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Optimal Localization of STATCOM for Voltage Sag Mitigation in Power Systems

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ABSTRACT

Static synchronous compensator (STATCOM) is a device in the Flexible AC Transmission System (FACTS) that can be used to keep a constant voltage profile at the buses in the power system and controls the power flow in a transmission line's specified bus. This paper shows how to utilize the STATCOM to calculate steady-state power flow in a power system in a simple way. The proposed algorithm is based on the Jumping Frog Practical Swarm Optimization (JFPSO) technique to determine the best location of the STATCOM in the power system as follow buses 11, 12, 13, and 14 of IEEE 14-bus and 6, 11, 24, 27, and 30 of IEEE 30-bus systems. The proposed algorithm is compared to the IEEE 14-bus and IEEE 30-bus systems in Matlab/Simulink. The simulation results demonstrate that the proposed algorithm is effective in terms of accuracy and improvement the voltage of buses with constrain.

Keywords

Static Synchronous Compensators (STATCOM), voltage Sag profile, Load flow analysis, Newton-Raphson (N-R) power flow, objective optimization, evolutionary algorithm, Jumping Frog Practical Swarm Optimization (JFPSO) .

1) Introduction

Voltage sags have frequently resulted in significant financial losses for numerous sensitive clients around the world [1]. Customers that have experienced severe sag-related losses need premium power from power suppliers and are willing to pay a higher price for it [2]. New regulations for various power quality issues, such as voltage sags in the transmission system, have recently been developed [3]. As a result, power suppliers are becoming increasingly interested in voltage sag mitigation. One of the most effective methods for reducing voltage sag is to install power electronic-based compensation devices [4]. The static synchronous compensator (STATCOM) has been shown in reference [5] to improve the voltage sag performance of the entire power system. Given the falling cost of electronic equipment and the advantages of STATCOM.

Despite the fact that numerous research on STATCOM allocation have been undertaken in the past, the majority of them have concentrated on power system challenges such as steady-state voltage stability, short-term voltage stability, and transient stability. Only a few research papers [7–12] addressed voltage sags. The pioneering work [6] proposed a voltage sag profile calculation approach for power systems with STATCOM, in which a mathematical model for voltage sag profile computation of power systems with FACTS is established**,** based on the system impedance matrix and STATCOM is modelled as a current source. Using the method [5] to determine voltage sag numbers, reference [13] provided an optimal Flexible AC transmission system (FACTS) devices allocation methodology using STATCOM for voltage sag reduction. In the optimization of FACTS allocation, the voltage sag performance of the entire system was employed as the goal. In [14], [15], a voltage sag index called the Bus Performance Index (BPI) was used as a technical constraint to guide the optimization of FACTS allocation for voltage sag mitigation. Time domain simulation was used to calculate the BPI index, and the solution with the fewest number of devices was chosen as the best. In addition, reference [16] proposed an optimal STATCOM allocation method to mitigate voltage sags below a certain magnitude, lowering the risk of commutation failure. It should be emphasized that the costs of mitigating devices were not taken into account [13–16], As a result, the best allocation system may not always be financially viable [17] Suggested a FACTS allocation approach for voltage sag mitigation that considered financial expenses. The benefit of STATCOM allocation was quantified by the economic value of reduced voltage sag losses, FACTS devices are optimally allocated to minimize the overall annual voltage sag financial losses which includes both voltage sag losses and FACTS devices investments. Candidate locations for STATCOM allocation were chosen [18], and a total annual budget was set. Based optimization model was developed that took into account both voltage sag loss and STATCOM investment. A

FACTS allocation optimization model was proposed [19], which used a financial penalty coefficient to transform the voltage sag index to a financial loss value. The financial penalty coefficient is determined by the voltage sag losses evaluation and has a significant impact on the optimization outcome. In fact, obtaining information regarding the financial repercussions of voltage sags on individual customers frequently necessitates thorough data and a time-consuming assessment procedure [20], limiting the use of a financial-based objective method. A model for optimizing expenditures based on objectives**.** STATCOM allocation for voltage sag mitigation problems is currently formulated in a single-objective optimization framework [17][18], in which only the voltage sag performance index is considered as an objective or it is converted to financial value and combined with STATCOM investment as a total financial objective. A few research have recently presented a multi-objective method for STATCOM allocation with the goal of enhancing power system voltage and transient stability. STATCOM investment and short-term voltage stability level were modelled as objectives [13]. The objective optimization model is solved using the (multi-objective evolutionary algorithm based on decomposition) technique.

