Power Quality Improvement Using TCSC and STATCOM

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Abstract **- Voltage stability analysis is essential for a secure power system operation. A lot of works have been developed for this analysis method to improve voltage stability. To investigates the enhancement of voltage stability using Flexible Alternative Current Transmission System devices. The objective is to enhance voltage stability based on static analysis. The continuation power flow methods are proposed in case of the increasing loading of contingency. Continuation Power flow is the analysis to determine the steady-state complex voltages at all buses of the network and also the real and reactive power flows in every transmission line. In this project, the proposed approach is based on Thyristor Controlled Series Compensator comparison with Static Synchronous Compensator compensation to increase the steady state voltage stability margin of power capability. For this project, Newton-Raphson method are being use to analyze this project. When Flexible Alternative Current Transmission System device are applied into the system, it can assist to reduce the flows in heavily loaded lines by controlling the reactance in the transmission lines. The IEEE 6 bus system is simulated to test the increasing loadability.**

Keywords**- static voltage stability, TCSC, STATCOM.**

I. INTRODUCTION

Many analysis methods of voltage stability determination have been developed on static analysis techniques based on the power flow model since they are simple, fast and convenient to use. These techniques have been practically viable that the voltage collapse is a relatively slow process thus being primarily considered as a small signal phenomenon. Traditionally, it is known that voltage collapse leads to the reason for several blackouts that have occur throughout many areas. The major reasons for voltage collapse are based on increasing loading, large disturbance and line outage. There are many papers investigate voltage stability on dynamic analysis, static analysis and sensitivity characteristics.

The dynamic analysis emphasizes on large disturbance or transient stability occurrence. However, static analysis is considered as a small signal phenomenon, load increasing and line outage. Thus, lot of work is carried out to determine voltage stability on static analysis instead generally, when online dynamic voltage stability is not available, static techniques may involve a conventional power flow study. The problem of conventional power flow analysis is the Jacobian of a Newton-Rephson power flow becomes singular at the steady state voltage stability limited.[4] In this paper, the continuation power flow locates a critical voltage point in P-V curve. The FACTS devices, TCSC & STATCOM, are proposed to compensate the transfer capability of transmission line. The advantages of FACTS are transient stability, voltage stability, and increase /or decrease reactive power and voltage adjustment.

II. THE CONTINUATION POWER FLOW ANALYSIS

The conventional power flow has a problem in the jacobian matrix which becomes singular at the voltage stability limit. The voltage stability limit is also called critical voltage or critical point.

The continuation power flow analysis uses iterative predictor and corrective steps (Fig. 1). The predictor step will start from point A, which the estimate solution is obtained from tangent of ABC triangle. Then corrector step determines the solution by using conventional power flow. The further increase in load voltage is then predicted on a new tangent predictor.

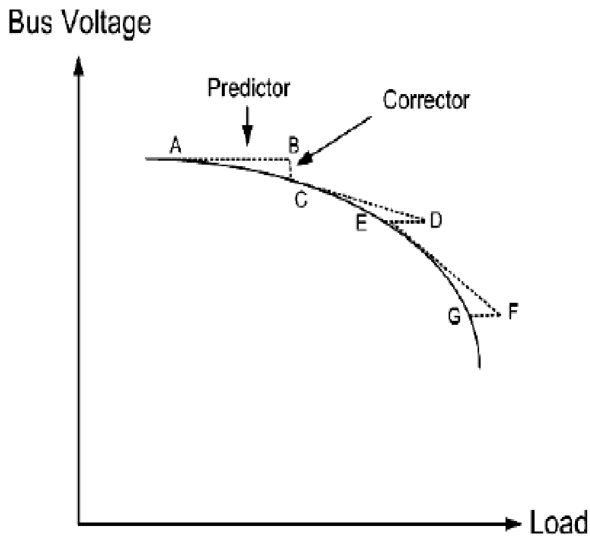

Fig 1. The predictor – corrector scheme used in the continuation power flow

The load flow equation consists of load factor (λ) can be written as

$$F(\delta, V, \delta) = 0$$

Where

$\lambda =$ the load parameter
$\delta =$ the vector of bus voltage angle and
$V =$ the vector of bus voltage magnitude

From the Newton Raphson load flow calculation is expressed as

$$P_i - \sum_{j=1}^{N} Y_{ij} V_i V_j \cos(\delta_i - \delta_j - \theta_{ij}) = 0$$

$$Q_i - \sum_{j=1}^{N} Y_{ij} V_i V_j \sin(\delta_i - \delta_j - \theta_{ij}) = 0$$

The system has N node and Nq number of source including slack bus. The total number of equation equal 2N - Nq - 1.

