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Optimal Siting and Sizing of Capacitor for Voltage Profile and Efficiency Enhancement in a Transmission System with N-1 Contingency

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Research Article

Abstract

This research work is centered on power loss minimization and voltage profile improvement using Genetic Algorithm (GA). Newton Raphson algorithm on the MATLAB environment was used to determine the network contingency. The Genetic Algorithm (GA) was used to determine the optimal capacitor placement and sizing. The technique was validated on the standard IEEE 30-bus system with a real power loss reduction of 17.5280MW and 13.3050MW before/after compensation was recorded indicating 24.09%. Also, reactive power loss reduction of 68.8880MVar and 53.4330MVar before/after compensation indicating 22.43% is associated with the network. A voltage deviation of 0.0245 and 0.0033 before/after compensation was also recorded in the IEEE network. The performance index result for N-1 contingency shows that outage of line 1 was the most severe case while outage of line 41 was the least was also recorded in the IEEE network. The method was then implemented to Kaduna Town 1 Transmission Station (KTTS). The Kaduna Town 1 Transmission Station has a real power losses reduction of 25.8380MW and 21.9230MW before/after compensation indicating 15.15%. Also, reactive power losses reduction of 14.8570Mvar and 13.2650Mvar before/after compensation indicating 10.72% was recorded. The Kaduna Town 1 has a total voltage deviation of 0.0652 and 0.0019 before/after compensation indicating better voltage condition in the network. The performance index result for N-1 contingency for KTTS shows that outage of line 23 was the most severe case while outage of line 3 was the least. These indicate that the system parameters go beyond their permissible limits. The affected buses have been improved after compensation due to the optimal placement of capacitor banks at appropriate buses.

Keywords

Kaduna; Losses; Network; Optimization; Transmission.

Article History

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1. Introduction

As transmission lines link generating plants with substations in power network, the reduction, computation and analysis of transmission losses in these power system are of much concern to engineers (Oyemaechi and Isaac, 2014). The two major methods for reduction in losses at distribution level are re-configuration and capacitors placement. Other than distribution network reconfiguration (DNR), the Distributed Generator (DG) can provide power losses reduction in the network system and improving the voltage profile (Anumaka and Maneme, 2015).

The security and stability of power system equipment are significant in operation of power system. Contingency Analysis (CA) is use to evaluate the system for future planning and to suggest possible ways to remedy the problem if it occurs. Also CA can be useful in the periodic or scheduled maintenance (Airoboman et al., 2019). Reactive power optimization is much concern in the operation and control of power systems. In order to decrease the active power losses and improve the voltage profile along the transmission lines under different operating conditions. The main objective of any power system is to ensure it is economically operated and it is safe such that its delivery will be effective, reliable and dependable (Airoboman et al., 2019). This work attempts to form a new topology of Kaduna Town 1 Transmission Station with a view to improving the system performance at different operating conditions. The increasing demand in power system is continuously all over the world. The accumulation of losses leading to poor power quality and voltage profile has been a major problem in the power sector, the transmission network is facing several outages as a result of load shedding, unstable voltage and other factors which also affects Kaduna Town one (1) Transmission Station. Hence, in order to effectively improve on the operations, control, and monitoring of Kaduna Town 1 Transmission Station (KTTS), this study minimize the losses experienced in this station and also improving these losses. Newton Raphson method was employed in the power flow analysis. N-1 Contingency Analysis was used to tackling the post-contingency operational voltage limits violations, and Genetic Algorithm was used to optimize the losses for the aforementioned issues in the network.

Transmission lines are the fundamentals of the electric power system connecting the load to the generation joining the generation lines of energy over a wide range of geographical area. Transmission of electricity is one of the most important contributions that engineering has presented to the modern civilization. The motivation of this research is to reduce the power losses, improve the voltage profile and advance the system reliability and dependability as to guarantee continuity of supply and stability in the network for efficient transmission. Contingency analysis in power system is a situation when the system is in an unusual situation. Due to this contingency condition, the whole system or some parts come under stress or congested. It occurs due to the sudden tripping condition of generators, sudden opening of transmission line, and rapid fluctuations in power generation, and rapid changes in the loads. Contingency selection process is used when the power system network is large (Retnamony and reglend, 2016).

The Genetic algorithms would be used for optimization and optimal capacitor placement. The optimization will be applied with respect to the voltage profile, network power losses and contingency analysis. This research work is basically focuses on load flow analysis, and contingency analysis of Kaduna Town 1 Transmission Station using MATLAB environment (version R2018a). In order to determine the steady state operating condition and reduced the losses associated with the network through the optimal capacitor placement.

Optimal capacitor placement and sizing in radial electric power systems was introduced by Elsheikh et al (2014). The proposed methodology uses loss sensitive factors to identify the buses that the capacitor will be connected and Particle Swarm Optimization algorithm (PSO) is used to determine the sizes of the capacitor to be installed. The proposed algorithm has been tested on the standard 10-bus, 15-bus and 34-bus radial distribution systems and its gives superior result compared with reported result in the literature with a relatively small number of iterations. Aman et al. (2016) presented Optimum Simultaneous DG and Capacitor Placement on the basis Minimization of Power Losses. The method worked out either DG unit placement or shunt capacitor placement as criteria for minimization of power system losses and better voltage regulation. PSO algorithm was used simultanous for finding of optimum DG and the size and location of the shunt capacitor bank. The proposed algorithm has tested on 12-bus, 30-bus, 33-bus, and 69-bus radial distribution network. The result shows that the proposed methods has significantly improved the overall loading factor and power system losses reduction. The voltage profile of the system has also improved and all the buses are operating within the allowable limit.

In a similar study, Airoboman and Tyo (2018) successfully implement Power Loss Determination, Assessment and Enhancement of the Nigerian Power System Network with the objective of carried the power flow analysis using the Newton Raphson Algorithm on the Electrical Transient Analyser Program (ETAP) on the Nigerian Power Sector NPS network using Maryland transmission station (MTS), Lagos, Nigeria as a case study. Results from the load flow indicated several voltage violations at load1 bus, load3 bus and load5 bus with magnitudes of 94.51, 94.91 and 94.79 % respectively. Consequently, transformers designated as T2A and T3A were said to have the highest and lowest branch losses of 150.0kW and 18.2kW respectively. Optimal capacitor placement (OCP) was used to Compensation the losses along the line. The results from the OCP showed that four capacitor banks on four of the candidate buses are optimally sized and placed in the network, which include load1 bus, load2 bus, load3 bus and load5 bus. An improvement of 2.26%, 1.12%, 1.93%, 1.12% and 2.006% were recorded for load1 bus, load2 bus, load3 bus, load4 bus and load5 bus respectively. Also, Salimon et al. (2015) presented Optimal Placement and Sizing of Capacitors in Radial Distribution Systems: A Two – Stage Method. This method presents a two – stage of Loss Sensitivity Factor (LSF) and Cuckoo Search Algorithm (CSA) to find the optimal location and size of the shunt capacitor with the objectives of minimizing cost due to power loss and reactive power compensation on the network. The proposed two stage method is tested on the standard IEEE 33-bus and Ayepe 34-bus Nigerian radial distribution network. The result shows a real and reactive power loss reduction of 34.28% and 28.94% as compared to the base case for the IEEE 33-bus system while the Ayepe 34-bus system has a real and reactive power loss reduction of 22.89% and 21.40%. The result also shows a technical benefit that reduced the total power loss, improved bus voltage stability and voltage profile. And the economic benefit reduced the total cost due to electrical power loss and compensation.

