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Improvement of Voltage Sag Using DPFC in Distribution System

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ABSTRACT*:*

Now-a-days, the demand for good power quality has been increased at the end user equipment because problems like voltage sag/swell, harmonic distortion, low power factor etc., will be occurred in distribution system during transmission of power. So, at the transmission side, FACTS devices which depend on PWM technique play a significant role in reducing those problems.

This paper reports the proposed method for enhancing power quality using DPFC. As, DPFC is the combination of both Shunt and Series converters, here the shunt device i.e., D-STATCOM is first designed then the series controllers are designed. The simulation results are observed in the test system.

Keywords*: Power Quality, FACTS, D-STATCOM, Distributed Power Flow Controller, Power Exchange, Voltage Sag*

I. INTRODUCTION

One of the most important needs of present power system is delivering power to the end user equipment at necessarily constant voltage. Now-a-days, there are more issues of power quality which affect the power system network. The proper characteristics of supply voltage and additionally reliable and efficient delivery of electrical energy for the customers is considered as Power Quality.

Mienski et al. [1] modeled and simulated the STATCOM controller for enhancement of power quality using Shunt compensation. Bollen [2] discussed the occurrence of voltage sag in three phase system and applied its solutions in industrial distribution systems. Gaurav [3] simulated and analysed D-STATCOM for compensation of load and improvement of power factor. Manish [4] presented modeling and simulation of IGBT-VSC based D-STATCOM in distribution system for power quality improvement. Sjoerd et al. [5] discussed about the distributed power flow controller which belongs to the FACTS family for improving the power quality.

II. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

D-STATCOM is based on a power electronic voltage source converter and acts either as a source or a sink of reactive AC power to an electricity network. It is a member of the FACTS family of devices. Suitable adjustment of the phase and magnitude of D-STATCOM output voltages allows effective control of active and reactive power exchange between D-STATCOM and ac system.

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A STATCOM can improve power system performance in the following areas:

- Dynamic voltage control in transmission and distribution system.
- Power oscillation damping in power transmission systems.
- Transient stability.
- Voltage flicker control.
- Control of active power in addition to reactive power in the connected line requiring dc energy source.

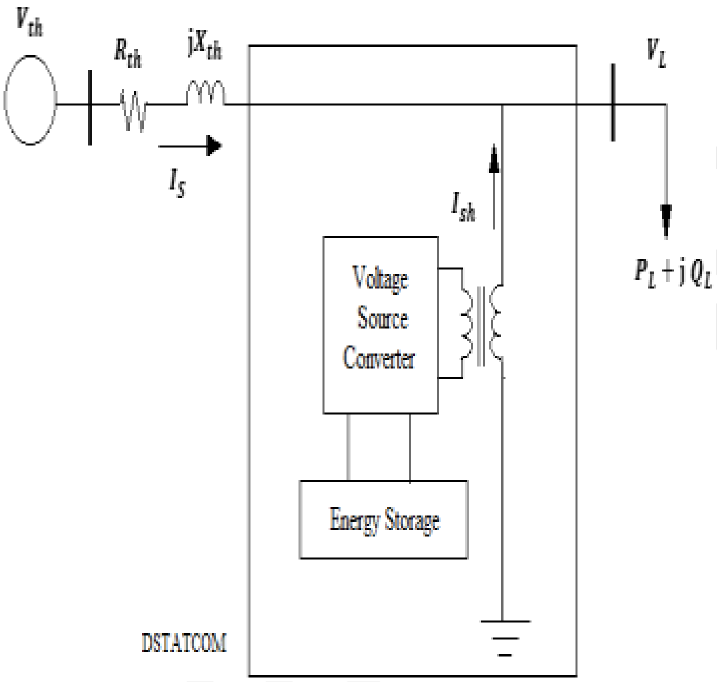

Fig.1 Block diagram of DSTATCOM

III. DISTRIBUTED POWER FLOW CONTROLLER (DPFC)

In proposed system, the advanced device of UPFC i.e., Distributed Power Flow Controller (DPFC) is introduced, which belongs to the family of FACTS device and also simultaneously controls all system parameters like transmission angle, bus voltage and line impedance.

In UPFC, the shunt and series converters are connected by common DC link with which exchange of active power between them is through this common DC link. But in case of DPFC, it is through the transmission line at 3rd harmonic frequency because each converter of DPFC has its own DC link.

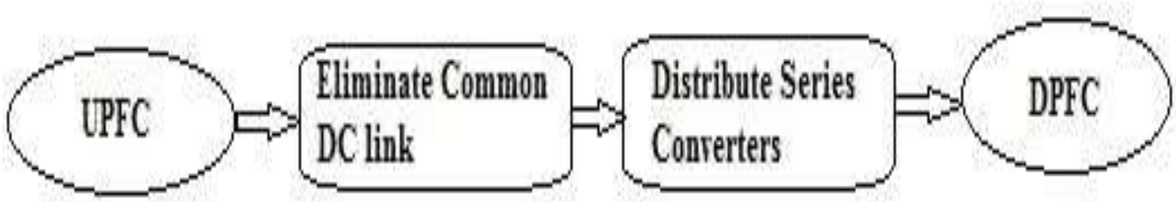

Fig.2 Flow Chart to convert UPFC to DPFC

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3.1 DPFC Control

The responsibility of basic control is to maintain DC voltages of DPFC converters and to generate the AC voltages as required by the central control. DPFC consists of 3 types of controllers which are used for controlling the multiple controls.

