Optimal Placement of TCSC to Improve Voltage Stability Limit Considering Impacts on Setting Zones of Distance Protection Relays

Mohammed AMROUNE[1], Mohamed ZELLAGUI[2], Tarek BOUKTIR[1], Abdelaziz CHAGHI[2]

[1]Faculty of Technology, University of Sétif 1, Algeria
[2]Faculty of Technology, University of Batna, Algeria

Abstract *: Voltage stability problems have been responsible for several major blackouts that have been experienced in many countries. Reactive power limit of power system is one of the major causes of voltage instability. Power system can be adapted to improve voltage stability by adding reactive power sources such as shunt capacitors or Flexible AC Transmission System (FACTS) devices at the appropriate locations. FACTS devices are very effective solution to prevent voltage instability due to their fast and very flexible control. Thyristor Controlled Series Capacitor (TCSC) is one of the most important FACTS devices which are connected to power system. TCSC has some important advantages; it can increase the transmission capability and reduce the active and reactive power loss. However, the insertion of TCSC in transmission line could affect the performance of the distance relay, by affecting the total impedance of a protected transmission line and settings relays. In this paper, the best placement for reactive power compensation with TCSC device to improve voltage stability margin is identified with respect to the impact of this device on distance relay settings. The simulation results are performed in MATLAB software. The study has been carried out on the IEEE 14-bus IEEE 30-bus test system.*

Keywords*: Optimal Placement, Voltage Stability, Fast Voltage Stability Index (FVSI), TCSC, Distance Protection, Settings Zones.*

1. INTRODUCTION

The operation of power systems closer to their load limits is dictated by the needs of deregulated electricity markets. However, as a result, several blackouts have occurred due to voltage instability [1]. According to the IEEE Power System Engineering Committee, voltage stability is being defined in the following way: “Voltage stability is the ability of a system to maintain voltage so that when load admittance is increased, load power will increase, and so that both power and voltage are controllable” [2]. The only way to save the system from voltage collapse is to reduce the reactive power load or add additional reactive power prior to reaching the point of voltage collapse. Introducing the sources of reactive power such as shunt capacitors and/or Flexible AC Transmission System (FACTS) controllers at the suitable location is the most effective technique for utilities to improve voltage stability of the system. FACTS make up a family of high power devices that are applied in power systems in shunt and/or in series. FACTS solutions are particularly justifiable in applications requiring rapid dynamic response, ability for frequent variations in output, and/or smoothly adjustable output. Under such conditions, FACTS is a highly useful option for enabling or improving the utilization of power systems [3]. The potential benefits offered by these controllers are reduced cost of operation, increased reliability of power system and improvement of voltage stability. FACTS are also applied to improve the performance of the power system under transient stability conditions [4], [5].

One of the most important FACTS devices which are connected to system in series is the Thyristor Controlled Series Capacitor (TCSC). TCSC has some important advantages on the system; it can be used to increase power transmission capability and to reduce the power system losses and also it can regulate the voltage levels by changing the firing angle of thyristors. Many works in the literatures has discussed the use of TCSC

---

for voltage stability enhancement. Most of these studies are based on the placement of this device in suitable placement for more improvement of voltage stability margins. So far no work has been reported in open literature for the best placement of TCSC taking in consideration the impact of this device on distance relay setting.

In the presence of series FACTS devices, the conventional distance relay characteristics such as MHO (or admittance) and quadrilateral are greatly subjected to mal-operation in the form of overreaching or under-reaching the fault point [6], [7]. Therefore, the conventional relay characteristics may not work properly in the presence of FACTS device. The effect of compensator TCSC on distance protection of transmission lines has been reported considering the influence of TCSC on the transmission lines protection. Reference [8] and [9] show the variation of the tripping characteristic of the distance relay for different installation points and control parameter of the TCSC. Impact of TCSC on impedance measured (Z_{seen}) by Distance Relay on 400 kV single transmission line in presence of earth fault is investigated in [10]. The Z_{seen} in the presence of inter phase faults with TCSC on a double transmission line is being studied in [11] and in [12] .The variation of Z_{seen} in the presence inter phase faults in presence of TCSC on adjacent transmission line by considering Metal Oxide Varistor (MOV) operation is also investigated in [12] . Impact of TCSC settings zones of distance protection on single transmission line is studied in [13].

In this paper, the best placement for reactive power compensation with TCSC device to improve voltage stability margin is identified with respect to the impact of this device on distance relay setting. The Fast Voltage Stability Index (FVSI) is used to identify the most suitable placement for TCSC device. The study has been carried out on the IEEE 30-bus test system.

2. VOLTAGE STABILY INDICATOR FORMULATION

Voltage stability indices are vital tools for estimating the proximity of a given operating point to voltage instability. Fast voltage stability indices can be successfully applied to online voltage stability assessment. The objective of the voltage stability indices is to quantify how near a particular operating point is to the static voltage stability limit. There are many indices currently in use to help in the analysis of static voltage stability. Some of them are Line Stability Factor [14], Maximum Loading Margin Index (MLM) [15], load proximity index [16], [17], impedance index [18], Fast Voltage Stability Index (FVSI) [19], Line stability index [20]. The results from this study could also identify the weak buses or lines in power system network.

In this work the Fast Voltage Stability Indicator proposed by Rahman [19] is used for stability assessment. This index is basically used to indicate maximum load-ability in a power system as well as to identify the weakest buses and/or lines. Identification of weakest bus or line is used to identify the best location for reactive power compensation for the improvement of static voltage stability margin. The FVSI can be calculated for any of the lines in the network and depends, essentially on reactive power. The value of FVSI that is closed to the unity indicates that the respective line is closed to its stability limit. Figure 1 illustrates a single line of interconnected network where the FVSI is derived from.