However, Abdulrazzaq (2015) presented a contingency ranking of power systems using a Performance Index (PI). Newton-Raphson method was used to run the load flow in order to determine the power system contingency ranking for the line outage based on the Voltage performance index and Active power performance index for standard IEEE 30-bus test system. The result indicates that the most dangerous contingency is the disconnection of a transmission line which leads to overloading of another transmission line, in term of the Performance index calculated based on the branches overload. The most dangerous contingencies from the voltage point of view are the disconnections of some lines in terms of the Performance index calculated for bus voltage.

In a similar study, Landeros et al. (2019) present a modified evolutionary algorithm on supply network reconfiguration in order to applied in the power distribution network reconfiguration. The proposed algorithm structures feasibility to preserve mutation and recombination operators that usually maintain the radial structure of the network at the entire steps of the optimization process, this method is demonstrated with many networks of several sizes on benchmarking. The repeatability result improved as well as lower computational overall complexity of the optimization process which result in reduction of the size search space. The optimization process considers only power losses and the voltage profile of the system, both aggregated into a scalar cost function. The limitation of this method is that the global solution is not guaranteed, there is need for future work to focused on extending the range of applications of the method, including multi-objective DNR (for both power loss reduction and voltage control), constrained optimization, as well as other types of networks (multi-source, non-radial).

Musa (2019) present an Ant Lion Algorithm (ALOA) minimization of power losses and improving voltage profile in distribution system by optimal allocation of Distributed

Generation (DG) for 3 DG unit. The result was achieved to the maximum value in terms of improving bus voltage of IEEE 33-bus Radial Distribution System (RDS) and also minimized overall power losses of the network using Multi – Objective Function (MOF). The drawback of the method is they used a Voltage Stability Index (VSI). Poornima and Titare (2015) proposed a power system contingency ranking using Fast Decoupled Load Flow (FDLF) method. This method was used for line outage based on the Voltage PI and Active power PI. The ranking was given by considering the overall PI, which is the summation of Voltage PI and Active power PI called the Overall performance index OPI. The proposed method was implemented on an IEEE 14-bus system. The result indicates that the OPI with highest value reflect a severe case, which has the highest potential to make the system parameters to go beyond their limits. Also, Fathy et al. (2017) presented a Binary Particle Swarm Optimization Gravity Search Algorithm (BPSOGSA) for optimal reconfiguration of distribution network for the determination of the positions for sectionalizing and tie switches. The reliability and active power loss reduction were considered as the member of the objective functions. They method used System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), and Energy Not Supplied (ENS) were used to determine the reliability of network. The drawback of the method has a large number of parameters and required more computational time. İmran et al.(2018) proposed integration technique for optimal network reconfiguration and DG placement in distribution system was presented with an objective of power loss minimization and voltage stability enhancement. Fireworks Algorithm (FWA) is used to simultaneously reconfigure and allocate optimal DG units in a distribution network. FWA is a new swarm intelligence based optimization algorithm which is conceptualized using the fireworks explosion process of searching for a best location of sparks. The radial nature of the network is secured by generating proper parent node-child node path of the network during power flow. Voltage Stability Index (VSI) is used to pre-identify the optimal candidate locations for DG installation. This method considered Six different scenarios during DG placement and reconfiguration of network to determine the performance of the proposed technique. The simulated results demonstrate in standard IEEE 33- and 69-bus test systems at three different load levels with well performance and effectiveness of the proposed method. However, FWA is quite slow, so there is need for fast and efficient tool for the solution. Moreover, Yan et al. (2018) improved the data structure of the simplified model of distribution network, in order to improve one of the objective of DNR; load balancing with the tie-switch as the core constraint satisfaction problem model for the load-balanced distribution network. The goal is to establish the constraints of the network reconstruction with load balancing and a load balancing index appropriate for constraint satisfaction problem is proposed. The simulation carried out on a typical distribution network, the load equalization rate is improved by 58.5%. However, the work considered only one objective, hence there is need to develop DNR with multiple objectives. In view of the recent research works carried out, it can be seeing that significant attention has been given to losses minimization using optimal capacitor placement and contingency analysis (CA) with various objectives. The major limitations of some of these approaches are transforming the multiple cost function into single objective function by using weighted parameter which are highly subjective and solve the problem with a slow algorithm with more computational time or violate some constraints.

However, there are still research gaps in this area that need to be filled, thus avoiding the complexity associated in solving a typical multi-objective problem. This research work considers the solution of multi-objective function of optimal capacitor placement using a Genetic Algorithm (GA) for the system losses reduction and the voltage profile improvement. To ascertain the effectiveness and practicability on this research, this scheme used MATLAB environment (version R2018a), and Newton Rapson method for carrying the load flow analysis because of its faster convergence ability with less computational time. And N-1 contingency analysis used to evaluate the future outage case on the system.

1.1 Genetıc Algorıthm (GA)

Genetic Algorithms (GA) is a heuristic method based on the Theory of Evolution and is characterized as derivative free population-based stochastic optimization method stimulated by the concept of natural selection and evolutionary progression (Abubakar et al., 2019 and Chidanandappa et al., 2015). The GAs search system used initialized with probabilistic selection of population centred on their fitness and searches for optima by updating generations. GAs work with a coding of the parameter set, not the parameters themselves. Consequently, GAs can easily handle the numerical or discrete variables. GAs uses only objective functions, not derivatives or other auxiillary information and can deal with non-smooth, non-continuous and non-differentiable functions which essentially in a practical optimization problem.

1.2 Losses reduction and voltage profile ımprovement

Even with a good design, there may still be losses in the power system. Electric power losses are wasteful energy caused by internal factors or external factors and energy imbalanced in the system. The losses in the network are reduced and the voltage profile improved on the buses using optimal capacitor placement. This is achieved through optimal sizing and placement of capacitors on the system.

1.2.1 Power loss reduction in Percentage

Power loss reduction in percentage can be achieved by the given equations

$$\%P_{Real} = \frac{P_{L_{before}} - P_{L_{after}}}{P_{L_{before}}} \ x \ 100 \tag{1}$$

$$\%Q_{Reactive} = \frac{Q_{L_{before}} - Q_{L_{after}}}{Q_{L_{before}}} \ x \ 100 \tag{2}$$

Where;$\%P_{Real}$ is the percentage of the real power loss reduction,

$P_{L_{before}}$ is the real power loss reduction before compensation,

$P_{L_{after}}$ is the real power loss reduction after compensation, $\%Q_{Reactive}$ is the percentage of the reactive power loss reduction,

$Q_{L_{before}}$ is the reactive power loss reduction before compensation,

$Q_{L_{after}}$ is the reactive power loss reduction after compensation

1.2.2 Total Voltage Deviation (TVD)

Voltage deviation can be defined as the difference between the nominal voltage and the actual voltage. The smaller the deviation of bus voltage from the nominal voltage, the better the voltage condition of the system. A voltage deviation index (TVD) is defined as the sum of the squared value of the absolute voltage difference between the nominal voltage and the actual voltage for all buses in the system (Le et al., 2007).

$$TVD = \sum_{i=1}^{N} |V_n - V_i|^2 \tag{3}$$

Where;

$N = the\ total\ number\ of\ buses$

$V_n = nominal\ voltage$

$V_i = actual\ voltage\ at\ bus\ i$

2. Methodology

The materials used in this study comprise the single line diagram of the IEEE 30 bus network been used as a test bed and the single line diagram of the Kaduna Town (1) network. These data are presented using Figure 1 and 2. Thereafter, the equations to run the load flow on these networks are presented in equations (4) – (5). The flow chart in Figure 3 Explained the process through which the contingency analysis was achieved. The optimization of the network was achieved through optimal sizing and placement of capacitors on the system using GA. This was achieved by describing the objective function and constraints as described in Equations (6) – (7) and Figure 4

