International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:2, No:10, 2008

Distribution Feeder Reconfiguration Considering Distributed Generators

R. Khorshidi , T. Niknam and M. Nayeripour

***Abstract*—**Recently, distributed generation technologies have received much attention for the potential energy savings and reliability assurances that might be achieved as a result of their widespread adoption. Fueling the attention have been the possibilities of international agreements to reduce greenhouse gas emissions, electricity sector restructuring, high power reliability requirements for certain activities, and concern about easing transmission and distribution capacity bottlenecks and congestion. So it is necessary that impact of these kinds of generators on distribution feeder reconfiguration would be investigated. This paper presents an approach for distribution reconfiguration considering Distributed Generators (DGs). The objective function is summation of electrical power losses A Tabu search optimization is used to solve the optimal operation problem. The approach is tested on a real distribution feeder.

***Keywords*—**Distributed Generator, Daily Optimal Operation, Genetic Algorithm.

I. INTRODUCTION

DISTRIBUTED generation technologies will be critical to the future energy. Energy access, energy security, poverty alleviation, and environmental considerations, combined with increasing fossil fuel prices, are key drivers for accelerating the adoption of affordable and reliable renewable energy and distributed generation. Distributed generation technologies, such as hydro (large and small), solar, geothermal, biomass, and wind, can deliver power with virtually zero emissions. Distributed generation (smaller generators that produce power locally apart from centralized grid) also has the potential to significantly reduce emissions and promote greater cost and network efficiencies.

A study done by the Electric Power Research Institute (EPRI) indicates that by 2010, 25% of the new generation will be distributed, and also, a study by Natural Gas Foundation concluded that this figure could be as high as 30%. Therefore, it is necessary that the impact of these generators on distribution systems would be studied [1]-[3].

Distribution feeder reconfiguration is one of the important control schemes at a distribution substation, which defined as altering the topological structure of distribution feeders by changing the open/closed states of sectionalizing and ties switches. Many researchers have investigated distribution feeder reconfiguration [4]-[16]. In most of them, the impacts of DGs on distribution system performance have not been studied in detail yet. Since the distribution feeder reconfiguration is a nonlinear optimization problem, one of the optimization algorithms should be used. Evolutionary methods can be used to solve these sorts of problems owing to independence on the type of objective function and constraints. In this paper an evolutionary method based on tabu search, is used to solve the optimization problem. The tabu search optimization has been used to solve several combinatorial optimization problems [17]- [20].

This paper presents a method for distribution feeder reconfiguration regarding DGs. The objective function is summation of electrical power losses.

Following this section, the proposed Distribution Feeder Reconfiguration is formulated in section II. Tabu search algorithm is presented in section III. Distributed generation modeling is discussed in section IV. In sections V, the feasibility of the proposed approach is demonstrated and compared with methods based on Differential Evolution and genetic algorithm for a real distribution test system.

II. DISTRIBUTION FEEDER RECONFIGURATION REGARDING DISTRIBUTED GENERATION

From a mathematical standpoint the distribution feeder reconfiguration with regard to distributed generation is an optimization problem with equality and inequality constraints.

A. Objective function

The objective function is the summation of electrical power losses as follows:

In below-mentioned equation:

N_{sub}: number of substations.
N_c: number of capacitors.
N_g: number of DGs.
N_{Sw}: number of switches.
N_{bus}: number of buses.
N_d : number of load variation steps.
N_t : number of transformers.
t: index which represents time steps of load level.
$\overline{X}$: state variables vector.
$\overline{Tap}$: tap vector representing tap position of all transformers for the next day.
$\overline{Tap_i}$: tap vector including tap position of the i[th] transformer for the next day.

This work was supported by Shiraz University of Technology.

R. Khorshidi is with Islamic Azad University–Fars Science and Research Branch, Iran.

T. Niknam and M. Nayeripour are with Shiraz University of technology, Shiraz, Iran (Email: niknam@sutech.ac.ir).

$Tap_i^{\,t}$:tap position of the i[th] transformer for the t[th] load level step.

$U_{ci}^{\,t}$: state of the i[th] capacitor in the light of turning on and off during time "t" ,which equals 0 or 1.

$\overline{U_{ci}}$: capacitors switching vector including state of i[th] capacitor for the next day.

