T.C.
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DEPARTMENT OF ELECTRICAL ELECTRONIC AND
COMPUTER ENGINEERING

IMPROVED RESPONSE OF POWER SYSTEM PROTECTION BASED FACTS CONTROLLER

MASTER OF SCIENCE THESIS

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SUPERVISOR
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Aksaray University, Institute Of Science And Technology Approval **Abdulwadood Sameer A. MAGED**, M.Sc. with thesis student No 172335801, successfully presented the M.Sc. thesis titled "**IMPROVED RESPONSE OF POWER SYSTEM PROTECTION BASED FACTS CONTROLLER**", prepared after satisfying all the requirements identified in the concerned bylaws, before the jury whose signatures are affixed below.

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DECLARATION

The idea for the current thesis was taken from the literature grading the topics. It was pronounced here that his all work presented in this study has been collected and originated by myself unless so their wise specified. The study was conducted totally under the supervision of Assist. Prof. Dr. Yusuf Erkan YENİCE

Abdulwadood Sameer A. MAGED

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GÜÇ SİSTEMİ KORUNMASI TABANLI FACTS KONTOLÖRLERİNİN GELİŞMİŞ TEPKİSİ

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ÖZET

Esnek Alternatif Akım İletim Sistemleri (FACTS) kontrolörleri esasen farklı güç sistemlerinin kararlı durumlarının belirlenmesi, voltaj geliştirilmesi ve Sistem koruma performansı amacıyla kullanılmaktadır. FACTS kontrolörleri elektriksel güç sistemlerinde kullanılmaya uygun olması bakımından avantajlıdır. Buçalışmada, FACTS kontrolörlerinin etkisi araştırılmaktadır. Bu kapsamda, ikili şebeke sistemi altı yollu olarak tasarlanmış, ilk devrede iki indirici transformatör (132/33kV, 66/33kV) bulunmaktadır. Voltaj profilini, açıyı, etkin gücü ve şebeke yollarının reaktif gücünü geliştirmek amacıyla şebekenin farklı noktalarına SVC kontrolü ve eşzamanlı dengeleyici eklenecektir. Bu çalışmada dengeleyici eklendikten sonra ve (0.20) p.u endüktif reaktans ve (0.50, 0.60, ve 0.70) p.u kapasitif reaktans öncesinde SVC değişkenlerinin yol-3, yol-5, ve yol-6'ya eklenmek üzere üç durumda sonuçlar elde edilmiştir. Devredeki üretimin ve güç kaybının belirlenmesi amacıyla devrenin yük değerleri değiştirilmiştir. İkinci devrede (132/33kV) 1 TCR/3TSC ile SVC Simulink modeli kullanılacak ve SVC eklenmesinden öncesinde ve sonrasında voltaj, akım ve reaktif gücün dalga biçimi çıktıları gözlemlenecek ve üç aşamalı deneyin etkileri değerlendirilecektir. Bu sayede güç transferi iletim hattının geliştirilmesi beklenmektedir. Sonuçlar Power System Analysis Toolbox (PSAT) ve MATLAB programları ile değerlendirilecektir.

Anahtar Kelimeler: Güç sistemi korunmasu, FACTS, Statik var kompanzatörü (SVC), Statik senkron kompanzatör, Güç akışı.

Ocak, 2020; 45 Sayfa

M.Sc. THESIS

IMPROVED RESPONSE OF POWER SYSTEM PROTECTION BASED FACTS CONTROLLER

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ABSTRACT

The Flexible AC Transmission System (FACTS) controllers have been essentially utilized for determining different power systems steady-state, voltage improvement and performance of system protection. The features and advantages of the FACTS controllers it is suitable and necessary to be applied in the electrical power system. In this thesis, the influence of FACTS controllers will be investigated therefore tow grid system will be designed with (six-buses), the first circuit has tow step-down transformer (132/33kV, 66/33kV), the SVC control and static synchronous compensator will be added to different location of grid, such as (bus-3, bus-5, and bus-6) to improve the voltage profile, angle, real power and reactive power of grid buses in power flow circuit. This study presents the effect of three cases after adding compensator and before of indictive reactance (0.20) p.u and capacitive reactance (0.50, 0.60 and 0.70) p.u on results of state variable of SVC by added to (bus-3, bus-5, and bus-6). The load values of the circuit will be changed gradually to determine generation and loss of power. The second circuit (132/33kV) will be using SVC Simulink modal with 1 TCR/3TSC, to demonstrate waveform output of voltage, current, reactive power before and after adding SVC and see the effect of three-phase of fault among lines and ground also we can say action of protection that will improve the power transfer throw transmission line. The results will be evaluated by Power System Analysis Toolbox (PSAT) also MATLAB program.

Keywords: Power system protection, FACTS, Static var compensator (SVC), Static synchronous compensator, Power flow.

January, 2020; 45 pages

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LIST OF ABBREVIATIONS

EF RELAY	Earth Fault Protection Relay
FACTS	Flexible ac transmission systems
FC	Fixed connected capacitor
OC RELAY	Over current protection relay
PSAT	Power system analysis toolbox
STATCOM	Static synchronous compensator (controller)
SVC	Static var compensator
TCR	Thyristor controlled reactor
TSC	Thyristor switched capacitor
VAR	Reactive power
VSC	Voltage source converter

1. INTRODUCTION

The power system peotection is acknowledged as the first line of defense in protecting the system from any distortion or an obstruction. It is very significant to clear up the performance of protection systems for dissimilar operating circumstances and system arrangements to keep the system running for a longer period without any troubles (Albasri et al., 2006; Bailey, 2012).

FACTS technology is major to relieve some problems in the transmission system such as speed control of the electrical system and power transportability (Narain and Hingorani, 1999). FACTS controllers are widely applying for power system protection in these modern years to preserve the transmission line Since the shunt compensator FACTS Controllers (SVC&STATCOM) become from the better controllers because of their quick response time. The fault when evaluating the effect on the O/C and EF relay measurements (El-Arroudi et al., 2002). It is very necessary to learn the reaction of performance to getting the steady-state solution of full power networks. It is only through the study of the power flow and is done during the devising of a new system or the extension of a present system. In the power system, power flows from generation stations to load stations. In this method, research is needed in thoughts to bus voltages and the quantity of power flow over transmission lines (Kim et al., 2007). Static synchronous compensator and SVC can improve the transmittable power, control the voltage and improve power stability along the transmission line if the shunt compensator instilled at the mid-point, the protection of the transmission line will be improved (Khederzadeh and Ghorbani, 2011; Singh et al., 2015; Patel et al., 2018). In this study, the fanaticism in the system is fluctuating and the voltage at a low level, for this reason, we connected SVC also static synchronous compensator to different many nodes in grid system, which will handle the low level of voltage, the capacitors of controllers such as SVC in simulink grid or synchronous compensator on power flow circuit will produce the reactive power (capacitive mode) and the system will be closed to-rated voltages and the reactive power also will be absorbed (inductive mode). The quantity of reactive power in the power system voltage becomes more stable and the power transferred will be better so the transmission line system is protected (Khederzadeh and Ghorbani, 2011; Ghorbani et al., 2012).

The radial line and ground-phase faults are made in the simulink grid depending on the conditions. In this thesis we study the adding of the shunt FACTS controller such as SVC control at mid-point of the transmission line, the regulation of voltage control is improved in the power system, besides that the loss values of power transmitted across lines reduced (Gyugyi, 1979). The SVC has been implemented on the power flow circuit to study SVC variable state such as (Alpha- Vm -Vref-Q) with three cases fixing inductive reactance at 0.20 p.u and changing capacitive reactance such as (0.50 p.u, 0.60 p.u, 0.70 p.u) have been applied in three buses (bus-3, bus-5, and bus-6) have been evaluated in six buses of electricity network (132/33, 66/33KV). Additional to that, the SVC has been implemented in simulink grid system with Three-phase fault between lines and ground also have been evaluated in (six) buses grid system (132/33).

1.1 Problem of Thesis

With the growing demand for electricity, the new generation has to be improved. Many new production sources, particularly the power sources are located away from centers of the load and hence, long transmission lines and cables with large transmission capacity necessary to connect the generation, and the load centers, the power-electronic regulators, such as (SVC) controller and (static synchronous compensator) which develop the value power transmitted by adding more of their capacity, the mechanical compensators use control devices such as compensators with a mechanical exchange that has been used to improve dynamic and static stability limits. Nevertheless, these controllers are not receptive, besides that they have numerous problems. In demand to avoid these problems, these issues have been investigated by the FACTS devices and static synchronous compensator and taken into control the power system due to the reliable and fast response organization and control in a wide range of parameter mechanisms to ensure the protection of the power system and reliability through suitable control aims as well to rise. Oscillation of the power, unimproving the reactive power in the system and the variable state of SVC in a designed power flow circuit, will be studied, etc.

1.2 Research Objective

1. Study the behavior of a practical test case from 132/33 kV power grid.
2. To develop an integrated control strategy based on the place of the FACTS family controller (SVC).
3. To enhance voltage regulation, active & reactive power and voltage & current, the power oscillation will be damped.
4. SVC controller and static synchronous compensator characteristics are investigated and simulated for different power circuits such as the IEEE-6 circuit, applying power flow; also SVC simulink is related to the number of capacitance values TCR, TSC, effect**,** Q (Mvar) with real power, voltages, and current.

1.3 Outcome of Thesis

Generally speaking, the outcomes of the present project are:

1. Using advanced techniques we can rise and gain good protection of the power system and the power oscillation will be damped.
2. Developing the FACTS controlling system based on stade-state and protecting the system.
3. Growing the dip voltage and efficiency of working of the power systems.
4. Improving the shunt action of the FACTS controller to enhance the voltage stability of IEEE-6 in the power flow system has been examined.

1.4 Thesis Outline

This thesis is arranged into five parts:

1) Chapter 1: Introduction to power system protection and an introduction to static synchronous compensator and FACTS family such as SVC controller.
2) Chapter 2: Literature Review of using FACTS controllers in power system protection.
3) Chapter 3: Methodology of the thesis, a short review of general compensation of FACTS controller, and shunt controllers such as SVC & static synchronous compensator, and the grid system; power flow circuit and SVC simulink will be described.

4) Chapter 4: The simulation results that realized are approved in the power system grid (IEEE-6 bus) by power flow and simulink.
5) Chapter 5: Conclusion of this study.

2. LITERATURE REVIEW

Many researchers have studied and developed the FACTS controller's properties. Improved the models of FACTS depending on their uses, applications, structures, and methods of connecting them to the network.

2.1 Related Work

In the past years, the growth and transfer of power generation have been severely restricted, as there was no need to build and develop plants and the transportation system was expanded because the population density of cities is not high. After that, the demand for energy has increased significantly. As a result, some transport lines are loaded intensively, leading to problems such as controlling the flow of energy in the network (Mohanty and Barik, 2011; Abdulrazzaq et al., 2014). The traditional control units, such as alternators, tap changer, alternators or mechanical switches, which have previously played a role in improving and regulating the flow of energy.

However, these controllers as mentioned above do not have a quick response and have a lot of disadvantages (Momoh et al., 2001). The FACTS notion has displayed the number of new techniques and approaches to address the stability of the power system (Hingorani, 1993). The SVC considered one of the older and better controllers from the FACTS family was introduced in the year1970 and the first fit was created in the City of Nebraska by General Electric Company. More than 800 SVCs with power ratings starting from 60 to 600 MVAR have been erected by electrical facilities until now. ABB has offered about 55% of the SVC market, with 3% in Asian, the SVC implemented for power quality in intelligent grids with renewable energy systems shown in (Gandoman et al., 2018).

The compares of benefits and limitations of the currently possible and most generally used shunt-compensation devices among capacitor shunt compensation and FACTS controllers like SVC for static voltage stability enhancement and different performance, measures are examined under various operating system circumstances for the IEEE 14 bus analysis system was reviewed in (Sode and Mithulananthan, 2004). However, what shunt capacitors suffer from problems of weakness and damage in the effort and unlike a certain level of compensation, cannot achieve a stable operating point. Moreover, the interactive power given by the conversion

Capacitor is proportional to the terminal voltage box; as lowering voltage conditions, VAR support loses, many problems occurred when applying SVC to improve voltage stability, choosing the right size when applying is an important problem. The single line diagram of the IEEE 14 bus as shown in Figure 2.1.

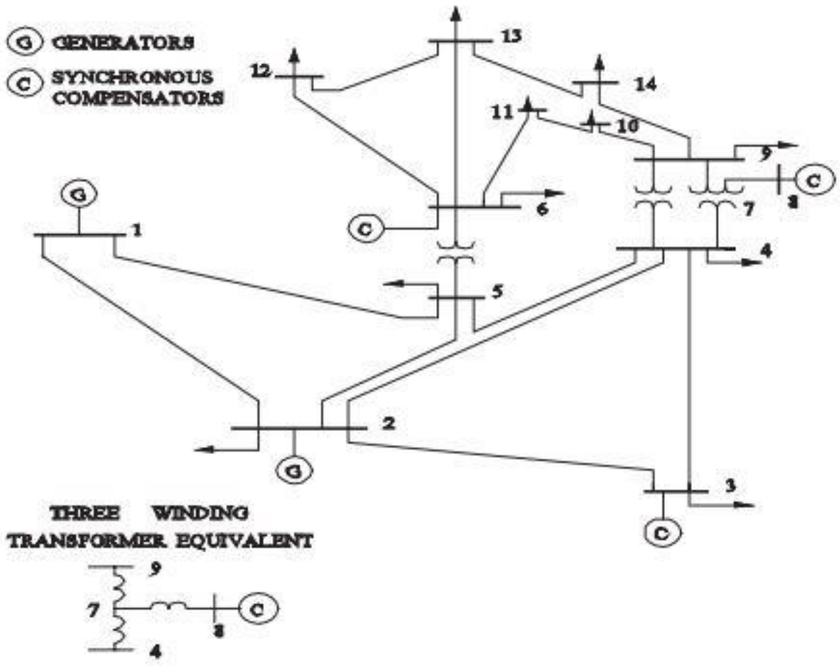


Figure 2.1. Single line diagram of the IEEE 14 bus.

