배전자동화시스템 적용을 위한 경제성 평가

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Economic Evaluation for the Application of the Distribution Automation System

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Abstract

This study considers the economic aspect of the distribution automation system, which is the decision-making criteria of the electric utilities for the investment. The feeder automation candidate region is divided into two types of the urban and the rural. The total investment cost of the feeder automation for each type is estimated. The annual cost is also estimated, by finding the fixed charge rate.

To compare the annual cost and the economic effect cost for the investment decision-making, the costs are quantitatively estimated on the following effects : the manpower replacement, the outage cost saving, the main transformer utilization improvement, the feeder utilization improvement, and the line loss reduction.

1. Introduction

In order to improve the reliability of the power supply and to provide the good quality of electricity to the customer, the electric utilities have tried to build the automation system of the power system operation and the facility on the basis of the computer and communication. The distribution automation systems are being developed on the aspects of the feeder automation for the supply reliability and quality improvement and the load control and automatic metering for the distribution system efficiency and the economics. The electric utilities in Japan have focused on the feeder automation in order to reduce the outage time, and the main function of the distribution automation in the United States is the load control for the economic system operation. ([1-3])

In this study, the main task of distribution automation system (DAS) is to automate the feeder operation. Since the total investment cost of the automation system is different according to the area, we consider two types of the candidate regions such as the urban and the rural, and the respective investment costs are estimated, in order to establish the decision-making criteria of the electric utilities' investment. To estimate the economic effect, 5 aspects are considered : i) the manpower replacement effect, ii) the outage cost saving, iii) the main transformer utilization improvement, iv) the feeder utilization improvement, v) the line loss reduction. In the following, the total investment cost, the annual cost with the fixed charge rate, and the economic effect cost estimation procedures are shown. Finally, the economic effect comparison is achieved by the ratio of the annual cost to the economic effect cost.

2. Investment Cost

The facility of the DAS is composed of the switch, the switch control unit, the central control unit, the substation communication control unit, the transmission line, the line equipment, and the other units such as the UPS, battery, etc. First, the total investment cost of the urban type DAS will be estimated. The number of automatic switches on each feeder is assumed to be 6. If the communication system of urban type DAS is the dedicated line, the transmission line cost is needed. For the rural type, two cases are analyzed such as the hybrid type of the dedicated line and the power line carrier, and the power line carrier type. Table 1 shows the total investment costs for the urban and rural.

As shown in Table 1, the feeder number of the urban type is 102, and the total switch number becomes 612. For the rural type with 22 feeders, 132 switches are needed. For the power line carrier type of the rural type DAS, a single repeater is installed at every 10 km, and the maximum repeater number on each feeder is limited to 3.

3. Annual Cost and Fixed Charge Rate

The annual cost is the cost occurring fixedly according to the total investment cost. And, the fixed charge rate is the ratio of the fixed cost to the total investment cost of the system. The main components of the annual cost are the capital cost, the depreciation cost, the insurance, the corporation tax & various tax, and the operation & maintenance cost. ([4])

3.1 Capital and Depreciation Cost

The capital cost is the cost to lead and retain the facility investment cost, and the depreciation cost is that to be reserved and used the part of the income as the form of the internal retention. The average capital cost during the life period can be found from the capital recovery factor.

3.2 Insurance

The insurance of the Korea Electric Power Corporation (KEPCO) is classified into the self-insurance and the nuclear power insurance according to the danger compensation fund regulation. The self-insurance is 3/1000 of insured facility, where the insured property value is the product of the facility cost and the insured rate. If the escalation rate and the interest rate are constant, and the tax and insurance during the construction period are not considered, the initial investment cost of DAS is assumed to be the property value.

In the total investment cost, the other cost is assumed to be the non-insured property value. Insured property is the value subtracted the non-insured property from the property value, and the insured rate is the division of the insured property by the property value. And, the product of insured rate and 0.003 is the self-insurance rate.

Actually, there is some difference between the property value at the starting operation time and the initial investment cost. The reason is that the interest for the invested capital, the insurance, and the escalation rate during the construction period are considered.

3.3 Corporation Tax & Various Tax

The KEPCO considers the resident tax as the various tax, and here, we will estimate the tax rates for the corporation and resident taxes. The corporation tax applies 5 % of the pure benefit, and the resident tax rate is 7.5% of the corporation tax, that is, 0.375 % (= 5 % x 0.075) of the pure benefit. The tax rate for the benefit including the corporation and resident taxes is 5.375 % = (5 % + 0.375 %).

