An Enhanced Investment Priority Decision of Facilities Considering Reliability of Distribution Networks

Jung-Hwan Choi†, Chang-Ho Park*, Kwang-Ho Kim and Sung-Il Jang*****

Abstract - This paper proposes an improved investment priority decision method of facilities considering the reliability of distribution networks. The proposed method decides an investment order of the facilities combining, by fuzzy rules, the investment priority decision by KEPCO and that by reliability evaluation indices. The reliability evaluation indices are *SAIFI* (System Average Interruption Frequency Index) and *SAIDI* (System Average Interruption Duration Index). The reliability analysis method of distribution networks applied in this paper utilizes the analytic method, where the used reliability data is the historical data of KEPCO. Particularly, we assumed that the failure rate increases as the equipment ages. To verify the performance of the proposed method, we applied it with the planned projects to reinforce the weak electrical facilities in KEPCO in 2004. The evaluation result showed that, under a limited budget, the reliability of KEPCO in the Busan region using the proposed method could be enhanced if used rather than the conventional method typically in place. Therefore, the results verify that the proposed method can be efficiently used in the actual priorities method for investing in the electrical facilities.

Keywords: Analytic method, facility investment priority, Fuzzy rule, reliability of distribution system, SAIDI, SAIFI.

1. Introduction

These days, distribution networks absolutely demand high quality and high reliability in regards to power supply. To meet these needs, utilities have set the target for providing reliable power of high quality to their customers by investing in the distribution facilities by the works. Currently, the investment method of distribution networks invested in bulk is excluded. Under budget limitations, the utilities have to try to maintain optimal power supply in a reliable manner and to maximize the efficiency of the exiting facilities [1-4].

The current investment of the facilities in KEPCO (Korea Electric Power Corporation) is planned to minimize the interruption time per customer as well as the power loss, and to maintain voltage quality. To achieve these aims, the utility has decided to implement the facility investment priority using length, management level, interconnection capability, load growth, number of distribution line failures, and so on. However, this decision method does not provide accurate assessment considering the potential failure rate, interruption time of distribution lines and the influence that customers have in the case of faults [5-7]. Thus, a novel investment decision of the facility to enable accurate assessment of the existing state of distribution networks has been demanded.

This paper proposes an improved investment priority decision method of the facilities considering the reliability of distribution networks to improve the problem of KEPCO's facility investment priority decision depending on the experience and knowledge of engineers. The proposed method decides the investment order of the facilities combining, by fuzzy rules [8], the investment priority decision by KEPCO and that derived by reliability evaluation indices. Reliability evaluation indices in this case are *SAIFI* (System Average Interruption Frequency Index) and *SAIDI* (System Average Interruption Duration Index)[9-13]. The reliability analysis method of distribution networks applied in this paper utilizes the analytic method, where the used reliability data is historical data of KEPCO. Particularly, we assumed that the failure rate increases as the equipment ages. To verify the performance of the proposed method, we applied it with the planned projects to reinforce the weak electrical facilities in KEPCO in 2004. The evaluation result showed that, under a limited budget, the reliability of KEPCO in the Busan region using the proposed method could be enhanced more

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significantly than by using the conventional method of KEPCO. Therefore, the results verify that the proposed method can be efficiently used in the actual priorities method for investing in the electrical facilities.

2. Investment Decision Criteria of the Facilities of Distribution Networks of KEPCO

As mentioned above, KEPCO invests in the facilities to enhance power supply reliability of distribution networks by the works. To decide the facility investment, KEPCO has used variable evaluation factors such as the investment priority of the branch offices, line average length, management level, the pollution level that an aging of the facilities accelerates, load growth, interconnection capability representing number of back up lines, number of permanent faults and temporary faults for the most recent 2 years of distribution line, and finally evaluation factor selected by a business type, as shown in Table 1. The project type planned in KEPCO includes five project categories such as an overloading solution business for the distribution lines, a voltage drop solution business, a load transfer capacity reinforcement business, a weak facility reinforcement business, and a load unbalance solution business. Where the evaluation factor for an overloading solution business is overloading coefficient, that for a voltage drop excess solution business is voltage drop ratio and load distribution, that for a load transfer capacity reinforcement business is load transfer ratio of the distribution line and load transfer ratio of the main transformer in a substation, that for the weak facility reinforcement business is the line route, and finally that for the load imbalance solution business is the load imbalance. For example, if we estimated weak facility reinforcement work, the driver of this project would be the investment priority of the branch office, line length, pollution grade, transferability, load growth ratio, failure history, and line route. Investment order of the project will determine which of those data to use.