1. Central control
2. Series control
3. Shunt control

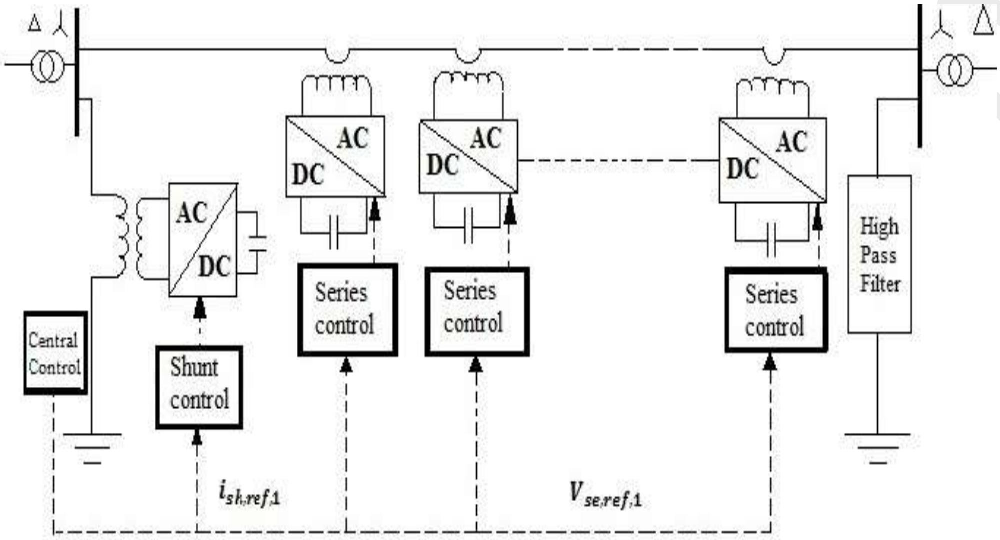

Fig.3 Basic Control Block

The series and shunt control, which act as local controllers, are responsible for maintaining their own parameters whereas the central control is responsible for functioning of DPFC.

A. Central control:

- For both series and shunt converters of DPFC, the reference signals are generated by the central control.
- Its main function is dependent on power flow control, power oscillation damping at low frequency and asymmetrical components balancing.
- Based on the requirements of system, series converters are provided with corresponding voltage reference signals and shunt converter is provided with reactive current signal as reference from the central control.
- The reference signals that are generated by the central control are related to the fundamental frequency components.

B. Series control:

- By using 3rd harmonic frequency components, it maintains the capacitor DC voltage of its own capacitor.
- At the fundamental frequency, the series voltage is generated which is commanded by the central control.

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C. Shunt control:

- For supplying active power for series converters, constant 3rd harmonic current is injected by it.
- By absorbing active power from the grid at the fundamental frequency, it maintains the DC voltage of Shunt converter's capacitor.
- At the fundamental frequency, it injects reactive voltage to the grid as commanded by the central control.

By using the Park's transformation, the AC components of DPFC can be transformed to DC components then these can be controlled by PI controllers.

3.2 Advantages

- High reliability
- High Controllability
- Low cost

IV. TEST SYSTEM

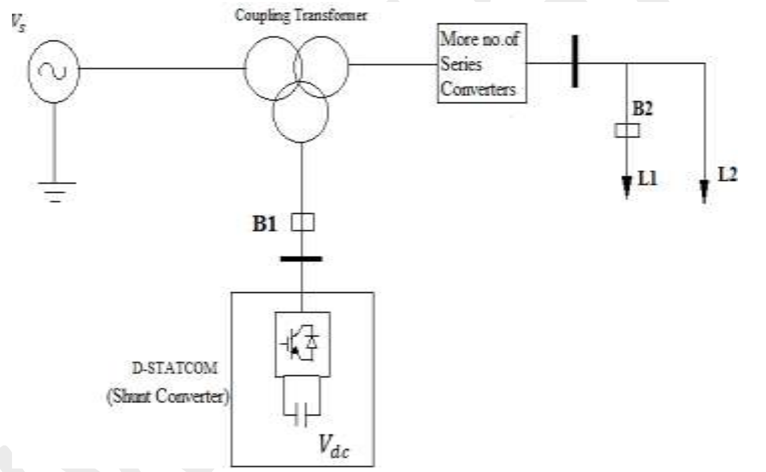

Fig.4 DPFC Test System

The above test system consists of transmission system with rating 50Hz, 230V, which is represented by the Thevenin equivalent circuit, is fed to the primary winding of three phase coupling transformer which is connected in Y/Y/Y with rating 230/11/11 kV. Secondary side (11kV) is connected to the Series converters block and then to varying load.

For providing the instantaneous voltage support, Tertiary side (11kV) is connected to a two-level D-STATCOM. For operating period of D-STATCOM, breaker 1(B1) is used and connection of load 1 is controlled by the breaker 2.

V. RESULTS AND DISCUSSION

For voltage sag analysis, the distortion has to be created in the distribution system by injecting different faults like Single Line to Ground (SLG), Line to Line (LL), Double Line to

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Ground (DLG) and Three Phase to Ground (TPG).In this section, study on voltage sag is carried out by comparing the results of D-STATCOM and DPFC.

