Sudan University of Science and Technology

College of Engineering

Electrical Engineering Department

Voltage Drop Control in Transmission Line Atbara-Portsudan 220 KV

التحكم في فقد الجهد في خط النقل عطبره–بورتسودان 220 كيلوفولت

A project Submitted in Partial Fulfillment for the Requirements of the Degree of the B.Sc.(Honor) In Electrical Engineering

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الآيــة

قال تعالى:

((إِنَّ فِي خَلْقِ السَّمَوَاتِ وَالأَرْضِ وَاخْتِلاَفِ اللَّيْلِ وَالنَّهَارِ لآيَاتٍ لِّأُوْلِي الألْبَابِ الَّذِينَ يَذْكُرُونَ اللّهَ قِيَاماً وَقُعُوداً وَعَلَىَ جُنُوبِهِمْ وَيَتَفَكَّرُونَ فِي خَلْقِ السَّمَوَاتِ وَالأَرْضِ رَبَّنَا مَا خَلَقْتَ هَذا بَاطِلاً سُبْحَانَكَ فَقِنَا عَذَابَ النَّارِ))

صدق الله العظيم

سورة آل عمران.
(190)

DEDICATION

We dedicate this research to our parents , the beacon that guided us along the way , standing by our side in every step , supporting us when we could not support our self .We dedicate it to those who gave the great gift of love , those who prayed for us to get through the difficulties of life , those who aimed us to our goals and pushed us towards achieving them .

ACKNOWLEDGEMENT

We thank Ust. Gaffar Babiker Osman for putting the effort to guide us through the research , for leading us through our university years , for encouraging us to look for knowledge always and never surrender in the hard situations.

Great thanks to the to the engineer Hassan Mahmoud for his help and dedication in the gathering of the information we needed from the control center to complete the research .

ABSTRACT

Transmission lines and network as a veins of electrical power systems and according to its importance we should focus about its operation and its problems.

In this research the issue of “Drop Voltage” was studied at long transmission lines in Atbara-Portsudan transmission line ,which has many problems related to loss of voltage .

The problem was solved by using Static Var Compensator (SVC) station which going to be temporary solution for drop voltage and it is not care about future considerations of power demands increasing.

The simulation of the effect of adding (SVC) have been done by using NEPLAN Program, and the results were obtained(voltage regulation) before and after using (SVC).

The results were obtained before and after adding the SVC from the simulation program, theregulation before adding the SVC was 23.5 percentbut after adding the SVC it was reduced to 2.78 percent

المستخلص

تعتبر خطوط النقل والشبكات الكهربائية بمثابة الشرايين لأنظمة القدرة ,ونسبه لأهميتها يجب الاهتمام بكل مشاكلها وطرق عملها .

في هذا المشروع تم دراسة مفهوم فقد الجهد في خطوط النقل الكهربائية الطويلة في خط نقل عطبرة بورتسودان , الذي يعاني العديد من المشاكل المتعلقة بهبوط الجهد الكهربائي.

تم حل المشكلة باستخدام معوضات القدرة غير الفعالة الاستاتيكية كحل مؤقت لمشكلة فقد القدرة ,وهذا الحل لا يراعي الزيادة في الطلب علي القدرة.

تم عمل محاكاة لدراسة تأثير اضافة معوضات القدرة غير الفعالة الاستاتيكية باستخدام برنامج NEPLAN وتم الحصول علي نتائج تتعلق بفولتية الخط عند القضيب الناقل للحمل قبل وبعد اضافه المعوض.

النسبه المئويه لفقد الجهد قبل اضافه الSVC كانت % 23.5 ثم انخفضت الي % 2.78 بعد اضافه الSVC .

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

SVC	Static Variable Compensator
TCR	Thyristor Controlled Reactor
TSC	Thyristor Switched Capacitor
TCT	Thyristor Controlled Transformer
FC	Fixed Capacitor
SCC	Self Commutated Converter
LCC	Line Commutated Converter
SR	Saturated Reactor
TSR	Thyritor Switched Reactor
AC	Alternating Current
FACTS	Flexible Alternating Current Transmission System

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CHAPTER ONE
INTRODUCTION

1.1 Overview:

Transmission line are sets of wires, called conductors , that carry electric power from generating plants to the substations that deliver power to customers. At a generating plant, electric power is “stepped up” to several thousand volts by a transformer and delivered to the transmission line. At numerous substations on the transmission system, transformers step down the power to a lower voltage and deliver it to distribution lines. Distribution lines carry power to farms, homes and businesses. The type of transmission structures used for any project is determined by the characteristics of the transmission line’s route, including terrain and existing infrastructure.

1.2 Problem Statement:

There are many problems in the transmission system with AC, the most important of these problems are losses high power transmitted across the line, especially when transport over long distances in addition to the high cost of construction line long distance transport, One of the problems that have been processed is to avoid the increase in reactive power, And the lack of over voltage, In addition to the possibility of controlling the transfer of electrical power

1.3 Objectives:

The objective of the research is to find a solution to the problems of voltage drop that existing in the high voltage Alternating current transmission system, which is at Atbra-Portsudan transmission line which has length 450 km approximately.

the static variable compensator was used in order to compensate the reactive power that needed to remain the system stable.

1.4 Methodology:

The load dispatch center (LDC) covered the whole electrical grid of Sudan country where Atbara substation covered the data requirements to operate the station.

The NEPLAN simulation program has been used to cover the system before & after using the static variable compensator..

1.5 Project Layout:

This research covers an abstract of five chapters , chapter one consists of :

Overview, statement of the research problem, objectives, research methodology and the project layout.

The second chapter was written about general information about transmission system that pave the way to get inside this problem and find as possible as prober way to solve any issues relevant with transmission line system such as types of transmission line.

The third chapter consists of general information about static variable compensator such as its operation principle and the place where the devices were constructed of SVC systems and voltage compensation of transmission line by using SVC or and the fields that use SVC inside it in order to improve their stability and also the construction of SVC devices and the effect of SVC on the reactive power.

The fourth Chapter is about the simulation , the whole system is simulated and all the data was obtained to get the result of adding SVC to the system, at port-Sudan station at load busbar.

After input the data of system components, transformers and the line which connected between them, SVC was added and the difference was showed before and after adding the SVC.

All that have been done by using the NEBLAN program which was designed for such things.

CHAPTER TWO

ELECTRIC POWER SYSTEM

2.1 Introduction:

An electric power system is a network of electrical components used to supply, transmit and use electric power. An example of an electric power system is the network that supplies a region's homes and industry with power - for sizable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centers to the load centers and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power - the standard for large-scale power transmission and distribution across the modern world. Specialized power systems that do not always rely upon three-phase AC power are found in aircraft, electric rail systems, ocean liners and automobiles.

2.2 Components of Electric Power Systems:

System consists electrical power from a huge number of elements associated with each other and that are integrated and functionally to achieve the objective for which it was set up the system, namely the production of electric power and distribution to consumers using them as they need purposes, where the system includes the ability of all machinery and equipment and devices for power generation, transmission, distribution or control various changes within the system and monitor the performance of parts of the system, or those that are used to protect the system components from various errors, as well as instrumentation and communication devices.

A modern electric power system consists of six main components:

i. The power station.
ii. A set of transformers to raise the generated power to the high voltages used on the transmission lines
iii. The transmission lines
iv. The substations at which the power is stepped down to the voltage on the distribution lines
v. The distribution lines
vi. The transformers that lower the distribution voltage to the level used by the consumer's equipment.

The figure (2.1) represents the power system.

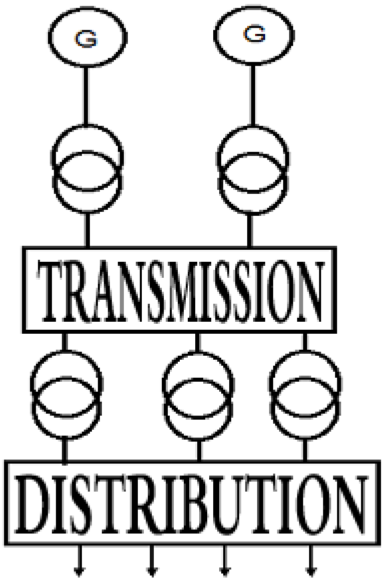


Figure 2.1: Power System

2.3 Generating System:

The power station of a power system consists of a prime mover, such as a turbine driven by water, steam, or combustion gases that operate a system of electric motors and generators. Most of the world's electric power is generated in steam plants driven by coal, oil, nuclear energy, or gas. A smaller percentage of the world's electric power is generated by hydroelectric (waterpower), diesel, and internal-combustion plants.

Types of generating stations:

2.3.1 Steam Power Station:

A steam-electric power station is a power station in which the electric generator is steam driven. Water is heated, turns into steam and spins a steam turbine. After it passes through the turbine, the steam is condensed in a condenser. The greatest variation in the design of steam-electric power plants is due to the different fuel sources.

Almost all coal, nuclear, geothermal, solar thermal electric power plants, waste incineration plants as well as many natural gas power plants are steam-electric. Natural gas is frequently combusted in gas turbines as well as boilers. The waste heat from a gas turbine can be used to raise steam, in a combined cycle plant that improves overall efficiency.

2.3.2 Gas Power Stations:

The combustion (gas) turbines being installed in many of today's natural-gas-fueled power plants are complex machines, but they basically involve three main sections:

The compressor, which draws air into the engine, pressurizes it, and feeds it to the combustion chamber at speeds of hundreds of miles per hour.

The combustion system typically made up of a ring of fuel injectors that inject a steady stream of fuel into combustion chambers where it mixes with the air. The mixture is burned at temperatures of more than 2000 degrees F. The combustion produces a high temperature, high pressure gas stream that enters and expands through the turbine section.

The turbine is an intricate array of alternate stationary and rotating aero foil-section blades. As hot combustion gas expands through the turbine, it spins the rotating blades. The rotating blades perform a dual function: they drive the compressor to draw more pressurized air into the combustion section, and they spin a generator to produce electricity.

2.3.3 Hydroelectricity Power Stations:

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water.

It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation 3,427 terawatt-hours of electricity production in 2010, and is expected to increase about 3.1% each year for the next 25 years. The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity.

2.4 Transmission System:

At first effort is to raise the value of obstetrics effort to transport, so at the beginning of the transmission line through a transformer station raising effort and the key element in the converter stations is the ability In addition , the station has other functions such as operation of circuit breakers in the event of a break in the transmission line or at the station itself Control the power flow to a certain area contain protection devices and adapters for the voltage and current protection devices and gauges Containing equipment and separation equipment and connect allow for maintenance of equipment intended for any station without cutting any service area is fed from the station

After raising the voltage substation transformer station is a transport line at the beginning and end of the transportation station to reduce the effort and lifting station characterized as dealing with much higher capacities of station distribution transformers.

Transmission system consists of two main parts of transformers and transmission lines, figure(2.2) represents the transmission system.

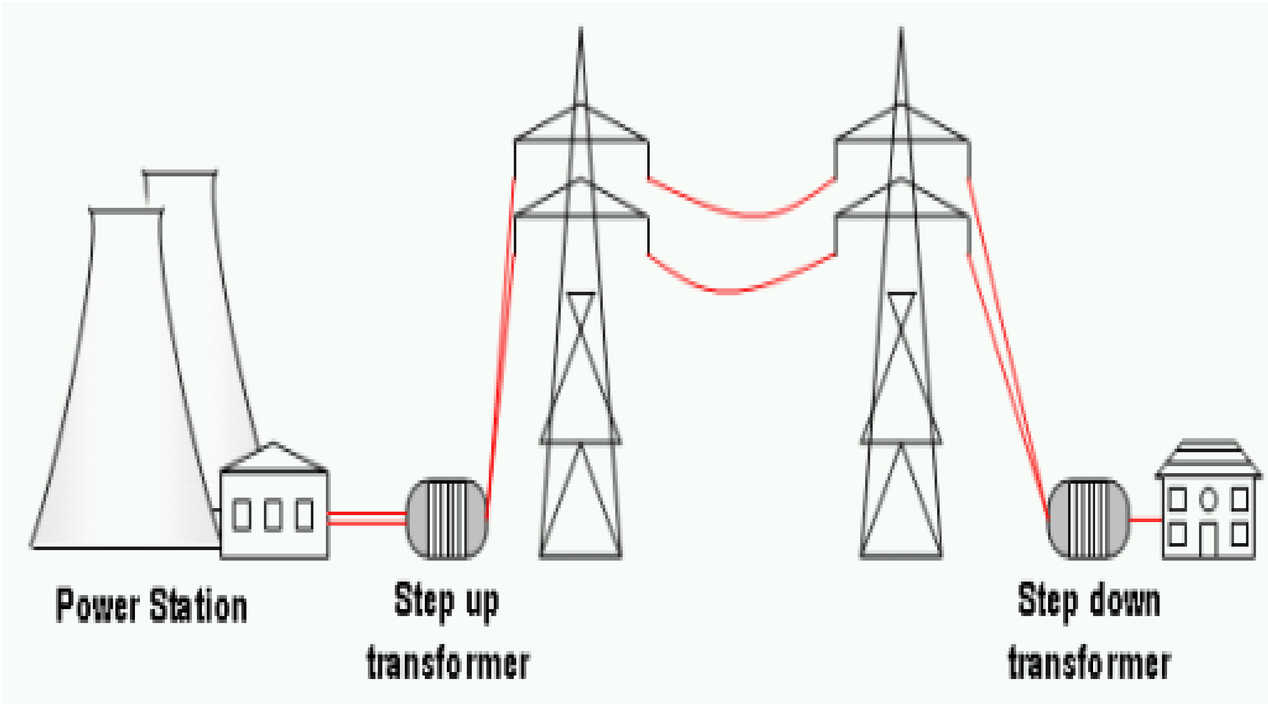


Figure 2.2: Transmission System

2.4.1 Transformers:

The transformer is the most prevalent components of the electric grid and in diverse forms and sizes and functions. The network of electric by dozens of generators, but they contain tens of thousands of transformers, and, of course, is not rivaled in this widespread within the system of the electric power only cables and overhead lines, but the diversity in size, shape and function of the transformer makes the study of electrical transformers most important elements of system electric power.

- **Transformer Action :**

We have seen that the number of coil turns on the secondary winding compared to the primary winding, the turn's ratio, affects the amount of voltage available from the secondary coil. But if the two windings are electrically isolated from each other.

We have said previously that a transformer basically consists of two coils wound around a common soft iron core. When an alternating voltage (VP) is applied to the primary coil, current flows through the coil which in turn sets up a magnetic field around itself, called *mutual inductance*, by this current flow according to Faraday's Law of electromagnetic induction. The strength of the magnetic field builds up as the current flow rises from zero to its maximum value which is given as $d\Phi/dt$.

As the magnetic lines of force setup by this electromagnet expand outward from the coil the soft iron core forms a path for and concentrates the magnetic flux. This magnetic flux links the turns of both windings as it increases and decreases in opposite directions under the influence of the AC supply.

However, the strength of the magnetic field induced into the soft iron core depends upon the amount of current and the number of turns in the winding. When current is reduced, the magnetic field strength reduces.

When the magnetic lines of flux flow around the core, they pass through the turns of the secondary winding, causing a voltage to be induced into the secondary coil. The amount of voltage induced will be determined by:

$N.d\Phi/dt$ (Faraday's Law), where N is the number of coil turns. Also this induced voltage has the same frequency as the primary winding voltage.

Then we can see that the same voltage is induced in each coil turn of both windings because the same magnetic flux links the turns of both the windings together. As a result, the total induced voltage in each winding is directly proportional to the number of turns in that winding. However, the peak amplitude of the output voltage available on the secondary winding will be reduced if the magnetic losses of the core are high.

If we want the primary coil to produce a stronger magnetic field to overcome the cores magnetic losses, we can either send a larger current through the coil, or keep the same current flowing, and instead increase the number of coil turns (NP) of the winding. The product of amperes times turns is called the "ampere-turns", which determines the magnetizing force of the coil.

So assuming we have a transformer with a single turn in the primary, and only one turn in the secondary. If one volt is applied to the one turn of the primary coil, assuming no losses, enough current must flow and enough magnetic flux generated to induce one volt in the single turn of the secondary. That is, each winding supports the same number of volts per turn.

- **Components of transformer voltage:**

Primary coil: coil of copper wire insulated connection limbs source of nutrition.

A secondary coil: coil insulated electric convey his limbs pregnancy or the consumer to be the driving force of electric supply

Iron heart: Closed made of wrought iron in the form of silicon thin slices isolated from each other.

- **Classification** of **transformers:**

Step-down transformer voltage: it shall be the secondary coil voltage less than the primary coil voltage.

