Voltage sag and swell,Electric power distribution modelA Coupling transformer, Programmable voltage source,D-STATCOM

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ABSTRACT: The objective of the paper is to design and impeliment a Fact devive that can be used for the improvement of voltage sag and swell. A voltage sag or voltage dip is a short duration reduction in r.m.s voltage which can be caused by a short circuit, overload or starting of electric motors. Voltage sag happens when the r.m.s voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute. 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 . The process has been done without connecting any FACTS device and then repeated once again by connecting D-STATCOM .The results obtained for the above cases have been compared to analyze the operation of Ds-STATCOM for improving the power quality disturbances. Results obtained shows that the developed D-STATCOM has good capability to starch the voltage level during voltage sag conditions.

KEYWORDS: *Voltage sag and swell,Electric power distribution modelA Coupling transformer, Programmable voltage source,D-STATCOM*

I.INTRODUCTION

The development of the modern power system has led to an increasing complexity in the study of power systems and also presents new challenges to power system stability, and in particular, to the aspects of power quality. Power quality control plays a significant role in ensuring the stable operation of power systems in the event of large disturbances and faults, and is thus significant area of research. The dynamics of the system is compared with and without the presence of series and shunt FACTS device. It is clear that the power quality and stability of the system is improved with FACTS devices and settling time in post fault case is reduced by connecting FACTS devices [2].

The PQ disturbances of voltage magnitude variation such as sag, swell and interruption are created by applying different types of faults and heavy load in the power distribution model. The frequency variation types of PQ disturbances like harmonics are generated by applying power electronic converter. The non-stationary or transient PQ disturbances are produced by applying a capacitor switching bank in distribution model. The process has been done without connecting any FACTS device and then repeated once again by connecting D-STATCOM .The results obtained for the above cases have been compared to analyze the operation of D-STATCOM for improving the power quality disturbances. Results obtained shows that the developed D-STATCOM has good capability to starch the voltage level during voltage sag conditions [12].

II.MATHEMATICAL MODEL OF PQ DISTURBSNCES Real-time PQ disturbances signals are difficult to capture. In the research of PQ disturbances, usually disturbance signals are produced by simulation for further analyzing them. Here we have six types of PQ disturbances are produced as shown in fig 1.2 by using mathematical models as shown in Table 1.1[10,11]. The PQ disturbances are easily generated and appear very similar to actual situation. . The signals generated by mathematical models can be easily used in the classification of PQ disturbances to extract their distinctive features.

Pure signal	$y(t) = A\sin(\omega t)$	$w=2\pi f$
Sag	$y(t)=A(1-\alpha(u(t-t_1)-u(t-t_2)))\sin(\omega t)$	$0.1\leq\alpha\leq0.9$; $T\leq t_2-t_1\leq 9T$
swell	$y(t)=A(1+\alpha(u(t-t_1)-u(t-t_2)))\sin(\omega t)$	$0.1\leq\alpha\leq0.9$; $T\leq t_2-t_1\leq 9T$
interruption	$y(t)=A(1-\alpha(u(t-t_1)-u(t-t_2)))\sin(\omega t)$	$0.9\leq\alpha\leq1$; $T\leq t_2-t_1\leq 9T$
harmonics	$y(t)= \alpha_1\sin(\omega t)+\alpha_3\sin(3\omega t)+\alpha_5\sin(5\omega t)+\alpha_7\sin(7\omega t)$	$0.05\leq\alpha_3\leq0.15$; $0.05\leq\alpha_5\leq0.15$; $0.05\leq\alpha_7\leq0.15$; $\sum\alpha_i^2=1$
Oscillatory transients	$y(t)=A[\sin(\omega t)+\beta e^{-(t-t_1)/\tau}\sin(\omega_n(t-t_1))(u(t_2)-u(t_1))]$	$0.1\leq\beta_3\leq0.8$; $0.0T\leq t_2- t_2\leq3T$; $8ms\leq\tau\leq40ms$; $300\leq f_n\leq900Hz$

