National Conference on Recent Research in Engineering and Technology (NCRRET-2015)
International Journal of Advance Engineering and Research Development (IJAERD)
e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

Literature review on Improvement of Voltage Stability Through Optimal Placement of TCSC

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Abstract—

The increase in power demand has forced the power system to operate closer to its stability limit. Voltage instability and line overloading have become challenging problems due to the strengthening of power system by various means. The nature of voltage stability can be analyzed by the production, transmission and consumption of reactive power. One of the major causes of voltage instability is the reactive power unbalancing which occurs in stressed condition of power system. Flexible AC transmission system (FACTS) devices play an important role in improving the performance of a power system, but these devices are very costly and hence need to be placed optimally in power system. FACTS device like thyristor controlled series compensator (TCSC) can be employed to reduce the flows in heavily loaded lines, resulting in a low system loss and improved stability of network. A method based on line stability index has been proposed to decide the optimal location of TCSC. The effectiveness of the proposed method is demonstrated on IEEE - 14 bus power system.

Keywords — FACTS, TCSC, IEEE - 14 bus

I. INTRODUCTION

1.1 VOLTAGE INSTABILITY

"Voltage Instability That May Result Occurs In The Form Of A Progressive Fall Or Rise Of Voltages Of Some Buses." A Major Factor Contributing To Voltage Instability Is The Voltage Drop That Occurs When Active And Reactive Power Flow Through Inductive Reactance Of The Transmission Network; This Limits The Capability Of The Transmission Network For Power Transfer And Voltage Support.

1.2 VOLTAGE COLLAPSE

"It Is The Process By Which The Sequence Of Events Accompanying Voltage Instability Leads To A Blackout Or Abnormally Low Voltages In A Significant Part Of The Power System." In Different Parts Of The World. Some Of The Incidences Of Voltage Collapse Are .

- New York State Pool Disturbance Of September 22, 1970.
- Jacksonville, Florida System Disturbance Of September 22, 1977.
- Zealand, Denmark System Disturbance Of March 2, 1979.
- Longview, Washington Area System Disturbance Of August 10, 1981.
- Central Oregon System Disturbance Of September 17, 1981.
- Belgium System Disturbance Of August 4, 1982.
- Florida System Disturbance Of December 28, 1982.

  Western French System Disturbance Of December 19, 1978 And January 12, 1987.
- Northern Belgium System Disturbance Of August 4, 1982.
- Northern California System Disturbance Of May 21, 1983.
- Swedish System Disturbance Of December 27, 1983.
- Japanese System Disturbance Of July 23, 1983.
- Northeast United States System Disturbance Of June 11, 1984.
- England System Disturbance Of May 20, 1986.
- Miles City Hvdc Links, May And July 1986.
- Tokyo System Disturbance Of July 23, 1987.

- Iiiinois And Indiana System Disturbance Of July 20, 1987.
- Mississippi System Disturbance Of July 28, 1987.
- South Carolina System Disturbance Of July 11, 1989.
- Western France System Disturbance Of February 3, 1990 And November 1990.
- Baltimore And Washington D.C. System Disturbance Of July 5, 1990.
- Sri Lanka Power System Disturbance Of May 2, 1995.
- Northern Grid Disturbance In Indian Power System Of December 1996.
- North American Power System Disturbance Of August 14, 2003.
- National Grid System Of Pakistan Disturbances Of September 24, 2006.

II. CLASSIFICATION OF VOLTAGE STABILITY

The Stability Classified Into Four Categories: Large Disturbance Voltage Stability, Small Disturbance Voltage Stability, Short-Term Voltage Stability And Long-Term Stability. Power System Stability Consists Of Rotor Angle Stability, Frequency Stability And Voltage Stability. Rotor Angle Stability Is Classified In Two Terms Transient And Small Signal Stability. Frequency Stability Consists Of Long Term And Short Term Stability. Voltage Stability Classified In Large And Small Disturbance And Both Are Classified In Short Term And Long Term Stability.A Short Summary Of The Classifications Is Given Below.

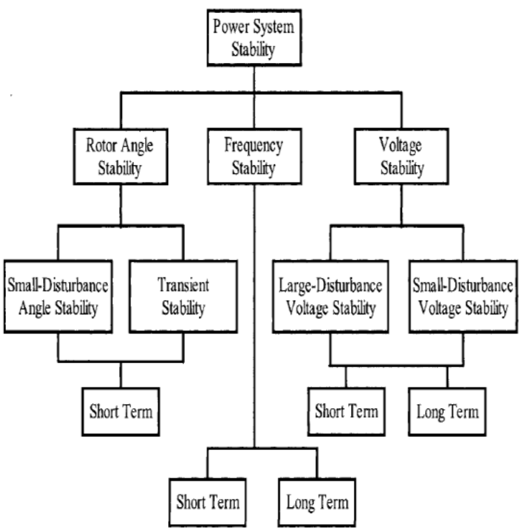


Figure 1: Classification of Stability

III. PRINCIPAL CAUSES OF VOLTAGE STABILITY PROBLEMS.

- Different In Transmission of Reactive Power Under Heavy Loads.
- High Reactive Power Consumption At Heavy Loads.
- Occurrence Of Contingencies.
- Voltage Sources Are Too Far From Load Centers.
- Due To Unsuitable Locations Of Facts Controllers.
- Poor Coordination Between Multiple Facts Controllers.
- Presence Of Constant Power Loads.
- Reverse Operation Of On Load Tap-Changer (Oltc).