Step-up transformer voltage: it shall be the secondary coil voltage is greater than the primary coil voltage.

2.4.2 Transmission Lines:

The transfer of electrical power from generating stations to the consumer is the main objective of the establishment of the transmission lines must also maintain the value of the voltage at different points within a particular transmission line is the means that have been on the way the transfer of electrical power from areas of generation to areas of consumption and the transmission line in mostly line antenna , and power system performance depends mainly on the performance of the transmission line in the system, and the important considerations in Contacts transmission lines and voltage drop in the line missing the ability and efficiency of the transmission line . It owns four electric transmission lines constants Are the resistance and inductance , respectively, and the conductivity of parallelism usually neglected connectivity to the small value.

An overhead power line is a structure used in electric power transmission and distribution to transmit electrical energy along large distances. It consists of one or more conductors (commonly multiples of three) suspended by towers or poles. Since most of the insulation is provided by air, overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy.

Towers for support of the lines are made of wood (as-grown or laminated), steel (either lattice structures or tubular poles), concrete, aluminum, and occasionally reinforced plastics. The bare wire conductors on the line are generally made of aluminum (either plain or reinforced with steel, or composite materials such as carbon and glass fiber), though some copper wires are used in medium voltage distribution and low voltage connections to customer premises. A major goal of overhead power line design is to maintain adequate clearance between energized conductors and the ground so as to prevent dangerous contact with the line, and to provide reliable support for the conductors, resilient to storms, ice load, earthquakes and other potential causes of damage. Today overhead lines are routinely operated at voltages exceeding 765,000 volts between conductors, with even higher voltages possible in some cases.

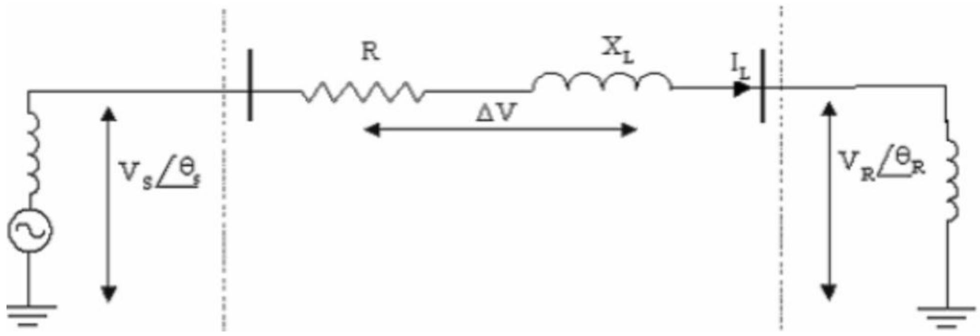
Classified as electric power transmission lines, according to:

i. The lengths to Short Transmission lines at least length of 88 Km.
ii. Medium and transmission lines ranging in length from 88 to 480 km.
iii. And long transmission lines longer than 480 Km.

And each group is different from the other in a way to represent the constants and take them into account or neglected, as the transmission lines in a short while neglecting capacity transmission lines in the middle are taken into account as a value focused at a certain point in line, but in the long transmission lines was needed considering the distribution of amplitude along the line where the rising value of the capacitive current on-line to increase the length.

- **Short Transmission lines**

Are the lines that have a length of less than 80 km and effort to run less than 20 kv, and the capacity to be very small so it can be neglected, and so the performance of the transmission lines Short depends on the resistance and inductance of the line. Figure(2.3) represents the short transmission lines.



Figure(2.3): Short Transmission Lines

- **Medium transmission lines:**

Are the lines that have a length of between 80 km to 200 km and effortless operation be between 20kv to kv 100 in these lines because of the effort and length have the effect of charging current remarkable so cannot neglect capacity where the regular distribution along the line, are represented by lines of transport medium in the form of π or T-shaped

Representation of the transmission lines in the form of medium π: In this way the capacity of the line is split into two halves, one half at the beginning of the line and the other half at the end of the line. Figure(2.4) represents medium transmission lines π type and figure(2.5) represents the T type.

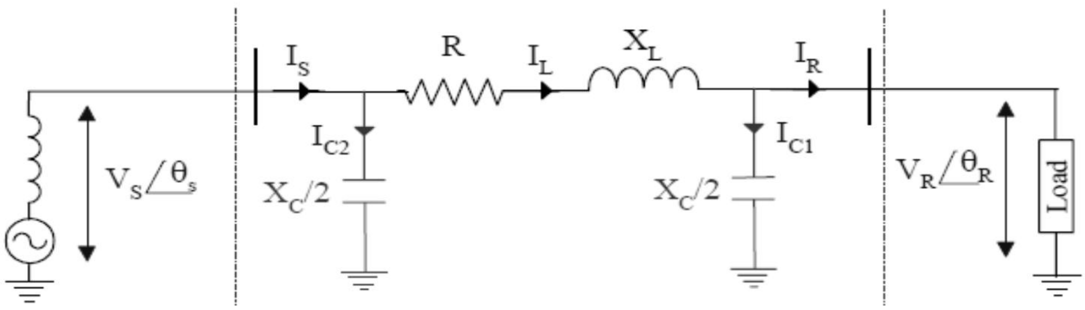


Figure (2.4): Medium Transmission Line π

Representation of the transmission lines in the form of medium-T:

In this way, is to focus capacity line at the middle of the line

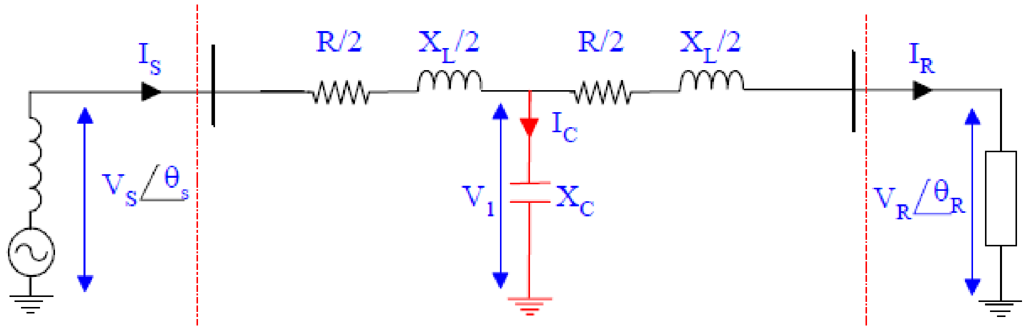


Figure (2.5): Medium Transmission Line T

- **Long Transmission lines:**

Are the lines that have a length greater than 200km and an operating voltage greater than kv100 In these lines must be considered that the impedance and Admittance regular distribution line can be considered a component of several lines of short lines Omtosth associated with each.

2.5 Distribution system:

The distribution system is commonly broken down into three components: distribution substation, distribution primary and secondary. At the substation level, the voltage is reduced and the power is distributed in smaller amounts to the customers. Consequently, one substation will supply many customers with power. Thus, the number of transmission lines in the distribution systems is many times that of the transmission systems. Furthermore, most customers are

Connected to only one of the three phases in the distribution system. Therefore, the power flow on each of the lines is different and the system is typically ‘unbalanced’. This characteristic needs to be accounted for in load flow studies related to distribution networks.

2.5.1 Distribution Substations:

The distribution system is fed through distribution substations.

These substations have an almost infinite number of designs based on consideration such as load density, high side and low side voltage, land availability, reliability requirements, load growth, voltage drop, cost and losses etc.. For a typical substation, the voltage of the high side bus can be anywhere from 34.5 kV all the way up to 345 kV. The average high side voltage level is approximately 115 to 138 kV. Twoor more feeders are normally connected to the low voltage bus through a feeder breaker.

2.5.2 Distribution Feeders:

On a primary distribution feeder, various equipment can be distinguished such as fuses, distribution transformers, recloses, switches. Much of this equipment, such as recloses, aroused only at the distribution level. Other equipment such as capacitors, transformers, and arresters are also used at the transmission levels but with considerably different rules of application. Most distribution feeders are three-phase and four-wire. The fourth wire is the neutral

Wire which is connected to the pole, usually below the phase wires, and grounded periodically. A three-phase feeder main can be fairly short, on the order of a mile or two, or it can be as long as30 miles. Actually, the length of feeders is closely linked with load density at location. For instance, for an area where the customer load density is strong, primary network will end very close of consumers and secondary feeders will be short. For a weak load density area, primary and secondary feeders will be longer. Distance separating substation from customers will be covered both by primary and secondary feeders in order to provide the best quality supply. These differences explain why a distinction is made between country distribution networks, where customers are spread, and urban distribution networks, where large urban agglomerations must be taken into consideration.

Some characteristics of the secondary spot network are going to be given because it is frequently used in the United States. Secondary spot network is characterized by maximum service reliability and an operating flexibility. It includes two or more ‘transformer / protector’

Units in parallel. The low voltage bus is continuously energized by all units, and automatic disconnection of any unit is obtained by sensitive reverse power relays in the protector.

Maintenance switching of Primary feeders can be done without customer interruption or involvement. This system represents the most compact and reliable arrangement of components and is the most reliable for all classes of loads.

2.5.3 Secondary Distribution:

The purpose of the distribution transformer is to reduce the primary voltage to a level where it can be used by the customer. Single-phase transformers range in size from 10 kVA to About 300 kVA with units in the 25 and 37.5 kVA size being the most popular for residential areas.

The secondary voltage level in the United States for residential service is 120/240 Volts Lower wattage devices, such as lights, are connected line-to-neutral across both sides of the transformer secondary. Higher wattage devices, such as ovens, clothes dryers, etc., are usually connected across the 240 volt circuit since this has the effect of reducing voltage drop and losses.

2.6 Supplementary Equipment:

Any electric-distribution system involves a large amount of supplementary equipment to protect the generators, transformers, and the transmission lines themselves. The system often includes devices designed to regulate the voltage or other characteristics of power delivered to consumers.

To protect all elements of a power system from short circuits and overloads, and for normal switching operations, circuit breakers are employed. These breakers are large switches that are activated automatically in the event of a short circuit or other condition that produces a sudden rise of current. Because a current forms across the terminals of the circuit breaker at the moment when the current is interrupted, some large breakers (such as those used to protect a generator or a section of primary transmission line) are immersed in a liquid that is a poor conductor of electricity, such as oil, to quench the current. In large air-type circuit breakers, as well as in oil breakers, magnetic fields are used to break up the current. Small air-circuit breakers are used for protection in shops, factories, and in modern home installations.

In residential electric wiring, fuses were once commonly employed for the same purpose. A fuse consists of a piece of alloy with a low melting point, inserted in the circuit, which melts, breaking the circuit if the current rises above a certain value. Most residences now use air-circuit breakers.

CHAPTER THREE

STATIC VAR COMPENSATOR

3.1 Introduction :

Static variable compensators (SVCs) are part of the flexible alternating current transmission systems (FACTS) device family. Their primary purpose is to supply a fast-acting, precise, and adjustable amount of reactive power to the system to which they are connected. SVCs achieve this by switching in or out one or more thyristor-switched capacitors (TSCs), and by adjusting the firing angle of a thyristor-controlled reactor (TCR). Some SVCs also comprise a number of fixed capacitors (FCs) which supply a steady amount of reactive power.

SVCs can be used for voltage compensation at the receiver end of ac transmission lines, thus replacing banks of shunt capacitors. When used for this purpose, SVCs offer a number of advantages over banks of shunt capacitors, such as much tighter control of the voltage compensation at the receiver end of the ac transmission line and increased line stability during load variations.

SVCs are also commonly used for dynamic power factor correction (i.e., dynamic reactive power compensation) in industrial plants operating with large random peaks of reactive power demand. SVCs increase the power factor of the plant, minimize the voltage fluctuations at the plant input (which prevents damage to the equipment), and reduce the plant's operating costs.

This course, Static Var Compensators (SVCs), teaches the basic concepts of voltage compensation in ac transmission lines and power factor correction in large industrial plants using SVCs. Students are introduced to the operation of SVCs and their different components. They also learn about different types of SVCs, and how each type of SVC operates. Students also verify the theory presented in the manual by performing circuit measurements and calculations.

3.2 Voltage Compensation of AC Transmission Lines Using an SVC:

The significant voltage drop occurs at the receiver end of ac transmission lines. The magnitude of this voltage drop increases with the length of the line, as well as with the load at the receiver end of the line. Such a voltage drop cannot be tolerated in ac power networks. This is due to the fact that many electrical devices such as motors, relays, and lighting equipment work properly only under stable voltage conditions (close to the voltage for which they are rated).

One way to compensate for the voltage drop occurring across an ac transmission line is to add substations containing shunt capacitors along the line. Adding shunt-capacitor substations in such a way produces the effect of dividing an AC transmission line into many segments of shorter length. Each substation serves the purpose of compensating the voltage drops across the ac transmission line (i.e., maintaining a constant voltage across each segment of the ac transmission line).

Figure (3.1) illustrates a typical ac transmission line used to transfer large amounts of electrical power over a long distance from a power generating station to the distribution network (which, in turn, distributes the electrical power to consumers).

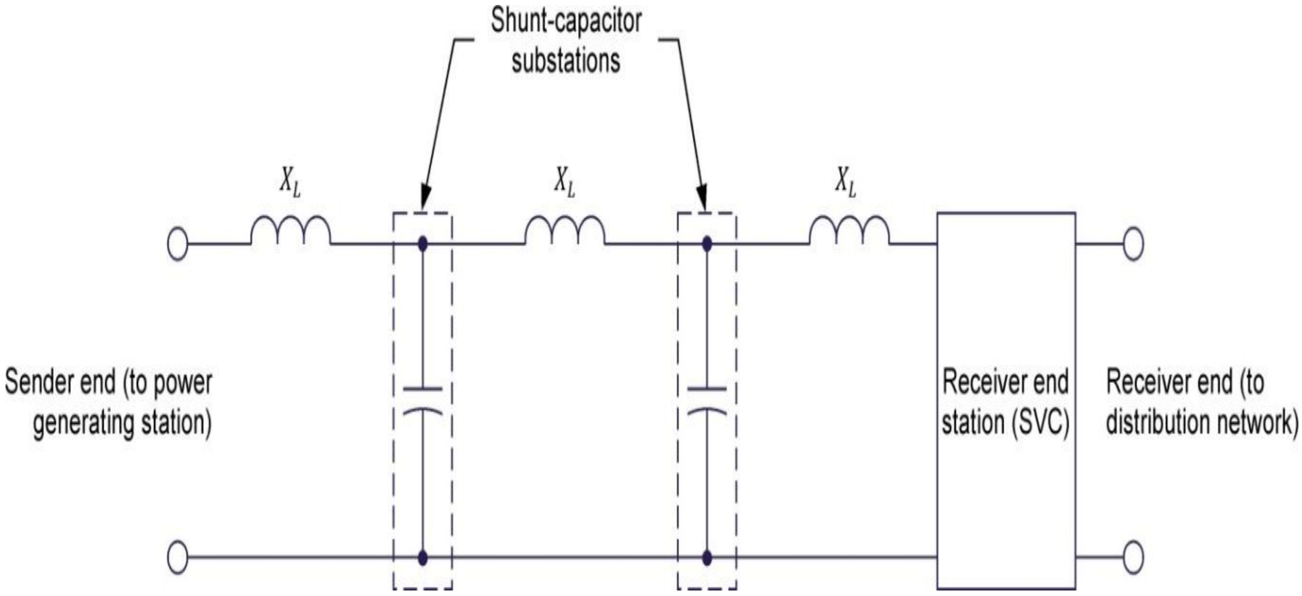


Figure (3.1) Typical ac transmission line used to transfer large amounts of electrical power over a long distance from a power generating station to the distribution network.

As Figure (3.1) shows, the AC transmission line is divided into three segments of equal length by two shunt-capacitor substations used for voltage compensation. The voltage at each substation is compensated by switching shunt capacitors in and out to maintain the voltage along the ac transmission line as close as possible to the nominal value of the ac power network voltage. As mentioned in the Introduction , shunt-capacitor substations have certain drawbacks, such as the difficulty in coordinating all substations and perfectly compensating the voltage across each segment of the ac transmission line. However, since the shunt-capacitor substations are located along the ac transmission line, and thus, do not directly supply power to consumers, it is not necessary for the voltage at the shunt-capacitor substations to be perfectly compensated at all times.

3.3 The Receiver Voltage :

The voltage at the end of the third segment (i.e., the receiver end) of the ac transmission line in Figure 29 is compensated using an SVC substation, instead of a shunt-capacitor substation. This is due to the numerous advantages SVCs offer over shunt capacitor substations, most notably a tight and fast compensation of the voltage across the line. Since the receiver end station is located at the end of the ac transmission line, it is important for the voltage at this station to be as perfectly compensated as possible before the electrical power is distributed to consumers; hence, a SVC substation is used here instead of a shunt-capacitor substation.

