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A GENETIC ALGORITHM APPROACH FOR PLANNING LOAD TRANSFER POINTS IN PRIMARY DISTRIBUTION NETWORKS

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Abstract. *This paper proposes an effective approach for planning the load transfer points in primary distribution networks, which is composed of radial and closed-loop feeder arrangements. First of all, the annual equivalent load at each bus is calculated. Next, a genetic algorithm approach has been proposed to solve this optimal combination problem, and the objective is minimization of the annual system power losses. Finally, the optimal load transfer points were chosen considering minimizing annual system power losses and the inequality constraints of maximum line voltage drops and ampere capacities of the conductor. The method presented in this paper are valuable to distribution engineers for planning the load transfer points between normally closed-loop and radial feeders.*
Keywords: Unbalanced distribution networks, Normally closed-loop feeder, Radial feeder, Genetic algorithm, Power losses

1. **Introduction.** In general, the distribution network can be divided into six common types; they are radial, link, open-loop, normally closed-loop, mesh, and interconnected network. The difficulty of the system operation and maintenance is all dependent on the configuration complexity. The radial network is the simplest type; on the contrary, the interconnected network is the most complex type. In Taiwan, radial and open-loop types of distribution network are usually served to the residential, commercial, and industrial customers; besides, the closed-loop type is to serve the science-based industrial parks, business districts, and computerized skyscrapers. According to the statistics of the frequency duration of customer outages in the Taipei City District of Taipower, it shows that the customer outages were mainly owing to faults occurring at the primary feeder. This major cause of customer outage accounted for more than forty percent of the total customer outages [1]. If we can make sure no service will be interrupted when a single fault occurs at the primary feeder, then service reliability can be improved considerably. A normally closed loop which is fed by the same power transformer is designed so that no customers connected to the loop will be out of service when a fault occurs at the primary feeder. However, this type cannot avoid interrupting while a fault occurs upstream the primary feeder. Once a fault occurs in the distribution substation or sub-transmission system, customers connected to the closed-loop circuit will be out of service. In order to improve the service reliability, the load transfer points must be designed and decided in system planning stage. In this paper, a genetic algorithm is proposed to search for load transfer points between the radial and normally closed-loop feeders.

2. Problem Description.

2.1. Configuration of the distribution networks. The operating scheme of the normally closed-loop feeders could be classified into normal and abnormal conditions. As shown in Figure 1, under normal condition, each closed-loop circuit is normally closed, and the tie breakers at two ends of the tie line are normally open. Under abnormal condition, there were five kinds of contingencies, which were busbar, lateral, feeder main, main transformer, and sub-transmission line faults. Only that sub-transmission line, main transformer, and busbars at 161kV/22.8kV distribution substation faults occur will cause outage, and then the load transfer procedure must be executed. Once there is a fault that occurs upstream the normally closed-loop feeders, a faulted closed-loop feeder will become two radial feeders, and the customers connected to faulted feeder will be transferred to healthy radial feeders using the load transfer facilities for power restoration. Therefore, the selection of the load transfer points is vital important in system planning stage. It will affect the operating performance and efficiency under abnormal operation conditions. Consequently, the better the load transfer points selected, the better the operation performance of the system becomes. In general, the major considering for planning the load transfer points is to keep the line flow distributions of transferred feeders uniformly as possible as it could be. This consideration will avoid the feeders over loading and reducing unbalanced among three phases. Accordingly, the optimal planning of the load transfer points must consider the ampere capacities of conductors and voltage drops in each feeder section to ensure the system operating safely during the faulted period. Additionally, a long-term operation under the load transfer condition must be considered; thus, this paper proposed an objective of minimizing system power losses with ampere capacity and voltage drop constraints to search for the optimal load transfer points under the abnormal condition. It will not only ensure the system is able to operate safely, but also increases the operating efficiency even under abnormal conditions.

