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LITERATURE REVIEW ON VOLTAGE STABILITY PHENOMENON AND IMPORTANCE OF FACTS CONTROLLERS IN POWER SYSTEM ENVIRONMENT

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Literature Review on Voltage stability phenomenon and Importance of FACTS Controllers In power system Environment

R.Siva Subramanyam Reddy [α] & Dr.T.Gowri Manohar [σ]

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I. Introduction

In recent years greater demands have placed on the transmission network, with this increased demands on transmission lines, hence it is the responsibility of the power suppliers to supply safe and economical electric power to customers with the existing transmission line efficiently.

"*Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance*"[1].

In power system environment voltage stability plays major role, it is integral part of the power system stability. In general Voltage stability problems occur more frequently in a heavily loaded system. The change in voltage is directly proportional to change in load and hence voltage stability is sometimes termed as load stability.

Voltage stability is a part of power system stability and hence is a subset of overall power system stability and is a dynamic problem. Thus voltage instability and collapse cannot be separated from the general problem of system stability. The reactive power compensation close to the load centres as well as at critical buses in the network is essential for overcoming voltage instability. The location, size and speed of control have to be selected properly to have maximum benefits. The SVC and STATCOM provide fast control and help improve system stability [2].

The suitable location of FACTS devices, under contingencies is more important than consideration of normal state of system. Now a day's many literatures are proposed various intelligent techniques to control FACTS devices in optimal manor for enhancing voltage stability which intern enhanced the power system stability.

II. Voltage Stability Phenomenon in Power System

In recent years, voltage instability has been responsible for several major network collapses in New York, Florida, French, Northern Belgium, Swedish, Japanese, Mississippi, Srilanka, North America, Pakistan and Tokyo etc.[1][3].

a) Major reasons for voltage stability problems in power system

There are some reasons for voltage stability problems in power system as follows

- Large load or large disturbance in a heavily stressed power system.
- Large disturbance between generation and load
- Unfavourable load characteristics
- More distance between Voltage sources and load centres.
- The source voltage is too low.
- In sufficient load reactive compensation.
- Action of ULTC during low voltage conditions and.
- Poor coordination between various control and protective systems.
- High reactive power consumption at heavy loads
- Unsuitable locations of FACTS controllers [3][4].

b) Classifications of voltage stability

The voltage stability may be broadly classified in to two categories:

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i. *Large-disturbance voltage stability*

It is define as the ability of the power system to maintain stable voltages for large disturbances such as such as system faults, loss of load, or loss of generation.

Large disturbance voltage stability may be further subdivided into two types

a) Transient stability

b) Long term stability

ii. *Small- disturbance (Small signal) voltage stability*

Small disturbance voltage stability is concerned with a system's ability to control voltages following small perturbations, such as gradual change in load, this types of stability can be studied with steady-state approaches that use linearization of the system dynamic equations at a given operating point.

c) Factors Affecting voltage instability and collapse

The main factor causing instability is the inability of the power system to meet the demand for reactive power.

i. *Transient voltage instability*

Under low voltage condition the electrical torque of an induction motor is not adequate to meet the required mechanical torque due to this effect the induction motor may not regain the original speed and continue to decelerate leading to stalling of motors which intern aggravates the low voltage problem. This phenomenon is called transient voltage instability. Transient voltage instability is also associated with HVDC links, particularly inverter terminals connected to AC systems with low short circuit capacity [2] [5] [6].

ii. *Long term voltage instability*

On-load tap-changing transformers and distribution voltage regulations act within a time frame of tens of seconds to tens of minutes to regulate the load a voltage is termed as long term voltage instability. An important factor in long term voltage stability is the current limiting generator [2] [7].

d) Typical scenario of voltage collapse

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 reserves carried by the generators and compensators.

Voltage instability may occur in several different ways. In its simple form it can be illustrated by considering the two terminal network of fig.1 it consists of a constant voltage source (Es) supplying a load (ZLD) through a series impedance (ZLN). This is representative of a simple radial feed to load or a load area served by a large system through a transmission line.