Due to its fast and precise compensation of the voltage at the receiver end of an ac transmission line, an SVC substation is able to compensate for the voltage fluctuations occurring across the line (generated by switching shunt capacitors in and out in the substations), and compensate for the voltage fluctuations caused by the variation of the load (i.e., the electrical power demand of the consumers).

3.3.1 The Level of Precision in The Voltage Compensation:

To obtain a level of precision in the voltage compensation comparable to an SVC while using a shunt-capacitor substation at the receiver end of an ac transmission line, a large number of capacitors of different reactance values would need to be installed in the shunt-capacitor substation. This would give the shunt-capacitor substation a large variety of possible shunt capacitor combinations, and therefore would enable the shunt-capacitor substation to precisely compensate the voltage at the receiver end of the ac transmission line. Such a shunt-capacitor substation, however, would be just as costly as an SVC substation (if not more so), while having a response time that is much slower than an SVC substation. This is why, for fast and precise voltage compensation at the receiver end of an ac transmission line, SVC substations are much more efficient than shunt-capacitor substations.

3.4 Replacement of The Shunt-Capacitor:

It would be possible to replace all the shunt-capacitor substations in the ac transmission line of Figure (3.1) with SVC substations to achieve even more effective voltage compensation. However, even though SVCs are more efficient than shunt-capacitor substations in every aspect, it is not common practice to systematically replace shunt-capacitor substations with SVC substations. This is primarily due to an SVC substation being much more costly (about 5 times more) than a shunt-capacitor substation with a comparable power rating. Since the use of shunt-capacitor substations to compensate the voltage along AC transmission lines already yields acceptable results, replacing all shunt-capacitor substations in an AC transmission line with SVC substations is usually not cost effective.

3.5 Benefits of SVC:

- Increase in the power factor by dynamic reactive power compensation.
- Eliminates the voltage distortion caused by harmonics.
- Stabilizes the voltage and reduce the voltage fluctuation and flicker.
- Balances the three-phase load current and eliminate the negative sequence current.

- Increases the operation safety of impact loading equipment and its adjacent electrical equipment.

3.6 Operating Principles :

The Static Var Compensator (SVC) is composed of the capacitor banks/filter banks and air-core reactors connected in parallel. The air-core reactors are series connected to thyristors. The current of air-core reactors can be controlled by adjusting the fire angle of thyristors.

The SVC can be considered as a dynamic reactive power source. It can supply capacitive reactive power to the grid or consume the spare inductive reactive power from the grid. Normally, the system can absorb the reactive power from a capacitor bank, and the spare part can be consumed by an air-core shunt reactor.

As mentioned, the current in the air-core reactor is controlled by a thyristor valve. The valve controls the fundamental current by changing the fire angle, ensuring the voltage can be limited to an acceptable range at the injected node(for power system var compensation), or the sum of reactive power at the injected node is zero which means the power factor is equal to 1 (for load var compensation).

Current harmonics are inevitable during the operation of thyristor controlled rectifiers, thus it is essential to have filters in a SVC system to eliminate the harmonics. The filter banks can not only absorb the risk harmonics, but also produce the capacitive reactive power.

The SVC uses closed loop control system to regulate busbar voltage, reactive power exchange, power factor and three phase voltage balance.

The figure (3.2) is representing the components and the structure of the SVC system.

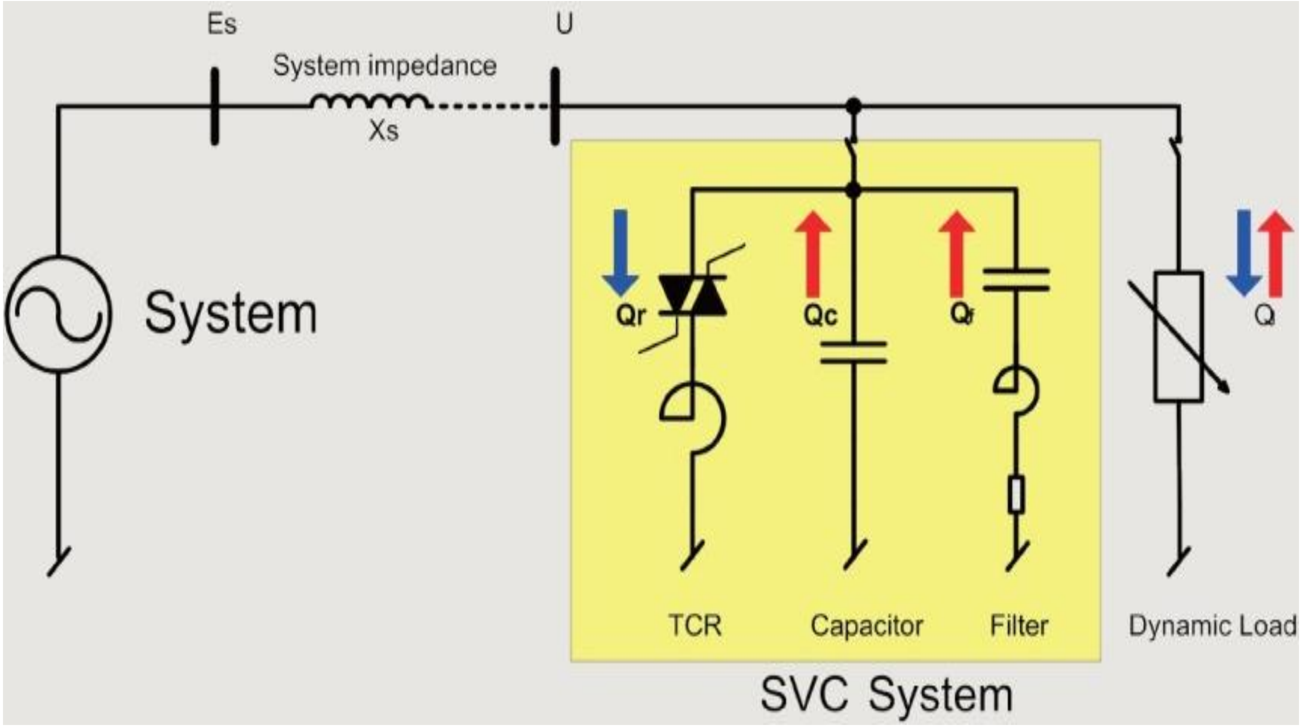


Figure (3.2) Svc system

3.7 The Traditional Reactive Power Regulation Methods Before The Invention of SVC:

Modern society has relied consistently on electrical power, requiring higher demands of power stability and power quality. High-power rapid impact loads, rapid growth of asymmetrical impact loads, e.g. electrified railway, increase in distributed wind power generation equipment, connections/disconnections of large load and inevitable power system faults, are adverse factors which can lead to considerable reactive disturbances in power system and affect power stability, power quality and economy of power grid operation. The overcurrent and overvoltage sequences caused by these disturbances may damage the associated electrical apparatus.

To solve this problem, it is essential to adjust reactive power in the power grid expeditiously to achieve a reasonable power flow distribution, which is also very important in phase modulation, voltage regulation and overvoltage restriction.

The traditional reactive power regulation methods before the invention of SVC are:

i. Reconfiguration of system structure
ii. Generator excitation regulation
iii. Synchronous compensator
iv. Change of voltage by transformer tap to adjust the power flow in the grid.
v. Series compensation capacitor
vi. Switching in/out of the shunt reactor or shunt capacitor
vii. Magnetic controlled reactor.

3.8 SVCs are used for:

i. Increasing power transfer in long lines.

ii. Stability improvement (both steady state and transient) with fast acting voltage regulation.

iv. Damping of low frequency oscillations (corresponding to electromechanical modes).

v. Damping of subsynchronous frequency oscillations (due to torsional modes).

v. Control of dynamic over voltage.

3.9 Types of Static Var Compensator:

Three basic types of SVCs:

- Variable impedance type
- Current source type

- Voltage source type

The following are the basic types of reactive power control elements which make up all or part of any static var system:

- saturated reactor (SR)
- thyristor-controlled reactor (TCR)
- thyristor-switched capacitor (TSC)
- thyristor-switched reactor (TSR)
- thyristor-controlled transformer (TCT)
- self or line-commutated converter (SCC/LCC) .

Figure(3.6) represents types of SVCs.

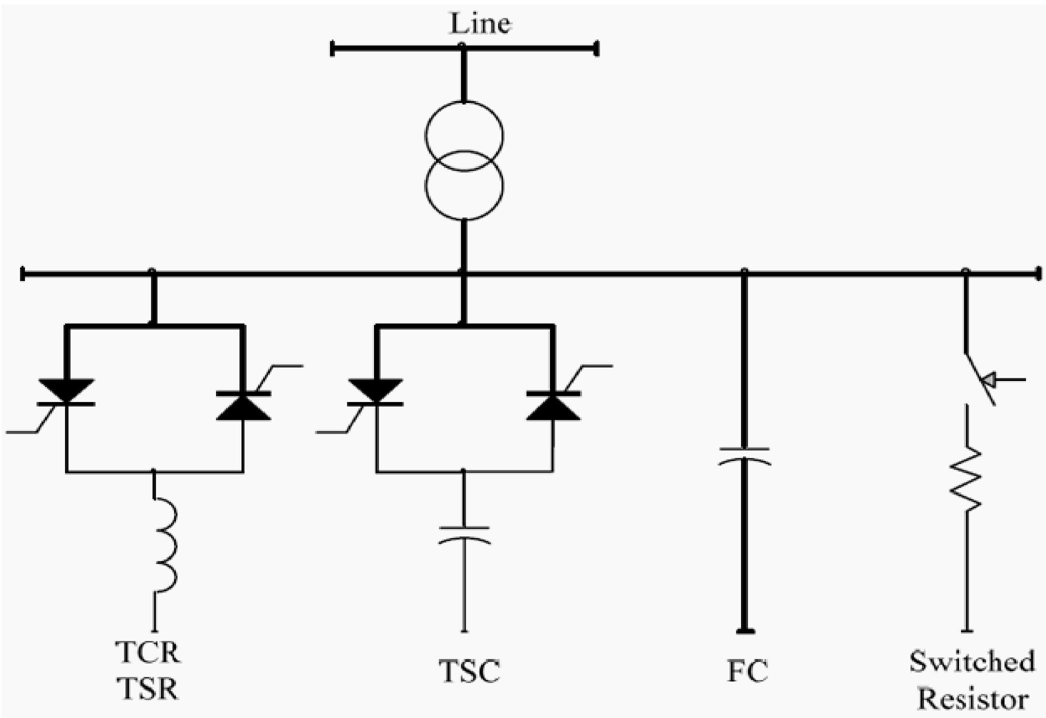


Figure (3.3)

3.10 Fields of Applications of SVC:

A complete set of SVC system can be used to generate a constant varying inductive and capacitive reactive power with fast response time. So far, SVC system has been extensively used in electric power system and industrial fields.

3.10.1 Power Transmission:

In the case of long-distance AC transmission, due to the influence of Ferranti Effect, the voltage in the middle of transmission lines will rise which will limit the transferred power. Therefore, to reduce the voltage rise and maximize the transferred power, the SVC is normally installed at the midpoint or several points in the middle of transmission line.

In addition, an SVC system installed on the AC side of DC converter station to provide sufficient reactive power with fast response and easy maintenance.

- **Benefits :**

i. Regulate the system voltage.
ii. Increase the static stability and transient stability of power system.
iii. Increase the line transmission capacity.
iv. Restrain the power oscillation and the sub-synchronous resonance.
v. Restrain the transient overvoltage.
vi. Balance the three-phase voltage.
vii. Control the voltage in DC converter station and provide reactive power.

3.10.2 Distribution System:

The SVC can be connected to the terminal substation in the power distribution system to reduce the reactive power exchange, improve the power factor, decrease the distribution system loss and reduce the damages caused by frequent switch-in of capacitor banks.

Benefits:

i. Reduce the reactive power exchange with system and improve system stability

i. Rapid and continuous compensation of the reactive power, increase in the power factor and improvement in the power quality

ii. Reduction in the power losses of distribution system

iii. Used in combination of stepped-switchover capacitor banck to reduce the damage caused by frequent switching of capacitor bank.

3.10.3 Wind Power Plant:

For small hydro-power plant or wind power plant in some remote locations, the connected large power grid can not efficiently provide enough reactive power, or the excess reactive power may result in a serious voltage drop and large line losses. Installing an SVC system at the connection point can efficiently stabilize the voltage at the connection point to an acceptable level and maximally prevent the harmful impact caused by faults in the power grid.

- **Benefits:**
  - Increase in the power factor by dynamic reactive power compensation
  - Eliminates the harmonics
  - Eliminates the voltage fluctuation and voltage flicker

- Provides the local reactive power, stabilizes the voltage and reduces the transmission line losses.

3.10.4 Industrial Consumers:

The electronic rectifiers applied to the electrolysis power supply and mill machine requires large amount of reactive power. The SVC system can not only supply sufficient reactive power, but also eliminate the harmonics generated by rectifiers and prevent the equipment from the voltage fluctuation.

The use of AC arc furnace usually comes with heavy harmonics and large negative sequence current. Large amount of reactive power demand and reactive power variation result in the voltage fluctuation and flicker , which also reduces the operation efficiency.

3.11 PLACEMENT OF SVC:

To improve the voltage stability level of the system, SVC has to be placed at the proper locations. To determine the best location . The bus with maximum L- index value is the most vulnerable bus in the given system and there the compensator devices have to be placed. Weak buses are identified based on the L-index values of the load buses. The buses with high values of L^{max} are the weak buses of the system from the voltage stability point of view. The L- indices are calculated for the system by running the power flow analysis. Computing L-index value for load buses (including the generator buses treated as PQ bus) , it is found that the L-index values are higher at each bus by repeating the power flow with only one generator bus and other generator buses as PQ buses. Hence it is concluded that the number of buses makes a significant change in the L-indices results. If we take SVC bus as generator bus and compute the L-indices, we get L-index values reduced significantly compared to the SVC bus treated as load bus. With same compensation as obtained for maintaining the same voltage as in previous output, obtain the L- indices. These L-indices are higher at each bus compared to previous case when SVC bus was assumed as PV bus. This gives indication that while computing L-indices, it is reasonable to treat SVC bus as load bus than generator bus.

3.11.1 PROBLEM FORMULATION:

With the increasing size of power system, there is a thrust on finding the solution to maximize the utilization of existing system and to provide adequate voltage support. VAR devices if placed optimally can be effective in providing voltage support, controlling power flow and in turn resulting into lower losses. The problem of voltage security enhancement is formulated as a multi-objective optimization problem. The objectives considered here are minimization of VAR cost and maximization of voltage stability margin. This is achieved by proper adjustment of real power generation, generator voltage magnitude, SVC reactive power generation of capacitor bank and transformer tap setting. Power flow equations are the equality constraints of the problems, while the inequality constraints include the limits on real and reactive power generation, bus voltage magnitudes, transformer tap positions and line flows.

3.12 Voltage compensation of AC transmission lines :

The a significant voltage drop occurs at the receiver end of ac transmission lines. The magnitude of this voltage drop increases with the length of the line, as well as with the load at the receiver end of the line. Such a voltage drop cannot be tolerated in ac power networks. This is due to the fact that many electrical devices such as motors, relays, and lighting equipment work properly only under stable voltage conditions (close to the voltage for which they are rated).

