



Development of an Optimized Network Reconfiguration with Capacitor Placement for Power Loss Minimization in Radial Distribution System

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ABSTRACT

This research work presents an improved solution to solve the problem of power loss in the distribution system by using Network Reconfiguration (NR) with Capacitor placement. The proposed solution has been determined by using Plant Growth Simulation Algorithm (PGSA) for Network Reconfiguration (NR) and Capacitor placement. Loss sensitivity factor was employed to determine the candidate locations of the buses where Capacitors have been placed while (PGSA) was used to determine the size of the Capacitor banks. Various case studies were presented to see the impact on the test system, in terms of power loss reduction and Voltage profile improvement. The developed approach was applied to a 33-bus test system and simulated by using MATLAB 2016a. The Load Flow in the Radial system was carried out by Forward / Backward Sweep Algorithm to determine the bus voltages, Branch currents and Power losses. Four different cases were chosen for this Thesis. to minimize power loss and voltage profile improvement. They are NR only, Capacitor placement only, Capacitor after NR, Capacitor and then NR. For Case 1, NR only was considered while the initial locations of the Tie switches are 33, 34, 35, 36, and 37. The Active power loss and the Minimum voltage obtained are 136.75kW and 0.9384p.u respectively. Therefore, the new locations of the Tie switches are 8, 10, 13, 31 and 37 branches. The percentage active power loss was found to be 32.54%. For Case 2, Capacitor only was considered. Different sizes of capacitors 450kVar, 300kVar, 300kVar, 150kVar and 600kVar were placed at each bus location 8, 13, 19, 27, and 30 buses respectively. After the location and size of each capacitor are determined by Loss Sensitivity Factor (LSF) and Plant Growth Simulation Algorithm (PGSA), the Active power loss and minimum voltage with Capacitor placement only are 103.02kW and 0.9258pu respectively. The percentage reduction in active power loss obtained was 49.79%. Capacitor placement after NR was considered for the third case. After reconfiguration, the same capacitor sizes used in Case 2 were placed at each bus location. The active power loss and minimum voltage are 87.827kW and 0.9422pu respectively. The percentage reduction in active power loss yielded 56.65%. Lastly in Case 4, Capacitor placement and NR was carried out with the same capacitor sizes followed by reconfiguration. The active power loss and minimum voltage are 90.03kW and 0.9413pu respectively. The percentage reduction in active power loss yielded 55.58%. This has shown that a

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combination of Capacitor placement after NR yielded a better reduction in active power loss and Voltage profile improvement when compared to other cases. The results obtained using PGSA Algorithm was validated on IEEE 33-bus system via comparison with hybrid Salp-swarm algorithm and Genetic algorithm approach. The proposed PGSA has yielded 1.08% reduction in active power loss compared to SSA-GA. The combination of Network Reconfiguration with the Capacitor placement has yielded positive impact on total power losses reduction as well as Voltage profile improvement when compared to other case studies in which only NR or Capacitor was implemented.

INTRODUCTION

An electrical Distribution System (DS) is the last stage of electrical energy supply chain in power system operation whereby electricity is being distributed to individual customers through a radial network (Abubakar *et al.*, 2019). During power distribution, the system experiences a lot of technical losses; primarily power loss (Anil *et al.*, 2010). Power losses significantly affect the quantity and quality of power delivery to the consumers most especially in a large-scale distribution network where power loss accounted for 70% of the total losses in the system. Different actions have been taken to improve the efficiency of the distribution network (Babaita *et al.*, 2022; Ibrahim *et al.*, 2023). One of the methods of improving the performance of the distribution system apart of Network Reconfiguration (NR) is the placement of capacitor. Network reconfiguration is performed by the opening of sectionalizing (normally closed) and closing tie (normally open) switches of the network.

There is an increasing trend to automate the distribution system. It has become possible to install distribution operating center to monitor and control the distribution networks as well as reconfiguring the distribution system to minimize the active power losses and balance loads under normal operating conditions (Iliyasu *et al.*, 2022). The operation and control of distribution system is carried out by two types of switches namely as sectionalizing switches (normally close) and tie switches (normally open). The distribution system has to run in a way that it must be radial, operating cost should be minimum as much as possible, all loads are serving and the bus voltages should be in the permissible limit (Sarfraz *et al.*, 2018).

Another approach of reducing the power losses is by installing capacitor bank in the distribution system. The objective of this approach is to inject certain amount of reactive power into the distribution system, to improve the feeder voltage profile, power factor, and to reduce power losses and cost (Musa *et al.*, 2018). Similar to the NR approach, there are many techniques that had been proposed by researchers to solve the capacitor problem. These techniques can be categorized into four which are analytical, numerical, heuristic and artificial intelligent. (Amanet *et al.*, 2014) had reviewed in details regarding capacitor placement conducted by previous researchers. In this work, the power loss with optimal capacitor placement will be minimized using Plant Growth Simulation Algorithm (PGSA) to determine the size of the candidate buses which Loss Sensitivity Factor (LSF) will be used to determine the locations of the candidate buses.

