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POWER QUALITY IMPROVEMENT WIND/PV HYBRID SYSTEM BY 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.

Key Words: Static Voltage Stability, TCSC & STATCOM

1. Introduction:

Non-Conventional Energy Sources are those energy sources that are not shattered if their energy is exploited. Human use of renewable energy requires technologies that govern natural phenomena such as solar, wind, waves, water flow, and organic processes such as anaerobic digestion, biological hydrogen production, and geothermal heat [10]. Throughout the foreknown sources of energy, there have been a lot of advances in the technology for extracting energy from the Solar & wind [12]. Solar and wind energy are stable, site reliant, non-polluting, and probable sources of back-up energy options. None of these are everlasting, thus by combining solar and wind power it forms a means of unblemished source of power generation. In case of unavailability of these two sources, load can be supplied with other sources of electrical energy [1][16]. The preeminent concern for power electronic devices in these systems is to provide interface between source and load. Another important factor is to disciple the generated DC Voltage into a suitable AC for end user side [11].

2. 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.

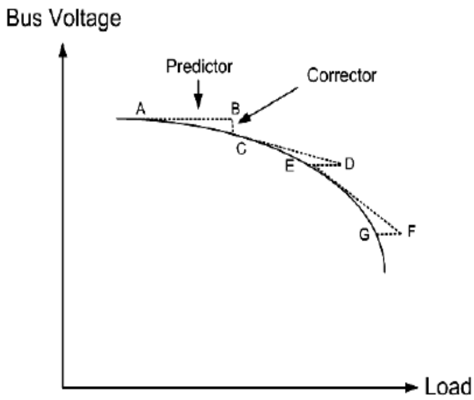

Figure 1: The predictor – corrector scheme used in the continuation power flow

The load flow equation consists of load factor (λ) can be written as $F(\delta, V, \delta) = 0$

Where λ = the load parameter, δ = 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

3. Thyristor Controlled Series Compensation (TCSC):

TCSC is the type of series compensator. The structure of TCSC are 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.

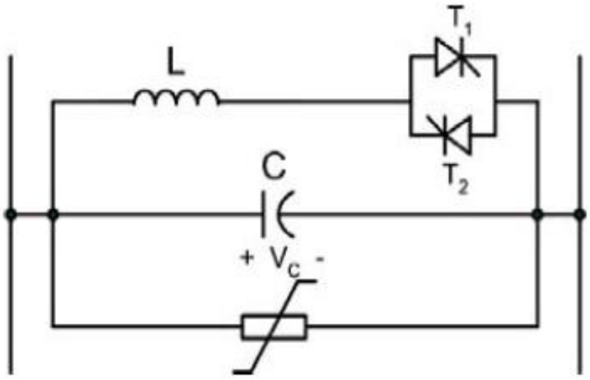

Figure 2: Basic Structure of TCSC

The characteristic of the TCSC depends on the relative reactances 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. This 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.

4. 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.

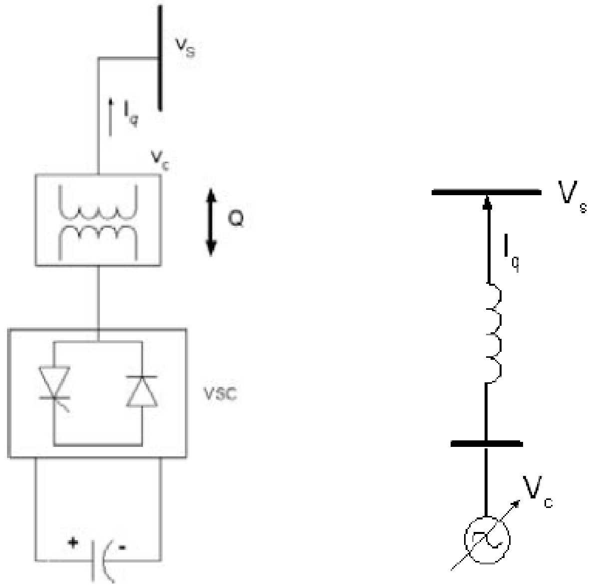

Figure 3a: STATCOM Model

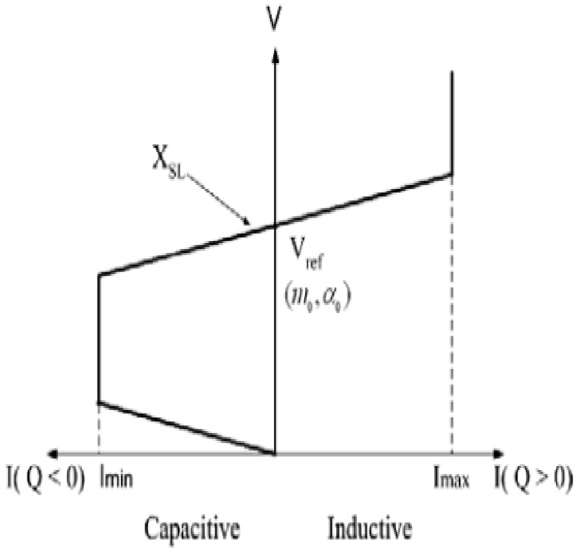

Figure 3b: Characteristic Curve of TCSC

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:

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

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

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

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

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

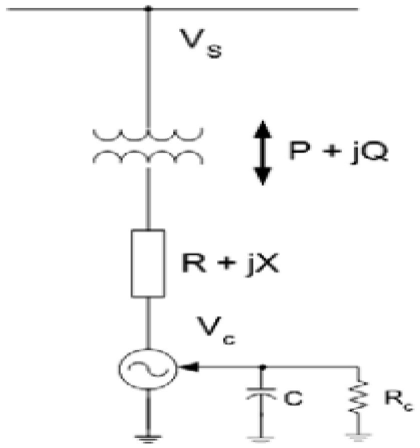

Figure 4: Equivalent circuit of STATCOM

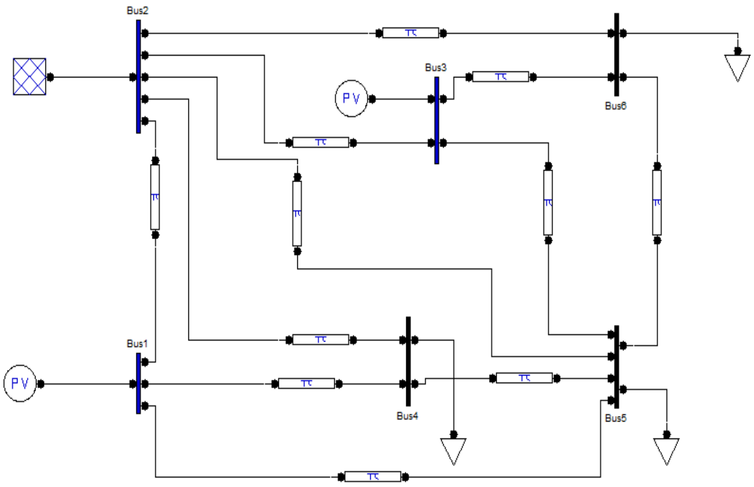

Figure 5: IEEE 6 Bus Test System

5. 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 simulations use 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.

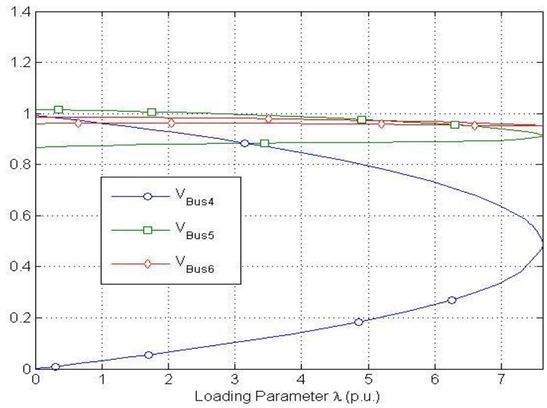

Figure 6: PV Curve of 6 Bus System without FACTS

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 put. Then the power capability of each bus is increase. The figure is shown in 7.

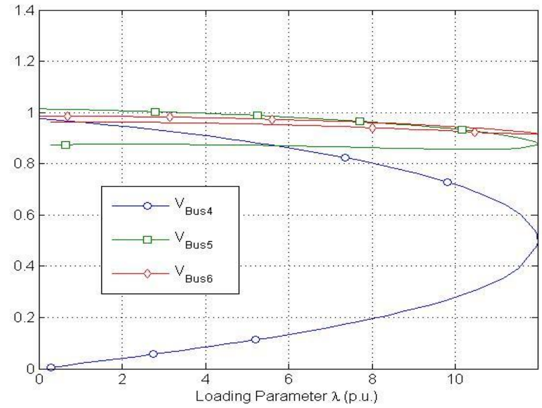

Figure 7: PV curve for 6 bus with TCSC at bus 1 – 4

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.

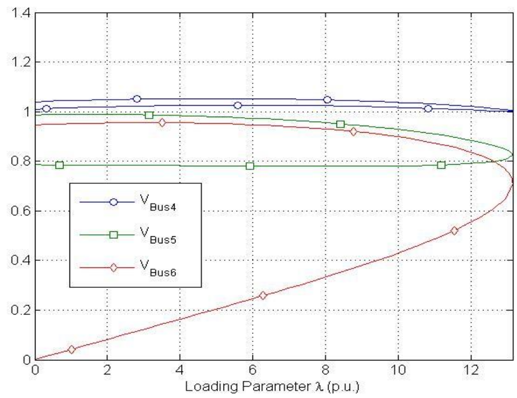

Figure 8: PV curve for 6 bus with STATCOM at bus 4

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 1 – 4.

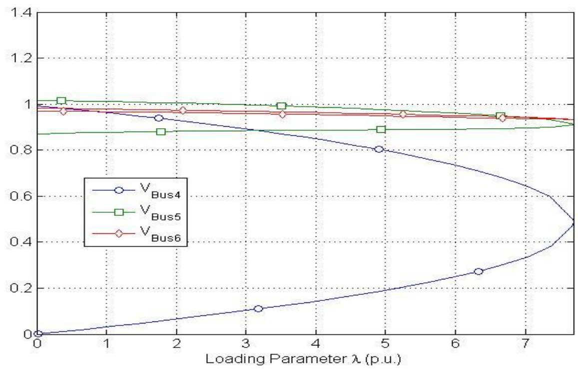

Figure 9: PV curve for 6 bus with TCSC at bus 6 – 2

6. 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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