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Multiobjective Power Loss Reduction using Flower Pollination Algorithm

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Abstract: Distribution network reconfiguration is a technique of closing the normally kept open tie switches and opening the normally kept closed sectionalising switches for achieving the objective of power loss reduction, In this paper additional objectives of improvement in distribution of loads measured by load balance index and improvement in voltage profile measured by voltage profile index are achieved in the presence of distributed generators. Flower pollination algorithm is used to select the best pareto optimal solution which gives the number of sectionalising switches to be opened along with place and values of distribution generation units to be connected in the distribution bus for achieving the multiple objectives which are compared with other published algorithms.

Keywords: Flower Pollination Algorithm (FPA), Distribution Network Reconfiguration (DNR), Distributed Generation (DG), Distributed Generation Units (DGU), Particle Swarm Optimization (PSO).

1. INTRODUCTION

The consumers are connected to the power supplying companies through distribution system at the connection point called point of common coupling (PCC), From the point of view for protection and metering the losses occurring in distribution system a radial system is generally preferred since the fault level of short circuit current is also less. One disadvantage of radial system is that end users are suffering due to low voltages and voltage fluctuations called as brown outs. For achieving reduction in loss of power, increasing the profile of voltage, increasing the balancing of loads and other benefits network reconfiguration [1] is done which is closing the position of normally kept open tie switches and opening position of the normally kept closed sectionalising switches, integration of energy sources like roof top solar power plants, roof top wind turbines, biogas plants in the distribution is called distributed generation (DG) which has many advantages like improvement in voltage profile and balancing of loads, reduction in power loss, reduction in global warming, postponement of need to invest in new transmission lines for catering the ever increasing demand especially in developing countries like India, Brazil, China, South Africa and others.

2. PROBLEM IDENTIFICATION

2.1. Objective Function of the Problem

The objective function of the problem has been formulated to achieve minimum power loss, load balance index (LBI) and voltage profile index (VPI) in the distributed system, which is given by the following standard equation generally used [2], [3].

Problem formulation:

$$\text{Min}F(X) = \text{Min}[P_{loss}, LBI, VPI]$$

Ploss-power loss in distribution system, LBI-load balance index, VPI-voltage profile index

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Subjected to $V_{\min} \leq |V_k| \leq V_{\max}$

and $|I_{k,k+1}| \leq |I_{k,k+1,\max}|$

$$\sum_{k=1}^{n} P_{GK} \leq \sum_{k=1}^{n} \left(P_k + P_{Loss,k}\right) \tag{1}$$

All available loads should be fed always for the distribution system considered.

where

Vk', Vkmax, Vkmin-voltage available at bus k after doing the operation of reconfiguration, maximum voltage, minimum voltage

Ik', K+1, Ik, K+1, max-the maximum current flowing in the line in between section k and k+1 before and after doing the operation of reconfiguration,

$$Ploss = \sum_{k=1}^{nf} Rk \frac{Pk^2 + Qk^2}{Vk^2} \tag{2}$$

$$LBI = \sum_{Fj} \left(\frac{I_{Fj}}{IF_{avg}}\right)^2 \tag{3}$$

IFj-the current which passes via line j

The decreasing value of LBI is an indication of improvement in load balancing.

$$VPI = \sum_{k=lb} |Vk - Vref_k)| \tag{4}$$

LB-the notation for collection of load buses

Vref-voltage available at load bus k.

2.2. Loss reduction using Network Reconfiguration

Net power loss reduction, ΔP^R_{Loss}, in the system is the difference of power loss before and after reconfiguration which is given below

$$\Delta P^R{}_{Loss} = \sum_{k=1}^{N} P_{T,Loss}\left(k, k+1\right) - \sum_{k=1}^{N} P'_{T,Loss}\left(k, k+1\right) \tag{5}$$

2.3. Power Loss Reduction using DG Installation

Installation of distribution generation units in optimal locations of a distribution system results in several benefits as seen above like peak demand shaving, relieving the overloading of distribution lines, increased overall energy efficiency and deferred investments to upgrade existing generation, transmission and distribution systems. The power loss when a DG is installed at an arbitrary location in the network is calculated using the following equations.

