Voltage Stability And Its Improvement With Fact Device Compensation Using Matlab Simulation.

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Abstract—the voltage stability plays major role in power system environment to meet the required demand. In this paper presents the phenomena of voltage stability in power system in which it reviews various reasons for voltage instability, types of voltage stability, characteristic of voltage stability, voltage control methods in power system environment, factors affecting voltage instability and collapse, are primarily discussed. STATCOM is one of the key shunt controllers in flexible alternating current transmission system (FACTS) to control the transmission line voltage and can be used to enhance the load ability of transmission line and extend the voltage stability margin. Voltage stability is analyzed with PV curve before and after compensation. It is analyzed with matlab simulation that stability limit is improved with compensation provided at load end.

Keywords: Voltage Stability, Voltage Instability, Voltage, Collapse, FACTS, STATCOM

1.Introduction- Now a days Power demand is increase then the operation and planning of large interconnected power system are becoming more and more complex, the use of stable, reliable, economical, secure and efficient electrical Power drastically increasing in many sectors but the generated power in not being supported as Much as increasing demand. The voltage stability plays major role in power system environment to meet the required demand. Voltage stability is a crucial issue in power systems especially under heavily loaded condition. In the new scheme of restructuring, voltage stability problem becomes even more serious. In order to solve the kind of this problem, Experts employ various methods for relieving congested difficulties. There are many new power-electronics-based devices using to solve the difficult problems recently. FACTS devices can maintain the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. Placing of FACTS devices in a suitable location is important to improves the voltage stability and reduce power system losses. MODERN, power systems are prone to extending over a wide area of failures. Power demand is increase then the operation and planning of large interconnected power system are becoming more and more complex, so the power system will be less secure system. So the problem of instabilities in entire system working environment, regular planning and method of operation. In power industry, voltage instability is one of the most important problems. Voltage collapse is the main reason for network blackouts. Many of the existing transmission lines could not deal with increasing power demand, the problem of voltage stability and voltage collapse has also become a major concern. To overcome this problem, FACTS devices are introduced. Effect of FACTS devices on power system reliability, loadability and security are studied according to control objectives in proper manner.

2. Literature Review- RECENTLY, several network blackouts have been related to voltage collapses. This phenomenon tends to occur from lack of reactive power supports in heavily stressed conditions, which are usually triggered by system faults. Therefore, the voltage collapse problem is closely related to a reactive power planning, where suitable conditions of reactive power reserves are analyzed for secure operations of power systems. In the conventional reactive power planning problem, two kinds of constraints have been used. Traditionally, the objective of the reactive power (VAR) planning problem is to provide a minimum number of new reactive power supplies to satisfy only the voltage feasibility constraints in normal and post-contingency states. Various researches have been carried out for this subject [1] and [4]. Recently, due to a necessity to include the voltage stability constraints, a few researches have been reported concerning new formulations considering the voltage stability problem [3] and [4], which provides more realistic solutions for the VAR planning problem. a new formulation and solution method are presented for the VAR planning problem including FACTS devices, taking into account the issues just mentioned. TCSC and SVC are used to keep bus voltages and to ensure the voltage stability margin. In recent years, voltage instability has been responsible for several major network collapses.

Some of papers have been tried to find suitable location for FACTS devices to improve power system security and loadability. Optimal allocation of these devices in deregulated power systems has been presented in.

Some of papers use heuristic approaches and intelligent algorithms to find suitable location of FACTS devices.

3. Power System Voltage Stability-

“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].

A system enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable decline in voltage. The main factor causing voltage instability is the inability of the power system to meet the demand for reactive power. Voltage stability problems normally occur in heavily stressed systems. While the disturbance leading to voltage collapse may be initiated by a variety of causes, the underlying problem is an inherent weakness in the power system. In addition to the strength of transmission network and power transfer levels, the principal factors contributing to voltage collapse are the generator reactive power/voltage control limits, load characteristics, characteristics of reactive compensation devices, and the action of voltage control devices such as transformer under load-tap changers (ULTCs).

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 centers 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].

3.1. Classification of Voltage Stability

Voltage instability in the power system occurs due to incapability of power system to supply loads under disturbances. Disturbances may be either large or small in nature. Accordingly, voltage stability can be classified in following two subcategories:

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. Determination of large disturbance voltage stability requires the examination of non-linear response of power system. The study period of interest may extend from a few seconds to tens of minutes.