The new load flow equations consists of load factor (λ) are expressed as

$$P_{Li} = P_{Lo} + \lambda(K_{Li} S_{\Delta base} \cos\phi_i)$$

$$Q_{Li} = Q_{Lo} + \lambda(K_{Li} S_{\Delta base} \sin\phi_i)$$

Where

$P_{Li}, Q_{Li} =$ the active and reactive power respectively
$K_{Li} =$ the constant for load changing at bus I, and
$S_{\Delta base} =$ the apparent power which is chosen to provide appropriate scaling of λ.

Then the active power generation term can be modified to

$$P_{Gi} = P_{G0}(1 + \lambda K_{Gi})$$

Where
$P_{G0} =$ the initial value of active power generation
$P_{Gi} =$ the active power generation at bus I, and
$K_{Gi} =$ the constant of changing rate in generation

A.Predictor Step

In the predictor step, a linear approximation is used to estimate the next solution in order to adjust the state variables. Taking the derivative of both side of (1), it can be expressed as:

$$F_\delta d\delta + F_V dV + F_\lambda d\lambda = 0$$

$$\begin{bmatrix} F_\delta & F_V & F_\lambda \end{bmatrix} \begin{bmatrix} d\delta \\ dV \\ d\lambda \end{bmatrix} = 0$$

B .Corrector step

The load flow equations are selected by

$$\begin{bmatrix} F(\delta, V, \lambda) \\ X_k - \eta \end{bmatrix} = [0]$$

Where

$X_k =$ the state variable selected as continuation parameter at k iterative and
$\eta =$ the predicted value of X_k

III. THYRISTOR CONTROLLED CONTROLLED SERIES COMPENSATION (TCSC)

TCSC is the type of series compensator. The structure of TCSC is capacitive bank and the thyrister controlled inductive brunch connected in parallel as shown in Fig. 2. [7] The principle of TCSC is to compensate the transmission line in order to adjust the line impedance, increase loadability, and prevent the voltage collapse.

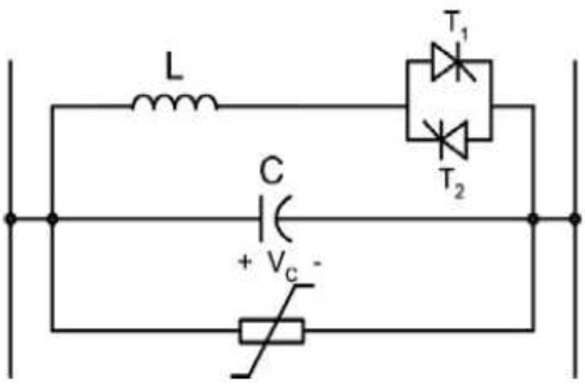

Fig 2. Basic Structure of TCSC

The characteristic of the TCSC depends on the relative reactance of the capacitor bank and thyristor branch. The resonance frequency (ω_r) of LC is express as:

$$X_c = -\frac{1}{\omega_n C}$$

And

$$X_L = \omega L$$

$$\omega_r = \frac{1}{LC} = \omega_n \sqrt{\frac{-X_C}{X_V}}$$

The principle of TCSC. in voltage stability enhancement is to control the transmission line impedance by adjust the TCSC impedance. The absolute impedance of TCSC which can be adjusted in three modes:

Blocking mode: The thyristor is not triggered and TCSC. is operating in pure capacity which the power factor of TCSC is leading.

By pass mode: The thyristor is operated in order to XL=XC. The current is inphase with TCSC Voltage.