$$P_{DG,Loss} = \frac{R_k}{V_k^2}\left(P^2{}_k + Q^2{}_k\right) + \frac{R_k}{V_k^2}\left(P^2{}_G + Q^2{}_G - 2P_kP_G - 2Q_kQ_G\right)\left(\frac{G}{L}\right) \tag{6}$$

Net power loss reduction, ΔP^{DG}_{Loss}, in the system is the difference of power loss before and after installation with DG unit.

$$\Delta P^{DG}{}_{Loss} = \frac{R_k}{V_k{}^2}\left(P^2{}_G + Q^2{}_G - 2P_kP_G - 2Q_kQ_G\right)\left(\frac{G}{L}\right) \quad (7)$$

The positive sign of ΔP^{DG}_{Loss} indicates that the system loss reduces with the installation of DG. In contrast, the negative sign of ΔP^{DG}_{Loss} implies that DG causes the higher system loss.

3. TEST SYSTEM DESCRIPTION, SIMULATION RESULTS AND ANALYSIS

3.1. Test system description

The base configuration of the system consisting of one supply point, 33 buses, 3 laterals, 37 branches, 5 loops or tie switches (Switches no. 33-37) which are normally open switches which are shown by dotted lines and 32 sectionalizing switches (Switches no. 1-32) are normally closed switches which are indicated

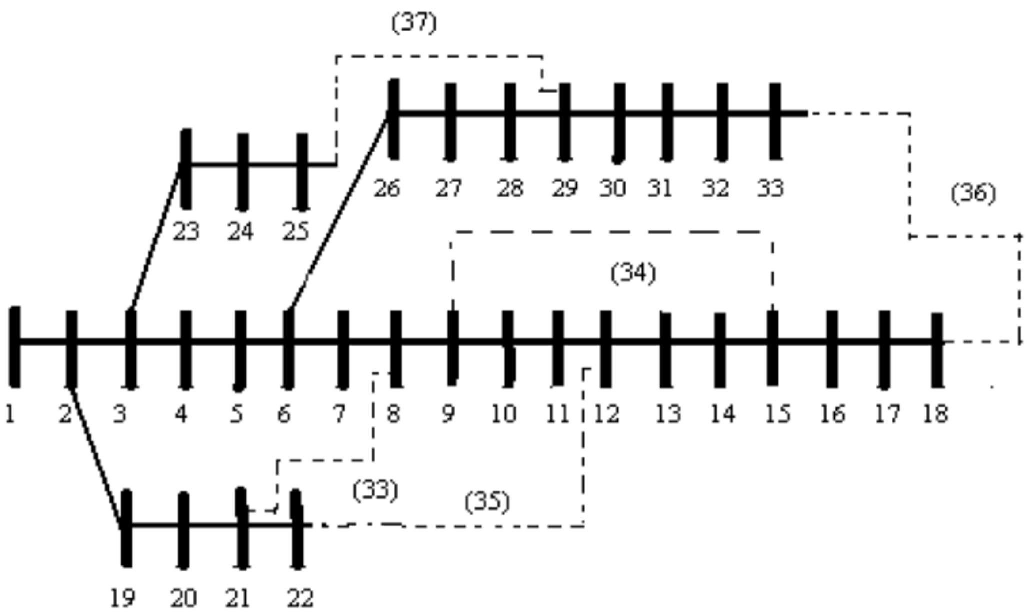

Figure 1: 33-bus radial power distribution system base configuration

by solid lines. The total real and reactive power for the whole system loads of the initial configuration are 3,715 kW and 2,300kVAR, respectively. The base real power loss is 202.67 kW for case 1 [4].

3.2. Flower Pollination Algorithm

The fusion of gametes causes reproduction in plants, when the stigma get a pollen which may be carried by air, animals, etc from different plants is called as biotic pollination. When pollen from anther of the same plant is transferred to stigma then this self pollination in same plant is called abiotic pollination .This fertilizatation process of reproduction is the cause for seeds and flowers in a plant to be produced. Nature aids biotic pollination by attracting inscets like butterflies, honey bees, wasps etc. by odour colour, honey. when these insects visit next plant the pollen of the previous visited plants sticked to their bodies causes biotic pollination.

