IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 6, June 2025
Impact Factor: 7.67

Enhancement of Voltage Stability by using SVC

Mr. Ankush S. Aloner and Prof. H.V. Takpire
Student, G H Raisoni University, Amravati
Assistant Professor, G H Raisoni University, Amravati

Abstract: *Power system stability is essential for maintaining reliable and continuous electricity supply in modern grids. Among the various solutions available, Static VAR Compensators (SVCs)—a key Flexible AC Transmission System (FACTS) device—play a pivotal role in improving stability by dynamically managing reactive power. By regulating voltage and damping oscillations, SVCs enhance grid performance and mitigate fluctuations that could lead to instability. This project investigates how SVCs contribute to power system stability through real-time reactive power control, ensuring voltages remain within safe limits while minimizing losses. Through simulation studies and case analyses, the effectiveness of SVCs is evaluated under diverse operating scenarios, demonstrating their ability to strengthen grid resilience. Additionally, PI-based control strategies are designed and implemented to optimize SVC performance, further enhancing power quality. The results underscore the importance of SVCs in modern power networks, highlighting their impact on reliability, efficiency, and overall system stability.*

Keywords: *Power system stability*

I. INTRODUCTION

The expanding complexity of advanced control frameworks, coupled with rising power request, has made steadiness a basic concern for control engineers and utilities. Control framework solidness alludes to the capacity of the electrical arrange to keep up consistent voltage and recurrence levels beneath typical and exasperates conditions. Voltage insecurity, control motions, and responsive control lopsided characteristics can lead to framework disappointments, power outages, and diminished productivity. To address these challenges, progressed control emolument methods are basic. Inactive VAR Compensators (SVCs), a key component of Adaptable AC Transmission Framework (Realities) innovation, have demonstrated to be viable in improving control framework solidness. SVCs control receptive control in real-time, making strides voltage steadiness, damping motions, and upgrading in general framework execution. By powerfully altering receptive control infusion or retention, SVCs offer assistance keep up voltage levels inside passable limits, diminish transmission misfortunes, and increment the unwavering quality of control systems. This venture centers on the execution of SVCs for steadiness improvement, with an accentuation on control techniques utilizing Proportional-Integral (PI) controllers. The integration of PI controllers empowers exact and versatile responsive control recompense, advance moving forward framework reaction to unsettling influences. Recreation thinks about are conducted to assess the execution of SVCs beneath distinctive working conditions, illustrating their adequacy in relieving flimsiness issues. The results of this inquire about highlight the significant part of SVCs in advanced control frameworks, emphasizing their commitment to unwavering quality, productivity, and generally lattice execution.

1.2 Need and Significance

- To consider the existing methods for Power quality improvement.
- To think about the working concept of shunt dynamic power channel techniques.
- To think about the existing sifting procedures in control system.
- Selection of legitimate MATLAB recreation pieces for planning shunt dynamic control filter-based framework.

OBJECTIVES

The main objective of propose methodologies are as follows:

1) To summarize the Power quality definition, issues and arrangements. SVC makes a difference keep up voltage levels inside secure limits by powerfully altering receptive control infusion or retention. Avoids voltage collapse amid overwhelming stack such as inductive stack conditions or disturbances.
2) To Execute the IEEE 5 BUS framework with and without SVC for the diverse blame inductive and capacitive.
3) For Controlling the SVC in this Extend PI controller is utilize.
The AC control transmission framework has assorted limits, classified as inactive limits and energetic limits [1]- [3]. These characteristic limits limit the control exchange, which lead to the beneath utilization of the existing transmission assets. Customarily, settled or mechanically exchanged shunt and arrangement capacitors, reactors and synchronous generators were being utilized to illuminate much of these issues. In any case, there are a few confinements as to the utilize of these ordinary gadgets. Wanted execution was being incapable to accomplish viably. Wear and tear in the mechanical components and moderate reaction were the major issues. As a result, it was required for the elective innovation made of strong state electronic gadgets with quick reaction characteristics. The necessity was advance fuelled by around the world rebuilding of electric utilities, expanding natural and productivity directions and trouble in getting allow and right of way for the development of overhead control transmission lines [4]. This, together with the innovation of semiconductor thyristor switch, opened the entryway for the improvement of Realities controllers. The way from authentic thyristor based Truths controllers to cutting edge innovatively progressed voltage source converters based Actualities controllers, was made conceivable due to quick advance in tall control semiconductors exchanging gadgets [1]-[3]. A inactive VAR compensator (SVC) is an electrical gadget for giving fast-acting responsive control emolument on tall voltage transmission systems and it can contribute to progress the voltages profile in the transitory state and subsequently, in making strides the quality exhibitions of the electric administrations. A SVC is one of Actualities controllers, which can control one or more factors in a control framework [5]. The energetic nature of the SVC lies in the utilize of thyristor gadgets (e.g. GTO, IGCT) [4]. The thyristor, as a rule found inside in a "valve house", can switch capacitors or inductors in and out of the circuit on a per-cycle premise, permitting for exceptionally quick prevalent control of framework voltage. The compensator considered in the display work is made up of a settled reactance associated in arrangement to a thyristor controlled reactor (TRC) based on bi-directional valves- and a settled bank of capacitors in parallel with the combination reactance-TRC. The thyristors are turned on by a appropriate control that directs the greatness of the current.