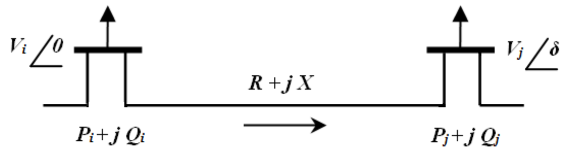


Fig. 1. Model of simple branch for voltage stability research.

By taking the sending bus (bus i) as the reference, the voltage of receiving end V_j can be calculated by [21]:

$$V_j^2 - \left(\frac{R}{X}\sin\delta + \cos\delta\right)V_i.V_j + \left(X + \frac{R^2}{X}\right)Q_j = 0 \quad (1)$$

In equation (1), the condition for obtaining the real roots of V_j is that the discriminate must be set greater than or equal to 0, i.e.:

$$\frac{4Z^2 Q_j X}{V_i^2\left(R\sin\delta + X\cos\delta\right)} \le 1 \quad (2)$$

Considering the angle difference δ very small, i.e. $0 \approx \delta$, the index is formulated as:

$$FVSI = \frac{4Z^2 Q_j}{V_i^2 X} \le 1 \quad (3)$$

Where: Z is the line impedance, X is the line reactance, V_i is the voltage at the sending end and Q_j is the reactive power at the receiving end.

3. TCSC MODELING AND OPERATION

Thyristor Controlled Series Capacitors (TCSC) is a type of series compensator which can provide many benefits for a power system such as controlling power flow in the line, damping power oscillations, reducing losses, and improving voltage stability.

Figure 2 shows a schematic representation of a TCSC. It consists of a capacitance (C) connected in parallel with an inductance (L) controlled by a valve mounted in anti-parallel thyristors conventional (T_1 and T_2) and controlled by an extinction angle (α) varied between 90° and 180°.

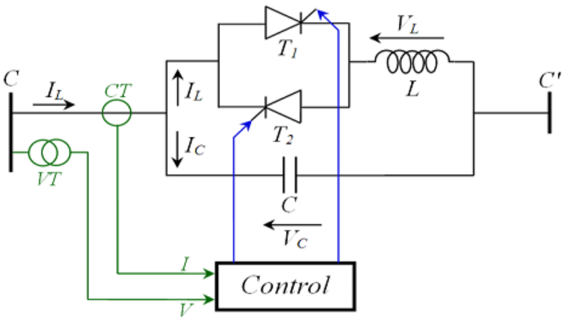


Fig. 2. Transmission line with TCSC controller.

The principle of TCSC is to control the transmission line impedance by adjusting the TCSC reactance (X_{TCSC}). The equivalent reactance of TCSC is a function of the firing angle (α). The curve of X_{TCSC} as a function of firing angle is divided into three different regions which are inductive, capacitive and resonance as shows in Figure 3.

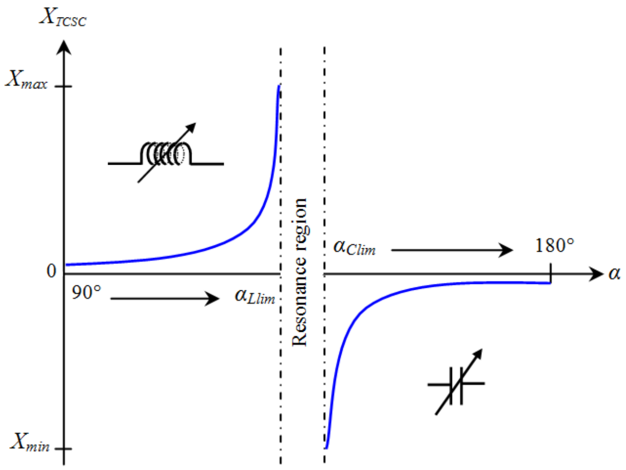


Fig. 3. Characteristic curve XTCSC = f (α).

In the steady-state, relationship between the firing angle α and the reactance X_{TCSC} can be described by the following equation [22]:

$$X_{TCSC}(\alpha)=\frac{X_C X_l(\alpha)}{X_l(\alpha)-X_C} \tag{4}$$

Where,

$$X_l(\alpha)=X_L\frac{\pi}{\pi-2\alpha-\sin\alpha} \quad \text{and,} \quad X_L=\omega L \tag{5}$$

Where, α is the firing angle, X_L is the reactance of the inductor and X_l is the effective reactance of the inductor at firing angle. A TCSC used for line reactance compensation in the transmission line between buses i and j is shown in figure 4.

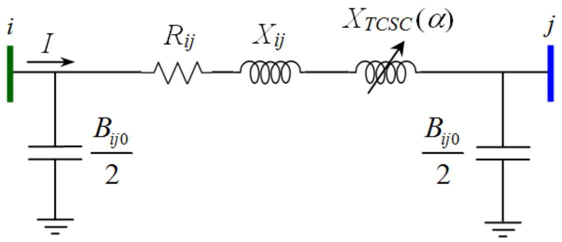


Fig. 4. Transmission Line with TCSC.

The effective series transmission impedance is given by:

$$X_{eff}=(1-K)X_{ij} \tag{6}$$

Where, K is the degree of series compensation.

$$K=\frac{X_{TCSC}(\alpha)}{X_{ij}} \quad \text{Where, } (0<K<1) \tag{7}$$

Practically up to 70% of series compensation is chosen for line reactance compensation [23] in order to avoid series resonance in transmission line. Choosing K, 100% compensation should not be provided.

4. DISTANCE PROTECTION RELAY PRINCIPAL AND SETTING ZONES

Since the impedance of a transmission line (Z_{ij}) is proportional to its length, for distance measurement it is appropriate to use a relay capable of measuring the impedance of a line up to a predetermined point (the reach point). Such a relay is described as a distance relay and is designed to operate only for faults occurring between the relay location and the selected reach point thus giving discrimination for faults that may occur in different line sections [24-26]. The basic principle of distance protection involves the division of the voltage at the relaying point by the measured current. Apparent impedance so calculated is compared with the reach point impedance. If the measured impedance is less than the reach point impedance, it is assumed that a fault exists on the line between the relay and the reach point as shown in Figure 5.

