The Development of Application Programs for Optimal Feeder Operation Through Distribution Automatic System

Bok-Nam Ha*, Ieel-Ho Seol* and Mi-Ae Jeong*

Abstract - This paper presents the various application programs for the Distribution Automation System (DAS) of the Korea Electric Power Corporation (KEPCO)'s distribution system. These programs are developed to allow for optimal operation in the areas of feeder automation, relay coordination, loss minimization and so on. They are single line diagram auto creation programs for the feeder, service restoration program, protection coordination program, data error detection program, and optimal network reconfiguration program. The details of these programs are presented for validity and effectiveness.

Keywords: DAS, Application programs, Distribution network, Optimal operation

1. Introduction

KEPCO has been improving the Korea Distribution Automation System (KODAS) since the development of an initial prototype. The original KODAS, which is a small system with a moderate structure and cost, can only monitor and control components from a distant control center. However, as distribution systems are becoming more large-scale and complicated, upgraded DAS is essential. To meet this requirement, KEPCO developed a Total Distribution Automation System (TDAS) for large-scale distribution systems. Because TDAS required many additional functions to improve efficiency as well as basic function, KEPCO developed various application programs. This paper introduces the key tasks and effectiveness of the application programs developed by KEPCO.

2. The Operational Status for the Korea Distributions Automation System.

KEPCO is a unique utility in Korea. It has 15 business offices as part of its first grade administrative district and 170 branch offices as its substructure of business offices needed to operate the distribution networks. Small scale DAS has already been installed throughout all branch offices.

TDAS will be set up in all business offices located in larger cities and metropolitan areas. Twenty TDAS were installed throughout branch offices in the capital region before 2003. An additional 13 TDAS will be established in larger cities in the year 2004.

Past achievement and future plans for DAS are as follows.

Table 1 Number of DAS in construction

Item	1998	1999	2000	2001	2002	2003	2004	Total
Small scale DAS	17	66	61	29		-8	-10	155
TDAS	1		1	1	9	8	13	33

The switch remote control rate was scheduled to improve from 75.8% to 81.9% based on the 3.5 switches per distribution line in 2003.

3. Explanation Concerning Application Programs for DAS

The distribution system in KOREA uses a multi-grounded Y design with 22.9kV that has higher fault currents in line-to-ground fault and line-to-line fault so as to easily achieve protection cooperation and operate protection devices. Faults frequently occur for the exposed environment in distribution networks. DAS, which is the automation system for monitoring the status and controlling components, was developed to appropriately operate remote-controlled switches in faults on distribution systems. The previous DAS was focused on remote monitor and control; however it was unable to improve system performance based on real-time data. Therefore, KEPCO developed the optimal operation programs to improve the efficiency of DAS. These programs are the

* Group of Power Distribution Technology, Korea Electric Power Research Institute, Korea (bnha@kepri.re.kr, seol15@kepri.re.kr, miaec@kepri.re.kr)
Received April 25, 2003 ; Accepted February 6, 2004

distribution diagram auto-creation program, outage restoration program, protection coordination program, data error detection program, and optimal network reconfiguration program, all of which have the ability to make efficient decisions resulting in cost-saving measures.

3.1 Distribution diagram auto-creation program

Electrical components are generally difficult to identify on a topological map using GIS information. Furthermore, the change in the status of electrical components cannot be easily recognized. Therefore, this program is developed for arranging information of the components in distribution systems. In this program, a distribution diagram is generated by two methods as follows.

1) Operators generate a distribution diagram by the editing function and display on screen, which is the technique used in the initial KODAS.

2) A distribution diagram is automatically generated by the information and status for components in distribution systems, which is a technique used in TDAS.

The latter method maintains consistency with the field data and can be conveniently applied. The feature of this program is as follows.

3.1.1 The topological map based on GIS and distribution diagram

The topological map based on GIS can easily recognize the location of components, which makes for efficient control and management of DAS. To perform a specific operation for a component, operators should be aware of the necessary information for the relation between it and other components. For this reason, when operators choose a component on a screen, the distribution diagram with the component is extracted from the topological map based on GIS.

