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Power loss minimization and voltage profile improvement on electrical power distribution systems using optimal capacitor placement and sizing

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Abstract
Distribution system operators are having difficulties maintaining a correct voltage profile across its network. As the standard of living of its customers increases, suppressed loads tend to come up and this in turn would require and increased demand in power supply. The increase in power demand and high load density at distribution ends have been seen to have key consequences of increasing the power loss and reducing the voltage profile in power systems, which seriously jeopardizes the ability of radial distribution networks to faithfully account for the power received from transmission stations. This work is aimed at improving the power quality that gets to the end users. Shunt capacitors have been suggested to be a suitable solution to this problem as they supply the reactive power needed for compensation. As a result, the optimum placement and size of these shunt capacitors have received a great deal of attention. Despite its efficacy, meta-heuristic algorithms are seldom utilized in the Nigerian RDS (radial distribution system), since most published research instead uses analytical and numerical programming methods. As a result, this research explains how to use a Hybrid Solution (HS) of Particle Swarm Optimization (PSO and GA) to identify and size shunt capacitors for real-time power loss reduction on an 11-kV distribution feeder. The backward-forward sweep load flow method with Loss Sensitivity Factor (LSF) is used to identify suitable buses for shunt capacitor installation, and the HS algorithm is then used to estimate the optimum size. This method was discovered to decrease the system's real power loss by 54.88% while raising the minimum bus voltage magnitude to the acceptable limit and thus improving the minimum system Voltage Stability Index (VSI). Based on these findings, the suggested technique is regarded as a viable way for placement and determining the size of shunt capacitors in a real-world Radial Distribution System. The numerical results shows that the approach has a high capability of improving the voltage profile of the distribution network, leading to an improved system power quality, minimize the system losses, correct the power factor, and maximize the net savings. The numerical results were gotten by using MATLAB package.

Keywords: hybrid solution (HS), particle swarm optimization (PSO), loss sensitivity factor (LSF), voltage stability index (VSI)

1. Introduction

Delivering Optimum Power Quality to end consumers has been a major challenge due to the high presence of reactive power on Radial Distribution Networks (RDN). It is associated with numerous technical and inevitable operational problems such as high voltage drops, low voltage stability, bad quality and reliability of power delivered to the end consumers, and, as the main challenge, high real power losses (Adeleke *et al*., 2020). It has been discovered that the largest portion of real losses amongst the three tiers of the Electricity Value Chain of Nigeria, which are generation, transmission, and distribution section, occurs at the distribution level and this has been discovered to constitute about 13% of the total power generation. These aforementioned problems have negative impact on the economic and effectiveness of the overall power system. Hence, many efforts have been made by researchers to significantly reduce the losses in the distribution networks. The capacitor placement is among the efforts used to mitigate this problem.

The reactive load of a distribution system varies continuously, utilizing an average of the reactive load to determine fixed capacitor sizes and placements is impractical (Abdelaziz *et al*., 2016) [1]. Even this number is subject to change as the load rises. When constructing a power distribution system, it is very difficult to supply continuous electricity within the Permitted Distribution Constraints (PDS) and this is due to varying load demands which is subject to several conditions. Reactive power can be further explained with the Pint of Beer analogy. Consider the figure below:

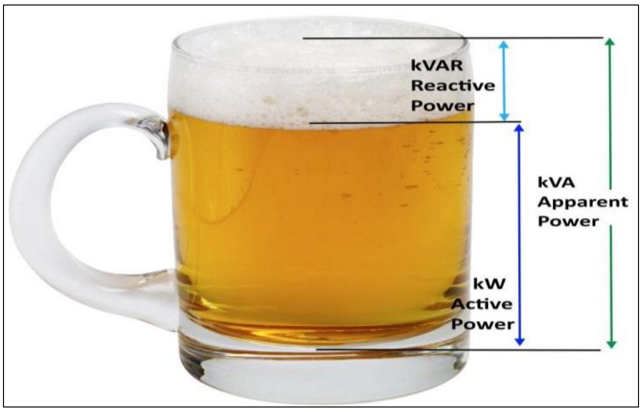

Fig 1: Reactive Power Explained using the Pint of Beer Analogy (Schneider Electric, Energy Management, 2018) [11]