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \tag{4}$$

Equation (4) can be further represented using equation (5)

$$\begin{bmatrix} \Delta P_i^k \\ \vdots \\ \Delta P_n^k \\ \Delta Q_i^k \\ \vdots \\ \Delta Q_n^k \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} \frac{\partial P_i}{\partial \delta_i} & \cdots & \frac{\partial P_i}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_i} & \cdots & \frac{\partial P_n}{\partial \delta_n} \end{bmatrix}^{(k)} & \begin{bmatrix} \frac{\partial P_i}{\partial |V_i|} & \cdots & \frac{\partial P_i}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial |V_i|} & \cdots & \frac{\partial P_n}{\partial |V_n|} \end{bmatrix}^{(k)} \\ \begin{bmatrix} \frac{\partial Q_i}{\partial \delta_i} & \cdots & \frac{\partial Q_i}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \delta_i} & \cdots & \frac{\partial Q_n}{\partial \delta_n} \end{bmatrix}^{(k)} & \begin{bmatrix} \frac{\partial Q_i}{\partial |V_i|} & \cdots & \frac{\partial Q_i}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial |V_i|} & \cdots & \frac{\partial Q_n}{\partial |V_n|} \end{bmatrix}^{(k)} \end{bmatrix} \begin{bmatrix} \Delta \delta_i^k \\ \vdots \\ \Delta \delta_n^k \\ \Delta |V_i|^k \\ \vdots \\ \Delta |V_n|^k \end{bmatrix} \tag{5}$$

2.1 Objective Function

The description of the objective function is designated as (Lohia *et al.*, 2016).

$$F = W_1 P_{loss} + W_2 Q_{loss} + W_3 \sum_{i=1}^{n} (1 - v_i)^2 \tag{6}$$

Where $W_1 = 0.2$, $W_2 = 0.79, W_3 = 0.01$ are weights used in the objective function corresponding to the active power loss, reactive power loss and voltage deviation. P_{loss} is total active power loss and Q_{loss} is the total reactive power loss. v_i is the voltage magnitude at i^{th} bus of the network.

2.2 Constraints

The leading constraints for optimal capacitor placement are to meet the load flow constraints. In addition, all voltage magnitude of load (PQ) buses should be within the tolerable limit. No Islanding in the network. The considerable constraint for all load (PQ) buses in this research work is shown below (Lohia et al., 2016).

Load Flow: $F(x, u) = 0$

$$V_{min} \le V \le V_{max} \tag{7}$$

Where;

V_{min}= minimum voltage limit

V_{max}= maximum voltage limit

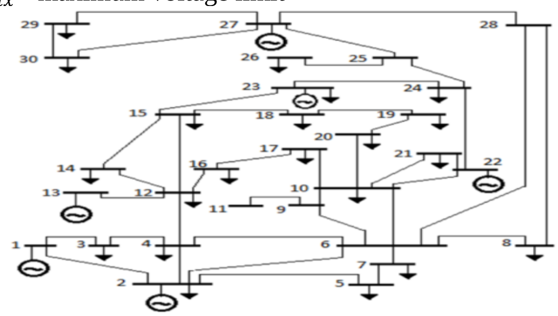

Figure 1**:** Single Line diagram of standard IEEE 30-Bus (Teyanih and Devaraji, 2010).