Small- disturbance- *voltage stability* refers to the system ability to maintain steady voltage under small disturbances such as incremental change in system load. With appropriate assumptions, system equations can be linearizing for analysis. The time frame of interest for voltage stability problem may vary from a few seconds to tens of minutes. Therefore, voltage stability may be either short-term or long-term phenomenon.

Short-term- *voltage stability* involves dynamic 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 different equations; this is similar to analysis of rotor angle stability.

Long-term- *voltage stability* involves dynamics of slower acting equipments 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

3.2 Causes of Voltage Stability Problems

Some of the causes for occurrence of voltage instability are

- •Different in Transmission of Reactive Power Under Heavy Loads.
- •High Reactive Power Consumption at Heavy Loads.
- • 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..
- • High reactive power consumption at heavy loads
- • Unsuitable locations of FACTS controllers.
- • Reverse Operation of ON Load Tap-Changer (OLTC).

3.3 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 [1] [3] [8].

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 [1].

4. Voltage stability of a simple 2-bus system

The basic concept of voltage stability can be explained with a simple 2-bus system shown in Fig. 1 The load is of constant power type. Real power transfer from bus 1 to 2 is given by [4],

$$P = \frac{EV}{X} Sin\delta \qquad (1)$$

Reactive power transfer from bus 1 to 2 is given by,

$$Q = -\frac{V^2}{X} + \frac{EV}{X} Cos\delta \qquad (2)$$

Where, $\boldsymbol{E} = E\angle\delta$ is the voltage at bus 1,
V = V∠0 is the voltage at bus 2,
X= impedance of the line (neglecting resistance),
d = power angle.
Figure

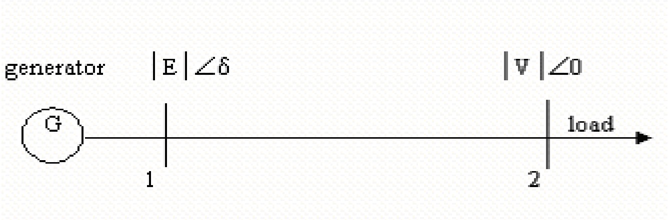

Fig.1 2-bus test system

Normalizing the terms in (1) and (2) with v = V/E

$p = P.X/E^2$ and $q = Q.X/E^2$, one obtains

p = v sin δ .... (3),

$q = -v^2 + v\cos\delta$ .... (4)

Squaring the two equations above and rearranging,

$$V^2 (\sin^2\delta + \cos^2\delta) = p^2 + (q + v^2)^2$$

or, $v^2 + v^2(2q - 1) + (p^2 + q^2) = 0$.........(5)

Positive real solutions of *v* from (5) are given by,

$$V = \sqrt{\frac{1}{2} - q \pm \sqrt{\frac{1}{4} - p^2 - q}} \quad ....(6)$$

Corresponding to each point (p,q), there are two solutions for voltage, one is the high voltage or stable solution, which is the actual voltage at the bus, and the other one is the low voltage or unstable solution. The equator, along which the two solutions of *v* are equal, represents maximum power points. Starting from any operating point on the upper part of the surface, an increase in p or q or both brings the system closer to the maximum power point. An increase in p or q beyond the maximum power point makes the voltage unstable

5. Tools for voltage stability analysis

Different methods exist in the literature for carrying out a steady state voltage stability analysis. The Conventional methods can be broadly classified into the following types.

1. P-V curve method.
2. V-Q curve method and reactive power reserve.
3. Methods based on singularity of power flow Jacobian matrix at the point of voltage Collapse.
4. Continuation power flow method.

5.1 P-V curve method

This is one of the widely used methods of voltage stability analysis. This gives the available amount of Active power margin before the point of voltage instability. For radial systems, the voltage of the critical bus is monitored against the changes in real power consumption. For large meshed networks, P can be the total active load in the load area and V can be the voltage of the critical or representative bus. Real Power transfer through a transmission interface or interconnection also can be studied by this method. For a simple two-bus system as shown in Figure 1, equation (6) gives real solutions of V^2, provided $(1 - 4q - 4p^2) \geq 0$.

Assuming a constant power factor load such that q/p = k (constant), the inequality can be expressed as,

$$p \leq \frac{1}{2}((1 + k^2)^{\frac{1}{2}} - k \quad ....(7)$$

For values of ‘p’ satisfying (7), there are two solutions of *v* as follows:

V_1= (1/2 – pk + $(1/4 - pk - p)^{1/2})^{1/2}$ ....(8)

And V_2 = (1/2 – pk - $(1/4 - pk - p)^{1/2})^{1/2}$.....(9)

For real values of V_1 and V_2, the terms under the square roots should be positive

Hence (1/2 – pk - $(1/4 - pk - p)^{1/2} \geq 0$

Or $p^2(k^2 + 1) \geq 0$ ....(10)

Which is always true.

