Study on Enhancing Power System Stability Using Static Var Compensator (SVC)

**A Project and Thesis submitted in partial fulfillment of the
requirements for the Award of Degree of
Bachelor of Science in Electrical and Electronic Engineering**

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Certification

This is to certify that this project and thesis entitled "**Study On Enhancing Power System Stability Using Static Var Compensator (SVC)**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 30 October 2020.

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The project and thesis entitled **" Study On Enhancing Power System Stability Using Static Var Compensator (SVC),"** submitted by **Name: Mohammad Rahan**, ID No: 162-33-286, Session: Summer 2016 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on ----------- 2020.

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This thesis is dedicated to
my parents & teacher’s

For their endless love,
support and
encouragement…

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List of Abbreviations

SVC	Static Var Compensator
FACT	Flexible Alternating Current Transmission
UPS	Uninterruptible power supply
SPS	Standby Power Supply
TV	Television
AC	Alternating Current
IEEE	Institute of Electrical and Electronics Engineers
PID	Proportional integral Derivative
HVDC	High Voltage Direct Current
TCR	Thyristor Controlled Reactor
TSC	Thyristor Switched Capacitor
SR	Self-Reactor
FC	Fixed Capacitor
PLL	Phase Locked Loop
PSS	Power System Stabilizes
EPRI	Electric Power Research Institute
GTO	Gate Turn-off
VSC	Voltage Source Converters
“TCSC”	“Thyristor Controlled Series Capacitor”
TCPS	Thyristor Controlled Phase Shifter
“STATCOM”	“Static Synchronous Compensator”
“SSSC”	“Static Synchronous Series Compensator”
“UPFC”	“Unified Power Flow Controller”
IPFC	Interline Power Flow Controller
DC	Direct Current
MVAR	Mega Volt Ampere Reactive
MVA	Mega Volt Ampere
MW	Mega Watt
VA	Volt Ampere
PU	Per Unit
PC	Personal Computer

MSC	Mechanically Switched Capacitor
MSR	Mechanically Switched Reactor
HMI	Human Machine Interface
IGBT	Insulated Gate Bipolar Transistor
DSP	Digital Signal Processing
PC	Personal Computer
MSC	Mechanically Switched Capacitor
MSR	Mechanically Switched Reactor
HMI	Human Machine Interface

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First of all, we give thanks to Allah. Then “I have to thank my parents for their love and support throughout my life”. “Thank you both for giving me strength to reach for the stars and chase my dreams”. “My sisters, little brother, auntie and cousins deserve my wholehearted thanks as well”.

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To all my friends, thank you for your understanding and encouragement in my many, many moments of crisis. Your friendship makes my life a wonderful experience. I cannot list all the names here, but you are always on my mind.

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This thesis is only a beginning of my journey.

ABSTRACT

The most common problem in a heavily loaded electrical network is voltage disparity, due to continuous load variations. The continuous increase in energy demand requires that a methodology be developed to be able to meet the energy demand. Therefore, such devices are needed, which can minimize energy loss and voltage drop in the power supply network. FACTS devices are a valuable option for improving voltage drop and reactive power in place of capacitors and shunt reactors. This article investigates the effects of the Static Variation Compensator (SVC) on the voltage stability of a power system. This paper will discuss and demonstrate how SVC has been successfully applied to the power system to effectively regulate the system voltage. One of the main reasons for installing an SVC is to improve dynamic voltage control and thus increase the load capacity of the system. This article introduces SVC modeling and simulation in MATLAB / Simulink. In this article, an SVC is used to regulate the voltage in a power system. When the system voltage is low, the SVC generates reactive power (capacitive SVC). When the system voltage is high, it absorbs reactive power (inductive SVC). SVC is rated +100 Mvar capacitive and 50 Mvar inductive. SVC more effectively improves voltage stability and increases transmission capacity in a power system.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Today, the power system is operated closer to its stability limits for economic and environmental reasons and for this reason the safe procedure of the power system is a very significant and stimulating topic. A system arrives a state of voltage variability when a trouble happens, the load demand rises, and the system situations change due to the voltage drop. According to the review, to compensate for this problem, SVC is used in the transmission system. These articles examine the effect of SVC on voltage stability and improvement of that stability in the power system. In this article, FACTS SVC bypass devices are used on a transmission line to improve “voltage profile and stability”. “The MATLAB Simulink platform was used in this study”. Voltage on various buses is calculated and weak buses are identified to position FACTS devices to improve voltage stability limits before and after svc placement.

1.2 “Basic Structure of Power System”:

“The structure of power system is shown in Fig. 1.1”

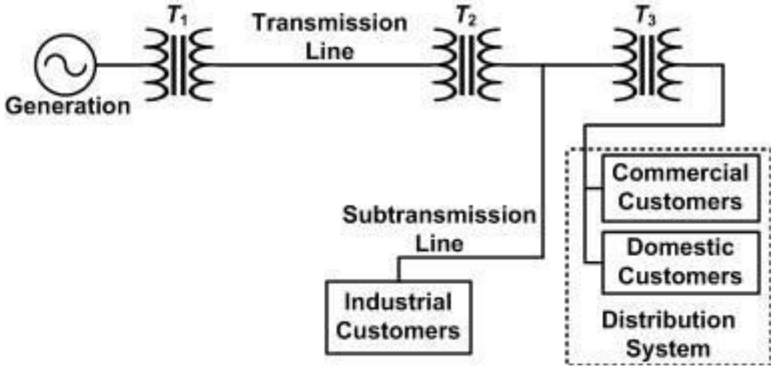


Fig. 1.1: Line Diagram of Power System

“It contains a generating plant”, “a transmission”, “a sub-transmission and a distribution system”. “These subsystems were interconnected via transformers T1, T2 and T3”. “Let's consider some typical voltage levels to understand how the power system works”. A typical voltage of 11 kV is generated in the boiler house ("voltage levels are usually definite line to line"). This is improved to levels like 400 kV through the transformer T1 for power transmission. The T2 step-down transformer then reduces this voltage to 66 kV to provide power through the secondary transmission line to industrial loads that require ground power at a higher voltage. Many industrial customers have their own transformers to reduce the 66 kV power supply to wanted levels. In this way, for these voltage variations, the cost of the transmission line is minimalized for a given power level. Distribution systems are considered for much lower power levels and are powered with medium level voltages. Where the transmission line is designed with a high range of power lines.

1.3 Problems of Power System

1.3.1 Symmetrical Faults on 3-Phase System

That fault in the power system that provides increase to symmetrical fault currents (that is, alike fault currents in lines with an offset of 120 °) "is named a symmetrical fault. Symmetrical fault occurs when the three conductors of a three-phase line are placed Together simultaneously in short circuit condition as shown in Fig. 1.2"

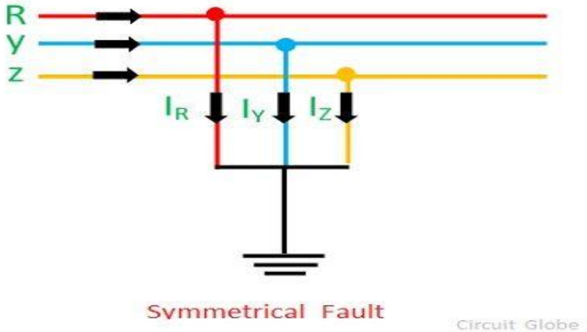


Fig. 1.2: Symmetrical Fault

1.3.2 "Unsymmetrical Faults on 3-Phase System"

"Those faults in the power supply system that give rise to asymmetrical fault currents" (i.e. irregular fault)

"Currents in lines with uneven phase shift) are known as asymmetric faults".

"There are three ways in which asymmetric failures can occur in a power".

System (see Fig.1.3).

(i) "Single Line to Ground Fault" (L - G)

(ii) "Line to Line Fault" (L - L)

(iii) "Double line to ground fault" (L - L - G)

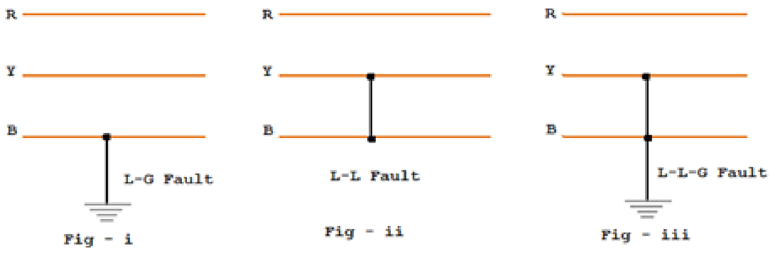
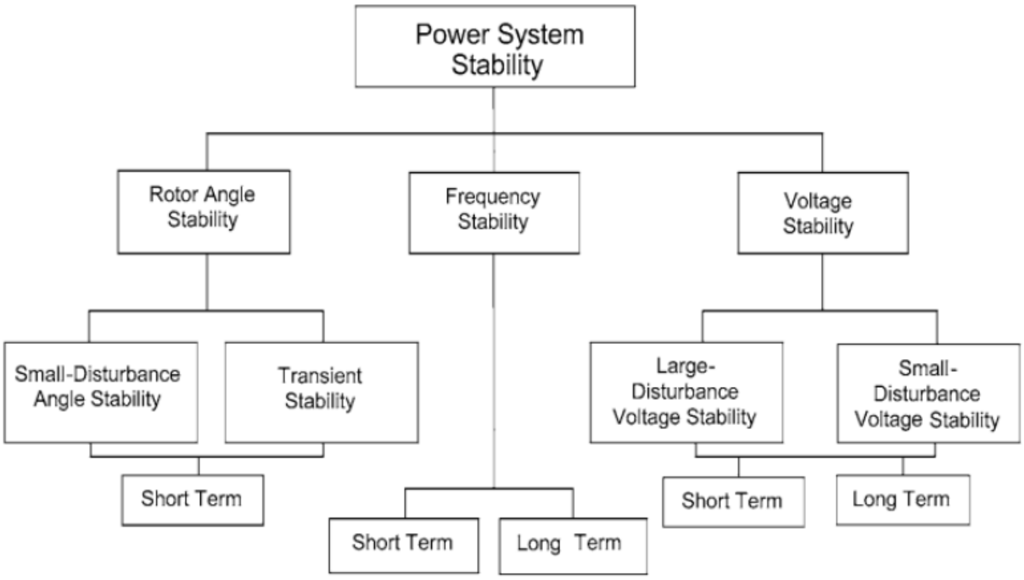


Fig. 1.3: Unsymmetrical Fault

1.4 “CLASSIFICATION OF VOLTAGE STABILITY”

“The classification of voltage stability is shown below”.



“Fig. 1.4: Classification of Voltage Stability”

1.5 “VOLTAGE INSTABILITY IN POWER SYSTEMS”

“Voltage instability generally occurs in a power system that is heavily loaded or failed or has a lack of reactive power”. “Voltage instability is a problem that affects many components of the power system”. “In fact, a voltage drop can involve an entire power system”. “Voltage instability is typically associated with the load's reactive power demand not being satisfied due to insufficient supply of reactive power in the system”.

“A system has an unstable voltage if it stops at least one bus in the system”, “the bus voltage decreases as the reactive power injection on the same bus increases”. “This implies that if the V-Q sensitivity is positive for each bus”, “the system is voltage stable and if the V-Q sensitivity is negative for at least one bus”, “the system is voltage unstable”. “In fact, the term in which voltage collapse is also often used for conditions of voltage instability”. “It is the process in which the sequence of events following voltage instability leads to abnormally low voltages or even a blackout across much of the system".

An important cause contributing to voltage unpredictability is the voltage drop across the line impedances as active and reactive powers flow through the line. As a result, the transmission network capability for power transfer and voltage stability is reduced. The voltage stability of a system is conceded when a trouble rises the demand for reactive power beyond the maintainable capability of the available reactive power properties.

1.6 Voltage Stabilization

SVC is the favorite apparatus for dynamic support of reactive power in high voltage transmission networks. Thanks to its essential ability to control variables on a cycle-by-cycle basis at high speed, it will counteract the often daring voltage dips that survey along with network outages. These extremely dynamic actions, wherever the growing procedure of induction motors (such as those in air preparing divisions and wind turbine generators) pressures the grid, will require an SVC to maintain grid voltage and protection the grid. Ability to recover in case of failure. In addition, if the SVC consist of variable absorption capacity, it will efficiently conquer short-term surges that may perform when clearing the error. The SVC will ensure that the mains voltage is continuously kept within suitable restrictions. In steady state, it will also assist operatives with precise voltage control to optimize the grid voltage profile.

