A Comprehensive review on Optimization Algorithms for Best Location of FACTS Controller

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Abstract - *Due to soaring demand and difficulties like excessive power transfer via transmission lines, overloading, massive transmission losses, unstable voltage, poor power quality, unreliability, voltage profile issues, and a prohibitively high cost of constructing a brand-new power grid, optimizing the use of the existing one is more important than ever. This paper summarizes the existing and proposed literature on optimal placement strategies for compensating devices. In total, 59 studies are reviewed, dissected, and analyzed for their aims, optimization techniques, and example applications. This paper is useful for analysts looking to expand their research and study of the power system's application in various fields related to location of compensating FACTS controller.*

Key Words: **FACTS, TCSC, TCPAR, STATCOM, SVC, UPFC, TCPST, met heuristic optimization technique, DE, GA, PSO, IPSO, ABC, OPF.**

1. INTRODUCTION

Transmission lines are being severely affected by continuously increasing load demand, dynamic load pattern and due to integration of system. They are operating either in overload or under load condition. This contradictory distribution of loads overwhelms the profile of voltage and thus causes the security of system voltage most unsafe to the faults. Hence, it set off very much difficult to enhance the performance of network and maintain its security and reliability [27]. Due to economic factor establishing a new transmission line is not feasible, hence indeed up gradation of existing transmission line is very much necessary rather its expansion. Rather than conventional method, which uses technologies depending on electro-mechanic devices having very less speed and huge cost, power electronics devices are more suitable. Hingorani and Gyugyi presented FACTS technology in 1999 for improvement of power transfer capability making transmission system more flexible and stable. By using power electronics based FACTS devices the performance of power network gets improved and also making it reliable and efficient [11]. For getting maximum relief from clogging, decrement in transmission line power loss is necessary. Proper location of FACTS compensating devices becomes important as they are not very cheap. Researchers for finding proper location of FACTS compensating devices propose different algorithms. Usual methods of placement of compensating devices are classified into analytical optimization technique, Met heuristic optimization techniques and hybrid met heuristic optimization techniques. Examination of prime parameters should be executed for showing the success of the suggested algorithm for obtaining the proper placement of FACTS compensator in transmission network [11]. Here a review of recent optimization methods for proper location of FACTS compensators for a given bus network is carried out.

2. Review of Research on Optimization Algorithms for location of FACTS Compensators

2.1 Sensitivity Analysis

For the inspection of power system and also for locating optimal location of FACTS compensating device, sensitivity analysis methods were proposed. In this analysis, firstly an index is explained and computed. Mostly indices used are voltage sensitivity index and power loss index. This analysis is also known as analytical approach has the advantage of effective calculations [11][55][56].

In [2] 2001, S.N. Singh used sensitivity approach to observe the worthiness of FACTS compensator in the power line, as emergency conditions in power system are more and hence unable to complete the optimal power flow for testing the worthiness of FACTS controller. TCSC and TCPAR are located optimally by using power loss sensitivity index. IEEE-5 bus power system is utilized as testing network. Results show improvement in the power system security. In [3] 2012, Kamel et.al, suggested sensitivity index algorithm depends on active power flow performance, it also suggest decrement of VAR losses in the network for proper placement of FACTS controller. Method is also used for another objective for reducing generation rescheduling cost. TCSC controller is taken as a FACTS compensator here. Standard 5-bus network is taken for Sensitivity study. In [4] 2012, A. Samimi et.al, focuses on the objective of proper placement and optimum rating of compensator. Algorithm is the combination of voltage sensitivity index and loss sensitivity index. Optimal placement and optimum rating of TCSC and STATCOM is done here which are used as a compensator. 14-bus network, standard IEEE case is taken for study. In [5] 2014, Anwar Shahzad Siddiquim et.al suggested the proper location of TCSC and Static Compensator to overcome over-loading conditions with fewer losses, less voltage deviation and least price of the device. Optimal location is identified on the basis of total reactive power loss reduction method. 14 buses IEEE power network was utilized as a test case. In [6] 2015, Chetan W. Jadhao et.al, applies the sensitivity indices method by decreasing reactive power loss of the network for proper placement of SVC in 14 buses IEEE network, thus enhances power system performance. In [7] 2017, V.Srinivasa Rao et.al, presents two-stage algorithm for optimal placement of STATCOM. Objective being enhancement of power system static security. Additionally the proper parameter of STATCOM was done with 14 buses IEEE network. N-R power flow method with five iteration was performed for optimizing STATCOM parameters. Also proper placement of STATCOM by sensitivity analysis is done. In [8] 2018, saptarshi ROY et.al, presented sensitivity analysis approach subjected for decreasing the line losses. Analysis is done using multiple contingencies, which is performed on WSCC 3-Machine 9-bus network and 57-bus test standard IEEE system. Proper location of TCSC and TCPAR was done. In [9] 2019, Fasda Ilhaq Robbani et.al, has analyzed influence of STATCOM placement on the most critical voltage profile buses by sensitivity analysis P-V curve method. For placement of STATCOM most critical line and bus is selected by considering its loading parameter. Java-Bali 500KV system is used as a test case. In [54] 2013, Mithu Sarkar suggested Newton-Raphson power flow algorithm used for allocation of UPFC. Effect of allocation of UPFC has been observed for minimizing the transmission power loss. 30-bus IEEE network was utilized for validation of objective. Steady-state modeling of UPFC is done. Results shows enhancement of voltage profile with proper allocation of UPFC. In [66] A.Hardas et.al has used real power flow performance index method for obtaining the optimal location of TCPAR. Output shows the system has less power loss, improves real power flow and overcome the congestion situation. 5-bus network is taken and implemented in MATLAB and results are compared with same system but in power world simulator 12.0 software.

