wjert, 2019, Vol. 5, Issue 3, 387-405. *Review Article* ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org SJIF Impact Factor: 5.218

LOSS MINIMIZATION AND VOLTAGE PROFILE IMPROVEMENT IN POWER SYSTEM: A REVIEW

Dr. Ganiyu Adedayo Ajenikoko* and Oluseyi Ayofe Ojeyinka

Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology, P.M.B, 4000, Ogbomoso, Nigeria.

Article Received on 30/03/2019 Article Revised on 20/04/2019 Article Accepted on 10/05/2019

***Corresponding Author**
Dr. Ganiyu Adedayo Ajenikoko
Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology, P.M.B, 4000, Ogbomoso, Nigeria.

ABSTRACT

Relieving the power system from the effects of heavy losses and higher voltage magnitude deviations is very important to improve the voltage profile at the load buses. This paper reviews various techniques and methods used for loss minimization and voltage profile improvement on power system. The techniques include analytical and optimization approach. This review will assist power system engineers with a view to enhancing the optimal operation of electrical power systems.

KEYWORDS: Power System, Loss Minimization, Voltage Profile, Analytical Technique, Optimization Technique, Electrical Power.

I. INTRODUCTION

In electrical power systems, the system loss and voltage stability are the most significant factors indicating the power quality delivered to the end users. These factors depend on uncertain circumstances such as power network expansion and load complexity (Singh et al, 2010). At the present time, power system is meeting different problems in maintaining power loss and voltage stability within the specified limit due to environmental, political, increased population, unscheduled loading, enhancement of electrical load, enlargement in transmission system, and other economical and ecological restrictions. These problems cause higher system losses of about 5-13% of the generated power. Hence, the load bus voltage should be within the tolerance for safety operation and to provide quality power to the consumers (Gandoman et al 2018, Olabode et al 2018, Subramanian 2012).

The power loss minimization in power systems is generally known as a main achievement in power system operations. In addition, a rapid growth in load demand usually brings more voltage instability into the system (Eseosa and Odiase 2012, Sultana et al 2017). Voltage instability is one of the phenomena which has resulted in a major blackout. It's eminent that, the voltage parameter of a power system is directly interrelated with reactive power; hence voltage instability occurs due to lack of management of reactive power. The only way to save the network from voltage collapse is to reduce the reactive power load or add reactive power prior to reaching the point of voltage collapse (Olabode et al 2018 Subramanian et al 2018).

The quest to improve system voltage profile substantially as well as to appreciably reduce the system loss is the emergent desire of power system engineers. Several implementations have been proposed for power loss reduction and voltage stability enhancement. Authors have adopted a variety of different approaches to achieve their loss minimization and voltage improvement objective (Sultanaet al 2017). These approaches can be classified as analytical and optimization techniques. The analytical approaches are; network reconfiguration, DG installation, capacitor placement, installation of energy storage system, installation of FACTS controllers, e.t.c (Jayachitra and Baskar 2015, Singh et al 2010).

The optimization techniques include Particle Swarm Optimization (PSO), Mixed–Integer Nonlinear Programming, Firefly Algorithm (FA), Evolutionary Programming (EA), Modified Teaching-Learning-Based Optimization (MTLBO), Gravitational Search Algorithm (GSA), Genetic Algorithm (GA), Fireworks Algorithm (FWA), Cuckoo Search Algorithm (CSA), Ant Colony Search Algorithm (ACS), Runner-Root Algorithm (RRA) and Shuffled Frog Leaping Algorithm (SFLA) (Onlam et al 2019, Singh et al 2010). Therefore, this study carries out a comprehensive review of different techniques and methods used for loss minimization and voltage profile improvement in power system. In addition, the study also presented the limitations of the method used.

II. Review on loss minimization and voltage profile improvement using Analytical technique

Aborisade *et al.* (2014) presented a comparison of the voltage enhancement and loss reduction capabilities of Static Synchronous compensator (STATCOM) and Static

Synchronous Series Compensator (SSSC) at low voltage buses on the Nigerian 330kV grid using Newton Raphson iterative algorithm. Power flow analysis of the transmission network was carried out to determine the weak buses and power loss of the system. STATCOM was incorporated into the weak buses and simulation was carried out with MATLAB. This procedure was repeated for SSSC. Voltage profile of the system buses were observed and power losses were computed. The result showed that STATCOM and SSSC performance on voltage profile enhancement were satisfactory but SSSC performance in power loss reduction is better than the STATCOM. However, the study only considered steady state of the power system but a further work can be done to compare transient stability of the two FACTS devices. The sizing of FACTS devices was not elucidated in the study.

Adebayo *et al.* (2013) presented the application of Static Synchronous Series Compensator (STATCOM) to control voltage magnitude at low voltage buses on the Nigerian 330 kV grid using Newton Raphson iterative algorithm due to its ability to converge after a few iterations. Simulation of power flow solutions without and with SSSC was done using MATLAB based programme. Where voltage drops were noticed, SSSC was incorporated and the new voltage magnitudes were computed. The results showed the weak buses and the power loss with and without incorporation of SSSC. The proposed method showed that incorporation of SSSC into the Nigerian 330kv grid system improved the steady state voltage stability and there was significant reduction in power loss.

