ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Congestion management considering voltage stability and loss minimization using FACTS devices

Rajesh Retnamony*, Jacob Raglend
Noorul Islam University, Kanyakumari District, TamilNadu -629180, India.
***Corresponding author: E-Mail: rajeshknky@gmail.com**

ABSTRACT

Congestion management is one of the technical challenges in a Deregulated power system environment. Two types of Methodologies used in congestion Management are non-cost free methods and cost free methods. In this research work congestion is relieved by using cost-free methods considering FACTS Devices such as STATCOM (Static Synchronous Compensator) and UPFC (Unified Power Flow Controller) device. The power system stability enhancement and line loss minimization via optimal location of FACTS devices like STATCOM and UPFC are studied in this paper and performance analysis of STATCOM, UPFC has been worked out for Western Science Coordinated Council (WSCC) 9 bus system for the improvement of small signal stability using PSAT (Power System analysis toolbox) software. The performance of STATCOM, UPFC is demonstrated through the sensitivity based Eigen value analysis. The results show that the proposed approach has a capability to improve the Voltage stability, small signal stability, Loss minimization of the power system network.

KEY WORDS: Congestion Management, STATCOM, UPFC, PSAT, Small Signal Stability, Voltage Stability.

1. INTRODUCTION

In a regulated power system environment Generation, transmission and Distribution are controlled in a single company, but in a deregulated power system environment has entities like GENCO (Generation Companies), TRANSCO (Transmission Companies), DISCO (Distribution Companies), ISO(Independent system operator), RESCO (Retailer). The ISO has the responsibility of ensuring the security and reliability of entire power system. The power transaction between the companies will create congestion in a transmission lines which may get overloaded. Modern day power systems have complicated networks .It has hundreds of power generating stations and substations. The power transfer in multi machine system is constrained by small signal stability, transient stability and voltage stability. That constraint limits a full utilization of a transmission lines. FACTS (Flexible Alternate Current Transmission Systems) is the technology that offers the needed stability in the transmission systems. Recently some FACTS devices have been designed and applied in power systems for Voltage stability, small signal stability and transient stability. STATCOM, UPFC FACTS devices are used to control the voltage by absorbing and generating the reactive power. It is also used to improve the small signal stability, transient stability and improves the power flow of the system. The optimal location of FACTS device such as SVC for dynamic stability analysis used on Eigen values. Eigen values can be calculated using state matrix and Jacobian matrix in power flow. Some papers have been proposed for the damping of low frequency oscillations using PSS and STATCOM. Some papers have been proposed for the designing of STATCOM .some papers have been presented for the small signal stability and transient stability. Some papers discussed for small signal stability analysis for small disturbances using PSS (Power System Stabilizer). The optimal location of STATCOM, UPFC plays a role to improve that stability. This paper presents the analysis of best location of STATCOM, UPFC used to improve the small signal stability, Voltage stability and Loss minimization in overloading conditions.

Proposed approach for stability: The simulations are done by using PSAT software to compute and plot the Eigen values with the participation factor of the power system. PSAT is the Mat lab toolbox for power system analysis and control.

PSAT used for

- Power Flow Analysis
- Continuous Power Flow Analysis
- N − 1 Contingency Analysis
- Optimization of power flow
  - ✓ Maximization of Social Welfare
  - ✓ Maximum Loading condition
  - ✓ Voltage Stability
  - ✓ Multi Objective Optimization
- Eigen Value Analysis
  - ✓ Small Signal Stability Analysis
  - ✓ Power Flow Sensitivity Analysis
- Time Domain Simulation (Transient Stability Analysis)

All these actions can be evaluated by graphical user interfaces (GUIs) and Simulink-based library provides a user friendly tool for power system design. Fig.1. shows the synoptic scheme of PSAT tool box. Once the power flow in electric network has been solved, the procedures are followed to find the optimal location of STATCOM, UPFC for small signal stability analysis based on sensitivity based Eigen value analysis. The advantages of the proposed approach that Eigen values are shifted from positive real axis to negative real axis. It gives more damping to reduce oscillations and high precision results in determining the stability of the system.