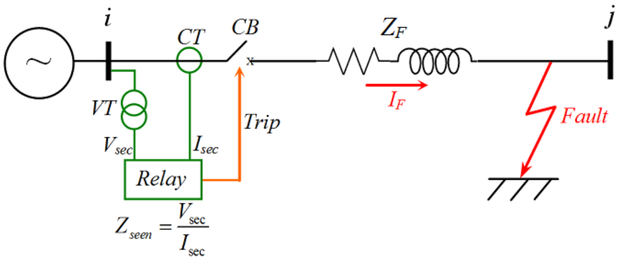


Fig. 5. Principle operation for distance protection.

4.1. Selectivity Protection

Time selectivity protection is given by the staggered trip time depending on the distance between measurement point and the fault [25, 27]. Following the setting philosophy of the distance protection in Sonelgaz group, three zones (Z_1, Z_2 and Z_3) are considered [28]: The first zone covers about 80% of the protected transmission line (Z_{ij}) and trips the circuit breaker in t_1. The second zone extends to 100% of the protected line *ij* and 20% of the adjacent line (Z_{jk}) and trips circuit breaker in the t_2 while the third zone extends to 100% of the protected line + 40% of the adjacent line and trips the circuit breaker in the t_3 as indicated in Figure 6.

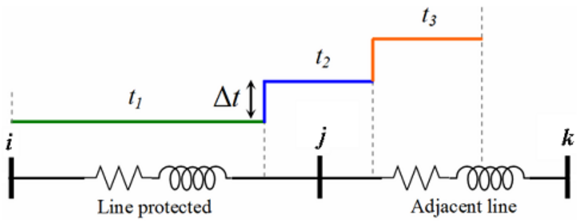


Fig. 6. Selectivity of distance protection.

4.2. Setting Zones

Line impedances are proportional to the line lengths (*l*) and this property is used to calculate the distance from the relay location to the fault. The relay, however, is fed with the current and voltage measured signals from the primary system via current transformers (CT) and voltage transformers (VT). Therefore, the secondary measured value by relay is used for the setting and is obtained by the following expression:

$$Z_{relay} = Z_{ij} \times l = \left[\left(R_{ij} + jX_{ij}\right) \times l\right] \times \left(\frac{k_{VT}}{k_{CT}}\right) \qquad (8)$$

Where,

$$k_{CT} = \frac{I_{pri}}{I_{\sec}} \quad \text{and} \quad k_{VT} = \frac{V_{pri}}{V_{\sec}} \qquad (9)$$

The setting zones for protected transmission line between bus *i* and *j* without TCSC are [27, 28]:

$$Z_1 = R_1 + jX_1 = 80\% Z_{ij} = 0,8 \times \left(R_{ij} + jX_{ij}\right) \quad (10)$$

$$Z_2 = R_2 + jX_2 = R_{ij} + jX_{ij} + 0,2 \times \left(R_{jk} + jX_{jk}\right) \quad (11)$$

$$Z_3 = R_3 + jX_3 = R_{ij} + jX_{ij} + 0,4 \times \left(R_{jk} + jX_{jk}\right) \quad (12)$$

Where, Z_{ij} and Z_{ik} is real total impedance of line *ij* and *jk* respectively. K_{VT} and K_{CT} is ratio of voltage and current respectively. The characteristic curves *X* (*R*) for MHO distance relay are represented in Figure 7.

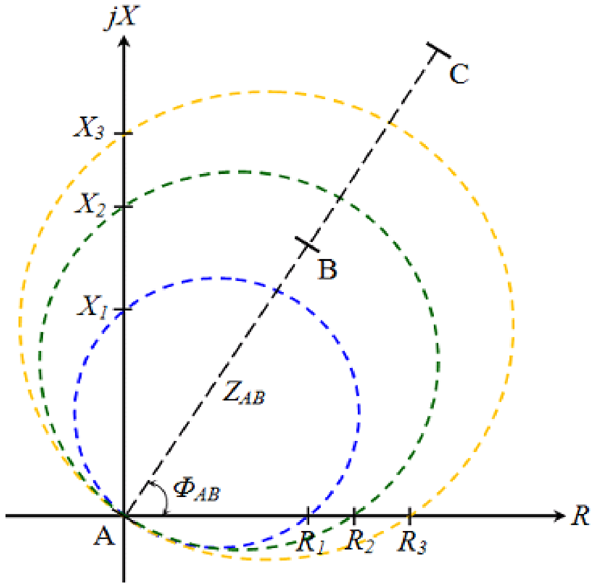


Fig. 7. Characteristic curves of MHO distance relay

The presence of TCSC systems with its reactor (X_{TCSC}) has a direct influence on the total impedance of the protected line (Z_{ij}), especially on the reactance X_{ij} and no influence on the resistance R_{ij}. The new setting zones for a protected transmission line with TCSC connected at midline are:

$$Z_1 = R_1 + jX_1 = 0,8 \times \left[R_{ij} + jX_{ij} + jX_{TCSC}(\alpha)\right] \quad (13)$$

$$Z_2 = \left[R_{ij} + jX_{ij} + jX_{TCSC}(\alpha)\right] + 0,2 \times \left(R_{jk} + jX_{jk}\right)$$
(14)

$$Z_3 = \left[R_{ij} + jX_{ij} + X_{TCSC}(\alpha)\right] + 0,4 \times \left(R_{jk} + jX_{jk}\right) \quad (15)$$

5. CASE STUDY, SIMULATION RESULTS AND DISCUSSION

The first case study simulation work conducted on the IEEE 14-bus test system is shown in figure 8. It consist five synchronous machines, three of which are synchronous compensators used only for reactive power support, 7 loads, 3 winding transformers, 20 lines and 40 distance relays. The line parameters and loads are taken from [29].

