ISSN No. 0976-5697

Volume 8, No. 3, March – April 2017

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

Congestion Management in Deregulated Electricity Power Market using STATCOM and TCSC

Akanksha Singh
Electrical Engineering Department
Madan Mohan Malaviya University of Technology
Gorakhpur, India

Santosh Kumar Singh
Electrical Engineering Department
Madan Mohan Malaviya University of Technology
Gorakhpur, India

Sudhir Kumar Srivastava
Electrical Engineering Department
Madan Mohan Malaviya University of Technology
Gorakhpur, India

*Abstract:*In last few years the electrical industry is deregulating all over the places. Deregulation has brought many changes in organization and operation of power industry. This deregulation increases competition among power utility and allows the customer to choose their supplier of electricity. Number of participant will increase in the competitive market of power industry and all the participant will try to get supply at low cost sources. After deregulation of power market, congestion in electric grid is quite often. So, it is very important to relieve problem of congestion. Problem of congestion, frequently occur in transmission system and distribution system. This paper proposes FACTS devices to relieve from congestion. FACTS devices will efficiently control the power flow. Modelling, simulation and analysis of 5 bus system using MATLAB is explained in this paper. Comparison with and without STATCOM and TCSC is done to control the power flow and result is obtained.

Keywords:congestion;deregulation; power market; STATCOM; TCSC

I. INTRODUCTION

Increasing load demand force to change the source of generation to smaller plant using renewable energy sources and with uncertainty of transaction has caused strain to existing power grid. This will lead transmission system to work nearby their operating limits and cause congestion. Therefore it is necessary to ensure that transmission system should be flexible to meet new and increasing demand of consumer. In India the power grid was mainly under the government in various state and central government, till 1991. In 1991, a process of restructuring and deregulation of power market was started in Orissa. Thereby after 1991, congestion management become an important issue for restructured system. Many new technologies came to maintain stability and reliability of power sector and also to handle large volume of transmission. One of such technology is facts controller, it has ability to support and control power flow in the system. The TCSC and STATCOM are the best example of facts controller, these are based on power electronic switches [1]. Due to increasing population, demand for electricity is also increasing. When consumer and producer of electricity aim to produce, and consume in quantity that would cause transmission network to work at or beyond one or more transfer limit, then system is said to be congested. Due to increasing demand, power trade, grid maintenance etc. becoming complicated problem. To fulfill the demand of electricity, private utility is being encouraged and this has brought competition in the power market. Competitive market is beneficial for the consumer, they can get electricity at less price and have choice. Tendency for getting for profit has cause overloading and congestion in transmission line.

.

II. METHODS TO SOLVE CONGESTION PROBLEMS

There are two methods that can be used to solve the congestion problem i.e. for the congestion management [2].

A. *Cost Free Means*

- Use of phase shifter or transformer tap changer
- Use of facts devices
- Out-aging of congested transmission line

B. *Non Cost Free Means*

- Curtailment of demands and exercise of load interruption option
- Re-dispatch of power generation

Congestion management can be done in different way in different country, it mainly depend on model of deregulation in particular country. Congestion management scheme should try to have these features

i. ***Economic efficiency***

For congestion management, intervention should be changed into competitive market, it should achieve system security. Method of congestion should achieve both short term and long term efficiency. Short term efficiency is related to generator dispatch and long term efficiency is related to investment in new transmission line and generation facilities.

ii. ***Non-discriminative***

There should be equality for each market participant. Network operator should not depend on market parties and should not take advantages from occurrence of congestion.

iii. Transparency

The congestion management scheme should be well defined and transparent for all the market participants.

iv. ***Robust-Scheme***

Should be robust in respect to storage manipulation by market participants.

Nodal pricing or optimal power flow based scheme is used for congestion management, it is said to satisfy the desired features, mostly related to economic efficiency. Congestion management can be done without disturbing the economic matters using facts devices.

