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Impact of Distributed Generation on Network Reconfiguration for Power Loss Minimization in Radial Distribution System by Hybrid Algorithm

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Abstract: ***Feeder reconfiguration is a planning to change the system configuration by altering the existing tie-line and sectionalizing switches status for minimizing the system losses. Hence, the network reconfiguration is essential in distribution system to minimizing system power losses. Reduction of power loss is much considerable role in power flow of distribution network in evaluating system performance. There are several methods have been proposed for reduction of system power losses and voltage improvement. This paper mainly employs feeder reconfiguration for power loss minimization and voltage improvement using opening and closing tie line and sectionalizing switches by hybrid binary particle swarm and cuckoo search algorithm. As a consequence in this operation, there is significant improvement of voltage profile, freeing up and power loss minimization. The system performance is evaluated and tested in 33 bus system, and simulation is carried out using Matlab simulation platform. For optimal switching strategy, the cuckoo search and hybrid particle swarm optimization algorithm are implemented and showed better improvement in voltage profile, minimization of real power loss and percentage of power loss reduction.***

Keywords : ***Feeder reconfiguration, cuckoo search algorithm, DG, power loss minimization, particle swarm optimization, voltage profile improvement.***

I. INTRODUCTION

In recent days there is increase of power demand and load capacity which makes the power system more complicated in fulfilling the requirement of load expansion and to increase the number of feeders. Due to technical and non technical aspects it's very intricate to achieve. Wherein increasing the capacity leads to reduction of losses, enhancement of voltage profile, increase in system reliability and quality, which plays a vital role in system performance. Various techniques have been proposed for reduction of losses by network reconfiguration.

The proposed optimization technique is used for optimal network reconfiguration for system loss reduction and voltage improvements in distribution system. The obtained results obtained described optimization technique have improved rate of convergence and computational time in solving and better system performance enhancement. In operational planning, feeder reconfiguration is essential in reducing real power loss, enhancing voltage profile thereby by increase in system capacity, reliability and power quality. This paper proposes feeder reconfiguration by opening and closing switches such as section and tie which makes use of hybrid particle swarm and cuckoo search algorithm, and it is tested in 33 bus system and modeled using Matlab simulation platform.

Several techniques and methodologies have been proposed for network reconfiguration in order to reduce power loss by considering single and multi. Nick et.al,[1] presents optimal energy storage placement in system. Badran et.al,[2] proposes meta- heuristic approach to reduce power loss by network reconfiguration. C.F. Chang[3] proposed the capacitor and network reconfiguration technique for power loss minimization. In automated system has simple implementation and low investment optimal sitting and sizing of capacitors provides better performance and reactive power compensation. Thuan Thanh Nguyen et.al,[4] has presented DNR using cuckoo search on 33, 69 and 119 bus distribution system. Power loss values of presented 33, 69, 119 bus system are similar to continuous genetic algorithm and particle swarm optimization. C.L.T. Borges et.al [5] describes DG sitting for power loss reduction V. Farahani et.al,[6] presents capacitor allocation and replacement in distribution. A. Zidan et.al,[7] presents the method for network reconfiguration by opening and closing the section and tie switches which play an essential role in reducing the power loss and enhancing the voltage profile. S. Chatterjee et.al.,[8],[9]. In distribution management system reconfiguration planning, main objective is to reduce the power loss and improve voltage profile. Steady state characteristics are obtained by power flow analysis. In transmission systems power analysis is done using Gauss-Seidel, Newton-Raphson. Meta heuristic algorithm families are widely applied to distribution network reconfiguration since it is multi model. K. Nara et.al.,[10]-[17] has proposed various methodologies for loss minimization,

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increase reliability and quality of power and voltage profile improvement such as generic algorithm, ant colony search algorithm, simulated annealing, cuckoo search algorithm, runner root algorithm, modified foraging optimization algorithm. J. Olamaei,[18] describes particle swarm optimization algorithm for reduction of loss and voltage profile improvement.

