



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)

Volume 4, Issue 3, May 2015

Performance Analysis of an IEEE 9-Bus System with TCSC and SSSC

Janhavi C G, K L Ratnakar

Abstract— Electrical power systems are widely interconnected inside utilities own territories which extend to inter – utility and then to inter – regional & international connections. Interconnection aids reduction in cost of electricity & improves reliability. Flexible AC transmission systems (FACTS) technology opens up new opportunities for controlling power & enhancing the usable capacity of present, as well as new and upgraded lines. FACTS controllers can enable to carry power closer to its thermal rating. Relatively recent development & the use of FACTS controllers in power transmission systems have led to many applications of these controllers to improve the power systems stability. Thyristor Controlled Series capacitor (TCSC) and Static Synchronous Series Compensator (SSSC) are the emerging FACTS devices designated to achieve this objective. In this regard, location of FACTS device is an important factor in reducing the loss & enhancing the system performance. This paper is aimed at conducting performance analysis of series FACTS devices. Use of Thyristor Controlled Series Capacitor (TCSC) and Static Synchronous Series Compensator (SSSC) as Flexible AC Transmission System (FACTS) device brings a number benefits for the user off the grid all contributing to an increase of the power transmission lines. These benefits include improvement in system stability, voltage regulation, reactive power balance, load sharing between parallel lines and reduction in transmission losses.

Index Terms— FACTS, TCSC, SSSC, SVC, Voltage regulation, Reactive power balance.

I. INTRODUCTION

The inherent power system restricts the power transaction which leads to under utilization of the existing transmission resources traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to solve much of the problems [4].

However, there are restrictions as to the use of these conventional devices. Desired performance was not being able to achieve effectively. Wear and tear in the mechanical components and slow response were the heart of the problems. There was a greater need for the alternative technology made of the solid devices with fast response characteristics. The need was further fueled by worldwide restructuring of electric utilities , increasing environmental and efficiency regulations and difficulty in getting permit and right of way for the construction of overhead transmission lines .This together with the invention of Thyristor Switch (semi conductor device), opened the door for the development of power electronic devices known as FACTS controller. The path from historical Thyristor based FACTS controller to modern state of the art voltage source converter based FACTS controllers was made possible due to rapid advance in high power semiconductor devices Flexible AC Transmission System (FACTS) controllers has been in use in utilities around the world since 1970's when the first utility demonstration of first formality of FACTS named as SVC was accomplished. The series devices like Thyristor Controlled Series Capacitor (TCSC) and Static Synchronous Series Compensator (SSSC) belongs to second generation of FACTS devices.

II. MODELLING OF TCSC AND SSSC

A. TCSC

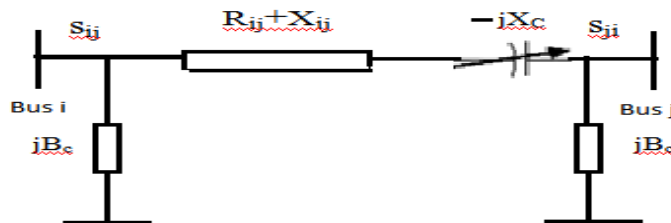


Fig 1 Model of TCSC

The transmission line model with a TCSC connected between the two buses i and j is shown in fig 2.1 equivalent pi model is used to represent the transmission line[6]. TCSC can be considered as a static reactance of magnitude equivalent to $-jx_c$. The controllable reactance x_c is directly used a control variable to be implied in the power flow equations.