Adeniji and Mbamaluikem (2017) applied Unified Power Flow Controller (UPFC) to Nigeria’s 330 kV transmission system using MATLAB to overcome the challenges of the conventional method of improving voltage stability. Newton-Raphson Power flow analysis was carried out on the test case with and without the UPFC. The results showed an improvement in the voltage magnitude at the buses. The active power loss was reduced to nearest minimum when UPFC was applied. Incorporation of UPFC improved the system’s voltage stability and reduced active power losses. The UPFC could therefore be deployed to minimize prolonged and frequent voltage instability in transmission networks and enhance system efficiency. However, the study only considered steady state of the power system while further investigation could be carried out on transient operation of the system. In addition, the study did not employ the use of any algorithm to place the UPFC.

Amaize *et al.* (2017) presented an evaluation of application of FACTS devices into the Nigerian 330kv transmission system. The study used available publications on the subject matter to provide the depth of application of FACTS devices on the Nigerian power system. It examined types of FACTS and their application strength in power system. The results from the previous publication on the application of FACTS on the Nigerian power system were presented. The performance of FACTS devices such as STATCOM, TCSC AND IPFC on voltage profile improvement and power loss reduction on the power system were discussed. However, applications of FACTS devices for contingency operation on the Nigeria power system were not mentioned.

Anthony *et al.* (2017) presented an approach to voltage stability analysis using Distributed Generation. The approach was analyzed on Port Harcourt transmission and distribution network. Two cases were considered: analysis of the distribution network with DG and without DG and both analysis were conducted under faulty condition. The voltage levels of the distribution system were 132KV, 33KV, 11KV and 0.415kv. Distributed Generation units were connected to each of the load buses. The load level remains constant as DG penetration level increases. The result of the distribution network without DG placement shows that the voltage profile collapsed to zero when three phase fault was applied and with DG placements the voltage profile improved. The approach proved effective in the improvement of voltage profile on the distribution network and suggested a viable means that will assist in power distribution system operation and planning. The study covered a small distribution network and it could be extended to consider a large area distribution network to improve its reliability.

Aribi *and Nwosu* (2014) investigated a way to improve the stability of the existing Nigerian North-East power system using STATCOM as a compensator to provide a fast dynamic reactive compensation for voltage profile improvement especially during contingencies on the Nigerian power network. The network was modeled and simulated within the environment of the PSCAD/EMTDC 4.3.1 version software and the load flow analysis was run with and without STATCOM so as to determine the effect on bus voltage profile improvement. Two scenarios were considered and analyzed in order to demonstrate the effect of STATCOM on the network: normal operating condition and faulty occurrence. The result confirmed that the STATCOM is capable of providing a swift voltage support to prevent the possibility of voltage sagging or system collapse of the Nigerian 330kV network especially during fault conditions. The effects of STATCOM towards improving voltage profile, reactive power and transient condition minimization have been fully achieved. However, the study failed to consider effect of STATCOM on power loss of the transmission line. The study focused on three phase fault occurrences and neglected other types of fault that may occur on the transmission line.

Arora *et al.* (2016) presented a review on different researches and developments in the voltage stability improvement by using different FACTS controllers. Several technical issues related to FACTS installations were focused, highlighted and performance comparison of different FACTS controllers were discussed. In addition, real-world installations, and semiconductor technology development were reviewed and summarized. Literatures were sourced from IEEE/IEE electronic library and Science Direct electronic databases. The paper provided an extract for FACTS devices technology and its potentials to improve power system performance cutting across transmission and distribution reliability, capacity utilization, stability and power transfer quality. However, the survey on application of FACTS devices publications is limited to IEEE and science direct only.

Ayodele *et al.* (2016) focused on improving transient stability of Nigerian 330kV Transmission Network using Static VAR Compensation (SVC). It considered the response of the transmission network to three phase balance fault in terms of Critical Clearing Time (CCT) and its effect on generator, bus voltage magnitudes and phase angle. Load flow analysis was performed to determine the steady state of the network before it was subjected to large disturbances. Critical lines were identified and generator that fell out of synchronism was also located when the system three phase faults were applied. The investigation was carried out with and without SVC and a commercially available Dig Silent Power Factory was used for the analysis. It was observed that the CCT was improved tremendously, voltage profile at seven (7) buses were improved to acceptable limit of the reference value while positive effect was noted on the phase angle. The study also showed that generators that were closer to the critical lines operated in synchronism. However, the study did not address power loss in the transmission system.

Bello *et al.* (2014) considered the 330KV of northern Nigeria transmission network with a view of estimating the real and reactive power flows, power losses in the entire network and phase angle using Power System Analysis Toolbox (PSAT). The study analyzes the bus voltage magnitude, real and reactive power loss on the transmission system with a view to validate the outcome of other researchers. The results was validated with IEEE 14-bus. The result shows that the power flows in the transmission lines and losses from both generators and lines were reduced to barest minimum. The bus voltages were also obtained to know the weak ones among them. From the result, it obvious that the power generated in Northern Nigeria is not adequate to meet the increasing demand. However, the available power generated also suffers losses due to ageing transmission lines and other power equipment. Furthermore, the approach is limited to Northern Nigeria which cannot be isolated operational from the country's grid system.