M. Imran et.al.[19] describes the loss obtained is smaller when applied fireworks algorithm, R. S. Rao et.al.[20] describes the GA, refined GA, improved TS, harmony search algorithm and improved adaptive imperative competitive algorithm. V. A. Boicea et.al,[21] explained the DNR approach in the presence of DG with hybrid optimization simulated annealing and immune algorithm are used to make objective feasible. The feeder reconfiguration with single DG placement [22] is described by particle swarm optimization and cuckoo search algorithm. An improvement is made in this work considering multiple DG allocations. Q. Peng et.al,[23] presents a convex relaxation of optimal power flow which introduces a branch reduction technique later simplified into complexity algorithm. Which has low complexity and it is globally convergent with only one switch open. Heuristic algorithm which is based on iterative application without proving convergence and test cases provides the good results.

In this paper, remaining part is organized as follows: section II explains the problem formulation and constraints of the system. Section III explains the solution methodology for network reconfiguration of radial distribution system. Section IV discussed the test case system and simulation results by employing the proposed optimization technique for minimizing system losses. The overall summary of this work is discussed in section V. In section VI, the conclusion of the work is discussed.

II. PROBLEM FORMULATION

The main objective of this paper is to reduce real power loss and enhance the voltage profile without breaking the limitations such as maintaining the voltage limits, radial structure and range of current by system reconfiguration.

A. Power Flow Equation

The power loss reduction of system is expressed by:

$$F_{\min imize} = \sum_{n}^{nb} Ri \frac{\left(P_i^2 + Q_i^2\right)}{V_i^2} \quad (1)$$

B. Radility

The system radiality is important while evaluating the network reconfiguration and obtained by:

$$det\left(B\right) = 1 \; or \; -1 \quad (2)$$

C. Bus Voltage Limits

Voltage limits is kept within limits.

$$V_{min} \leq \left|V_i\right| \leq V_{max}$$

(3)

D. Feeder Current Range

Line current range is lies between.

$$0 \leq \left|I_i\right| \leq I_{i,max} \quad (4)$$

where; n_b is total number of lines, R_i is resistance of line i, P_i is real power, Q_i is reactive power, V_i is sending end voltage at line i, B is incidence matrix, $V_{\min}$ is minimum bus voltage (0.9 p.u), $|Vi|$ is voltage magnitude at ith bus, $V_{\max}$ is maximum bus voltage (1.0 p.u), $|Ii|$ is current magnitude, $I_{i\max}$ is maximum current.

III. SOLUTION METHODOLOGY

The solution methodology adopts the particle swarm optimization and cuckoo search algorithm to develop hybrid algorithm in this paper.

A. Particle Swarm Optimization

Particle swarm optimization is stochastic method. Each swarm member updates velocity, position from the previous one. The velocity V_n^d and position x_n^d of the d^{th} dimension of the nth particle is given by [22]:

$$V_n^d = w.V_n^d + c_1.r_1.(p_{best\,n}^{\;d} - x_n^d) + c_2.r_2.(g_{best\,n}^{\;d} - x_n^d) \quad (5)$$

$$x_n^{d+1} = x_n^d + v_n^d \quad (6)$$

where;

x_i: position of the nth particle

v_n: velocity of nth particle

$p_{best\ n}$: best location searched by nth particle

g_{best} : best location

w : inertia weight which controls effect of earlier velocity

r1, r2: random distributed variables with range (0, 1)

c1, c2: positive constants coefficients which controls max step size.

New velocity is evaluated using equation (5) from the previous velocity value and new position distance from its own best and other swarm position. The range of velocity is expressed by -vmax to vmax. In order to control the distance travelled by particle out of the area. Next the particle flies and reaches to new position and this process is repeated until condition is satisfied. The inertia weight is updated by equation:

$$w^k = w_{\max} - \frac{w_{\max} - w_{\min}}{k_{\max}}.k \quad (7)$$

where, k_{max} is maximum iteration.

B. Cuckoo Search Algorithm

The cuckoo search algorithm [22] is mentioned below:

1) Read the system line and load data of test system.
2) Initial switch status, voltage magnitude and loss values are saved and run the system base load by backward/forward load flow analysis.
3) Switches status are changed.
4) Parameters, range, limitations and number of iterations to be define.
5) Initialization of random population of host nest for iteration.
6) Obtain random cuckoo value by levy flight.
7) Calculate fitness value and choose random nest.

