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# MITIGATION OF POWER QUALITY PROBLEMS BY D-STATCOM

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***Abstract:*** **In this paper facts devices used for power quality improvement is presented. In addition, the power electronics-based equipment, which are called power conditioners are used to solve power quality problems. Since the topologies of these equipment are similar to those used in FACTS equipment, power conditioners are also called Distribution FACTS (DFACTS). Shunt connected STATCOM may be used to inject reactive power. ASTATCOM will provide general voltage support to the Distribution network and, if this is not desired, a solid state switch can also be used to isolate the load and STATCOM for the duration of the sag.The principle operating modes and applications whichever one of equipment in transmission and distribution system (such as STATCOM, SSSC, UPFC, D-STATCOM, DVR and UPQC) will be discussed.**

***Keywords:*** **POWER QUALITY, FACTS DEVICES.**

## 1. INTRODUCTION

Modern power system is a complex network comprising of numerous generators, transmission lines, variety of loads and transformers. As a consequence of increasing power demand, some transmission lines are more loaded than was planned when they were built. With the increased loading of long transmission lines, the problem of transient stability after a major fault can become a transmission limiting factor. Now power engineers are much more concerned about transient stability problem due to blackout in northeast United States, Scandinavia, England and Italy. Transient stability refers to the capability of a system to maintain synchronous operation in the event of large disturbances such as multi-phase short-circuit faults or switching of lines. The resulting system response involves large excursions of power angle relationship. Stability depends upon both the initial operating conditions of the system and the severity of the disturbance. Recent development of power electronics introduces the use of flexible ac transmission system FACTS can be exploited to improve the voltage stability, and steady state and transient stabilities of a complex power system.[1]

## 2. TYPE OF FACTS DEVICES

Mainly FACTS controller and they can be divided in 4 categories:

1. Shunt controllers
2. Series controllers
3. Combined series -series controllers
4. Combined series- shunt controllers

Depending on the power electronics devices used in the control, the FACT controller can be classified as

1. Variable impedance type
2. Voltage source converter(VSC)-based

The variable impedance type controllers include:-

1. Static var compensator (SVC), (shunt connected)
2. Thyristor controlled series capacitor or compensator(TCSC),(series connected)
3. Thyristor controlled phase shifting transformer (TCPST), of static PST combined shunt series.

The Voltage sources converter (VSC)-based FACT controller are:-

1. Static synchronous compensator (STATCOM),(shunt connected)
2. Static synchronous series compensator(SSSC), (series connected)
3. Unified power flow controller(UPFC)

Some of the special purpose FACTs controllers are:-

1. thyristor controlled based resistor(TCBR)
2. Thyristor controlled voltage limiter(TCVL)
3. Thyristor controlled voltage regulator(TCVR)
4. Inter phase power controller(IPC)
5. NGH-SSR damping

## 3. SHUNT CONNECTED CONTROLLER STATIC VAR COMPENSATOR

Static Var Compensators are shunt connected static generators / absorbers whose outputs are varied so as to control voltage of the electric power systems. In its simple form, SVC is connected as Fixed Capacitor-Thyristor Controlled Reactor (FC-TCR) configuration as shown in Fig. 1. The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated. The effective reactance of the FC-TCR is varied by firing angle control of the anti parallel thyristor. The firing angle can be controlled through a PI (Proportional + Integral) controller in such a way that the voltage of the bus, where the SVC is connected, is maintained at the reference value. [2]