METHODOLOGY

Problem Formulation for Power Loss Reduction in Network Reconfiguration (NR)

The objective function of the network reconfiguration to minimize the power loss in the system is given below.

$$\text{Minimize } F = \text{Min}(P_{T,LOSS} + \lambda_v Scv + \lambda_i Sci) \quad (1)$$

Where, $P_{T,LOSS}$ is the total active power loss in the system, λ_v and λ_i parameters are the penalty constants of the voltage and current respectively, Sci is the squared sum of the violated current constraints, Scv is the squared sum of the violated voltage constraints. Moreover, the penalty constants are determined as follows:

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(i) Constant λ_i is given a value of '0', if the associated current (voltage) constraint is not violated and λ_v given a value of '0', if the associated voltage constraint is not violated.
 (ii) λ_i and λ_v are given a significant value if the associated current and voltage constraint are violated respectively.

These considerations make the objective function to move away from the unfeasible solutions. The voltage magnitude at each node must be maintained within specified limits. The current in each branch must satisfy the branch current carrying capacity. These constraints are expressed as follows:

$$|V_{min}| \leq |V_i| \leq |V_{max}| \tag{2}$$

$$|I_j| \leq |I_{jmax}| \tag{3}$$

Where,
 $|V_i|$ is the voltage magnitude of node i ,
 $|V_{min}|$ and $|V_{max}|$ are the minimum and maximum node voltage magnitude limits,
 $|I_j|$ and $|I_{jmax}|$ are the magnitude and maximum current limit of branch j , respectively

Steps to implement Plant Growth Simulation Algorithm for Network Reconfiguration

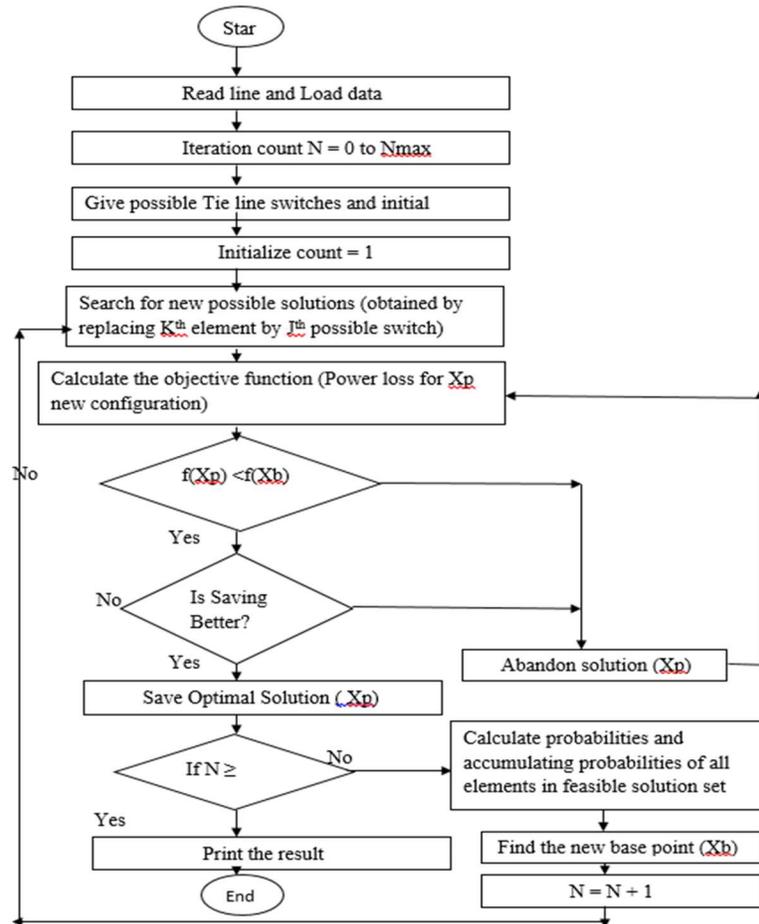


Figure 1: Flow Chart for Network Reconfiguration using PGSA

Problem formulation for loss reduction with optimal location and sizing of Capacitor in a radial distribution system

The objective of capacitor placement in the distribution system is to minimize the annual cost of the system, subjected to certain operating constraints and load pattern. For simplicity, the operation and maintenance cost of the capacitor placed in the distribution system is not taken into consideration. The three-phase system is considered as balanced and loads are assumed as time invariant (Srinivasa and Narasimham, 2008). Mathematically, the objective function of the problem is described as:

$$\text{Min } F = \text{min}(\text{COST}) \quad (4)$$

Where, COST is the objective function which includes the cost of power loss and the capacitor placement. The voltage magnitude at each bus must be maintained within its limits and is expressed as:

$$|V_{\min}| \leq |V_i| \leq |V_{\max}| \quad (5)$$

Where,

$|V_i|$ is the voltage magnitude of bus i , V_{\min} and V_{\max} are bus minimum and maximum voltage limits respectively.

$$P_{i+1} = P_i - P_{Li+1} - R_{i,i+1} * \frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (6)$$

$$Q_{i+1} = Q_i - Q_{Li+1} - X_{i,i+1} * \frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (7)$$

$$|V_{i+1}|^2 = |V_i|^2 - 2(R_{i,i+1} * P_i + X_{i,i+1} * Q_i) + (R_{i,i+1}^2 + X_{i,i+1}^2) * \frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (8)$$

Where,

P_i and Q_i are the real and reactive powers flowing out of bus i , P_{Li} and Q_{Li} are the real and reactive load powers at bus i ,

The resistance and reactance of the line section between buses i and $i+1$ are denoted by $R_{i,i+1}$ and $X_{i,i+1}$.