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8) Verify fitness condition if yes replace with new value.
9) Discard Pa of bad nest and build new one by retaining best value.
10) If condition is satisfied and then save best value for the network reconfiguration.

C. Proposed Hybrid Algorithm

The proposed algorithm is described below:

1) Read the system line and load data of test system.
2) Initial switch status, voltage magnitude and loss values are saved and run the system base load by backward/forward load flow analysis.
3) Generate new switching configuration and solution vector of BPSO.
4) Deduce the minimal cut sets for each load points.
5) Check for feasibility.
6) Find the uncertainty.
7) Compute the fitness function
8) Update the position and velocity of swarm by BPSO.
9) Initiate cuckoo search algorithm.
10) Check for optimal switching configuration.
11) If yes stop the process. Else go to step 3.

IV. TEST CASE RESULTS AND DISCUSSION

The proposed hybrid optimization method has been implemented and tested for IEEE 33 bus with voltage 12.66kV, total real power demand is 3.715MW and reactive power demand is 2.295MAVr. The work is carried out in Matlab simulation tool platform.

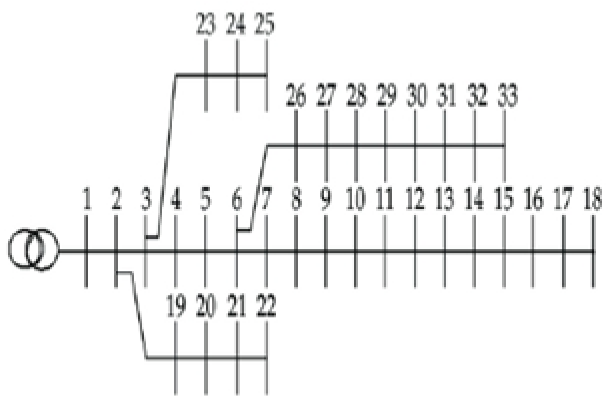

Fig. 1.Single line diagram of 33 bus distribution feeder [24]

Fig. 2.

The system power losses and voltage profile are evaluated using backward/forward load flow analysis and results are discussed in tables. Simulation results obtained is checked using hybrid particle swarm optimization and cuckoo search algorithm for network reconfiguration problem with allocation of DG. The bus voltage at every node is adjusted within the range in all cases mentioned. This paper proposes feeder reconfiguration with and without DG placement planning in radial distribution system. The following are the cases are considered for the evaluation of the 33 bus test case system.

Case 1: Network reconfiguration without DG

Case 2: With DG only

Case 3: Network reconfiguration with single DG

Case 4: Network reconfiguration with multi DG

Table I show results of status of tie-switches before and after reconfiguration, wherein power loss, power reduction and voltage profile and elapsed time are listed. Table II shows results of power loss, percentage power reduction and elapsed time with DG placement. The Table III and Table IV shows results of power loss, percentage power reduction and elapsed time with single DG and multi DG placement.

Table- I: Simulation results of 33 bus system for network reconfiguration without DG

Particular	Network Reconfiguration without DG place	
	Before Reconfiguration	*After Reconfiguration*
Tie switches	33 34 35 36 37	7 32 33 34 37
Power loss in kW	202.418	77.7733
Power loss reduction in %	----	61.5779
Minimum voltage in p.u	0.91075	0.92934
Elapsed time in seconds		37.555060

p.u. is per unit, kW is kiloWatt

The figure 2 shows the voltage profile of 33 bus test with network reconfiguration.