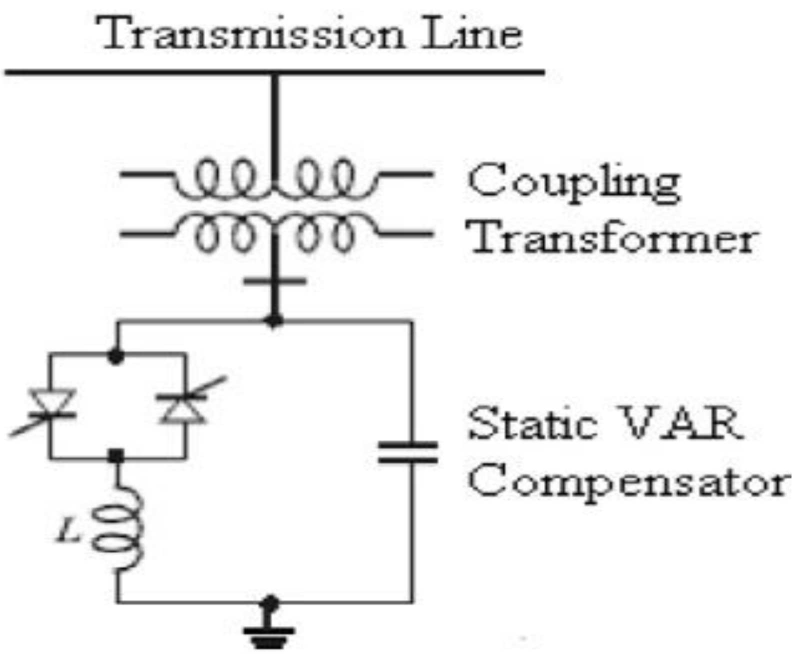



**Fig. 1 Configuration of SVC**

***Thyristor controlled reactor (TCR)***

Static thyristor controlled reactors are connected in parallel with the load for the control of reactive power flow. With increase in the size of industrial connected loads, fast reactive power compensation has become necessary .for such loads TCRs are now becoming increasingly popular.

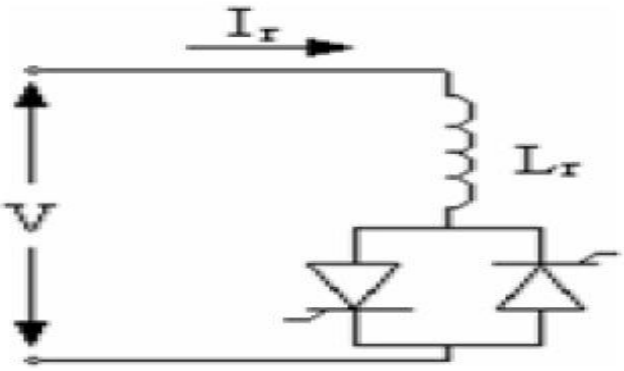



**Fig. 2 Configuration of TCR**

## 4. SHUNT CONNECTED CONTROLLERS

***Static Synchronous Compensator***

The basic STATCOM's structure is presented in Fig4 The STATCOM is a power electronic based Synchronous Voltage Generator (SVG) that, from a dc capacitor, generates a three-phase voltage in synchronism with the transmission line voltage, and it is connected to it by a coupling transformer. By controlling the STATCOM's output voltage magnitude, the reactive power exchanged between STATCOM and the transmission system, and hence the amount of shunt compensation, can be controlled [3]. The STATCOM is based on the principle that it regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive). When system voltage is high, it absorbs reactive power (STATCOM inductive). The variation of reactive power is performed by means of a Voltage-Sourced Converter (VSC) connected on the secondary side of a coupling transformer.

