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Mitigation of Voltage sag using DSTATCOM

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Abstract: The paper describes the modelling and simulation of a Distribution Static Synchronous Compensator (DSTATCOM) which injects the current at the point of common coupling in the network to eliminate or mitigate the voltage sag. It shows the capability and performance of DSTATCOM to mitigate and void out the voltage sag & a control technique based on Bang Bang controller and Hysteresis current controller is modelled to check the results. A VSC based D-STATCOM is modelled using MATLAB simulink tool. Thus the simulations are performed without & with DSTATCOM. Simulation results lead to the showings that the D-STATCOM mitigates voltage sag as well as improves power quality of system.

Keywords: DSTATCOM, Voltage Sag, Power Quality, VSI, Distribution System, Induction motor, Hysteresis Controller

I. INTRODUCTION

POWER quality is a major issue in recent times due to the increase in sensitive loads. There are different power qualities events occurring in today's power distribution system, in which, voltage sag is the exacting for industrial sector with reference to different research and studies carried out. [1], [2].Voltage sag is reduction in value for value RMS PCC voltage for duration around 0.5 sec to 300 sec [3]. Voltage sag problems occur due the use of as heavy large and non linear loads, power electronic drives, IM, control equipments etc. Mitigation and voltage sag correction techniques have been developed in the certain time period and still research is going on. The DSTATCOM has emerged as a promising device to suppress power quality disturbances like as voltage sags and swells, voltage flicker, correction of power factor and harmonic elimination. Three phase Induction Motor (IM) is a main component or we can say work horse of industrial and agricultural sector. IM is always preferred over different other types of motors because of its low cost & rugged construction. It takes high current while starting which heats up the motor and causes voltage reduction in supply lines. Thus, it affects on the performance of other equipments, usually, the starting period is about 1 sec, hence, and there is a sag in the voltage while starting of motor. There are various control techniques and various converter topologies used for DSTATCOM. The technique used in this paper includes of a six pulse IGBT-based voltage source inverter which permits fast inductive and capacitive compensation [4]. The controllers used are Bang Bang Controller and Hysteresis current control strategies [4]-[6]. MATLAB is used for analysis and simulation and the findings and results are analyzed. The VSI converts the capacitor voltage into a set of balances ac voltages (3ϕ) which are injected to the network through the isolation transformer. The DSTATCOM regulates the flow of current in accordance with the requirements at the point of connection of load. This paper aims for the verification of D-STATCOM ability for mitigation of voltage sag due to the switching of heavy inductive loads or non linear loads & starting of Induction motor. The results are analyzed by using simulation.

II. CONFIGURATION & WORKING OF DSTATCOM

The D-STATCOM is a VSI based FACTS device which is connected in parallel or shunt to the source. It is always connected at load side. The device utilizes a 6 pulse VSI, which injects or absorbs current ,as required, system by transforming DC link voltage into AC voltage [3][7]. The below Figure 1 shows the arrangement of DSTATCOM. The DSTATCOM comprises of DC link source prior to the inverter using six switching devices like MOSFET's or IGBT's, DC capacitance and a leakage reactance in the form of coupling transformer. It is configured such that it performs different functions such as;

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- Voltage correction/Mitigation and compensation of reactive power.
- Power factor correction
- Harmonics reduction.

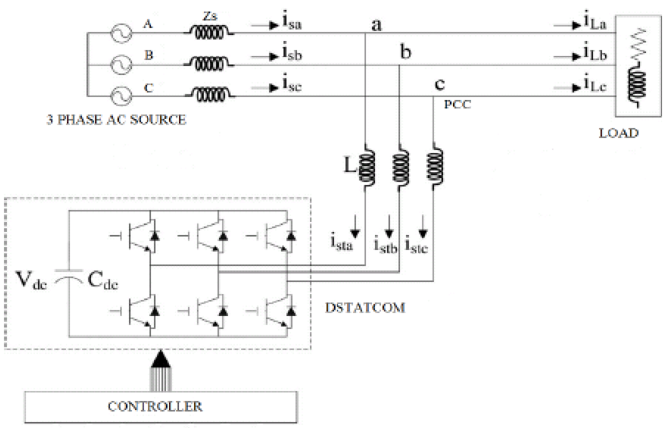

Figure 1 Basic Circuit Diagram of the DSTATCOM

The capacitance in the device is used to provide/maintain DC voltage to converter. The actual magnitude of converter voltage Vi is changes according to the change in capacitor voltage which also modifies as per the energy stored in capacitor. The active power generation takes and it flows through the inverter causing charging and discharging of capacitor as per the change in phase angle or phase shift. The charging or discharging of the capacitor has an impact on voltage level and thus the ac voltage also. The controller of DSTATCOM stabilizes the voltage and thus enhances the power quality by mitigation or correcting the voltage sag value.

