Optimal Placement of UPFC to Enhance Power System Voltage Stability

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Abstract-**In the last some decades, power demand has increased regularly while the expansion of power generation and transmission has been limited due to the limited resources and environmental sources. In power system there are so many types of stability. One of main problem concern with Power system is Voltage Stability. For That problem the solution is to install the FACTS devices in the transmission line. Using Modal Analysis we can find weak buses & branches using Bus Participation Factor & Branch Participation Factor.Voltage Stability can be enhanced using unified power flow controller, for controlling the flow of power in the transmission line.**

***Keywords* – Voltage stability, model analysis, UPFC, eigenvalue, Power world simulator.**

I. INTRODUCTION

In the past few decades the power demand has been increasing. With the recent development in the new non-conventional forms of energy and its connection with the Power system has increased the complexity of structure and its operation. Modern electrical power system is widely interconnected. It minimizes total power generation and fuel cost. Because of the increased power demand while the generation is limited due to that some of the transmission lines get over loaded. This causes serious stability issues. Stability is the heart of any system. When two or more generators are connected to the power system synchronization has to be maintained. In the facts devices there are so many types of devices are using for the stability purpose but from that It is using the UPFC (unified power flow controller) for the stability purpose. It the combination of the STATCOM and SSSC. With the use of it we can control the active power, reactive power, voltage and magnitude of the transmission line. So by this, Facts devices are helpful in the transmission line for the voltage stability and many other purposes. In the model analysis we have to find the bus and branch which is respectively weak bus and more loss done in the branches.

II. POWER SYSTEM STABILITY

Power system stability may be broadly defined as that property of a power system that enables it to remain in
A state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to disturbances.
In the power system stability there are so many types of stability like voltage, angle, long term and short term and medium term etc... System enters a state of voltage instability when a disturbances increase in the load demand or change in system condition. [2]

Voltage Stability Analysis: Voltage stability is the ability of power system to maintain the steadily acceptable bus voltage at each node under normal operating condition, after sudden increase in load or when the system is being subjected to disturbance. Voltage instability stems from the load dynamics to restore power consumption beyond the capability of the combined transmission and generation system. [2]

The progressive and uncontrollable drop in voltage results eventually in a wide spread voltage collapse. Voltage collapse is the process by which voltage instability leads to the loss of voltage in a significant part of the system. This condition results from reactive losses significantly exceeding the reactive resources available to supply system.[2]

Causes of Voltage Instability:

Voltage instability can occur due to the following reasons

- The initiating event may be due to small gradual system changes such as natural increase in load or loss of generating unit or a heavily loaded line.
- Voltage sources are too far from the load centers

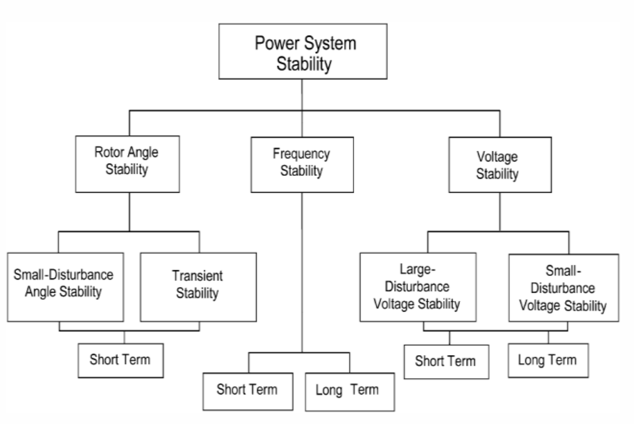

Fig.1

The heart of the problem is the inability of the system to meet its reactive demands. Usually, but not always, voltage collapse involves system conditions with heavily loaded lines. When transport of power from neighboring areas is difficult, any change that calls for additional reactive power support may lead to voltage collapse.