2.2 Metheuristic optimization Algorithm

For determining the optimal placement of FACTS controller, most commonly used technology is met heuristic optimization method. This method is highly efficient in consideration with multi-objective and may be population-based optimization. [11]

2.2.1 Evolution based Algorithm

Evolution strategies were discovered in 1965 [12]. Evolution based optimizations techniques are genetic algorithm, differential evolution etc [11].

2.2.1.1 Genetic Algorithm (GA)

Prof.John Holland firstly introduced a Simple GA in 1975 [34]. It is based on biological evolution method mentioned in Darwin's theory. It is a conventional method, which has faster and better result [13]. Selection, recombination and mutation are used as operators by GA. Recombination are known as crossover [12].

In [13] 2018, Naseer M. Yasin et.al, aim is to decrease the reactive power loss and maximize the power flow. Proper location and proper rating of Static Synchronous compensator is done on standard 5 IEEE network, 30-bus power network and Iraqi National Grid by genetic algorithm method. Mean power factor method is also used for finding the weakest bus in the system. In [14] 2009, Prashant Kumar Tiwari et.al, developed a technique to obtain the active power sharing of generators and to get the rating and best location of FACTS controllers, Which will be responsible for overall system cost using genetic algorithm and traditional N-R method. IEEE-30 bus system is utilized for simulation purpose. Compensator like Static VAR Compensator, Thyristor Controller Series Compensator and Unified Power Flow Controller are utilized as a compensating power FACTS device. In [15] 2010, Prakash g.Burade et.al, uses IEEE-30 bus system for obtaining proper location of TCSC, SVC, TCPAR & UPFC by genetic algorithm. This algorithm also efficiently optimizes the type, and rated value of compensator. In [16] 2003, L.J. Cai et.al, objective is to find economic operation of generators in the network and its dispatch, which is carried out by genetic algorithm method to allocate the FACTS controller with its rated values. 14 buses IEEE network is utilized as a sample for allocation of TCSC, UPFC, TCPST and SVC. In [17] 2012, Jigar S.Sarda et.al, suggested Genetic Algorithm for proper location of Multi-FACTS compensator like here TCSC, SVC and UPFC tested on 30-bus network. Three criteria results shows, without FACTS controller, with FACTS controller and for increased loading on the system. In [18] 2010, A. Y. Abdelaziz et.al, For improving the load ability of power lines and minimizes its total loss genetic algorithm by considering its thermal and voltage limit is used and tested on 9 bus network for proper placement of TCSC. In [19] 2011, A. Bhattacharyya et.al, objective is to improve performance of power network and upgrading an economy of power network. Case study is performed on 30 buses IEEE network. GA based approach is also used for improvement of power transfer capability for interconnected power network. Reactive load is increased from base value upto 200%. Firstly, active and reactive power flow calculations are done and then applied GA to find the amount of magnitudes of FACTS devices. Results show improvement in performance and economy of system. In [30] 2018, Omar M. Abo Gabl et.al, objective is to get optimal location and its optimum size for FACTS controller. Two alternatives TCSC, STATCOM and TCSC, SVC are tested. At different overloading conditions optimization is performed and is formulated for steady state condition. GA is applied on standard 30-bus network.

2.2.1.2 Differential Evolution

It is the kind of evolutionary algorithm suggested by Price and Storn used for optimization problem. It is simpler, significantly faster and robust [20].

In [20] 2008, M. Basu, Objective is to decrease the fuel cost of generator by optimizing power flow control using TCSC and TCPS controller. Modified IEEE 30 bus network is utilized. Differential evolution gives satisfactory results and need minimum computational time. Findings are compared with evolutionary programming and genetic algorithm. In [21] 2011, Ghamgeen I. Rashed et.al, has minimizes the active power losses in the network. Differential Evolution (DE) is used for proper location and the proper parameter setting of TCSC. Comparison has been done between DE and GA. Algorithm is tested on 3-bus power network, 5 bus power networks and 14 bus power networks. Findings show that DE is user-friendly, rapid optimization method compared with genetic algorithm (GA). In [22] 2011, Ahmad Rezaee Jordehi et.al, In this more than one type of FACTS controller optimization has been solved using evolution strategies. 30 buses IEEE network is used for testing. TCSC, SVC, UPFC and its combination were tested using evolution strategy algorithm.