Working Modes

The working principle of DSTATCOM depends upon the generation of reactive current, it calculates the load voltages and currents, manipulates the compensation amount for disturbances. The angle between the source and o/p voltages of DSTATCOM transmits the active & reactive power flow enhanced by the difference of the voltages. The operating modes of DSTATCOM are explained in the Figures 2& 3 below [8]. If the amplitudes of AC system voltages and DSTATCOM output voltages of device are equal then there will be no reactive power exchange i.e. no generation or absorption and the reactive current produced is null. If the amplitude of voltages at the output side of DSTATCOM are higher than the system voltages then the current will regulate or flow from the DSTATCOM to the system and the device operates in capacitive mode i.e. it produces reactive power If the amplitude of voltages at the output side of DSTATCOM are lower than the system voltages then the current will regulate or flow from the system to the DSTATCOM and the device operates in inductive mode i.e. it absorbs reactive power. The current is lagging the voltage by 90° in inductive mode.

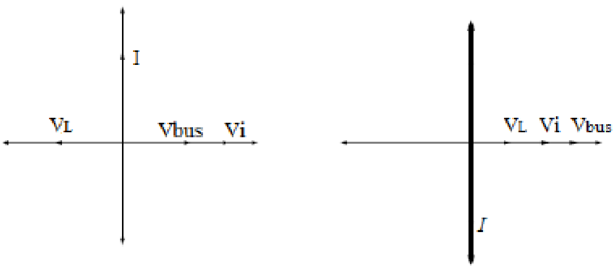

Figure 2 Modes of Operation of Reactive Power (a) Capacitive (b) Inductive

The ac power present in distribution system consumed by the losses due to transformer and switching devices upto some extent which produces a small phase difference α between V_{bus} and V_i to extinct the losses and regulate the flow

Vol. 8, Issue 12, December 2020
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of the active power from the system. The Phase angle α is positive while operating in inductive mode and negative while operating in capacitive mode. Fig.3 shows the phasor diagram of DSTATCOM for active power in inductive and capacitive mode [9]. The powers can be calculated by following equations:

$$P = \frac{V_{BUS}V_i}{X_L}\sin\alpha \ ; \ Q = \left(\frac{V_{BUS}^2}{X_L}\right) - \left(\frac{V_{BUS}V_i}{X_L}\right)\cos\alpha \qquad (1)$$

The common point voltage is regulated by injecting of current on network impedance during voltage sag period. This impedance is the source impedance when connected in shunt with load impedance. The DSTATCOM can achieve the voltage sag correction or mitigation when Vi is in quadrature with the I_{sh} without injecting real power.

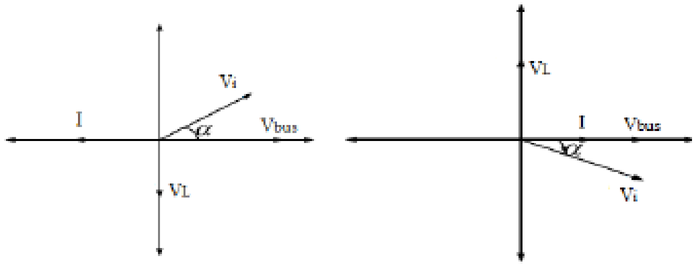

Figure 3 Modes of Operation of Active Power (a) Inductive (b) Capacitive

The shunt injecting current I_{sh} and V_L can be given as,

$$I_{ch} = I_L - I_S = \left(\frac{V-VL}{}\right); \ V_L = V + (I_{ch} - I_L)Z_S \qquad (2)$$

III. CONTROL SYSYTEM REQUIREMENTS

The significant properties of a compensating device or any compensation methods are time of response, feasibility and simplicity in application. Following is the procedure or steps for implementing an algorithm for control of DSTACOM:

- Measurements of system Voltage and Current
- Signal Conditioning
- Calculations of compensating Signal
- Firing angles generation for Thyristors/IGBTs/MOSFETs

The Transient and dynamic performances are affected by the firing pulses generated for switching devices creates problem for DSTATCOM Control. Some of the basic control schemes used are

- Phase angle control
- Decoupled Current Control [10]
- AC bus & DC voltage regulation
- Synchronous reference frame method [10]

Compensation scheme (Bang Bang Controller)

Bang Bang Controller is used as control scheme for current injection at point of common coupling along with Hysteresis Current controller is used here. The Current Controller is fed with reference current and an actual current as input signals and the difference between the two activates the operation of DSTATCOM in current control mode. This method enables to keep the control system between levels of hysteresis band and provide proper switching signals for DSTATCOM operation [5]. Figure 4 presents represents Bang Bang controller used with DSTATCOM.

