Université Mohamed Khider de Biskra
Faculté des Sciences et de la Technologie
Département de génie électrique

MÉMOIRE DE MASTER

Sciences et Technologies
Électrotechnique
Réseau électrique

Réf. :

Présenté et soutenu par :
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Le : samedi 6 juillet 2019

Amelioration of the voltage stability of the electrical network by PSAT

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Année universitaire : 2018 - 2019

الجمهورية الجزائرية الديمقراطية الشعبية
République Algérienne Démocratique et Populaire
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Université Mohamed Khider Biskra
Faculté des Sciences et de la Technologie
Département de Génie Electrique
Filière: Electrotechnique
Option: Réseaux électrique

Mémoire de Fin d'Etudes
En vue de l'obtention du diplôme:

MASTER

Thème

Amelioration of the voltage stability of the electrical network by PSAT

Présenté par :

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Cachet et signature

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Thème :

Amelioration of the voltage stability of the electrical network by PSAT

Proposé et Dirigé par : Dr. Naimi Djemai

RESUMES (Français et Arabe)

Résumé:

Le projet actuel a pour objectif l'amélioration de la stabilité statique par le PSAT pour objectif d'éducation. La principale caractéristique de se travail est de faire une analyse pour connaitre les jeux de barres sensible dans le réseaux électrique a fin de l'enchainements des ces jeux barre avec le dispositif d'un des FACTS.

Bien qu'il existe déjà le SVC, un des dispositif des system FACTs qui permet d'améliorer le réseaux électrique par l'emplacement de SVC au endroit précise et connaitre la valeur exact de la puissance réactive que le jeux de barre a besoin .

Une partie fondamentale du travail est sur la programmation de l'interface de bureau. Pour cette raison, un aperçu des technologies disponibles sera fait. Certaines options seront discutées et la technologie la plus appropriée sera sélectionnée.

Après l'approche théorique, le PSAT permet de exécuter le calcul de écoulement de puissance de se réseaux électrique et aides a analyser tout le travail pour une interprétation correct et une gestion de travail bien définie

Mot clés : Stabilité statique , réseaux électrique. PSAT , FACTS , SVC .

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ملخص:

يهدف المشروع الحالي إلى تحسين إستقرار الساكن عن طريق برنامج PSAT للأغراض التعليمية. الميزة الرئيسية للعمل هي إجراء تحليل لمعرفة القضبان الحساسة في الشبكة , في نهاية نستخدم تقنية FACTS لتحديد نتائج قريبة من الواقع .

إن أحد أجهزة نظام FACTs التي تسمح بتحسين الشبكة الكهربائية هي SVC الذي يتميز بدور فعال عند وجوده في الموقع الدقيق و به يمكن معرفة القيمة الدقيقة للطاقة التفاعلية التي يحتاجها القضيب الكهربائي .

جزء أساسي من العمل هو على برمجة واجهة سطح المكتب. لهذا السبب ، سيتم إجراء نظرة عامة على التقنيات المتاحة. ستتم مناقشة بعض الخيارات وسيتم اختيار أنسب التقنيات.

بعد النهج النظري ، تتيح PSAT تنفيذ حساب تدفق الطاقة لشبكاتها الكهربائية وتساعد على تحليل جميع الأعمال للحصول على تفسير صحيح وإدارة عمل مفصلة جيدًا.

كلمات مفتاحيه : , شبكة الكهربائية , PSAT , FACTS , SVC, إستقرار الساكن.

Thanks

Above all, we thank God Almighty for giving us courage, and health during all these years and that thanks to him this work could be realized.

Our thanks also go to the **Dr. Naimi Djemai, Maansa Sabrina** for helping me writing this memoir as well as monitoring the process of this work and preaching us.

I also thank the members of the jury **Salhi Ahmed**, **Hammoudi Med.Yacine** who increases the honor of residing my work.

Dedications

Dedicate this work to the dearest people to my heart my mother and my father who always helped me to consecrate.

To my brother and sister.

To my friends, my classmates.

To all my teachers.

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List of abbreviations

- IEEE : Institute of Electrical and Electronics Engineers.
- PSAT : Power System Analysis Toolbox.
- CPF : Continuation power flow.
- FACTS : Flexible Alternating Current Transmission System.
- SVC : Static Var Compensator.
- λ max. : The maximum load factor
- V_{init} : The voltage module in its initial state
- V_{CPF} : The voltage module after the continuous calculation of the power flow continuous

Abstract

The current project aims to improve voltage stability through PSAT as an educational objective. The main characteristic of this work is to make an analysis to know the sensitive buses in the electrical network at the end of the chain of these busbars with the device of one of the FACTS. Although there is already the SVC, one of the devices of the FACT systems that allows to improve the electrical network by locating the SVC at the precise location and knowing the exact value of the reactive power that the busbar system needs. A fundamental part of the work is on the programming of the desktop interface. For this reason, an overview of the available technologies will be made. Some options will be discussed and the most appropriate technology will be selected. After the theoretical approach, the PSAT allows to perform the calculation of the power flow of the electrical networks and helps to analyze all the work for a correct interpretation and a well defined work management

Key words: Electrical network, Voltage stability, PSAT , FACTS , SVC.

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General introduction

The electricity supply industry is undergoing a profound transformation worldwide. Market forces, scarcer natural resources, and an ever-increasing demand for electricity are some of the drivers responsible for such unprecedented change. Against this background of rapid evolution, the expansion programs of many utilities are being thwarted by a variety of well-founded, environment, land-use, and regulatory pressures that prevent the licensing and building of new transmission lines and electricity generating plants. These limits define the maximum electrical power to be transmitted without causing damage to transmission lines and electrical equipment.

In principle, limitations on power transfer can always be relieved by the addition of new transmission lines and generation facilities.

The main objective of this work is to enhancement the one of the system power stability which has a huge impact in the electrical grid , the voltage stability and by the Flexible Alternating Current Transmission System (FACTS) controllers can enable the same objectives to be met with no major alterations to power system layout. FACTS are alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.

What is the voltage stability and how the Flexible Alternating Current Transmission System (FACTS) controllers can make a big change in the transport lines ?

Chapter 1: Voltage Stability

Introduction

As electrical energy is very difficult to store, there must be a permanent balance between production and consumption. The generators, the receivers and the electrical networks which connect them have mechanical and or electrical inertia which make it difficult to maintain an equilibrium guaranteeing a relatively constant frequency and tension.

Faced with a power variation, the electrical system must normally return to a stable state. In some cases, the oscillatory regime may diverge. Studies are needed to avoid this phenomenon and ensure the stability of the electricity grid. They are particularly so in the case of industrial networks that include one or more generators and engines..

1.1 **Definition**

- What is voltage stability?

Recently lEEE/CIGRE task force proposed various definitions related to power system stability including voltage stability and Fig. 1.1 summarizes these definitions.

In general terms, voltage stability is defined as the ability of a power system to maintain steady voltages at all the buses in the system after being subjected to a disturbance from a given initial operating condition. It depends on the ability to maintain/restore equilibrium between load demand and load supply from the power system. Instability that may result appears in the form of a progressive fall or rise of voltages of some buses. A possible outcome of voltage instability is loss of load in an area, or tripping of transmission lines and the other elements by their protection leading to cascading outages that in turn may lead to loss of synchronism of some generators.

This task force further classified the voltage stability into four categories: large disturbance voltage stability, small disturbance voltage stability, short-term voltage stability and long-term voltage stability. A short summary of these classifications is given below. [VEN 06]

- let us follow this descriptive definition word by word :

1.1.1 **Voltage**

as already stated, the phenomenon is manifested in the form of large , uncontrollable voltage drops at number of network buses. Thus term “voltage” has been universally accepted for its description.[VEN 06]

1.1.2 **Instability**

having crossed the maximum deliverable power limit , the mechanism of load power restoration becomes unstable, reducing instead of instead of increasing the power consumed. This mechanism is the heart of voltage instability. [VEN 06]

1.1.3 **Dynamic**

any stability problem involves dynamics. These can be modelled with either differential equations (continuous dynamics, or with difference equations (discrete dynamics). We will refer later to the misconception of labeling voltage stability a “static” problem. [VEN 06]

1.1.4 **Loads**

are driving force of voltage instability, and for this reason phenomenon has also been called load instability. Note, however, that loads are not the only players in this games.[VEN 06]

1.1.5 **Transmission systems**

have a limited capability for power transfer, as is well known from circuit theory. This limit (as affected also by the generation system) marks the onset of voltage instability. [VEN 06]

1.1.6 **Generation**

generators are not ideal voltage sources. Their accurate modelling (including controllers) is important for correctly assessing voltage stability. [VEN 06]

- One term used conjunction with voltage stability problems is voltage collapse. In this these used term “collapse” to signify a sudden catastrophic transition that is usually due to an instability occurring is a faster time- -scale than one considered. As we will see, voltage collapse, or may not be the final outcome of voltage instability

1.2 **Classification of power system stabilities**

voltage-stability characteristics, making voltage stability one of the most important issues regarding system security. It has even been suggested that part of the problems that led to the North American blackout of August 2003 might be linked to short-term voltage instability. In recent years, voltage instability has been responsible for several network collapses and blackouts and is now receiving special attention in many systems. This chapter will provide an overview of voltage stability problems and methods of effectively addressing th em in the design and operation of electrical power systems. This includes the basic concepts, physical aspects of the phenomenon, methods of analysis, examples of major power grid blackouts due to voltage instability and methods of preventing voltage instability.

This chapter addresses issues of power system voltage stability and identifies different categories of voltage stability behavior that are important in power system stability analyses. In addition, the modeling of power system devices under consideration will be discussed. [JAN 14]

Figure 1. 1 Classification of the power system stability

1.2.1 **Large-disturbance voltage stability**

refers to the system's ability to maintain steady voltages following large disturbances such as system faults, loss of generation, or circuit contingencies. This ability is determined by the system and load characteristics, and the interactions of both continuous and discrete controls and protections. The study period of interest may extend from a few seconds to tens of minutes. [VEN 06]

1.2.2 **Small-disturbance voltage stability**

refers to the system's ability to maintain steady voltages when subjected to small perturbations such as incremental changes in system load. This form of stability is influenced by the characteristics of loads, continuous controls, and discrete controls at a given instant of time. [VEN 06]

1.2.3 Short-term voltage stability

involves dynamics of fast acting load components such as induction motors, electronically controlled loads and HVDC converters. The study period of interest is in the order of several seconds, and analysis requires solution of appropriate system differential equations. [VEN 06]

1.2.4 Long-term voltage stability

involves slower acting equipment such as tap-changing transformers, thermostatically controlled loads and generator current limiters. The study period of interest may extend to several or many minutes, and long-term simulations are required for analysis of system dynamic performance. Instability is due to the loss of long-term equilibrium, post-disturbance steady-state operating point being small disturbance unstable, or a lack of attraction towards the stable post disturbance equilibrium. The disturbance could also be a sustained load buildup.[VEN 06]

1.3 Power System Stability and Voltage Stability

Power system stability is the ability of an electrical power system, for given initial operating conditions, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. Figure 1.1 gives the overall picture of the power system stability problem, identifying its categories and subcategories.

The concept of voltage stability addresses a large variety of different phenomena depending on which part of the power system is being analyzed; for instance, it can be a fast phenomenon if induction motors, air conditioning loads or high-voltage DC transmission (HVDC) links are involved or a slow phenomenon if, for example, a mechanical tap changer is involved. Today, it is well accepted that voltage instability is a dynamic process since it is related to dynamic loads.

Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system and maintain or restore equilibrium between load demand and load supply from its given initial operating conditions after it has been subjected to a disturbance. Instability may result in progressive voltage falls or rises at some buses. A possible outcome of voltage instability is the loss of load in an area, and possible tripping of transmission lines and other elements by their protective systems which can lead to cascading outages. Voltage collapse is more complex than voltage instability and is the process by which the sequence of events accompanying voltage instability lead to a blackout or abnormally low voltages in a significant part of a power system. The main symptoms of voltage collapse are: low voltage profiles; heavy reactive power flows ; inadequate reactive support; and heavily loaded systems. The collapse is often precipitated by low-probability single or multiple contingencies. When a power system is subjected to a sudden increase of reactive power demand following a system contingency, the additional demand is met by the reactive power reserves of generators and compensators. Generally, there are sufficient reserves and the system settles to a stable voltage level. However, it is possible, due to a combination of events and system conditions, that the lack of additional reactive power may lead to voltage collapse, there by causing a total or partial breakdown of the system. [JAN 14 a]

1.4 Voltage and Angle Instability

Power system instability is essentially a single problem; however, the various forms of instability that a power system may undergo can not be properly understood and effectively dealt with by treating it as such. Because of the high dimensionality and complexity of stability problems, it helps to simplify models in order to analyze specific types of problems using an appropriate degree of detail of the system representation and appropriate analytical techniques.

There is no clear distinction between voltage and angle instability problems but, in some circumstances, one form of instability predominates over the other. Distinguishing between the two types is important for understanding their underlying causes in order to develop appropriate design and operating procedures but, although this is effective, the overall stability of the system should be kept in mind. Solutions for one problem should not be at the expense of another. It is essential to look at all aspects of the stability phenomena and at each aspect from more than one view point.

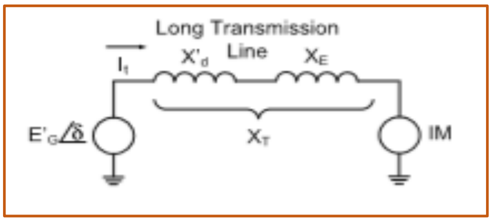


Figure 1. 2 Pure voltage stability

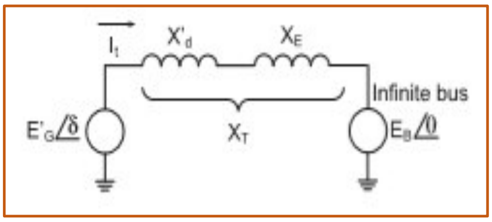


Figure 1. 3 Pure angle stability

Generator connected by transmission lines to a large system–angle stability dominates (one machine to an infinite-bus problem); and (2) a synchronous generator or large system connected by long transmission lines to an asynchronous load–voltage stability dominates. Figures **1.2** and **1.3** show these extremes.

Voltage stability is concerned with load areas and load characteristics. For rotor angle stability, we are often concerned with integrating remote power plants to a large system over long transmission lines. Basically, voltage stability is load stability and rotor angle stability is generator stability. In a large interconnected system, voltage collapse of a load area is possible without the loss of synchronism of any generator. Transient voltage stability is usually closely associated with transient rotor angle stability but longer-term voltage stability is less linked with rotor angle stability. It can be said that if voltage collapses at a point in a transmission system remote from the load, it is an angle instability problem. If it collapses in a load area, it is mainly a voltage instability problem. [JAN 14 b]

1.5 **Main Causes of Voltage Instability**

The driving force for voltage instability is usually the loads; in response to a disturbance, power consumed by the loads tends to be restored by the action of motor slip adjustment, distribution voltage regulators, tap-changing transformers and thermostats. Restored loads increase the stress on a high-voltage network by increasing the reactive power consumption and causing further voltage reduction. A run-down situation causing voltage instability occurs when load dynamics attempt to restore power consumption beyond the capability of the transmission network and the connected generation. A major factor contributing to voltage instability is the voltage drop that occurs when both active and reactive power flow through the inductive reactance of a transmission network; this limits the capabilities of the transmission network, in terms of power transfer and voltage support, which are further limited when some of the generators hit their field , or armature current, time-overload capability limits. It is worth noting that, in almost all voltage instability incidents, one or several crucial generators were operating with a limited reactive capability.