2.2. Proposed genetic algorithm approach.

2.2.1. *Objective function.* Generally, the load transfer points have two load transfer conditions; one is the fault that occurs in distribution substation A, and the faulted closed-loop circuit was transferred to distribution substation B, C, and D; the other is the fault that occurs in distribution substation B, C, or D, and the faulted radial feeders were transferred to distribution substation A. In this paper, only the former condition was considered. Therefore, the system power losses can be formulated as (1).

$$TL_{loss} = \sum_{j=1}^{n} \sum_{p=a}^{c} \left(I_j^p\right)^2 \cdot R_j^p \tag{1}$$

where I_j^p is the current of the jth feeder section in phase a, b and c. Besides, R_j^p is the resistances of the jth feeder section in phase a, b and c. Using (1), the optimization problem can be expressed as (2).

Minimize

$$f = TL_{loss} \tag{2}$$

Subject to

$$VD_k^p < \max(VD_k^p)$$
$$I_j^p < \max(I_j^p)$$

where $\max(VD_k^p)$ is the maximum value for line voltage drop, and it is 3% of the system nominal voltage. Besides, the $\max(I_j^p)$ is the maximum allowable line current in feeder section j in each phase under load transfer condition, and the value is 450 A for 500 MCM cable in Taipower distribution system.

2.2.2. *Genetic model.* Genetic algorithm is based on the Darwinian principle of natural evolution [2,3]. This optimal search algorithm has been successfully applied to many fields applications, such as optimal sizing of shortest length problem [4], optimization of the gains of a PID controller [5], PV-Diesel-Battery system [6], optimization of short-haul airline crew pairing problems [7], multi-user detection in DS-CDMA systems [8], simulating fuzzy numbers for solving fuzzy equations [9] and fuzzy PID controller [10]. According to the genetic algorithm, each MV/LV substation, which was corresponding to a load transfer point, was mapped to a gene according to the bus number in different distribution substations. Hence, the length of chromosome (string) was decided by the number of interconnected distribution substations. In this paper, the gene of ith MV/LV load transfer substation (LTS_i) in an interconnected distribution substation was encoded by binary code, B_i, and was decoded by (3).

$$LTS_i = D_{i,\min} + \frac{(D_{i,\max} - D_{i,\min}) \times B_i}{2^{n_i} - 1} \tag{3}$$

where $D_{i,\min}$ and $D_{i,\max}$ denote the lower and upper limits of the substation number; n_i is the binary bits of B_i. In this paper, the chromosome represented the load transfer points. Owing to the fact that each load transfer substation pair is formed with a tie line and two load transfer substations at two line ends, the length of chromosome, which is composed of six load transfer substation pairs, is twelve times of the LTS_i. Equation (4) showed the fitness function for the proposed algorithm.

$$FIT = TL_{loss} \tag{4}$$

Minimize

$$FIT \tag{5}$$

It is needed to evaluate the fitness of individuals within the population for every generation. Consequently, a three-phase Newton-Raphson power flow program was developed and used to compute the total system power losses, voltage drops and line currents in unbalanced distribution network. From the proposed approach, an algorithm can be organized by the following steps:

Step 1: Input system topology, bus data, branch data, and basic setting, etc.
Step 2: Encode all the load transfer points into corresponding chromosome.
Step 3: Initialize the population, set probabilities of crossover and mutation.
Step 4: Evaluate the fitness for each individual in population of the first generation by three-phase Newton-Raphson power flow method.
Step 5: Crossover, mutation between individuals, and then reproduction, ordering, selections of individuals to form the next generation populations.
Step 6: Evaluate the fitness with respect to every chromosome strings by three-phase Newton-Raphson power flow method.
Step 7: Meet the convergence rule? If it is convergence, output the optimal load transfer points and corresponding system power losses, voltage and current profiles, etc.; else go to Step 6.

3. **Numerical Results.** A practical distribution network with 68 MV/LV substations as shown in Figure 1 was used to demonstrate the proposed approach. Table 1 showed the equivalent annual loads, which is calculated based on the type of distribution transformer bank and the load on secondary side with their corresponding load patterns; besides, the line length of each line section is shown in Table 2. The initial population and its corresponding string were generated randomly. The execution procedure will last until generations meet convergence condition. The simulation results are shown in Figures 2-5. The outcomes demonstrate that the optimal load transfer points are 7&38, 8&33, 16&38, 17&59, 26&33, and 27&53, respectively, where "7&38" means that bus 7 and bus 38 are

tied together, and so on. Moreover, the corresponding annual system power losses are 5.954 MW as shown in Figure 2. Finally, the voltage profile, current profile, as well as real and reactive power line flow are listed in Figures 3-5. According to the results, it is sure that the system can operate stably and with high efficiency without violating voltage drop and ampere capacity constraints even more under abnormal conditions.