3. Fuzzy Inference System for Investment Priority Decision

This section describes the investment priority decision method of the facilities using the fuzzy inference system that has the features to obtain a result using the variable inputs based on the experience of an engineer. We define the evaluation parameters, membership functions, and the facility investment priority decision fuzzy rules to determine the investment priority of the facilities. Partially, it consists of two fuzzy rules. One of two fuzzy rules is consisted of only reliability indices and the other is consisted of decision result by reliability indices and KEPCO's investment decision result.

Table 1 The Facility Investment Priority Evaluation Factor for Reinforcement of Distribution Lines

Evaluation factor			W_j	k_j
Operation condition (30)		Investment priority of branch offices	30	1=1.0, 2=0.8, ≤ 3 = 0.6
		Line length	10	>50 =1.0, ≤50 = 0.8 ≤40 = 0.6, ≤30 = 0.4
Management condition (30)		Management level	5	1=1.0, 2=0.9, 3=0.7 4=0.6, 5=0.5
		Pollution grade	5	D=1.0, C=0.9 B=0.7, A=0.5
		Transferability	5	No = 1.0, 1=0.9 2=0.7, ≥ 3=0.5
		Load growth	5	≥ 8% =1.0, ≥ 7% =0.9 ≥ 6% =0.8, ≥ 5% =0.7 ≥ 4% =0.6, ≥ 3% =0.5
		Failure history f_p	5	≥ 4 =1.0, ≥ 3 =0.8 ≥ 2 =0.7, ≥ 1 =0.6
		Failure history f_t	5	≥ 6=1.0, ≥ 5 =0.8 ≥ 4 =0.7, ≥ 3 =0.6
Projects (30)	Overloading	Overload coefficient	30	≥1.2=1.0, ≥1.1 =0.8 ≥1.0 =0.7, ≥ 0.9 =0.6
	Voltage Drop excess	Voltage drop	20	≥ 15% =1.0, ≥ 13% =0.9 ≥ 11% =0.8, ≥ 9% =0.7
		Load distribution	10	Terminal=1.0, Distributed=0.7 Supply=0.5
	Load transferability reinforcement	Load transferability (D/L)	20	≥ 0.8 =1.0, ≥ 0.7 =0.9 ≥ 0.6% =0.8, ≥ 0.5% =0.7
		Load transferability (M.Tr)	10	≥ 0.8 =1.0, ≥ 0.7 =0.9 ≥ 0.6% =0.8, ≥ 0.5% =0.7
	Weak facility reinforcement	Route of D/L	30	Mountain=1.0, hill=0.8, Road=0.6, Plot=0.5
	Load imbalance	unbalance	30	≥ 30% =1.0, ≥ 25% =0.9 ≥ 20% =0.8, ≥ 15% =0.7
Total			100	

3.1 The evaluation parameter of the proposed method

In this section, we define the evaluation parameters of the proposed method. The parameters of the proposed evaluation model are the existing investment decision result in KEPCO and *SAIFI* and *SAIDI* obtained by reliability analysis of distribution lines.

Firstly, the conventional evaluation parameter is decided by the evaluation factor shown in Table 1, which is defined by the following equation,

$$IPofKEPCO = \sum_j k_j W_j \tag{1}$$

where *j* is *the* evaluation factor for investing the facility in KEPCO, k_j is the weighted value for evaluation factor j, W_j is the application ratio for evaluation factor j.

In (1), *IPofKEPCO* is difficult to assess the reliability for power supply and the effect that the occurrence of a fault has on customers.

Therefore, in this paper, secondly we define *SAIFI* and *SAIDI*, as equations (2) and (3). But the reliability evaluation results of the distribution lines invested by a work are difficult to compare as to how to affect the power supply reliability of the utility because those are the average values. Thus, we redefine equations (2) and (3) as equations (4) and (5),

$$SAIFI_{DL,i} = \left. \frac{\sum_j^{N_{LP}} \lambda_j N_j}{\sum_j^{N_{LP}} N_j} \right|_{DL,i} \tag{2}$$

$$SAIDI_{DL,i} = \left. \frac{\sum_j^{N_{LP}} U_j N_j}{\sum_j^{N_{LP}} N_j} \right|_{DL,i} \tag{3}$$

