Performance Evaluation of D-STATCOM for Voltage Sag Mitigation in Induction Motor

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Abstract **- A Power quality problem is an occurrence manifested as an unusual voltage, current or frequency that results in a failure of end user equipments. Voltage sag is most important power quality problem faced by many industries and utilities. Three phase Induction Motor (IM) is a work horse of industrial and agricultural sector. IM is always preferred over other types of electric motors. In many of these applications IM is started using DOL starter. Voltage sag which lasts for only few seconds may severely affect their working. This case study gives detailed information about D-STATCOM, which is used to mitigate voltage sag produced in three phase induction motor. The model of D-statcom has been implemented in MATLAB/Simulink software. The model is based on voltage source converter (VSC) principle. This case study also gives brief information of voltage sag, its characteristics, basic structure and operation of D-statcom. The behaviour of this system during voltage sag caused by starting of motor load has been examined. Simulation result shows the fast response and the D- STATCOM capability for mitigate voltage sag.**

Index Terms **–Three phase induction motor, voltage sag, voltage sag mitigation, D-statcom, modelling, simulation, power quality, power system, MATLAB**

1. INDRODUCTION

In the early days various industrial equipment's we are using were mainly mechanical in nature which were used to control the industrial processes and were rather tolerant to the voltage sag or voltage disturbances. But in the modern era industrial sector uses a very considerable amount of the electronics equipment's and switches. For example the logic gate controller s like the programmable logic controller (PLC) the sensitive to voltage drives of machines , speed control or process control power electronics drives etc., so one thing is evident that these things are very sensible to the power quality like the magnitude, supply frequency, phase angle, harmonics quantity etc. So it has to be ensured that care must be taken to make them intact with the type of power supply they demands. In industries too there are many appliances and machinery they demands the exactness in the supply unless the systems supply disruption happens and sometimes the various devices that's get connected might get damaged in that processes. So one of the pressing problem out of the power quality problems is the voltage sag problem. This very frequent in nature and causes damage to the system equipment and the process can be interrupted. Voltage sag is defined as a decrease between 0.1 and 0.9 p.u. in the m voltage at the network fundamental frequency with duration from 0.5 cycles to few seconds. This definition assumes that the sag can be defined by a magnitude and duration. The duration is usually associated with the time taken by the protection system to clear the fault. Three phase Induction Motor (IM) is a work horse of industrial and agricultural sector. Due to its low cost and rugged construction, IM is always preferred over other types of electric motors. In many of these applications IM is started using DOL starter. Thus, IM draws high current during its starting period which not only heats the motor, but also causes voltage drop in supply lines. Nowadays due to wide usage of sensitive electronic equipments such as computers, even voltage sag which lasts for only 0.1 sec may severely affect their working [3]. Also, there are severe power crisis in India, especially in Maharashtra state. Therefore, the voltage profile of the supply lines is always at its lowest. The voltage sag caused by IM starting leads to further lowering down the voltage profile which results in deterioration of power quality. Making this problem worth for giving attention by researcher to find out its effective and economical solution. In industrial sector the voltage sag caused by DOL starting of IM can cause severe loss in production due to unadvertised tripping of switchgear, which makes this problem more pressing [5].

2. VOLTAGE SAG:

Voltage sag is defined as a sudden drop in the root mean square (R.M.S) voltage and is usually characterized by the remaining (retained) voltage. Voltage sag is thus, short duration reduction in RMS voltage, caused mainly by short circuits, overloads and starting of large motors. In the IEEE standard 1159-1995, the term "sag" is defined as decrease in RMS voltage or current to values from 0.1 to 0.9 per unit for duration of 0.5 cycles to one minute [3].

2.1 Characteristics of Voltage Sag:

Following are the important characteristics of voltage sag.

i. Voltage sag Magnitude
ii. Voltage sag Duration

Voltage sag magnitude is defined as the remaining voltage during the event. The voltage sag duration is the time interval of presence of sag.