The weakest bus is the one who suffers from instability in the voltage and from this condition we can draw the best place to add the compensators to regulate and improve the values of voltage.

The distance protection performance is evaluated to control the voltage when the FACTS was added to the middle of the transmission line of the system, the effect of FACTS on the transmission line distance protection were calculated for various fault types, fault locations, and system conditions, the grid lines as presented in Figure 2.2 so the SVC effect on the system is examined in enhancing the voltage and decreasing the loss and reducing the time operating relay when the fault current occurred in the buses (Albasri et al., 2006).

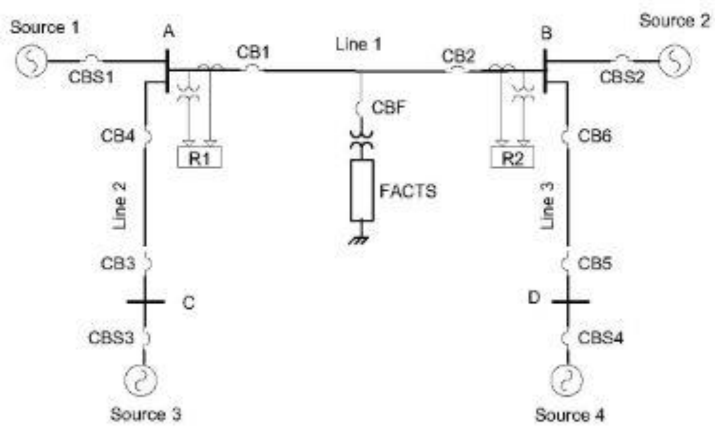


Figure 2.2. Single line diagram of the system with distance relay.

By applying 4 bus and the distance relay protection employed with SVC the real-time dynamic simulation was studied and the SVC impact is seen before and after adding (Albasri et al., 2006). By the transmission line distance relay the effect of 48-pulse SVC on the apparent impedance has been regarded. The dissimilar power system operating circumstances, the settings of control system and scenarios of fault were investigated in (Khederzadeh and Ghorbani, 2011). The implications of considering the real line model on the power transferability and stability when the shunt FACTS device is joined to the line. An effort was made to discover the optimal positioning for locating the FACTS device in case of a 5-bus system to estimate voltage stability and power flow angle features for both the clear and actual model was achieved in (Kowsalya et al., 2009). The time of the relay using multi-agent was improved (Shalash and Ahmad, 2013). This is considered new reliability in the protection of the energy system, that the multi-agent system consists of two factors, the first factor of the current line, i.e., determining the current line at all points of the system after and before the run. While the second factor to regulate the run time of the relay before and after the modification of the current defect of the system of the Iraqi national network (132) kV. Via power flow, the IEEE-6 bus system is explored. First work for the load change on the weakest bus achieved without the SVC and the breakdown point for the same is been determined, then the second work breakdown point var at the load side is raised by 5%, 10% and so on in steps of 5% up to 30%. The load flow solution is being taken out by the Newton-Raphson method (Singh and Kashiv, 2015).

3. COMPENSATORS AND DESIGN OF POWER SYSTEM CIRCUITS

In this chapter of our thesis, we will talk about the FACTS controllers types and we will explain SVC controller and design two circuits to prove and analyze the outcome of static synchronous compensator also SVC work, starting with the selection of static synchronous compensator and how to change the effect of adding compensators on a different location (buses) in power flow grid system, and SVC, as well as the considerations for (TCR), (TSC). Finally, SVC (detailed modal) that will be used in the thesis.

3.1 General Compensation of Facts Controller

FACTS compensate reactive power for regulating the voltage and make it near to-rated system voltage, so its two way depends on the method of connecting the capacitor in the circuit: series and shunt compensation, the FACTS shunt compensation method will be applying in this thesis project by adding SVC control to the busses of our grid system.

3.1.1 Series compensation and objectives

The capacitor is in the series situation to provide the required power to power lines. In the controlling the selection transmitted power which, at a defined transmission voltage. Circuit, and phasor diagram before adding series compensators as presented in Figure 3.1 the series compensation is more effective is permanently instigated by the series line impedance and the angle between the end voltages of line (Narain and Hingorani, 1999).

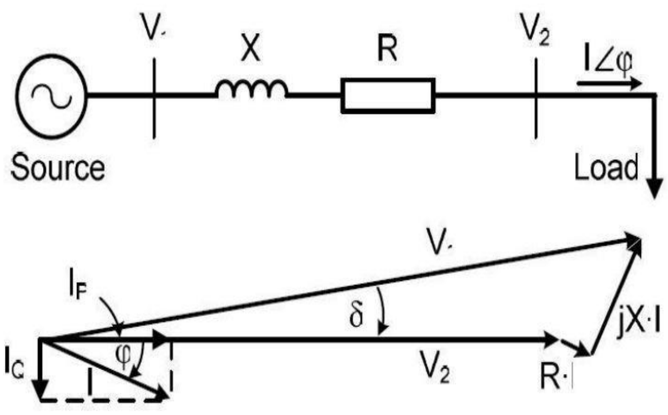


Figure 3.1. Circuit and Phasor Diagram before adding series compensators.

It was always acknowledged that ac power transmission over long lines was mainly restricted by the series reactive impedance of the line. In years ago the series capacitive compensation was presented to eliminated apart of the reactive line impedance and consequently increase the transmittable power (Narain and Hingorani, 1999). The circuit and phasor diagram after adding a series compensator as displayed in Figure 3.2.

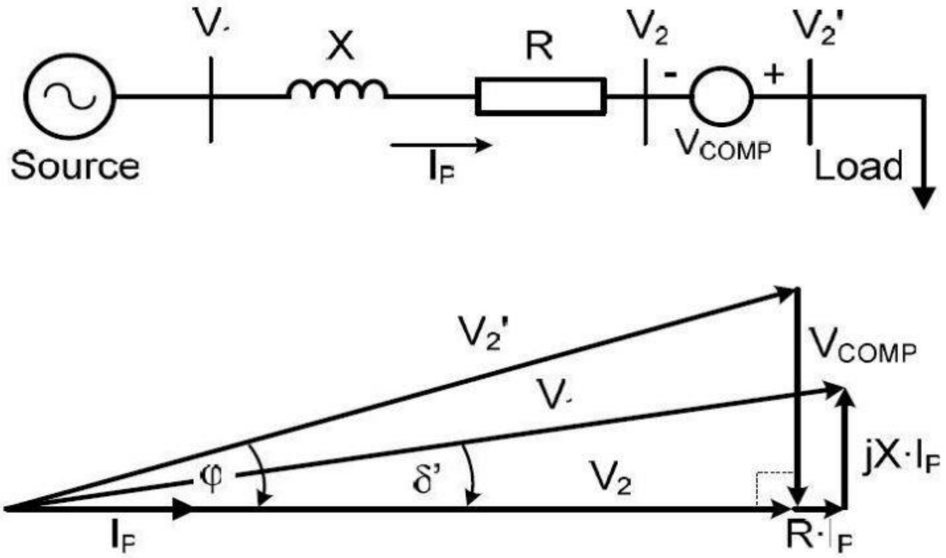


Figure 3.2. Circuit and Phasor Diagram after adding series compensators.

3.1.2 Shunt compensation and objectives

The capacitors are connected in a shunt situation when the power required to be produced to the power line, besides that its behavior like a condenser. This way of compensation to control the parameters under to submit enhanced reactive power compensation.

The circuit and phasor diagram before adding shunt compensators as shown in Figure 3.3 the aim of this reactive compensation is to change the natural electrical properties of the transmission line to make it more conformity with the prevailing load demand. A mainly shunt compensation is employed nowadays in FACTS devices (Narain and Hingorani, 1999; Desai and Arya, 2018).

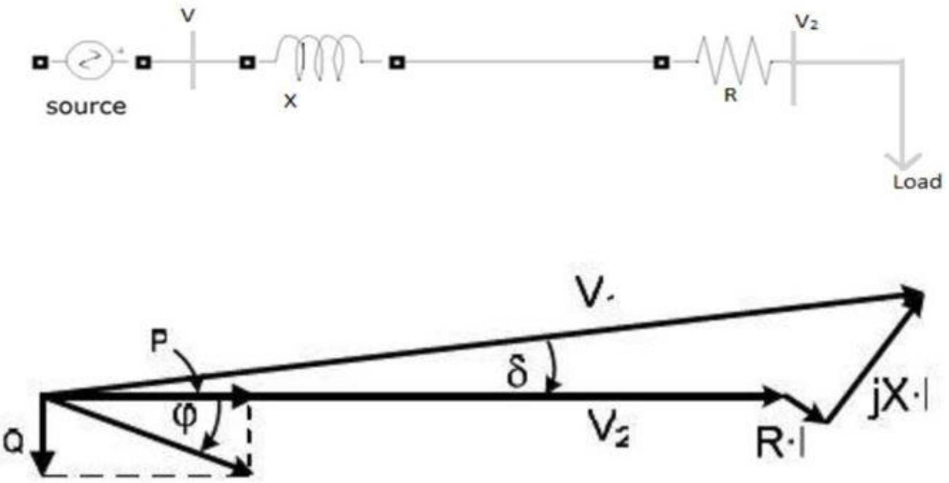


Figure 3.3. Circuit and Phasor Diagram before adding shunt Compensators.

The circuit and phasor diagram after adding shunt compensators as shown in Figure 3.4 the final purpose of implementing reactive shunt compensation in a transmission system is to grow the transmittable power VAR compensation is there for utilized the voltage organization at the midpoint to section the transmission line and at the end of the (radial) line to block voltage instability (Narain and Hingorani, 1999).

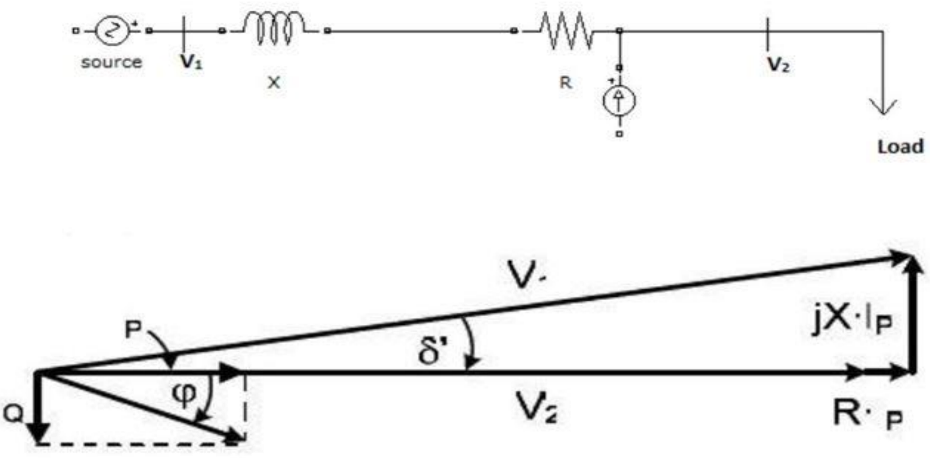


Figure 3.4. Circuit and Phasor Diagram after adding shunt compensators (Desai and Arya, 2018).

3.2 Classification of Facts Controllers

In common, FACTS controllers could be categorized to the series controller, shunt controllers, combined series-series shunt controllers, and combined series-shunt shunt controllers, that is according to the method in which it is linked to the power system.

3.2.1 Series controllers

Even variable impedance doubled by the current flow through it, the series controllers are presented in Figure 3.5 provide voltage in series with the line (Narain and Hingorani, 1999).

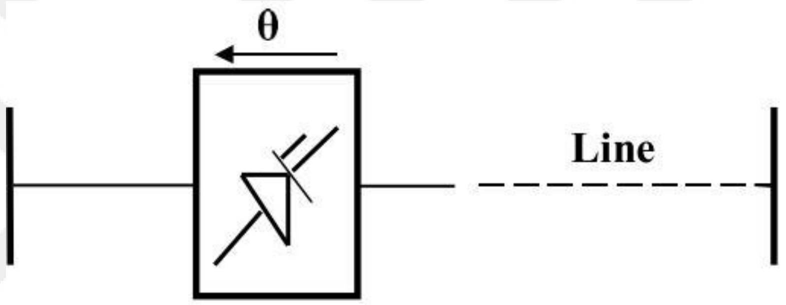


Figure 3.5. Series controllers (Khatoon and Shaik, 2017).

3.2.2 Shunt controllers

Even variable shunt impedance connected to the line voltage causes a variable current flow. The shunt controllers as shown in Figure 3.6 provide current into the system at the point of connection (Narain and Hingorani, 1999).

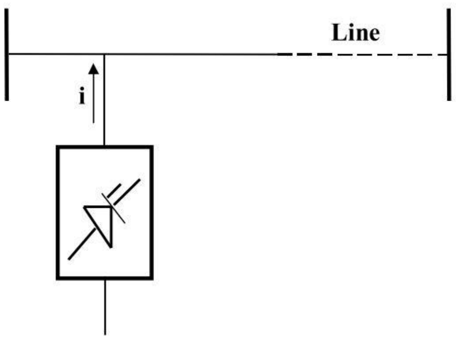


Figure 3.6. Shunt controllers (Khatoon and Shaik, 2017).