The STATCOM allocation problem was also developed as a multi-objective optimization model [10], with the goal of increasing both static and short-term voltage stability. Also [12] proposed a novel systematic multi-objective strategy for STATCOM allocation that took into account short-term voltage stability as well as transient stability. Due to severe contingencies and probable bus selection, a set of optimal solutions for decision makers to make trade-offs between investment cost, short-term voltage stability level, and transient stability level can be obtained. In comparison to the traditional single-objective optimization approach, a multi-objective optimization model can better reflect the cost-benefit characteristic of STATCOM allocation by providing a range of trade-off solutions known as Pareto optimal solutions, which provide more options for decision makers and provide more options for decision makers. Support the STATCOM allocation decision-making process better. In reality, choosing between the benefits of voltage sag reduction and the cost of mitigation equipment is a tradeoff [21]. To the best of the authors' knowledge, no research has yet looked at the multi-objective optimization method for STATCOM allocation for voltage sag mitigation, despite the importance of offering a group of equally effective solutions for voltage sag mitigation being noted [13]. The fundamental contribution of this paper is that the STATCOM allocation for voltage sag mitigation problem is described as a multi-objective optimization model that considers both voltage sag performance and STATCOM cost. The optimization outcomes will not be impacted by subjective penalty coefficients or faulty voltage sag banking information, as they would be in a single optimization model. It is possible to find a collection of Objective functions that can provide trade-off information between the economic implications of STATCOM, better enhance STATCOM allocation decision-making by using jumping frog particle swarm optimization. Moreover, an alternative mathematical formulation for voltage sag profile calculation of power systems with STATCOMs and corresponding solution algorithm is proposed, which can simplify the calculation process and improve coding ease. This analytical voltage sag profile calculation model of power systems with STATCOMs can be used to reduce the computation burden of the proposed multi-objective optimization model.

2) DESCRIPTION OF THE PROBLEM

2.1 STATCOM Configuration

A voltage source converter (VSC) based device having the voltage source behind a reactor is known as a STATCOM. Because the voltage source is a DC capacitor, the STATCOM has a relatively low active power capability. However, if a suitable energy storage device is placed across the DC capacitor, its active power capability can be boosted. The amplitude of the voltage source determines the reactive power at the STATCOM terminals. The STATCOM generates reactive current when the terminal voltage of the VSC is higher than the AC voltage at the point of connection; conversely, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power [25] as shown in Fig. 1. A STATCOM has a faster response time than a static VAR compensator (SVC), owing to the fast switching times provided by the voltage source converter's IGBTs. Because the reactive power from a STATCOM drops linearly with the AC voltage, it provides greater reactive power support at low AC voltages than an SVC (as the current can be maintained at the rated value even down to low AC voltage) [25].

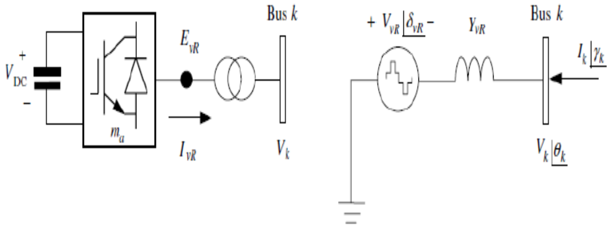

Fig. 1. Basic Structure of STATCOM

2.2 Power System Modeling Using STATCOM Controllers

For analyzing challenges in power system management and control, power flow calculations are required [26]. These computations can result in a balanced steady-state functioning condition. The following are the specific objectives for the power flow study with STATCOM:

- Determine appropriate STATCOM sites and ratings.
- Provide information on the effects on the system active and reactive power flows under normal and abnormal systems conditions.

