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Optimal Placement of Distributive Generation Using Crow search Algorithm

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Abstract- The current power system relies on centralized large power plants, which are often located far from consumers, leads to increased loss and poor voltage regulation in the system. This has led to the need for new generating stations and increased investment requirements. Distributed Generation at the point of consumption is considered a promising solution to these issues, as it can provide power for increased load demand and improve system performance. The restructured power system environment promotes DG integration in distribution networks, addressing concerns over load growth, environmental issues, and rebate policies. This is to optimize and combination of DG systems in radial distribution system to minimize power loss. The Crow Search Algorithm help's in reducing the power loss, and the approach is tested by using MATLAB on the IEEE 33 Bus system to analyze the performance of the system.

Index Terms - Crow search algorithm, optimal DG placement

I. INTRODUCTION

Increased electricity demand and limited conventional power generation with the traditional generation creates a viable solution in the integration of distributed generation (DG) as a solution to lowering the overall electricity prices and improving the system performance. DG deployment is known to lead to the enhancement in voltage profile, feeder loading reduction, power losses minimization, and supports the use of green pricing, which is an environmentally sustainable means of power. Nevertheless, the successful functionality of power systems with DG necessitates the proper management of reactive power to maintain the stability of voltages and to satisfy the reactive power requirements all over the network.

B. LITERATURE REVIEW

This paper discusses the most important issues related to the optimal location and capacity of distributed generation (DG) units within the electrical distribution system, especially to the issue of coordinated position of capacitor placement. The non-linear and multi-objective nature of the problem is solved using the meta hyper-optimization methods, including the Ant Colony Optimization (ACO) algorithm and Genetic Algorithm (GA). The system reliability and energy loss minimization are taken into consideration as the main performance indicators in the analysis and the objective is to maximize the operational benefits of the DG integration.

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PL=l=1∑nm=1∑n[Alm(PlPm+QlQm)+Blm(QlPm−PlQm)]

Represent, the active and reactive power injections bus.

$$B_{lm} = \frac{R_{lm}\sin(\delta_l - \delta_m)}{V_l V_m}$$

As penetration of DG units in the modern power distribution networks has increased, their contribution has gained more importance in minimization of power losses, improvement of voltage profiles, and postponement of expensive network reinforcement.

As well, DGs provide auxiliary services that enhance the quality of power and enhance electricity market security. As a result, the literature has offered a large number of optimization methodologies that can be used to come up with optimal DG allocation with the aim of ensuring that the system loses are minimized, the system voltage stability is enhanced and overall performance of the distribution system.

P_l= Real power (Net)

Q_l= Reactive power (Net)

R_{lm} = Resistance of line in between i and j

V_l = Voltage i

δ_m = angle i

The equation for power loss can be written mathematically as below:

Minimize,

$P \ = \sum^{NSC} Loss$

II. PROBLEM FORMULATION

The best location and size for distributed generation is approached as a minimization issue. In order to formulate the problem, it is important to both meet the operating constraints and define the objective function that needs to be optimized. The primary goal in this part is to minimize power loss. An efficient power system can lower the real power loss in a distribution system and increase overall system

$L \qquad a=1 \qquad a$

$Loss_a$ = Distribution loss at a

B. Objective Function

To reduce the negative effects of the increasing load on the distribution system's performance, DGs should be positioned and sized appropriately. This study aims to maximize VSI, minimize power losses, and improve AVDI. The system's multi- objective function for power losses is provided by:

$f_1(t) = min \sum^{br}$

$R_n * I^2$, Power Loss

performance. The power loss is computed using the equations below.

$f_1(t) = min \sum^{br}$

$R_n * I^2$, Power Loss

where R_i is the resistance of the n^{th} branch,

I_n *is the* current flowing in the n^{th} branch,

n is branch number, b_r *is the* total number of branches. Where ΔU is maximum divergence of all bus voltage values with

$$, F(k) = min\,\{w_1 f_1(k) + w_2 f_2(k) + w_3 (\frac{1}{f_3(k)})\}$$

respect to standard bus voltage magnitude

Where,

of 1.0 p.u; AVDI is given as:

w , w , w

represent the weighting factors.