3.2.3 Combined series-series controller

The capability of the real power transfer of the standard series-series controller, indicated to as interline power flow controller, makes it enabled to balance each of the real and reactive power flow in the lines and therefore optimize the exploitation of the transmission system (Narain and Hingorani, 1999; Khatoon and Shaik, 2017). The combined series-series controller as shown in Figure 3.7.

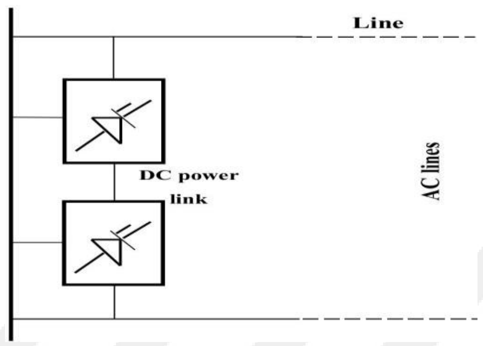


Figure 3.7. Combined series-series controller (Khatoon and Shaik, 2017).

3.2.4 Combined series-shunt controller

The combined shunt and series controllers provide current into the system with the shunt part of the Controller and voltage in series in the line with the series part of the controller (Narain and Hingorani, 1999). The combined series-series controller as shown in Figure 3.8.

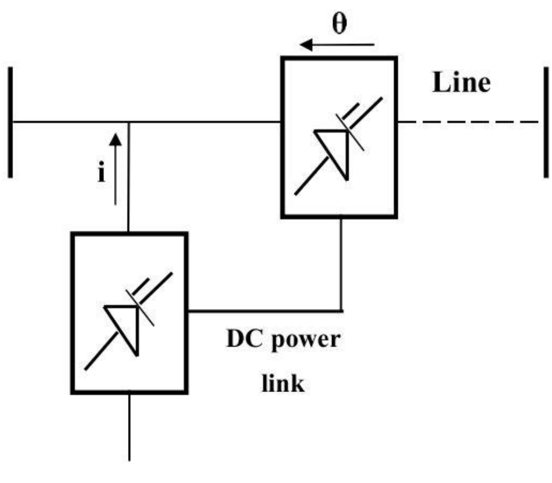


Figure 3.8. Combined series-shunt controller (Narain and Hingorani, 1999).

3.2.5 Variable impedance and voltage source converter (VSC).

As a result of their advantages and characteristics in the development and improvement of the transferred power in the electric power system, the SVC will be selected to study in this thesis (Khatoon and Shaik, 2017; Patel et al., 2018).

3.3 Analysis of Static Var Compensator (SVC) Controller

It is basically a shunt device contain from a fixed capacitor beside a thyristor controlled reactor and the thyristor-switched capacitor and filter (Hammad, et al., 1986). The TCR is typically bigger than the TSC parts that persistent control is achieved. The most important thing is to choose the right place in the network**,** so that the role is clear and useful in limiting the loss and improve the voltage on the network and raise the energy transmitted through the lines, preferably connecting at the center point of the trans feminine to be effective role (Khederzadeh and Ghorbani, 2011).

The TSC generates VAR when the voltage is disintegrated, trying to reach the system voltage to the reference system voltage (rated voltage). When the voltage is has grown to maximum voltage, the TCR absorbs excess voltage and returns it to the rated voltage (Patel et al., 2018; Noroozian et al., 2003). The configuration of a static var compensator as shown in Figure 3.9.

The configuration of the SVC controller are:

1) Fixed Capacitor
2) Thyristor Controlled Reactor (TCR)
3) Thyristor Switched Capacitor (TSC)

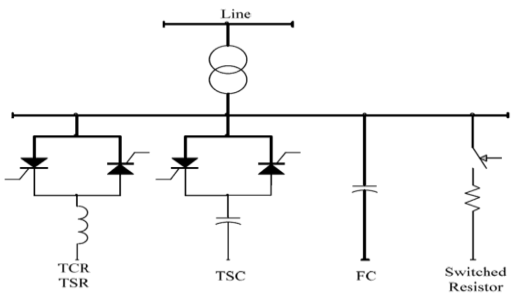


Figure 3.9. Structure of the SVC controller (Patel et al., 2018).

3.3.1 Fixed capacitor

It is common to find fixed shunt capacitors in parallel with controlled susceptance. The FC is very often tuned with small reactors to harmonic frequencies which may be of integer or nonintegrated order. The reason for the tuning is to absorb harmonics generated by controlled susceptance (TCR) or to avoid troublesome resonance. The (FC) sometimes connecting on the side of the high voltage from the transformer or they share with a medium-voltage compensator bus with the control element.

3.3.2 Thyristor controlled reactor (TCR)

The elementary of TCR as shown in Figure 3.10 the thyristor controller is the controlling element shown as two reversed poled thyristors which take place on gated alternate half-cycles of the supply frequency.

Completely connection outcome in the reactor if the thyristors are tabbed to connection accurately at the peaks of the voltage, beside that the current with the thyristor controller was short-circuited, the current is basically reactive, lag behind the voltage by approximately 90 degree, includes little in phase composed because of the missing power in the rector, that probably of the demand of 0.5-2% of the VAR (Miller, 1982).

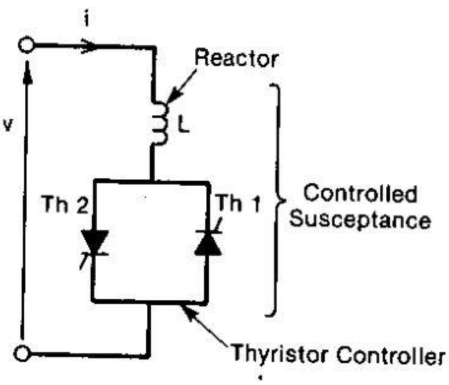


Figure 3.10. Elementary thyristor -Thyristor Controlled Reactor (TCR).

The impact of TCR compensator on operating point as shown in Figure 3.11 the TCR gets the wavelength of the case if the pulse has been delayed in equal quantities on both the thyristor. A router produced from TCR corresponds to a specific value of the pulse angle measured by zero voltage junction. The full conductivity is obtained with the spring angle 90. Also, between the 90 and 180 angles, partial conduction is achieved. The basic harmonic component of the current is diminished by improving the pulsating angle. This is equivalent to increasing the inductance of the reactor, thus limiting its interactive power as well as current. As far as the primary component of the current is disturbed, the reactor controlled by the thyristor is controllable and therefore applied as a fixed compensator (Miller, 1982).

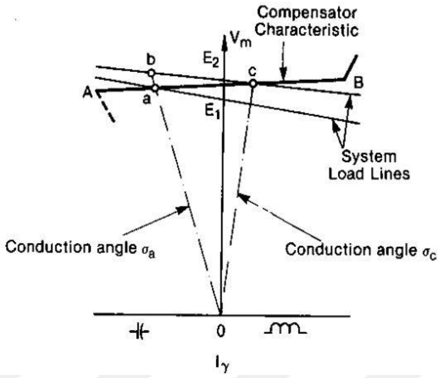


Figure 3.11. Effect of TCR compensator on the operating point.

3.3.3 Thyristor switched capacitor (TSC)

The TSC includes a control system that observers the voltage as shown in Figure 3.12 when the voltage deflects from the required value by some previously fault (dead band) in other trends, the control switched in or out once or more than bank even the voltage goes back inside the dead band assuming a TSC with zero one, or two capacitor banks, operating point a would prevail with normal conditions would drop to stage until the TSC control switches in the second bank to bring the voltage up to stage. In high-voltage applications the total of shunt capacitor banks is restricted to a small number (three or four) due to the expense of the thyristor switches.

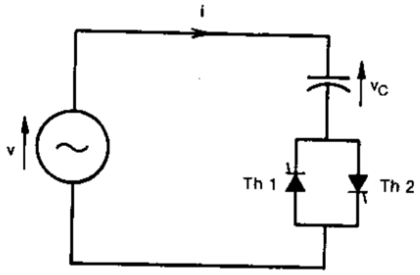


Figure 3.12. Elementary thyristor-Thyristor Switched Capacitor.

Figure 3.13 illustrated the effect of TSC on the operating point, when increasing the number of compensators in SVC, the current value will be increased and compensates in the transmission line which is produced for the purpose of handling and optimizing the voltage system.

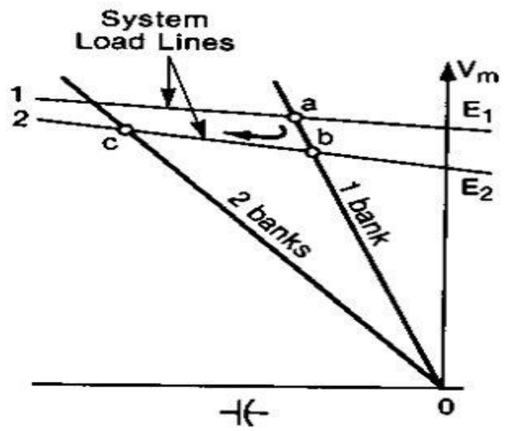


Figure 3.13. Effect of TSC compensator on the operating point.

3.3.4 V-I characteristic of (SVC) controller

The SVC could be performed in both various in VAR control and in voltage regulation status. The SVC susceptance (B) continues in the greatest and smallest values required by the overall reactive power of the capacitor banks (B max) and reactor banks Bl (max), while the voltage is managed at the balance or reference voltage V ref. The capacitive mode is when the voltage will be low cause high load (load is inductive), the capacitive will be working automatically, so when the system voltage is low V(in) is more than (Vs). By this step, we will make it equal, so the capacitors will be working and the svc will generate and compensate reactive power to the system to the needed value of voltage (rated voltage) and makes the system in balance (Kumar et al., 2014). The reference voltage of the system appears lower than inductive mode beside that the load is capacitive (Vin less than Vs), the load needs reactive power to the supply. This area belongs to (maximum voltage) in the system. The important thing of the reactor is reducing system voltage by absorbing the excess of reactive power (Hao and Papalexopoulos, 1997). The voltage of the system will be in balance level turn on TCR that makes (Vin=Vs.). The V-I characteristic of (SVC) controller as shown in Figure 3.14.

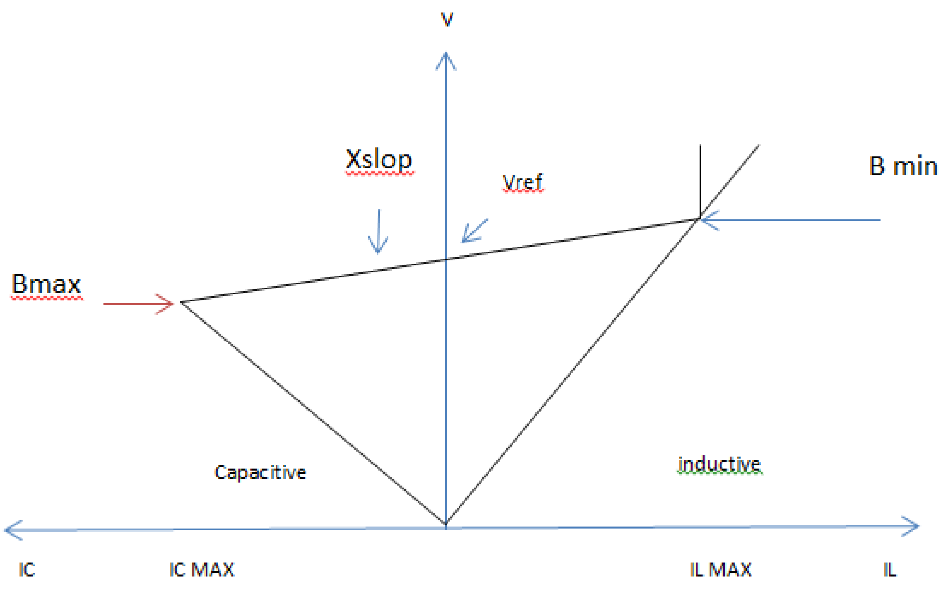


Figure 3.14. V-I Characteristic OF (SVC) controller.

3.3.5 Mathematical equations of SVC

Without Adding SVC, the voltage at the mid-point of the transmission line is given by,

$$V_{TH} = V_M = \frac{\cos\frac{\delta}{2}}{\cos\frac{\theta}{2}} \qquad (3.1)$$

Where: V_{TH} is Thevenin voltage

V_M: is the voltage at the mid-point

After connected SVC, when the SVC is inductive the current regarded as a positive value.

$$I_{SVC} = -B_{svc} V_{svc} \qquad (3.2)$$

The system properties are a direct line with a negative slope and are identified by

$$V_{SVC} = V_M - X_{TH} I_{svc} \qquad (3.3)$$

Where: X_{TH} = reactance observed from the SVC bus, thevenin reactance

$$\frac{V_{svc}}{V_{svc}} = \frac{V_M}{Vsvc} - Xth\frac{-Bsv}{V} \qquad (3.\ 4)$$

$$\frac{V_M}{V_{SVC}} = 1 - X_{TH}B_{SVC} \qquad (3.\ 5)$$

When the SVC exceed the maximum limit can be signified as a fixed susceptance (Bsvc) substituting Isvc from Equation (2) in Equation (4) we get

$$V_{SVC} = \frac{V_M}{1 - X_{TH}B_{SVC}} = \frac{V\cos\frac{\delta}{2}}{(1 - X_{TH}B_{SVC})\cos\frac{\theta}{2}} \qquad (3.\ 6)$$

The power flow in the line is assumed by

$$P\frac{P_0}{1 - X_{TH}B_{SVC}} = \frac{V^2\sin\delta}{Z_n(1 - X_{TH}B_{SVC})\sin\theta} \qquad (3.\ 7)$$

The power flow equation at any bus can be written as follows:

$$S_{i=}P_{i+}jQ_{i=}Vi_l \qquad (3.\ 9)$$

When P: real power

And Q: reactive power

Vi_l: voltage and current

Generally, system losses are the difference between generation and load, so the apparent power, real power loss and reactive power loss presented in Eq 3.10, Eq 3.11, and Eq 3.12 in the line is assumed by:

$$S_{L=}S_{Gen} - S_{Load} \qquad (3.10)$$

$$P_{L=}P_{Gen} - P_{Load} \qquad (3.11)$$

and

$$Q_{L=}Q_{Gen} - Q_{Load} \qquad (3.12)$$

3.3.6 SVC and static synchronous compensator using power flow grid system

Power flow is reporting the necessary analysis to study power systems. It supplies you the information about what is occurring in a system and it is applied for normal, steady-state operation. The inputs and outputs of power flow analysis and (IEEE-6) circuit as presented in Figure 3.15, Figure 3.16 respectively.