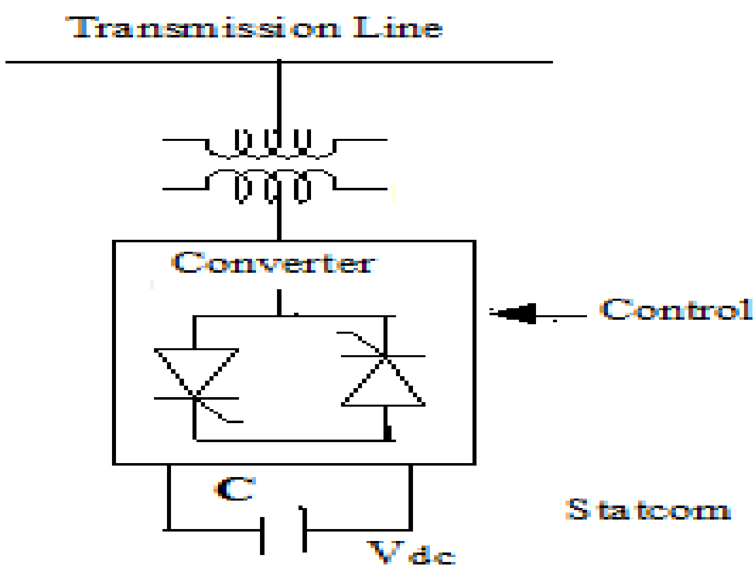



**Fig.3 Configuration of STATCOM**

## 5. SERIES CONNECTED CONTROLLERS

***Static Synchronous Series Compensator (SSSC)***

The SSSC is one of the most recent FACTS devices for power transmission series compensation. It can be considered as a synchronous voltage source as it can inject an almost sinusoidal voltage of variable and controllable amplitude and phase angle, in series with a transmission line. The injected voltage is almost in quadrature with the line current. A small part of the injected voltage that is in phase with the line current provides the losses in the inverter. Most of the injected voltage, which is in quadrature with the line current, provides the effect of inserting an inductive or capacitive reactance in series with the transmission line. The variable reactance influences the electric power flow in the transmission line. [2] The basic diagram of SSSC is shown in figure.

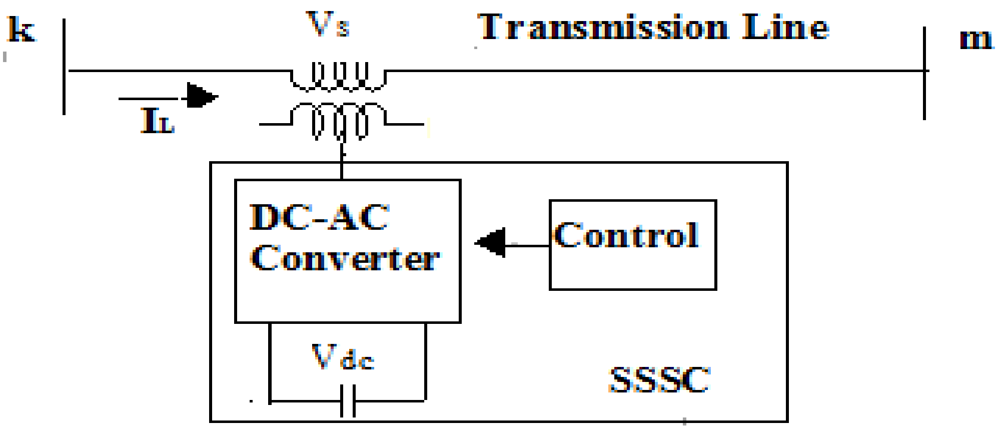



**Fig. 4Configuration of SSSC**

## 6. COMBINED SERIES AND SHUNT CONNECTED CONTROLLER

***Unified Power Quality Controller (UPQC)***

The best protect for sensitive loads from voltage sources with inadequate quality, is shunt-series connection power conditioner (UPQC) (Fig.5) in which the shunt part supplies the required power of the series part in the condition of voltage sags.

UPQC is consisted of two PWM converters and a dc link capacitor. Shunt converters in spite of supplying the required active power by in series converters, they also can have applying D-STATCOM modes. Series converter injects a series voltage to the supply voltage and can possess DVR advantages.