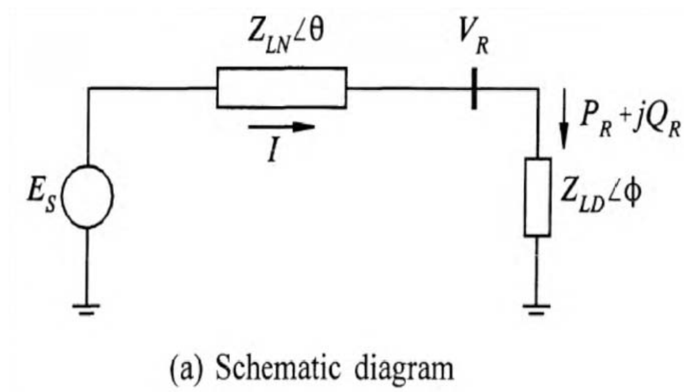

Fig.1 : A simple radial system for illustration of voltage stability phenomenon.

Voltage stability, in facts, depends on the relationships between P, Q and V. The traditional forms displaying these relationships are shown in fig.2.The V_R-P_R relationship for different values of load power factor. The locus of critical operating points is shown by the dotted line in the fig.Normally; only the operating points above the critical points represent satisfactory operating conditions. sudden reduction in the power factor(increase in QR) can thus cause the system to change from a stable operating condition to an unsatisfactory, and possibly unstable, operating condition represented by the lower part of a V-P curve [1][2][8][9].

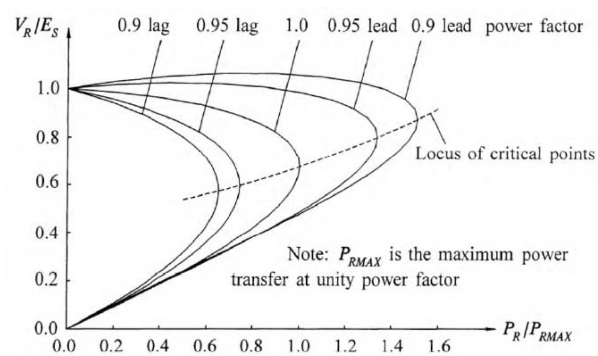

Fig.2 : V_R-P_R characteristics of the system of fig.1 with different load-PF

e) Characteristics of voltage collapse

- The initiating event may be due to a variety of decay of voltage.
- The collapse generally manifests itself as a slow decay of voltage.
- The duration of voltage collapse dynamics in some situations may be much shorter, being on the order of a few seconds.
- The time frame of this class of voltage instability is the same as that of rotor angle instability [1][10].

f) Prevention of voltage collapse in power system

i. *System design measures*

- Application of reactive power-compensating devices.
- Control of network voltage and generator reactive output.
- Coordination of protections/controls
- Control of transformer tap changers
- Under voltage load shedding

ii. *System operating measures*

- Stability margin
- Spinning reserve
- Operators' action

g) Voltage control methods in power system

The control of voltage levels is accomplished by controlling the production, absorption, and flow of reactive power at all levels in the system. The devices used for this purpose may be classified as follows

- Sources or sinks of reactive power, such as shunt capacitors, shunt reactors, synchronous condensers, and static var compensators (SVCs)
- Line reactance compensators, such as series capacitors.
- Regulating transformers, such as tap-changing transformers and boosters [1].

h) Characteristics of compensating devices

i. *Shunt capacitors*

- They can be effectively used up to a certain point to extend the voltage stability limits by correcting the receiving end PF.
- Shunt capacitors, however, have a number of inherent limitations from the viewpoint of voltage stability and control.
- In heavily shunt capacitor compensated system, the voltage regulation tends to be poor.
- Beyond a certain level of compensation, stable operation is unattainable with shunt capacitor.
- The reactive power generated by a shunt capacitor is proportional to the square of the voltage; during system conditions of low voltage the var support drops, thus compounding the problem.

ii. *Series capacitors*

- Series capacitors are self-regulating.
- The reactive power supplied by series capacitors is proportional to square of the line current and is independent of the bus voltages.
- This has favourable effect on voltage stability.

The present trend is to operate the existing transmission system more close to their stability and thermal limits with reliable and optimal. Power electronics based Flexible AC transmission system (FACTS) gives efficient solution for optimal utilization of transmission systems with minimal installation and operational cost [1][4].