Capacitive boost mode: XC > XL, and then Inductive mode: XL>XC, respectively.

IV. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM is a same type of shunt compensator FACTS device as TCSC. The principle of STATCOM is the reactive power compensates which the reactive power and voltage magnitude of system can be adjusted. It consists of three paths: transformer, voltage source convertor (VSC), and capacitor. The reactive power is distributed in power system by the convertor control.

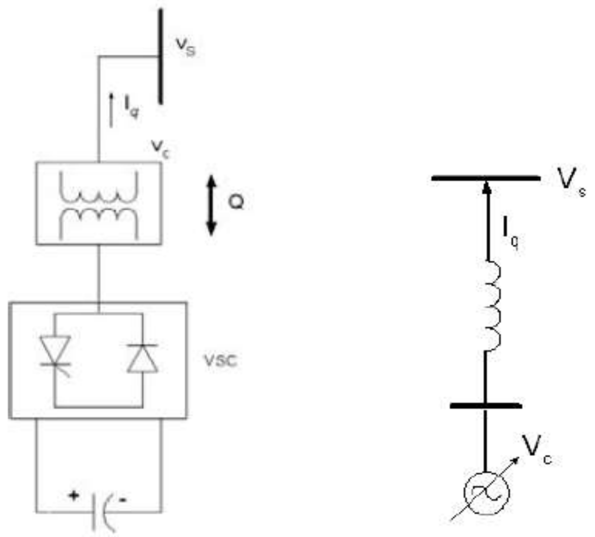

Fig 3a. STATCOM Model

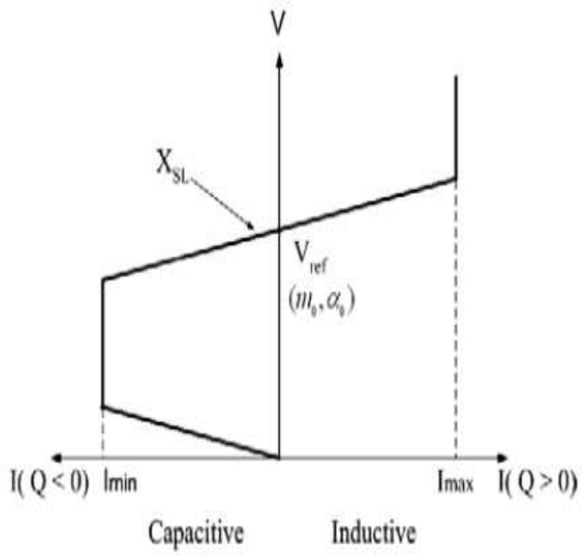

Fig 3b. Characteristic Curve of TCSC

From Fig. 3, the characteristic of STATCOM shows the status of STATCOM either inductive or capacitive which is depended on the convertor voltage adjustment.

The steady state equation is expressed as:

$$V_{dc^{\cdot}} = \frac{P}{CV_{dc^{\cdot}}} - \frac{V_{dc}}{R_c C} - \frac{R(P^2 + Q^2)}{CV^2 V_{dc^{\cdot}}}$$

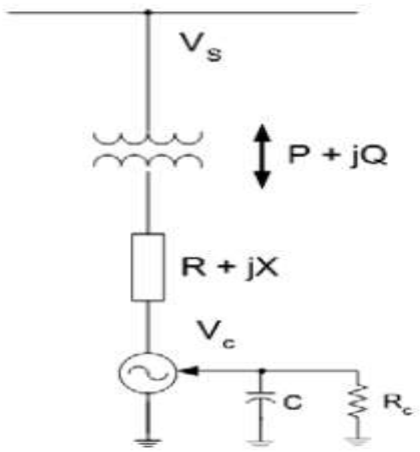

Fig 4. Equivalent circuit of STATCOM

The power injection at A.C. bus has the following form:

$$P_{\cdot} = V^2 G - kV_{dc^{\cdot}} VG\cos(\theta - \alpha) - kV_{dc^{\cdot}} B\sin(\theta - \alpha)$$

$$Q = -V^2 B - kV_{dc} VB\cos(\theta - \alpha) - kV_{dc} G\sin(\theta - \alpha)$$

where

G : the conductance of STATCOM and
B : the subceptance of STATCOM.

