International Journal of Precious Engineering Research and Applications
www.ijpera.com
ISSN : 2456-2734, Vol. 2, Issue 2, May 2017, pp.11-18

RESEARCH ARTICLE OPEN ACCESS

Hierarchical Steady State Control of System wide Distributed Multi-FACTS Devices for Operational Enhancement Objectives

I.A Araga[1], I.I Alabi[2] A.O Anibasa[3]
Department of Electrical/Electronic Engineering Faculty of Engineering, Nigerian Defence Academy, Kaduna

ABSTRACT
Developed power systems in the world are well meshed with local, inter-regional and international connection making the increasing complex to operate. With advancement in power electronics, the control of these systems are faster with the aid of Flexible AC Transmission system devices (FACTs) introduced as control element in the system. As more of these devices are installed optimally in the transmission line at various locations, it is unarguable that it has the capabilities to control powerflows in major transmission line power corridors as well as improve voltage profiles of some critical buses within their respective operational domains of dominant influence. In addition, there tends to be a mutual conflict within the system. These unhealthy interactions within the system where these devices tend to operate beyond their operational domain. This paper is meant to x-ray and resolve these advance conflict as they occur in the system.

I. INTRODUCTION

It is unarguable that optimally installed FACTSdevices possess flexible capabilities to control powerflows in major transmission line power corridors as well as improve voltage profiles of some critical buses within their respective operational domains of dominant influence. This is abstractly illustrated in Figure 1.0 as overlapping circular domains that encompass transmission lines and buses where mutual influences might occur. This has import on there maiming part of the grid including the line sand buses where other FACTS devices are placed. Basically, the control of the FACTS devices is local,i.e.no supervisory control that coordinates the actions of different devices. There is need therefore to incorporate higher level steady state coordinator to resolve and/or mitigate mutual influences among devices that could possibly result in adverse interactions in interconnected power systems.

A two level supervisory steady state control based on optimal power flow has been developed as shown in Figure 1.0.The objective is to prevent conflicts among the devices by coordinating their actions to mitigate the danger of induced overloaded equipment and transmission line congestions. The optimal power flow solution yields voltage profile and active power losses for the system with embedded FACTS devices are
Compared withthe base case scenario without FACTSdevices to establish, if any, voltage profile, technical losses and load ability improvements.

Referring to Figure 1.0, each local controller dedicated to a FACT device that relies on local measurements such as line flows and bus voltage to adjust its parameter settings and transmit such information to central coordinator for further processing. The central coordinator acquires global system data to calculate sensitivity matrix to identify conflicts amongst FACTS devices and then implement OPF to determine their parameters to resolve such conflicts and insure optimum operational steady state performance at all times. Expectedly where conflicts do not exist, decentralized implementations of multi-FACTS devices are retained as optimal.

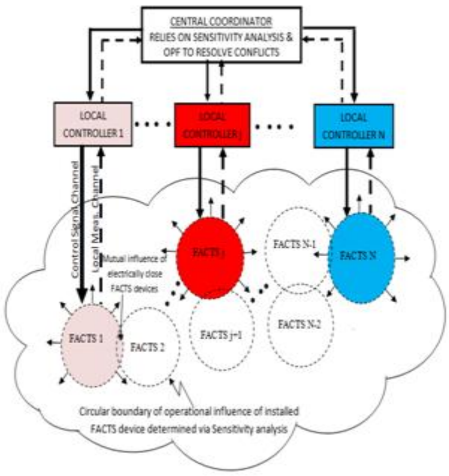


Figure 1.0: Interconnected Power System Equipped with Distributed N FACTS Devices under Hierarchical steady State Control Structure to

Resolve Operational Conflicts

Table 1.0: Graph Theory Based Parameter Characterizations of the Two Test Systems

Graph Parameters	Nigerian Grid***	IEEE 30 bus**
Nodes/Buses	39	30
Elements (Transmission line + Transformers)	58	41
Diameter*	10	7
Number of Maximum Shortest Path	1	2
Average Node Degree	2.795	2.73
Clustering Coefficient	0.1457	0.2347
Average path length	2.123	3.47
Hub (Maximum number of connected lines)	Benin Bus	Node 6

