Review paper on voltage stability and second generation FACTS devices for power flow improvement

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Abstract
As the load demand is increasing day by day, we need to meet the surplus demand by boost in generation capacity. The reason for voltage instability is due to external and internal unbalance due to which bus voltage change and fluctuates. FACTS device are used to achieve the stable and constant voltage along with increase power flow in transmission line. This paper presents the review and analysis of Voltage stability and its methods along with second generation FACTS devices.

Keywords:-*UPFC,STATCOM,Voltage collapse,voltage instability,UPFC,STATCOM,.*

I. INTRODUCTION

In recent years, the demand for electricity is tremendously increasing day by day. As the demand increases, there is need to increase power generation along with new infrastructure for transmission of power. But due to certain economic and environmental restrictions it is not possible always to build new power system structure (transmission lines).Therefore, there is need to transfer the incremented power demand by means of existing infrastructural unit of power system. This can be achieved by utilizing FACTS system in transmission line and improve the voltage stability of the system.

Now a day's Power system faces different types of stressed condition which can leads power system instability. Instable operation of power system may leads to whole blackout. Power system stability can be divided as rotor angle stability, frequency stability, voltage stability. Major Black outs which are happed they are mainly due to the voltage collapse in power system [1].In modern power system voltage stability is most significant component in planning and actual operational conditions. As the inability to expand transmission network may result in overloading the system due to increasing demand may lead to voltage collapse. As non-recoverable voltage drop occurs at the bus voltage and if it is ignored this can cause complete system shut-down.

This paper consists of review on voltage stability of the power system with different causes of the voltage instability. Various types of tools which are used to calculate voltage stability limits along with second generation FACTS devices for power flow improvement.

II. LITERATURE REVIEW

In early 80s, the concept of FACTS was introduced by Hingorani &Gyugi[3]. They had demonstrated the improvement of power system performance by using power electronic devices i.e.FACTS devices. TCPS, SVC and TCSC were first generation FACTS devices while STATCOM, SSSC and UPFC etc. are second generation FACTS devices. Improvement in load ability of power system using FACTS devices was shown by Singh and Srivastava[4]. They had demonstrated the proposal of IEEE-14 and IEEE-30 bus system. had estimation of voltage stability and line load ability of FACTS devices were carried out by Kessel and Glavitsch[5]. They showed that FACTS devices could improve line load ability as well as stability of the system.

III. THEORY

A. Definitions

As per IEEE:

Voltage stability: it is the system ability by which both voltage and power are controllable by maintaining the voltage level, because of which when load admittance is increased, load power will increase.

Voltage Collapse: during voltage collapse voltage loss occurs because of instability in significant part of the system.

Voltage security: it is the ability of system to operate stable even in the unfavorable system change.

Power system stability:- Power system stability is defined as the feature of electrical power system, to come back to stable operating conditions after facing the physical disturbance with given initial operating condition along with most of system variables lies in limit so that practically system remains undamaged[2].

B. Classification of power system stability

Study of power system stability, finding key factors responsible for system instability and also finding new method to improve stability of system are become very easy by classification of stability into different categories.

1. Rotor angle stability: In interconnected power system ability of synchronous machines to continue in synchronism after the occurrence of disturbance is known as rotor angle stability. Rotor angle stability mainly depends on the capacity of each synchronous machine in power system to maintain electromagnetic torque and mechanical torque equilibrium. Instability in rotor angle may occur due to increasing angular swings in some generator which causes loss of synchronism with other generators. As changing electromagnetic torque can be resolved in two components

• Synchronizing torque component, this is in phase with rotor angle deviation.

• Damping torque component, this is in phase with the speed deviation.

Both the components are required for maintaining the system rotor angle stability.

2 Voltage Stability: It is ability of power system to maintain stable voltage at all buses after faced by disturbance with given initial conditions. Voltage stability mainly depends upon capacity of maintaining or retuning equilibrium in between the load demand and load supply of the system.

3. Frequency Stability: it is ability of system to maintain steady frequency after serious system upset causing a notable imbalance between load and generation. Frequency instability may leads to tripping of generators and loads due to continued frequency swings.

C. Causes of voltage instability:

Mainly three causes for voltage instability.

