Loss minimization and load-ability improvement in distributed power system using mixed-integer flower pollination optimization algorithm

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Abstract- The increasing need for electricity shows the importance of electricity generation on the distribution side. The transmission loss reduction also becomes as one of the key issues to be resolved. The location of Distributed Generators (DG) and size of DG has to be identified, as the power system has many buses. So optimal allocation and sizing of DG is required. The distribution system is reconfigured with new tie switches, which improves the voltage profile and minimizes the loss. In this paper, the loss minimization and system load-ability improvement are used as multi-objective. The 25 % weight is given for loss and 75 % is given for load-ability. And a new mixed integer flower pollination algorithm is used here for solving this multi-objective function. Here the DGs considered are the synchronous inverter. So, it supplies both real as well as reactive power. The power factor can be optimally chosen from the algorithm. Here the test system of IEEE 33-bus distribution system is used. And the results are compared with previous technique.

Keywords: Distribution generation, placement, reconfiguration, mixed-integer flower pollination algorithm, optimal location and sizing.

1. Introduction

The distribution side of the power system is facing a major problem due to the need for power generation. And the existing power system is old [1-3]. These power systems are not capable to generate and transmit the power required at the distribution side as it is old and causes more loss [4]. The electricity transmission loss in the whole world is 8.10% and distribution loss is 54.6%. This loss affects the cost of the generation and transmission too [5]. So, there is a need for planning in the existing resources.

In many kinds of literature, the minimization of power loss is the main task with the existing power system [6]. Literature is proposed for reconfiguration, distribution generation (DG) placement and shunt capacitor placement approaches to reduce the power loss in the system [6]. The huge amount of loss causes sag in the voltage level. There is literature discussing the maximum load-ability which is one of the causes for the voltage limit violations [7]. The calculation of maximum load-ability is important to prevent the voltage collapse in the power system. The voltage stability terminology given in [8] is KVA margin to maximum load-ability (KMML). Using the continuous power flow [9,10] the voltage profile increased by load-ability. In [11-15] authors combined the optimum DG placement and reconfiguration to reduce the power loss. The reliability improvement of the power system is discussed in [16] by combining the DG placement and reconfiguration.

Many optimization techniques are used to solve the reconfiguration problem [17-20]. The optimization based on the integer number using gaussian formulation [21], adding mutation to the PSO algorithm [22], and ABC [23] are not providing the global fitter results. Many authors used binary optimization technique in PSO [24] and GA [25] for reconfiguration problems. A new modified artificial bee colony optimization is used in [26] and a new method of reconfiguration is also used and due to that, the load-ability is improved. The optimal allocation of DG and optimal reconfiguration are discussed by many authors by changing the different methods and solution techniques. In [27-30] optimal DG placement, optimal reconfiguration, optimal placement of capacitors and combined reconfiguration with optimal placement of DG and reconfiguration with capacitor placements are discussed. Many objective functions like minimization of loss, improvement of voltage profile and maximization of load-ability are also discussed. But the multi-objective problem with loss and load-ability is not formulated. As per [26] considering the load-ability improvement, the reconfiguration losses can be reduced more.

In this paper a new multi-objective function is used for minimization of loss as well as maximization of load-ability is done and the new mixed integer flower pollination algorithm (MIFPA) is used for analyzing the improvement. MATLAB code is written for four different cases with improvement and effect of multi-objective with MIFPA is represented in tabular.

2. Proposed method of multi-objective

This paper proposes the load ability improvement and reduction of loss by simultaneous placement of DG and reconfiguration. There are two objectives used here one is system loss minimization. Loss minimization equation is given below,

$$F1= \sum_{i=1}^{Ln} I_i^2 * R_i \quad (1)$$

Here,
i-transmission line number
Ln-total number of transmission lines
R_i-Resistance in pu of transmission line i

The next objective is to improve the system load-ability improvement,

$$F2= max(\lambda_{max}) \quad (2)$$

Where,
λ_{max}-maximum load-ability index

$$P_{lnew}=P_{load}*\lambda$$
$$Q_{lnew}=Q_{load}*\lambda$$

Where,
λ_{max}-maximum achievable load
λ-load multiplication factor
P_{lnew}-new load real power after adding new load
Q_{lnew}-new load reactive power after adding new load
P_{load}-real load available in the system
Q_{load}-reactive load available in the system

