International Journal Of Engineering Research And Development
E-ISSN: 2278-067X, P-ISSN: 2278-800X, Www.Ijerd.Com
Volume 4, Issue 6 (October 2012), PP. 01-05

Performance Analysis of 48-Pulse VSC-Based STATCOM in Mitigation of Voltage Dip Caused by The Starting of A High Power Induction-Motor

Ganesh P. Prajapat[1], Prof. S. Chhatterji[2], Mrs. Lini Mathew[3]
[1]Assistant Professor, Electrical Engineering Department, Govt. Engineering College,
Bikaner, Rajasthan, India
[2]Professor, Electrical Engineering Department,
National Institute of Technical Teacher's Training and Research, Chandigarh, India
[3]Associate Professor, Electrical Engineering Department,
National Institute of Technical Teacher's Training and Research, Chandigarh, India

***Abstract:*—**This paper describes the performance of a Flexible Alternating Current Transmission Systems (FACTS) device, namely, STATic synchronous COMpensator (STATCOM) based on 48-pulse Voltage Source Converter (VSC), for the mitigation of voltage-dip caused by the starting of a high power induction motor. It improves the voltage profile feeding to a high power induction motor at starting by injecting a controllable current to the supply line having an acceptable limit of harmonics as per the standards of IEEE. Its capability to compensate reactive power to the system when the voltage dip occurs due to starting of high power induction motor load is described. The 48-pulse VSC employed in the STATCOM injects an almost sinusoidal current of variable magnitude, in quadrature with the line voltage, thereby emulating an inductive or a capacitive reactance at the point of connection with the line. Investigator has developed a 48-pulse VSC- based STATCOM and implemented it into a power-system consists a high power induction motor in MATLAB Simulink environment. The results show that the fast response and the STATCOM capability to inject reactive power during voltage dip within the acceptable limit of harmonics make it an acceptable device.

***Keywords:*—**Voltage-dip mitigation, Static Synchronous Compensator, multiple-pulse Voltage Source Converter, Voltage Injection Capability, Reactive Power Compensation, Harmonic Analysis

I. INTRODUCTION

In the past, equipment used to control industrial process was mechanical in nature, which was rather tolerant of voltage disturbances. Nowadays, modern industrial equipment typically uses a large amount of electronic components, such as program logic control (PLC), adjustable speed drives and optical devices, which can be very sensitive to the voltage disturbances. The majority of disturbances that cause problems for electronic equipments are voltage dip or voltage sag as in [1]-[2]. Voltage dips may cause tripping, production disturbances and equipment damages. Voltage dips are huge problem for many industries and they have been found especially troublesome because they are random events lasting only a few cycles. However, they are probably the most pressing power quality problem facing many industrial customers today [3]. The concern for mitigation of voltage dip has been gradually increasing due to the huge usage of sensitive electronic equipment in modern industries. When heavy loads are started, such as large induction motor drives, the starting current is typically 600% to 700% of the full load current drawn by the motor. This high current cause dips in the voltage during starting intervals, because there is a lot of voltage drop across the distribution conductor. Since the supply and the cabling of the installation are dimensioned for normal running current and the high initial current causes a voltage dip. This voltage dips are short duration reductions in rms input voltage as shown in Fig.1 [2]. It is specified in terms of duration and retained voltage, usually expressed as the percentage of nominal rms voltage remaining at the lowest point during the dip. Another reason for high starting current is the inertia of the load as high starting torque is required to start the high inertia loads, which can be obtained by using high starting current. This problem becomes more severe at peak loading time. This is due to the fact that at peak loading time the voltage of the system is less than the rated voltage.