Source Synchronisation

The Vrms magnitude (in balanced three phase system) is calculated at the random frequency using source phase voltage V_{sa} ,V_{sb} ,V_{sc} and is expressed as V_{sm} sampled peak voltage , as in (1).

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$$V_{sm} = \{2/3\,(V^2_{sa} + V^2_{sb} + V^2_{sc})\}^{1/2} \qquad (1)$$

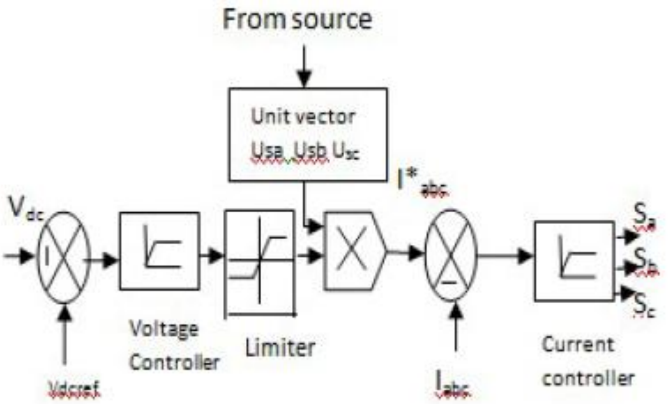

Figure 4 Schematic of Bang Bang Controller

The phase unit vectors are calculated from source and root mean square value of unit vector U_{sa}, U_{sb} ,U_{sc} as show in (2)

$$U_{sa} = V_{sm} / V_{sa}$$
$$U_{sb} = V_{sm} / V_{sb}$$
$$U_{sc} = V_{sm} / V_{sc} \qquad (2)$$

The generated reference phase currents are calculated using generated phase reference currents and in-phase unit voltage template as, in (3)

$$i_{sa} = I^*U_{sa}$$
$$i_{sb} = I^*U_{sb}$$
$$i_{sc} = I^*U_{sc} \qquad (3)$$

Where I corresponds directly to amplitude of filtered Vs for each phase. Thus, current obtained is to be sinusoidal. The unit vectors play an important role in the network connection for the connection for DSTATCOM. This method is less complicated, proven and useful as compared to other methods [5].

Hysteresis Controller

It is implemented in the current control scheme. The reference currents are calculated as in equation (3).The actual currents are sensed and are removed for obtaining an error for a HCC based bang-bang controller. Thus the switching command for IGBTs of DSTATCOM are derived from hysteresis controller [1] .The switching signal S_A for phase 'a' is given as:

$$(i_{sa} - i^*_{sa}) < HB = S_A = 1$$
$$(i_{sa} - i^*_{sa}) > HB = S_A = 0$$

This is similar for phases 'b 'and 'c.

IV. MODELING AND SIMULATION

1. Modeling

Induction Motor model

Figure 5 represents the complete system modelled in MATLAB simulink software to run simulations with and without DSTATCOM for induction motor load. The model comprises of Measurement buses, Distribution transformer and circuit breaker for switching of load. The circuit breaker shown acts a DOL starters which is

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initially in open condition and then switched to close mode at 0.1 sec. The model of DSTATCOM system is included in the lower side of the model. The DSTATCOM consists of 3 phase VSI with and DC link as capacitor. Voltage source converter is linked to the test system through a coupling transformer and circuit breaker with specified switching time. The control system is modelled in two parts, one for reference current signal and other for pulse generation signal.

Non linear load model

Figure 6 represents the complete system modelled in MATLAB simulink software to run the simulations with and without DSTATCOM for switching of heavy inductive load or Non linear load. Voltage sag is created due to the switching of heavy inductive load. The model comprises of Measurement buses, Distribution transformer and circuit breaker for switching of inductive load. The circuit breaker is initially in opened conditions and then switched to close mode from 0.3 to 0.6 seconds. The model of DSTATCOM system is included in the lower side of the model. The DSTATCOM consists of 3 phase VSI with and capacitor as DC link. Voltage source converter is linked to the test system through a circuit breaker with specified switching condition. The control system is modelled in two parts, one for reference current signal and other for pulse generation signal.