The total fitness function minimized can be represented as

$$F=(\alpha*F1)+\left(\beta*\left(\frac{1}{F2}\right)\right) \quad (3)$$

Where,
F-total fitness value
α,β-weight factor chosen between $(0\text{-}1)$

Constraints,

Size limit of DG

$$0\leq \sum_{j=1}^{Bn} S_{DG}^j \leq \sum S_{load} \quad (4)$$

Where,
S_{DG}^j-KVA of DG selection
j-Bus number
S_{load}-KVA load available
Bn-total bus number

Position of DG can be represented as below,

$$2\leq DG\ position \leq Bn \quad (5)$$

Where,

$$S_{load}=\sqrt{\sum_{j=2}^{Bn} P_{load}^2 + \sum_{j=2}^{Bn} Q_{load}^2} \quad (6)$$

The power factor as per the recent DGs it can be chosen based on the inverter operation

$$P_{DG}=S_{DG}*\text{optimal power factor} \quad (7)$$
$$Q_{DG}=\sqrt{S_{DG}^2\text{-}P_{DG}^2} \quad (8)$$
$$KMML=S_{load}*\lambda_{max} \quad (9)$$

Here,

KMML-the maximum KVA load which can be connected

Voltage constraint,

$$0.95\leq V_{bus}^j \leq 1.05 \quad (10)$$

Where,
V_{bus}^j-Voltage amplitude at bus j

$$0.7\leq PF\leq 0.99$$

PF-power factor

The λ_{max} is identified as given in [2].

3. Mixed integer flower pollination algorithm (MIFPA)

The flower constancy and pollinator behavior are taken as an algorithm by [1]. This algorithm is formulated for the solution of multi-objective with 11 control variables simultaneously. These variables are the switch numbers of the transmission system for reconfiguration DG location and size with the power factor of each DG.

Biotic and cross-pollination is considered as the pollination process with the pollen carrying the pollinations which perform levy flights. The abiotic and self-pollination are the local pollination behavior. Reproduction probability is proportional to the similarity of the two flowers involved. The local pollination and global pollination are controlled by switch probability p ∈ [0, 1].

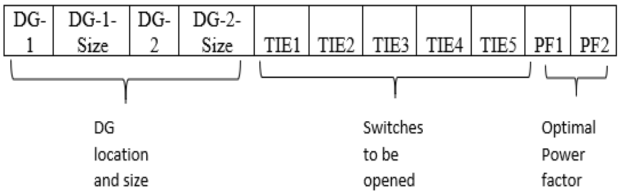

Figure1. Data representation

The factors such as wind, the local pollination has a significant fraction of 'p' in all over the pollination activities. Each flower patch release billions of pollens gametes. We assume that each plant has only one flower and each flower produce only one pollen gamete. Here ‘Xi’ is the search space or it is equivalent to the flowers/pollen gametes. Here we consider one plant has eleven flowers and each flower has one pollen gamete. These eleven pollen gametes have 5 switches which have to be removed,2 DG location and 2 DG sizes and 2 power factors for each of the DG. Here switch numbers and DG locations are integers, and power factors and sizes of DG are not integers.

Fig 1. Shows the pollens passed into the objective function, TIE- the switch which has to be open and PF- is the power factor.

And here the pollens are carried by the legs of Levey flights. The first rule plus flower constancy can be represented mathematically as,

$$X^{t+1}_{ij} = X^{t}_{ij} + L\left(X^{2}_{ij} - g^{*}\right) \qquad (11)$$

Where,

X^{t+1}_{ij}-it represent a pollen gamete
t-iteration count
i-number of pollen
j-it has 11 values
$g^*$is the current global best solution
L-Levy distribution

These Levy flights are insects used here for pollen gamete movement, it is used $L>0$ from a levy distribution,

$$L \sim \frac{\lambda\Gamma(\lambda)\sin\left(\frac{\pi\lambda}{2}\right)}{\pi}\frac{1}{s^{1+\lambda}} \; (s \geq s_0 \geq 0) \qquad (12)$$