$\overline{U_C}$: capacitors switching state vector including state of all capacitors for the next day.

$Sw_i^{\,t}$: state of the i[th] switch in the light of turning on and off during time "t" ,which equals 0 or 1.

$\overline{Sw_i}$: switching vector including state of i[th] switch for the next day.

$\overline{Sw}$: switching state vector including state of all switches for the next day.

$\overline{Q_G}$: DGs reactive power vector including reactive power of all DGs for the next day.

$\overline{Q_{gi}}$: DGs reactive power vector including reactive power of i[th] DG for the next day.

$Q_{gi}^{\,t}$: reactive power of the i[th] DG for the t[th] load level step.

$\overline{P_G}$: DGs active power vector including active power of all DGs for the next day.

$\overline{P_{gi}}$: DGs active power vector including active power of i[th] DG for the next day.

$P_{gi}^{\,t}$: active power of the i[th] DG for the t[th] load level step.

In this problem, it is assumed that tap position of transformers changes stepwise.

$$Min\ \ f(\overline{X}) = \sum_{t=1}^{N_d} Ploss^t \tag{1}$$

$$\overline{X} = [\overline{Tap}, \overline{U_C}, \overline{Sw},\ \overline{P_G}, \overline{Q_G}]$$
$$\overline{Tap} = [\overline{Tap_1}, \overline{Tap_2}, ..., \overline{Tap_{Nt}}]$$
$$\overline{Tap_i} = [Tap_i^{\,1}, Tap_i^{\,2}, ..., Tap_i^{\,Nd}];$$
$$\overline{Sw} = [\overline{Sw_1}, \overline{Sw_2}, ..., \overline{Sw_{Nsw}}]$$
$$\overline{Sw_i} = [\overline{Sw^1{}_i}, \overline{Sw^2{}_i}, ..., \overline{Sw^{Nd}{}_i}]$$
$$\overline{Q_G} = [\overline{Q_{g1}}, \overline{Q_{g2}}, ..., \overline{Q_{gNg}}]$$
$$\overline{Q_{gi}} = [Q^1{}_{gi}, Q^2{}_{gi}, ..., Q^{Nd}{}_{gi}]$$
$$\overline{U_C} = [\overline{U_{c1}}, \overline{U_{c2}}, ..., \overline{U_{cNc}}]$$
$$\overline{U_{ci}} = [U_{ci}^{\,1}, U_{ci}^{\,2}, ..., U_{ci}^{\,Nd}];$$
$$\overline{P_G} = [\overline{P_{g1}}, \overline{P_{g2}}, ..., \overline{P_{gNg}}]$$
$$\overline{P_{gi}} = [P_{gi}^{\,1}, P_{gi}^{\,2}, ..., P_{gi}^{\,Nd}];$$

B. *Constraints*

1. active power constraints of DGs:

$$(P_{gi}^{\,t})^2 + (Q_{gi}^{\,t})^2 \le S^2{}_{gi,\max} \tag{2}$$

$P_{gi}^{\,t}$ *and* $S_{gi,\max}$ are active power for tth load level step and apparent power of ith DGs respectively.

In this paper, it is assumed that active power of DGs has been previously specified and fixed by distribution operator.

2. Distribution line limits:

$$\left|P_{ij}^{Line}\right|^t < P_{ij,\max}^{Line} \tag{3}$$

$\left|P_{ij}^{Line}\right|^t$ and $P_{ij,\max}^{Line}$ are absolute power flowing over distribution lines and maximum transmission power between nodes i and j respectively.

3. Tap of transformers:

$$Tap_i^{\min} < Tap_i^{\,t} < Tap_i^{\max} \tag{4}$$

$Tap_i^{\min}$, $Tap_i^{\max}$ and $Tap_i^{\,t}$ are the minimum, maximum and current tap positions of the ith transformer respectively.

4. Unbalanced three-phase power flow equations:

Maximum allowable daily operating times of transformers:

$$DOT_i^{Trans} \le MADOT_i^{Trans} \tag{5}$$

DOT_i^{Trans} and $MADOT_i^{Trans}$ are the daily operating times and maximum allowable daily operating times of the ith transformer respectively.