One way to compensate for the voltage drop occurring across an ac transmission line is to add substations containing shunt capacitors along the line. Adding shunt-capacitor substations in such a way produces the effect of dividing an ac transmission line into many segments of shorter length. Each substation serves the purpose of compensating the voltage drops across the ac transmission line (i.e., maintaining a constant voltage across each segment of the ac transmission line). Figure (3.4) represents a typical AC transmission line with SVC station

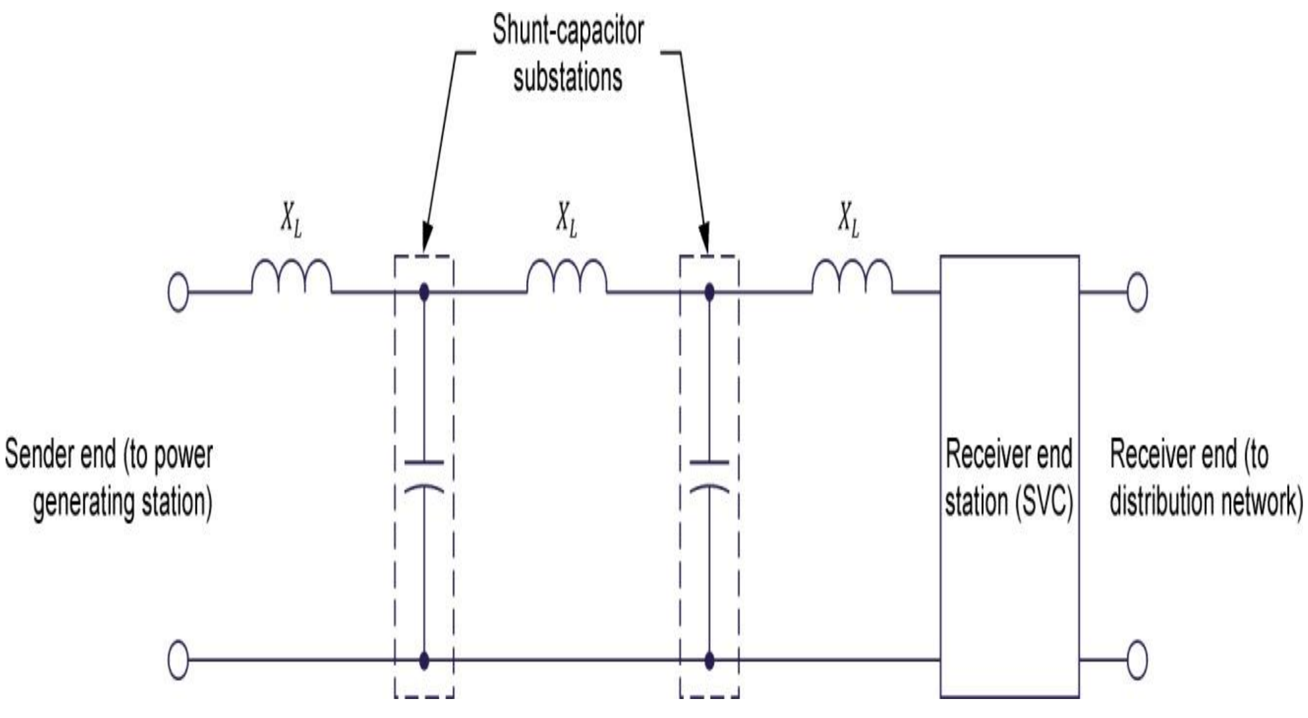


Figure (3.4): a typical ac transmission line with svc station

Figure (3.4) illustrates a typical ac transmission line used to transfer large amounts of electrical power over a long distance from a power generating station to the distribution network (which, in turn, distributes the electrical power to consumers).

3.13 Automatic Voltage Compensation:

Figure(3.5) represents voltage compensation using SVC .

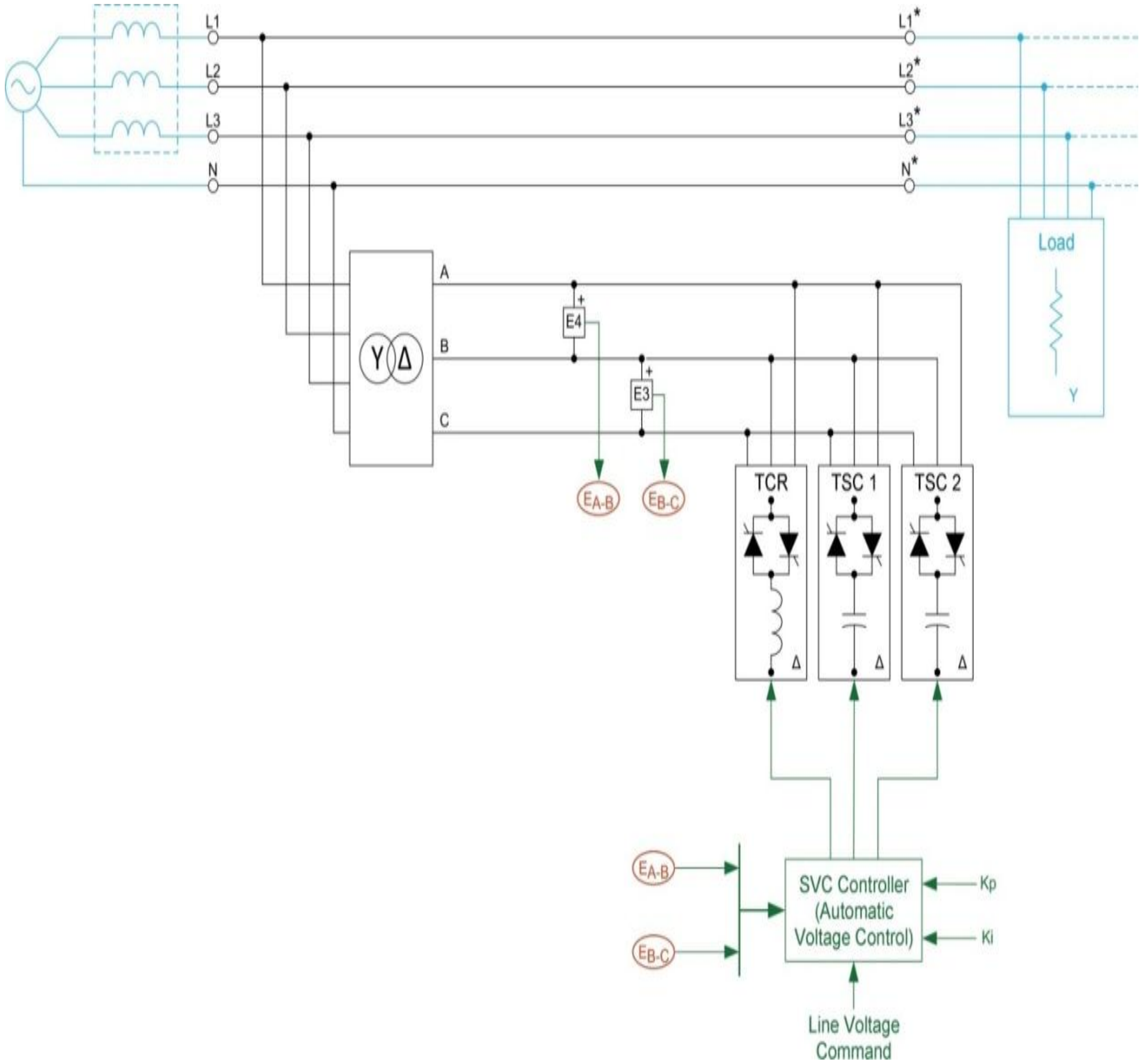


Figure (3.5) Block diagram of an SVC designed for voltage compensation.

When an SVC is used for compensating the voltage across an AC power system (typically ac transmission lines), the voltage across the SVC is regulated using a voltage control loop implemented in the SVC controller.

This controller monitors the voltage across the SVC and determines the number of TSCs (if any) that must be switched in and the TCR firing angle required in order to maintain the voltage measured across the SVC at the desired value (usually the nominal voltage of the ac power system to which the SVC is connected). The block diagram of an SVC designed for voltage compensation (i.e., automatic voltage control) is shown inFigure (3.5)**.**

As Figure (3.5) shows, two voltage sensors measure line voltages E_{A_B} and E_{B_C} across the SVC side of the step-down transformer and send these voltages to the SVC controller (which is set for automatic voltage control). The SVC controller compares the measured line voltages to the line voltage command E_{Ref} of theSVC, and determines the error in the measured line voltage across the SVC side of the step-down transformer. Using the determined error, the SVC controller switches TSCs in and out, and adjusts the TCR firing angle, so that the amount of reactive power which the SVC exchanges with the ac power system precisely compensates the voltage measured across the SVC side of the step-down transformer. This maintains the measured voltage as close as possible to the line voltage command of the SVC. Note that linevoltage E_{A_B} is also used to properly synchronize the firing of the thyristors in the TCR, as well as to provide the phase angle (0) information required to perform mathematical calculations in the controller. The operation of an SVC controller designed for automatic voltage control.

3.14 Reactive Power Control:

The injection of reactive power (Q) is only necessary when for some reason the system requires reactive power assistance. When *Q* is set to zero ($IQ_{(REF)} = 0$), the compensating system automatically generates the *Q* required for all loads connected after the multilevel converter. In other words, when Q is set to zero, the mains always see a unity power factor, independent of the type of contaminating load being compensated. If Q is set to a positive value, then the multilevel converter can assist the mains, injecting additional reactive power to the grid. Q can also be set to negative values, but this operation is normally not required. According to this explanation, the system works like a synchronous machine, where the reactive power is controlled through the excitation coil. In this case, it is controlled through Q (ref).

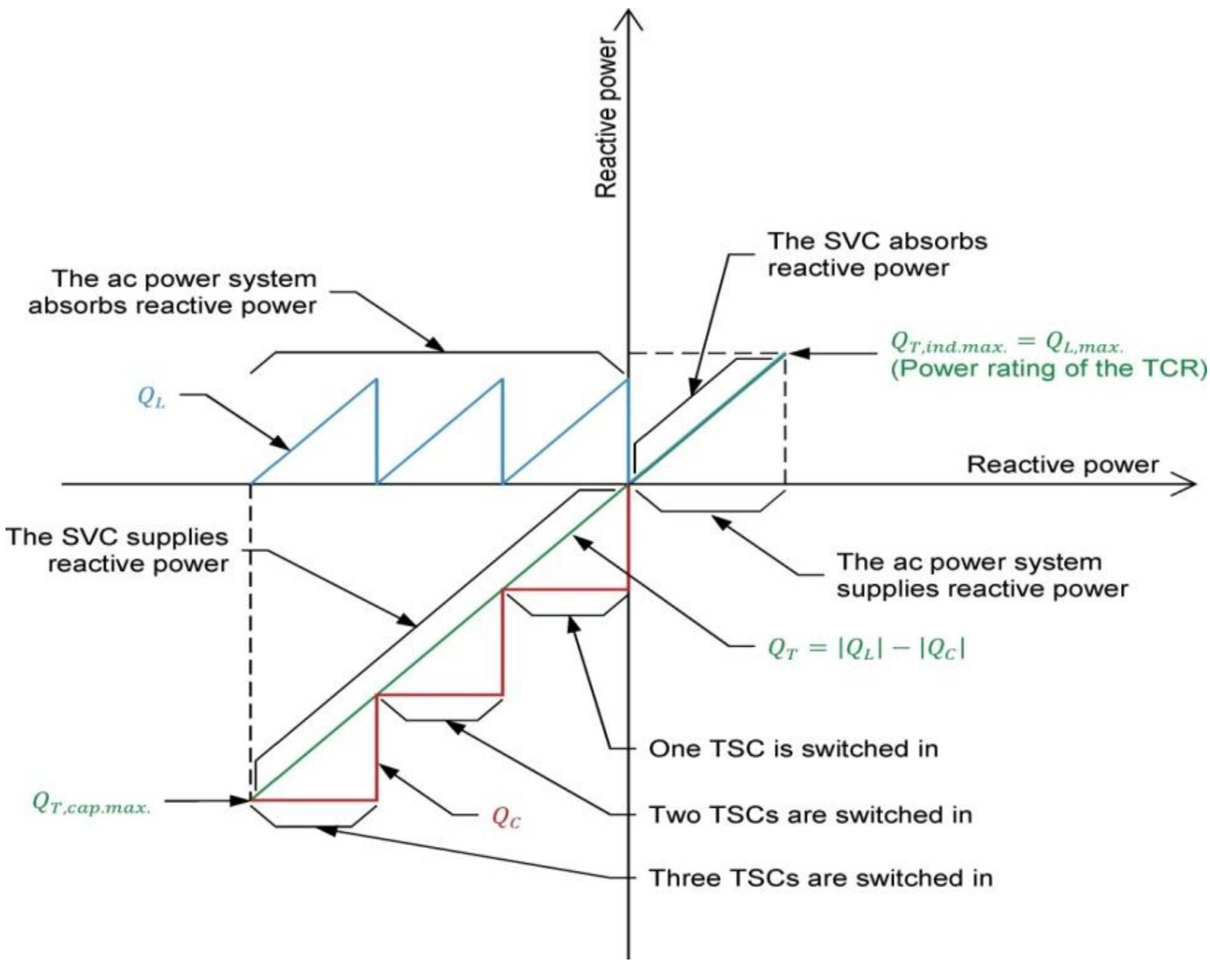


Figure (3.6) Reactive power exchange characteristic of an SVC

As the figure shows, the total reactive power Q_T which an SVC of the

TCR-TSC type exchanges with the ac power system to which it is connected is equal to the variable reactive power Q_L absorbed by the TCR minus the reactive power Q_c (stepwise variable) supplied by the TSCs. The total reactive power Q_T of an SVC of the TCR-TSC type thus ranges from the maximal capacitive reactive power Q_{TICA}P.MAX,, which is equal to the total reactive power rating of the TSCs, to the maximal inductive reactive power Q_T,MD.MAX., which is equal to the reactive power rating ($Q_{L>MAX}$.) of the TCR. When the total reactive power Q_T in an SVC is negative, the SVC supplies reactive power. Conversely, when the total reactive power Q_T in an SVC is positive, the SVC absorbs reactive power.

3.15 Reactive power exchange characteristic of an SVC of the TCR-FC type:

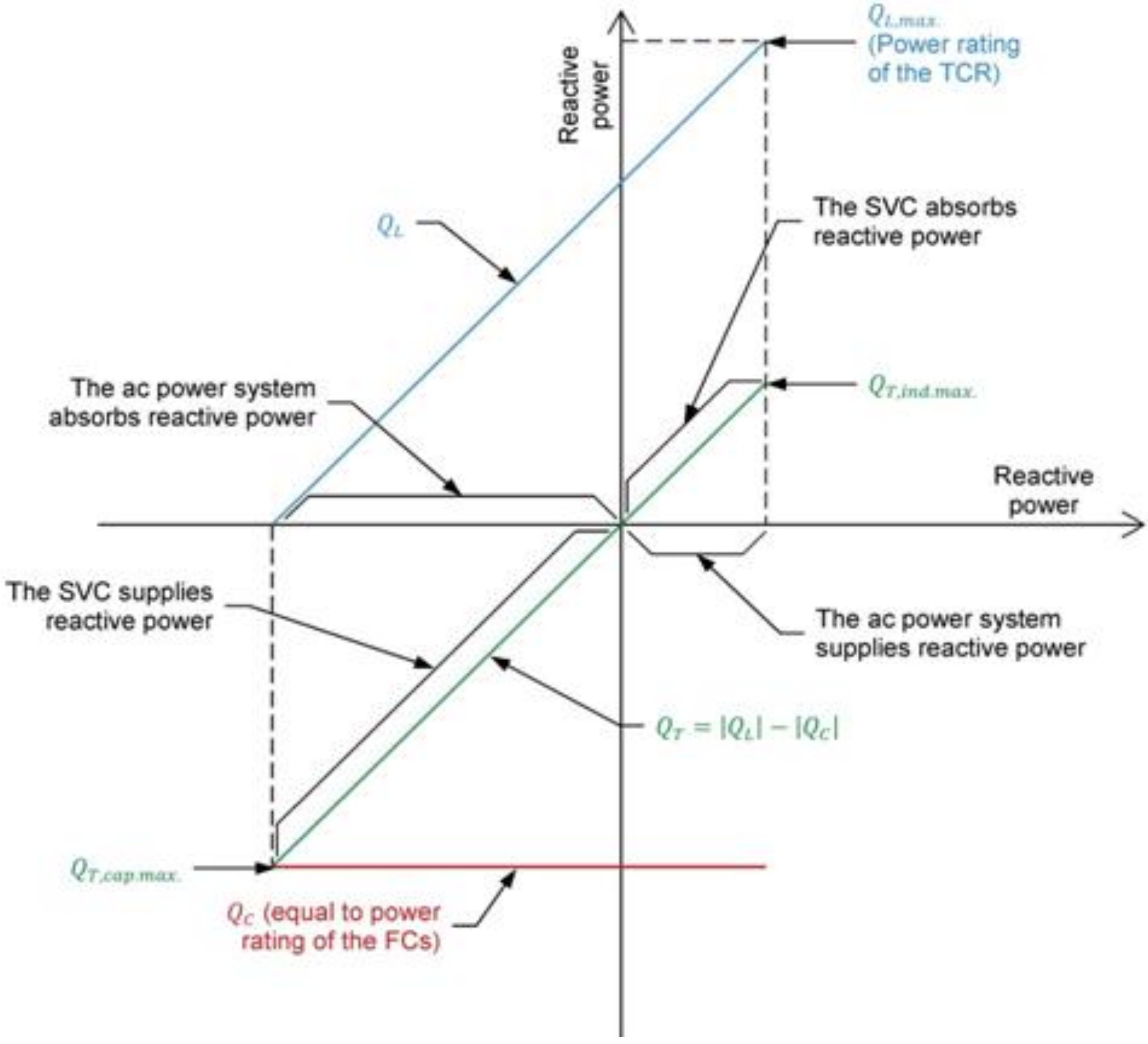


Figure (3.7) Reactive power exchange characteristic of an svc of the TCR-type

As the figure shows, the total reactive power Q_T which an SVC of the TCR-FC type exchanges with the ac power system to which it is connected is equal to the variable reactive power Q_L absorbed by the TCR minus the fixed reactive power Q_c supplied by the FCs. The total reactive power Q_T of an SVC of the TCR-FC type thus ranges from the maximal capacitive reactive power Q_T,*cap.max*, which is equal to the reactive power rating Q_c of the FCs, to the maximal inductive reactive power Q_T,*ind.max.*, which is equal to the reactive power rating $Q_{L>max}$.of the TCR minus the reactive power rating Q_c of the FCs. When the total reactive power Q_T in the SVC is negative, the SVC supplies reactive power. Conversely, when the total reactive power Q_T in the SVC is positive, the SVC absorbs reactive power.