The following equations are used to model TCSC. Let the voltages at bus i and j are represented as $V_i \angle \delta_i$ and $V_j \angle \delta_j$. The complex power from i and j is given by

$$S_{ij}^* = P_{ij} - jQ_{ij} = V_i^* I_{ij} \tag{1}$$

$$= V_i^* [(V_i - V_j) Y_{ij} + V_i (jB_c)]$$

$$= V_i^* [(G_{ij} + j(B_{ij} + B_c)) - V_i^* V_j (G_{ij} + jB_{ij})]$$

$$G_{ij} + jB_{ij} = 1 / (R_L + jX_L - jX_C) \tag{2}$$

Where

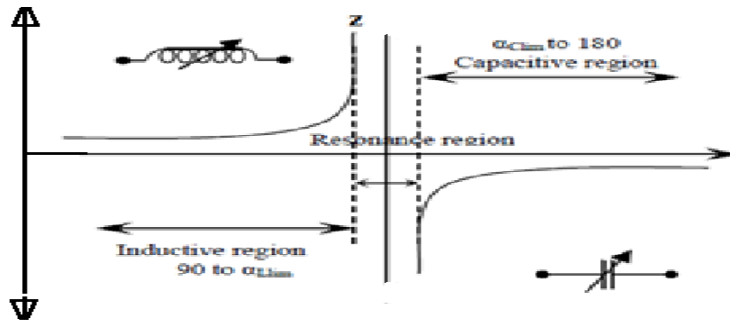


Fig 2 Impedance v/s Firing angle characteristics curve

From $90 < \alpha < \alpha_{Lim}$ Inductive region.

$180 < \alpha < \alpha_{Clim}$ Capacitive region

Between $\alpha_{Lim} < \alpha < \alpha_{Clim}$ Resonance region.

B. SSSC

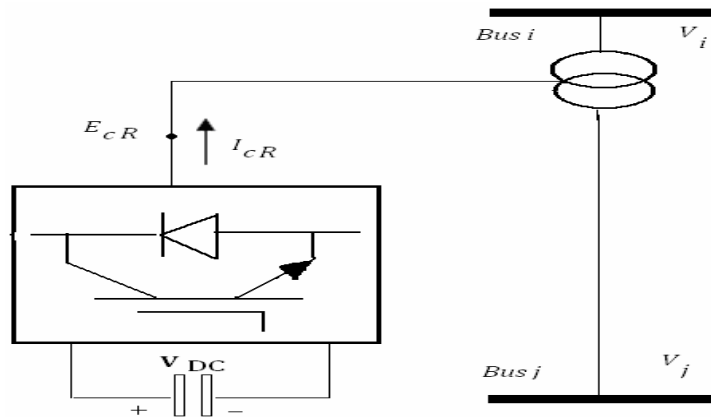


Fig 3. Schematic diagram for the SSSC

The voltage source can be described in mathematical form as follows:

$$V_n = -jkXI \tag{3}$$

V_n is the compensating value of the injected voltage, I is the phasor of the line current, X is the impedance of the series reactive line, and k is the series compensation degree. For conventional series compensation, k is defined as X_C/X , where X_C is the impedance of the series capacitor.

III. LOCATION OF TCSC AND SSSC

The objective for the location of FACTS device may be one of the following:[5]

- i. To allow a reduction in the real power loss of a particular line.
- ii. To improve the efficiency by reducing the total system real power loss.
- iii. To reduce reactive power loss of the total system.
- iv. For congestion management and to provide maximum relief of congestion in the system.

In this paper we placed the TCSC inclined with the transmission line having high line losses. By implementing this method in IEEE 9 bus system we obtain location of TCSC between the buses 5 and 7.

IV. RESULTS AND SIMULATION

A. System under consideration

An IEEE 9 bus system is taken as the test system. The single line diagram of IEEE 9 bus system is as shown in the figure 4.1.

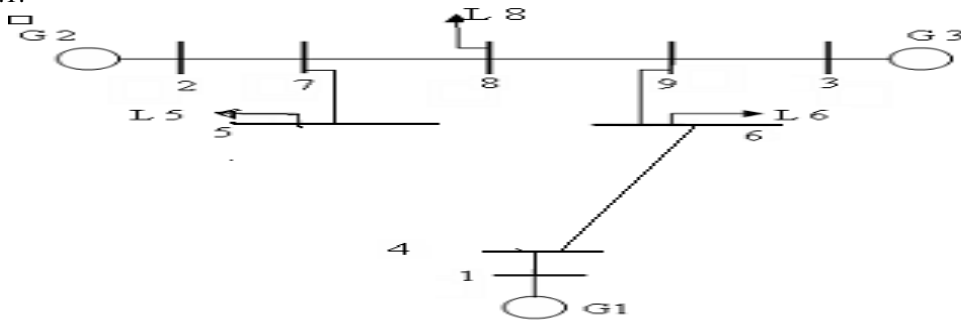


Fig 4 Single line Diagram of IEEE 9 Bus System.