Table 1.1 Mathematical Model Of PQ Disturbances

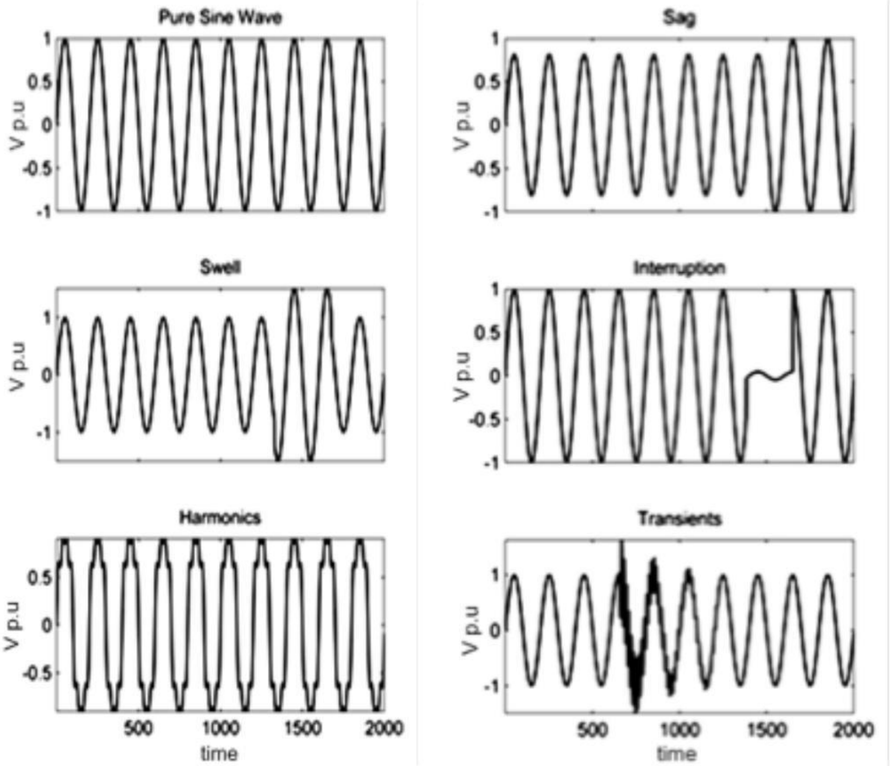

Fig.1.2: PQ disturbances waveforms

Monitoring Electric Power Quality has defined them as follows:

Sag (dip) can be defined as, “A decrease to between 0.1 and 0.9 pu in r.m.s voltage or current at the power frequency for durations of 0.5 cycles to 1 minute.” Fig1.3

Swell can be defined as, “An increase to between 1.1 pu and 1.8 pu in r.m.s voltage or current at the power frequency durations from 0.5 to 1 minute.”

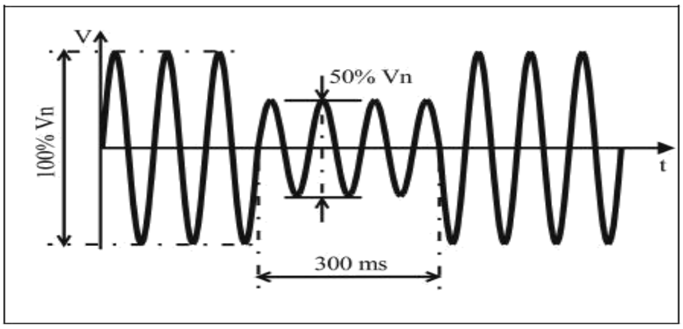

Figure 1.3 Voltage Sag Depictions

With respect to an outage or interruption, sag is differentiated by the amplitude being greater than or equal to 0.1 per unit (of nominal voltage). The IEEE 1159 document further categorizes the duration values into: Instantaneous, momentary, and temporary, as illustrated in the following table 1.5. According to the IEEE Std. 1995-2009 a voltage sag is "A decrease in r,m.s voltage or current at the power frequency for duration of 0.5 cycle to 1 minute".
IEC has the following definition for a dip (IEC 61000-2-1, 1990) "A voltage dip is a sudden reduction of the voltage at a point in the electrical system, followed by a voltage recovery after a short period of time, from half a cycle to a few seconds".

