DSTATCOM with PI Controller for Voltage Sag Mitigation

T. Divya Sree, M. Devi Shankar

Abstract-Fault at transmission or Distribution level cause transient voltage sag in entire system or large part of it. Disturbances such as voltage sag, swell, short duration interruption, transient and harmonic occurs. Fault on 11Kv system or at load point affects voltage profile of other feeders. Unsymmetrical fault effect on distribution line and voltage restoration using DSTATCOM which is a custom power device. This paper deals with two control methods such as PI controller and Fuzzy logic controller implemented for the injection of current. The proposed method is implemented by using MATLAB/SIMULINK.

Keywords: DSTATCOM, Voltage sag, FIS, PI controller, MATLAB SIMULINK.

I. INTRODUCTION

Power quality is major concern in the present era. Sophisticated devices made power quality important. The custom power device performance is very sensitive to power supply quality. The power quality problem is an occurrence manifested as a nonstandard current, voltage or frequency which in turn results in a failure of end user equipments. Power quality problems comprises of a wide range of disturbances such as voltage sags, voltage swells, flickers, harmonics, distortion, impulse, transient and interruptions. Among this problem, voltage sags is the frequently occurring problems in terms of power quality problems. In the IEC terminology, IEC 60050- 604, 1998 defines a voltage sag as a "sudden reduction of the voltage at a point in the electrical system, followed by voltage recovery after a short period of time, from the half a cycle to a few seconds". Likewise, in more clearly A sag, as defined by IEEE Standard 1159, IEEE Recommended Practice for Monitoring Electric Power Quality, is "a decrease in RMS voltage or current at the power frequency for durations from 0.5 cycles to 1 minute, reported as the remaining voltage". Voltage sags are appearing due to faults, transformer energizing and motor starting. Typical values are in between 0.1p.u and 0.9p.u. and the typical clearing fault time range from three to thirty cycles depending on the fault current magnitude and the type of over current detection and interruption [1]. There are different ways to mitigate power quality problems in transmission and distribution systems. The sophisticated devices are custom power device for the low voltage distribution, for improving the poor quality and reliability of supply affecting the sensitive loads. Custom power device is very similar to the FACTS. Custom power devices be classified into two major categories namely configuring type ands compensating type.

The compensating type devices include DSTATCOM (Distribution Static compensator), DVR, UPQC[2]. Among these, D-STATCOM is one of the most effective devices. A Distribution Static Compensator (D-STATCOM) is the most efficient and effective modern custom power device used in power distribution networks. Its advantage includes lower cost, smaller size, and its fast dynamic response to the disturbance. The importance of this paper is to resolve voltage sag problem manifested in voltage deviations that result in failure of customer equipment. The model of the custom power device, namely, D-STATCOM and its control application to mitigate voltage sag[3]. The D-STATCOM has been utilized mainly for regulation of voltage, correction of power factor and elimination of current harmonics. It provides a continuous voltage regulation. In this paper, the D-STATCOM is used to regulate the voltage at the point of connection. The control is based on sinusoidal PWM and only requires the measurement of the rms voltage at the load point [4]. The DSTATCOM has the capability of generating continuous variable inductive or capacitive shunt compensation at a level up to its maximum MVA rating [5].

II. MODELLING OF DSTATCOM

Among power quality problems (voltage sag and swell, interruptions, harmonics), voltage sag causes the most severe disturbances in the power system. In order to overcome sag, the concept of custom power devices is introduced. DSTATCOM is regarded as the most efficient and effective modern custom power device used in power distribution networks. The general configuration of DSTATCOM consists of voltage injection transformer, LC filter, an energy storage device, voltage Source Inverter (VSI).DSTATCOM can be represented in schematic diagram as shown in Figure 1.

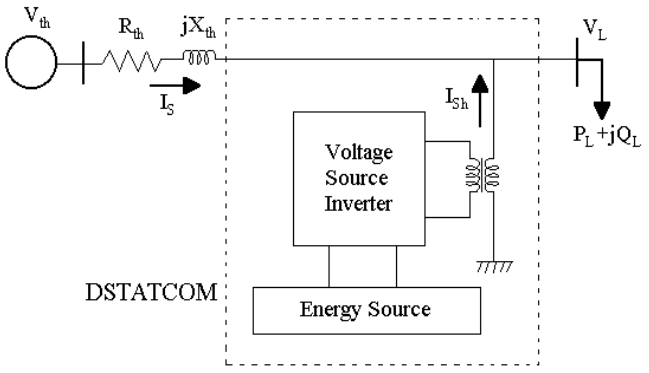

Fig. 1: Schematic representation of DSTATCOM

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A. Voltage Source Converter (VSC)

A voltage-source converter is a device connected in shunt to the system. It can generate sinusoidal voltage with required magnitude, frequency and phase angle.