B. Simlink model and output of IEEE 9 bus system.

i Simulink model of IEEE 9 bus system without FACTS device

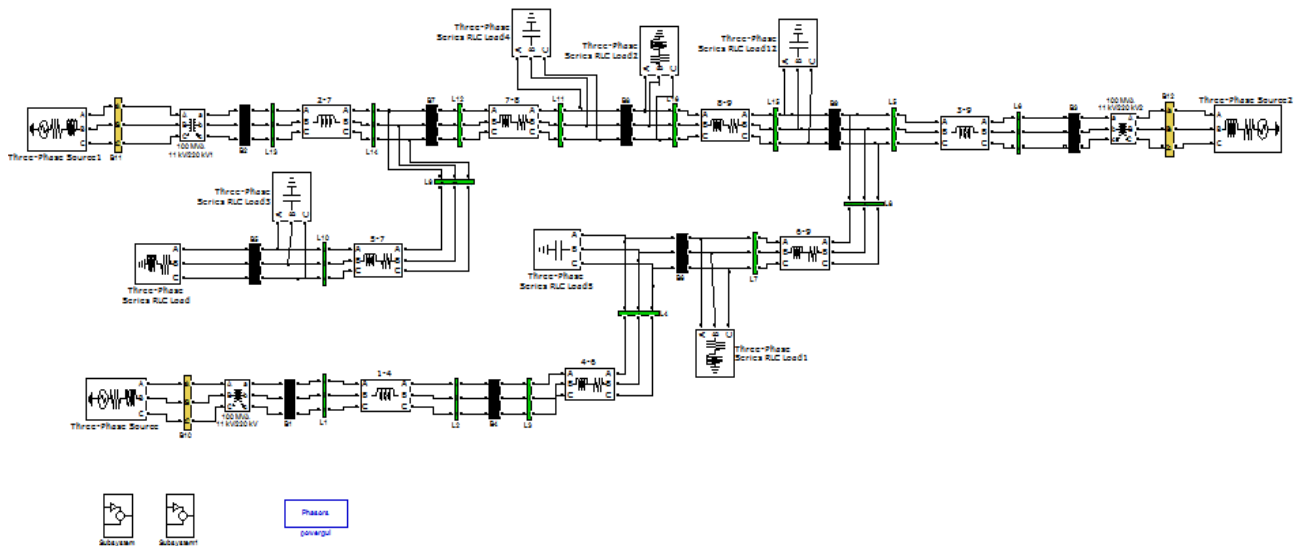


Fig 5 Simulink model of IEEE 9Bus System without FACTS device

ii. Simulink Output without FACTS device:

Table .1 Output of IEEE 9 Bus System

BUS	V	P(MW)
1	1	93.31
2	0.9743	126.7



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)

Volume 4, Issue 3, May 2015

3	0.9902	93.53
4	0.9918	93.31
5	0.9979	124.5
6	0.9687	91.78
7	0.9817	3.603
8	0.9793	3.605
9	0.9928	100.7

Table 2 Losses between line power buses

LINE INDICATOR	LINE FLOW P (MW)	LINE LOSSES P (MW)
L1- L2	93.29-93.29	0
L3 - L4	93.29-91.76	1.53
L5-L6	93.49-93.49	0
L7-L8	7.337-7.218	0.119
L9-L10	130.1-124.3	5.8
L11-L12	3.661-3.658	0.003
L13-L14	126.5-126.5	0
L15-L16	100.7-99.48	1.22
Total Line Losses =8.672 MW		