III. MODAL ANALYSIS

Voltage stability characteristics of the system can be identified by computing the Eigen values and Eigenvectors of the reduced Jacobian Matrix defined by the equation.

$$J_{R}= \varepsilon \eta \Lambda \qquad (1)$$

Where

ε=Right eigenvector matrix of J_R

η=Left eigenvector matrix of J_R

Λ=Diagonal eigenvector matrix of J_R

Where $J_R=[J_{QV} - J_{Q\theta} J_{P\theta}^{-1} J_{PV}]$

And JR is the reduced Jacobianmatrix.We can write,

$$\Delta V = J_R^{-1} \Delta Q \qquad (2)$$

From the above equation we get

$$J_R^{-1} = \varepsilon \Lambda^{-1} \eta \qquad (3)$$

Substitute equation 3 in equation 2 we get

$$\Delta V = \varepsilon \Lambda^{-1} \eta \Delta Q \qquad (4)$$

$$\Delta V = \Sigma(\varepsilon_j * \eta_i / \lambda_i) \Delta Q \qquad (5)$$

Where ε_j is the i^{th}column of right eigen vector & η_i the i^{th} row left eigenvector of J_R. Each eigenvalue λ_i and the corresponding right &left eigenvalue ε_j & η_i defines the i^{th} mode of Q-V response.

Bus Participation Factor:

The relative participation of bus k in mode i is given by the Bus Participation Factor.

$$P_{Ki}= \varepsilon_{KI} * \eta_{iK} \qquad (6)$$

Branch Participation factor:

$$P_{ji}= \frac{\Delta Q_{loss} \text{ for branch } j}{\text{maximum } \Delta Q_{loss} \text{ for all branches}}$$

Bus no.	Bus Participation Factor
1	0.000328
2	0.000456
3	0.000503
4	0.000183
5	0.0035

From bus	To bus	Branch participation Factor
1	2	1.00000000
2	5	0.42738625
4	3	0.04712424
3	2	0.60949963
3	5	0.24600416

IV. UPFC (Unified Power Flow Controller)

STATCOM:-

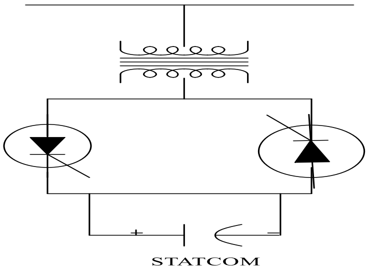

Fig.2

The static synchronous compensator (STATCOM) is another shunt connected GTO based FACTS equipment. It is a static synchronous generator operated as a static VAR compensator which can inject lagging or leading VAR into the system. It has several advantages. It has no rotating parts, very fast in response, requires less space as bulky passive components are eliminated, less maintenance and no problem as loss of synchronism. [6]

In heavy loaded condition in transmission line, if Output of VSC is more than the line voltage, than the converter supplies lagging VARs to the transmission line. And During the low load condition if line voltage is more than converter absorbs lagging VAR from the system. [6]

SSSC:-

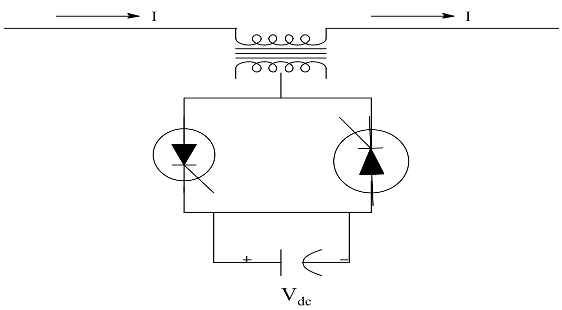

Fig.3

This device also works on the same way as the STATCOM. It has a voltage source converter which is easily connected to a transmission line through a transformer. It is necessary that the energy source to provide a continuous voltage through a condenser and to compensate the losses of the VSC.this device is able to exchange active and reactive power with the transmission system.[5]

When the voltage across series capacitor is –jXcI (where Xc is the capacitive reactance of the series capacitor) and voltage drop across line inductance (XL) is +jXLI cancel each other thus reducing the effect of line inductance. By this the power transfer capability is increased.[5]