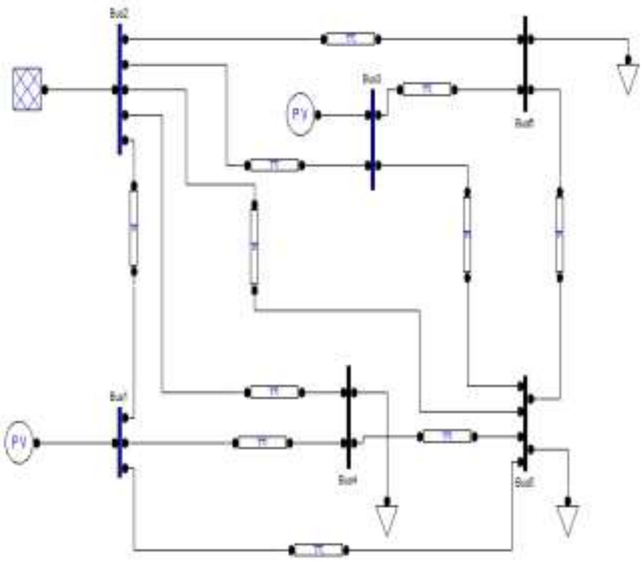

Fig 4. IEEE 6 Bus Test System

V. THE SIMULATION

A 6-Bus test system as shown in Fig. 5 is used for this paper. The test system consists of three generators and three PQ bus (or load bus). The simulation uses a PSAT simulation software [7].

5.1 Using continuation power flow to create the PV curve of system and show the critical bus. From figure 6 the sequence of voltage stability limit point in each bus are 4, 5, 6 in which the bus 4 is the weak bus. The maximum loading point or critical voltage point is at λ =7.61 p.u.

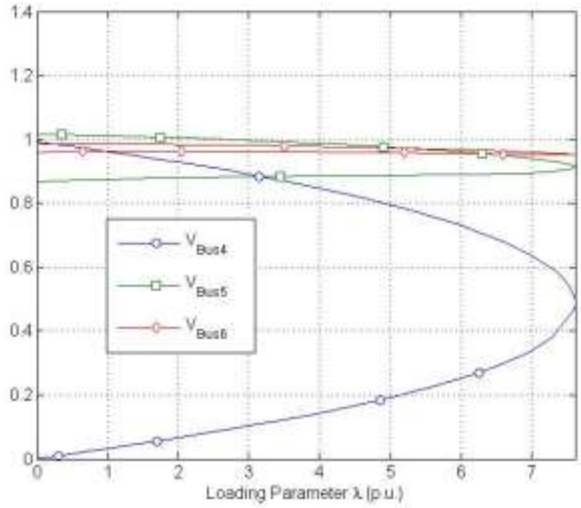

Fig 6. PV Curve of 6 Bus System without FACTS

5.2. Insert the TCSC between bus 1 and bus 4 which is the long transmission line, and then repeat to create PV curve again. The maximum loading point is increased at λ =11.97 p.u. .Then the power capability of each bus is increase. The figure is shown in 7.