2.2.2 Swarm based algorithm

Algorithm based on the behavior of flying insects for tracking and reaching their food source optimally.

2.2.2.1 Particle Swarm optimization (PSO)

In 1995 Kennedy et.al, introduces PSO. It is a new met heuristic algorithm. As species go to their destination in ideal way, such fact is implemented for finding correct solution for many types of optimization problem. It is a simple and robust technique [12].

In [23] 2013, Noopur Sahu et.al, explains how PSO method is utilized for optimal location of STATCOM for improvement of voltage profile, loss minimization, and total Harmonic Distortion reduction in distribution & transmission networks. 14-bus network is used for simulation, results show that PSO was able to give statistical significance and a great degree of convergence. In [24] 2008, E. Nasr Azadani et.al, in this paper objective is to enhance voltage profile, decreasing power network total losses and increasing network loadability. Using STATCOM with its proper rating fulfills objective. Particle Swarm technique and continuation power flow method is applied. This technique is demonstrated on 57 buses IEEE network. The algorithm is very easy to implement and enable flexible operation. In [25] 2013, K. Ravi et.al, proposed improved PSO for optimizing the power system performance. Objective is to decrease the voltage deviation at busses in a power system. Static Compensator (STATCOM) is used for fulfilling the objective with proper sizing. To illustrate the technique, 30-bus system is used. Results show IPSO proves very efficient. In [26] 2018, Reza Sirjani, power loss index and adaptive particle swarm optimization technique is used. Objective here being enhancement in voltage profile, decrement in power losses in network and also optimization of cost. Placement and sizing PV-STATCOM is done.

2.2.2.2 Ant Colony optimization (ACO)

Ant Colony optimization algorithm was first introduced in 1992 by Dorigo et al [12]. Ant finds the best and shortest route for finding food source [32]. ACO technique can be used for optimization.

In [31] 2009, S.Sreejith et.al, Touring Ant Colony Optimization (TACO) algorithm solve two sub-problem simultaneously i.e. controlling power flow problem and secondly conventional OPF problem. TCSC is used here. Standard 30-bus network is utilized for validation purpose. Outcome proves that TACO is suited to deal with fuzzy, discontinuous, non-differentiable and non-convex problem, like optimization power flow with FACTS controller. In [32] 2019, B Brindha Sakthi et.al, proposed ant colony optimization for finding out the proper locations, and the proper parameter of UPFC (Unified Power Flow Controller) device to obtain large network load-ability in the network with less installation price. For validation 14 and 30 bus network is used.

2.2.2.3 Harmony search optimization algorithm:-

Harmony search optimization technique was first developed in 2001[12]. This optimization method is inspired by music phenomenon [34].

In [33] 2009, A. Kazemi et.al, for improvement of power system security, HSA has applied to obtain best location of more than one type of power controller device. SVC compensator, TCSC compensator and UPFC compensator has been used using 30 buses network. Comparison by considering result is done between GA and harmony search optimization technique. In [34] 2018, D. Karthikaikannan et.al, proper location with setting of controller SVC and TCSC have been done by harmony search optimization technique. It is applied on modified 30-bus power network. It is tested on lightly loaded and heavily loaded power network used.

2.2.2.4 Gravitational search optimization algorithm:-

Gravitational search optimization technique was first introduced in 2009 [12]. GSA is based on Newtonian Laws and mass interaction [36].

In [36] Dr. E. NandaKumar et.al, optimal location of UPFC has been done by using gravitational search optimization technique. Location and rating of UPFC is optimized using standard IEEE 39 bus system. In [37] 2015, Venkata Padmavathi S et.al, Gravitational search algorithm is utilized for proper placement of FACTS controller like TCSC, SVC and UPFC. The execution of the proposed GSA method was performed on 30, 57-bus network. Results exhibit improved security indexes and hence the power system security is enhanced.

2.2.2.5 Chemical reaction optimization algorithm (CRO):-

Chemical reaction optimization (CRO) was presented by Lam et.al, in the year 2010. It is a recent algorithm depending on the different chemical reactions [38].

In [38] 2015, Susanta Dutt et.al, shows the application of CRO in order to fulfill objectives of enhancement of voltage profile, improving voltage stability and reduction in losses present in the power network. For obtaining these objective proper placements of STATCOM is done. 30-bus and 57-bus IEEE network are utilized for testing. Results implies fulfillment of objectives with better performance. In [39] 2018, Susanta Dutta et.al, proper reactive power dispatch (RPD) problem with flexible AC transmission network controller has been done using quasi-oppositional chemical reaction optimization algorithm. Compensating devices used here are SVC and TCSC. To check the supremacy of technique, it is applied on 14 buses and 30-bus network.

2.2.2.6 Artificial Bee Colony optimization algorithm (ABC):-

Artificial Bee Colony introduced by Karaboga in 2005 as optimization technique which shows the foraging behavior of bee colony [40].

