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Develop of Methods for an Overhead Cable Asset Soundness Evaluation Considering Economic Feasibility

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Abstract: To supply stable and high-quality power according to the advancement of industrial growth, electric power companies have performed maintenance of power facilities using various methods. In the case of domestic power distribution facilities, there are limitations in performing diagnostic management on all facilities owing to the large number of facilities; therefore, old facilities are managed by the health index assessment method. The health index assessment comprises only facility operation data and external environmental data and is managed only for four types of distribution facilities, including overhead/underground transformers and switchgear. In the case of extra high–voltage overhead wires, there is no standard for old replacement, despite the large number of wires, such as transformers and switchgear, and the large ripple effect of power failure in the event of a power outage. Therefore, in this paper, a health index assessment methodology for extra-high voltage overhead cables was developed. In this paper, we developed an economic health index assessment methodology that additionally considers risk cost, which is different from the existing health index assessment method that uses only operational data and external environmental data to determine facility performance evaluation and aging replacement criteria. Using the health index assessment methodology developed in this paper, it is possible to expect a reduction in facility operating costs and investment costs from the perspective of electric power companies through the replacement of old extra-high voltage overhead cables. In addition, from the perspective of consumers, it is expected to increase power reliability and reduce the ripple effect of failure by preferentially replacing equipment with a high probability of failure.

Keywords: health index; distribution; overhead line; power facilities; evaluation

1. Introduction

As economic growth develops, consumers continue to demand a stable and high-quality power supply, and power companies continuously develop and maintain power facilities to meet this. Thus, the failure of power facilities causes enormous economic losses to consumers and power companies. For this reason, power companies manage power facilities in various ways, and power facility management technology has been developed accordingly. Conventional power facilities depend on a time-based maintenance (TBM) method with regular cycles before exhausting the life of the facility [1]. In introducing the TBM management method, the life of the power facility must be predicted through an experimental life evaluation. Accordingly, the overall lifespan of power facilities is predicted through life evaluation based on accelerated tests, and the TBM management method is operated accordingly.

Since the 1990s, condition-based maintenance (CBM) methods have been applied to monitor the condition of facilities online by attaching a sensor to the power facility, optimizing maintenance according to abnormal signs of the facility and predicting the facility's life. As the CBM method is applied, methods for predicting the life of power facilities have become more diverse. However, these have certain limitations, such as limitations in sensing technologies and expensive diagnostic systems. Thus, most countries use the health index to predict the state of power facilities. The health index means expressing the overall state of power facilities as an indicator to establish a strategy for replacing power facilities. The health index defined in the Council on Large Electric Systems (CIGRE) technical document is shown in Table 1 [2,3,4].

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Table 1. Defining the CIGRE health index.

Tech. Brochure	Health Index Definition
TB309	To develop an understanding of the overall condition of the asset base and the effect of aging on the ability of equipment to perform its intended function, many utilities have begun to develop and apply indicators, which are representative of asset condition
TB422	The health index is one single overall indicator of the condition of an asset
TB541	The health index is an indicator of the asset's overall health and is typically given in terms of percentage

In the case of distribution facilities in Korea, old facilities are being replaced through power distribution facility diagnosis and health index assessment to increase the efficiency of facility operation and minimize damage to power companies and consumers. Recently considering the probability of failure of devices and the complex impact on systems, the environment, and the safety of workers, research has been conducted on the risk-Based Maintenance (RBM) method, which is a maintenance direction that can meet the preferences of facility operators and managers [5]. The RBM method determines the priority of facility replacement based on the risk factors affecting a facility. Risk assessment is quantitatively derived by calculating the interaction between the probability of power facility failure and the ripple effect that ensues when failure occurs, where the facility operator analyzes and evaluates a case using calculated risks to establish replacement priorities [6]. Although many research institutes and papers have applied or studied asset management of power equipment using the RBM method, most of them were only for transmission and transformation power facilities [7,8]. In contrast, distribution power facilities lack sufficient diagnostic failure data for asset management using the RBM method, and failure data are insufficient because facilities are demolished as a preventive measure before failure occurs. Therefore, the RBM method is hard to apply to power distribution facilities. In addition, as the risk cost calculation used in RBM is determined by policy decision-making, the health index and diagnosis results are mainly used in the asset management of distribution facilities in Korea. Therefore, in this paper, we propose a new risk-based health index assessment method that applies facility risk costs to health index assessment as a quantitative concept.