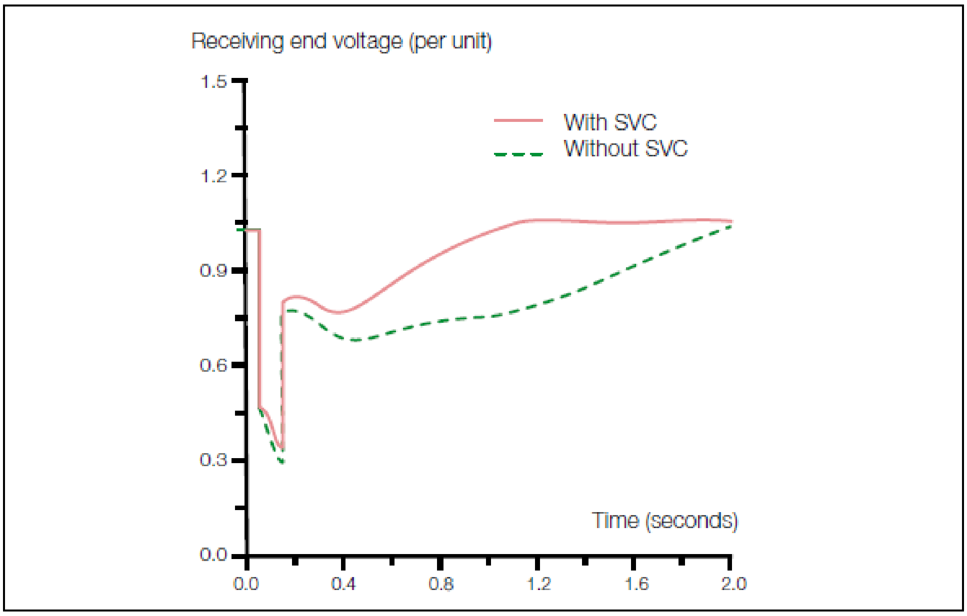


Fig. 1.5: Post error voltage regaining with and without SVC.

1.7 Increasing Transmission Capability

The SVC will make sure that the system voltage doesn’t drop though the power movement rises. This suggests that extra power are often transferred through the system below constant situations on existing lines.

1.8 FLEXIBLE AC TRANSMISSION SYSTEM DEVICE

A FACTS is a system collected of static apparatus used for the AC transmission system in the power system. It can improve controllability and growth the power transfer capacity of the network. It is mainly a power electronic device.

FACTS is defined by IEEE as "a system based on power electronics and other static equipment that provides control of one or more parameters of the AC transmission system to improve controllability and increase power transfer capacity".

In the power supply system the load variant is not stable, in other words it is variable in nature and these static variation compensators are very effective in controlling voltage fluctuations. Currently the demand for electricity is very intense, but at the time of actual operation there are some limitations because a balance is maintained between the supplies of a demand with the allowed level of stability limits of the power system. Whenever there is a load change or a fault occurs, “the system voltage level changes, as the voltage level drops, the reactive power demand increases, if the reactive power demand is not met, then it” decreases bus voltage and this will also affect the neighboring region. The disturbance occurs in the system due to an abnormal fault condition, it goes into transient oscillations. This unwanted oscillation can change the performance of the transmission network application. This is required for control and is done using FACTS bypass procedures, for example the static variation compensator (SVC) designed with required control. SVC dampens oscillations then improves overall system stability. The Proportional Integral Derivative (PID) controller is used in SVC. This is applicable when the system is faced with a large disturbance at the time of failure.

You need to have devices that can control random fluctuations and transient noise entering the transmission line. The system needs to have less overshoot and less settling time to keep the voltage at the steady state level. In recent years, the Static Var Compensator plays an important role in regulating the voltage in the AC drive system.

Flexible AC Drive System Controllers (FACTS) are mainly use for solve several power system difficulties. The FACTS controller widely used for control the voltage, phase angle and impedance of the AC transmission system. SVC is the most promising FACTS controller used to improve power system stability. In this document, the maximum load capacity limit of the power system has been improved by placing the SVC.

1.8.1 Benefits of FACTS technology

- The following benefits will be achieved with the help of FACTS devices
- Solve stability problems and energy transfer limits
- Thermal limit
- Voltage limit
- Stability limit
- Transient stability limit
- Small signal stability limit
- Voltage stability limit
- Control of power flow as ordered
- Increase system security
- Reduce reactive power flows, thus allowing lines to carry more reactive power
- Reduce loop flows
- Increase the utilization of cheaper generation
- Increase the power transfer (control) capacity of the line
- Better energy quality
- Load compensation
- Limit the short circuit current
- Increase the load capacity of the system

1.9 “Static Var Compensator”

“SVC is a solid state reactive power compensation device based on high power thyristor technology”. “An SVC can improve the transmission and distribution performance of” the power system “in several ways”. “Installing an SVC in one or more suitable points on the network can increase transfer capacity and reduce losses by maintaining a uniform voltage profile under different network conditions”. It can also “improve dynamic grid stability and mitigate active power surges”. By increasing proficient semiconductors (thyristors) sized for great power scores, this machinery has similarly proven very operative in HVDC applications and thyristor energies for industry.

The SVC is capable of adjusting “reactive power” continuously “over an unlimited range without any delay”. Improve “system stability and system power factor”. The “most commonly used SVC” schemes “are as follows”

- Thyristor controlled reactor (TCR)
- Thyristor-switched capacitor (TSC)
- Thyristor controlled reactor – Fixed capacitor (TCR-FC)
- Self-Reactor (SR)
- Thyristor-switched capacitor – Thyristor controlled reactor (TSC-TCR)

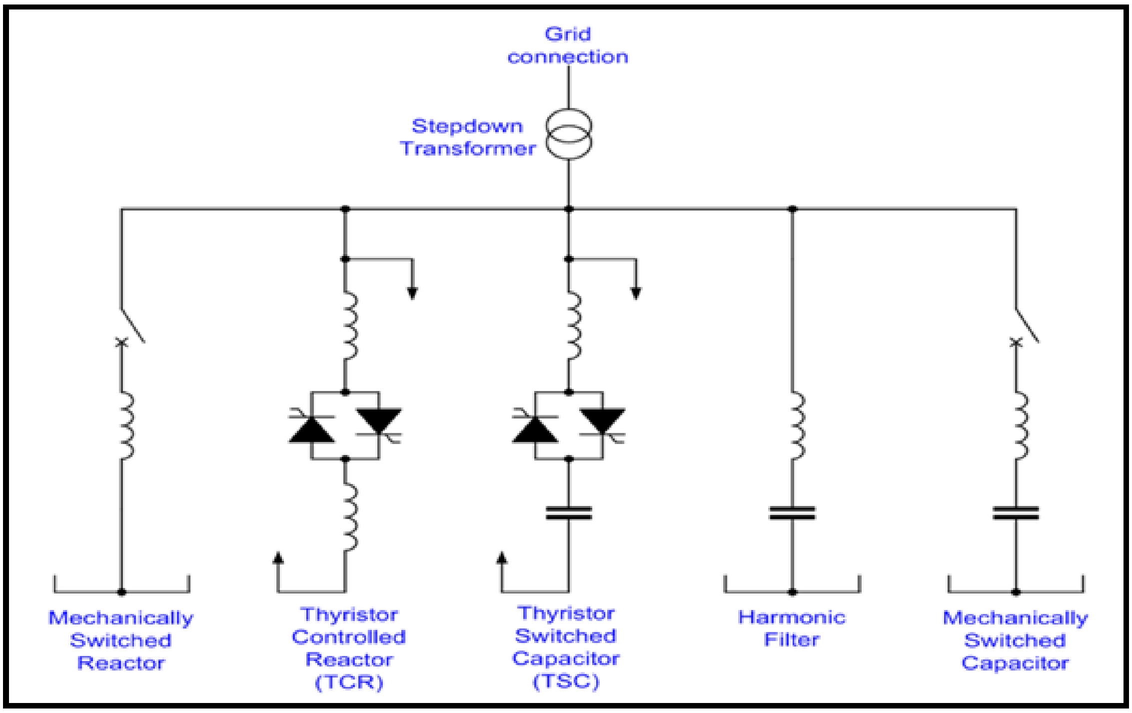


Fig. 1.6: Block Diagram of SVC

1.9.1 Thyristor controlled reactor (TCR):

A reactor and a thyristor valve are incorporated in each single-phase branch. The power is changed by controlling the current through the reactor through the thyristor valve. The on-state interval is controlled by delaying the activation of the thyristor valve with respect to the natural passage of zero current. A thyristor controlled reactor (TCR) is used in combination with a fixed capacitor (FC) when reactive power generation or, alternatively, absorption and generation is required. This is usually the optimal solution for sub-transmission and distribution.

TCR/FCs are characterized by

— Continuous control

— No transients

— Elimination of harmonics by tuning the FCs as filters

— Compact design

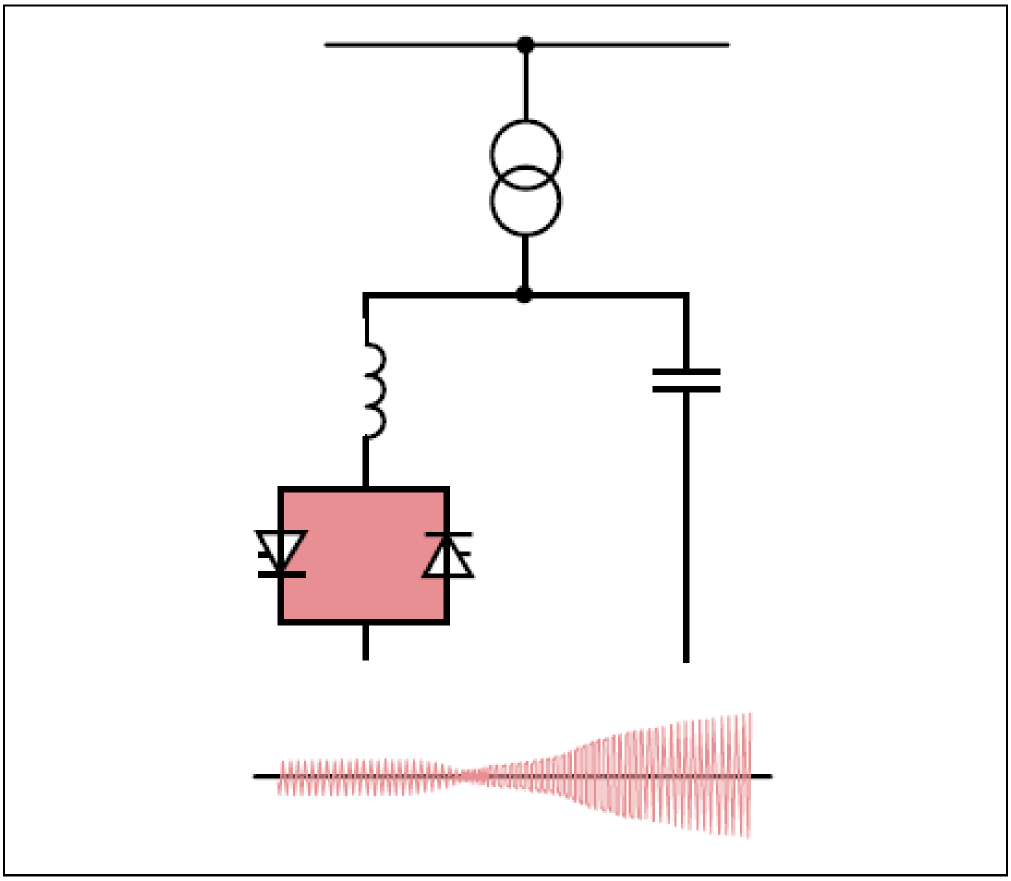


Fig. 1.7: Thyristor controlled reactor (TCR)

1.9.2 Thyristor-switched capacitor (TSC):

A bank of shunt capacitors is split into an proper quantity of divisions. Every division is turned on or off separately by a thyristor valve. Switching happens while the voltage through the thyristor valve is nil, creating it practically freed from transients. The discontinuation happens by conquering the firing pulses to the thyristors which can block while the present reaches zero.