III. FACTSDEVICES

The emergence of power electronic devices inaugurates facts devices in power market. Facts devices can increase controllability of power flow and enhance the power transfer capability of the transmission line in a fast manner. Facts devices offer a flexible and multifaceted replacement to conventional supplementing methods with advantages of lower cost and impact on environment [3]. Parameter of transmission network like voltage, current, series impedance, phase angle, shunt impedance, improving damping of oscillation in complex system can be controlled by facts devices. Facts devices can be connected in series to system or parallel to the system for the power compensation. Active power loss and reactive power flow in the transmission line can be diminish by use of facts devices [4]. The idea of facts devices was first initiated by Hingorani[10]. Facts devices are capable of managing different electrical parameter of power system. How to increase the power transfer capacity of the line are explained in [11]. In [12], locations for positioning of facts devices are found. Facts devices are also used for enhancing the transient and steady state stability of power system. Facts controller are best equipment to relieve all challenges[13].

A. There are four types of facts devices.

- Series facts controller
- Shunt facts controller
- Series series facts controller
- Series shunt facts controller

The series facts devices are introduced to transmission line to inject voltage in series to the transmission line. These fact devices can supply or consume reactive power till voltage is in phase with line current. Example of series controller are TCSC, SSSC, TSSC, TCSR. These are mostly used to control power flow in the power system.

The shunt fact devices are injected to the transmission line to inject current. Impedance of shunt devices can vary current flow. These devices can adjust reactive power until current is in phase with line voltage and can also adjust real power if current is not in phase with line voltage. Example of shunt devices are SVC, STATCOM etc.

B. There are following advantages of facts controller-

- Load ability of transmission line can be increased.
- System loss can be reduced.
- Stability can be improved including both steady state and transient.
- It eliminates need of new transmission line.
- It upgrades the transmission line.
- It can control the voltage stability.
- Reduces cost of production.

IV. TCSC

TCSC is a series fact controller. It can increase power transmission capability, reduces system loss, improve system stability, improve voltage profile of the lines. It is a better device for controlling power flow in transmission line. TCSC consists of series capacitor, thyristor controller inductor. Series compensating capacitor is connected in series with transmission line and TCR is connected directly in parallel with capacitor. There is no requirement of any interfacing equipment like high voltage transformer. TCR consists of variable inductor and back to back connected thyristor [2,14].

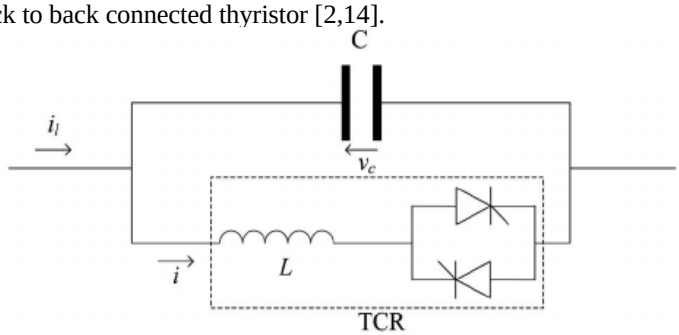

Figure 1. Simple diagram of TCSC

Diagram of TCSC is shown in figure1. It can rapidly change the reactance of transmission line and change the power flow in transmission line. Operation of TCSC can be explained with circuit analysis. TCR is a inductive reactance $X_L$controlled by firing angle α[6].

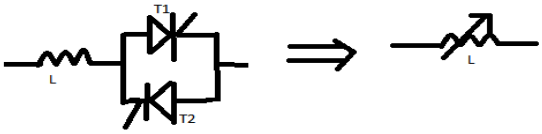

Figure 2. Equivalent circuit of TCR

Variation of X_L with respect to α is given in figure 2.

$$X_L = X_L \frac{\pi}{\pi - 2\alpha - \sin 2\alpha} \quad (1)$$

Controlled reactors connected across capacitor, so that variable capacitive reactance is obtained across TCSC to modulate the transmission line impedance [6].TCSC reactance with respect to α is given as[7,8,9,10].

$$X_{TCSC} = -X_C + C_1\big(2(\pi - \alpha)\big) - C_2 \cos(\pi - \alpha)^2 \left(\omega \tan\big(\omega(\pi - \alpha)\big) - \tan(\pi - \alpha)\right) \quad (2)$$