STATIC VAR COMPENSATOR

a) **Setup of SVC** SVC gives an great source of quickly controllable receptive shunt recompense for energetic voltage control through its utilization of high-speed thyristor switching/controlled gadgets [6]. A SVC is regularly made up of coupling transformer, thyristor valves, reactors, capacitance (frequently tuned for consonant sifting).
b) **Points of interest of SVC** The primary advantage of SVCs over basic mechanically exchanged emolument plans is their near-instantaneous reaction to alter in the framework voltage. For this reason they are regularly worked at near to their zero-point in arrange to maximize the responsive control rectification [7]-[10]. They are in common cheaper, higher-capacity, speedier, and more dependable than energetic stipend plans such as synchronous compensators (condensers). In a word: 1) Moved forward framework steady-state solidness. 2) Moved forward framework temporal steadiness. 3) Way better stack division on parallel circuits. 4) Decreased voltage drops in stack ranges amid extreme unsettling influences. 5) Diminished transmission misfortunes. 6) Way better alteration of line loadings. c) Control Concept of SVC An SVC is a controlled shunt susceptance (B) as characterized by control settings that infuses receptive control (Q) into the framework based on the square of its terminal voltage. Fig. 1 outlines a TCR SVC, counting the operational concept. The control objective of the SVC is to keep up a craved voltage at the high-voltage transport. In the steady-state, the SVC will give a few steady-state control of the voltage to keep up it the high-voltage transport at a pre-defined level. If the high-voltage transport starts to drop underneath its set point extend, the SVC will infuse receptive control (Qnet) Into in this manner expanding the transport voltage back to its net

IJARSCT
ISSN: 2581-9429
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 5, Issue 6, June 2025
Impact Factor: 7.67

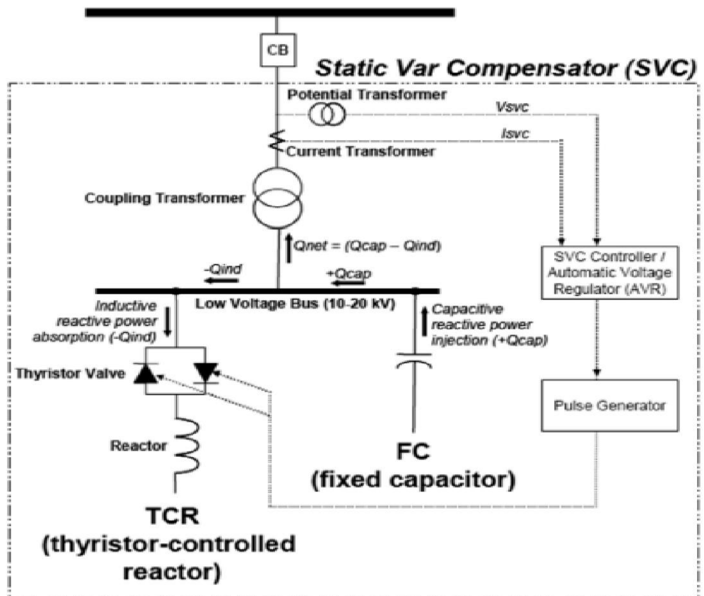

Fig.1: SVC with control concept

wanted voltage level. If transport voltage increments, the SVC will infuse less (or TCR will retain more) receptive control, and the result will be to accomplish the craved transport voltage. From Fig. 1, +Qcap is a settled capacitance esteem, subsequently the greatness of responsive control infused into the framework, Qnet, is controlled by the size of – Qind receptive control retained by the TCR. The crucial operation of the thyristor valve that controls the TCR is depicted here. The thyristor is self commutates at each current zero, subsequently the current through the reactor is accomplished by gating or terminating the thyristor at a craved conduction or terminating point with regard to the voltage waveform [11].