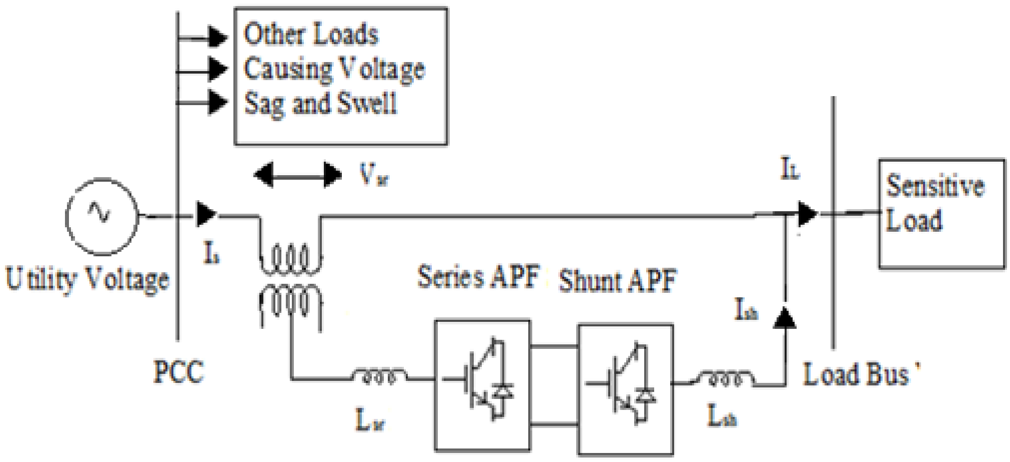



**Fig 5 Configuration of UPQC**

***Unified Power Flow Controller (UPFC)***

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to enhance steady state stability, dynamic stability and transient stability. The basic configuration of a UPFC is shown in Fig. 6. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor, which provides dc voltage for the converter operation. The power balance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real power absorbed from or injected into the power system by the series converter plus the losses by regulating the dc bus voltage at a desired value.

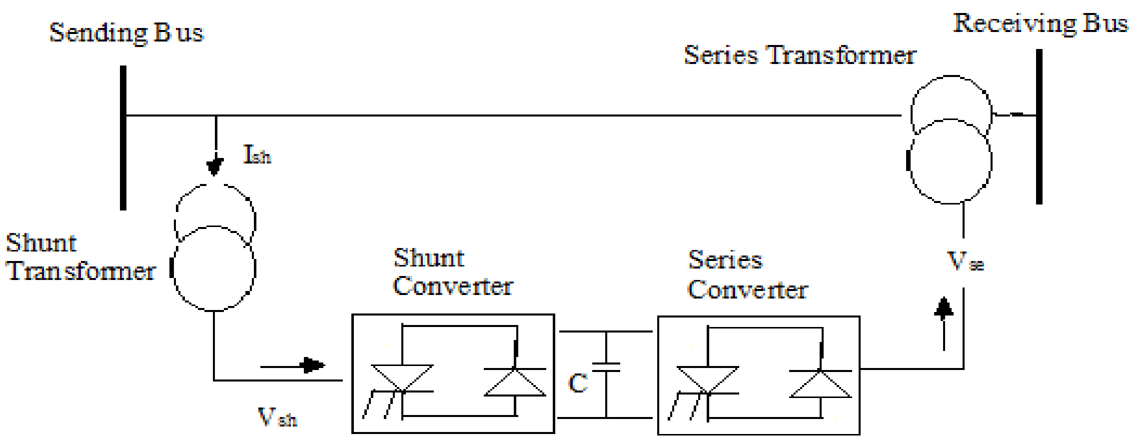



**Fig. 6 Configuration of UPFC**

***Distribution Statcom (D-STATCOM)***

It is a shunt device which is generally used to solve power quality problems in distribution systems. D-STATCOM is a shunt device used in correcting power factor, maintaining constant distribution voltage and mitigating harmonics in a distribution network. The coupling of D-STATCOM is three phase, in parallel to network and load.