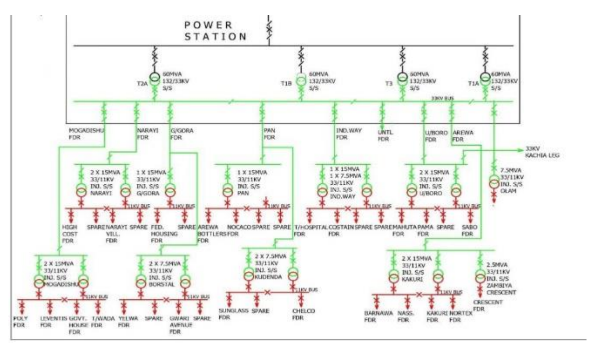

Figure 2: Diagram of 132kV Kaduna Town 1 Transmission Station

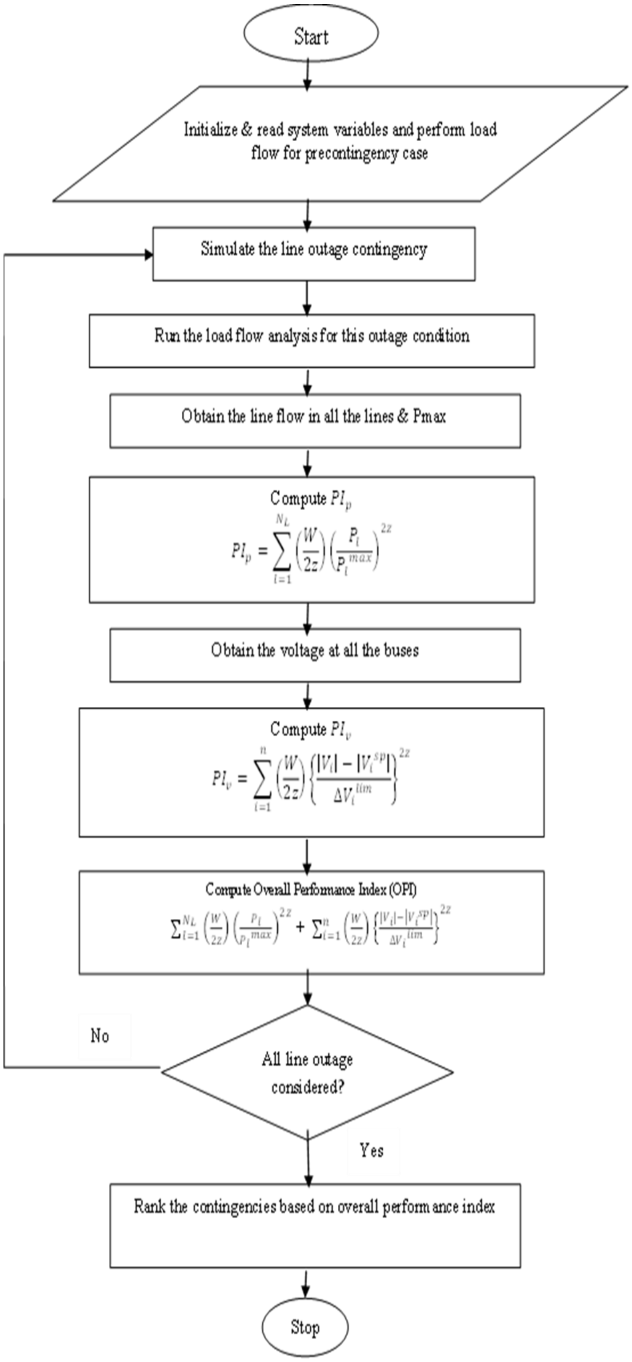

Figure 3: Flow Chart for Contigency Analysis

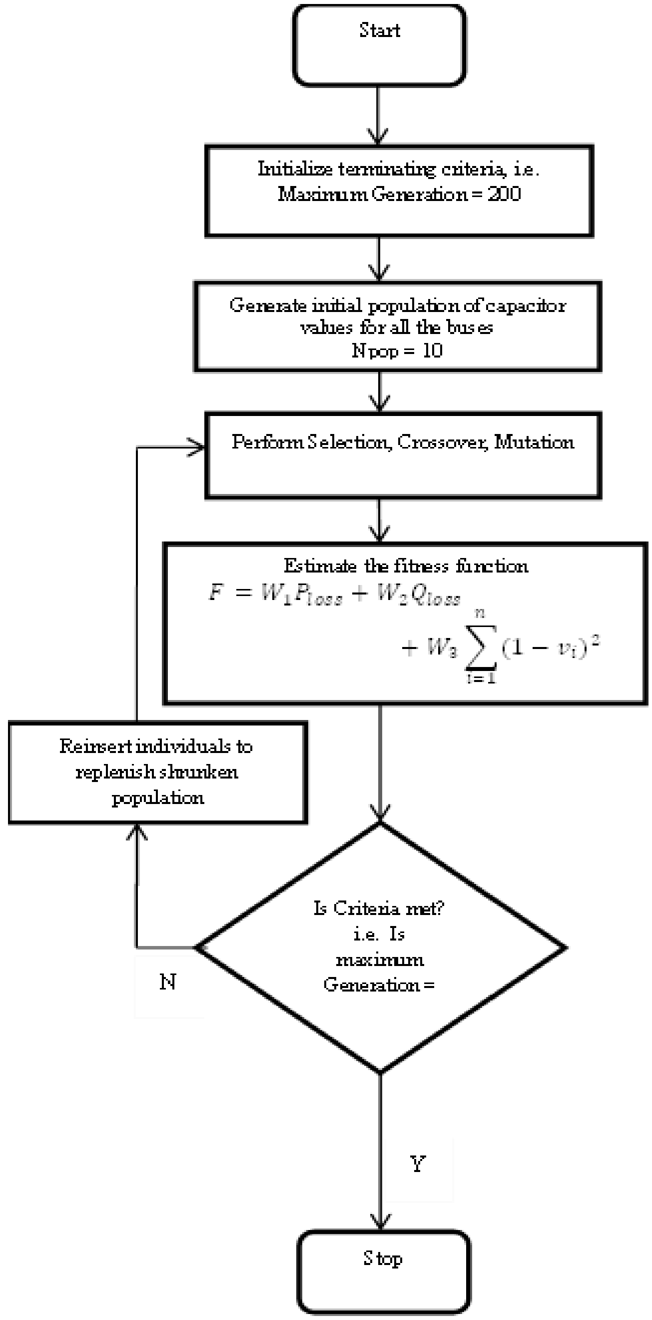

Figure 4: The GA Algorithm

3. Results and Discussion

Table presented are the output result for before and after compensation. Table 1 represents the Voltage profile of buses before/after compensation for IEEE 30 bus system while Table 2 represents the System Losses before/after compensation for IEEE 30 bus system network. Also, Table 3 represent Total Voltage Deviation for IEEE 30 bus system. It shows that the deviation before and after compensation. The smaller the deviation of bus voltage from the nominal voltage, the better the voltage condition of the system. Consequently, Table 4 shows the performance index of the IEEE network for N-1 contingency analysis and optimal placement of the capacitor bank and the value for IEEE 30 bus system after compensation, and Figure 5represent the N-1 contingency graphical. The arrow shows that outage of line 1 was the most severe case while outage of line 41 was the least according to the ranking. The indices with higher values shows a severe case which has the highest potential to make the system parameters go beyond their permissible limits.

Table 1: Voltage profile of buses before/after compensation for IEEE 30 bus system

Buses	**Voltage magniude before compensation**	**Voltage magnitude after compensation**
1	1.0600	1.0600
2	1.0430	1.0430
3	1.0217	1.0371
4	1.0129	1.0266
5	1.0100	1.0100
6	1.0121	1.0197
7	1.0035	1.0083
8	1.0100	1.0100
9	1.0507	1.0606
10	1.0438	1.0554
11	1.0820	1.0820
12	1.0576	1.0707
13	1.0710	1.0710
14	1.0429	1.0554
15	1.0384	1.0508
16	1.0445	1.0568
17	1.0387	1.0503
18	1.0282	1.0400
19	1.0252	1.0369
20	1.0291	1.0407
21	1.0293	1.0408
22	1.0353	1.0470
23	1.0291	1.0407
24	1.0237	1.0354
25	1.0202	1.0325
26	1.0025	1.0149
27	1.0265	1.0392
28	1.0109	1.0177
29	1.0067	1.0199
30	0.9953	1.0087

Table 2: System Losses before/after compensation for IEEE 30 bus system

SYSTEM LOSSES			
Before Compensation		**After Compensation**	
MW	**MVAr**	**MW**	**MVAr**
17.5280	68.8880	13.3050	53.4330

Table 3: Total Voltage Deviation IEEE 30 bus system

TVD	
Before Compensation	**After Compensation**
0.0245	0.0033

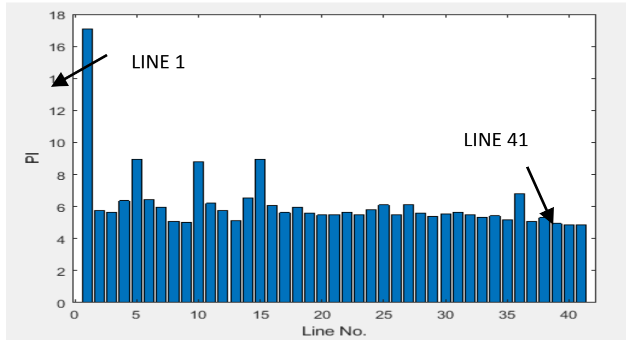

Figure 5**:** Overall Performance Index of IEEE 30 Bus System

Table 4: Performance indices of IEEE 30-bus system with the optimal location and capacitor value(s).

Tripped Line	**PIv**	**Pip**	**PI**	**Rank**	**Optimal bus location (s)**	**Capacitor Value (s) (kVAr)**
1	0.0151	17.0875	17.1026	**1**	**1**	**-**
2	0.0086	5.7597	5.7684	17	2	-
3	0.0092	5.6499	5.6592	19	3	-
4	0.0103	6.3519	6.3622	8	4	-
5	0.0097	8.9212	8.9309	3	5	-
6	0.0089	6.4077	6.4166	7	6	-
7	0.0085	5.9662	5.9748	13	7	-
8	0.0111	5.0789	5.0900	36	8	-
9	0.0144	5.0014	5.0158	38	9	-
10	0.0122	8.7706	8.7828	4	10	-

11	0.0119	6.1810	6.1929	9	11	-
12	0.0110	5.7602	5.7712	16	12	-
13	0.0085	5.1172	5.1257	35	13	-
14	0.0069	6.5101	6.5170	6	14	-
15	0.0047	8.9664	8.9711	2	15	-
16	0.0092	6.0624	6.0717	12	16	-
17	0.0103	5.6120	5.6224	21	17	-
18	0.0082	5.9375	5.9457	14	18	-
19	0.0100	5.5990	5.6091	23	19	-
20	0.0119	5.4469	5.4588	29	20	-
21	0.0117	5.4705	5.4822	26	21	-
22	0.0109	5.6512	5.6621	18	22	-
23	0.0118	5.4653	5.4771	27	23	-
24	0.0116	5.8098	5.8214	15	24	-
25	0.0107	6.0782	6.0889	11	25	-
26	0.0114	5.4726	5.4839	25	26	-
27	0.0102	6.0905	6.1007	10	27	-
28	0.0110	5.5995	5.6104	22	28	-
29	0.0118	5.3653	5.3771	31	29	-
30	0.0116	5.5468	5.5584	24	30	56.0453
31	0.0119	5.6382	5.6501	20	-	-
32	0.0118	5.4537	5.4655	28	-	-
33	0.0123	5.3082	5.3204	32	-	-
34	0.0092	5.4079	5.4172	30	-	-
35	0.0112	5.1821	5.1933	34	-	-
36	0.0346	6.7624	6.7970	5	-	-
37	0.0136	5.0660	5.0796	37	-	-
38	0.0135	5.2997	5.3132	33	-	-
39	0.0122	4.9264	4.9386	39	-	-
40	0.0117	4.8677	4.8794	40	-	-
41	0.0097	4.8677	4.8774	**41**	**-**	**-**

Table 5: Voltage profile of buses before/after compensation for KTTS.