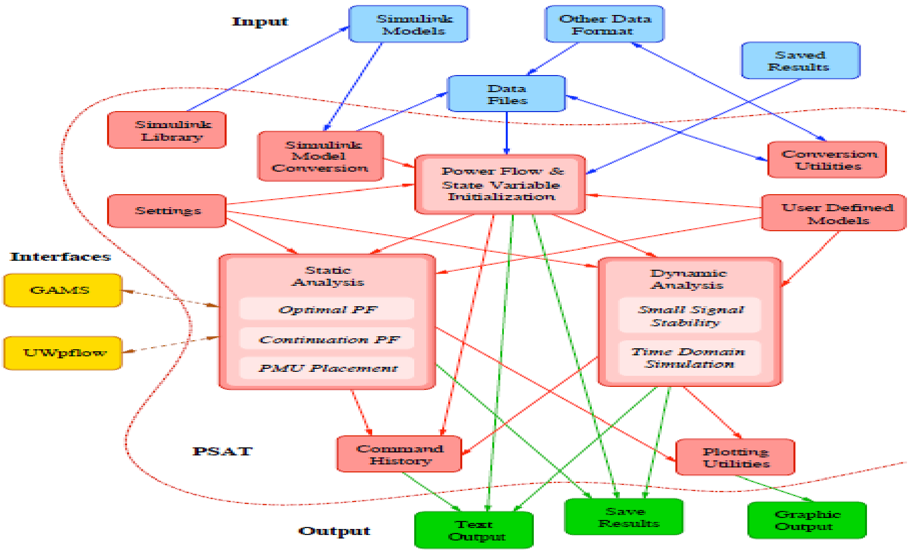


Fig.1.PSAT Synoptic Scheme

Small signal stability of the power system: The power system is to maintain synchronism due to small disturbances is small signal stability. A DAE (Differential Algebraic Equation) set is used for the small signal stability in PSAT in the form:

$$x = f(x,y) \quad (1)$$

$$0 = g(x,y) \quad (2)$$

Here, x = vector of the state variable, y = vector of the algebraic variable.

Concept of Eigen value in Power system: The Eigen-values are used to determine the system stability. The real Eigen values are related to non-oscillatory mode and complex Eigen values are related to oscillatory mode. Negative Eigen value represents the stability of the system and Positive Eigen value represents the instability of the system [8]. The damping is represented by real part of the Eigen values. The frequency of the oscillation is represented by imaginary part of the Eigen values.

For complex pair of the Eigen values:

$$\lambda = \sigma + j\omega \quad (3)$$

The frequency of the oscillation is signified by:

$$f = \omega/2\pi \quad (4)$$

The damping ratio is signified by

$$\varsigma = -\sigma/\sqrt{\sigma^2+\omega^2} \quad (5)$$

The rate of the decay is concluded through the damping ratio.

The parameters σ and ω are used to calculate the effects of damping in the system. The damping ratio and the frequency of oscillation are the main factors to calculate the damping of the system [9] and [10]. Damping ratio is more means the system will give more damping to oscillate.

Procedure for power system stability:

Step 1: Prepare the PSAT model.
Step 2: Run the NR (Newton Raphson) power flow.
Step 3: Run the Time domain simulation.
Step 4: Run the Eigen value analysis.
Step 5: Check the values of positive Eigen values.
Step 6: If positive Eigen values found, then find the weakest buses of the system.
Step 7: Apply the STATCOM to the weakest buses of the System and tune the parameters of STATCOM.
Step 8: Run the power flow and time domain simulation.
Step 9: Check the values of positive Eigen values in system.
Step 10: If there is a positive Eigen value, continues the Process from 7-9.
Step 11: If there is no positive Eigen values in the system, System is stable.
Step 12: End the process.

ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Power system study in 9 bus system: The system under consideration is a WSCC (Western Science Coordinated Council) 9 bus power system shown in below Fig. 2. It has 3 generators, 6 transmission lines, 3 loads A, B, C and a local load D.