The mug capacity represents apparent power (kVA). The beer itself represents active power (kW). The foam represents reactive power (kVAR). Power factor is the ratio between the active power (kW) and the apparent power (kVA). Using the beer analogy, we obtain the power factor by dividing the beer by the mug capacity, and it's clear, you're getting less beer than you're paying for with all that foam taking up space. Who wants to pay for foam? (Schneider Electric, Energy Management, 2018) [11]. It is clear from the above explanation that electric consumers end up paying more for useless power instead of useful power. In Nigeria today, the grid code states clearly the system parameters that must be abided when transmitting electrical energy from one electricity value chain to another. These parameters include the voltage limits, the real power losses and the system frequency. The three tiers of the value chain GENCOs, TCN and the DISCOs must abide to these parameters and this can only be achieved by effectively balancing the load demand and the available generation.

Because electrical distribution networks suffer from significant power losses and a poor voltage profile to maximize customer satisfaction, excellent power quality should be anticipated on such systems. This, however, is far from the case. Many mitigating techniques have been suggested during the last few decades. The easiest method to compensate for reactive power is to place the right size of shunt capacitor in the best feasible position. A shunt capacitor helps balance power transmission issues such as low voltage regulation, poor reliability. It has several functions that changes from time to time depending on its application. However, it is useful in stabilizing power to avoid a lag between the voltage and current within a power system (Chint Global, 2021) [14]. There is Power loss when changing a system's voltage profile (Muthukumar & Jayalalitha, 2016) [7] with properly designed shunt capacitors, active and reactive power losses are reduced, system power factor increases, system voltage profile is maintained within permissible limits, and feeder and transformer capacity is freed up. (Razak *et al.*, 2020) [15]. When shunt capacitors are positioned and constructed improperly, voltages may exceed acceptable limits and an undesired decrease in power factor below unity occurs, hence system vulnerability will be increased (Uchendu, 2020) [16]. Reduced power system losses enhance the system's economic and technical performance. According to (Sudhakara Reddy & Damodar Reddy, 2017) [12], distribution losses account for the bulk of power system losses. The amount of reactive power used in distribution networks directly affects power system losses. The use of reactive power is widespread, resulting in a substantial decrease in operating voltage throughout a distribution feeder (Sharma *et al*., 2017) [13].

Switched capacitors aids in mitigating the negative consequences of utilizing extremely inductive loads. Switched capacitors also improves the distribution voltage profile and frees up system power transmission capacity in addition to reducing power system losses thus causing more power to be transmitted across the route length of the radial distribution system. (Salimon *et al*., 2020) [9]. The problem of Optimal Capacitor Placement and Sizing (OCPS) has made several researchers look for the best possible way of optimizing the number of capacitors and sizes in a radial distribution system. This has given life to several methods of optimization techniques that aims at solving the problem. Some work has concentrated on hybrid methodologies whereby two or more heuristic methods are combined to solve the problem and this also boosts the results.

2. Literature review

Losses on distribution feeders have always been a major issue when transmitting electrical energy from one point to another. Due to the nature of our consumer loads, we tend to experience high level voltage dip especially when we have substandard network. Due to these issues, our consumers tend to experience a decreased voltage level which cannot be used to power any of their appliances and this in turn creates both technical and commercial losses. Due to these constraints, Researchers have tried to find the best possible solution to this issue and it has been discovered that the placement of shunt capacitors on distribution system can effectively reduce the losses on the line and thereby improve the voltage profile to the statutory limits.

Assumptions like having a radial feeder, ensuring that the feeder is of uniform voltage level to avoid complexities and also the capacitors are of discrete sizes are considered. Some methods consider capacitors that fixed in nature and some consider capacitors that a variable in nature.