TSCs are considered by

— Stepped controller

— No transients

— No harmonics

— Small damages

— Redundancy and flexibility

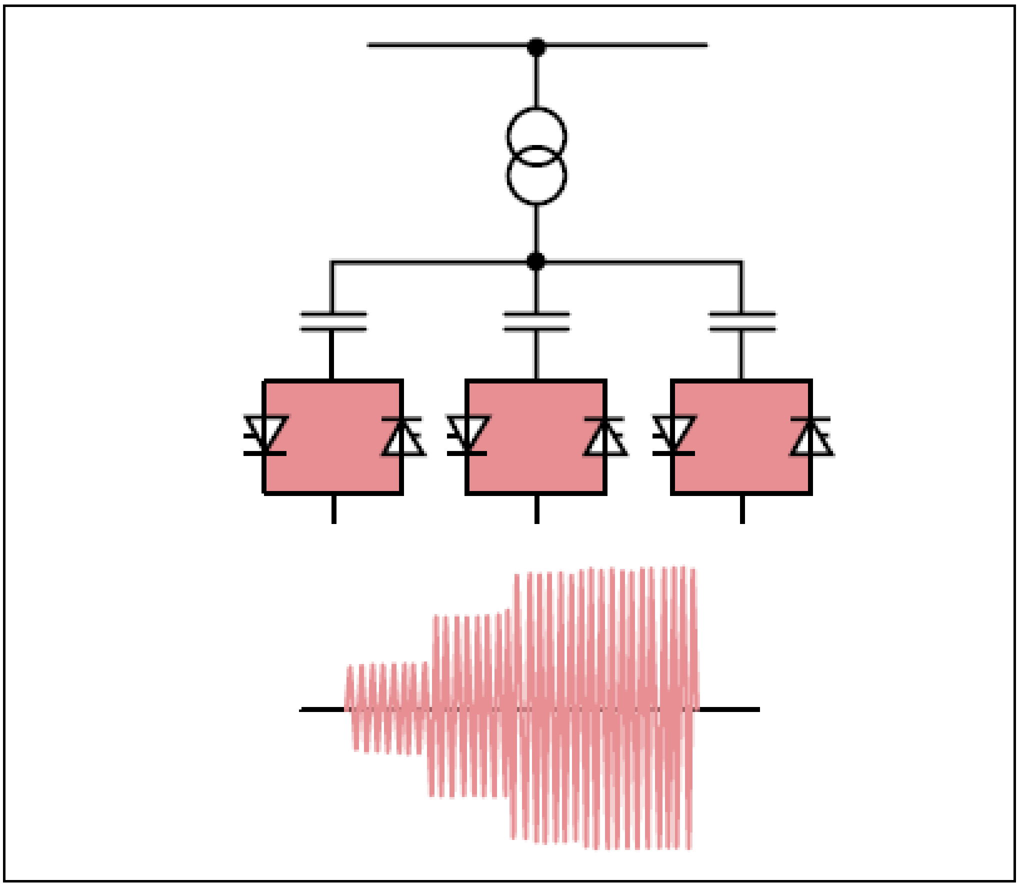


Fig. 1.8: Thyristor Switched reactor (TCR)

1.9.3 “Thyristor-switched capacitor” – “Thyristor controlled reactor” (TSC-TCR)

“A combined TCR and TSC is the optimal solution in many cases”. “With a TCR / TSC compensator”, “you get continuously variable reactive power over the entire control range as well as full control of the inductive and capacitive parts of the compensator”. “The main benefit is optimum performance during major electrical system disturbances”, for example line failures then load rejects.

TCR/TSC combinations are categorized by

— Nonstop controller

— No transients

— Removal of harmonics by filters or TSR

(thyristor switched reactor) controller

— Small damages

— Redundancy

— Elastic controller then procedure

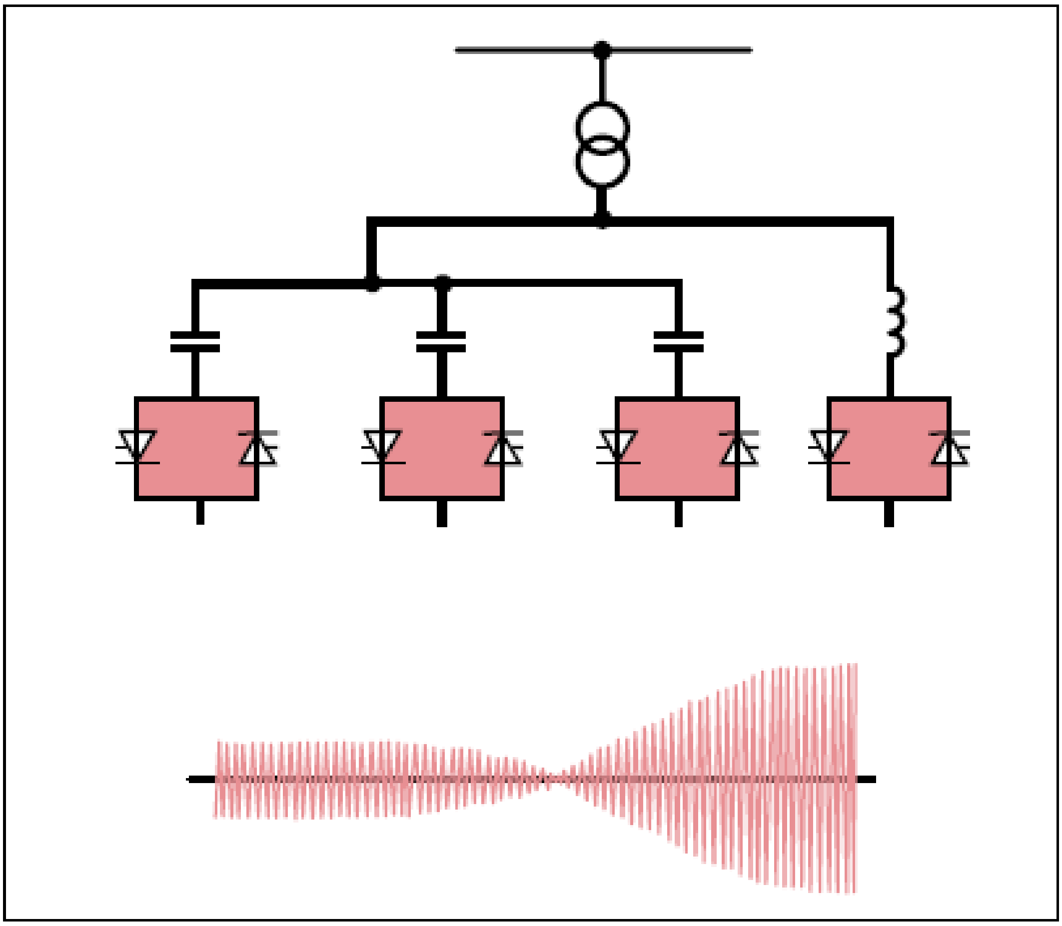


Fig. 1.9: Thyristor-switched capacitor – Thyristor controlled reactor (TSC-TCR)

1.10 OBJECTIVE FUNCTION

Due to the non-linearity of the load, when changing the load socket, or unsatisfactory supply of reactive power, the phenomenon of voltage unpredictability can happen. In this work the main objective is to improve the voltage unpredictability problem through the use of SVC. Therefore, the simulation model comes with and without SVC.

1.11 WORKING PRINCIPLE

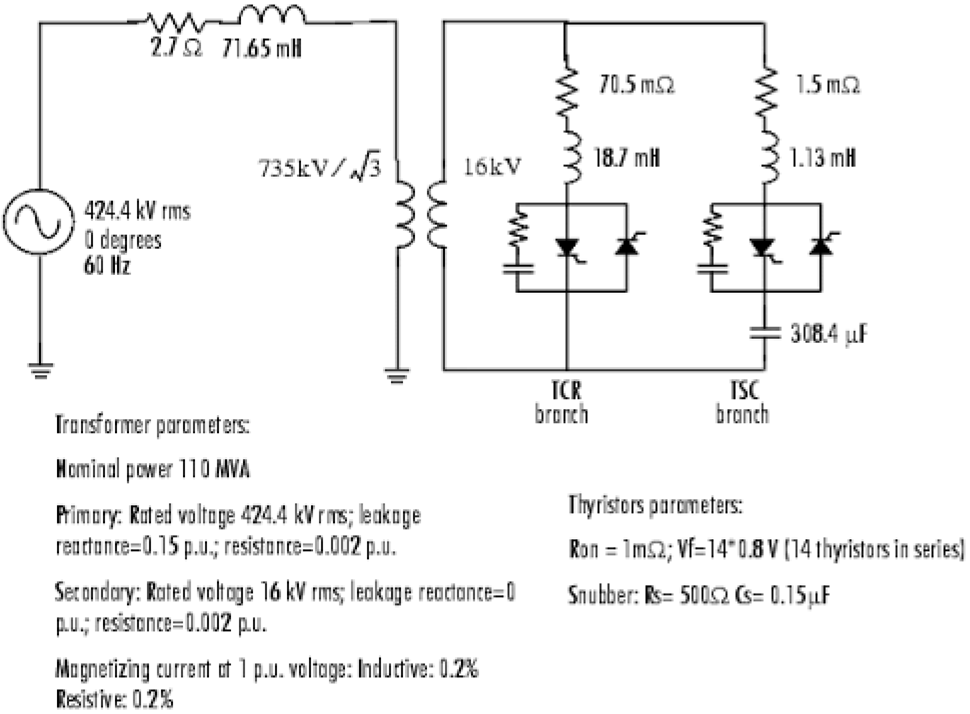
The Static Var Compensator is "a static Var generator or absorber connected to a shunt whose output is regulated to exchange capacitive or inductive current to maintain or control specific parameters of the power supply system (typically bus voltage)". SVC is established on thyristors without gate stop ability. The principle of operation and the features of the thyristors understand a variable reactive impedance of SVC. The SVC comprises two main mechanisms and their combination: thyristor controlled reactor and thyristor reactor (TCR and TSR); and switched thyristor capacitor (TSC). Both TCR and TSR consist of a shunt-connected reactor controlled by two thyristors connected inversely in parallel. TCR is controlled with correct firing angle input for continuous operation, while TSR is controlled without firing angle control, resulting in a gradual change in reactance. Both the switched thyristor reactor and the thyristor capacitor are trying to stabilize the voltage instability problem by generating and absorbing reactive power in the system. By doing this simultaneous absorption and discharge of reactive power, this FACTS device is stabilizing the voltage.

1.12 Modeling

“SVC is a thyristor based controller that provides quick voltage control to withstand electrical power transmission voltages immediately after large disturbances”. “Since the advent of deregulation and separation of generation and transmission systems in the electrical industry”, “voltage stability and system restrictions related to reactive power have become a growing concern for utilities”. “When voltage congestion or safety problems are observed during the planning study process”, “a cost-effective solution to such problems” should be considered. Voltage constancy, voltage regulation and power system immovability, hampering can be developed by consuming these devices and their appropriate control. Static variation compensators (SVCs), the best significant FACTS devices, have been used for several years to improve the economy of the “transmission line by solving dynamic voltage problems”. “Accuracy, availability and fast response enable SVCs to provide high performance steady state and transient voltage control”

An SVC generally consists of the following main apparatuses:

1. Coupling transformer
2. Thyristor valves
3. Reactors
4. Capacitors (often tuned for harmonic filtering)



Transformer parameters:

Nominal power 110 MVA

Primary: Rated voltage 424.4 kV rms; leakage reactance=0.15 p.u.; resistance=0.002 p.u.

Secondary: Rated voltage 16 kV rms; leakage reactance=0 p.u.; resistance=0.002 p.u.

Magnetizing current at 1 p.u. voltage: Inductive: 0.2% Resistive: 0.2%

Thyristors parameters:

Ron = 1mΩ; Vf=14*0.8 V (14 thyristors in series)

Snubber: Rs= 500Ω Cs= 0.15μF

Fig. 1.10: Single Phase of a TCR/TSC SVC

In general, the two thyristor valve controlled / switched conceptions used with SVC are the thyristor controlled reactor (TCR) and the thyristor switched capacitor (TSC). The TSC offers a "gradual" response and the TCR delivers a "regular" or nonstop variable vulnerability. A TCR contains a fixed reactor in series with a bidirectional thyristor valve. A TSC consists of a series capacitor with a bidirectional thyristor valve and a buffer reactor. The thyristor switch acts to turn the capacitor on or off for a whole number of half cycles of the applied voltage. The capacitor is not phase controlled, it is simply on or off. For this reason, TSC does not produce harmonic distortion. The reactor in the TSC circuit serves to limit the current under abnormal situations, as well as to tune the TSC circuit to the wanted frequency. A thorough study of the power system is necessary to develop correct model that underscores the specific problems that SVC applications must solve.

1.13 SVC CONTROL SYSTEM

Bypass susceptibility control is the basic concept of the SVC control system and can be controlled by changing the firing angle of the thyristor. The SVC control objective is to maintain the desired voltage on the high voltage bus. The SVC regulates the voltage at its terminal by controlling the amount of reactive power injected or absorbed by the power system.

- When the system voltage is low, the SVC generates reactive power (capacitive SVC)
- When the system voltage is high, it absorbs reactive power (inductive SVC)

On the secondary side of the coupling transformer there are “three-phase capacitor banks and inductor banks” based on the switching operation.

- If “each capacitor is turned on and off by three thyristor switches”, it is called a thyristor capacitor
- Similarly, each of the ballasts is turned on and off by three thyristor switches called Thyristor Controlled Reactors.