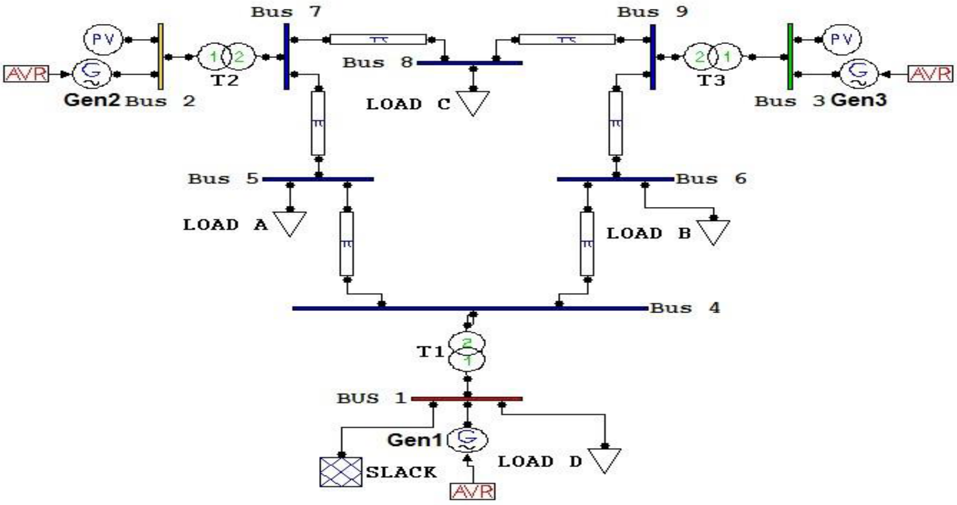


Fig.2.WSCC 9 bus in power system

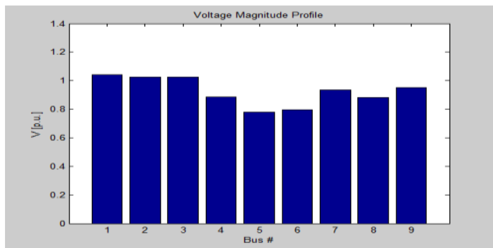
Congestion in wscc 9 bus in power system: Under normal loading condition the system is in stable condition. If the demand is increased in the load A, B, C, D (per Unit) as real power 2.4, 2.2, 2, 2 and reactive power 1.3, 1, 1.05, 1.05 respectively the system is get congested, the bus 5 voltage has been identified that it has very low voltage profile and it found as the weakest bus of the system at over loading condition. So, this bus is the suitable place to apply the STATCOM and UPFC.

Congestion management of the power system and discussion: The Eigen values analyses are taken after the time domain simulation for over loading .The result are shown in the table 1. Here the positive Eigen values are two. This shows the system is in unstable condition. It is observed that from the Fig. 3, the voltage profile of the buses 4, 5, 6 are low compared to other buses. Because of the over loading, the voltage profiles of the buses have been affected severely and reach 0.78 p.u in without FACTS. Table 2 shows the Power flow result with voltage, real and reactive power for generation and load. Table 3 shows the summary report includes total load and generation with losses.

Table.1.Eigen value analysis of the system without FACTS Devices

With Out FACTs Devices	
Dynamic Order	24
Buses	9
Positive Eigens	2
Negative Eigens	20
Complex Pairs	6
Zero Eigens	2

Fig.3. Voltage profile without FACTS



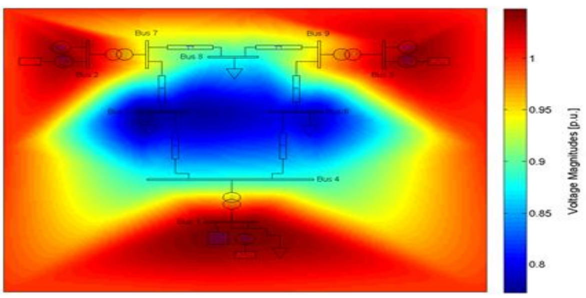


Fig.4. 2D View of voltage profile without FACTS

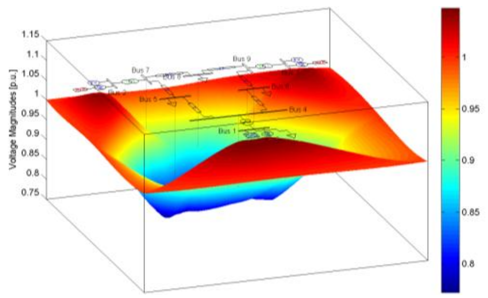


Fig.5. 3D view of voltage profile without FACTS

Table.2.Power Flow without FACTS

Bus Number	V [p.u.]	Phase [rad]	P gen [p.u.]	Q gen [p.u.]	P load [p.u.]	Q load [p.u.]
1	1.04	0.00	6.41	4.45	2.00	1.05
2	1.03	-0.41	1.63	1.55	0.00	0.00
3	1.03	-0.50	0.85	1.31	0.00	0.00
4	0.89	-0.28	0.00	0.00	0.00	0.00
5	0.78	-0.54	0.00	0.00	2.40	1.30
6	0.79	-0.55	0.00	0.00	2.20	1.00
7	0.94	-0.52	0.00	0.00	0.00	0.00
8	0.88	-0.63	0.00	0.00	2.00	1.05
9	0.95	-0.55	0.00	0.00	0.00	0.00