3.16 System Configuration:

A Static Var Compensator mainly consists of following components which is represented by figure (3.8)

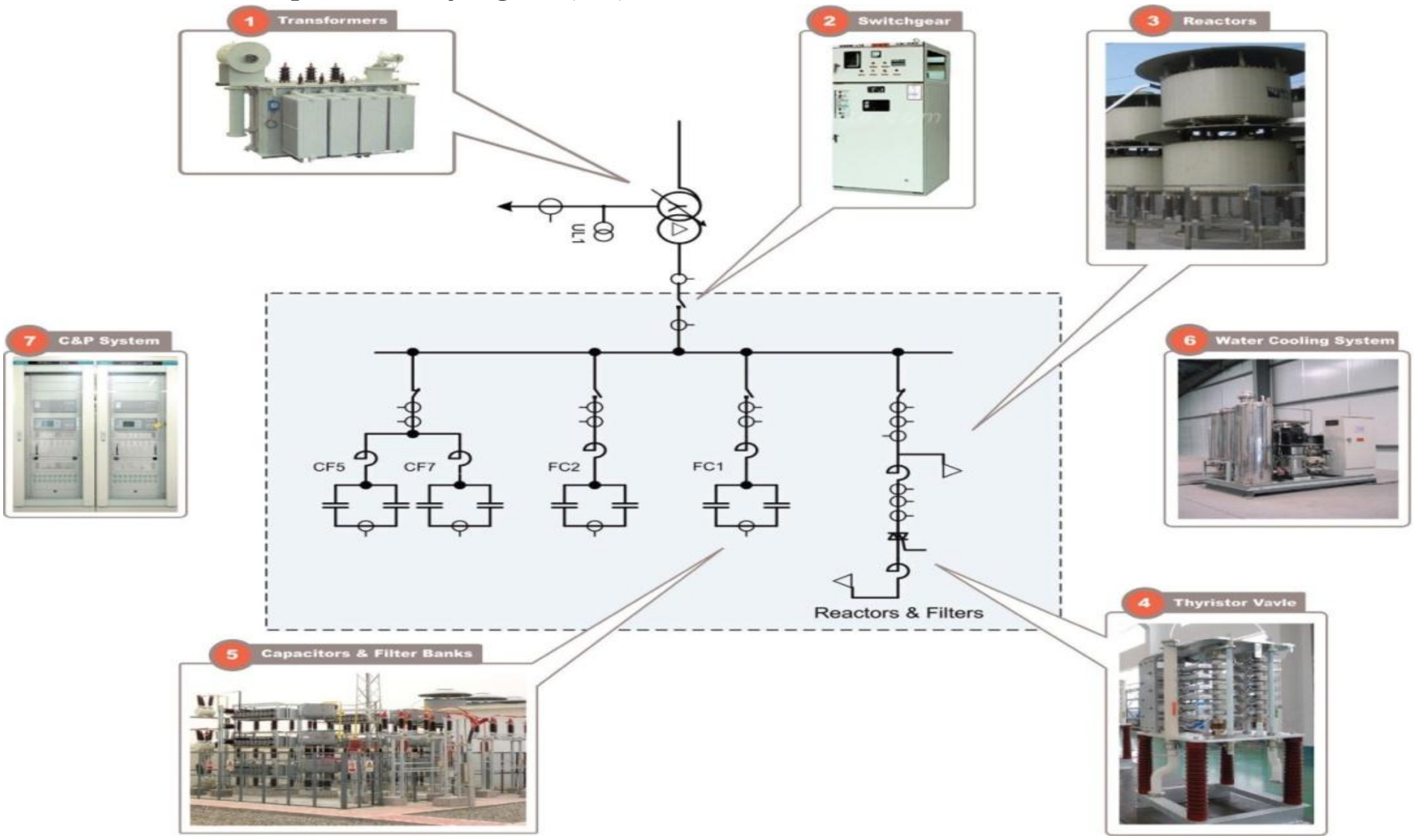


Figure (3.8) System Configuration

3.17.1 Step-down Transformer:

The static var compensator is normally installed at low voltage side of main transformer, otherwise a step-down transformer is needed to reduce the voltage.

3.16.2 switch-gear:

The medium voltage switchgear typically includes isolating switches, grounding switches and transformers. It can be installed indoor or outdoor

3.16.3 Linear (Air-core) reactor:

The air-core reactor in static var compensator has high stability and high linearity. It is used to absorb reactive power under the control of thyristors. Usually the air-core reactor is series connected to the thyristor valve in delta-connection and then connect the delta bridge to power grid.

3.16.4 Thyristor valve:

The thyristor valve is the main control part in a SVC system. It is composed of several series/paralleled connected thyristors and its auxiliary components. The thyristors are triggered by electrical lighting system and it adopts water cooling as the main cooling method.

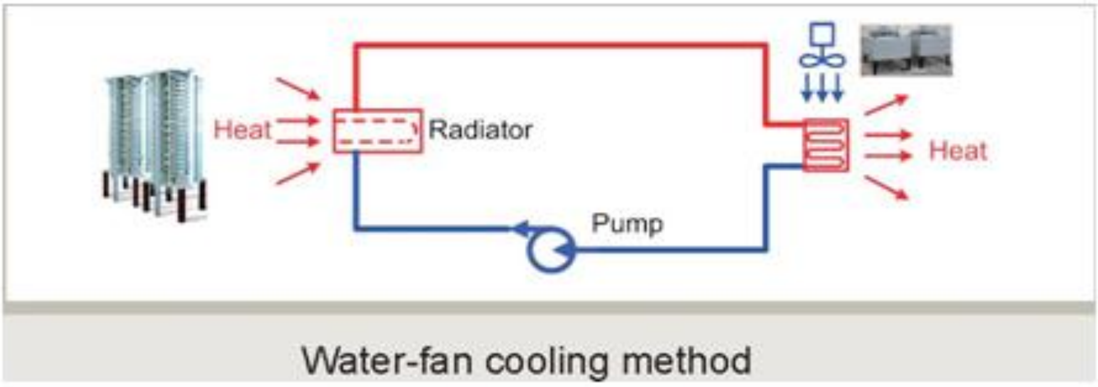
3.16.5 Capacitor/filter banks:

The capacitor/filter banks can supply sufficient capacitive reactive power to power grid and filter the harmful harmonics. The filter is composed of capacitors, reactors and resistors, providing capacitive reactive power to the entire system.

In practical, the capacitor/filter banks are divided into several sub-banks which can be switched-in/switched-off by mechanical breakers or other electrical switches according to the actual situation.

3.16.6 Water cooling system:

The heat produced by thyristor valve will be harmful to thyristors if the heat is not dissipated in time. The de-ionized water cooling system is sufficient for the thyristor valves which have a high operating voltage. The cooling system uses the de-ionized pure water for internal cooling and regular industrial recycling water for external cooling. Figure(3.9) shows the water cooling system



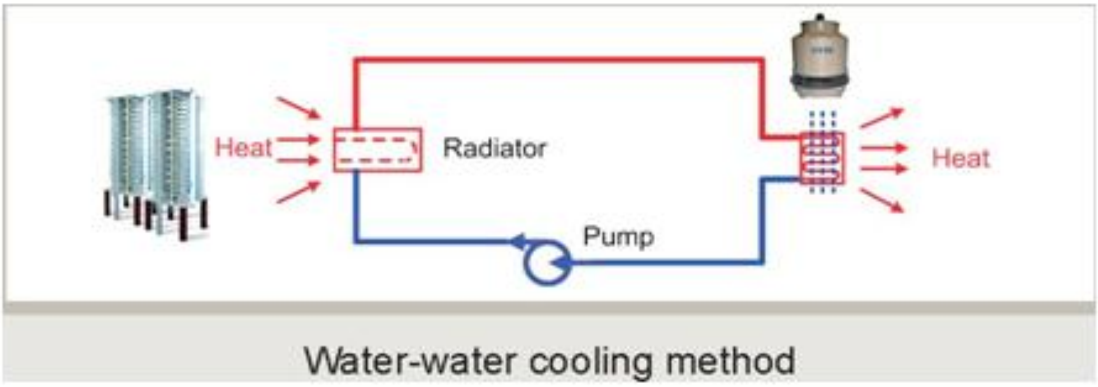


Figure (3.9) Water Cooling System

3.17 Protection of svc system :

Static Var Compensator (SVC) protection is presented. SVC systems come in a wide number of arrangements, and are custom designed for specific applications. For SVC applications the control and protection system plays an essential role in the overall performance of the power system. From protection standpoint, an extensive protection system is generally required for SVCs to optimise the equipment operational limits for maximum utilisation.

This paper outlines the experience gained from, and design aspects of relay protection for SVC’s. The paper analyzes different fault cases and describes different relay protection principles applicable to SVCs. It also includes an overview of SVC protection methods.

It covers the protection of the connection of the SVC to the substation busbars. For the SVC itself the power transformer, the SVC medium voltage busbar and the active branches, i.e. TCR, TSC and harmonic filters are of specific interest. These branches are exposed to severe current and voltage transient during system disturbances. Insensitivity to harmonics and DC current are essential.

SVCs are normally ungrounded on the MV bus and residual voltage protection is used to detect ground faults. If selective earth fault protection is required for the SVC, this can be accomplished by using either a grounding transformer or an automatic reclosure scheme.

Special protection functions are integrated in the SVC control system to detect abnormal operating conditions and to react rapidly to avoid damage and unnecessary tripping by the plant protection system. Those protection functions and their interaction with power system is an important criterion for selection and application of each protection device are covered in the topic.

3.17.1 Transformer and Busbar Protection:

Utility SVCs normally make use of a power transformer between the power grid and the SVC medium voltage (MV) busbar. On this bus harmonic filters, thyristor controlled reactors and capacitors are connected. In many cases, an auxiliary power transformer is also connected to this bus. It is important to note that the power transformer is the only connection of this bus to the mains. There are never several infeeds or more than one power transformer in the circuit.

SVC transformers are, like generator transformers, made with a large turn ratios. The voltage on the SVC MV bus is typically in the span of 15-30 kV irrespective of the voltage level on the mains. A very normal transformer turn ratio is 400/25 kV. This large ratio results in very high short circuit currents on the MV bus, it is frequently in the range of 50-90 kA (rms symmetrical). The transformer current in its MV bushings also become large due to large power and low voltage, 5-15 kA are normal values. The large fault and load current currents must be considered when designing the protection system.

3.17.2 TCR Protection:

A TCR or TSR branch is delta connected where each phase consists of a thyristor valve and two reactor stacks. The thyristor valve is electrically located between the reactors. By combining one line Current Transformer (CT) with two branch CTs, a protective zone encompassing two reactor halves and a thyristor valve is created in a main differential protection. By permutation, three such zones are aggregated in the TCR to provide detection and clearance of inter-zone faults. Time delayed overcurrent relays, with an added instantaneous step sensing the branch currents are generally used as back-up. The reactors are protected by thermal overload relays. The split arrangement of the reactors in each phase provides extra protection to the thyristors in event of a reactor fault, i.e. fault current is limited and the risk for steep front voltage surges eliminated. The valves are also protected against thermal overload by a specific function (TCR current limiter) in the SVC control system. Figure(3.10) is representing the protection of the SVC system.

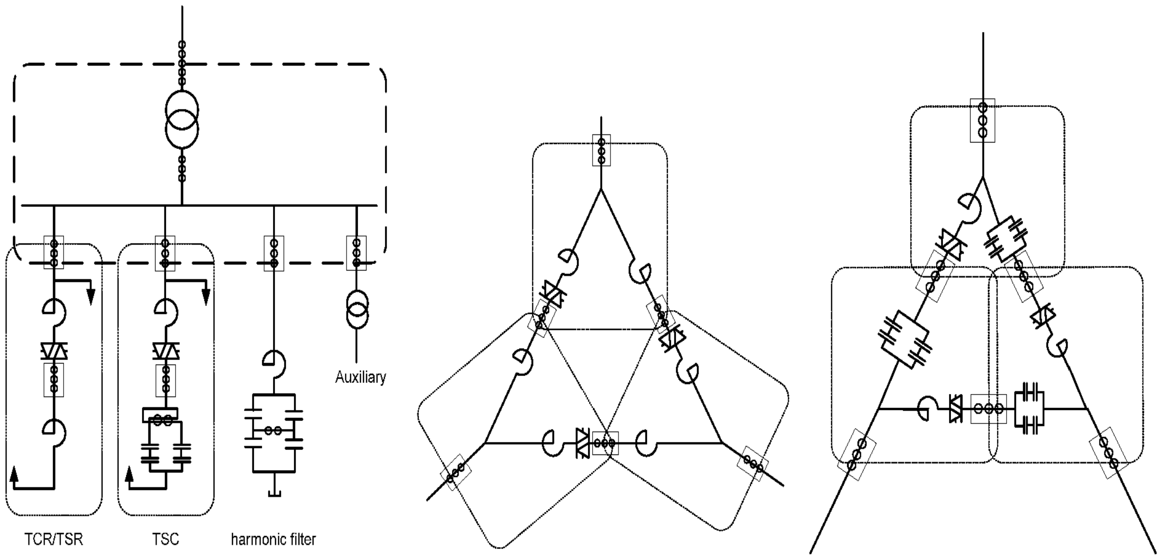


Figure (3.10) typical arrangements for transformer and SVC bus (left), TCR/TSR (middle) and TSC (right) differential zones.

Protection zone to also include the SVC MV busbar. In this design the CTs in all the other SVC branches are used to close the differential zone.
Standard transformer protective functions shall be used, differential current, restricted earth fault current and overcurrent functions are recommended.

3.17.3 TSC Protection:

A TSC is delta connected where each phase consists of a thyristor valve, a reactor and a capacitor bank. The thyristor valve is electrically located between the reactor and the capacitor. The capacitor bank is generally divided into two parallel halves with a number of capacitor units connected in series and parallel. The differential protection scheme is described in section 4 (TCR protection). An overcurrent relay sensing the line currents in the TSC provides backup. Unbalance protection function supervises the voltage across capacitor by measuring unbalance current. Unbalance current can be measured in different configurations as indicated in Figure (3.10). Two overvoltage criterion are used: One overvoltage criterion for the unit and one criterion for internal elements. In case of excessive capacitor voltage, an alarm or a trip command is issued.

In the TSC branches the thyristors are protected by arresters across the valve. Arresters shall preferable be located so that a current flow in an arrester will not be seen as a transient fault by the differential relay and cause false tripping. In TSC topologies where currents are bypassed from differential CT’s, extra time delays must be added to avoid false tripping.

3.18 Protective Control Features in SVC control system:

Fundamental frequency current or voltage overload in any branch in the SVC is prevented by the control system. There are control functions making sure that the total SVC current i.e. the current through the power transformer or the current in the TCR cannot become higher than the component ratings. The voltage on the SVC MV bus is also controlled to make sure it cannot exceed its design value.

DC current in the TCR is actively suppressed by a control function manipulating the thyristor firing instants.

When it comes to detecting malfunctions in the plant the most important function is to compare the actual currents in thyristor controlled branches with currents simulated in the control system. The simulation is based on measured system voltage and actual firing orders to the thyristors. In case there is a deviation between the two values exceeding a limit the plant is considered faulty. There are also a number of self supervision functions and hardware checks making sure the control system is working properly.

In case of a detected faulty control system the operation will automatically be transferred to a redundant system, in case such a system is not available the SVC will trip.