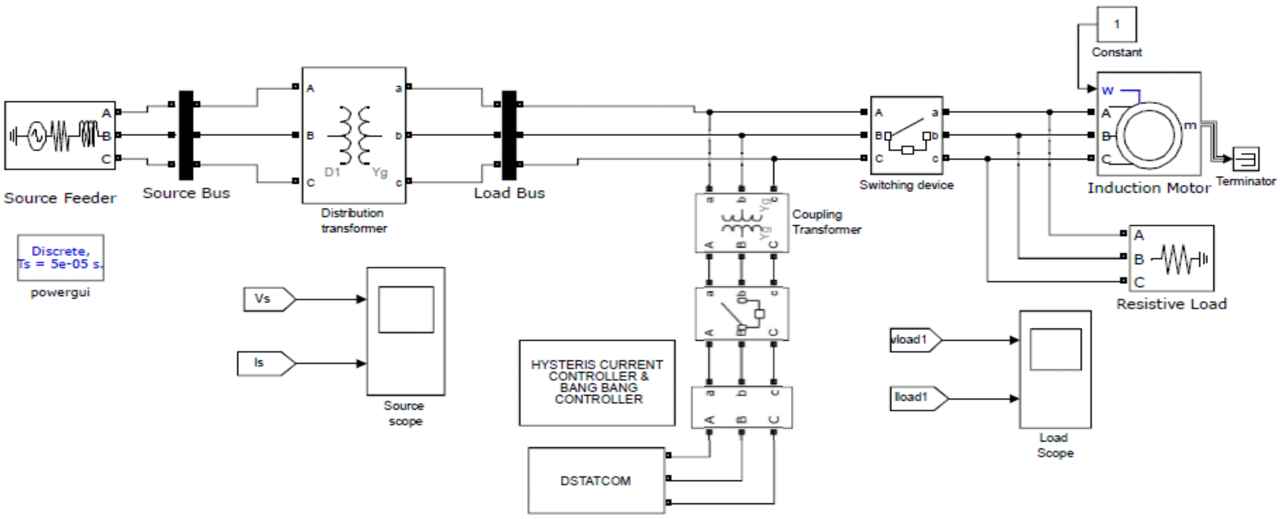

Figure 5 Simulink model for Starting of Induction Motor

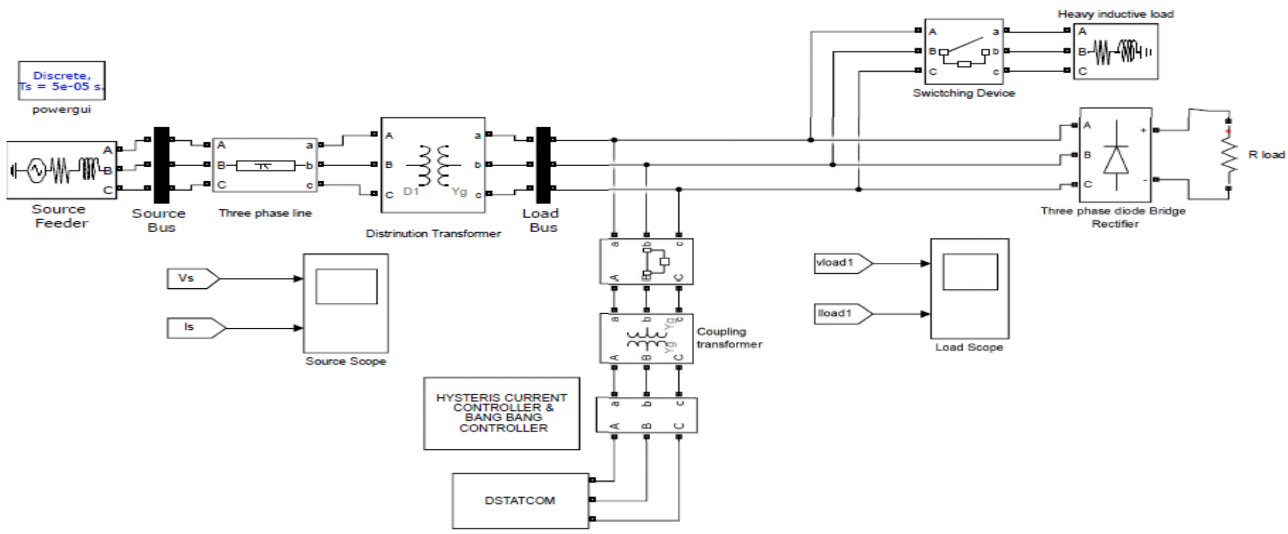

Figure 6 Simulink model for Non linear load

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All the systems are modelled differently and then combined to form one system as shown in Figures 5&6

The simulation Parameters used for the systems are given as below in TABLE I

TABLE I Test system parameters

Sr no	Parameters	Ratings	
		Induction motor model	**Non Linear load Model**
1	Source voltage	3 phase,11kV,50Hz	3 phase,33kV ,50Hz
2	Two winding Transformer	3 phase ,11kV/400V,50 Hz	3 phase ,33kV/415V,50 Hz
3	Switching time for contactor	0.1 sec	0.3 sec to 0.6 sec
4	Load	100HP,400V,50Hz IM with a constant three phase load in parallel	Three phase diode bridge rectifier with R load and a heavy inductive load in parallel connected through a switch.