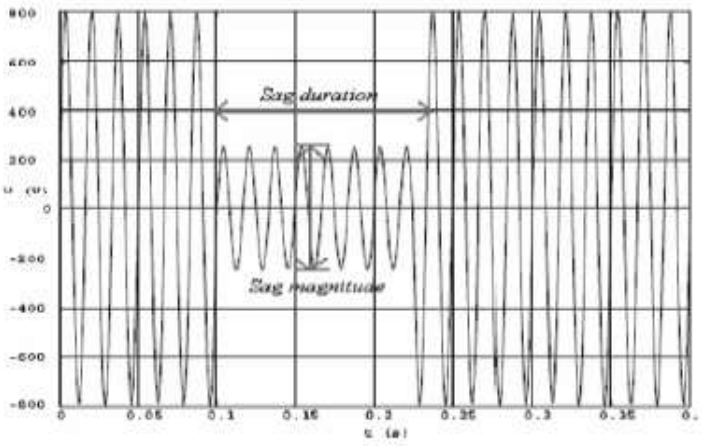

Fig. 2 Depiction of Voltage Sag

Based on the time duration and voltage magnitude, sag is further classified as:

a) Instantaneous Sag: Instantaneous sag is said to occur when the rms voltage decreases to between 0.1 and 0.9 per unit for time duration of 0.008333 second to 0.5 second.
b) Momentary Sag: Momentary sag is said to occur when the rms voltage decreases to between 0.1 and 0.9 per unit for time duration of 0.5 second to 3 seconds.
c) Temporary Sag: Temporary sag is said to occur when the rms voltage decreases to between 0.1 and 0.9 per unit for time duration of 3 to 60 seconds.

3. DISTRIBUTION STATIC COMPENSATOR (D-STATCOM)

When used in low voltage distribution systems the Static Compensator (STATCOM) is normally identified as Distribution STATCOM (D-STATCOM). In general, D-STATCOM is used to generate or absorb reactive power [9].

3.1 Basic Operation

Distribution Static Compensator (D-STATCOM) also known as shunt voltage controller consists of a two level voltage source converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network and associated control circuit [9,10] as shown in the fig below. 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 through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allow effective control of active and reactive power exchanges between the D-STATCOM and ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

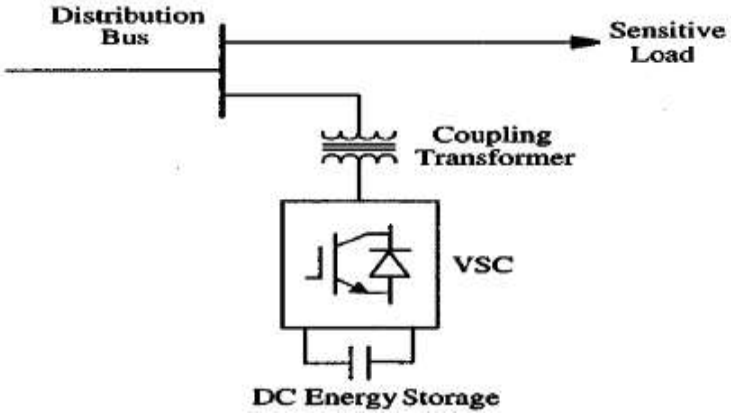

Fig.3.1 (a) Schematic diagram of D-STATCOM

Regulating the amplitude of the D-STATCOM output voltage controls the reactive power exchange of the D-STATCOM with the AC system. If the amplitudes of the D-STATCOM output voltage and the AC system voltage are equal, the reactive current is zero and the DSTATCOM does not generate/absorb reactive power.

If the amplitude of the D-STATCOM output voltage is increased above the amplitude of the AC system voltage, the current flows through the transformer reactance from the D-STATCOM to the AC system, and the device generates reactive power (capacitive). If the amplitude of the D-STATCOM output voltage is decreased to a level below that of the AC system, then the current flows from the AC system to the D-STATCOM, resulting in the device absorbing reactive power (inductive). Since

the D-STATCOM is generating/absorbing only reactive power, the output voltage and the AC system voltage are in phase, when neglecting circuit losses.

The current drawn from the D-STATCOM is 90° shifted with respect to the AC system voltage, and it can be leading (generates reactive power) or lagging (absorbs reactive power). A capacitor is used to maintain dc voltage to the inverter. An uncontrolled rectifier based six diodes used to keep the capacitor charged to the required level.