Unified Power Flow Controller

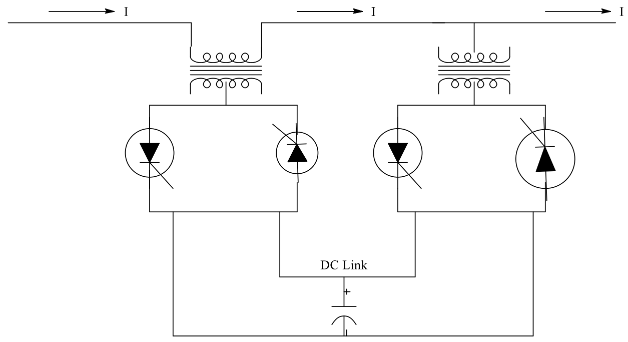

Fig. 4

The above is the basic diagram of Unified Power Flow Controller (UPFC).which is the combination of STATCOM and SSSC. Because of the combination of these two devices it is able to control active power, reactive power, angle and stability. So with the use of STATCOM we can control the current while with the help of SSSC we can control the voltage of the transmission line.

UPFC is the most versatile device among all the FACTS devices which can be used to enhance steady-state stability, dynamic stability, and real and reactive power flow and so on. In this there are two convertors which are coupled through a common dc link which provides bidirectional flow of real power between series o/p SSSC and shunt output STATCOM respectively. For balancing of power between series and shunt controller. [6]

	Load flow control	**Voltage control**	**Transient stability**	**Dynamic stability**
SVC	Good	Best	Good	Better
STATCOM	Good	Good	Better	Better
TCSC	Better	Best	Best	Better
UPFC	Best	Best	Better	Better

Table 1 Comparison of FACTS devices [4]

Control Scheme

There are different types of control scheme are used in the system like ANN based, NR method, fuzzy based, ANFIC based and liapunov based, IGBT based, simple GTO based. From these all the techniques which is using for the system is simple GTO based system.

Normal thyristors are not fully controllable switches (a "fully controllable switch" can be turned on and off at will). Thyristors can only be turned ON and cannot be turned OFF. Thyristors are switched ON by a gate signal. but even after the gate signal is removed, the thyristor remains in the ON-state until any turn-off condition occurs (which can be the application of a reverse voltage to the terminals, or when the current flowing through (forward current) falls below a certain threshold value known as the "holding current"). Thus, a thyristor behaves like a normalsemiconductor diode after it is turned on or “fired".

The GTO can be turned-on by a gate signal, and can also be turned-off by a gate signal of negative polarity.Turn on is accomplished by a "positive current" pulse between the gate and cathode terminals. As the gate-cathode behaves like PN junction there will be some relatively small voltage between the terminals.

V. POWER WORLD SIMULATOR DIAGRAM

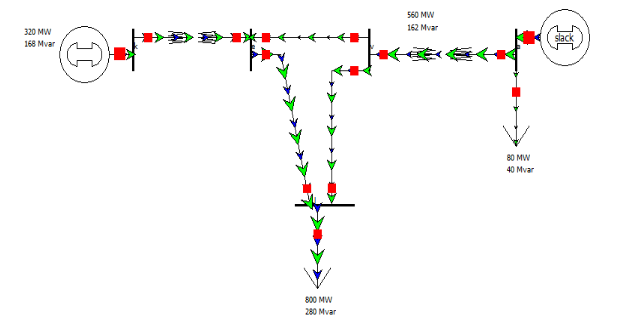

Fig.5

BLUE- Reactive power
GREEN- Active power

Power World Simulator

Power World simulator is a power system visualization, simulation, and analysis tool. Assume that we plan to simulate the system whose one line diagram is shown above. The System has the following parameters:
Generator: Rated voltage 66 kV, maximum active power generation: 350 MW, reactive power limits ±90 MVAr
Transmission line: R = 0.01 p.u., X = 0.06 p.u, B = 0.10 p.u.
Transformer: 66/11 kV, X = 0.05 p.u. Load: 100 MW, 45 MVAr.

In the above diagram at 1 and 3 buses have been connected generator as so in fig. and at the bus no.2 the load is given so by this the power is going but when 1 generator is tripped all the load is converted on the other generator and if there is a fault occurs in the system than supply going through the other bus. The above is the circuit which is without placing UPFC. So if we place the UPFC in the system we can enhance the stability by this system.

VI. CONCLUSION

By the model analysis we can find the unstable branch in the transmission line to place UPFC.
And by the use of power world simulator we can find the Real & Reactive Power flow of IEEE 5 Bus System.

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