A. Without insertion of D-STATCOM

Table5.1.Results of voltage sag for different faults

Fault Resistance R_f ,Ω	Voltage Sag for SLG fault (p.u)	Voltage Sag for LL fault (p.u)	Voltage Sag for DLG fault (p.u)	Voltage Sag for TPG fault (p.u)
0.66	0.8259	0.7587	0.7070	0.6600
0.76	0.8486	0.7918	0.7487	0.7107
0.86	0.8679	0.8210	0.7833	0.7515

Table5.1 shows overall results of voltage sag in p.u without D-STATCOM under different faults. It can be observed from the table that the voltage sag will be increased with increment in the fault resistance.

5.1 Simulation results under fault conditions without D-STATCOM

In the existed system, the different faults are injected without placing D-STATCOM in transmission line and voltage sag results are observed from this system.

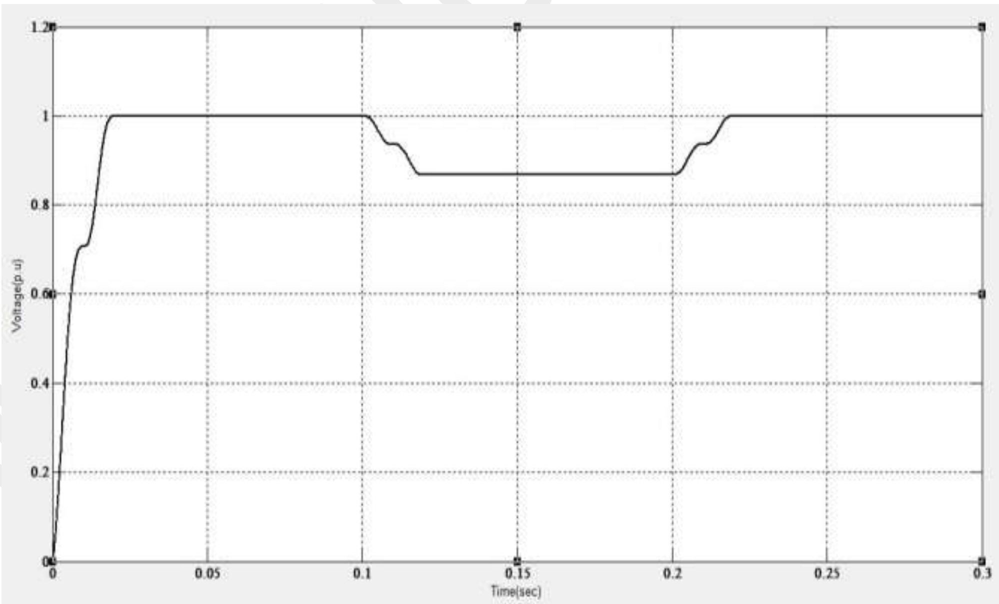

Figure5.1 (a).Voltage at load point is 0.8679p.u

In above fig.5.1 (a), if the SLG fault is injected, the voltage sag at load point is observed at 0.8679p.u with reference to 1p.u during the time interval 0.1 to 0.2sec with fault resistance 0.86**Ω**.

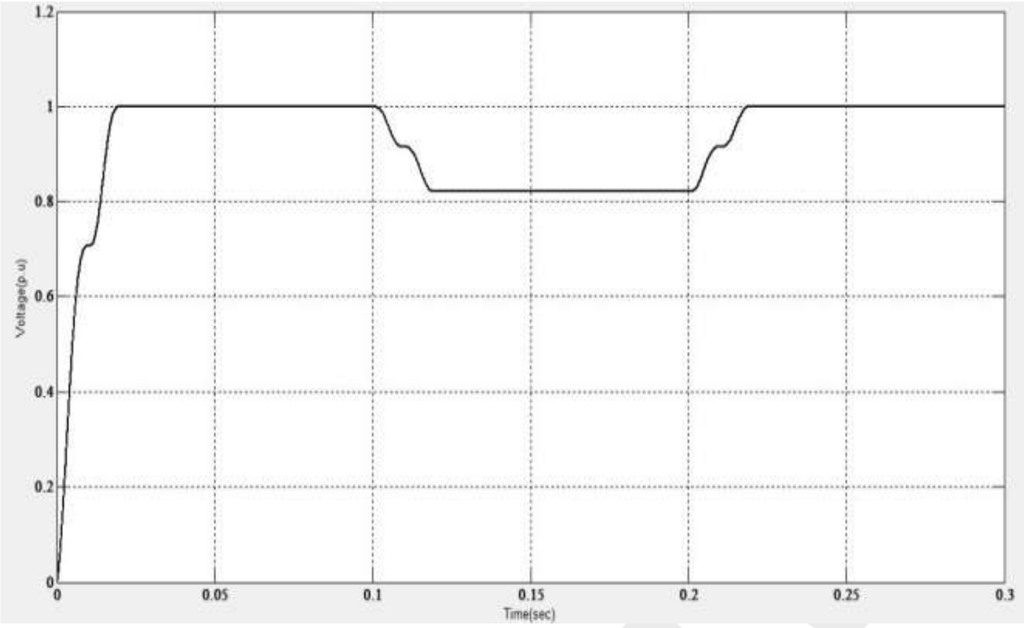

Figure5.1 (b).Voltage at load point is 0.8210p.u

In the above fig.5.1 (b), if the LL fault is injected, the voltage sag at load point is observed at 0.8210p.u with reference to 1p.u during the time interval 0.1 to 0.2sec with fault resistance 0.86**Ω**.