*****Maximum number of direct links between buses i and j within a given network;
******Extracted from reference [34];
******* Computed via algorithmic procedure based on standard equations given in [69];

1.1Description of Hierarchical Control Structure Implementation for Optimally Placed Multi-FACTS Devices in the Nigerian Grid System

The Nigerian grid system is described as structurally deficient because of its radial topology as further confirmed by its graph theory based characteristic features summarized in Table 1.2. The inadequacy of transmission infrastructure has called for construction of new transmission power corridor to provide alternative route for power delivery to consumers in case of critical N-1 contingency or to carry diverted power from heavily loaded transmission lines during bilateral electricity transaction. In order to make up for its inadequate transmission outlay, this research goal has pursued the optimal placements of FACTS devices in the Nigerian transmission system in order to secure the following steady state operational improvements:

1. Minimization of network losses;
2. Relief of transmission congestion during peak demand;
3. Voltage stability enhancement; and
4. **Possible deferment of transmission reinforcement.**

Figure 1.3 portrays the functional representation of the Nigerian national grid equipped with optimally designed multi-SVC and TCSC based on MILP solution of OPF formulation to realize the aforementioned operational improvements. The distributed SVCs and TCSC are then supervised by two-level hierarchical controller in keeping with the generalized hierarchical control structure of Figure 1.0. The functional task of the central coordinator is to resolve negative mutual interactions amongst installed FACTS devices if and when so identified on the basis of sound algorithmic framework that relies on periodic synchronous data information received from all local controllers. Note that each local controller is dedicated to specific FACTS device with demarcated zone of operational influence. The local controllers, in turn, rely wholly on local information of system quantities such as bus voltages, line flows and local network information to change optimal settings for their respective FACTS devices as system operating point changes. Central to the implementation of the proposed control structure are bi-directional communication and data acquisition channels configured around distributed phasor measurement units (PMUs) and wireless communication infrastructure[]. At the local controller level, relying on data acquired periodically and the local neighbour network the optimal settings for each FACTS device are then determined using sensitivity analysis.

International Journal of Precious Engineering Research and Applications
www.ijpera.com
ISSN : 2456-2734, Vol. 2, Issue 2, May 2017, pp.11-18

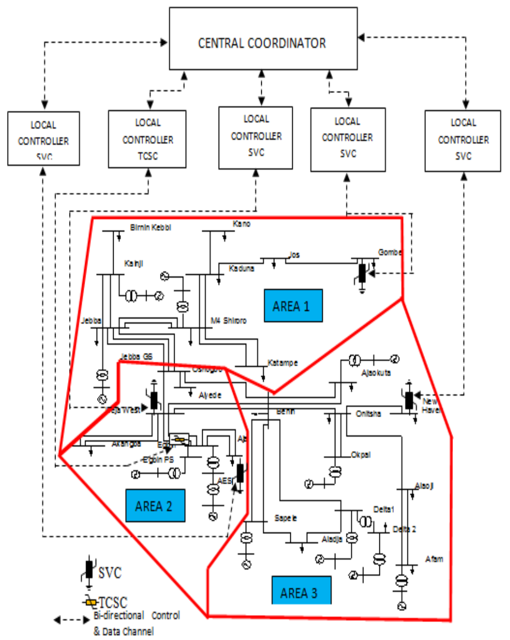


Figure 1.3: Functional Representation of Hierarchical Steady State Control of Optimal Placement of Multi-SVC and TCSC in Three- Area Nigerian Grid System

The central coordinator relies on the global data received and sensitivity computations to identify any existence of mutual interactions amongst electrically close FACTS devices. Upon detection of negative mutual interactions amongst FACTS devices will trigger implementation of OPF formulation to determine new optimal settings to override their locally computed settings. In the absence of mutual interactions amongst FACTS devices, their respective settings determined at local controller level are returned by the central coordinator as optimal for implementation. For the sake of completeness, the operating ranges of the various SVC and TCSC optimally sited in the Nigerian national grid and expected steady state operational improvements are presented in Table 5.2.