Voltage stability is threatened when a disturbance increases the reactive power demand beyond the sustainable capacity of the available reactive power resources. While the most common form of voltage instability is progressive drops in bus voltages, the risk of over-voltage instability also exists and has been experienced in at least one system. This is caused by the capacitive behavior of a network (EHV transmission lines operating below surge impedance loading) as well as by under excitation limiters preventing generators and/or synchronous compensators from absorbing the excess reactive power. In this case, instability is associated with the inability of the combined generation and transmission systems to operate below some load level. In their attempt tore store this load power ,transformer tap changers may cause long-term voltage instability.

Voltage stability problems may also be experienced at the terminals of HVDC links used for either long-distance or back-to-back applications. They are usually associated with HVDC links connected to weak AC systems and may occur at rectifier or inverter stations, and are associated with the unfavorable reactive power load characteristics of converters. A HVDC link’s control strategies have a very significant influence on such problems, since the active and reactive power at the AC/DC junction is determined by the controls. If the resulting loading on an AC transmission stresses it beyond its capability, voltage instability occurs. Such a phenomenon is relatively fast with the time frame of interest being in the order of one second or less.

Voltage instability may also be associated with converter transformer tap-changer controls which is a considerably slower phenomenon. Recent developments in HVDC technology (voltage-source converters and capacitor-commutated converters) have significantly increased the limits for the stable operation of HVDC links in weak systems compared with the limits for line-commutated converters. One form of the voltage stability problem, that results in uncontrolled over voltage, is the self-excitation of synchronous machines. This can arise if the capacitive load of a synchronous machine is too large. Examples of excessive capacitive loads that can initiate self-excitation are open-ended high-voltage lines, and shunt capacitors and filter banks from HVDC stations. The over-voltages that result when a generator load changes to a capacitive load are characterized by an instantaneous rise at the instant of change followed by a more gradual rise. This latter rise depends on the relationship between the capacitive load component and the machine reactance, together with the excitation system of the synchronous machine. The negative field current capability of an exciter is a feature that has a positive influence on its limits for self-excitation.

A voltage collapse may be aggravated by the excessive use of shunt capacitor compensation, due to the inability of the system to meet its reactive demands, or large sudden disturbances, such as the loss of either a generating unit or a heavily loaded line, or cascading events or poor coordination between various control and protective systems. [JAN 14 c]

1.6 Maximum power derived from load flow equations

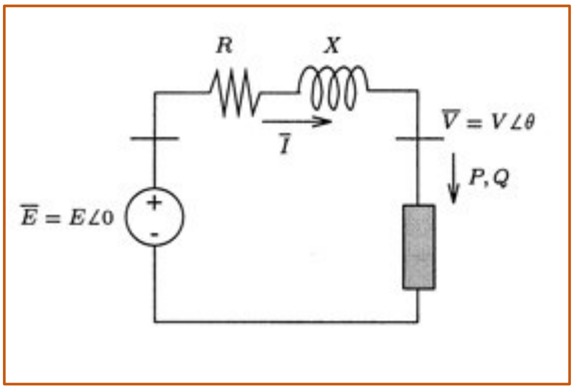


Figure 1. 4 circuit representation

For the sake simplicity, it has been neglected the transmission resistance R (see Fig 1.4) and also take the ideal voltage source as the phase reference by setting $\bar{E} = E\angle 0$. With denote the load voltage magnitude and phase angle by V and θ respectively.

One easily obtains Fig 1.4:

$$\overline{V} = \overline{E} - jX\overline{I} \qquad (1\ .1)$$

The complex power absorbed by the load is:

$$S = P + jQ = \overline{V}\overline{I^*} = \overline{v}\frac{\overline{E^*} - \overline{v^*}}{-jX} \qquad (1.2)$$

$$= \frac{j}{X}(E \quad V\cos\theta \quad + j \quad E \quad v \quad \sin\theta \quad - V^2) \qquad (1.3)$$

Which decomposes into:

$$P = -\frac{EV}{X}\sin\theta \qquad (1.4a)$$

$$Q = -\frac{v^2}{x} + \frac{Ev}{x}\cos\theta \qquad (1.4b)$$

Equation (2.1a,b) are the power flow or load flow equation of the lossless system. For a given load (P,Q), they have to solved with respect to V and θ, from which all other variable can be computed. Let us determine for which values of (P,Q) there is one solution.

Eliminating θ from (2.10a,b) gives:

$$(v^2)^2 + (2QX - E^2)V^2 + X^2(P^2 + Q^2) = 0 \qquad (1.5)$$

This is a second-order equation with respect to V^2. The condition to have at least one solution is:

$$(2QX - E^2)^2 - 4X^2(P^2 + Q^2) \geq 0 \qquad (1.6)$$

Which can be simplified into:

$$-p^2 - \frac{E^2}{X}Q + \left(\frac{E^2}{2X}\right)^2 \geq 0 \qquad (1.7)$$

The equation in (1.7) corresponds to parabola in the (P,Q) plane, as shown in Fig 1.5 . all points “inside” this parabola satisfy (1.7) and thus lead to two load flow solution. Outside there is no solution while on the parabola there is single solution.

This parabola is the locus of al maximum power points. Points with negative P correspond to a maximum generation while each point with positive P corresponds to the maximum load under given power factor, as derived in the previous section.

The locus is symmetric with respect to the Q-axis (i.e. with respect to changing P into -P). in other words, the maximum power than can be injected at the load end is exactly equal to the maximum power that can be absorbed.

However, this symmetry disappears if one takes into account the line resistance.

Setting P = 0 in (1.7) one obtains:

$$Q \leq \frac{E^2}{4X} \tag{1.8}$$

Nothing that $\frac{E^2}{X}$ is the short-circuit power at the load bus, i.e the product of the no-load voltage E by the short-circuit current $\frac{E}{X}$, the maximum of purely reactive load in one fourth of the short-circuit power.

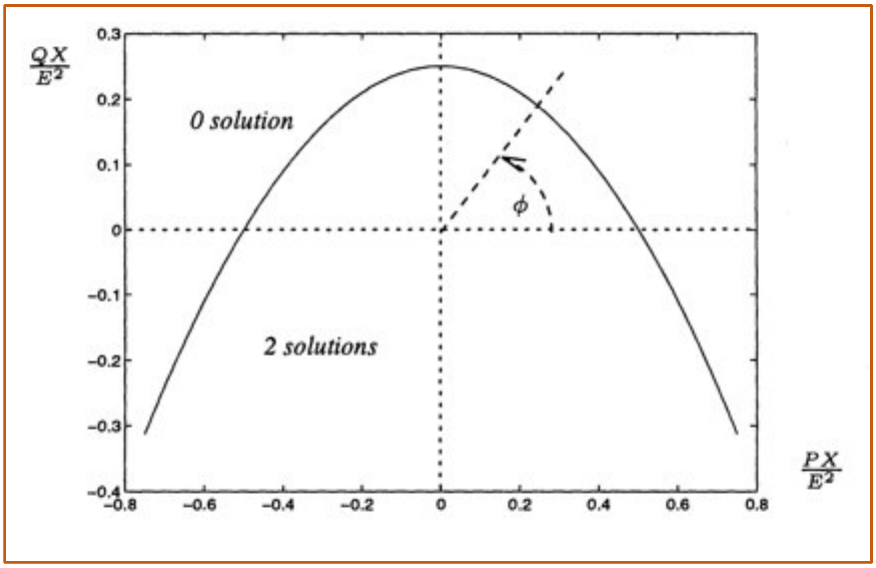


Figure 1. 5 Domain of existence of a load flow

Similarly, by setting Q = 0 in (1.7) one gets:

$$P \leq \frac{E^2}{2X} \tag{1.9}$$

Which is the same power limit and derived for a lossless line with unity power factor, and corresponds to half the short-circuit power.

As can be seen, there is a fundamental difference between the active and reactive powers: any active power can be consumed provided that enough reactive power is injected at the load bus ($Q < 0$), while the reactive load power can never exceed $\frac{E^2}{4X}$. This difference comes from the inductive nature of the transporting large amounts of reactive power. Note that in practice the large reactive support that is required for large active power will finally result in unacceptably high load bus voltage. [THI 08 a]

1.7 Power-voltage relationships

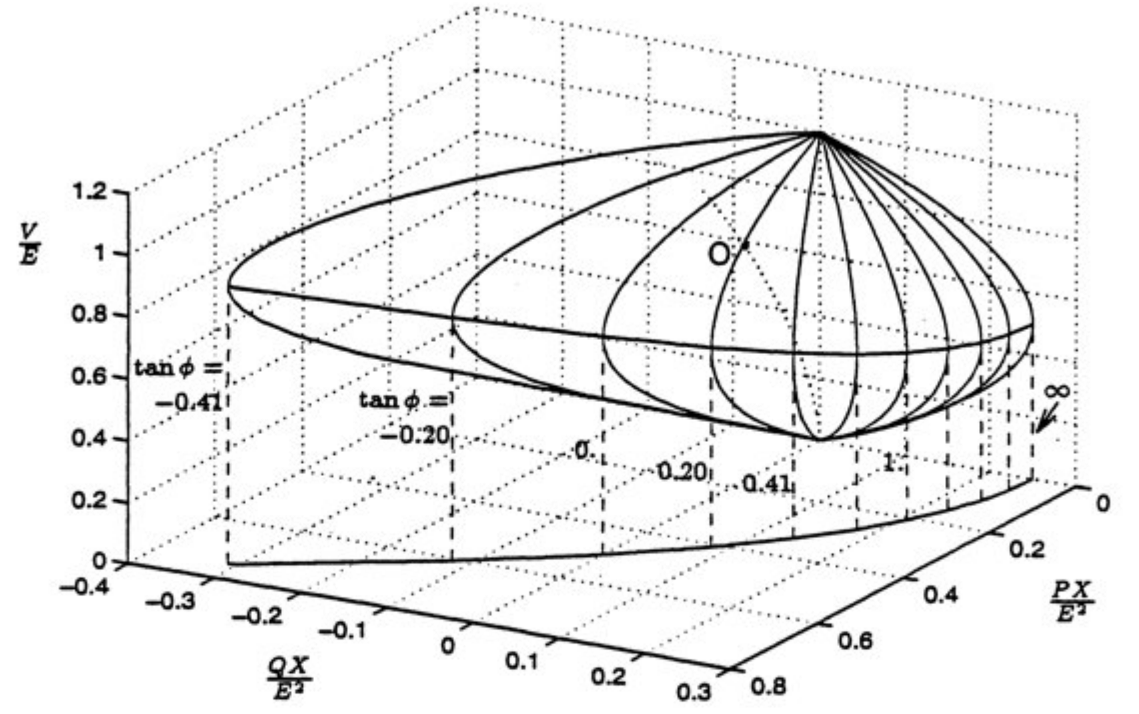


Figure 1. 6 voltage as a function of load active and reactive powers

Assuming that condition (1.7) holds, the two solution of (1.5) are given by :

$$v = \sqrt{\frac{E^2}{2} - QX \pm \sqrt{\frac{E^4}{4} - X^2P^2 - XE^zQ}} \qquad (1.10)$$

In the (P,Q,V) space, equation (1.7) defines two dimensional surface shown in Fig 1.6. The upper part of this surface corresponds to the solution with the plus sign in (1.10), or the higher voltage solution, while the lower part corresponds to the solution with the minus sign, which is the low voltage one. The “equator” of this surface, along which the two solutions are equal corresponds to the maximum power points as given with the parabola of Fig 1.5 .

The “meridians” draw with solid lines in fig 1.6 correspond to intersections with vertical planes $Q = P \tan \phi$, for ϕ varying from $\frac{-\pi}{8}$ to $\frac{\pi}{2}$ by steps of $\frac{\pi}{16}$. Projecting these meridians onto the (P,V) plane provides the curves of load voltage as a function of active power, the various $\tan \phi$. these famous curves, shown in role in understanding and explaining voltage instability.

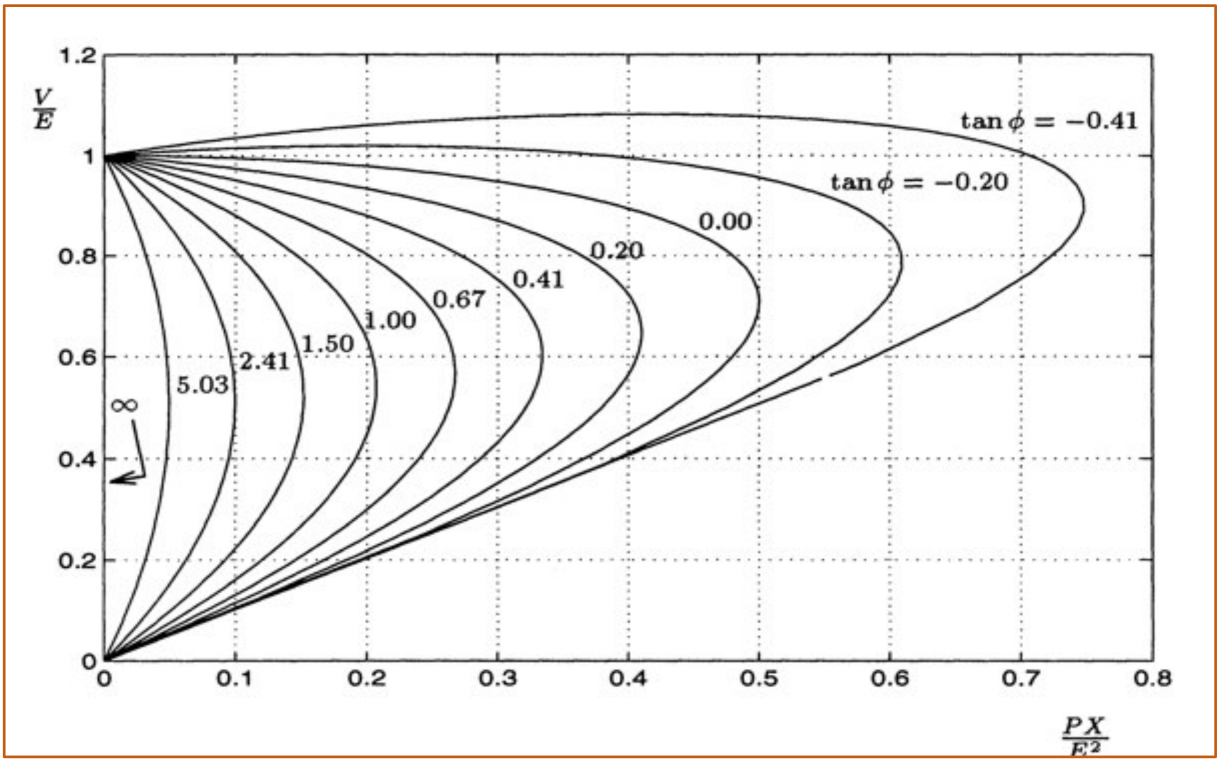


Figure 1. 7 PV curves

Although they are probably the most popular, the PV curves are not only possible projection of the surface Fig 1.7 onto a plane could similarly:

- Project the meridians onto the (Q,V) plane, there by producing QV curves
- Take the apparent power $S = \sqrt{P^2 + Q^2}$ as the abscissa, and consider SV curves
- Consider QV curves corresponding to constant active power P or PV curves under constant reactive power Q.

All the these curves have basically the shape show in Fig 1.7 the only difference being that curves drawn under constant P or constant Q do not go through zero voltage (expect, of course, when the power held constant is equal to zero)

The following observations can be made regarding the curves of Fig 1.7:

- For a given load below the maximum , there are two solutions: one with higher voltage and lower current, the other with lower voltage and higher current. The former corresponds to “normal” operation condition at the lower solutions is unacceptable, as will discussed in the next section.
-
- As the load is more and more compensated (which corresponds to smaller tan ϕ), the maximum power increases. However. The voltage at which its maximum occurs also increase, this situation is dangerous in the sense that maximum transfer capability may be reached at voltage close to

norm operation to the maximum. Also, for a high degree of compensation and load power close to the maximum, the two voltage solutions are close to each other and without further analysis it may be difficult to decide if a given solution is the “normal” one.