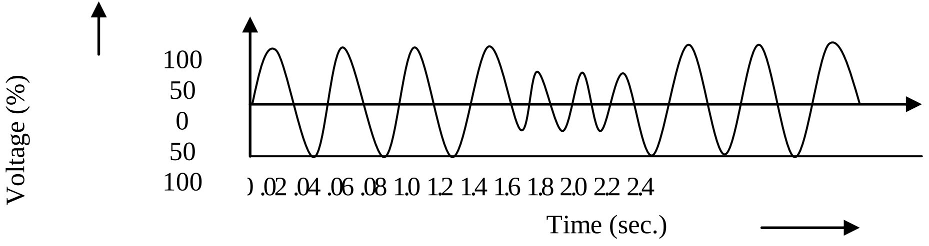


Fig.1 A Typical Voltage Dip

As the STATCOM is a solid-state voltage source converter coupled with a transformer, tied to a line can injects reactive current or power to the system to compensate the voltage-dip. The Voltage-Source Converter (VSC) is the main building block of the STATCOM. It produces square voltage waveforms as it switches the direct voltage source ON and OFF. The main objective of VSC is to produce a near sinusoidal AC voltage with minimum waveform distortion or excessive harmonic content. This can be achieved by employing multiple-pulse converter configuration [4]. To obtain the multiple-pulse converters i.e. 12- pulse, 24-pulse and 48-pulse VSC, a two, four or eight, 6-pulse VSC can be used, with the specified phase shift between all converters. A 48-pulse VSC can be used for high power applications with low distortion, because it can ensure minimum power quality problems and reduced harmonic contents. A 48-pulse GTO based VSC can be constructed using two (24-pulse GTO based) converters, shifted by 7.5° from each other. In this kind of converters there is no need of AC filters due to its low harmonic distortion content on the ac side. This new multiple-pulse converter configuration produces almost three phase sinusoidal voltage and maintains THD (Total Harmonic Distortion) well below 4%. [5]

Srinivas K. V. et al in [6] developed a three-level 24-pulse STATCOM with a constant dc link voltage and pulse width control at fundamental frequency switching, validated the inductive and capacitive operations of the STATCOM with satisfactory performance. The harmonic content of the STATCOM current is found well below 5% as per IEEE standards. Sahoo A. K. et al in [7] developed a simulation model of 48-pulse VSC based STATCOM FACTS devices. This full model is validated for voltage stabilization, reactive power compensation and dynamic power flow control. It produces a sinusoidal AC voltage with minimal harmonic distortion from a DC voltage with variable loads.

Huang S. P. et al in [8] also investigated that the GTO based STATCOM consisting a 48-pulse three-level inverter regarding minimal harmonic distortion. It has fine dynamic response and can regulate transmission system voltage efficaciously.

II. THE STATCOM

The STATCOM is a VSC-based shunt device. It is made up of a voltage source converter (VSC), DC capacitor, shunt transformer and a controller associated with VSC as depicted in Fig.2. In general, STATCOM is capable of generating or absorbing independently controllable real and reactive power at its output terminals, when it is fed from an energy source or energy storage device at its input terminal. If there is no energy storage device coupled to the DC link and the losses are neglected, then shunt converter is capable of absorbing or generating reactive power only. Functionality, from the standpoint of reactive power generation, their operation is similar to that of an ideal synchronous machine whose reactive power output is varied by excitation control.

A. Operating Principle

A STATCOM is a controlled reactive-power source. It provides the desired reactive power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage-source converter (VSC). The reactive power exchange of STATCOM with the AC system is controlled by regulating the output voltage amplitude of voltage source converter.

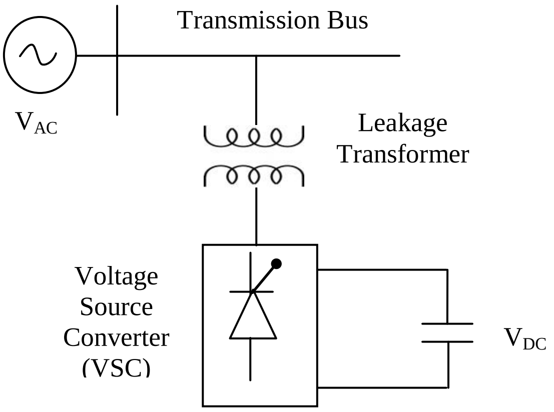


Fig.2. Voltage Source Converter based STATCOM

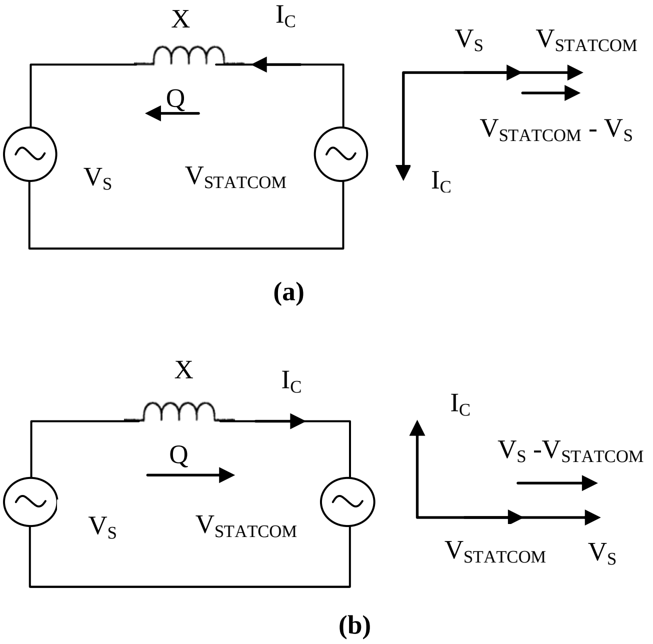
If the amplitude is increased above that of the AC system voltage, then the current flows from the STATCOM to the AC system and the device generates capacitive reactive power. If the amplitude is decreased to a level below that of the AC system, then the current flows from the AC system to STATCOM. The amount of type (capacitive or inductive) of reactive power exchange between the STATCOM and the system can be adjusted by controlling the magnitude of STATCOM output voltage with respect to that of system voltage. The reactive power supplied by the STATCOM is given by:

$$Q = \frac{V_{STATCOM} - V_S}{X} * V_S \qquad (1.1)$$

(1.1)

Where Q is the reactive power, $V_{STATCOM}$ is the magnitude of STATCOM output voltage, V_S is the magnitude of system voltage and X is the equivalent impedance between STATCOM and the system. When Q is positive the STATCOM supplies reactive power to the system. Otherwise, the STATCOM absorbs reactive power from the system. The DC capacitor voltage controls the output voltage of voltage source converter. The output voltage of voltage source converter can be lead or lag with respect to AC system voltage by increased or decreased DC capacitor voltage respectively. When the voltage source converter voltage leads the bus voltage, the capacitor supplies real power to the system, acting as capacitive power source. On the other hand, when the voltage-source converter voltage lags the bus voltage, than the capacitor charged by consuming real power from the AC system having inductive reactance property, so that act as an equivalent inductor as illustrated by the phasor-diagrams shown in Fig. 3.

When the STATCOM output voltage ($V_{STATCOM}$) is lower than the system bus voltage (V_S), the STATCOM acts like an inductance absorbing reactive power from the system bus. When the STATCOM output voltage ($V_{STATCOM}$) is higher than the system bus voltage (V_S), the STATCOM acts like a capacitor generating reactive power to the system bus. In steady-state operation and due to inverter losses, the system bus voltage (V_S) always leads the converter ac voltage by a very small angle to supply the required small active power losses.



(a)

(b)

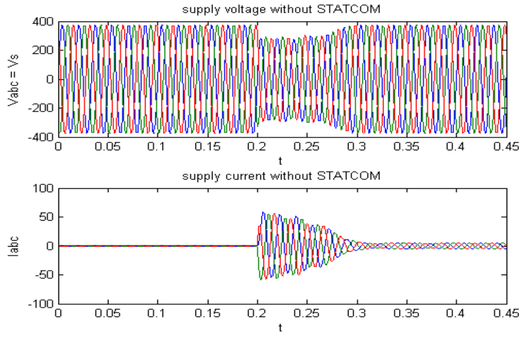
Fig. 3 STATCOM operation (a) Inductive operation (b) Capacitive operation

B. SIMULATION MODEL

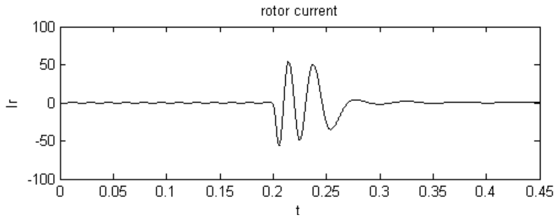
The complete model of voltage-dip mitigation by 48-pulse STATCOM during the starting of an induction motor simulated is as shown in Fig.4. The design of the system is according to the line voltage and 100HP, 460V and 50 Hz asynchronous motor under consideration.

III. SIMULATION RESULTS

The complete model with the voltage-dip caused by the starting of a squirrel-cage induction motor of 100HP, 460V and 50 Hz is simulated first without STATCOM. A 3-phase breaker is chosen to start the induction motor and it is set to close at an instant t = 0.2 sec. The 3-phase voltage source with a small resistance in series with each phase is taken to implement a practical supply system. The measurement of the system voltage and supply current is provided by the 3-phase V-I measurement block and the stator current, rotor current, speed of rotor and electromagnetic torque are measured at bus-selector available in asynchronous-motor block. The system-voltage and current of all three phases during the motor-start at t = 0.2 sec and rotor current is as shown in Fig.5. The type of simulation used in *powergui* to simulate the problem is *continuous* with variable step-size and the solver chosen is ode23tb (stiff/TR-BDF2).