Buses	**Voltage profile before compensation (pu)**	**Voltage profile after compensation (pu)**
1	1.0000	1.0000
2	0.9834	0.9877
3	0.9674	0.9731
4	**0.9460**	**0.9533**
5	**0.9383**	**0.9463**
6	**0.9324**	**0.9408**
7	**0.8813**	**0.8961**
8	**0.9371**	**0.9452**
9	**0.9246**	**0.9338**
10	**0.9462**	**0.9543**
11	**0.9413**	**0.9505**
12	0.9608	0.9695
13	0.9795	0.9885
14	**0.9402**	**0.9494**
15	**0.9362**	**0.9457**
16	1.0455	1.0539
17	1.0423	1.0506
18	1.0413	1.0495
19	1.0408	1.0491
20	1.0351	1.0432

21	1.0324	1.0407
22	1.0238	1.0322
23	1.0234	1.0318
24	1.0219	1.0303
25	0.9612	0.9721
26	1.0161	1.0244

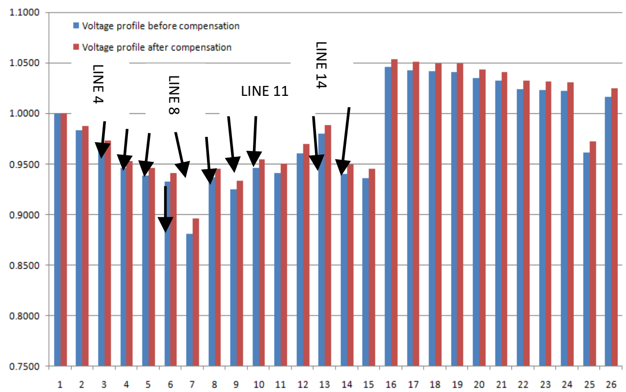

Figure 6**:** Voltage profile of Kaduna Town 1 buses before and after compensation.

The load flow result of Kaduna Town one (1) Transmission Station was presented in the Table 5 with the voltage profiles of the buses before and after compensation. It can be observed that, the voltage violations of the buses (buses 4,5, 6, 7, 8, 9, 10, 11, 14 and 15) with the magnitude of 0.9460pu, 0.9383pu, 0.9324pu, 0.8813pu, 0.9371pu, 0.9246pu, 0.9462pu, 0.9413pu, 0.9402pu and 0.9362pu before compensation respectively. The result shows voltage profile at the affected buses has improved to 0.9533pu, 0.9463pu, 0.9408pu, 0.8961pu, 0.9453pu, 0.9338pu, 0.9543pu, 0.9505pu, 0.9494pu and 0.9457pu after compensation with an optimization elapsed time of 14.954663 seconds and represented graphically using Figure 6.

Table 6 depicts the performance indices of the Kaduna Town 1 network and the details of the optimal placement of capacitor banks with their values at the appropriate buses after compensation. And Figure 7 represent graphically the performane indices of Kaduna town 1. The Table contains the voltage, active power and overall performance indices of the various line outages designated by PIv, Pip, PI, bus no. and capacitor values respectively. The performance indices result shows that outage of line 23 was the most severe case while outage of line 3 was the least according to the ranking. The ranking was given by considering the overall PI, which is the summation of PIv and PIp. The indices with higher values shows a severe case which has the highest potential to make the system parameters go beyond their permissible limits. In appendices I-VI the active power flow due to line outage and voltage magnitude of KTTS are presented.

Table 6: Performance indices of Kaduna Town 1with the capacitor sizing and placement

Tripped Line	**PIv**	**Pip**	**PI**	**Rank**	**Bus No.**	**Capacitor Values (kVAr)**
1	0.0326	2.1837	2.2163	24	1	-
2	0.0276	4.9176	4.9452	22	2	-
3	0.0286	0.5471	0.5757	**25**	**3**	**-**
4	0.0288	19.7892	19.8181	7	4	94.05
5	0.0276	19.6921	19.7197	13	5	-
6	0.0288	19.6750	19.7038	16	6	56.05
7	0.0280	19.6700	19.6980	17	7	-
8	0.0288	19.6998	19.7287	11	8	106.05
9	0.0276	19.6804	19.7080	15	9	-
10	0.0278	19.6920	19.7198	12	10	77.05
11	0.0276	19.6680	19.6955	18	11	-
12	0.0321	3.4590	3.4911	23	12	-
13	0.0288	20.1298	20.1586	3	13	-
14	0.0288	19.6524	19.6812	20	14	-
15	0.0316	19.6493	19.6809	21	15	89.05
16	0.0331	19.7415	19.7746	9	16	-
17	0.0396	19.6774	19.7170	14	17	-
18	0.0325	19.7862	19.8187	6	18	-
19	0.0336	19.7357	19.7693	10	19	-
20	0.0288	20.0219	20.0507	4	20	-

21	0.0337	20.1257	20.1594	2	21	-
22	0.0285	19.9752	20.0038	5	22	-
23	0.0277	20.3593	20.3870	**1**	23	-
24	0.0280	19.7713	19.7993	8	24	-
25	0.0284	19.6656	19.6940	19	25	-
					26	-

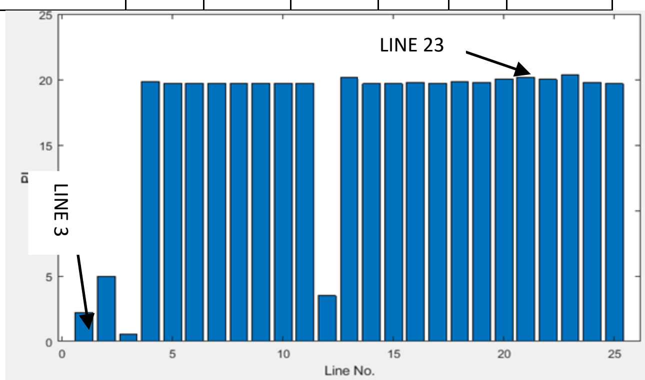

Figure 7: Overall Performance Index of Kaduna Town 1

Table 7 represents the system losses of the Kaduna Town 1 network before and after compensation. It shows a reduction in real power loss from 25.8380MW to 21.9230MW indicating a 15.15% and reactive power loss from 14.8570Mvar to 13.2650Mvar indicating a 10.72% reduction in the network for power loss using the proposed method respectively and Figure 8 depicts the graphical representation of the real and reactive system losses of Kaduna Town 1 before and after compensation for the Table 7. Table 8 represent the total voltage deviation of the network. Since the smaller the deviation of bus voltage from the nominal voltage, the better the voltage condition of the system. Consequently, the result shows voltage profile at the affected buses has improved after compensation due to the optimal placement of capacitor banks at appropriate buses.