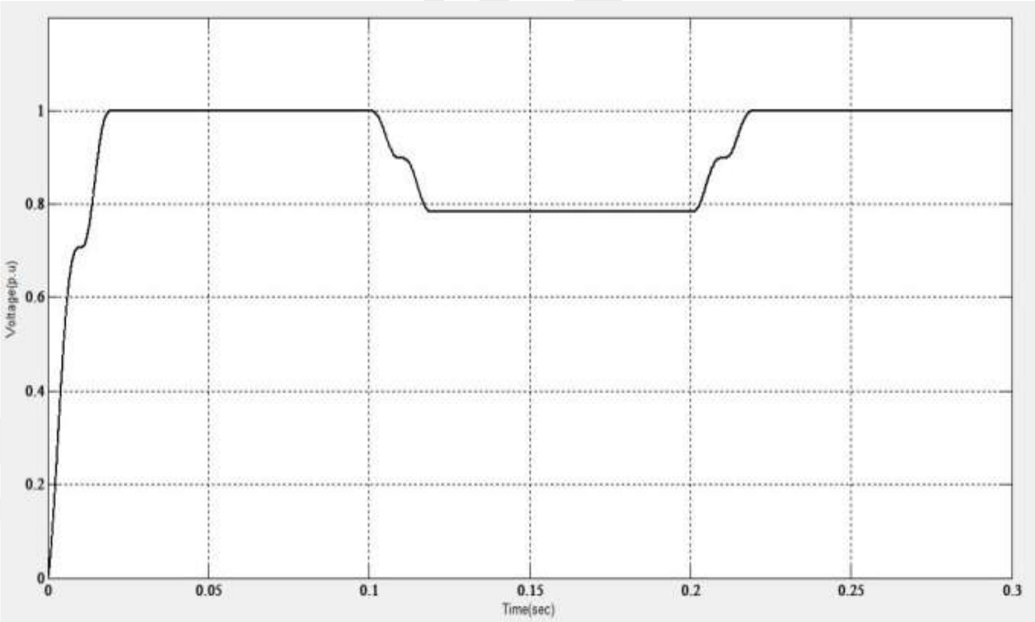

Figure5.1 (c).Voltage at load point is 0.7833p.u

In the above fig.5.1 (c), if the DLG fault is injected, the voltage sag at load point is observed at 0.7833p.u with reference to 1p.u during the time interval 0.1 to 0.2sec with fault resistance 0.86**Ω**.

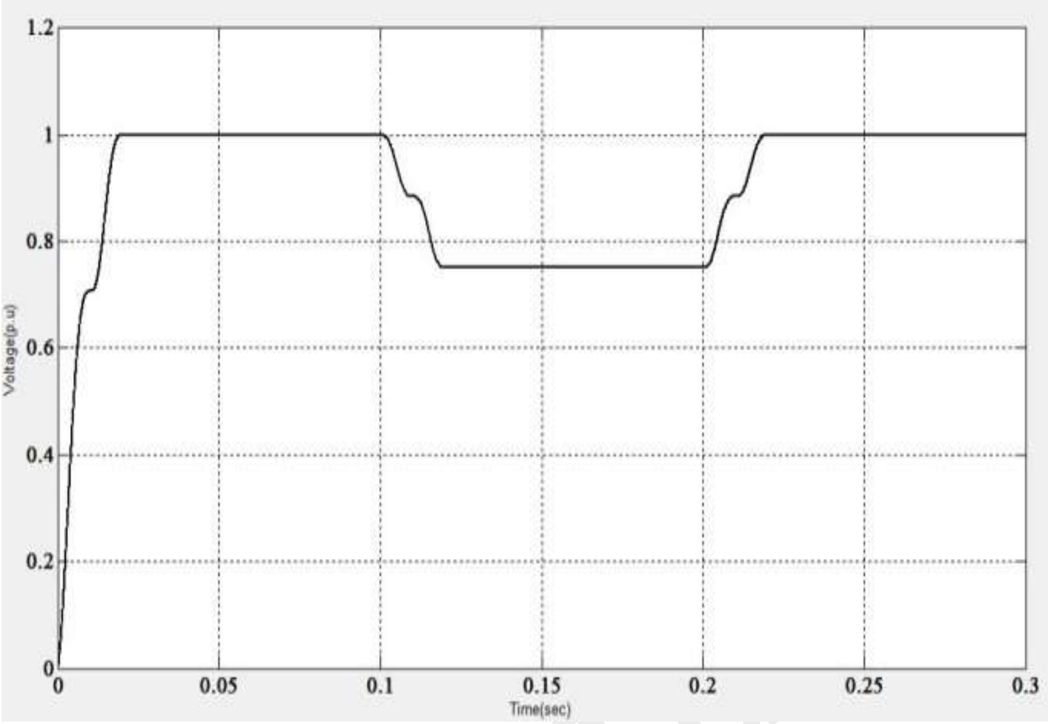

Figure5.1 (d).Voltage at load point is 0.7515p.u

In the above fig.5.1 (d), if the TPG fault is injected, the voltage sag at load point is observed at 0.7515p.u with reference to 1p.u during the time interval 0.1 to 0.2sec with fault resistance 0.86**Ω**.

B. With insertion of D-STATCOM

Table5.2.Results of voltage sag for different faults

Fault Resistance R_f ,Ω	Voltage Sag for SLG fault (p.u)	Voltage Sag for LL fault (p.u)	Voltage Sag for DLG fault (p.u)	Voltage Sag for TPG fault (p.u)
0.66	0.9837	1.0168	0.9800	0.9367
0.76	0.9817	1.0142	0.9806	0.9450
0.86	0.9863	1.0152	0.9858	0.9543

Table5.2 shows overall results of voltage sag in p.u with D-STATCOM under different faults. It can be observed from the table that by inserting the D-STATCOM, voltage sag is improved. The voltage sag improves to the value, within the range 0.9 to 1.02 p.u.