The SVC can be used in two different methods:

- In voltage regulation mode
- In var control mode (SVC vulnerability remains constant)

While the SVC is operating in voltage regulation mode, outfits the following V-I

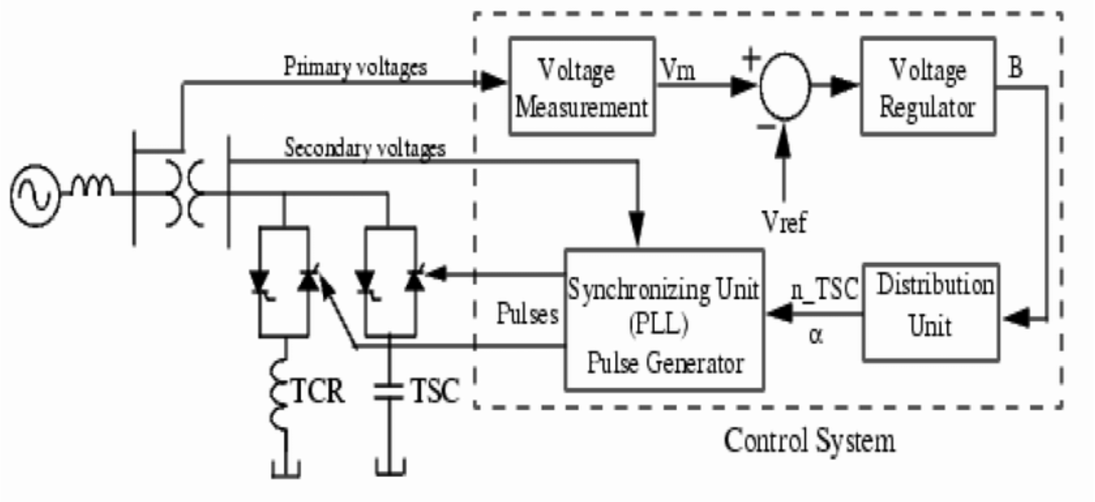


Fig. 1.11: Control System of SVC

The voltage measurement in positive sequence is performed by a measuring element. A voltage regulator that uses voltage errors (difference between the measured voltage Vm and the reference voltage Vref to determine the susceptibility of SVC B needed to keep the system voltage constant. The following units calculate the firing angle of the controlled reactor thyristor a timing system that uses “a phase locked loop (PLL) synchronized with the secondary voltage” “and a pulse generator that sends the appropriate pulses to the thyristor”.

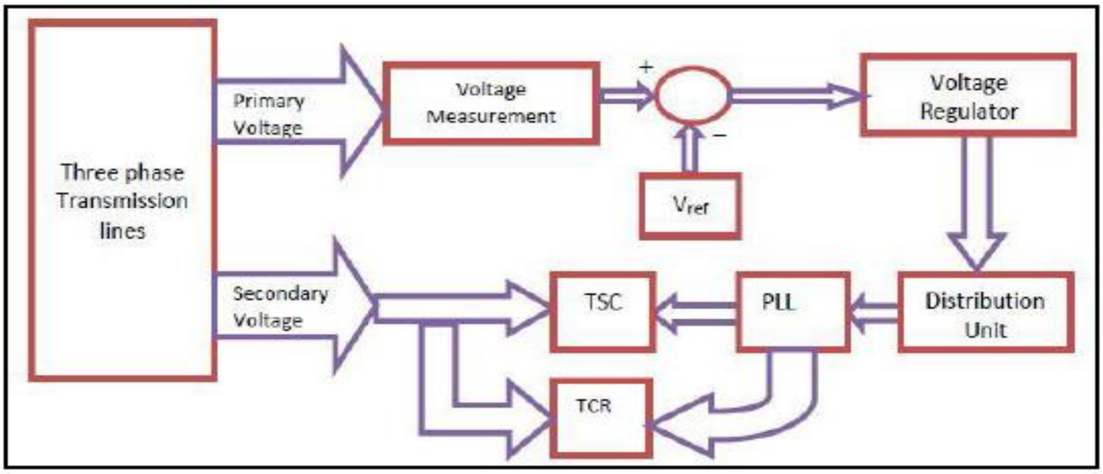
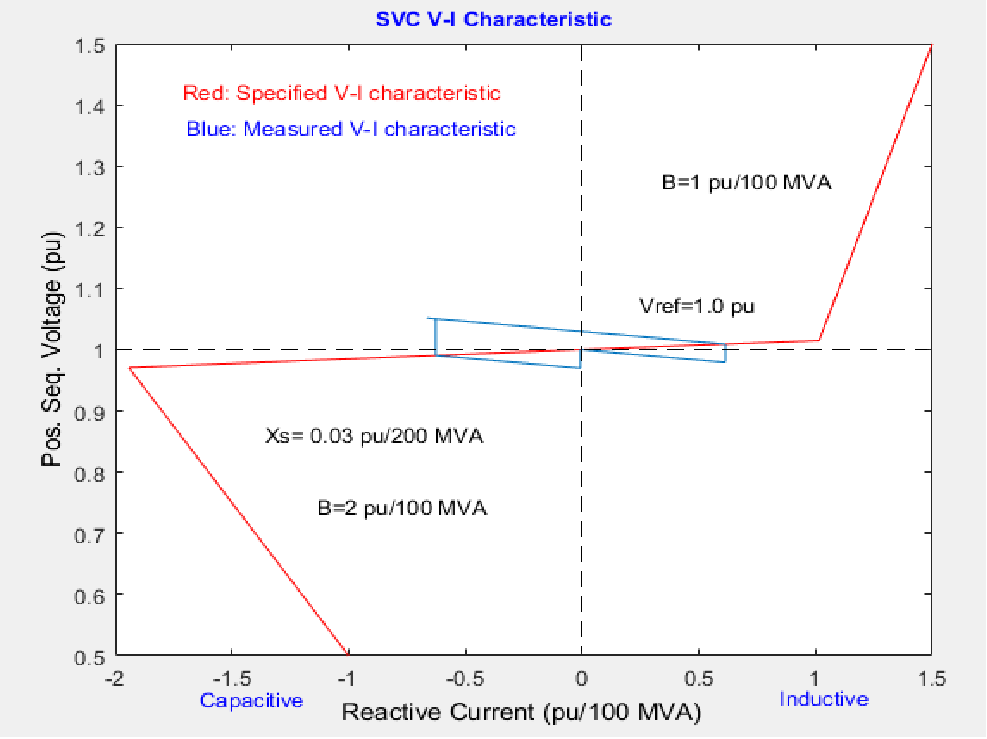


Fig. 1.12: SVC control system

1.14 V-I CHARACTERISTICS OF SVC



“Fig. 1.13”: “V-I Characteristics of SVC”

“The V-I characteristics represent the steady-state relationship”, shown in Figure 1.11. A typical characteristic of “V-I determines the range of inductive and capacitive current provided by the SVC”. “The V-I characteristics of the SVC indicate that adjustments with the given slope around the rated voltage can be achieved in the normal operating range defined by the maximum capacitive and inductive currents of the SVC”.

As long as the “SVC B” susceptibility “remains within” the minimum and maximum susceptibility “values imposed by the total reactive power of the capacitor banks (Bcmax) and reactor banks (Blmax)”, “the voltage is regulated to the reference voltage Vref. However, a voltage drop of between” 1% and 4% is normally used at maximum reactive output power).

The V-I characteristic is defined by the next three equations

V = Vref + Xs. I SVC is in the adjustment range (-Bmax <B <BLmax) (1)

V = -I / Bcmax SVC is fully capacitive (B = Bcmax) (2)

V = I / Blmax SVC is completely inductive (B = BLmax) (3)

Where, V = positive sequence voltage (p.u.)

I = Reactive current (p.u./Pbase) (I> 0 indicates an inductive current)

Xs = slope or drop reactance (p.u./Pbase)

BCmax = Maximum capacitive susceptibility (p.u./Pbase) with all TSC in service, without TSR or TCR BLmax = Maximum inductive susceptibility (p.u./Pbase) with all TSR in service or TCR in full conduction, without TSC Pbase = Three-phase base power

1.15 “Advantage of Static VAR Compensator”

- Increase in “the power transmission capacity of the transmission lines”.
- “Improved transient stability of the system”.
- “Controlled steady state and temporary over voltages”.
- “Improved load power factor and thus reduced line losses and improved system capacity”.
- Static and dynamic voltage control
- Damping of oscillations
- Sub-synchronous resonance
- Reactive power support
- Increase the energy transfer capacity

The SVC has no rotating or moving parts like the synchronous capacitor. The main purpose of using SVC on the transmission line is to quickly check the voltage profile at the weak spots.

1.16 Objectives

The objectives of this project and thesis are

- Increase the transfer of energy “in long lines”
- To “improve stability with fast acting” tension adjustment
- Wet “low frequency oscillations due to” oscillation modes (rotor)
- “Sub-synchronous wet frequency oscillations due to torsional modes”

1.17 Project/Thesis Outline

This project / thesis is organized as follows:

- Chapter 1 presents the SVC of FACT devices
- Chapter 2 reviews the literature on implementing FACT devices
- Chapter 3 analyzes and simulates the theoretical work of SVC
- Chapter 4 describes the development of SVC hardware
- Chapter 6 concludes with some recommendations

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

“Since the development of interconnection of large power supply systems”, “spontaneous oscillations of the system have occurred at very low frequencies of the order of 0.2-3.0 Hz”. “Once started, they would continue for a long period of time”. “In some cases they continue to grow causing system separation due to the lack of damping of the mechanical modes”.

“Over the past three decades”, “Power System Stabilizers (PSS) have been widely used to increase system damping for low frequency oscillations”. Power companies around the world are deploying PSS as operative excitation controls to develop system strength. Though, problems with PSS occurred over the years of process. Several of these were due to the partial ability of the PSS, to dampen merely local oscillation modes and not between areas. In adding, PSS can cause large deviations in the voltage outline in the presence of severe disturbances, and can even cause the main power factor to function and lose system constancy. This condition required a evaluation of the conceptions and performs of traditional energy systems to achieve a greater margin of stability, “greater operational flexibility and better use of existing energy systems”.

“Flexible AC Drive Systems” (FACTS) have received “great interest” in recent years, thanks to current developments in power electronics. FACTS procedures were mostly used to solve several steady-state control complications of the power system, “such as voltage regulation”, “power flow control”, “and transfer capability” improvement. “As complementary functions”, “the damping of the inter-area mode and” the development of the stability of the power supply system using the “FACTS controllers have been extensively studied and studied”. In general, “it is not convenient to install FACTS devices for the sole purpose of improving the stability of the power supply system”.

2.2 FACTS DEVICES

2.2.1 Overview

In the late 1980s, the Electric Power Research Institute (EPRI) expressed the prophecy for CA Flexible

Transmission systems (FACTS) in which several controllers based on power electronics normalize the power flow and the transmission voltage and moderate dynamic turbulences. In general, the main objects of FACTS are to rise the usable transmission capability of the lines and to control the flow of energy on the selected transmission roads. Hingorani and Gyugyi and Hingorani offered the idea of FACTS. Edris et al. Terms and classifications offered for different FACTS controllers.

Here are two generations of power electronics-based FACTS controllers: the first generation uses predictable thyristor capacitors and reactors and quadrature switching transformers, the second generation uses gate-stop thyristor converters (GTOs) as power converters. Voltage sources (VSC). The first generation produced the Static Var Compensator (SVC), the Thyristor Controlled Series Capacitor (TCSC) and the Thyristor Controlled Phase Shifter (TCPS). The second generation produced STATCOM (Static Synchronous Compensator), SSSC (Static Synchronous Series Compensator), Unified Power Flow Controller (UPFC) and Interlinear Power Flow Controller (IPFC). The two groups of FACTS controllers have definitely different working and performance appearances.

The thyristor controlled group employments capacitor and reactance banks with fast solid state switches in old-fashioned series or shunt configurations. Thyristor switches control the on and off stages of stationary banks of capacitors and reactors and thus perform a variable reactive impedance. With the exception of “losses”, “they cannot exchange real energy with the system”.

“The FACTS Voltage Source Converter (VSC) controller group employs self-switching DC to AC converters”, “using GTO thyristors”, “which can internally generate capacitive and inductive reactive power for transmission line compensation”, “without the use of a power bank”. Reactors or capacitors. The energy loading converter can also interchange genuine power with the system, as well as individually controllable reactive power. VSC can be used consistently to control transmission line voltage, impedance and angle by provided that reactive shunt compensation, series compensation and phase shift, or to directly control real and reactive power flow in the line.