2. Simulation results

Induction motor model

The D-STATCOM test system was simulated in the MATLAB Simulink. The system was operated twice, first without D-STATCOM and then with it, in both conditions, the CB is set initially open and it is closed at 0.1 sec after the beginning of the simulation [12]. Figure 7 shows the load voltage and current without DSTATCOM. It is seen that the terminal voltage is decreased from 327V to 255 V i.e. around 72 V (22%) for duration of about 0.2 sec. Figure 8 shows the load voltage and current with DSTATCOM. It is seen that the terminal voltage is almost compensated to 315V for sag duration and then regain its original value (sag magnitude is only 4% as compared to that of without DSTATCOM. The data can be given in as below in TABLE II

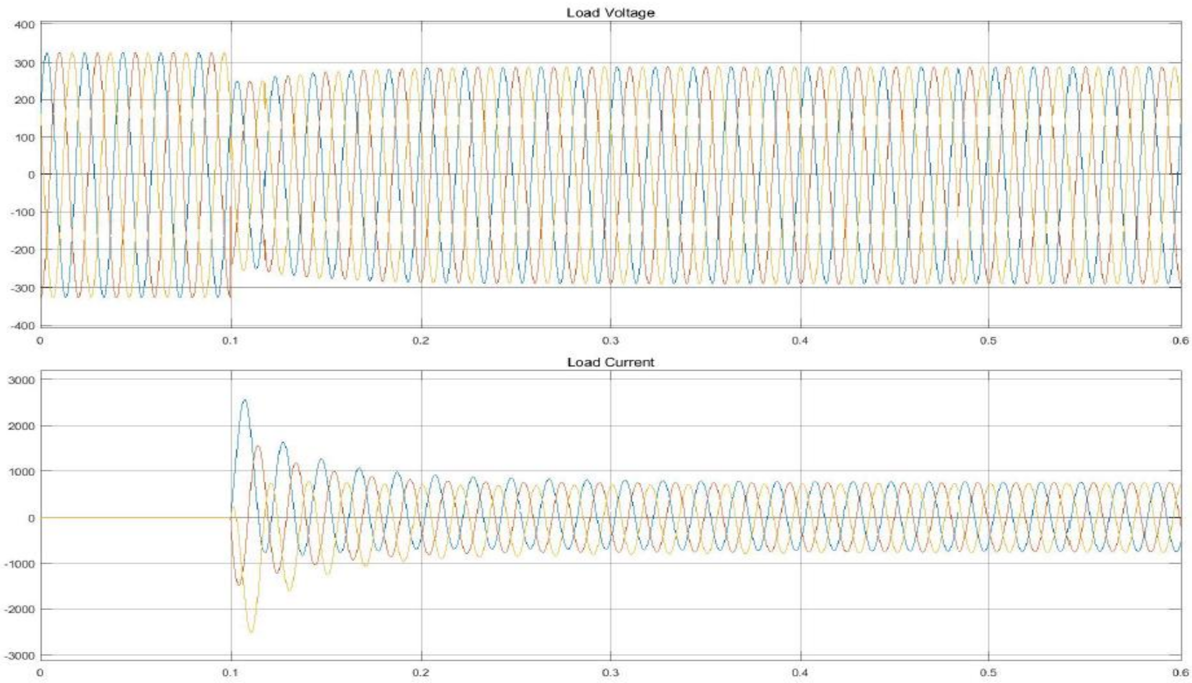

Figure 7 Load Voltage and Load current waveforms for Induction motor model without DSTATCOM