Hence (7) is the inequality that determines the maximum value of p. Thus, representing the load as a constant power factor type, with a suitably chosen power factor, the active power margin can be computed from (7). For different values of load power factors, i.e., for different corresponding values of ‘k’, the normalized values of load active power are shown in Figure 2.

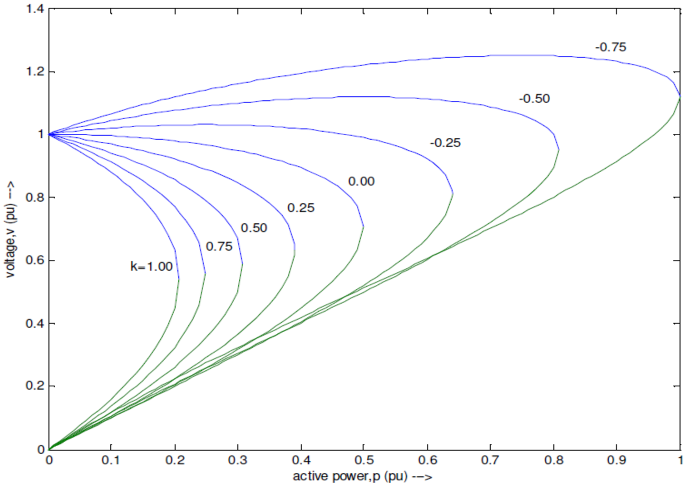

Fig.2: Normalized P-V curves for the 2-bus test system

6. Simulation Model Description-

The Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. Based on a voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage.

The Model taken from matlab 7.7.0 consists of one 500-kV, 3000 MVA alternator connected by a 300-km transmission line with resistive load in MW.

When the STATCOM is not in operation, the "natural" power flow on the transmission line to load. In this paper, the STATCOM rating +/- 100MVA is located near to load. This STATCOM is a phasor model of a typical three-level PWM STATCOM. Simulation model before and after compensation is shown in fig.3 and fig.4

