정전비용을 고려한 배전계통 설비의 투자 계획 수립 방안연구

(Study on a Scheme of Investment Considering Customer Interruption Cost in Power Distribution System)

추철민* · 김재철* · 이희태* · 문종필**

(Cheol-Min Chu · Jae-Chul Kim · Tae-Hee Lee · Jong-Fil Moon)

Abstract

It is concentrated on a methodology to establish a scheme of investment on power distribution systems of components. This paper provides a methodology to estimate the scheme as using a customer interruption cost regarding reliability indices in power distribution systems. The proposed method basically uses the failure rate depending on time for explaining the deterioration of a component. Therefore, the theory of the sensitivity is used for deciding the precedence of the investment to consider an effect of each component's failure rate on the system reliability. After Estimating the sensitivity on component, investment cost making incremental reliability level is produced by component's investment cost accumulated according to the precedence of the sensitivity. After that, the failure rate corresponding with reliability level on the curve of investment cost is used as producing the curve of customer interruption cost. Two curves have the crossing point that is proposed to acceptable reliability level for customer and utility. In this paper, the acceptable reliability level for customer with the utility is assessed to analyze customer interruption cost and sensitivity of reliability indices. In conclusion, the result of investment based on this method is shown to the reliability level with two cost.

1. Introduction

Recently, the basic purpose of an electric power system is to give electric power to its customer at the lowest cost with acceptable reliability levels. Therefore, these aspects of economical and reliability should be considered on management of power systems. In the past, a problem of a reliability on utilities is to provide high reliability regardless of economical cost ofcustomers. The planning of operation about a high reliability, however, can bring about an increment of cost to customers. So, the recognition about flexible planning considering economical efficiency and reliability is necessary for both a customer and an operator. For example, if the reliability is increased to reduce the interruption, the cost that a customer pays for high reliability is dramatically increased.

It is necessary to estimate effect of investment in customer side considering relation between a reduction of an interruption cost by an increasing reliability and a propriety of an operation planning such as an investment of facilities.

Under this situation, the decision making a appropriate reliability level depends on many aspects such as a facilities' failure rate depending on time, demands of customer andsurveys showing that the cost of an interruption depends on the type of customer and on the magnitude and the duration of the interruption. In many aspects, this paper considers an affection of a facilities' failure rate depending on time in a reliability indices, and suggests an appropriate reliability level comparing investment cost by the system reliability indices with interruption cost.

For quantified investment cost, the sensitivity of reliability indices can be used. This paper presents the calculation of an accumulative investment cost using sensitivity ofreliability indices. Therefore, using the increment of reliability level following the cost is used to calculate an interruption cost. All data used in this paper are assumed from.

2. Assessment the reliability indices

1. Application to a typical example

The feeder in Fig. 1 is a typical example feeder in distribution systems. A sample model is required to evaluate appropriate reliability level and cost. This model includes the distribution system components, such as lines, breakers, fuses, disconnect switches and alternate supplies, the load models and the customer sector interruption cost models.

In Fig.1, there are four types of customer such as residential, commercial, industrial and agriculture. Therefore, all components' failure rate depends on time. However, the transformer and the disconnect switch is not considered the rate because the periodical inspection is done to these components. The approach of reliability assessment described as following section is used to evaluate appropriate reliability level in this sample model.

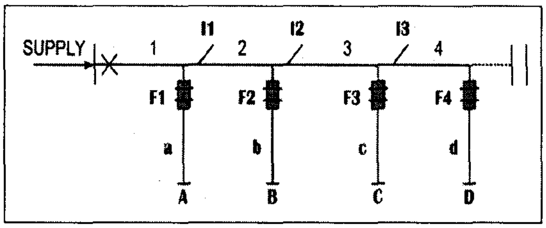

Fig. 1 A typical example feeder in distribution systems

In this model, all of the information that needs for calculating reliability indices and the sensitivity of SAIDI is used the constants in Reference [1] except a failure rate.

Table 1. Reliability parameters for system of the model

component	Length(km)	r(hours)
section		
L1	2	4
L3	1	4
L5	3	4
L7	2	4
distributor		
L2	1	2
L4	3	2
L5	2	2
L7	1	2

Table 2. Customers and connected to the system of the model

Load point	Number of customers	Average load connected (kW)
A	1000	5000
B	800	4000
C	700	3000
D	500	2000

2. Failure rate depending on time

Facilities in distribution systems have the failure rate depending on time which has two categories, random failure rate and deteriorated failure rate. The random failure rate is any accidents without concerning time. The deteriorated failure rate is the rate of abrasion and ageing by time. Total failure rate is sum of random failure rate and deteriorated failure rate. In this, total failure rate is presumed that the failure rate is worsened gradually by time.[1][7]

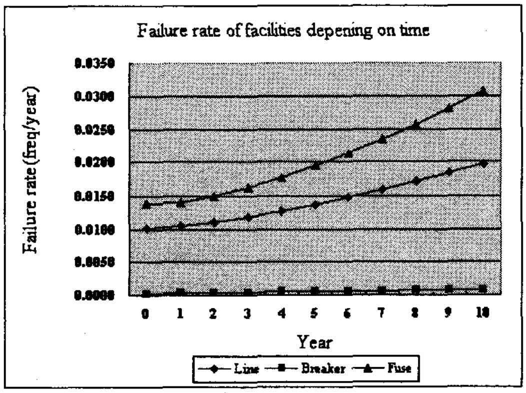

Fig. 2 Failure rate of facilities depending on time

3. Reliability indices

The distribution system is the part of an overall power system which connects the bulk system to the customer. The increment of facilities has a consequence in a relatively high proportion of customer interruption.