DISTURBANCE	VOLTAGE	DURATION
VOLTAGE SAG	0.1- 0.9 pu	0.5- 30 cycles
VOLTAGE SWELL	1.1- 1.8 pu	0.5- 30 cycles

Table 1.4 IEEE definitions of Voltage Sags and Voltage Swells

It is blatant from the previous definitions that both voltage sag and voltage dip relate to the same disturbance. Moreover, IEC states that "voltage sag is an alternative name for the phenomenon voltage dip" (IEC 61000-2-8, 2002).

Categories		Typical Duration	Typical Magnitude
Instantaneous	Sag	0.5- 30 cycles	0.1- 0.9 pu
	Swell	0.5- 30 cycles	1.1-1.8 pu
Momentary	Interruption	0.5- 3 cycles	<0.1 pu
	Sag	0.5- 3 cycles	0.1- 0.9 pu
	Swell	0.5- 3 cycles	1.1-1.8 pu
Temporary	Interruption	3Sec-1 minute	<0.1 pu
	Sag	3Sec-1 minute	0.1- 0.9 pu
	Swell	3Sec-1 minute	1.1-1.8 pu

Table 1.5. IEEE Std. 1995-2009 Instantaneous, momentary, and temporary illustration

III.MODEL OF D-STATCOM IN SIMULINK

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 25-kV distribution network. Two feeders (21 km and 2 km) transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 440-V load connected to bus B3 through a 25kV/440V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker. The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced PWM inverter. When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the D-STATCOM acts like a capacitor generating reactive power.