$$SAIFI_{Util,i} = SAIFI_{DL,i} \times \frac{N_{Total,DLi}}{N_{Total}} \tag{4}$$

$$SAIDI_{Util,i} = SAIDI_{DL,i} \times \frac{N_{Total,DLi}}{N_{Total}} \tag{5}$$

where j is load point, λ_j is failure rate, U_j is and annual outage time, N_j is the number of customers of load point j, N_{LP}, is the number of load points, $N_{TotalDLi}$, is the number of customers of distribution line *i*, N_{Total} is the number of customer supplied by a utility. Particularly, N_{Total} set the total number of customers of KEPCO's Busan branch at 1,609,220. Meanwhile, the distribution lines and project contents change in the category of projects yearly. Finally the proposed method uses equations (6) and (7), normalized by the maximum value of equations (4) and (5),

$$SAIFI_{fis,i} = \frac{SAIFI_{Util,i}}{SAIFI_{Util,Max}} \tag{6}$$

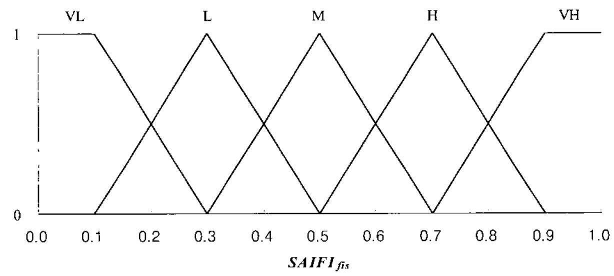
$$SAIDI_{fis,i} = \frac{SAIDI_{Util,i}}{SAIDI_{Util,Max}} \tag{7}$$

where $SAIFI_{Util,Max}$ and $SAIDI_{Util,Max}$ are the maximum value of $SAIFI_{Util}$ and $SAIDI_{Util}$ respectively

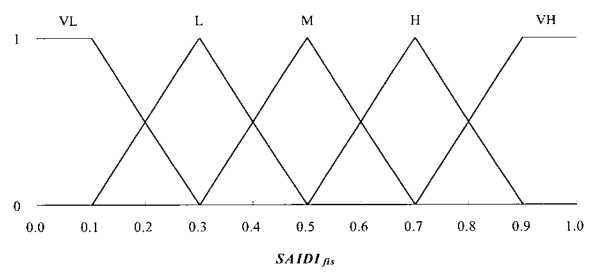
3.2 Investment priority strategy on reliability indices

Generally, utilities set the target concerning reliability of power supply that must be maintained, and invest the facilities to achieve it. And its' priority has to first of all replace the section in which fault frequencies are high and the facilities in which the effect of power supply reliability is the worst.

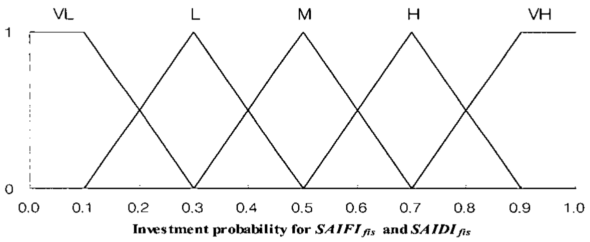
According to reference [2], ordering is determined by *SAIFI* and *SAIDI*. Feeders that have high *SAIFI* and *SAIDI* indices are given the highest priority for reliability investment. Feeders that have only *SAIFI* index are given the next priority, and lastly feeders that have only high *SAIDI* index are given the next priority. In the consequence of investment, we think that the *SAIFI* index can obtain more of a reduction of the *SAIDI* index if fault frequency reduces. Therefore, this study makes the fuzzy rule for the facility investment priority by $SAIFI_{fis}$ and $SAIDI_{fis}$.



(a) Membership function for $SAIFI_{fis}$



(b) Membership function for $SAIDI_{fis}$



(c) Membership function for output fuzzy set

Fig. 1 Membership function for input variable of facility investment priority decision model by reliability

Table 2 The Facility Investment Priority Decision Fuzzy Rule for Reliability Indices

$SAIDI_{fis}$\\$SAIFI_{fis}$	***VL***	***L***	***M***	***H***	***VH***
VL	*VL*	*VL*	*L*	*H*	*H*
L	*VL*	*L*	*L*	*H*	*H*
M	*L*	*L*	*M*	*H*	*H*
H	*M*	*M*	*M*	*VH*	*VH*
VH	*M*	*M*	*M*	*VH*	*VH*

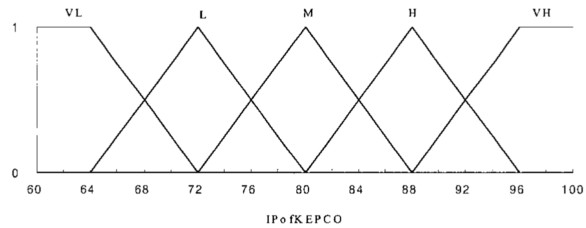
The fuzzy rules are represented as a 5-by-5 linguistic matrix in Table 2, where the input variables, $SAIFI_{fis}$ and $SAIDI_{fis}$, take five fuzzy set values: *VL*(*Very Low*), *L*(*Low*), *M*(*Medium*), *H*(*High*), *VH*(*Very High*). The membership function of the fuzzy sets is shown in Fig. 1. Each matrix entry equals one of five investment probability fuzzy sets. We use the fuzzy centroid defuzzification scheme to translate fuzzy output statements into crisp output values.