At (Kim et al., 2007). The buses in the power system can be categorized into three types:

1. Slack bus: The voltage magnitude (V) & voltage angle is identified, but active power (P) and reactive power (Q) are unidentified.
2. Generator buses: (P), (V) are identified, but (Q), the angle is unidentified.
3. load buses: (P), (Q) are identified, but (V), the angle is unidentified.

At (Kim et al., 2007). The power systems are ordinarily balanced so the single-phase design is enough, related to each bus, there are four amounts:

1. Active power (P) P.u, MW
2. Reactive power (Q) P.u, MW
3. Voltage magnitude (V) P.u, KV
4. Phase angles (voltage angles) Rad, Deg

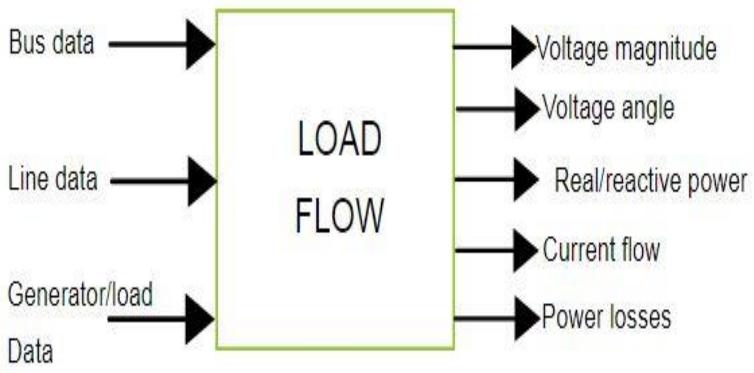


Figure 3.15. Inputs and outputs of power flow analysis.

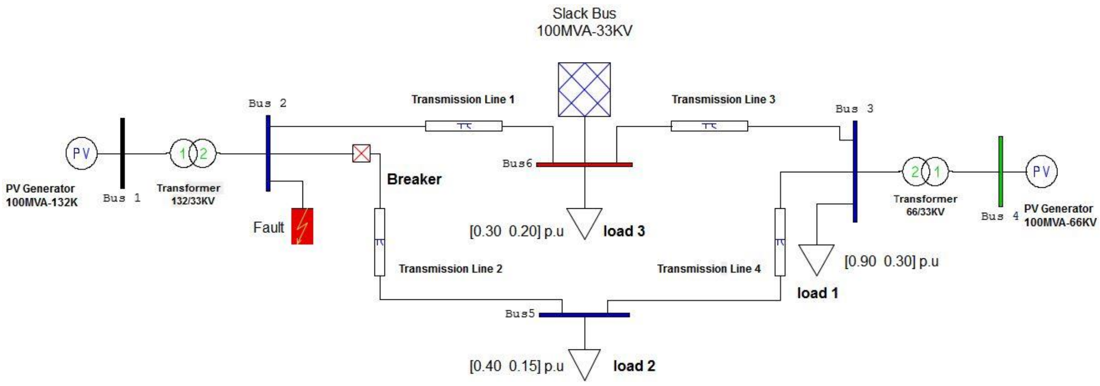


Figure 3.16. Power flow circuit.

Table 3.1 shows the simple grid system components used for the study of the power flow circuit (IEEE-6) bus circuit.

Table 3.1. Components of the power flow circuit.

Camponent name	Number of bus	Valuement
PV generator PV generator	1 4	100MVA-132KV 100MVA-66KV
Slack Bus	6	100MVA-33KV
step-down transformer step-down transformer	Between 1-2 Between 4-3	132/33KV 66/33KV
Load 1 Load 2 Load 3	3 5 6	[0.90 0.30] p.u [0.40 0.15] p.u [0.30 0.20] p.u
Three-phase fault and Circuit breaker	2	[0.10 0.10] fault [Resistance reactance]

The parameters of PV generator in circuit as shown in Table 3.2 the transmission lines, ZL1 = 0.0085+j 0.072 X/ km, ZL2 = 0.032 + j 0.161 X/ km, ZL3 = 0.0119+j 0.1008 X/ km, ZL4 = 0.01+j 0.085; power base = 100 MVA; system frequency = 60 Hz . The starting time is (0) sec and ending time is (20) sec.

Table 3.2. Parameters of PV generators in the circuit.

PV generator at bus1:	PV generator at bus4:
Active Power 1.63 [p.u.],	Active Power 1.25[[p.u.],
TheVoltage Magnitude 1.025 [p.u.],	The Voltage Magnitude 1.50[[p.u.],
Vmax and Vmin is [1.1 0.9] [p.u.]	Vmax and Vmin is [1.1 0.9] [p.u.]

The parameters of the slack bus at bus 6; The voltage magnitude 1.04 p.u. , reference phase angle [rad] is 0 p.u., active power guess is 0.80 p.u.

The parameters of transformer between bus (1-2), (3-4); power, voltage and frequency ratings [100MVA, 132kV, 60Hz] and [100MVA, 66kV, 60Hz], primary and secondary voltage ratio [132/33] kV, [66/33] kV, resistance and reactance is [0, 0.0625] p.u.and [0, 0.0586] p.u. The circuit breaker (CB) at bus 2: is one of the most important components of electrical circuits (control), CB isolates and opens the trouble area of the power, works when the fault or short circuit occurs in the system.

3.3.7 SVC and static synchronous compensator circuits simulation design

Static VAR Compensator (SVC) & Static Synchronous compensator were used to design and simulate a power flow and line flow of (six buses) grid system with multi-cases of (SVC) .In this thesis two modal of techniques have used. In particular, a multi-cases of (SVC) will be considered (i.e. one-case, tow-case, and three-case,) and the buses will be tested (i.e. bus-three, bus-five, and bus-six) in the grid system, the first techniques is modeling the power flow, and second one applying SVC simulink on mid-point of transmission line of the grid that we designed.

The power flow circuit diagram, the profile voltage of buses, real power, reactive power, angles, and power loss throw line also from bus to another will be determined, besides that number of iterations and maximum Q mismatch [p.u.], variable state of SVC, line flows from and to buses addition to that the total generation, load and loss of grid before and after adding static synchronous compensator also will be measured. The data format of SVC that we have been used presented in Figure 3.17.

Column	Variable	Description	Unit
1	-	Bus number	int
2	S_n	Power rating	MVA
3	V_n	Voltage rating	kV
4	f_n	Frequency rating	Hz
5	2	Model type	int
6	T_2	Regulator time constant	s
7	K	Regulator gain	p.u./p.u.
8	V_{ref}	Reference Voltage	p.u.
9	$\alpha_{f\,\max}$	Maximum firing angle	rad
10	$\alpha_{f\,\min}$	Minimum firing angle	rad
11	K_D	Integral deviation	p.u.
12	T_1	Transient regulator time constant	s
13	K_M	Measure gain	p.u./p.u.
14	T_M	Measure time delay	s
15	x_L	Reactance (inductive)	p.u.
16	x_C	Reactance (capacitive)	p.u.
17	u	Connection status	$\{0, 1\}$

Figure 3.17. The data format of SVC.

Static synchronous compensator it may act like a capacitor (capacitive) power that generates a reactive power to the transmission system, or it is like a reactor that absorbs the reactive power(inductive) power when it increases or decreases in the system voltage (Desai and Arya, 2018).

The first result was collected with the employment of (SVC) on different location of the grid (bus-three, bus-five, and bus-six) to get different the variable state of SVC with applying three values (cases) of inductive and capacitive reactance (Xl, Xc). The case one (0.20, 0.50) p.u, case two (0.20, 0.60) p.u and case three (0.20, 0.70) p.u. The maximum Q mismatch increases with increasing, (the number of SVC cases value of (capacitive reactance) p.u. However, increasing the number of cases leads to increased reactive power passage through the line, which raises the protection of the system from over voltage. The report of all results has been kept for proportional analysis. The outcomes of the unique system & the system with SVC performed are hence determined to be nearly similar and hereafter the system is voltage stable with SVC (Singh and Kashiv, 2015). The second results of work will be collected with adding static synchronous compensator on (bus-five) as well as (bus-three) and (bus-six) were tested in voltage profile state, voltage profile, reactive power, maximum Q mismatch and angles of the buses will be improved. Figure 3.18 shows the design of the power flow circuit with SVC and adding static synchronous compensator to (IEEE-6) circiut . Note we will see the best and weakest (bus) in the planned diagram. The IEEE-6 bus system is considered via (PSAT) library through the MATLAB program. Power flow problems solved by the Newton-Raphson method (Singh and Kashiv, 2015).

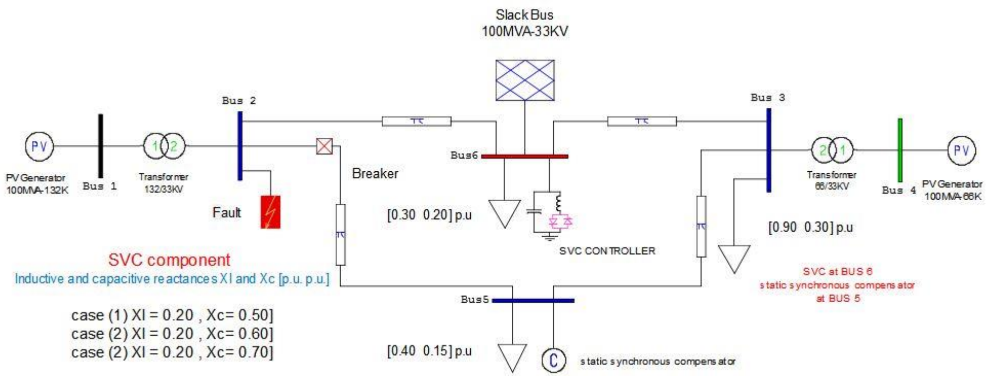


Figure 3.18. SVC & Static synchronous compensator in *(*IEEE-6) circuit.

3.3.8 SVC analysis using simulink

The transmission line of the simulink circuit contains from the programmable voltage source has positive-sequence: [1.004*132e3 60], which is connected with three-phase series RLC branch (132kV 6000 MVA) to (Yg/d), 100 MVA coupling transformer. The three-phase fault has been added with three RLC loads respectively. The transmission line of the simulink circuit as exposed in Figure 3.19.

The grid system contains:

1) Load: The active power of three-phase and inductive reactive power QL series RLC branchs (1, 2, 3) are {5e3 (W), 10e3 (W), 6e3 (W) }, the capacitive reactive power Qc is zero of loads.
2) Fault: Enforcement short-circuits between lines and ground, when the external switching time type is designated, switching times (s): [1/60 5/60], the initial status:0, fault resistance Ron (Ohm): 10e-3, ground resistance Rg (Ohm): 0.01, snubber resistance Rs (Ohm): 1e6.
3) Programmable voltage source has a neutral node of the three sources, it is available through input 1 (N) of the block, this block employment a 3-ph zero-impedance voltage source. The variation of time for the frequency, amplitude, and phase of the fundamental can be pre-programmed also, two harmonics can be assumed on the fundamentals.
4) SVC Control: Containing one (TCR) and three (TSCs) banks, the outputs TCR, TSC1, TSC2, and TSC3 are courses of six pulses for each bank. TCR bank has quality factor:50, the thyristor snubber and thyristor data of both banks: [R (ohm) C (F): [500, 250e-9] and [Ron (ohm) Vf (volt)] [1e-31*15] , the operation

mode is voltage regulation, ref voltage (pu): 1.0, droop (pu/100MVA): 0.01and min.and max.primary suscptance (-1.04, 3.23), the powergui mode is time descreate.

5) 3-phase Power Instantaneously: This block has two inputs for (voltage and current) collected from 3-ph voltage-current measurements, the waveforms of real and reactive power will be displayed throw three scopes between (2-3), (3-4), (5-6).