The power loss of the line section connecting buses i and $i+1$ computed as:

$$P_{Loss(i,i+1)} = R_{i,i+1} * \frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (9)$$

The total power loss of the feeder P_{TLoss} may then be determined by summing up the losses of all line sections of the feeder, which is given as:

$$P_{TLoss} = \sum_{i=0}^{n-1} P_{Loss(i,i+1)} \quad (10)$$

Considering the practical capacitors, there exists a finite number of standard sizes which are integer multiples of the smallest size Q_c^0 . Besides, the cost per kVAr varies from one size to another.

In general, capacitors of larger size have lower unit prices. The available capacitor size is usually limited to

$$Q_{max}^c = L Q_c^0 \quad (11)$$

Where L is an integer, therefore, for each installation location, there are L capacitor sizes

$\{ Q_c^0, 2 Q_c^0, 3 Q_c^0, \dots, L Q_c^0 \}$ available,

Given the annual installation cost for each compensated bus, the total cost due to capacitor placement and power loss change is written as

$$\text{COST} = K_p P_{TLoss} + \sum_{i=1}^n (K_{cf} + K_{ic} Q_{ic}) \quad (12)$$

Where n is number of candidate locations for capacitor placement, K_p is the equivalent annual cost per unit of power loss in \$/(kW-year); K_{cf} is the fixed cost for the capacitor placement. The constant K_{ic} is the annual capacitor installation cost, and, $i=1, 2, \dots, n$ are the indices of the buses selected for compensation. The bus reactive compensation power is limited to

$$Q_{ic} \leq \sum_{i=1}^n Q_{li} \quad (13)$$

Where Q_{ic} and Q_{li} are the reactive power compensated at bus i and the reactive load power at bus i , respectively.

Loss Sensitivity Factor for Capacitor placement

The candidate nodes for the placement of capacitors are determined using the loss sensitivity factors. The estimation of these candidate nodes basically helps in reduction of the search space for the optimization procedure. Consider a distribution line with impedance $R + jX$ and a load of $P_{eff} + jQ_{eff}$ are connected between 'p' and 'q' buses as given below:

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Active power loss in the K^{th} line is given by $[I_k^2] * [R_k^2]$ which can be expressed as,

$$P_{line\ loss}[q] = \frac{P_{eff}^2[q] + Q_{eff}^2[q] R[k]}{(V[q])^2} \quad (14)$$

$$Q_{line\ loss}[q] = \frac{P_{eff}^2[q] + Q_{eff}^2[q] X[k]}{(V[q])^2} \quad (15)$$

$P_{eff}[q]$ = Total effective active power supplied beyond the node 'q'

$Q_{eff}[q]$ = Total effective reactive power supplied beyond the node 'q'.

Then, both the Loss Sensitivity Factors can be obtained as shown below:

$$\alpha_i = \frac{\partial P_{line\ loss}}{\partial Q_{eff}} = \frac{2 * Q_{eff}[q] * R[k]}{(V[q])^2} \quad (16)$$

$$\alpha_i = \frac{\partial P_{line\ loss}}{\partial Q_{eff}} = \frac{2 * Q_{eff}[q] * X[k]}{(V[q])^2} \quad (17)$$

The Loss Sensitivity Factors α_i calculated from the base case load flows and the values are arranged in descending order for all the lines of the given system. A vector bus position 'bpos[i]' is used to store the respective 'end' buses of the lines arranged in descending order of the values). The descending order of α_i element of bpos[i] vector will decide the sequence in which the buses are to be considered for compensation. This sequence is purely governed by the α_i and hence the proposed 'Loss Sensitive Coefficient' factors become very powerful and useful in capacitor allocation or Placement. At these buses of 'bpos[i]' vector, normalized voltage magnitudes are calculated by considering the base case voltage magnitudes given by

$$(\text{Norm}[i] = V[i] / 0.95).$$

Now for the buses whose norm[i] value is less than 1.01 are considered as the candidate buses requiring the Capacitor Placement. These candidate buses are stored in 'rank bus' vector. It is worth note that the 'Loss Sensitivity factors' decide the sequence in which buses are to be

considered for compensation placement and the 'norm[i]' decides whether the buses needs Q - Compensation or not. If the voltage at a bus in the sequence list is healthy (i.e., norm[i] > 1.01) such bus needs no compensation and that bus will not be listed in the 'rank bus' vector. The 'rank bus' vector offers the information about the possible potential or candidate buses for capacitor placement. The sizing of Capacitors at buses listed in the 'rank bus' vector is done by using Plant Growth Simulation Algorithm.

RESULTS AND DISCUSSIONS

This section presents the results obtained and the discussion of the results. Power flow and optimal reconfiguration with Capacitor placement are simulated on MATLAB 2016a and the results are validated using standard IEEE 33 bus radial distribution network for power loss minimization in a radial distribution system. Four cases are considered here:

Case I: Only Network reconfiguration (NR)

Case II: Capacitor placement only

Case III: Capacitor placement after NR

Case IV: Capacitor placement and then NR

Analysis of Simulation

The IEEE 33 bus radial distribution system has 5 tie-switches and 32 sectionalizing switches. The system has total load of 3.715 MW and 2.30 MVAR. The base case power loss is 202.70 kW and tie switches are 33, 34, 35, 36, 37.