Emmanuel *et al.* (2016) determined the appropriate means to enhance the electric power transmission system towards seeking ways to enhancing the performance of the grid for better asset utilization. The transmission line was modeled and simulated at different loading levels. The simulation was carried out in MATLAB platform using power system analysis toolbox. The sending-end to receiving-end relationships were observed at the different loading levels to determine the voltage drop characteristics of the line. The result revealed that no significant effect on voltage stability and angular stability were observed when the line was subjected to line re-conducting while increase in voltage level enhanced the transfer capability. Hence, the study is limited to single transmission line that connected two substations. Its outcome would be far reaching if the transmission scope is extended.

Ignatius et al. (2017) considered the load flow study of the Nigerian 330 kV consisting of 32 buses, 11 generating stations and 36 transmission lines using Newton-Raphson iteration technique to carry out the analysis in order to determine bus voltage magnitudes as well as real and reactive power loss because of its fast convergence nature as compared to other iterative techniques. The data was obtained from Nigeria utility company. MATLAB/SIMULINK software was used to carry out the simulations. Additionally, weak buses on the system were identified for possible installation of FACTS devices to improve voltage profile and minimize the power loss. The result showed that the transmission line bus voltage was within the limit. The result also showed that the total active reactive power losses of the system were reduced to barest minimum. In addition, the study revealed that the reactive power loss on the Nigerian 330 kV grid network is still very high, hence, the need for reactive power compensation. However, the study failed to propose method for reactive power compensation. Optimization technique for incorporation of FACTS devices for reactive power compensation was not considered in the research. Furthermore, the choice of 330-Kv, 32 bus transmission network was not justified.

Okwe *et al.* (2015) deals with voltage stability improvement of power transmission system in Nigeria using Thyristor-Controlled Series Compensator (TSCS) to improve voltage stability of a system under static condition. Power flow solution was developed in MATLAB program to perform the load flow computation so as to optimize the computing time for corrective action to be taken in order to maintain stable and reliable power supply using Newton-Raphson iterative method. The results were achieved without and with TCSC where voltage drops were noticed, at the buses. The results showed a considerable improvement in the voltage magnitude with the failed incorporation of TCSC and consequently a significant reduction in the system losses. In this way, the efficiency of the system is enhanced while the prolonged and frequent voltage collapse in the transmission network was minimized. However, the analysis carried out did not consider multi-line FACTS such as Inter-line Power flow controller (IPFC) and generalized Unified power flow Controller (GUPFC).The study did not consider any algorithm for placement of the FACTS. Furthermore, only steady state operation of the power system was considered in the study.

Usman et al. (2015) analyzed the effect of Unified Power Flow Controller (UPFC) on the Nigerian 330kV transmission network using ERACS and MATLAB SIMULLINK to implement load flow and identification of weak buses on the system. The network was simulated with 31 buses and 33 branches which included Seven (7) power stations providing electric supply to different load centers. This was to investigate the significance of installing new power plant on the network and how it affected the optimum location of siting a UPFC. Simulation was run at a study base of 100 MVA. Newton-Raphson algorithm and Linear programming was adopted for optimization of power flow controller. The result showed that Egbin power plant had the maximum voltage value while Gombe had the minimum voltage value at the bus. Thus, the result showed the optimum location of UPFC was in between Jos and Gombe. However, the work did not address power loss reduction on the transmission line. In addition, incorporation of evolving algorithm in the optimization technique was not considered in the study.

III. Review on loss minimization and voltage profile improvement using Optimization technique

Ali (2017) used Particle Swarm Optimization (PSO) technique for placement of SSSC on Iraqi grid system to achieve voltage profile improvement and power loss minimization. Voltage Stability Index was introduced to locate the weak buses on the grid system.

Simulation of the developed code for PSO algorithm was implemented in MATLAB environment. The proposed approach was tested on IEEE – 9bus system and a practical Iraqi National Supper Grid (400kv) was used and the result from the two cases was compared. The improvement of voltage profile was noticed on the entire transmission network system and it was not limited to the buses where SSSC were placed. The system was able to maintain stability under fault condition for an extended time when compared to the time duration for maintaining stability under fault without the placement of SSSC. There was significant power loss reduction on the two tested systems under fault conditions with and without SSSC placement. However, the research did not consider reactive power loss reduction on the grid system.

Amrutha and Deepu (2015) presented an approach to enhance Available Transfer Capability (ATC) by optimal placement of TCSC using Firefly Algorithm. The ATC of a system is the unused transfer capabilities for the transfer of power for further commercial activity. The methods for calculating ATC are AC/DC Power Transfer Distribution Factor (AC/DCPTDF) and Continuation Power Flow (CPF). FA is used for placement and sizing of TCSC in the power system. The result of ATC obtained before and after placement of TCSC showed that the proposed method achieved considerable increase in ATC across the test system transmission line. The results showed that there was an enhancement of ATC value when TCSC was placed at the location obtained using Firefly Algorithm. The study was carried out under steady state condition. Further study should consider contingence operation of the system.

Aribi and Nwohu (2014) introduced the ant colony meta-heuristic technique to optimally locate STATCOM in 330 kV Nigerian network. The Ant Colony Optimization (ACO) algorithms used the STATCOM parameters and probabilistic model to generate solutions to the problem of sitting STATCOM in Nigerian network. ACO code was developed in MATLAB software programme. Load Flow Analysis was performed with and without STATCOM placement on the network. The simulation was carried out on IEEE 14- bus and Nigeria 330kV network to demonstrate the effectiveness of the method. The result showed the best result for minimum number of iteration required for convergence and the optimal bus location in the two cases considered. The study only considered shunt connected FACTS device.