- For over-compensated loads ($\tan \phi < 0$), there is a portion of the upper PV curve along which the voltage increase with load power. The explanation is that under negative $\tan \phi$, when more active power is consumed, ,more reactive power is produced by the load. At low load, the voltage drop due to the former is offset.
- By the voltage increase due to the latter. The more negative $\tan \phi$ is, the larger the portion of the PV curve where this takes place. [THI 08 b]

Conclusion

This chapter is devoted to presenting the different types of power system stability. We studied the principle causes of voltage stability , the types of voltage stability , their performance in instability zone and the influence of this stability in load.

Chapter 2: Facts Devices

Introduction

In this chapter, we will present concepts of the TCSC fact system and its different types as well as the technique for improving stability by FACTS .

2.1 Voltage Stability and FACTS Devices

During the past two decades, the increase in electrical energy demand has presented higher requirements for the power industry. In recent years, thein creases in peak load demands and power transfers between utilities have elevated concerns about system voltage security. Voltage instability is mainly associated with a reactive power imbalance. Improving a system's reactive power-handling capacity via FACTS devices is a remedy for the prevention of voltage instability and, hence, voltage collapse. With the rapid development of power electronics, FACTS devices have been proposed and installed in power systems. They can be utilized to control power flow and enhance system stability. Particularly with the deregulation of the electricity market, there is an increasing interest in using FACTS devices for the operation and control of power systems with new loading and power flow conditions. For a better utilization of existing power systems, i.e., to increase their capacities and controllability, installing FACTS devices becomes imperative. In the present situation, there are two main aspects that should be considered when using FACTS devices: the flexible power system operation according to their power flow control capability; and improvements in the transient and steady-state stability of power systems. FACTS devices are the right equipment to meet these challenges and different types are used in different power systems.

The most commonly used devices in present power grids are shunt capacitors and mechanically-controlled circuit breakers (MCCBs). Within limits, static reactive sources, such as shunt capacitors, can assist in voltage support. However, unless they are converted to pseudo-dynamic sources by being mechanically switched, they are not able to help support voltages during emergencies, when more reactive power support is required. In fact, shunt capacitors suffer from a serious drawback of providing less reactive support at the very time that more support is needed, i.e., during a voltage depression volt-ampere-reactive (VAR) output being proportional to the square of the applied voltage. Long switching periods and discrete operation make it difficult for MCCBs to handle the frequently changing loads smoothly and damp out the transient oscillations quickly. In order to compensate for these drawbacks, large operational margins and redundancies are maintained in order to protect the system from dynamic variation and recover from faults. However, this not only increases the cost and lowers the efficiency, but also increases the complexity of a system and augments the difficulty of its operation and control. Severe black-outs in power grids which have happened recently world wide have revealed that conventional transmission systems are unable to manage the control requirements of complicated interconnections and variable power flows.

Greatly increase computation costs and could be impractical for industrial application. To study the problem of modeling, all the components of a power system should be considered for their performance. Based on the requirements of stability study, different modeling schemes can be used for the same device; for example, three kinds of models of a system or device are necessary in order to study a power system's long term, midterm and transient stabilities.

Traditional system modeling has been based on generators and their controls as well as the transmission system components. Only recently load modeling has received more and more attention for stability analysis purposes. Test systems considered in this dissertation consist of conventional generators, wind generators, PV units, generator control systems including excitation control, automatic voltage regulators (AVRs), power system stabilizers (PSSs), transmission lines, transformers, reactive power compensation devices, new developed FACTS devices and loads of different kinds. Each piece of equipment has its own dynamic properties that may need to be modelled for a stability study.

The dynamic behaviors of these devices are described through a set of nonlinear differential equations while the power flow in the network is represented by a set of algebraic equations. This gives rise to a set of differential-algebraic equations (DAEs) describing the behavior of a power system. After suitable representations of these elements, one can arrive at a network model of a system in terms of its admittance matrix. Generally, because of a large number of nodes in the system, this matrix will be large but can be reduced by making suitable assumptions. Different types of models have been reported in the lite rapture for each type of power system component depending upon its specific applications. In this chapter, the relevant equations governing the dynamic behaviors of the specific types of models used in this dissertation are described. [JAH 14 d]

2.2 Continuation Power Flow

One of the simple methods of calculating the load margin is the calculation of power flow at each incrementation of the load, until the divergence of the program. Unfortunately this method provides unclear results because of the singularity or poor conditioning of the Jacobian matrix around the collapse point. In addition, this conventional method does not trace the lower part of the voltage curve that is used by other methods of analysis. [KEZ 04]

The advantage of continuous power flow is not only its ability to find the critical point of voltage collapse, but also the determination of the complete PV curve (top and bottom sections) in an exact way .

Its interesting features lead several power generation companies to use this method as an efficient index of the proximity of the collapse point system. [LAK 06]

2.3 Continuous calculation of the power flow (CPF)

Continuous power flow calculation techniques are widely recognized as a valuable tool for determining power system V (P) curves and for estimating maximum loading conditions and "critical" solutions (eg saddle-node and induced limits of bifurcation points). Although large systems require a demanding numerical computation, the CPF is not affected by numerical instabilities. In fact, it is able to determine the stable and unstable portion of the V (p) curves and can provide additional information, such as the sensitivity factors of the current solution with respect to the relevant parameters.

From a mathematical point of view, the CPF is a homotopy technique and makes it possible to explore the stability of the equations of the electrical system by varying a parameter of the system, which, in typical static and dynamic stress stability studies, is the load parameter λ.

In general, the CPF consists of a predictive step made by calculating the tangent vector and a corrective step that can be obtained either by means of a local parameter setting or by a perpendicular intersection.

2.3.1 Without predictor

At the generic equilibrium point p, the following relation applies:

$$f(x_{\mathrm{p}}, \lambda_{\mathrm{p}}) = 0 \Rightarrow \left.\frac{\mathrm{d}f}{\mathrm{d}\lambda}\right|_{\mathrm{p}} = \mathrm{D}_x f|_{\mathrm{p}} \left.\frac{\mathrm{d}x}{\mathrm{d}\lambda}\right|_{\mathrm{p}} + \left.\frac{\mathrm{d}f}{\mathrm{d}\lambda}\right|_{\mathrm{p}} = 0 \tag{2.1}$$

And the tangent vector can be approximated by :

$$\tau_{\mathrm{p}} = \left.\frac{\mathrm{d}x}{\mathrm{d}\lambda}\right|_{\mathrm{p}} \approx \frac{\Delta x_{\mathrm{p}}}{\Delta\lambda_{\mathrm{p}}} \tag{2.2}$$

From Equation (IV.4) and (IV.5) we have :

$$\tau_p = -\mathrm{D}_x f|_{\mathrm{p}}^{-1} \left.\frac{\partial f}{\partial\lambda}\right|_{\mathrm{p}}$$

$$\Delta x_{\mathrm{p}} = \tau_p \Delta\lambda_{\mathrm{p}} \tag{2.3}$$

At this point a step of magnitude k of control must be chosen to determine the quantity Δx_p and Δλ_p with a normalization in order to avoid big steps when ‖τp‖ is large .

$$\Delta\lambda_p \triangleq \frac{k}{\|\tau_p\|} \qquad \Delta x_p \triangleq \frac{k\,\tau_p}{\|\tau_p\|} \tag{2.4}$$

Where ‖.‖ is the Euclidean norm and k = ± 1. The sign of k determines the increase or decrease of λ..

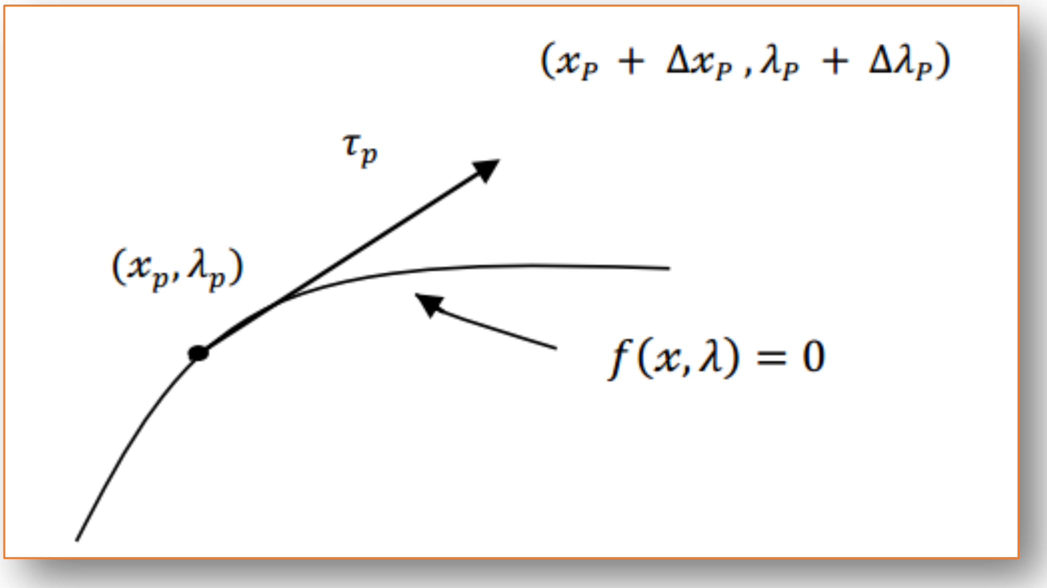


Figure 2. 1 Continuous calculation of the power flow without predictor obtained by means of the tangent

2.3.2 No corrector

For the corrective step, the set of equations n + 1 is solved :

$$\boldsymbol{f} = (\boldsymbol{x}, \boldsymbol{\lambda}) = \boldsymbol{0} \tag{2.5}$$

$$\boldsymbol{\eta} = (\boldsymbol{x}, \boldsymbol{\lambda}) = \boldsymbol{0} \tag{2.6}$$

Where the solution of f must be in the bifurcation manifold and η is an additional equation to guarantee a nonsingular set at the point of bifurcation. For the choice of η there are two options: the perpendicular intersection and the local parameterization.

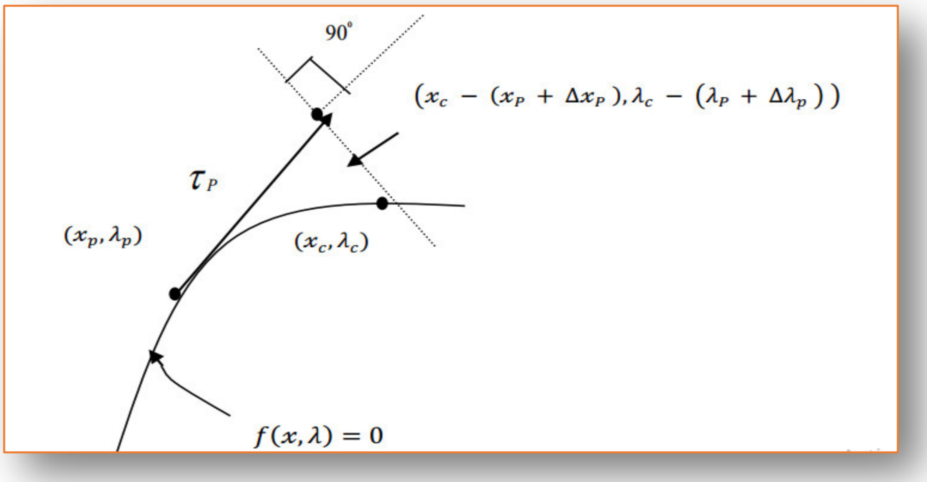


Figure 2. 2 Continuous calculation of the power flow no corrector obtained by the perpendicular intersection means

in the case of the perpendicular intersection, whose representation is given by the figure (2.2), the expression of η becomes (equation 2.7) :

$$\eta\ (x\ ,\lambda) = \begin{bmatrix}\Delta x_{\mathrm{p}}\\ \Delta\lambda_{\mathrm{p}}\end{bmatrix}^{\mathrm{T}} \begin{bmatrix}x_{\mathrm{c}} - (x_{\mathrm{p}} + \Delta x_{\mathrm{p}})\\ \lambda_{\mathrm{c}} - (\lambda_{\mathrm{p}} - \Delta\lambda_{\mathrm{p}})\end{bmatrix} = 0 \tag{2.7}$$

Whereas for the local parameterization, either the parameter λ or the variable 〖x〗 _i is forced to be a fixed value.

$$\eta(x,\lambda) = \lambda\ c - \lambda\ p - \Delta\lambda\ p \tag{2.8}$$

Or

$$\eta(x,\lambda) = xci - \Delta\ \ x\ pi - x\ pi \tag{2.9}$$

The choice for the variable to be fixed depends on the deflection collector def, as it is presented in Figure (2.3) . [OUM 13]

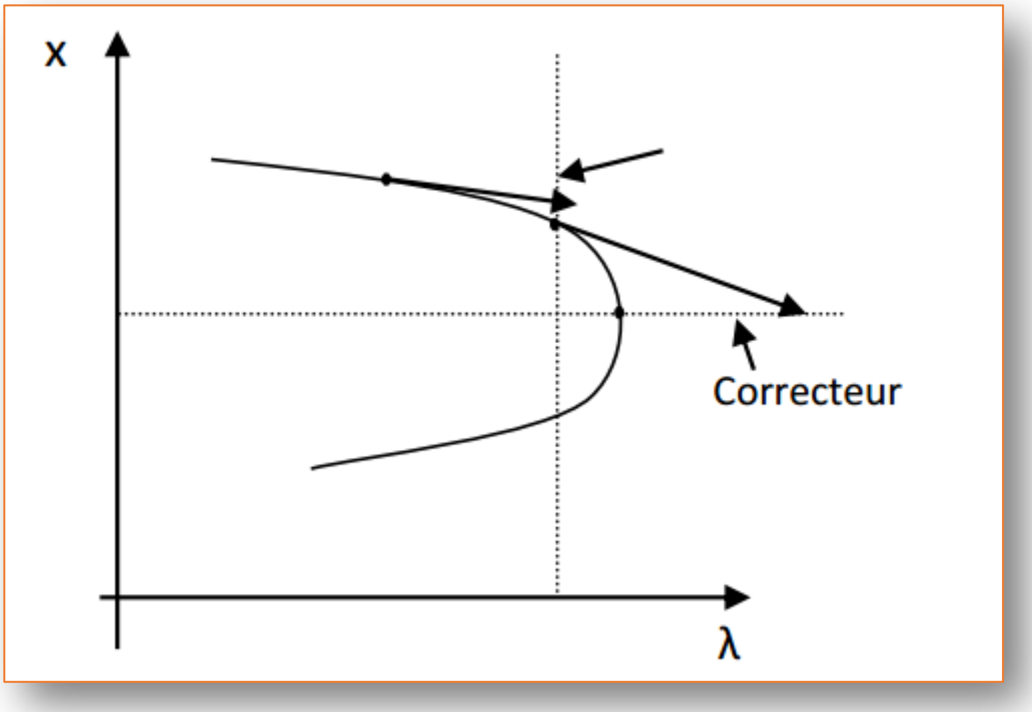


Figure 2. 3 Continuous calculation of the power flow no corrector obtained by means of local parameterization

2.4 Recent methods for improving stability

Figure 2. 4 Method of improving stability

2.5 Stability enhancement by FACTS

Faced with power transit problems, the American company EPRI (Electric.
In 1988, the Power Research Institute launched a project to study FACTS systems in order to better control power transit in power lines. [BEL01]

2.6 FACTS devices

According to the IEEE (Institute of Electrical and Electronics Engineers), the definition of the term FACTS is as follows: Alternating Current Transmission Systems comprising devices based on power electronics and other static devices used to increase the controllability and increase the power transfer capacity of the network.