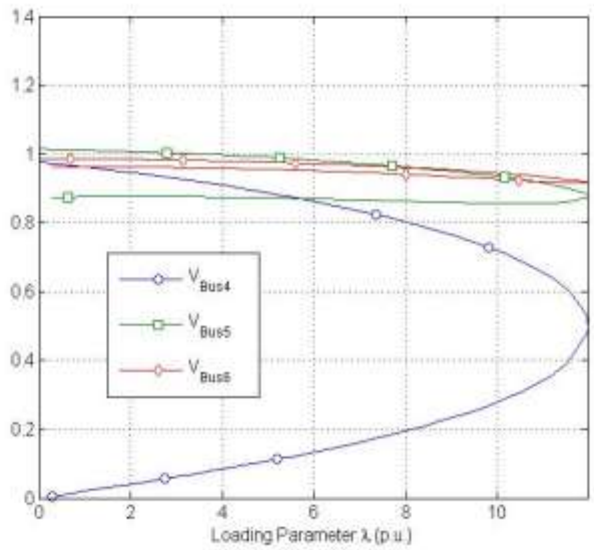

Figure 7. PV curve for 6 bus with TCSC at bus 1 – 4

5.3. Remove the TCSC and insert the STATCOM at the bus 4 which the lowest the critical point and repeat the simulation. The maximum loading point is increasing further at λ =13.15 p.u. The figure is shown in 8. The ability of STATCOM can more extend the maximum point than TCSC. The effectiveness of compensation is increase the stability margin of the local bus.

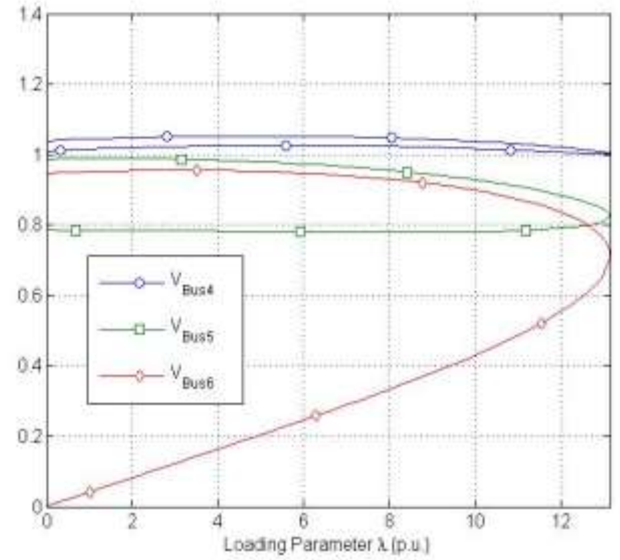

Figure 8. PV curve for 6 bus with STATCOM at bus 4

5.3. Finally , Insert the TCSC between the bus 6 and bus 2 which the one weak bus and repeat the simulation again. The maximum loading point is increasing at λ =7.69 p.u. . The Figure is shown in 9. The ability of TCSC can extend the maximum loading point which the TCSC connected at bus –
4.

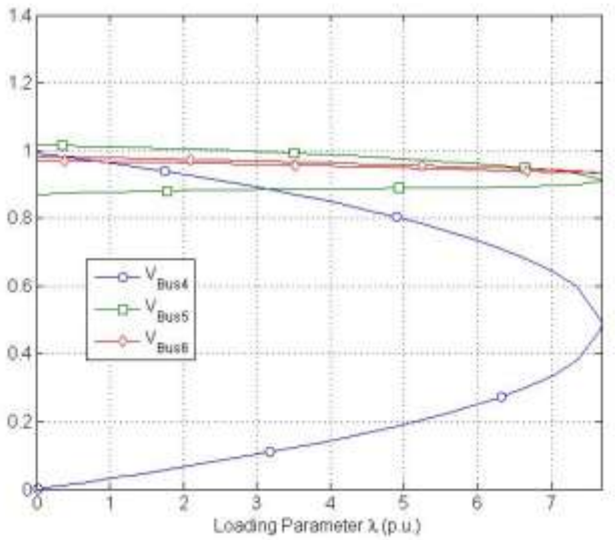

Figure 9. PV curve for 6 bus with TCSC at bus 6 – 2

VI. CONCLUSION

In this work, the continuation power flow with the simulation of system is studied and investigated using IEEE 6 bus test system. Here the FACTS controllers TCSC and STATCOM are employed for enhancement of static voltage stability. The test system requires reactive power the most at the weakest bus, which is located in the distribution level. Introducing reactive power at this bus using STATCOM can improve loadability margin the most. TCSC is a series compensation device, which injects reactive power through the connected line. This may not be effective when the system needs reactive power at the load level. It was found that TCSC and STATCOM are significantly enhanced the voltage profile and thus the loadability margin of the power system. The usage of these FACTS controllers can prevent the voltage collapse which is reveled in the simulation results. However STATCOM provides higher voltage stability margin than TCSC.

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