-To establish baseline conditions for transient stability research.

-Determine essential system conditions, contingencies, and power transfer restrictions.

The admittance matrix can be used to simulate the interconnection of different components in a transmission network (Y matrix). It is worth noting that the system's power flow model connects each bus's net injected active/reactive power to all other bus voltages (both magnitude and angles). Furthermore, any power flow algorithm, particularly the Newton-Raphson power flow algorithm, can simply incorporate such a model. Without a FACTS controller, the conventional power flow equations for a generic bus (bus i of the power system are as follows:

$$P_i = P_{Gi} - P_{Li} = \sum_{j=1}^{N} V_i V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) \tag{1}$$

$$Q_i = Q_{Gi} - Q_{Li} = \sum_{j=1}^{N} V_i V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) \tag{2}$$

where i = 2, 3…N with bus number 1 as slack bus and N is total number of buses. Referred to Fig. 1 with presence of FACTS devices at buses, say k and t respectively, (1) is modified as:

$$P_k = P_{Gi} - P_{Li} + P_{statcom} = \sum_{j=1}^{N} V_k V_j Y_{jk} \cos(\delta_k - \delta_j - \theta_{jk}) \tag{3}$$

$$Q_k = Q_{Gi} - Q_{Li} + Q_{statcom} = \sum_{j=1}^{N} V_k V_j Y_{jk} \sin(\delta_k - \delta_j - \theta_{jk}) \tag{4}$$

The buses t and k, as other buses of the network, can be introduced as PV or PQ buses. The power flow equations shown in (1) are iteratively solved using the linearized Jacobian equation given in [26].

$$P_t = P_{Gt} - P_{Lt} + P_{statcom} = \sum_{j=1}^{N} V_t V_j Y_{jt} \cos(\delta_t - \delta_j - \theta_{jt}) \tag{5}$$

$$Q_t = Q_{Gt} - Q_{Lt} + Q_{statcom} = \sum_{j=1}^{N} V_t V_j Y_{jt} \sin(\delta_t - \delta_j - \theta_{jt}) \tag{6}$$

The bus at which STATCOM is connected is represented as PV bus, which may change to a PQ bus in the event of the limits being violated. In such a case, the generated or absorbed reactive power would correspond to the violated limit [27].

2.3 Power Flow Analysis

The power flow equation for the STATCOM is given as

$$P_{statcom} = V_{n+1} V_i Y_{n+1,i} \cos(\theta_{n+1} - \theta_i - \emptyset_{n+1,i}) + V_{n+1}^2 V_i Y_{n+1,n+1} \cos(\emptyset_{n+1,n+1}) \tag{7}$$

If the number of generator buses is ‘m’, the power flow problem for a ‘n’ bus system incorporating ‘p’ STATCOMs can be formulated as [28]:

$$\theta^{new} = [\theta_2 \dots\dots\dots\dots\dots\dots.. \theta_{n+p}]^T \tag{8}$$

