iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: XI Month of publication: November 2025

DOI: https://doi.org/10.22214/ijraset.2025.75346

Review on Optimal Placement and Sizing of Static VAR Compensator (SVC) for Voltage Stability Enhancement in Wind Integration Power System

Dr. Nilesh Bodne[1], Dr. Kiran Kimmatkar[2], Rahul Vilas Kukadkar[3]
[1]*Project Guide, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, Maharashtra*
[2]*Project Co-Guide, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, Maharashtra*
[3]*Student, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, Maharashtra*

Abstract: This project focuses on the modelling and simulation of a Static Var Generator (SVC) in power system studies using MATLAB. Initially, we mathematically modelled the SVC's rating analysis using MathCAD. Next, we modelled the Static Var Compensator (SVC) in power systems to analyze its behavior within and outside the control range, integrating load flow analysis for SVC implementation. Then, we separately modelled the SVC transfer functions with open-loop control in various control elements, including the measuring module, thyristor susceptance control module, and voltage regulator module. We applied lag/lead compensator theories to configure open and closed-loop transfer functions with respective gain/phase margins. Finally, we controlled the voltage and reactive power flow in the power system using the SVC device.
Keywords: Power Factor; Reactive Power; FACTS, SVC, Var and Voltage Control etc.

I. INTRODUCTION

With the rapid advancement of power electronics technology and computer control technology, various new types of automatic, rapid reactive power compensation devices have emerged. Early in the development of power grids, mechanical switching capacitor devices were utilized, which were switched on and off through circuit breakers or contactors. However, significant changes and advancements occurred with the introduction of circuit breakers in power grids for capacitor or filter insertion. Stretching discharge phenomena and other issues emerged, reducing the action times of circuit breakers and necessitating less frequent switching. Static Var Compensator (SVC) represents a shunt compensation device of the thyristor-switched type, built on the foundation of parallel capacitor and inductor mechanisms. Unlike mechanical circuit breakers, SVC employs large capacity thyristors for switching, making it widely used in distribution systems. The utilization of thyristors allows for nearly unlimited operations and precise control over switching time. Thyristors connect capacitors, reactors, and other equipment to the power grid, enabling rapid, impact-free switching with superior performance. The adoption of thyristors significantly reduces operational difficulties and the impact of inrush current, with a dynamic response time ranging from 0.01 to 0.02 seconds. Static Var Compensators play a crucial role in reactive compensation within power systems, albeit requiring substantial initial investment and higher maintenance costs. Conducting direct power tests is impractical due to safety, economic, and technical considerations. To better analyze the characteristics of Static Var Compensators in grid applications, this paper employs MATLAB.

II. OBJECTIVE

The main objectives of this study can be outlined as follows:
1) Conduct Load flow studies to analyze the usage of SVC.
2) Perform Small and large disturbance studies to assess system stability.
3) Investigate the modulation technique employed for Static Var Generator (SVC) and its impact on Harmonic and Electromagnetic transient behavior, as well as Fault studies.
4) Validate the proposed system through simulation experiments.

III. LITERATURE SURVEY

R.H. Lasseter et. al. 1982, This paper presents a method for the simultaneous digital simulation of thyristors, their gate pulse generating (G.P.G.) circuit, the regulating (Reg.) circuit, and the power system, as shown in Figure 1. The power system impedance is denoted as Zs and the load as ZL. Results are presented, showing a voltage regulator's response to changes in voltage and faults.

K. Ram Mohan Reddy et. al. 2012, This paper focuses on the application of FACTS (Flexible AC Transmission Systems), which utilize advanced power electronic devices and techniques to electronically control the high-voltage side of the power network. D-STATCOM (Distribution Static Compensator) is a shunt device commonly employed to address power quality issues in distribution systems. It is used to correct power factor, maintain constant distribution voltage, and mitigate harmonics in distribution networks. The main objective of this paper is to demonstrate the effectiveness of using DSTATCOM to mitigate voltage fluctuations such as sag and swell conditions in distribution systems. Custom Power, on the other hand, is a technology aimed at improving power quality in low-voltage distribution systems. It addresses concerns related to poor power quality and reliability of supply affecting various settings such as factories, offices, and homes. With Custom Power solutions, end-users can expect tighter voltage regulation, minimal power interruptions, low harmonic voltages, and better accommodation of rapidly fluctuating and nonlinear loads nearby. The paper also highlights the various applications of D-STATCOM, including its use in grid-connected power systems, voltage fluctuation mitigation, wind power smoothening, and hydrogen generation. The performance of DSTATCOM is evaluated through modeling and simulation using a proposed control strategy, comparing its effectiveness in a radial distribution system with and without DSTATCOM.