Table 7: Losses before/after compensation

SYSTEM LOSSES			
Before Compensation		**After Compensation**	
MW	**MVAr**	**MW**	**MVAr**
25.8380	14.8570	21.9230	13.2650

Table 8: Total Voltage Deviation for Kaduna Town 1

TVD	
Before Compensation	**After Compensation**
0.0652	0.0019

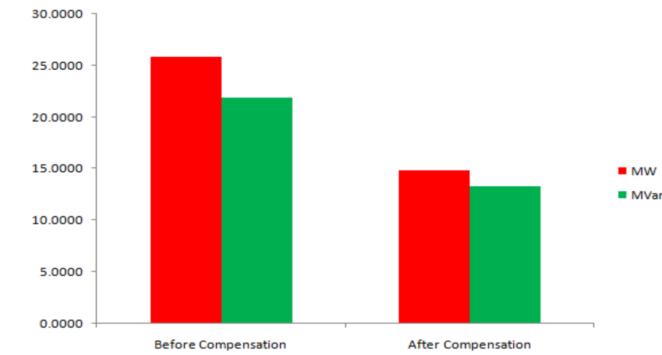

Figure 8: System losses of Kaduna Town 1 before and after compensation

Table 9: Comparison between the proposed method (GA) and that of Musa(2019).

	Proposed Method		**Musa (2019)**
Network	**KTTS**	**IEEE 30-bus**	**IEEE 33-bus**
Algorithm	**Genetic Algorithm (GA)**		**Ant Lion Algorithm (ALOA)**
Methodology	**Capacitor placement**		**Distributed Generation placement**
Real Power loss reduction	15.15%	24.09%	44.1234%
Reactive Power loss reduction	10.72%	22.43%	-
Voltage Deviation Index	97.085%	86.53%	36.133%
Voltage Stability Index	-		-14.516%

From the study of the Table 9, it can be seen that, although the ALOA presented a better real power loss reduction by optimal placement of DGs, the GA also presented a better voltage improvement with the capacitor placement. Furthermore, the proposed method also carried out loss reduction on the reactive power.

4. Summary of Findings

The research aim and objectives has been achieved, the summary of this research results are as follows;The standard IEEE 30-bus system when validated with the proposed method has a real power loss reduction of 17.5280MW before compensation and 13.3050MW after compensation indicating 24.09% of real power loss reduction. The reactive power loss reduction before compensation is 68.8880MVar and 53.43330MVar after compensation indicating 22.43% of reactive power loss reduction respectively.

i - The standard IEEE 30-bus system has a total voltage deviation of 0.0245 and 0.0033 before/after compensation indicating better voltage condition in the network.

ii - The performance index result of the IEEE 30-bus system shows that outage of line 1 was the most severe case while outage of line 41 was the least. This indicate that, the system parameters will go beyond their permissible limits.

iii - The Kaduna Town 1 Transmission Station has a real power loss reduction of 25.8380MW before compensation and 21.9230MW after compensation, indicating 15.15% of real power loss reduction. And the reactive power loss reduction of 14.8570MVar before compensation and 13.2650MVar after compensation, indicating a 10.72% of reactive power loss reduction in the network.

iv - The Kaduna Town 1 Transmission Station has a total voltage deviation of 0.0652 before compensation and 0.0019 after compensation indicating better voltage condition in the network. Since the TVD after compensation is small.

v - The performance index result of Kaduna Town 1 Transmission Station shows that outage of line 23 was the most severe case while outage of line 3 was the least which implies that, the system parameters will go beyond their permissible limits.

The result shows voltage profile at the affected buses has been improved after compensation due to the optimal placement of capacitor banks at appropriate buses.

5. Conclusion

This research work presented a proposed losses minimization of power system network of Kaduna Town one (1) Transmission Station (KTTS) using Genetic Algorithm (GA). The N-R algorithm was used to determine the load flow analysis of the network. While the performance index measured the deviation of power system variables like bus voltages and power flows from its rated value, it is also used to evaluate the relative stability of a contingency.

The GA algorithm optimization technique was used to determine the optimal placement and size of capacitor banks at appropriate buses. GA calculation are minimal because it has least number of populations (iterations). GA is the popular strategy use to optimize non-linear systems with a large number of variables. It works with codimg of parameter set not the parameters them selve. It also uses probabilistic transition rules not deterministic rules.

The proposed method was validated on IEEE 30-bus system and results obtained are as follows: The standard IEEE 30-bus system has a power loss reduction 17.5280MW to 13.3050MW indicating 24.09% and reactive power loss reduction from 68.8880MVar to 53.43300MVar indicating 22.43% is associated with the network respectively. The standard IEEE 30-bus system has a total voltage deviation of 0.0245 before compensation and 0.0033 after compensation indicating better voltage condition in the network. Since the smaller the deviation of bus voltage from the nominal voltage, the better the voltage condition of the system. The performance index result shows that outage of line 1 was the most severe case while outage of line 41 was the least. The indices with higher values shows a severe case which has the highest potential to make the system parameters go beyond their permissible limits.

The proposed method was applied to Kaduna Town 1 Transmission Station(KTTS) in Kaduna State, Nigeria. The result obtained were as follows: The result shows a loss reduction in real power from 25.8380MW to 21.9230MW indicating a 15.15% and reactive power loss from 14.8570Mvar to 13.2650Mvar indicating a 10.72% power loss reduction in the network. The Kaduna Town 1 has a total voltage deviation of 0.0652 and 0.0019 before/after compensation indicating better voltage condition in the network. Since the smaller the deviation of bus voltage from the nominal voltage, the better the voltage condition of the system. The result shows voltage profile at the affected buses has improved after compensation due to the optimal placement of capacitor banks at appropriate buses. From the performance index of the KTTS, the result shows that outage of line 23 was the most severe case while outage of line 3 was the least. The indices with higher values shows a severe case which has the highest potential to make the system parameters go beyond their permissible limits. Going by the following, the research aim and objectives has been met.

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Appendix I: Active power flow of Kaduna Town 1 due to line outages of Lines 1-10

L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**
104.6090	105.7431	106.7202	108.9712	106.6089	105.9546	105.7211	106.8630	106.1789	106.6079
61.8920	63.0261	64.0032	66.2542	63.8919	63.2376	63.0041	64.1460	63.4619	63.8909
-267.7080	-266.5739	-265.5968	-263.3458	-265.7081	-266.3624	-266.5959	-265.4540	-266.1381	-265.7091
36.1160	37.2501	38.2272	40.4782	38.1159	37.4616	37.2281	38.3700	37.6859	38.1149
19.2860	20.4201	21.3972	23.6482	21.2859	20.6316	20.3981	21.5400	20.8559	21.2849
5.5370	6.6711	7.6482	9.8992	7.5369	6.8826	6.6491	7.7910	7.1069	7.5359
8.4850	9.6191	10.5962	12.8472	10.4849	9.8306	9.5971	10.7390	10.0549	10.4839
5.0280	6.1621	7.1392	9.3902	7.0279	6.3736	6.1401	7.2820	6.5979	7.0269
5.0190	6.1531	7.1302	9.3812	7.0189	6.3646	6.1311	7.2730	6.5889	7.0179
24.7320	25.8661	26.8432	29.0942	26.7319	26.0776	25.8441	26.9860	26.3019	26.7309
12.1690	13.3031	14.2802	16.5312	14.1689	13.5146	13.2811	14.4230	13.7389	14.1679
-86.3680	-85.2339	-84.2568	-82.0058	-84.3681	-85.0224	-85.2559	-84.1140	-84.7981	-84.3691
4.7150	5.8491	6.8262	9.0772	6.7149	6.0606	5.8271	6.9690	6.2849	6.7139
4.5280	5.6621	6.6392	8.8902	6.5279	5.8736	5.6401	6.7820	6.0979	6.5269
4.5200	5.6541	6.6312	8.8822	6.5199	5.8656	5.6321	6.7740	6.0899	6.5189
4.0190	5.1531	6.1302	8.3812	6.0189	5.3646	5.1311	6.2730	5.5889	6.0179
2.0060	3.1401	4.1172	6.3682	4.0059	3.3516	3.1181	4.2600	3.5759	4.0049
2.0040	3.1381	4.1152	6.3662	4.0039	3.3496	3.1161	4.2580	3.5739	4.0029
2.0030	3.1371	4.1142	6.3652	4.0029	3.3486	3.1151	4.2570	3.5729	4.0019
35.7660	36.9001	37.8772	40.1282	37.7659	37.1116	36.8781	38.0200	37.3359	37.7649
16.8040	17.9381	18.9152	21.1662	18.8039	18.1496	17.9161	19.0580	18.3739	18.8029
1.5010	2.6351	3.6122	5.8632	3.5009	2.8466	2.6131	3.7550	3.0709	3.4999
1.5010	2.6351	3.6122	5.8632	3.5009	2.8466	2.6131	3.7550	3.0709	3.4999
9.1410	10.2751	11.2522	13.5032	11.1409	10.4866	10.2531	11.3950	10.7109	11.1399
6.0130	7.1471	8.1242	10.3752	8.0129	7.3586	7.1251	8.2670	7.5829	8.0119