The procedure as given in Figure 2 is given below,

(i) Initialize the iteration count, number of pollens in a flower. Randomly generate the pollens.
(ii) Evaluate the multi-objective fitness function for initial conditions. Select a g^* best. And define p[0,1].
(iii) For all pollens if the random number is less than p. Then generate levy distribution (global pollination). And identify the newX_{ij}^{t+1}
(iv) If the random number is greater than p. then use uniform distribution (ε) (local pollination). And calculate below equation

$$X^{t+1}_{ij} = X^{t}_{ij} + \varepsilon(X^{2}_{ij} - g^{*}) \qquad (13)$$

(v) Evaluate fitness for new X values.
(vi) If new X values are giving lesser fitness then replace it with the old one.
(vii) Repeat step (iii) by incrementing the iteration count.

Stop if the final iteration reached.

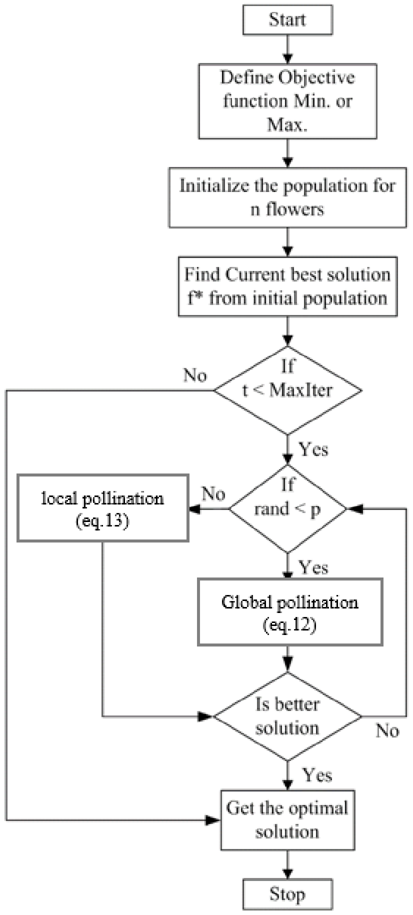

Figure 2. Flow chart of Flower pollination algorithm.

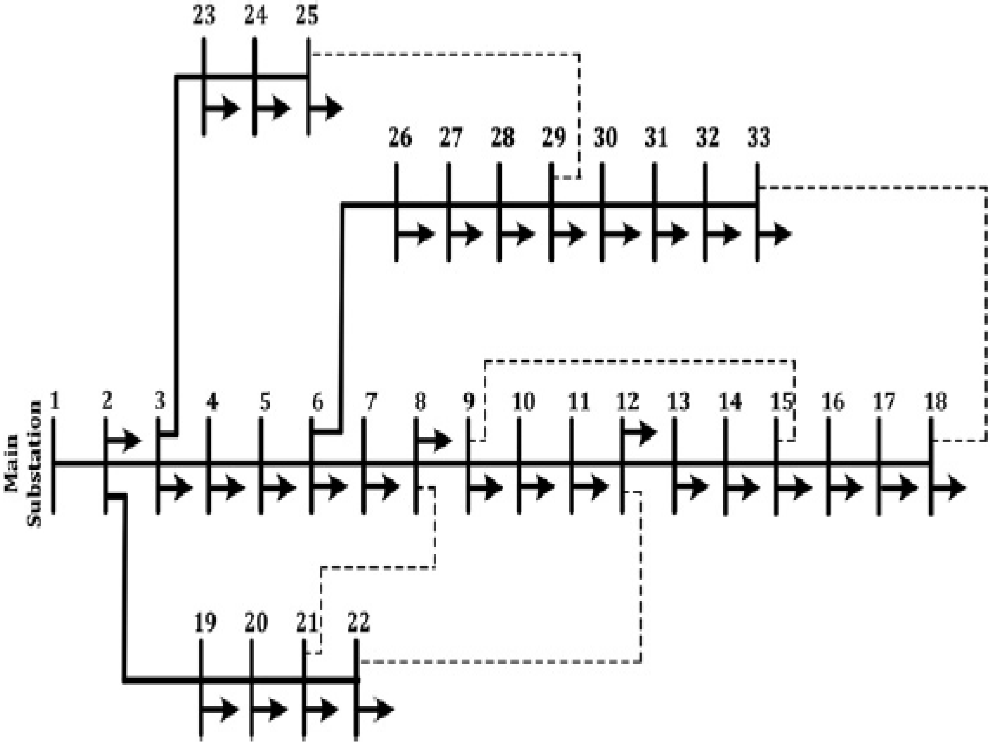

Figure 3. IEEE 33 Bus system

4. Test system

Here the IEEE 33 bus system is used as a base system/test system. The single-line diagram of the 33-bus system is presented in the Figure 3. It has the following properties,