$$V^{new} = [V_{m+1} \dots\dots\dots\dots\dots\dots.. V_{n+p}]^T \tag{9}$$

$$P^{new} = [P_2 \dots\dots\dots\dots\dots\dots.. P_{n+p}]^T \tag{10}$$

$$Q^{new} = [Q_{m+1} \dots\dots\dots\dots\dots\dots.. \theta_{n+p}]^T \tag{11}$$

2.4 Jumping frog particle swarm optimization (JFPSO)

The jumping frog particle swarm optimization (JFPSO) approach introduced in [29] is based on the particle point of view rather than solutions or particle placements. JFPSO was inspired by a school of frogs seeking for food while leaping from lily pad to lily pad. This bunch of frogs competes for food by jumping to the best positions, so if one frog is in a good spot, the others will follow. The JFPSO approach uses an unusual strategy that does not require the use of velocity to update the particle positions. Instead, the position is updated via a follower–attractor mechanism. When a particle desires to hop to a new, better location, it uses a better-positioned particle as a reference. Each particle remembers its previous best position, known as the local best (pbest), as well as its fitness. Each particle in the swarm has many pbests, with the swarm's global best (gbest) being the particle with the best fitness. The primary premise of the PSO technique is to use a random weighted acceleration to propel each particle towards its pbest and gbest positions at each time step. The positive constants c1 and c2, which are the acceleration constants responsible for altering the particle velocity towards pbest and gbest, respectively, represent the cognitive and social components. The variables r1 and r2 are two random functions in the range [0, 1] that are based on uniform probability distribution functions. The accuracy of calculation is set to 0.001. The usage of variable w is responsible for dynamically altering the particle velocity, balancing between local and global searches, and thus requiring less iterations for the algorithm to converge. JFPSO has now been improved, adapted, and successfully used to a wide range of engineering and technology challenges [30].

$$V_{id}^{o} = w * v_{id} + c_1 * r_1 + (p_{best} - x_{id}) + c_2 * r_2 * (g_{best} - x_{id}) \tag{12}$$

$$x_{id}^{o} = x_{id} + c v_{id}^{o} \tag{13}$$

3) The proposed algorithm

In figure 2 illustrate the flow chart of proposed algorithm with STATCOM device, the input parameters of JFPSO and input system data such as number of particles, number of dimension, initial velocity and initial position, number of buses, type bus, voltage and angle of buses, active and reactive power of buses, impedance and admittance transmission lines.

In the STATCOM allocation for voltage sag mitigation problem, two fitness function STATCOM investments costs and the benefits of STATCOM allocation for voltage sag mitigation are considered in the objective function within equality and inequality constrains, which is describe as follow:

$$min. F = \sum F_1 (x,u), F_2(x,u) \tag{14}$$

where the x is the decision variable, i.e., the location and corresponding capacity of STATCOMs, u stands for the state variables, including bus and fault point voltage, STATCOM injected current and fault current which are unknown in the voltage sag profile calculation.

$$F_{1=} \sum VSAG_i \tag{15}$$

where, $VSAGi$ is the voltage sag index of buses, with obtained STATCOM allocation scheme, the voltage sag performance of whole network is optimized, but at some buses where no sensitive customers are connected, the voltage sag performance may be even better than the buses where sensitive customers are connected, which is clearly not an efficient solution for voltage sag mitigation.

The second objective $F2$ is the annual investment costs of STATCOMs, which consists of two components; the annual STATCOM devices costs $[Cdevice]$ and annual operating and maintenance costs $[Cmant]$. The objective function of $F2$ as:

$$F_2 = \sum N * (C_{device} + C_{mant}) \tag{16}$$

where N is a binary variable which indicates whether the STATCOM is installed at the candidate buses, C_{device} is the annual STATCOM devices costs at the candidate bus i and C_{mant} annual operating and maintenance costs.

The devices costs of STATCOM objective function as:

$$C_{device\,=}Q_{statcom} * C_{statcom} \tag{17}$$

where $Cstatcom$ is the price of STATCOM (£/MVAR) at candidate bus i,$Qstatcom$ is the installed STATCOM capacity (MVAR) at candidate buses, and the annual operating and maintenance costs of STATCOM is usually proportionally determined by the total devices costs.

$$C_{statcom} = 553 * [0.0004 * (Q_{statcom}^2) - 0.3225 * Q_{statcom} + 127.38\,] \tag{18}$$