1 2 3

$$f_2(t) = \frac{1}{b}\sum_{t=1}^{b} |1 - V_t|^2, \text{AVDI}$$

where, t is the bus number, b is the total number of buses and V_t is the voltage at the kth bus. The VSI of a receiving end bus of a branch can be determined by [27]:

$f_3(t) = [|V_t|^4 - 4(P_x x_{st} + Q_t r_{st})^2 - 4(P_t r_{st} + x_{st})|V_t|^2]$, VSI

where V_t is the voltage at t'th bus, Pt is the total real power demand at the t'th bus, Q_t is the total reactive power demand at the kth bus, r_{st} is the resistance of the branch 'st, and x_{st} is the reactance of the branch 'st'.

VSI_k should be greater than 0 for stable RDS operation. The least value of VSI will be responsible for determining the overall stability of the claimed system. A combination of overall objective function is formulated to minimize the losses in power, average voltage deviations and enhance the voltage stability index.

Mathematically:

The objective function The summation of weights should not exceed 1 here $\omega_1 = 0.3$, $\omega_2 = 0.3$, $\omega_3 = 0.3$ considered $f_1, f_2, and\ f_3$ by providing equal weights for objectives.

C. Constraints

The important constraints as listed below,

- Voltage constraints
- DG constraints

Voltage constraints

$|V_i|^{min} \le |V_i| \le |V_i|^{max}$

DG constraints

constraints are imposed on DG sizes to have a considerable impact of DG on system and to avoid voltage rise problem.

Active power generated by DG is represented as $DGPmin \le DGPi \le DGPmax$.

The active power generated by the DG at any bus is assumed to be within limits given above.

$DGPmin$ is set as the 25 % of the total active power load on the system and is the minimum active power of DG .

$DGPmax$ is set as the 80 % of the total active power load on the system and is the maximum active power of DG.

And reactive power generated by DG is limited within following limits.

$DGQmin \le DGQi \le DGQmax$.

$DGQmin$ is the minimum reactive power of DG and is set as the 25% and $DGQmax$ is the maximum reactive power of DG and is set as the 80 % of the total reactive power load on the system.

III. CROW SEARCH ALGORITHM

CSA, a new swarm intelligence algorithm, mimics the behavior of the crow in storing and retrieving excess food.

It searches for the global optimal solution by simulating crow intelligence and has gained global interest due to its simplicity, flexibility, and few parameters. Crow Search Algorithm (CSA) is a population-based algorithm, which mimics the intelligent crow's food hiding behavior and memory. Moreover, the exploration and exploitation of CSA can be learned from Figure Given below. Overall, the pseudocode of CSA can be explained as given in the below pseudo code, Figure.5.2 is the flowchart of CSA, and its main functions can be shown as follows:

1) Initializing crows swarm in d- dimensional randomly.

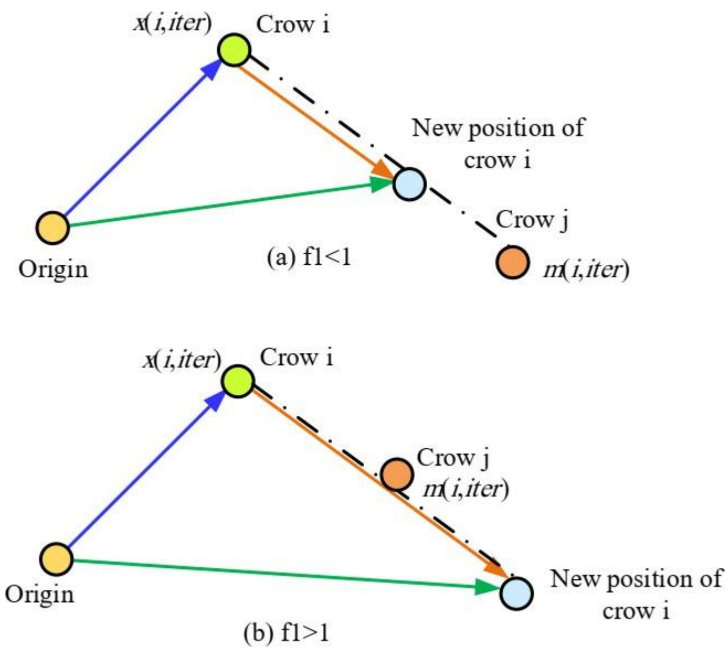
2) A fitness function is used to evaluate each crow, and its value is put as an initial memory value. Each crow stores its hiding place in its memory variable m_k