1. Load dynamics: changing load condition is mainly cause’s voltage instability in power system. Load dynamics can occur due to devices such as tap changing transformers, thermostats, induction motors, etc. Tap changing transformer mainly used to maintain the load side voltage at rated value. Because of disturbance load voltage drops at load. To maintain load voltage tap are changed in tap changing transformer step by step with time. As the voltage increases power demand also goes on increasing which leads to weakening of power system. Thermostats are the devices which turn on and off to control electrical heating. Which causes sudden change in power demand so the voltage rise or drop occurs, also in induction motors having short time constant as motor must supply continue mechanical power output at changing torque condition causing fluctuation in voltage.

2. Transmission system: Elements used in transmission system such as transformer, conductors have definite capacity. This capacity depends upon different factors:

- Impedance of elements
- Load power factor
- Different type of voltage control sources used in system at one or both ends such as generators, static Var compensators.
- Different reactive compensation devises used

3. Generation system: As the power flow in system increases, reactive power consumption by transmission system also increases. To feed increased reactive power demand generator must increase reactive power generation to operate stably. From capability curve generator can operate at operational point but due to over excitation and stator current limiter voltage control can’t be done.

D. Methods to analyse voltage stability

Different methods are proposed to analyse steady state voltage stability. Some of them mentioned below

1. PV curve method: In this method calculations are made to find the amount of active power that can be feed by the system up to the point of voltage instability. in which voltage at critical bus and the power consumption are monitored for radial system, whereas in meshed network total active load and voltage of the bus are monitored.

2. VQ curve method: In this method curve is drawn depending upon the voltage and the reactive power at the bus. In this method imaginary generator is connected at the bus which having no limits for active and reactive power. Tests are taken at different rated voltages. From the test reactive power is noted at different voltages and graph is plotted. Voltage security at the bus depends upon the reserve reactive power at the bus which can be easily calculated from Q-V curve.

3. Modal analysis: in this technique Jacobean matrix is calculated by using power flow equation given below:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{p\delta} & J_{pV} \\ J_{q\delta} & J_{qV} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta V \end{bmatrix}$$

In which change in real and reactive powers are shown by ΔP and ΔQ respectively; whereas $\Delta\delta$ and ΔV represents change in bus voltage angle and change in voltage respectively. For calculating reactive power and voltage relation assume $\Delta P=0$. If the Eigen values of system are positive then the system is stable, if one of the Eigen values comes out negative system becomes unstable.

4. Continuation power-flow method:

It is become difficult to find out power flow solution using modal analysis method as the Jacobean matrix become singular at point of voltage collapse. To overcome this continuation power flow method is used to find out solution at the point of collapse. By using continuation power flow method complete PV curve can be drawn easily with nose point and curve lower part.

E. Classification of FACTS controllers

In 1980, EPRI (Electric Power Resear.ch Institute) launched a new program called as Flexible AC

Transmission System (FACTS).The main motto behind the program is to increase the controllability and optimize the utilization of the existing power system capabilities and optimum utilization of existing power system. capacities through replacement of mechanical controller by reliable and high-speed electronic device. The FACTS controller controls mainly four parameters, phase angle, series impedance, damping oscillation and voltage of transmission line. The FACTS controllers are categorized as: -

1.Series controllers -Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Angle Regulator(TCPR), and Static Synchronous Series Compensator (SSSC).

2.Shunt controllers -Static Var Compensator (SVC), and Static Synchronous Compensator (STATCOM).

3.Combined series-series controllers - Interline Power Flow Controller (IPFC)

4.Combined series-shunt controllers - Unified Power Flow Controller (UPFC)

On the basis of generation: -

1. First generation: - Static Var compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Angle Regulators (TCPAR or TCPST).

2. Second generation: - Static Synchronous Compensator (STATCOM), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC).

F. Review of second-generation FACTS devices

- TCSC

The main function of thyristor controlled series capacitor(TCSC)is to increase voltage stability by controlling the impedance. The connection of TCSC is in series with capacitor while thyristor-controlled inductor is connected in parallel to capacitor. There are three modes for adjustment of impedance of TCSC: -

1) Blocking Mode: In this mode, the thyristor valve is in non-conducting stage.

2) Capacitive and Inductive Mode: Here, the thyristor is conducting state, and line current flows through the capacitors which leads to increase in reactance of the circuit.

3) Bypass Mode: In this mode, the line current flows through thyristor. When the resonance condition takes place (X_L= Xc), then the thyristor starts to work.

The main advantages of TCSC is increasing the level of power flow to control the fault current and dynamic stability.

