NETWORK CONTROLLER BASED DSTATCOM FOR VOLTAGE SAG MITIGATION AND POWE QUALITY ISSUE

One of the most important electric power systems problems, it's a voltage sag. When this phenomenon occurs, the impact on devices and equipment used in all types of domestic, commercial and industrial loads, which leads to malfunction, many of which will be a serious and very significant effects, particularly in industrialized loads being represent the backbone of life. This made as a major part of electric power quality provides the consumers. Power quality is one of the most important areas of generation, transmission and distribution systems of the power system. In this paper, design model of the electric power system which has been generating a voltage sag phenomenon has also been the study and analysis of the reasons for it.

8. MITIGATION TECHNIQUE FOR VOLTAGE SAG & SWELL BY USING DYNAMIC VOLTAGE RESTORER

DVR is one of the compensating types of custom power devices. An adequate modeling and simulation of DVR, including controls in MATLAB, show the flexibility and easiness of the MATLAB environment in studying and Understanding such compensating devices. Simulation results are presented to illustrate and understand the performances of DVR in supporting load voltages under voltage sags/swells conditions.

DISTRIBUTION STATIC COMPENSATOR (STATCOM)

A D-STATCOM consists of a two-level VSC, a dc energy storage device, controller and a coupling transformer connected in shunt to the distribution network. STATCOM is often used in transmission system. When it is used in distribution system, it is called DSTATCOM (STATCOM in Distribution system). DSTATCOM is a key FACTS controller and it utilizes power electronics to solve many power quality problems commonly faced by distribution systems. Potential applications of D-STATCOM include power factor correction, voltage regulation, load balancing and harmonic reduction. Comparing with the SVC, the D-STATCOM has quicker response time and compact structure. It is expected that the D-STATCOM will replace the roles of SVC in nearly future D-STATCOM and STATCOM are different in both structure and function, while the choice of control strategy is related to the main-circuit structure and main function of compensators, so D-STATCOM and STATCOM adopt different control strategy. At present, the use of STATCOM is wide and its strategy is mature, while the introduction of D-STATCOM is seldom reported. Refer to the strategies for STATCOM, in this paper, a compound control strategy used in D-STATCOM is presented to achieve the purpose of rapid-response compensation. A PWM-based control scheme has been implemented to control the electronic valves in the two-level VSC used in the D-STATCOM. Reactive power compensation is an important issue in the control of distribution systems. Reactive current increases the distribution system losses, reduces the system power factor, shrink the active power capability and can cause large-amplitude variations in the load- side voltage. Various methods have been applied to mitigate voltage sags. The conventional methods use capacitor banks, new parallel feeders, and uninterruptible power supplies (UPS). However, the power quality problems are not completely solved due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but also for a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction, and harmonic control. DSTATCOM is a shunt device that generates a balanced three-phase voltage or current with ability to control the magnitude and the phase angle. Generally, the D-STATCOM configuration consists of a typical 12-pulse inverter arrangement, a dc energy storage device; a coupling transformer connected in shunt with ac system, and associated control circuits. The configurations that are more sophisticated use multi-pulse and/or multilevel configurations. The VSC converts the dc voltage across the storage device into a set of three -phase ac output voltages. These voltages are in phase and coupled with the ac system of network through the reactance of the coupling transformer. A control method based on RMS voltage measurement has been presented in and where they have been presented a PWM-based control scheme that requires RMS voltage measurements and no reactive power measurements are required. In addition, in this given method, Clark and Park transformations are not required. However, they have been investigated voltage sag/swell mitigation due to just load variation while no balanced and unbalanced faults have been investigated. A new control method for mitigating the load *voltage sags caused by all types of fault is proposed. A Lookup Table is used to detect the proportional gain of PI controller, which is based only on Trial and Error. While in this paper, the proportional gain of the PI controller is fixed at a same value, for all types of faults, by tuning the transformer reactance in a suitable amount. Then the robustness and reliability of the proposed method is more than the mentioned methods. In this method, the dc side topology of the D-STATCOM is modified for mitigating voltage distortions and the effects of system faults on the sensitive loads are investigated and the control of voltage sags are analyzed and simulated.*

BASIC OPERATING PRINCIPLE

The basic operating principle of a D-STATCOM is similar to that of synchronous machine. The synchronous machine will provide a lagging current when under excited and leading current when over excited.

DSTATCOM can generate and absorb reactive power similar to the synchronous machine and it can also exchange real power if provided with an external active DC source.