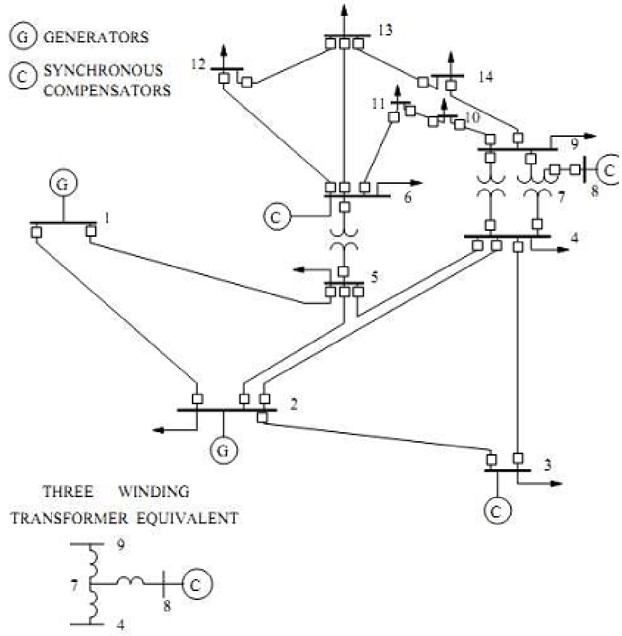


Fig. 8. Single line diagram of the IEEE 14-bus system

The second case study simulation work conducted on the IEEE 30-bus test system is shown in figure 9. It consists of six generators (bus 1 is a slack, buses 2, 5, 8, 11 and 13 are PV buses), 24 loads, 41 lines, 4 power transformers and 82 distance relays. The line parameters and loads are taken from [30].

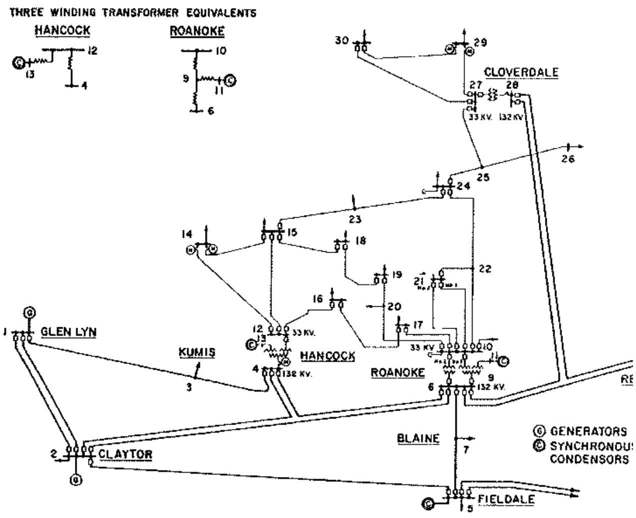


Fig. 9. Single line diagram of the IEEE 30-bus system

For two transmission networks study, the simulation results have been obtained by using MATLAB software package.

5.1. Identification of Best Placement for TCSC Considering Voltage Stability Improvement

The ideal location for Series compensation is still under investigation. However, a commonly used method is by placing the series compensator one at a time in the lines between weakest buses (weakest line).

Figures 10 and 11 give the maximum reactive power margin at different buses in IEEE 14-bus and IEEE 30-bus test systems with respecting of generators reactive power limits. Busbars 4, 5 and 14 in IEEE 14-bus system and busbars 26, 29 and 30 in IEEE 30-bus system have the lowest margin of reactive power. This indicates that these are the most critical buses in the system.

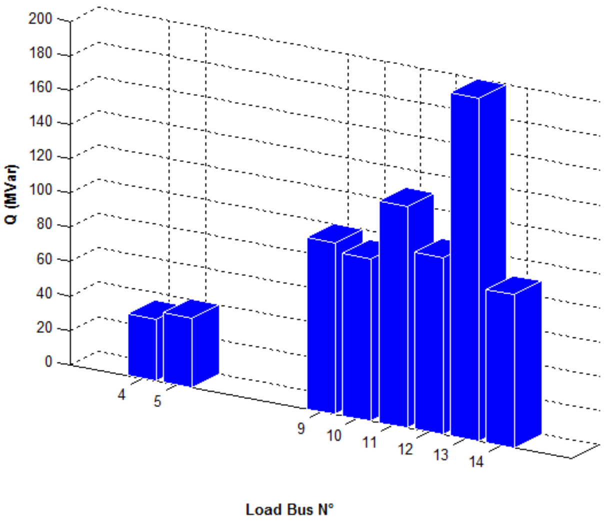


Fig. 10. Reactive power margin in IEEE 14-bus test system

The margin of reactive power of load buses for IEEE 30 bus is given in Figure 11. It shows that buses 26, 29 and 30 have the lowest margin of reactive power and lines 25-26, 27-30, 27-29 have the highest values of FVSI. These buses and lines are considered as the best placement to provide desired reactive power support. To outline the most critical line the reactive power demand (*Q*) in the test system was increased gradually at the following observed busses (buses 26, 29 and 30).