5. Maximum allowable daily operating times of capacitors:

$$\sum_{t=1}^{Nd} U_{ci}^{\,t} \le MADOT_i^{Cap} \qquad i=1,2,3,\dots,Nc \tag{6}$$

$MADOT_i^{Cap}$ is the maximum allowable daily operating times of the ith capacitor.

6. Substation power factor:

$$Pf_{\min} \le Pf^{\,t} \le Pf_{\max} \tag{7}$$

$Pf_{\min}$, $Pf_{\max}$ and $Pf^{\,t}$ are the minimum, maximum and current power factor at substation bus during time t.

III. Tabu Search Algorithm

The basic concept of Tabu Search as described by Glover (1986) is "a meta-heuristic superimposed on another heuristic. The overall approach is to avoid entrainment in cycles by forbidding or penalizing moves which take the solution, in the next iteration, to points in the solution space previously visited. The Tabu search is fairly new, Glover attributes it's origin to about 1977 (see Glover, 1977). The method is still actively researched, and is continuing to evolve and improve. The Tabu method was partly motivated by the observation that human behavior appears to operate with a random element that leads to inconsistent behavior given similar circumstances. As Glover points out, the resulting tendency to deviate from a charted course, might be regretted as a source of error but can also prove to be source of gain. The Tabu

International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:2, No:10, 2008

method operates in this way with the exception that new courses are not chosen randomly. Instead the Tabu search proceeds according to the supposition that there is no point in accepting a new (poor) solution unless it is to avoid a path already investigated. This insures new regions of a problems solution space will be investigated in with the goal of avoiding local minima and ultimately finding the desired solution. The Tabu search begins by marching to a local minimum. To avoid retracing the steps used the method records recent moves in one or more Tabu lists. The original intent of the list was not to prevent a previous move from being repeated, but rather to insure it was not reversed. The Tabu lists are historical in nature and form the Tabu search memory. The role of the memory can change as the algorithm proceeds. At initialization the goal is make a coarse examination of the solution space, known as 'diversification', but as candidate locations are identified the search is more focused to produce local optimal solutions in a process of 'intensification'. In many cases the differences between the various implementations of the Tabu method have to do with the size, variability, and adaptability of the Tabu memory to a particular problem domain.

IV. Distributed Generator Modeling

Generally, DGs in distribution networks can be modeled as PV or PQ models.

Since distribution networks are unbalanced three phase systems, DGs can be controlled and operated in two forms:

- Simultaneous three-phase control
- Independent three-phase control or single phase control

Therefore, regarding the control methods and DGs models, four models can be defined for simulation of these generators (Fig.1):

- PQ model with simultaneous three-phase control
- PV model with simultaneous three-phase control
- PQ model with independent three -phase control
- PV model with independent three -phase control

It must be taken into account that when DGs are considered as PV models, they have to be able to generate reactive power to maintain their voltage magnitudes. In order to model DGs as PV buses many researchers have presented several procedures [21] and [22]. In this paper, DGs are modeled as the PQ buses with simultaneous three-phase control.

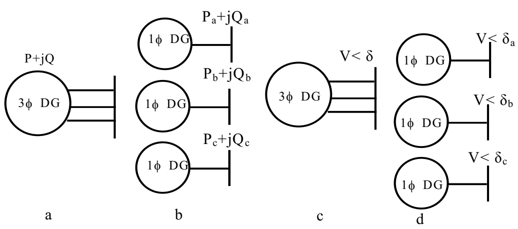

Fig. 1 Models of DGs
(a). PQ Model with simultaneous three-phase control
(b). PQ Model with separately three- phase control
(c). PV Model with simultaneous three- phase control
(d). PV Model with independent three- phase control

V. Simulation

In this section the proposed method is applied to distribution feeder reconfiguration on a realistic radial distribution test feeders (Fig 2).

It is assumed that there are 3 generators whose specifications are given in Table I.

Daily load variations are shown in Figs.3.