2. Health Index in Korea

2.1. Power Facility Operation Environments

For domestic power facilities, health index assessment based on preventive diagnosis is mainly used. In Korea, as the main purpose is to stably provide high-quality power, the high reliability of power systems is maintained through advance replacement before equipment failure occurs [9]. Because transmission and substation facilities have large power facilities, a few facilities, and a large ripple effect due to facility failures, periodic preventive diagnosis is performed on all facilities, and breakdowns are prevented through 24-h monitoring by attaching diagnostic sensors [10]. However, as shown in Table 2, performing activities such as patrols and inspections on all power distribution facilities is difficult because power distribution facilities are numerous but small in size and many facilities are exposed to the outside environment. Thus, attaching diagnostic sensors to and monitoring power distribution facilities are impossible. Therefore, health index assessment for major power distribution facilities has been introduced and operated to prevent the failure of power distribution facilities.

Table 2. Power distribution facility quantity.

Facility Classification		Installation Location	Quantity
Route length (c-km)	High voltage	Overhead power	197,996
		Underground power	49,703
		Underwater power	147
	Low voltage	Overhead power	265,542
		Underground power	11,783
Supporter		Concrete pole	9,525,065
		Panzer mast	413,947
		Wooden pole	170
		Steel pole	177
		Steel tower	1,081
Transformer number		Overhead power	2,368,002
		Underground power	66,978
Static condenser number		Overhead power	123,754
		Underground power	81,636

2.2. Health Index Standards

Health index assessment is currently applied only to the management of power distribution facilities and is introduced and operated only for a total of four facility types: overhead transformers, overhead switchgear and underground switchgear, and transformers. Although the health index assessment items for each facility are different, all four types are composed of a perfect score of 100. Meanwhile, a score of 81 or higher is considered a very poor grade, thus requiring replacement. The criteria for health index assessment for each facility are evaluated using the items of operation data and external environmental data, as shown in Table 3.

Table 3. Evaluation items for the health index of power distribution facilities.

Evaluation items
Lifetime loss rate (%)
Number of lightning strike days per year
Salt damage grade
Construction plan
Months of usage
Monthly average temperature difference
Average load
Number of operations of DAS switchgear
Failure rate by specification
Utilization rate
Ambient temperature
Type of insulation
Failure experience
Diagnostic inspection

The Korea Electric Power Corporation (KEPCO) has established and is operating its own standards for old replacement through health index assessment. According to an analysis of the ratio of old replacement by health index assessment among power distribution facilities removed by KEPCO over the past 10 years, about 30% of power distribution facilities were replaced through health index assessment. Table 4 shows the demolition rate of overhead transformers according to the reasons for demolition from January 2013 to December 2022 [13].

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Table 4. Ratio of overhead transformer demolition according to the reason for demolition.

Fault	Burnout	Overload	Old age	Expansion	Relocation	etc
8.55%	3.36%	2.44%	24.63%	11.69%	11.41%	37.91%

2.3. Difficulties and Solutions in the Health Index Evaluation of Distribution Facilities

Domestic health index assessment is evaluated using external environment data and operational data. However, there is a limit to securing diagnostic data, and there is a tendency for the old replacement quantity to be excessively calculated because economic feasibility is not considered. If the allocated replacement budget is insufficient, old facilities may not be replaced. In addition, because health index assessment is performed only for overhead and ground switchgear/transformers among various power distribution facilities, there are no standards for health index assessment for overhead wires, which account for a large number of power distribution facilities, and equipment is instead replaced after an operator's visual inspection and regular inspection once every 4 years. Overhead wires are among the power distribution facilities installed in external environments, yet there is still no standard for health index assessment for overhead wires despite the high risk of accidents due to corrosion and deterioration caused by the external operating environment.

In this study, we present a methodology for health index evaluations to determine the criteria for replacing aging extra-high-voltage overhead wires. This methodology can evaluate overall conditions by reflecting operational data, external environmental conditions, and economic evaluation items, which can be used as health index assessment items to evaluate the performance of overhead wires. In addition, the existing section-weighted summation methodology is disadvantageous given that the health index assessment score differs greatly depending on the difference in section 1. Therefore, in this study, we propose a methodology for health index assessments based on a linear equation rather than a stepwise weighted summation format.