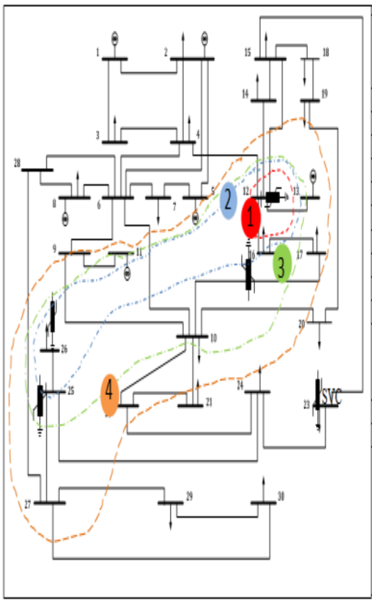
Table 5.3: Summary of

DESCRIPTION	FACTS Type	Bus Name	Line	Operating Limits Of FACTS Devices	
				Minimum	Maximum
39- BUS NIGERIAN NATIONAL GRID FACTS DEVICE PLACEMENT	SVC1	Gombe	-	-20mvar	50mvar
	SVC2	Ikeja-West	-	-50mvar	150mvar
	SVC3	New-Haven	-	-10mvar	50mvar
	SVC4	Ajah	-	-10mvar	75mvar
	TCSC	-	Egbin HT-Ikeja West Line 5	$X_{TCSC_{min}} = -j($	$X_{TCSC_{max}} = j$
SYSTEM OPERATIONAL IMPROVEMENT SPECIFICATIONS	Network Loss Reduction For: • SVC1+SVC2 (2-Type) Installation; • SVC1+SVC2+SVC3 (3-Type) Installation; • SVC1+SVC2+SVC3+SVC4 (4-Type) Installation;			5.5% 7.4% 8.7%	13.75% 15.8% 16.8%
	Loadability Improvement Margin For: • SVC1+SVC2 (2-Type) Installation • SVC1+SVC2+SVC3+SVC4 (4-Type) Installation;			21% 24%	33% 38%
	Voltage Stability Margin Improvement For: • SVC1+SVC2 (2-Type) Installation i. SVC1+SVC2+SVC3+SVC4 (4-Type) Installation;			12% 14%	16% 19%

Optimum number of FACTS required for minimum installation cost

We reiterate again that the Nigerian national grid admitted more of shunt FACTS type (SVC or STATCOM) and less of series FACTS type (TCSC) due to its radial topology. With the completion of on-going transmission reinforcements for more reliable and secure delivery of electricity to consumers, it is envisioned that more series or series-shunt FACTS types will be admitted. Fortunately, FACTS devices are re-locatable and expandable if and when their respective ratings and/or locations become suboptimal as consequence of rapid expansion of network infrastructure. Indeed, the expectation is that the Nigerian transmission infrastructure will witness rapid expansion driven primarily by opening of transmission entity to private participation but under unified operational management of regional independent system operators (ISOs)1US$=N200

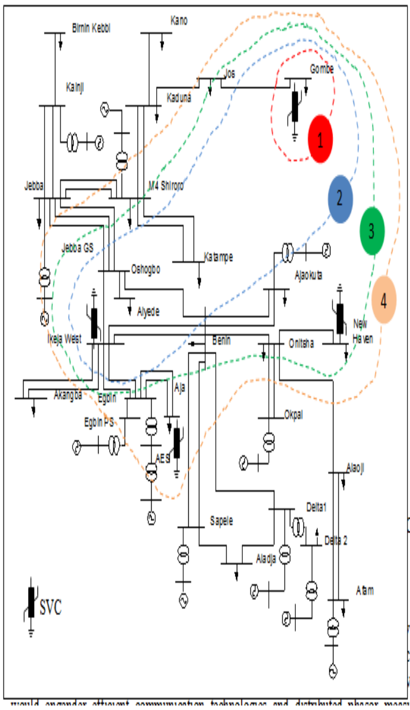
International Journal of Precious Engineering Research and Applications
www.ijpera.com
ISSN : 2456-2734, Vol. 2, Issue 2, May 2017, pp.11-18