(Salama *et al*., 1995) performed the research using fuzzy set theory. He determined the optimal capacitor location by differentiating the saving equations with respect to how far the capacitors can be placed and then equating it to zero and in determining the capacitor size, he implemented the same technique. The results did not give the exact bus number on which the capacitors should be installed. He experimented on some buses until the optimal bus was gotten. (Chen *et al*., 2021) on the other hand used a two-stage procedure to identify the optimal locations and sizes of capacitors in the distribution system. In the first stage approach, he used the loss sensitivity analysis using two-loss sensitivity indices (LSIs) to select the most candidate capacitors' locations. In the second stage, the Ant Colony Optimization Algorithm (ACOA) was used to find the optimal locations and sizes of capacitors considering the minimization of energy loss and capacitor costs as objective functions while system constraints like the voltage limits and the active and reactive power limits were incorporated. The ant colony optimization algorithm gave a better result as the objective function was minimized drastically. Increasing the distribution size might introduce more complexities that would require a more advanced heuristic approach like the PSO algorithm. (Damodar Reddy *et al*., 2017) [12] Also extended Chen work by using the Ant Lion Optimization process to perform the research but this time he used another approach to determine the Load Flow on the Distributed Network. The approach is modelled based on the hunting mechanism of ant lions and it involves five steps which are; Ants walking randomly, Setting the trap structure, trapping in the ant lion's pit, sliding of the ants inside the trap and consuming the prey and remodifying the trap (Wikiversity, 2019) [17]. The backward-forward sweep approach was used to determine the load flow on the radial distribution system. The best solution of each phase was determined by saving the fittest one and naming it the elite. Although the solution was compared to other well-known methods and gave better result but it didn't specify whether the results would be better at peak periods as it is known that these losses occur more at the peak periods.

(Naji *et al*., 2019) [8] obtained the solution using the Particle Swarm Optimization (PSO) and Open-Source Distribution System Simulator (OPENDDS) approaches. The OPENDDS was used in determining the load flow on the distribution network while the PSO Algorithm was used to determine the optimal capacitor placement and location. Although the Distribution Generator placements gave an improved result in terms of loss reduction but the loss reduction was just about 0.8% when only the capacitors were placed which is not significant enough compared to other results. The DGs are the ones that actually mitigated the losses to a very large extent which also emphasis on the superiority of using DGs to minimize power flow losses. (Majid *et al*., 2020) implemented this research using the Success Rate Group Search Algorithm (SRGSO). He did the same thing with (Naji *et al*., 2019) [8] but this time a different algorithm was used. The loss reduction using only the capacitors was about 21% which is more significant than (Naji *et al*., 2019) [8] and this shows that the SRGSO approach gives better result. The method will require a high investment cost as so many assumptions had to be in place so as to achieve this. (Satish *et al*., 2018) improved on the work of both (Naji *et al*., 2019) [8] and (Majid *et al*., 2020) by using a newly developed algorithm called the Firefly Algorithm (FFA) and the Back-Tracking Search Algorithm (BSA). The FFA copies the mode in which the fireflies interact using their flashing lights. The attractiveness of a firefly is directly proportional to its light intensity which solely depends on the objective function. For minimization problems, the solution with the smallest functional values will be assigned the highest intensity of light (Waqar. A. Khan *et al*. 2016) [18] The limitation with this algorithm is that it takes a long time before the solution converges and easily gets trapped in local optimum for multimodal problems (Waqar. A. Khan *et al*. 2016) [18]. BSA is one of the latest populations based evolutionary algorithms. It is typically based on an iterative process which aims to minimize the objective function. It consists of five evolutionary mechanisms: initialization, selection-I, mutation, crossover, and selection-II (K. Guney *et al*., 2014) [4], Despite its shortfalls, the results from the FFA algorithm gave better loss reduction and voltage profile improvement than that of the BSA algorithm. The number of capacitors required from the FFA algorithm was lesser than that of the BSA algorithm showing its superiority over other metaheuristic methods.

(Hossein *et al*., 2016), Cut down on power losses, improve voltage profiles, and increase transmission line capacity by using the best-capable shunt capacitors. Transfer lines may function to their maximum potential when using shunt capacitors, which cut down on power loss and enhance voltage profiles (EE, Reference book, 2003). This research introduced a novel method for organizing capacitors in radial distribution networks called Improved Particle Swarm Optimization (IPSO). This method combines a shuffled Frog-leaping algorithm (SFLA) with a particle swarm algorithm (PSO). The optimum placement and size of the capacitor are determined by combining the power loss costs with the capacitor installation costs under certain restrictions, such as a minimum and maximum voltage. On a 34-bus system, the simulation was then tested against current design and implementation techniques. The proposed method lowers overall costs while also reducing power losses.