3) Crow updates its position by selecting a random another crow, i.e x_l and generating a random value. if this value is greater than Awareness Probability 'AP', then crow

$x_k$will follow x_l to know m_l

4) Crow updates its position by selecting a random other crow i.e x_l and following it to know m_l. Then new x_l is calculated as follows:

$$x_{k,iter+1}$$
$$x_{k,iter} + r_k \times$$
$$fl_{k,iter} \times$$



Figur1. Exploration and exploitation of CSA

$= \begin{cases} (m_{l,iter} - x_{k,iter})\ r_l > AP_{l,iter} \end{cases}$

{a random position otherwise

where $AP_{l,iter}$ refers to crow l awareness probability, iter refers to iteration number, r_k, r_l refers to random numbers, $fl_{k,iter}$ is the crow k flight length to denote crow l memory

(5) Pseudo Code of Crow Search Algorithm

$$m_{k,iter+1} = \begin{cases} x_{k,iter} + 1 & f(x_{k,iter+1}) \leq f(m_{k,iter}) \\ m_{k,iter} & otherwise \end{cases}$$

Input: *n* Number of crows in the population. *itermax* Maximum number of iterations.

Output: Optimal crow position Initialize position of crows.

Initialize crows' memory.
while *iter* < *itermax* **do**
for *crow k* belong to crows **do**
choose a random crow.
determine a value of awareness probability AP

Update *xi; iter*+1 using First **Eq. end for**

Check solution boundaries. Calculate the fitness of each crow

Update crows' memory using Second Eq.
end while

IV. Computation

A. *Optimal DG Capacity using CSA*

Step 1: Without DG units, do load flow analysis on a radial distribution test system to find the voltage profile, VSI, and power loss.

Step 2: Using the load flow solution data that you have acquired, compute power loss, VSI, and AVDI.

Step 3: Determine which bus sites are best for both single and multiple DG units.

Step 4: Set the initial population size, number of iterations, and minimum and maximum capacities for both single and multiple DG units.

Step 5: Use the following equation to generate the population size of the DG unit at random:

$$population = (DG_{max} - DG_{min}) \times rand() + DG_{min}$$

Step 6: Determine the resulting population's fitness values.

Step 7: Set the birds' initial position and memory.

Step 8: Calculate the awareness probability and make the necessary updates to Equations (4) and (5).

Step 9: Execute the load flow analysis to ascertain the fitness values for the revised population.

Step 10: When the predetermined number of iterations is reached, the algorithm should be stopped.

Loss Minimization Approach

In this work, the loss minimization methodology based on the analytical expressions has been used for optimal placement of DG for minimizing real power loss in primary distribution. systems. The proposed methodology can be used to find the connecting location of DG at a time for maximum loss reduction. In this work, IEEE 33 radial distribution networks is considered for testing.

A. structure for 33 Bus Radial system

Figure.2 shows the radial structure of 33 bus system. For all branches of the system data structure is created. Complete array of the same is shown in Table 4.1 IEEE 33 bus RDS comprises of 32 load buses and 32 branches.

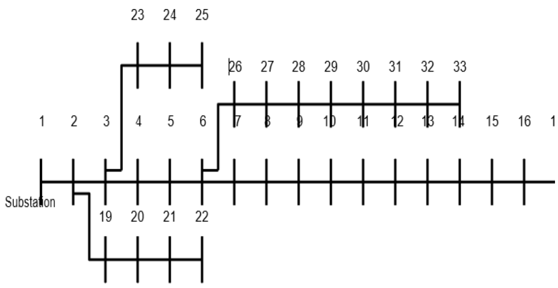


Figure.2 IEEE- 33 bus radial distribution system

Table 1. IEEE-33 Bus and Line Data.