In [40] 2016, Mohammad Rafee Shaik et.al, for improvement in the voltage profile of power network, an artificial bee colony optimization technique is used. Simulation is done with and without FACTS device, STATCOM is used as a FACTS device here and for demonstration IEEE 30-bus system. Sizing of STATCOM is also taken in consideration here for overall enhancement of performance of power system. In [42] 2018, Kadir Abacı et.al, to stabilize the voltage and voltage profile and to decrease active power loss and utilizing minimum number of compensators, the artificial bee colony method is used. Comparison of result is done with differential evolution technique. SVC and STATCOM is considered here and tested over IEEE 57-bus system. Technique is also tested at over-loading and to optimize the fuel cot function. In [43] 2015, Kadir ABACI et.al, uses the technique for proper power flow in the network using SVC as a compensator. IEEE 11-bus network and 30-bus network is utilized. Outcomes are checked with differential evolution technique also with reduced Hessian method. The results obtained from differential evolution and artificial bee colony is better than from reduced Hessian method, but from both artificial bee colony algorithms gives much better results. Sensitivity and continuous power flow method is tested for real time data as 22 bus power system data of Turkey. In [44] 2013, T L V Naga Lathish et.al, ABC-OPF is tested with and without compensator SSSC on IEEE 14-bus system. Decrement of generation fuel price and improvement of power system performance is taken as objective. In [45] 2019, Shaik Mohammad Rafee et.al, For improvement of system loadability, enhancement of voltage profile and decrement in losses an artificial bee colony technique is utilized for simultaneously locating more than one FACTS controller. SVC, TCSC and STATCOM is used and tested the algorithm on 14-bus network and 30 bus network. In [46] 2019, Bairu Vijay Kumar, for enhancement of performance of power network ABC algorithm is used. UPFC is used as a compensator. Bus with a maximum power loss is taken as a best location for UPFC. ABC technique is used to find optimum location during generator outages. Both single generator outage and double generator outages are taken in consideration for optimum location of UPFC with ABC technique which is checked on IEEE-30 bus system

2.2.2.7 Firefly algorithm optimization algorithm:-

It is developed by Yang, which uses flash signals to attract other fireflies [47].

In [47] 2018, P. Balachennaiah et.al, Real powers loss minimization by optimizing transformer tap values and optimization of location of UPFC is carried-out by using Firefly algorithm. Firefly algorithm results are verified and compared with another algorithm. Also bacteria foraging technique was used to validate result. New England 39 bus network and 14-bus IEEE network are utilized for testing. In [48] 2019, Ahmed El-Sherif et.al, Optimal setting and optimal placement of TCSC, SVC and TCPST are carried-out for reactive power compensation by firefly optimization technique. It is checked on 30 buses and 57 IEEE bus network. Output show this method provides excellent solutions within a very less operational time.

2.2.2.8 Whale Optimization algorithm:-

Lewis and Mirjalil first proposed this technique in 2016 [49]. WOA is initiated by Humpback–whale special hunting technique [49][50].

In [49] 2020, Muhammad Nadeem, et.al, main objective is to obtain proper location and rating of controller TCSC, SVC controller and UPFC controller in power network. Decrement in operating price of network that consists of compensator and real power losses cost. Comparative study is based on the results with Genetic Algorithm and PSO. 14 and 30 bus network is used to check results obtained from method.

2.2.2.9 Cat Swarm Optimization:-

Shu-Chuan Chu , Pei-wei Tsai , and Jeng-Shyang Pan introduced this technique in 2006. This method is motivated PSO and ACO [58].

In [58] 2006, Shu-Chuan Chu et.al, Introduces the algorithm and also the comparison with particle swarm optimization technique. Performance comparison is done by applying PSO, CSO and weighting factor PSO into six test functions. In [59] 2013, Enhancement of voltage stability under large contingency is done. Optimal location of UPFC as well as its size is determined by CSO. 3 and 14 bus IEEE network is taken for verification.

2.3 Hybrid met heuristic optimization algorithm:-

Hybrid met heuristic optimization technique is the combination of different optimization techniques like evolution based technique, analytical based technique or particle swarm based techniques. It will be more advantageous. In [51] population based evolutionary optimization technique is used for optimal location and sizing of TCSC.

In [52] 2017, Prof.R.K.Verma et.al, Particle swarms and optimization technique as a hybrid optimization technique is used for optimal location SVC. IEEE 40-bus system is used for simulation purpose. Initial population creation is done by PSO and after GA is used for initial population and thus continues the optimization. In [53] 2016, Sai Ram Inkollu et.al, for enhancing the voltage profile by proper setting of controller UPFC and IPFC is done by a new hybrid technique PSO adaptive GSA hybrid algorithm. 30-bus IEEE network is utilized for validation of objectives. Power losses and injected voltages were also analyzed. In [57] 2019, Stita Pragnya Dash et.al, Moth flame optimization and its hybrid form as JAYA blended MFO is used for reducing the transmission loss of system. TCSC and SVC is used as a compensating device. 14 and 30 bus network is taken for validation of algorithm.