Equality constraints, this optimization, the equality constraints are the power flow equations, which are given in general form as follows:

$$P_{Gi} - P_{Di} = P_i \tag{19}$$

$$Q_{Gi} - Q_{Di} = Q_i \tag{20}$$

Inequality constraints,

$$V_{imin} \le V_i \le V_{imax} \tag{21}$$

$$Q_{imin} \le Q_{istatcom} \le Q_{imax} \tag{22}$$

4) Confirmation of the Methodology Proposed

4.1 Description of the test system

On the IEEE 14-bus studied test system [31], the proposed algorithm was put to the test. Five generators, fourteen buses, twenty transmission lines, and nine loads make up the system. For transmission purposes, the generating buses' voltage is 230 kV, with a base of 100 MVA. Bus B8 has a three-phase fault, however, chosen as possible STATCOM nodes, and the IEEE 30 bus system, which is a meshed sub-transmission/distribution system. It has 30 buses, including 132 kV and 33 kV buses, 9 shunt capacitors, 41 lines, and 4 tap changing transformers, as well as line and bus data, limitations, and limit values [32]. Six generators are located on buses 1, 2, 5, 8, 11, and 13, as well as the slack bus. The buses 3, 4, 6, 7, 9, 10, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, and 30 are, however, chosen as possible STATCOM nodes. The main goal functions of studying the appropriate location and reactive power of STATCOM are to mitigate the voltage sag in power systems.

The IEEE 14-bus standard and IEEE 30-bus standard are simulated in MATLAB to demonstrate the efficiency of the JFPSO algorithm in solving the STATCOM placement optimization problem. STATCOM is utilized to keep all buses' reactive powers and voltage buses within acceptable limits. Figure 3 and 4 provide a comparison of the buses voltage without STATCOM, with STATCOM and with proposed algorithm in a 14-Bus system and 30-Bus system. In addition, Tables 1 and 3 compare the reactive power without STATCOM, with STATCOM and with proposed algorithm in a 14-Bus system and 30-Bus system.

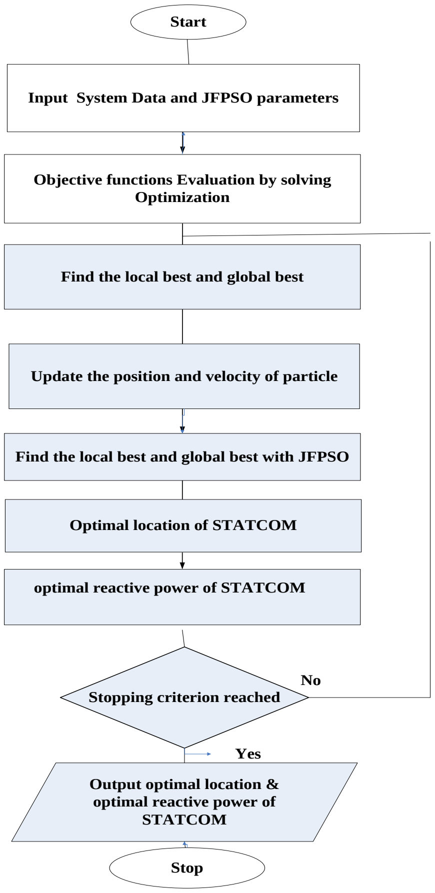

Fig. 2. Flow chart of STATCOM and proposed algorithm

5) Results and discussion

In addition, Tables 2 and 4 compare the real power loss for various location of STATCOM for IEEE 14 bus system and 30-Bus system at the candidate buses location of STATCOM. This is accomplished by calculating the power flow through transmission lines under various conditions. The reactive power deviations (ΔQ) and voltage variances (ΔV) are determined. These deviation values are utilized to calculate the required reactive power and injected buses using the suggested JFPSO algorithm. The proposed approach is also utilized to choose the best position for the compensators (STATCOM) and the optimal solution is obtained after 100 iterations based on the computed required power.