(a)



(b)

Fig.5 (a) System Voltage and Current during the Starting of the Motor and (b) Rotor Current

Now, after the implementation of the STATCOM consisting 48-Pulse three-level converter, the STATCOM voltage and current delivered at load terminal are as shown in Fig.6 below. The capacitors employed in the STATCOM act as a variable DC voltage source. Here, the capacitors modelled and simulated are initially charged (initial conditions) by the system voltage. The variable amplitude voltage produced by the inverter is synthesized from the variable DC voltage.

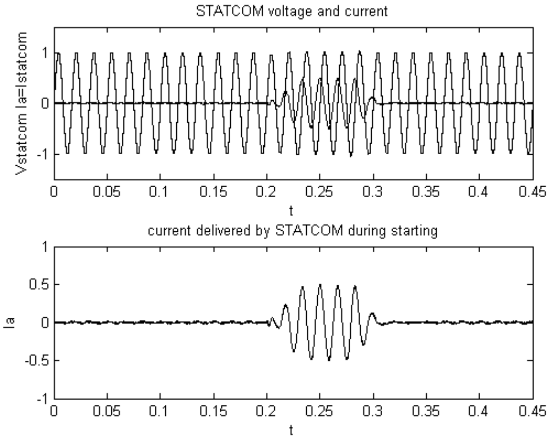


Fig. 6 STATCOM Voltage and Current Delivered during Voltage-Dip

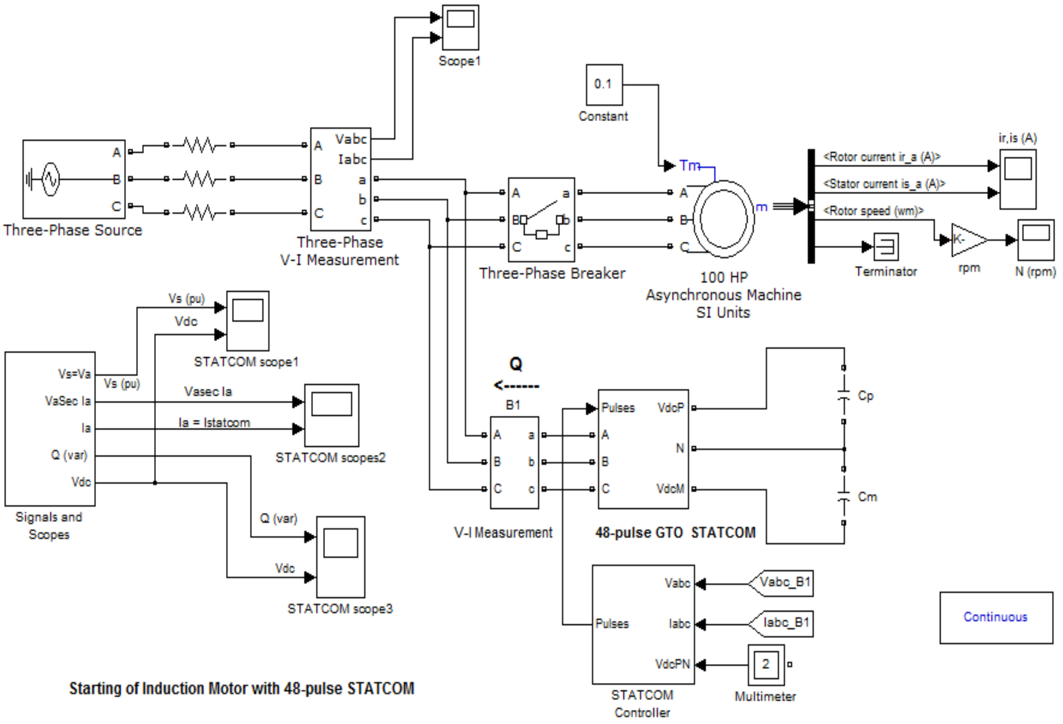


Fig.4 Implementation of the 48-Pulse VSC-based STATCOM

As soon as the motor is started at t=0.2sec, the dip in the rms voltage introduced is mitigated well. A slight voltage-dip, ΔV, is there even after the implementation of the STATCOM as depicted in Fig.7. It is seen from the response that the current is lagging by an angle of 90° from system voltage i.e. a reactive power is fed to the system by the STATCOM during voltage-sag.