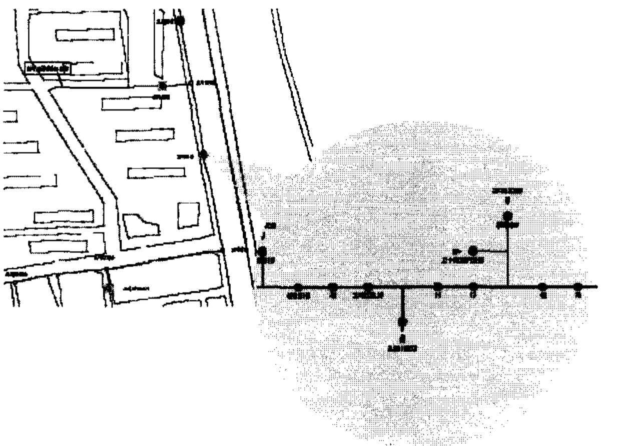


Fig. 1 Hybrid operation between GIS map and single line diagram

3.1.2 The offer of various operational information

In this program operators can choose to highlight pertinent information because unnecessary information interferes with efficient operation. The knowledge that can be displayed concerns automatic switches, communication methods and protocols, length of sections, load currents, type of lines, impedance and voltage drop. Also, the margin capacity and adjacent feeders with tie switches are provided, which allows for recognition of the capability for load transfer.

3.1.3 Selective individual indication for operational purposes.

Protection devices, automatic devices, manual devices and branches can be selectively omitted on the distribution diagram. For example, there are automatic switches and adjacent feeders in a service restoration operation, single phase branches in the voltage drop, and line type in protection cooperation.

3.2 Service restoration program

This program can detect a fault section by the FI's (Fault Indicator) operating status on the distribution system. It provides a load transfer scheme to the operator for unfaulted out-of-service areas. The final service restoration scheme is proposed based on two steps involving candidate search and evaluation. After a service restoration scheme is proposed by considering the margin capacity and voltage drop, the final solution is provided by fuzzy theory based on the switching number, load balance, and other factors.

TDAS has 2 MMI (Man and Machine Interface) monitors. MMI #1 displays out-of-service area information and restoration schemes. MMI #2 displays FI operating status on a single line diagram as shown in Fig. 2 and can change it to a topographical map

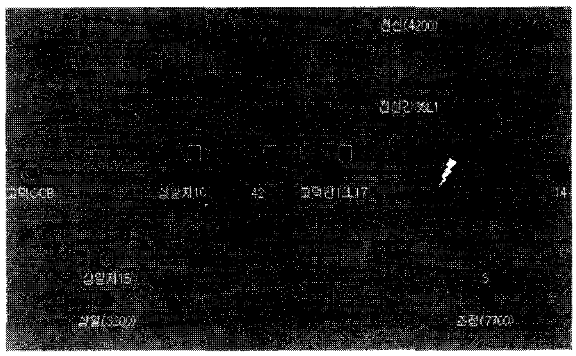


Fig. 2 Execution illustration

3.2.1 Restoration way candidate search

KEPCO's distribution feeders are divided into 4 sections. Generally, 3 adjacent feeders are tied together by automatic switches. For this reason, this program can provide a total of 6 solutions based on the assumption that load-transfer can be performed by 3 tie switches in the fault feeder.

Fig. 3 represents one of among 6 solutions, which is the expressed restoration plan using 2 adjacent lines.

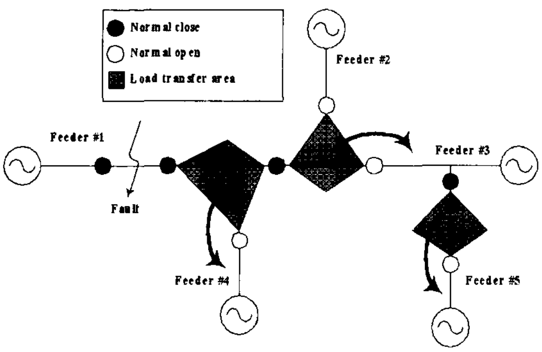


Fig. 3 Service restoration plan

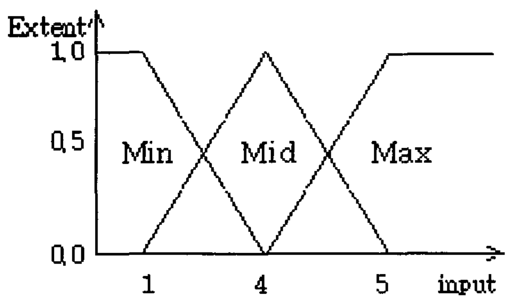
3.2.2 Priority for the service restoration