With their ability to modify the apparent characteristics of lines, FACTS are able to increase the capacity of the network as a whole by controlling power flows. FACTS devices do not replace the construction of new lines. They are a way to defer investment by allowing more efficient use of the existing network. [NOB 85]

2.7 Role of FACTS devices

The development of FACTS devices is mainly due to advances in power semiconductors and more particularly controllable elements such as the thyristor and the GTO thyristor. FACTS are an alternative to power control devices using passive techniques:

Induction coil and capacitor tripped by circuit breaker, phase shifter transformer with regulator under mechanical load, etc. In FACTS devices, electromechanical switches are replaced by electronic switches. They thus have very high control speeds and do not encounter the wear and tear problems of their predecessors. As a result, FACTS have very high reliability and almost unlimited flexibility.

In an electrical network, FACTS can be used to perform functions both in a steady state and in a transient state. They generally act by absorbing or providing reactive power, controlling line impedance or changing voltage angles. In steady state, FACTS are used mainly in the following two contexts:

- Maintaining the voltage at an acceptable level by providing reactive power when the load is high and the voltage is too low, while conversely they absorb it if the voltage is too high,
- Control of power transits in order to reduce or even eliminate overloads in lines or transformers and to avoid looping flows in the network. They then act by controlling the reactance of the lines and adjusting the phase shifts. Due to their high control speed, FACTS have many qualities in dynamic operation.[BEN 07]

2.8 Classification of FACTS devices

Since the first compensators, three generations of FACTS devices have been developed. They are distinguished by the semiconductor technology and power elements used:

A. The first generation is based on conventional thyristors. These are generally used to switch the components on or off to supply or absorb reactive power in the control transformers.

B. The second generation, called advanced, was born with the advent of power semiconductors controllable at closing and opening, such as the GTO thyristor. These elements are assembled to form voltage or current converters to inject controllable voltages into the grid.

C. A third generation of FACTS using hybrid components that is adapted to each case. Unlike the first two generations, this one does not use bulky auxiliary devices such as transformers for coupling to

- the grid. FACTS components can be classified into three categories:
    - Parallel compensators,
    - Serial compensators,
    - Hybrid "series - parallel" compensators. [GYN 00]

Figure 2. 5 Classification of FACTS devices

2.9 Static Var Compensator (SVC)

The main role of the SVC (static compensator reactive energy) is to compensate the reactive power in the line and this to avoid the voltage drops caused by consumers, this compensation can be achieved in many ways and with many means. Most of the means used for compensation are effective but have drawbacks:

- high reaction time.
- generation of harmonics.

Currently, pulsed inverters are used which have several advantages, to avoid these disadvantages. The combination of TCRs, TSCs, fixed capacitance batteries and harmonic filters is the hybrid compensator, better known as SVC, the first example of which was installed in 1979 in South Africa. The static characteristic is given by the figure (2.6) Three zones are distinct :

- an area where only the capacities are connected to the network,
- a control zone where the reactive energy is a combination of TCRs and TSCs,
- an area where the TCR gives its maximum energy, the capacitors are disconnected.

All are used to control the voltage. [PAS 98]

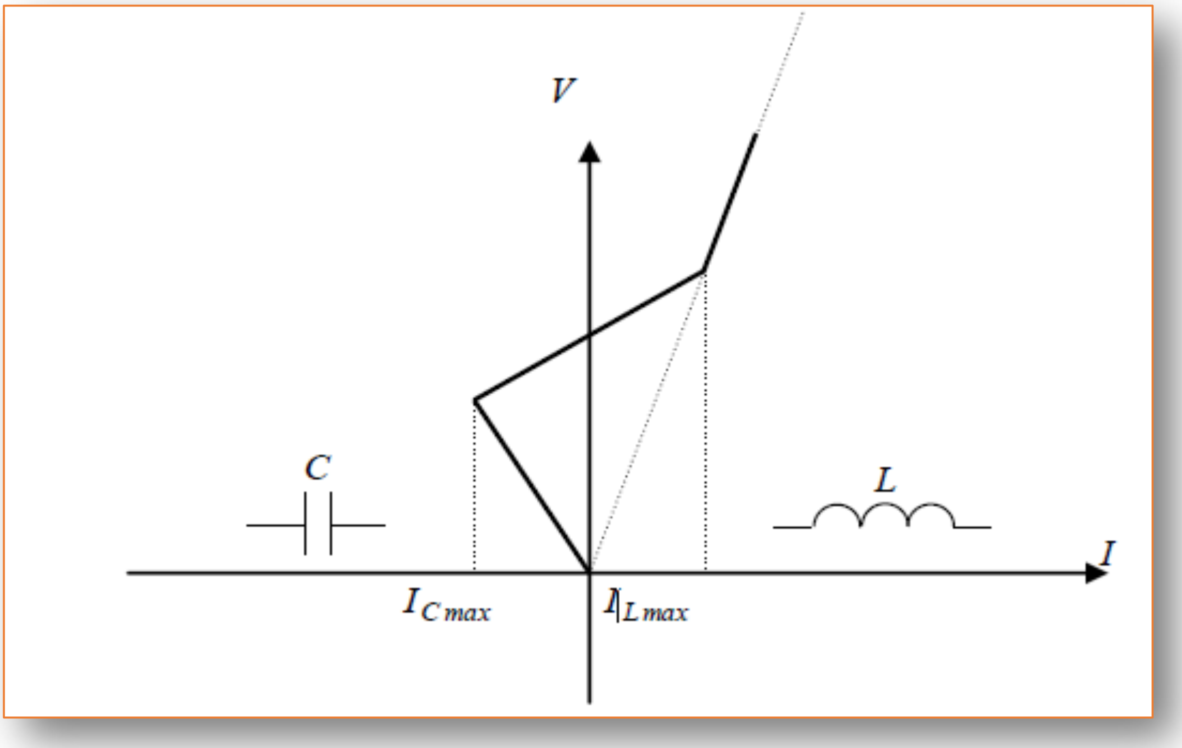


Figure 2. 7 Characteristic of SVC

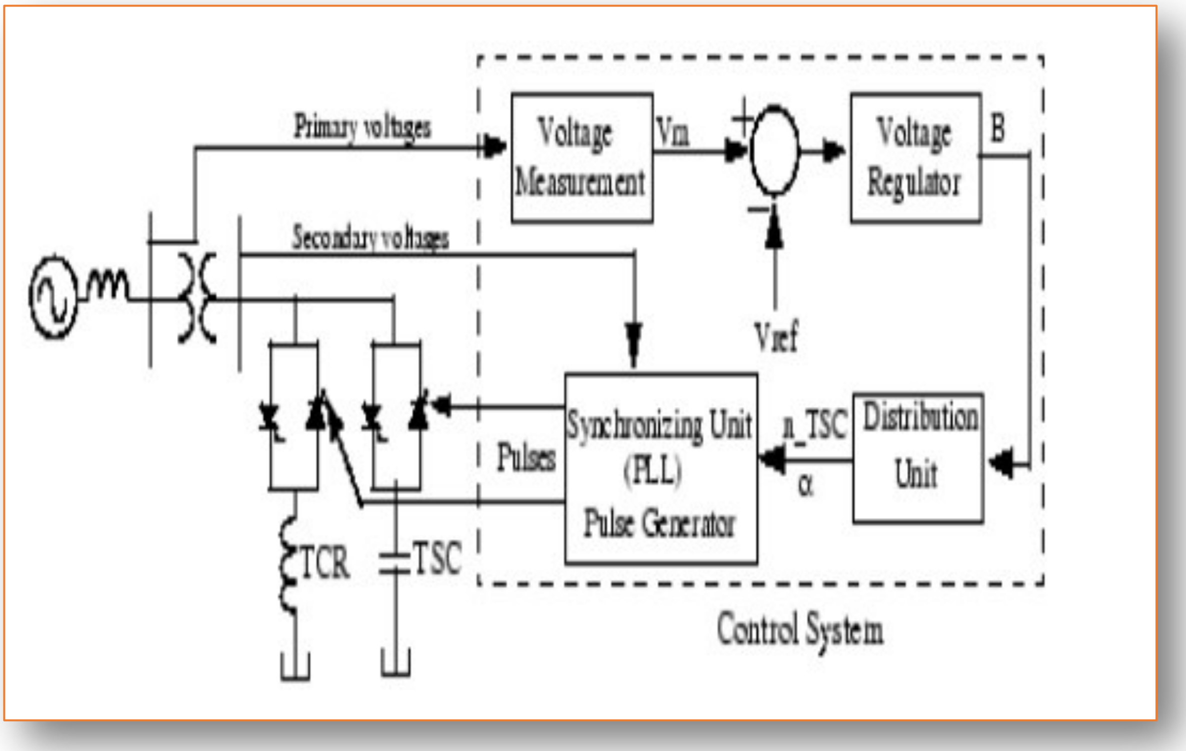


Figure 2. 6 Diagram of a branch of SVC

2.10 Operating principle of the SVC

A branch of SVC is composed of three circuits, a capacitor C1 is connected in series with two thyristors and a circuit composed of an inductor in parallel with a resistor, the current can be adjusted continuously between zero and its nominal value, the Capacitive branches are controlled in all where nothing according to the states of the thyristors lead or not. An identical circuit containing capacitor C2 capacitive power.
When the inductance in service and the capacitors are disconnected and the secondary voltage of the transformer is of maximum value, the starting angle of the thyristors controlling the inductive branch at 90 °, the current of the inductance and the reactive power have maximum values.
When the inductance is disconnected and the two capacitors are in use, the total current per phase under voltage is of maximum value but of negative sign therefore the reactive power is supplied . [BOU 10]

2.11 Advantages and Disadvantages of FACTS Device Technology

2.11.1 Advantages

- Controls the transit of the active power.
- Increases the safety of energy systems (increase of transient stability limit, damping of oscillations …)
- Reduces the transit of reactive energy.
- Optimizes the powers generated, thus reducing the cost of producing energy.
- Improved interconnection and energy exchange.

2.11.2 Disadvantages

The introduction of harmonics of the electrical network which makes it polluted, ie the signal will be taut and not sinusoidal. It makes the network vulnerable to over voltage due to repetitive switching.

Conclusion

In this chapter, we have provided a brief description and definitions of the various types of FACTS devices. This description is adopted as the universal classification of FACTS systems. Most of them are already in use in practice. If today FACTS are still little used compared to their potential, the technical evolutions of power electronics will make FACTS solutions more and more competitive in the face of network reinforcements, We have chosen to study SVC as FACTS devices to control and improve voltage and reactive power.

Chapter 3: Realization and Results

Introduction

Since in reality, the demand for electricity is always increasing, so the surcharge is very likely or it is very easy to cope with this surcharge and the stability of our network, there is a simpler solution; to the power to the power to the power to the power to the power, not to the poll, not to the heat, but to say, is not to the power, the systems can improve our network ? That's what we're going to look at in this chapter.

3.1 Study of the static stability of the model of 30 buses system diagram by PSAT

3.1.1 The Power System Analyzes Toolbox (PSAT)

PSAT is a freely distributed software designed by Federico Milano based on MATLAB for the analysis and optimization of electrical networks. The graphical interface interactive PSAT allows the user to perform static and dynamic functions following :

- Power flow calculation (PF).
- Optimal Power Flow (OPF) calculation.
- Continuous Power Flow (CPF) calculation.
- Small Signal Stability Analysis (SSSA).
- Time Domain Simulation (TDS).
- Electromagnetic Magnetic Transient Analysis (EMT).
- Graphical User Interface (GUI).

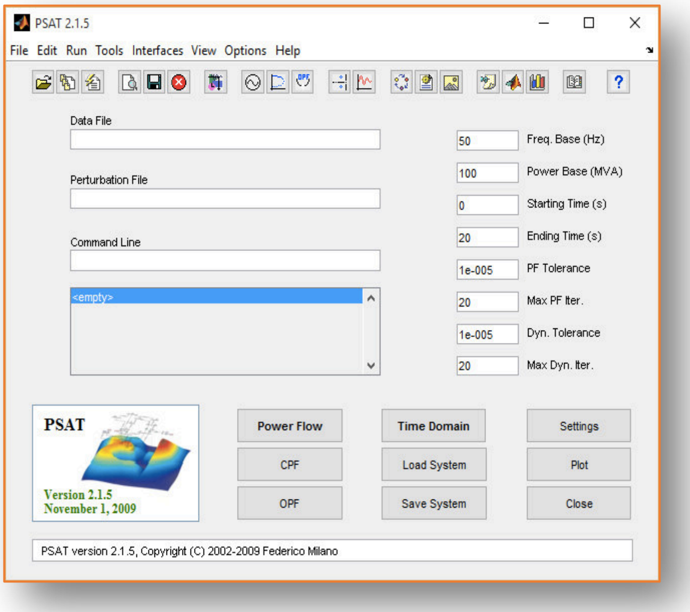
A- Graphical Network Editor (GNE) All PSAT operations can be divided into two types of analysis:

The first analysis is to solve power flow problems.

This application is done in a command page or an editor as shown in the figure (3.1).

B- The second analysis is to implement the network to be studied using a library

which contains many models for the implementation of electrical systems, as shown in the figure (3.2)



50 Freq. Base (Hz)
100 Power Base (MVA)
0 Starting Time (s)
20 Ending Time (s)
1e-005 PF Tolerance
20 Max PF Iter.
1e-005 Dyn. Tolerance
20 Max Dyn. Iter.

PSAT version 2.1.5, Copyright (C) 2002-2009 Federico Milano

Figure 1. 9 PSAT Home Page

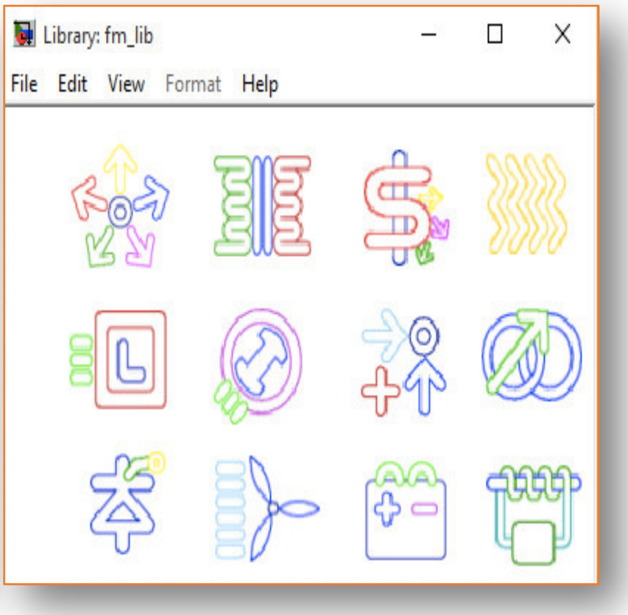


Figure 1. 8 Simulink Library

Although PSAT works in the MATLAB environment, it can only be launched from MATLAB version 9.0.0 and higher.

After the PSAT file has been saved, for Launching the PSAT, the following steps must be followed:

- Open Matlab 9.0.
- Go to PSAT folder
- Type “ PSAT ” in the Matlab command.
- Click on “data file” to load the model.
- Once the model is loaded, click on “Power Flow” to perform the power flow.

3.1.2 **Study networks**

3.1.2.1 IEEE 30 buses system diagram

The choice of the IEEE 30 grid buses is justified by the possibility of making comparisons with similar research work as it is widely used.