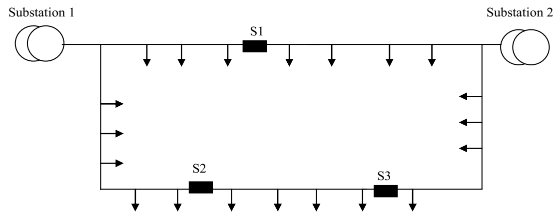

Fig. 2 Single Line Diagram

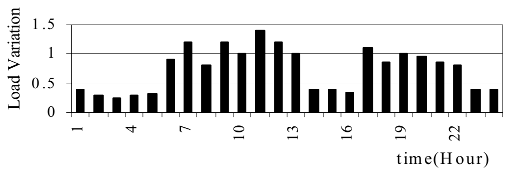

Fig. 3 Daily load variations

Table I presents a comparison among the results of Tabu search and Genetic Algorithm and Differential Evolution (DE) for 300 random tails.

TABLE I
COMPARISON OF AVERAGE AND STANDARD DEVIATION OF THE OBJECTIVE FUNCTION VALUES FOR 300 TRAILS

Method	Average (kW)	Standard Deviation	Best solution (kW)	Worst solution (kW)
Tabu Search	2498.40 6	15.67852	2475.55	2516.61
GA	2516.87	36.28	2481.38	2563.75
DE	2500.81	15.08	2484.436	2519.655

Fig.4 shows the convergence characteristic of the Tabu search for the best solution.

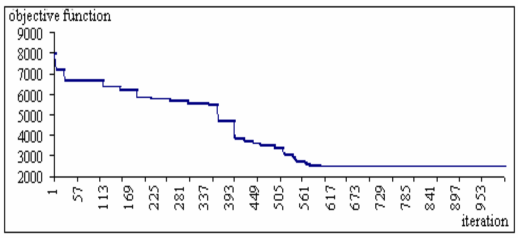

Fig. 4. Convergence Characteristics of the TABU SEARCH for the best solution

Table II give the comparison of results between the Tabu search and Genetic Algorithm for the best solution.

TABLE II
COMPARISON RESULT FOR THE BEST SOLUTION

	Tabu search	DE	GA
Objective function Value ($/h)	2475.55	2484.43	2481.38
Execution Time (S)	~600	~450	~400

Table IV shows status of switches.

TABLE IV
STATUS OF SWITCHES

Hour	S1	S2	S3	Max Voltage
1	0	1	1	82.61
2	0	1	1	109.1
3	0	1	1	124.8
4	0	1	1	109.8
5	0	1	1	104.
6	0	1	1	47.31
7	0	1	1	92.36
8	0	1	1	154.2
9	0	1	1	230.3
10	0	1	1	278.8
11	0	1	1	153.9
12	0	1	1	229.8
13	0	1	1	19.39
14	0	1	1	82.11
15	0	1	1	81.77
16	0	1	1	95.01
17	0	1	1	47.13
18	0	1	1	153.9
19	0	1	1	153.4
20	0	1	1	19.50
21	0	1	1	12.41
22	0	1	1	14.26
23	0	1	1	82.55
24	0	1	1	82.30

As shown in Tables I and II and Fig4, the Tabu Search can be used to apply to distribution feeder reconfiguration. The results of these Tables and Figs can be summarized as follows:

1. The method can be applied to a wide variety of similar optimization problems. On the other hand, this method can be used to non-differential and non-continuous objective function and constraints.
2. Active power losses in the Tabu Search are less than GA and DE.

VI. CONCLUSION

Since the number of DGs will be increasing and also DGs affect on distribution network, it is necessary, that impact of DGs on this part of power system to be studied. This paper presented an efficient algorithm for distribution feeder reconfiguration in distribution with DGs. Tabu search optimization is used to obtain the solution of the optimization problem The simulation result showed that the Tabu search could be implemented in practical distribution networks.

REFERENCES

[1]. T. Ackerman, G. Anderson and L. Soder, "Distributed generation: A definition", *Elsevier Science,* pp. 195-204, Dec 2000.

[2]. P. Chiradeja, and R. Ramakumar, "An approach to quantify the technical benefits of distributed generation", *IEEE Trans. On Energy Conversion*, vol.19, No.4, pp.764-773, Dec. 2004.

[3]. Losi and M. Russo, "Dispersed generation modeling for object-oriented distribution load flow" *IEEE Trans. On Power Delivery*, Accepted for future publication, 2005.

[4]. A. Merlin, H. Back, "Search for a minimal-loss operating spanning tree configuration in an urban power distribution system", in Proc. 5th Power System Computation Conf., Cambridge, U.K., pp. 1–18, 1975.