The D-STATCOM operation is illustrated by the phasor diagrams shown in Fig.3.2 (b). When the secondary voltage (V,) is lower than the bus voltage (VB), the D-STATCOM acts like an inductance absorbing reactive power from the bus. When the secondary voltage (V,) is higher than the bus voltage (VB), the D-STATCOM acts like a capacitor generating reactive power to the bus. In steady state, due to inverter losses the bus voltage always leads the inverter voltage by a small angle to supply a small active power.

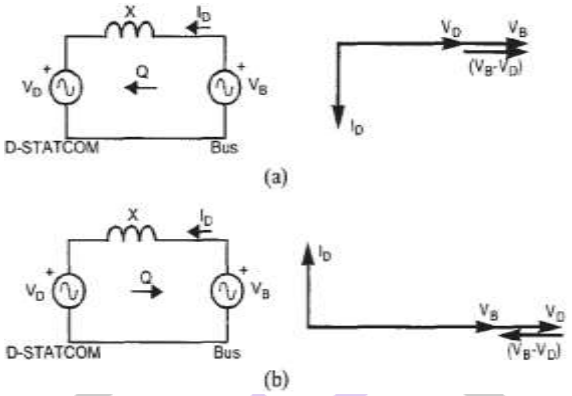

Fig.3.2 (b) D-STATCOM Operation

(a) Inductive operation, (b) Capacitive operation

The STATCOM has several advantages as compared to "conventional" Static Var Compensator (SVC) using thyristors. It is faster, can produce reactive power at low voltage, does not require thyristor controlled reactors (TCR) or thyristor switched capacitors (TSC), and does not produce low order harmonics.

4. LITERATURE SURVEY

"Unified Approach for Mitigating Voltage Sag and Voltage Flicker Using D-STATCOM" A. Elnady, Student Member, IEEE, and Magdy M. A. Salama, Fellow, IEEE, IEEE Transactions on Power Delivery, vol. 20, no. 2, April 2005.

This paper introduces a novel method for the mitigation of the voltage sag and voltage flicker by using Kalman filter and its derivatives (adaptive, and extended). The Kalman filter is used as a tool to extract both the instantaneous envelope of the voltage sags, and to extract the instantaneous Flicker Level (IFL) of the voltage flicker. Also, this paper demonstrates the advantages of using the Kalman filter instead of the existing tools for tracking and extracting voltage disturbances.

"Mitigation of Power Quality Problem Due to Starting of Induction Motor" Vishal K. Patil, Ajit P. Chaudhari, Girish K.Mahajan, Volume: 04 Issue: 04, Apr-2015.

This paper gives information about Power quality problems such as voltage sag which is to be generate effect on industrial distribution system. In this paper analyses the application of custom power devices using dynamic voltage restorer for mitigation of power quality problems voltage sag due to starting of three phase induction motor. Control strategies for DVR is based on transformation feed forward control techniques. DVR to have less THD in distribution system. The propose control scheme simulation results carried out by MATLAB Simulink. The result shows that although period of voltage sag and rating of the load changes even then voltage sags are totally compensated.

"STATCOM Simulation Model to Improve Voltage Sag Due to Starting of High Power Induction Motor", A.F. Huweg, S.M.Bashi and N.Mariun, National Power & Energy Conference (PECon) 2004 Proceedings, Kuala Lumpur, Malaysia.

This paper illustrates; a simulation model of STATCOM has been constructed on Matlab/Simulink software to examine its capability for voltage sag mitigation due to starting high power induction motor. In this paper, the main structure of Simulink (STATCOM) model is described briefly. Its capability to compensate reactive power to the system when the voltage sag occurs was described. A phase control thyristor (SCR) based voltage source inverter (VSI) is employed for this application. The influences of the initial operation point and DC capacitance are considered. The behaviour of this system during voltage sag caused by starting of motor load has been examined. Simulation result shows the fast response and the STATCOM capability for mitigate voltage sag.

"Modeling and Simulation of a Distribution STATCOM using Simulink's Power System Blockset" Pierre Giroux Gilbert Sybille Hoang Le-Huy, IECON'0l: The 27th Annual Conference of the IEEE Industrial Electronics Society.