The Mine Blast Algorithm (MBA) was used by (Sahar *et al*.) to analyze this problem. To finalize the capacitor bus candidate designs, two stages of finalization were employed. LSF (Loss Sensitivity Factors) first locates such buses, whereas MBA determines the best capacitor values and locations. Two of the study's goals are to save money by decreasing losses and to improve the voltage profile and this was greatly achieved, However, while utilizing it to solve the Capacitor placement and Sizing problem, the expenses of adding capacitors were not taken into account in its model. A hybrid optimization approach, including the Scalp Swarm Optimization Algorithm (SSOA) and techniques for loss sensitivity, was used by (Milovanovic *et al*., 2021) [6] to address Optimal Capacitor Placement problems. A 34.98% reduction in active power losses was achieved using this technique on IEEE 69, IEEE 85, and the East Delta Network (EDN) bus systems. (Othman, 2016) used a combination of voltage stability indices and LSFS to identify the best placement locations, and the Improved Bacterial Foraging Optimization Technique (IBFOA), was then used to determine the optimal Capacitor size. These techniques are also very expensive to achieve but gives better results. Optimal Capacitor Placement and Sizing Problem was solved using FET and real coded GA by (Milovanovic *et al*., 2021) [6] to maximize net savings and improve the voltage stability of RDSs. Improved system stability and power factor (pf) was achieved by cutting down on power loss.

3. Methodology

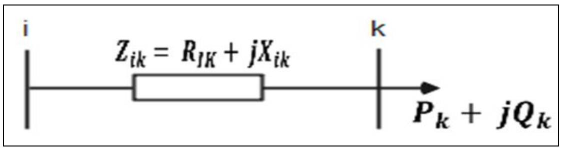

Fig 2: Equivalent circuit of a radial distribution system

The above diagram depicts a transmission line 'l' that is connected to buses i and 'k'. According to the active power loss standard for this line, $I_l^2 R_{ik}$, which can be given by:

$$P_{ik-loss} = \frac{\left(P_k^2 + Q_k^2\right) R_{ik}}{\left(V_k\right)^2} \quad (1)$$

This line's reactive power loss may be calculated as follows:

$$Q_{ik-loss} = \frac{\left(P_k^2 + Q_k^2\right) X_{ik}}{\left(V_k\right)^2} \quad (2)$$

The following formulae may be used to calculate the LSF:

$$\frac{\partial P_{ik-loss}}{\partial Q_k} = \frac{2Q_k * R_{ik}}{\left(V_k\right)^2} \quad (3)$$

$$\frac{\partial Q_{ik-loss}}{\partial Q_k} = \frac{2Q_k * X_{ik}}{\left(V_k\right)^2} \quad (4)$$

Based on the base case load flow, the appropriate values for all transmission lines are presented. Following that, normalized voltages are determined by dividing the original voltages by 11kV (Base Value). The base KVA was also chosen to be 500kVA as this was the highest load value. This is to have a normalized value by converting the data to per-unit values. The lower and upper limits of the voltages were taken as 0.95 and 1.05 p.u respectively and if the voltage value on any bus exceeds these limits, they may be candidates for compensating devices.
This amount of complex power that is put into the bus n is given as:

$$S_{L,n} = P_{L,n} + jQ_{L,n} = V_n I_{L,n}{}^* \quad (5)$$

The load current on any of the n buses is calculated as follows:

$$I_{L,n} = \left(\frac{P_{L,n} + jQ_{L,n}}{V_n}\right)^* = \frac{P_{L,n} - jQ_{L,n}}{V_n^*} \quad (6)$$

Using a forward sweep over the line, the voltages at the receiving end may be predicted by deducting the line section drop from the line section's transmitting end voltages. To update the voltage on each bus, Kirchhoff's voltage law (KVL) is used. Iteration starts at the root node and continues through all subsequent branches down to the leaf node. If branch b is connected to both the transmitting and receiving ends A and B, the voltage at the receiving end B at the ith iteration may be computed as shown below.

$$V_B^{(t)} = V_A^{(t)} - Z_b \times I_b^{(t)} \quad (7)$$

$$V_A^{(t)} = V_B^{(t)} + Z_b \times I_b^{(t)} \quad (8)$$

where $V_B^{(t)}$, $V_A^{(t)}$ the voltages at the other end of the wire, respectively.
The Kirchhoff current law (KCL) is then applied to each branch during the backward sweep to calculate the current at the iteration. Begin with a branch connected to the last node to determine the total distance from that node to the substation.