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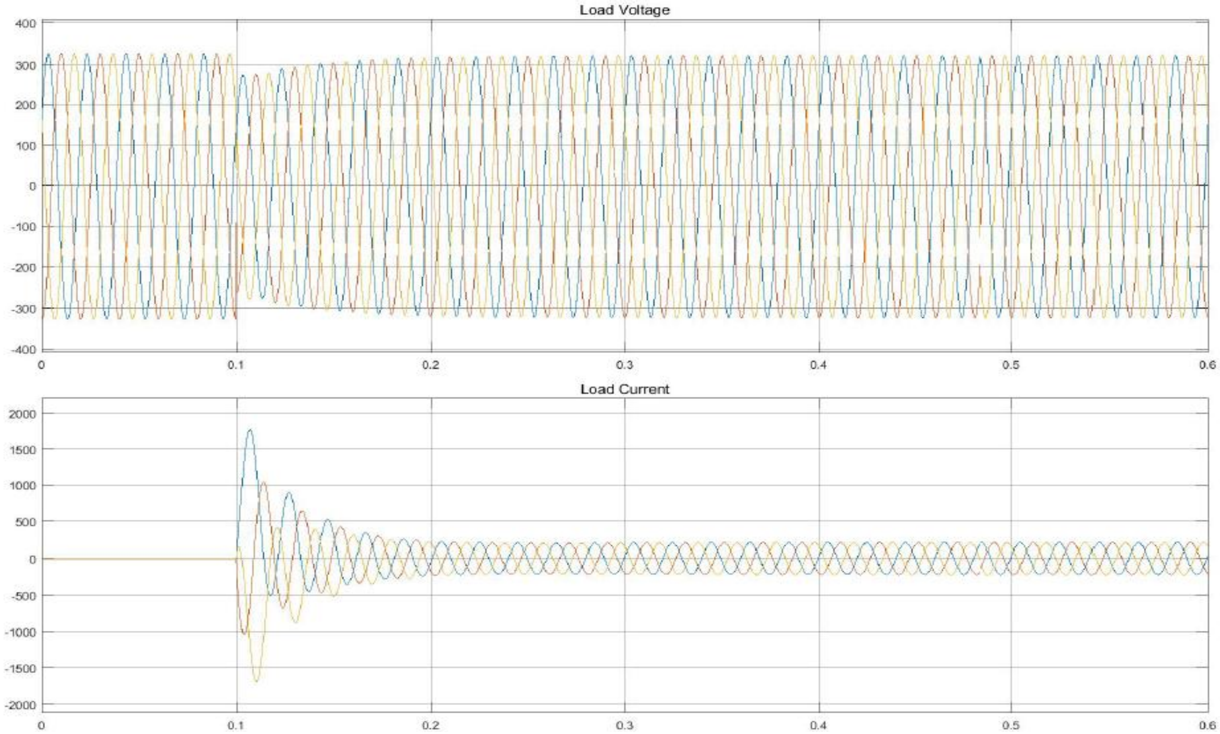

Figure 8 Load Voltage and Load current waveforms for Induction motor model with DSTATCOM

TABLE II Voltage Data Induction motor model

Voltage without DSTATCOM	Voltage with DSTATCOM
255 V (78% of actual load voltage) for 0.2 sec	315 V (97 % of actual load voltage) for 0.15 sec

The model was also simulated for different ratings of induction motor as per data in TABE III

TABLE III Voltage data for different ratings of Induction Motor

Motor rating	Terminal Voltage during sag	Terminal voltage with DSTATCOM
5.4 HP 400V 50Hz	289V	323V
10 HP 400 V 50 Hz	285V	323V
20 HP 400 V 50 Hz	280V	320V
50 HP 400 V 50 Hz	270V	315V
100 HP 400 V 50 Hz	255V	315V
150 HP 400 V 50 Hz	233V	310V
215 HP 400 V 50 Hz	220V	300V

Non linear load model

Initially the DSTATCOM is not connected to the system; the load is a three phase diode bridge rectifier with R load in parallel with a heavy inductive load connected through a switching device. The breaker is open at initial stage and it closes at 0.3 sec to 0.6 sec, thus, the sag duration is around 0.3 seconds Figure 9 shows the waveform for load voltage and current without DSTATCOM. The terminal voltage is decreased from 338 V to 290 V i.e. around 48 V .Figure 10 shows the waveform for load voltage and current with DSTATCOM which is connected through a breaker in closed

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condition. The waveforms below show the effectiveness of compensation performed by DSTATCOM for 0.3 sec, the load voltage is almost compensated to 0.92 pu of actual voltage without any disturbances ,quite smoothen waveforms are obtained with DSTATCOM as seen from waveforms. The data can be given as in TABLE IV