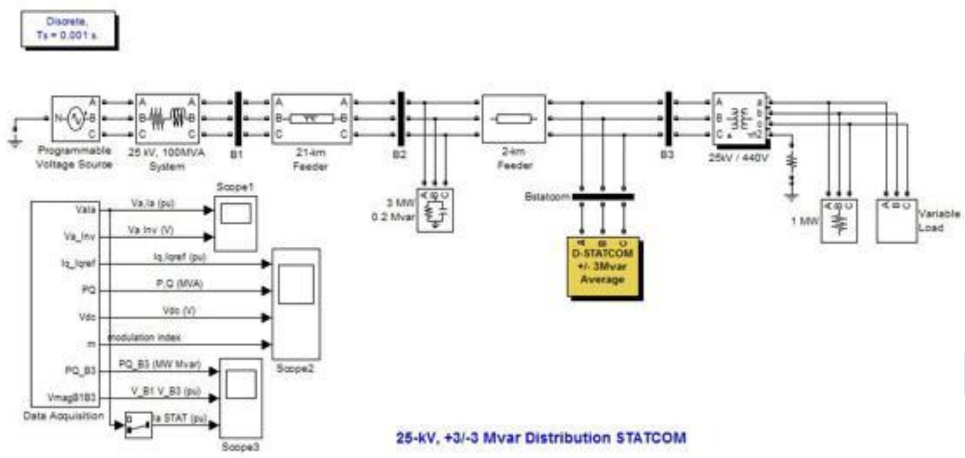

Fig.2.1 Average Model Of Dstatcom

IV.ELECTRICAL DISTRIBUTION MATHEMATICAL MODEL WITHOUT D-STATCOM AND ITS OUTPUT USING SIMULINK

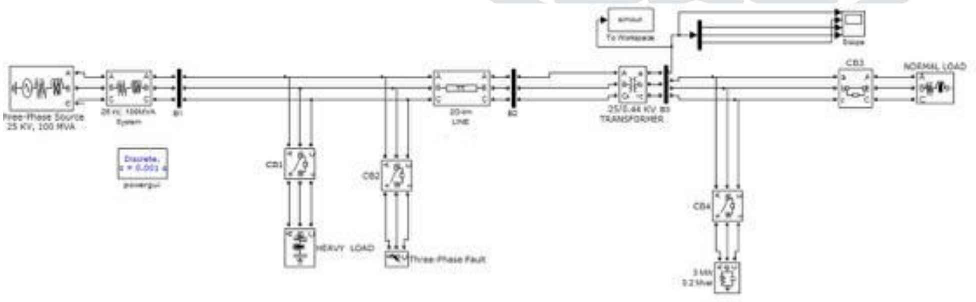

Fig.3.1 simulink model without Dstatcom

The test model of the distribution system is simulated in SimPowerSystem and Simulink Blockset of MATLAB which is shown in Fig.3.1. The simulink model without Dstatcom is used to study various PQ disturbances in power system due to system faults, heavy loads and capacitor switching.

The transmission line is of 20 km length and -model. The PQ disturbances are captured at the end of the load i.e., at bus B3. A single line-to ground fault is created at bus B1 which causes voltage sag and interruption in the fault phase and swell in the non-fault phase. A capacitor bank is connected at bus B3.A variable load causes voltage flicker and fluctuation .The non-linear load creates steady-state distortions such as harmonics. The capacitor bank creates transients types of PQ disturbances. The simulation time for all disturbances is selected as 0.2s (10cycles). The voltage sag, swell and interruption types of PQ disturbances are created in the power distribution supply system due to short circuit faults, switching of starting of large induction motors. Fig. 3.2 shows a three phase voltage waveform at bus B3. The voltage sag is created in the phase-A due to single-phase to ground fault occurred at 0.08s and cleared at 0.16 as shown in fig 3.3.When the fault is cleared at 0.16s,the voltage in the all phases is normal .In Fig.3.3, line to line fault is created in phases A and C for a period of 0.08s to 0.16s . Therefore sag is produced in phases A and C where as swell in phase B . Fig.3.4 shows interruption in phase A and swell in phases B and C between 0.04s and 0.14s due to heavy load on phase A.

The capacitor bank is energized when circuit breaker CB4 in Simulink model is switched on. A transient is produced in supply voltage due to operation of a the capacitor bank .The transient frequency depends upon the size of the capacitor bank .The large size of capacitor has lower transient frequency [7].