From this paper we know that this paper presents a study on the modelling of a STATCOM (Static Synchronous Compensator) used for reactive power compensation on a distribution network. The power circuits of the D-STATCOM and the distribution network are modelled by specific blocks from the Power System Blockset while the control system is modelled by Simulink blocks. Static and dynamic performance of E3 Mvar D-STATCOM on a 25-kV network is evaluated. An average modelling approach is proposed to simplify the PWM inverter operation and to accelerate the simulation for control parameters adjusting purpose. Simulation performance obtained with both modelling approaches are presented and compared.

"Application of D-STATCOM to Mitigate Voltage Sag Due to DOL Starting of Three Phase Induction Motor" L. S. Patil and Ms. A. G. Thosar, International Conference On "Control, Automation, Communication And Energy Conservation - 2009, 4th-6th June 2009.

This paper explains about "A mathematical model of Distribution STATCOM has been implemented in MATLAB/Simulink to validate its capability for mitigation of voltage sag due to DOL starting of induction motor. This paper organized with brief introduction to voltage sag problem followed by characteristics of voltage sag, basic structure & operation of D-STATCOM. The model is subjected to, first without D-STATCOM and then with it. The results obtained in both the cases are analyzed. Based on this analysis the capability of D-STATCOM to mitigate the voltage sag due to DOL starting of IM is validated."

"Digital Simulation of D-statcom System for Improving Power Quality" S. Premalatha, G. Punitha Valli, IEEE - International Conference on Advances in Engineering, Science and Management (ICAESM -2012) March 30, 31, 201 2666.

This paper deals with "The paper illustrates the use of MATLAB /SIMULINK software for the modelling of D-statcom system. The dynamic behaviour of the system is learned by testing the basic system under large and small disturbances. The voltage sag mitigation associated with different configurations of the system is observed. To show the effect of controller on the voltage sag mitigation and reactive power compensation under these disturbances, D-statcom is added, modelled and tested."

"VSC Based DSTATCOM & Pulse-width modulation for Power Quality Improvement" Rodda Shobha Rani, B. Jyothi M.Tech, Dept. of EEE, Nimra College of Engineering & Technology, A.P., India. Assoc. Professor, Dept. of EEE, Nimra College of Engineering & Technology, A.P., India. Volume2 Issue2 - 2011.

This paper proposed voltage-sourced converter (VSC) with Pulse-width modulation (PWM) provides a faster control that is required for flicker mitigation purpose. The voltage regulation in the distribution feeder is improved by installing a shunt compensator. The proposed DSTATCOM is modelled and its performance is simulated and verified for power factor correction and voltage regulation along with neutral current compensation. The three phase three wire Distribution Static Compensator (DSTATCOM) is proposed for power quality improvement. DSTATCOM is based on a three leg VSC and is controlled to compensate reactive power, harmonic current and unbalances in the load.

"Application of DSTATCOM for Improvement of Power Quality using MATLAB Simulation" Archana M. Kadam, Satyen Dhamdhere, D.S.Bankar, International Journal of Science and Modern Engineering (IJISME) ISSN: 2319- 6386,Volume-1, Issue-1, December 2012.

In this paper; an increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. This paper presents the reduction of voltage sags, using Distribution Static Compensator (DSTATCOM) with LCL Passive Filter in Distribution system. The model is based on the Voltage Source Converter (VSC) principle. D-STATCOM can use with different types of controllers. The D-STATCOM injects a current into the system to mitigate the voltage sags. LCL Passive Filter Was then added to D-STATCOM to improve harmonic distortion and low power factor. The simulations were performed using MATLAB SIMULINK.

"Voltage Sag Analysis and Solution for an Industrial Plant with Embedded Induction Motors" Angel Felce, Guillermo Matas, Ysmael Da Silva, IAS 2004 IEEE.

In this paper a power quality (PQ) problem in an industrial plant is analyzed and its possible solutions explored, specifically regarding voltage sags. It is analyzed a plant's electrical system sensitivity regarding voltage sags, how does the magnitude depression and its duration affect the performance of the electrical loads (mainly induction motors). Several proposals are discussed and explored for voltage sag mitigation and their feasibility for the plant's PQ problem. Finally, settings of the voltage sag mitigation equipment (timer or "latching" relay) are made analysing voltage recovery times after voltage sag has occurred.