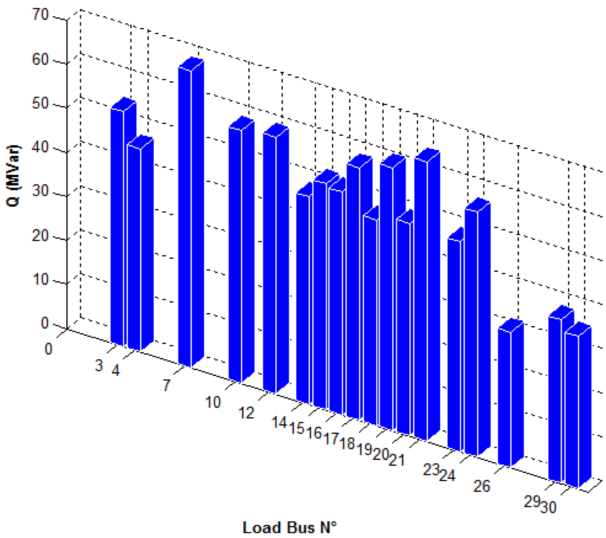


Fig. 11. Reactive power margin in IEEE 30-bus test system

To define the weakest line for placement of TCSC device, the Fast Voltage Stability Index (FVSI) of lines between most critical buses in the two transmission networks is computed, the results are recorded in Figures 12 and 13.

Figure 12 gives the idea of most critical line in the IEEE 14 bus system with reactive power demand increases at bus 4, 5 and 14 separately. The line connected between buses 4 and 7 is most critical line with respect to bus 4. Bus 4 is ranked the highest with maximum loadability Q_{max} equal to 36.1 MVar indicating that this bus sustains the lowest load.

Figure 13 gives the idea of most critical line in the IEEE 30 bus system with reactive power demand increases at bus 26, 29 and 30 separately. The line connected between buses 25 and 26 is most critical with variation in reactive power loading at bus 26 as its FVSI value is close to 1.

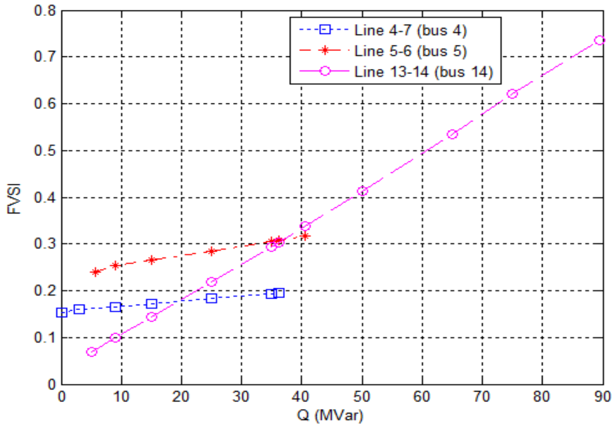


Fig. 12. FVSI profiles computed with load vary at bus 4, 5 and 14 in IEEE 14-bus system

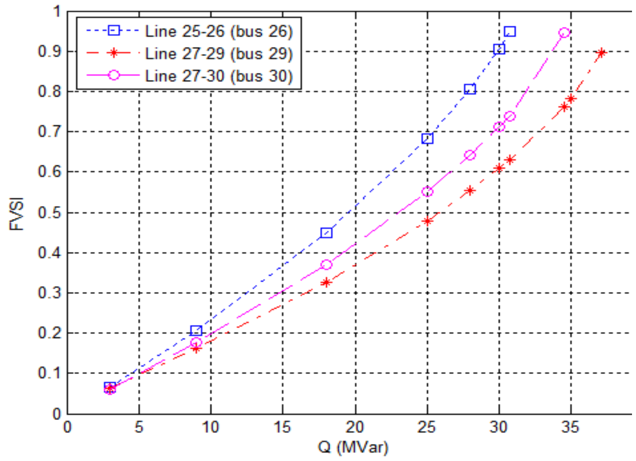


Fig. 13. FVSI profiles computed with load vary at bus 26, 29 and 30 in IEEE 30-bus system

The results for lines ranking are tabulated in Table I. It is clear from the Table that the first three suitable placements for TCSC to improve voltage stability are found to be the lines between buses (4 – 7), (5 – 6) and (13 – 14) in the IEEE-14 bus system and lines between buses (25 – 26), (27 – 30), (27 – 29) in the IEEE 30-bus system with this arrangement.

Table I. The highest ranked lines according to FVSI for two case studies

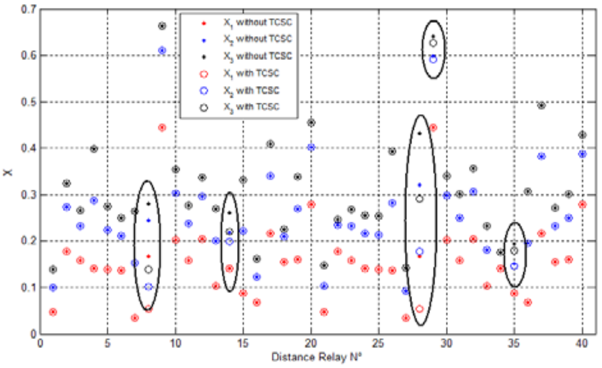
Rank	**Lines**	**Q_{Max} (MVar)**	**FVSI**
IEEE 14-Bus			
1	4 - 7	36,1	0,195
2	5 - 6	40,6	0,317
3	13 - 14	89,5	0,753
IEEE 30-Bus			
1	25 - 26	30,7	0,947
2	27 - 30	34,5	0,945
3	27 - 29	37,1	0,894