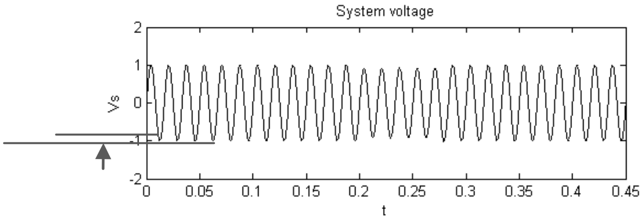
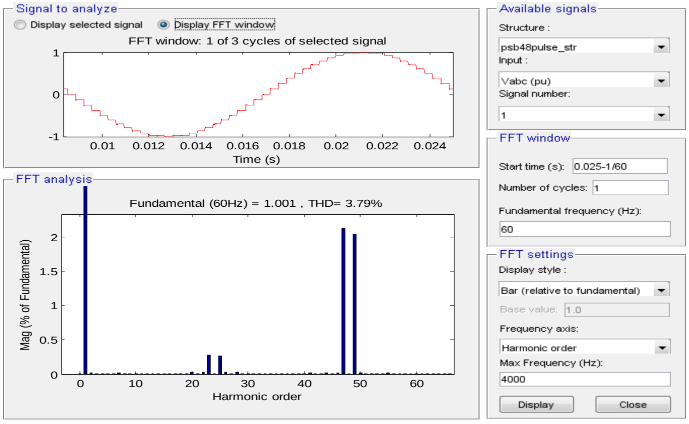


Fig.7 System Voltage with 48-Pulse STATCOM

The FFT analysis of STATCOM's output clearly shows the 48-pulses of a cycle of output voltage containing a fewer harmonics (THD = 3.79%) as shown in Fig.8 below. It is also seen that only 48n±1 harmonics are present in the voltage as expected.

IV. CONCLUSION

The results shows that whenever an induction motor is started, a voltage-dip of up to 25% is there in the system-voltage as shown in Fig.5 (a).Now, as soon as the multiple-pulse STATCOM is implemented into the system and comes under action, the voltage-dip, caused by the starting of the motor at t = 0.2sec onwards for 4-5 cycles, is mitigated well as the comparative results shows in Fig.5 and Fig.7 above. A slight voltage-dip, ΔV only is found after the implementation of the STATCOM as shown in Fig.7. The results also show that the voltage fed by the 48-pulse STATCOM adds a fewer harmonics into the system having THD = 3.79% which is within the accepted limit of IEEE standards.


Signal to analyze
○ Display selected signal ● Display FFT window

Available signals
Structure : psb48pulse_str
Input : Vabc (pu)
Signal number: 1

FFT window
Start time (s): 0.025-1/60
Number of cycles: 1
Fundamental frequency (Hz): 60

FFT settings
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Harmonic order
Max Frequency (Hz): 4000

Fundamental (60Hz) = 1.001 , THD= 3.79%

Fig.8 FFT Analysis of 48-pulse STATCOM

REFERENCES

[1] Huweg A. F., Bashi S. M., Mariun N. "Application of Inverter based Shunt Device for Voltage Sag Mitigation due to Starting of an Induction Motor Load", Proceedings of the IEEE International Conference on Electricity Distribution, pp.1-5, June, 2005.

[2] Huweg A. F ., Bashi S. M., Mariun N., "A STATCOM Simulation Model to Improve Voltage Sag Due to Starting of High Power Induction Motor" Proceedings of the IEEE National Conference on Power and Energy, pp. 148-152, November , 2004

[3] El-Moursi M. S., Sharaf A. M., "Novel Controllers for the 48-Pulse VSC STATCOM and SSSC for Voltage Regulation and Reactive Power Compensation", IEEE Transactions on Power systems, Vol. 20, No.2, pp. 1985-1997, November, 2005.

[4] Priyanath D., Beniwal J. L., "Modeling of Voltage Source Model STATCOM," Proceedings of the International Conference on Electrical Power and Energy Systems, MANIT, Bhopal, pp. 43-49, September, 2010

[5] Geethalakshmi B., Dananjayan P., DelhiBabu K., "A Combined Multi-pulse Voltage Source Inverter Configuration for STATCOM Applications", Proceedings of the IEEE International Conference on Power System Technology, pp. 1-5, October, 2008

[6] Srinivas K. V., Singh B., "Three-level 24-Pulse STATCOM with Pulse Width Control at Fundamental Frequency Switching", IEEE Industry Applications Society Annual Meeting (IAS), pp. 1-6, October, 2010

[7] Sahoo A. K., Murugesan K., Thygarajan T. "Modelling and Simulation of 48-pulse VSC based STATCOM using Simulink's Power System Blockset", Proceedings of India International Conference on Power Electronics, pp. 303-308, December, 2006.

[8] Huang S. P., Li Y. J., Jin G.B., Li L. "Modelling and Dynamic Response Simulation of GTO-based STATCOM" Proceedings of the International Conference on Electrical and Control Engineering, pp. 1293-1296, June, 2010.