No of SVC/Bus Location	SVC Rating Specifications (pu)		
	Min	Ave	Max
1 /16	-0.32	0.35	0.38
2/16	-0.21	0.23	0.26
2/25	-0.11	0.13	0.16
3/16	-0.11	0.12	0.14
3/25	-0.19	0.23	0.26
3/24	-0.10	0.12	0.14
4/16	-0.21	0.23	0.25
4/25	-0.33	0.35	0.37
4/24	-0.15	0.16	0.18
4/27	-0.21	0.23	0.26

Bus No	Highest (H) & Lowest (L) Voltage Mag.(pu)		
	min	ave	max
11 (H)	0.946	1.011	0.987
5(L)	0.931	0.953	0.958

Figure 4.15: IEEE 30-Bus System Showing SVC Locations and Their Concatenated Grouping Installation Sequence



No of SVC/Bus Location	SVC Rating Specifications (pu)		
	Min	Ave	Max
1 /14	-1.27	1.33	1.41
2/14	-1.24	1.29	1.34
2/29	-0.48	0.52	0.55
3/14	-1.22	1.29	1.38
3/29	-0.32	0.34	0.36
3/39	-0.48	0.52	0.54
4/14	-1.25	1.32	1.39
4/29	-0.49	0.52	0.54
4/39	-0.48	0.51	0.53
4/23	-0.78	0.81	0.85

Bus No	Highest (H) & Lowest (L) Voltage Mag.(pu)		
	min	ave	max
14(H)	0.946	0.967	0.987
5(L)	0.931	0.948	0.958

Figure 4.18: 39-Bus Nigerian Grid System Showing SVC Locations and Their Concatenated Grouping Installation Sequences

II. CONCLUSION

Generalized hierarchical control architecture has been proposed to determine the steady state control setting of each distributed multi- FACTS devices in large interconnected network enabled by dedicated controllers at local level, resolve all control conflicts and optimize parameter settings at supervisory level (Coordinator). This would engender efficient communication technologies and distributed phasor measurement units for data acquisition system. The design of a hierarchical control framework for the Nigerian grid and IEEE 30 Bus systems has been set forth as closure to this work.

REFERENCES

[1]. Chen, L., et al., Components of nodal prices for electric power systems. Power Systems, IEEE Transactions on, 2002. **17**(1): p. 41-49.

[2]. Baskar, G. and M.R. Mohan, Contingency constrained economic load dispatch using improved particle swarm optimization for security enhancement. Electric Power Systems Research, 2009. **79**(4): p. 615-621.

[3]. Leonidaki, E.A., D.P. Georgiadis, and N.D. Hatziargyriou, Decision trees for determination of optimal location and rate of series compensation to increase power system loading margin. Power Systems, IEEE Transactions on, 2006. **21**(3): p. 1303-1310.

[4]. Glanzmann, G. and G. Andersson. Using FACTS devices to resolve congestions in transmission grids. in CIGRE/IEEE PES, 2005. International Symposium. 2005: IEEE.

[5]. Cai, L., Robust coordinated control of FACTS devices in large power systems. 2004, UniversitÃ¤t Duisburg-Essen, FakultÃ¤t fÃ¼r IngenieurwissenschaftenÂ» Elektrotechnik und Informationstechnik.

[6]. Xiao-Ping, Z., C. Rehtanz, and B. Pal, Flexible Ac transmission systems: Modelling and control. 2006, Springer-Verlag Berlin Heidelberg.

[7]. Overbye, T.J. and C.L. De Marco, Voltage security enhancement using energy based sensitivities. Power Systems, IEEE Transactions on, 1991. **6**(3): p. 1196-1202.

[8]. Singh, J.G., S.N. Singh, and S.C. Srivastava. Placement of FACTS controllers for enhancing power system loadability. in Power India Conference, 2006 IEEE. 2006: IEEE.

[9]. Fisher, E.B., R.P. O'Neill, and M.C. Ferris, Optimal transmission switching. Power Systems, IEEE Transactions on, 2008. **23**(3): p. 1346-1355.