C. Simulink model of IEEE 9 Bus System with FACTS device.

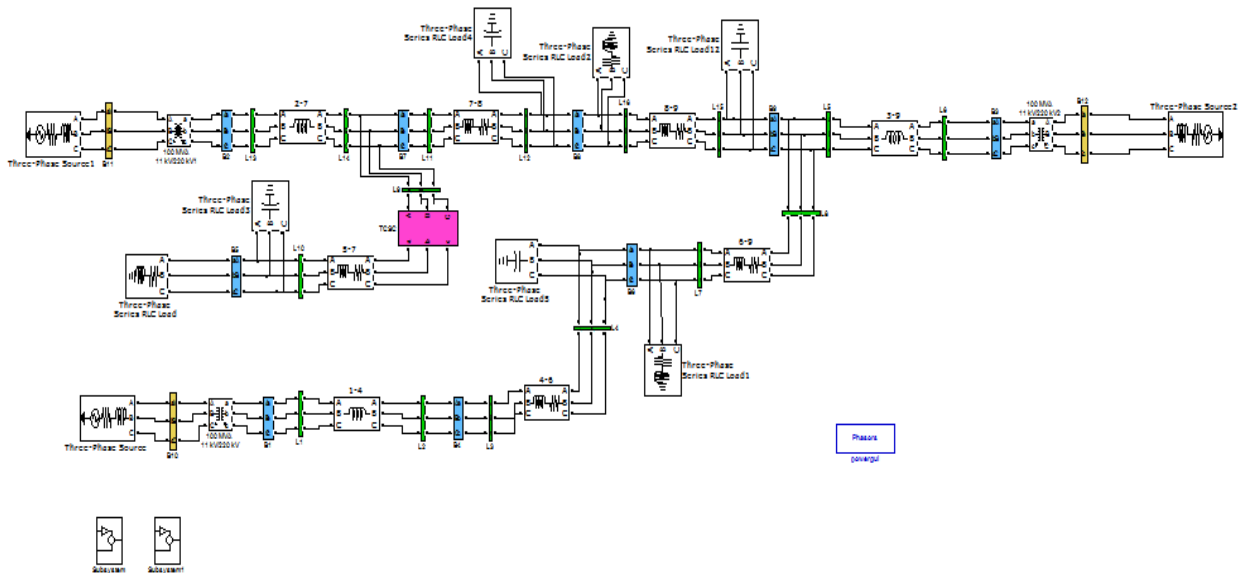


Fig 6 Simulink model of IEEE 9 bus system with TCSC.

i Simulink Output of 9 Bus system with TCSC

Table 3 Output of IEEE 9 Bus system with TCSC.

BUS	V	P(MW)
1	1.01	93.62
2	1.037	125.6



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)

Volume 4, Issue 3, May 2015

3	1.023	94.18
4	1.007	93.62
5	0.9301	108.1
6	0.9926	92.15
7	1.006	12.44
8	1.043	12.38
9	1.034	97.41

Table .4 Losses between the line power buses.

LINE INDICATOR	LINE FLOW P (MW)	LINE LOSSES P (MW)
L1- L2	93.23-93.23	0
L3 - L4	93.23-91.78	1.45
L5-L6	93.57-93.57	0
L7-L8	2.721-2.46	0.261
L9-L10	109.3-104.5	4.8
L11-L12	14.86-14.79	0.07
L13-L14	124.2-124.2	0
L15-L16	96.03-94.98	1.05
Total Line Losses =7.631 MW		