Balachennaiah et al. (2016) worked on optimal location of UPFC in the presence of transformer Tap-changing on a large transmission network. FA algorithm was proposed for optimal location of UPFC. Real coded Genetic Algorithm (RCGA) and Interior Point Successive Linear Programming (IPSLP) were used to validate the result of FA optimization. Continuous Power Flow method was used to obtain real power loss and voltage stability limit. Incorporation of UPFC in the transmission network was to reduce Real Power Loss (RPL) besides improvement in Voltage Stability Limit (VSL) of the system. Implementation of the developed FA, RCGA and IPSLP codes was run on MATLAB software. The method was tested on New England 39-bus system. Three cases were considered in the optimization of the RPL, RPL and VSL objectives with the incorporation of Tap Changing transformer. In all the cases, FA provided a superior performance in the minimization of RPL and maximization of VSL. The proposed method was not adopted on any practical system. Better performance of FA algorithm may be due to the type of FACTS device used in the study.

Balachennaiah et al. (2018) proposed a Firefly Algorithm based technique to optimize the control variables for simultaneous optimization of real power loss and voltage stability limit of the transmission system. Transformer taps, unified power flow controller and its parameters were included as control variables in the problem formulation. The effectiveness of the algorithm was tested on IEEE 14-BUS and New England 39-bus system. From the results, it was observed that optimization of the control variables for single objective of Real Power Loss (RPL) led to deterioration of VSL, but for multi-objective case, even though the loss has increased slightly, the combined cost function has reduced with significant improvement in VSL. The proposed method was not adopted on any practical system.

Dixit et al. (2015) presented an overview of application of different optimization techniques in the placement of FACTS devices. It explained the use of Particle Swarm Optimization (POS), Evolutionary Programming, Differential Programming and Genetic Algorithm for the optimal placement of Thyristor-Controlled Series Compensator (TCSC). The placement of the TSCS was to control transmission line parameters for the purpose of power flow operation, control, voltage stability and power loss reduction. Flow chart for the optimal placement of TSCS for all the techniques was presented. This explained the sequential order of implementation of the algorithm in MATLAB environment. These techniques were implemented in IEEE 30-bus and IEEE 57-bus tests systems. The implementation of the techniques on IEEE test system showed that enhancement of power system stability was achieved. However, the proposed methods were not tested on practical power systems to validate its versatility.

Nwohu et al. (2016) introduced Thyristor-Controlled Series Compensator (TSCS) on Nigeria 330kV transmission grid to minimize real power loss. Genetic Algorithm (GA) was used for optimal placement of TSCS. The study demonstrated the effective use of TSCS over generation rescheduling and load shedding method of loss management in transmission network. TSCS model was incorporated into the power flow equation using the TSCS parameters as the lower and upper bound. GA code was developed for optimal location of the TSCS. Simulation of the model was implemented in MATLAB to evaluate the candidate bus for placement by considering the bus with the highest fitness function. The grid network was simulated with and without placement of TSCS to actualize the effect on power loss and voltage improvement. The result showed that the bus with highest fitness function level was found to be Shiroro bus with corresponding highest voltage profile improvement at Kano bus. The work indicated that with TCSC installed on the power system, power loss in the transmission lines reduced to minimum. However, the result of the research was not validated. Nothing was mentioned about the effect of reactive power compensation in the study as this was an important parameter that affected voltage profile in the power transmission system.

Olabode *et al.* (2018) presented an approach for optimal location of reactive power source for voltage profile improvement on Nigerian 330kv, 24 - buses Transmission System. Load flow analysis was carried out using Newton-Raphson Method. The method was implemented on MATLAB software toolbox. Installation of appropriate size of capacitor on the identified weak buses was implemented using predetermined power factor of the power flow without and with reactive power source. The result showed voltage profile improvement at the identified four (4) weak buses within the lower and upper bounds of the voltage magnitude. Power loss reduction was significant with the installation of appropriate capacitor size on the transmission system. Optimal location and sizing of shunt-type capacitor was achieved with its positive effect on voltage profile improvement and power loss reduction. However, the study was limited to steady state operation of the transmission system.

Olabode et al. (2017) presented the application of Firefly Algorithm (FA) for placement of TCSC and SVC and evaluated the performance of FACTS devices on voltage profile enhancement and power system loss without any special attention on cost. TCSC is a series compensator that is used to vary the effective impedance of the transmission line while SVC is a shunt compensator used to inject or absorb reactive power at the PV and PQ buses. FA was used to obtain the location and sizing of the FACTS devices. FA code developed in MATLAB programming language was implemented to perform the simulation of the IEEE 14-bus system. The result of the work showed that there was power loss reduction when TCSC and SVC were placed on the system with considerable voltage profile enhancement within the desired limits. The simulation of the test system was carried out under normal operating condition. The result was compared with other method for placement of the FACTS.

Olaniyan et al. (2015) presented a combined method which integrated the analytical approach into a Firefly Algorithm for optimal location and sizing of Distributed Generators (DG) in power system distribution networks. The combined method was then tested on the standard IEEE 30-bus radial distribution system and the results showed high precision for location and accuracy in sizing. The result showed that the impact of DG installation has significantly improved voltage profile and further power loss reduction was recorded. The results showed that the problem of inaccuracy associated with the Firefly Algorithm solution and the time consumption associated with the analytical method has been successfully addressed by this method. The study was carried out on a test system with nearly accurate parameters. The approach was carried out on practical system to demonstrate its effectiveness in real time situation.