3.3 Investment priority strategy by KEPCO and reliability indices

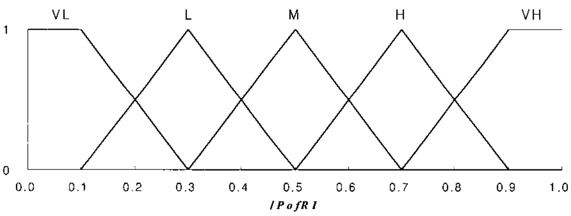
In this section, we describe the relation of the investment probability for reliability indices, *IPofRI* and KEPCO's investment decision, *IPofKEPCO*.

In the case of facility investment, the considerations are the effect of load growth and pollution, frequency of permanent and temporary faults for the last 2 years, management level, current load, route, voltage drop, overloading of distribution line, and so on. But reliability analysis makes it difficult to consider those effects. Thus this paper represents the fuzzy rules in Table 3, prior to *IPofKEPCO*, referred as KEPCO's decision method.

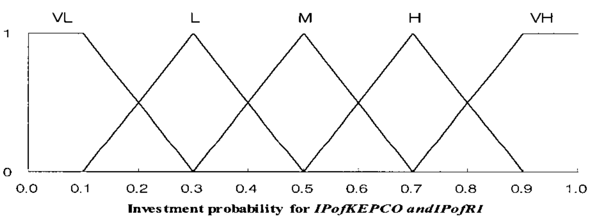
As an example, if investment probability for reliability indices was the very worst, referred to as *VH* ("*Very High*"), we elevate the investment priority because the fault occurrence probability and its effect is high: if *IPofKEPCO* is "H" and *IPofRI* is "VH", we decide to change investment probability from *H* to *VH.* Otherwise, if investment probability for reliability indices was the very worst, referred to as *VL* ("*Very Low*"), we elevate the investment priority because the fault occurrence probability and its effect is high: if *IPofKEPCO* is "H" and *IPofRI* is "VL", we decide to change the investment probability from *H* to *M.* Te input variables take five fuzzy set values: *VL* (*Very Low*), *L* (*Low*), *M* (*Medium*), *H* (*High*), *VH* (*Very High*). And the membership function of the fuzzy sets is shown in Fig. 2, where each matrix entry equals one of five investment probability fuzzy sets. We also use the fuzzy centroid defuzzification scheme to translate fuzzy output statements into crisp output values. Finally investment priority is decided as a magnitude of output values. The overall process of deciding the facility investment priority is shown in Fig. 3.



(a) Membership function for *IPofKEPCO*



(b) Membership function for *IPofRI*



(c) Membership function for output fuzzy set

Fig. 2 Membership function of fuzzy system for final facility investment priority decision

Table 3 The Facility Investment Priority Decision Fuzzy Rule for Reliability Indices

IPofRI\\IPofKEPCO	***VL***	***L***	***M***	***H***	***VH***
VL	*VL*	*VL*	*L*	*M*	*H*
L	*VL*	*L*	*M*	*H*	*VH*
M	*VL*	*L*	*M*	*H*	*VH*
H	*VL*	*L*	*M*	*H*	*VH*
VH	*L*	*M*	*H*	*VH*	*VH*

4. Case Study

4.1 Data for case study

In this section, we recapitulate a work list for weak facility reinforcement as planned in KEPCO in 2004 and reliability data used to evaluate the proposed method.

Table 4 summarizes distribution line and work contents planned to reinforce distribution networks in 2004 and Table 5 describes line length, load data, and customer data of the distribution line to be invested by the works. Fig. 4 represents model of feeder A of distribution lines for projects planned in 2004, where GS is Gas insulated switch. CS is Cut-off-Switch, R is recloser, dotted line arrow is low voltage customer, full line arrow is high voltage customer, and 101 is the number of sections. Table 6 and Fig. 5 indicate results that analyze failure data of the facilities during the decade, where Table 6 represents average failure rate, repair time and sectionalizing time. Fig. 5 represents failure rate for facility aging [5]. The transfer ratio used to analyze reliability of the distribution networks is 100 %.

Table 4 List of Weak Equipment Reinforcement Projects

No.	D/L	Contents	Budget
1	A	Replace ACSR 160 to ABC240 2.0km	176,166
2	B	Replace conductor 1.5km, pole trans former 32 units, insulator 43 units	163,833
3	C	Replace conductor 1.6km and inferior LP insulator and suspension insulator 202 units, install new overhead ground line 1.6km,	68,000
4	D	Replace pole 15, conductor 4.2km and install new overhead line 3.5km	418,641
5	E	New installation of underground cable 0.5km.	262,897
6	F	Remove overhead line 0.17km and install underground cable 0.57km	172,037
7	G	Replace conductor 7.4 km from ACSR 160 to ABC240 and install of new pole 25 units	585,174
8	H	Replace conductor 2.3km and pole 30 units	182,616
9	I	Replace pole 25unit, conductor 3km, insulator 1350 units and overhead ground line 3km	419,200
10	J	Replace aging conductor 1.4km and inferior LP insulator and suspension insulator 198 units and install new overhead ground line 1.4km	75,000
11	K	Replace conductor 3EH LOC160/ ABC240 0.6 km.	54,098
12	L	Install new pole 60 units, remove pole 28 units, and replace conductor 15.48 km	258,488
13	M	Replace pole 30 units and conductor 1.45km	128,752
14	N	Replace conductor 1.6km and GS 2 units.	184,489
15	O	Replace pole 20 units and conductor 1.8km	132,708
16	P	Replace pole 20 units, conductor 1.5km, overhead ground line 1.5km and insulator 830 units	247,750
17	Q	Replace pole 20 units, conductor 1.7km, overhead ground line 1.7km and insulator 860 units	269,950
18	R	Install new pole 31 units, remove pole 18 units, and replace conductor 1.14km	98,671
19	S	Replace pole 12 units, ACSR-160 0.6km and GS 2 units	93,941

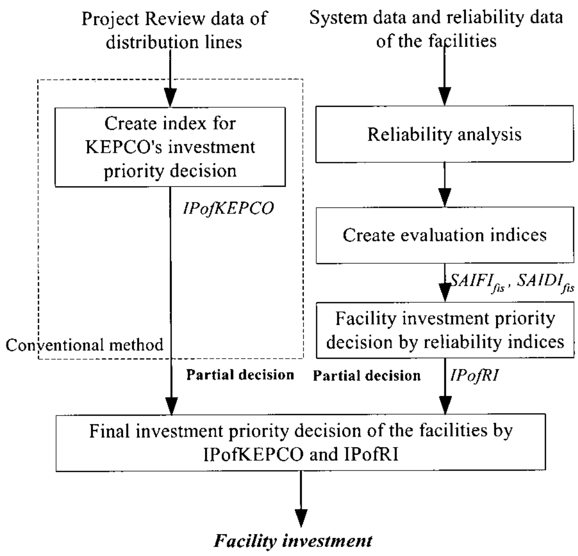


Fig. 3 Facility investment priority decision flow of proposed method

Table 5 Data of Distribution Line for Weak Equipment Reinforcement Projects

D/L	No of sec	L (m)	High voltage customer			Low voltage customer		
			P_{max}	P_{rated}	Cust.	P_{max}	P_{rated}	Cust.
A	14	19434	7154	8623	6	1546	1864	542
B	13	8394	1394	3875	318	4900	9741	3645
C	12	6928	1035	2437	927	4465	10509	2741
D	27	49115	1,006	10055	21	225	8454	1514
E	15	19794	2050	5050	12	5150	12688	2274
F	7	6896	1767	6275	321	1133	4021	1055
G	12	21157	4701	4875	2417	3487	4459	760
H	13	8864	1257	3275	11	4943	12883	5245
I	10	9177	7776	22850	2519	1524	4478	451
J	10	11471	4019	12323	16	981	3007	472
K	6	12022	3401	2829	488	5299	4408	468
L	8	9258	8100	2000	7	0	0	0
M	3	5251	8793	14970	5	407	693	120
N	3	1899	6298	13068	26	802	1665	55
O	31	7975	3670	11358	27	3630	11236	1825
P	7	4056	2033	5875	256	1567	4527	531
Q	4	3035	2521	2839	1070	2179	2453	199
R	22	57030	4393	10940	24	2707	6742	1767
S	2	2690	4906	9523	9	394	764	31

Table 6 Historical Reliability Data for the Electric Facilities in Distribution Network

Facility type	λ [f/yr]	r [hours]	Sw [hours]
Overhead line	5.79E-02	1	0.5
Underground Cable	4.58E-02	2	0.5
IS	1.77E-02	3	
GS	3.20E-02	3	
COS	1.72E-03	3	
P.Tr	4.58E-04	2	