5.2. Identification of Best Placement for TCSC Considering Settings Distance Relays

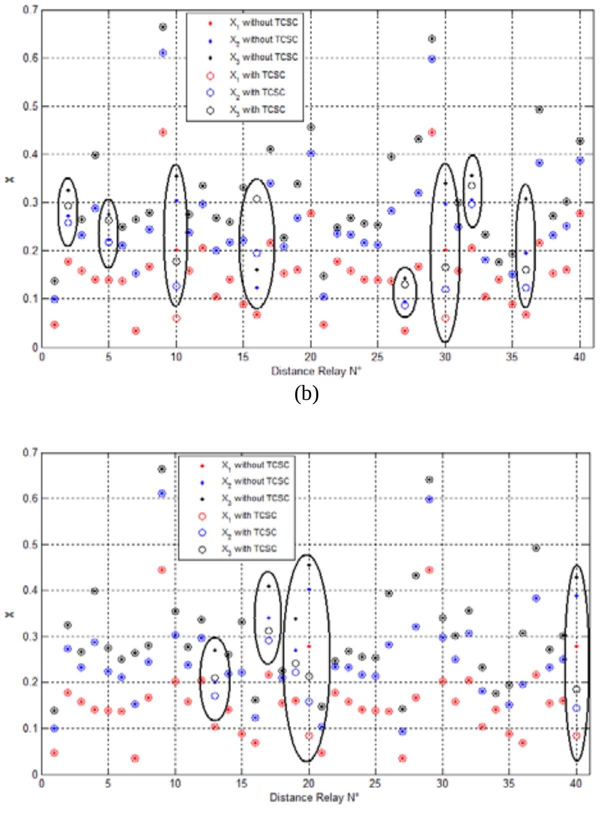
In first case study (IEEE 14 bus), as can be seen from the results above that the first three suitable placements for TCSC to improve voltage stability are the lines between buses (4 – 7), (5 – 6) and (13 – 14) with this arrangement. In second case study (IEEE 30 bus), as can be seen from the results above that the first three suitable placements for TCSC to improve voltage stability are the lines between buses (25 – 26), (27 – 30) and (27 – 29) with this arrangement.

The man objective of this sub-section is to identify the suitable placements for TCSC with respect to the impact of this device on distance relay setting. For this reason, a TCSC with a compensation level of 70% can be connected in the weakest lines previously mentioned.

Figures 14 and 15 shows the impact of the different placements of TCSC (at three lines) on IEEE 14 and IEEE 30 bus transmission systems respectively, on the three settings zones reactance (X_1, X_2 and X_3) of distance relays.



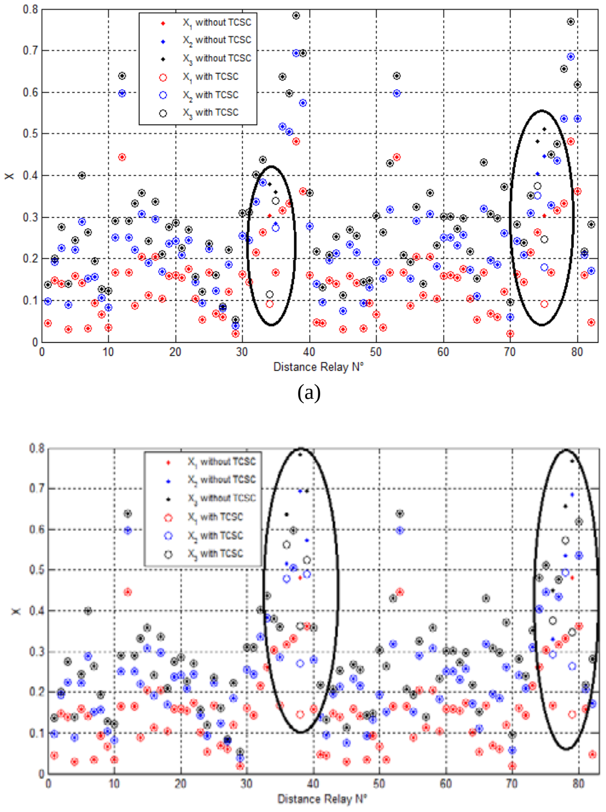
(a)



(b)

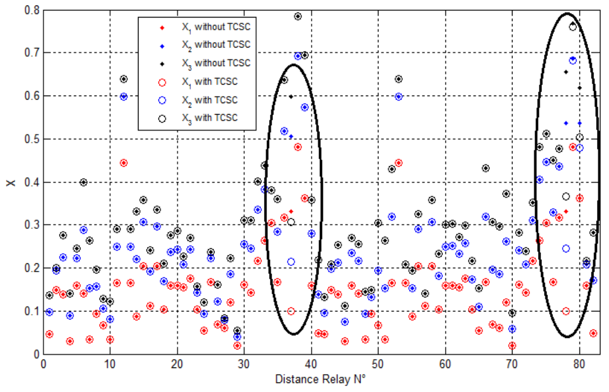
(c)

Fig. 14. Settings reactance zones for different placement of TCSC for 14 buses
a). Line (4-7), b). Line (5-6), c). Line (13-14)



(a)

(b)



(c)

Fig. 15. Settings reactance zones for different placement of TCSC for 30 buses
a). Line (25-26), b). Line (27-30), c). Line (27-29)

From Figures 11 and 12, the presence of TCSC with its apparent reactance has a direct influence on the settings zones for distance relays especially on the setting reactance and no influence on the setting resistance.

The best location of TCSC with respecting the number of changed distance relays for two case studies is represented in table II.

Table II. Impact of TCSC placement on number of changed distance protection relays

Rank	Lines	Relays Changed	Number of Relays
IEEE 14 bus			
1	4 - 7	8, 14, 28, 29, 35	5
2	13 - 14	13, 17, 19, 20, 40	5
3	5 - 6	2, 5, 16, 27, 30, 32, 36	7
IEEE 30 bus			
1	27 - 29	37, 78, 79, 80	4
2	25 - 26	33, 34, 35, 74, 75	5
3	27 - 30	36, 38, 39, 76, 78, 79	6

From the Table II, the best location of TCSC in first case for voltage stability limit enhancement with considering settings zones of distance relays (number of distance relays changed) are the lines between busses (4 – 7), (13 – 14) and (5 – 6) with this arrangement. In the second case, the best placement of TCSC are the lines between busses (27 – 29), (25 – 26) and (27 – 30).