5.2 Simulation results under fault conditions with D-STATCOM

In the existed system, the D-STATCOM is added to test system in transmission line, the analysis on test system is done under different faults and voltage sag results are observed from this system.

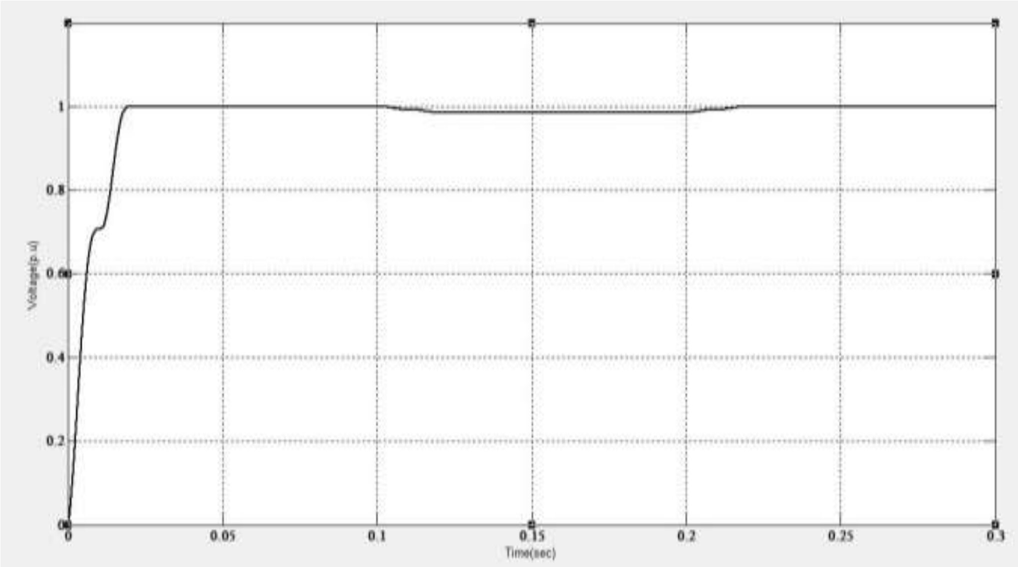

Figure5.2 (a).Voltage at load point is 0.9863p.u

In the above fig.5.2 (a), if the SLG fault is injected, the voltage sag at load point is observed at 0.9863p.u with reference to 1p.u during the time interval 0.1 to 0.2 sec with fault resistance 0.86**Ω**.

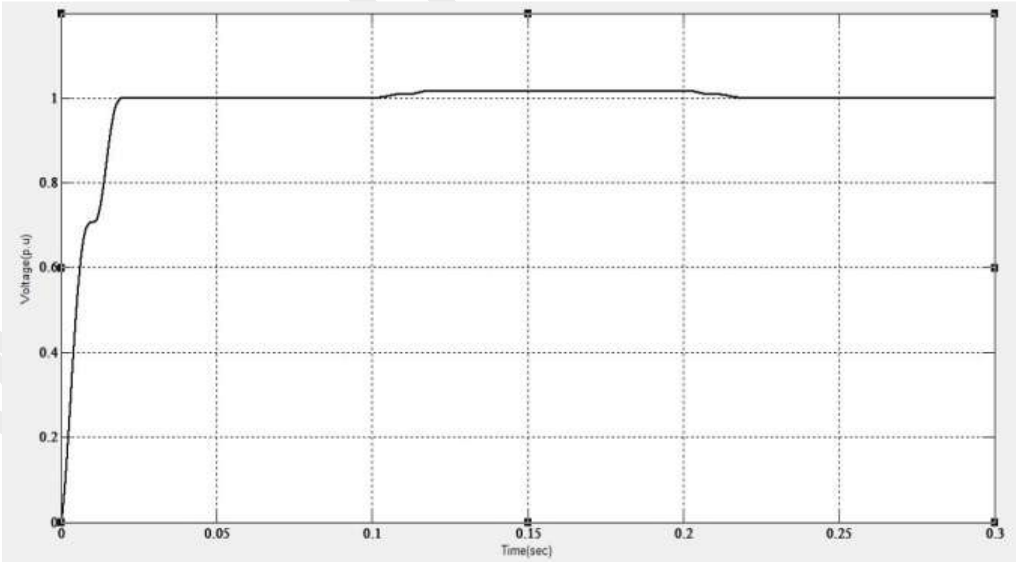

Figure5.2 (b).Voltage at load point is 1.0152p.u

In the above fig.5.2 (b), if the LL fault is injected, the voltage sag at load point is observed at 1.0152p.u with reference to 1p.u during the time interval 0.1 to 0.2sec with fault resistance 0.86**Ω**.