Ciprian Mihai Coman et. al. 2020, This paper discusses the importance of power factor correction (PFC) in electrical systems connected to the grid, whether three-phase or single-phase. The power factor is a measure of efficiency in electrical energy usage, and improving it through correction methods can reduce the load on transformers and power conductors, leading to lower losses in the mains power supply and a more sustainable grid system. A notable example of a load that can generate a low power factor is a motor without a mechanical load or with a small mechanical load. Implementing power factor correction can reduce costs by eliminating penalties, which typically apply at the common coupling point (CCP). Additionally, using equipment for power factor correction offers advantages such as long operational lifespan and easy installation. This paper introduces a new device that leverages advances in information and communication technology (ICT) to provide telemetry and remote configuration for PFC. This approach offers flexibility and versatility, allowing adaptation to various loads by easily adjusting capacitance steps and settings of the power factor correction device.

Houari Boudjella et. al. 2018, This paper outlines the process of modeling and simulating Static Var Compensator (SVC) in power system studies using MATLAB. The first step involves mathematically modeling the SVC rating analysis using MathCAD. In the second step, the behavior of SVC within and outside the control range is analyzed, along with conducting power system studies anchored with load flow analysis for SVC realization. The third step focuses on modeling the SVC transfer functions separately for various control elements, including the measuring module, thyristor susceptance control module, and voltage regulator module. Lag/lead compensator theories are employed to configure open and closed-loop transfer functions with respective gain/phase margins. Finally, the voltage and reactive power transit in the power system are controlled using the SVC device.

Yanzhou Sun et. al. 2013, This paper introduces a novel approach to voltage control using Static Var Compensator (SVC), which can swiftly, accurately, and continuously regulate the voltage of an installation area. By sustaining the voltage level of the installation area, SVC enhances transient stability and reduces oscillation damping in the power system. To investigate the characteristics of SVC, a system comprising Thyristor Switched Capacitor and Thyristor Controlled Reactor sections was constructed using the Simulink toolbox of MATLAB. The model was then utilized for simulation experiments, wherein relevant parameters were set to analyze the characteristics of Static Var Compensation in the power grid. Simulation results demonstrate that SVC effectively maintains bus voltage during dynamic and steady moments in the power grid, highlighting its stability control capability. Thus, SVC serves as a vital component of reactive power compensation devices in power networks.

IV. EXISTING CONFIGURATION

Improving the power factor is essential for efficient utilization of electrical energy in both three-phase and single-phase grid systems. Implementing power factor correction methods helps alleviate the burden on transformers and power conductors, thereby minimizing losses in the main power supply and promoting a sustainable grid infrastructure. Financially, the implications are significant, particularly in reducing costs associated with penalties, which are primarily applied at the common coupling point (CCP). An example of a load contributing to poor power factor is a motor operating without a mechanical load or with a minimal one. By addressing power factor correction (PFC), expenses can be curtailed, ensuring more efficient energy consumption.

The benefits of utilizing power factor correction equipment extend to their extended operational lifespan and ease of installation. Leveraging advancements in information and communication technology (ICT), the device introduced in this article introduces a novel method for telemetry and remote configuration of power factor correction (PFC).

This innovative approach offers flexibility and adaptability, allowing it to be customized for various loads by easily adjusting capacitance steps and settings within the power factor correction device.

Reactive power, a crucial component of electrical power, contributes to a diminished power factor and is influenced by reactive elements and imbalances in three-phase systems. AC rotary machines, for instance, incur additional losses due to unbalanced load currents and absorbed reactive power from single-phase loads. Low power factors resulting from unbalanced currents can significantly disrupt sensitive electronic equipment. Many researchers have investigated methods to mitigate the additional costs associated with reactive power. Improved power factor correction reduces the strain on transformers and conductors in electrical installations, leading to enhanced efficiency in electricity utilization. The financial implications of a low power factor include increased costs for consumed electrical energy. [6–11].

V. PROPOSED CONFIGURATION WORK

The SVC, a member of the FACTS family, is a shunt device utilizing power electronics to regulate power flow and enhance transient stability within power grids. Initially employed for arc furnace flicker compensation in the mid-1970s, it later found applications in power transmission systems. One of the earliest 40 Mvar SVC installations occurred at the Shannon Substation of the Minnesota Power and Light system in 1978. The SVC offers several benefits, including,

1) Voltage support, and regulation,
2) Transient stability improvement, and
3) Power system oscillation damping,
4) Reactive power compensation,
5) Power transfer capacity increase and line loss minimization.

In electric power systems, controlled reactive compensation is typically accomplished through various configuration corridors, including Thyristor Controlled Reactor (TCR), fixed capacitor (FC), Thyristor Switched Capacitor/Reactor (TSC/TSR), and mechanically switched capacitor/reactor SVC. This discussion focuses on the TCR/TSR SVC combination and its associated control system Fig.1.