2.2.2 Interest Measure for FACTS

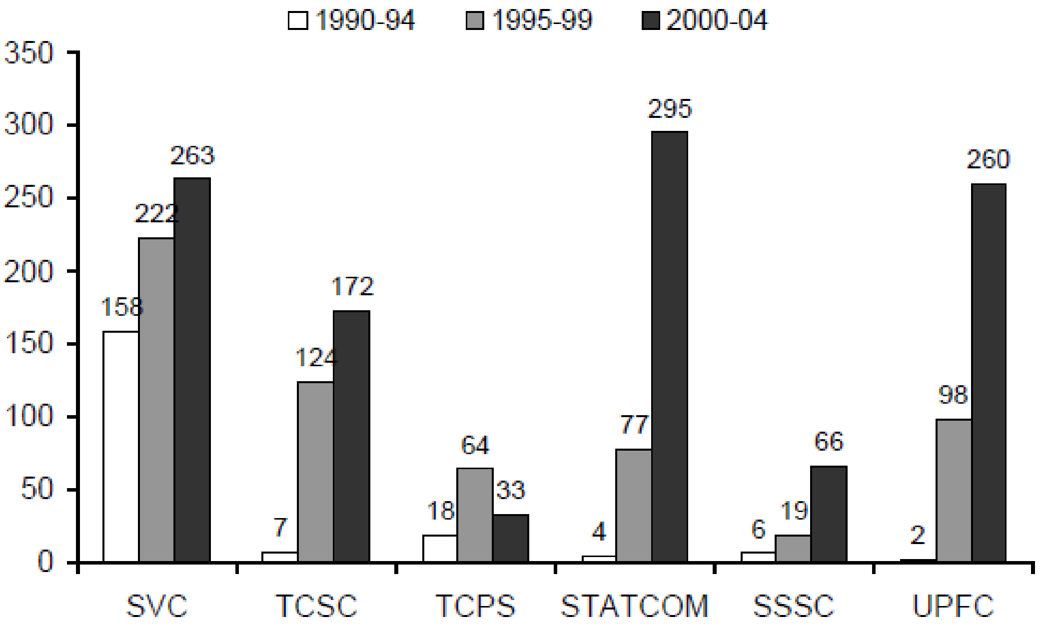
For the determination of this evaluation, a bibliographic study was showed that contains two of the most essential and collective databanks, namely the IEEE / IEE electronic library and the Science Direct electronic databases. The study covers the last 15 years from 1990 to 2004. For suitability, this period has been separated into three sub-periods; 1990–1994, 1995–1999 and 2000–2004. The number of publications discussing FACTS applications for different power systems studies was noted. The study outcomes are shown in Figure 2.1. It is clear that the applications of FACTS to many electrical systems studios have enlarged naturally over the past five years. This surveillance is more pronounced with second-generation devices, as interest nearly triples. This shows enlarged interest in VSC-based FACTS applications. The results also show reducing interest in TCPS however interest in SVC and TCSC growths marginally.

In general, both generations of FACTS have been functional to different regions in power systems studies, containing optimum power flow, economical power distribution, voltage constancy, power system safety, and power quality. .

The applications of FACTS to the stability of the electrical system in particular were made “using the same databases”. “The results of this survey are shown in Figure 2.1”. The ratio between the FACTS applications and the stability study compared to other studies on electrical systems was found to be overall greater than 60%. This clearly reflects the growing “interest in the” different “FACTS controllers” as possible “solutions to the problem” of improving the stability of the electrical system. “It is also clear that the interest in the second generation of FACTS has increased significantly while the interest in the first generation has decreased”.

Noorozian and Anderson discussed the potential of FACTS controllers to improve power system stability, where a complete study of electromechanical vibration hampering of the power system using FACTS was presented. Wang and Swift analyzed the damping torque provided by the FACTS devices, wherever some important points were evaluated and established through simulations.

Number of Publications (General)



“Figure 2.1. Statistics for FACTS applications studies”

Quantity of Publications (Stability)

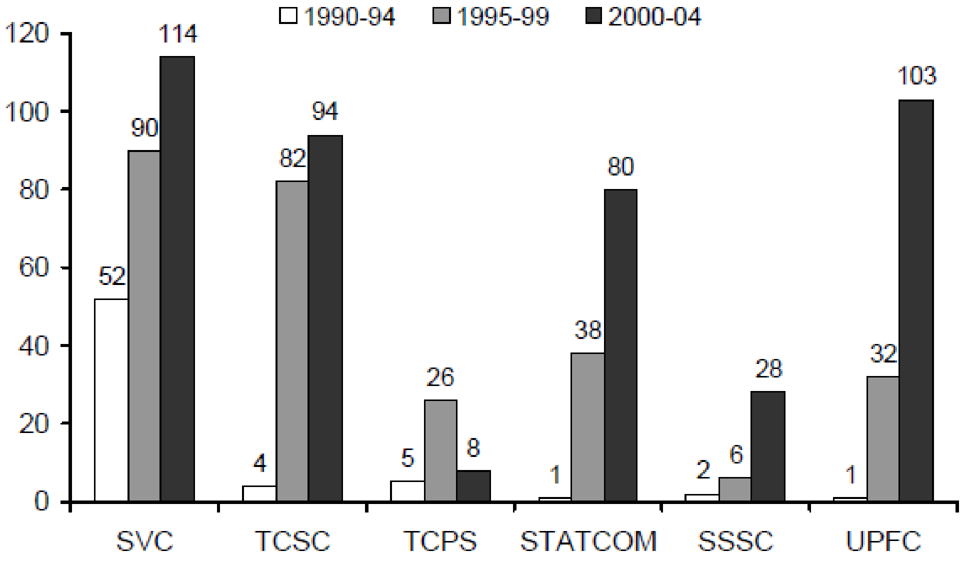


Figure 2.2: Statistics for FACTS applications to power system stability

2.3 Some Example of Installed SVC Power Plant’s

<u>2.3.1 “Karavia”</u>

“SVC for dynamic voltage control of a 220 kV transmission system fed by HVDC link”

A 75 Mvar inductive to 75 Mvar capacitive (-75 / + 75 Mvar) 220 kV Var static compensator (SVC) supplied by ABB was put into operation at the end of 2013 as a turnkey installation at the Karavia substation a National Electricity Society (SNEL) of the Democratic Republic of Congo. Three MSCs (mechanically switching capacitors) are part of the installation, each from 30 Mvar to 220 kV.

The SVC is part of the rehabilitation of the 220 kV HVAC corridor for energy export to the mineral rich Katanga province in the south which contains, among other things, some of the largest copper and cobalt deposits in the world . The 220 kV corridor receives large amounts of environmentally friendly hydroelectricity from the Inga Falls on the Congo River via the 1,700 km HVDC Inga-Kolwezi link. The Karavia 220 kV substation is located approximately 290 km from the Kolwezi converter station at the receiving end of the HVDC link.

The SVC has the following activities:

- Improves the voltage and angular stability of the Katanga's 220 kV AC grid
- Compensate for the lack of reactive energy in the grid, otherwise it will be imported from neighboring Zambia
- Improves first swing strength by maintaining system voltage during large troubles

2.3.2 Extremoz

SVC for integration of wind power into a 230 kV grid

A static Var Compensator (SVC) from 75 Mvar inductive to 150 Mvar capacitive (-75 / + 150 Mvar) at 230 kV, delivered and connected by ABB, went into procedure at the substation of Chesf Extremoz, a Brazilian transmission and generation situated in the state of Rio Grande do Norte, in northeastern Brazil. This apparatus is part of an expansion of the transmission system essential to simplify the integration of renewable energy of more than 1,000 MW composed from a multitude of wind turbines situated in that area. Wind energy is first composed at two main points of the grid, João Câmara and João Câmara II, and from there it is transferred to the National Interconnected System (NIS) through the Extremoz 230 kV substation and 500/230 kV transformers.

Extremoz SVC has been intended to allow the next activities:

- Check the 230 kV bus bar voltage for steady state and contingencies;
- To supply reactive power with fast and dynamic response after system unexpected events (for example, short circuits in the network, disconnections of lines and generators);
- Improve stability at the first turn by keeping the system voltages within the established limits during major disturbances in the electrical network.

2.3.3 Black Oak

"SVC to Increase reliability and reduce congestion over multiple 500 kV lines"

In late 2007, "a large static compensator (SVC) supplied by ABB was put into service at Allegheny Power's Black Oak substation near Rawlings", "Maryland". "The installation improves" "reliability on Allegheny Power's" 500 kV "Hatfield-Black Oak-Bedington transmission line", "one of the most loaded lines in the PJM" interconnection area ("Pennsylvania, Jersey, Maryland"), by rapidly "changing reactive power levels" "to check the line voltage". "n addition to improving reliability", "SVC" will allow for greater transmission capability through the PJM area. Allowing extra energy to run on remaining lines is an effective usage of assets and an essential stage in keeping step using the growing demand for electricity in the region.

"The project began as part of PJM's Regional Transmission Expansion Plan", "which identifies upgrades and additions to ensure the reliability of the electric transmission system across its multistate region."

System	SVC
Controlled voltage	500 kV
SVC rating	145 Mvar inductive to 575 Mvar capacitive
Control system	Voltage control by means of a closed loop system with control of the positive-phase sequence voltage around a dead-band and switching control of external MSC

Thyristor valves	PCT type thyristors, water cooled, indirect light firing

2.3.4 Golden Valley Electric Association, Alaska

SVC for voltage support of pipeline drives

System voltage	138 kV
System fault level	84 MVA to 765 MVA
Ambient temperature range	-52 to +35 degrees C
SVC rating	8 Mvar inductive to 36 Mvar capacitive (continuously); 8 Mvar inductive to 45 Mvar capacitive (2 minutes).
Control system	Positive sequence voltage control by means of a closed loop regulator.
Thyristor valve	Water cooled, BCT type thyristors, indirect light firing.
MSC	138 kV, 2 x 5 Mvar

2.3.5 Chénier, Canada

SVC to stabilize a large 735 kV transmission system in Canada

In Canada, Hydro-Québec uses a total of eight static variant compensators (SVCs) on its 735 kV broadcast system, delivered by ABB. The 735 kV grid transfers a total of 15,000 MVA of ecologically friendly hydroelectric power through six lines from power plants along La Grande Riviera in James Bay to the Montreal area, approximately 1,000 km to the south.

Contracting year:	2011
Controlled voltage	735 kV

SVC rating	-300/+300 Mvar
Control system	Three-phase voltage control by means of a voltage regulator
Thyristor valves	Water cooled, with indirect light firing
Ambient temperature range	-40°C to +40°

2.3.6 Atlantic steelworks

“SVC for mitigation of flicker from electric arc furnaces”

“A static 0-120 Mvar (capacitive)” Var Compensator (SVC) “supplied by ABB has been in operation” “since 1997 at the Marcial Ucin” Steelworks of the Atlantic (ADA) steel plant in Bayonne, France.

System	SVC
Commissioning year	1997
Controlled voltage	32 kV
Dynamic range	0-120 Mvar capacitive
Control system	“Phase-wise reactive power control by means of fast-acting open-loop controller, plus three-phase closed-loop power factor control”.

2.3.7 AUAS

SVC for mitigation of dynamic constraints on intertie between RSA and Namibia

To cope with a rapidly growing economy and provide a secure supply of electricity to the mining and mining industry in Namibia, a 400 kV 400 km AC transmission system was put into operation in 2000 to interconnect Manpower grids. In Namibia and Eskom in South Africa. .

System	SVC
Commissioning year	2000
Controlled voltage	400 kV
Dynamic range	-250/+180 Mvar
Control system	The Control System (MACH 2) is of fully redundant design.
Thyristor valve	The Auas SVC has an individual cooling system for each TCR valve.

2.3.8 Bang Saphan

"Increased power transmission capacity over AC intertie by improved transient stability by means of SVC"

A static var compensator (SVC) supplied by ABB was commissioned in 1994 in the Bang Saphan 230 kV substation of the Electricity Generating Authority of Thailand (EGAT).

System	SVC
Commissioning year	1994
Controlled	230 kV

voltage	
Dynamic range	50 Mvar inductive to 300 Mvar capacitive
Control system	Three-phase voltage control by means of a voltage regulator. Regulator functions include POD, strategy selection and gain supervision/optimisation.
Thyristor valve	Water-cooled three-phase valves with magnetic firing.

2.3.10 Barnstable

“SVC for Dynamic Voltage Control” and “Prevention of Voltage Collapse on a 115 kV Power Transmission System”

Since 2009, NSTAR Electric & Gas Corporation has operated an ABB-supplied Static Var Compensator (SVC).

System	SVC
Commissioning year	2009
“Controlled voltage”	115 kV
“SVC rating”	**Short-time** (2 seconds): 0-225 Mvar capacitive, continuously variable **Long-time** (6 hours): 0-112.5 Mvar capacitive, continuously variable **For 3 seconds**: 112.5 Mvar inductive (fixed)
“Control system”	“Three-phase symmetrical voltage control by means of a closed loop voltage regulator”

“Thyristor valve”	“PCT type thyristors, water cooled, indirect light firing.”