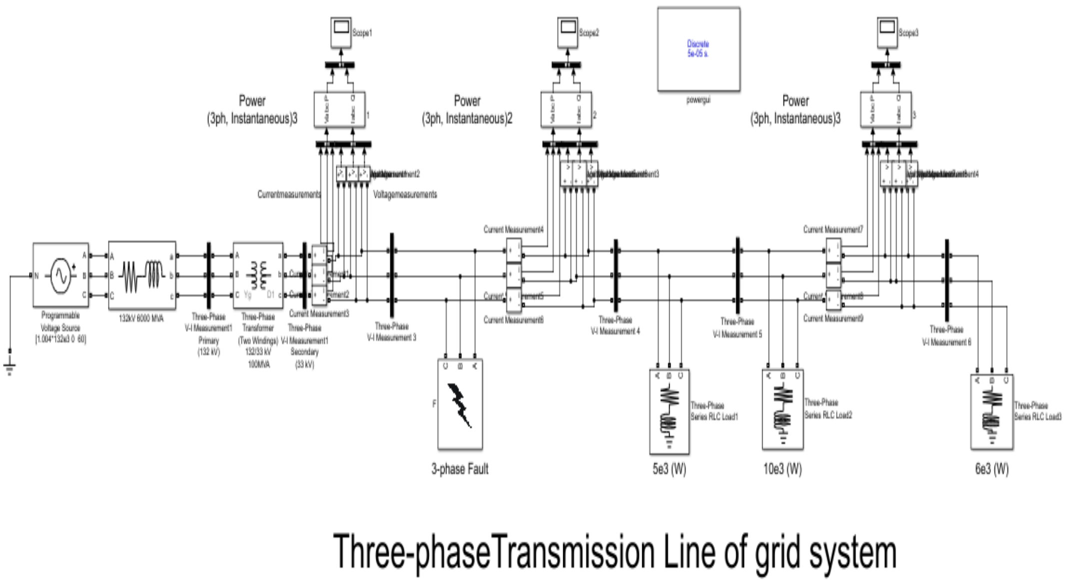
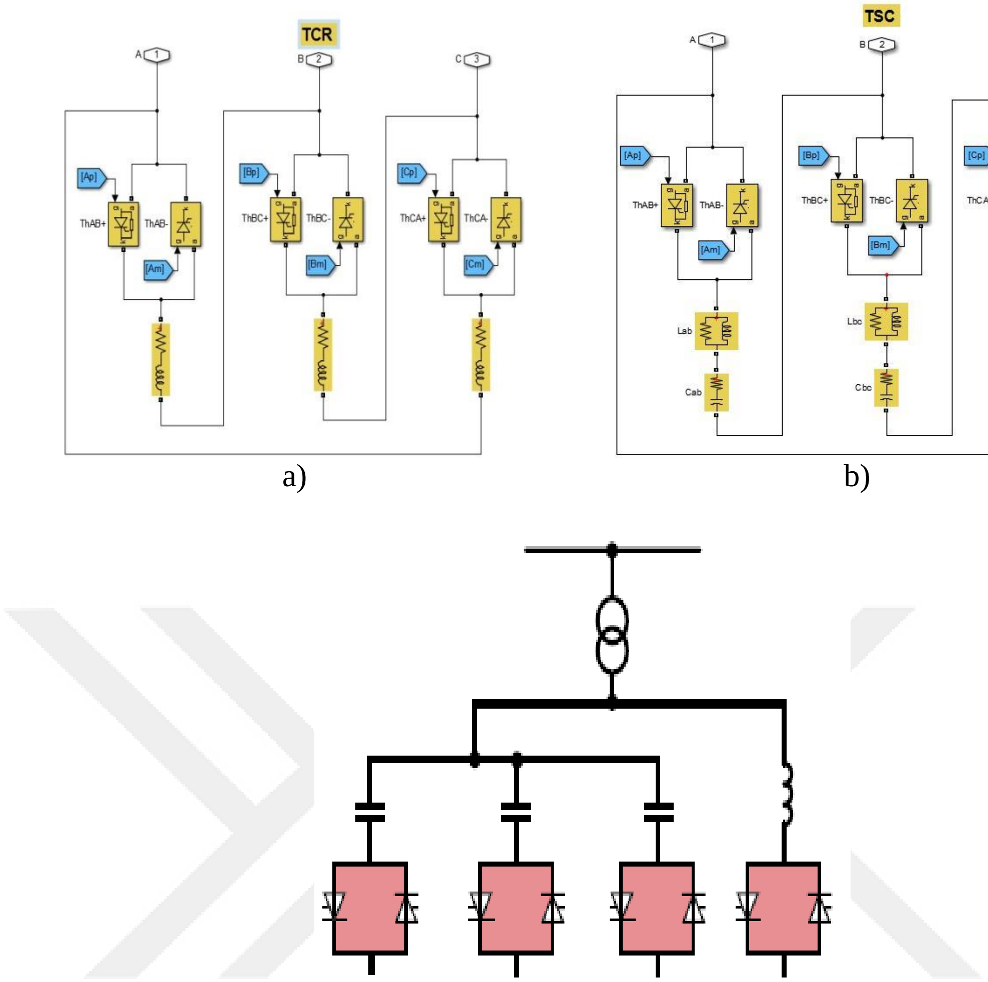


Figure 3.19. The transmission line of the simulink circuit.

SVC with 300 Mvar will control the voltage on a 6000-MVA 132-kV system. The system contains from132kV/33-kV, 250 MVA coupling transformers, TCR bank is109 Mvar, beside that three values of 94 Mvar in (TSC) bank, TSC (1-2-3) linked to another sideways of the transformer. the phase control of the TCR permits a continuous variation from (0-109) Mvar inductive. The TSC permits from (0-282) Mvar capacitive. The power system is denoted by an inductive equivalent (6000 MVA short circuit level) the programmable source can diverse the internal voltage of the equivalent for detecting the dynamic response of SVC in system voltage. The three-phase of (TCR) and (TSC) banks as shown in Figure 3.20.



a) b)

c)

Figure 3.20. a) Three-phase of TCR, b) Three-phase of TSC banks, c) TCR&TSC banks together in SVC modal.

All the outcomes of applying FACTS devices will be exposed in the next chapter. The three results by designed SVC (detailed) 1TCR-3TSC modal with (six buses) will be proving and analyzing the SVC effect that will be adding and before adding it to the network. The output waveforms of voltage, current, comparison between real power and reactive power with three-phase Fault between lines and ground and without fault, also with applying SVC and without applying will be illustrated and measured. One of thyristor controlled reactor (TCR) and three of thyristor switched capacitor (TSC) were employed in this modal. The power oscillation before and after adding SVC with the time as displayed in Figure 3.21, Figure 3.22 shows the simple system modeling it comprehends the transmission line of (six buses) with SVC connected in the middle of Line (between bus 2-3), design of power SVC (detailed Modal) 1TCR-3TSC has applied in the transmission line.

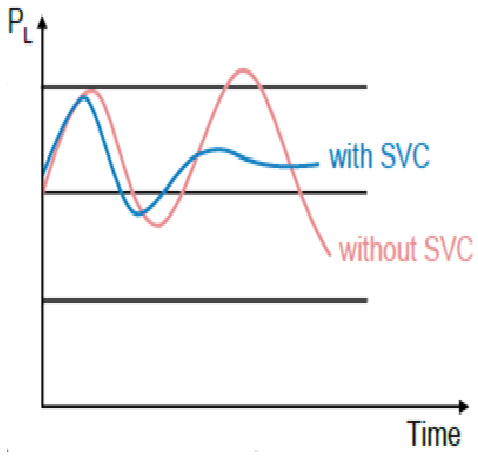


Figure 3.21. Damping of power oscillation.

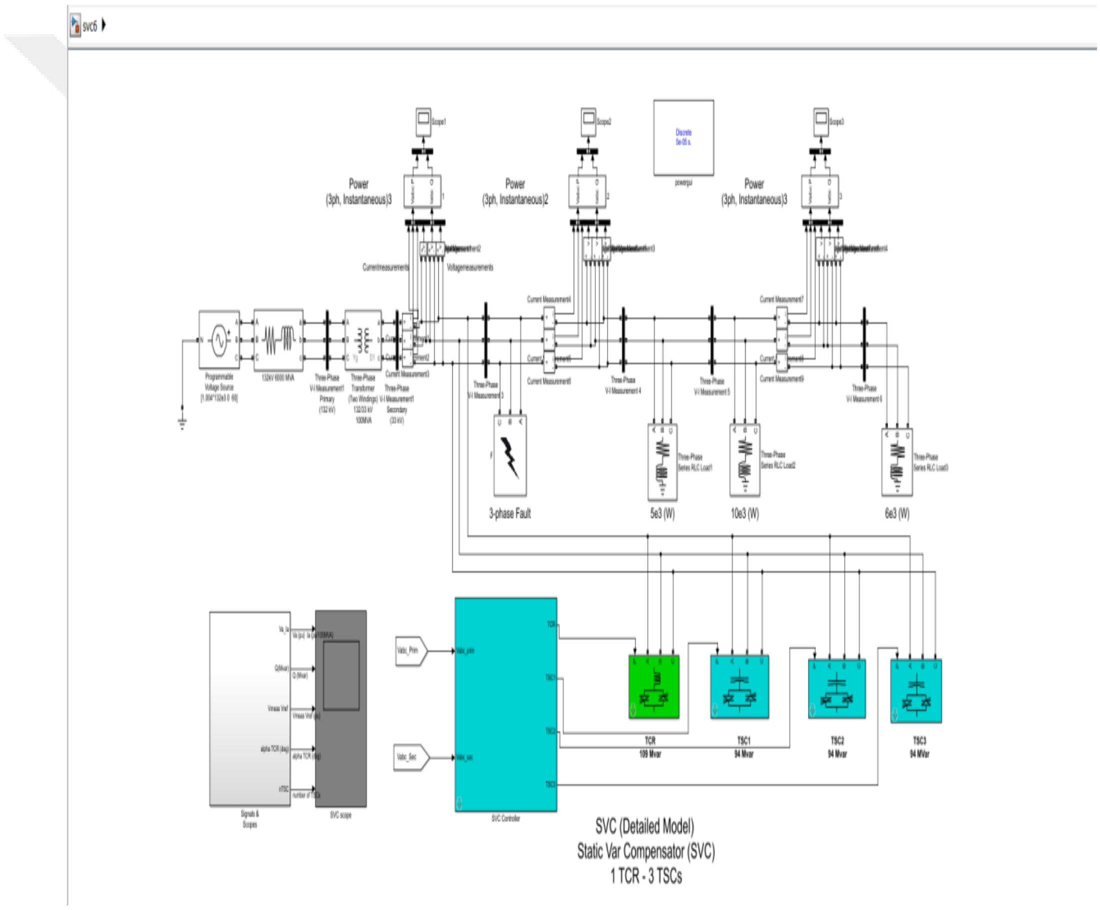


Figure 3.22. SVC (detailed Modal) 1TCR-3TSC.

4. SIMULATION RESULTS

4.1 The Power Flow And Line Flow Circuit

We obtained deffrient results of power at the buses, line flow, and line loss, different inductive and capacitive reactances Xl and Xc respectively (0.20) p.u and (0.50 – 0.60 – 0.70) p.u, are applied with SVC parameters in power flow circuit with various buses number (bus-3, bus-5, bus-6) of (IEEE-6) bus system with SVC modal type (2) , so we divided that into three cases. The power rate in the grid system, voltage, and frequency ratings are:[100MVA, 33kV, 60Hz]. The power flows and Line flows report of the circuit as shown in Table 4.1, and Table 4.2 respectively.

Table 4.1. Power flows report of the circuit.

Bus	V	phase	P gen	Q gen	P load	Q load
	[p.u.]	[rad]	[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus 1	1.025	0.168208	1.63	-0.73567	0	0
Bus 2	1.074465	0.075573	7.57E-16	5.8E-15	0	0
Bus 3	1.3003	-0.00573	5.55E-16	-1.2E-15	0.9	0.3
Bus 4	1.5	0.03183	1.25	5.135246	0	0
Bus5	1.227333	-0.00062	-7.2E-16	-8.3E-15	0.4	0.15
Bus6	1.04	0	-1.14528	-2.96192	0.3	0.2

Table 4.2. Line flows report of the circuit.

From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
			[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus 3	Bus6	1	0.315116	3.144157	0.078316	0.373667
Bus 2	Bus6	2	1.220718	0.328496	0.012236	-0.06294
Bus 3	Bus5	3	0.034884	0.963584	0.007326	-0.21908
Bus 2	Bus5	4	0.409282	-1.25441	0.036841	-0.22175
Bus 1	Bus 2	5	1.63	-0.73567	0	0.19025
From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
Bus6	Bus 3	1	-0.2368	-2.77049	0.078316	0.373667
Bus6	Bus 2	2	-1.20848	-0.39143	0.012236	-0.06294
Bus5	Bus 3	3	-0.02756	-1.18266	0.007326	-0.21908
Bus5	Bus 2	4	-0.37244	1.032664	0.036841	-0.22175
Bus 2	Bus 1	5	-1.63	0.925917	0	0.19025

We added SVC to (bus-3), (bus-5), and (bus-6) without adding synchronous compensator to power flow (IEEE-6) circuit as shown in Figure 4.1, Figure 4.2, and Figure 4.3.

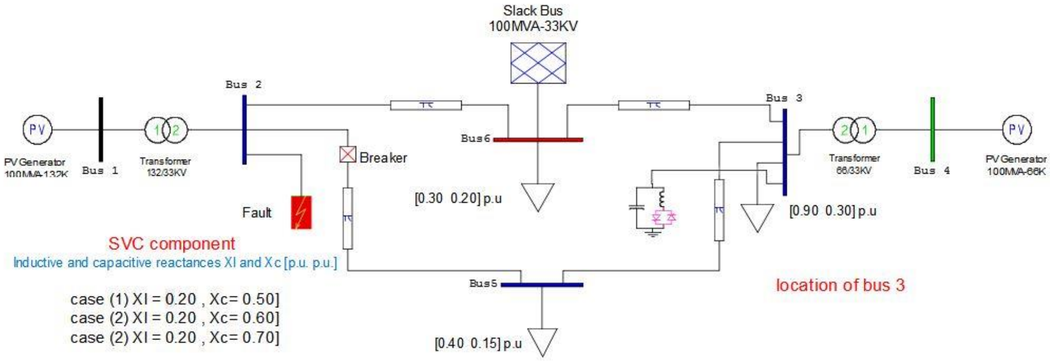


Figure 4.1. Adding SVC to (bus-3) without synchronous compensator.