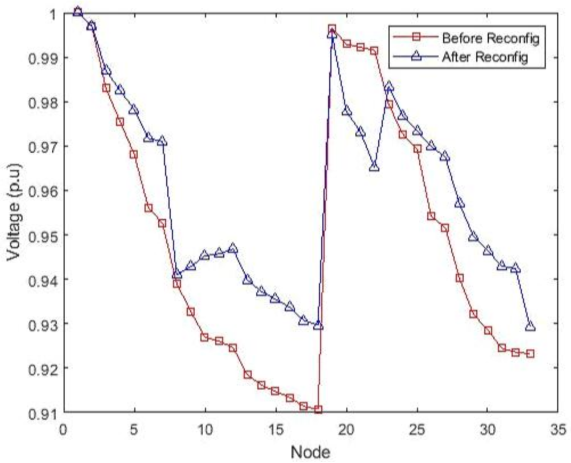

Fig. 3.Voltage profile of 33 bus test system with reconfiguration

Table- II: Simulation results of 33 bus system with DG only

Particular	DG place only	
	Before DG place	*After DG place*
Tie switches	33 34 35 36 37	33 34 35 36 37
Power loss in kW	202.418	96.1283
Power loss reduction in %	----	52.5156
Elapsed time in seconds	----	4.933210

p.u. is per unit, kW is kilowatt

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Table- III: Simulation results of 33 bus system for network reconfiguration with single DG

Particular	Network reconfiguration with single DG place	
	Before reconfiguration with DG place	*After reconfiguration with DG place*
Tie switches	33 34 35 36 37	6 2 5 13 1
Power loss in kW	202.418	68.6304
Power loss reduction in %	----	72.9936
Optimal DG allocation	----	DG place – 31 DG size - 0.4MW
Elapsed time in seconds	----	4.231090

p.u. is per unit, kW is kilowatt, MW is Megawatt

Table- IV: Simulation results of 33 bus system for network reconfiguration with multi DG

Particular	Network reconfiguration with multi DG place	
	Before reconfiguration with DG place	*After reconfiguration with DG place*
Tie switches	33 34 35 36 37	24 10 11 24 32
Power loss in kW	202.418	52.8826
Power loss reduction in %	----	77.7796
Optimal DG allocation	----	DG place – 23, 3, 16 DG size – 0.4MW
Elapsed time in seconds	----	4.618141

p.u. is per unit, kW is kilowatt, MW is Megawatt

The figure 3 shows the system power losses at different cases, where the highest losses found at case 2 is about 96.1283 kilowatt.

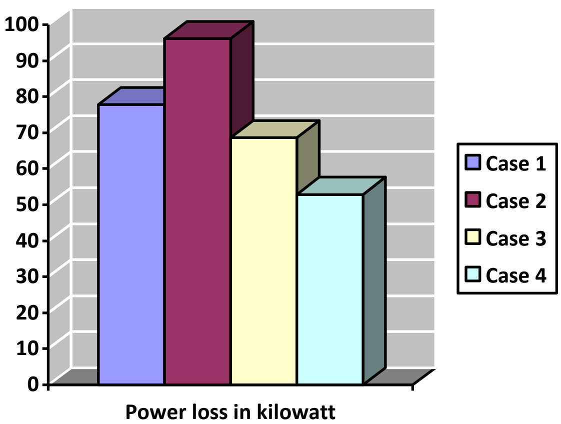

Fig. 4. Power loss in 33 bus test case system

In figure 4, the percentage of power loss reduction of the system is as shown. At case 4, the highest power loss reduction was found and is about 77.7796%.

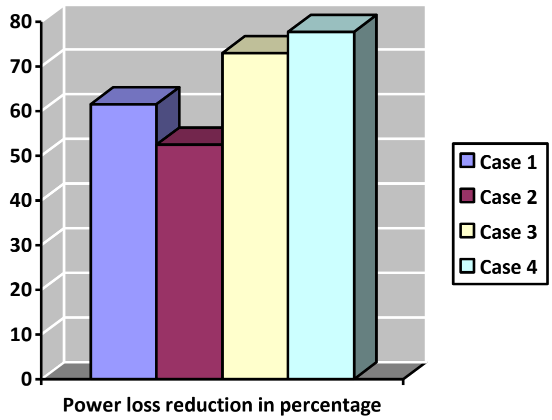

Fig. 5.Power loss reduction in 33 bus test case system

V. SUMMARY OF PROPOSED APPROACH

The solution methodology The presented hybrid particle swarm optimization and cuckoo search algorithm provides solution for reduction power losses from 202.418 kilowatt to 77.7733 kilowatt at case 1, to 96.1283 kilowatt at case 2, to 68.6304 kilowatt at case 3 and 52.8826 at case 4. The voltage profile improvement is achieved from 0.91075 per unit to 0.92934 per unit when single DG placed. The percentage power loss reduction also achieved to 61.5779% at case 1, 52.5156% at case 2, 72.9936% at case 3 and maximum loss reduction at case 4 is 77.7796%.