2.3.9 Birchtree

“SVC for increased hydro power transmission and power quality improvement in northern Manitoba’s 230 kV transmission grid”

System	SVC
Commissioning year	2011
Controlled voltage	230 kV
SVC rating	60 Mvar inductive to 110 Mvar capacitive (-60/+110 Mvar); 60/+165 Mvar for 10 sec every 30 min.
Control scheme	Closed loop, three-phase symmetrical control by means of a voltage regulator; Negative-phase sequence voltage control for flicker reduction
Thyristor valve	PCT and BCT type thyristors, water cooled, indirect light firing

2.3.11 Bonnyville

SVS improves power supply in major industrial area

System	SVC
Commissioning year	1985

Controlled voltage	144 kV
SVC rating	25 Mvar inductive to 25 Mvar capacitive
Control system	Three-phase voltage control by means of a voltage regulator
Thyristor valve	Air-cooled, three-phase valves with magnetic triggering and redundant fans

2.3.12 CERN

SVC for supporting the voltage of a big pulsating capacity

System	SVC
Commissioning year	2002
Controlled voltage	18 kV
SVC rating	20 Mvar inductive to 130 Mvar capacitive
Control system	Three-phase symmetrical voltage control by means of a closed-loop regulator
Thyristor valve	Water cooled, with indirect light triggering

2.3.13 Chester

“SVC to stabilize an AC system connected to a large HVDC interconnection”

System	SVC
Commissioning year	1990
Controlled voltage	345 kV
SVC rating	125 Mvar inductive to 425 Mvar capacitive
Control system	Fully reduntant, three-phase voltage control by means of a voltage regulator. Regulator functions include Supplementary Modulation Control, strategy selection and gain supervision.
Thyristor valve	Water cooled three-phase thyristor valves with magnetic firing.

2.3.14 Chumphon

SVC for voltage control and improvement of stability

System	SVC
Commissioning year	1985
Controlled voltage	115 kV
SVC rating	“20 Mvar (inductive) to 60 Mvar”(capacitive)
Control system	“3-phase voltage control by means of

	a voltage regulator”
Thyristor valve	“Water cooled with outdoor dry type air/water heat exchanger”

2.3.15 Arcelor Mittal

“SVC Light® to maintain power quality in a 110 kV grid feeding a large twin ladle furnace”

System	STATCOM
Commissioning year:	2011
Feeding grid voltage	110 kV, 50 Hz
Furnace bus voltage	30 kV
Rated LF power	45 MVA
SVC Light rating	30 kV, -28 / +52 Mvar
VSC	- 40 MVA; Three-level, neutral point clamped converter; - IGBT based, pulse-width modulated
Control system	- Open-loop, phase-wise dynamic var control; - Closed-loop power factor control

2.3.16 Barking, Singlewell, Sellindge

SVCs for load balancing and trackside voltage control

System	7 SVCs
Commissioning year:	2000-2002

Rated voltage	25 kV/1-phase and 33 kV/3-phase
Rated power	-5/+40 Mvar to -80/+170 Mvar
SVC purposes	Dynamic voltage support and Dynamic load balancing

2.3.17 Oyu Tolgoi

"SVCs for voltage support and stability enhancement in a 220 kV ore mine feeder"

Commissioning year:	2012
Controlled voltage:	220 kV
"SVC rating"	"100 Mvar inductive to 100 Mvar capacitive, continuously variable"
Control system	- "Three-phase symmetrical voltage control by means of a closed loop voltage regulator" - In cases of single-phase line faults, a negative-phase sequence voltage control is activated
Thyristor valves	PCT (Phase Control Thyristors) water cooled, indirect light firing

2.3.18 “Iron ore mine at Malmberget”

“SVC for voltage support, power factor control and power quality improvement”

Commissioning year:	2013
Controlled voltage:	21,5 kV
Dynamic rating:	0-41 Mvar (capacitive), continuously controlled
Harmonic filters:	3rd harmonic / 7 Mvar 7th harmonic / 18 Mvar 13th harmonic / 16 Mvar
Control system:	- Closed loop control, based on power factor control or Mvar control, - Open loop reactive power control
Thyristor valve:	Water cooled, BCT type thyristors, indirect light firing

2.3.19 Gerdau plant in Charlotte, US

SVC Light® for powerful flicker reduction from EAF operation

Commissioning year:	2006
Supply grid voltage:	100 kV
Furnace bus voltage:	13.2 kV
Rated EAF power:	30/33 MVA
Rated LF power:	18 MVA

SVC Light rating:	13.2 kV, 0-64 Mvar (capacitive)
VSC	32 MVA, Three-level, neutral point clamped converter, IGBT based, pulse width modulated.
Control system:	Open-loop, phase-wise dynamic var control, plus closed-loop power factor control.
Flicker reduction factor:	> 5

2.4 Summary

A brief analysis of FACTS applications for optimum power flow and liberalized electricity market was offered. About 200 and 27 research journals have been categorized, discussed and attached for quick reference. For the convenience of readers and broad spectrum, the different applications of the first and second generation of FACTS devices over the past two decades can be reviewed through annotated bibliographies.

CHAPTER 3

ANALYSIS AND SIMULATION

3.1 Introduction

Efficient voltage regulation with the help of the static compensator based voltage regulator VAR has been studied and successfully implemented in a Simulink. The reference voltage is taken as 1.0 pu. The figure below shows the waveforms of voltage Va and current Ia as a function of time across the three-phase transmission line subject to line-to-ground fault. The fault is introduced in a time alternating from .4 ms to .6 ms, then the voltage drops and the current increases suddenly and these are represented in figure 3.1.

3.2 CASE STUDY OF SVC SIMULATION MODEL

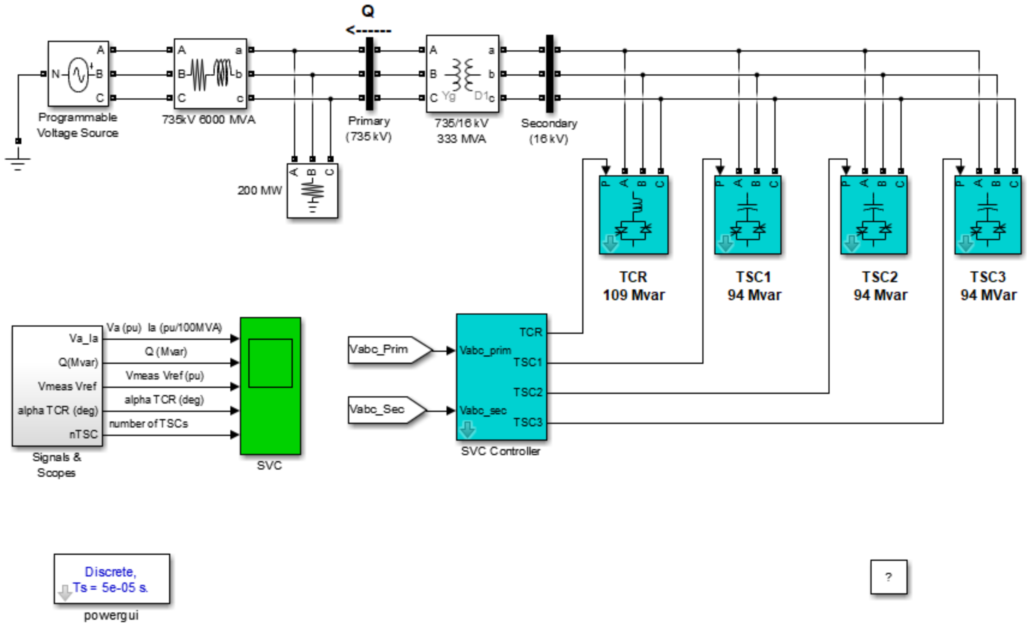


Fig. 3.1: SVC Simulation Model

A 300 Mvar Variable Static Compensator (SVC) normalizes the voltage in a 6000 MVA system at 735 kV. The SVC contains of a 333 MVA 735 kV / 16 kV coupler transformer, “a

109 Mvar thyristor reactor (TCR) bank and three 94 Mvar thyristor capacitor banks (TSC1 TSC2 TSC3) secondary side of the transformer”. The activation and deactivation of the TSCs agrees a distinct disparity of the secondary reactive power from zero to 282 capacitive Mvar (at 16 kV) in steps of 94 Mvar, while the phase control of the TCR allows a continuous variation from zero to 109 Mvar inductive. Taking into account the leakage reactance of the transformer (15%), the SVC equivalent susceptibility seen from the primary side can be continuously varied from -1.04 pu / 100 MVA (fully inductive) to +3.23 pu / 100 Mvar (fully capacitive). The SVC controller displays the primary voltage and sends the suitable pulses to the 24 thyristors (6 thyristors per three-phase bank) to acquire the susceptibility required by the voltage regulator.

Use the search mask below to see how the TCR and TSC subsystems are assembled. Each three-phase bank is delta connected so that, during normal balanced operation, the zero sequence triple harmonics (3rd, 9th ...) remain trapped inside the delta, thus reducing the injection of harmonics into the power system . The power system is signified by an inductive equivalent (short circuit level 6000 MVA) and a load of 200 MW. The internal equivalent voltage can be varied by a programmable source to detect the dynamic response of the SVC to changes in system voltage. Open the voltage source menu and observe the sequence of the programmed voltage phases.

3.3 Dynamic Response of the SVC

Run the simulation and notice the waveforms on the SVC oscilloscope block. The SVC is in voltage control mode and its reference voltage is set to Vref = 1.0 pu. The voltage drop of the regulator is 0.01 pu / 100 VA (0.03 pu / 300 MVA). Therefore, when the duty point of the SVC changes from fully capacitive (+300 Mvar) to fully inductive (-100 Mvar), the voltage of the SVC varies between 1-0.03 = 0.97 pu and 1 + 0, 01 = 1.01 pu.

Primarily, the source voltage is set to “1.004 pu”, resultant in a voltage of 1.0 pu across the “SVC terminals” “when SVC is out of order”. “Since the reference voltage Vref is set to 1.0 pu”, “SVC is initially floating (zero current)”. “This duty point is obtained with TSC1 in service and TCR close to full conduction (alpha = 96 degrees)”. “At t = 0.1 s, the voltage suddenly increases to 1.025 pu”. “The SVC reacts by absorbing reactive power (Q = -95 Mvar)” “to bring the voltage back to 1.01 pu”. “The 95% stabilization time is approximately

135 ms”. “At this point, all TSCs” are out of order and the TCR is exactly completely conductive (alpha = 94 degrees). At t = 0.4 s, the source voltage unexpectedly drops to 0.93 pu. The SVC reacts by generating 256 Mvar of reactive power, so raising the voltage to 0.974 pu. At this point, all three TSCs are in service and the TCR draws almost 40% of their nominal reactive power (alpha = 120 degrees). Observe in the last trace of the oscilloscope how the TSCs turn on and off in sequence. Whenever a TSC is turned on, the alpha angle of the TCR suddenly changes from 180 degrees (no guide) to 90 degrees (full guide). Finally, at t = 0.7 s, the voltage increases to 1.0 pu and the SVC reactive power drops to zero.

3.4 Misfiring of TSC1

When a TSC is turned off, a voltage is trapped across the TSC's capacitors. If you look at the "TSC1 misfire" scope within the "Signals and Scope" subsystem, you can note the TSC1 voltage (first trace) and TSC1 current (second trace) for the AB branch. The voltage across the positive thyristor (positive current conducting thyristor) is shown in the third track and the pulses sent to this thyristor are shown in the fourth track. Note that the positive thyristor trips at the maximum negative TSC voltage, when the valve voltage is minimum. If by mistake the trigger pulse is not sent at the right time, very high overcurrents can be observed in TSC valves.

See inside the SVC controller block how to simulate a misfire on the TSC1. A timer block and an OR block are used to add the pulses to the normal pulses upcoming from the release. Open the Timer lock menu and remove the multiplication factor 100. The timer is now programmed to send a fault pulse lasting a sampling time at instant t = 0.121 s. Restart the simulation. Note that the misfire pulse is sent when the valve voltage is maximum positive instantaneously after the TSC has locked out. This thyristor misfire produces a large thyristor overcurrent (18 kA or 6.5 times the maximum rated current). Also, immediately after the thyristor locks, the thyristor voltage reaches 85 kV (3.8 times the maximum rated voltage). To avoid such overcurrent’s and overvoltage’s, thyristor valves are normally protected by metal oxide lightning rods (not simulated here).