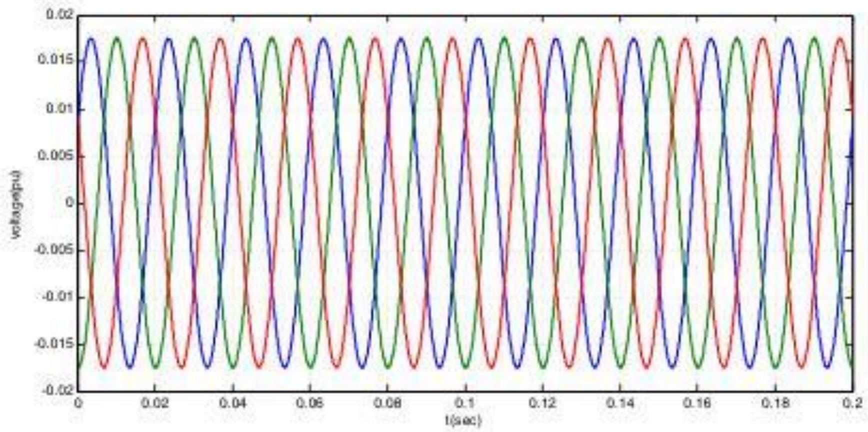

Fig 3.2 Three-phase waveform

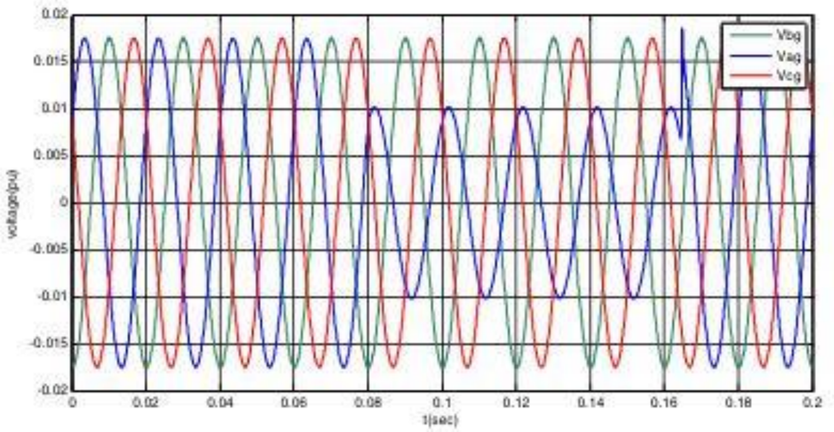

Fig 3.3 voltage sag due to single line to ground fault

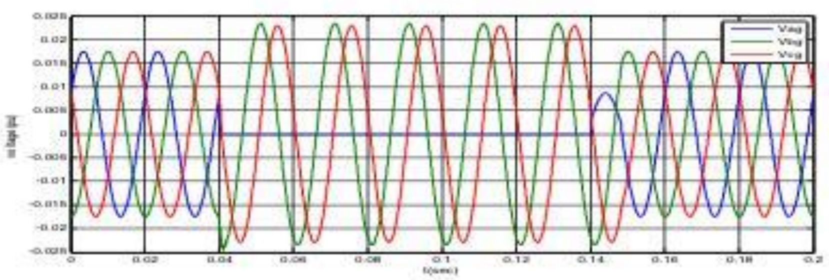

Fig .3.4 voltage swell and interruption due to heavy load

V.ELECTRICAL DISTRIBUTION MATHEMATICAL MODEL WITH D-STATCOM USING SIMULINK

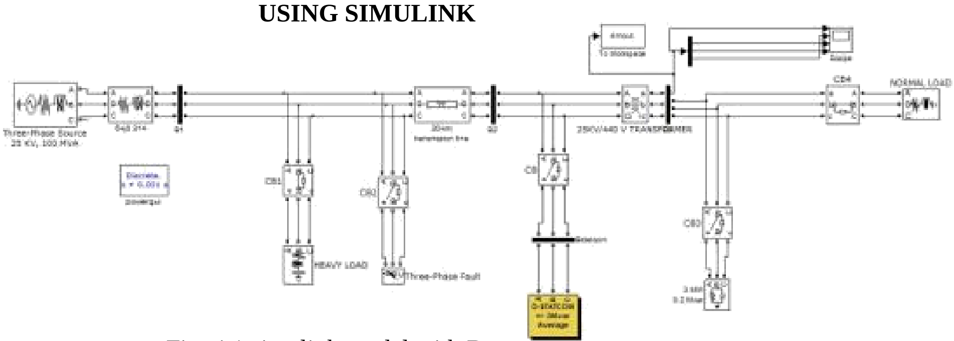

Fig. 4.1 simulink model with Dstatcom

In this test model of the distribution system is simulated in SimPowerSystem and Simulink Blockset of MATLAB which is shown in Fig.4.1. The simulink model Dstatcom is used for the improvement of various PQ disturbances in power system due to system faults, heavy loads and capacitor switching.
In this part, the PQ disturbances are simulated using Dstatcom for the improvement of various PQ disturbances in power system using simulink models.The PQ disturbances in system occurs by applying various types of loads and faults such as short circuit faults and capacitor bank switching as shown in model.