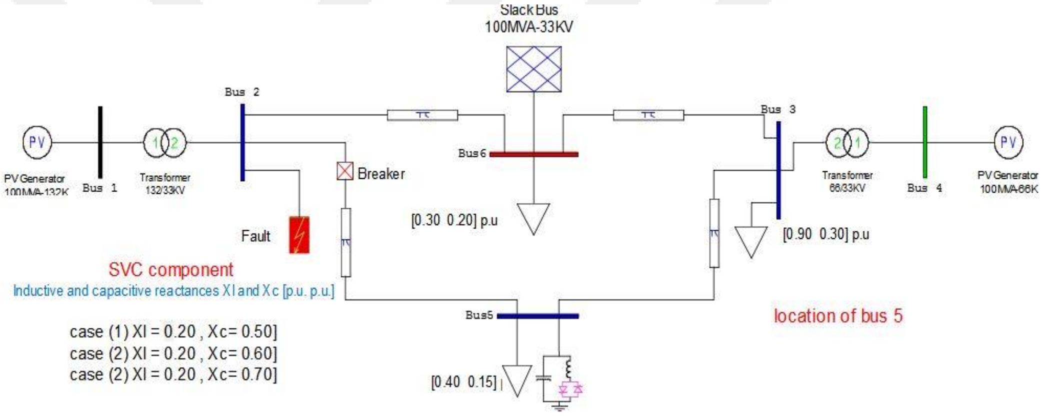


Figure 4.2. Adding SVC to (bus-5) without synchronous compensator.

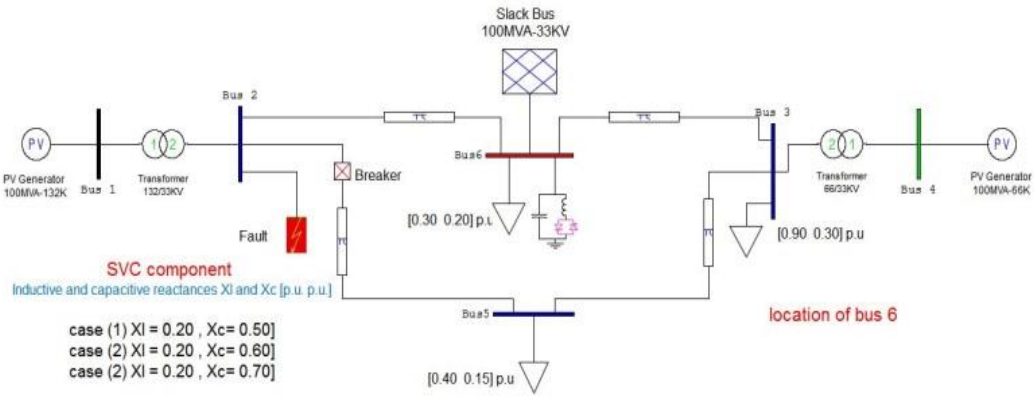


Figure 4.3. Adding SVC to (bus-6) without synchronous compensator.

We can divide the simulation results of the SVC state variable in power flow circuit into three cases:-

1. Case (1), in this case, we added indictive and capacitive reactance [0.20 0.50] p.u to the parameters of SVC, in addition to that, the buses (3-5-6) have tested.
2. Case (2), in this case, the capacitive reactance is increased [0.20 0.60] p.u and we added that to the parameters of SVC in extra to that, the buses (3-5-6) have experienced.
3. Case (3), in this case, the capacitive reactance is greater than before [0.20 0.70] p.u and we added that to the parameters of SVC in extra to that, the buses (3-5-6) have experienced.

In addition, the SVC with a capacitive of 0.70 p.u is better compensation of reactive power than the 0.60 p.u and 0.50 p.u in protecting the power system of the grid according to the simulation result as shown in Figure 4.4.

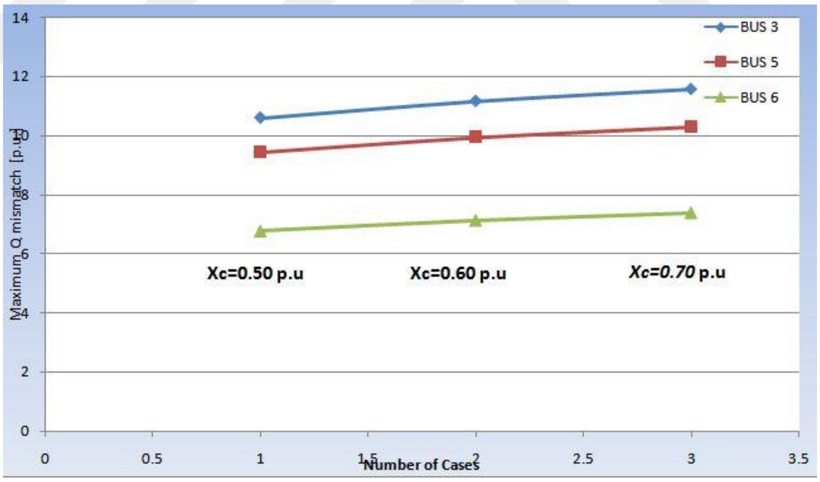


Figure 4.4. Maximum Q of the buses without adding the compensator.

4.1.1 Improving power flow circuit and SVC state variable

At first static synchronous compensator is one of many methods of voltage control in the power system. It can receive or produce VAR in single and triple AC systems. It can eliminate and protect from problems such as a sudden increase in voltage or decrease, trying to put it in a constant balance. the value of voltage magnitude of compensator that will be adding to bus number five is 1.5 KV.

Related for adding static synchronous compensator at (bus-5) to the circuit, the report of power flow and power line as shown in Table 4.3 and Table 4.4.

Table 4.3. Power flows report of the circuit after adding a compensator.

Bus	V	phase	P gen	Q gen	P load	Q load
	[p.u.]	[rad]	[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus 1	1.025	0.150554	1.63	-1.51024	0	0
Bus 2	1.121501	0.061815	3.01E-15	4.41E-14	0	0
Bus 3	1.383759	-0.02249	2.92E-13	4.96E-12	0.9	0.3
Bus 4	1.5	0.012806	1.25	2.997519	0	0
Bus5	1.5	-0.03645	3.31E-13	5.309805	0.4	0.15
Bus6	1.04	0	-0.91631	-4.53942	0.3	0.2

Table 4.4. Line flows report of the circuit after adding a compensator.

From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
			[p.u.]	[p.u.]	[p.u.]	[p.u.]
Bus 3	Bus6	1	0.233205	4.495026	0.137338	0.850209
Bus 2	Bus6	2	1.138384	1.072333	0.017946	-0.02227
Bus 3	Bus5	3	0.116795	-2.07221	0.018998	-0.20502
Bus 2	Bus5	4	0.491616	-2.87631	0.189412	0.416293
Bus 1	Bus 2	5	1.63	-1.51024	2.22E-16	0.293738
From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
Bus6	Bus 3	1	-0.09587	-3.64482	0.137338	0.850209
Bus6	Bus 2	2	-1.12044	-1.0946	0.017946	-0.02227
Bus5	Bus 3	3	-0.0978	1.867197	0.018998	-0.20502
Bus5	Bus 2	4	-0.3022	3.292607	0.189412	0.416293
Bus 2	Bus 1	5	-1.63	1.803981	2.22E-16	0.293738

The results of applying static synchronous compensators are illustrated without and with adding as shown in Table 4.5.

Table 4.5. Variable states of SVC controllers with and without adding synchronous compensator to bus 5.

SVC variable state	Without Adding	With Adding
alpha_Svc bus3	1	1
vm_Svc_bus 3	1.3003	1.3838
vref_Svc_bus 3	1.300321	1.38378
alpha_Svc bus5	1	1
vm_Svc_bus 5	1.227333	1.5
vref_Svc_bus 5	1.227354	1.50004
alpha_Svc bus6	1	1
vm_Svc_bus 6	1.04	1.04
vref_Svc_bus 6	1.040016	1.040017

Maximum Q mismatch [p.u.] of (bus-3) and (bus-5) with and without adding a synchronous compensator.as shown in Figure 4.5 and Figure 4.6.

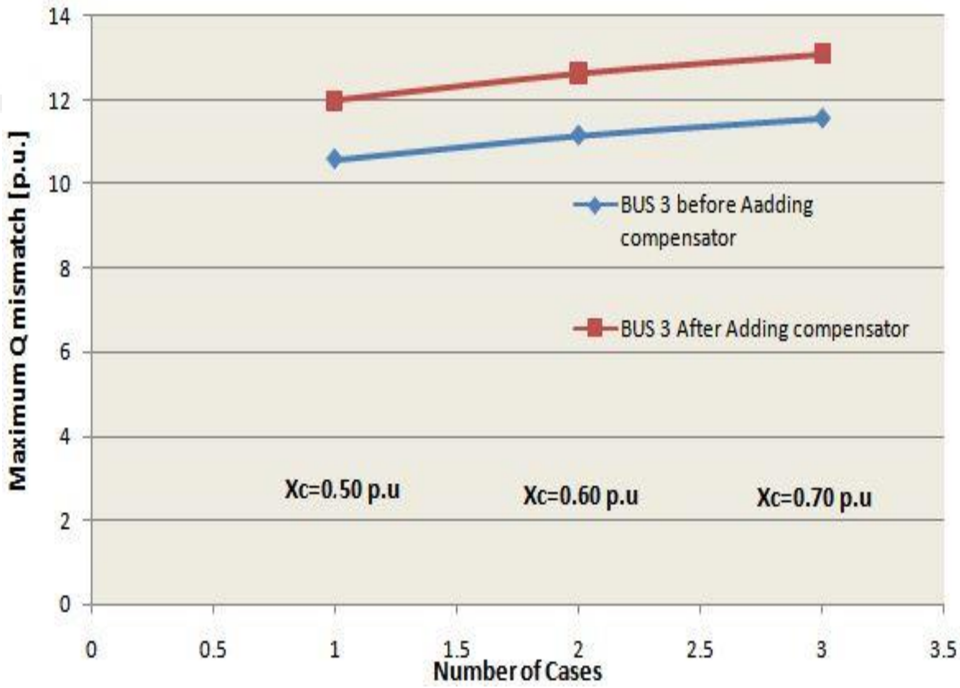


Figure 4.5. Maximum Q of (bus-3) with and without adding the compensator.

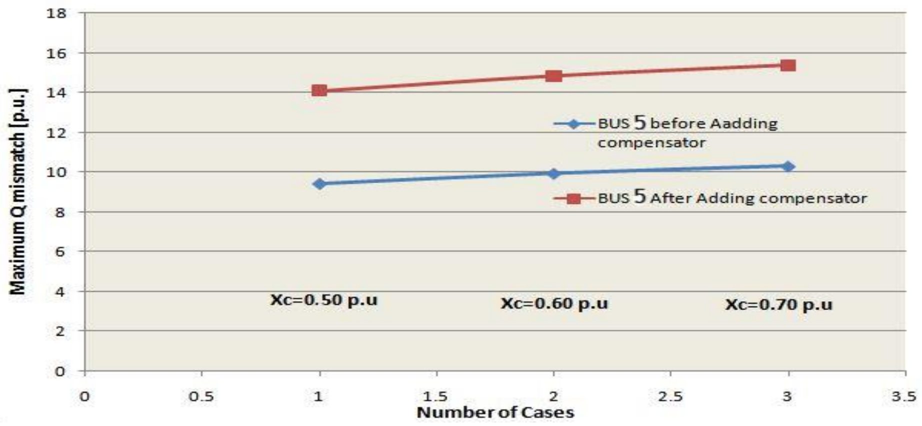


Figure 4.6. Maximum Q of (bus-5) with and without adding the compensator.

4.2 Improving The Voltage Profile of The Grid System Buses

The static synchronous compensator is one of the greatest impactive devices for developing the voltage of magnitude stability identified. The various component of the power system is designed to work at rated voltage, the voltages are a various point in power system should be maintained at rated value, if the equipment is not operated value then the performance of the equipment will be poor and the life will be reduced. Figure 4.7 is shown the voltage profile of buses before adding compensator at (bus-5) of adding 1.5 KV of the synchronous compensator to different buses number, the voltage profile comparison of buses with and without adding will be analyzed in Figure 4.8.

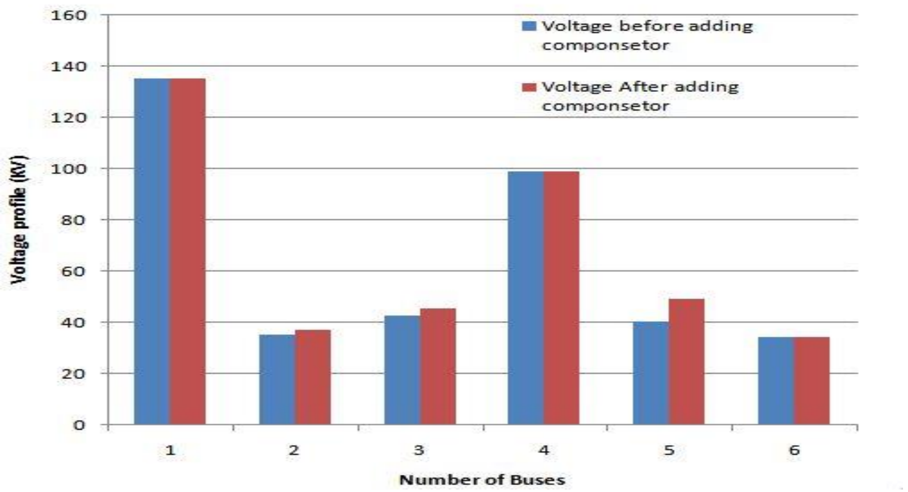


Figure 4.7. Voltage profile before after adding compensator at (bus-5).