[10]. Hingorani, N.G., L. Gyugyi, and M. El-Hawary, Understanding FACTS: concepts and technology of flexible AC transmission

systems. Vol. 1. 2000: IEEE press New York.
[11]. Zhang, X.-P., C. Rehtanz, and B. Pal, Flexible AC transmission systems: modelling and control. 2006: Springer.
[12]. Sikiru, T.H., et al., Reactive Power Reserve Improvement Using Power Systems Inherent Structural Characteristics. Energy and Power Engineering. **5**: p. 986.
[13]. Song, S.-H., J.-U. Lim, and S.-I. Moon, Installation and operation of FACTS devices for enhancing steady-state security. Electric Power Systems Research, 2004. **70**(1): p. 7-15.
[14]. Srivastava, S.C. and R.K. Verma. Impact of FACTS devices on transmission pricing in a de-regulated electricity market. in Electric Utility Deregulation and Restructuring and Power Technologies, 2000. Proceedings. DRPT 2000. International Conference on. 2000: IEEE.
[15]. Benabid, R., M. Boudour, and M.A. Abido, Optimal location and setting of SVC and TCSC devices using non-dominated sorting particle swarm optimization. Electric Power Systems Research, 2009. **79**(12): p. 1668-1677.
[16]. Bacher, R. and H. Glavitsch, Loss reduction by network switching. Power Systems, IEEE Transactions on, 1988. **3**(2): p. 447-454.
[17]. Ajjarapu, V. and B. Lee, Bibliography on voltage stability. Power Systems, IEEE Transactions on, 1998. **13**(1): p. 115-125.
[18]. Seifi, H. and M.S. Sepasian, Electric Power System Planning: Springer.
[19]. Hingorani, N.G., Power electronics in electric utilities: role of power electronics in future power systems. Proceedings of the IEEE, 1988. **76**(4): p. 481-482.
[20]. Verma, K.S. and H.O. Gupta, Impact on real and reactive power pricing in open power market using unified power flow controller. Power Systems, IEEE Transactions on, 2006. **21**(1): p. 365-371.
[21]. Cai, L.J., I.n. Erlich, and G. Stamtsis. Optimal choice and allocation of FACTS devices in deregulated electricity market using genetic algorithms. in Power Systems Conference and Exposition, 2004. IEEE PES. 2004: IEEE.
[22]. Oudalov, A., Coordinated control of multiple facts devices in an electric power system. 2003, École Polytechnique Fédérale de Lausanne, Switzerland.
[23]. Gotham, D.J. and G.T. Heydt, Power flow control and power flow studies for systems with FACTS devices. Power Systems, IEEE Transactions on, 1998. **13**(1): p. 60-65.
[24]. Baskaran, J. and V. Palanisamy, GENETIC ALGORITHM APPLIED TO OPTIMAL LOCATION OF FACTS DEVICE IN A POWER SYSTEM NETWORK CONSIDERING ECONOMIC SAVING COST. Academic open internet journal, 2005. **15**: p. 1-7.
[25]. Mubeen, S.E., R.K. Nema, and G. Agnihotri, Power Flow Control with UPFC in Power Transmission System. World Academy of Science, 2008.
[26]. Ambriz-Perez, H., E. Acha, and C.R. Fuerte-Esquivel, Advanced SVC models for Newton-Raphson load flow and Newton optimal power flow studies. Power Systems, IEEE Transactions on, 2000. **15**(1): p. 129-136.
[27]. Orfanogianni, T. and R. Bacher, Steady-state optimization in power systems with series FACTS devices. Power Systems, IEEE Transactions on, 2003. **18**(1): p. 19-26.
[28]. Del Rosso, A.D., C.A. CaÃ±izares, and V.M. Dona, A study of TCSC controller design for power system stability improvement. Power Systems, IEEE Transactions on, 2003. **18**(4): p. 1487-1496.
[29]. Coffrin, C., P. Van Hentenryck, and R. Bent. Approximating line losses and apparent power in AC power flow linearizations. in Power and Energy Society General Meeting, 2012 IEEE: IEEE.
[30]. Hug-Glanzmann, G., Coordinated power flow control to enhance steady-state security in power systems. 2008, ETH ZÃ¼rich.
[31]. Hammad, A.E., Analysis of power system stability enhancement by static var compensators. Power Systems, IEEE Transactions on, 1986. **1**(4): p. 222-227.
[32]. Sen, K.K. and E.J. Stacey, UPFC-unified power flow controller: theory, modeling, and applications. Power Delivery, IEEE Transactions on, 1998. **13**(4): p. 1453-1460.
[33]. Acha, E., et al., FACTS: modelling and simulation in power networks. 2004: John Wiley & Sons.
[34]. Sikiru, T.H., et al., Reactive Power Reserve Improvement Using Power Systems Inherent Structural Characteristics. Energy and Power Engineering, 2012. **5**(04): p. 986.
[35]. Larsen, E.V., et al., Characteristics and rating considerations of thyristor controlled series compensation. IEEE Transactions on Power Delivery, 1994. **9**(2): p. 992-1000.