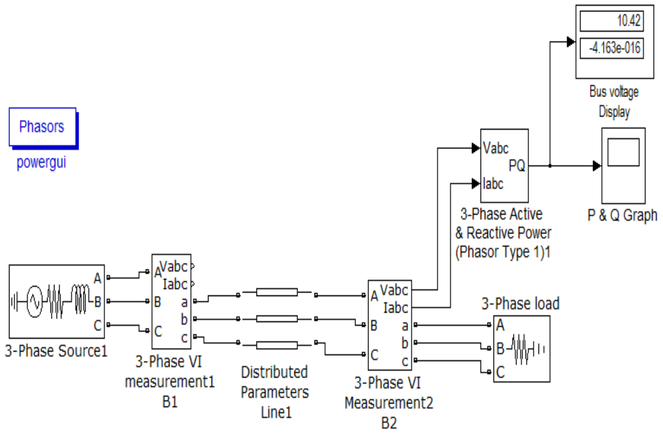

Fig.4 Simulation model before Compensation

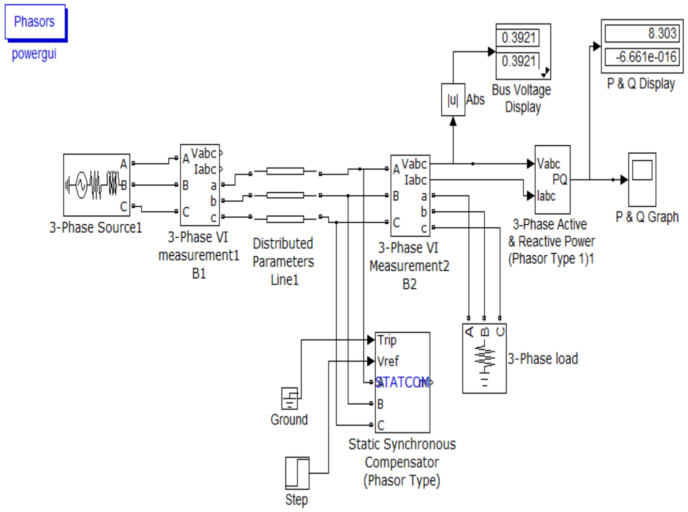

Fig.3 Simulation Model after Compensation

7. Simulation Results and Discussion-

Simulation result is given in table no.1 at different load in MW. Fig.4 shows a model before compensation and load is varies 100 MW to 3600 MW. The corresponding value of bus voltage and real power after simulation are taken then compensation is provided shown in fig.5 and also corresponding value of bus voltage and real power are taken. Data shows that real power is increased as load increased but at certain value of load real power starts decreasing gradually in increasing as load. Load at which real power starts decrease is called critical voltage stability point beyond that system being unstable and may collapse. Value of bus voltage decrease as increase in load. In table.1 At load 1800 MW real power at without compensation is 12.36 pu and after compensation provided it is 13.5 pu it shows that compensation increases the voltage stability margin. It is also shown in PV curve curve in fig.5 and fig.6 also.

Table 1. Receiving end real power and bus voltage with different load

S.No	Receiving end load In MW	Receiving End Real Power in p.u.		Receiving End Bus Voltage in p.u.	
		Before Compensation	After Compensation	Before Compensation	After Compensation
1	100	2.6	2.27	1.31	1.23
2	200	5.02	4.3	1.29	1.2
3	400	8.94	7.87	1.22	1.14
4	600	11.54	10.26	1.13	1.13
5	800	12.99	12.35	1.04	1.04
6	1000	13.58	14.42	0.95	0.98
7	1200	13.63	14.8	0.87	0.9
8	1400	13.36	14.39	0.79	0.82
9	1600	12.9	13.81	0.73	0.75
10	1800	12.36	13.15	0.67	0.69
11	2000	11.79	12.48	0.62	0.64
12	2200	12.23	11.83	0.58	0.59
13	2400	10.68	11.21	0.54	0.55
14	2500	10.52	10.91	0.52	0.53
15	2600	10.16	10.63	0.51	0.52
16	2800	9.67	10.09	0.47	0.49
17	3000	9.22	9.58	0.45	0.46
18	3200	8.79	9.12	0.42	0.43
19	3400	8.4	8.69	0.4	0.41
20	3600	8.04	8.3	0.38	0.39

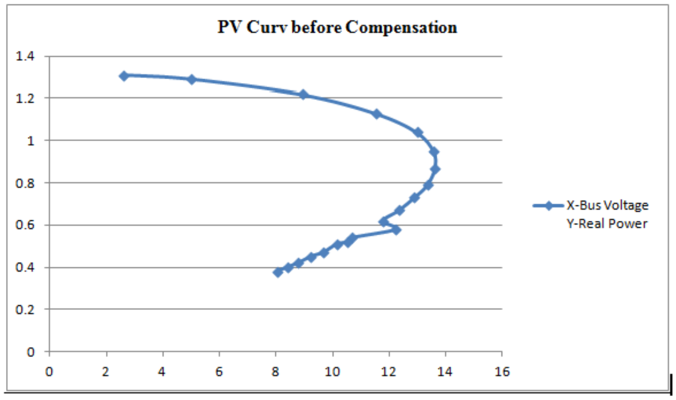

Fig.5 PV Curve before Compensation

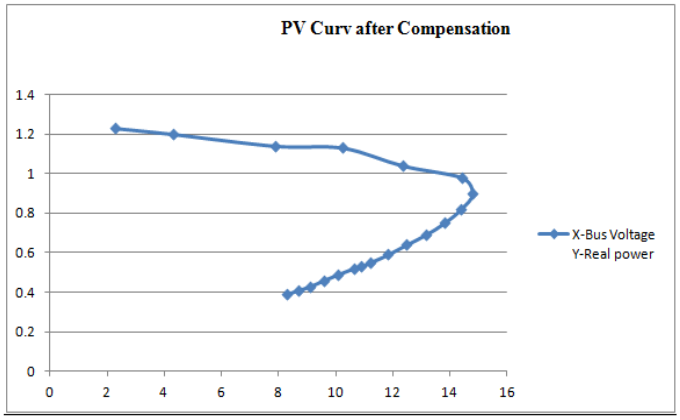

Fig.6 PV curve after compensation

8. Conclusion- In this paper we show the phenomena of voltage stability, stability limit, its causes and control. The matlab simulation work is carried out for analyzed the effect of FACT compensation on voltage stability margin of a two bus power system model. It is analyzed that voltage stability limit stability is increased with reactive power compensation. Fig.5 shows PV curve before compensation and fig.6 shows PV curve after compensation it is clear that stability limit is increased with compensation.

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