

SCIENCE | ENGINEERING | TECHNOLOGY

e-ISSN: 2319-8753 | p-ISSN: 2347-6710

EDIA

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 9, September 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

 \bigcirc

e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 7.569



Volume 10, Issue 9, September 2021

DOI:10.15680/IJIRSET.2021.1009076

Dynamic Analysis of STATCOM for Voltage Stability under different Load Condition

Bandlamudi Sravani¹, J.Anand²

P.G. Student, Department of EEE, St.Mary's Group of Institutions Guntur, India¹

Associate Professor, Department of EEE, St.Mary's Group of Institutions Guntur, India²

ABSTRACT: With the rapid development and improvement of power electronics devices in past decades changing the scenario in the field of controlling and improving the power quality issues and related problems very significantly. FACTS devices are the good examples of these. So in this paper one FACTS device known as STATCOM a powerful shunt controller, for discussing its impact and depth how to improve the power quality by reviewing the past literature published on the various types and configurations of STATCOM using different techniques and configurations in order to reduces harmonics and improved dynamic performance. A review is done on the past literature published on the various types and configurations of STATCOM generally current source inverter based or voltage source inverter based.

KEYWORDS: VSC, STATCOM, FACTS, GTO's, SSSC, SVC, Voltage Stabilization, Reactive Compensation, Power Quality.

I. INTRODUCTION

In power system, real power and reactive power is controlled by the voltage and phase angle difference between the sending end and receiving end respectively. Impedance of the transmission line can also be used to control real and reactive power. Flexible AC Transmission Systems (FACTS) are used to improve the power transfer capability of transmission line. FACTS is defined as 'Alternating current transmission systems incorporating power electronic based and other static controllers to enhance controllability and increase power transfer capability.

Depending on the power electronic devices used to control, FACTS controllers can be classified as Variable Impedance type and Voltage Source Converter (VSC) based. Static VAR Compensator (SVC) comes under Variable Impedance type, whereas Static Synchronous Compensator (STATCOM), Static Synchronous Series.

Compensator (SSSC), etc. are Voltage Source Converter based. FACTS controllers provide voltage support at critical buses in the system (with shunt connected controllers) and regulate power flow in critical lines (with series connected controllers). The power electronic control is quite fast and this enables regulation both under steady state and dynamic conditions.



Fig 1-Basic interfacing of STATCOM with transmission line



| e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 7.569

Volume 10, Issue 9, September 2021

| DOI:10.15680/LJIRSET.2021.1009076 |

II.WORKING OF STATCOM

The STATCOM is basically a DC-AC voltage source converter with an energy storage unit, usually a DC capacitor. It operates as a controlled Synchronous Voltage Source (SVS) connected to the line through a coupling transformer. Fig. 1 shows the schematic configuration of STATCOM. The controlled output voltage is maintained in phase with the line voltage, and can be controlled to draw either capacitive or inductive current from the line in a similar manner of a synchronous condenser, but much more rapidly. Compared to SVC and other conventional reactive power compensators, STATCOM has several advantages listed below. STATCOM has a dynamic performance far exceeding the other var compensators. The overall system response time of STATCOM can reach 10 ms or less. STATCOM has the ability to maintain full capacitive output current at low system voltage, which also makes it more effective than SVC in improving the transient stability. Simulations indicate that 1.3Mvar SVC and 1 Mvar STATCOM have similar effects in maintaining dynamic voltage stability. STATCOM has much larger operating range as compared with that of SVC. Compared with SVC, STATCOM can easily realize redundancy design, which brings a higher reliability. IGCT, IGBT, used in STATCOM, require simpler gate drives and snubber circuits, and also make STATCOM more reliable. STATCOM has a smaller installation space, about 50% of that for SVC. The STATCOM of Alstom and Mitsubishi are made relocatable, with a power density of 1Mvar/m3. The main objective of STATCOM is to obtain an almost harmonic neutralized and controlled three-phase AC output voltage waveforms at the point of common coupling (PCC) to regulate reactive current flow by generation and absorption of controllable reactive power by the solid-state switching algorithm. The P-Q relation of STATCOM is found by following equation.

$$S = \frac{3VsVc}{X}\sin\alpha - j3\left(\frac{VsVc}{X}\cos\alpha - \frac{Vs^2}{X}\right) = P - jQ$$

where S is the apparent power flow, P the active power flow, Q the reactive power flow, Vs the main AC phase voltage to neutral (rms), Vc the STATCOM fundamental output AC phase voltage (rms), X is the leakage reactance, L the leakage inductance, f the system frequency and α is the phase angle between Vs and Vc..