3.4 Operation and Maintenance Cost

The operation and maintenance cost includes the labor cost, the repair maintenance cost and the other. The fixed charge rates for each cost are as follows.

a. Labor Cost

When the distribution system electrician number is constant, the average annual labor cost is found on the basis of the revenue and the past record, and multiplied by the electrician number, and then divided by the total investment cost, in order to find the labor cost rate.

b. Repair Cost

Generally, the repair cost rate at the initial operation year is 1/2 of the average repair cost rate, and will be increased linearly. The repair cost rate at the final year becomes 3 times of that of the initial year.

c. Other Cost

On the basis of the average record or revenue at the initial year and on the life period, the other cost rate during the life time period is estimated.

From the 5 fixed charge rates as above, the total fixed charge rate of the facility and the estimated annual cost will be shown in Table 2.

Table 2. Average Fixed Charge Rate during the Life Period

Region	Facility	Life year	Fixed charge rate (%)		
			DR 9 %	DR 10 %	DR 12 %
Urban	Switch control unit Central control unit S/S comm. control unit	10	22.91	23.58	24.98
	Switch, Trans. Line	15	19.64	20.36	21.85
Rural (Hybrid)	Switch control unit Central control unit S/S comm. control unit Line equipment	10	21.85	22.55	23.97
	Switch, Trans. line	15	18.65	19.38	20.90
Rural (PLC)	Switch control unit Central control unit S/S comm. control unit Line equipment	10	21.85	22.55	23.97
	Switch	15	18.65	19.38	20.90

(Note) DR : discount rate

Table 3. Investment Cost and Annual Cost for the Urban and Rural DAS
(unit : million won)

Region	Facility	Total Investment Cost		Average Annual Cost		
				DR 9 %	DR 10%	DR 12%
Urban	Switch control unit Central control unit S/S comm. control unit	7,070	9,210	2,040	2,103	2,234
	Switch, Trans. Line	2,140				
Rural (Hybrid)	Switch control unit Central control unit S/S comm. control unit Line equipment	1,568	2,560	528	546	583
	Switch, Trans. line	992				
Rural (PLC)	Switch control unit Central control unit S/S comm. control unit Line equipment	1,628	1,892	405	418	445
	Switch	264				

4. Economic Effect Analysis for DAS

When the distribution system is automated, we can consider the economic effects such as : i) the manpower replacement caused by the switch remote control and the remote measurement of the line voltage and current, ii)

Table 1. Investment Costs for the Urban and the Rural type DAS (Base year of cost : 1992, Business year : 1992)
(unit : million won)

Communication System		Dedicated Line			Hybrid Type					Power Line Carrier Type				
Unit	Life period (year)	Urban Type			Rural type (3 Re/feeder)			Rural (1Re/10km)		Rural type (3 Re/feeder)			Rural (1Re/10km)	
		Cost/unit	Unit #	Cost	Cost/unit	Unit #	Cost	Unit #	Cost	Cost/unit	Unit#	Cost	Unit #	Cost
Feeder			102			22		22			22		22	
Substation			10			4		4			4		4	
Switch	15	2	612	1,224	2	132	264	132	264	2	132	264	132	264
Switch control unit	10	5	612	3,060	3.5	176	616	176	616	3.5	176	616	176	616
Central control unit	10	3,000	1	3,000	600	1	600	1	600	600	1	600	1	600
S/S Comm. control unit	10	71	10	710	45	4	180	4	180	45	4	180	4	180
Trans. Line	15	2	458km	916	2	364 km	728	364 km	728	-	-	-	-	-
Line Equip.	10	-	-	-	3	24	72	102	306	3	44	132	161	483
Other	10			300			100		100			100		100
Total cost				9,210			2,560		2,794			1,892		2,243

(Note) 1. The transmission line is represented in km. 2. Re/feeder : Repeater number on each feeder the outage cost saving by the reduction of the forced and planned outages, iii) the facility investment delay by the utilization rate improvement of the MTr, iv) the facility investment delay by the utilization rate improvement of the feeder, v) the line loss reduction by the automatic load transfer.

4.1 Manpower Replacement Effect

The manpower saving effect is expected on the DAS through the switch remote controls for the forced and planned outages, the waiting electricians mobilized for the special events, and the remote measuring for the line voltage/current.