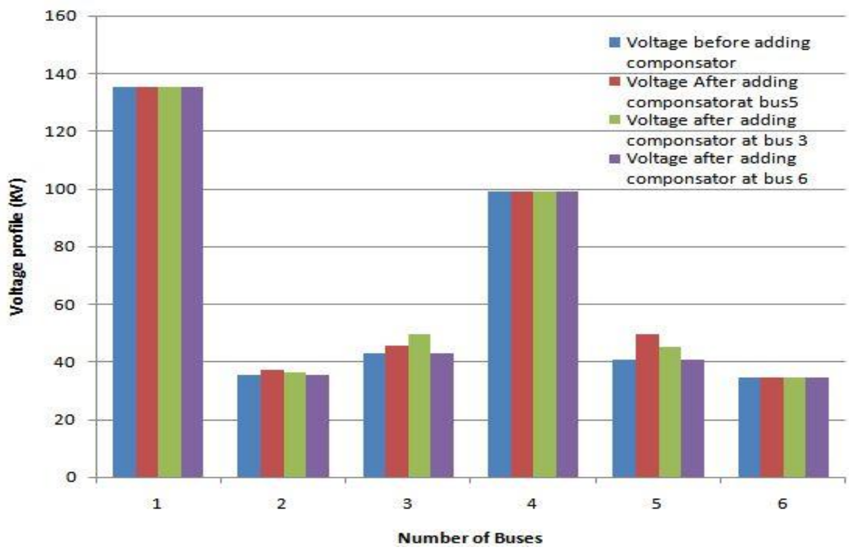


Figure 4.8. Voltage profile before and after adding the compensator.

In Table 4.6 the difference among improved profile voltage of buses before and after adding compensator will be calculated. The best bus is bus-5 and the weakest is a bus 6.

Table 4.6. Voltages profile of buses.

Number of bus	Without adding	Adding at bus3	Adding at bus5	Adding at bus6
bus2	35.4573	36.2653	37.0095	35.4573
bus3	42.9099	49.5	45.664	42.9099
bus5	40.502	45.1751	49.502	40.502

4.3 Reactive Power and Real Power

The reactive power can smoothly be varied beside that can be delivered and absorbed from and to buses, the overloaded for short periods also can be applied by Static synchronous compensator. The reactive power before and after adding compensator at (bus-5) to grid system is showed in Figure 4.9 and 4.10 by using the difference between total generated values and total load values of reactive power of the system. The real power before and after adding compensator at (bus-5) to power flow circuit presented in Figures 4.11 and 4.12 according to SVC simulink the real power and active power before and after adding SVC to (bus-2, bus-3, and bus-5) grid system also with fault and without fault, waveforms will be presented the Figure 4.13 and Figure 4.14 without the fault and Figure 4.15 and Figure 4.16 with the fault, when the fault has occurred, the real and reactive power will be zero.

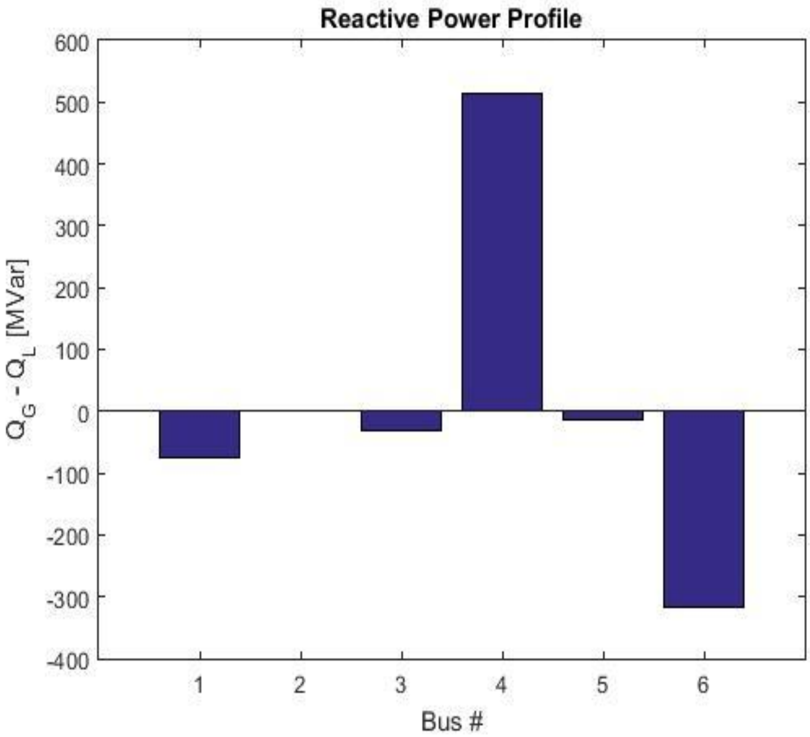


Figure 4.9. The reactive power of buses before adding a compensator.

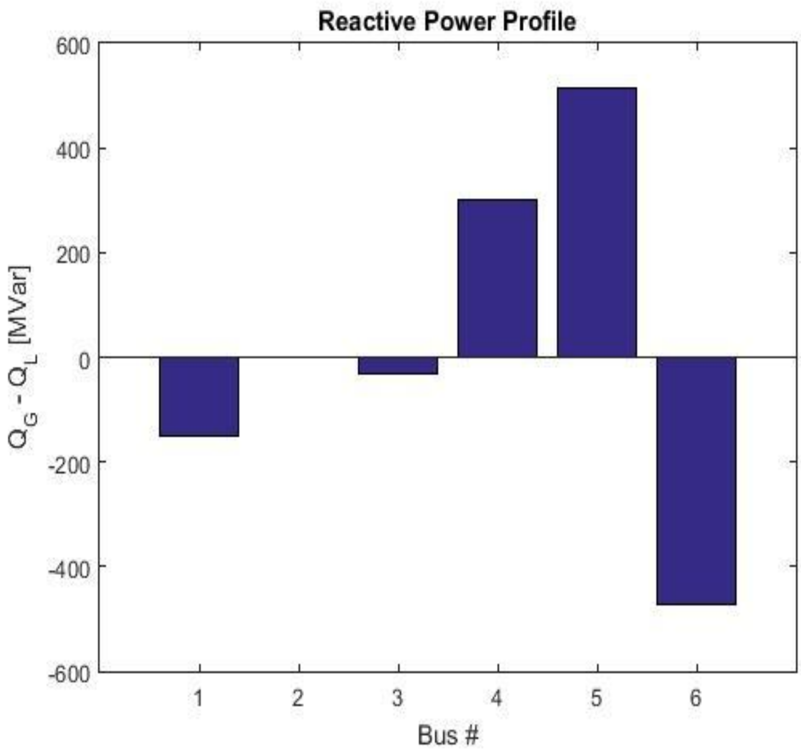


Figure 4.10. The reactive power of buses after adding a compensator.

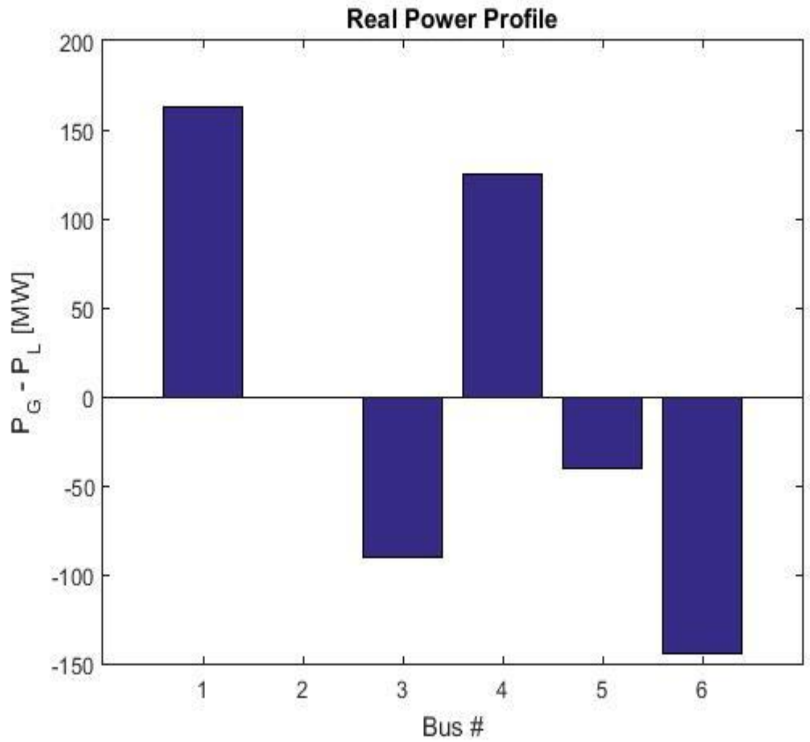


Figure 4.11. The real power of buses before adding a compensator.

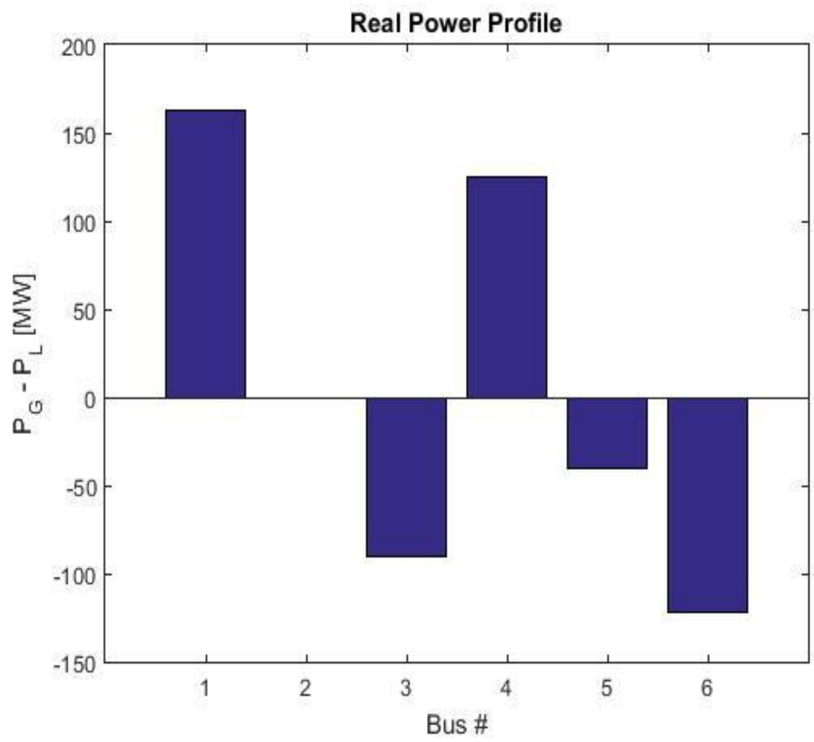


Figure 4.12. The real power of buses after adding a compensator.

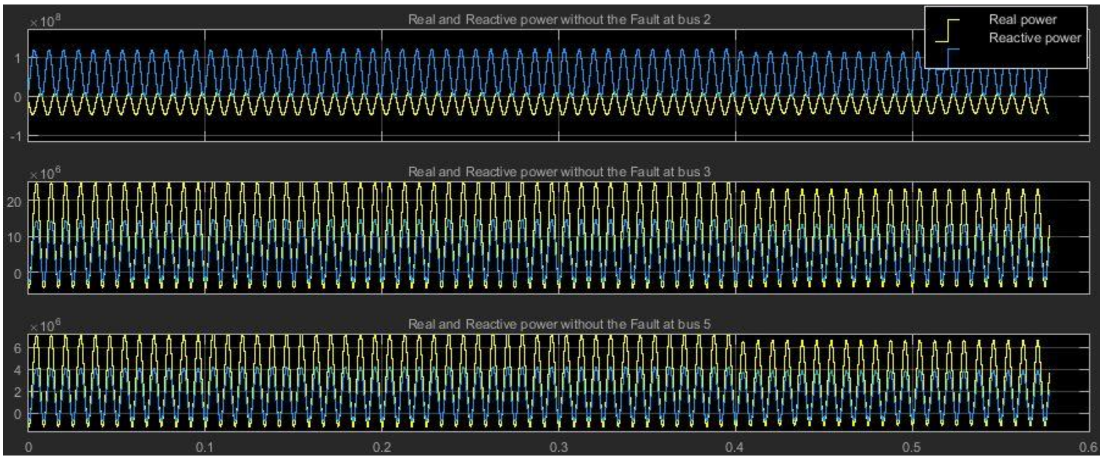


Figure 4.13. The waveform of real and reactive power before adding SVC without the fault.

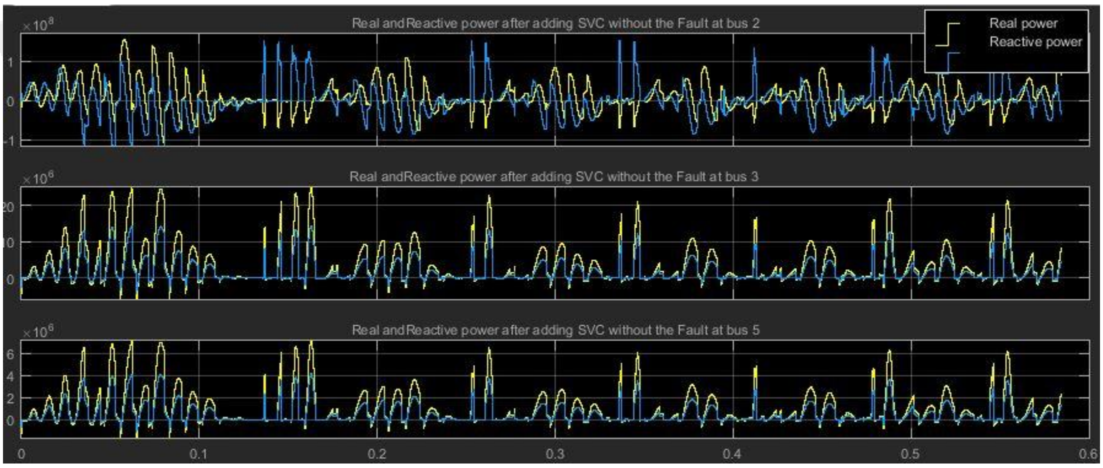


Figure 4.14. The waveform of real and reactive power after adding SVC without the fault.