Omorogiuwa and Onohaebi (2015) modeled and analyzed the application of Interline Power Flow Controller (IPFC), which is a modern control Flexible Alternating Current Transmission System (FACTS) device on the network using Genetic Algorithm (GA) for its optimal placement and to improve voltage profile and maximize power loss reduction on Nigeria power system. The results of the work showed that there was an obvious improvement in voltage profile and improvement in power transfer in the network. The essence of using GA was to ensure that they were optimally placed in the network since these devices were very expensive. However, the sizing of the FACTS devices was not considered in the approach. The research only considered steady state operation of the power system therefore further study could be on transient stability of the power system.

Rajasekaran and Muralidharan (2016) used Firefly Algorithm in determining maximum load utilization point and its enhancement through optimal placement of TCSC and SVC. The method used was to maximize the objective function of real power load of the system while satisfying all the linear and non-linear control variables. FA was used to place and size the FACTS devices. Three standard IEEE bus systems IEEE 30 bus system, IEEE 57 bus and IEEE 118 bus system were used to exhibit the proposed theme of Firefly based maximum loadability enhancement. The result of determination of loadability point in the presence of FACTS devices is significant enhancement of the loading limit. The results of Firefly algorithm provided better maximum loading point compared to the other evolutionary algorithm. The FACTS device involvement of TCSC and SVC in determining the maximum loading point enhanced the load utilization point in normal state and also helped to overcome the system violation in transmission line contingency state. The proposed method did not consider fault occurrence at the generator side of the system.

Ramesh and Reddy (2013) presented an approach for optimal location of Unified Power Flow Controller (UPFC) for power loss reduction and voltage stability improvement. FA was used for UPFC parameter settings and optimal location. The transmission lines were represented with the voltage stability index to improve load ability of the lines, minimize total loss and improve the voltage profiles. The results are compared with GA optimization. The L-index was obtained for the load buses only. FA and GA optimization codes were implemented in MATLAB software. The proposed method was tested on IEEE 14 and IEEE 30-bus system. With the placement of UPFC on the weak buses, significant voltage profile improvement and substantial power loss reduction were achieved. FA optimization technique also performed better than the GA. The method was not adopted on any practical system.

Selvarasu *et al.* (2018) presented an approach for optimal placement of TSCS to minimize power loss and voltage profile improvement using Self-Adaptive Fire Fly Algorithm. Self-Adaptive FA used better parameter settings of the algorithm to improve the accuracy of the global solution. The strategy was implemented in MATLAB software program. IEEE test system was used to validate the approach. The results in terms of the locations and the TCSC parameters showed an improvement in voltage magnitude with the acceptable limit and power loss reduction was significant. The result of POS algorithm was compared with Honey Bee Algorithm and Bacterial Foraging Algorithm. It was observed that FA performed better than the HB and BFA. The approach was tested on practical system for both steady and transient states operation. Reactive power loss minimization was not considered in the study.

Selvarasu and Kalavathi (2014) presented an approach for SVC placement for Voltage Enhancement Using Self Adaptive Firefly Algorithm (SAFA). SAFA is a modified Firefly Algorithm with the tuning of FA parameters to improve convergence and accuracy of the optimal solution. The method was tested with three (3) IEEE test systems. FA codes were developed and it was implemented in MATLAB environment. Simulation of the test system was carried out with and without SVC to obtain the bus voltages. The sizing of SVC was performed with the FA. It was seen from the result that the identified placement of SVC enhanced the bus voltage profile. The simulation of the proposed method on test systems yielded a significant voltage profile enhancement on the systems. The study did not consider power loss reduction after the SVC placement.

Subramanian et al. (2012) used Cuckoo Search Algorithm (CSA) in the placement of SVC for voltage profile enhancement of power system. Objective functions for voltage deviation and power loss subject to equality and inequality constraint were formed. Power Flow analysis was carried out to determine the voltage profile of the power system. MATLAB code was developed for CS and simulation was carried out on IEEE 14, 30 and 57 bus test system. The results of the CS were compared with that of GA and PSO based approaches for all the three test systems with a view to demonstrate the effectiveness. The location and parameters of FACTS devices were obtained. The results clearly showed that CS provided accurate solution with high convergence rate. Thus the method proved more proficient, robust and should be widely used in real world applications. However, the proposed method did not consider power system operation under contingency. The method was tested on practical power system.

Sugirtha and Latha (2016) presented a Firefly optimization approach for optimal power flow in the presence of wind power generation plant by incorporating Static Synchronous Compensator STATCOM to improve voltage profile of the system. Newton-Raphson based approach was used to solve the Optimal Power Flow (OPF) problem. OPF was carried out to minimize fuel cost. The method was simulated in two cases: incorporation of wind power to the power system and incorporation of wind power and STATCOM to the power system. Implementation of FA code developed for placement of STATCOM in MATLAB environment was carried out. Load flow was performed in both cases to observe the voltage magnitude profile on the weak buses and power loss minimization of the lines. This result was compared with other research work outcome that used Modified Cuckoo Search (MCS) and Modified Particle Swarm Optimization (MPSO). The proposed FA method provided superior performance. The real power loss greatly reduced bus voltages and were within the stability limit but the method should be adopted on practical system.