Table 1:- Outline of reviewed model

Reference paper number	Method	FACTS Device	Test Case / IEEE network
2	Sensitivity based analysis	TCSC and TCPAR	5-bus network
3	Sensitivity based method	TCSC	5-bus network
4	Sensitivity based method	TCSC and Static Synchronous Compensator	14-bus network
5	Sensitivity based analysis	TCSC and Static Synchronous Compensator	14-bus network
6	Sensitivity based analysis	SVC	14-bus network
7	Sensitivity based analysis	STATCOM	14-bus network
8	Sensitivity based analysis	TCSC and TCPAR	WSCC-3-Machine-9 bus network and 57-bus network
9	Sensitivity based analysis	STATCOM	Java-Bali 500KV network
13	Genetic Algorithm	STATCOM	5 bus, 30 bus network and Iraqi national grid
14	Genetic Algorithm	SVC controller, TCSC controller and UPFC controller	30 bus network
15	Genetic Algorithm	TCSC controller, SVC controller, TCPAR and controller UPFC	30 bus network
16	Genetic Algorithm	TCSC controller, UPFC controller, TCPST and controller SVC	14-bus network
17	Genetic Algorithm	TCSC controller, SVC controller and controller UPFC	30 bus network
18	Genetic Algorithm	TCSC	9 bus network
19	Genetic Algorithm	SVC, TCSC, UPFC	30 bus network
30	Genetic Algorithm	TCSC, STATCOM and SVC	30 bus network
20	Differential Evolution Algorithm	TCSC and TCPS	30 bus network
21	Differential Evolution Algorithm	TCSC	5 and 14 bus network

22	Differential Evolution Algorithm	TCSC, SVC, UPFC	30 bus network
23	Particle Swarm method	STATCOM	14 bus network
24	Particle Swarm Algorithm	STATCOM	57-bus network
25	Particle Swarm Algorithm	STATCOM	30 bus test network
31	Ant Colony Optimization technique	TCSC	30 bus test network
32	Ant Colony Optimization technique	UPFC	14 bus and 30 bus network
33	Harmony search optimization technique	SVC, TCSC and UPFC	30 bus test network
34	Harmony search optimization technique	SVC and TCSC	30 bus test network
36	Gravitational search Optimization technique	UPFC	39 bus test network
37	Gravitational search Optimization technique	TCSC, SVC and UPFC	30 and 57 bus network
38	Chemical reaction Optimization technique	STATCOM	30 and 57 bus network
39	Chemical reaction Optimization technique	SVC and TCSC	14 and 30 bus network
40	Artificial Bee Colony Optimization	STATCOM	30 bus test network
42	Artificial Bee Colony Optimization	SVC and STATCOM	57 bus network
43	Artificial Bee Colony Optimization	SVC	11, 30 bus power network and 22 bus power network data of Turkey
44	Artificial Bee Colony Optimization	SSSC	14 bus network
45	Artificial Bee Colony technique	SVC, TCSC and STATCOM	14 and 30 bus network
46	Artificial Bee Colony technique	UPFC	30 bus network
47	Firefly Optimization technique	UPFC	New England 39 and 14-bus network
48	Firefly algorithm Optimization technique	TCSC, SVC and TCPST	30 and 57 bus network
49	Whale Optimization technique	TCSC controller, SVC controller and UPFC controller	14 and 30 bus network
52	Hybrid met heuristic optimization techniques (PSO + GA)	SVC	40 bus network
53	Hybrid met heuristic optimization techniques (PSO + adaptive GSA)	UPFC and IPFC	30 bus network
57	JAYA blended MFO hybrid met heuristic	SVC and TCSC	14 and 30 bus network
59	Cat Optimization Technique	UPFC	3 and 14 bus network
60	Real Power Flow Performance Index	TCPAR	5 bus network

3. CONCLUSIONS

This paper furnishes a reported literature work done on various optimization methods for best location of power controllers or FACTS controllers. The paper also confers a brief overview on optimization methods used for accomplishing various objectives for power system network along with various test cases of power network.

REFERENCES

[1] Hingorani NG, Gyugyi L (2000) Understanding FACTS: concepts and technology of flexible AC transmission systems. IEEE Press, New York.

[2] S.N. Singh, “Location of FACTS Devices for Enhancing Power Systems’ Security”, 2001 Large Engineering Systems Conference on Power Engineering., IEEE Xplore, 11-13 July 2001, pp-162-166.

[3] TLIJANI Kamel , GUESMI Tawfik , HADJ ABDALLAH Hsan and OUALI Abderrazak ENIS, Sfax, “Optimal location and parameter setting of TCSC based on Sensitivity analysis”, 2012 First International Conference on Renewable Energies and Vehicular Technology, IEEE Xplore, 26-28 March 2012, pp- 420-424.

[4] A.Samimi, M.A.Golkar, " A Novel method for optimal placement of FACTS based on sensitivity analysis for enhancing power system static security", Asian Journal of applied science, 2012.