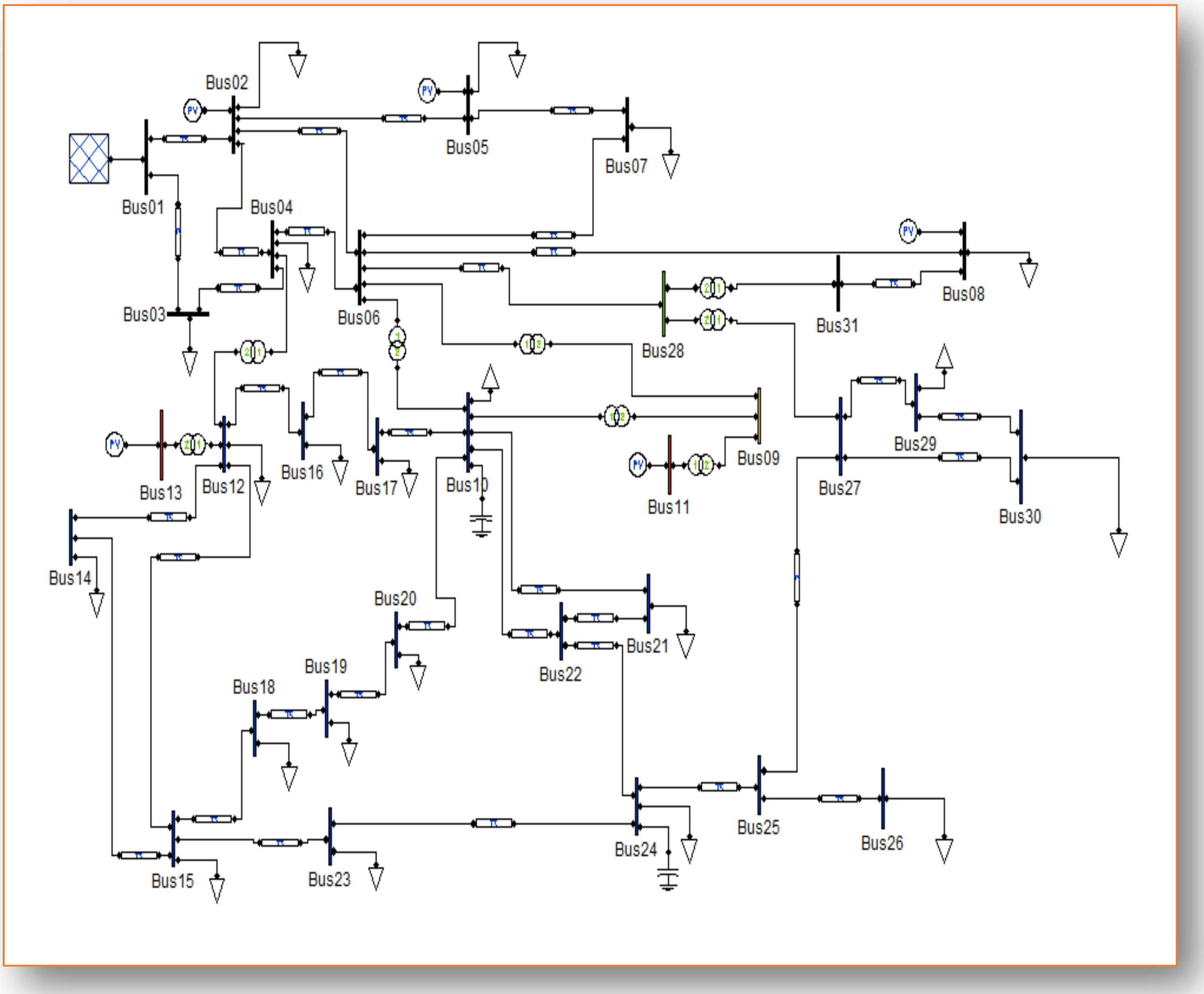


Figure 3. 1 Characteristic of the 30 buses system study Model

- ❖ And this is the Technical data contain of tthis network :

Table 3. 1 Technical data of the Study Model

Number of buses	**Number of loads**	**Number of lines**	**Number of generators**	**Number of transformers**
30	**21**	**33**	**6**	**7**

3.2 Model Network Analysis of 30 buses

3.2.1 Initial state

Table 3. 2 Power flow results

Jeu de **Barre (JB)**	La tension **de JB [pu]**	Angle **[rad]**	Pgen **[pu]**	Qgen **[pu]**	Pcharge **[pu]**	Qcharge **[pu]**
Bus01	1.06	0	2.1157	-0.16401	0	0
Bus02	1.045	-0.07733	0.4	0.37437	0.217	0.127
Bus03	1.0317	-0.11334	0	0	0.024	0.012
Bus04	1.0248	-0.13639	0	0	0.076	0.016
Bus05	1.01	-0.20995	0.1	0.27702	0.942	0.19
Bus06	1.0183	-0.15961	0	0	0	0
Bus07	1.0072	-0.18943	0	0	0.228	0.109
Bus08	1.01	-0.16632	0.1	0.11332	0.3	0.3
Bus09	1.0511	-0.19709	0	0	0	0
Bus10	1.0384	-0.22862	0	0	0.058	0.18489
Bus11	1.082	-0.18549	0.12	0.305	0	0
Bus12	1.0375	-0.21556	0	0	0.112	0.075
Bus13	1.071	-0.20044	0.12	0.25724	0	0
Bus14	1.0275	-0.2304	0	0	0.062	0.016
Bus15	1.0282	-0.23275	0	0	0.082	0.025
Bus16	1.0348	-0.22272	0	0	0.035	0.018
Bus17	1.0323	-0.23055	0	0	0.09	0.058
Bus18	1.0196	-0.24362	0	0	0.032	0.009
Bus19	1.0176	-0.2468	0	0	0.095	0.034
Bus20	1.022	-0.24319	0	0	0.022	0.007
Bus21	1.0251	-0.23677	0	0	0.175	0.112
Bus22	1.0254	-0.23661	0	0	0	0
Bus23	1.0172	-0.24045	0	0	0.032	0.016
Bus24	1.01	-0.24403	0	0	0.087	0.02313
Bus25	0.99912	-0.23974	0	0	0	0
Bus26	0.98111	-0.24734	0	0	0.035	0.023
Bus27	1.0011	-0.2325	0	0	0	0
Bus28	1.0138	-0.16841	0	0	0	0
Bus29	0.98077	-0.25495	0	0	0.024	0.009
Bus30	0.96901	-0.27109	0	0	0.106	0.019

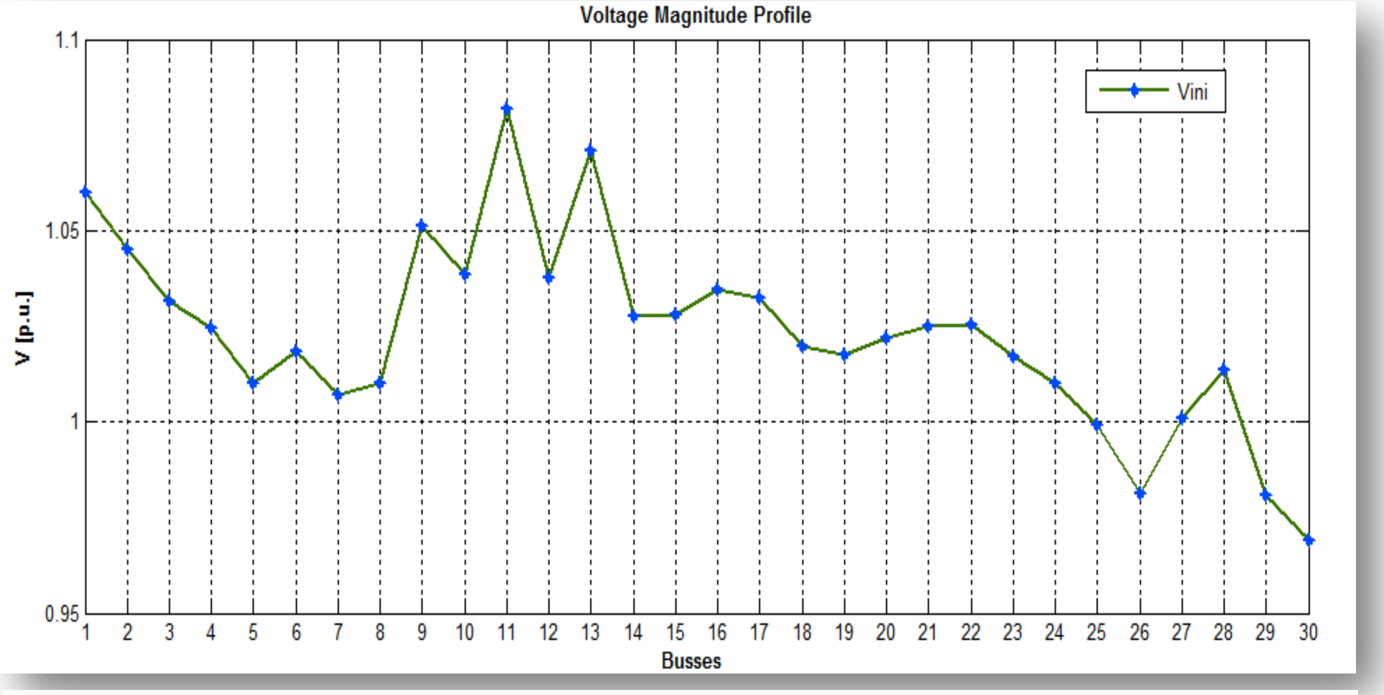


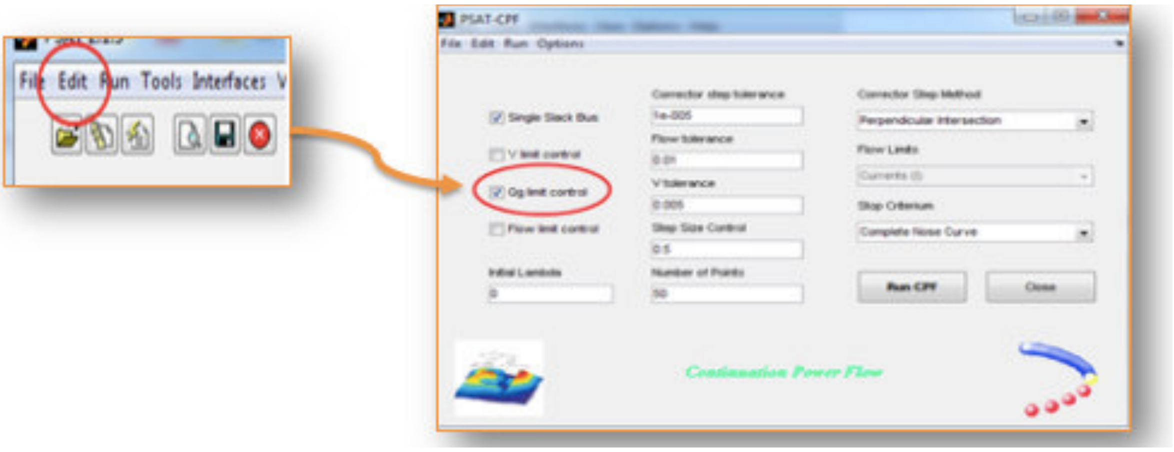
Figure 3. 2 voltage profile in initial state

3.2.2 Method of analysis

To examine the influence of overload in the electrical grid on its stability and identify the limit of this overload, we adopted on :

- ✓ Gradually increase the load at the load level (with the CPF method).
- ✓ Vary the power value at each load (active and reactive power).
- ✓ Note the influence of this variation on PSAT results (report).
- ✓ Compare with the initial result
- ✓ This is the overload limit to obtain, extracts the profiles of the voltage, phase and power module.

3.3 Network analysis with the CPF method



☑ Single Slack Bus
☐ V limit control
☑ Qg limit control
☐ Flow limit control
Initial Lambda: 0
Corrector step tolerance: 1e-005
Flow tolerance: 0.01
V tolerance: 0.005
Step Size Control: 0.5
Number of Points: 50
Corrector Step Method: Perpendicular Intersection
Flow Limits: Currents (I)
Stop Criterium: Complete Nose Curve

Figure 3. 3 Changing the CPF parameter

The 30 buses study in this state is based on the "CPF" method; then the modification of the CPF parameter as follows

- Click on "Edit".
- Choose "CPF Setting".
- Set the limits for the reactive power Q.

3.3.1 The main objective of the CPF analysis

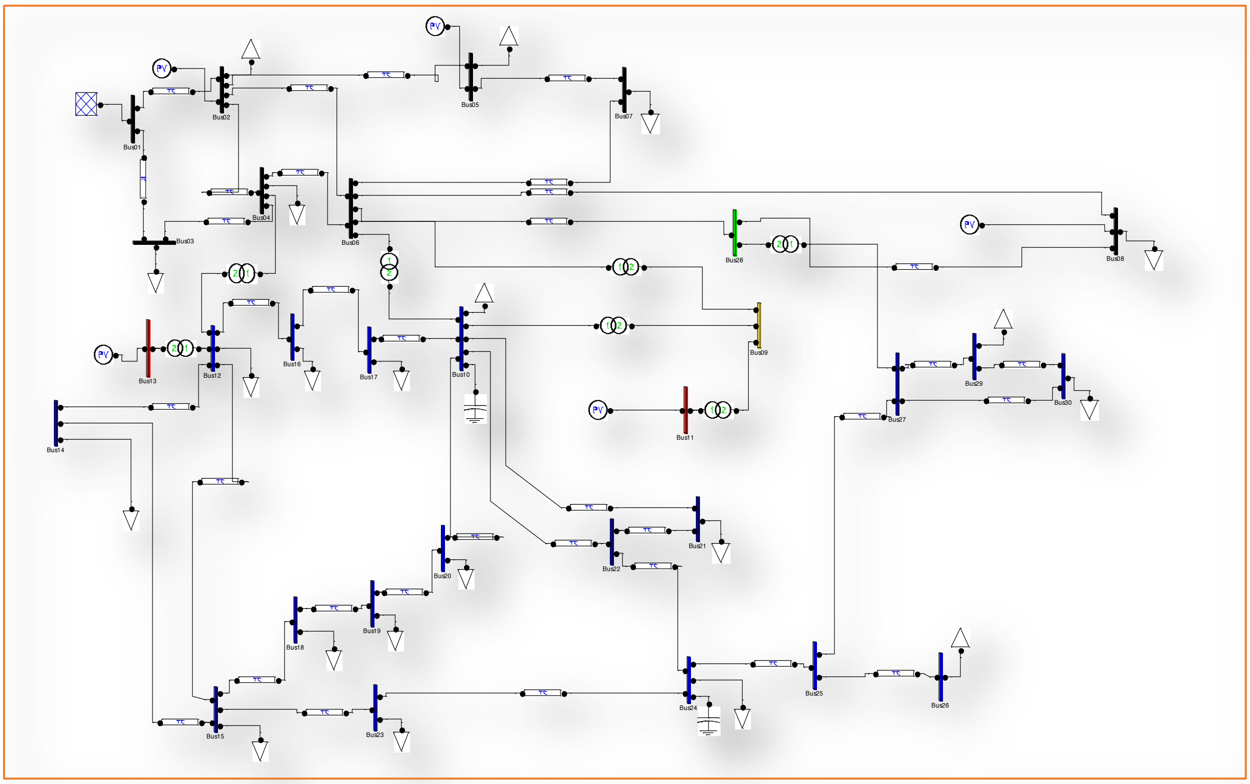


Figure 3. 4 Characteristic of 30 buses Study Model without Generator Blocks

The goal of "Continuous Power Flow" is the gradual increase of the load to reach the point where the network can no longer support this load , It allows you to:

- ✓ Know the maximum capacity that the network can support for an overload
- ✓ Conclude the most sensitive JBs for the variation of the load for its buses or candidate the buses for a possible location of compensation elements such as compensation capacitors and FACTS

After following the above steps; click on "Run CPF" to obtain the following results:

Table 3. 3 Continuous power flow (CPF) results

Jeu de **Barre (JB)**	La tension **de JB [pu]**	Angle **[rad]**	Pgen **[pu]**	Qgen **[pu]**	Pcharge **[pu]**	Qcharge **[pu]**
Bus 01	1.06	0	3.9265	3.0181	0	0
Bus 02	0.91179	-0.1237	0.6436	0.5	0.34915	0.20434
Bus 03	0.8291	-0.19679	0	0	0.03862	0.01931
Bus 04	0.78245	-0.2447	0	0	0.12228	0.02574
Bus 05	0.75293	-0.45528	0.1609	0.4	1.5157	0.30571
Bus 06	0.74431	-0.30342	0	0	0	0
Bus 07	0.72767	-0.39298	0	0	0.36685	0.17538
Bus 08	0.73191	-0.32699	0.1609	0.4	0.4827	0.4827
Bus 09	0.6839	-0.433	0	0	0	0
Bus 10	0.62528	-0.56439	0	0	0.09332	0.03218
Bus 11	0.71994	-0.38985	0.19308	0.24	0	0
Bus 12	0.65716	-0.52339	0	0	0.18021	0.12067
Bus 13	0.70378	-0.46491	0.19308	0.24	0	0
Bus 14	0.62503	-0.58737	0	0	0.09976	0.02574
Bus 15	0.622	-0.59675	0	0	0.13194	0.04022
Bus 16	0.64069	-0.55148	0	0	0.05631	0.02896
Bus 17	0.61645	-0.57783	0	0	0.14481	0.09332
Bus 18	0.58757	-0.64256	0	0	0.05149	0.01448
Bus 19	0.57635	-0.65482	0	0	0.15285	0.05471
Bus 20	0.58601	-0.63599	0	0	0.0354	0.01126
Bus 21	0.58765	-0.60192	0	0	0.28157	0.18021
Bus 22	0.58844	-0.601	0	0	0	0
Bus 23	0.58047	-0.6286	0	0	0.05149	0.02574
Bus 24	0.54601	-0.63739	0	0	0.13998	0.1078
Bus 25	0.54658	-0.64356	0	0	0	0
Bus 26	0.48783	-0.68852	0	0	0.05631	0.03701
Bus 27	0.57628	-0.62199	0	0	0	0
Bus 28	0.71731	-0.3279	0	0	0	0
Bus 29	0.49992	-0.74524	0	0	0.03862	0.01448
Bus 30	0.45569	-0.85356	0	0	0.17055	0.03057

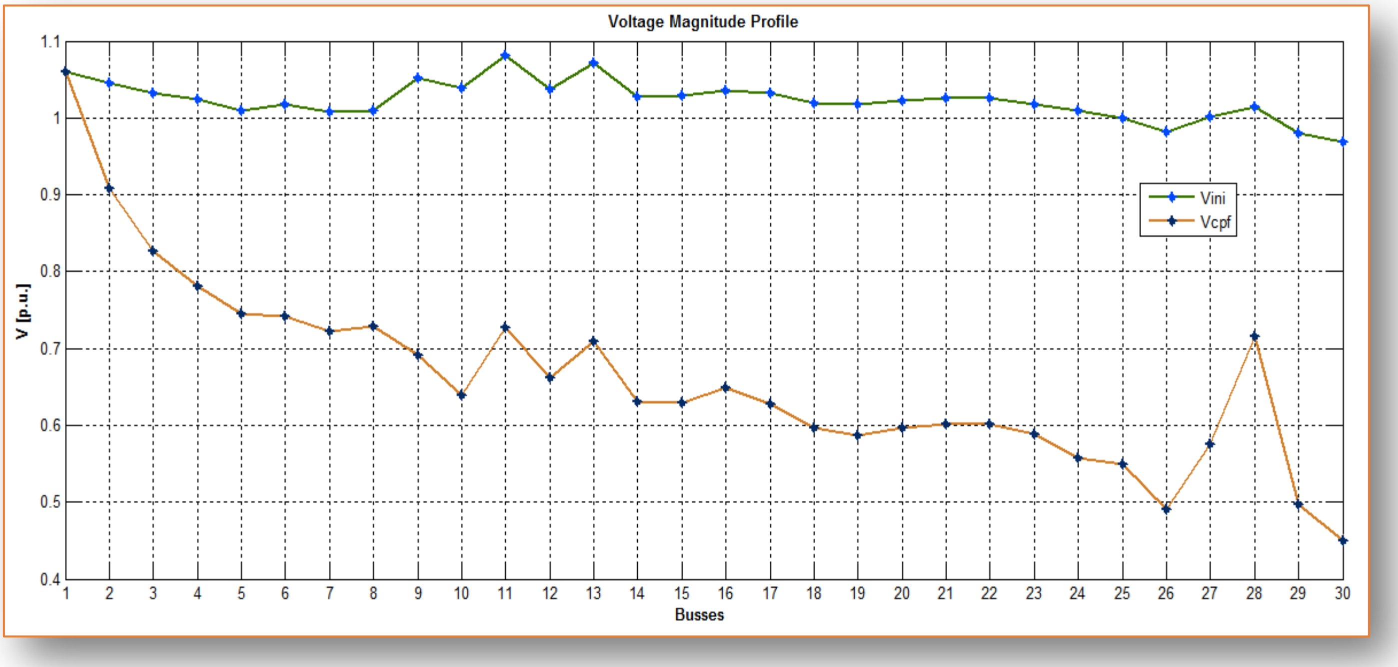


Figure 3. 5 Variation profile of the voltage modules between Vint and VCPF of each bus

❖ Comparison and interpretation :

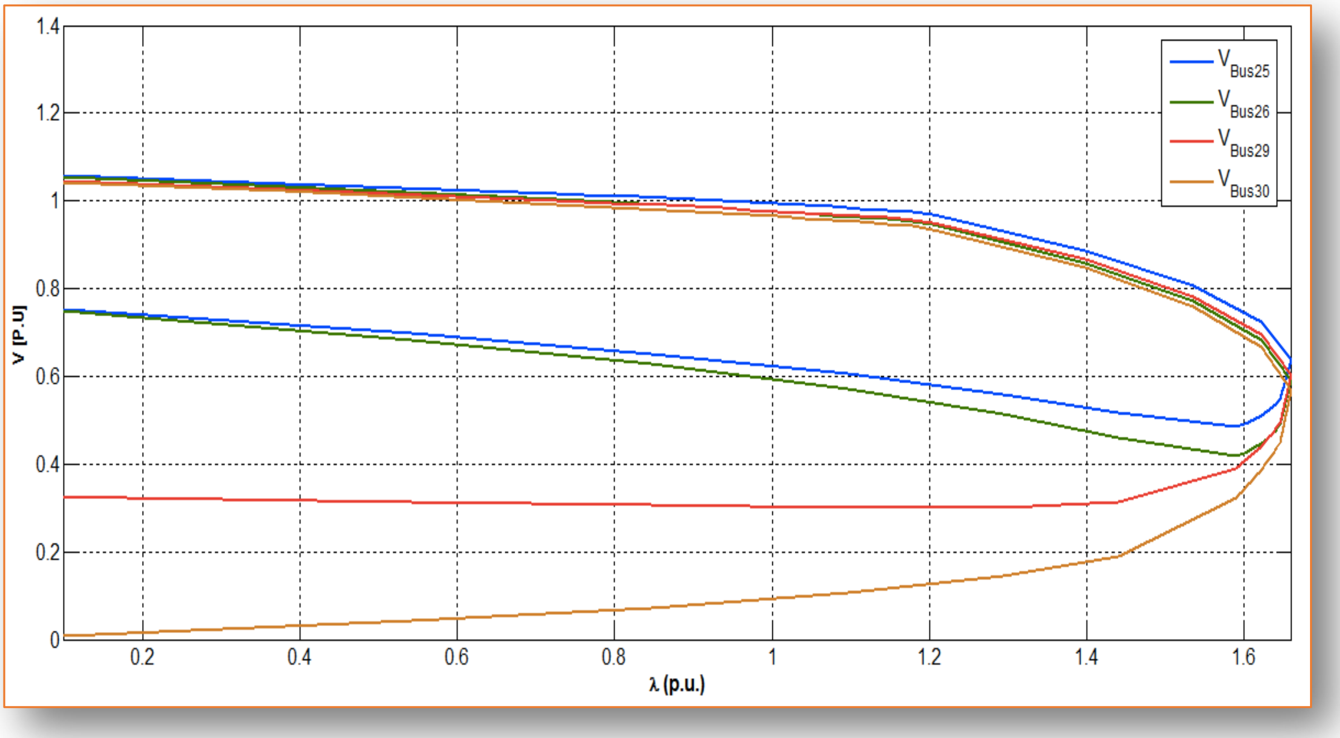


Figure 3. 6 Maximum overload coefficient

- According to the results of "Run CPF" we can see that lambda max = 1.6517
- **λ max :** The maximum load factor that the network can support without losing its stability, i. e. our network can support 65.17% of the load without losing its stability, after this value the network will be unstable **.**

- From the two voltage module profiles we can extract the most obvious load variations:

Table 3. 4 The variation of voltage modulus between the initial state and CPF analysis

Number of buses	**21**	**23**	**24**	**25**	**26**	**27**	**29**	**30**
$\frac{\Delta V}{V}$ (%)	54.09	49.40	42.5	50.03	44.94	44.84	42.09	41.39

$\frac{\Delta V}{V}$: the variation of the voltage modulus between the initial state and the state of the analysis by the method CPF ($\frac{\Delta V}{V} = \frac{V_{ini} - V_{CPF}}{V_{ini}}$).

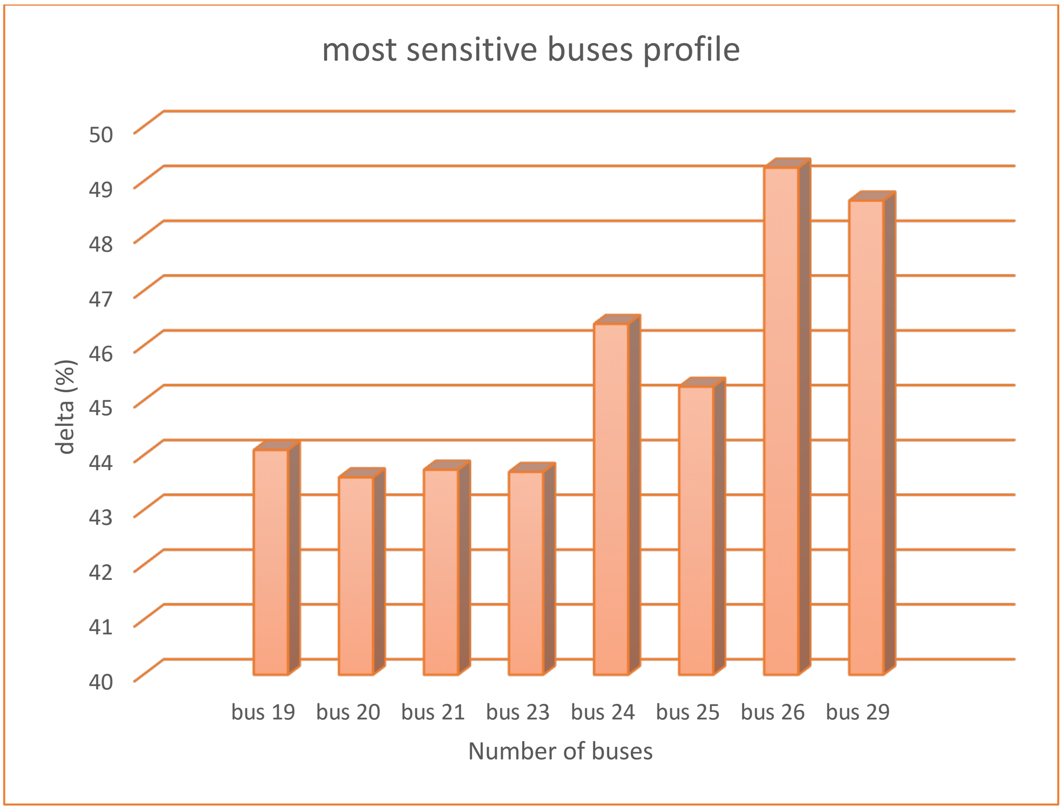


Figure 3. 7 sensitive buses profile by the CPF method

3.4 Optimal choice of SVC location

Voltage reference of the SVC is fixed In this phase the compensator. SVC is installed in the network to solve the problem of voltage variation due to voltage drops and also problems related to over voltage. For this case the control voltage of the SVC is considered fixed. At the beginning we integrated the SVC to the most sensitive buses then the network behavior is evaluated by the integration of the SVC in different points.

Table 3. 5 the maximum load factor for the compensation case with SVC

	Number of buses	**Bus 19**	**Bus 23**	**Bus 24**	**Bus 25**	**Bus 26**	**Bus 29**	**Bus 30**
λma	Le compensateur SVC	1.8778	1.8722	1.8887	1.9002	1.7976	1.8223	1.8102

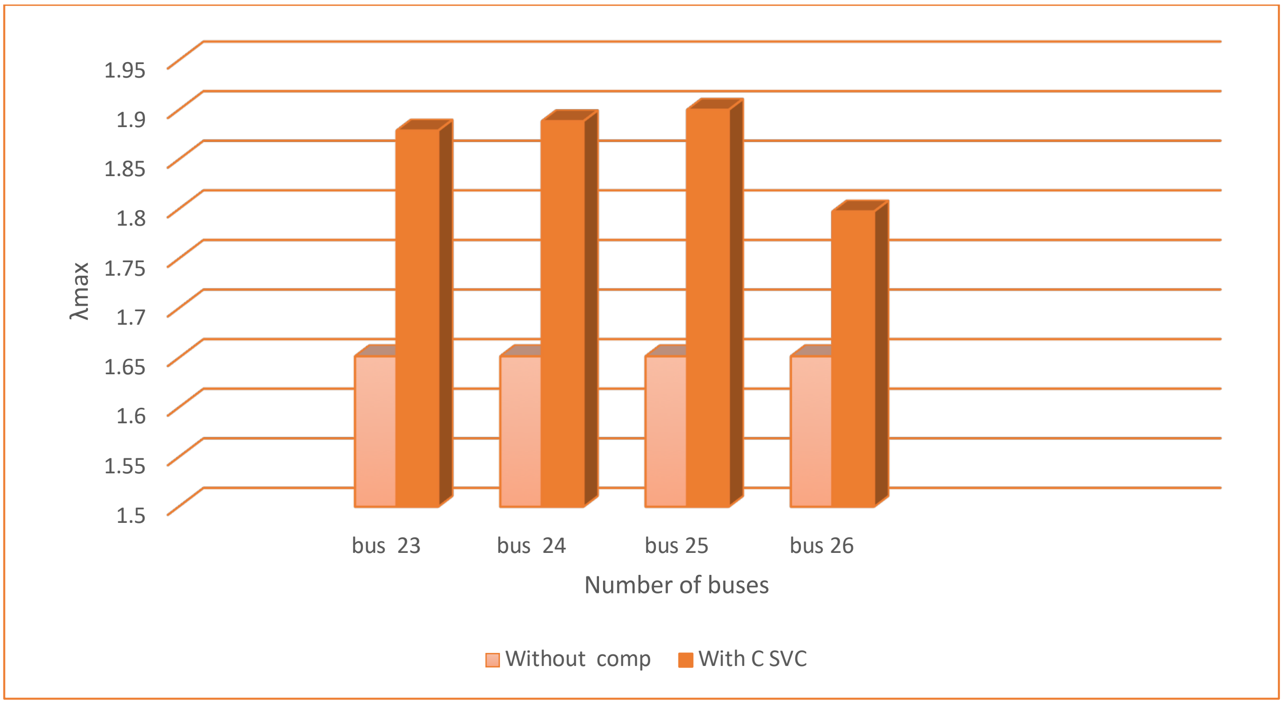


Figure 3. 8 Load factor variation without compensation and with SVC compensation at sensitive buses level

The following figures clearly illustrate the programming results for this step. We presented the variation of the voltage modules initial state, without compensation and with compensation at the various points in the network.

Fig (3.9), Fig (3.10), Fig (3.11), Fig (3.12), show the voltages at the buses levels, for a single SVC installed at the level of the bus .