III. Overview of Major FACTS Controllers

The development of FACTS-devices has started with the growing capability of power electronics components. Devices for high power levels have been made available in converters for higher and even highest voltage levels. Several FACTS have been introduced for various applications worldwide.

a) Basic Types of FACTS controllers

- Shunt controllers
- Series controllers
- Combined shunt-series controllers
- Combined series-series controllers

The shunt controllers are applied to control voltage at and around the operating point by injecting reactive current.

Series controllers are applied to improving voltage profile in a cost effective way ware voltage fluctuations are large. However the series controllers are several times more powerful than the shunt controllers.

The combined controllers provide the best of both i.e. an effective power/current flow and line voltage control.

FACTS-devices provide a better adaption to varying operational conditions and improve the usage of existing installations

b) Applications of FACTS controllers

- Control of power flow in a transmission line
- Increase the loading capability of line to their thermal limit.
- Control of voltage in a line
- Control of reactive power in a power line
- Improvement of system stability, security & reliability
- power quality improvement in a line
- Provide greater flexibility insisting new generation
- Upgrade of lines
- Reduce reactive power flows
- Increase utilization of lowest cost generation
- Rapid dynamic response
- Ability for frequent variation in output
- Smooth adjustable output
- Minimized transmission losses.

The voltage and stability limits shall be shifted with the means of the several different FACTS-devices shown in below fig.[11][13]-[16].

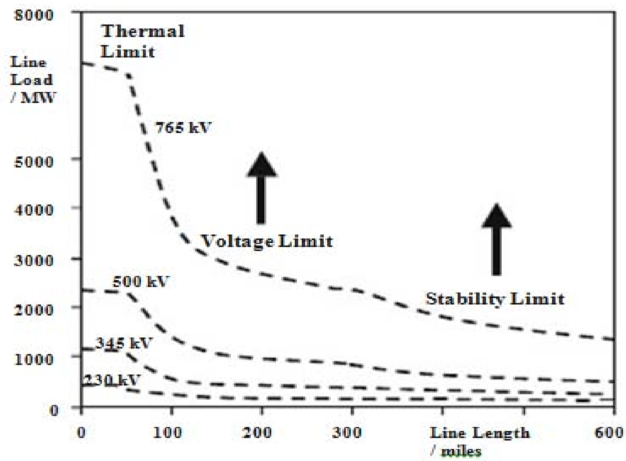

Fig. 3 : Operational limits of transmission lines for different voltage levels

The ability of FACTS controllers to control the interrelated parameters that govern the operation of transmission systems including series impedance, shunt impedance, current, voltage, phase angle and the damping of oscillations at various frequencies below the rated frequency. These constraints cannot be overcome, while maintaining the required system reliability, by mechanical means without lowering the useable transmission capacity.

There are a number of stability issues that limit the transmission capacity these include transient, dynamic, steady state stabilities, frequency collapse , sub synchronous resonance and voltage collapse. The FACTS technology can certainly be used to overcome any of the stability limits. An over-view of problems occurring in the grid and which FACTS to be used to solve these problems are given in the table blow. The application of these devices depends on the problem which has to be solved, below table shows various problems in the grid and which FACTS device to be used to solve these problems [12][16].

Subject	Problem	Corrective action	FACTS
Voltage limits	Low voltage at heavy load	Supply reactive power	SVC, STAT-COM
		Reduce line reactance	TCSC
	High voltage at low load	Absorb reactive power	SVC, STAT-COM
	High voltage following an outage	Absorb reactive power, prevent overload	SVC, STAT-COM
	Low voltage following an outage	Supply reactive power, prevent overload	SVC, STAT-COM
Thermal limits	Transmission circuit overload	Increase transmission capacity	TCSC,SSSC, UPFC
Load flow	Power distribution on parallel lines	Adjust line reactance	TCSC,SSSC, UPFC
		Adjust phase angle	TCSC,SSSC, PAR
	Load flow reversal	Adjust phase angle	TCSC,SSSC, PAR
Short circuit power	High short circuit current	Limitation of short circuit current	TCSC, UPFC
Stability	Limited transmission power	Decrease line reactance	TCSC,SSSC

Table 1 : Examples of use of FACTS

IV. Conclusion

This paper gives a summary of voltage stability analysis, importance of voltage stability & voltage instability in power system, and various reasons for voltage instability, methods of preventing voltage instability, characteristics of reactive power compensating devices (shunt & Series) and also explains the importance of FACTS controllers in power system environment enhancing voltage stability which intern enhance the power system stability.

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