6. CONCLUSION

The basic principle governing the operation of a distance relay is the measured impedance of the faulty line between the relay placement and the point of fault occurrence. Then the measured impedance is compared to the set impedance. However, this impedance may be affected by the insertion of TCSC.

In this paper, the suitable placement of series FACTS device i.e. TCSC for voltage stability limit enhancement considering its impact on setting zones of distance relays is studied. Fast Voltage Stability Index (FVSI) is used for identifying the best placement for TCSC device by identifying the weakest lines in the system.

The result indicated that the placement of TCSC cannot be only determined by voltage stability indexes but it is important to consider both voltage stability improvement and the different effects on distance relays specially setting zones (resistance and reactance) for reduce the number of changed distance relays.

REFERENCES

1. P. Kundur, “Definition and Classification of Power System Stability”, IEEE/CIGRE, Joint Task Force on Stability Terms and Definitions, IEEE Transaciosn on Power Systems, Vol. 19, No. 3, pp. 1387-1401, 2004.
2. A. Wiszniewski, “New Criteria of Voltage Stability Margin for the Purpose of Load Shedding”, IEEE Transactions on Power Delivery, Vol. 22, No. 3, pp. 1367-1371, July 2007.
3. R. Grünbaum, M. Noroozian, and B. Thorvaldsson, “FACTS: Solutions to Power Flow Control and Stability Problems”, ABB Review, Vol. 5, september 1999.
4. A. Hernandez, M.A. Rodriguez, E. Torres, and P. Eguia, “A Review and Comparison of FACTS Optimal Placement for Solving Transmission System Issues”, Renewable Energy and Power Quality Journal, No.11, March 2013.
5. M. Amroune, A. Bourzami, and T. Bouktir, “Improvement of Transient Stability Margin in Power Systems with Integrated Wind Generation Using the SVC”, 13th International Conference on Sciences and Techniques of Automatic Control & Computer Engineering (STA), Monastir, Tunisia, December 17-19, 2012,
6. P.K. Dash, A.K. Pradhan, G. Panda, and A.C. Liew, “Digital Protection of Power Transmission Lines in the Presence of Series Connected FACTS Devices”, IEEE/PES Summer Meeting, Washington - USA, 19 July, 2000.
7. P.K. Dash, A.K. Pradhan, and G. Panda, “Apparent Impedance Calculations for Distance Protected Transmission Lines Employing Series-Connected FACTS Devices”, Electric Power Components and Systems, Vol. 29, No. 7, pp. 577-595, 2001.
8. M. Khederzadeh, and T.S. Sidhu, “Impact of TCSC on the Protection of Transmission Lines”, IEEE Transactions on Power Delivery, Vol. 21, No.1, pp. 80-87, 2006.
9. S. Jamali, and H. Shateri, “Effect of TCSC on Distance Relay Tripping Characteristic”, 39th International Universities Power Engineering Conference, (UPEC), Bristol - UK, 6-8 September, 2004.
10. M. Zellagui, and A. Chaghi, “Impact of TCSC on Measured Impedance by MHO Distance Relay on 400 kV Algerian Transmission Line in Presence of Phase to Earth Fault”, Journal of Electrical Systems (JES), Vol. 8, No. 3, pp. 273-291, September 2012.
11. S. Jamali, A. Kazemi, and H. Shateri, “Measured Impedance for Inter Phase Faults in Presence of TCSC Considering MOV Operation", IEEE Canada Electric Power Conference (EPEC), Vancouver - Canada, 6-7 October, 2008.
12. S. Jamali, A. Kazemi, and H. Shateri, “Measured Impedance by Distance Relay for Inter Phase Faults with TCSC on a Double Circuit Line”, 18th Australasian Universities Power Engineering Conference (AUPEC), Sydney - Australia,14-17 December, 2008.
13. M. Zellagui, and A. Chaghi, "A Comparative Study of Impact Series FACTS Devices on Distance Relay Setting in 400 kV Transmission Line”, Journal of Electrical and Electronics Engineering (JEEE), Vol. 5, No. 2, pp. 111-116, October 2012.
14. A. Mohamed, and G.B. Jasmon, "Voltage Contingency Selection Technique for Security Assessment”, IEE Proceedings C : Generation, Transmission and Distribution, Vol. 136, No.1, pp. 24-28, Jan. 1989.
15. A.Sode-Yome, N. Mithulananthan, and K.Y. Lee, “A Maximum Loading Margin Method for Static Voltage Stability in Power Systems”, IEEE Transactions on Power Systems, Vol. 21, No. 2, pp. 799-808, 2006.
16. T. Nagao, K. Tanaka and K. Takenaka, “Development of Static and Simulation Programs for Voltage Stability Studies of Bulk Power System”, IEEE Transactions on Power Systems, Vol. 12, No. 1, pp. 273-281, 1997.
17. K. Lba, H. Suzuki, M. Egawa, and T. Watanabe, “Calculation of Critical Loading Condition with Nose Curve using Homotopy Continuation Method”, IEEE Transactions on Power Systems, Vol. 6, No. 2, pp. 584-593, 1991.
18. Liu Zhuo. “The Impedance Analyses of Heavy Load Node in Voltage Stability Studies”, Proceedings of the CSEE, Vol. 20, pp. 35-39, April 2000.
19. I. Musirin, and T.K.A. Rahman, “Estimating Maximum Loadability for Weak Bus Identification Using FVSI”, IEEE Power Engineering Review, Vol. 22, No. 11, pp. 50-52, 2002.
20. M. Moghavvenni, M.Faruque, “Estimation of Voltage Collapse From Local Measurement of Line Power Flow and Bus Voltages”, International Conference on Electrical Power Engineering (ICEPE), Budapest - Hongary, February 1999.
21. B.Gao, G.K.Morison, and P.Kundur, “Voltage Stability Evaluation Using Modal Analysis”, IEEE Transactions on Power Systems, Vol. 7, No.4, pp. 1529-1542, 1992.
22. C. Schaffner and G. Andersson, “Performance of a TCSC for Congestion Relief”, Conference on Power Technology, St. Petersburg, Rusia, 23-27 June, 2005.
23. S. Meikandasivam, R.K. Nema, and S.K. Jain, “Selection of TCSC Parameters: Capacitor and Inductor”, International Conference on Power Electronics (IICPE), India, 28-30 January 2011.
24. K.S. Sundar, and H.M. Ravikumar, “Selection of TCSC Location for Secured Optimal Power Flow under Normal and Network Contingencies”, International Journal of Electrical Power and Energy Systems, Vol. 34, No.1, pp. 29-37, 2012.
25. G. Zigler, “Numerical Distance Protection - Principles and Applications”, Third Edition, published by Publics Corporate Publishing, Germany, June 2008.
26. J.L. Blackburn, and T.J. Domin, “Protective Relaying: Principles and Applications”, Third Edition, Published by CRC Press and Taylor & Francis Group, USA, January, 2006.
27. M. Zellagui, and A. Chaghi, “Distance Protection for Electrical Transmission Line: Equipments, Settings Zones and Tele-Protection”, published by LAP Publishing, Germany, June 2012.
28. N. Manamani, “Principles and Settings of Distance Relay”, Group Sonelgaz, Training at GRTE Sétif, Algeria, June, 2009.
29. N. Mithulananthan, C. A. Canizares, and J. Reeve. “Indices to Detect Hopf Bifurcation in Power Systems”. In Proc. of NAPS-2000, pp. 15–18–15–23, October 2000.
30. E. De Tuglie, S.M. Iannone, and F. Torelli, “A Coherency based Method to Increase Dynamic Security in Power Systems”, Electric Power Systems Research, Vol. 78, No. 8, pp.1425-1436, 2008.