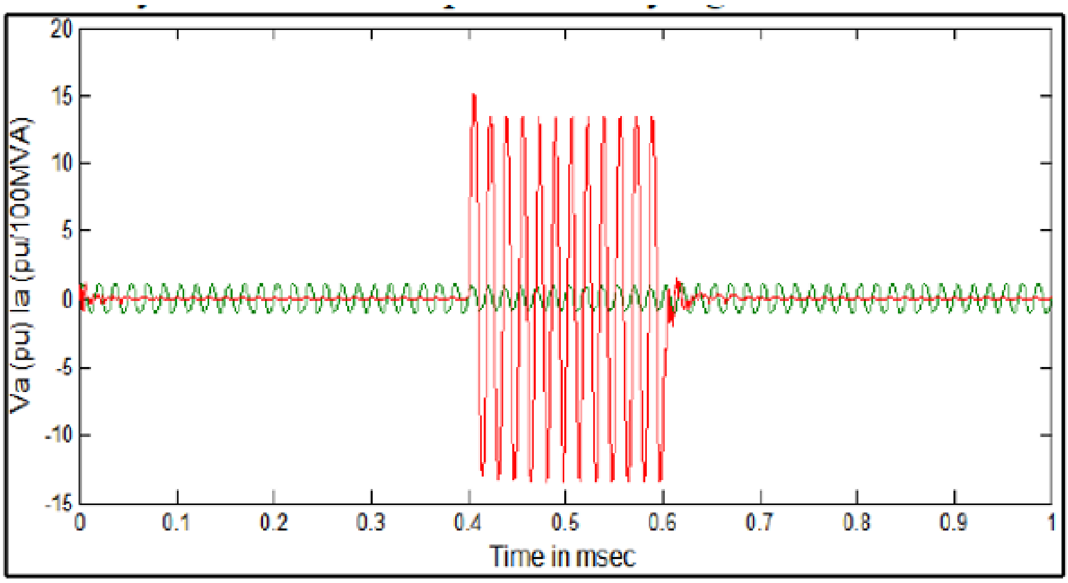


Fig. 3.2: voltage goes down and current increase suddenly

The waveform of reactive power versus time shows here. We can clearly see from the waveform that the system required reactive power from the input source. We can see these changes in the waveform between time intervals from 0.4 msec to 0.65 msec..

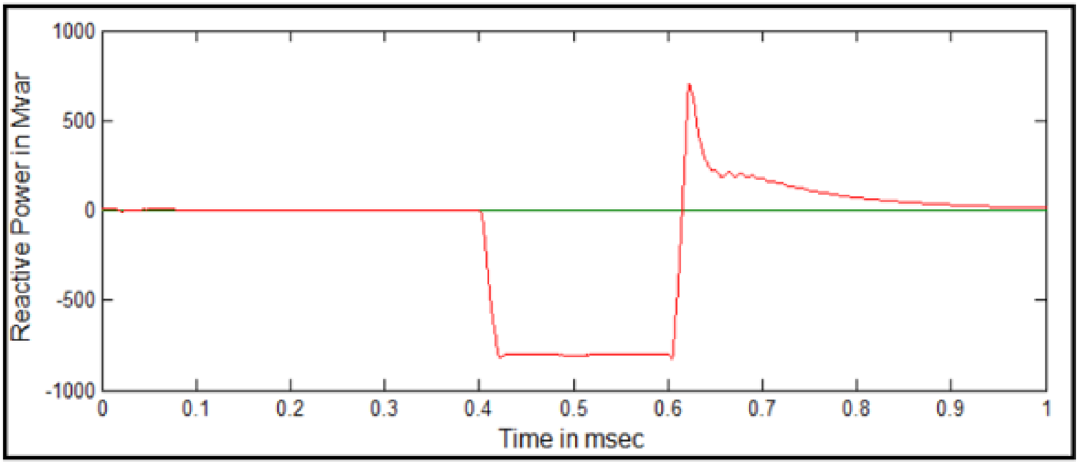


Fig. 3.3: waveform of reactive power verses time

Fig. 3.3 “shows the waveform of the measured voltage Vmea”, “the reference voltage Vref and the time”. “The reference voltage is set to 1.0 pu”. “Under normal operating conditions”, “the measured voltage follows the 1.05pu reference voltage”. “At the moment of failure between t = 0.4 m sec”. “At 0.6m sec”, “the voltage drops after 1.2m sec”. “The SVC control system activates and returns to voltage control from 1.12 pu to 1.0 pu in a time of 1.8

seconds".

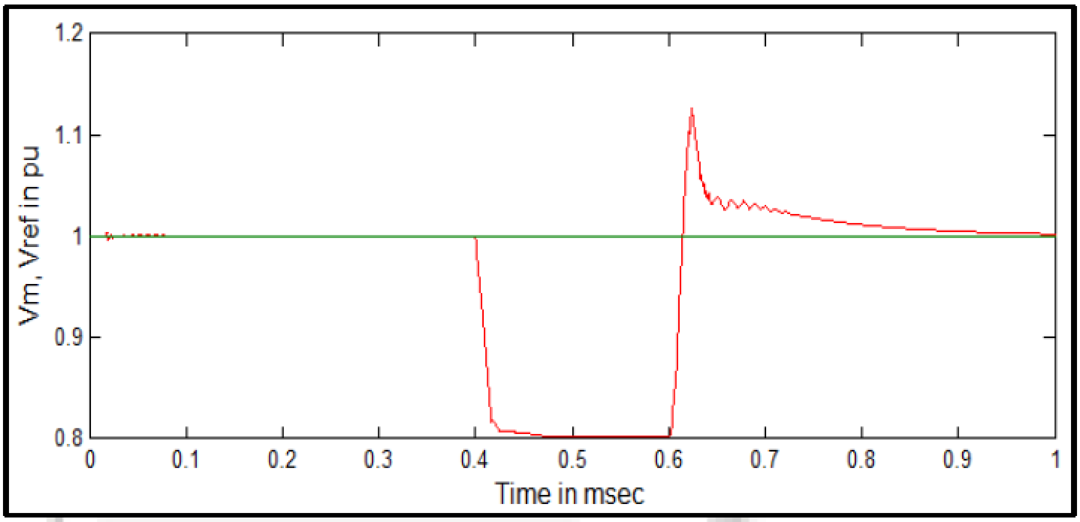


Fig. 3.4: waveform of measured voltage Vmea, reference voltage Vref and time

Fig. 3.4 shows the variation of the TCR firing angle over time. At the time of the failure, the TCR begins to skyrocket to 170 * and eventually reaches 180 * in the unguided region. When the fault occurs at t = 0.4m sec, the TCR starts tripping and generates trip pulses for the TSC. The alpha angle suddenly changes from 90 * to 180 *, which means that a full guide is in a no-guide state. Finally t = 0.65 m sec. The measured voltage value has reached the nominal reference voltage of 1.0 pu and that is the result of SVC for reducing reactive power to zero level.

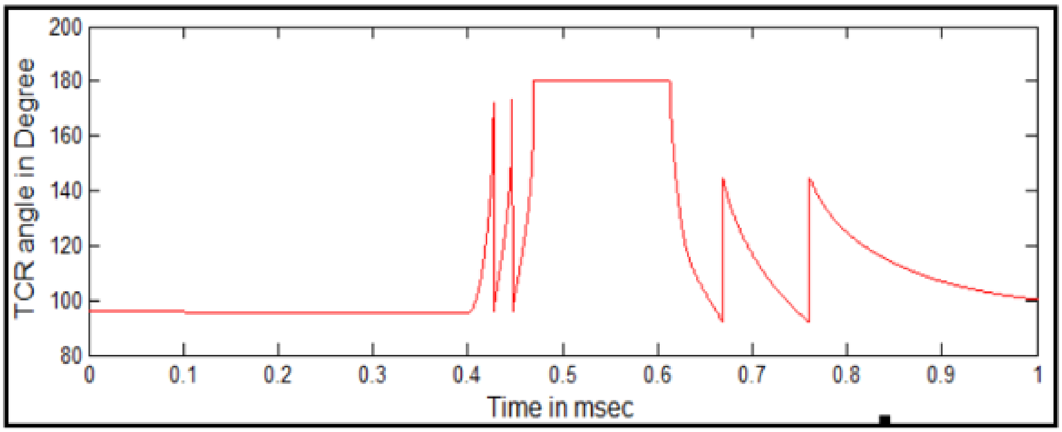


Fig. 3.5: Variation in firing angle of TCR with respect to time

CHAPPTER 4

HARDWARE DEVELOPMENT

4.1 Introduction

This chapter will explain the development of SVC hardware and how the hardware controls it..

4.2 Control and Protection by MACH

SVC controls are established on a high performance platform named MACH. The platform is used in all FACTS and HVDC applications and thus becomes a well-known partner in the power transmission industry. The platform is established on standardized hardware, Windows applications, an easy to use high-level useful programming instrument and undefended boundaries. MACH is designed to be easily accepted. SVC presentation desires are great as sub-cycle act is habitually required. MACH usages an industrialized PC equipped using state-of-the-art indicator processors, influential sufficient to confirm correct switching of SVC thyristors, even for the greatest demanding applications. The computer capability can be simply extended and, equally, the input and output circuits can be modified to be compatible with local situations.

4.2.1 Field Proven Controls Include

- control of negative phase voltage and symmetrical sequence
- adaptive advantage controller
- transient voltage controller approaches
- power alternation hampering algorithms
- corresponding control of other reactive power elements (machine-driven switching capacitors and reactors (MSC, MSR))
- SVC self-test mode

The MACH idea is made with open interfaces. This permits for an well-designed implementation of remote control and interrogation. ABB has developing an internet-based conception for remote control and observation of FACTS fittings, we call it FACTS ON-LINE. This method we will never be far away.

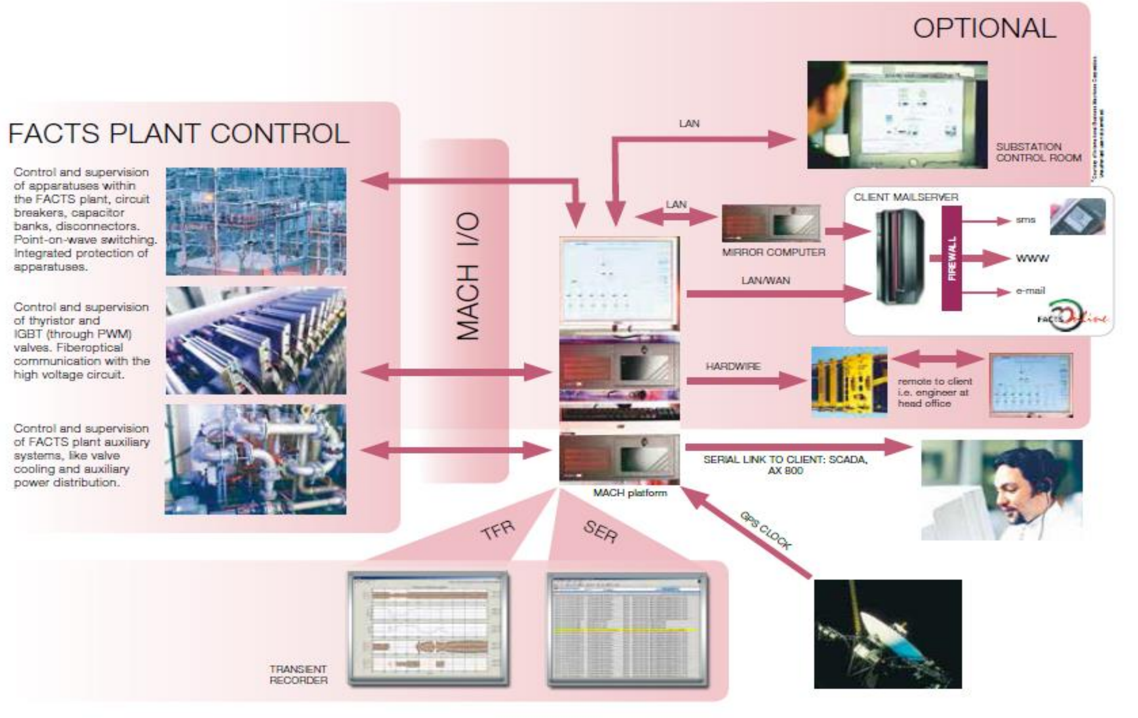


Fig. 4.1: Block Diagram of MACH Control

The FACTS control applications within MACH support a Human Machine Interface (HMI). The HMI uses the hardware platform (dedicated industrial PC), on which easy-to-use databases and information applications are programmed. The client receives thorough, relevant and thorough training, moreover locally or via industry standard communication links. Ever since an SVC is typically unmanned, the goal of HMI is to deliver easiness and accurateness while desired, instead of continually requiring responsiveness. Extensive analytic systems and occasion management abilities ensure that the operative and / or troubleshooting technician always has the accurate and appropriate information. In this method, the SVC will be dependable, available and perform at its greatest in serious positions.