1)Exchange of Reactive Power: If the output voltage of the voltage source converter is greater than the system voltage then the DSTATCOM will act as an inductor connected in shunt with the distribution system and absorb reactive power (i.e. provide lagging current to the system).

2)Exchange of Real Power: As the switching devices are not loss less there is a need for the DC capacitor to provide the required real power to the switches. Hence there is a need for the real power exchange with the AC system to make the capacitor voltage constant in case of direct voltage control. There is also a real power exchange with the AC system if the DSTATCOM is provided with an external DC source to regulate the voltage in case of very low voltage in the distribution system or in case of faults.

If the VSC output voltage lags behind the system voltage then the inverter will absorb real power from the AC system to charge the capacitor. And if the VSC output voltage leads the system voltage then the real power from the capacitor or the DC source will be supplied to the AC system to regulate the system voltage to 1p.u. or to make the capacitor voltage constant.

Hence the exchange of real and reactive power of the voltage source converter with the AC system is the major required phenomenon for the regulation of voltage in the transmission as well as in the distribution system.

D-STATCOM CIRCUIT

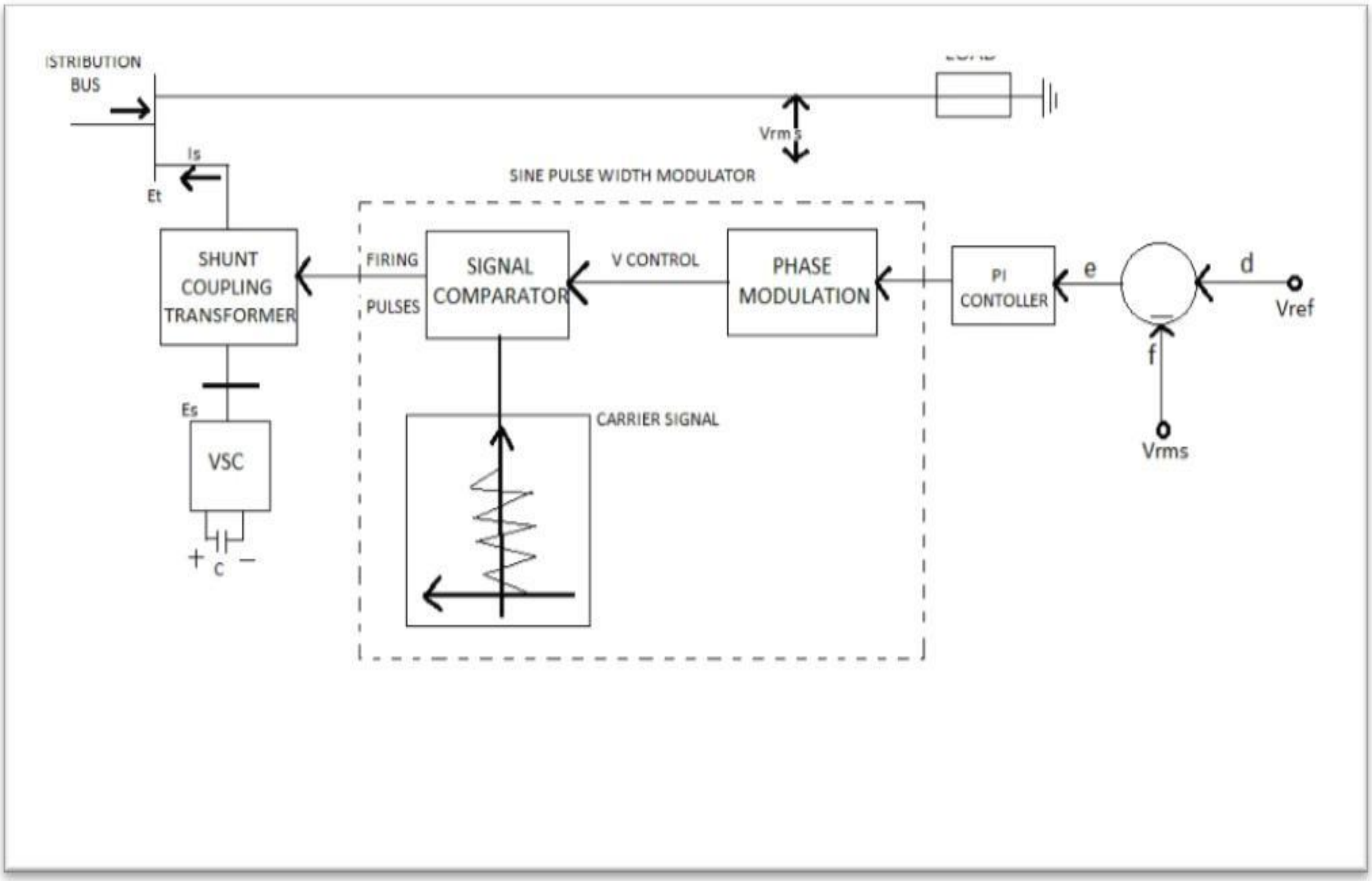
The main aim of the DSTATCOM is to provide voltage regulation at the load point. An IGBT based DSTATCOM with voltage source converter and a DC capacitor of 10,000F as the DC source with a capacity of 25 MVA is connected in shunt with the system through a transformer of 11KV. The dc capacitor should charge up to a voltage of 4000V in order to invert it into an ac voltage of 2000V as the line-line rms voltage is given by