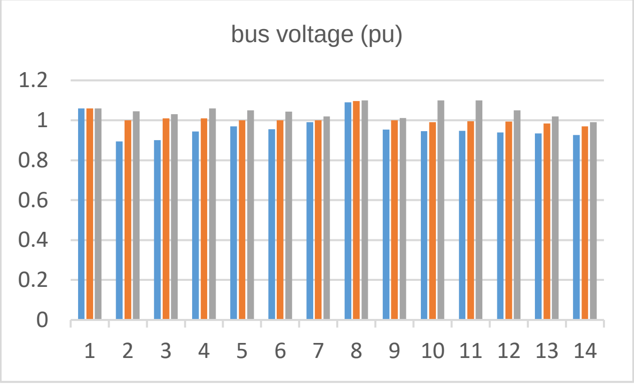

Fig.3 A comparison between the voltage magnitudes of the cases; without STATCOM, with STATCOM and with proposed algorithm (14-Bus system)

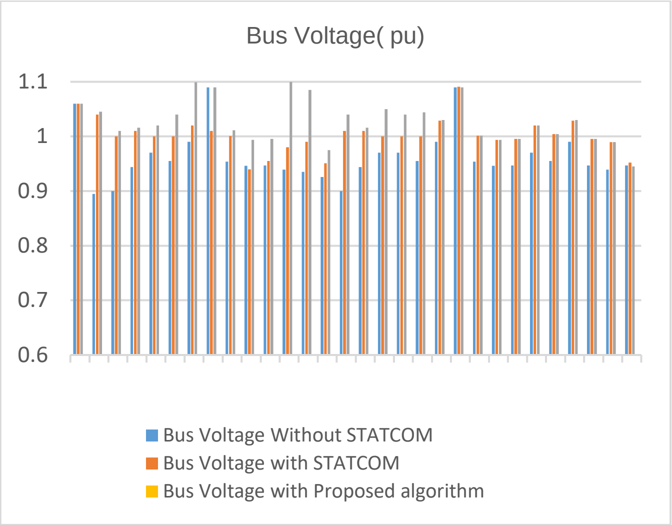

Fig. 4: A comparison between the voltage magnitudes of the cases; without STATCOM, with STATCOM and with proposed algorithm (30-Bus system)

TABLE 1: A comparison between the reactive power of cases; without STATCOM, with STATCOM and with proposed algorithm (14-Bus system)

Location of STATCOM	**Without STATCOM**	**With STATCOM**	**With proposed algorithm**
11	12.15	13.13	13.56
12	15.88	16.11	16.33
13	20.234	21.857	22.453
14	21.99	22.76	23.187

TABLE 2: A comparison of real power loss for various location of STATCOM for IEEE 14 bus system

Location of STATCOM (i)	**Min. Loss Value MW**
11	12.2688
12	12.2497
13	12.215
14	12.1838

TABLE 3: A comparison between the reactive power flow of cases; without STATCOM, with STATCOM and with proposed algorithm (30-Bus system)

Location of STATCOM (i)	**Without STATCOM**	**With STATCOM**	**With proposed algorithm**
6	10.61	12.11	13.56
11	12.75	13.44	13.98
24	15.14	15.88	16.02
27	15.81	16.33	16.989
30	16.44	17.033	18.05

TABLE 4: A comparison of real power loss for various location of STATCOM for IEEE 30 bus system

Location of STATCOM (i)	**Min. Loss Value MW**
6	15.857
11	15.857
24	15.8861
27	15.8323
30	15.76

The proposed algorithm is used the optimal reactive power problem utilizing STATCOM has been successfully solved using JFPSO in this paper to minimize active power loss and improve the voltage at all buses.

Conclusion

The optimal reactive power dispatch problem utilizing STATCOM has been successfully solved using JFPSO in this paper to minimize active power loss. This tactic has been tested and shown using systems such as the IEEE 14-bus and IEEE 30-bus. The results obtained were contrasted with those that were reported in the paper using the JFPSO approach. Here, it has been noted that JFPSO has the ability to effectively decrease active power loss while abiding by all rules. In addition, when compared to other approaches like BPSO and PSO, JFPSO has better convergence features. JFPSO is therefore preferred after considering the simulation results in contrast to different algorithms.