4.2.2 Cooling System

The refrigeration arrangement contains of a closed loop piping circuit wherever a combination of deionized liquid and glycol is impelled through the thyristor valves and the outer water to the air heat exchangers. Here are double circulating water pumps, one is running and the additional is on standby. In the event of a pump miscarriage, an automatic switch to standby unit will start. A little part of the flow passes through a water management circuit wherever the refrigerant is constantly deionized and cleaned. An external thirsty air cooler is used, attached straight to the chief circuit. Low-noise fans are used to reduce sound levels. Every fans are separately controlled to confirm necessary cooling with negligible damages. The cooling arrangement is automatically controlled by the MACH system.

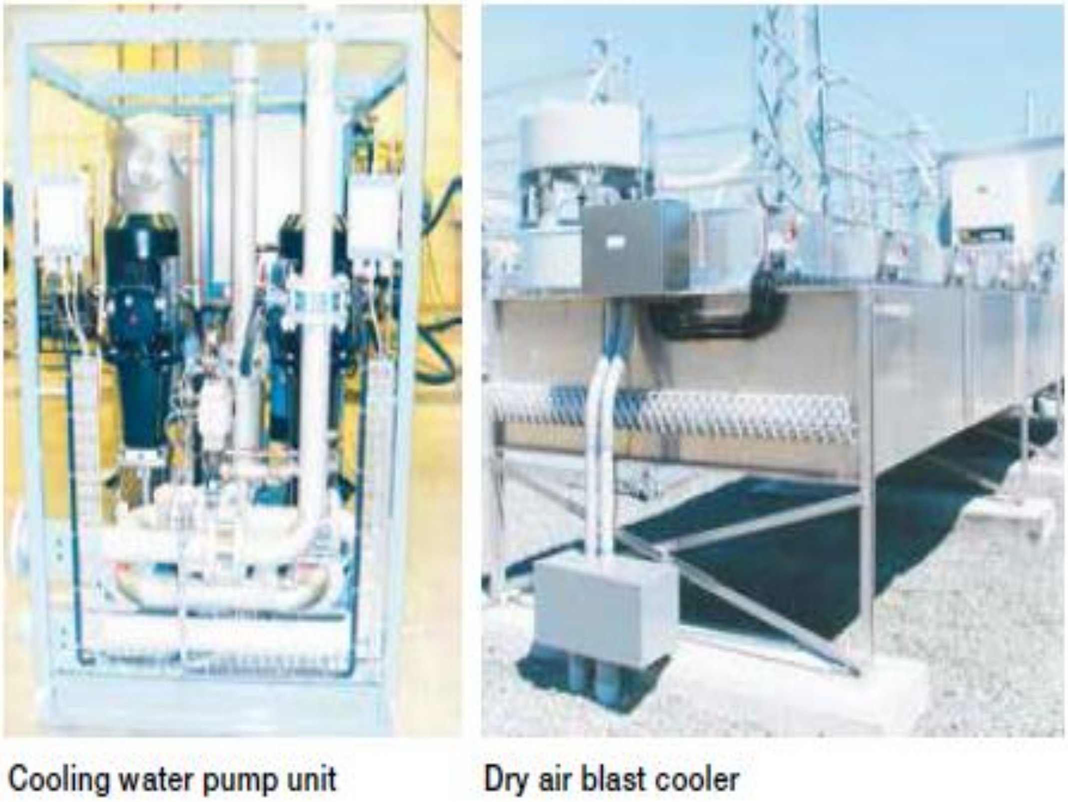


Fig. 4.2: Cooling System

4.2.3 Directly Connected SVC

It is an SVC wherever it is not necessary to connect a step-down transformer among the SVC and the power system. ABB suggest direct connection for system voltages up to 69 kV. This, of course, carries profits to the development of few types:

- An simplified SVC scheme
- Significant savings on hardware costs
- Savings on transport costs, weight and volume
- Space saving on the site
- Savings on system losses
- There is no necessity to handle transformer oil
- Nope risk of fire
- No maintenance costs for transformers
- Cool expansion as transformer power and secondary voltage growth are no problem while adding divisions.
- Smaller lead periods, not affected by the lengthy lead periods of the transformer

Directly connected SVC

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Fig. 4.3: Directly Connected SVC

4.2.4 Shunt Capacitors and Reactors

Fig. 4.4: Shunt capacitors and reactors

4.3 Summary

To enhance controller quickness and stability at varying grid powers. Containing active voltage support during system errors and modification of probable over voltages at fault clearance

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

The system and study of the results gave an indication that SVCs are very suitable while it comes to organizing and maintaining the power system. SVC is the dynamic simulation system where the distribution of the system power flow between the transmission lines can be adjusted quickly and efficiently and there is no important impact on other functioning parameters of the system. At the same time, SVC can improve the stability of the system, to reduce the problem of line unpredictability and sway.

Therefore, it can be finished that SVC will effectively control the dynamic performance of the power supply system and efficiently regulate the system oscillatory turbulences and voltage regulation of the power supply system. The simulations performed authorize that SVC could deliver the necessary fast performing voltage provision to avoid the probability of voltage drop and voltage collapse. This document examines Positive sequence voltage in a system model with or without SVC. This article presents the SVC reactive power (pu) output analysis in reaction to voltage steps. Though, it is well known that these FACTS controllers have the added benefit of being able to control the "fast" oscillations of the system due to their rapid answer. Therefore, by adequately forming these controllers in transient stability programs, it would be stimulating to govern other probable benefits of these controllers in voltage stability educations.

5.2 Limitations of the Work

I read about 55 books to write this book. I wrote this book by collecting data from all the books. Tired of reading books many times, but I keep reading them. Because my goal was to collect data from all the books and write a good quality thesis book.

5.3 Future Scopes of the Work

The variable bypass compensation used by “SVC can be extended to large” sorting “machines and large interconnected feeding systems”. “SVC can also be produced using IGBT and the test can also be performed using DSP”. “TSC-TCR based SVC can also be implemented for the SMSL test system”.

5.3.1 Wind and Railways

For wind energy, SVC helps with a quantity of activities:

— Stabilization of static and dynamic tension

— Continuous control of the power factor

— Allow the overcoming of faults in the wind farm

— Energy quality controller by mitigating the sparkle (affected by the shadow effect of the tower, fluctuating wind and / or starting and stopping the wind turbine); also harmonic reduction and phase imbalance reduction.

For offshore wind generation, complete offshore AC cable networks require elaborate additional control of “reactive power”. “The general scope of reactive power control” “must cover both the wind farm and the marine cables”, “to achieve a well regulated reactive power balance of the entire system, responding to the same reactive power” regulation demands as any other generator of a size to be medium to large. Serve the grill.

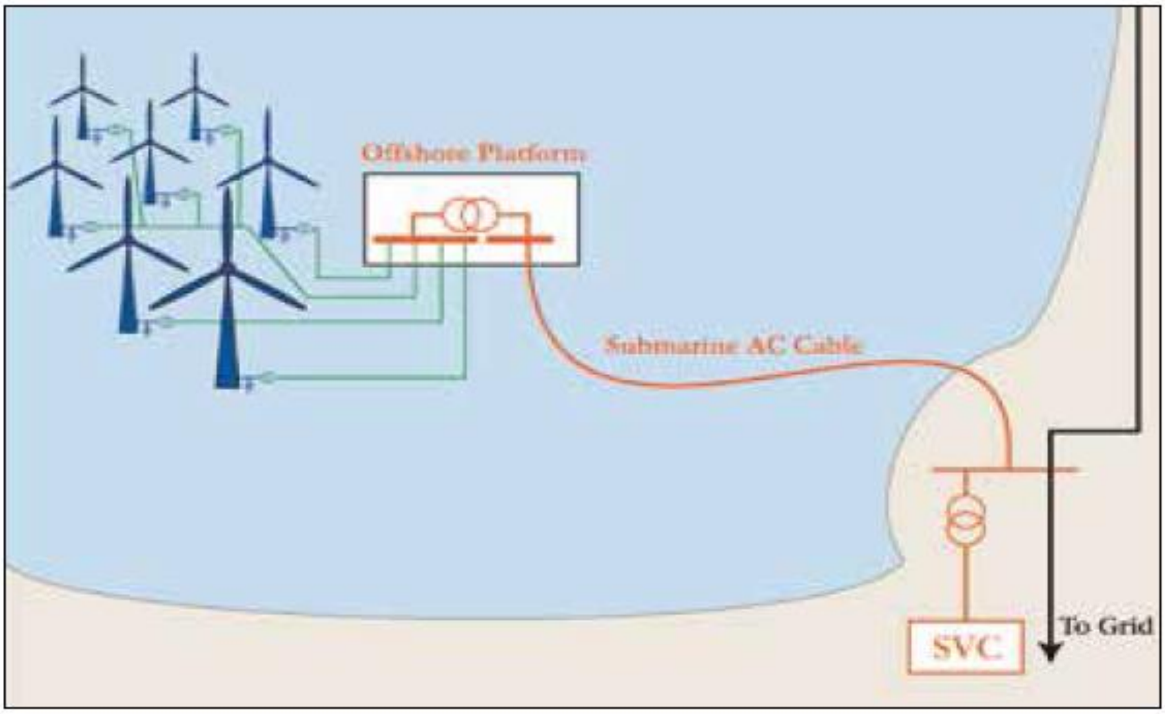

Fig. 5.1: Wind Power

5.3.2 Railways

The growth in traffic on current paths joined with new high-speed rail projects means that rail traction is fast becoming a major burden on electricity supply networks. This, in turn, is focusing a lot of consideration on the productivity of the catenary, as well as on the energy superiority of the surrounding networks. Trains taking power from the catenary must ensure that supply voltages are steady and will not sag. Voltage and current disparities among phases of three-phase AC power systems must also be limited in amplitude and prevent them from propagating through the grid to other parts of the system. In addition, voltage fluctuations and harmonics must be controlled so that they remain within the established limits. This is where SVC comes in.

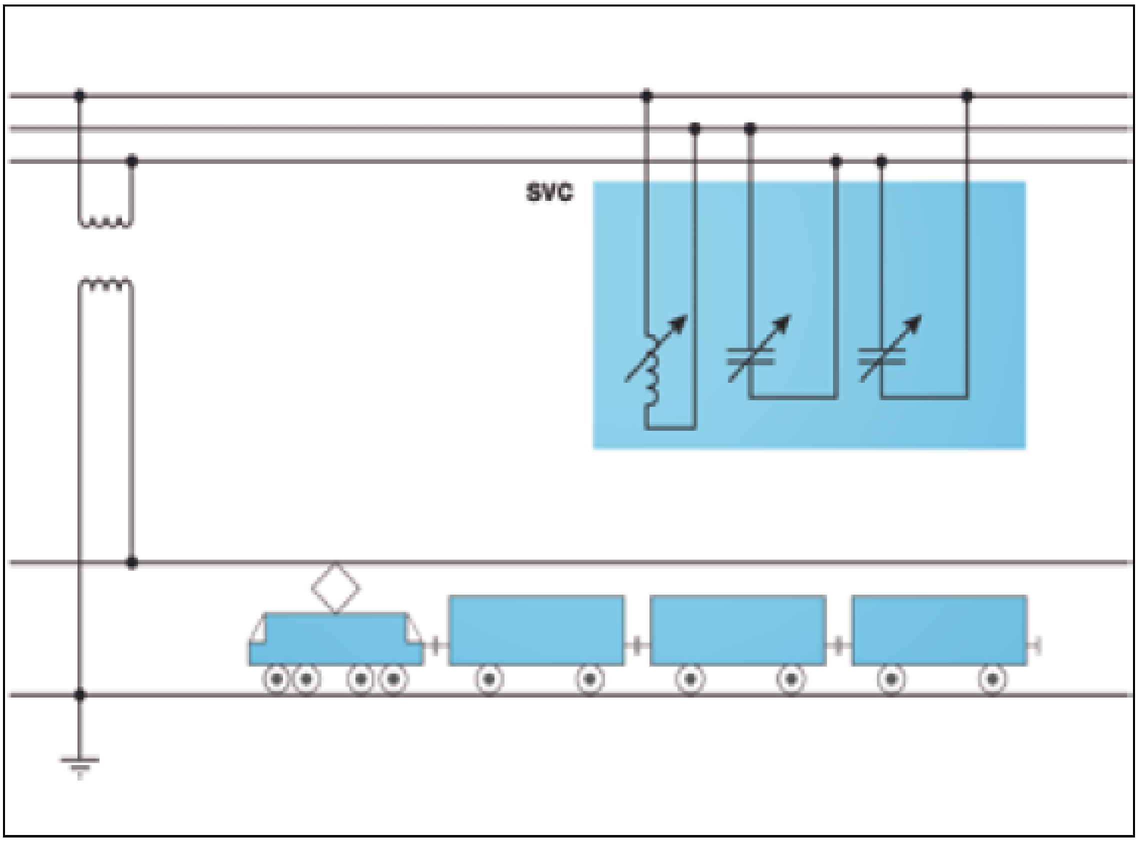

Fig. 5.2: Railways

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