Yang (2010) presented the background to the formulation of Firefly (FA) Algorithm in sequential order. It traced the origin of optimization algorithms from traditional algorithms to biological nature inspired meta-heuristic algorithm. Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) and FA belong to the latter family of algorithms. Standard test objective functions were used to validate the effectiveness of FA over PSO and GA. The results showed the superior performance of FA in attaining optimal solution with less number of iteration under the same set of initial conditions. This paper has formulated FA and analyzed its similarities and differences with PSO. FA performance was affected by the degree of randomness and parameter setting was relative to the search space of the objective function.

Yang (2009) presented the principles of development of Firefly Algorithm and stated its similarities compared to the known algorithms (PSO and GA). It also elucidated the superior performance of FA over the stated algorithms. Further, implementation of the FA was carried out on test functions and the developed functions. These functions have elements of deterministic and randomization. It was revealed that FA out-performed these algorithms in efficiency and convergence. However, performance of FA should be compared with other known optimization algorithm other than PSO and GA.

IV. Analysis of the reviewed papers

The analysis of the papers reviewed in this study is depicted in Figure 1. The Figure shows the trends of the reviewed papers for a period of ten years (2009-2018). In 2009, a paper was reviewed. The paper discussed the concept of loss minimization and voltage profile improvement method. In 2010, a paper was reviewed. In 2013, two papers were reviewed on loss minimization and voltage profile improvement while in 2014, three research papers were reviewed. In addition, seven papers were review in 2015 while ten prominent papers were reviewed in 2016. This shows that the number of papers reviewed in 2016 was three times the number of papers reviewed in 2014. In 2017, six papers were reviewed which were about 60% in reduction from the number of papers reviewed in 2016. While in 2018, two papers were review. The drawbacks of each approach were clearly pointed out. In addition, from the list of papers reviewed so far, thirteen papers were reviewed on analytical techniques for loss minimization and voltage profile improvement, while nineteen papers were reviewed on optimization techniques for loss minimization and voltage profile improvement problems.

V. Contribution to Knowledge

A comprehensive analysis of the various techniques for loss minimization and voltage profile improvement that will assist system engineers in recommending the most appropriate optimization technique in solving loss minimization and voltage profile improvement problem has been presented.

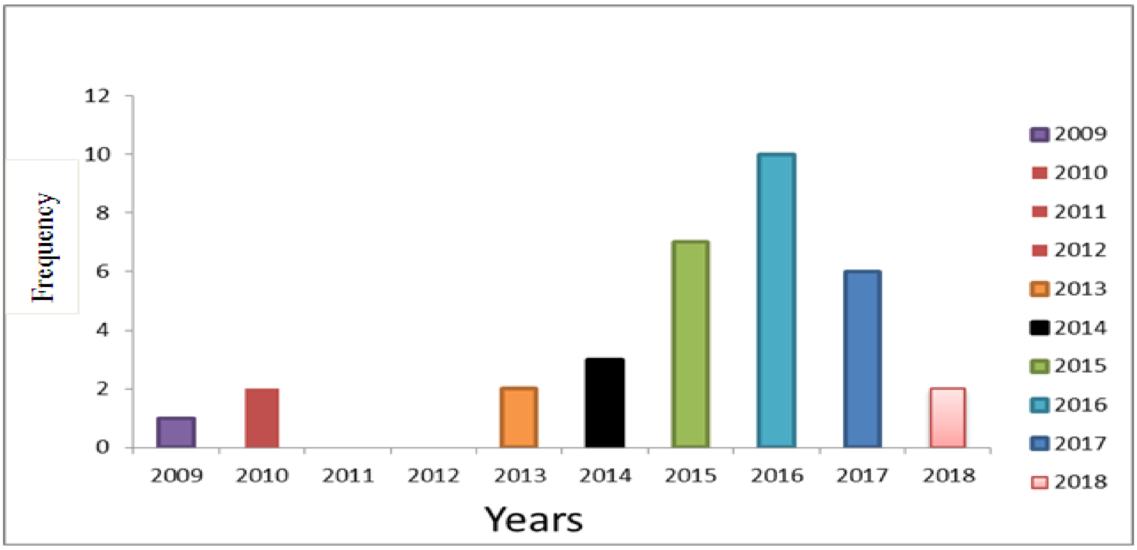

Figure 1: Frequencies of the Reviewed Papers.

VI. CONCLUSION

A comprehensive review on loss minimization and voltage profile improvement techniques has been presented in this paper. Most of the techniques used by the researchers are classified as either analytical or optimization method. Analytical methods include network reconfiguration, DG installation, capacitor placement, installation of energy storage system, installation of FACTS controllers. While the optimization techniques include Particle Swarm Optimization (PSO), Mixed–Integer Nonlinear Programming, Firefly Algorithm (FA), Evolutionary Programming (EA), Modified Teaching-Learning-Based Optimization (MTLBO), Gravitational Search Algorithm (GSA), Genetic Algorithm (GA), Fireworks Algorithm (FWA), Cuckoo Search Algorithm (CSA), Ant Colony Search Algorithm (ACS), Runner-Root Algorithm (RRA) and Shuffled Frog Leaping Algorithm (SFLA). Based on the reviewed papers, the problem of loss minimization and voltage profile improvement are yet to be completely solved in power system. Therefore, the study will assist the power policy makers and regulators to come up with better technique for the full realization of power sector reform.