B. Energy Storage Circuit

It is important for energy to be stored in the DC form such as flywheels, batteries, superconducting magnetic energy storage (SMES) and super capacitors. They can be used as energy storage devices and supply the real power requirement of the system when DVR used for compensation

C. Voltage Injection Transformer

In a three-phase system, three single-phase transformer units or one-three phase transformer unit can be used to inject the voltage in the proposed system.

D. LC Filter

LC filter is more effective for the reduction of harmonic distortion.

III. OPERATION OF DSTATCOM

DSTATCOM injects controlled voltage in shunt through the coupling transformer. The system impedance depends on the fault level. DSTATCOM injects a shunt voltage through the injection of transformer so that the desired load voltage magnitude can be maintained.

IV. PARK'S TRANSFORMATION

PI controller employs a-b-c to d-q-0 transformation. During abnormal conditions, the voltage change. After comparison of d-voltage and q-voltage with the desired voltage error, d and q are generated. This error component is converted into a-b-c component using d-q-0 to a-b-c transformation. The d-q-0 transformation, Park's transformation is used to control of DSTATCOM. The d-q-0 method gives sag depth and phase shift information of the starting and ending of voltage sag.

V. PI CONTROLLER

Proportional-integral controller (PI Controller) is a feedback controller which is the error signal. Error signal is difference between the reference voltage and load voltage.PI controller processes the error signal to zero. [6]

VI. ADVANTAGES OF DSTATCOM

Advantages of DSTATCOM are as follows-DSTATCOM can be used for load balancing. It is used to mitigate harmonics in distribution system. Also for the improvement of power quality to unity and voltage regulation in Distribution system [7].

VII. DSTATCOM TEST SYSTEM

The entire system can be represented in single line diagram as in figure 2

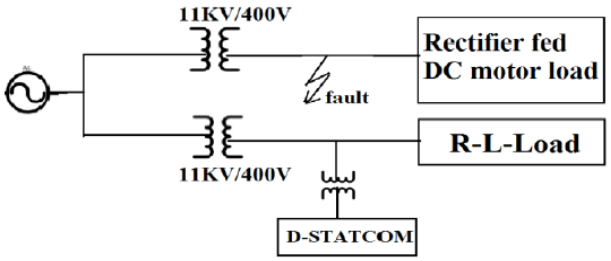

Fig. 2: Single line diagram

The system parameters are given as below

TABLE 1

Source voltage	11KV
Distribution transformer rating	11KV/400V,63KVA
DC Motor rating	50H.P
RL Load	5 KVA (0.8 p.f lag)
DC Link voltage	200V
transformer ratio	1:2
Filter Inductance	6mH
Filter Capacitance	800μF
Carrier frequency	2000HZ
Armature voltage	450V
Excitation Voltage	200V

The system be implemented by using MATLAB Simulink in figure 3 and simulink model of DC motor in figure 4