CHAPTER FOUR

SIMULATION

4.1 Introduction:

When using the high voltage alternating current transmission system for long distances, many problemswere found such as voltage drop,high losses in transmitted power, and instable power factor in case of loads varying.

Therefore, using static var compensator is suggested which is used to supply the system with reactive power in order to maintain it stable. And also to take advantage of features of static var compensator to reduce the high losses.

4.2 Linkage system between Atbara station and Port Sudan Station:

The Linkage system used in all Sudan electrical networks is high voltage alternating current transmission system.

The link transmission system between Atbara station and Port Sudan Station of the longest distance lines in Sudan Electrical network and this is the main reason for the high losses in line.

In addition to the long distance between Atbara station and Port Sudan Station the three-phase transmission line which connects between them consists just one circuit.

Figure(4.1)

4.3 Simulation program:

NEPLAN program is one of the programs used to simulate power systems and is used by project managers in companies.NEPLAN is a very user friendly planning and information system for electrical-, gas and water-networks. It can also be used in the formulation of simple electrical circuits. . NEPLAN was used to simulate the drop voltage at Atbra-Portsudan transmission line exactly at laod busbar in Portsudan station and it give us the result off adding (SVC) .The interface of the NEPLAN program is shown in figure(4.1).

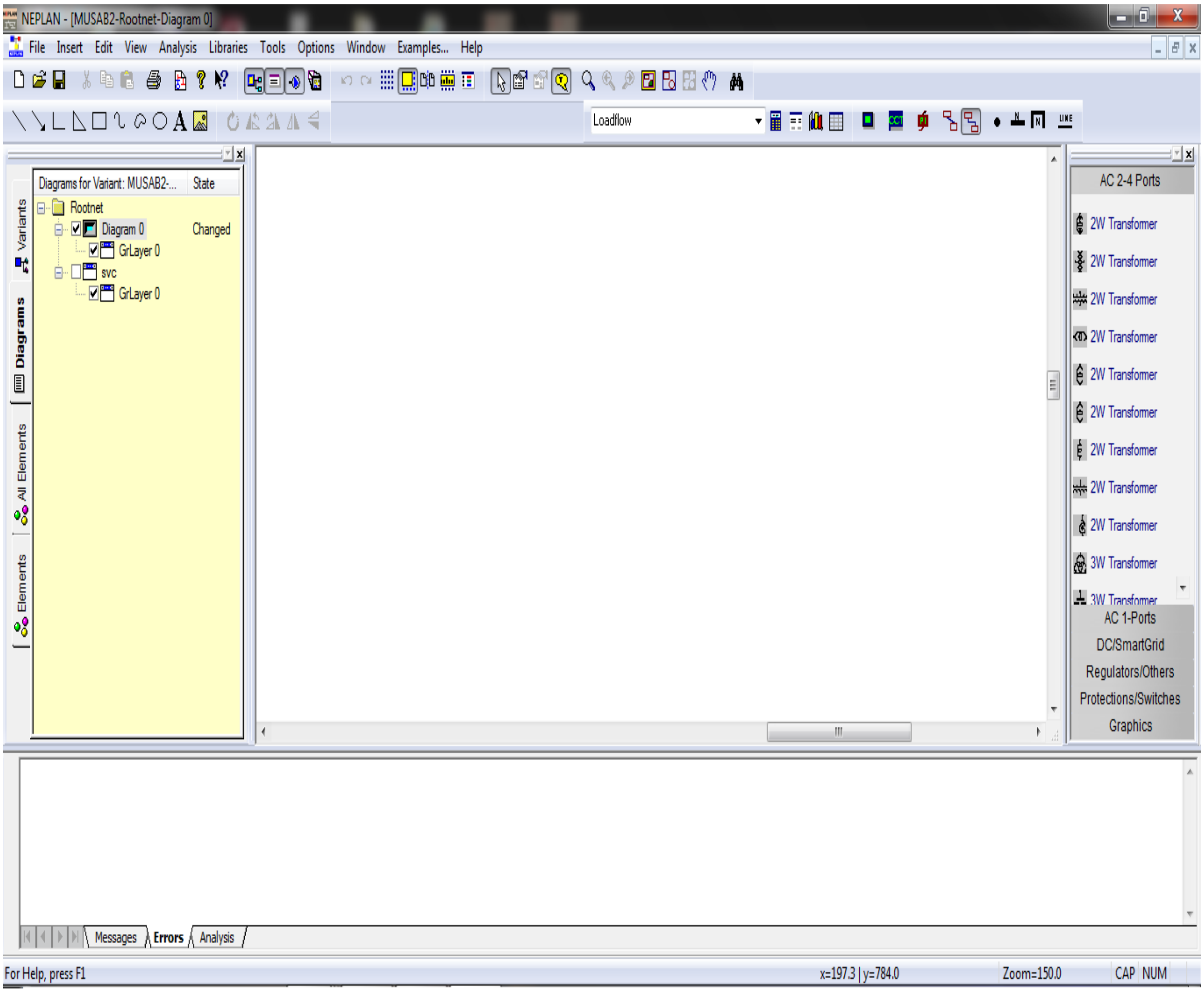


Figure (4.1): shows the interface of Neplan program

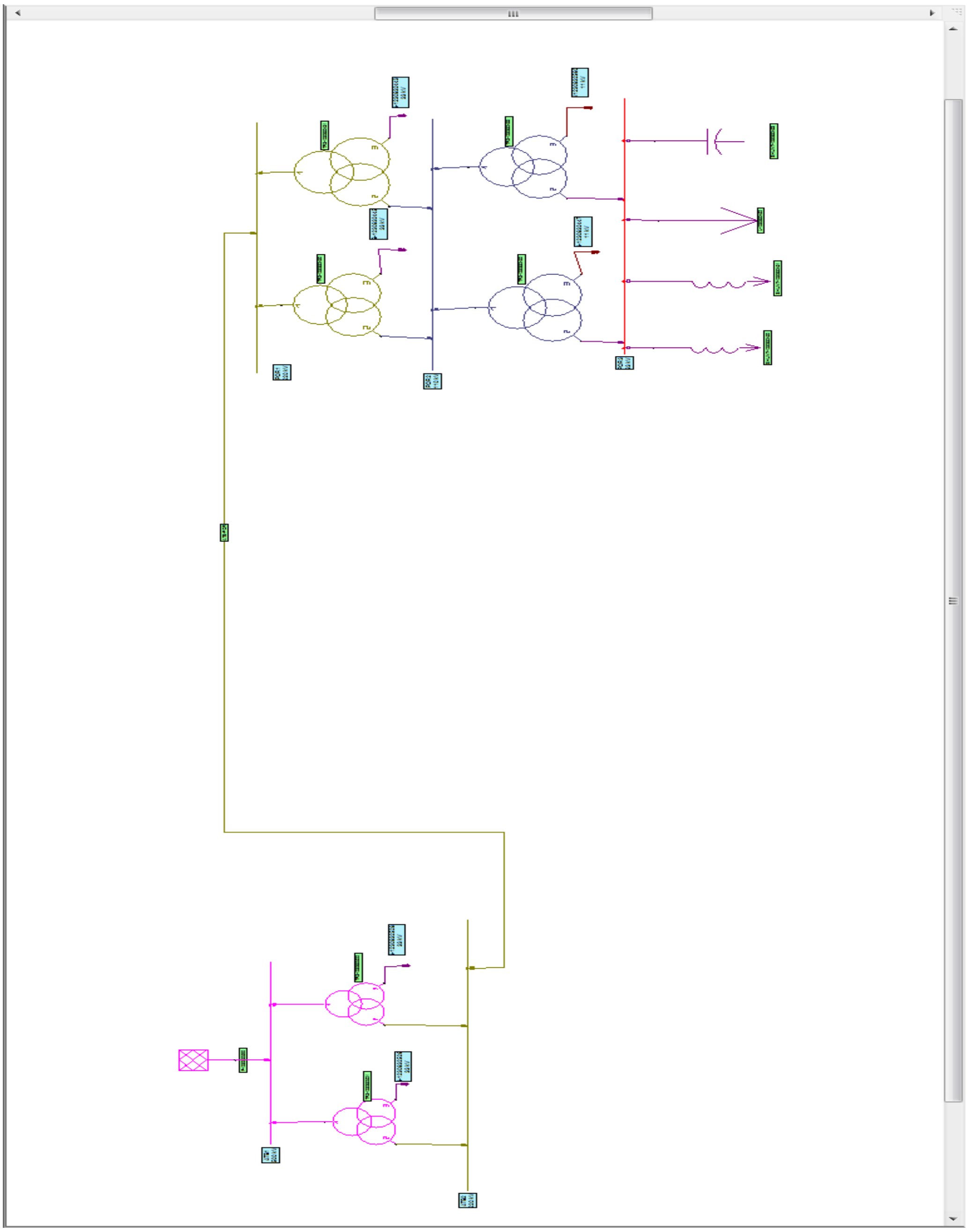


Figure (4.2): shows the interface of program after drawing the line connected between Atbra and Port Sudan substations

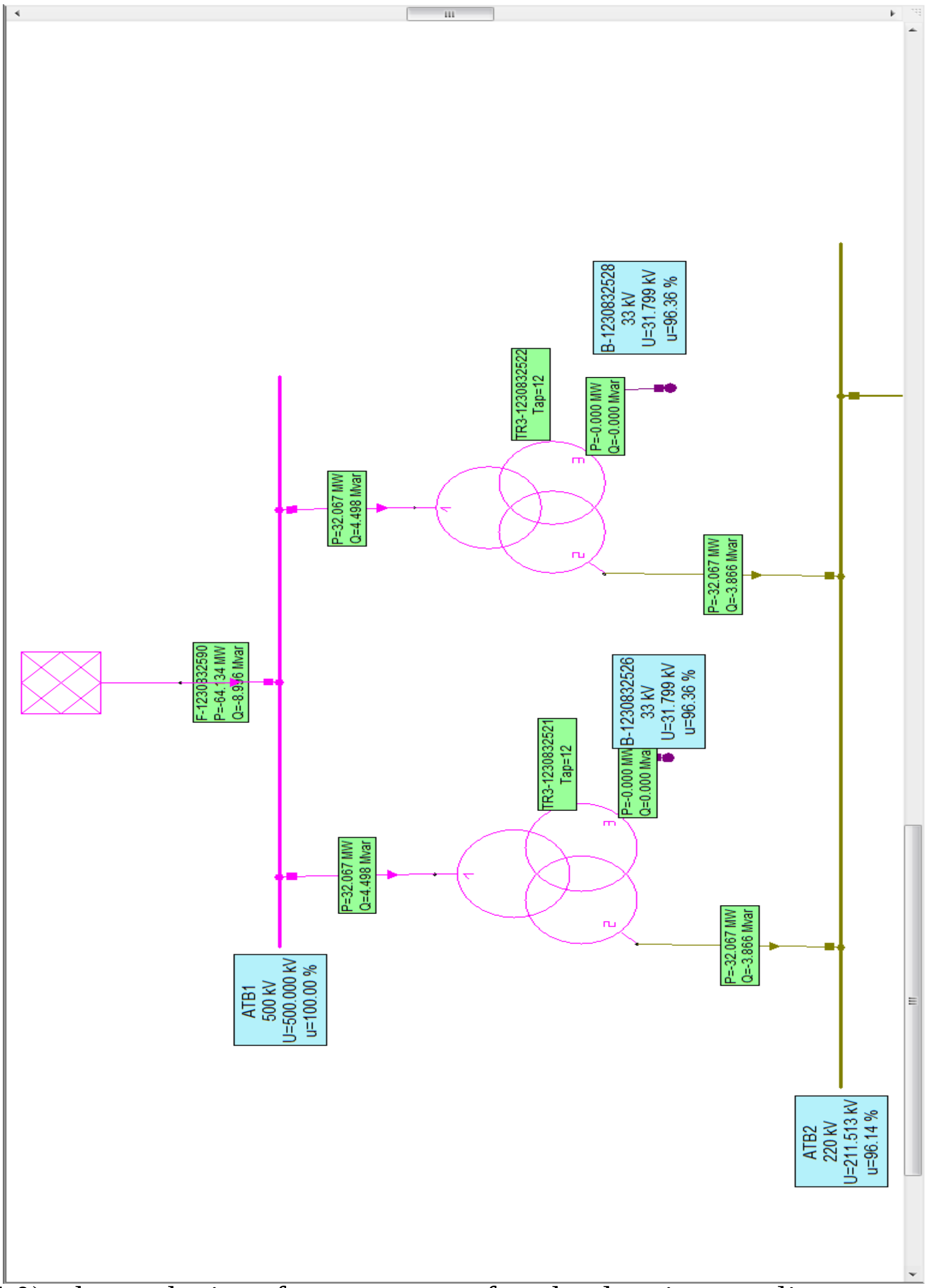
4.4 Atbara Substation:

It consists from three transformational zones:

First zone consists two transformers fed directly from Marawe dam by 500KV and convert it to 220 KV and other zone from 220KV to 110KV and the third one from 110KV to 33KV.

the simulation was done by taking the busbar of 220 KV which transmitted directly to Port Sudan.

Figure(4.3) shows the interface program after the drawing one line diagram of Atbara substation



Figure(4.3) shows the interface program after the drawing one line diagram of Atbara substation