$$VLL = 0.612MaVd$$

Where , VLL = Output AC voltage
Ma = Amplitude modulation ratio
Vd = Input DC voltage

The base voltage is taken as 11KV and base MVA is 25MVA. A filter circuit is connected at the output of the DSTATCOM circuit to eliminate the harmonics produced during switching. The reference PWM signals are given to the PWM generator to generate PWM pulses for the inverter.

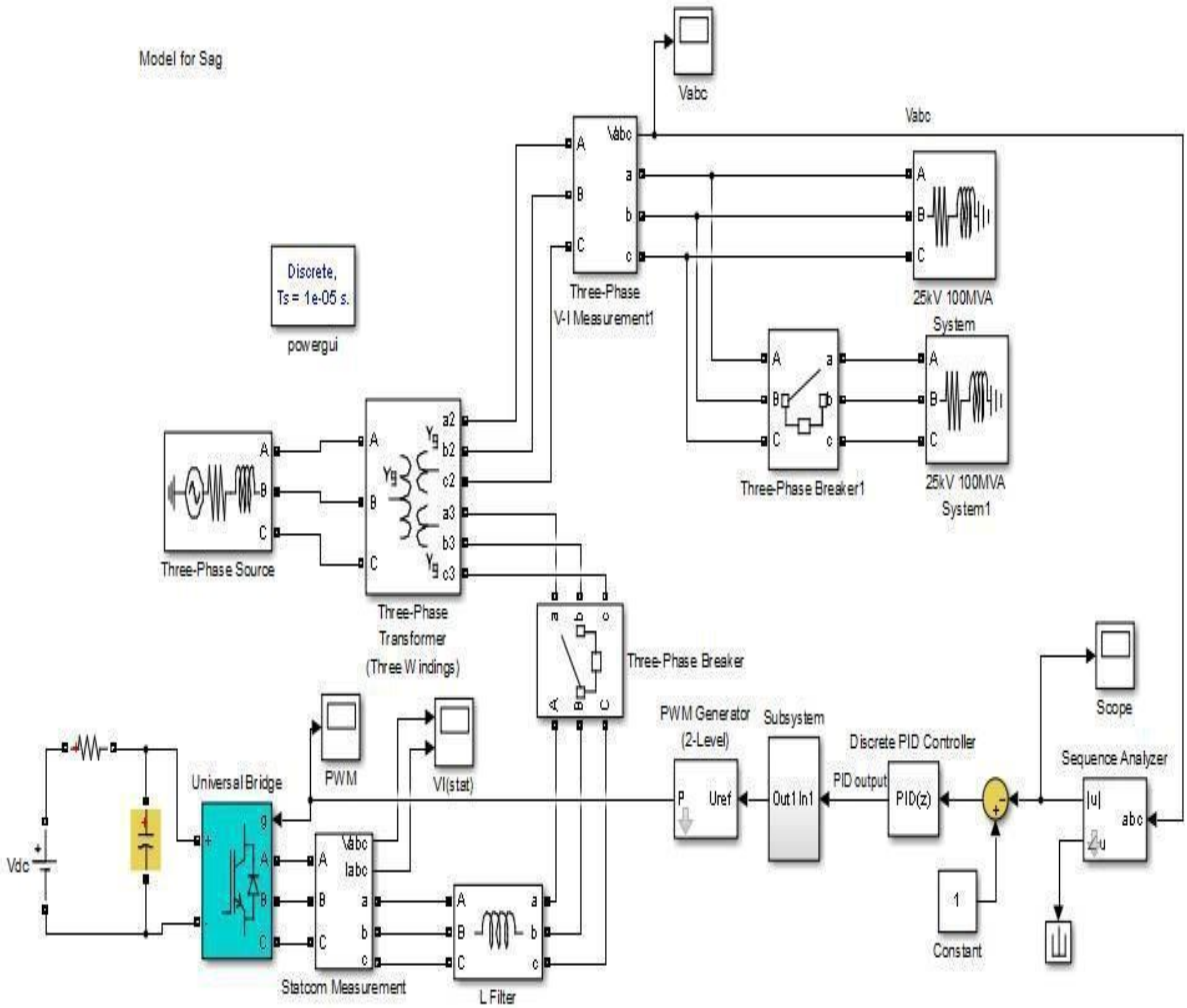
BLOCK DIAGRAM