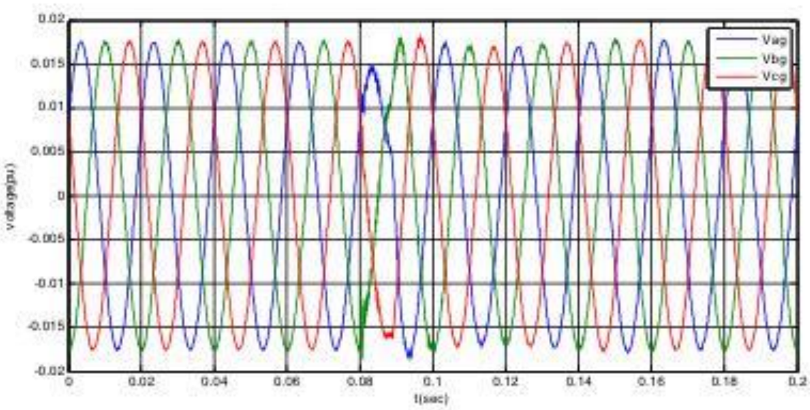

fig.5.17 Improvement in voltage sag due to single line to ground fault Fig.4.2 shows a three phase voltage waveform at bus B3,when the system is simulated with Dstatacom connected as shown in fig.4.1.
when a single line to ground fault is applied on the system at time 0.08s ,statcom is also switched at the same time .Results in the fig 4.2.shows the improvement in voltage profile of the system when Dstatcom is switched .The sag and swell condition shown in the fig.3.3 due to single line to ground fault and switching a heavy load on the system is mitigated transient behavior in the waveform is due to switching of Dstatcom.

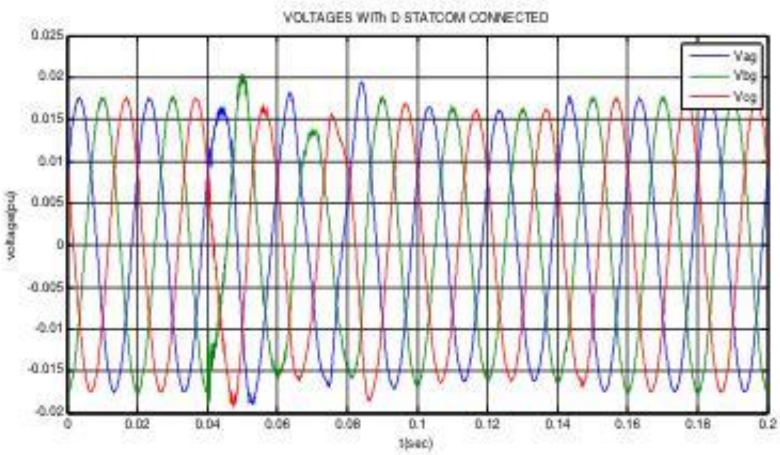

Fig.4.3.Improvement in voltage sag due to line to line fault

Similarly, the voltage waveforms shown in fig 4.3 also shows the improvement in voltage profile of the system measured at bus 3.The Dstatcom is switched at time 0.04s same time at while line to line fault is applied .Results show the improvement in voltages.

VI.CONCLUSION

The PQ disturbances of voltage magnitude variation such as sag, swell and interruption are created by applying different types of faults and heavy load in the power distribution model. The non-stationary or transient PQ disturbances are produced by applying a capacitor switching bank in distribution model.The D-STATCOM can be designed using a current source inverter. An integrated D-STATCOM controller can be design for voltage regulation, reactive power

compensation, This work presents development, simulation and analysis of a D-STATCOM using MATLAB/ SIMULINK .To enhance the voltage sag restoration capability of the D-STATCOM. Accordingly, simulations are first carried out to illustrate the use of D-STATCOM in mitigating voltage sag in a system. Simulation results prove that the facts devices are capable of mitigating voltage sag as well as improving power quality of a system.

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