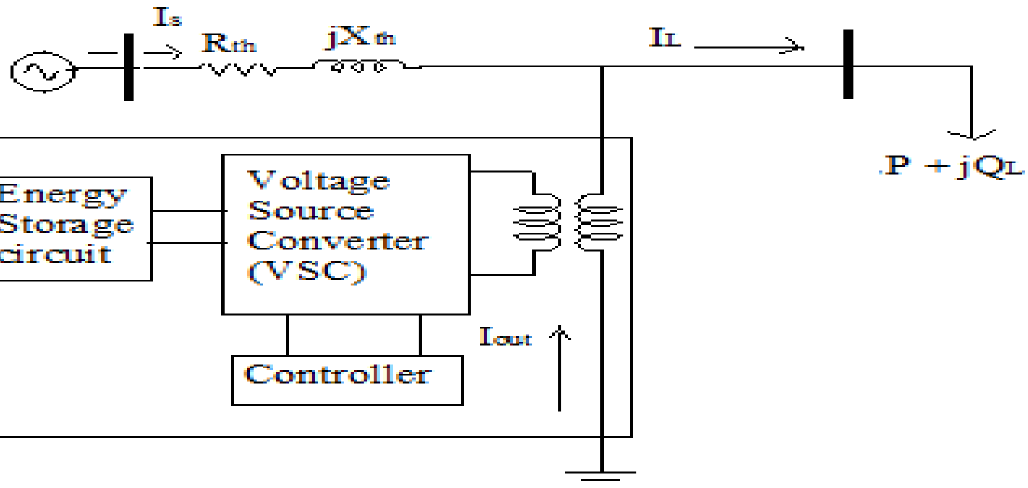



**Fig.7 Schematic diagram of a D-STATCOM**

D-STATCOM injects Currents into the point of common coupling (Fig 8). The injected current compensates undesirable components of the load current. There are two possible modes of operation: standard mode and flicker mode. [3]

***Standard mode:*** This mode features four distinct control tasks. A list of priorities can be specified by the customer, defining the most important control tasks for the application at hand. In standard mode, D-STATCOM can perform the following four tasks simultaneously:

***Active harmonic filtering:*** The current, flowing from the load into the network, is measured, and separated into fundamental and harmonic components.

D-STATCOM injects currents such that unwanted harmonic currents are exclusively exchanged between D-STATCOM and the load and therefore do not flow into the network. Rather than a broadband elimination, D-STATCOM filters certain discrete harmonics (e.g. 5th and 7th). Up to four discrete harmonics at a time can be eliminated. The highest harmonic which can be filtered in this manner by the standard equipment is the 13th. As only problematic harmonics are filtered, based on the D-STATCOM power and economical survey.

***Reactive power compensation:*** D-STATCOM can dynamically supply step-less reactive power, in both capacitive and inductive modes. Power factor control is also possible in this mode.[4]

***Dynamic load balancing:*** D-STATCOM can inject both, positive and negative sequence currents into the point of common coupling. It is thus possible to eliminate negative sequence currents associated with unbalanced loads, thereby performing dynamic load balancing.

***Active power transfer*****:** Energy storage devices such as chemical batteries or flywheel systems connected to the dc link capacitor allow energy to be transferred in to the network. [5]

***Flicker mode:*** In general, to reduce the negative impact of flicker producing loads on the network voltage, a highly dynamic means of compensating for varying load currents must be available. The flicker controller features a current control with a response time of less than half a cycle, thus offering the capability of reducing variation in load current with high dynamic performance. In case of short disconnection of power supply due to an outage, shunt equipment using energy storage can be used to deliver energy during the outage. In this application the power conditioner act like a UPS for the duration of the outage. For undisturbed continuous load operation the supply must be disconnected immediately by an electronic switch. For example the shunt connected power conditioner must work like a generator. When the supply is fault free again, the power conditioner re- synchronizes back to the system and the electronic switch is closed.

## 7. MODELLING& SIMULATION OF D-STATCOM

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. D-STATCOM was designed using MATLAB simulink version R2010a.