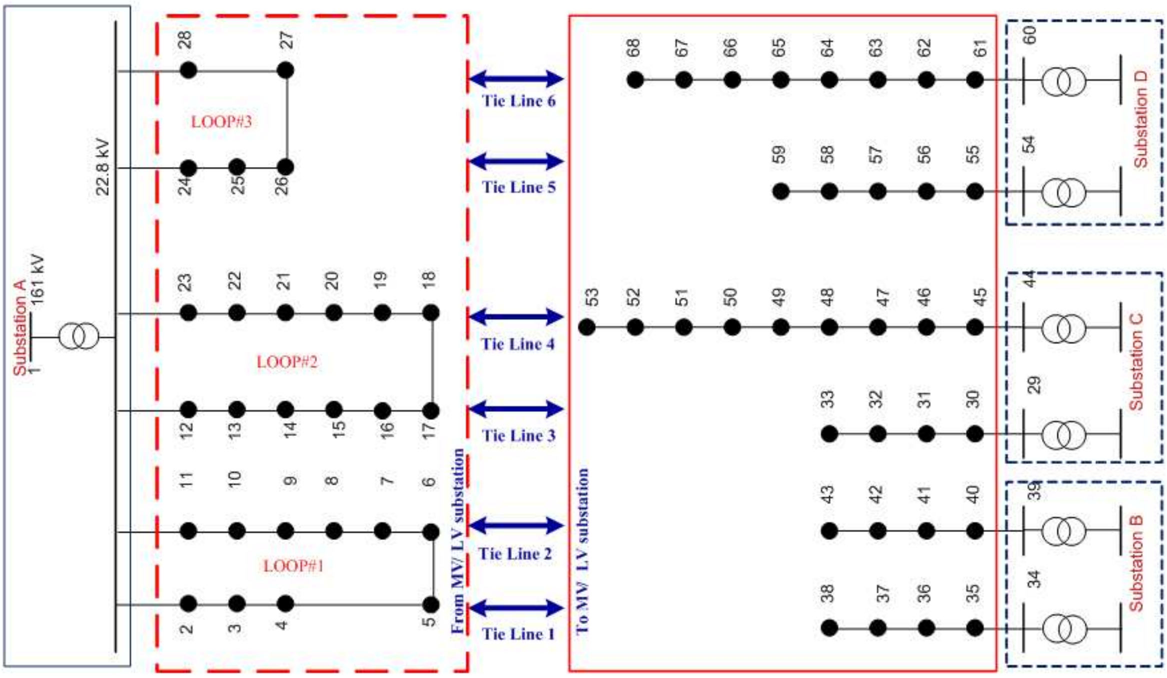

FIGURE 1. Schematic of the radial and normally closed-loop feeders

TABLE 1. Equivalent annual loads

Bus No.	MW	Mvar	Bus No.	MW	Mvar
1	0	0	35	1.075	0.353
2	0.256	0.084	36	1.168	0.384
3	0.213	0.07	37	2.769	0.91
4	2.943	0.967	38	2.049	0.673
5	0.126	0.041	39	0	0
6	2.575	0.846	40	1.417	0.465
7	1.908	0.627	41	1.692	0.556
8	4.717	1.55	42	2.743	0.901
9	0.387	0.127	43	0	0
10	1.075	0.353	44	0	0
11	1.349	0.443	45	0.266	0.087
12	0.569	0.187	46	0.357	0.117
13	1.377	0.452	47	1.303	0.428
14	0.836	0.274	48	1.938	0.636
15	5.347	1.757	49	1.389	0.456
16	1.123	0.369	50	0.666	0.219
17	2.26	0.742	51	0.289	0.095
18	0.877	0.288	52	2.109	0.693
19	1.021	0.335	53	1.285	0.422
20	0.902	0.296	54	0	0
21	0.367	0.12	55	1.662	0.546
22	1.126	0.37	56	0	0
23	0.47	0.154	57	3.992	1.312
24	1.321	0.434	58	1.52	0.499
25	1.462	0.48	59	1.384	0.454
26	3.709	1.219	60	0	0
27	5.88	1.932	61	1.279	0.42
28	3.021	0.993	62	1.544	0.507
29	0	0	63	1.209	0.397
30	0.905	0.297	64	0.191	0.063
31	1.1	0.361	65	1.305	0.429
32	1.114	0.366	66	0.563	0.185
33	3.407	1.12	67	0.979	0.321
34	0	0	68	1.161	0.381