IV.PREVENTION OF VOLTAGE INSTABILITY.

- Placement Of Series And Shunt Capacitors.
- Installation Of Synchronous Condensers.
- Placement Of Facts Controllers.
- Coordination Of Multiple Facts Controllers.
- Under-Voltage Load Shedding.
- Blocking Of Tap-Changer Under Reverse Operation.

V.OVERVIEW OF TCSC

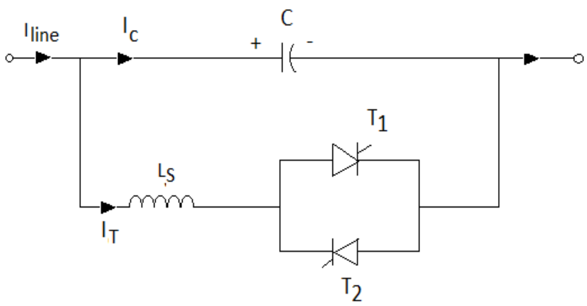


Fig.2 Basic TCSC Model

It consists of the series compensating capacitor shunted by a Thyristor-Controlled Reactor. In a practical TCSC implementation, several such basic compensators may be connected in series to obtain the desired voltage rating and operating characteristics. This arrangement is similar in structure to the TSSC and, if the impedance of the reactor, XL, is sufficiently smaller than that of the capacitor, Xc, it can be operated in an on/off manner like the TSSC. However, the basic idea behind the TCSC scheme is to provide a continuously variable capacitor by means of partially canceling the effective compensating capacitance by the TCR. Since the TCR at the fundamental system frequency is a continuously variable reactive impedance, controllable by delay angle a, the steady-state impedance of the TCSC is that of a parallel LC circuit, consisting of a fixed capacitive impedance, Xc, and a variable inductive impedance, XL(α), that is,

$$XTCSC(\alpha)=\frac{XCXL}{XL\,(\alpha)-XC}$$

$$\frac{XCXL}{XL\,(\alpha)-XC}\,)\ =\ XL(\ \frac{\pi}{\pi-2\alpha-\sin\alpha}), \quad XL \leq XL(\alpha) \leq \infty$$

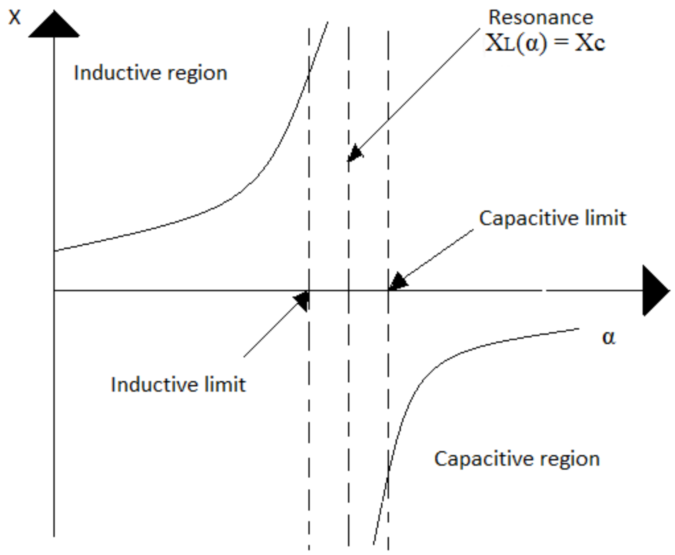


Fig. 2 TCSC Characteristics

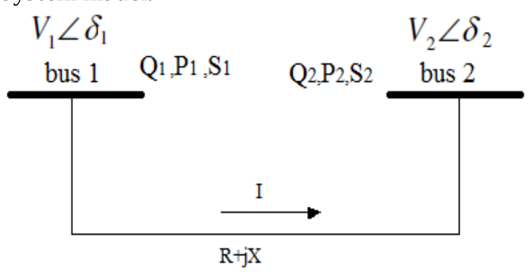
TCSC arrangement in which the impedance of the TCR reactor, XL, is smaller than that of the capacitor, Xc, the TCSC has two operating ranges around its internal circuit resonance:

(a) αClim ≤ α≤ π/2 range, where XTcsc(α) is capacitive, and
(b) the other is the 0 ≤ α≤ αLlim range, where Xrcsc(α) is inductive, as illustrated in Figure

An actual TCSC system usually comprises a cascaded combination of many such TCSC modules, together with a fixed-series capacitor, CF. This fixed series capacitor is provided primarily to minimize costs. A conceptual TCSC system with basic TCSC modules is shown in Figure 5.1. The capacitors—C1, C2, . . . , Cn—in the different TCSC modules may have different values to provide a wider range of reactance control. The inductor in series with the anti parallel thyristors is split into two halves to protect the thyristor valves in case of inductor short circuits.