***Test System***

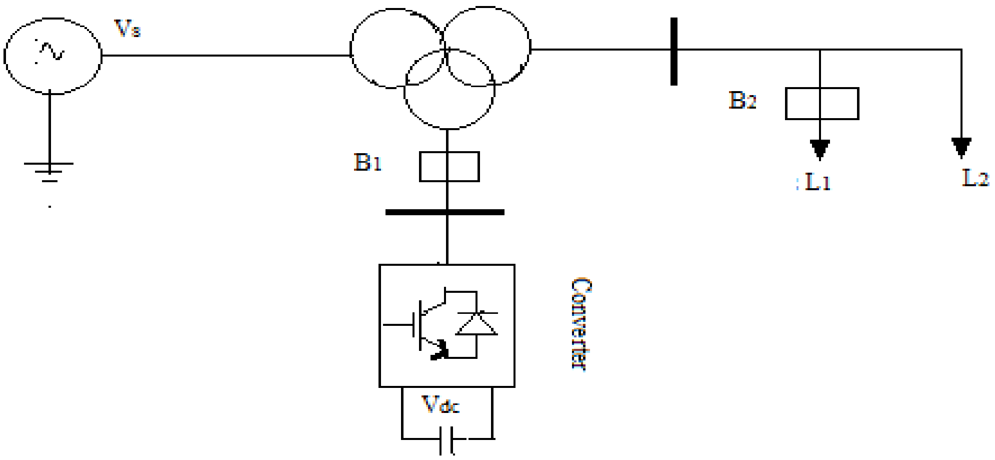



**Fig 8 test system**

The test system shown in figure 8 comprises a 220kV, 50Hz transmission system, represented by a Thevenin equivalent, feeding into the primary side of a 3-winding transformer connected in Y/Y/Y, 