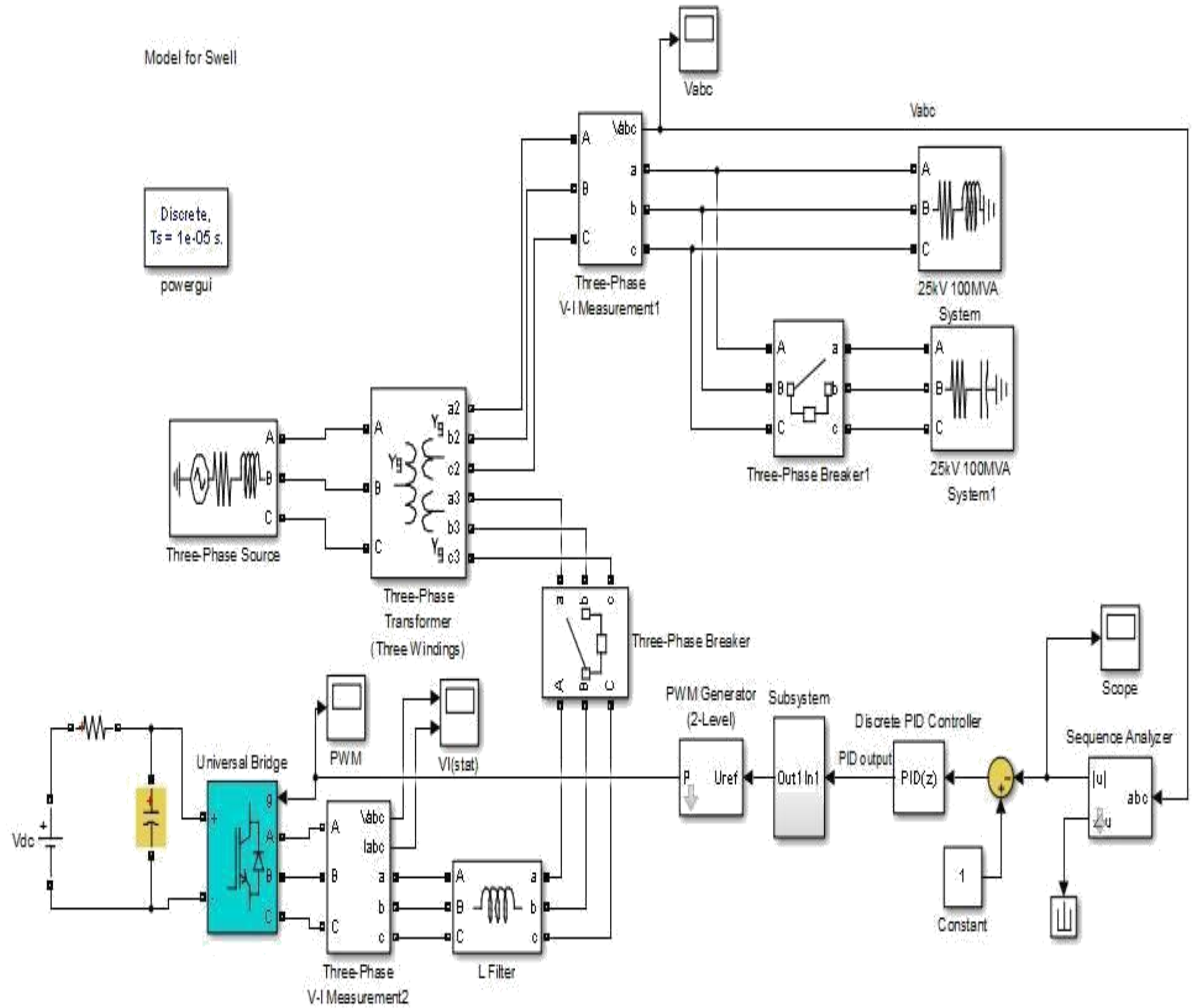
The block diagram of the control scheme designed for the DSTATCOM is shown in Fig. It is based only on measurements of the voltage VRMS at the load point. The voltage error signal is obtained by comparing the measured VRMS voltage with a reference voltage, VRMS Ref. A PI controller processes the difference between these two signals in order to obtain the phase angle δ that is required to drive the error to zero.