[5] Anwar Shahzad Siddiqui, Mohd Tauseef Khan, Fahad Iqbal, "Determination of optimal location of TCSC and STATCOM for congestion management in deregulated power system", Int J Syst Assur Eng Manag, _ The Society for Reliability Engineering, Quality and Operations Management (SREQOM), India and The Division of Operation and Maintenance, Lulea University of Technology, Sweden 2015, Springer.

[6] Chetan W. Jadhao, K. Vadirajacharya, " Performance improvement of power system through static VAR compensator using sensitivity indices analysis method", 2015 International Conference on Energy Systems and Applications (ICESA 2015),Dr. D. Y. Patil Institute of Engineering and Technology, Pune, India 30 Oct - 01 Nov, 2015, pp-200-202.

[7] V.Srinivasa Rao, R.Srinivasa Rao, " Optimal Placement of STATCOM using two stage algorithm for enhancing power system static security", 1st International Conference on Power Engineering, Computing and Control, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus, Energy Procedia 117 (2017) 575–582, ELSEVIER.

[8] saptarshi ROY, Dr. p suresh BABU, "Optimal Placement of TCSC and TCPAR using Sensitivity Analysis", Journal of Electrical Engineering · April 2018.

[9] Fasda Ilhaq Robbani, Chico Hermanu B. A., and Irwan Iftadi, "Optimal placement of static synchronous compensator (STATCOM) to improve voltage stability based on sensitivity analysis in 500 kV Java-Bali electrical power system", AIP Conference Proceedings 2097, 030014 (2019), pp-030014-1-6.

[10] G Rasmitha, P Suguna Ratnamala, "Optimal Location of FACTS Devices in Power Systems era: Models, Methods", 2019 IJRAR May 2019, Volume 6, Issue 2, 78-83.

[11] Ahmad AL Ahmad, Reza Sirjani, "Optimal placement and sizing of multi-type FACTS devices in power systems using met heuristic optimization techniques: An updated review", Ain Shams Engineering Journal, Oct 2019, ELSEVIER.

[12] Rahul Dubey, Shishir Dixit, Ganga Agnihotri, "Optimal Placement of Shunt FACTS Devices Using Heuristic Optimization Techniques: An Overview", 2014 IEEE, Fourth International Conference on Communication Systems and Network Technologies, pp 518-523.

[13] Naseer M. Yasin, Haider A. Talib, " Genetic Based Optimal Location of STATCOM Compensator", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10 (2018) pp. 7516-7521.

[14] Prashant Kumar Tiwari, Yog Raj Sood, "Optimal location of FACTS devices in power system using Genetic Algorithm", 2009 World Congress on Nature & Biologically Inspired Computing (NaBIC), 9-11 Dec. 2009, IEEE.

[15] Prakash g.Burade, Dr.J.B.Helonde, "By using genetic algorithm method for optimal location of facts devices in the deregulated power system", journal of theoretical and applied information technology, © 2005 - 2010 jatit & lls, pp 64-71.

[16] L.J. Cai, I. Erlich, "Optimal Choice and Allocation of FACTS Devices using Genetic Algorithms", Proceedings on twelfth intelligent systems application, 2003.

[17] Jigar S.Sarda, Manish J. Chauhan, Viren B. Pandya, Dhaval G. Patel, "Optimal location of multi-types of facts devices using genetic algorithm", International Journal of Research in Computer Science eISSN 2249-8265 Volume 2 Issue 3 (2012) pp. 11-15.

[18] A. Y. Abdelaziz, M. A. El-Sharkawy, M. A. Attia, "Optimal Allocation of TCSC Devices Using Genetic Algorithms", 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, 2010,pp 428-432.

[19] A. B.Bhattacharyya, B. S.K.Goswami, "OPTIMAL Placement of FACTS Devices by Genetic Algorithm for the Increased Load Ability of a Power System", World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering Vol:5, No:3, 2011,pp 235-240.

[20] M. Basu, "Optimal power flow with FACTS devices using differential evolution", Electrical Power and Energy Systems 30 (2008) 150–156, 2007 Elsevier Ltd.

[21] Ghamgeen I. Rashed, Yuanzhang Sun, H. I. Shaheen, "Optimal Location of Thyristor Controlled Series Compensation in a Power System Based on Differential Evolution Algorithm Considering Transmission Loss Reduction", Proceedings of the 8th World Congress on Intelligent Control and Automation June 21-25 2011, Taipei, Taiwan, IEEE , PP 610-616.

[22] Ahmad Rezaee Jordehi, and Mahmood Joorabian, "Optimal Placement of Multi-Type FACTS Devices in Power Systems Using Evolution Strategies", 5th International Power Engineering and Optimization Conference (PEOCO2011), Shah Alam, Selangor, Malaysia : 6-7 June, 2011, IEEE, pp 352-357.

[23] Noopur Sahu, Ankit Dubey, "Optimal Location of Statom Using Particle Swarm Optimization in IEEE-14 Bus System to Improve Voltage Profile & THD Reduction",

International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, vol 4, Issue 3, pp 2595-2601.