Table.3.Summary report without FACTS

Summary Report without Facts Device	
Total Power Generation	
Real Power [p.u.]	8.887
Reactive Power [p.u.]	7.302
Total Loads	
Real Power [p.u.]	8.600
Reactive Power [p.u.]	4.400
Total Power Losses	
Real Power [p.u.]	0.287
Reactive Power [p.u.]	2.902

The STATCOM is used in bus 5 based on Eigen value analysis and the voltage and power losses are listed below. Figs.6, 7 and 8 shows the voltage profiles using STATCOM and Table 4 and5 shows the Power flow result and summary report.

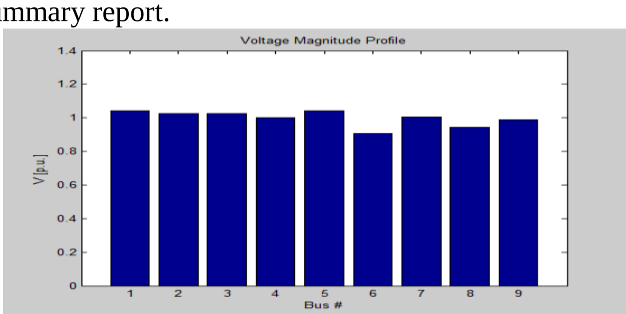


Figure.6. Voltage Profile using STATCOM

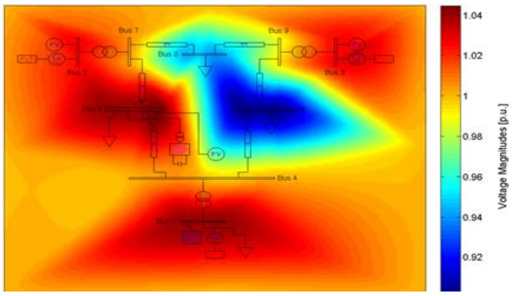


Fig.7. 2D View of Voltage Profile With STATCOM

Fig.8. 3D View of Voltage Profile With STATCOM

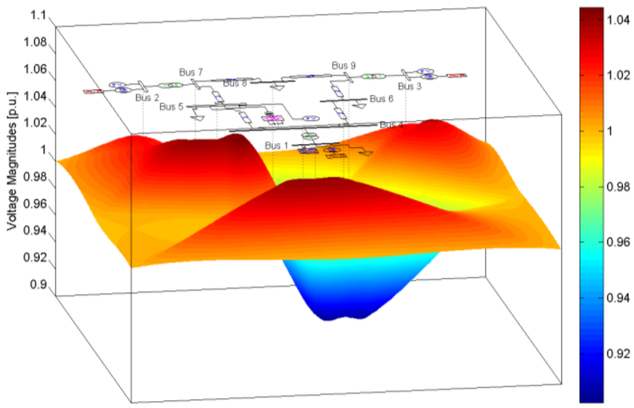


Table.4.Power Flow with STATCOM

Bus Number	V [p.u.]	phase [rad]	P gen [p.u.]	Q gen [p.u.]	P load [p.u.]	Q load [p.u.]
1	1.04	0.00	6.30	2.28	2.00	1.05
2	1.03	-0.28	1.63	0.41	0.00	0.00
3	1.03	-0.37	0.85	0.62	0.00	0.00
4	1.00	-0.24	0.00	0.00	0.00	0.00
5	1.04	-0.43	0.00	2.27	2.40	1.30
6	0.90	-0.44	0.00	0.00	2.20	1.00
7	1.00	-0.38	0.00	0.00	0.00	0.00
8	0.95	-0.48	0.00	0.00	2.00	1.05
9	0.99	-0.42	0.00	0.00	0.00	0.00

Table.5.Summary report with STATCOM

Summary report with STATCOM	
Total Power Generation	
Real Power [p.u.]	8.779
Reactive Power [p.u.]	5.589
Total Loads	
Real Power [p.u.]	8.600
Reactive Power [p.u.]	4.400
Total Power losses	
Real Power [p.u.]	0.179
Reactive Power [p.u.]	1.189

The UPFC is used in bus 5 based on Eigen value analysis and the voltage and power losses are listed below. Figs. 9 and 10 shows the voltage profiles using UPFC and Table 6 and 7 shows the Power flow result and summary report.