In service restoration problems, the final solution can be obtained by considering the priority of utilities. In general, the service restoration scheme is designed to restore unfaulted out-of-service areas as soon as possible. If feasible, the load balance, voltage drop, line loss, switching number, and protection cooperation should be considered. The priority in this program is presented in Table 2.

Table 2 Consideration item and precedence of restoration

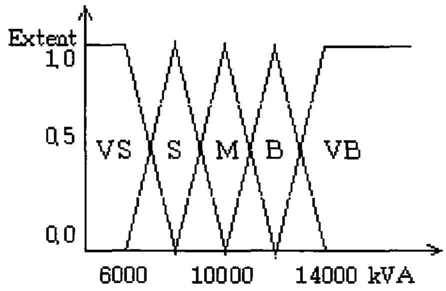
order	Consideration item
1	Restoration speed, area, switching number of times
2	Provision emergency, load equalization, voltage drop, normal load transfer, loss
3	Protection coordination

Fuzzy theory is applied to propose a solution with the priority and examples for switching number and load balance. Results are presented in Fig. 4 and Fig. 5, respectively.



If switching number of times is Minimum then plan is Very-good
If switching number of times is Middle then plan is Medium
If switching number of times is Maximum then plan is Very-poor

Fig. 4 Estimation regarding number of switching times



If peak is Very Small then plan is Very-good
If peak is Small then plan is Good
If peak is Medium then plan is Medium
If peak is Big then plan is Poor
If peak is Very Big then plan is Very-poor

Fig. 5 Estimation regarding load equalization

3.3 DAS protection coordination program (DASPRO)

TDAS acquires real-time data from automation devices on distribution systems, which manages the database containing information such as the length of lines, type of lines, and other factors for protection cooperation.

In the past, operators generally perform protection cooperation based on their expertise and incomplete data. However, TDAS can perform protection cooperation by remote control. It has the following function and processing.

Table 3 Function of DASPRO.

Item	DASPRO
Diagram for protection coordination	Auto-creation
Substation and load information	All
T-C curve	offer
In case cooperation is not achieved	Auto-correction
Remote setting	offer

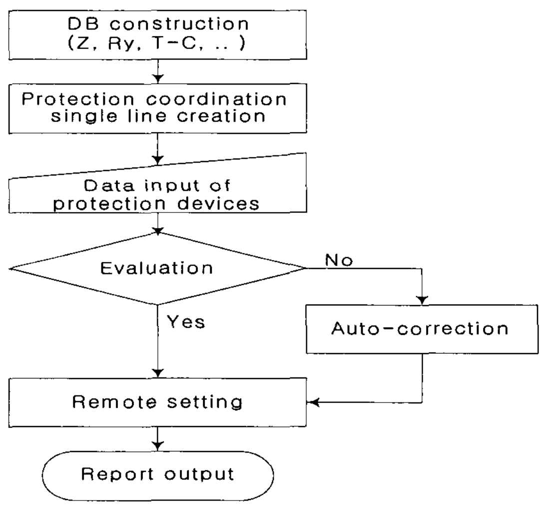


Fig. 6 DASPRO processing flowchart

Convenient for user because it can confirm all T-C (Time-Current) curves of protection devices and cooperation results as shown in Fig. 7.

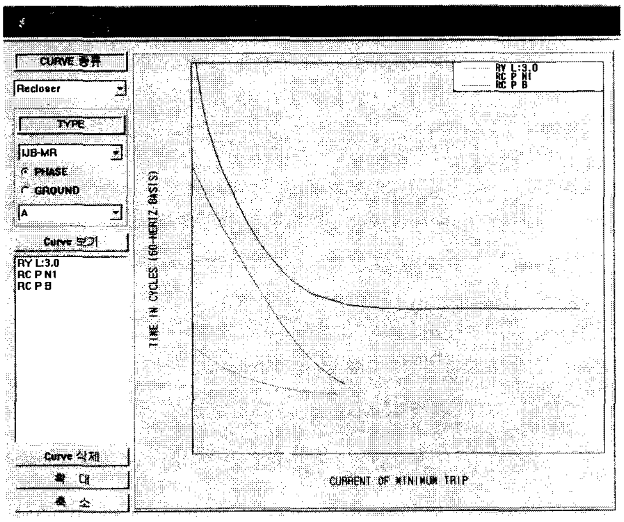


Fig. 7 T-C curve for coordination between Relay and Recloser

3.3.1 DB construction of existing data

For protection coordination, information such as M.Tr (Main Transformer in substation), impedance of a bus-bar, relay information, setting values of protection devices, type of lines and impedance, length of sections, T-C (Time-Current) curves and load currents is stored at the front of the feeders.

3.3.2 Diagram creation for protection coordination

The diagram for protection coordination illustrates relays (substation and customer), protection devices (recloser, sectionalizer, fuse, and so on) and automated switches on the evaluated distribution lines.

3.3.3 Protection coordination examination

Setting values of operating protection devices can be changed by remote control and inputted by the diagram for protection coordination and the topological map on screen. Especially, most setting values of automatic devices can be obtained by remote controlling techniques, which decrease the amount of input items.

Protection cooperation is evaluated by calculating the fault current on switches based on the impedance and line information in DB.

3.3.4 Automatic correction

If appropriate protection cooperation cannot be performed by the current setting values, the automatic correction function generates appropriate setting values for protection cooperation and changes them by remote technique.

The flowchart for automatic correction is as follows.

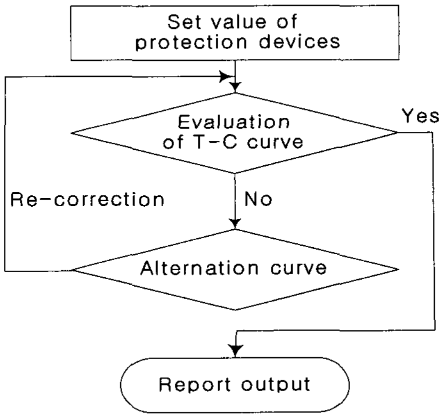


Fig. 8 Automatic correction processing flowchart

3.4 Error detection program

The accurate performance of application programs depends on the consistency of data for the distribution diagram, setting values of protection devices, status of switches, and other factors. There are many components of distribution systems making it impossible to manually correct errors. For this reason, an error detection program is developed and consists of the following.

1) Internal loop: a loop created in a feeder.

2) External loop: a loop is created between two feeders by closing a tie switch.

3) Section isolation: some sections are isolated by opening two or more sectionalizing switches

4) ID redundancy: the allocated ID on automatic switches (especially pad switches).

The above mentioned errors are detected and the latest details for the status of switches are provided, making it easy to correct the errors.

3.5 Optimal reconfiguration program

Distribution systems should be operated to minimize power loss as well as to increase supply reliability. To do this, the number of tie switches among feeders should be increased and load balance should be performed for margin capacity. Distribution systems are optimally reconfigured by this program, which can increase use of lines, release overload, and arrange new customers.

The optimal network reconfiguration program is performed as follows.

1) Estimation of network: Calculation for power loss and voltage drop.

2) Load equalization operating between lines: Load balance by network reconfiguration.

3) Power loss minimization operation of network: Power loss minimization by network reconfiguration.

4) Output with analysis result: Operation sequence of

switches, comparison with load amount and power loss following network reconfiguration.

3.5.1 Application method

A genetic algorithm based on natural selection and laws of inheritance is used for the application.

Object function is consisted in four terms, each of which has a normalized value ranging form 0 to 1. The second and third terms of the fitness function represent the essential conditions and therefore they have the value of either 0 or 1.

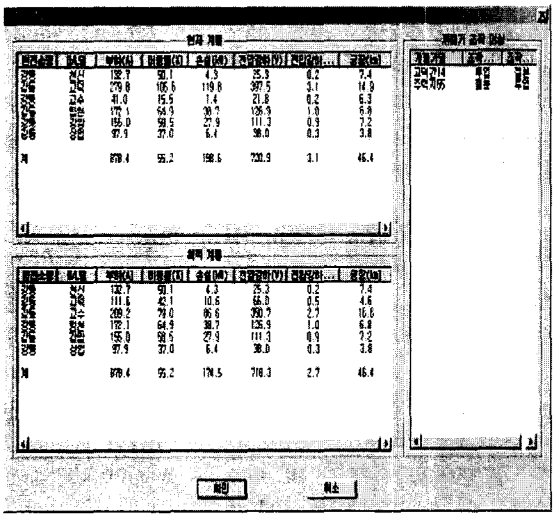
$$F_{fitness} = F_1(P_l) + F_2(V_D) + F_3(S_{kVA}) + F_4(RC) \qquad (1)$$

P_l : *Total loss line*
V_D : *Voltage drop*
S_{kVA} : *Maximum feeder load*
RC : *Minimum restoration index*

This program is generally implemented for loss minimization and load balance and operators can adjust fuzzy functions if necessary. Although this program is performed for 1 of the 4 terms, similar results are obtained for the relation between other objectives.

3.5.2 Calculation result

The calculation result for loss minimization of six feeders in the *Gangdong* business office is presented in Fig. 9.



System condition *Number of feeder : 6*
Sum of currents: 878.4A
Average of voltage drop: 3.1% → 2.7%

Fig. 9 The result of loss minimization program

As shown in Fig. 9, switch control list, load amount, utilization ratio of facility, power loss, voltage drop and length of line are presented on a window. Power loss in initial and optimal configurations is 198.6kW and 174.5kW, respectively. Loss reduction is 24.1kW by this program, and the reduced loss can be converted per year by multiplying billing cost and operation time.

3.6 Simulation mode

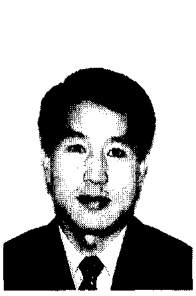
TDAS has both on-line and simulation modes. The on-line mode has application programs that can be performed in the actual network. However we can introduce and train for operators in simulation mode using the current data from the on-line mode. To prevent confusion, the background color in the on-line and simulation modes is black and blue respectively. The simulation mode has received favorable comments by operators because beginners for DAS can easily simulate all functions of the on-line mode in the simulation mode.

4. Conclusion

In the past, utilities have been unable to calculate the fault current, load current in time, and voltage drop due to the lack of real time data. The introduction of DAS can help achieve convenience in the management of distribution systems, and also help optimal operation based on real-time data. Requirements for power quality and supply reliability have been significantly increased in recent years. To meet these requirements, we will develop improved DAS with power quality monitoring and diagnostic components using on-line monitoring and state estimation techniques.

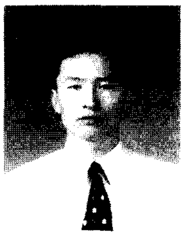
References

[1] B. N. Ha, N. H. Cho and M. H. Kang, "The development of application for distribution automation and the research for system interface", KEPRI, Oct 2002.



Bok-Nam Ha

He was born in Daejeon, Korea in 1958. He received the M.S.E.E and Ph.D. degrees from Chungnam National University, Korea. He is currently working at the Korea Electric Power Research Institute of the Korea Electric Power Corporation, which he joined in 1978. He has been a principal member and project leader of the distribution automation system development project since 1990. His research interest is in the application program of the distribution automation system and its field application.



Ieel-Ho Seol
He was born in Jeonbuk, Korea in 1968. He is qualified as a Professional Engineer in the fields of generation transmission and distribution. He joined KEPRI of KEPCO in 2002, where he is currently a Senior Researcher of the Distribution Technology Group.

Mi-Ae Jeong
She was born in Daejeon, Korea in 1979. She graduated form Hanbat National University in 2002. She is currently studing for the M.S course in Power and Automatic Systems. She researches programs for database management and reports. She is currently working in the Distribution Technology department of KEPRI.