Prof. Xin SheYang of Cambridge University on observing the natural process of flower pollination mathematically modeled the process by following the procedure given below [5].

Flower Pollination Algorithm (FPA)

Step 1 Formulation of the objective function

Minimize or maximize f(x) objective = (x1, x2,.......xd)

Step 2 Initialize ‘n’ flowers or population with random solutions

Step 3 Best solution (g*) is identified in the initial population.

Step 4 Express a switch probability p which form 0 to 1 here it is chosen as 0.8 by trial and error to give best values at a faster time, these values will vary for different applications

$$P(\varepsilon) = [0,1]\ p = 0.8$$

Step 5 Iterate continuously in the loop up to maximum iteration for i = 1: n (for all the n flower available in the population) generate a random number rand if that random number rand is <0.8 then biotic global pollination is carried out using a step vector L from distribution using levy’s flight step (L).

$X_{i^{t+1}} = X_{i^t} + \Upsilon L(g^* - x_{i^t})$ where initial *Xi* and *g** best solution available

If rand is more than or 0.8 then local pollination is carried out using ε.

$$X_{i^{t+1}} = X_{i^t} + \varepsilon(X_j^t - X_k^t)$$

Where ε is a random number between (0 to 1) then the new solution are evaluated. If the new solution are better than they are replaced as best solution.

Step 6 all the above steps are repeated up to maximum number of iterations, while output for best solution is found.

Proposed algorithm (FPA Algorithm) decides DG connection location also

The chance for local pollination or abiotic pollination is more so the p value is biased toward this local pollination but p values chosen here as 0.8 may work better for most of application. The value of P can be changed based on the applications by trial and error because there is no one such value called best value for all algorithms as shown by no free lunch theorem [6].A multi objective problem is finding a solution in search space which can minimize or maximize all objective functions simultaneously as shown in the equation given below

$$f = \sum_{i=1}^{m} WiFi \tag{8}$$

Where the random weight *Wi* are generated with constraint. (all positive numbers with sum of all weight values equal to one)

$$\sum_{i=1}^{n} Wi = 1, Wi > 0 \tag{9}$$

Wi are calculated positive weights and *Ui are* random number generated

$$Wi = \frac{ui}{\sum_{i=1}^{m} ui} \tag{10}$$

The weighted coefficients act as preference for the multi objectives. For a given set of weights (w1, w2, w3.........wm) multiple pareto points are generated so that optimal pareto point can be selected by selecting any three random numbers and calculating weights with constraints mentioned above.

3.3. For Solving the Multi Objective Optimizatation Problem

The types of DG, scenarios (I and X), constraints and assumptions are considered same as in [3] for comparing the simulation results using proposed algorithm.

Simulation Results and Discussion

The proposed method has been implemented by using Matlab programs and run on a personal computer with intel core (octal) i7 processor having 4 GHz speed and 6 GB RAM. To validate the effectiveness of the proposed algorithm, the algorithm has been implemented to 33 – bus radial distribution system and simulation results are compared with other techniques as reported in the literature for all objective function values for ten scenarios or cases. Maximum number of iteration is 40 and dimension of the problem used is 5, 11, and 14. The ten scenarios considered are various scenarios in literature are compared for finding the effectiveness of the proposed FPA algorithm. The various scenarios tested are

Scenario I The base system which is having no reconfiguration or no DG connection [4]

Scenario II The multi objective reconfiguration is executed on the base system and there is no DG connection

Scenario III The base system multiobjective reconfiguration, but with DG type 1allocation computed to base system.

Scenario IV The base system with no multi objective reconfiguration, but with DG type 3allocation connected to base system.

Scenario V Simultaneous operation of multi objective reconfiguration along with DG type 1 allocation to base system.