References

A. R. Bhowmik and C. Nandi, "Implementation of Unified Power Flow Controller (UPFC) for Power Quality Improvement in IEEE 14-Bus System", International Journal Computer, Technology, Vol 2, No. 6, 1996, pp. 1889-1896.

B. Singh, R. Saha, A. Chandra, and K. Al-Haddad, "Static synchronous compensators (STATCOM): A review," IET Power Electron., vol. 2, no. 4, pp. 297–324, Jul. 2009.

C. S. Chang and Z. Yu, "Distributed mitigation of voltage sag by optimal placement of series compensation devices based on stochastic assessment," IEEE Trans. Power Syst., vol. 19, no. 2, pp. 788–795, May 2004.

CIGRE Working Group C4.27, "Benchmarking of power quality performance in transmission systems,"CIGRE,Tech.Rep.TB718, Paris, France, 2018

CIGRE/CIRED Joint Working Group C4.107, "Economic framework for power quality," Tech. Rep. TB 467, CIGRE/CIRED, Paris, France, 2011.

H. Liao and J. V. Milanovic, "On capability of different FACTS devices to mitigate a range of power quality phenomena," IET Gener. Transmiss. Distrib., vol. 11, no. 5, pp. 1202–1211, May. 2017.

H. Liao and J. V. Milanovic, "Techno-economic analysis of global power quality mitigation strategy for provision of differentiated quality of supply," Int. J. Electr. Power Energy Syst., vol. 43, no. 1, pp. 159–166, 2019.

H. Liao, S. Abdelrahman, and J. Milanovic, "Zonal mitigation of power quality using FACTS devices for provision of differentiated quality of electricity supply in networks with renewable generation," IEEE Trans. Power Del., vol. 32, no. 4, pp. 1975–1985, Aug. 2017.

H. Mehrjerdi, E. Ghahremani, S. Lefebvre, M. Saad, and D. Asber, "Authenticated voltage control of partitioned power networks with optimal allocation of STATCOMusing heuristic algorithm," IETGener. Transmiss. Distrib., vo1. 7, no. 9, pp. 1037–1045, Sep. 2013.

Haddi Sadat Power System Analysis, Tata Mc-Graw Hill, 2012.

IEEE Guide for Voltage Sag Indices, IEEE Standard 1564-2014, 2014.

J. E. Dennis and R. B. Schnabel, Numerical Methods for Unconstrained Optimization and Nonlinear Equations. Philadelphia, PA, USA: SIAM, 1996.

J. V. Milanovic and Y. Zhang, "Global minimization of financial losses due to voltage sags with FACTS based devices," IEEE Trans. Power Del., vol. 25, no. 1, pp. 298–306, Jan. 2010.

J. V. Milanovic and Y. Zhang, "Modeling of FACTS devices for voltage sag mitigation studies in large power systems," IEEE Trans. Power Del., vol. 25, no. 4, pp. 3044–3052, Oct. 2010.

J. Y. Chan, J. V. Milanovic, and A. Delahunty, "Risk based assessment of financial losses due to voltage sag," IEEE Trans. Power Del., vol. 26, no. 2, pp. 492–500, Apr. 2011.

Kyu-Ho Kim, Yu-Jeong Lee, Sang-Bong Rhee, Sang-Kuen Lee and Seok-Ku You, "Dispersed generator placement using fuzzy-GA in distribution systems", IEEE Power Engineering Society Summer Meeting 2002, Vol. 3, pp. 1148-1153, July 2002

M. H. J. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions. New York, NY, USA: IEEE Press, 1999.

M. Li, S. Yang, and X. Liu, "Shift-based density estimation for Paretobased algorithms in many-objective optimization," IEEE Trans. Evol. Comput., vol. 18, no. 3, pp. 348–365, Jun. 2014.