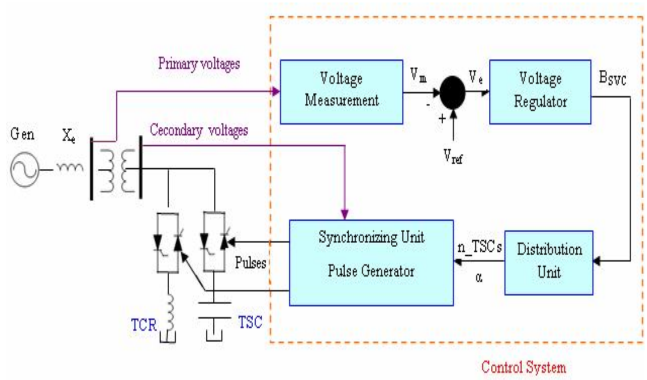


Fig. 1. Single-line Diagram of an SVC and Its Control system.

The output of the compensator is controlled in steps by sequentially switching TCRs and TSCs. This stepwise switching of reactors, rather than continuous control, eliminates the need for harmonics filtering as part of the compensator scheme.

VI. CONCLUSION

In this article, we have modeled small disturbances, including control action, to determine the required rating of SVC for the given subject matter. Furthermore, we have determined the appropriate control signal for adequate transient stability, as well as control structures corridors, to provide the most viable and composite perception of the SVC control system. Therefore, power system stability describes the voltage control at the point of SVC connection to the system. This technique may be used to verify the adequacy of the control parameters. Finally, we connect an SVC to a power grid to control the voltage and the reactive power.

VII. ACKNOWLEDGMENT

I would want to utilise this occasion to offer our genuine thanks and respect for the project guide at the Tulsiramji Gaikwad College of Engineering in Nagpur, who gave us direction and space to complete this assignment.

REFERENCES

[1] Gu Yonggang, Xiao Guochun, Wang Zhaoan. "Progress of thyristor switched capacitor's technology", High Voltage Apparatus, Vol. 39, No. 2, 2003, pp. 49-52

[2] Li Tao. "Application of 10kV thyristor switched capacitors in the substation", Electric Age, No. 7, 2008, pp. 96-98.

[3] Zhao Xinwei, et al. "Practical techniques of reactive power compensation in low-voltage system", Publishing House of Electronics Industry, Beijing , 2011.

[4] Kamari, N.A.M., Musirin, I., Hamid, Z.A., Rahim, M.N.A.. "Optimal design of SVC-PI controller for damping improvement using new computational intelligence approach", Journal of Theoretical and Applied Information Technology, Vol 42, No 2, 2012, pp. 271-280.

[5] Chen Guiming, Zhang Mingzhao. "Application of MATLAB Modeling and Simulation", Science Press, Beijing , 2001.

[6] Zhang Li, Li Qingmin, Wang Wei, Siew Wah Hoon. "Electromagnetic interference analysis in HV substation due to a static var compensator device", IEEE Transactions on Power Delivery, Vol. 27, No.1, 2012, pp.147- 155.

[7] Huang Shao-Ping, Li Yong-Jian, Jin Guo-Bin, Li Ling. "Simulation study for steady-state and dynamic performance of the static var compensator", 2009 International Conference on Energy and Environment Technology, ICEET 2009, Vol. 2, 2009, pp. 287-290, 2009 International Conference on Energy and Environment Technology, ICEET 2009.

[8] Wang Jing, Weng Guoqing, Zhang Youbing. "Simulation and application of MATLAB/SIMULINK in power system", Xi'an University of Electronic Science and Technology Publishing House, Xian , 2008.

[9] Li Hua. "Simulation of power systems using Power System Blockset", Sichuan Electric Power Technology, Vol. 24, No. 3, 2001, pp. 27-32.

[10] Ashwin Kumar Sahoo. An Improved UPFC Control to Enhance Power System Stability. Modern Applied Science. Vol. 4, No. 6; June 2010. 37-48

[11] Hasan Fayazi Boroujeni. Robust Controller Design for LFO Damping. International Journal of Academic Research in Applied Science. 2012. 1-8

[12] G.SUNDAR, S.RAMAREDDY. Digital Simulation of Multilevel Inverter Based STATCOM. Journal of Theoretical and Applied Information Technology. 2009. 19-24.

[13] M.Mohammadha Hussaini. Dynamic Response of Wind Power Generators using STATCOM. International Journal of Engineering and Technology Vol.2 (4), 2010, 297-304.

[14] Surinder Chauhan. Designing of STATCOM Controllers for Transient Stability Improvement of Two Machine System. Master of Engineering. Thapar University Patiala, Punjab-147004. July 2012.

[15] Bhim Singh and Sanjay Gairola. A Zigzag Connected Auto-Transformer Based 24-Pulse AC-DC Converter. Journal of Electrical Engineering & Technology, Vol. 3, No. 2, 2008. 235-242.