[24] E. Nasr Azadani · S. H. Hosseinian · P. Hasanpor, "Optimal placement of multiple STATCOM for voltage stability margin enhancement using particle swarm optimization", Electr Eng (2008) 90:503–510, © Springer-Verlag 2008, pp 503-510.

[25] K. Ravi, M. Rajaram, "Optimal location of FACTS devices using Improved Particle Swarm Optimization", Electrical Power and Energy Systems 49 (2013) 333–338, SciVerse ScienceDirect, pp 333-338 ELSEVIER.

[26] Reza Sirjani, "Optimal Placement and Sizing of PV-STATCOM in Power Systems Using Empirical Data and Adaptive Particle Swarm Optimization", Sustainability 2018, 10, 727; doi:10.3390.

[27] Dipesh Gaur and Lini Mathew, "Optimal placement of FACTS devices using optimization techniques: A review", 3rd International Conference on Communication Systems (ICCS-2017) , IOP Conf. Series: Materials Science and Engineering 331 (2018) 012023.

[28] Javad Modarresi, Eskandar Gholipour n, Amin Khodabakhshian, "A comprehensive review of the voltage stability indices", Renewable and Sustainable Energy Reviews 63(2016)1–12, ELSEVIER.

[29] V. Tejaswini, D. Susitra, "A review on optimal placement and sizing of custom power devices/FACTS devices in electrical power systems", International Journal of Power Electronics and Drive System (IJPEDS) Vol. 10, No. 2, June 2019, pp. 900~908.

[30] Omar M. Abo Gabl, Amgad El-Deib, Magdy El-Marsafawy, "Optimal Location and Size of FACTS Devices for Distributed Voltage Control", 2018 Twentieth International Middle East Power Systems Conference (MEPCON), Cairo University, Egypt,IEEE.

[31] S.Sreejith, K.Chandrasekaran, Sishaj.P.Simon, "Application of Touring Ant colony Optimization technique for Optimal Power Flow incorporating Thyristor Controlled Series Compensator", TENCON 2009 - 2009 IEEE Region 10 Conference, Singapore.

[32] B Brindha Sakthi, A V Suganya, L N Ramya and P. Deiva Sundari, "Optimal Location and Parameter Setting of Unified Power Flow Controller Using Ant Colony Optimization Technique", Easy Chair Preprint, Nov 12 2019.

[33] A. Kazemi, A. Parizad, H.R. Baghaee, "On the use of harmony search algorithm in optimal placement of facts devices to improve power system security", IEEE EUROCON 2009, 21 July 2009, pp 570-576.

[34] D. Karthikaikannan & G. Ravi, "Optimal Location and Setting of FACTS Devices for Reactive Power Compensation Using Harmony Search Algorithm", Automatika Journal for Control, Measurement, Electronics, Computing and Communications, © 2016 Taylor and Francis Group , pp 881-892.

[35] Lalit Kumar, Dr. Sanjay Kumar, Sushil Kumar Gupta, Brijesh Kumar Raw, "Optimal Location of FACTS Devices for Loadability Enhancement using Gravitational Search Algorithm", 2019 IEEE 5th International Conference for Convergence in Technology (I2CT), IEEE, 12 March 2020, Bombay, India.

[36] Dr. E. NandaKumar, R.MANI, "Optimal Location of UPFC in Power System Using Gravitational Search Algorithm", International Journal of Innovative Research in Technology & Science (IJIRTS), ISSN:2321-1156.

[37] Venkata Padmavathi S, Sarat Kumar Sahu, A Jayalaxmi, "Application of Gravitational Search Algorithm to Improve Power System Security by Optimal Placement of FACTS Devices", J. Electrical Systems 11-3 (2015): 326-342.

[38] Susanta Dutta, Provas Kumar Roy, Debashis Nandi, "Optimal location of STATCOM using chemical reaction optimization for reactive power dispatch problem", Ain Shams Engineering Journal (2015), 2015 Production and hosting by Elsevier B.V. on behalf of Ain Shams University.

[39] Susanta Dutta, Sourav Paul, Provas Kumar Roy, "Optimal allocation of SVC and TCSC using quasi-oppositional chemical reaction optimization for solving multi-objective ORPD problem", Journal of Electrical Systems and Information Technology 5 (2018) 83–98, © 2017 Electronics Research Institute (ERI). Production and hosting by Elsevier B.V.

[40] Mohammad Rafee Shaik, Dr. A. Srinivasula Reddy, "Optimal Placement of STATCOM with ABC algorithm to improve Voltage Stability in Power Systems", International conference on Signal Processing, Communication, Power and Embedded System (SCOPES)-2016, IEEE, PP 648-652.

[41] Dervis Karaboga, "An idea based on honey bee swarm for numerical optimization", technical report-tr06, october, 2005.

[42] Kadir Abacı, Volkan Yamaçlı, "A new method based on artificial bee colony algorithm for the optimal location of shunt connected FACTS devices", Journal of Engineering Technology and Applied Sciences, 2018, Vol 3, No.1.