The reliability indices in basic distribution system are the three load indices of average failure rate λ, the average outage duration r and the annual outage duration U. These basic indices are important to estimate individual load point parameter.

The system reliability indices of SAIFI, SAIDI, CAIDI, ASAI and ASUI can be calculated from the basic load point indices. In this paper, SAIDI and SAIFI are considered to estimate an investment cost according to increment of reliability level. The interruption cost is also calculated using the three basic load point indices.

In this model, the result of system reliability indices (SAIDI) is as following Fig 3.

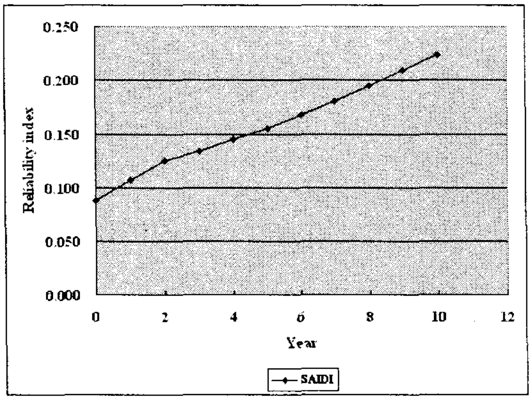

Fig. 3 Change of the system reliability index(SAIDI) by facilities failure rate depending on time

4. Sensitivity of system indices

In this paper, the investment cost is decided by the sensitivity of reliability indices on facility failure rate. The analysis of sensitivity is to estimate how much facility failure rate affect system reliabilities (SAIDI, SAIFI) and interruption cost. The higher sensitivity has the more effect to the assessment indices of systems. The mathematical expression of this theory is as follows.

$$\alpha = \left[\frac{(\text{Assessment index})_{jk} - (\text{Assessment index})_{(j\text{-}1)k}}{\lambda_{jk} - \lambda_{(j-1)k}} \right] \quad (1)$$

In equation (1), the k is a kind of facility, and the j is an appliance period of a facility k [4].

5. Interruption cost of Sample model

Interruption cost assessment is currently receiving considerable attention as providing the opportunity to include the monetary losses incurred by utility customers as a result of the system fault. There are many approaches utilized to assess the interruption cost.

The survey can easily include the effects of many factors on interruption. This approach involves two main variables of which one is the type of customer. A Standard Industrial Classification(SIC) can usually be used for this purpose ,and identified as seven sector such as residential, commercial, industrial, agriculture and government & institutions include large user. The second variable is the duration of the interruption. Individual customer damage function (ICDF) can be used to relate an interruption duration to the cost associated with the interruption.

The customer survey is first done for analyzing interruption cost. In this paper, customers are divided into four categories such as residential, commercial, agriculture and government & institutions. Postal surveys are utilized to estimate the customer interruption losses for the different customer sector shown in Fig. 4.

Postal surveys have been utilized to estimate the customer interruption losses for the different customer sector. The surveys show that the cost depends on type of customer interrupted, and on the duration of interruption. The survey data have been analyzed to present the sector customer damage function (SCDF). The SCDF are as following Fig 4.

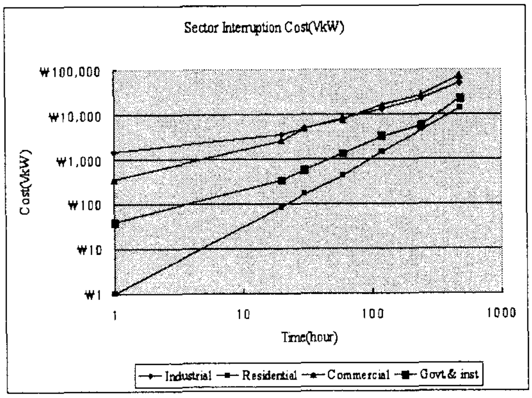

Fig. 4. Sector interruption damage function

Fig. 4 gives the interruption costs for seven discrete interruption durations.

6. Methodological approach

In this paper, the basic procedure used in the sensitivity of reliability indices and the generalized analytical method to estimate the appropriate reliability level for flexible planning can be summarized in the following steps:

Step 1: Find the average failure rate λ_j calculating random failure rate and deteriorated failure rate from a history of facilities' fault data. Also, the average repair time rj and annual interruption time Uj for a failed element j are identified.