PERFORMANCE ANALYSIS OF SVC CONTROLLER

a) Modeling for Energetic Execution Investigation with SVC Applications When examining framework energetic execution and voltage control, framework modeling is an critical viewpoint particularly in and around the particular region of ponder. It is ordinary for numerous electric utilities to share expansive framework models made up of thousands of buses speaking to the interconnected framework. Points of interest on modeling "system" components such as transformers, generators, transmission lines, and shunt responsive gadgets (i.e. capacitors, reactors), etc., for short-term soundness investigation are talked about. A critical and ceaselessly talked about modeling perspective is the "load" show. For short-term soundness investigation, loads are modeled with both inactive (e.g. genuine control, receptive control) and energetic characteristics [12]. The programmed voltage controller (AVR) control piece is an imperative portion of SVC models that works on a voltage blunder flag. The non specific AVR control square is characterized by the exchange work as appeared in Fig. 2.

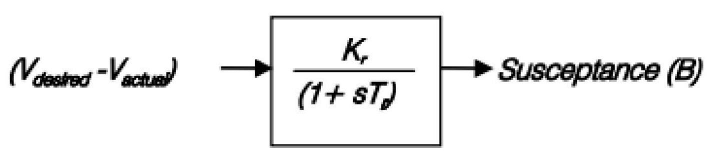

Fig. 2 : Transfer function of AVR control block.

Where Kr and Tr signifies the pick up and time consistent, separately. The incline setting, most extreme and least susceptance limits, thyristor terminating transport slack, voltage estimation slack, etc are the extra commonly utilized

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 6, June 2025
Impact Factor: 7.67

control piece capacities of SVC energetic models. b) Controller Plan Examination The SVC is worked as a shunt gadget to give capacitance for voltage bolster or inductance to decrease the transport voltage. The settled capacitors are tuned to assimilate the sounds which are produced by the TCR operation. In spite of the fact that the SVC is competent of giving bolster for short-term soundness and control swaying damping, its major work is to give voltage back and energetic receptive control. A SVC in vital is a controlled shunt susceptance (+/-B) as characterized by the SVC control settings that infuses receptive control (+Q) or expels responsive control (-Q) based on the square of its terminal voltage. In this application Q=B×V2 , and L and C are components which are measured such that Q≥ 0 is the as it were working extend. The AVR in the shape of corresponding and indispensably control, works on a voltage mistake flag Performance Criteria of SVC Operation The control objective is to keep up the framework voltage at 115 kV transport at 1.01 p.u. voltage. If the transport starts to drop underneath 1.01 p.u., the SVC will infuse receptive control (Q) into the framework (inside its controlled limits), subsequently expanding the transport voltage back to its craved 1.01 p.u. voltage agreeing to its slant setting, Xsl. On the opposite, if transport voltage increments, the SVC will infuse less (or TCR will retain more) responsive control (inside its controlled limits), and the result will be the wanted transport voltage at transport [9]-[10. The VI characteristic is utilized to outline the SVC rating and steady-state execution with the commonplace steady state working locale being based basically on the Vref , Xsl setting, and the impedance of the framework.

Paper Implementation

This project implementation will be done using MATLAB Simulink software. The major blocks will be design in MATLAB Simulink as follows:

•Simulation of power system using simpower system toolbox.

•Simulation of active filter using sim power system toolbox.

•Simulation of fault in power system using simpower system toolbox.