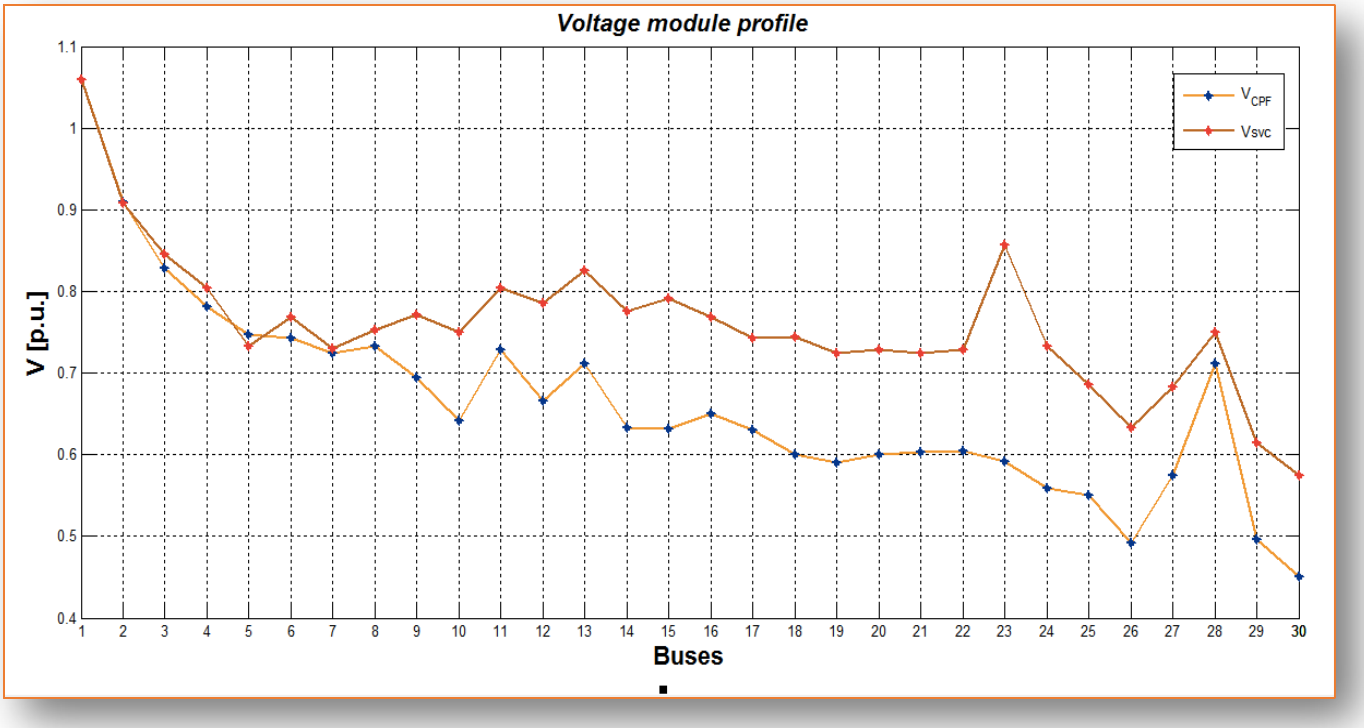


Figure 3. 9 Variation of voltage modules without compensation and with compensation at bus N °23

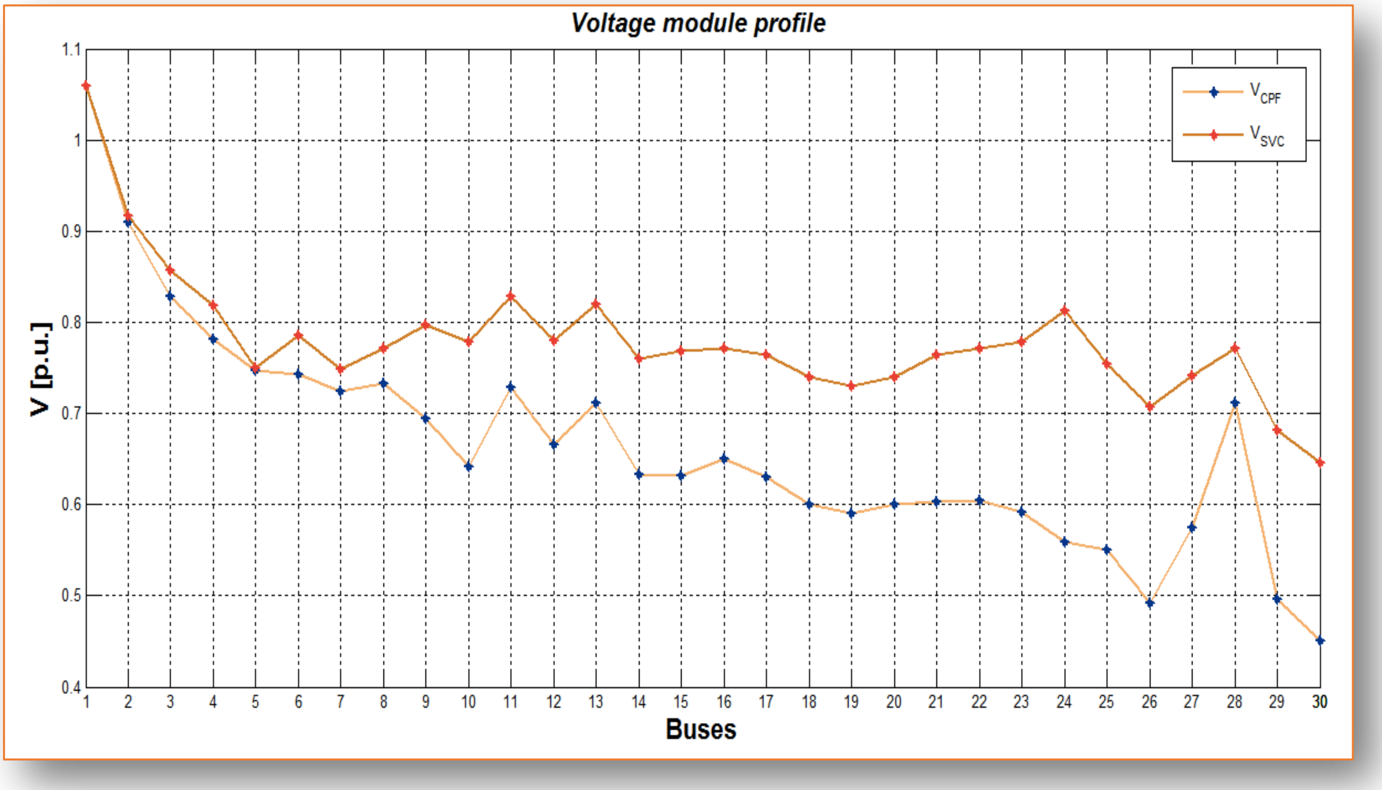


Figure 3. 10 Variation of voltage modules without compensation and with compensation at bus N °24

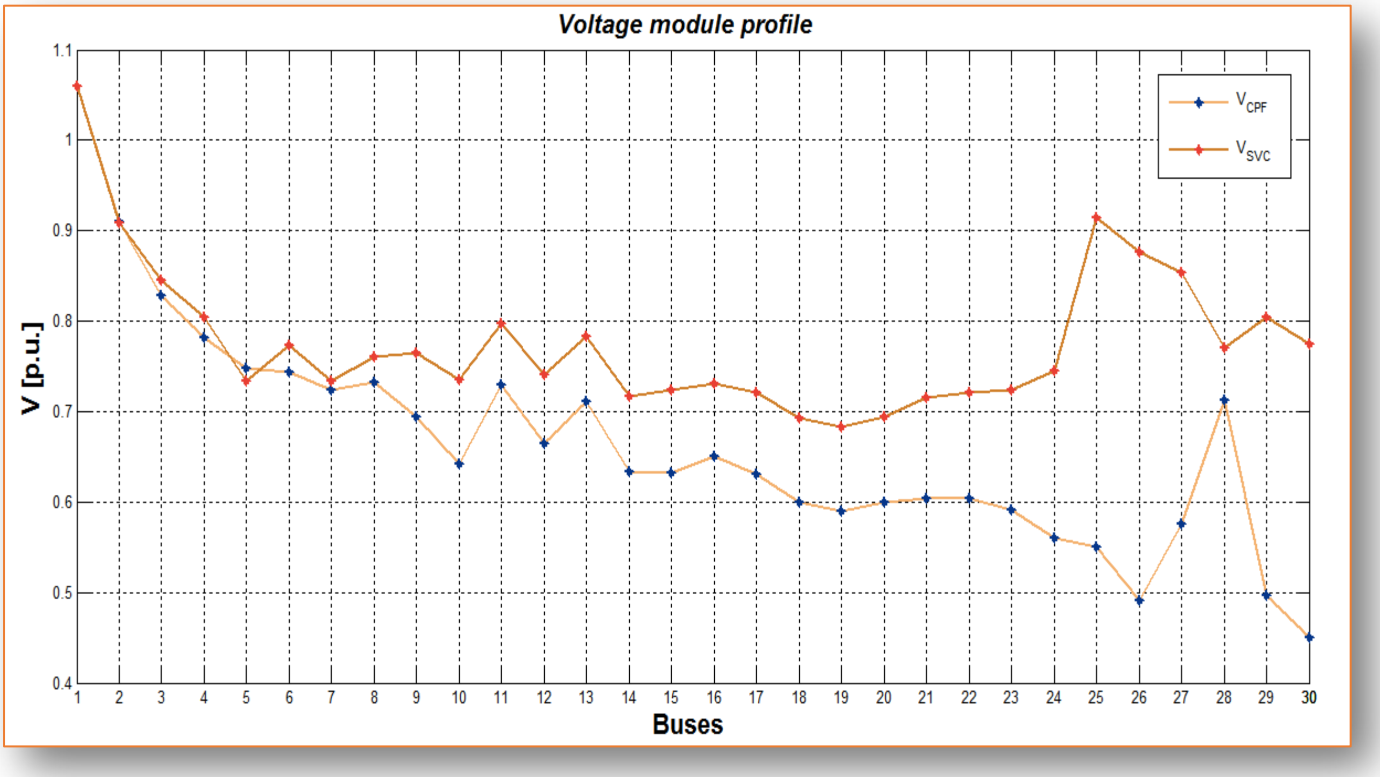


Figure 3. 12 Variation of voltage modules without compensation and with compensation at bus N °25

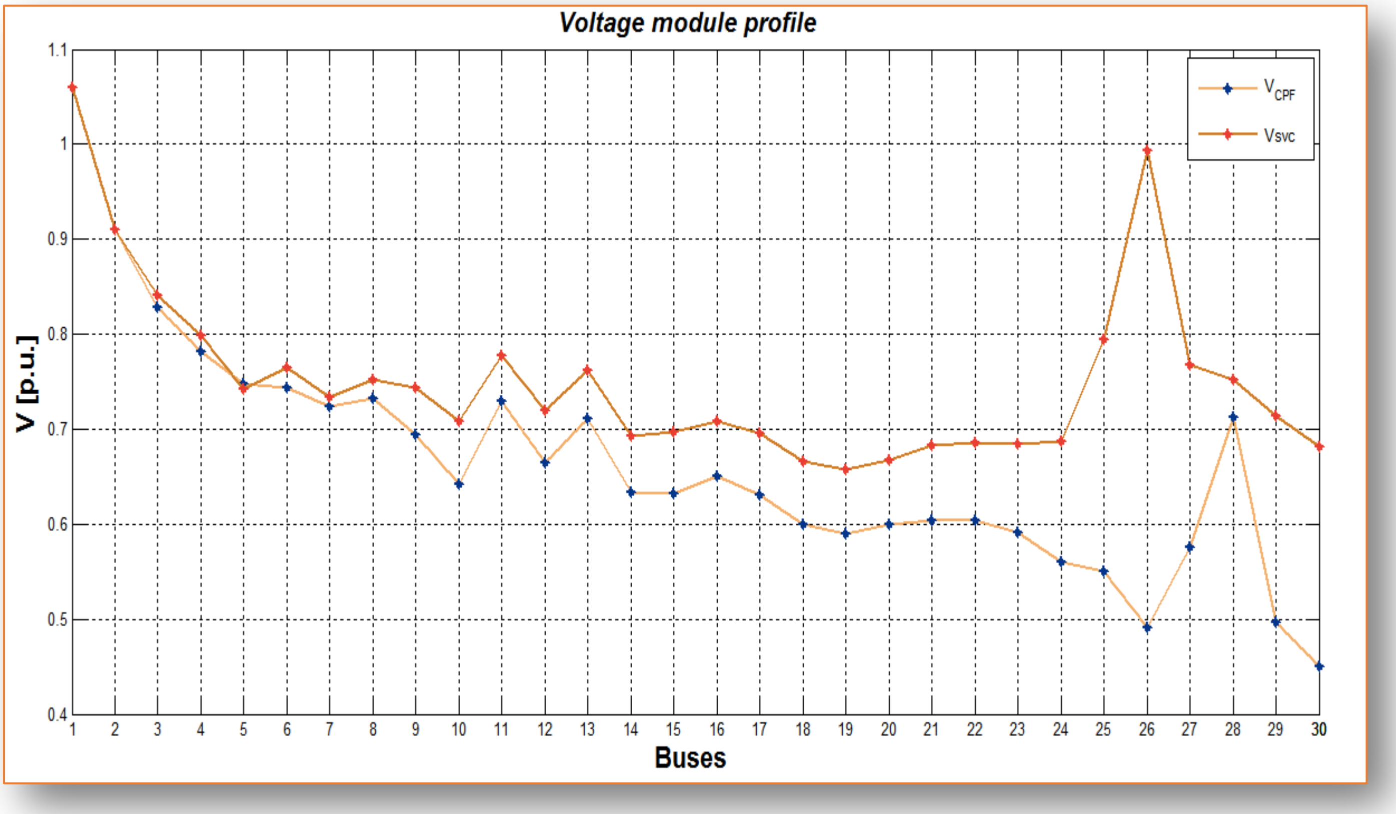


Figure 3. 11 Variation of voltage modules without compensation and with compensation at bus N °26

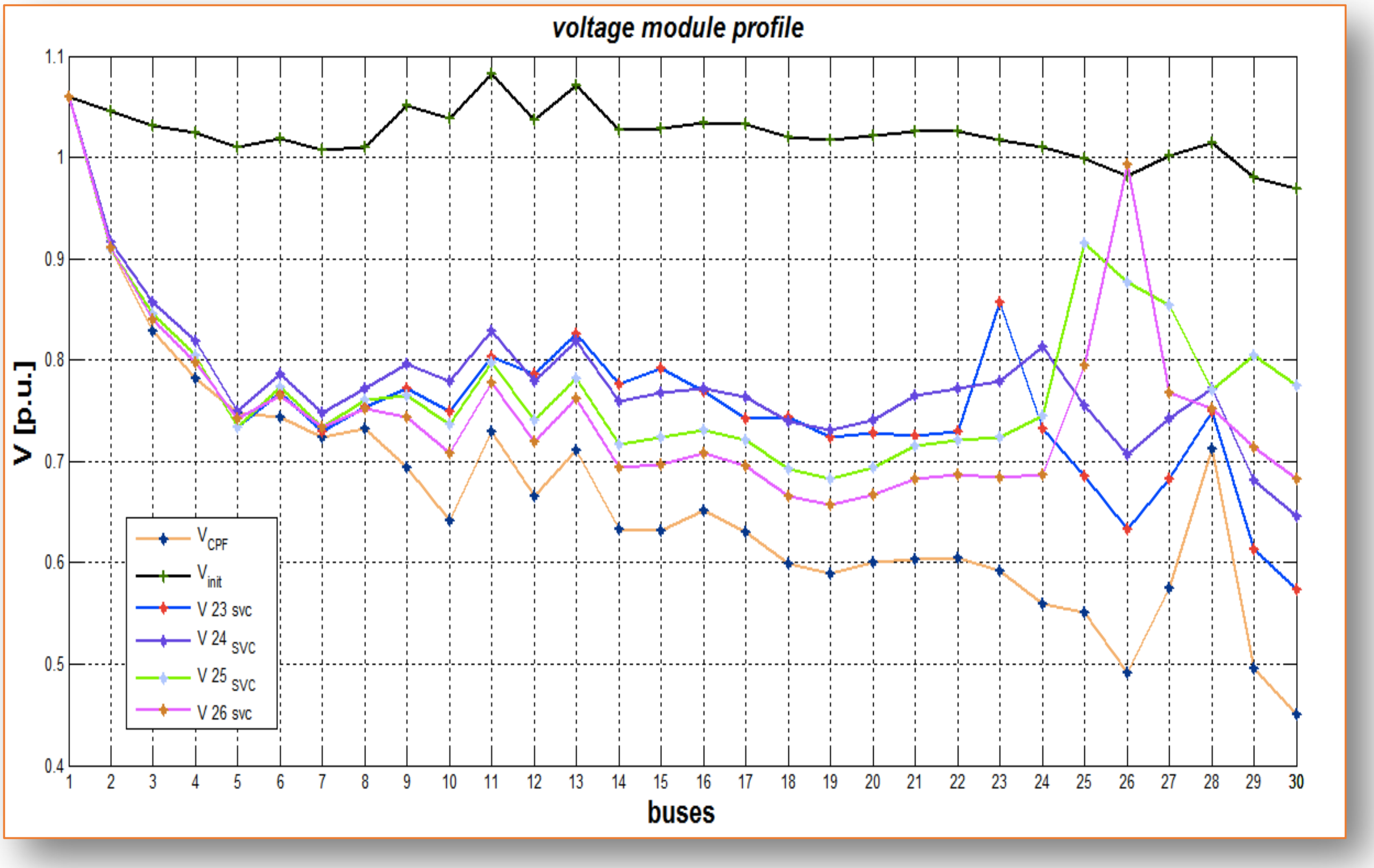


Figure 3. 13 Variation of voltage modules without compensation, initial state & with compensation at buses N° 23,24,25,26

3.5 Results discussions

From the previous curves, it can be noticed that after compensation by SVC, the voltage profile improves with respect to the location of the latter.