Scenario VI Simultaneous operation of multi objective reconfiguration along with DG type 3 allocation to base system.

Scenario VII The base system with no multi objective reconfiguration but with DG type 2 allocation to base system.

Scenario VIII The base system with no multi objective reconfiguration but with DG type 4 allocation to base system.

Scenario IX Simultaneous operation of the multi objective reconfiguration along with DG type 2 allocation to base system.

Scenario X Simultaneous operation of multi objective reconfiguration along with DG type 4 allocation to base system.

4. TEST RESULTS

The results of the proposed method applied for four types of DG is shown in the comparison tables above as ten scenarios. The base case of power loss is reduced from 202.67 kW to 133.68, 96.32, 74.43, 43.77, 29.32, 102.33, 120.37, 60.91, 68.93kW from scenario II to X. The value of VPI is improved from 1.7 in the base case to 1.395, 1.295, 1.156, 1.068, 1.986, 1.298, 1.492, 1.082, 1.104 for scenario II to X. The value for LBI improves from 67.71 in the base case to 49.27,47.96,47.32,46.73,45.99,47.69,48.43,46.32,47.56 for scenario II to X. The proposed method is compared with other published algorithm shown in the tables 1, 2 and 3 the inference from analysing the results indicate the proposed method has given better values compared with fuzzy bees algorithm and particle swarm optimization algorithm for power loss as well as LBI and VPI values.

Table 1
Flower Pollination Algorithm FPA (Proposed Method) used with Multi Objectives for a 33 Bus Distribution System Compared With Fuzzy Bees Algorithm Method [3] for Scenario I To V

Scenario (Algorithm)	Tie switches	DG sizes (MVA) @ buses	P_{Loss}(kW) (%Loss Reduction)	VPI (%VPI Imp)	LBI (%Load balance Imp)	Worst voltage@bus (%incremet In Worst voltage)
I (FPA)	33,34,35,36,37	-	202.67	1.7	67.71	0.9131 @ 18
I (FBA)	33,34,35,36,37	-	202.5	1.7	67.71	0.9131 @ 18
II (FPA)	7,13,9,32,37	-	133.68 (34.04)	1.395 (17.94)	49.27 (27.23)	0.9412 @ 33 (3.08)
II (FBA)	10,14,17,20,28	-	136.19 (32.74)	1.403 (17.47)	49.43 (26.99)	0.9380 @ 32 (2.72)
III(FPA)	33,34,35,36,37	0.647,1.625,0.595 @ 7,9,14	96.32 (52.47)	1.295 (23.82)	47.96 (29.17)	0.9599 @ 15 (5.12)
III (FBA)	33,34,35,36,37	0.638,1.619,0.568 @ 6,9,14	97.65 (51.77)	1.351 (20.52)	48.16 (28.87)	0.9529 @ 14 (4.35)
IV(FPA)	33,34,35,36,37	0.524,0.278,0.86 @ 6,11,33	74.43 (63.28)	1.156 (32.0)	47.32 (30.11)	0.9687 @ 9 (6.09)
IV (FBA)	33,34,35,36,37	0.519,0.249,0.72 @ 6,10,33	75.34 (62.79)	1.257 (26.05)	48.42 (28.48)	0.9639 @ 9 (5.56)
V (FPA)	7,13,10,33,27	0.78,1.423,1.108@ 6,13,33	43.77 (78.40)	1.068 (37.17)	46.73 (30.99)	0.9765 @ 18 (6.94)
V (FBA)	7,9,14,32,37	0.8,1.138,1.004 @ 6,12,33	44.28 (78.13)	1.166 (31.41)	47.01 (30.57)	0.9701 @ 18 (6.24)

Table 2
Flower Pollination Algorithm FPA (Proposed Method) used with Multi Objectives for a 33 Bus Distribution System Compared with Existing Fuzzy Bees Algorithm Method (FBA) [3] For Scenario VI To X