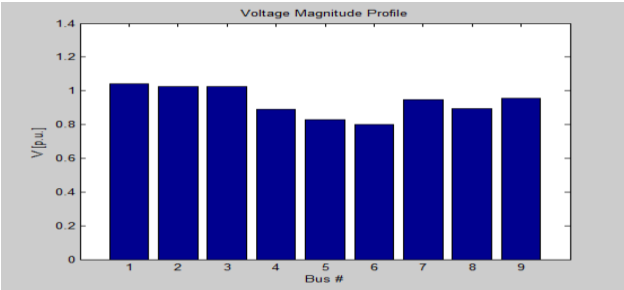


Figure.9. Voltage profile using UPFC

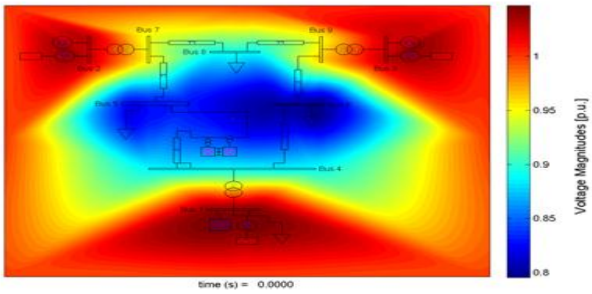


Fig.10. 2D View of Voltage Profile With UPFC

Table.6.POWER FLOW with UPFC

Bus Number	V [p.u.]	phase [rad]	P gen [p.u.]	Q gen [p.u.]	P load [p.u.]	Q load [p.u.]
1	1.04	0.00	6.30	4.35	2.00	1.05
2	1.03	-0.34	1.63	1.35	0.00	0.00
3	1.03	-0.45	0.85	1.22	0.00	0.00
4	0.89	-0.27	0.00	0.00	0.00	0.00
5	0.83	-0.45	0.00	0.00	2.40	1.30
6	0.80	-0.52	0.00	0.00	2.20	1.00
7	0.95	-0.44	0.00	0.00	0.00	0.00
8	0.89	-0.56	0.00	0.00	2.00	1.05
9	0.96	-0.50	0.00	0.00	0.00	0.00

Table.7.Summary report with UPFC

Summary Report with UPFC	
Total Power Generation	
Real Power [p.u.]	8.781
Reactive Power [p.u.]	6.925
Total Loads	
Real Power [p.u.]	8.600
Reactive Power [p.u.]	4.400
Total Power Losses	
Real Power [p.u.]	0.181
Reactive Power [p.u.]	2.525

Table 8: EIGEN VALUE ANALYSIS OF THE SYSTEM with and Without FACTS Devices

	With Out FACTS Devices	With STATCOM	With UPFC
Dynamic Order	24	25	27
Buses	9	9	9
Positive Eigens	2	0	0
NegativeEigens	20	23	25
Complex Pairs	6	8	8
Zero Eigens	2	2	2

Table.9.Summary report with and without FACTS

Summary Report	Without FACTS	With STATCOM	With UPFC
Total Power Generation			
Real Power [p.u.]	8.887	8.779	8.781
Reactive Power [p.u.]	7.302	5.589	6.925
Total Loads			
Real Power [p.u.]	8.600	8.600	8.600
Reactive Power [p.u.]	4.400	4.400	4.400
Total Power Losses			
Real Power [p.u.]	0.287	0.179	0.181
Reactive Power [p.u.]	2.902	1.189	2.525

The Eigen value analysis comparison report taken without and with STATCOM and UPFC devices are shown in above table 8 and the positive Eigens changed 2 to 0 using STATCOM and UPFC system get stable. It is observed that fig.3, 6, 9 shows how the voltage profile improved and system is in stable using FACTS devices. The comparison chart shown in the table 8, 9 shows the system get stable and losses get reduced using STATCOM and UPFC device.

2. CONCLUSION

The performance of stability improvement has been achieved by using STATCOM,UPFC and the Eigen values has been changed from 2 to 0.The graphs show voltage profile increased and stabilized when STATCOM and UPFC is used. The Eigen value analysis has been carried out for overloading condition and the small signal stability, Voltage stability in the system are analyzed and Power losses are reduced using PSAT (Power System Analysis Tool) software. The future work can be carried out using computational algorithms like PSO, Neural network, Firefly algorithm, ACO.