4.2 Outage Cost Saving Effect

We will find the total outage time and outaged electricity for all outage events, with the electricity saving and outage cost reduction by the automation. Two types of outage costs are considered : i) the outage cost that the electric utility can not earn from the customer by the outage, ii) the outage cost that is lost on the aspects of the gross national product or gross regional product ([5]). The latter outage cost is calculated on the basis of the electricity selling price multiple ([6]), which is found by using the macro approach related to the national economics.

4.3 Main Transformer Utilization Improvement Effect

On the DAS, the load of the heavily-loaded feeder can be transferred to the lightly-loaded one through the automatic load transferring so that the utilization rate of the MTr is improved, and therefore, the investment delay effect can be expected. Based on the result of the Tokyo Electric Co. ([3]), it is assumed that the MTr utilization improvement rate is 3 % for both urban and rural. The MTr construction cost per MVA is 31,000 thousand won. The cost savings by the MTr facility investment delays of the urban and the rural are found.

4.4 Feeder Utilization Improvement Effect

Under the DAS, it is possible to automatically transfer the load by using the feeder reconfiguration algorithm where some load of the heavily-loaded feeder is transferred to the lightly-loaded one. Then, the feeder utilization rate can be improved by the facility investment delay. We assume that the feeder utilization rate improvement is 5 %, which is the result of Tokyo Electric Co. ([3]). The feeder construction cost is 15 million won per feeder. Then, the facility investment cost savings for the urban and rural are considered.

4.5 Distribution Line Loss Reduction Effect

By automatically transferring the load on the DAS, the electricity loss on the distribution line can be reduced. To find the satisfactory solution rapidly, the heuristic search method of the expert system can be adopted. The distribution line loss reduction of Wagner, Chikhani & Hackam ([7]) is 8.8 %, which is the simulation result applied to the 44 kV, 150 MW distribution system of Kingston Public Utilities Commission. We adopt this as the loss reduction rate for the urban and rural DAS.

The results of the above 5 economic effects for the DAS of the urban and rural are shown in Table 4.

5. Comparison of Evaluation Results and Conclusions

In this section, we will compare the evaluation results of the urban and rural DAS with the DASs of Sapporo region of Hokkaido Electric Co. ([2]) and Kangdong branch of Tokyo Electric Co. ([3]), which have already been constructed and is partially being operated.

Table 4. Economic Effects of the Urban and Rural DAS

Effect	Analysis Content	Urban	Rural
Manpower Replacement Effect	Electrician Number	1.83	3.34
	Labor Cost Saving	2,745	5,010
Outaged Electricity Saving Effect	Saved Outage Electricity	169.78	21.82
	Outage Cost Saving	32,087	1,168
MTr Util. Rate Improvement	Reduced Capacity (MVA)	37.20	3.78
	Investment Cost Saving	115,320	11,718
Feeder Util. Rate Improvement	Reduced Feeder Number	5.1	1.1
	Investment Cost Saving	76,500	16,500
Distribution Line Loss Reduction	Reduced Lost Electricity	4,944	2,414
	Lost Cost Saving	26,811	13,091
Total Economic Effect of DAS		253,463	47,487

(Note) 1. Unit : Cost - ten thousand won, electricity - MWH
2. The annual average labor cost of distribution electrician : 15,000 thousand won in 1991.

Table 5. DAS Economic Evaluation Result Comparison

Contents	Sapporo Region	Kangdong Branch	Urban	Rural (Hybrid)	Rural (PLC)
Unit	thousand yen		million won		
Investment cost	3,942,350	98,600,000	9,210	2,560	1,892
Annual Cost	865,852	15,200,000	2,103	546	418
Economic effect	365,361	16,160,000	2,535	475	475
1. Manpower replacement	48,164	610,000	28	50	50
2. Outage cost saving		8,500,000	321	12	12
3. MTr util. rate improvement		3,440,000	1153	117	117
4. Feeder util. rate improvement	190,127	3,610,000	765	165	165
5. Line loss reduction	127,070		268	131	131
Effect/Annual Cost	0.42	1.06	1.21	0.87	1.14

Note) 1. The discount rate of 10 % is applied for the annual cost.

As shown in the above table, the ratio of economic effect to the annual cost of the urban DAS is as good as the Kangdong branch of Tokyo Electric Co. When the rural DAS including the very long transmission line adopts the hybrid communication system, the economic effect is not so good. However, the rural DAS with the PLC type is expected to be cost effective.

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