Appendix II: Active power flow of Kaduna Town 1 due to line outages of Lines 11-20

L11	**L12**	**L13**	**L14**	**L15**	**L16**	**L17**	**L18**	**L19**	**L20**
105.6211	111.0901	113.4817	104.4969	103.4559	107.9754	106.0557	108.9132	107.8390	112.3116
62.9041	68.3731	70.7647	61.7799	60.7389	65.2584	63.3387	66.1962	65.1220	69.5946
-266.6959	-261.2269	-258.8353	-267.8201	-268.8611	-264.3416	-266.2613	-263.4038	-264.4780	-260.0054
37.1281	42.5971	44.9887	36.0039	34.9629	39.4824	37.5627	40.4202	39.3460	43.8186
20.2981	25.7671	28.1587	19.1739	18.1329	22.6524	20.7327	23.5902	22.5160	26.9886
6.5491	12.0181	14.4097	5.4249	4.3839	8.9034	6.9837	9.8412	8.7670	13.2396
9.4971	14.9661	17.3577	8.3729	7.3319	11.8514	9.9317	12.7892	11.7150	16.1876
6.0401	11.5091	13.9007	4.9159	3.8749	8.3944	6.4747	9.3322	8.2580	12.7306
6.0311	11.5001	13.8917	4.9069	3.8659	8.3854	6.4657	9.3232	8.2490	12.7216
25.7441	31.2131	33.6047	24.6199	23.5789	28.0984	26.1787	29.0362	27.9620	32.4346
13.1811	18.6501	21.0417	12.0569	11.0159	15.5354	13.6157	16.4732	15.3990	19.8716
-85.3559	-79.8869	-77.4953	-86.4801	-87.5211	-83.0016	-84.9213	-82.0638	-83.1380	-78.6654
5.7271	11.1961	13.5877	4.6029	3.5619	8.0814	6.1617	9.0192	7.9450	12.4176
5.5401	11.0091	13.4007	4.4159	3.3749	7.8944	5.9747	8.8322	7.7580	12.2306
5.5321	11.0011	13.3927	4.4079	3.3669	7.8864	5.9667	8.8242	7.7500	12.2226
5.0311	10.5001	12.8917	3.9069	2.8659	7.3854	5.4657	8.3232	7.2490	11.7216
3.0181	8.4871	10.8787	1.8939	0.8529	5.3724	3.4527	6.3102	5.2360	9.7086
3.0161	8.4851	10.8767	1.8919	0.8509	5.3704	3.4507	6.3082	5.2340	9.7066
3.0151	8.4841	10.8757	1.8909	0.8499	5.3694	3.4497	6.3072	5.2330	9.7056
36.7781	42.2471	44.6387	35.6539	34.6129	39.1324	37.2127	40.0702	38.9960	43.4686
17.8161	23.2851	25.6767	16.6919	15.6509	20.1704	18.2507	21.1082	20.0340	24.5066
2.5131	7.9821	10.3737	1.3889	0.3479	4.8674	2.9477	5.8052	4.7310	9.2036
2.5131	7.9821	10.3737	1.3889	0.3479	4.8674	2.9477	5.8052	4.7310	9.2036
10.1531	15.6221	18.0137	9.0289	7.9879	12.5074	10.5877	13.4452	12.3710	16.8436
7.0251	12.4941	14.8857	5.9009	4.8599	9.3794	7.4597	10.3172	9.2430	13.7156

Appendix III: Active power flow of Kaduna Town 1 due to line outages of Lines 21-25

L21	**L22**	**L23**	**L24**	**L25**
113.4399	111.7532	115.5949	108.6199	105.4958
70.7229	69.0362	72.8779	65.9029	62.7788
-258.8771	-260.5638	-256.7221	-263.6971	-266.8212
44.9469	43.2602	47.1019	40.1269	37.0028
28.1169	26.4302	30.2719	23.2969	20.1728
14.3679	12.6812	16.5229	9.5479	6.4238
17.3159	15.6292	19.4709	12.4959	9.3718
13.8589	12.1722	16.0139	9.0389	5.9148
13.8499	12.1632	16.0049	9.0299	5.9058
33.5629	31.8762	35.7179	28.7429	25.6188
20.9999	19.3132	23.1549	16.1799	13.0558
-77.5371	-79.2238	-75.3821	-82.3571	-85.4812
13.5459	11.8592	15.7009	8.7259	5.6018

13.3589	11.6722	15.5139	8.5389	5.4148
13.3509	11.6642	15.5059	8.5309	5.4068
12.8499	11.1632	15.0049	8.0299	4.9058
10.8369	9.1502	12.9919	6.0169	2.8928
10.8349	9.1482	12.9899	6.0149	2.8908
10.8339	9.1472	12.9889	6.0139	2.8898
44.5969	42.9102	46.7519	39.7769	36.6528
25.6349	23.9482	27.7899	20.8149	17.6908
10.3319	8.6452	12.4869	5.5119	2.3878
10.3319	8.6452	12.4869	5.5119	2.3878
17.9719	16.2852	20.1269	13.1519	10.0278
14.8439	13.1572	16.9989	10.0239	6.8998

Appendix IV: Voltage Magnitudes of Kaduna Town 1 due to line outages of Lines 1-10