[5]. S.Civanlar,J. J. Grainger, H. Yin, and S. S. H. Lee, "Distribution feeder reconfiguration for loss reduction," IEEE Transactions on Power Delivery, vol. 3, no.3, pp. 1217–1223, July 1988.

[6]. M. E. Baran ,F. F.Wu, "Network Reconfiguration in Distribution Systems for Loss Reduction and Load Balancing," IEEE Transaction on Power System , vol. 4, no. 3, pp. 1401–1407, August 1989.

[7]. K Aoki, H Kuwabara, "An Efficient Algorithm for Load Balancing of Transformers and Feeders by Switch Operation in Large Scale Distribution Systems," LEEE Transactions on Power Delivery, vol. 3, no. 4, pp. 1865-1872, 1987.

[8]. T.Mc Dermott,I. Drezga, and R. P. Broadwater, "A Heuristic Nonlinear Constructive Method for Distribution System Reconfiguration," IEEE Transaction on Power System, vol. 14, no. 2, pp. 478–483, May 1999.

[9]. V. Borozan, D. Rajicic, and R. Ackovski, "Improved method for loss minimization in distribution networks," IEEE Transaction on Power System, vol. 10, no. 3, pp. 1420–1425, August 1995.

[10]. V. Gomes, s. Carneiro, " A New Reconfiguration Algorithm for Large Distribution Systems," IEEE Transaction on Power System, vol. 20, no. 3, pp. 1373–1378, August 2005.

[11]. S. K. Goswami , S. K. Basu, "A New Algorithm for the Reconfiguration of Distribution Feeders for Loss Minimization," IEEE Transaction on Power Delivery., vol. 7, no. 3, pp. 1484–1491, Jul. 1992.

[12]. RJ. Sarfi, M.M.A. Sarama and A.Y. Chikhani, "Distribution System Reconfiguration for Loss Reduction: An Algorithm Based on Network Partitioning Theory," Proceedings of PICA 1995, May 7-12, Salt Lake City, Utah, pp. 503-509, May 1995.

[13]. M.A.Kashem, loss Reduction in Distribution Networks Using Network Reconfiguration." p.p.93-103, PSC-96.

[14]. G.J. Peponis, W. Papadopoulos and ND. Hatziargyriou, "Distribution Network Reconfiguration to Minimize Resisive Line Losses," EEE Tms4ctions on Power Delivety, Vol. IO, No. 3, July, 1995, pp. 1338-1342.

[15]. L.Roytelman, V. Meinick, S. Lee, and R. Lugta,"Multi-Objective Feeder Reconfiguration by Distribution Management System," Proceedings of the 1995 LEEE Power 1 n d . s ~ ~ Compter Applications Confernce, Salt Lake City, Utah, May 7-12, 1995.

[16]. D. Shirmohammadi, H. W. Hong, "Reconfiguration of Electric Distribution Networks for Resistive Line Loss Reduction," IEEE Transaction on Power System, vol. 4, no. 1, pp. 1492–1498, April 1989.

[17]. W.M. Lin, F.-S. Cheng and M.T. Tsay, "An Improved Tabu Search for Economic Dispatch With Multiple Minima", IEEE Trans. On Power Systems, VOL. 17, NO. 1, FEB. 2002.

[18]. Glover F., Laguna M., "Tabu Search ", available: www.geocities.com/francorbusetti/laguna.pdf).

[19]. K.Nara and H. Hu, "A Reactive Power Resource Planning Method By Tabu Search In Competitive Markets", Power Con 2000 Proceedings of International Conference on Power Systems Technology, Vol. 2, 2000, p.p.1089-1094.

[20]. C.S. Chang, J.S. Low and D. Srinivasan, "Application of Tabu Search in Optimal System Design and Operation of MRT Power Supply Systems", IEE Proc. Electrical Power application, Vol.146, No.1, Jan. 1999.

[21]. Losi and M. Russo, "Dispersed generation modeling for object-oriented distribution load flow" *IEEE Trans. On Power Delivery*, Accepted for future publication, 2005.

[22]. Y. Zhu and K. Tomsovic, "Adaptive power flow method for distribution systems with dispersed generation", *IEEE Trans. On Power Delivery*, vol.17, No.3, pp. 822-827, July 2002.