Mr. Mohammed AMROUNE
Pr. Tarek BOUKTIR

Department of Electrical Engineering,
Faculty of Technology, University of Sétif 1, Algeria
E-mail : amrounemohammed@yahoo.fr
tarek.bouktir@esrgroups.org

Mr. Mohamed ZELLAGUI
Pr. Abdelaziz CHAGHI

LSP-IE Laboratory, Department of Electrical Engineering,
Faculty of Technology, University of Batna, Algeria
E-mail : m.zellagui@ymail.com
az_chaghi@univ-batna.dz

Mohammed AMROUNE was born in Setif, Algeria in 1982. He has a B.S degree and a MSc degree in Electrical Engineering (Power Systems) from University of Setif 1, Algeria. Currently, he is pursuing Doctoral Degree in Electrical Engineering (Power Systems) at University of Setif 1, Algeria. His areas of interest are the power system stability, power system optimization, FACTS controllers and smart grids.

Traek BOUKTIR, was born in Ras El-Oued, Algeria in 1971. He received the B.S degree in Electrical Engineering Power system from Setif University (Algeria) in 1994, his MSc degree from Annaba University in 1998, his PhD degree in power system from Batna University (Algeria) in 2003. He is the Editor-In-Chief of Journal of Electrical Systems (Algeria), the Co-Editor of Journal of Automation & Systems Engineering (Algeria). He currently serves on the editorial boards of the Journals: Leonardo Electronic Journal of Practices (Romania) and Technologies, Leonardo Journal of Sciences (Romania), WSEAS Transactions on Power Systems (Greece) and Telkomnika indonesian journal of electrical engineering, Indonesia. He serves as reviewer with the Journals: Journal IEEE Transactions on SYSTEMS, MAN, AND CYBERNETICS, IEEE Transactions on Power Systems (USA), ETEP - European Transactions on Electrical Power Engineering, Journal of Zhejiang University SCIENCE (JZUS), China. He is with the Department of Electrical Engineering in Setif 1 University, ALGERIA. He currently serves as President of the Scientific Council of the department of Electrical Engineering and also a member of the Board of the University of setif 1. He is also the responsible of the research team "SMART GRID". His areas of interest are the application of the meta-heuristic methods in optimal power flow, FACTS control and improvement in electric power systems, Multi-Objective Optimization for power systems, FACTS devices, voltage stability and security Analysis.

Mohamed ZELLAGUI was born in Constantine, Algeria, 1984. He received the engineer (Honors with first class) and MS degree in Electrical Engineering (Power System) from department of Electrical Engineering at University of Constantine, Algeria in 2007 and 2010 respectively, PhD student and member LSP-IE research laboratory from department of Electrical Engineering at Batna University, Algeria. Membership at International Association of Engineers (IAENG), and Institution of Engineering and Technology (IET), Senior Member of Universal Association of Computer and Electronics Engineers (UACEE) and International Scientific Academy of Engineering & Technology (ISAET), obtained the national award for best PhD student (science and technology) in the year 2012. He serves as reviewer with the Journals: Journal of Electrical Systems (JES), Electric Power Components and Systems (EPCS), Canadian Journal of Electrical and Computer Engineering (CJECE). His areas of interest include electrical networks, power system protection, distance relay, renewable energy, and FACTS devices.

Abdelaziz CHAGHI was born in Batna, Algeria, 1954. He received his engineer degree from the University of Oran, Algeria 1980, and MS from the Manchester University, England 1984, and received his PhD from Batna University, Algeria 2004. He is currently a Professor at department of electrical engineering. He is also the responsible of the research team at LSP-IE research laboratory, University of Batna. Pr. Chaghi has published more than 50 papers in reputable journals and international conferences. His areas of interest include power systems optimization, protection, harmonic and power quality, voltage stability and FACTS devices.