"Application of D-STATCOM for Mitigation of Voltage Sag for Motor Loads in Isolated Distribution systems" Bhim Singh, A. Adya, A.P.Mittal, J.R.P.Gupta, B.N.Singh, IEEE ISIE 2006, July 9-12, 2006, Montreal, Quebec, Canada.

This paper deals with one of the potential applications of distribution static compensator (DSTATCOM) to industrial systems for mitigation of voltage dip problem. The dip in voltage is generally encountered during the starting of an induction motor. Isolated distribution systems are comparatively not as stiff as grid systems; so large starting currents and objectionable voltage drop during starting of an induction motor could be critical for the entire system. DSTATCOM is one effective solution for isolated power systems facing such power quality problems. The model of DSTATCOM connected in shunt configuration to such an isolated system (3phase, 42.5kVA alternator) feeding dynamic motor loads is developed using Simulink and PSB of MATLAB software. Simulated results demonstrate that DSTATCOM can be a considered as a viable solution for solving such voltage dip problems.

"Application of Inverter Based Shunt Device for Voltage Sag Mitigation Due to Starting of an Induction Motor Load" A.F. Huweg, S. M. Bashi MIEEE, N. Mariun SMIEEE, 18th International Conference on Electricity Distribution, 6-9 June 2005.

This paper shows a study of the static synchronous compensator (STATCOM) behaviours for voltage sag mitigation to an induction motor. The proposed of STATCOM stability model is justified based on the basic operation characteristics of phase control strategies. The simulation of 6 pulses STATCOM based on voltage source inverter (VSI) using Matlab Simulink is presented to show its good performance under balanced voltage sag condition due to the motor starting. Experimental testing has been made by using thyristor firing board control (FS36M). The STATCOM response of compensated reactive power to the system during voltage sag has been shown. Finally simulation results and experimental results have been described and compared once and good performance has been obtained.

"On Comparing the performance of Voltage Source Converters based D-STATCOM for Voltage Sag Mitigation" Kanagaraj Pillay1, Mohamed S.A. Dahidah1 and Norman B. Mariun2, IEEE International Conference of Power Energy, Nov 29 – Dec 1, 2010.

This paper studies the utilization of PWM voltage source converters in Distribution Static Synchronous Compensator (D-STATCOM) for voltage sag mitigation. Three different voltage source converter topologies based DSTATCOM; namely the two

level, three level neutral point clamped and the three level flying capacitor are investigated and compared. The comparison is drawn based on harmonic profile, response time and the steady state time of the point of common coupling voltage for different VSCs based D-STATCOM. The investigation is carried out using MATLAB-SIMULINK Power System Blockset for different operating points and a comparison between the different topologies is provided.

"Mitigation of voltage sag using Distribution Static Compensator (D-Statcom)" S. Elango, Dr. E.Chandra Sekaran, 2011 IEEE.

This paper presents a study and simulation of D-STATCOM (Distribution Static Compensator) used for mitigating voltage sag on a distribution network. The power circuits of the D-STATCOM and the distribution network are modelled by specific blocks from the Power System Block set while the control system is modelled by Simulink blocks. A main feeder feeding a 10 MW load is abruptly disturbed by the inclusion of a sudden load of 10 MW thereby creating voltage sag. This voltage sag is corrected by the static compensator.

RESEARCH OBJECTIVE

To study the operation of D-STATCOM.
To study the characteristics of the voltage sag.
To simulate mitigation of voltage sag/swell in the three phase induction motor by D-STATCOM system using MATAB SIMULINK software.
To analyse the voltage sag/swell problems and solve it using D-STATCOM.
In addition to this a case study is planned taking the parameter of industrial load.

CONCLUSION

After doing the literature survey it has been concluded that, DSTATCOM is a voltage-source inverter (VSI) based shunt device generally used in distribution system to improve power quality. The main advantage of D-STATCOM is that, it has a very sophisticated power electronics based control which can efficiently regulate the current injection into the distribution bus. The second advantage is that, it has multifarious applications like cancelling the effect of poor load power factor, Suppressing the effect of harmonic content in load currents, Regulating the voltage of distribution bus against sag/swell Compensating the reactive power requirement of load and so on. The performance of the DSTATCOM is very much dependent on the D-STATCOM controller.

The utility of D-STATCOM is examined under simulated condition. For validation of its utility in real life situation, it needs to be further investigated and implemented under actual working conditions.

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