TABLE 2. Line length of each line section

Line No.	From	To	Length (m)	Line No.	From	To	Length (m)
1	2	3	322	34	37	38	655
2	3	4	368	35	1	39	0
3	4	5	506	36	39	40	1271
4	5	6	483	37	40	41	3067
5	6	7	161	38	41	42	424
6	7	8	253	39	42	43	524
7	8	9	184	40	1	44	0
8	9	10	759	41	44	45	339
9	10	11	115	42	45	46	187
10	12	13	161	43	46	47	412
11	13	14	35	44	47	48	136
12	14	15	115	45	48	49	917
13	15	16	23	46	49	50	197
14	16	17	81	47	50	51	169
15	17	18	161	48	51	52	1185
16	18	19	184	49	52	53	207
17	19	20	92	50	1	54	0
18	20	21	621	51	54	55	804
19	21	22	460	52	55	56	716
20	22	23	828	53	56	57	449
21	24	25	265	54	57	58	116
22	25	26	391	55	58	59	253
23	26	27	230	56	1	60	0
24	27	28	299	57	60	61	422
25	1	29	0	58	61	62	611
26	29	30	345	59	62	63	1130
27	30	31	357	60	63	64	1335
28	31	32	564	61	64	65	2456
29	32	33	322	62	65	66	519
30	1	34	0	63	66	67	422
31	34	35	153	64	67	68	115
32	35	36	511				
33	36	37	45				