The aim of the control scheme is to maintain constant magnitude of voltage at the point where a sensitive load is connected, under system disturbances. No reactive power measurements are required; control system only measures the rms voltage at the load point. The switching strategy of VSC is based on a sinusoidal PWM technique which offers simplicity and good response. Modern semiconducting switches such as MOSFETs or IGBTs are suitable components for high efficiency controllers. High switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses in inverter. The input of controller is typically an error signal, which is the difference between reference signal and actual system output signal. The controller input is an error signal obtained from the reference voltage and measured rms voltage of terminal. Such a error is processed by a PI controller and the output is the angle δ, which is provided to the PWM generator. The error signal is generates by comparing the reference value and the actual value. Proportional-integral controller (PI Controller) is a feedback loop controller which drives the system to be controlled with the weighted sum of the error signal and the integral of that value. In this case, PI controller will process the error signal to zero that means the load rms voltage is brought back to the reference voltage by comparing the reference voltage with the measured rms voltages.

SIMULATION DIAGRAM



Simulation diagram of sag



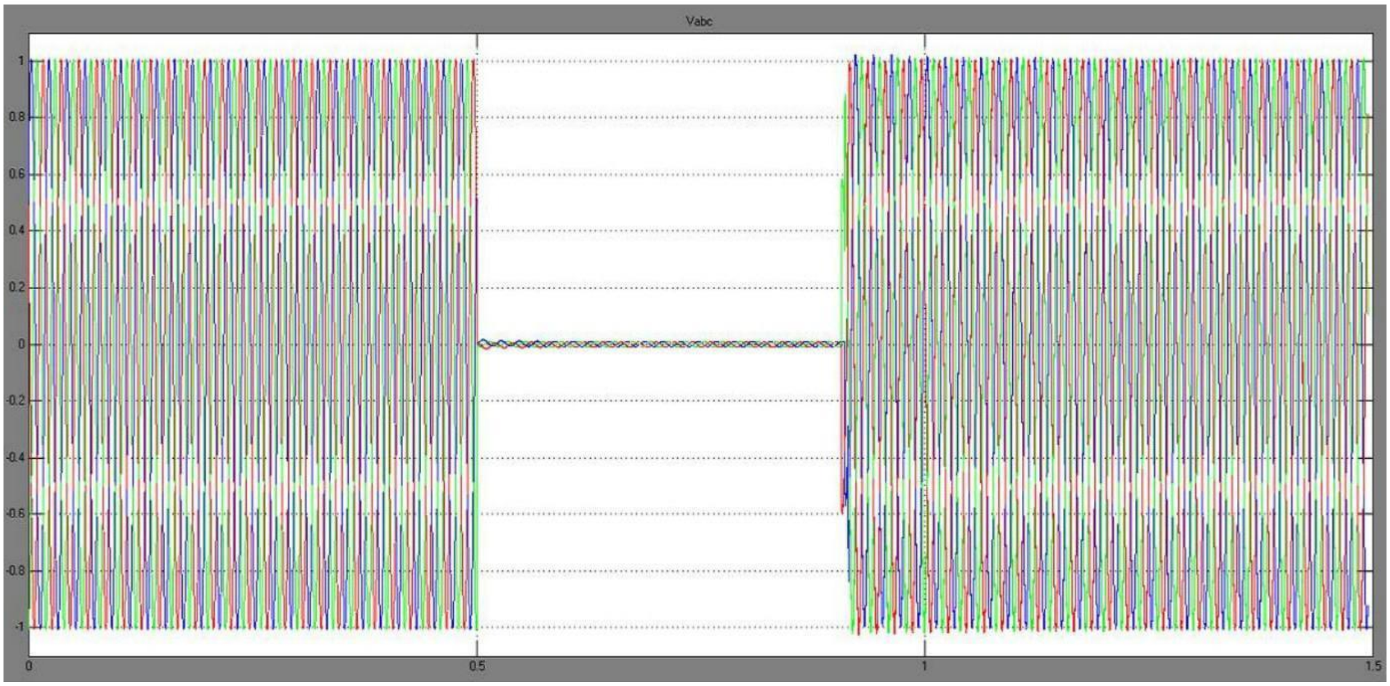
Simulation diagram of swell

To enhance the performance of distribution system, D-STATCOM is connected to the distribution system. DSTATCOM is designed using MATLAB Simulink .The figure comprises a 230kV, 50Hz transmission system, feeding into the primary side of a 3-winding transformer connected, 230/11/11kv. A varying load is connected to the11kV, secondary side of the transformer. The capacitor on the dc side provides the DSTATCOM energy storage capabilities. Circuit breaker is used to control the period of operation of the DSTATCOM.