Where,

$$X_{LC} = \frac{X_L X_C}{X_C - X_L} \quad (3)$$

$$C_1 = \frac{X_C + X_L}{\pi} \quad (4)$$

$$C_2 = 4\frac{X_{LC}^2}{X_L \pi} \quad (5)$$

$$\omega = \sqrt{\frac{X_C}{X_L}} \quad (6)$$

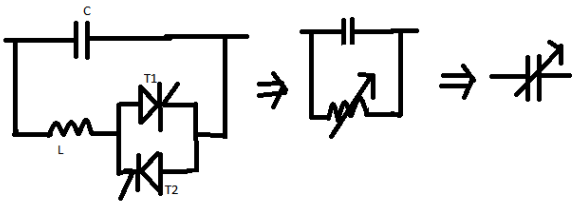

Figure 3. Equivalent circuit of TCSC

V. STATCOM

It is a power electronic device having force commutated device as GTO, IGBT etc. It controls the reactive power flow of the line and enhance the stability of the network.it is shunt fact controller which is introduced in shunt with line. It can absorb reactive power or generate reactive power, depend on the demand. Component of statcom are voltage source converter, dc capacitor, inductive reactance, harmonic filter [5].

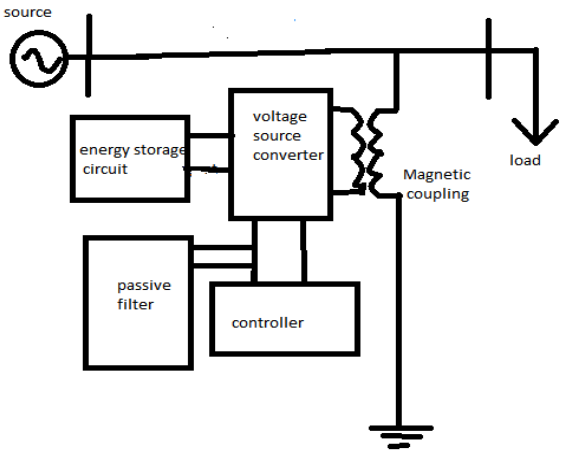

Figure 4. Diagram of statcom

VSC converts dc voltage to ac voltage. There are two types of vsc i.e. square wave inverter and pwm inverter. Here, I have used pwm inverter. It make use of pulse width modulation technique and create sinusoidal waveform using dc voltage source by chopping frequency of few khz. Dc capacitor is applied to provide constant dc voltage to voltage source converter. A coupling transformer is connected between power system and output of vsc. Coupling transformer is also used to minimize harmonic contained in output produced by voltage source converter. Active or passive filter are used to attenuate the harmonic produced by voltage source converter.

Assume

$$Ra=0$$

Reactive power

$$Q = \frac{V2}{X}(V1\cos\delta - V2)$$

δ is the angle between inverter voltage and source voltage

Now,

$$Q = \frac{V2}{X}(V1 - V2)$$

Real power,

$$P = \frac{V1V2\sin\delta}{X} = 0$$

When $\delta = 0$ then real power become zero and reactive power depend on V1-V2. If V1 is greater then V2 then it means reactive power flow from V1 toV2. Here V1 is output voltage of statcom and V2 is voltage of power system. If output voltage of statcom is higher as compare to voltage of transmission line than statcom will supply voltage to the line but if output voltage of statcom is less than it absorb the power. Thus statcom can act as both supplier and absorber of reactive power.

VI. MODELING AND SIMULATION RESULTS

The aim of this paper is to:

- Simulate 5 bus power system network with MATLAB software.
- Model STATCOM and TCSC in 5 bus power system and find the power flow.
- Perform the analysis of 5 bus power system network before and after applying TCSC and STATCOM.