Scenario (Algorithm)	Tie switches	DG sizes (MVA) @ buses	P_{Loss}(kW) (%LossReduction)	VPI (%VPI Imp)	LBI(%Load balance Imp)	Worst voltage@bus (%incremet in worst voltage)
VI (FPA)	7,14,10,33,37	1.210,1.256,0.867 @ 6,14,33	29.32(85.53)	0.986(42.0)	45.99(32.8)	0.9810 @ 32(7.44)
VI (FBA)	7,10,14,32,37	1.107,1.112,0.781 @ 6,14,30	30.41(84.98)	1.073(36.88)	47.32(30.11)	0.9741 @ 32(6.68)
VII (FPA)	33,34,35,36,37	0.624,0.432,0.591 @ 6,10,34	102.33(49.51)	1.298(23.65)	47.69(29.57)	0.9581 @ 33(4.93)
VII (FBA)	11,33,34,36,37	0.501,0.406,0.579 @ 6,9,34	104.43(48.42)	1.389(18.29)	48.96(27.69)	0.9441 @ 33(3.39)
VIII (FPA)	33,34,35,36,37	1.259,0.415,0.295 @ 6,10,18	120.37(40.60)	1.492(12.24)	48.43(28.47)	0.9352 @ 7(2.42)
VIII (FBA)	6,14,32,35,37	1.023,0.338,0.109 @ 6,9,17	122.57(39.47)	1.573(7.47)	49.18(27.36)	0.9266 @ 7(1.47)
IX (FPA)	7,11,14,33,37	0.832,1.490,0.956 @ 6,30,32	60.91(69.95)	1.082(36.35)	46.32(31.59)	0.9732 @ 10(6.58)
IX (FBA)	7,10,14,32,37	0.725,1.352,0.809 @ 6,30,33	62.78(68.99)	1.1.98(29.52)	47.86(29.31)	0.9687 @ 9(6.08)
X (FPA)	14,11,20,33,36	1.354,0.996,0.815 @ 6,12,15	68.93(65.99)	1.104(35.05)	47.56(29.76)	0.9756 @ 18(6.84)
X (FBA)	10,14,20,32,36	1.209,0.984,0.728 @ 6,12,14	70.31(65.27)	1.237(27.23)	48.05(29.03)	0.9642@ 18(5.59)

Table 3
Comparisons of different Evolutionary Algorithm with proposed Flower Pollination Algorithm (FPA) for 33 Bus Systems

Methods	Case	Scenario II	Scenario V	Scenario VI
flower pollination algorithm (FPA) (Proposed Algorithm)	Tie open Switches	7,13,9,32,37	7,13,10,33,27	7,14,10,33,37
	$P_{Loss\ (kW)}$	133.68	43.77	29.32
	VPI value	1.395	1.068	0.986
	LBI value	49.27	46.73	45.99
	DG sizes(MVA) @ buses	-	0.78,1.423,1.1081 @ 6,13,33	1.210,1.256,0.867 @ 6,14,33
particle swarm optimization(PSO) [3]	Tie open Switches	31,7,9,14,37	33,34,35,36,37	11,20,24,32,34
	$P_{Loss\ (kW)}$	138.12	96.50	74.76
	VPI value	1.496	1.179	1.182
	LBI value	51.87	49.14	50.07
	DG sizes(MVA) @ buses	-	0.851,0.720,0.990 @ 17,24,27	1.591,0.373,0.602 @ 32,9,10

5. CONCLUSION

The DG used here can supply reactive power also in addition to real power, Multiple DG units are used for optimal solution of multi objective reconfiguration problem. The algorithm has been tested under ten different scenarios considering 3 DG and reconfiguration. The best scenario results are obtained for DG types 3 because of its ability to inject real and reactive power for scenario VI out of ten scenarios which are compared with a least power loss of 29.32 kW with a 85.53% improvement in power loss reduction, 32.8% improvement in load balanced index and a voltage profile index improvement of 42% on comparison with the base system. The results obtained are compared with particle swarm optimization algorithm and fuzzy bees algorithm all the simulation results compared are at nominal load values. The proposed flower pollination algorithm is found to be having more reliable convergence with better value of convergence on comparison with other compared algorithms.

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