[43] Kadir ABACI, Volkan YAMAC¸ LI, Ali AKDAGLI, "Optimal power flow with SVC devices by using the artificial bee colony algorithm", Turkish Journal of Electrical Engineering & Computer Sciences, December 2015 DOI: 10.3906/elk-1305-55.

[44] T L V Naga Lathish, A.V.Naresh Babu, S.Sivanagaraju, "A Solution to Optimal Power Flow Problem using Artificial Bee Colony Algorithm Incorporating FACTS device", IOSR Journal of Electrical and Electronics Engineering, Volume 7, Issue 6, Sep. - Oct. 2013, PP 26-31.

[45] Shaik Mohammad Rafee, A. Srinivasula Reddy, "Enhancing system loadability with multiple FACTS devices using Artificial Bee Colony Algorithm", EasyChair Preprint, № 2069, December 1, 2019.

[46] Bairu Vijay Kumar, "Optimal Location of Upfc to Improve Power System Voltage Stability Using Artificial Bee Colony Algorithm", American Journal of Electrical Power and Energy Systems 2019; 8(2): 42-49.

[47] P. Balachennaiah, M. Suryakalavathi, P. Nagendra, "Firefly algorithm based solution to minimize the real power loss in a power system", Ain Shams Engineering Journal, Production and hosting by Elsevier, pp 89-100.

[48] Ahmed El-Sherif, Galal Elkobrosy, Yasmine Abouelseoud, and Yahya Helmy, "Optimal Placement and Settings of FACTS Devices for Reactive Power Compensation Using a Firefly Algorithm", 2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe).

[49] Muhammad Nadeem, Kashif Imran, Abraiz Khattak, Abasin Ulasyar, Anamitra Pal, Muhammad Zulqarnain Zeb, Atif Naveed Khan, and Malhar Padhee, "Optimal Placement, Sizing and Coordination of FACTS Devices in Transmission Network Using Whale Optimization Algorithm", Energies 2020, 13, 753.

[50] Seyedali Mirjalili, Andrew Lewis, "The Whale Optimization Algorithm", Advances in Engineering Software, 0965-9978/© 2016 Elsevier Ltd, pp 51-67.

[51] Rahul Agrawal, S.K. Bharadwaj, , D.P. Kothari, "Population based evolutionary optimization techniques for optimal allocation and sizing of Thyristor Controlled Series Capacitor", Journal of Electrical Systems and Information Technology, Volume 5, Issue 3, December 2018, Pages 484-501.

[52] Prof.R.K.Verma, Amit Kumar Sahu, P.A.Patil, "Optimization Technique Based for Optimal Location of FACTS Devices, International Journal of Interdisciplinary Innovative Research & Development (IJIIRD), Vol. 01 Issue 02, pp 71-76.

[53] Sai Ram Inkollu , Venkata Reddy Kota, "Optimal setting of FACTS devices for voltage stability improvement using PSO adaptive GSA hybrid algorithm ", Engineering Science and Technology, an International Journal, t © 2016, Karabuk University. Production and hosting by ELSEVIER B.V.

[54] Mithu Sarkar, "Effect of UPFC Allocation on Transmission System Power Loss", 2013 International Conference on Energy Efficient Technologies for Sustainability, IEEE.

[55] P.S. Vaidya , V.P. Rajderkar, "Optimal Location of Series FACTS Devices for Enhancing Power System Security", 2011 Fourth International Conference on Emerging Trends in Engineering & Technology, IEEE, pp 185-190.

[56] P.S. Vaidya , V.P. Rajderkar, " Enhancing Power System Security by Proper Placement of Thyristor Controlled Series Compensator (TCSC)", IACSIT International Journal of Engineering and Technology, Vol. 4, No. 5, October 2012, pp 622-625.

[57] Stita Pragnya Dash, K. R. Subhashini, J. K. Satapathy, "Optimal location and parametric settings of FACTS devices based on JAYA blended moth flame optimization for transmission loss minimization in power systems", Springer-Verlag GmbH Germany, part of Springer Nature 2019.

[58] Shu-Chuan Chu, Pei-wei Tsai, Jeng-Shyang Pan, "Cat Swarm Optimization", Q. Yang and G. Webb (Eds.): PRICAI 2006, LNAI 4099, © Springer-Verlag Berlin Heidelberg 2006, pp 854 – 858.

[59] G. Naveen Kumar, M. Surya Kalavathi, "Cat Swarm Optimization for optimal placement of multiple UPFC's in voltage stability enhancement under contingency", Electrical Power and Energy Systems 57 (2014) 97–104., © 2013 Elsevier Ltd.

[60] Ameya V. Hardas, Vedashree Rajderkar , V.K. Chandrakar , V.D. Hardas, "Optimum Location of Thyristor Controlled Phase Angle Regulator Based on Performance Index", 2018 International Conference on Smart Electric Drives and Power System (ICSEDPS)