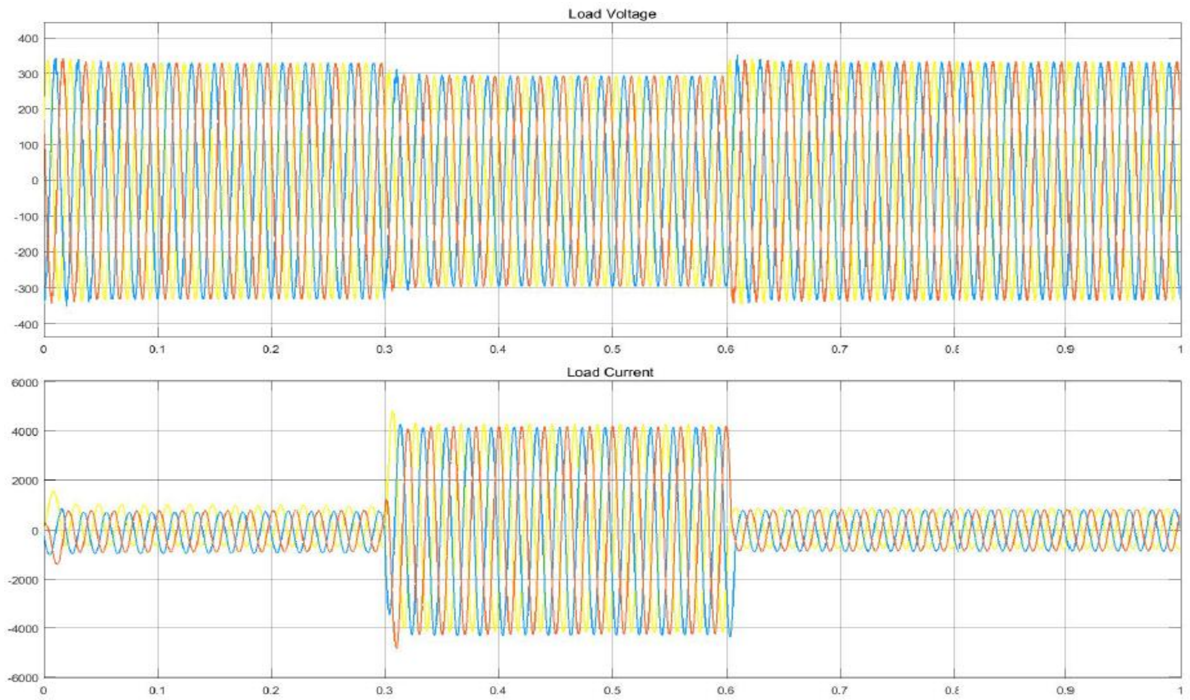

Figure 9 Load Voltage and Load current waveforms for Non linear load Model without DSTATCOM