D. Simulink model of IEEE 9 bus system with SSSC.

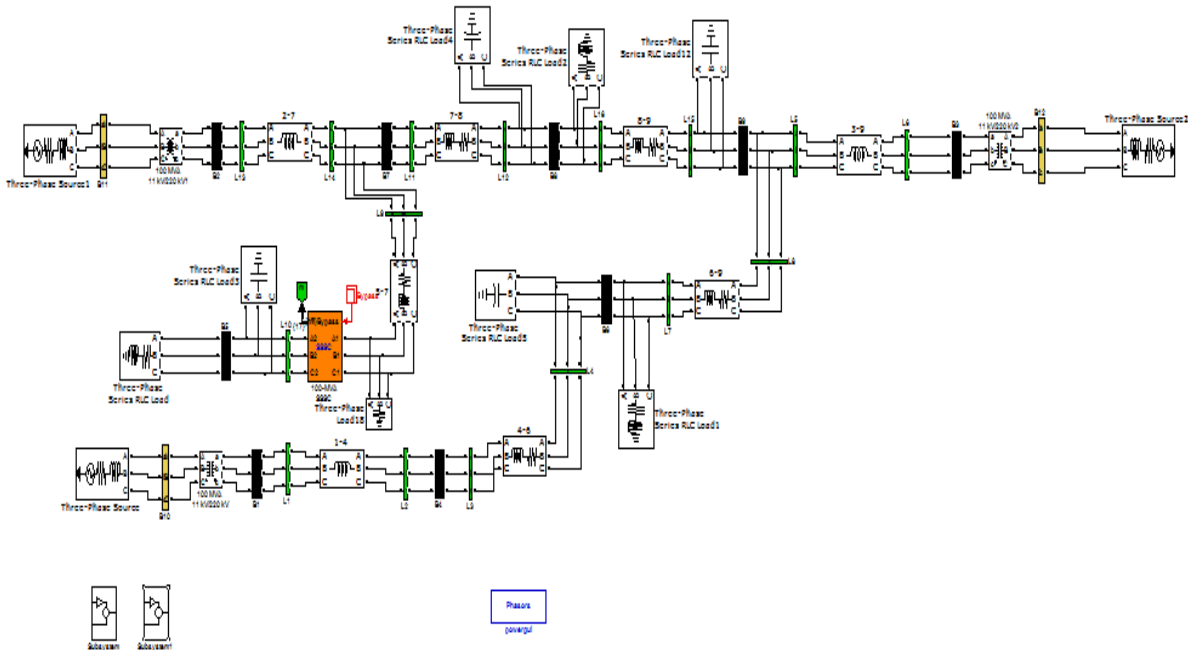


Fig 7 Simulink model with SSSC.



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)

Volume 4, Issue 3, May 2015

Table .5 Output of IEEE 9 Bus System with SSSC.

BUS	V	P(MW)
1	1.01	91.05
2	1.029	117.7
3	1.02	90.06
4	1.006	91.05
5	0.8806	96.94
6	0.9903	89.65
7	1.048	16.59
8	1.034	16.54
9	1.029	91.23

Table .6 Losses between the line power buses.

LINE INDICATOR	LINE FLOW P (MW)	LINE LOSSES P (MW)
L1- L2	91.05-91.05	0
L3 - L4	91.05-89.65	1.4
L5-L6	90.06-90.06	0
L7-L8	1.383-1.171	0.212
L9-L10	101.196.94	4.16
L11-L12	16.59-16.54	0.05
L13-L14	117.7-117.7	0
L15-L16	91.23-90.28	0.95
Total Line Losses =6.772 MW		

V. CONCLUSION

Table 7 Comparison of Line Losses.

Line Losses b/w bus 5 and bus 7		
WITHOUT FACTS	WITH TCSC	WITH TCSC
5.8 MW	4.8MW	4.16MW

Table 8 Comparison of Line Losses.

Total system losses with and without FACTS Devices.		
WITHOUT FACTS	WITH TCSC	WITH TCSC
8.672 MW	7.631MW	6.772MW



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)