Branch No	From Bus	To Bus	R(pu)	X(pu)	P k kVar	Q kVar
1	1	2	0.0922	0.0470	0	0
2	2	3	0.4930	0.2511	100	60
3	3	4	0.3660	0.1864	90	40
4	4	5	0.3811	0.1941	120	80
5	5	6	0.8190	0.7070	60	30
6	6	7	0.1872	0.6188	60	20
7	7	8	0.7114	0.2351	200	100
8	8	9	1.0300	0.7400	200	100
9	9	10	1.0440	0.7400	60	20
10	10	11	0.1966	0.0650	60	20
11	11	12	0.3744	0.1238	45	30
12	12	13	1.4680	1.1550	60	35
13	13	14	0.5416	0.7129	60	35

14	14	15	0.5910	0.5260	120	80
15	15	16	0.7463	0.5450	60	10
16	16	17	1.2890	1.7210	60	20
17	17	18	0.7320	0.5740	60	20
18	2	19	0.1640	0.1565	90	40
19	19	20	1.5042	1.3554	90	40
20	20	21	0.4095	0.4784	90	40
21	21	22	0.7089	0.9373	90	40
22	3	23	0.4512	0.3083	90	40
23	23	24	0.8980	0.7091	90	50
24	24	25	0.8960	0.7011	420	200
25	6	26	0.2030	0.1034	420	200
26	26	27	0.2842	0.1447	60	25
27	27	28	1.0590	0.9337	60	25
28	28	29	0.8042	0.7006	60	20
29	29	30	0.5075	0.2585	120	70
30	30	31	0.9744	0.9630	200	600
31	31	32	0.3105	0.3619	150	70
32	32	33	0.3410	0.5302	210	100

B. Implementation of CSA Algorithm for the Optimal Placement of DG

step 1: Perform the base case load flow without DG insertion and determine the active and reactive power losses in the network.

Step 2: Specify the number of DGs to be placed in the network.

Step 3: Optimal Sizing of DG using CSA

Step 4: Optimum size of DG should be kept at some bus instead of a source.

Step 5: Decide values of Pi and Qi with its tant amount and using that calculate PLoss and Q Loss.

Step 6: Verify the satisfaction of all the constraints;

Step 7: Do steps 4 to 6, at every bus.

Step 8: Save the optimum location as the location of DG that has minimum real power loss.

Step 9: Change the size of iteration and the iteration itself and the number of DGs.

Step 10: If the new solution has less loss, then compare the new solution with old solution, then store the new solution in old solution.

Step 11: If the power loss is higher than the previous, stop and take the previous solution as optimal along with its size.

Step 12: Repeat the above process for each bus of the radial system and calculate the best-size DG for that specific bus.

I. RESULTS AND DISCUSSIONS

A. Case-1 No of DG-1

First in this section we have studied the result analysis of CSA with number of DG=1. A 33-bus radial distribution system is taken as a case study application. Base case real power loss of 33 bus radial distribution system is obtained as 202.6771 When one DG is considered, the real power loss is 104.2486 kw, the optimized DG location is 31, 831kw, 402.4717 kvar. The detailed results are given in Table.2

Table 2. Optimal allocation and sizing for Number of DG=1

PARAMETERS	BASE CASE	DG PLACEMENT
Power Loss, F1 KW	202.6771	104.2486
Average Voltage Deviation Index, F2 PU	0.0035498	0.0016937
Voltage Stability Index, F3 PU	0.69501	0.74861
Network Tie Switch Number	33 34 35 36 37	33 34 35 36 37
Optimal DG Bus Location	NIL	31
Optimal DG Size P KW	NIL	831
Optimal DG Size Q KVAR	NIL	402.4717
Total DG KW	NIL	831
Voltage Minimum @ Bus	0.91306 @ Bus No 18	0.93017 @ Bus No 18
Execution Time in Seconds	0.03299	11.1354