220/11/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11 kV tertiary winding.

***Simulink Model for the test system***

The test system was design using MATLAB simulink is shown in figure 9 below.

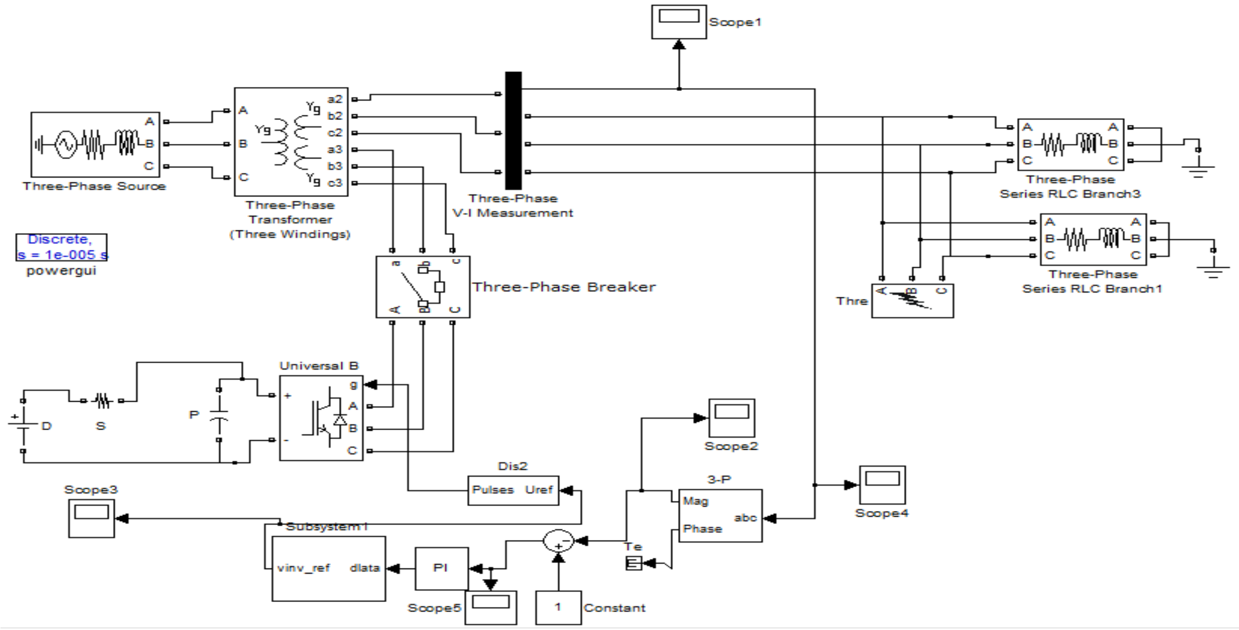
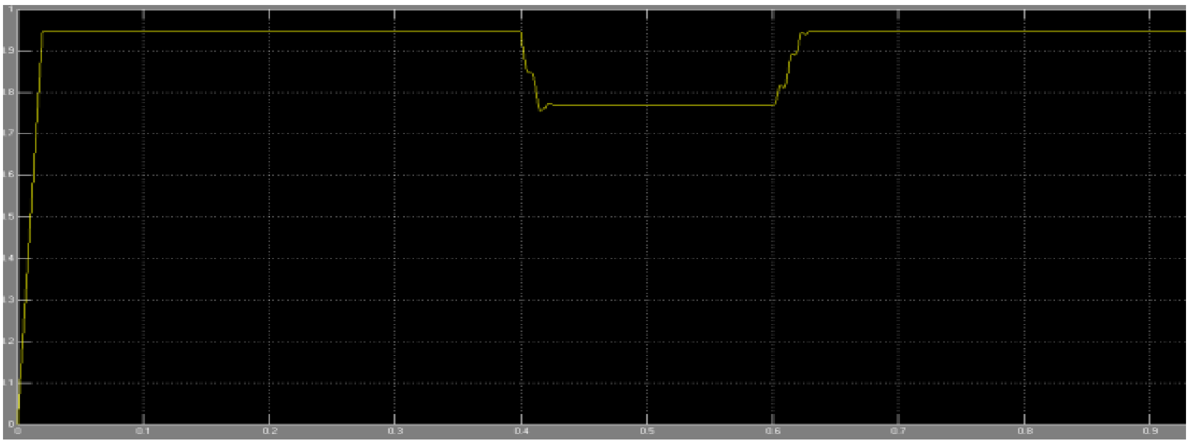