Case 1 Only Network Configuration

For the Case 1, only NR was considered for power loss and voltage profile improvement and the results is shown below.

The optimal locations of the normally opened switches were found to be **8, 10, 13, 31** and **37** and there was **32.54%** reduction in active power loss when compared to the base case after

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NR when PGSA was implemented in the IEEE system. Thus, Figure 3 and Figure 4 show the result of the Voltage profile and Active power loss

for the base case and after reconfiguration for 100 numbers of iterations.

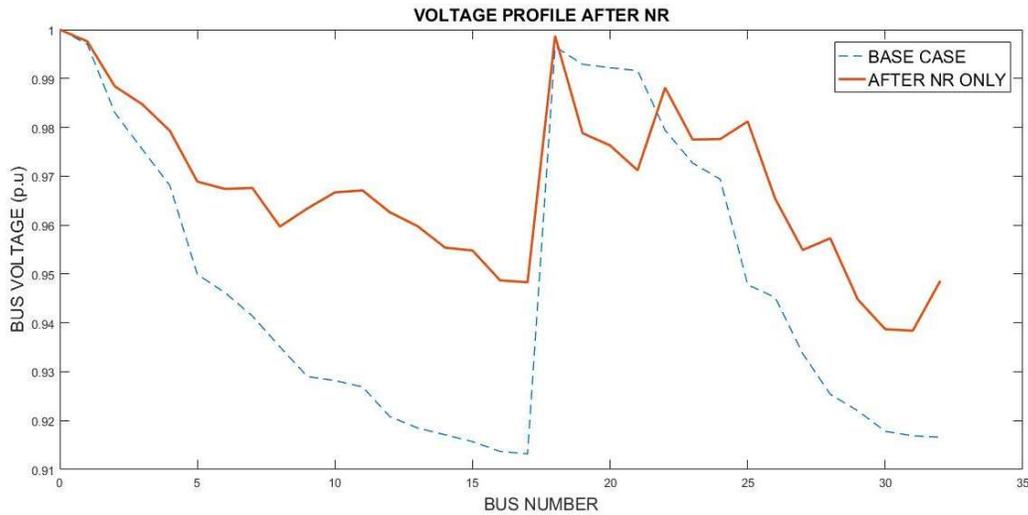
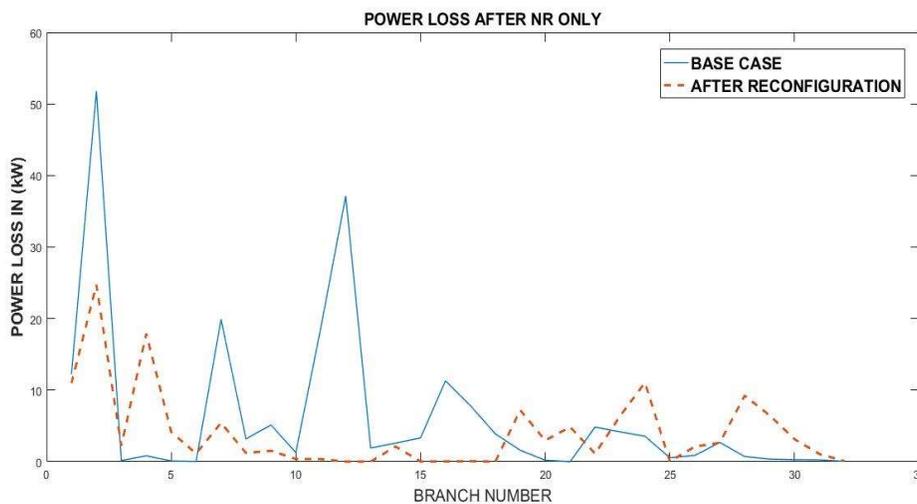


Figure 3: Voltage profile of 33bus system after Reconfiguration only

From Figure 4.1, the blue dotted and the red thick lines represent the bus voltages at base case and after reconfiguration respectively. The minimum voltage before reconfiguration (base

minimum voltage after reconfiguration was 0.9384 which occurred at bus 31. This shows an improvement in voltage profile after reconfiguration.



case) was found to be 0.9130 at bus 17 while the

Figure 4: Power Losses of 33 Bus Radial System after Reconfiguration Only

From the Figure 4, the blue thick and the red dotted lines indicate the active power loss at base case and after reconfiguration respectively. The sum of the power loss at each bus for the base case and after reconfiguration respectively is

202.70kW and 136.75kW. This shows that there was reduction in active power loss at each bus after reconfiguration as compared to the base case.

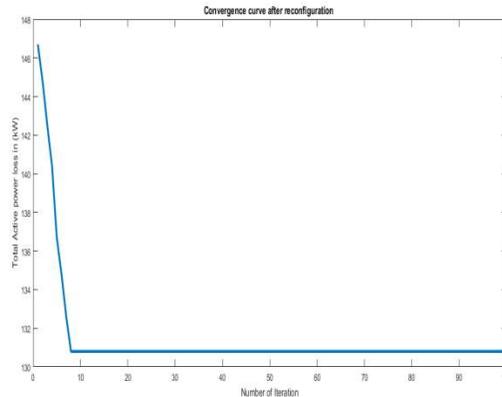


Figure 5: Convergence Characteristics of PGSA

Figure: 5 Convergence characteristics of 33 node radial distribution system after reconfiguration. It can be seen that the convergence occurred at the eighth (8th) iteration. This shows the fast convergence time of the Algorithm.