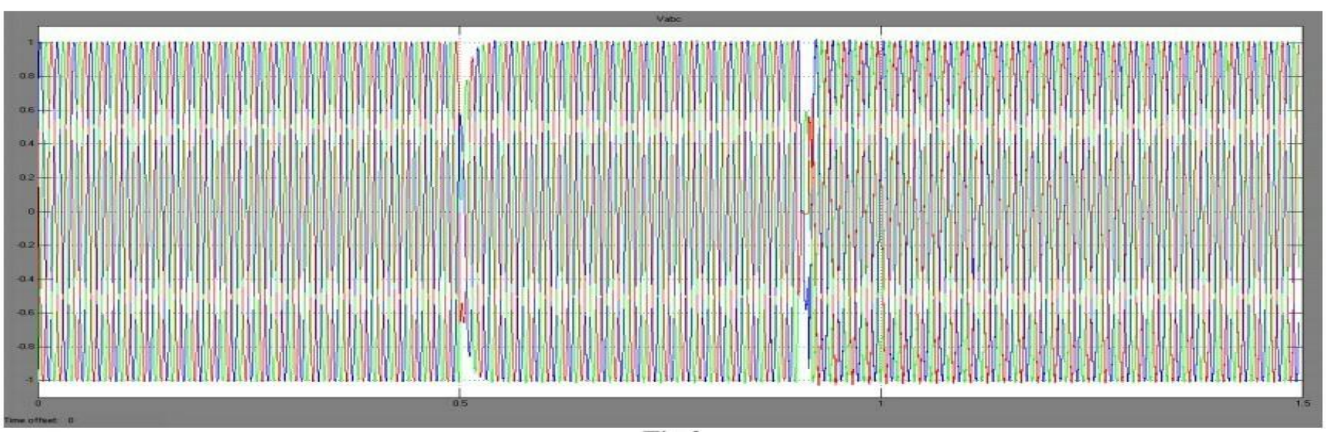
For the simulation study a three phase source is treated as the primary distribution substation and the distribution line is considered as the lumped inductance in series with the resistance. A fixed load is connected to the distribution line and a heavy inductive and capacitive load is connected at the required instants to study the performance of the DSTATCOM in case of voltage sag and swell conditions. The DSTATCOM circuit is connected in shunt with the distribution system nearer to the load point through a Y/· transformer.

Figure shows the test system used for the performance analysis of the DSTATCOM. The test system comprises a 11KV, 100 MVA, 50 Hz, substation ,represented by a Thevenin equivalent, feeding a distribution network where there is a DSTATCOM connected in shunt with the system through a 11KV , Yg/· , transformer. The compensation capacity of the DSTATCOM is 25Mvar and the DC capacitor can charge to a voltage level of about 4 KV . To study the performance of the DSATCOM , a variable load is connected to the bus and the substation voltage is made to increase (capacitive load) or decrease (inductive load) during the simulation. A VSC based DSTATCOM is connected at the load side to provide instantaneous voltage support at the load point.