Volume 4, Issue 3, May 2015

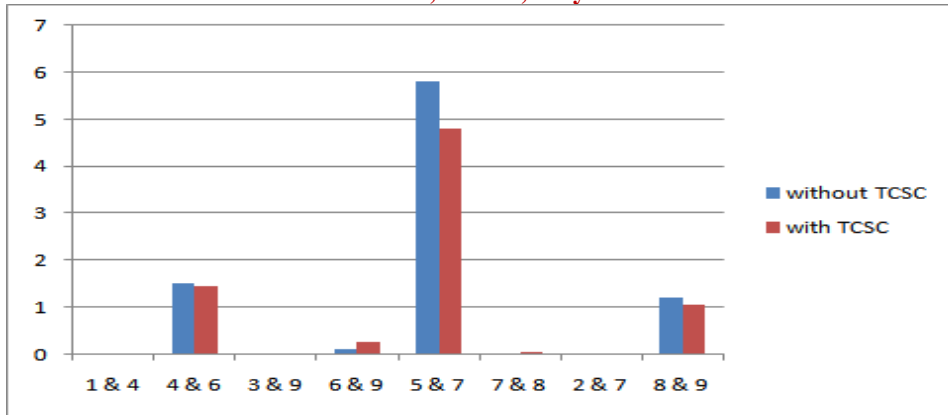


Fig 8 Comparison of Line losses of 9-bus system with & without TCSC.

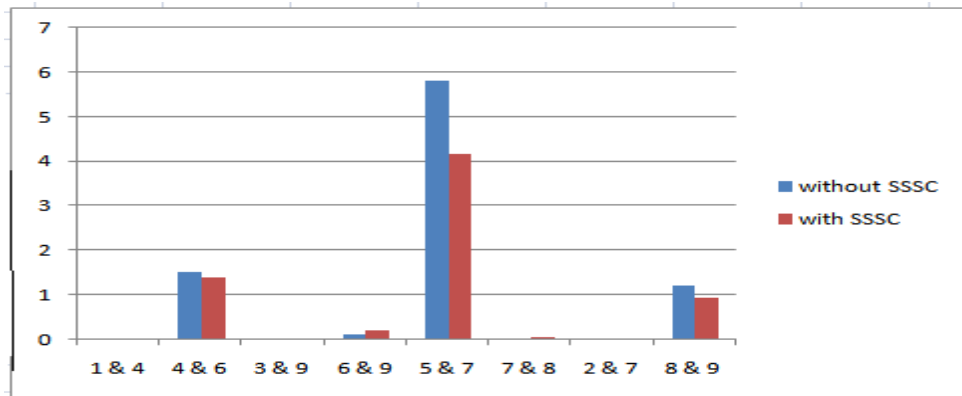


Fig 9 Comparison of Line losses of 9-bus system with & without SSSC.

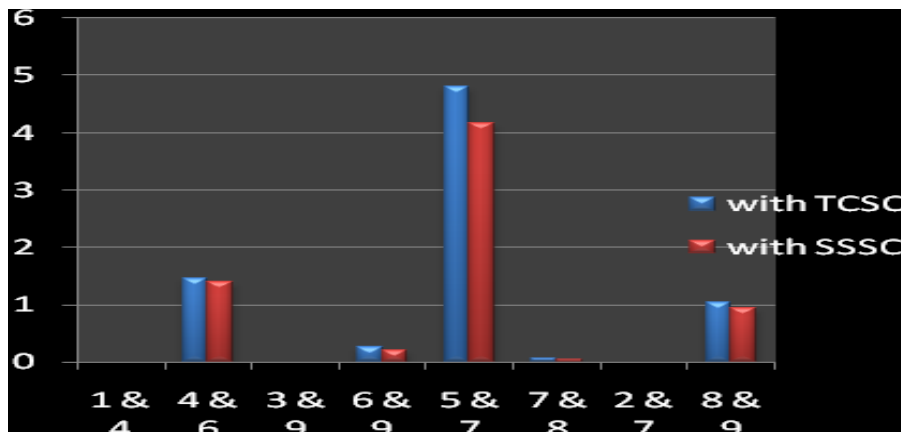


Fig 10 Comparison of Line losses of 9-bus system

It can be found by placing TCSC and SSSC between the busses 5 and 7 in line no 5, SSSC reduces the line losses more effectively than the TCSC. With cost constraint TCSC is suitable compare to the SSSC.

This project has aimed at locating the TCSC and SSSC comparing the performance of the IEEE 9 bus system without FACTS Device and with FACTS Device.