Case 2: Capacitor placement only

For the Case 2 scenario, placement of capacitor was considered only for active power loss reduction and voltage profile improvement. The active power loss and minimum voltage of the system with capacitor placement are 103.02kW and 0.9258p.u respectively. The rank bus vector of 33-bus system contains set of sequence of

buses given as {8, 13, 18, 19, 23, 24, 25, 27 and 30}. From the rank bus vector, the top five buses {8, 13, 19, 27 and 30} are selected as optimal candidate locations. The capacitor ratings of 450, 300, 300,150 and 600 kVAr are placed at the optimal candidate buses respectively.

After the PGSA was implemented in 33-bus system, the percentage active power loss obtained after capacitor placement only is 48.79%. The minimum voltage occurred at bus 16 which is **0.9258**. The Total Voltage Deviation (TVD) has also been minimized from base case **0.087p.u to 0.07422p.u**. Figure 6 and Figure 7 show the result of the Voltage profile and Active power loss for the Capacitor placement only.

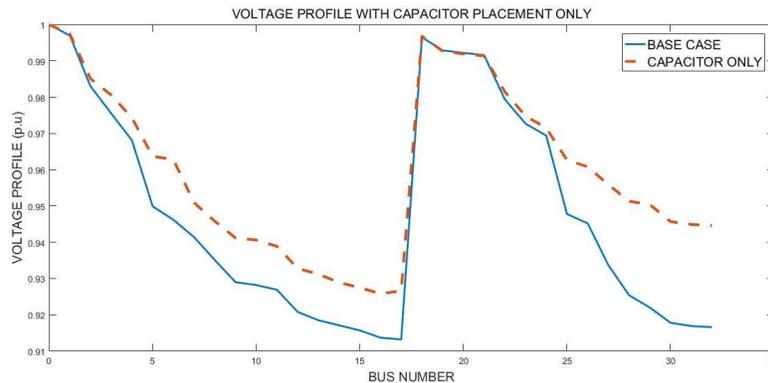


Figure 6: Voltage profile of 33 bus radial system for Capacitor placement only

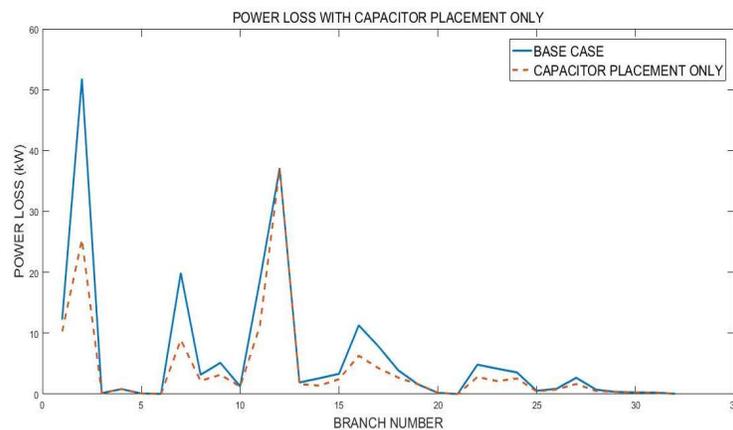


Figure 7: Active power loss of 33 bus radial system for Capacitor placements only

It was observed that, there was a reduction in active power losses when Capacitors were placed as compared to the Base case.

Case 3: Capacitor placement after NR

For the Case 3 scenario, placements of capacitors were considered after reconfiguration

for active power loss reduction and voltage profile improvement. The active power loss and minimum voltage of the system with capacitor placement after reconfiguration are 87.872kW and 0.9422p.u respectively. This is shown in Table 1.

Table 1: Optimum Capacitor placement after NR

Cases	Solution obtained			Min voltage (p.u)	TVD (p.u)	Ploss in(kW)
Base case	Capacitor size in Kvar	Capacitor locations	Tie switches	0.9130	0.087	202.70
Case III	450, 300, 300,150, 600	8, 13, 19, 27, 30	8, 13, 19, 27, 30	0.9422	0.0578	87.872

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As seen in Table 1 after the PGSA was implemented in 33-bus system, the percentage active power loss obtained with Capacitor placement after reconfiguration is 56.65%. The Minimum voltage has also been improved from base case (0.9130) to 0.9422. The Total Voltage Deviation (TVD) has also been minimized from base case (0.087p.u) to 0.0578p.u. This shows that optimal capacitor placement after reconfiguration yielded a better reduction of active power loss and improvement in voltage profile.

Case 4: Capacitor placement and then NR

For the Case 4 scenario, Capacitor placement and then reconfiguration was considered for active power loss reduction and voltage profile improvement. The active power loss and minimum voltage of the system with reconfiguration after Capacitor placement are 90.037kW and 0.9412p.u respectively.

Figure 8 and Figure 9 show the result of voltage profile and active power loss with Capacitor placement and then reconfiguration.