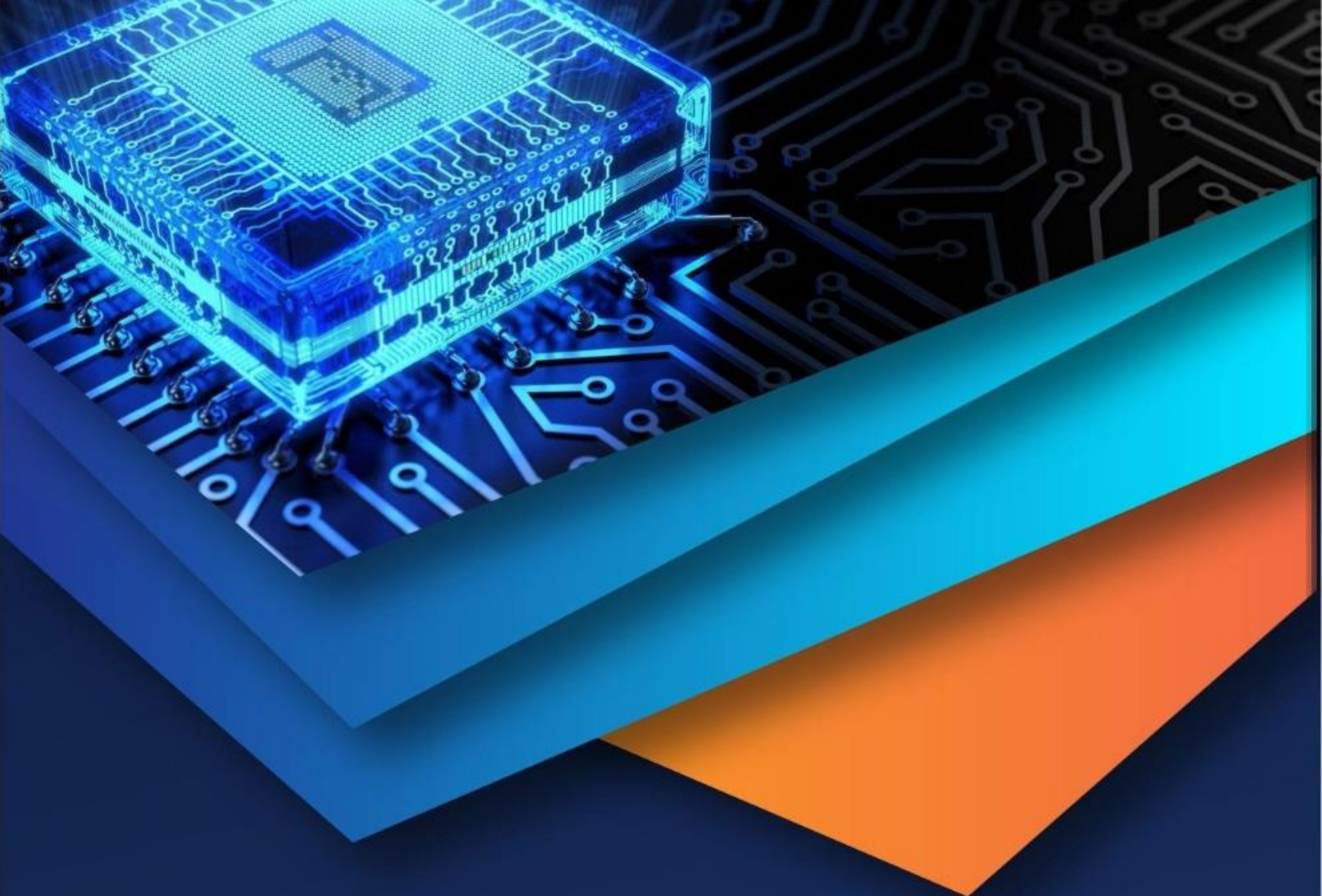
[16] Surin Khomfoi and Leon M. Tolbert. Multilevel Power Converters. The University of Tennessee. 1-50.

[17] Oscar Plasencia. Modeling and Analysis of a Four-Switch Buck-Boost Dynamic Capacitor. Masters of Science in Electrical Engineering. California Polytechnic State University. December 2011.

[18] Ricardo Dávalos Marín. Detailed analysis of a multi-pulse STATCOM. Unidad Guadalajara, May 2003.

[19] Dr. Y. Rajendra Babu. Design of d-q Domain Control Strategy for Static Synchronous Series Compensator. International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 4, April - 2013. 904-908.

[20] Power Quality In Electrical Systems (2013). Static Synchronous Series Compensator (SSSC). Retrieved on January 12, 2013, from http://www.powerqualityworld.com/2012/05/sssc-static-synchronous-series.html.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

TOGETHER WE REACH THE GOAL

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY