Parallel Genetic Algorithm-Tabu Search Using PC Cluster System for Optimal Reconfiguration of Distribution Systems

Kyeong-Jun Mun*, Hwa-Seok Lee and June-Ho Park†**

Abstract - This paper presents an application of the parallel Genetic Algorithm-Tabu Search (GA-TS) algorithm, and that is to search for an optimal solution of a reconfiguration in distribution systems. The aim of the reconfiguration of distribution systems is to determine the appropriate switch position to be opened for loss minimization in radial distribution systems, which is a discrete optimization problem. This problem has many constraints and it is very difficult to solve the optimal switch position because of its numerous local minima. This paper develops a parallel GA-TS algorithm for the reconfiguration of distribution systems. In parallel GA-TS, GA operators are executed for each processor. To prevent solution of low fitness from appearing in the next generation, strings below the average fitness are saved in the tabu list. If best fitness of the GA is not changed for several generations, TS operators are executed for the upper 10% of the population to enhance the local searching capabilities. With migration operation, the best string of each node is transferred to the neighboring node after predetermined iterations are executed. For parallel computing, we developed a PC-cluster system consisting of 8 PCs. Each PC employs the 2 GHz Pentium IV CPU and is connected with others through switch based rapid Ethernet.

To demonstrate the usefulness of the proposed method, the developed algorithm was tested and is compared to a distribution system in the reference paper. From the simulation results, we can find that the proposed algorithm is efficient and robust for the reconfiguration of distribution system in terms of the solution quality, speedup, efficiency, and computation time.

Keywords: Distribution system reconfiguration, Genetic Algorithm, Parallel Genetic Algorithm-Tabu Search (GA-TS), PC-cluster system, Tabu Search

1. Introduction

Because there are many kinds of load type, distribution systems are widely spread and complicated. Also, because distribution system load changes frequently and load demand increases annually, effective distribution system reconfiguration strategy is needed to reduce the power loss of distribution systems. Distribution systems in urban areas operate radially by opening relevant tie sectionalizing switches. Moreover, effective distribution system reconfiguration by changing feeder configuration through remote controlled switch, one of the important functions of the distribution, makes it possible to reduce power loss, subject to several operational constraints such as line/transformer capacity limits and voltage drop limits.

However, the number of switches and constraints to be considered in the distribution reconfiguration problem is very large, and it is difficult to obtain optimal reconfiguration in a reasonable time limit because it is a non-linear optimization problem.

Recently, several works on reconfiguration of distribution systems have been reported. Shirmohammadi and Hong [1] proposed the branch and bound method. To get the optimal solution, they opened the switch with the lowest current derived in the load flow while all switches were closed. Baran and Wu [2] proposed branch exchange operation to solve the reconfiguration problem for the distribution systems. Taylor and Lubkeman [3] used the heuristic method for reconfiguration problems. Brauner and Zabel [4] implemented the expert system. However, the results of these methods are only approximates and local minima.

Therefore, algorithms with global searching capability such as simulated annealing (SA) [5], genetic algorithm (GA) [6], and tabu search (TS) [7] are proposed to solve the power system optimization problem, especially the reconfiguration of distribution systems. Unfortunately, SA requires a great deal of time to obtain optimal solution. GA can attain near optimal solution quickly, but it takes much time to get global optimal solution due to its probabilistic

The Transactions of the Trans. KIEE, Vol.53A, No.10, pp.556-564, OCT. 2004: A paper recommended and approved by the Editorial Board of the KIEE Power Engineering Society for translation for the KIEE International Transaction on Power Engineering.

* Korea Atomic Energy Research institute (KAERI), Korea. (kjmun@kaeri.re.kr)

** Dept. of Electrical Engineering, Koje College, Korea. (hslee@koje.ac.kr)

† Corresponding Author: Division of Electrical and computer Engineering, Pusan National University, Korea .(parkjh@pusan.ac.kr)

Received August 11, 2004 ; Accepted September 7, 2004

searching characteristics. TS is based on heuristics and it generally finds a good solution. However, its performance is affected by the initial solution. Furthermore, if local minima are encountered, it takes a long time to escape them by diversification operation. Therefore, recently, several hybrid algorithms by paralleling GA, SA, and TS have been proposed to obtain better solutions, and to reduce the computation time by mixing the advantages of each algorithm [8, 9].

In parallel computing, problems are divided into several sub problems, and allocated to each processor. This reduces computation time and enhances computation efficiency. To realize parallel algorithm, parallel computers like the transputer have been introduced. But these computers are costly to use. Recently, PC clustering, one of the types of parallel or distributed processing systems, which is composed of a collection of interconnected workstations or PCs working together as single, integrated computing resources, has been used for parallel computing [10, 11].

In this paper, parallel hybrid Genetic Algorithm-Tabu Search(GA-TS) has been developed for the reconfiguration of distribution systems. In parallel hybrid GA-TS, GA operators for searching globally and TS operators for searching locally are mixed together. The proposed algorithm is paralleled by the PC cluster system to enhance both the solution quality and computation time. Therefore, the proposed algorithm obtains superior solution and reduces the computation time rather than GA and TS.

To verify the usefulness of the proposed method, the newly developed algorithm has been tested and compared with a 32 and a 69 bus distribution system in the reference paper [5]. From the simulation results, it is found that the proposed algorithm reaches optimal solution faster than GA and TS. Also as computation nodes increase, the computation time required by the proposed algorithm greatly reduces with good solution quality.

2. Reconfiguration of the Distribution System

Distribution systems deliver power to customers from distribution substations feeders. The aim of the distribution system reconfiguration is to determine the correct switch position to be opened for loss minimization in a radial distribution system. The monitoring and control functions of the distribution automation system make it possible to control remote switches relevantly according to the decision of dispatchers. In this paper, the open switch positions are determined for reconfiguration to minimize power losses while satisfying several operational constraints such as line/transformer capacity limits, voltage drop constraints, and radial constraints. Objective function is expressed as below by Eq. (1).

$$Min \quad P_{loss} = Min \sum_{i=1}^{n} \frac{P_i^2 + Q_i^2}{|V_i|^2} r_i^2 \tag{1}$$

where, P_i, Q_i : real and reactive power injected to the i-th node

V_i : node voltage of the i-th node

r_i : resistance of the i-th section

Constraints considered in this paper are line current capacity constraint, voltage drop limit constraint, and radial constraint. Constraints are described as below.

a) line current capacity constraint

$$I_k \le I_{\lim} \tag{2}$$

where, I_k : current of the k-th section

$I_{\lim}$: line current capacity

b) voltage drop limit constraint

$$V_{\min} \le V_k \le V_{\max} \tag{3}$$

where, V_k : node voltage of the k-th node

$V_{\min}$: lower bound of the node voltage

$V_{\max}$: upper bound of the node voltage

3. Parallel Genetic Algorithm-Tabu Search Using PC Clustering

GA, one of the probabilistic optimization methods, is robust, and it is able to solve complex and global optimization problems. However, the disadvantage of GA is that it suffers from excessive computation time before providing an accurate solution because of minimal use of prior knowledge and no utilization of local information [6]. Whereas TS is a meta- heuristic method that guides the search for the optimal solution making use of a flexible memory system that allows the search history to be taken into consideration [7].

In this paper, parallel hybrid Genetic Algorithm-Tabu Search(GA-TS) has been developed for the reconfiguration of distribution systems. In parallel hybrid GA-TS, GA with global searching capability locates relevant solutions quickly. With this population, TS operation obtains better solutions quickly, that is, TS searches locally for the near optimal solution found by GA operation. Furthermore, both solution quality and computation time are enhanced by paralleling the proposed algorithm with the PC-cluster system.

3.1 PC Cluster System

Since the mid 1980s, high performance computers have been needed according to the development of large-scale science and engineering. Since supercomputers are expensive, cluster systems were developed to replace supercomputers because of their availability of inexpensive high performance PCs, high speed networks, and development of integrated circuits.

PC cluster systems provide higher availability as well as enhanced performance by lower cost through the interconnection of several PCs or workstations. PC cluster systems are very competitive with parallel machines in terms of the ratio of cost to performance because clustering is one of the types of parallel or distributed processing systems, which is composed of a collection of interconnected low cost PCs working together as single and integrated computing resources. Also, it is easy to add nodes that construct the PC cluster. A basic construction diagram for the PC cluster is shown in Fig. 1.

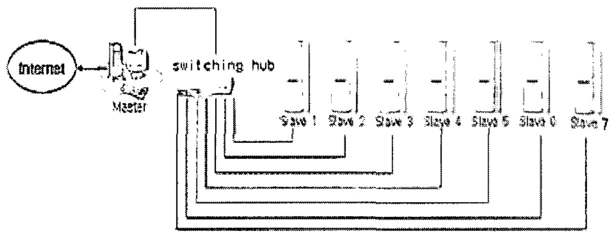


Fig. 1 Structure of PC cluster system

The performance of the PC cluster system depends on the quality of the message passing system, libraries, and compilers for parallel programming and performance of individual nodes. Therefore, it is important to select each component described above properly to obtain superior performance. The PC cluster system implemented in this paper is composed of 8 nodes based on fast Ethernet with Ethernet switch. For the operating system, the master node uses a Windows 2000 server, and slave nodes use Windows 2000 pro. To connect each node, fast Ethernet cards and switching hubs were used. In data communication, a MPI library was utilized, which is effective for parallel application by using the message-passing method through TCP/IP over the Internet. Symantec PC-anywhere was used for remote control of each node, and MS visual C++ 6.0 was used for compilers of parallel programming. Table 1 describes the specifications of the 8-node PC cluster system developed in this paper.

Table 1 Specifications of 8-node PC cluster system

CPU	Intel 2.0 GHz
Mother Board	LeoTech P4XFA
Chipset	VIA P4X266A
RAM	DDR SD RAM 256MB
HDD	Samsung 40GB 5600rpm
NIC	3Com 3CSOHO 100-TX
Network Switch	3Com 3C16465C Switch
Operating System	Window 2000 Server Window 2000 Pro
MPI Library	MPICH 1.2.5
Compiler	Visual C++ 6.0

3.2 Parallel Hybrid Genetic Algorithm-Tabu Search

GA, one of the probabilistic optimization methods, is robust, and it is able to solve complex and global optimization problems. However, the disadvantage of GA is that it can suffer from excessive computation time before providing an accurate solution because of minimal use of prior knowledge and no utilization of local information [6]. On the other hand, TS is a meta-heuristic method that guides the search for the optimal solution making use of a flexible memory system that allows the search history to be taken into consideration [7]. But TS is affected by initial solution, and if a local minimum is encountered, it takes an extensive amount of time to execute a diversification operation to escape that local minimum.

In this investigation, parallel hybrid GA-TS was developed, which uses both GA with good global search capability and TS with good local search capability. The proposed algorithm is paralleled by the PC cluster system to enhance both the solution quality and computation time. Fig. 2 shows the connection structure among each GA-TS node.

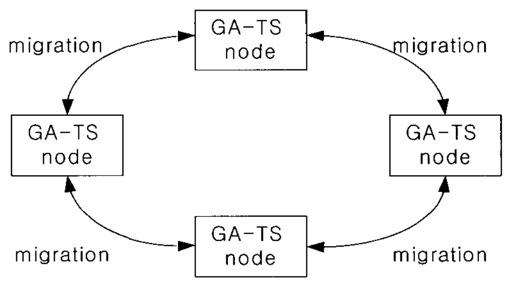


Fig. 2 Connection Structure of each GA-TS node

In parallel hybrid GA-TS, GA operators are executed for each node during several generations. But individuals of the GA-TS node are not enhanced for a specified generation; TS operation is executed for the upper 10% of the GA population to enhance the local search capability. That is, after sorting GA population according to the fitness, the upper 10% of strings are set as the initial solution of the TS and search processes are executed for specified iterations. Furthermore, strings below the average fitness that are not to appear in the next generation are saved during the specified generations. If the string saved does appear, the fitness is lowered so as not to select it again in the next generation so as to enhance the global search capability of GA. With each GA-TS node that is connected to the neighboring GA-TS node as a ring type, as shown in Fig. 2, the best solution of each GA-TS node is transferred to the neighboring GA-TS nodes by migration operation.

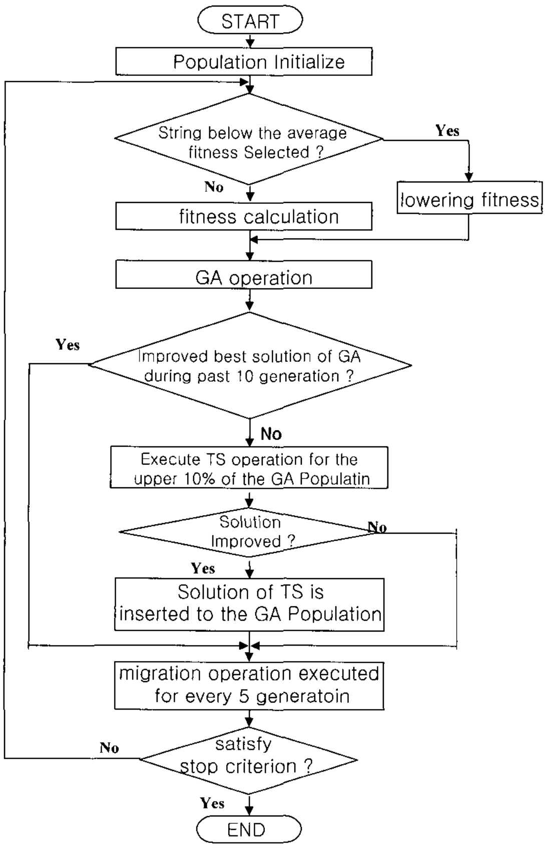


Fig. 3 Flowchart of the proposed method

The proposed parallel GA-TS algorithm is composed of the global searching procedures by GA operation, local searching procedures by TS operation, procedures of prohibiting the strings below the average fitness of each generation, procedures of the TS operation with upper 10% of the GA population and migration operation among GA-TS nodes. The major procedures of the parallel GA-TS are as follows:

(1) ***Global searching procedures by GA operation***: For each GA-TS node, population of the GA-TS node is divided and allocated to each GA-TS node to enhance the solution quality and computation time.

(2) ***Procedures of prohibiting the strings below the average fitness of each generation***: Strings below the average fitness that are not to appear in the next generation are saved during the specified generations. If the string saved does appear, the fitness is lowered so as not to that string in the next generation. This enhances the global search capability of GA.

(3) ***Procedures of the TS operation with upper 10% of the GA population to enhance the searching capability***: When individuals of GA-TS node are not enhanced for a specified generation, TS operation is executed for the upper 10% of the GA population to enhance the local search capability. That is, after sorting GA population according to the fitness, the upper 10% of strings are set as the initial solution of the TS and search processes are executed for specified iterations.

(4) ***Migration operation among GA-TS nodes***: The best solution of each GA-TS node is transferred to the neighboring GA-TS nodes by migration operation.

The flowchart for searching optimal solutions using the proposed parallel GA-TS is presented in Fig. 3.

3.3 Genetic Algorithm and Tabu Search for the Reconfiguration of Distribution Systems

To minimize the power loss in distribution system reconfiguration problems, we should determine the switch ON/OFF state while the distribution system is in operation, which is the combinatorial optimization problem. To get the effective reconfiguration of a distribution system by the proposed parallel GA-TS, we should design GA-TS appropriately for the distribution system reconfiguration problem.

To solve the reconfiguration problem by TS, initial solution for TS is randomly selected as open switch for each loop of the distribution system to satisfy radial constraint and set it as tabu status. As shown in Fig. 4, neighborhood solutions are defined by changing the status of the adjacent 2 switches to the normal open switch of the current solution. TS continues the search process by moving the current solution to the best solution among neighborhoods, which is not in the tabu list to prevent

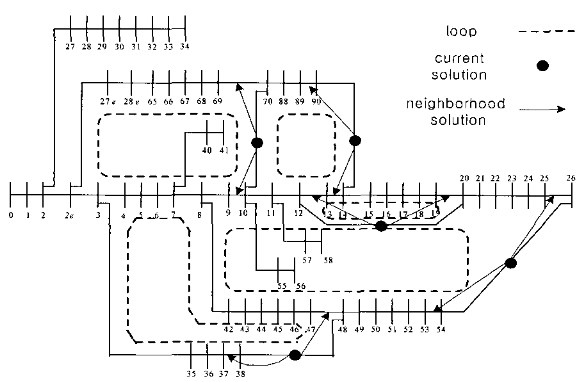


Fig. 4 Generation method of neighborhood solutions for distribution system reconfiguration

cycling. In the neighborhood search procedure of TS, TS carries out a local search around the current solution. TS represents good global searching capabilities if diversification operation and aspiration criteria procedures are added. In the intensification procedure, if the generated neighborhood displays a better solution than the current solution, a move to this direction is executed until there is no improvement.

Whereas, GA encodes the open switch position of each loop for the distribution system, and generates initial population. GA operations, i.e., crossover and mutation operations are applied to the individuals of the present generations to create the next generation. GA shows the global search capability. Fig. 5 represents the string architecture of the GA for the distribution system reconfiguration problem. As shown in Fig. 5, each string represents the open switch position of each loop for the distribution system.

string 1	SW_{11}	SW_{12}	···	SW_{1N}
string 2	SW_{21}	SW_{22}	···	SW_{2N}
·		·		
·		·		
·		·		
string p	SW_{p1}	SW_{p2}	···	SW_{pN}

Where, SW_{ij} : open switch position of the j-th loop of the i-th string

N : no. of loops in distribution system

p : no. of strings

Fig. 5 Coding method of GA for distribution system reconfiguration

In the evaluation procedures of hybrid GA-TS, the fitness of each string can be obtained by the following equations. As shown in Eq. (4), fitness is composed of power losses and several constraints such as line/ transformer capacity limit, voltage drop limit, and radial constraint.

$$Fitness = \frac{\alpha}{\beta + Loss + \sum_i penalty_i} \quad (4)$$

where, $Loss$: power loss [kW]

$penalty_i$: penalty of the i-th constraint, $i = 1, 2, 3$

$$penalty_1 = \begin{cases} 0 & if \ I_a < I_{\max} \\ \gamma_1 & otherwise \end{cases}, \quad a = 1, 2, \cdots, T$$

$$penalty_2 = \begin{cases} 0 & if \ V_a < V_{\max} \\ \gamma_2 & otherwise \end{cases}, \quad a = 1, 2, \cdots, T$$

$$penalty_3 = \begin{cases} 0 & if \ radial \ constraint \ satisfied \\ \gamma_3 & otherwise \end{cases}$$

I_a : line current of section a

V_a : voltage of section a

$V_{\max}$: allowable maximum voltage drop

$I_{\max}$: line current capacity

T : no. of section

$\alpha, \ \beta, \ \gamma_1, \ \gamma_2, \ \gamma_3$: constants

In the reproduction procedure, population of the next generation is selected by roulette wheel selection according to the fitness. Crossover, mutation operation and elitism are used for the GA operation.

4. Case Studies

To demonstrate the usefulness of the proposed method, the reconfiguration of distribution systems was conducted on a 32 bus and a 69 bus distribution system [5]. The performance of the proposed algorithm is compared to that of GA, TS and GA with tabu list.

4.1 32 bus distribution system

The 32 bus distribution system has 5 loops, and sectionalizing switches are placed between load buses. Fig. 6 shows the test system. Feeder voltage is set to 12.66 kV, loads are modeled as constant power, and the total loads are 3,715 kW and 2,300 kVAR, respectively. Table 2 describes the simulation parameters of the proposed method. Fig. 7 describes the PC cluster system developed in this paper.

To demonstrate the usefulness of the proposed method, results of the proposed methods are compared with those of GA , TS only and GA with tabu list for the string below the average fitness not to be alive in the next generation. Fig. 8 presents the loss according to the generation for each method.

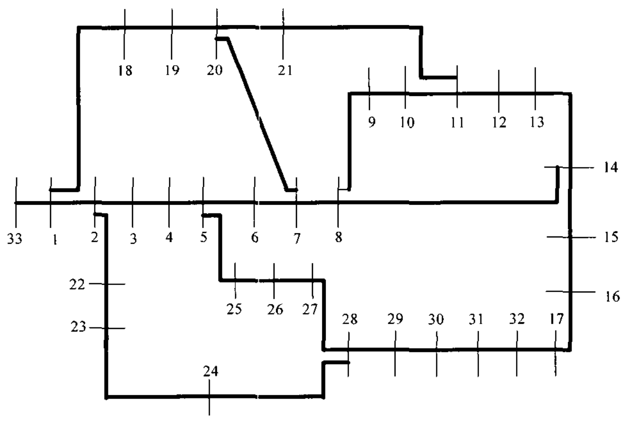


Fig. 6 Example distribution system with 32 buses

Table 2 Simulation coefficients in the parallel GA-TS

Method	Coefficient	Value
GA	no. of generations	200
	no. of populations	40
	crossover probability	0.8
	mutation probability	0.01
TS	no. of iterations	400
	tabu list length	30
α		500
β		0

Fig. 7 PC cluster system for the proposed method

As generation increased, the loss found in each generation decreased to 131.85 kW with switches of (6-7), (8-9), (13-14), (24-28), and (31-32) opened approximately after 20 generations. As compared with the loss of 186.04 kW of the initial configuration, loss of the optimal solution reduced 29.1% and minimum voltage increased 2% from 11.69 kV to 11.89 kV. Also, GA with tabu list found optimal solution faster than GA alone. From the simulation results, we can find that the global searching capability enhances by relevantly combining the advantages of GA and TS. Also computation time is greatly reduced by parallel computation with PC clustering. Table 3 describes open switch position and loss of the initial solution and optimal solution by the proposed method, respectively. Fig. 9 presents the initial and optimal configuration by the proposed method.

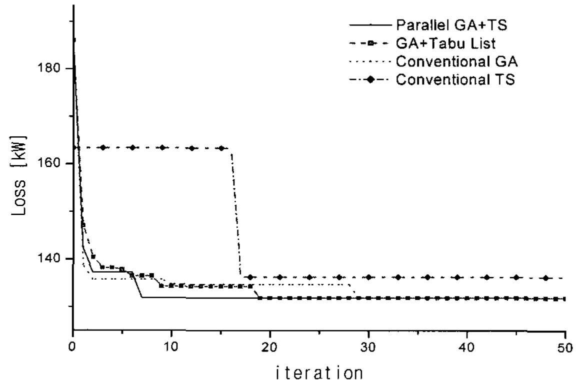


Fig. 8 Loss vs. generation curves for GA, TS, GA+Tabu List and the proposed method

Table 3 Opened switch positions and losses for initial and optimal solutions

Initial Configuration	Open Switch Position	24 -28	7 -20	17 -32	11 -21	8 -14
	Loss	186.04[kW]				
Optimal Configuration	Open Switch Position	24 -28	6 -7	31 -32	8 -9	13 -14
	Loss	131.85[kW]				

To demonstrate the effects of the parallel operation by PC clustering, speedup and efficiency are evaluated. Speedup and parallel computation efficiency are described below:

- speedup (S_p)

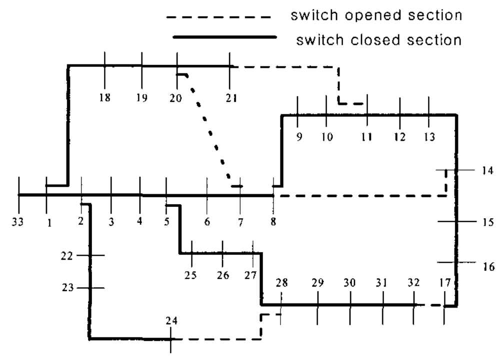
$$S_p = \frac{T}{T_p} \tag{5}$$

where, T : run time on one processor
T_p : run time on p processors

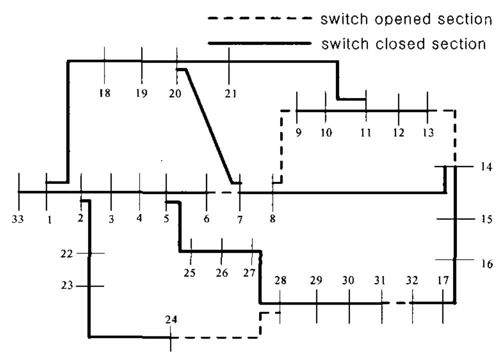
- parallel computation efficiency (E_p)

$$E_p = \frac{S_p}{p} \tag{6}$$

where, p : no. of processors



(a) initial configuration



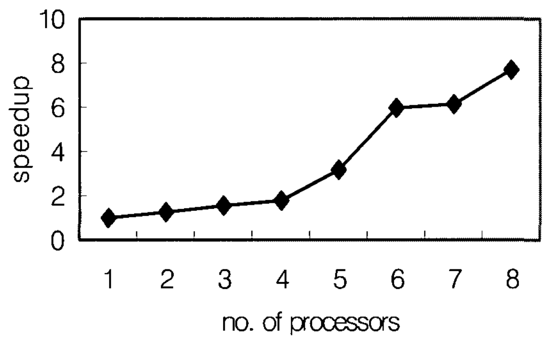
(b) optimal configuration by the proposed method

Fig. 9 Initial and optimal configuration by the proposed method

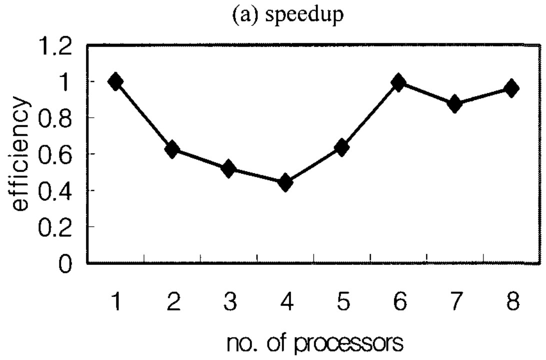
Fig. 10 shows the speedup, parallel computation efficiency, and computation time as the number of nodes increases. From Fig. 10, it is found that computation time is decreased while solution quality is maintained. Speedup increased as the number of nodes increased almost linearly, but somewhat lowered because there exists overhead when communication was executed between nodes.

4.2 69 bus distribution system

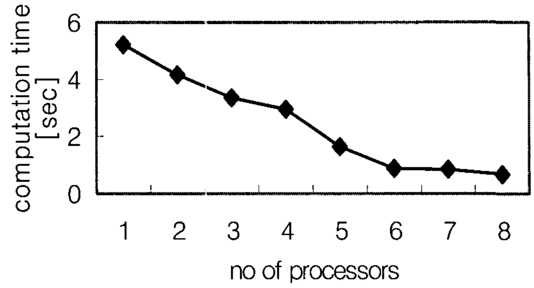
The 69 bus distribution system has 5 loops, and sectionalizing switches are placed between load buses. Fig. 11 shows the test system. Feeder voltage is set to 12.66 kV, loads are modeled as constant power, and the total loads are 3,802.12 kW and 2,694.60 kVAR, respectively. Simulation parameters of the proposed method are the same as those of the 32 bus distribution system case. To reveal the usefulness of the proposed method, results of the proposed methods are compared with those of GA alone, TS alone, and GA with tabu list. Fig. 12 shows the loss according to the generation. As generation increased, the loss found in each generation decreased to 93.79 kW with switches of (10-70), (13-14), (47-48), (50-51), and (12-20) opened at about generation 7. As compared with the loss of 204.8 kW of the initial configuration, loss of the optimal solution reduced 54.2% and minimum voltage increased 4% from 11.56 kV to 11.98 kV. Table 4 describes open switch position and loss of the initial solution and optimal solution by the proposed method, respectively. Fig. 13 shows the initial and optimal configuration by the proposed method.



(a) speedup



(b) efficiency



(c) computation time

Fig. 10 Speedup, efficiency, and computation time according to the node number

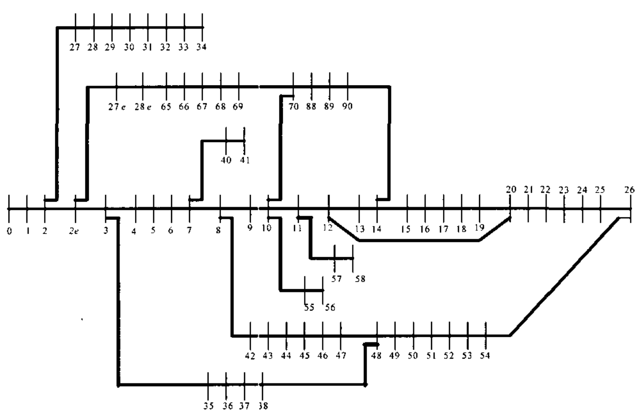


Fig. 11 Example distribution system with 69 buses

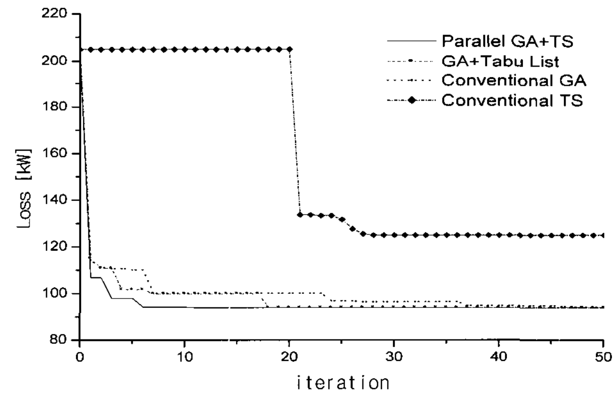
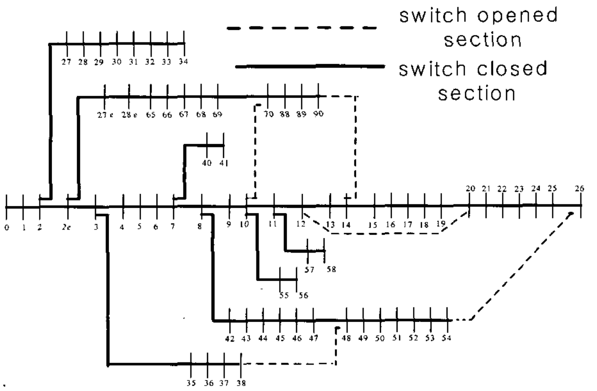


Fig. 12 Loss vs. generation curves for GA, TS, GA+Tabu List and the proposed method (69 buses)

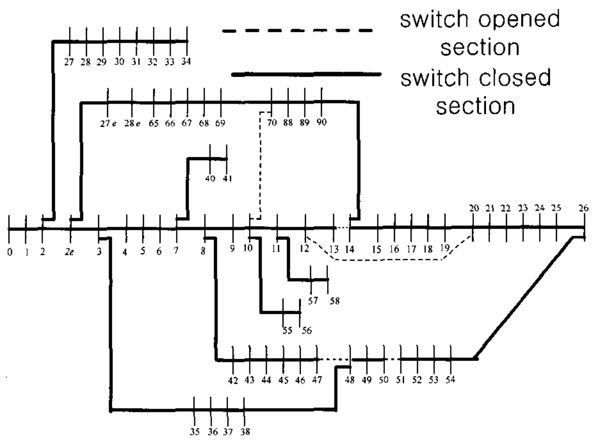
Table 4 Opened switch positions and losses for initial and optimal solutions

Initial Configu-ration	Open Switch Position	10 -70	14 -90	38 -48	26 -54	12 -20
	Loss	204.08[kW]				
Optimal Configu-ration	Open Switch Position	10 -70	13 -14	47 -48	50 -51	12 -20
	Loss	93.79[kW]				

Fig. 14 indicates the speedup, parallel computation efficiency, and computation time as the number of nodes increases. From Fig. 14, it is found that computation time is decreased while solution quality is maintained. Speedup increased as the number of nodes increased almost linearly, but somewhat lowered because there exists overhead when communication was executed between nodes.



(a) Initial Configuration



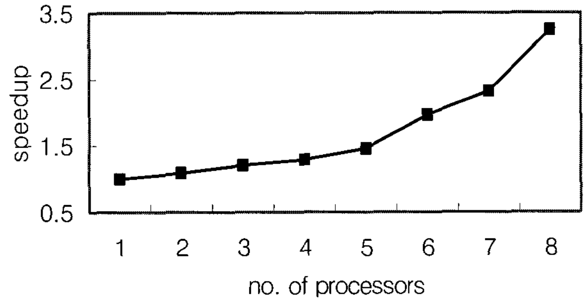
(b) optimal configuration by the proposed method

Fig. 13 Initial and optimal configuration by the proposed method

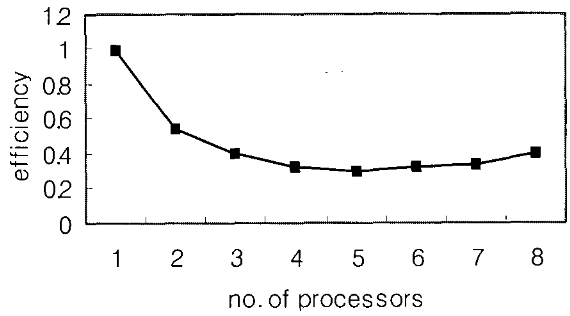
5. Conclusion

This paper presents an application of parallel hybrid GA- TS with pc clustering to search an optimal solution for reconfiguration in distribution systems. The aim of the proposed method is to enhance the solution quality and reduce the computation time. For parallel computing, a PC cluster system consisting of 8 PCs were developed. For compilers of parallel programming, MS visual C++ 6.0 was used under the Windows operating system.

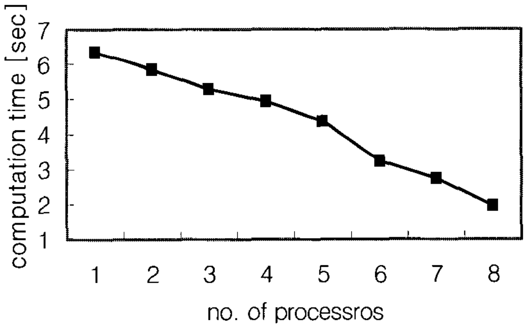
The proposed parallel hybrid GA-TS uses both GA with good global search capability and TS with good local search capability. The proposed algorithm is paralleled by the PC cluster system to enhance both the solution quality and computation time, and it is very competitive with the parallel machine in terms of cost/performance.



(a) speedup



(b) efficiency



(c) computation time

Fig. 14 Speedup, efficiency, and computation time according to the node number

To indicate the usefulness of the proposed method, results of the proposed methods are compared with those of GA with tabu list, GA only and TS only.

From the simulation results, it is found that the proposed algorithm is efficient and robust for distribution system reconfiguration in terms of the solution quality, speedup, efficiency, and computation time.

Acknowledgements

This work has been supported in part by EESRI (R-2002-B-044), which is funded by MOCIE (Ministry of Commerce, Industry and Energy).

References

[1] D. Shirmohammadi and H. W. Hong, "Reconfiguration of electric distribution networks for resistive losses reduction," *IEEE Trans. on Power Delivery*, vol. 4, no. 2, pp. 1492-1498, April 1989.

[2] M. E. Baran and F. F. Wu, "Network reconfiguration in Distribution systems for loss reduction and load balancing," *IEEE Trans. on Power Delivery*, vol. 4, no. 2, pp. 1401-1407, April 1989.

[3] Tim Taylor and David Lubkeman, "Implementation of heuristic search strategies for distribution feeder reconfiguration," *IEEE Trans. on Power Delivery*, vol. 5, no. 1, pp. 239-246, Jan. 1990.

[4] Günther Brauner and Manfred Zabel, "Knowledge based planning of Distribution networks," *IEEE Trans. on Power Systems*, vol. 9, no. 2, pp. 942-948, May 1994.

[5] Young-Jae Jeon, Jae-Chul Kim, Jin-O Kim, Joong-Rin Shin, Kwang Y. Lee, "An Efficient Simulated Annealing Algorithm for Network Reconfiguration in Large-Scale Distribution Systems," *IEEE Trans. on Power Delivery*, vol. 17, no. 4, pp. 1070-1078, Oct. 2002.

[6] K. Nara, A. Shiose, M. Kitagawa, and T.Tshihara, "Implementation of genetic algorithm for distribution system loss minimum reconfiguration," *IEEE Trans. on Power Systems*, vol. 7, no. 3, pp. 1044-1051, Aug. 1992.

[7] K. Nara, Y. Mishima, A. Gojyo, T. Ito and H. Kaneda, "Loss minimum reconfiguration of distribution system by tabu search," *Proc. of IEEE PES T&D Conference and Exhibition 2002 Asia Pacific*, vol. 1, pp. 232-236, Oct. 2002.

[8] H. Mori and K. Takeda, "Parallel simulated annealing for power system decomposition," *IEEE Proc. of PICA 93,* pp. 366-372, May 1993.

[9] R. Tanese, "Parallel genetic algorithm for a hypercube," *Proc. of 2th ICGA'87*, pp. 177-183, 1987.

[10] D. E. Goldberg, *Genetic Algorithms in Search, optimization, and Machine Learning*, Addison-Wesley publishing Company, INC., 1989.

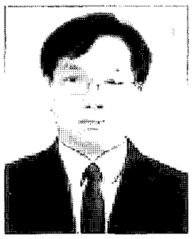
[11] D. B. Fogel, "An Introduction to Simulated Evolutionary Optimization," *IEEE Trans. on Neural Networks*, vol. 5, no. 1, Jan. 1994.

[12] J. Arabas, Z. Michalewicz, and J. Mulawka, "GAVaPS-a Genetic Algorithm with Varying Population Size," *IEEE International Conference on Evolutionary Computation*, pp. 73-78, 1994.

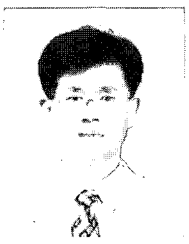
[13] D. Schlierkamp-Voosen and H. Muhlenbein, "Adaptation of Population Sizes by Competing Subpopulations," *IEEE International Conference on Evolutionary Computation*, pp. 330-335, 1996.

[14] D. B. Fogel, L. J. Fogel and J. W. Atmas, "Meta-Evolutionary Programming," *Proceedings 2sth Asilomar Conference on Systems, Signals, and Computers*, pp. 540-545, 1991.

[15] Z. Michalewicz, *Genetic Algorithms+Data Structures = Evolution Programs*, Springer-Verlag, 1992.



Kyeong-Jun Mun
He received his B.S., M.S. and Ph.D. degrees in Electrical Engineering from Pusan National University. He is currently a Post Doc. at the Korea Nuclear Energy Research Institute (KAERI). His research interests are intelligent systems, and power system operation and control, especially related to distribution systems.



Hwa-Seok Lee
He received his B.S., M.S. and Ph.D. degrees in Electrical Engineering from Pusan National University in 1991, 1993, and 1997, respectively. He is currently an Associate Professor at Koje College. His research interests include power quality, intelligent systems, and distribution automation.

June-Ho Park
He received his B.S., M.S. and Ph.D. degrees from Seoul National University of Korea in 1978, 1980, 1987, respectively, all in Electrical Engineering. He is currently a Professor at Pusan National University. His areas of interest are intelligent systems applications to power systems. Dr. Park has been a member of the IEEE Power Engineering Society, Control System Society, and Systems, Man and Cybernetics Society.