VII. REFERENCES

1. Aborisade, D.O., Adebayo, I.G., and Oyesina, K.A. A comparison of the voltage enhancement and loss reduction capabilities of STATCOM and SSSC FACTS controllers. *American Journal of Engineering Research (AJER),* 2014; *03*(01): 96-105.
2. Adebayo, I.G. Aborisade, D.O. and Oyesina, K.A. Steady state voltage stability enhancement using Staticsynchronous Series Compensator (SSSC); a case study of Nigerian 330 kV grid system. *Research Journal in Engineering and Applied Sciences,* 2013; *2*(1): 54-61.
3. Adeniji, A. O. and and Mbamaluikem, P.O. Voltage stability enhancement and efficiency improvement of Nigerian transmission system using Unified Power Flow Controller. *American Journal of Engineering Research,* 2017; *6*(1): 37-43.
4. Ali, I. I. Optimal location of SSSC based on PSO to improve voltage profile and reduce Iraqi grid system losses. *Engineering and Technology Journal,* 2017; *35*(4): 372-380.
5. Amaize, P., Anthony, A., Awosope, C. and Airoboman A. A review of application of facts devices on Nigerian 330kV transmission system. *Journal of Engineering and Applied Sciences,* 2017; *12*(20): 5182-5185.
6. Amrutha, B. and Deepu, E. K. Available transfer capability enhancement with TCSC using Firefly Algorithm. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* 2015; *4*(9): 7496-7501.
7. Anthony, O. I., Eseosa, O. and Kayode, I. Voltage stability analysis of Nigerian power system using Distributed Generation. *Applied Research Journal,* 2017; *3*(2): https://www.civilica.com/Paper-JR_ARJ-JR_ARJ-3-2_002.html.
8. Aribi, F. and Nwohu, M. N. Optimal location of STATCOM in Nigerian 330 kV network using Ant Colony Optimization Meta-Heuristic. *Global Journal of Researches in Engineering: F Electrical and Electronics Engineering,* 2014; *14*(3): 45-50.
9. Aribi, F., Nwohu, M. N., Sadiq, A. A. and Ambafi, J. G. Voltage profile enhancement of the Nigerian North-East 330kV power network using STATCOM. *International Journal of Advanced Research in Science, Engineering and Technology,* 2015; *2*(1): 330-337.
10. Arora, R., Gupta, V. P., Gautam, V. K. and Khandelwal, A. A review on voltage stability improvement by using facts controllers in power systems. *Asian Journal of Information Technology,* 2016; *1*(4): 70-76.

11. Ayodele, T. R., Ogunjuyigbe, A. S. O. and Oladele, O. O. Improving the transient stability of Nigerian 330kv transmission network using Static Var Compensation part i: the base study. *Nigerian Journal of Technology (NIJOTECH),* 2016; *35*(1): 155 – 166.
12. Balachennaiah, P., Suryakavathi, M. and Nagendra, P. Optimizing real power loss and voltage stability limit of a large transmission network using Firefly Algorithm. *Engineering Science and Technology, an International Journal,* 2016; *19*(2*)*: 800-810.
13. Balachennaiah, P., Suryakavathi, M. and Nagendra, P. Firefly algorithm based solution to minimize the real power loss in a power system. *Ain Shams Engineering Journal,* 2018; *9*(1): 89-100.
14. Bello, I, Umar, M. B. and Idakwo, H. O. Determination of bus voltages, real and reactive power losses in the Northern Nigeria 330 kV network using Power System Analysis Tool (PSAT). *Science Journal of Energy Engineering,* 2016; *4*(5): 35-43.
15. Dixit, S, Srivastava, L., Singh, A. and Agnihotri, G. Optimal placement of TCSC for enhancement of power system stability using heuristic methods: an overview. *International Journal of Hybrid Information Technology,* 2015; *8*(6): 367-374.
16. Emmanuel, U. O., Samuel N. N. and Gerald K. I. Electric power transmission enhancement: a case of Nigerian electric power grid. *American Journal of Electrical and Electronic Engineering,* 2016; *4*(1): 33-39.
17. Eseosa, O. and Odiase, F. O. Efficiency improvement of Nigeria 330KV network using Flexible Alternating Current Transmission System (FACTS) devices. *International Journal of Advances in Engineering and Technology,* 2012; *4*(1): 26-41.
18. Gandoman, F. H., Ahmadib, A., Sharaf, A. M., Siano, P., Poub, J., Hredzak, B. and Agelidis, V. G. Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems. *Renewable and Sustainable Energy Reviews,* 2018; *82*: 502–514.
19. Ignatius K. O., Emmanuel A. O. and Patrick A. O. Load Flow Assessment of the Nigeria 330-kV Power System. *American Journal of Electrical and Electronic Engineering,* 2017; *5*(4): 159-165. doi: 10.12691/ajeee-5-4-6.
20. Jayachitra, S. and Baskar, G. Power loss minimization and voltage stability enhancement in power system by optimal allocation and sizing of STATCOM using enhanced PSO. *IEEE Sponsored 2nd International Conference on Innovations in Information, Embedded and Communication systems* (ICIIECS), 2015; 15905-15909.
21. Nwohu, M. N., Isah, A., Usman, A. U. and and Sadiq, A. A. Optimal placement of Thyristor Controlled Series Compensator (TCSC) on Nigerian 330 kV transmission grid