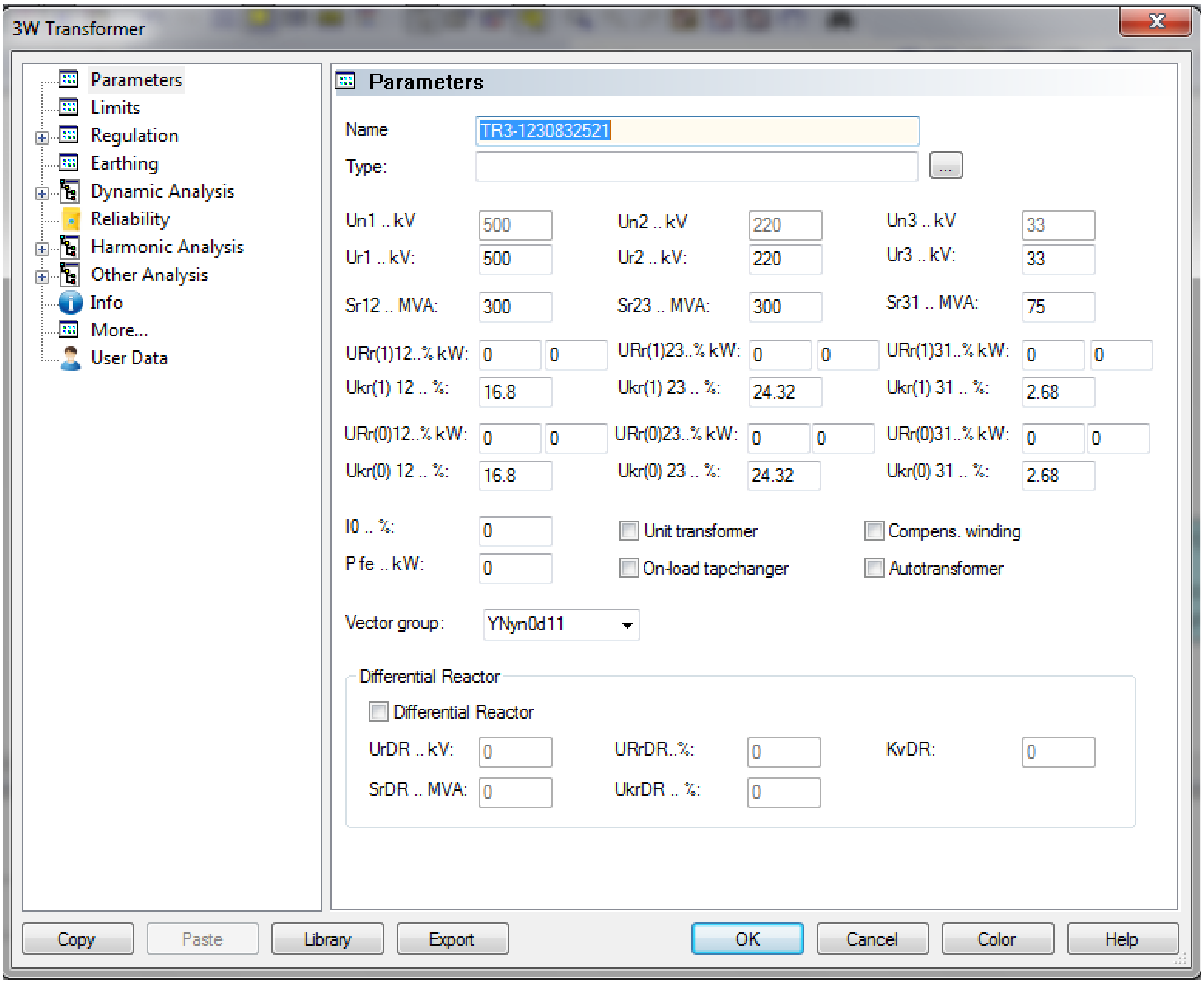
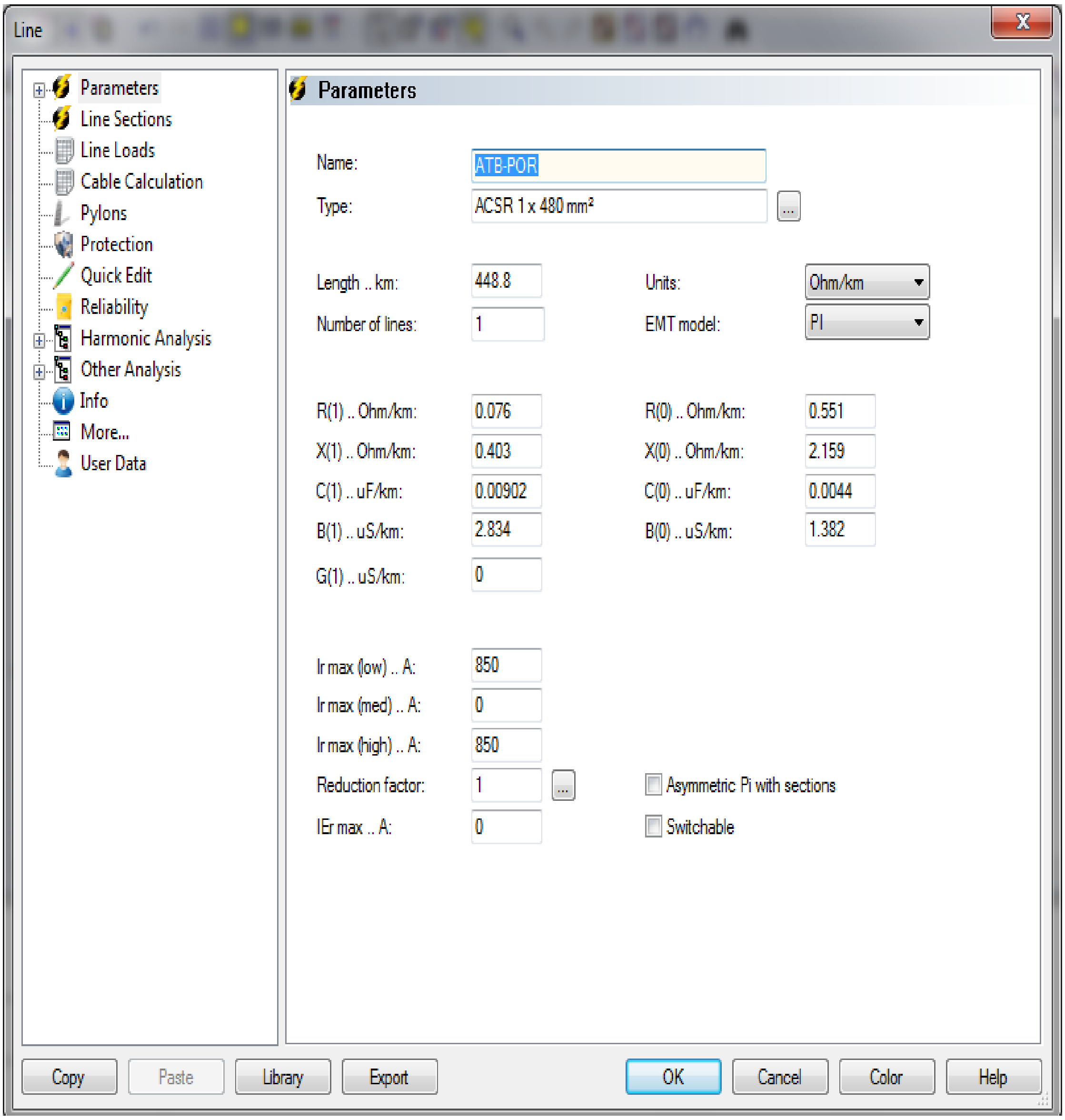


Figure (4.4) shows The specifications of step-down transformers(500-220KV) in Atbra station.



Figure(4.5) shows parameters of transmission line which connected between Atbra and Port Sudan Substation

4.5 Port Sudan Substation:

It consists two transformational each one of them consist two transformers zones from 220KV to 110KV and from 110KV to 33KV.and we are going to set (SVC) station at load busbar.

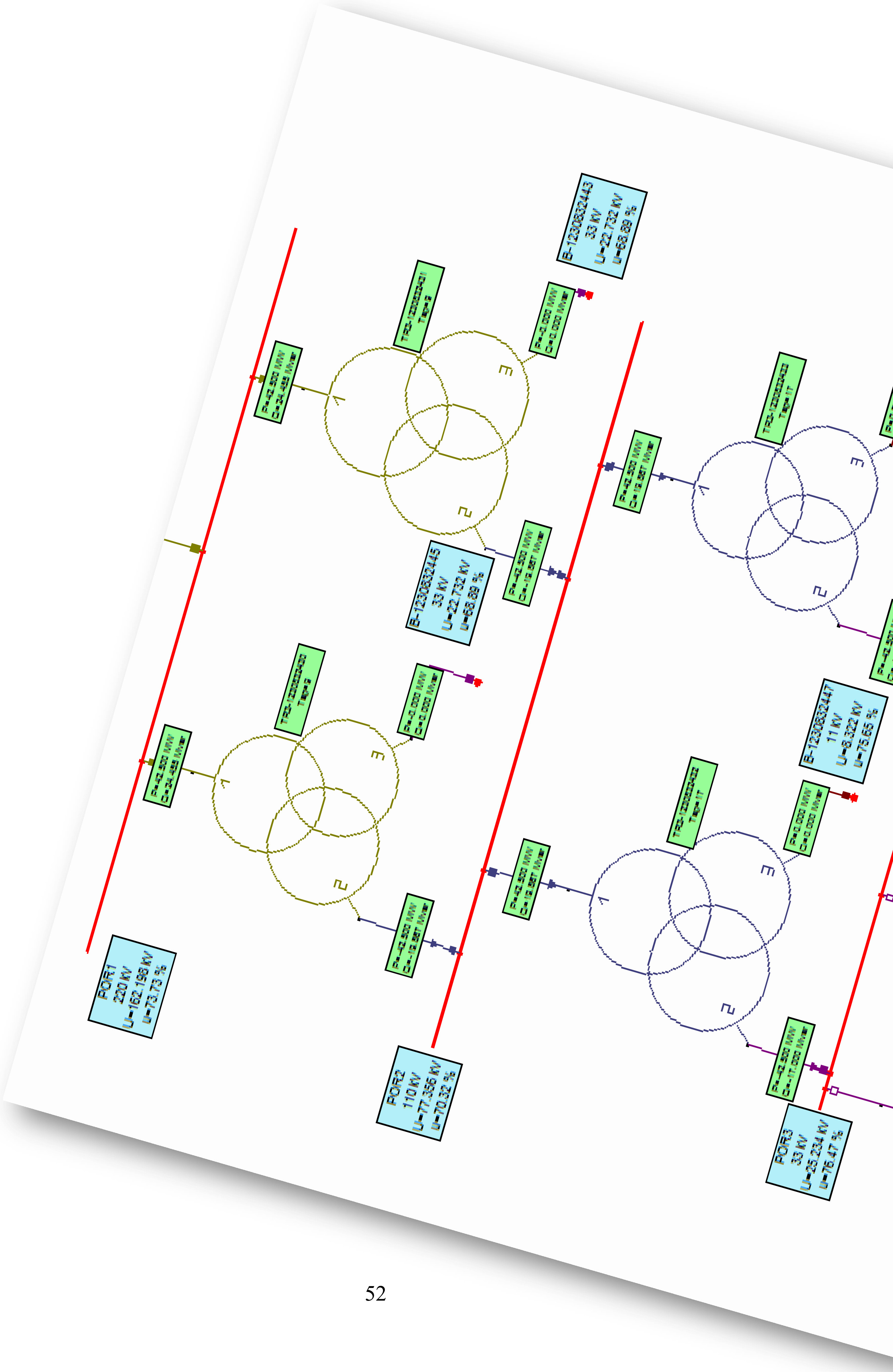

POR1
220 kV
U=162.198 kV
u=73.73 %
POR2
110 kV
U=77.356 kV
u=70.32 %
POR3
33 kV
U=25.234 kV
u=76.47 %
B-1230832443
33 kV
U=22.732 kV
u=68.89 %
B-1230832445
33 kV
U=22.732 kV
u=68.89 %
B-1230832447
11 kV
U=8.322 kV
u=75.65 %

Figure (4.6):shows the load busbar at Port Sudan substation before using static var compensator (SVC)

After the analysis of load flow in the high-voltage transmission line We found that the value of drop in voltage is equal:33KV-25.234KV =7.766 KV

The drop voltage ratio is 23.5% and this is high value comparing with allowed ratio (±5).

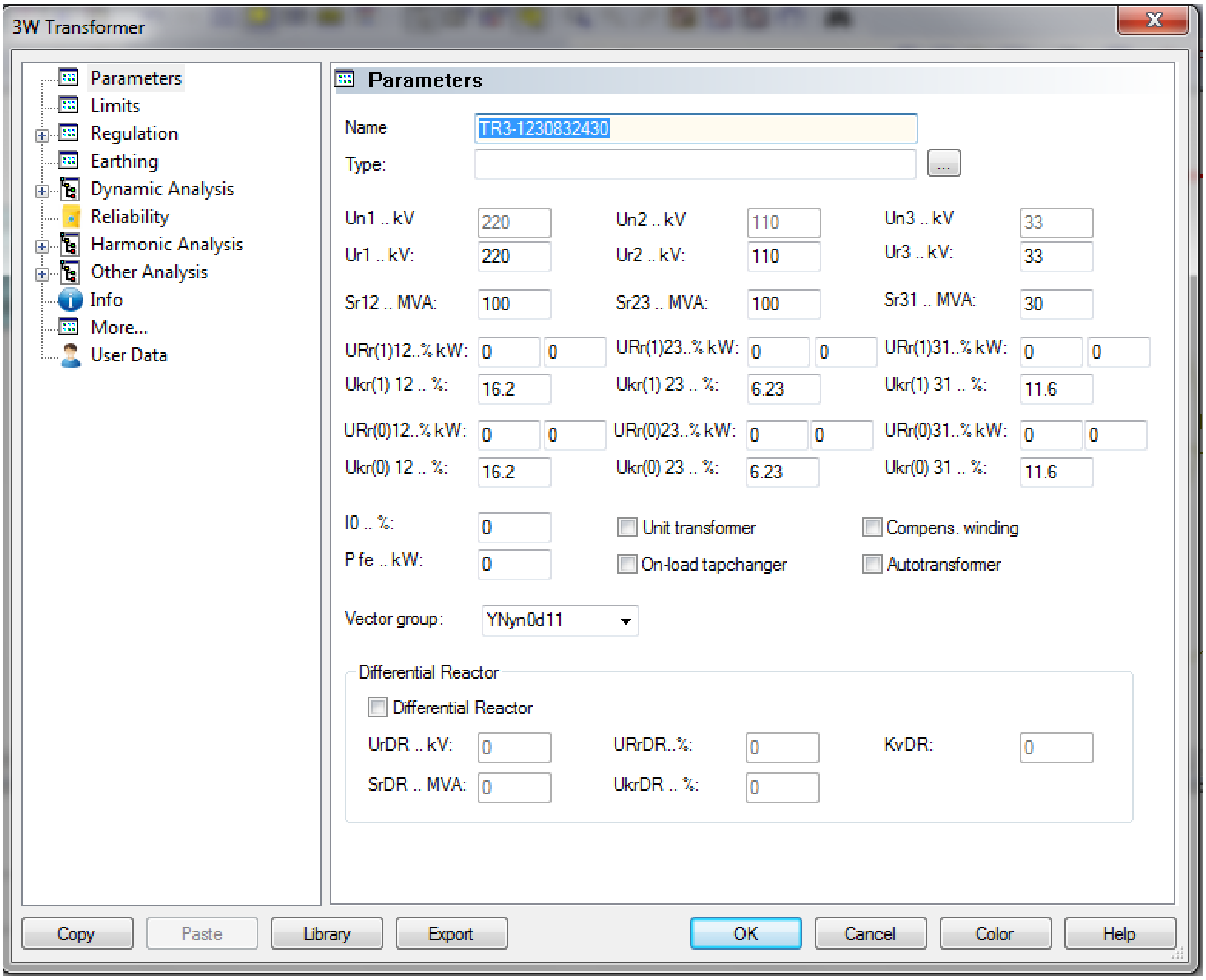


Figure (4.7): shows The specifications of step-down transformers (220-110 KV) in Port Sudan station.

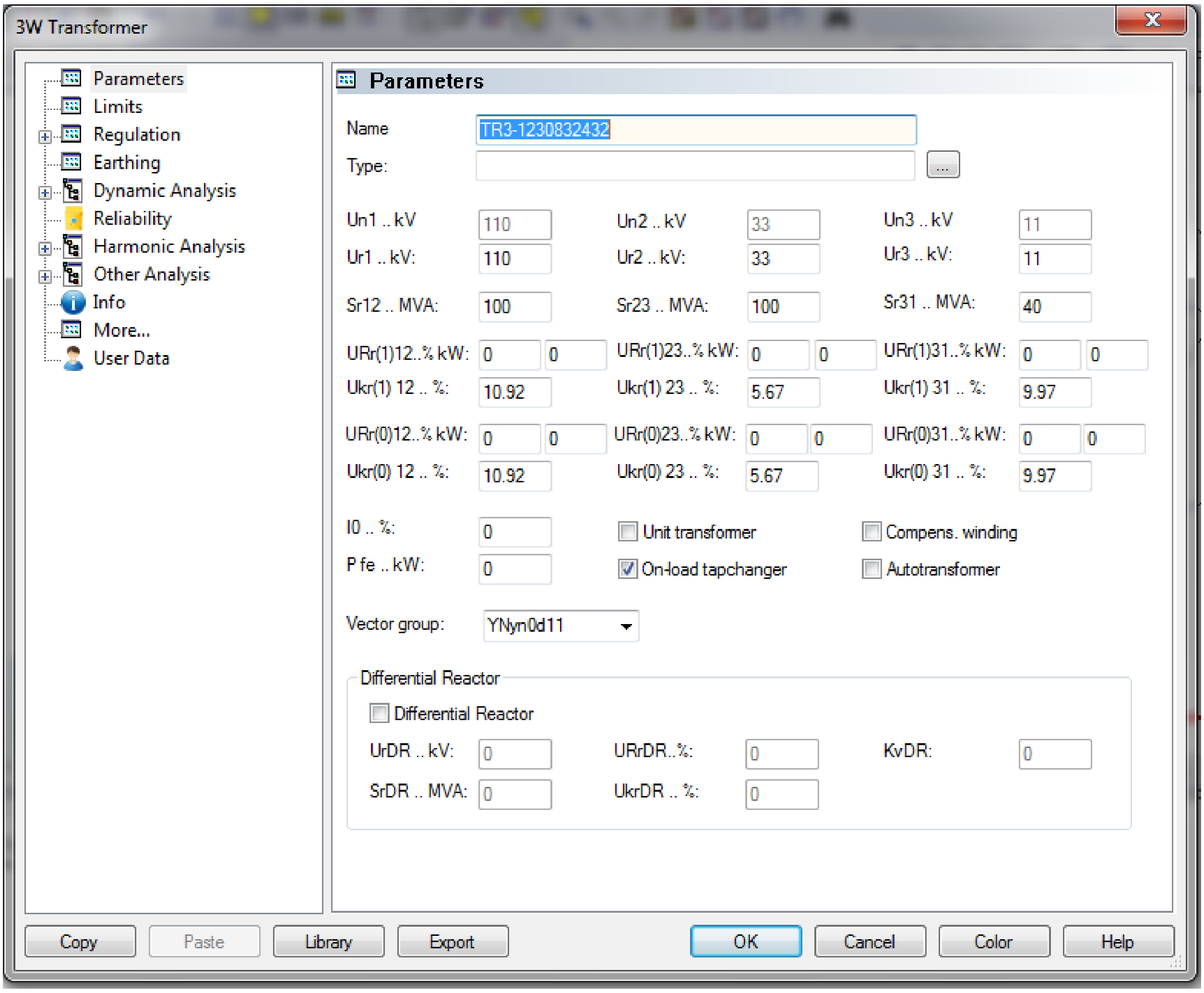


Figure (4.8) shows The specifications of step-down transformer(110-33 KV) in Port Sudan station.