[36]. Canizares, C.A. and Z.T. Faur, Analysis of SVC and TCSC controllers in voltage collapse. Power Systems, IEEE Transactions on, 1999. **14**(1): p. 158-165.
[37]. Eghbal, M., N. Yorino, and Y. Zoka, Comparative Study on the Application of Modern Heuristic Techniques to SVC Placement Problem. Journal of Computers, 2009. **4**(6): p. 535-541.
[38]. Jumaat, S.A., et al. Transmission loss minimization using SVC based on particle swarm optimization. in Industrial Electronics and Applications (ISIEA), 2011 IEEE Symposium on: IEEE.
[39]. Liun, E., ECONOMIC ASPECT OF HVDC TRANSMISSION SYSTEM FOR INDONESIA CONSIDERATION IN NUCLEAR POWER DEVELOPMENT. Jurnal Pengembangan Energi Nuklir, 2009. **11**(2).
[40]. Kazemi, A. and H. Andami. FACTS devices in deregulated electric power systems: a review. in Electric Utility Deregulation, Restructuring and Power Technologies, 2004.(DRPT 2004). Proceedings of the 2004 IEEE International Conference on. 2004: IEEE.
[41]. Gerbex, S.p., R. Cherkaoui, and A.J. Germond, Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms. Power Systems, IEEE Transactions on, 2001. **16**(3): p. 537-544.
[42]. Huang, J.S., Z.H. Jiang, and M. Negnevitsky, Loadability of power systems and optimal SVC placement. International Journal of Electrical Power & Energy Systems. **45**(1): p. 167-174.
[43]. Cai, L.-J. and I. Erlich, Simultaneous coordinated tuning of PSS and FACTS damping controllers in large power systems. Power Systems, IEEE Transactions on, 2005. **20**(1): p. 294-300.
[44]. Elgerd, O.I. and H.H. Happ, Electric energy systems theory: an introduction. Systems, Man and Cybernetics, IEEE Transactions on, 1972. **2**(2).
[45]. L'Abbate, A., et al. Advanced steady-state models of UPFC for power system studies. in Power Engineering Society Summer Meeting, 2002 IEEE. 2002: IEEE.
[46]. Lima, F.G.M., et al., Phase shifter placement in large-scale systems via mixed integer linear programming. Power Systems, IEEE Transactions on, 2003. **18**(3): p. 1029-1034.
[47]. Breuer, W., et al. Role of HVDC and FACTS in future Power Systems. in CIGER Symposium, Shang Hai. 2004.
[48]. Hingorani, N.G., Power electronics in electric utilities: role of power electronics in future power systems. Proceedings of the IEEE, 1988: p. 481-482.
[49]. Xiao, Y., Y.H. Song, and Y.Z. Sun, Power flow control approach to power systems with embedded FACTS devices. Power Systems, IEEE Transactions on, 2002. **17**(4): p. 943-950.
[50]. Carpentier, J.L. Optimal power flows: uses, methods and developments. in Proceedings of IFAC Conference. 1985.
[51]. Dommel, H.W. and W.F. Tinney, Optimal power flow solutions. power apparatus and systems, IEEE transactions on, 1968(10): p. 1866-1876.
[52]. Alsac, O., et al., Further developments in LP-based optimal power flow. Power Systems, IEEE Transactions on, 1990. **5**(3): p. 697-711.
[53]. Burchett, R.C., H.H. Happ, and K.A. Wirgau, Large scale optimal power flow. power apparatus and systems, IEEE transactions on, 1982(10): p. 3722-3732.
[54]. Papalexopoulos, A.D., C.F. Imparato, and F.F. Wu, Large-scale optimal power flow. IEEE Trans. Power Syst.;(United States), 1989. **4**(2).
[55]. Wei, H., et al., An interior point nonlinear programming for optimal power flow problems with a novel data structure. Power Systems, IEEE Transactions on, 1998. **13**(3): p. 870-877.
[56]. Sun, D.I., et al., Optimal power flow by Newton approach. power apparatus and systems, IEEE transactions on, 1984(10): p. 2864-2880.
[57]. Burchett, R.C., H.H. Happ, and D.R. Vierath, Quadratically convergent optimal power flow. power apparatus and systems, IEEE transactions on, 1984(11): p. 3267-3275.
[58]. Karmarkar, N. A new polynomial-time algorithm for linear programming. in Proceedings of the sixteenth annual ACM symposium on Theory of computing. 1984: ACM.
[59]. Cai, L.J., I. Erlich, and G. Stamtsis. Optimal choice and allocation of FACTS devices in deregulated electricity market using genetic algorithms. in Power Systems Conference and Exposition, 2004. IEEE PES. 2004: IEEE.