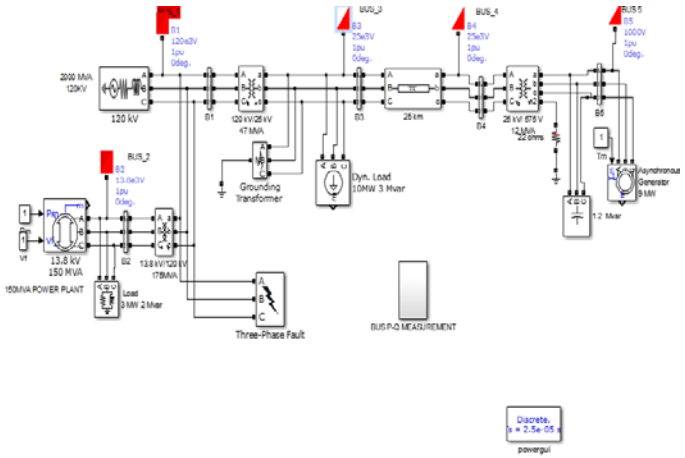

Fig Simulink model of 5bus uncompensated system

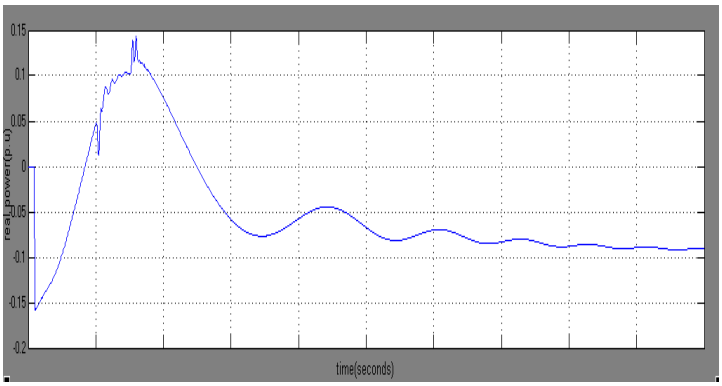

Fig Real Power at Bus 3

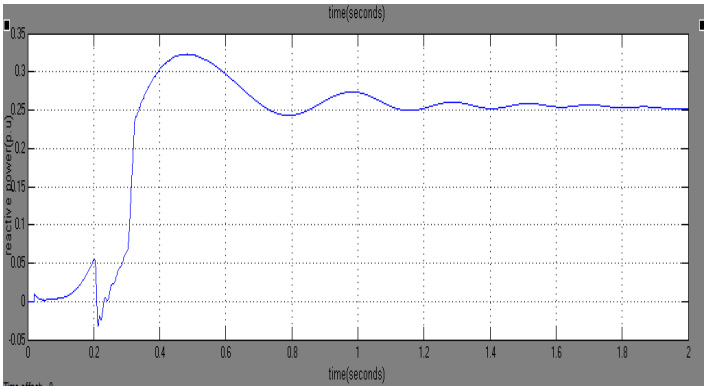

Fig Reactive Power at Bus 3

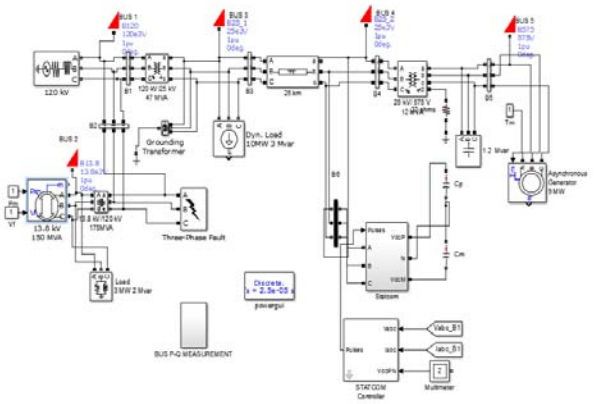

Fig Simulink model of 5bus STATCOM compensated system

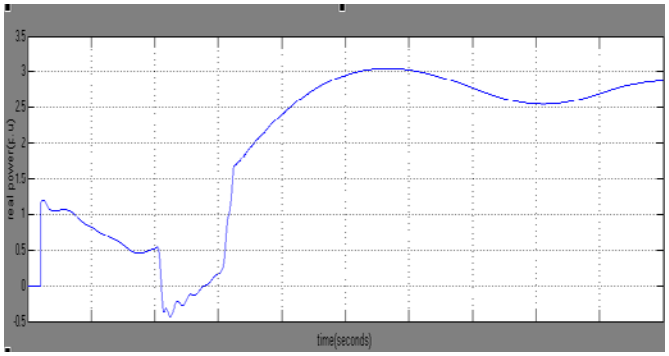

Fig Real Power at Bus 3

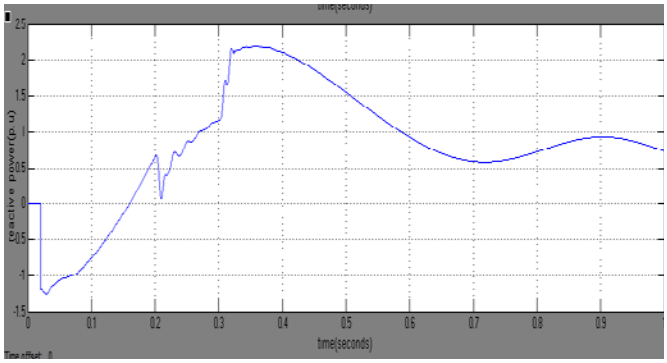

Fig Reactive Power at Bus 3

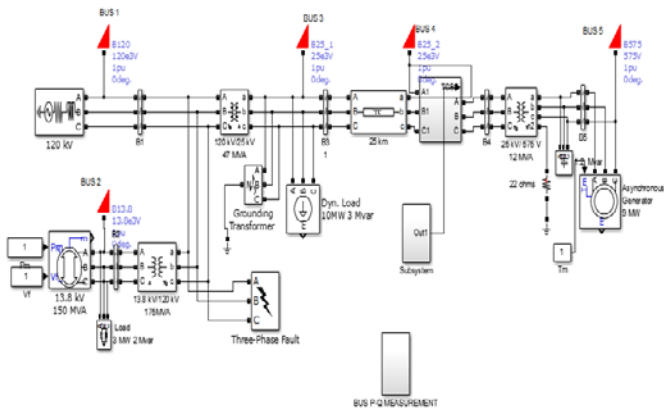

Fig Simulink model of 5bus TCSC compensated system

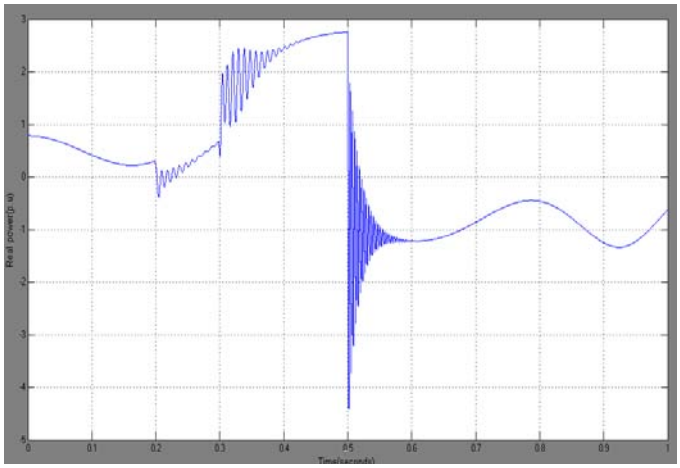