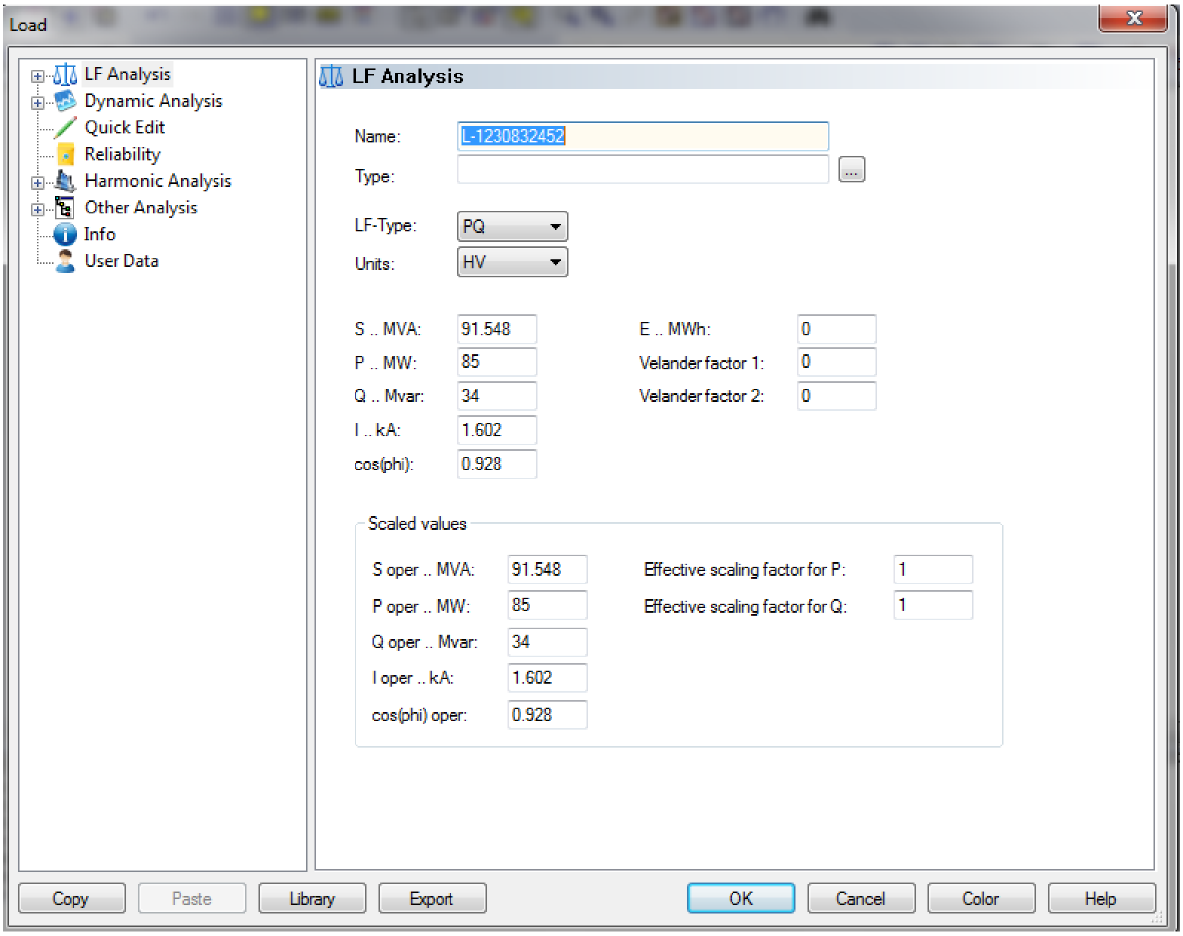


Figure (4.9)The rated load at Port Sudan

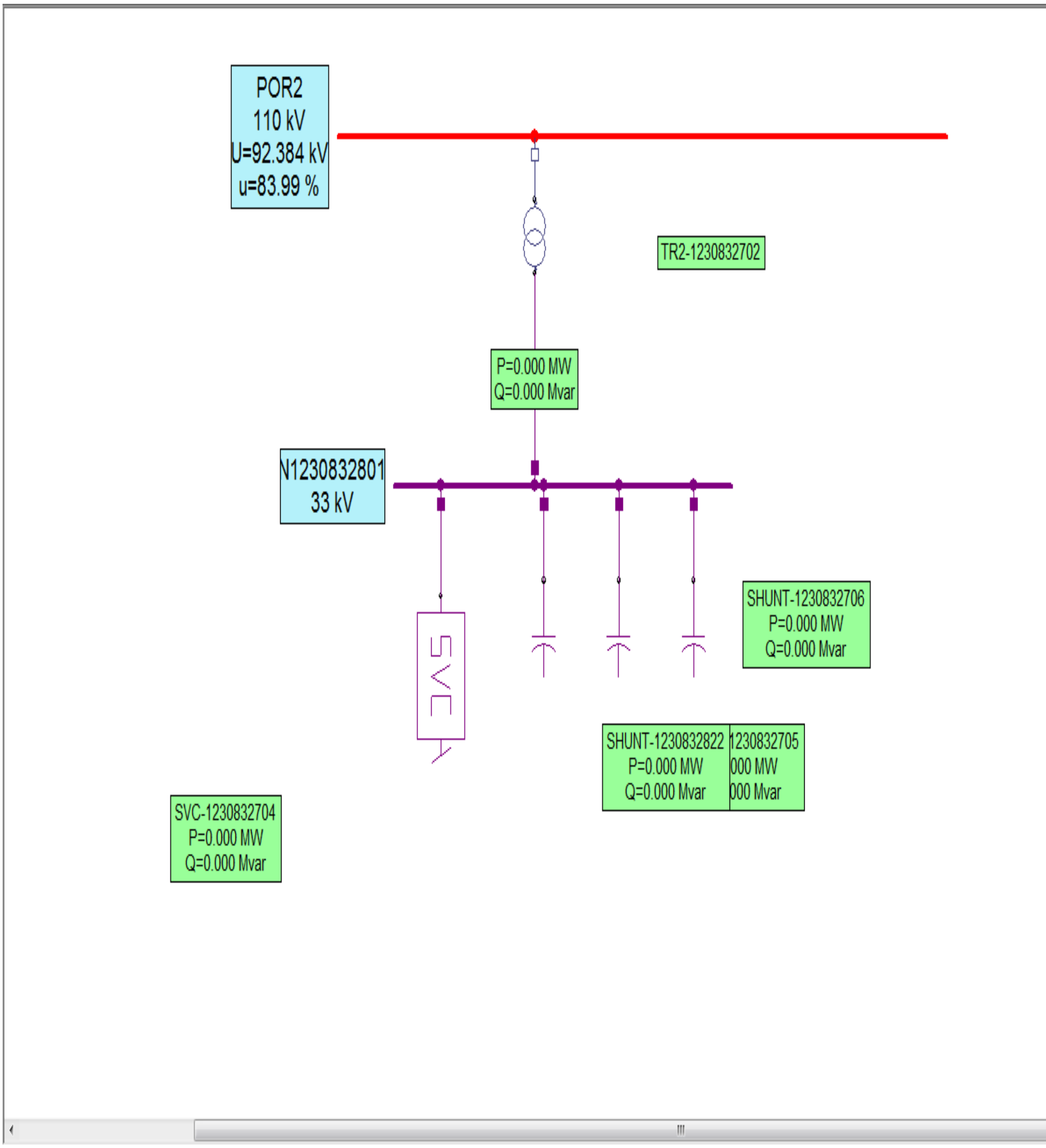


Figure (4.10) shows the component of (SVC)station

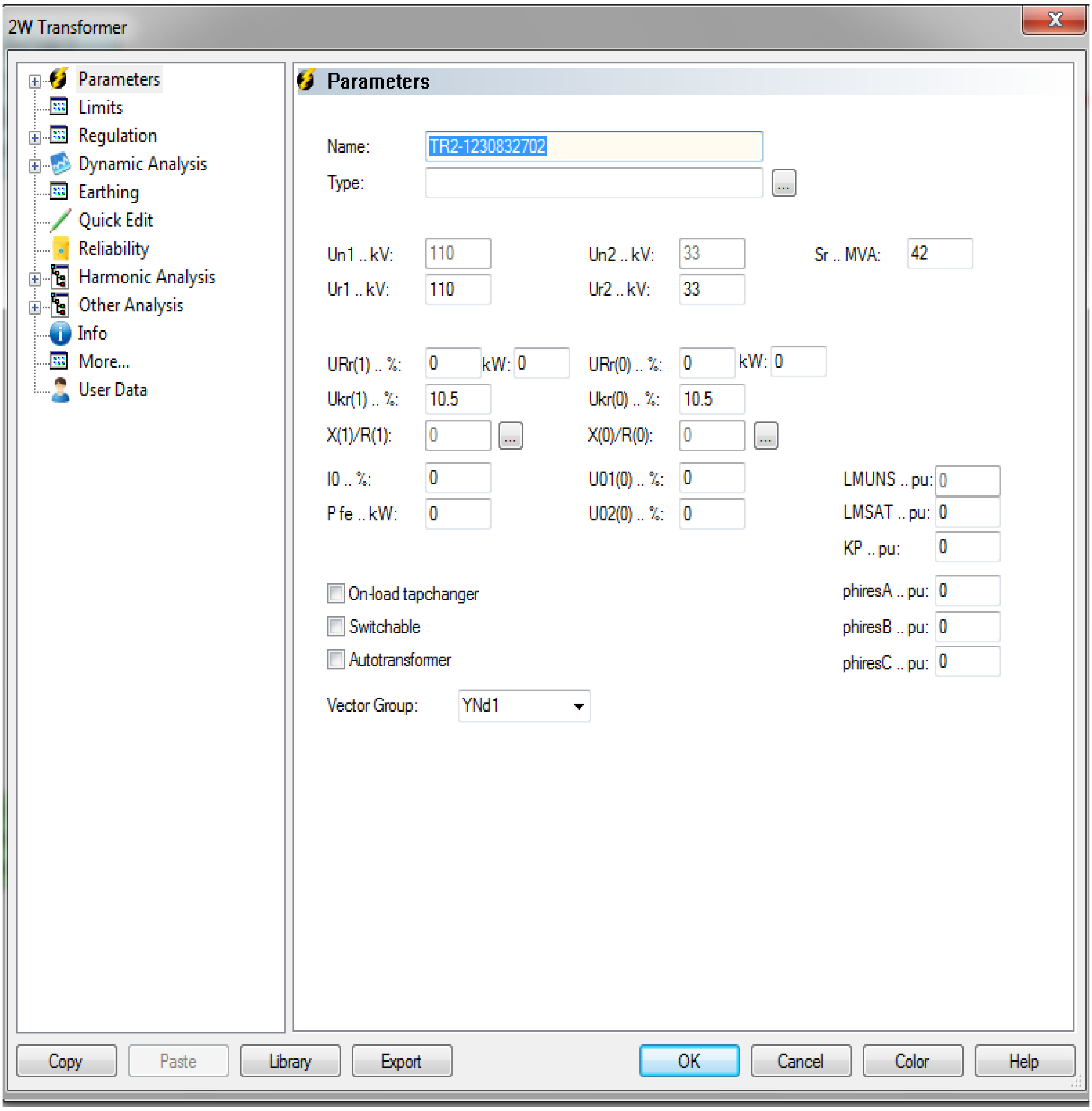


Figure (4.11) shows the parameters of the transformer which feed the (SVC) station

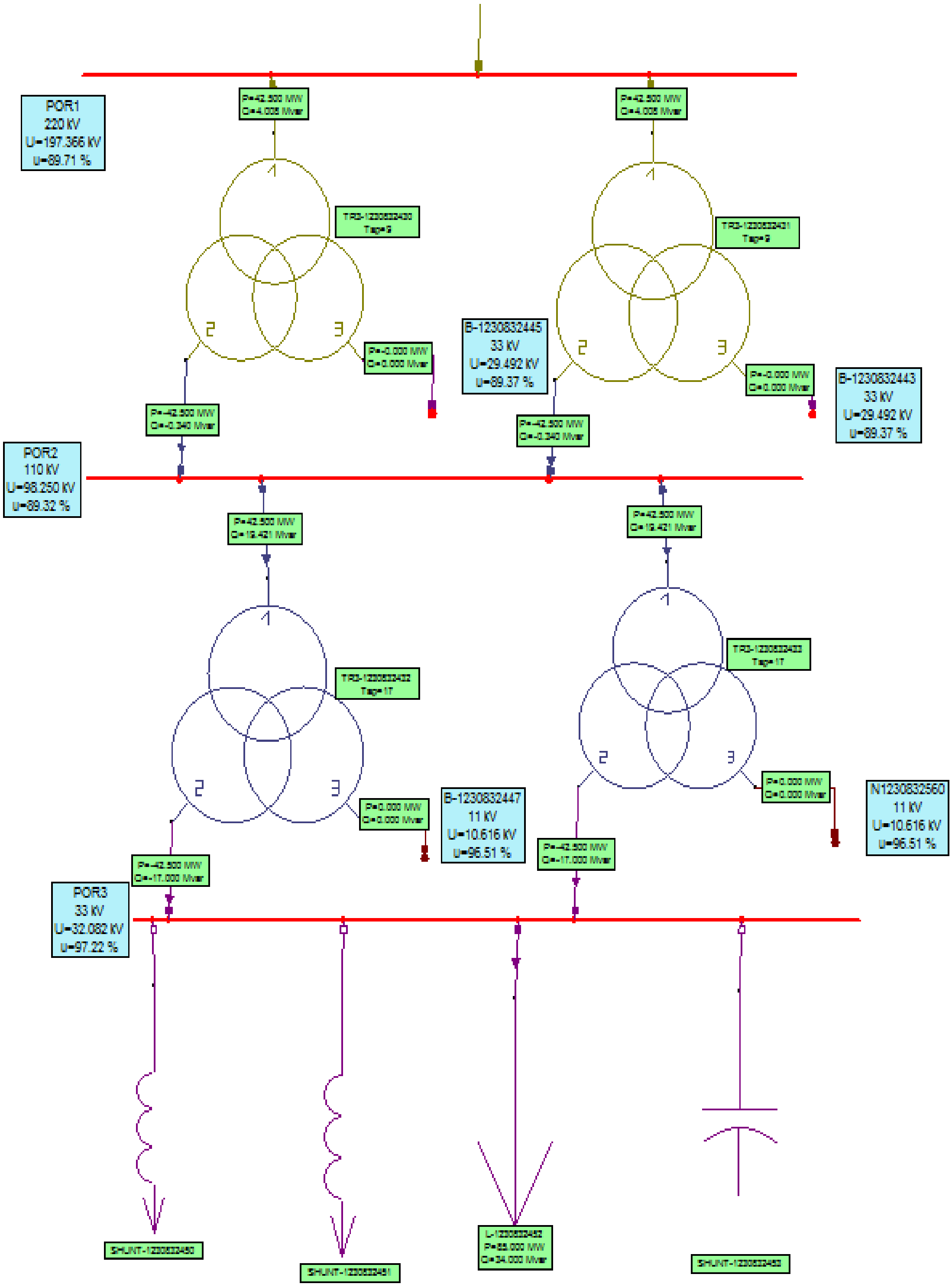


Figure (4.12)shows the load busbar at Port Sudan substation after using static var compensator (SVC)

From the figure(4.12) the result of adding (SVC) of reducing drop voltage was shown :

The received voltage at the load busbar=32.082KV

The drop voltage ratio =2.78%

CHAPTER FIVE

CONCULOTION AND RECOMMENDATIONS

5.1 Conclusion:

The main factor causing instability of voltage is the inability of the power system to meet the demand for reactive power. The heart of the problem is usually the voltage drop that occurs when active power and reactive power flow through inductive reactances associated with the transmission network.

, The bus voltage magnitude increases as the reactive power injection at the same bus is increased. A system is voltage unstable if, for at least one bus in the system, the bus voltage magnitude (V) decreases as the reactive power injection (Q) at the same bus is increased.

The voltage regulation before adding the compensator was obtained using NEPLAN simulation program and after adding the SVC the regulation was reduced so it is clearly that the SVCs reduce the voltage regulation and voltage drop in the transmission line.

5.2 Recommendations:

Changing the line design between the Atbara station and Port Sudan Station from single circuit to double circuit which is will be a solution to many of the obstacles facing the present system.

Another simulation programs can be used and it can perform many functions in electrical systems, such like E-TAP and SIMULINK programs.

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Sharma Kolluri, PE,IEEE Octoper 10,2012

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