[60]. MÃ-nguez, R., et al., Optimal network placement of SVC devices. Power Systems, IEEE Transactions on, 2007. **22**(4): p. 1851-1860.

[61]. El-Dib, A.A., et al., Optimum VAR sizing and allocation using particle swarm optimization. Electric Power Systems Research, 2007. **77**(8): p. 965-972.

[62]. Haque, M.H., Best location of SVC to improve first swing stability limit of a power system. Electric Power Systems Research, 2007. **77**(10): p. 1402-1409.

[63]. Lie, T.T. and W. Deng, Optimal flexible AC transmission systems (FACTS) devices allocation. International Journal of Electrical Power & Energy Systems, 1997. **19**(2): p. 125-134.

[64]. Ippolito, L. and P. Siano, Selection of optimal number and location of thyristor-controlled phase shifters using genetic based algorithms. IEE Proceedings-Generation, Transmission and Distribution, 2004. **151**(5): p. 630-637.

[65]. Hao, J., L.B. Shi, and C. Chen, Optimising location of unified power flow controllers by means of improved evolutionary programming. IEE Proceedings-Generation, Transmission and Distribution, 2004. **151**(6): p. 705-712.

[66]. Leonidaki, E.A., G.A. Manos, and N.D. Hatziargyriou, An effective method to locate series compensation for voltage stability enhancement. Electric Power Systems Research, 2005. **74**(1): p. 73-81.

[67]. Sharma, A.K., Optimal number and location of TCSC and loadability enhancement in deregulated electricity markets using MINLP. International Journal of Emerging Electric Power Systems, 2006. **5**(1).

[68]. Rao, S.S. and S.S. Rao, Engineering optimization: theory and practice. 2009: John Wiley & Sons.

[69]. Jabr, R.A., et al., Contingency constrained VAr planning using penalty successive conic programming. Power Systems, IEEE Transactions on. **27**(1): p. 545-553.

[70]. Koster, A.M.C.A. and S. Lemkens, Designing AC power grids using integer linear programming, in Network Optimization, Springer. p. 478-483.

[71]. Yang, G.Y., et al., TCSC allocation based on line flow based equations via mixed-integer programming. Power Systems, IEEE Transactions on, 2007. **22**(4): p. 2262-2269.

[72]. Preedavichit, P. and S.C. Srivastava, Optimal reactive power dispatch considering FACTS devices. Electric Power Systems Research, 1998. **46**(3): p. 251-257.