The optimal tie-switches strategy is found as 7, 32, 33, 34 and 37 after network restructuring from initial tie-switches 33, 34, 35, 36, 37 of the network where the maximum percentage loss reduction occurs. Hence, obtained solution found to be the best in reduction of system real power losses and voltage profile improvement. Therefore, this proposed work provides better solution for optimal network reconfiguration with and without DG placement.

VI. CONCLUSION

In this paper, the proposed hybrid optimization method has been tested for IEEE-33 bus system with standard bench mark. The optimal network reconfiguration planning is made with and without placement of DG for minimizing the system real power losses and to improve the voltage profile with different cases. The method is implemented for constant load with constant power factor is taken into consideration. Hence, the obtained results from the proposed algorithm gives very promising results with reducing the real power loss by network reconfiguration planning with placement of DG in system than certain methods. Hence, the problem proposed in this paper found better results on minimizing the system power losses, voltage profile enhancement. From these results, the proposed hybrid binary particle swarm and cuckoo search algorithm gives best solution for network reconfiguration operational planning in radial distribution system.

APPENDIX

This paper is implemented on IEEE 33 bus system for case study. The 33 bus system line data, tie-line data and load data of test case system [25] are mentioned in Table A.1, Table A.2, and Table A.3 respectively.

Tie-lines		
p-q	*R (ohm)*	*X (ohm)*
8-21	2	2
9-15	2	2
12-22	2	2
18-33	0.5	0.5
25-29	0.5	0.5

Table- A.1: Line data of the 33-bus radial distribution System

Line data					
p-q	*R (ohm)*	*X (ohm)*	*p-q*	*R (ohm)*	*X (ohm)*
1-2	0.0922	0.0470	17-18	0.7320	0.5740
2-3	0.4930	0.2511	2-19	0.1640	0.1565
3-4	0.3660	0.1864	19-20	1.5042	1.3554
4-5	0.3811	0.1941	20-21	0.4095	0.4784
5-6	0.8190	0.7070	21-22	0.7089	0.9373
6-7	0.1872	0.6188	3-23	0.4512	0.3083
7-8	0.7114	0.2351	23-24	0.8980	0.7091
8-9	1.0300	0.7400	24-25	0.8960	0.7011
9-10	1.0440	0.7400	6-26	0.2030	0.1034
10-11	0.1966	0.0650	26-27	0.2842	0.1447
11-12	0.3744	0.1238	27-28	1.0590	0.9337
12-13	1.4680	1.1550	28-29	0.8042	0.7006
13-14	0.5416	0.7129	29-30	0.5075	0.2585
14-15	0.5910	0.5260	30-31	0.9744	0.9630
15-16	0.7463	0.5450	31-32	0.3105	0.3619
16-17	1.2890	1.7210	32-33	0.3410	0.5302

Table A.2: Tie-line data of the 33 bus radial distribution system

Table A.3: Load data of the 33 bus radial distribution system

Bus Number	Load		Bus Number	Load	
	P (kW)	*Q (kVAr)*		*P (kW)*	*Q (kVAr)*
1	-	-	18	90	40
2	100	60	19	90	40
3	90	40	20	90	40
4	120	80	21	90	40
5	60	30	22	90	40
6	60	20	23	90	50
7	200	100	24	420	200
8	200	100	25	420	200
9	60	20	26	60	25
10	60	20	27	60	25
11	45	30	28	60	20
12	60	35	29	120	70
13	60	35	30	200	600
14	120	80	31	150	70
15	60	10	32	210	100
16	60	20	33	60	40
17	60	20		--	--

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