As seen from the results the loss reduction is around 1 MW with TCSC and 1.64 MW in the line 5-7 and total system losses reduced by 1.041 MW with TCSC and 1.9 MW with SSSC.



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)

Volume 4, Issue 3, May 2015

REFERENCES

- [1] Facts about Flexible AC transmission systems (FACTS) and Controllers: Practical installations and benefits, Naresh Acharya, Arhit Sode-Yome, Nadarajah Mithulanathan.
- [2] G. Hingorani and L. Gyugyi, "Understanding FACTS: concepts and technology of flexible AC transmission systems," IEEE Press, 2000. Journal Of Engineering And Development, Vol. 15, No.4, Des 2011 ISSN 1813- 7822.
- [3] Naresh Acharya, Arhit Sode-Yome, Nadarajah Mithulanathan, Facts about Flexible AC transmission systems (FACTS) and Controllers: Practical installations and benefits.
- [4] R.Saravana kumar , M. Prabhakar, Power system Stability enhancement using Interline power flow controller.
- [5] S. Panda, S. Swain, A. Baliarsingh, "Optimal Supplementary Damping Controller Design for TCSC Employing RCGA", International Journal of Computational Intelligence 2009.
- [6] V. Mahajan, "Thyristor Controlled Series Compensator" IEEE International Conference on Industrial Technology, Volume Issue 15-17 Dec. 2006

AUTHOR BIOGRAPHY



Janhavi C G received B.E. degree in Electrical & Electronics Engineering from VTU Belgaum in 2013. She is currently studying in 4th Sem M.Tech (Computer Application in Industrial Drives) in SSIT Tumkur. Her area of interest in Power systems, FACTS devices. Attended National Symposium and National conference in different institutions.



K.L.Ratnakar had the privilege to get both B.Tech., and M.Tech., degrees from Jawaharlal Nehru Technological University, College of Engineering, Kakinada and stood first in M.Tech., with 85.25%. He has vast teaching experience of 30 years at undergraduate and postgraduate levels. He has presented around 20 technical papers in the national and International conferences, including one at Brisbane, Australia. He has authored a text book on "Electrical Power Transmission and Distribution" for Engineering students. His main area of interest is Power Systems and High Voltage Engineering. He has a life membership of Indian Society for Technical Education (ISTE) and The Institution of Engineers (India). Presently he is working in Sri Siddhartha Institute of Technology from December 1985.

APPENDIX

A. Details of IEEE 9 Bus System.

S_{base} = 100 MVA

V_{base} = 220KV

V_{max} = 1.06 p.u

V_{min} = 1 p.u

NUMBER OF LINES = 8

NUMBER OF BUSES = 9

BUS DATA

Bus No.	P _G	Q _G	P _L	Q _L	V _{Spc}
1	0.0	-	0.0	0.0	1.04
2	1.63	0.0	0.0	0.0	1.025
3	0.85	0.0	0.0	0.0	1.025
4	0.	0.0	0.0	0.0	1.0
5	0.0	0.0	1.25	0.5	1.0
6	0.0	0.0	0.9	0.3	1.0



ISSN: 2319-5967

ISO 9001:2008 Certified

International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 4, Issue 3, May 2015

7	0.0	0.0	0.0	0.0	1.0
8	0.0	0.0	1.0	0.35	1.0
9	0.0	0.0	0.0	0.0	1.0

LINE DATA

Bus No.		Resistance (p.u)	Reactance (p.u)	Half line charging Admittance(p.u)
From Bus	To Bus			
1	4	0.0	0.0576	0.0
4	6	0.017	0.092	0.079
3	9	0.0	0.0586	0.0
6	9	0.039	0.17	0.179
5	7	0.032	0.161	0.153
7	8	0.0085	0.072	0.0745
2	7	0.0	0.0625	0.0
8	9	0.0119	0.1008	0.1045

B. Specification of TCSC.

Frequency = 50 Hz

Manual alpha (deg) = 78

TCSC capacitance (F) = 20e-6

TCSC reactance (H) = 10e-3

Average firing delay (s) = 4e-3