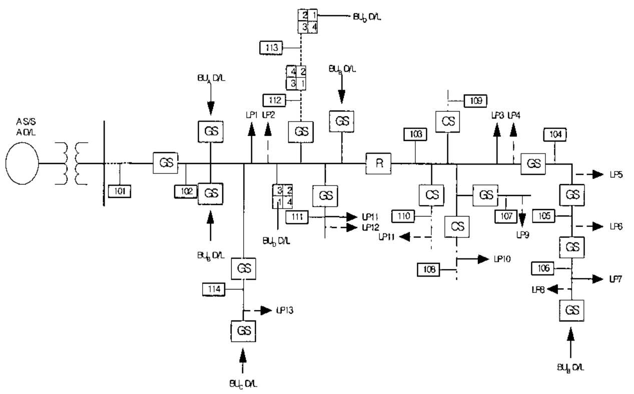


Fig. 4 Model distribution system of line A

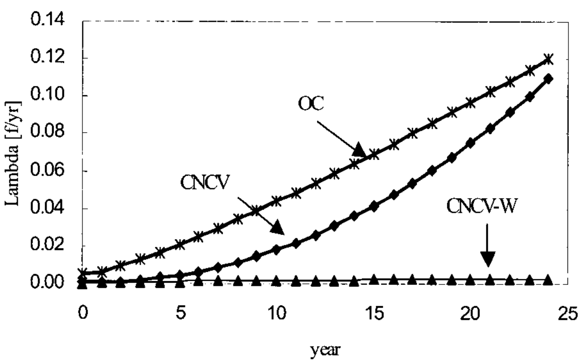
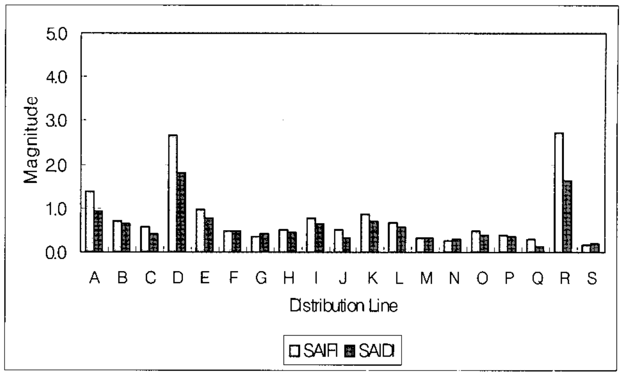


Fig. 5 Failure rate for facility aging of distribution lines

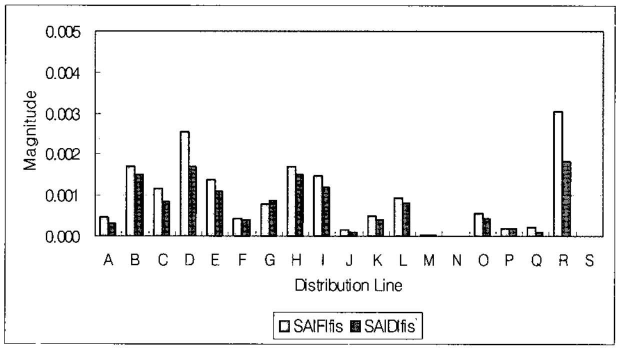
4.2 The investment priority decision result of the electrical facilities

In this section, we described the decision result of the proposed method using the work list of Table 4. We also verify the performance of the proposed model using the improved value of the conventional method and the proposed method. The improved value represents the differences of $SAIFI_{Util}$ and $SAIDI_{Util}$ before we invest the facility and after, by reliability analysis of distribution networks.

Table 7 represents KEPCO's investment priority decision for projects. Fig. 6 describes *SAIFI* and *SAIDI* of distribution lines and the result that converts those of the distribution lines into the effect that affects the power



(a) *SAIFI, SAIDI*



(b) $SAIFI_{Util}$, $SAIDI_{Util}$

Fig. 6. Reliability evaluation result of distribution line

supply reliability of Busan in KEPCO, $SAIFI_{Util}$ and $SAIDI_{Util}$. From the result of Fig. 6, we reveal that the damage that affects the power supply reliability of Busan branch in KEPCO depends on the number of customers that the feeder occupies. As an example, feeder B, which has 3953 customers shows that *SAIFI* and *SAIDI* are 0.754 and 0.644 respectively, but $SAIFI_{Util}$ and $SAIDI_{Util}$ are 0.0017 and 0.0015. Therefore we reveal that this feeder has more damage by fault than that of the other feeder. Otherwise feeder A, which has 548 customers shows that *SAIFI* and *SAIDI* are 1.38 and 0.91 respectively, but $SAIFI_{Util}$ and $SAIDI_{Util}$ are 0.000469 and 0.000317. Therefore we show that this feeder has less damage by fault than that of the other feeder. Table 8 represents the comparison of the evaluation result of the conventional method and that of the proposed method, where the project list used Table 2. Observing Table 8, we show that the investment priority of feeders D, F, and R changes considerably. In feeder D, the conventional method shows that investment probability and priority represent 84 and 4th, but the proposed method indicates that investment probability and priority represent 0.777 and 1st. As the negative effect that affects the power supply reliability of the Busan branch in KEPCO is represented higher than those of the different feeders, the result indicates that *IPofRI* is 0.883, where $SAIFI_{Util}$ and $SAIDI_{Util}$, the effect of which affects the power supply reliability of the Busan

Table 7 Priority of Project by Facility Investment Decision in KEPCO

Feeder	Investment priority of office	Line length	Management level	Pollution level	Interconnection capability	Load growth	Failure history		Line route	Total	Priority
							f_P	f_T			
A	30.0	10.0	5.0	4.5	3.5	4.5	4.0	4.0	30.0	95.5	1
B	24.0	10.0	5.0	5.0	3.5	4.0	4.0	4.0	30.0	89.5	2
C	18.0	10.0	5.0	5.0	3.5	5.0	4.0	4.0	30.0	84.5	3
D	18.0	10.0	5.0	4.5	3.5	5.0	4.0	4.0	30.0	84.0	4
E	18.0	10.0	4.5	4.5	3.5	4.5	4.0	4.0	30.0	83.0	5
F	18.0	10.0	5.0	5.0	3.5	4.0	3.5	4.0	30.0	83.0	6
G	18.0	8.0	5.0	5.0	3.5	5.0	3.5	4.0	30.0	82.0	7
H	18.0	10.0	5.0	4.5	4.5	3.0	3.0	4.0	30.0	82.0	8
I	18.0	10.0	4.5	3.5	4.5	3.5	3.5	3.0	30.0	80.5	9
J	18.0	8.0	4.5	5.0	3.5	3.5	4.0	4.0	30.0	80.5	10
K	18.0	8.0	5.0	3.5	2.5	5.0	3.5	4.0	30.0	79.5	11
L	18.0	8.0	5.0	4.5	2.5	4.0	3.5	4.0	30.0	79.5	12
M	18.0	10.0	5.0	4.5	3.5	5.0	3.0	3.0	24.0	76.0	13
N	18.0	8.0	5.0	4.5	3.5	4.5	3.0	3.0	24.0	73.5	14
O	18.0	8.0	5.0	5.0	2.5	2.5	3.0	3.0	24.0	71.0	15
P	18.0	6.0	4.5	3.5	4.5	3.5	3.5	3.0	24.0	70.5	16
Q	18.0	8.0	4.5	4.5	4.5	4.5	3.5	3.0	18.0	68.5	17
R	18.0	8.0	4.5	5.0	2.5	4.5	3.5	4.0	18.0	68.0	18
S	18.0	8.0	4.5	4.5	4.5	4.5	0.0	0.0	24.0	68.0	19

Table 8 Priority Comparison of Project by Facility Investment Decision by an Existing Method and a Proposed Method

Feeder	IPofRI	IPofKEPCO	Result	*Priority*	
				Conventional method	*Proposed method*
A	0.186	95.5	0.764	1	2
B	0.607	89.5	0.726	2	3
C	0.384	84.5	0.610	3	4
D	0.883	84.0	0.777	4	1
E	0.435	83.0	0.580	5	5
F	0.170	83.0	0.478	6	10
G	0.294	82.0	0.558	7	7
H	0.616	82.0	0.558	8	6
I	0.475	80.5	0.518	9	8
J	0.106	80.5	0.350	10	13
K	0.194	79.5	0.406	11	11
L	0.319	79.5	0.485	12	9
M	0.106	76.0	0.253	13	14
N	0.106	73.5	0.193	14	16
O	0.206	71.0	0.249	15	15
P	0.106	70.5	0.137	16	19
Q	0.121	68.5	0.173	17	17
R	0.894	68.0	0.401	18	12
S	0.106	68.0	0.157	19	18

branch in KEPCO, are 0.00254 and 0.0017, respectively. Thus, as the facility does invest urgently in the current year, the proposed method changes the investment priority from 4th to 1st. In feeder F, the conventional method shows that investment probability and priority represent 83 and 6th, but the proposed method shows that investment probability and priority represent 0.478 and 10th. As the negative effect that affects the power supply reliability of the Busan branch in KEPCO is represented lower than those of the different feeders, the result shows that *IPofRI* is 0.17, where $SAIFI_{Util}$ and $SAIDI_{Util}$, the effect of which affects the power supply reliability of the Busan branch in KEPCO, are 0.000425 and 0.000417 respectively. Thus, as the facility does not invest in the current year, the proposed method changes the investment priority from 6th to 10th.

Under the limited budget of 20 billion, we compared the enhanced value of the conventional method with that of the proposed method in Table 9. Table 9 shows that the conventional method and the proposed method select the seven projects together. Particularly, the proposed method removes feeder F, and selects feeder H. The evaluation result indicates that in the conventional method the improved values of $SAIFI_{Util}$ and $SAIDI_{Util}$ are 0.000129 and 0.000122 respectively, while in the proposed method they are 0.000295, 0.00022 respectively. Therefore, the results verify that the proposed method can be efficiently used in the actual priorities method for investing in the electrical facilities.

Table 9 Priority Comparison of Project by the Facility Investment Decision by a Conventional Method and a Proposed Method

	The selected feeder	Improvement degree of reliability	
		$SAIFI_{Util}$	$SAIDI_{Util}$
Conventional method	A, B, C, D, E, F, G	0.000129	0.000122
Proposed method	D, A, B, C, F, H, G	0.000295	0.000220

5. Conclusion

In this paper, we propose a novel investment priority decision method of the electrical facilities considering reliability of distribution networks. The proposed method decides investment priority considering the existing KEPCO investment method and reliability evaluation indices of the distribution networks by the fuzzy rule. Particularly, the reliability evaluation indices are *SAIFI* and *SAIDI*, and the reliability evaluation method uses the analytical method. To verify the proposed method, we use the weak facility reinforcement work list of project category for distribution systems reinforcement planned in KEPCO in 2004. The evaluation result showed that, under a limited budget, the reliability of KEPCO in the Busan region using the proposed method could be enhanced more significantly than using the conventional KEPCO method. Therefore, the results verify that the proposed method can be efficiently used in the actual priorities system for investing the electrical facilities. And when utilities set the investment plan of electrical facilities in KEPCO from now on, the proposed method is expected to be used as fundamental data.

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References

[1] G.W. Ault, C.E.T. Foote, J.R. McDonald, "Distribution system planning in focus," *IEEE Power Engineering Review*, Vol. 22, Issue: 1, pp. 60-62, January 2002.
[2] Richard E. Brown, *Electric Power Distribution Reliability*, New York: Marcel Dekker, 2002.
[3] H. Lee Willis, *Aging Power Delivery Infrastructures*, New York: Marcel Dekker, 2001.
[4] R. Billinton and R. N. Allan, Reliability Evaluation of Power Systems- 2th, New York: Plenum Press, pp. 220-326, 1996.
[5] MOCIE, the technical report on development of asset management system in distribution networks, pp. 5-101, 2003.
[6] Management statistics in KEPCO, pp. 133, 2003.
[7] Guide book on distribution electrical facility investment plan in KEPCO in 2004-2006, pp. 1-35, 2003.
[8] Timothy J. Ross, Fuzzy Logic With Engineering Applications, McGraw-Hill, pp. 46-369, 1995.
[9] IEEE Standard 1366-1998, IEEE trial-use guide for electric power distribution reliability indices, April 1999.
[10] Brian P. Lang, Anil Pahwa, "Power Distribution System Reliability Planning Using a Fuzzy Knowledge-Based Approach," IEEE Trans. on Power Delivery, Vol. 15, No. 1, pp. 279-284, January 2000.
[11] S.R. Gilligan, "A method for estimating the reliability of distribution circuits", IEEE Transactions on Power Delivery, Vol. 7, Issue: 2, pp. 694-698, April 1992.
[12] Billinton, R. P. Wang, "Reliability-network-equivalent approach to distribution-system-reliability evaluation", IEE Proceedings, Vol. 145, Issue 2, pp. 149-153, Mar. 1998.
[13] R. N. Allan, R. Billinton, I. Sjarief, L. Goel, K. S. So, "A reliability test system for educational purposes - basic distribution system data and results", IEEE Transactions on Power Systems, Vol. 6, No. 2, pp. 813-820, May 1991.

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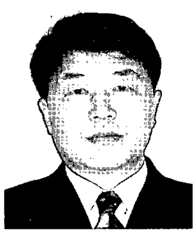

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