REFERENCES

Anju Gupta, Sharma, Optimal location of svc for dynamic stability enhancement based on eigenvalue analysis, ELELIJ Journal, 3 (1), 2014.

Bharadwaj R, Sathyanarayana, and Gerald Thomas Heydt, Sensitivity-Based Pricing and Optimal Storage Utilization in Distribution Systems, IEEE Transactions on Power Delivery, 28 (2), 2013.

Devendra P Parmar, Dholakiya M, and Santosh C, Optimal Placement of Power System Stabilizers (PSS): Simulation Studies on a Test System, IIT, Nirma University, Ahmedabad – 382 481, 2011.

Federico Milano, Luigi Vanfretti, and Juan Carlos Morataya, An Open Source Power System Virtual Laboratory: The PSAT Case and Experience, IEEE Transactions, 51 (1), 2008.

Hajforoosh S, Nabavi S.M.H, Masoum M.A.S, Coordinated aggregated-based PSO algorithm for congestion management in restructured power market by placement and sizing of UPFC, IET Science Measurement Technology, 6 (4), 2012, 267–278.

Jagabondhu Hazra, Avinash K Sinha, Congestion Management Using Multi-objective PSO, IEEE Transactions, 22 (4), 2007.

Kanwardeep Singh, Narayana Prasad Padhy, and Jaydev, Influence of Price Responsive Demand Shifting Bidding on Congestion and (LMP) Locational Marginal Price in Pool-Based Day-Ahead Electricity Markets, IEEE Transactions ON Power Systems, 26 (2), 2011.

Kumar A, Charan Sekhar, Comparison of Sen Transformer and Unified Power Flow Controller for congestion management in hybrid electricity markets, International Journal of Electrical Power and Energy Systems, 47, 2013, 295–304.

Kyaw Myo Lin, Wunna Swe, Coordinated Design of PSS and STATCOM for Power Systems Stability Enhancement Using Bacteria Foraging Algorithm, International Journal of Electrical, Computer, Electronics and Communication Engineering, 7 (2), 2013.

Lini Mathew, Chatterji S, Transient Stability Analysis of Electrical Power Systems by means of Lab view based Simulation of STATCOM, International Journal of Advances in Engineering Sciences, 1 (2), 2011.

Masoud Esmaili, Fatemeh Ebadi, Heidar Ali Shayanfar, Shahram Jadid, Congestion management in hybrid power markets using modified Benders decomposition (BD), International Journal of Applied Energy, 102, 2013, 1004–1012.

Mojtaba Khanabadi, Hassan Ghasemi, and Meysam, Optimal Transmission Switching Considering Voltage Security and N-1 Contingency Analysis, IEEE Transactions on Power Systems, 28 (1), 2013.

Neeraj Gupta, and Sanjay K Jain, Comparative Analysis of Fuzzy Power System Stabilizer (PSS) Using Different Membership Functions, IJCEE, 2 (2), 2010.

Nima Amjady, Mahmood Hakimi, Dynamic voltage stability constrained congestion management framework for deregulated electricity power markets, International Journal of Energy Conversion and Management, 58, 2012, 66–75.

Saket Saurabh, Md Irfan Ahmed, Optimal placement of STATCOM for improving voltage stability using GA, IJSET, 2 (6), 2014.

Samrajyam K, Prakash, Optimal Location of STATCOM for Reducing Voltage Fluctuations, IJMER, 2 (3), 2012, 834-839.

Shao-Hong Tsai, Yuan-Kang Wu, and Ching –Yin Lee, A critical Eigen values Tracing Method for the small signal stability in Power systems, International Journal of Energy and Power engineering, 5, 2013, 677-682.

Singh A.K, Parida S, Congestion management with distributed generation and its impact on electricity power market, International Journal of Electrical Power and Energy Systems, 48, 2013, 39–47.

Sudipta Dutta, and Singh S, Optimal Rescheduling of Generators for Congestion Management Based on Particle Swarm Optimization (PSO), IEEE Transactions On Power Systems, 23 (4), 2008.

Tiwari P.K, Sood Y.R, Efficient and optimal approach for location and parameter setting of multiple UPFC controllers for a deregulated power sector, IET Generation, Transmission, Distribution, 6 (10), 2012, 958-967.

Yousefi A, Nguyen T.T, Zareipour H, Malik O.P, Congestion management using demand response and Flexible AC Transmission systems (FACTS) devices, International Journal of Electrical Power and Energy Systems, 37, 2012, 78–85.