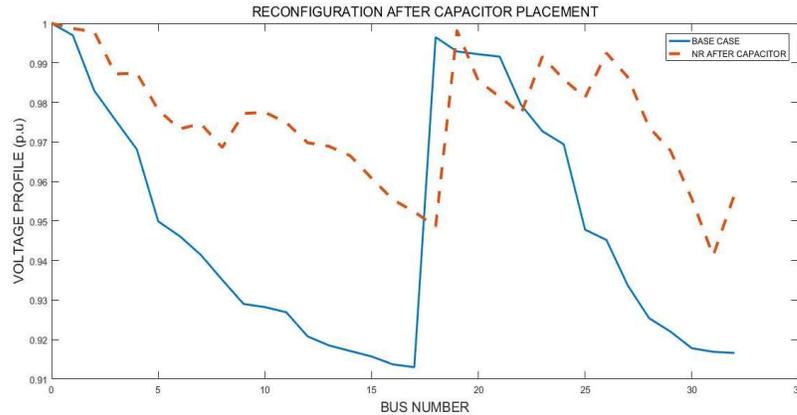


Figure 8: Voltage profiles of 33 bus systems with Capacitor placement and then NR

From Figure 8, the blue thick and the red dotted lines represent the Base case and Capacitor placement before reconfiguration respectively. The minimum voltages for the Base

case and NR after Capacitor placement are 0.9130p.u and 0.9413p.u respectively. This shows an improvement in voltage profile for reconfiguration after Capacitor placement.

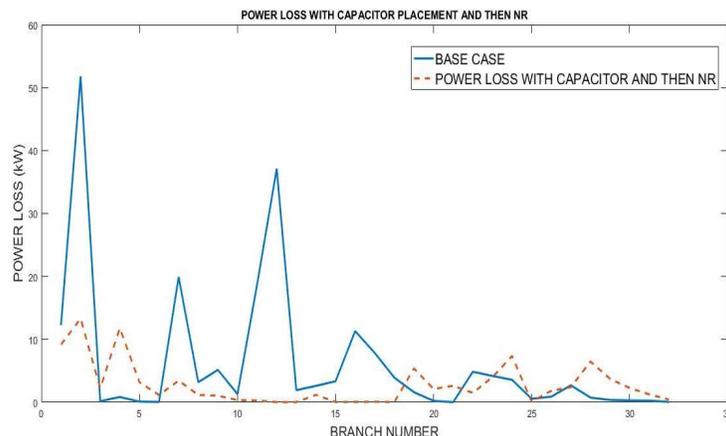


Figure 9: Active power loss of 33 bus system with Capacitor placement and then NR



Figure 9 indicates that the blue thick and the red dotted lines are active power losses for the Base case and NR after Capacitor placement. There

was a reduction in active power loss with NR after Capacitor placement when compared with the Base case.

Table 2: The simulation results obtained from the work of (Yodphet *et al.*, 2018) (SSA-GA) in a 33 bus system

Items	Initial configuration	Reconfiguration with capacitor Placement	
Tie switches	33, 34, 35, 36, 37	7, 9, 14, 32, 37	
The power loss (kW)	202.70	90.05	
Minimum voltage (p.u.)	0.9130 (Bus 18)	0.9410 (Bus 33)	
Maximum voltage (p.u.)	1.000 (Bus 1)	1.000 (Bus 1)	
The elapsed time (s)	-	81.72	
Bus number	Bus voltage (p.u)	Capacitor placed (kVAr)	Bus voltage (p.u)
1	1.000	-	1.000
2	0.997	-	0.998
3	0.983	-	0.991
4	0.975	-	0.987
5	0.968	-	0.985
6	0.950	300	0.979
7	0.946	-	0.978
8	0.941	-	0.974
9	0.935	300	0.972
10	0.929	-	0.976
11	0.928	-	0.976
12	0.927	300	0.977
13	0.921	-	0.974
14	0.919	-	0.973
15	0.917	-	0.966
16	0.916	-	0.965
17	0.914	-	0.962
18	0.913	-	0.963
19	0.997	-	0.996
20	0.993	-	0.985
21	0.992	-	0.982
22	0.992	-	0.980
23	0.979	300	0.988
24	0.973	-	0.983
25	0.969	300	0.981
26	0.948	-	0.978
27	0.945	-	0.976
28	0.934	-	0.971
29	0.926	-	0.968
30	0.922	600	0.966
31	0.918	300	0.964
32	0.917	-	0.964
33	0.917	-	0.961



Table 3: Comparison of Active power losses for Network Reconfiguration with Capacitor placement