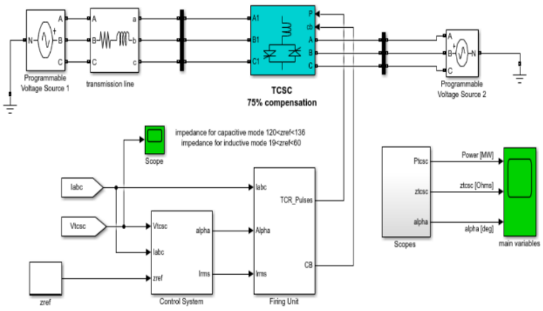

Fig 1:- Simulink Model of TCSC

- SSSC

Static synchronous series compensator (SSSC) comprises of power electronic devices which acts as voltage source(synchronized). By using GTO, the inverter in SSSC coverts DC to AC. Itis capable to generate 3-ph voltage which is inserted in transmission line using insertion transformer. This transformer is connected in series with transmission line. Injection of current leads to indirectly controlling of line voltage by means of SSSC. The main advantage of SSSC is that it remains unaffected by change in impedance in transmission line.

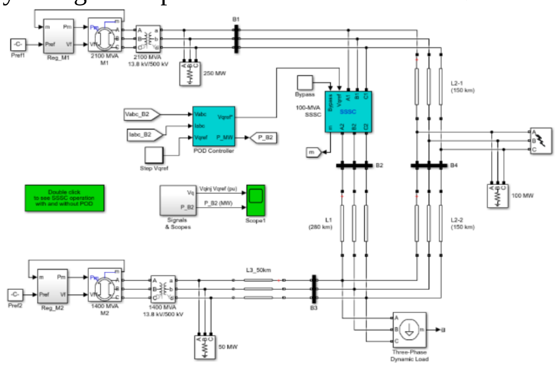

Fig 2: - Simulink model of SSSC

- STATCOM

The function of STATCOM is to convert DC into AC output voltage. It's basic features include to generate a sinusoidal voltage at fundamental frequency along with quick control of amplitude. It compensates both active and reactive power.

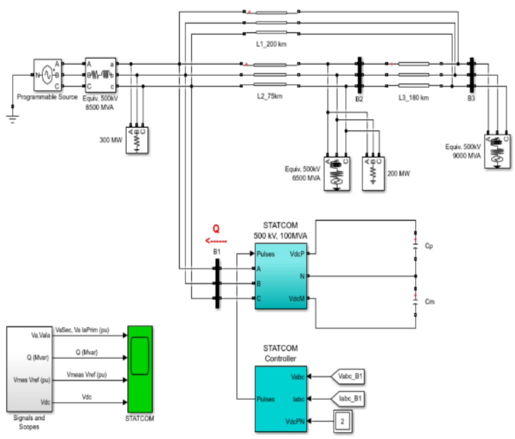

Fig 3: - Simulink model of STATCOM

- UPFC

UPFC is a combination of STATCOM and SSSC.The three parameters can be adjusted in UPFC, i.e. the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently.). UPFC consists of two switching converters i.e. Voltage source converters which are coupled using a common DC link. The main function of dc link is to facilitates the flow of real power in both directions between the terminals. Each converter is capable of generating or absorbing reactive power at its ac terminal. Series connected converter converts demand or excess of real power of transmission line to common dc bus as supply or absorb the real power while shunt converter converts the demand at dc link to ac and feeds to the line with the help of shunt connected transformer. This forms a closed path for real power exchange.

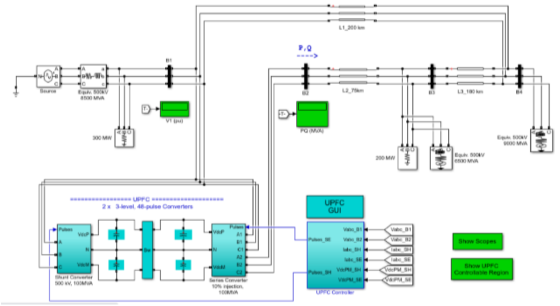

Fig 4: - Simulink model of UPFC

IV. CONCLUSION

This paper presents an overview of voltage stability along with different tools used to compute the voltage stability. description of the UPFC concept to manage the power in electrical transmission line. transmission capacity and system stability.

This paper also discusses classification of FACTS devices along with review about the second-generation FACTS devices used for power flow improvement in transmission systems.

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