[73]. Carpinelli, G., et al., Single-objective probabilistic optimal allocation of capacitors in unbalanced distribution systems. Electric Power Systems Research. **87**: p. 47-57.

[74]. Allgower, E. and K. Georg, Simplicial and continuation methods for approximating fixed points and solutions to systems of equations. Siam review, 1980. **22**(1): p. 28-85.

[75]. Balamurugan, G. and P. Aravindhababu, Online VAR support estimation for voltage stability enhancement. International Journal of Electrical Power & Energy Systems. **49**: p. 408-413.

[76]. Panigrahi, B.K., Locational Marginal Pricing (LMP) in Deregulated Electricity Market.

[77]. Cardell, J.B., Marginal loss pricing for hours with transmission congestion. Power Systems, IEEE Transactions on, 2007. **22**(4): p. 1466-1474.

[78]. Gautam, D. and N. Mithulananthan, Optimal DG placement in deregulated electricity market. Electric Power Systems Research, 2007. **77**(12): p. 1627-1636.

[79]. Kumar, A., S.C. Srivastava, and S.N. Singh, Congestion management in competitive power market: a bibliographical survey. Electric Power Systems Research, 2005. **76**(1): p. 153-164.

[80]. Panigrahi, B.K., Locational Marginal Pricing (LMP) in Deregulated Electricity Market. International Journal of Electronics Signals and Systems. **1**(2).

[81]. Nasiruzzaman, A.B.M. and H.R. Pota. Transient stability assessment of smart power system using complex networks framework. in Power and Energy Society General Meeting, 2011 IEEE: IEEE.

[82]. Coffrin, C., P. Van Hentenryck, and R. Bent. Approximating line losses and apparent power in AC power flow linearizations. in Power and Energy Society General Meeting, 2012 IEEE. 2012: IEEE.

[83]. Overbye, T.J., X. Cheng, and Y. Sun. A comparison of the AC and DC power flow models for LMP calculations. in System Sciences, 2004. Proceedings of the 37th Annual Hawaii International Conference on. 2004: IEEE.

[84]. Paserba, J.J., et al., A thyristor controlled series compensation model for power system stability analysis. Power Delivery,

IEEE Transactions on, 1995. **10**(3): p. 1471-1478.

[85]. Hedman, K.W., et al., Optimal transmission switchingâ€"sensitivity analysis and extensions. Power Systems, IEEE Transactions on, 2008. **23**(3): p. 1469-1479.

[86]. Khodaei, A. and M. Shahidehpour, Transmission switching in security-constrained unit commitment. Power Systems, IEEE Transactions on. **25**(4): p. 1937-1945.

[87]. Xiao, Y., et al., Available transfer capability enhancement using FACTS devices. Power Systems, IEEE Transactions on, 2003. **18**(1): p. 305-312.

[88]. Zhang, X.-P., E. Handschin, and M. Yao, Modeling of the generalized unified power flow controller (GUPFC) in a nonlinear interior point OPF. Power Systems, IEEE Transactions on, 2001. **16**(3): p. 367-373.

[89]. Geidl, M., Implementation of FACTS and Economic Generation Dispatch in an Interactive Power Flow Simulation Platform.Zurich, 2003.

[90]. Willis, H.L. and L. Philipson, Understanding electric utilities and de-regulation. Vol. 27. 2005: CRC Press.

[91]. C. A. Canizare and Z. T. Faur, "Analysis of SVC and TCSC Controllers in Voltage Collapse," IEEE Trans. Power Systems, Vol. 14, No. 1, pp. 158-165, 1999.

[92]. S. A. Taher and H. Besharat, "Transmission Congestion Management by Determining Optimal Location of FACTS Devices in Deregulated Power Systems," American Journal of Applied Sciences 5(3), pp. 244-247, 2008.

[93]. M. Eghbal, N. Yorino and Y. Zoka, "Comparative Study on the Application of Modern Heuristic Techniques to SVC Placement Problem," Journal of Computers, Vol. 4, No. 6, pp.535-541, 2009.