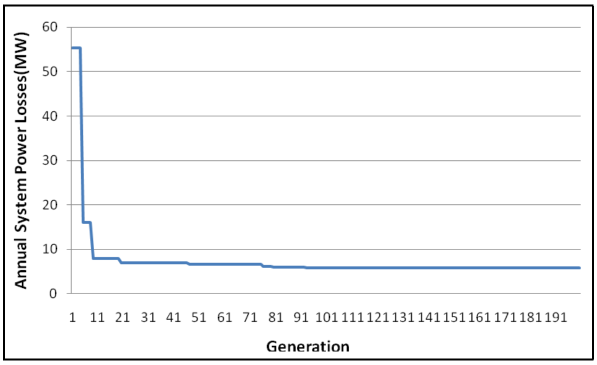

FIGURE 2. Simulation result with 200 generations

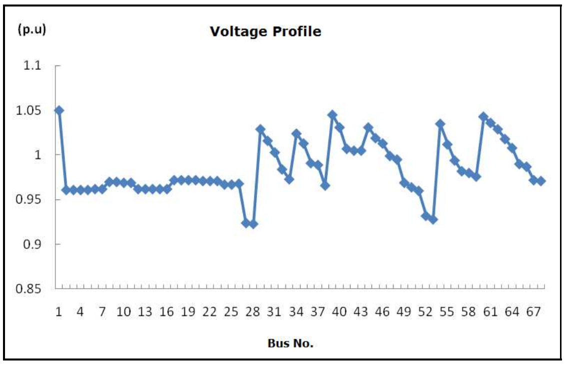

FIGURE 3. Simulation result of voltage profile

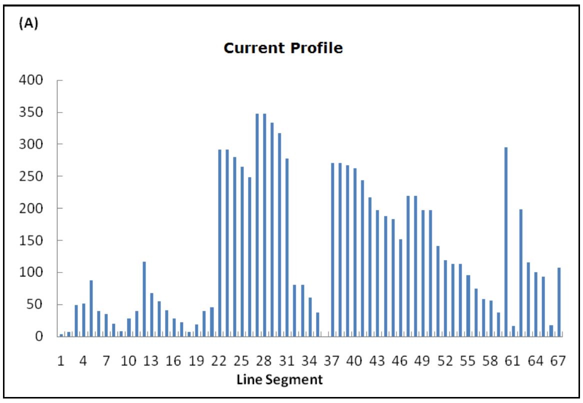

FIGURE 4. Simulation result of current profile

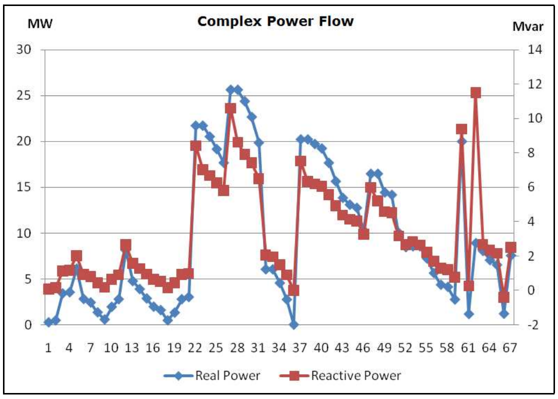

FIGURE 5. Simulation result of complex power flow

4. Conclusion. An effective genetic algorithm approach has been presented to search for an optimal load transfer points between radial and normally closed-loop primary feeders in primary distribution networks. Based on the proposed approach, a program that is composed of genetic algorithm and three-phase Newton-Raphson power flow method has been developed to perform the optimal load transfer points considering minimizing annual system power losses and the given constraints. Numerical results of the practical distribution network showed that the selected optimal load transfer points are with minimum power losses and safely operating range of voltage and current profiles. Thus, the proposed method presented in this paper is helpful for distribution engineers for planning the load transfer points between radial and normally closed-loop primary feeders in primary distribution network.

REFERENCES

[1] T. H. Chen, W. T. Huang, G. C. Pu, Y. F. Hsu and T. Y. Guo, Feasibility study of upgrading primary feeders from radial and open-loop to normally closed-loop arrangement, *IEEE Transactions on Power Systems*, pp.1308-1316, 2004.

[2] Z. Michalewicz, *Genetic Algorithms + Data Structures = Evolution Programs*, Springer-Verlag Berlin, Heidelberg, NY, 1996.

[3] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addition-Wesley Publishing Company, Inc., 1989.

[4] F. T. Lin and T. S. Shih, Solving the shortest path problem with imprecise ARC length using a two-stage two-population genetic algorithm, *International Journal of Innovative Computing, Information and Control*, vol.7, no.12, pp.6889-6904, 2011.

[5] M. S. Ricardo, A. Rodriguez, O. Castillo and L. T. Aguilar, Gain optimization for inertia wheel pendulum stabilization using particle swarm optimization and genetic algorithms, *International Journal of Innovative Computing, Information and Control*, vol.8, no.6, pp.4421-4430, 2012.

[6] H. Suryoatmojo, A. A. Elbaset, Syafaruddin and T. Hiyama, Genetic algorithm based optimal sizing of PV-Diesel-Battery system considering CO2 emission and reliability, *International Journal of Innovative Computing, Information and Control*, vol.6, no.10, pp.4631-4649, 2010.

[7] C.-H. Chen, T.-Y. Chou, T.-K. Liu, J.-H. Chou and C.-N. Lee, Optimization of short-haul airline crew pairing problems using a multiobjective genetic algorithm, *International Journal of Innovative Computing, Information and Control*, vol.6, no.9, pp.3943-3959, 2010.

[8] T.-H. Tan, Y.-F. Huang and F.-T. Liu, Multi-user detection in DS-CDMA systems using a genetic algorithm with redundancy saving strategy, *International Journal of Innovative Computing, Information and Control*, vol.6, no.8, pp.3347-3364, 2010.

[9] F.-T. Lin, Simulating fuzzy numbers for solving fuzzy equations with constraints using genetic algorithms, *International Journal of Innovative Computing, Information and Control*, vol.6, no.1, pp.239-253, 2010.

[10] L. Yao and C.-C. Lin, On a genetic algorithm based scheduled fuzzy PID controller, *International Journal of Innovative Computing, Information and Control*, vol.5, no.10(B), pp.3593-3602, 2009.