M.O Okelola, S. Salimon, and B. A. Aderemi, "Optimal Siting and Sizing of D-STATCOM in Distribution System using New Voltage Stability Index and Bat Algorithm", Conference: 2021 International Congress of Advanced Technology and Engineering (ICOTEN), July 2021.

S Sriharan, and M.S. Balasubramanian,"A Functionally Reconstructed and Refined Power Flow Algorithm for FACTS Devices", 7th International Conference on Electrical Energy Systems (ICEES), Feb 2021.

S. F. Mekhamer, R. H. Shehata, Al. Y. Abdelaziz, and M A Al-Gabalawy, "Enhancing radial distribution system performance by optimal placement of DSTATCOM", International Journal of Electrical and Computer Engineering, June 2020, 10(2088-8708):2850-2860, DOI:10.11591/ijece.v10.pp2850-2860.

S. Li,Y.Li,Y. Cao,Y.Tan, andB.Keune, "Capacity optimisationmethod of distribution static synchronous compensator considering the risk of voltage sag in high-voltage distribution networks," IET Gener. Transmiss. Distrib., vol. 9, no. 16, pp. 2602–2610, Sep. 2015.

S.Wildenhues, J. L. Rueda, and I. Erlich, "Optimal allocation and sizing of dynamic VAR sources using heuristic optimization," IEEE Trans. Power Syst., vol. 30, no. 5, pp. 2538–2546, Sep. 2015.

T. Han, Y. Chen, J. Ma, Y. Zhao, and Y. Chi, "Surrogate modeling based multi-objective dynamic VAR planning considering short-term voltage stability and transient stability," IEEE Trans. Power Syst., vol. 33, no. 1, pp. 622–633, Jan. 2018.

W. Huang, K. Sun, J. Qi, and J. Ning, "Optimal allocation of dynamic VAR sources using the Voronoi diagram method integrating linear programming," IEEE Trans. Power Syst., vol. 32, no. 6, pp. 4644–4655, Mar. 2017.

X. Y. Xiao, Y. Q. Ma, Y. Zhang, Y. Liu, and Y. Wang, "Premium power valuation method based on customer perception of utility for high technology manufacturing customers," IEEE Trans. Power Del., vol. 31, no. 4, pp. 1655–1662, Aug. 2016.

X. Zhang, C. Rehtanz, and B. Pal, Flexible AC Transmission Systems: Modelling and Control. Berlin, Germany: Springer, 2006.

Xiao-Ping Zhang, Christian Rehtanz, Bikash Pal, Flexible AC Transmission Systems: Modelling and Control, Springer 2006.

Y. Xu, Z. Y. Dong, C. Xiao, R. Zhang, and K. P. Wong, "Optimal placement of static compensators for multi-objective voltage stability enhancement of power systems," IET Gener. Transmiss. Distrib., vol. 9, no. 15, pp. 2144–2151, Nov. 2015.

Y. Xu, Z. Y. Dong, K. Meng,W. F. Yao, R. Zhang, and K. P.Wong, "Multiobjective dynamic VAR planning against short-term voltage instability using a decomposition-based evolutionary algorithm," IEEE Trans. Power Syst., vol. 29, no. 6, pp. 2813–2822, Nov. 2014.

Y. Zhang and J.V. Milanovic, "Global voltage sag mitigationwith FACTSbased devices," IEEE Trans. Power Del., vol. 25, no. 4, pp. 2842–2850, Oct. 2010.

Y. Zhou, H. Wu, W. Wei, Y. Song, and H. Deng, "Optimal allocation of dynamic VAR sources for reducing the probability of commutation failure occurrence in the receiving-end systems," IEEE Trans. Power Del., vol. 34, no. 1, pp. 324–333, Feb. 2019.

Y.Zhang, Shu. Wang and J. Genlin, "A Comprehensive Survey on Particle Swarm Optimization Algorithm and Its Applications", Hindawi Publishing Corporation Mathematical Problems in Engineering, Vol.2, pp. 38, 2015.