Bus No.	Voltage Magnitude (pu)									
	L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9834	1.0044	0.9944	0.9934	1.0054	0.9935	0.9974	0.9934	1.0054	0.9994
3	0.9674	0.9884	0.9784	0.9774	0.9894	0.9775	0.9814	0.9774	0.9894	0.9834
4	0.9460	0.9670	0.9570	0.9560	0.9680	0.9561	0.9600	0.9560	0.9680	0.9620
5	0.9383	0.9593	0.9493	0.9483	0.9603	0.9484	0.9523	0.9483	0.9603	0.9543
6	0.9324	0.9534	0.9434	0.9424	0.9544	0.9425	0.9464	0.9424	0.9544	0.9484
7	0.8813	0.9023	0.8923	0.8913	0.9033	0.8914	0.8953	0.8913	0.9033	0.8973
8	0.9371	0.9581	0.9481	0.9471	0.9591	0.9472	0.9511	0.9471	0.9591	0.9531
9	0.9246	0.9456	0.9356	0.9346	0.9466	0.9347	0.9386	0.9346	0.9466	0.9406
10	0.9462	0.9672	0.9572	0.9562	0.9682	0.9563	0.9602	0.9562	0.9682	0.9622
11	0.9413	0.9623	0.9523	0.9513	0.9633	0.9514	0.9553	0.9513	0.9633	0.9573
12	0.9608	0.9818	0.9718	0.9708	0.9828	0.9709	0.9748	0.9708	0.9828	0.9768
13	0.9795	1.0005	0.9905	0.9895	1.0015	0.9896	0.9935	0.9895	1.0015	0.9955
14	0.9402	0.9612	0.9512	0.9502	0.9622	0.9503	0.9542	0.9502	0.9622	0.9562
15	0.9362	0.9572	0.9472	0.9462	0.9582	0.9463	0.9502	0.9462	0.9582	0.9522
16	1.0455	1.0665	1.0565	1.0555	1.0675	1.0556	1.0595	1.0555	1.0675	1.0615
17	1.0423	1.0633	1.0533	1.0523	1.0643	1.0524	1.0563	1.0523	1.0643	1.0583
18	1.0413	1.0623	1.0523	1.0513	1.0633	1.0514	1.0553	1.0513	1.0633	1.0573
19	1.0408	1.0618	1.0518	1.0508	1.0628	1.0509	1.0548	1.0508	1.0628	1.0568
20	1.0351	1.0561	1.0461	1.0451	1.0571	1.0452	1.0491	1.0451	1.0571	1.0511
21	1.0324	1.0534	1.0434	1.0424	1.0544	1.0425	1.0464	1.0424	1.0544	1.0484
22	1.0238	1.0448	1.0348	1.0338	1.0458	1.0339	1.0378	1.0338	1.0458	1.0398
23	1.0234	1.0444	1.0344	1.0334	1.0454	1.0335	1.0374	1.0334	1.0454	1.0394
24	1.0219	1.0429	1.0329	1.0319	1.0439	1.0320	1.0359	1.0319	1.0439	1.0379
25	0.9612	0.9822	0.9722	0.9712	0.9832	0.9713	0.9752	0.9712	0.9832	0.9772
26	1.0161	1.0371	1.0271	1.0261	1.0381	1.0262	1.0301	1.0261	1.0381	1.0321

Appendix V: Voltage Magnitudes of Kaduna Town 1 due to line outages of Lines 11-20

Bus No.	Voltage Magnitude (pu)									
	L11	**L12**	**L13**	**L14**	**L15**	**L16**	**L17**	**L18**	**L19**	**L20**
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.0034	0.9844	0.9935	0.9934	0.9854	0.9824	0.9724	0.9835	0.9814	0.9935
3	0.9874	0.9684	0.9775	0.9774	0.9694	0.9664	0.9564	0.9675	0.9654	0.9775
4	0.9660	0.9470	0.9561	0.9560	0.9480	0.9450	0.9350	0.9461	0.9440	0.9561
5	0.9583	0.9393	0.9484	0.9483	0.9403	0.9373	0.9273	0.9384	0.9363	0.9484
6	0.9524	0.9334	0.9425	0.9424	0.9344	0.9314	0.9214	0.9325	0.9304	0.9425
7	0.9013	0.8823	0.8914	0.8913	0.8833	0.8803	0.8703	0.8814	0.8793	0.8914
8	0.9571	0.9381	0.9472	0.9471	0.9391	0.9361	0.9261	0.9372	0.9351	0.9472

9	0.9446	0.9256	0.9347	0.9346	0.9266	0.9236	0.9136	0.9247	0.9226	0.9347
10	0.9662	0.9472	0.9563	0.9562	0.9482	0.9452	0.9352	0.9463	0.9442	0.9563
11	0.9613	0.9423	0.9514	0.9513	0.9433	0.9403	0.9303	0.9414	0.9393	0.9514
12	0.9808	0.9618	0.9709	0.9708	0.9628	0.9598	0.9498	0.9609	0.9588	0.9709
13	0.9995	0.9805	0.9896	0.9895	0.9815	0.9785	0.9685	0.9796	0.9775	0.9896
14	0.9602	0.9412	0.9503	0.9502	0.9422	0.9392	0.9292	0.9403	0.9382	0.9503
15	0.9562	0.9372	0.9463	0.9462	0.9382	0.9352	0.9252	0.9363	0.9342	0.9463
16	1.0655	1.0465	1.0556	1.0555	1.0475	1.0445	1.0345	1.0456	1.0435	1.0556
17	1.0623	1.0433	1.0524	1.0523	1.0443	1.0413	1.0313	1.0424	1.0403	1.0524
18	1.0613	1.0423	1.0514	1.0513	1.0433	1.0403	1.0303	1.0414	1.0393	1.0514
19	1.0608	1.0418	1.0509	1.0508	1.0428	1.0398	1.0298	1.0409	1.0388	1.0509
20	1.0551	1.0361	1.0452	1.0451	1.0371	1.0341	1.0241	1.0352	1.0331	1.0452
21	1.0524	1.0334	1.0425	1.0424	1.0344	1.0314	1.0214	1.0325	1.0304	1.0425
22	1.0438	1.0248	1.0339	1.0338	1.0258	1.0228	1.0128	1.0239	1.0218	1.0339
23	1.0434	1.0244	1.0335	1.0334	1.0254	1.0224	1.0124	1.0235	1.0214	1.0335
24	1.0419	1.0229	1.0320	1.0319	1.0239	1.0209	1.0109	1.0220	1.0199	1.0320
25	0.9812	0.9622	0.9713	0.9712	0.9632	0.9602	0.9502	0.9613	0.9592	0.9713
26	1.0361	1.0171	1.0262	1.0261	1.0181	1.0151	1.0051	1.0162	1.0141	1.0262

Appendix VI: Voltage Magnitude of Kaduna Town 1 due to line outages of Line 21-25

Bus No.	**Voltage Magnitude (pu)**				
	L21	**L22**	**L23**	**L24**	**L25**
1	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9813	0.9946	1.0064	0.9974	0.9954
3	0.9653	0.9786	0.9904	0.9814	0.9794
4	0.9439	0.9572	0.9690	0.9600	0.9580
5	0.9362	0.9495	0.9613	0.9523	0.9503
6	0.9303	0.9436	0.9554	0.9464	0.9444
7	0.8792	0.8925	0.9043	0.8953	0.8933
8	0.9350	0.9483	0.9601	0.9511	0.9491
9	0.9225	0.9358	0.9476	0.9386	0.9366
10	0.9441	0.9574	0.9692	0.9602	0.9582
11	0.9392	0.9525	0.9643	0.9553	0.9533
12	0.9587	0.9720	0.9838	0.9748	0.9728
13	0.9774	0.9907	1.0025	0.9935	0.9915
14	0.9381	0.9514	0.9632	0.9542	0.9522
15	0.9341	0.9474	0.9592	0.9502	0.9482
16	1.0434	1.0567	1.0685	1.0595	1.0575
17	1.0402	1.0535	1.0653	1.0563	1.0543
18	1.0392	1.0525	1.0643	1.0553	1.0533
19	1.0387	1.0520	1.0638	1.0548	1.0528
20	1.0330	1.0463	1.0581	1.0491	1.0471
21	1.0303	1.0436	1.0554	1.0464	1.0444
22	1.0217	1.0350	1.0468	1.0378	1.0358
23	1.0213	1.0346	1.0464	1.0374	1.0354
24	1.0198	1.0331	1.0449	1.0359	1.0339
25	0.9591	0.9724	0.9842	0.9752	0.9732
26	1.0140	1.0273	1.0391	1.0301	1.0281