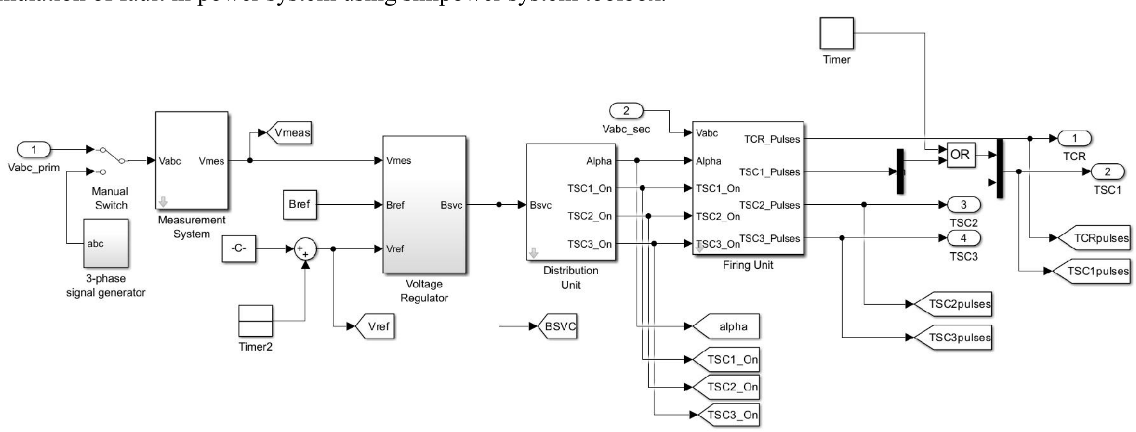

Fig.3 Matlab simulation of SVC controller

1. Input Source and Measurement (Left Side)

- **Vabc_prim**: Primary 3-phase voltage source input.
- **3-phase signal generator**: Simulates a 3-phase voltage source.
- **Manual Switch**: Allows manual control of the signal injection.
- **Measurement System**: Measures the 3-phase voltage (Vabc) and produces a scalar voltage magnitude (Vmes).

2. Voltage Regulation Loop

- **Vmes**: Measured voltage magnitude from the system.
- **Vref**: Reference voltage to maintain.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 6, June 2025
Impact Factor: 7.67

- **Bref**: Desired susceptance based on voltage difference.
- **Voltage Regulator**: Compares Vmes and Vref and generates Bsvc (required compensating susceptance) to regulate voltage.

3. Distribution Unit
Inputs: Bsvc, which is the required susceptance.
Outputs:
Alpha: Trigger angle for the Thyristor Controlled Reactor (TCR).
TSC1_On, TSC2_On, TSC3_On: Signals to switch on the Thyristor Switched Capacitors (TSCs).
The **Distribution Unit** determines whether to turn on capacitors or adjust reactor angle based on Bsvc.

4. Firing Unit
This block generates the gating pulses for the TCR and TSC devices:
TCR_Pulses, TSC1_Pulses, TSC2_Pulses, TSC3_Pulses: Control signals for thyristor devices.
These are derived from Alpha and TSC ON/OFF commands.

5. Power Electronics (Right Side)
TSC1, TSC2, TSC3: Thyristor Switched Capacitors – inject capacitive reactive power when turned on.
TCR: Thyristor Controlled Reactor – absorbs reactive power; its reactance is controlled via Alpha.
OR Gate: Combines TSC outputs for power path control.

6. Timer Blocks
There are Timer and Timer2 blocks which likely serve as simulation timers or triggers for enabling certain actions at specific simulation times.

Summary of Operation
Measure the system voltage (Vmes).
Compare with desired reference voltage (Vref).
Compute how much reactive power (susceptance Bsvc) is needed.
Distribution Unit decides how to achieve this:
Use **TSCs** if capacitive power is needed.
Use **TCR** with appropriate firing angle (Alpha) for inductive power.
Firing Unit generates gating signals for thyristors.
TSCs/TCR are fired to adjust voltage levels and keep the system stable.
The SVC comprises of a 735kV/16-kV 333-MVA coupling transformer, one 109-Mvar thyristor-controlled reactor bank (TCR) and three 94-Mvar thyristor-switched capacitor banks (TSC1 TSC2 TSC3) associated on the auxiliary side of the transformer. Exchanging the TSCs in and out permits a discrete variety of the auxiliary receptive control from zero to 282 Mvar capacitive (at 16 kV) by steps of 94 Mvar, while stage control of the TCR permits a persistent variety from zero to 109 Mvar inductive. Taking into account the spillage reactance of the transformer (15%), the SVC comparable susceptance seen from the essential side can be shifted persistently from -1.04 pu/100 MVA (completely inductive) to +3.23 pu/100 Mvar (completely capacitive). The SVC controller screens the essential voltage and sends fitting beats to the 24 thyristors (6 thyristors per three-phase bank) in arrange to get the susceptance required by the voltage regulator.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 6, June 2025
Impact Factor: 7.67