Fig Real Power at Bus 3

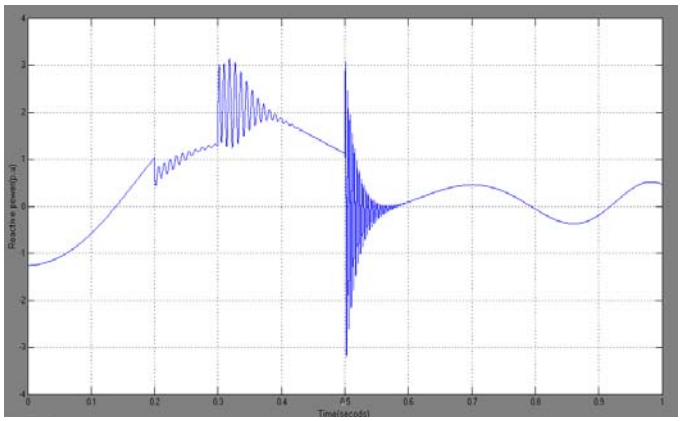

Fig Reactive Power at Bus 3

Table 1:Bus voltage result with and without FACTS devices

Bus No.	Without FACTS devices (pu)	With STATCOM (pu)	With TCSC (pu)
1	1.03	1.03	1.03
2	0.964	0.982	0.976
3	0.287	0.876	0.991
4	0.678	1.45	0.975
5	1.01	0.978	1.003

The simulation shows the power flow of lines and active power and reactive power at buses which is tabulated. From the below table, it is cleared that voltage magnitude at bus 2, bus3,bus4 are less than 1.0 p.u. So, these are buses in which Facts devices can be placed.