III.STATCOM MAIN CIRCUIT TOPOLOGY

There are mainly two types of STATCOM main circuit configurations: multipulse converter, multilevel converter [4-5] In the multipulse converter, the 3-phase bridges are connected in parallel on the DC side, as shown in Fig. 2. The bridges are magnetically coupled through a zigzag transformer, and the transformer is usually arranged to make the bridges appear in series viewed from the AC sides. Each winding of the transformer is phase-shifted to eliminate selected harmonics and produce a multipulse output voltage. Pulse Width Modulation (PWM) can be applied to improve the harmonics content, at the expense of higher switching and snubber loss, plus reduced fundamental var rating. The disadvantages of multipulse converter configuration are: the phase-shift transformer makes the system complex and bulky; there will be a unique transformer design for each STATCOM installation. Compared to the multipulse converter based STATCOM multilevel converters are more flexible and have a wide application. They can be used as active power filters and to handle unbalanced loads. No phase shift transformer is required in this configuration, so a lower investment cost, plus a lower power loss, can be expected. The multilevel converter configuration can be further classified into three different configurations: 1) Diode-clamped converter, [6] 2) Flying capacitor converter, 3) Cascade converter. The concept of the cascade multilevel converter is put forward by Fang Zheng Peng in 1996 [7-8]. A cascade converter is constructed by standard H-bridges in series. Each H-bridge converter unit provides three voltage levels (-U+ 0, U-). A single phase STATCOM based on this configuration is shows in Fig.3 and in Fig. 3. is a typical output waveform of a three level cascade converter

e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 7.569



Volume 10, Issue 9, September 2021

DOI:10.15680/IJIRSET.2021.1009076



Fig. 4 Typical output voltage waveform of a three level cascaded converter.

Compared with the other two multilevel configurations and the multipulse converter, the cascade converter eliminates clamping diodes, flying capacitors, or the bulky zigzag transformer, and so requires least component mounts, and the modularity of this configuration makes it much easier to implement converters with a large number of levels. Larger dcside capacitors are required compared to the diode clamped and flying capacitor converter under balanced condition but it provides separate phase control to support significant voltage unbalance.

IV.CONTROL THEORY OF STATCOM PROPOSED

The control system is the heart of state-of-the-art STATCOM controller for dynamic control of reactive power in electrical system. Based on the operational requirements, type of applications, system configuration and loss optimization, essential control parameters are controlled to obtain desired performance and many control methodologies in STATCOM power circuits have been presented in [9-11]. In a square-wave mode of operation, phase angle control (α) across the leakage reactance (L) is the main controlling parameter. This control is employed in a twolevel converter structure, where DC voltage (Vdc) is dynamically adjusted to above or equal to or below the system voltage for reactive power control. In a three-level configuration, the dead-angle or zero-swell period (β) is controlled to vary the converter AC output voltage by maintaining Vdc constant. The control system for STATCOM operated with PWM mode employs control of α and m (modulation index) to change the converter AC voltages keeping Vdc constant. For voltage regulation, two control-loop circuits namely inner current control loop and external/outer voltage control loop are employed in STATCOM power circuit. For voltage regulation, two control-loop circuits namely inner current control loop and external/outer voltage control loop are employed in STATCOM power circuit. The current control loop produces the desired phase angle difference of the converter voltage relative to the system voltage and in turn, generates the gating pulses, whereas the voltage control loop generates the reference reactive current for the current controller of the inner control loop. This control philosophy is implemented with proportional and integral control (PI control) algorithm or with a combination of proportional (P), integral (I) and derivative (D) control algorithm in d-q synchronous rotating frame. The general mathematical approach, modelling and design of control systems for compensator circuits are proposed in [13-15]. In the process of designing and implementation of control system, acquisition of many signals is involved. Initially, the essential AC and DC voltages and current signals (instantaneous values/vectors) are sensed using sensors. In the next step, these signals are synthesised by techniques such as d–q synchronous rotating axis transformation, α - β stationery reference frame of transformation and so on.