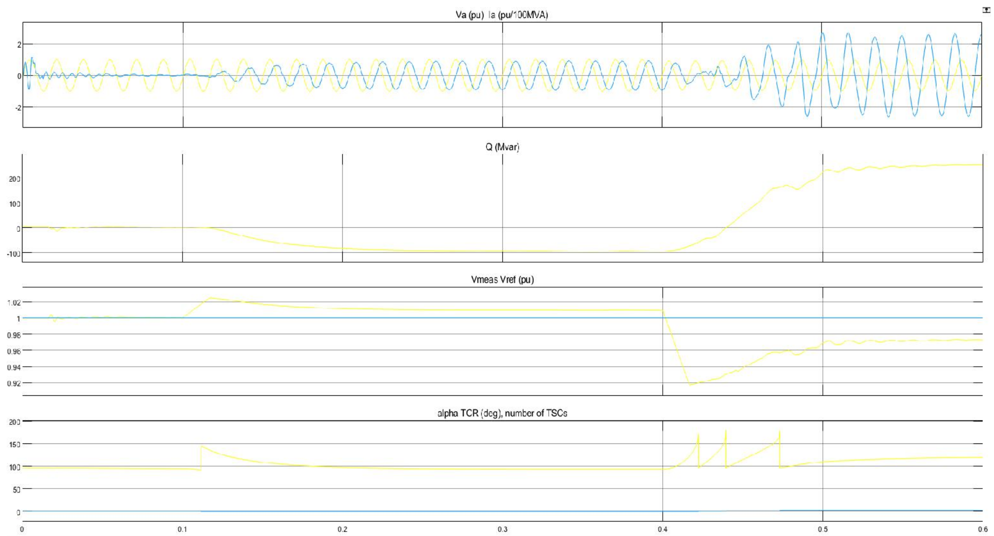

Fig.3 Result of SVC A 300-Mvar Static Var Compensator (SVC) regulates voltage on a 6000-MVA 735-kV system.

Use See beneath Cover to see how the TCR and TSC subsystems are built. Each three-phase bank is associated in delta so that, amid ordinary adjusted operation, the zero-sequence tripplen sounds (3rd, 9th...) stay caught interior the delta, hence diminishing consonant infusion into the control framework. The control framework is spoken to by an inductive identical (6000 MVA brief circuit level) and a 200-MW stack. The inside voltage of the comparable can be changed by implies of programmable source in arrange to watch the SVC energetic reaction to changes in framework voltage. Open the voltage source menu and see at the arrangement of voltage steps which are programmed. Simulation

Dynamic reaction of the SVC

Run the reenactment and watch waveforms on the SVC scope piece. The SVC is in voltage control mode and its reference voltage is set to Vref=1.0 pu. The voltage hang of the controller is 0.01 pu/100 VA (0.03 pu/300MVA). Hence when the SVC working point changes from completely capacitive (+300 Mvar) to completely inductive (-100 Mvar) the SVC voltage shifts between 1-0.03=0.97 pu and 1+0.01=1.01 pu.

Initially the source voltage is set at 1.004 pu, coming about in a 1.0 pu voltage at SVC terminals when the SVC is out of benefit. As the reference voltage Vref is set to 1.0 pu, the SVC is at first drifting (zero current). This working point is gotten with TSC1 in benefit and TCR nearly at full conduction (alpha=96 degrees). At t=0.1s voltage is all of a sudden expanded to 1.025 pu. The SVC responds by retaining responsive control (Q=-95 Mvar) in arrange to bring the voltage back to 1.01 pu. The 95% settling time is roughly 135 ms. At this point all TSCs are out of benefit and the TCR is nearly at full conduction (alpha = 94 degrees). At t=0.4 s the source voltage is all of a sudden brought down to 0.93 pu. The SVC responds by creating 256 Mvar of responsive control, hence expanding the voltage to 0.974 pu. At this point the three TSCs are in benefit and the TCR assimilates roughly 40% of its ostensible responsive control (alpha =120 degrees). Watch on the final follow of the scope how the TSCs are consecutively exchanged on and off. Each time a TSC is exchanged on the TCR alpha point changes abruptly from 180 degrees (no conduction) to 90 degrees (full conduction). At long last, at t=0.7 s the voltage is expanded to 1.0 pu and the SVC receptive control is diminished to zero.