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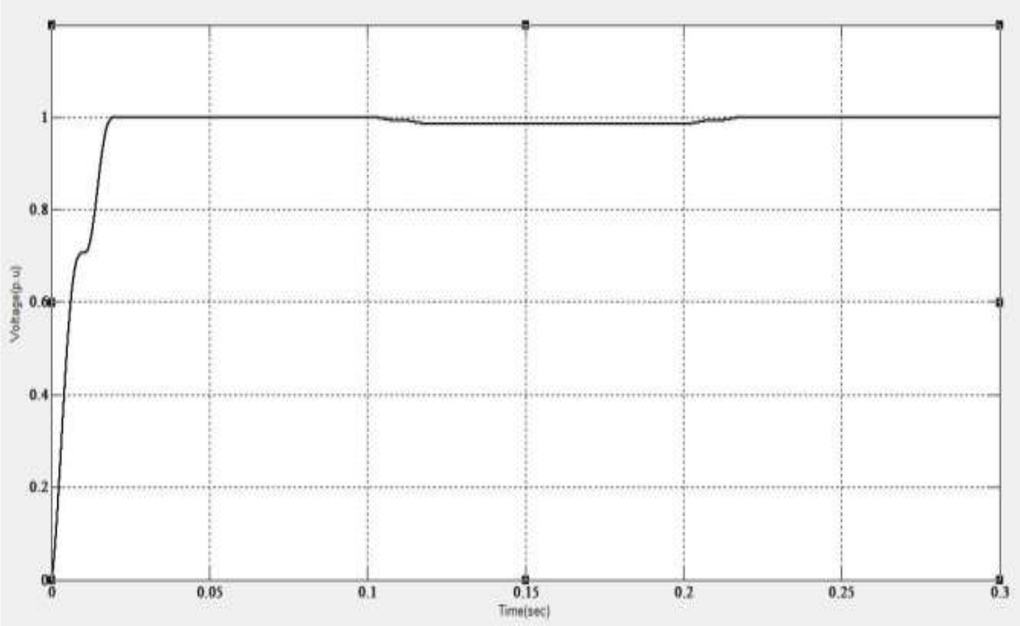

Figure5.2 (c).Voltage at load point is 0.9858p.u

In the above fig.5.2 (c), if the DLG fault is injected, the voltage sag at load point is observed at 0.9858p.u with reference to 1p.u during the time interval 0.1 to 0.2sec with fault resistance 0.86**Ω**.

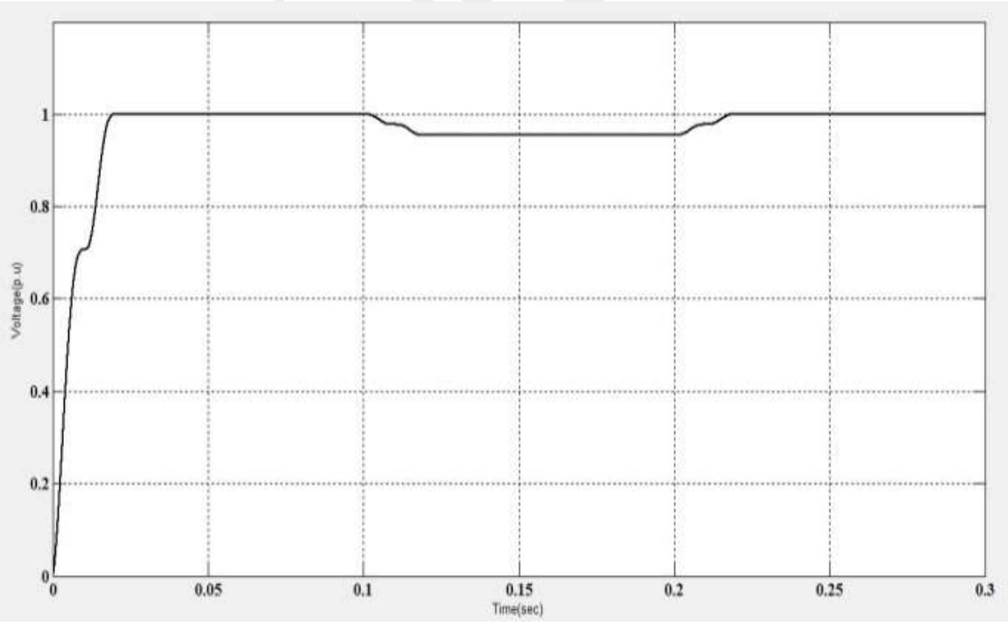

Figure5.2 (d).Voltage at load point is 0.9543p.u

In the above fig.5.2 (d), if the TPG fault is injected,the voltage sag at load point is observed at 0.9543p.u with reference to 1p.u during the time interval 0.1 to 0.2 sec with fault resistance 0.86**Ω**.

C. With insertion of DPFC

Table5.3.Results of voltage sag for different faults

Fault Resistance R_f ,Ω	Voltage Sag for SLG fault (p.u)	Voltage Sag for LL fault (p.u)	Voltage Sag for DLG fault (p.u)	Voltage Sag for TPG fault (p.u)
0.66	0.9937	1.1168	0.9850	0.9567
0.76	0.9917	1.1142	0.9900	0.9650
0.86	0.9963	1.1152	0.9950	0.9843

Table 5.3 shows the overall results of voltage sag in p.u with DPFC under different faults. From the table, it can be observed that voltage sag is very much improved with increase in the fault resistance.

5.3 Simulation results under fault conditions with DPFC

In the proposed system, the DPFC is modeled in transmission line, the analysis on test system is done under different faults and voltage sag results are observed from this system.