$$I_b^{(t)} = -I_A^{(t)} - \sum_{x=1}^{X}\left(\frac{S_x}{V_A^{(t)}}\right)^* \quad (9)$$

$$S_B^{(t)} = \left(V_A^{(t)} + Z_b + I_b^{(t)}\right)\left(I_b^{(t)}\right)^* \quad (10)$$

where $I_A^{(t)}$ how much current shunt components pump onto bus A, while $I_b^{(t)}$ ith iteration's quantity of branch current flow. Bus A has a total of X branches linked to it, with Sx representing the sending end complex power on branch x. $V_A^{(t)}$ bus A's voltage, Z_b impedance of the branches and $S_B^{(t)}$ is the branch b apparent power flow.
The source node must be linked to all load buses. The following equation may be written in terms of graph theory and applied to trees.

$$N_{br} = N_{no} - 1 \quad (11)$$

Where N_{br} is the number of branches and N_{no} is the number of nodes.
When a balanced radial distribution system with B branches is used, the total actual power loss may be expressed as

$$P_{LT} = \sum_{k=1}^{B} I_k^2 . R_k \quad (12)$$

The Genetic Algorithm is a derivative free population based stochastic optimization method inspired by the concept of natural selection and evolutionary process. The development of the method is largely credited to the work of (Holland, 1975) [3] and (Goldberg, 1989) [2] as they were the pioneers of the concept. Algorithms based on modeling natural evolution systems have been successfully applied to a broad variety of real-world problems. Crossover and Mutation methods are employed during the recombination process to exchange chromosomes, resulting in offspring having genetic information from both parents. Natural selection determines evolution, with the best surviving. To that aim, a fitness-based selection technique is used to determine the solutions that will be passed down to the next generation. GA has also been proposed as a possible method for finding the best capacitor bank size and switching schedule. The probabilistic roulette wheel technique has many phases, which are as follows:

Step 1: Calculate eval(w_i), i.e., the fitness value of each chromosome w_i.

Step 2: Calculate the fitness of the total population, F, using

$$F = \sum_{j=1}^{popsize} eval\left(w_j\right) \quad (13)$$

Where population size is the total number of populations.

Step 3: Calculate the probability of selection for each chromosome, P (i), as

$$P(j)=\frac{eval(w_j)}{F} \quad (14)$$

Step 4: Calculate the cumulative probability for each chromosome, Q (i),

$$Q(i)=\sum_{j=1}^{i}P_j, \quad (15)$$

Step 5: Generate a random number, v, between one and zero.

Step 6: If v < Q(1), P(1) is selected. Otherwise, chromosome i, which satisfies

$2 \le i \le popsize,\ Q(i-1) \le v \le Q(i)$, is selected (16)

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behaviour of bird flocking or fish schooling [40]. PSO and GA has some similarities in the sense that it also initializes with a population of random solutions and then searches for the optimum solution by constantly updating the generations. But Unlike GA, PSO doesn't have the Crossover and Mutation operators. In PSO each particle is updated following two 'best' values. The first value is the Pbest which is the best solution that has been archived so far while the global best known as the Gbest represents the best value obtained by any of the particles so far [40]. PSO also determine particle speed and location. updated with

$$V_i(k+1) = w(k).\ V_i(k) + c_1r_1\left(P^i_{best}(k) - pi(k)\right) + c_2r_2\left(g_{best}(k) - p_i(k)\right) \quad (17)$$

$$p_i(k+1) = p_i(k) + V_i(k+1), \quad (18)$$

where $p_i(k)$ is the current position of each particle and $p_i(k + 1)$ is the next position of each particle. $P^i_{best}(k)$ denotes the best position of each particle. $g_{best}(k)$ is the best position in the whole population. $V_i(k)$ and $V_i(k+1)$ are the previous and next velocities of each particle, respectively. c_1r_1 and c_2r_2 are the constant coefficients. w(k) is a constant coefficient, in which its value decreases with a constant rate in each iteration.

4. Result

The numerical results can be presented in three cases;

- Measured cases which is before the reactive power compensation.
- Measured case which is after the Hybrid algorithm has been applied to solve the capacitor placement and size problem.
- Comparative analysis with other heuristic algorithm (PSO and Differential Evolution) tested on the same input data from the BFS.