Misfiring of TSC1

Each time a TSC is exchanged off a voltage remains caught over the TSC capacitors. If you see at the 'TSC1 Misfiring' scope interior the "Signals and Scope" subsystem you can watch the TSC1 voltage (to begin with follow) and the TSC1 current (moment follow) for department AB. The voltage over the positive thyristor (thyristor conducting the positive current) is appeared on the 3rd follow and the beats sent to this thyristor are appeared on the 4th follow. Take note that

the positive thyristor is let go at most extreme negative TSC voltage, when the valve voltage is least. If by botch the terminating beat is not sent at the right time, exceptionally expansive overcurrents can be watched in the TSC valves.
Look interior the SVC Controller square how a misfiring can be recreated on TSC1. A Clock piece and a OR square are utilized to include beats to the typical beats coming from the Terminating Unit. Open the Clock piece menu and expel the 100 increase calculate. The clock is presently modified to send a misfiring beat enduring one test time at time t= 0.121 s. Restart reenactment. Watch that the misfiring beat is sent when the valve voltage is greatest positive quickly after the TSC has blocked. This thyristor misfiring produces a huge thyristor overcurrent (18 kA or 6.5 times the ostensible crest current). Moreover, quickly after the thyristor has blocked, the thyristor voltage comes to 85 kV (3.8 times the ostensible top voltage). In arrange to avoid such overcurrents and over voltages, thyristor valves are regularly secured by metal oxide arresters (not recreated here).

II. CONCLUSION

The integration of a Static Var Compensator (SVC) into transmission networks operating at 735 kV and stepped down to 16 kV plays a vital role in enhancing power quality and system reliability. Through the dynamic regulation of reactive power using thyristor-based capacitor and reactor switching, the SVC effectively stabilizes voltage levels and mitigates disturbances caused by fluctuating load conditions.Simulation analysis confirms that the SVC contributes to improved voltage stability, reduced fluctuations, and better power flow control across both high and medium voltage levels. This is particularly important for long-distance transmission, where voltage support becomes essential to prevent power quality degradation in the lower-voltage distribution network.In summary, the SVC proves to be a valuable solution for maintaining consistent voltage profiles, minimizing power quality issues, and supporting stable operation in complex power systems involving wide voltage ranges.

.

REFERENCES

[1]. N.G. Hingorani, and L. Gyugyi, "Understanding FACTS: concepts and technology of flexible ac transmission systems," IEEE Press, NY, 1999.

[2]. Y. H. Song, and A. T. Johns, "Flexible AC transmission system (FACTS)," IEE Power and Energy Series 30, London, U.K., 1999.

[3]. "FACTS application," FACTS application task force, IEEE Power Engineering Society, 1998.

[4]. J. J. Paserba, "How FACTS controllers benefit AC transmission systems," IEEE Power Engineering Society General Meeting, Denver, Colorado, 6-10 June 2004.

[5]. T.J.E. Miller, Reactive Power Control in Electric Systems. Wiley & Sons, New York, (1982).

[6]. P. Lips, "Semiconductor power devices for use in HVDC and FACTS controllers," CIGRE Technical Brochure 112, Paris, France, April 1997.

[7]. A.E. Hammad, "Comparing the voltage control capabilities of present and future VAR compensating techniques in transmission systems," IEEE Trans. Power Delivery, vol.11, no.1, pp. 475- 484, Jan. 1996.

[8]. J. Verseille, Convenor, CIGRE task force 39.02, "Voltage and reactive control," Electra No.173, pp. 115-143, Aug. 1997.

[9]. C. Taylor, Power System Voltage Stability. Textbook ISBN 0-07-113708-4, McGraw Hill, 1994.

[10]. P. Kundur, Power System Stability and Control. Textbook ISBN 0-07-0359580-X, McGraw Hill, 1994.

[11]. R.J. Koessler, "Dynamic simulation of SVC in distribution systems," IEEE Trans. Power System, vol.7, no.3, pp. 1285-1291, Aug. 1992.

[12]. D. J. Sullivan, J.J. Paserba, G.F. Reed, T. Croasdaile, R. Pape, R., D.J. Shoup, et. Al., "Design and application of a static VAR compensator for voltage support in the Dublin, Georgia Area," FACTS Panel Session, IEEE PES T&D Conference and Exposition, Texas, May 2006.

[13]. T. Petersson, "Analysis and optimization of SVC use in transmission system," CIGRE Technology Brochure 77, Paris, France, April, 1993