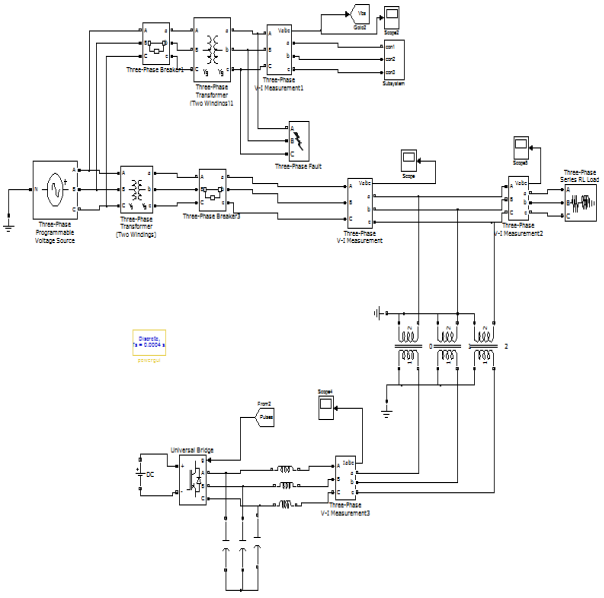

Fig. 3: Simulation model for proposed method

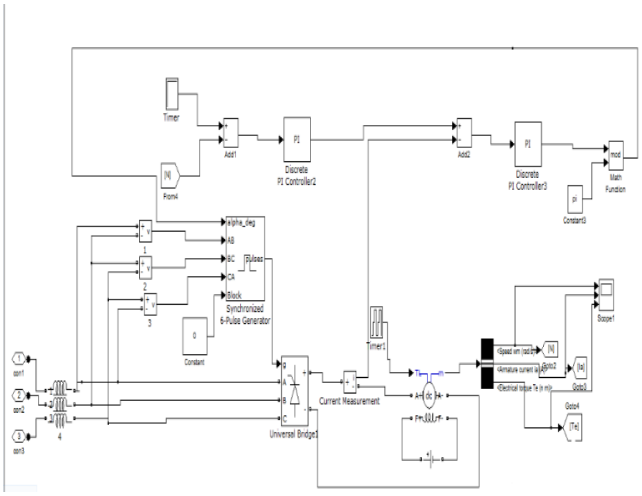

Fig. 4: Simulink model of motor

A. CONTROL CIRCUIT:

The reference voltage and the load voltage is converted from three phase quantity to two phase quantity using parks transformation and from the difference error is calculated. Error rate and error is given as input to fuzzy controller to get the actuating signal. The actuating signal is converted from two phase to three phase quantity as a sinusoidal waveform. Sinusoidal waveform is compared with triangular carrier signal. When the control signal is greater than the carrier signal, three switches of the six are turned on and the counter switches are turned off with the triggering pulses. The PI control circuit is implemented in figure 5

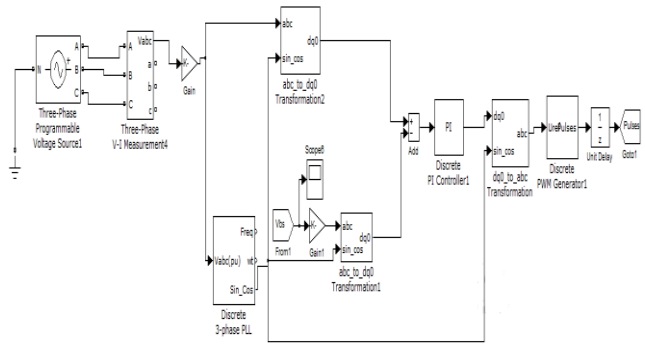

Fig. 5: PI control circuit

VIII. RESULTS

A. LG FAULT:

When LG fault occurs on feeder which feeds DC motor load the voltage sag occurs on the RL load. As RL load is connected to same finite source. voltage restoration is done by using DSTATCOM Current; DSTATCOM injects three phase current. Thus the voltage is restored by using DSTATCOM. DC Motor is a non-linear load. The voltage sag occurs in voltage waveform from 0.1 to 0.2 duration represented in figure 6.the DSTATCOM current is shown in figure 7 and the restored voltage be given in figure 8.