V. STATCOM PERFORMANCE

Self-commutating GTO devices in VSC technology are widely used as main controllable switching element for high power rating compensators, and operated either in square wave or quasi square wave mode by means of GTO triggering once per cycle of fundamental power frequency. In the state of the art dynamic reactive power compensator, use of multipulse topology along with fundamental frequency switching control of GTO-VSC is a mature technique employed to achieve a close to sinusoidal AC output voltage from GTOVSCs. In this topology, a number (P) of elementary six-pulse converters

International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)



e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 7.569

Volume 10, Issue 9, September 2021

DOI:10.15680/IJIRSET.2021.1009076

waveforms are electro-magnetically added to produce a multi-pulse waveform which contains harmonics in the order of 6NP + 1, where N=1, 2, 3, 4,...and P=1, 2, 3, 4... number of six pulse VSC. For example, in a 4x6-pulse STATCOM, AC voltage output waveform will contain harmonics of the order of 23rd, 25th 47th 49th .etc. In [16] is focused on design and modeling of a new fundamental frequency switching based 24-pulse 2-level + 100MVAR STATCOM in MATLAB platform for high power applications. Only four 6-pulse elementary Gate Turn off voltage source converters (GTO-VSC) along with single stage magnetics meeting dual objectives of magnetic summing circuit and coupling transformer at PCC, and PI-controllers employing principle of phase angle control, are modeled to achieve an improved performance to regulate load voltage in an ac network with THD values within limits. Multi-pulse GTO based voltage source converter (VSC) topology together with a fundamental frequency switching mode of gate control is a mature technology being widely used in static synchronous compensators (STATCOMs) is presented in [17]. High number of pulses in the STATCOM, preferably a 48-pulse along with matching components of magnetics for dynamic reactive power compensation, voltage regulation, etc. in electrical networks is proposed. With an increase in the pulse order, need of power electronic devices and inter-facing magnetic apparatus increases multifold to achieve a desired operating performance. In [17], a competitive topology with a fewer number of devices and reduced magnetics is evolved to develop an 18-pulse, 2-level 100MVAR STATCOM in which a GTO-VSC device is operated at fundamental frequency switching gate control. The inter-facing magnetics topology is conceptualized in two stages and with this harmonics distortion in the network is minimized to permissible IEEE-519 standard limits. This compensator is modeled, designed and simulated by a SimPowerSystems tool box in MATLAB platform and is tested for voltage regulation and power factor correction in power systems. The operating characteristics corresponding to steady state and dynamic operating conditions show an acceptable performance. In [18] the dynamic operation of novel control scheme for both Static Synchronous Compensator (STATCOM) and Static Synchronous Series Compensator (SSSC) based on a new full model comprising a 48-pulse Gate Turn-Off thyristor voltage source converter for combined reactive power compensation and voltage stabilization of the electric grid network is investigated. The STATCOM scheme and the electric grid network are modeled by specific electric blocks from the power system blockset, while the control system is modeled using Simulink. Two novel controllers for the STATCOM and SSSC are presented in this paper based on a decoupled current control strategy. The performanceof both STATCOM and SSSC schemes connected to the 230-kV grid are evaluated. The proposed novel control schemes for the STATCOM and SSSC are fully validated by digital simulation. If the no. of pulses are increased then the output voltage of the STATCOM becomes more and more sinusoidal and harmonics contents in the voltage waveforms decreases.