The bas voltage of the network is set at 11kV and bus 1 is made the slack bus. The voltage limits are set at 0.95 and 1.01p.u. Any bus voltage found beyond those limits will be considered as candidate buses for compensation.

The Algorithm was applied to an 11kv Feeder located in Lagos state which had 15 buses. The values of the Line and bus data is given below;

Table 1: Line Data

S/N	From Bus	To Bus	L(km)	R(Ω)	X(Ω)
1	Gen bus	1	0.67	0.1942	0.325
2	1	2	0.87	0.971	1.75
3	2	3	0.07	0.1942	0.325
4	3	4	0.01	0.1942	0.325
5	4	5	0.04	0.2752	0.353
6	5	6	0.05	0.1942	0.325
7	6	7	0.04	0.2752	0.353
8	7	8	0.02	0.1942	0.325
9	8	9	0.05	0.3884	0.65
10	2	10	0.02	0.1942	0.325
11	10	11	0.03	0.3884	0.65
12	11	12	0.14	0.3884	0.65
13	12	13	0.11	0.3884	0.65
14	13	14	0.08	0.3884	0.65
15	14	15	0.01	0.36833	0.2906

To accommodate for power loss and increasing voltage stability, capacitor banks were initially installed in a 15-bus network. Buses 4, 11, and 15 are good candidates for capacitor installation, according to PLI's / BFS results. As a result, the Hybrid algorithm (PSO&GA) was then applied to determine the optimal capacitor bank sizes. The same input data was then tested on two other algorithms, the Particle Swarm Optimization (PSO) & Differential Evolution (DE) and a performance comparison was done between the three methods. The Hybrid Solution Indicated that using 750-kVAR capacitor bank on bus 4 gave a better result. The Voltage Stability Index (VSI) also reached improved value of 0.9615. The HS method resulted in a 54.88% reduction in overall real power losses. PSO and DE both gave reduction of 47.22% and 47.86% respectively. The VSI rose significantly when the capacitors were put using the HS method. The algorithm was implemented on the MATLAB package and the results for the voltage and real power losses improvement are given below:

Table 2: Voltage Improvement after running the algorithm

Bus no.	Voltage (v)	Per unit value
1	11000	1.00
2	10950	1.00
3	10939	0.99
4	10670	0.97
5	10929	0.99
6	10943	0.99
7	10937	0.99
8	10942	0.99
9	10947	1.00
10	10945	1.00
11	10935	0.99
12	10927	0.99
13	10922	0.99
14	10931	0.99
15	10929	0.99

Table 3: Real Power Loss Reduction on each bus after Compensation

Bus no.	Real power losses (watts)
1	8.1
2	31.2
3	8
4	393.5
5	69.2
6	133.8
7	69.1
8	86.8
9	121.9
10	48.2
11	804.2
12	8.1
13	7.1
14	70.3
15	3870.2
Total	5729.7

From the results shown above, it is clear that the voltage profile on the candidate buses improved and also the losses on those buses actually reduced. The total losses also reduced leading to an improved power flow on the feeder. A graphical representation of the results before and after compensation is given below:

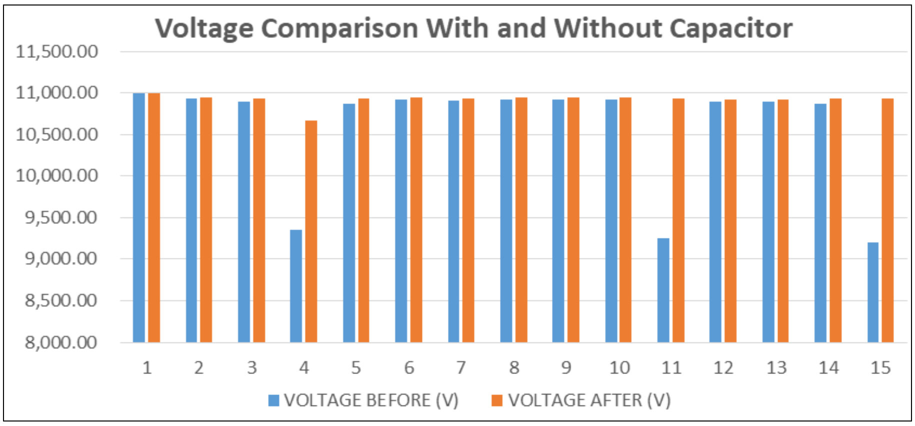

Fig 3: Voltage drop on the buses before and after compensation

From the fig.3 above it can be seen that the voltage profile improved on the candidate buses after the algorithm was performed. Below shows the power loss reduction as well:

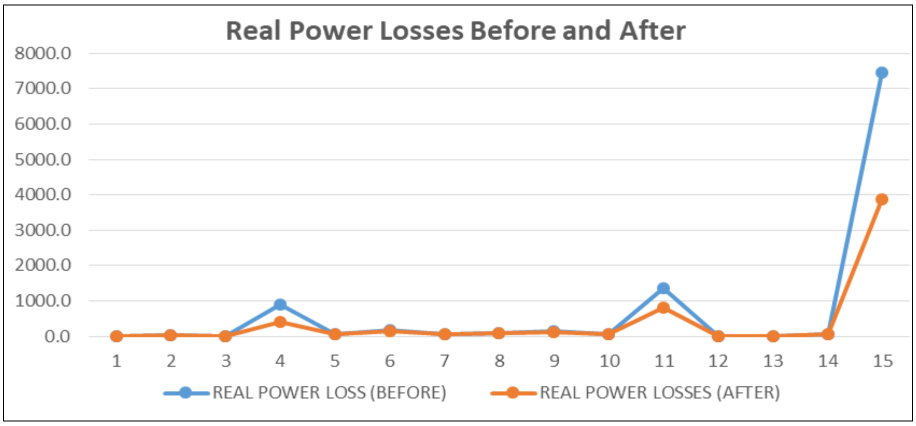

Fig 4: Real power losses before and after compensation

From the results of the algorithm shown in fig.4, the recommended sizes for the capacitor banks are given below:

Table 4: Capacitor Sizes Recommended by the Hybrid Algorithm

Bus Number	4
Capacity (kVAR)	750

To validate the appropriateness of the proposed method, the size of capacitor banks is also calculated using PSO and DE algorithms on the same input data. The results are then compared with the Hybrid solution and the table below gives the details:

Table 5: Results for the Hybrid Algorithm Compared with the Results for PSO and DE

HS		DE		PSO		Initial	
5.9912496		5.2248762		5.1550074		10.917	Loss Reduced (kW)
54.88		47.86		47.22		-	Loss reduction%
4.9257504		5.6921238		5.7619926			New Losses (kW)
0.9014		0.7981		0.8029		0.6127	VSI
750	4	436	3	880	6	-	Bus number and Size (kVAR)
		485	6	296	11	-	
		185	11	-	-	-	

The table above indicates that the proposed method outperforms the other two alternatives. In terms of loss reduction, the HS method beat Particle Swarm Optimization by 7.66% while it also outperforms the Differential Evolution by 7.02% respectively, thus proving its superiority.

5. Conclusion

An 11-kV Lagos feeder with 15 buses is used as a case study to determine the best location and size of shunt capacitor for the Radial Distribution Network when a Hybrid Solution of PSO and GA is employed to minimize actual power loss and the improve the voltage profile of candidate buses. The method is divided into two stages: first, we used BFS in conjunction with the LSF to identify the optimum locations, and then HS to determine how large a shunt capacitor you'll need. This research provided an objective function which was to minimize the real power losses and also the size of capacitor banks to be installed on the candidate buses The BFS in conjunction with the LSF also helped to restrict the search area for the algorithm when choosing where to place shunt capacitors, resulting in a substantial overall reduction in the system's actual power loss. Convergence times were shortened in part due to the careful selection of optimal values for the algorithm's main parameters. Simulations indicate that using this technique reduces actual power loss while improving the voltage profile of the system. The Solution recommended that capacitor size of 750kVAR should be installed on Bus number 4. Power loss was reduced by 54.88%, and also the voltage profile on the candidate buses was also improved considering the voltage constraints in the optimization equations. In this study, rather than analytical or numerical programming, a meta-heuristic method was used to discover how to optimally position and size shunt capacitors for a particular voltage profile on the Nigerian RDS's power supply. One of the most difficult parts of our research was locating distribution data. It was discovered that by doing this research, a knowledge gap on the employment of effective AI methods to address the joint optimum placement and size of shunt capacitors was successfully filled, reducing actual power loss on the Nigerian distribution Network.

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