Branch number	Ploss (kW) Before NR (Base Case)	Ploss(kW) After NR	Ploss (kW) with Capacitor placement only	Ploss (kW)After NR then Capacitor placement	Ploss (kW) After Capacitor placement then NR
1	12.2400	10.9600	10.2800	8.5800	9.1700
2	51.7900	24.7100	25.3600	13.2400	13.2800
3	0.1600	2.2300	0.1600	2.1800	2.2300
4	0.8300	17.9000	0.8300	11.6200	11.770
5	0.1000	4.1600	0.1000	3.7300	3.1800
6	0.0400	1.1400	0.0400	1.1200	1.1500
7	19.900	5.4300	8.9100	3.6700	3.4300
8	3.1800	1.2200	2.1700	1.1800	1.1600
9	5.1400	1.5300	3.1800	1.4600	1.0400
10	1.2900	0.3800	1.2300	0.3200	0.3300
11	18.700	0.3700	11.2000	0.2800	0.2700
12	37.2800	0.0130	37.1200	0.0120	0.1500
13	1.9100	0.0160	1.6500	0.0160	0.0180
14	2.6000	2.1300	1.4000	1.1500	1.1700
15	3.3300	0.0270	2.4500	0.0280	0.0340
16	12.300	0.0410	6.3000	0.0360	0.0450
17	7.8300	0.0720	4.2600	0.0680	0.0780
18	3.9000	0.0100	2.7000	0.0100	0.0300
19	1.5900	7.2000	1.6300	4.8000	5.3700
20	0.2100	2.9700	0.2200	1.9800	2.1000
21	0.0100	4.8500	0.0100	2.4700	2.6200
22	4.8400	1.1400	2.8100	1.1200	1.4800
23	4.1800	6.3600	2.1400	3.8800	3.9700
24	3.5600	11.0400	2.5600	7.1600	7.3400
25	0.5500	0.0520	0.4400	0.0320	0.0660
26	0.8800	2.1100	0.7700	1.8100	1.8200
27	2.6900	2.6500	1.6600	2.3500	2.3900
28	0.7300	9.2300	0.5200	6.2800	6.4700
29	0.3600	6.4800	0.3900	3.9400	3.7100
30	0.2800	3.1600	0.2600	2.1700	2.2600
31	0.2500	1.0700	0.2300	1.0800	1.2400
32	0.0500	0.1000	0.0400	0.1000	0.4200
Total	202.700	130.7510	133.0200	87.8720	90.037
Power Loss					



Table 4: Summary of the Power losses and Voltage profile for Network Reconfiguration and Capacitor placement

Items	Base case	NR only	Capacitor placement only	Capacitor placement after NR	NR after Capacitor placement
Tie switches	33,34,35,36,37	8, 10, 13,31,32	8, 10, 13, 31, 37	8, 10, 13, 31, 37	8, 10, 13, 31, 37
Capacitor sizes(kVAr)	7		450,300,300,150, 600	450,300,300,150, 600	450,300,300,150, 600
Ploss(kW)	202.70	136.75	133.020	87.8720	101.037
Vmin (p.u)	0.9130	0.9384	0.9258	0.9422	0.9412
Elapsed time (sec)		12.32	60.30	52.86	54.20
NODE NO.	V (p.u) with NR only	V (p.u) with Capacitor placement only	V (p.u) with Capacitor placement after NR	V (p.u) with Capacitor placement	Capacitor value Q in (kVAr)
0	1.0000	1.0000	1.0000	1.0000	0
1	0.9976	0.9974	0.9997	0.9987	0
2	0.9884	0.9851	0.9988	0.9979	0
3	0.9847	0.9806	0.9884	0.9872	0
4	0.9793	0.9743	0.9876	0.9874	0
5	0.9689	0.9637	0.9786	0.9781	0
6	0.9674	0.9628	0.9742	0.9733	0
7	0.9676	0.9509	0.9718	0.9746	0
8	0.9597	0.9458	0.9695	0.9686	450
9	0.9634	0.9412	0.9773	0.9772	0
10	0.9667	0.9406	0.9784	0.9775	0
11	0.9671	0.9389	0.9757	0.9749	0
12	0.9626	0.9328	0.9698	0.9689	0
13	0.9598	0.9312	0.9674	0.9665	300
14	0.9554	0.9289	0.9611	0.9608	0
15	0.9548	0.9275	0.9567	0.9554	0
16	0.9487	0.9258	0.9532	0.9523	0
17	0.9483	0.9266	0.9489	0.9486	0
18	0.9987	0.9968	0.9994	0.9982	0
19	0.9788	0.9927	0.9862	0.9855	300
20	0.9763	0.9919	0.9822	0.9814	0
21	0.9712	0.9914	0.9796	0.9771	0
22	0.9881	0.9815	0.9928	0.9916	0
23	0.9775	0.9748	0.9863	0.9858	0
24	0.9776	0.9715	0.9821	0.9813	0
25	0.9812	0.9627	0.9931	0.9925	0
26	0.9654	0.9608	0.9873	0.9864	0
27	0.9549	0.9559	0.9744	0.9737	150
28	0.9573	0.9513	0.9681	0.9678	0
29	0.9448	0.9504	0.9566	0.9556	0



30	0.9387	0.9457	0.9498	0.9473	600
31	0.9384	0.9449	0.9422	0.9413	0
32	0.9486	0.9446	0.9588	0.9587	0

Table 5: Comparison of the results obtained with the work of Daranpob et al 2018

Techniques	Tie Switches		Total Capacitor size in (kVAr)	Active power loss in (kW)	% Loss reduction	Min bus Voltage	
	Initial NR	NR with capacitor				Initial reconfiguration	NR with capacitor placement
SSA-GA	33, 34, 35, 36, 37	7, 9, 14, 32, 37	2400	90.05	55.57	0.913 (Bus 18)	0.9410 (Bus 33)
Proposed PGSA	33, 34, 35, 36, 37	8, 10, 13, 31, 37	1700	87.872	56.65	0.9258 (Bus 16)	0.9422 (Bus 31)

It is observed from the result obtained that the percentage active power losses for NR only, Capacitor only, Capacitor after NR and NR after Capacitor are 32.54%, 48.97%, 56.65% and 55.58% respectively. The percentage active power loss for reconfiguration only stands at 32.54%. This shows that capacitor placement after NR has the highest percentage of reducing active power loss as compared to other three cases.