Step 2: Using the basic three indices at load point i, determine the total value of each basic three indices in load point

$$\lambda_i = \sum_j \lambda_{ij} \quad (2)$$

$$U_i = \sum_j \lambda_{ij} r_{ij} \quad (3)$$

$$r_i = \frac{U_i}{\lambda_i} \quad (4)$$

Step 3: Using results of step 2, evaluate system reliability index SAIDI, and calculatesensitivity of SAIDI on the facility of failure rate depending on time.

In this step, consider the failure rate depending on time in order to estimate an increment of SAIDI which means that the system reliability is getting worse.

Step 4: Determine the order of facilities' sensitivity from more effective to less effective in system reliability index SAIDI, and decide investment cost according to the order.

In this step, it is possible to find an accumulate investment cost according to improvement reliability level.

Step 5: Find the basic load point indices of improving reliability level, determined according to an accumulate investment cost for calculating interruption cost.

Step 6: After step 5, using the interruption time rij and the customer type in load point i, determine the interruption cost Cij per unit(kW) using the corresponding sector customer damage function(SCDF).

$$CIC_{i,j,k} = L_{i,k} \cdot C_i(r_j) \cdot \lambda_j \,(won/yr) \quad (5)$$

Step 7: Estimate the CICi,j of each contingency j in load point i using following equation.

$$CIC_{i,k} = \sum_{j=1} CIC_{i,j,k} (won/yr) \quad (6)$$

Step 8: Repeat 7 until the CICi,j of all load points are evaluated, and evaluate the total system ECOST in system using equation (7).

$$CIC_k = \sum_{j=1} \sum_{i=1} CIC_{i,j,k} \,(won/yr) \quad (7)$$

Step 9: Find appropriate reliability level comparing investment cost with interruption cost. The appropriate reliability level is the crossing point by two cost curves.

This approach is focused to apply the failure rate depending on time and to find the crossing point by two cost curves. In this paper, this point is suggested as appropriate reliability level.

Table 3. The order of facilities' sensitivity and investment cost

Order	facility	Cost per Unit (won per Unit)	investment cost per facility (won per facility)
1	L1	38,934	77,868
2	L3		38,934
3	L5		38,934
4	L7		116,802
5	L2		116,802
6	L4		77,868
7	L6		77,868
8	L8		38,934
9	F4	4,500	4,500
10	B3		4,500
11	F3		4,500
12	B2		4,500
13	F2	208,086	208,086
14	B1		208,086
15	F1		208,086

3. Conclusion

The order of the sensitivity was evaluated on facilities in this example. The result is in Table 3. Therefore, this table presented the investment cost per facility. Fig.5 show a relation between improvement of reliability level and increment of investment cost.

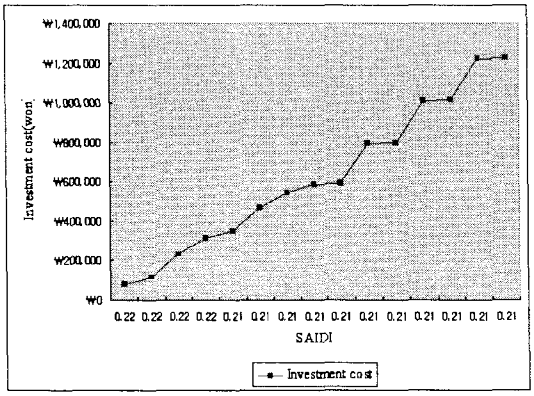

Fig. 5 Increment of Investment cost based on the sensitivity of SAIDI

According to the procedure for calculating appropriate reliability level in a distribution system, the interruption cost compared with the investment cost is produced. Fig.6 shows the point of appropriate reliability level.

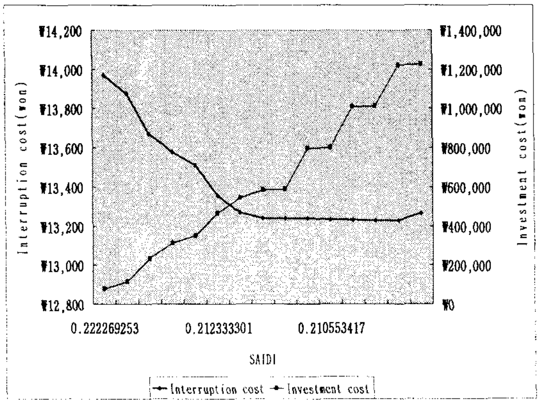

Fig. 6 The investment cost vs the Interruption cost based on SAIDI

Fig.6 shows that the appropriate reliability point is 0.2110677. Also, the point of the reliability is approximately of 543,700(won) on investment cost and 13,300(won) on interruption cost. Hence, we suggest that the sample model in Fig.1 is conducted maintenance for keeping the reliability value at a point of 0.2110677. Also, the investment cost is suggested to take 543,700(won) for maintaining this reliability level, and the interruption cost is paid 13,300(won) to the customer.

Although the appropriate reliability point is produced by this method presented in this paper, this reliability level is not absolutely correct. If the most appropriate reliability level is produced in the sample model suggested in this paper, this method should have to consider variable path of the precedence for the investment and apply the theory of the optimization. Therefore, the ratio of maintenance is considered for accurate failure rate depending on time.

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