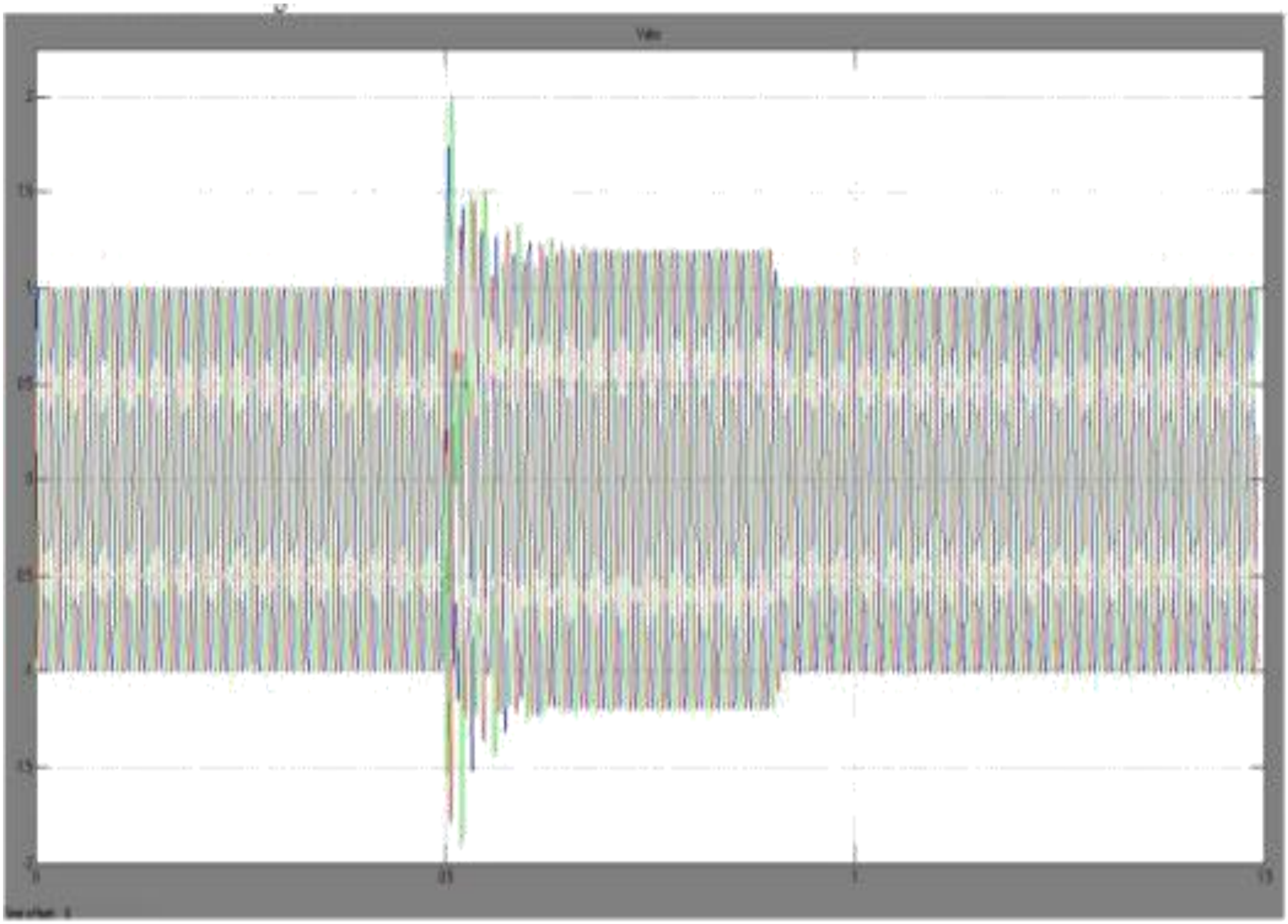
SIMULATION RESULTS



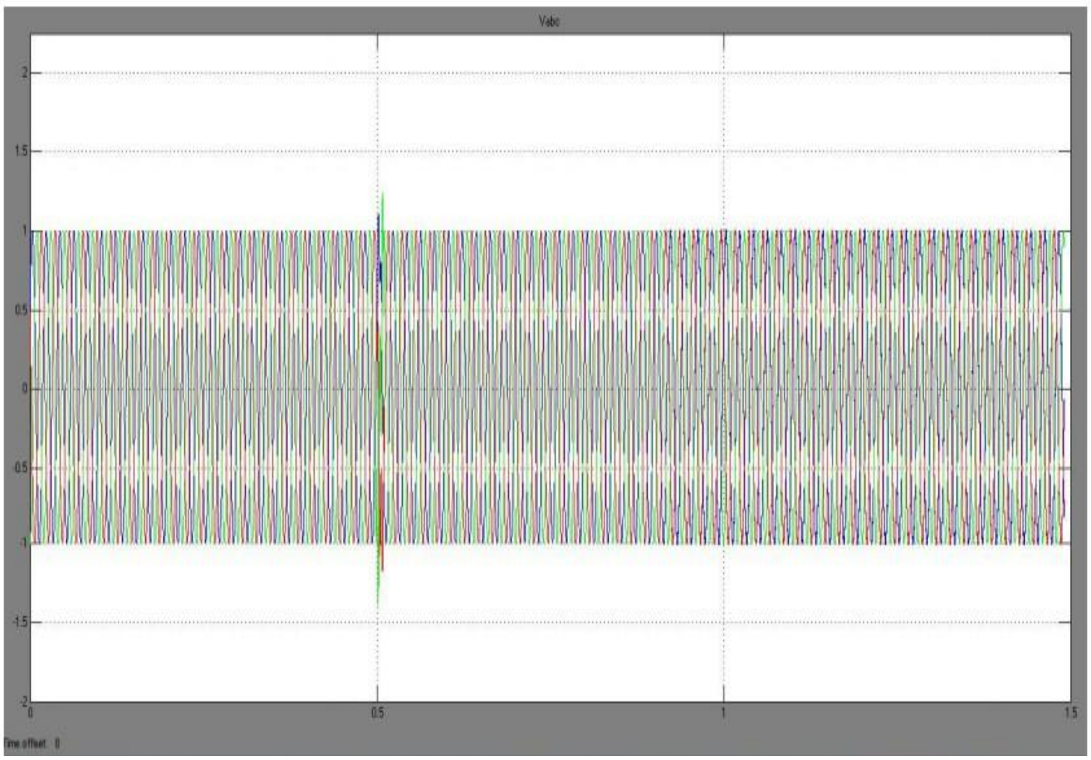
Simulation result of voltage sag



Simulation result of Vol. sag with DSTATCOM



Simulation result of swell



Simulation result of vol.swell with DSTATCOM

Under normal conditions D-STATCOM continuous monitors the load voltage and generates the error voltage. The voltage sag can be created by using either load switching or by using three *phase fault. The load voltage corresponding to sag is shown in Fig. The d-statcom can mitigate the sag as shown in Fig.*

Voltage swell created by using a capacitor bank switching during a period of 0.5s to 0.9s under this condition voltage swell is experienced. By using D-statcom it can be eliminated. The corresponding wave forms are shown in Figs.

Hardware components required

- *Bread board*
- *Thyristors*
- *Heat sink*
- *Power diodes*
- *Capacitor*
- *Wires*

CONCLUSION AND FUTURE SCOPE

The performance of a DSTATCOM in mitigating voltage sag/ swell is demonstrated with the help of MATLAB. The modeling and simulation results of a DSTATCOM are presented. D-STATCOM is promising device which is used for voltage sag, swell mitigation at distribution side. In this work only the Vrms value is required to measure. DSTATCOM compensator is a flexible device which can operate in current control mode for compensating voltage variation, unbalance and reactive power and in voltage control mode as a voltage stabilizer. The latter feature enables its application for compensation of dips coming from the supplying network. In addition, the regulated VRMS voltage showed a reasonably smooth profile. It was observed that the load voltage is very close to the reference value, i.e., 1pu and the voltage sags are completely minimized. The hardware results showed clearly the performance of the DSTATCOM in mitigating