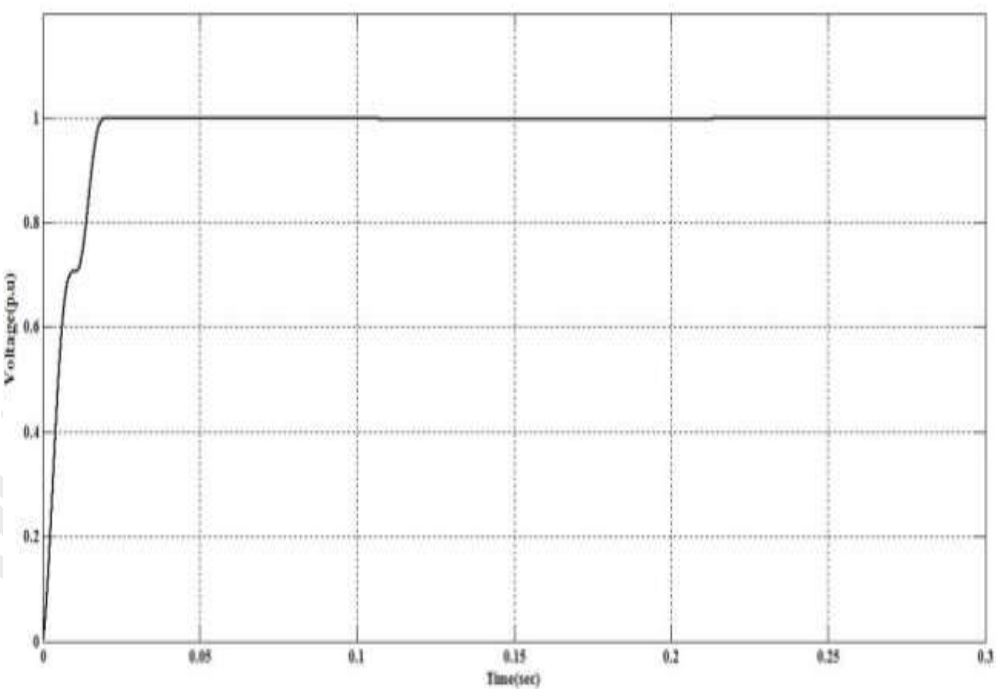

Figure5.3 (a).Voltage at load point is 0.9963p.u

In the above fig.5.3 (a), if the SLG fault is injected, the voltage sag at load point is observed at 0.9963p.u with reference to 1p.u during the time interval 0.1 to 0.2 sec with fault resistance 0.86**Ω**.

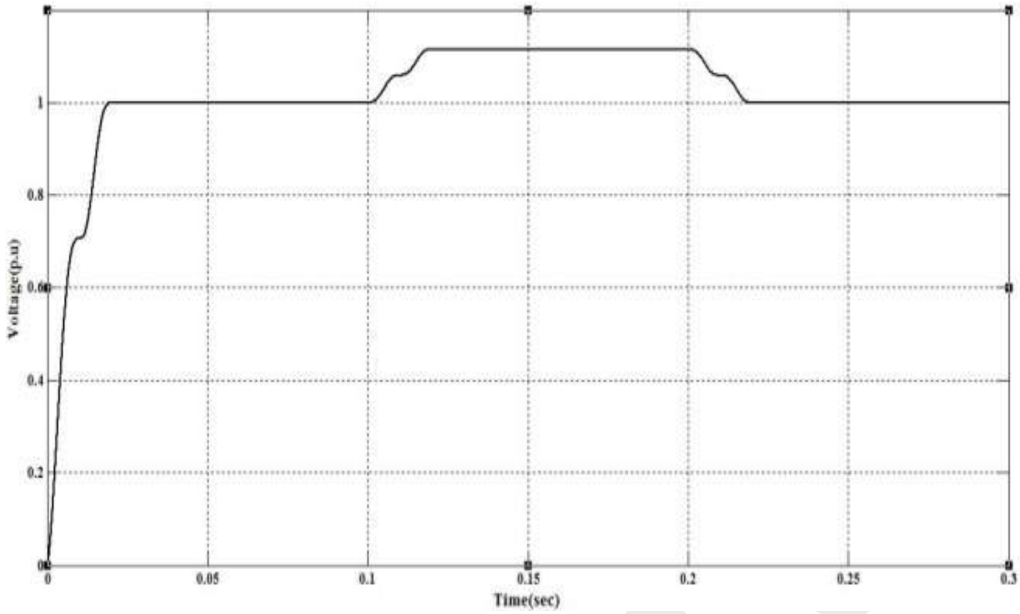

Figure5.3 (b).Voltage at load point is 1.152p.u

In the above fig.5.3 (b), if the LL fault is injected, the voltage sag at load point is observed at 1.1152p.u with reference to 1p.u during the time interval 0.1 to 0.2 sec with fault resistance 0.86**Ω**.