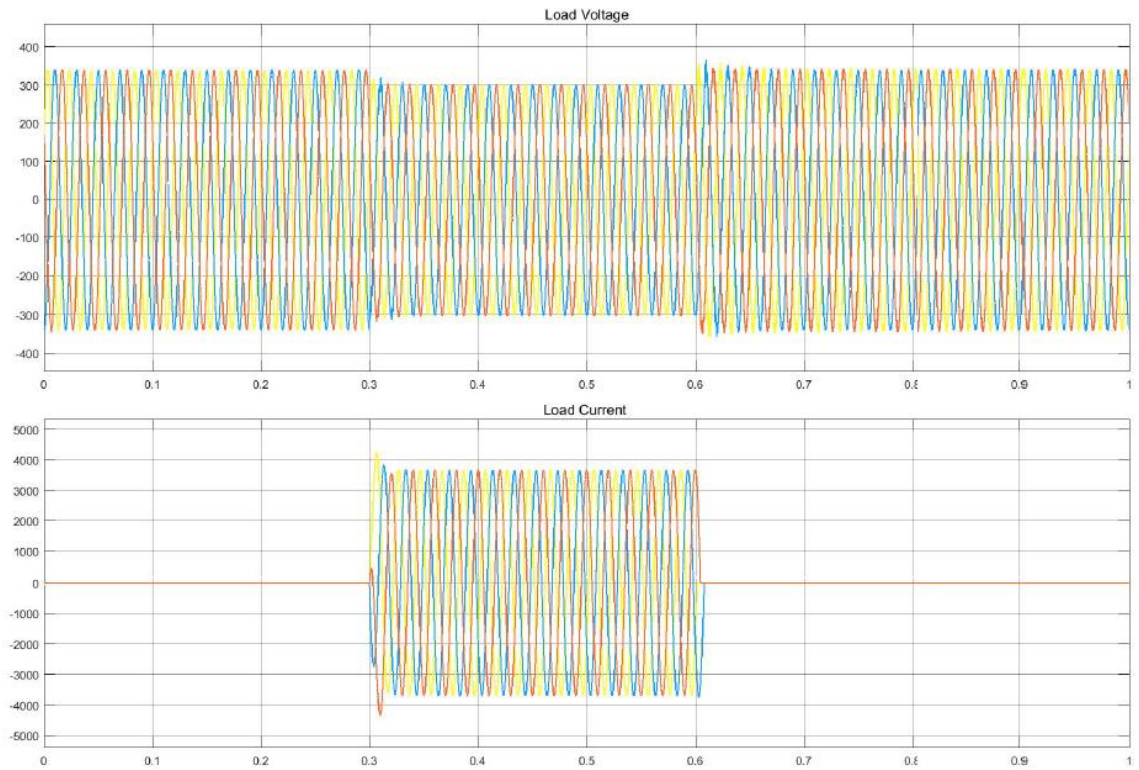

Figure 10 Load Voltage and Load current waveforms for Non linear load Model with DSTATCOM

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TABLE IV Voltage sag Magnitude Data Non linear load model

Voltage without DSTATCOM	Voltage with DSTATCOM
290 V (86% of actual load voltage) for 0.3 sec	310 V (92 % of actual load voltage) for 0.3 sec

V. CONCLUSION

This paper presents the modeling and simulation of DSTATCOM with control system for mitigation of voltage sag generated due to starting of induction motor and switching of heavy inductive load or non-linear load in the system. The results obtained justify the capability of DSTACTOM to mitigate the voltage sag generated due to the sudden application of load. A three phase VSI based Distribution Static compensator was modeled and simulated in MATLAB SIMULINK. The system was operated with and without DSTATCOM, in both cases, the waveforms for load voltage and load current are observed. The results and waveforms obtained in both the cases are compared and analyzed. The analysis shows that DSTATCOM stabilizes the voltage and reduces the duration of voltage sag in both the load conditions. The sag magnitude reduced from 28% to 3% in case of Induction Motor (with and without DSTATCOM respectively) and from 14% to almost 8% in case of switching of heavy inductive load or Non-Linear load (with and without DSTATCOM respectively). The model cannot compensate the 100% voltage during sag but all the results obtained are under the acceptable norms as per the voltage sag characteristics. The model is not that effective as compared to that of induction motor, so a better compensating device like DVR may be simulated for heavy inductive loads and can be checked for the results as future scope. The induction motor load model is also simulated for different ratings of induction motor. The results show that the voltage sag magnitude increases with the increase in rating of Induction motor, the same DSTATCOM model is capable to mitigate voltage sag even for different ratings of IM effectively.

REFERENCES

[1] R. Rao, “Harmonic analysis of Small scale Industrial Loads & Mitigation Techniques in Industrial Distribution System”, IJERA, August 2013, 1511-1540
[2] “Power quality Monitoring and Troubleshooting”, April 2010-2011.
[3] L. S. Patil, and A. G. Thosar, Application of D-STATCOM to Mitigate Voltage Sag Due to DOL Starting of Three Phase Induction Motor" ,ICCACEC, June 2009
[4] B.Singh, Adya, A.Mittal, .Gupta, B.N.Singh, “Application of DSTATCOM for Mitigation of Voltage Sag for Motor Loads ", IEEE ISIE 2006, July.
[5] S.Mohad, and M.Aware, “A STATCOM control scheme for Grid connected Wind energy Systems for Power Quality Improvement”, IEEE SYSTEMS JOURNAL, SEP 2010.
[6] Ms. M. Aggarwal1, S. Gupta, “DSTATCOM control in LVDS with Distributed Generation", 3rd, ICETET.2010.
[7] M. Rao, T. Kumar, P.Puthra. “Mitigation of Voltage Sag & Swell by using DSTATCOM and PWM switched Auto Transformer”.IJEIEE,, Sep 2013
[8] B Singh, J.Solanki, “Comparison of Control Algorithms for DSTATCOM", IEEE Transactions, JULY 2009
[9] S.Sundeep1, Dr.Rao, “Modeling and Analysis of Custom Power Devices for Improve Power Quality", International IJECE, Sept. 2011
[10] D.Chen, S. Xie, "Review of the control strategies applied to active power filters", 2004 IEEE International Conference, Mar 04
[11] A.Albanna, “Modeling and Simulation of Hysteresis Current Controlled Inverters Using MATLAB", September, 2011
[12] P.Giroux, Gilbert Sybille, Hoang Le-Huy “Modeling and Simulation of a Distribution STATCOM using Simulink Power System Block set”, IECON
[13] B. Mathew & V. Purushothaman, “Voltage Sag Correction in Distribution System Using DSTATCOM with PI and Hysteresis Controllers” IEEE, 2013.
[14] Sim Power Systems For Use with Simulink, User’s Guide, The Math- Works Inc., September 2003
[15] www.mathworks.com.