Table 2:Bus result without FACTS devices

Bus No.	P(p.u)	Q(p.u)
1	0.182	0.304
2	2.16	0.26
3	-0.05	0.252
4	-0.68	1.623
5	-0.06	0.15

Table 3: Bus result with STATCOM

Bus No.	P(p.u)	Q(p.u)
1	0.435	0.145
2	1.016	-1.502
3	2.532	0.685
4	1.884	0.525
5	1.734	0.525

Table 4: Bus result with TCSC

BUS NO.	P(p.u)	Q(p.u)
1	1.047	-1.923
2	0.852	-2.387
3	0.652	0.488
4	0.587	0.629
5	1.103	0.528

In comparison to bus 2, bus3 and bus 4, it is cleared that by installing STATCOM at bus3 active and reactive power is increased more as compare to TCSC and without FACTS devices. Installation of STATCOM and TCSC also improve voltage profile.

VII. CONCLUSION

This paper included cost free method of congestion management. Simulation method is used for study of dynamic and steady state operation of power system with STATCOM and TCSC. STACOM is shunt controller while TCSC is series controller. 5 bus systems was studied with and without using any controller and power flow in each line is calculated. After installing STATCOM , active power and reactive power increases in large amount as compare to TCSC. The congestion in transmission line can be managed by using FACTS controller.

VIII. REFERENCES

[1] D. Povh, D. Retzmann Siemens, Erlangen, Germany ―Development of facts for transmission systems.

[2] Karthika P L, Jasmy Paul," Congestion management in power system using TCSC" International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 05 | Aug-2015

[3] Sankalp Asawa, Sam Al-Attiyah," Impact of FACTS device in Electrical Power System" International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – 2016

[4] Biplab Bhattacharyya , Sanjay Kumar," Approach for the solution of transmission congestion with multi-type FACTS devices" IET Generation, Transmission & Distribution

[5] AlirezaSeifi , , Amin Shabanpour SasanGholami, ― Power Flow Study and Comparison of FACTS: Series (SSSC), Shunt (STATCOM),

[6] S. Meikandasivam, , Shailendra Kumar Jain, Rajesh Kumar Nema" Behavioral Study of TCSC Device – A MATLAB/Simulink Implementation"

[7] Guowen H U, Ming CHENG, and Guilong CAI, "Relation between Fundamental Frequency

[8] Equivalent Impedance and Resonant Point for Thyristor Controlled Series Compensation", 30th Annual

[9] Conference IEEE Industrial Electronics Society, vol. 2, pp. 1128- 1132, 2004.

[10] [8] C. R. Fuerte-Esquivel, E. Acha, and H. Ambriz-PBrez, "A Thyristor Controlled Series Compensator Model for the Power Flow Solution of Practical Power Networks", TEEE Transactions on Power Systems. vol. 15, no. 1, pp. 58- 64, February 2000.

[11] [9] Geng juncheng, Tong luyuan, and Wang Zhonghong, and Ge Jun, "Mathematical Model for describing characteristics of TCSC", IEEE 2002 PP- 14981-502.

[12] [10] L. F. W. de Souza, E. H. Watanabe, J . E. R. Alves, and L. A. S.Pilotto, "Thyristor and Gate Controlled Series Capacitors Comparisonof Components Rating", IEEE, 2003, pp: 2542-2547.

[13] Ramey, D., Nelson, R., Bian, J., et al.: 'Use of FACTS power flow controllers to enhance transmission transfer limits'. Proc. American Power Conf., 1994, vol. 56, no. Part 1, pp. 712–718

[14] Rajaraman, R., Alvarado, F., Maniaci, A., et al.: 'Determination of location and amount of series compensation to increase power transfer capability', IEEE Trans. Power Syst., 1998, 13, (2), pp. 294–299