Comparing the voltage profiles for the different cases, the minimum voltages for NR only, Capacitor only, Capacitor after NR, NR after capacitor are 0.9384p.u, 0.9258p.u, 0.9422p.u and 0.9412p.u respectively. Therefore, Capacitor placement after NR gave the highest voltage profile improvement as compared to other three Cases.

Based on the results obtained, the developed method of PGSA recorded a better reduction of power loss from 87.872kW as against 90.050kW obtained from the SSA – GA approach. The percentage power loss for the proposed PGSA Algorithm is 56.65% while that of the existing method of SSA-GA is 55.57%. The difference in percentage Active power loss reduction is 1.08% which shows that PGSA has slightly yielded better reduction in power loss.

CONCLUSION

This research proposed Optimal Network Reconfiguration with capacitor placement for power loss minimization in radial

distribution system. Network reconfiguration simply means restructuring the power lines which connect various buses in a power system. Restructuring of specific power lines leading to alternate system configurations. System reconfiguration can be accomplished by opening and closing of Tie and Sectionalizing switches into network. Capacitors were also introduced to further minimize power losses and improve voltage profile of the network. The combination of both NR and Capacitor has greater advantage of reducing active power loss, improving voltage profile, power factor of the distribution system. The loss sensitivity factor was employed to determine the candidate locations of the candidate's buses where capacitors were placed. Plant growth simulation algorithm (PGSA) was used to determine the Network Reconfiguration and size of capacitor placement. The proposed method was validated on IEEE 33 bus system and the implementation was carried out on MATLAB R2016a. Forward and Backward Algorithm Load Flow was used to determine the Active power losses, each bus voltage and Branch currents. The simulation results achieved by PGSA are compared with that of SSA- GA algorithms. It was found that the active power loss and convergence time obtained by PGSA are remarkably less than that of SSA-GA. Lower capacitor sizes have also been used for the minimization of active power loss and improvement of voltage profile. The combination of NR and Capacitor placement has yielded better minimization of power loss and

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voltage profile improvement as compared to only NR or Capacitor placement.

REFERENCES

- Abdulwahab, I., Faskari, S. A., Belgore, T. A., & Babaita, T. A. (2021). An Improved Hybrid Micro-Grid Load Frequency Control Scheme for an Autonomous System. *FUOYE Journal of Engineering and Technology*, 6(4).
- Abubakar, A. S., Olaniyan, A. A., Ibrahim, A., & Sulaiman, S. H. (2019). *An Improved Analytical Method For Optimal Sizing And Placement Of Power Electronic Based Distributed Generation Considering Harmonic Limits*. Paper presented at the 2019 IEEE PES/IAS PowerAfrica 122-127.
- Aman M. M, Jasmon G.B, Bakar AHA, Mokhlis H., Karimi M. (2014). Optimum shunt capacitor placement in distribution system, A review and comparative study, *Renewable and Sustainable Energy Review*, 30: 429-439.
- Anil & Niazi (2010). Minimal Loss Configuration for Large-Scale Radial Distribution Systems using Adaptive Genetic Algorithms. *16th National Power Systems Conference, Department of Electrical Engineering, University, Hyderabad, A.P, India*. 647-652.
- Babaita, A., Mati, A., Jibril, Y., Kunya, A., & Abdulwahab, I. (2022). DEVELOPMENT OF A LOAD FREQUENCY CONTROL SCHEME FOR AN AUTONOMOUS HYBRID MICROGRID. *Zaria Journal of Electrical Engineering Technology*, 11(1).
- Ibrahim, A., Musa, U., Sarip, S., Mas'ud, A. A., Muhammad-Sukki, F., Faskari, S. A., & Mahmud, A. T. (2023). *Non-Linear Model Predictive Speed Control of Six Phase Squirrel Cage Generator in Wind Energy System*. Paper presented at the 2023 IEEE 6th International Conference on Electrical, Electronics and System Engineering (ICEESE) 50-54.
- Iliyasu, M. U., Ozohu, M., Yusuf, S. S., Abdulwahab, I., Ehime, A., & Umar, A. (2022). Development of an Optimal Coordination Scheme For Dual Relay Setting In Distribution Network Using Smell Agent Optimization Algorithm. *COVENANT JOURNAL OF ENGINEERING TECHNOLOGY*.
- Musa, U., Bakare, G., Mati, A., Mohammad, A., & Umar, A. (2018). Radial Distribution Network Enhancement with DSTATCOM using Bacterial Foraging Algorithm. *Arid Zone Journal of Engineering, Technology Environmental Sciences Proceedings*, 14(2), 249-260.
- Sarfraz Nawaz, Sonali Singh and Supriya Awasthi. (2018). Power Loss Minimization in Radial Distribution System using Network Reconfiguration and Multiple DG Units, *European Journal of Scientific Research* ISSN 1450-216X / 1450-202X Vol. 148 No 4, pp. 474-483
- Srinivasa Rao, Narasimham. (2008). Optimal Capacitor Placement in a radial distribution using Plant Growth Simulation Algorithm, *World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering*, Vol:2, No:9.
- Yodphet, D., Onlam, A., Chatthaworn, R., Surawanitkun, C., Siritaratiwat, A., & Khunkitti, P. J. I. J. E. R. T. (2018). Network reconfiguration and capacitor placement for power loss reduction using a combination of salp swarm algorithm and genetic algorithm. *11(9)*, 1383-1396.

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