voltage sag as well as swell. This thesis explained the two level VSC based DSTATCOM and can be extended to multilevel inverter based DSTATCOM to reduce the harmonic content in current. The DSTATCOM can be designed using a current source inverter. An integrated DSTATCOM controller can be design for voltage regulation, reactive power compensation, power factor improvement and unbalanced load compensationIn System design document the different type of modules are identified in this project illustrated different type of circuit diagrams for the modules to describe about the Statcom devices.

A flexible D- STATCOM is proposed that could both mitigate unbalanced faults and operate as a DG, when it supplies power to sensitive loads while the main utility source is disconnected.

As a result, DSTATCOM operates same as a FDG and consequently, it is called FD-STATCOM.

In addition, this project has proposed a new control method for mitigating the voltage sags, caused by unbalanced faults and islanding condition, at the PCC.

REFERENCES

- *[1] DR. Patil & Komal K Madhale "Design And Simulation Studies of Voltage Sag, Swell Mitigation" IRNet Transaction on Electrical and Electronics Engineering.*

- *[2] Amin Nazarloo, Student Member, IEEE, Seyed HosseinHosseini, Member, IEEE, Ebrahim Babaei, Member, IEEE,"Flexible DSTATCOM Performance as a Flexible*
- *Distributed Generation in Mitigating Faults" 2011 2nd Power Electronics, Drive Systems and Technologies Conference.*
- *[3] N.Srinivasa Rao & H. J.Jayatheertha ,"Modeling and Simulation of DSTATCOM for Power Quality Enhancement in Distribution System" International Journal of*
- *Engineering Research & Technology, ISSN:2278-0181,Vol.1 Issue 5, July-2012.*
- *[4] Simulation of DSTATCOM and DVR in power systems by S.V. Kumar*

and SIVA NAGARAJU J.N.T.U College of Engineering, Kakinada,A.P, India.