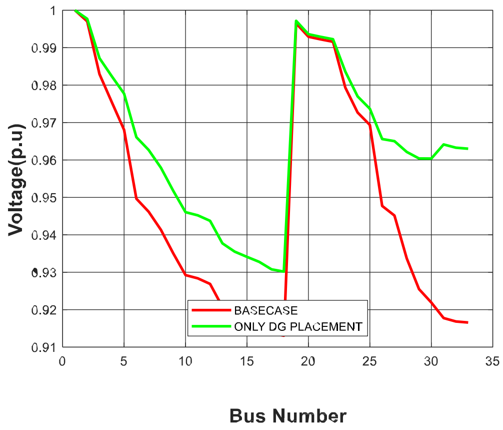


Figure.3. Voltage Profile for DG=1

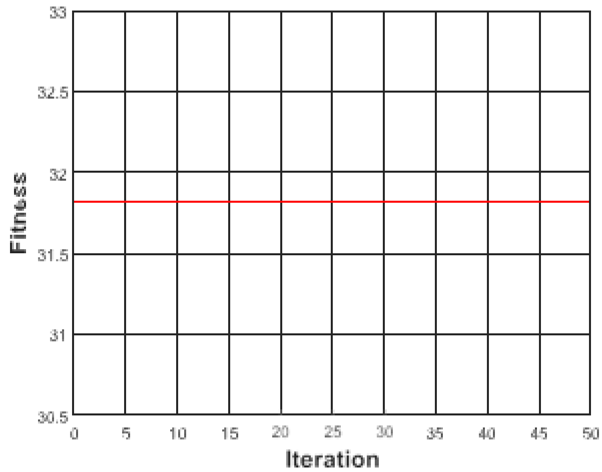


Figure.4. Convergence Graph for DG=1

Figure.3. shows the voltage level comparison for the 33-bus system with and without installation of DG system

B. Case-2 No of DG-2

Now in this section we have studied the result analysis of CSA with number of DG=2. A 33-bus radial distribution system is considered as a case study. Base case real power loss of 33 bus radial distribution system is found to be 202.6771 when two DG is considered the real power loss is 43.7336 kw and optimized DG location is 15 and 31 while the sizing is 794,960kw and 384.5518,464.9492 kvar. The detailed results are given in Table.3.

Table 3. Optimal allocation and sizing for Number of DG=2

PARAMETERS	BASE CASE	DG PLACEMENT
Power Loss, F1 KW	202.6771	43.7336
Average Voltage Deviation Index, F2 PU	0.0035498	0.00017849
Voltage Stability Index, F3 PU	0.69501	0.91574
Network Tie Switch Number	33 34 35 36 37	33 34 35 36 37
Optimal DG Bus Location	NIL	15 31
Optimal DG Size P KW	NIL	794 960
Optimal DG Size Q KVAR	NIL	384.5518 464.9492
Total DG KW	NIL	1754
Voltage Minimum @ Bus	0.91306 @ Bus No 18	0.97824 @ Bus No 25
Execution Time in Seconds	2.1239	2.8015

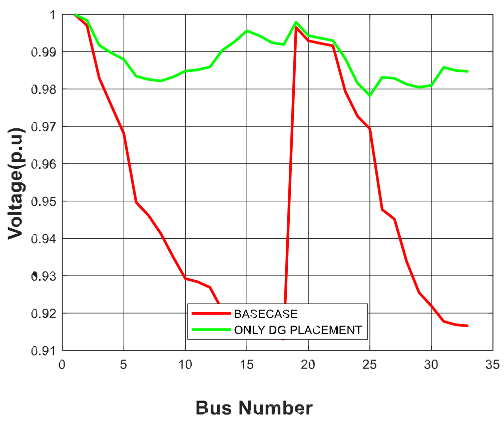


Figure.5. Voltage Profile for DG=2

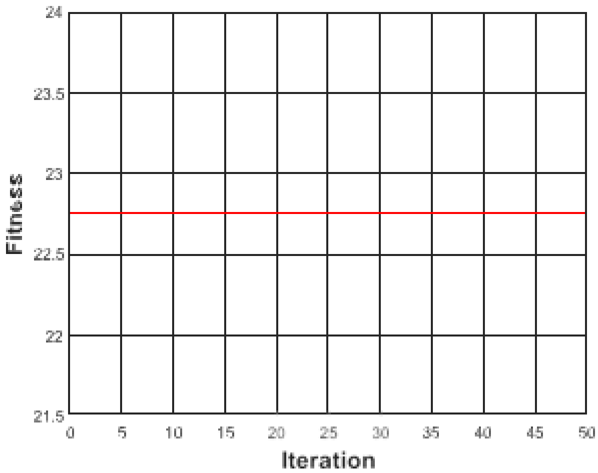


Figure.6. Convergence Graph for DG=1

Figure. 5. Shows line voltage with and without Installation of DG at 33-Bus System. The minimum voltage values are 0.91306 p.u for basecase (no CSA) at bus 18 and respectively 0. 97824 p.u at Bus 25 (with CSA). This way, loss can be decreased to 78.42% of the origin loss. The results show that DG units' installation greatly enhances the voltage profile. Figure 5.4. shows the Performance of CSA on Multi-objective function.