to minimize real power losses. *International Journal of Research Studies in Electrical and Electronics Engineering*, 2016; *2*(4): 18-26.
22. Okwe, G. I., Akwukwaegbu, I.O, Uneze, I. M. and Nwaogwugwu, C. N. Voltage stability improvement of power transmission system in Nigeria using TCSC. *US Open Electrical & Electronics Engineering Journal*, 2015; *1*(1): 1-15.
23. Olabode, O. E., Ayantunji, O. D. and Nwagbara, V. U. Performance evaluation of reactive power compensation of TCSC and SVC on voltage profile enhancement and power system loss minimization using Firefly Algorithm. *International Journal of Scientific & Engineering Research*, 2017; *8*(8): 1514-1519.
24. Olabode, O. E., Okakwu, I. K., Ade-Ikuesan, O. O. and Fajuke, I. D. A survey of application of Static Synchronous Compensator on Nigerian longitudinal transmission system. *Advances in Electrical and Telecommunication Engineering*, 2018; *1*: 49-54.
25. Olabode, O.E., Arowolo M.P and Olugbemi A.O. Optimal allocation and sizing of reactive power source for voltage profile improvement on Nigerian 330 kV, 24-bus grid system. IOSR *Journal of Electrical and Electronics Engineering*, 2016; *11*(5): 40-48.
26. Olaniyan, A., Boyi, J. and Jibril, Y. Application of Analytical-Firefly Algorithm for optimal location and sizing of Distributed Generator in standard IEEE 30-bus distribution network. *Conference: International Engineering Conference (IEC 2015)*, Federal University of Technology, Minna, 2015; 1-6.
27. Omorogiuwa, E., Onohaebi, S. O. Optimal location of IPFC in Nigeria 330 kV integrated power network using GA technique. Journal of Electrical and Electron System, 2015; 4: 145. doi:10.4172/2332 0796.1000145.
28. Onlam, A., Yodphet, D., Chatthaworn, R., Surawanitkun, C., Siritaratiwat, A. and Khunkitti, P. Power loss minimization and voltage stability improvement in electrical distribution system via Network Reconfiguration and Distributed Generation placement using Novel Adaptive Shuffled Frogs Leaping Algorithm. *Energies*, 2019; *12*: 553; 1-12.
29. Rajasekaran, S. and Muralidharan, S. Firefly Algorithm in determining maximum load utilization point and its enhancement through optimal placement of FACTS device. *Circuits and Systems*, 2016; *7*: 3081-3094.
30. Ramesh, P. and Damodara R. Loss reduction through optimal placement of Unified Power-Flow Controller using Firefly Algorithm. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 2013; *2*(10): 4657-4667.

31. Selvarasu, R. Christober Asir Rajan.C and Surya Kalavathi. M. Optimal placement of TCSC for voltage constrained loss minimization using Self-Adaptive Firefly Algorithm. *Journal of Electrical Engineering*, 2018; 1-8.
32. Selvarasu. R and Kalavathi, S. SVC placement for voltage profile enhancement using Self Adaptive Firefly Algorithm. *TELKOMNIKA Indonesian Journal of Electrical Engineering*, 2014; *12*(8): 5976-5984.
33. Singh, B., Verma, K. S., Singh, D., Singh, C. N., Singh, A., Agrawal, E., Dixit, R. and Tyagi, B. Introduction to FACTS controllers a critical review. *International Journal of Reviews in Computing*, 2010; *8*: 18-34.
34. Subramanian, A., Jaisiva, S., Swathana, R. and Neelan, S. Optimal allocation of FACTS device for voltage profile enhancement. *International Journal of All Research Education and Scientific Methods*, 2015; *1*(2): 1-7.
35. Subramanian, A., Ravi, G. and Gopal, D. A. Loss minimization and voltage profile improvement incorporating multiple SVC using PSO algorithms. *International Journal of Computer Applications*, 2012; *46*(22): 15-20.
36. Sugirtha, M. G and Latha, P. Firefly Algorithm based multi-objective optimal power flow in the presence of wind power. *Asian Journal of Information Technology*, 2016; *15*(4): 703-711.
37. Sultana, U., Khairuddin, A., Mokhtar, A. S., Qazi, S. H. and Sultana, B. An optimization approach for minimizing energy losses of distribution systems based on Distributed Generation placement. *Jurnal Teknologi (Sciences & Engineering)*, 2017; *79*(4): 87–96.
38. Usman, R., Sigalo, M. B. and McDonald, S. Analysis of the effect of Flexible Alternating Current Transmission System (FACTS) on the Nigerian 330 kV transmission network using ERACS and MATLAB SIMULLINK. *European Journal of Engineering and Technology*, 2015; *4*(3): 18-34.
39. Yang X. S. Firefly Algorithm for multimodal optimization tasks**.** *Foundations and Applications, SAGA*, Lecture Notes in Computer Sciences, 2009; *5792*: 169-178.
40. Yang, X. S. Firefly Algorithm, stochastic test functions and design optimization *International Journal of Bio-Inspired Computation*, 2010; *2*(2): 1-12.