VI.VOLTAGE STABILITY INDEX.

Voltage stability and contingency analyses are two important procedures to be conducted especially, when voltage security assessment is discussed. Although voltage stability can be categorized in to two namely static and dynamic; however, static voltage stability analysis is commonly performed on a system and the results are indicative in determining the voltage stability condition of a system. Static voltage stability and contingency analyses are performed based on the line voltage stability index termed as NVSI. The mathematical formulation for the voltage stability index is derived by first obtaining the current equation through a line in a 2 bus system. Fig.6.1 illustrates the two-bus power system model.



By choosing the sending bus as the reference ($\delta_1 = 0, \delta_2 = \delta$) then the power equation at bus 2 is as follows;

$$S_2 = V_2 \times I \qquad (1)$$

The quantity of I given by;

$$I = \frac{V_1 \angle 0 - V_2 \angle \delta}{R + jX} \qquad (2)$$

Where V_1, V_2 are the voltages of the sending and receiving buses respectively. R, X are resistance and reactance of line respectively. With substituting equation (2) in equation (1) we can obtain these following equations;

$$V_1 V_2 \sin \delta - RQ_2 + XP_2 = 0 \qquad (3)$$

$$V_2^2 - V_1 V_2 \cos \delta + RP_2 + XQ_2 = 0 \qquad (4)$$

$$V_2 = \frac{V_1 \cos \delta \pm \sqrt{V_1^2 COS^2 \delta - 4(P_2 R + Q_2 X)}}{2} \qquad (5)$$

Where, P_1 ,Q_1 are the active and reactive power at the sending buses respectively. P_2 ,Q_2 are the active and reactive power at the receiving buses. d is angle difference between the sending and receiving buses.

To obtain real value for V_2 , the discriminate of equation (5) must be grater than or equal to zero. There for we can obtain this statement.

$$\frac{PR + QX}{0.25 V_1^2 \cos^2 \delta} \le 1 \qquad (6)$$

Since the difference in the angle between the sending bus and the receiving busd , is normally very small, therefore, $\cos \delta = 1$ .Taking the i as the sending bus and the j as the receiving bus, the novel line stability index (NLSI) can be expressed as,

$$LSI = \frac{R_{ij} P_j + X_{ij} Q_j}{0.25 V_i^2} \qquad (7)$$

Where, R_{ij} , X_{ij} are the resistance and reactance between sending and receiving buses. Q_j, P_j are the reactive and active power at receiving bus. V_i is voltage at sending bus.

Any line in the system that exhibits NLSI closed to unity indicates that the line is approaching its stability limit hence may lead to system violation. Therefore, NLSI has to be maintained less than unity in order to maintain a stable system. To comprise the other methods with describe index that discussed above.

VII.OPTIMAL LOCATION OF TCSC

1 Line Stability Index

The line stability index determines the critical line and the voltage collapse point of the system. And interconnected system the value of line index that closed to one indicates the line has reached its instability limit. The overall voltage stability of the system can be determined by the largest value of index. There are different types of voltage stability indexes. Here, we use line stability index (LSI). The line stability index considers both active and reactive power to determine voltage stability. This index gives more accurate results than other voltage stability indexes. For the security of the system voltage stability and contingency analysis both are important factors. In any power system the voltage stability analysis is done in two ways:

(a) Any voltage stability index that determines about how any system close to its instability Limit.

(b) which is the critical line or weak bus in a system. voltage stability and contingency analysis are based on this index. The mathematical formulation for line stability index is deduced from analysis of two-bus system model.

$$LSI = \frac{R_{ij} P_j + X_{ij} Q_j}{0.25V_i^2}$$

VIII. CONCLUSION

Power system operation faces new challenges due to deregulation and restructuring of the electric supply industry. Due to this, voltage instability and line overloading problems have become of great concern to power system operators.

To improve the voltage profile and voltage stability of a power system an alternative solution is to locate an appropriate Flexible AC transmission system (FACTS) device. FACTS devices are the solid state converters having capability of improving power transmission capacity, improving voltage profile, enhancing power system stability, minimizing transmission losses etc. In order to optimize and to obtain the maximum benefits from their use, the main issues to be considered are the type of FACTS devices, the settings of FACTS devices and optimal location of FACTS devices.

And this method is very useful compare to conventional method. Because its reduce the cost of that we reduce from placing facts at only most weakest line.

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