C. Case-3 No of DG-3

In this the number of DG considered is 3. Base case real power loss of 33 bus radial distribution system is found to be 202.6771 when one DG is considered the real power loss is 41.2367 kw and optimized DG location is 30 ,31 and 10 while the sizing is 995,14 ,831 and 481.9005 6.780509, 402.4717 kvar. The detailed results are given in Table.4.

Table 4. Optimal allocation and sizing for Number of DG=3

PARAMETERS	BASE CASE	DG PLACEMENT
Power Loss, F1 KW	202.6771	41.2367
Average Voltage Deviation Index, F2 PU	0.0035498	0.00027551
Voltage Stability Index, F3 PU	0.69501	0.89312
Network Tie Switch Number	33 34 35 36 37	33 34 35 36 37
Optimal DG Bus Location	NIL	30 31 10
Optimal DG Size P KW	NIL	995 14 831
Optimal DG Size Q KVAR	NIL	481.9005 6.780509 402.4717

Total DG KW	NIL	1840
Voltage Minimum @ Bus	0.91306 @ Bus No 18	0.97214 @ Bus No 18
Execution Time in Seconds	0.04667	18.6831

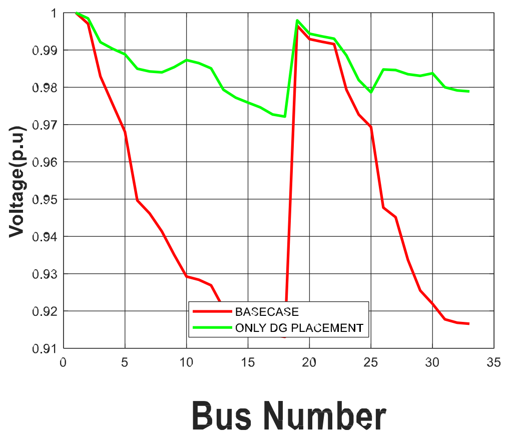


Figure.7 Voltage Profile for DG=3

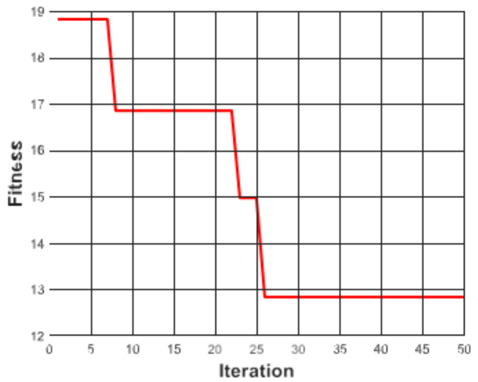


Figure.8 Convergence Graph for DG=3

Figure.7 shows the voltage level comparison for the 33-bus system with and without installation of DG system.

Minimum voltage values are 0.91306 p.u in basecase (without CSA) at bus 18 and 0.97214 p.u (with CSA) at bus 18. With the proposed method, the loss is reduced by 79.62% of its original loss. The results shows that DG units' installation greatly enhances the voltage profile. Figure.8 shows the performance of CSA for multi- objective function.

I. CONCLUSION

Increased concerns about fossil fuel depletion, rising transmission costs, deregulation trends, environmental issues, and technological advancements have created great interest in the development and use of distributed generation (DG) worldwide. This study investigates optimal DG placement and addresses associated issues, aiming to integrate DG into distribution systems for economic, technical, and qualitative benefits. Placement of DG units within the system is crucial for reducing losses and improving voltage profiles. The proposed methodologies are particularly relevant for developing countries like India, as they enhance system performance and alleviate power shortages. An analytical approach is used to determine the optimal size and location of DGs, considering factors like loss reduction and computational efficiency, and tested on 33-bus distribution

systems with varying DG numbers. ; the following conclusions have been drawn:

- "DG placement optimizes loss reduction in distribution system.
- Optimal allocation of DG also improves the voltage profiles of the system.
- CSA benefits DG placement in large networks.

An optimal approach for placing distributed generation (DG) is proposed in this thesis, which compensates both real and reactive power to reduce losses and improve voltage profile. The maximum DG capacity is set at 30% of the total substation capacity. The impact of power factor variation on system losses is also analyzed. Results show that DG placement significantly reduces the size of required DG, improves bus voltage, and avoids limit violations.

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