Bus numbers – 33
Branch numbers – 32 (sectionalizing switches)
Tie branches-5 (Tie switches)
Total apparent power – 4369.35 kVA.
Real power loss- 211 kW
Reactive power loss- 143.01 kVAR

For the DG placement, the real power is taken as the negative value as the load value is positive. For reconfiguration whenever the sectionalizing switches are open the tie switches are closed to satisfy the radial nature of the power system.

5. Results and discussion

Here case 1- is base case power flow with tie switches opened.
Case 2- is only network reconfiguration using the multi-objective function
Case 3- is only the placement of DG placement
Case 4- is DG placement with reconfiguration
Here all three (cases 2-4) uses the multi-objective function.

Case 1 is independent of the algorithm and fitness function. Case 2 has significant improvement in load-ability (5.25%) with KMML improvement of 1266.65, loss reduction of 9.97% (13.96 kW) and the number of bus voltage violated buses reduces from 7 to 3. And also, the voltage deviation index improves 20.69%. And achieves the Qualified Load Index value of 0.01.

In case 3 and case 4 there is no improvement in load-ability and KMML value, but the real loss and reactive loss of case 3 values are reduced by 48.12KW and 47.92 kVAR respectively. And the size of the DG selected for the proposed objective is also reduced. The real power of DG is reduced by 321 kW and reactive power of DG reduced by 47.92 kVA. This is the significance of synchronous inverter based DGs. In case 4 also real loss reduced by 61.43 kW and reactive loss reduced by 44.35 kVAR. DG1 size of case 4 is reduced by 1401.76 MVA but there is no reduction in DG2. These DGs operate in optimal power factor for the derived multi-objective.

Table 1. Comparative results with proposed technique

	33-bus system		
	Identified parameters	DABC [2]	MIFPA
Case 1	Switches opened	33,34,35,36,37	33,34,35,36,37
	active power loss (kW)	210.99	210.99
	reactive power loss (kVAR)	143.01	143.01
	system loading margin λ_{max}	3.4	3.4
	KMML	10486.44	10486.44
	NBVV	21	21
	VDI	0.0245	0.0245
	QLI	3.52	3.52
Case 2	Switches opened	7,9,32,28,14	7, 28,14,32,11
	active power loss (kW)	139.97	126.01
	reactive power loss (kVAR)	104.87	105.32
	system loading margin λ_{max}	5.23	5.52
	KMML	18482.35	19749
	NBVV	7	3
	VDI	0.0023	0.0029
	QLI	3.58	3.59
Case 3	Switches opened	33,34,35,36,37	33,34,35,36,37
	DG locations	32,14	31, 14
	Power factor	0.95, 0.95	0.76, 0.79
	DG sizes in kVA	2072, 1637.1	1751, 1428
	active power loss (kW)	113.15	58.7
	reactive power loss (kVAR)	90.63	47.2
	system loading margin λ_{max}	4.99	4.79
	KMML	17433.71	16560
	NBVV	0	0
	VDI	0	0
	QLI	3.76	3.74
Case 4	Switches opened	7,10,14,28,32	7,28,33,34,36
	DG locations	25, 9	12, 30
	DG sizes in kVA	3117.5, 956.6	1715.74,1751.9
	Power factor	0.95, 0.95	0.93, 0.81
	active power loss (kW)	58.86	22.7
	reactive power loss (kVAR)	46.54	25.9
	system loading margin λ_{max}	6.31	6.13
	KMML	23201.25	22415
	NBVV	0	0
	VDI	0	0
	QLI	3.72	3.7