CIRCUIT



| e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 7.569|



|| Volume 10, Issue 9, September 2021 ||

| DOI:10.15680/IJIRSET.2021.1009076 |

PROPOSED STATCOM CONTOL THEORY

RESULTS



Time offset: 0

Simulation Results Without Statcom .

ÌÌRSET

e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 7.569

Volume 10, Issue 9, September 2021

DOI:10.15680/IJIRSET.2021.1009076

STATCOM controllers have been reported in research publications. Simulation of various configurations/topologies, control strategies, magnetics, filter requirements, component level designing and so on, have been presented by various researchers with the help of many standard software simulation tools. MATLAB/SIMULINK/PSB, EMTP, PSCAD/EMTDC, SPICE, EUROSTAG and so on, are some of the software tools being extensively used by researchers and engineers to simulate various power electronics devices in power system circuits, electrical machines and so on. Detailed modelling of STATCOM controllers and performance analysis and sensitivities of various passive components under varying system-operating conditions ensure the researchers and engineers to firm up the design parameters in pre-fabrication stage.

VI. CONCLUSION

In this research, a review of past literature published on the various control strategies of STATCOM is presented. In this work, we have found that with the advancement of power electronics converters, the power engineers find various occasions to develop the control strategy so that harmonics are reduced as possible. We can also see that a multilevel cascaded multi-pulse STATCOM have found great applications in today power system .There is a great scope for power quality researchers for developing fast adaptive controllers for STATCOM. Different configuration of STATCOM has been discussed. Different types of software tools which can be used for simulation of STATCOM are also been discussed.

REFERENCES

[1] R. Adapa. "Flexible AC Transmission System (FACTS): System Studies to Assess FACTS Device Requirements on the Entergy System. Electric Power Research Institute. TR-105260. August 1995.

[2] M. R. Iravani, P. L. Dandeo, K. H. Nguyen, D. Zhu, d. Maratukulam, "Applications of static phase shifters in power systems," IEEE Trans on Power Delivery, Vol 9, No. 3, July 1994, pp. 1600-1608.

[3] A. Krämer, J. Ruff, "Transformers for phase angle regulation considering the selection of On-load tap-changers," IEEE Trans on Power Delivery, Vol. 13, No.2, April 1998, pp. 518-523.

[4] Solo, D., Grcen. T.C., "A comparison of high-powsr converter topologics for the implementation of FACTS controllers", IEEE Trans. on Industriol ElecImnic~, Volume: 49 Issue: 5 ,Oct. 2002: 1072 -1080

[5] Lee, C.K., Leung, J.S.K., Hui. S.Y.R., Chung, H.S.-H., "Circuit-level comparison of STATCOM technologies", IEEE Trom. on Power Electronics, Volume: 18 Issue: 4, July 2003: 1084 -1092

[6] Chai, N.S., Cho, J.G, Cho, GH., "A gencnl circuit topola&y of multilwCI inverler", PESC '91, 22nd Annual IEEE, 24-27 June 1991:

[7] Meynard, T.A., Fach, H., "Multi-level conversion: high voltage choppers and voltage-source inverted', PESC '92 Record, 23rd Annsol IEEE, 29 June-3 July 1992 397 403 vol. 1

[8] Fang Zheng Peng, lih-Sheng Lai, McKeever, J., VanCaevning. J., "A multilevel voltage-source inverter with separate DC sources for static VAr generatian", Conference Record of the Thirtieth /AS Annual Meeting, /AS 95, 1995 1EEE, Volume: 3, 8-12 Oct. 1995: 2541 -2548

[9] Hanson D.J., Woodhouse M.L., Horwill C., Monkhouse D.R., Osborne M.M.: 'STATCOM: a new era of reactive compensation', Power Eng. J., 2002, 16, (3), pp. 151–160

[10] Kincic S., Chandra A., Babic S.: 'Five level diode clamped voltage source inverter and its application in reactive power compensation'. IEEE Large Engineering Systems Conf. Power Engineering, LESCOPE, 2002, pp. 86–92





Impact Factor: 7.569





INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY





www.ijirset.com