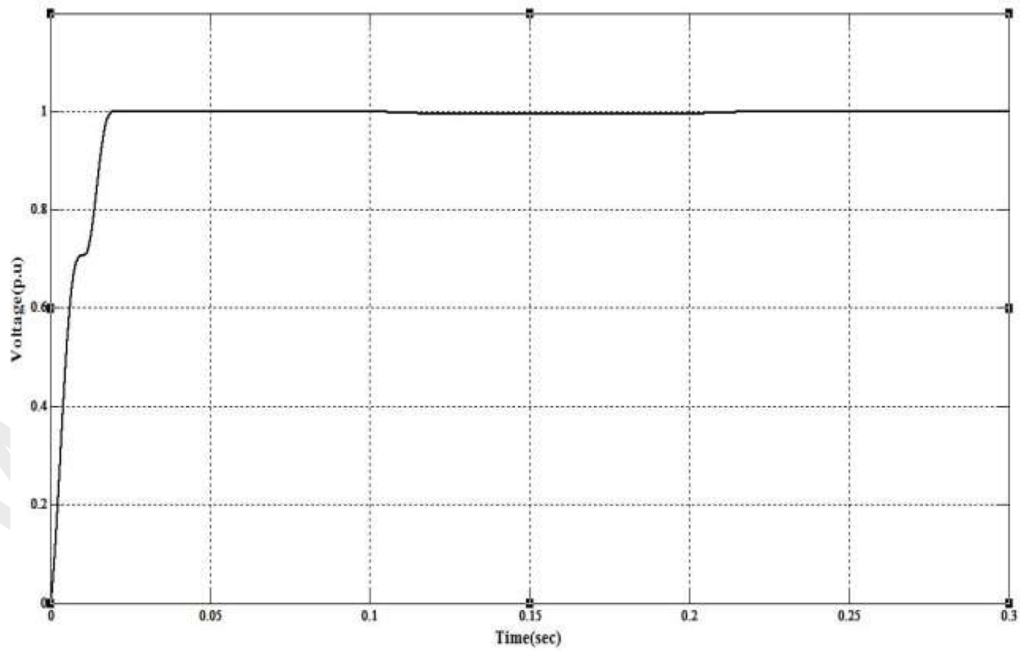

Figure5.3 (c).Voltage at load point is 0.9950p.u

In the above fig.5.3 (c), if the DLG fault is injected, the voltage sag at load point is observed at 0.9950p.u with reference to 1p.u during the time interval 0.1 to 0.2 sec with fault resistance 0.86**Ω**.

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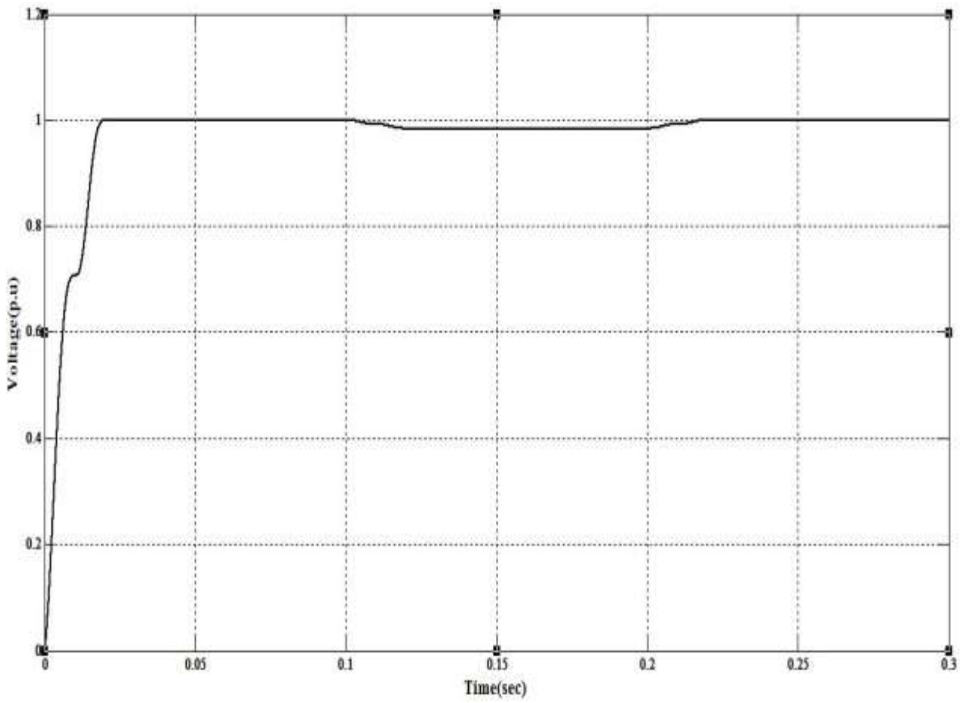

Figure5.3 (d).Voltage at load point is 0.9843p.u

In the above fig.5.3 (d), if the TPG fault is injected, the voltage sag at load point is observed at 0.9843p.u with reference to 1p.u during the time interval 0.1 to 0.2 sec with fault resistance 0.86**Ω**.

After inserting the DPFC, the simulation results voltage sag for different faults is observed from figure5.3 (a) to 5.3(d) with fault resistance R_f=0.86**Ω**. The voltage sag results with DPFC are improved when compared to voltage sag results with D-STATCOM.

Table5.4.Results of voltage sag with D-STATCOM and DPFC

Type of fault	With D- STATCOM (p.u)	With DPFC (p.u)
SLG	0.9863	0.9963
LL	1.0152	1.1152
DLG	0.9858	0.9950
TPG	0.9543	0.9843

From the above table 5.4, it can be observed that with D-STATCOM and DPFC, the voltage sag is improved approximate to 1.0p.u and 1.2p.u respectively.

VI. CONCLUSION

In the existed system, the D-STATCOM is connected in parallel with the transmission line. In this device, the reactive current is injected into the system as a result mitigation of the voltage sag takes place in distribution system.

In the proposed system, the DPFC is placed in the transmission line. DPFC is the combination of shunt and series converters, D-STATCOM acts as shunt converter whereas series converters are designed in simulink diagram. In this device, the exchange of active power between the series and shunt converters takes place through the transmission line.

Both D-STATCOM and DPFC are tested under different faults and simulation results are observed. From the simulation results, it can be concluded that the voltage sag in DPFC is highly improved when compared to voltage sag in D-STATCOM.

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