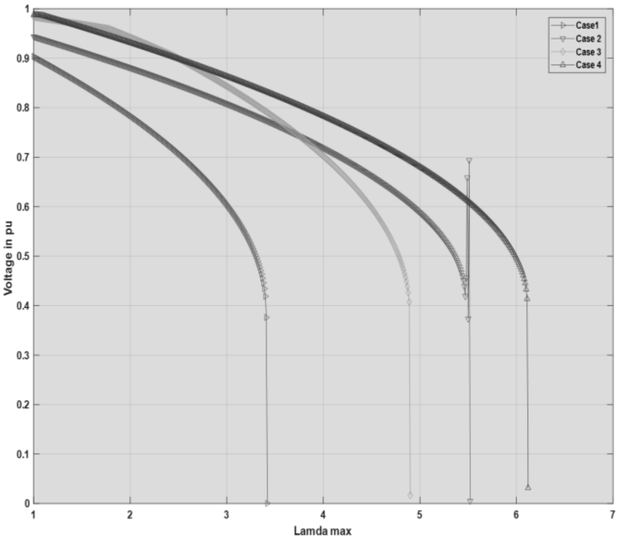

Figure 4. Load-ability Vs Voltage curve for identification of lambda max

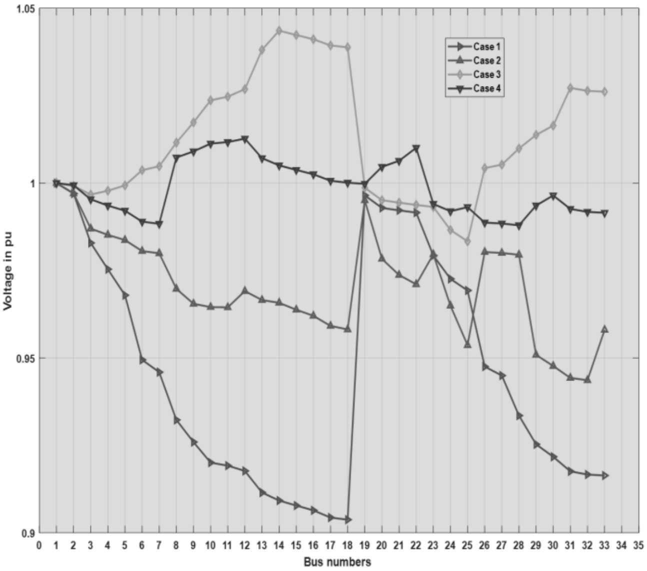

Figure 5. Voltage profile of Case 1,2,3 and 4.

Table 2. percentage improvement in load-ability and reduction in losses and DG size findings.

	Parameters considered	DABC	MIFPA	% improvement
case 2	active power loss (kW)	139.97	126.01	9.97
	system loading margin λ_{max}	5.23	5.52	5.25
	KMML	18482.35	19749	6.41
	NBVV	7	3	57.14
	VDI	0.0023	0.0029	20.69
	QLI	3.58	3.59	0.28
case 3	DG locations	32,14	31, 14	-
	DG1 size in kVA	2,072.00	1751	15.49
	DG2 size in kVA	1,637.10	1428	12.77
	active power loss (kW)	113.15	58.7	48.12
	reactive power loss (kVAR)	90.63	47.2	47.92
case 4	DG locations	25, 9	12, 30	-
	DG1 size in kVA	3117.5	1715.74	44.96
	DG2 size in kVA	956.6	1751.9	45.40
	active power loss (kW)	58.86	22.7	61.43
	reactive power loss (kVAR)	46.54	25.9	44.35

Table 2 shows it clearly that the how much percentage the loss and sizes reduced and lambda increased. Figure 4 shows the lambda values Vs minimum voltage at a particular bus when lambda values are increased.The Figure 5 shows the voltage profile of case 1,2,3 & 4. It can be seen that except case 1 and case 2 all the voltage profiles are within the limits. Case 3 has better voltage profile comparatively.

6. Conclusion

The change of the multi-objective function with the solution of the mixed integer flower pollination algorithm significantly improved the results. The case 2 has improved in all the parameter of measure. Case 3 and case 4 are also reduced the size of the DGs and losses in the system. As the fitness function is loss minimization and load-ability maximization, the optimal results with synchronous inverter considered DGs are used here and the results have a reflect of the multi-objective consideration compared to the conventional method in [2].

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