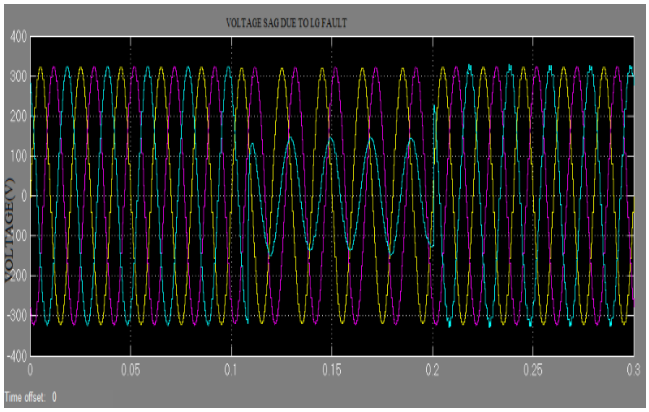

Fig. 6: Voltage sag due to LG fault

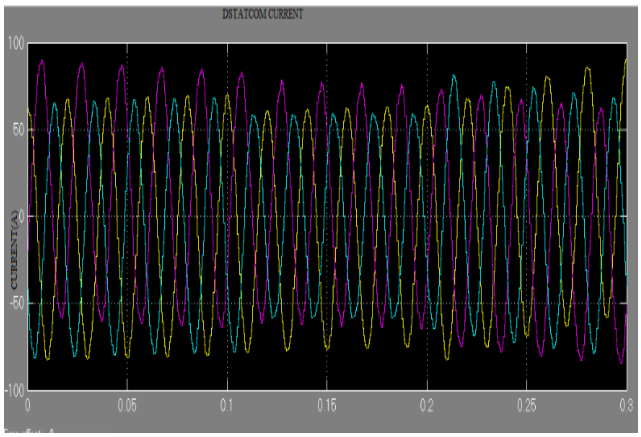

Fig. 7: DSTATCOM CURRENT

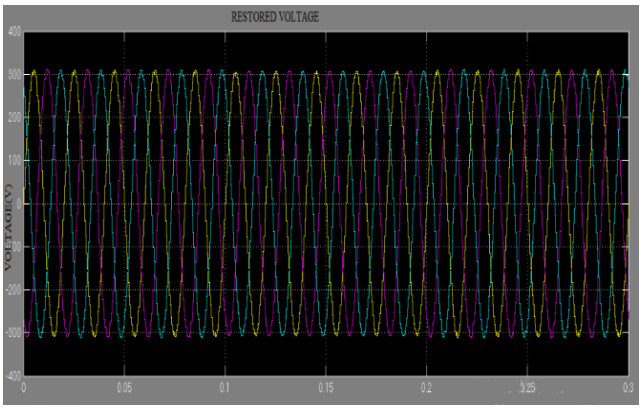

Fig. 8: Restored voltage

B. LL FAULT:

Whenever LL fault occurs on the DC Motor load feeder the voltage on the RL load affects. As the RL load is connected to same finite source. DSTATCOM induces three phase current for the voltage restoration. DC Motor is a non-linear load. The System is simulated with PI controller and LL fault on the DC motor load which causes sag from the duration of 0.1 to 0.2 on the RL load is represented in figure 9.the induced DSTATCOM current is in figure 10 and restored voltage in figure 11.

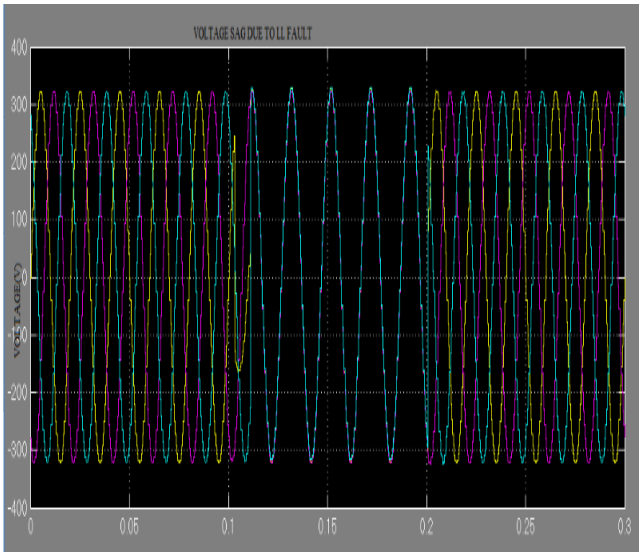

Fig. 9: Voltage sag due to LL fault

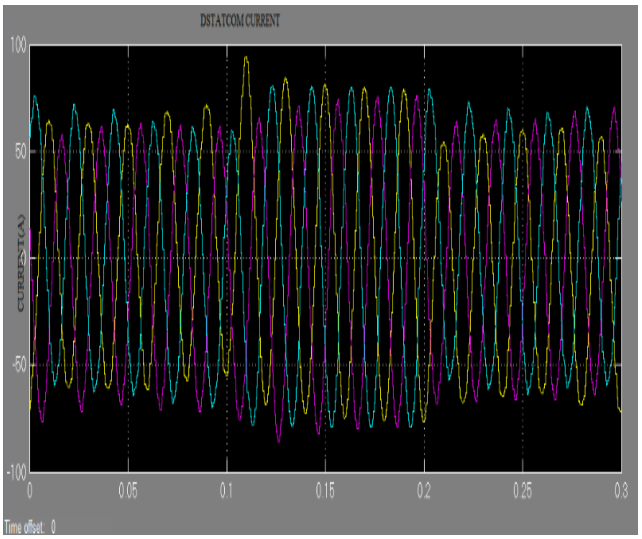

Fig. 10: DSTATCOM current

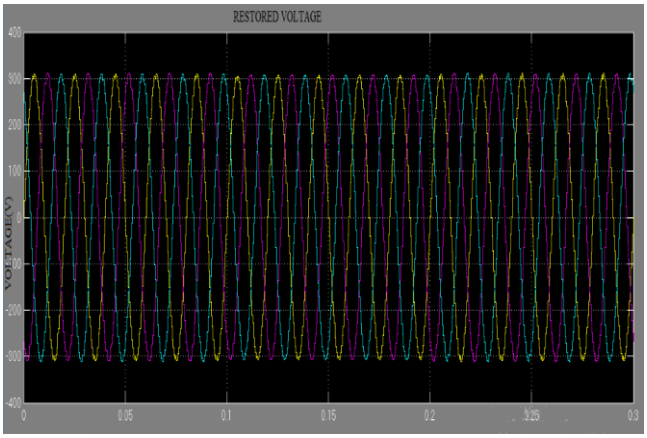

Fig. 11: Restored voltage

IX. CONCLUSION

DSTATCOM with PI controller is applied to compensate voltage sag. The voltage across the load is distorted in waveform and consists of harmonics which are displaced from its original phase. In case of the L-G & L-L faults the voltage magnitude in the individual phase decreases. The D-STATCOM corrects all the voltage magnitudes, phase deviations and harmonics at the desired load point. The simulation results clearly indicates that D-STATCOM provide excellent voltage compensation capability.

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