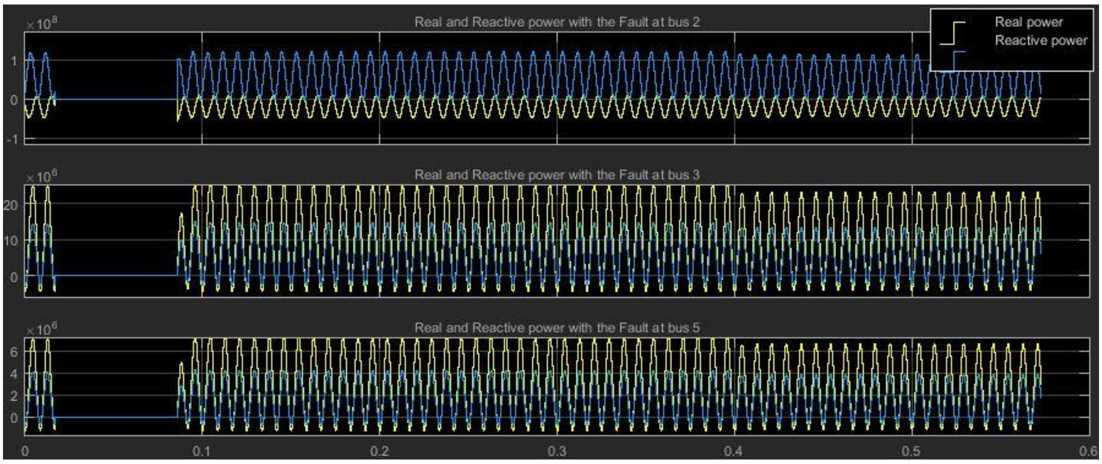


Figure 4.15. The waveform of real and reactive power before adding SVC with the fault.

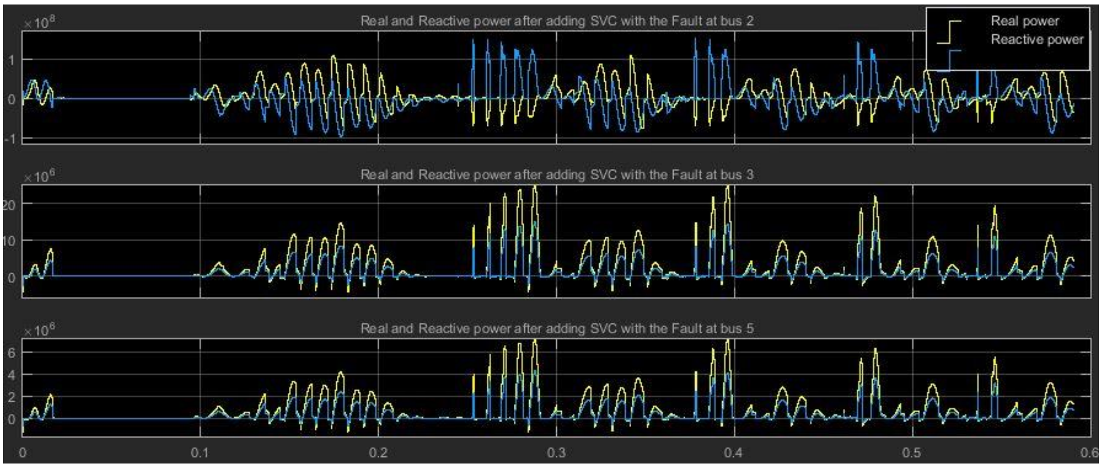


Figure 4.16. The waveform of real and reactive power after adding SVC with the fault.

The real power & reactive power waveforms have been tested by using power (3-ph instantaneous) at (bus-2, bus-3, and bus-5), the three-phase voltage measurements and the three-phase current measurements taken voltage and the current signal from the region that we wanted to test in the transmission line.

4.4 Reactive Power & Voltages and Current

In SVC simulink, three-time of adding capacitance to 3/TSC at three times, capacitance (F) : (100 e-6, 500 e-6, 800 e-6) and TCR inductance (H): 20e-3, 1/TCR is 100 Mvar). The output waveforms are shown as Figure 4.18., 4.19., and 4.20. The simulation results will be presented three waveforms of reactive power Q (MVar) & voltage and currents will be more smoothly when the values of capacitance being increased gradually. The damping of minor disturbances and voltage control stability has been improved, besides that; the power oscillation has been damped.

When will be running the project we will notice the simulation output of waveforms from the scop of SVC. The SVC voltage reference is fixed to (Vref) = 1.0 pu , when SVC is in the mode of voltage control. the operating point of SVC changed from completely capacitive (+100, +500, and +800 Mvar) to totally inductive (-100 Mvar) due to the droop voltage of the controller is (0.01 pu/100MVA, 0.05 pu/500MVA, and 0.08 pu/800MVA), to (0.01 pu/100 VA. The voltage drop of the control is 0.01 pu/100 VA (0.03 pu/300MVA) in normal after our work, we applied (0.01 pu/100MVA), (0.05 pu/500MVA), (0.08 pu/800MVA) at three times as shown in Figure 4.17, Figure 4.18 and Figure 4.19 to see the differences among results, the voltage of the source is fixed at 1.004 pu.The number of TSC bank as shown in Figure 4.20.

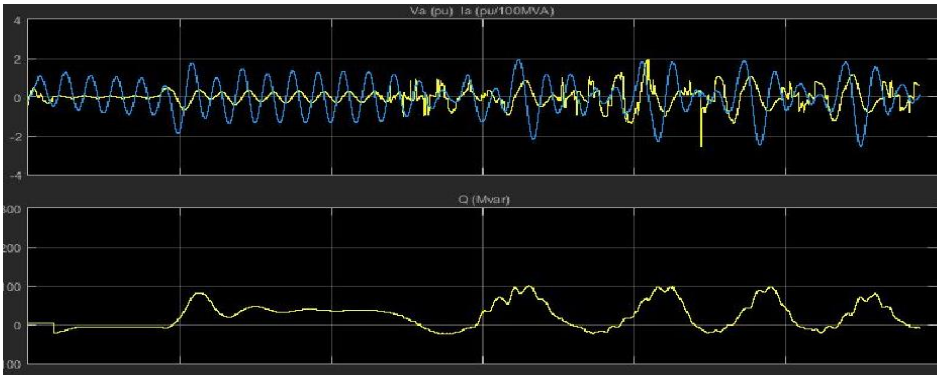


Figure 4.17. The waveform of Q (Mvar) & voltage and current by 100 capacitance of 3/ TSC adding to SVC.

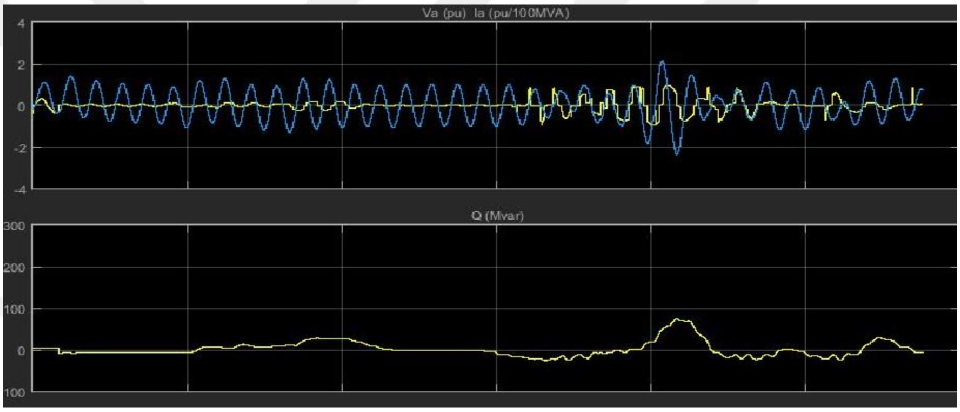


Figure 4.18. The waveform of Q (Mvar) & voltage and current by 500 capacitance of 3/ TSC adding to SVC.

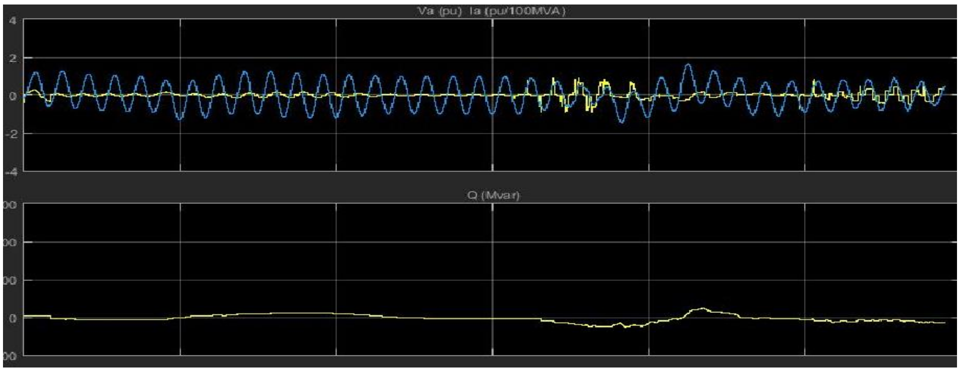


Figure 4.19. The waveform of Q (Mvar) & voltage and current by 800 capacitance of 3/ TSC adding to SVC.

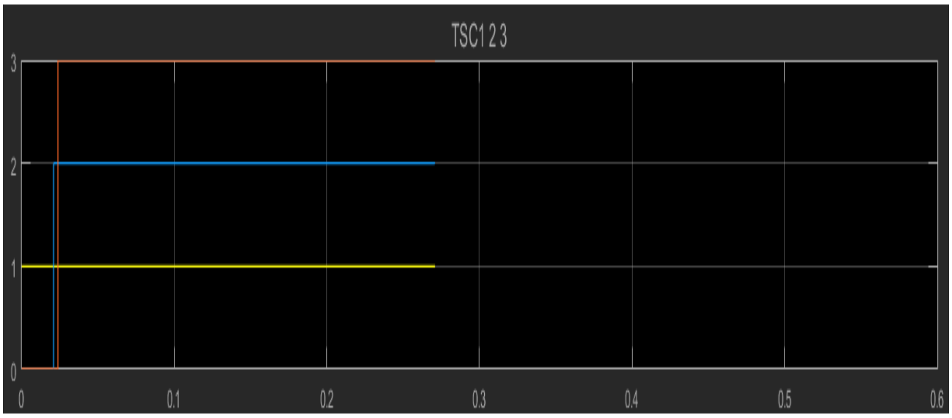


Figure 4.20. Number of TSC bank in the system.

5. CONCLUSION

The mechanical compensators use control devices such as compensators with a mechanical exchange that has been used However, these controllers are not responsive and have many problems. In order to avoid these problems therefore in this thesis, the FACTs controllers such as the SVC controller were investigated. The FACTS controllers such as SVC (shunt compensation) that added in the power system by different stages at 6 buses of grid system Initially, this thesis discussed the influence of FACTS devices on power system protection.

The advanced power system performance, protection is attained, with respect to optimized voltage control, increased reactive power reserves by a dilution generator. The SVC & static synchoruns compensator installation strategy is proposed to enhance the power protection such that the existing transmission networks can accommodate more power transfers besides that we obtained the best location (bus-5) and the weakest location is (bus-6) for placement of these devices at IEEE-6 buses in power flow circuit grid. The static voltage stability and power transfer capability were increased by SVC and static synchoruns compensate however, it provides better behavior in terms of loss reduction and voltage profile. There are several practices obtainable that can be utilized to cover this project, over which the best or weakest bus for any greater system can be calculated very exactly and precisely. In this study, Newton-Raphson power flow is applied, besides steady-state models of FACTS are utilized for the study.

We explained the types of compensation, methods of linking the compensators and their goals also impact of compensating VAR in the transmission system.

SVC is been applied to the power flow circuit to study.

a) SVC variable state such as alpha, VM, vref, Maximum Q mismatch before and after adding a static synchronous compensator to produce VAR to the grid, it has been at three cases or stages.

b) The profile voltage of buses, real power, reactive power, angles, and power loss throw line also from bus to another before and after adding static synchronous compensator was determined.

The profile voltages of the grid are tested when we added compensator with voltage magnitude 1.5KV to (bus-3, bus-5, and bus-6).

c) The results were evaluated by employment the power system analysis toolbox (PSAT) with MATLAB program in the (IEEE-6) electrical grid system (132\33, 66\33KV).

SVC is been implemented to simulink grid system (IEEE-6) as (1/TCR, 3/TSC) to study.

a) The effect of increasing the capacitance values (F) : (100 e-6, 500 e-6, 800 e-6) in three-phase of Thyristor Switched Capacitors (TSC) banks three times to inject VAR in the system.
b) The waveforms of active power, reactive before and after employment SVC with and without three-phase fault between lines and ground power at (bus-2, bus-4, and bus-5) were evaluated, the voltages have been studied in weak systems.
c) The simulation results are presented by using the MATLAB program in the (IEEE-6) electrical grid system (132\33KV).

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