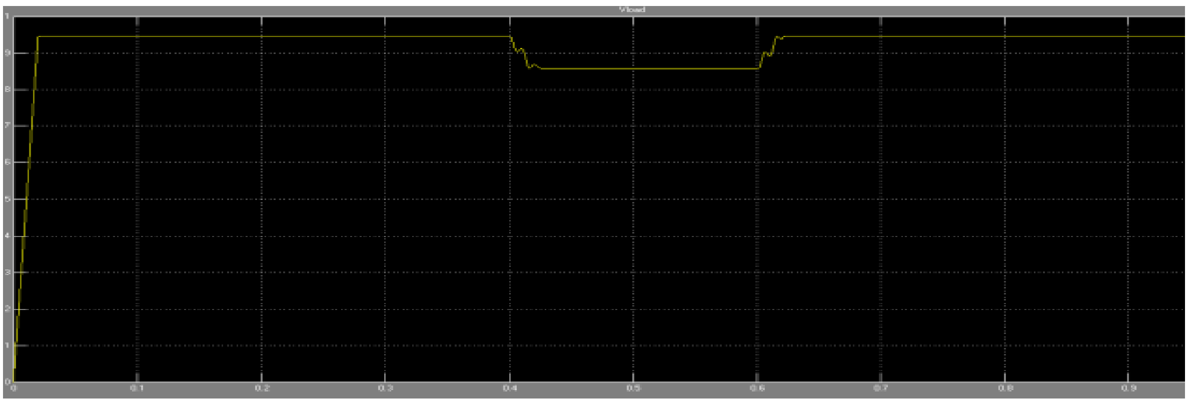

**Fig. 9 Simulation diagram**

## 8. SIMULATION RESULT & DISCUSSION

***Waveform of DLG & SLG before D-STATCOM***

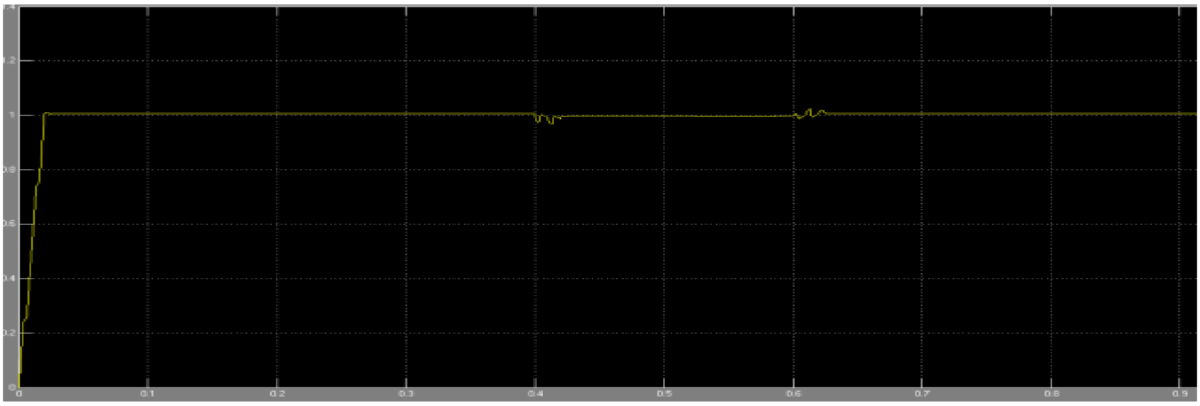


**Voltage at load point is 0.755 p.u. in DLG fault**

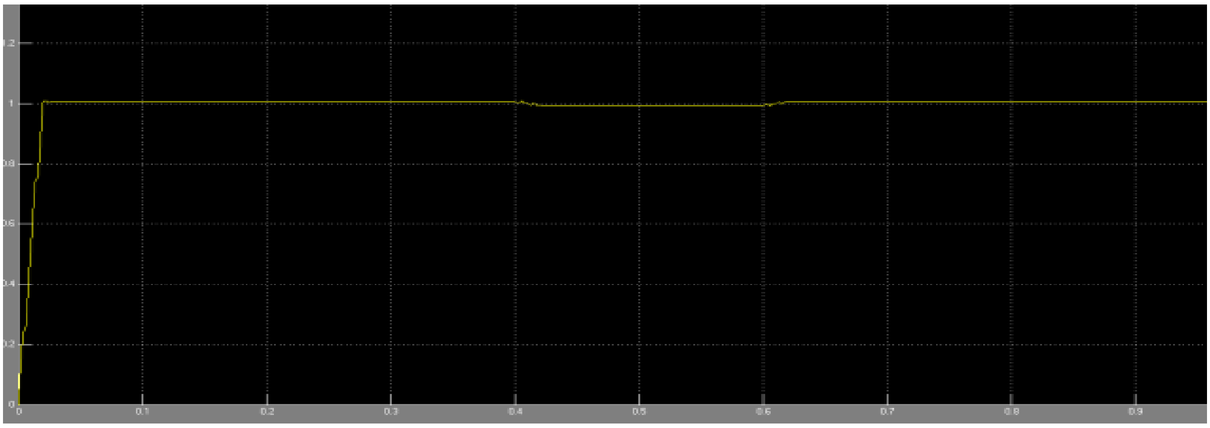


**Voltage at load point is 0.8577 p.u. in SLG fault**

***Waveform of DLG & SLG after inserting D-STATCOM***



**Voltage at load point is 0.975 p.u.in DLG fault**



**Voltage at load point is 0.995p.u.in SLG fault**

## 9. CONCLUSION

The simulation results show that the voltage sags can be mitigate by inserting D-STATCOM. Power factor can also increases close to unity. Thus it can be concluded that by adding D-STATCOM the power quality is improved.

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