After the determination of the fragile JB of the considered network and which needs to be supported, the compensation with the SVC is placed at the level of the busbar 23, 24, 25,26 and the profile of the voltage has improved but a very high way representing voltage drops at the buses which make their voltage profile and the load factor of the system increase

When the SVC is connected to the bus 24 one observes, according to the figure (3.10) That have a voltage profile flatter than the state of without compensation and to introduce the SVC will increase the load factor to the maximum value.

Conclusion

In this chapter we have presented a study on improving the stability of electricity networks by inserting FACTS systems: the SVC (Static Var Compensator).

The network used for the simulations is the IEEE_30 buses network. The analysis of the network performance focuses on the support of the voltage profile, the increase of voltage stability and the decrease of active and reactive losses for voltage collapse.

The program used is a power flow calculation (PF) software and the continuous power flow calculation (CPF) the PSAT.

General conclusion

As part of the preparation of the Master's degree in Electrical Engineering, this work aims to present a theoretical study, and practical realization of the analyze the voltage stability , that took place at the laboratory of the Department of Electrical engineering at the university of Mohammed Khider Biskra.

This work is organized in three chapters, starting with an introduction. In the first chapter, after the presentation we presented general notions about voltage stability and its different categories and some of obvious problems with some other tips to solve them. .

The second chapter was devoted to explain the application of FACTS devices and how they connect together; we gave the diagram of the internal structure of the SVC.

The third chapter we talked about the realization of the project, we gave an overview diagram, then went through each part of the project, from MATLAB interface, to PSAT, passing by calculating the power flow of the grid , and finally to the CPF. We presented the results of experimental in three different control technique.

1. Objectives achieved

- ✓ Mastering PSAT software.
- ✓ Understand the notion of power system stability and especially voltage stability.
- ✓ The principle operation of the FACTS system, in special way the SVC.
- ✓ Know how to use the continuous power flow "CPF" by PSAT

2. Further developments

- ❖ To extend the study of this problem by applying other FACTS devices such as the SVC .
- ❖ Develop a program based on heuristic methods that simulates the optimal location of FACTS in an electrical grid.
- ❖ Integration of other types of renewable energy as wind energy fuel .

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Chapter 02

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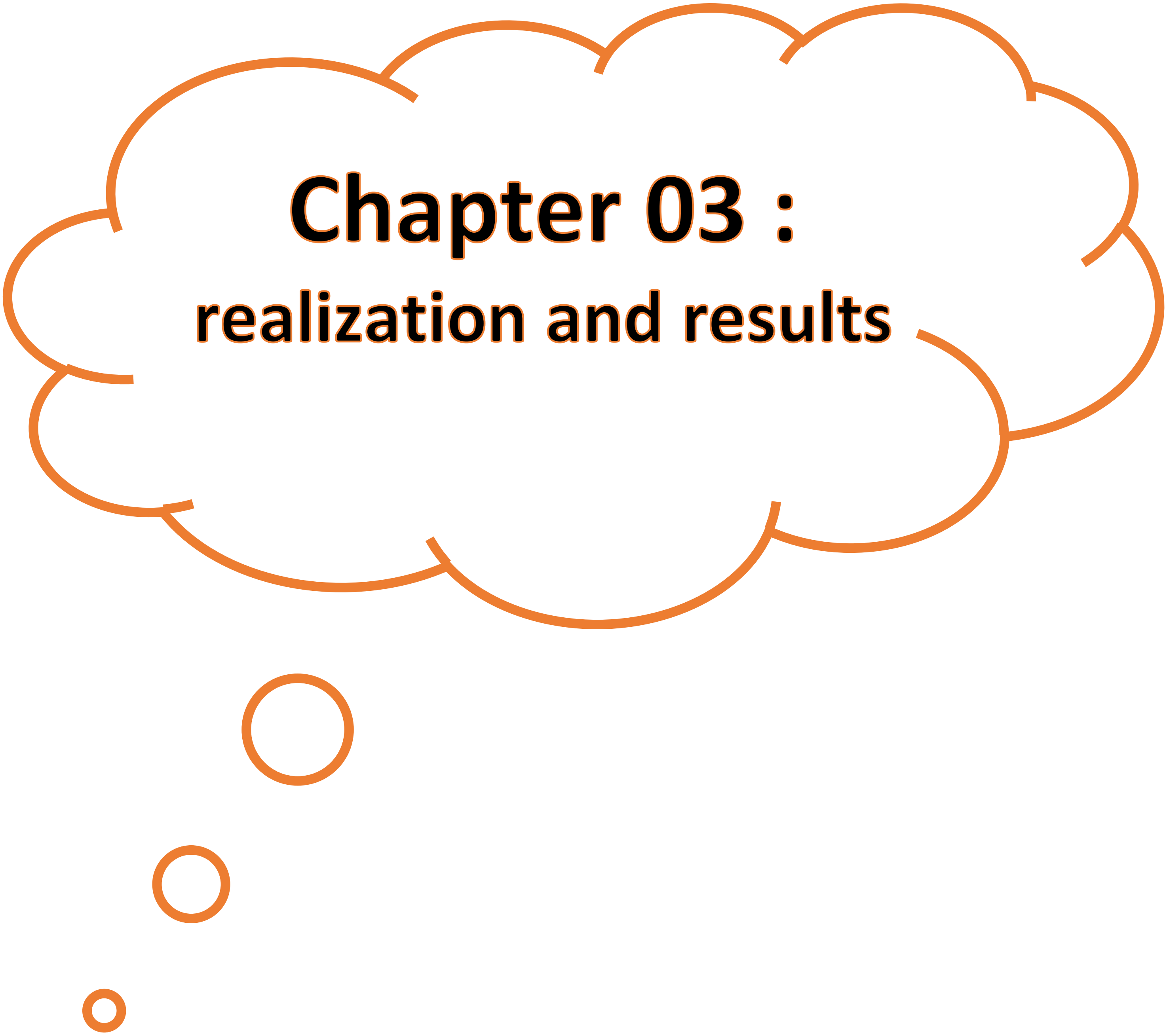
Chapter 01 :

The voltage stability

Chapter 02 :

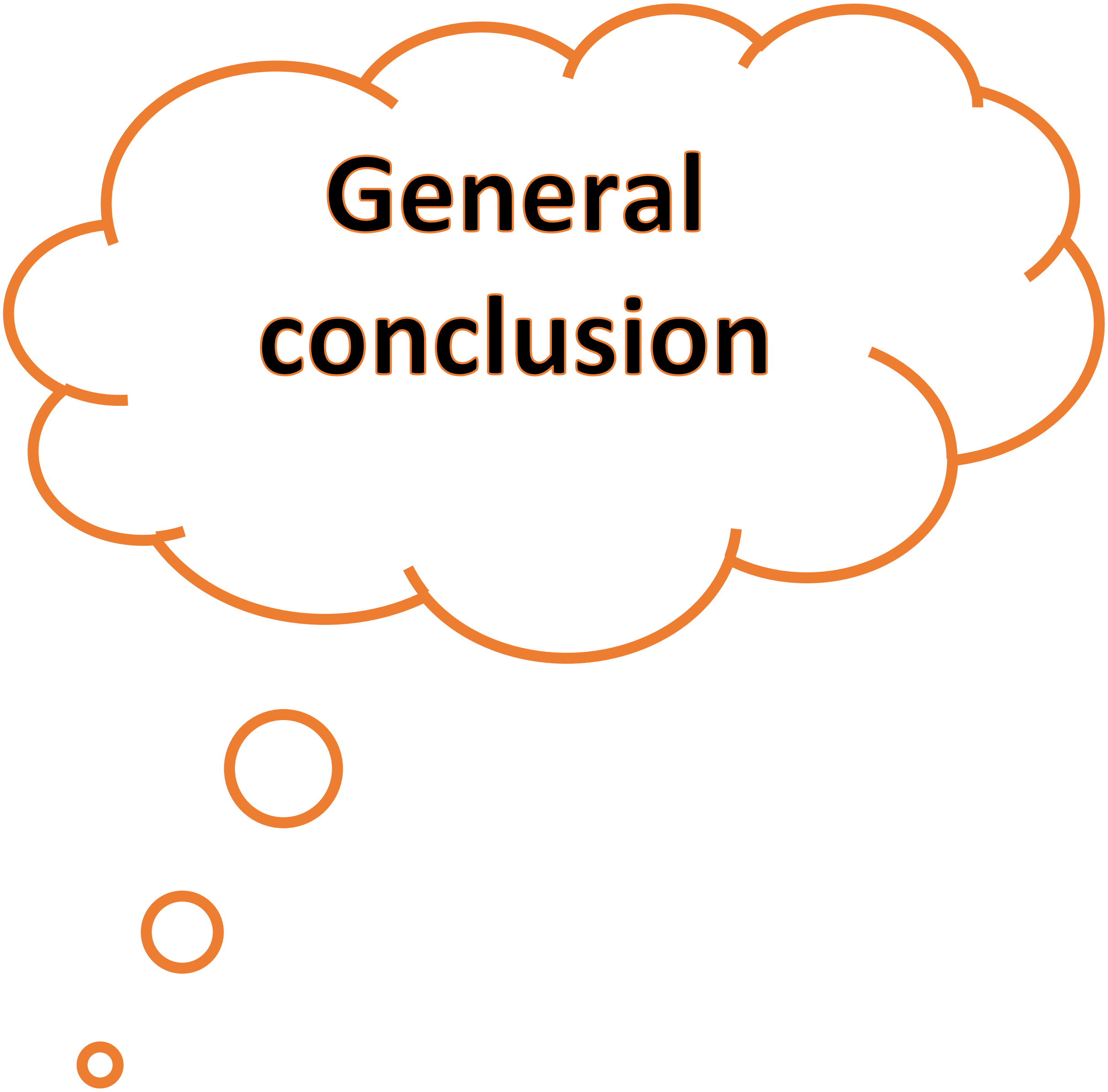
FACTS devices



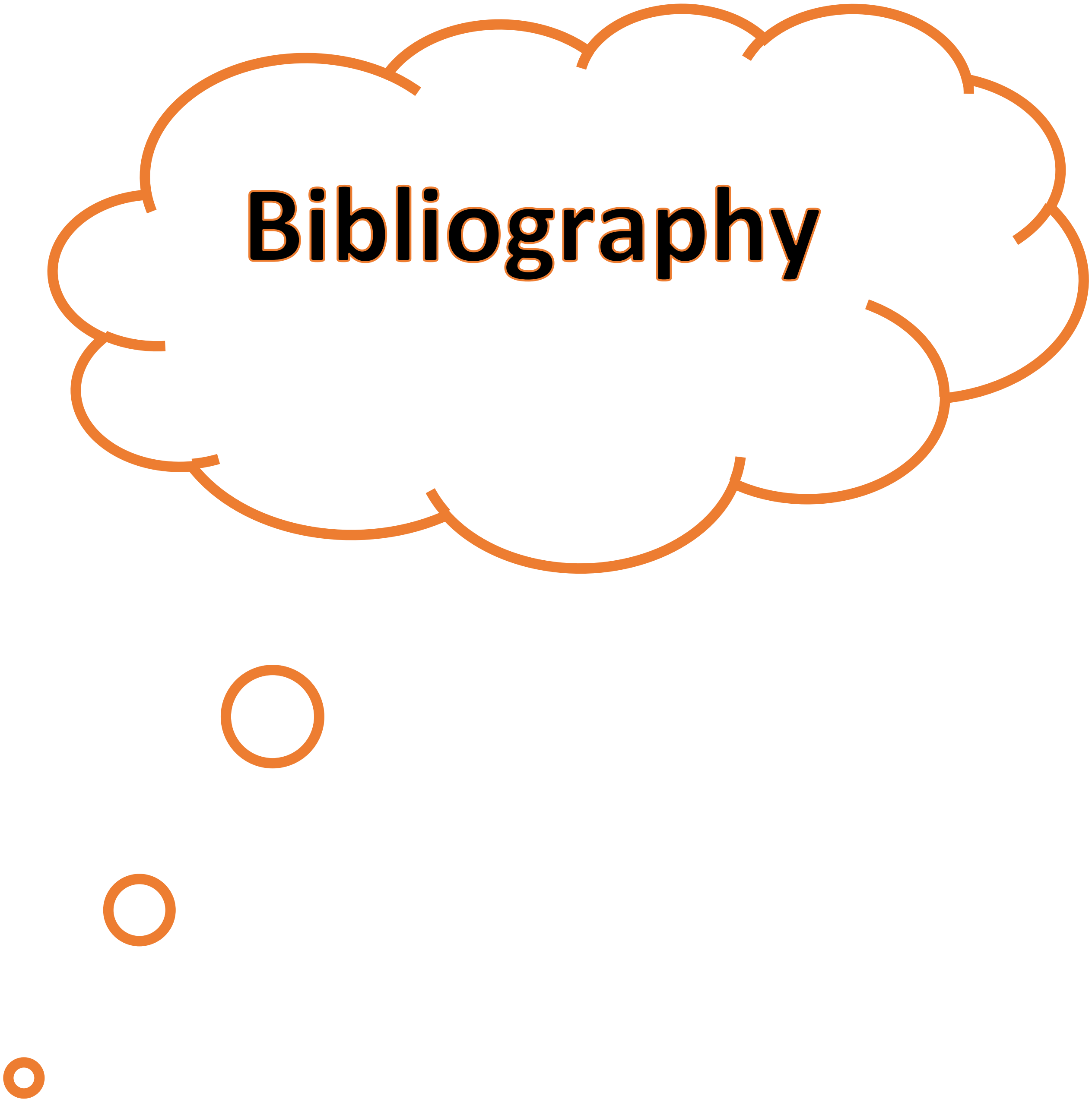
Chapter 03 :

realization and results

General introduction



General conclusion



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