3. Proposed method

Figure 1 shows the health index assessment method proposed in this paper. Herein, the operation health and risk cost health are calculated to determine the overall health score.

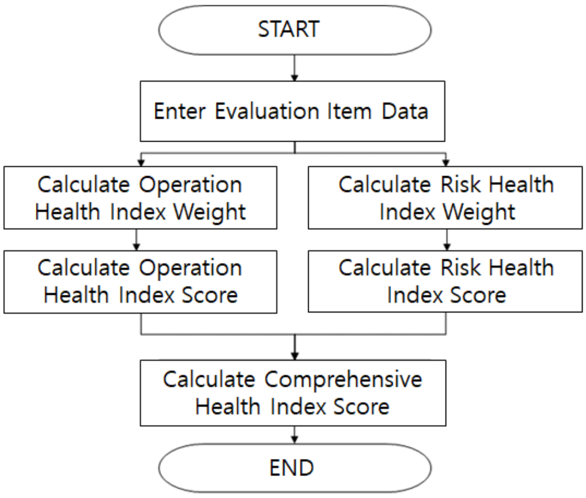

Figure 1. The health index assessment method.

3.1. Operation Health Index Weight

The weights of operation health index assessment items were calculated using survival analysis. The calculation process is shown in Figure 2.

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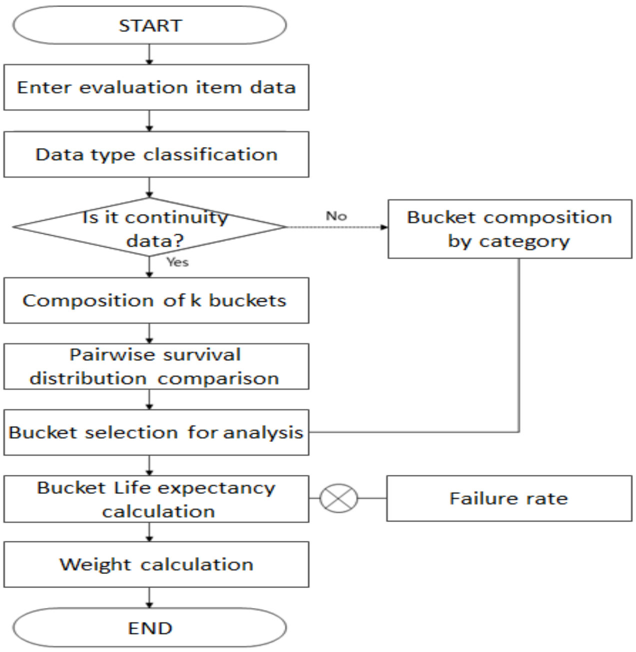

Figure 2. The calculation algorithm process of operation health index weight.

Using the weights calculated for each evaluation item, the operation health index assessment formula was constructed as shown in Equation (1). At this time, the operation health index assessment score was based on a perfect score of 100 points.

$$\mathrm{Score}_{\mathrm{Operating}} = \sum_{i=1}^{n} [(\frac{\mathrm{Feature\ Data}_i}{\mathrm{Bucket\ of\ Feature\ Data}_i}) \times \mathrm{weight} \quad (1)$$

In case the $\mathrm{Maximum\ value\ of\ Feature\ Data}_i \ \leq \mathrm{amum\ valData}_i$,

$$\frac{\mathrm{Feature\ Data}_i}{\mathrm{Bucket\ of\ Feature\ Data}_i} \mathrm{atae}$$

3.2. Risk Health Index Weight

In the event of a breakdown of the line, the customer suffers from power failure and the power company incurs costs to solve it. In the event of a facility failure, the cost of sales loss for each line that suffers from the failure to supply power to the power company and the line replacement cost for restoring power facilities in the event of a failure are defined. Therefore, in this paper, two items, the power outage equipment cost and line replacement cost in the event of a line failure, were defined and used as risk costs.

When calculating the risk cost, the failure probability of each line calculated through the survival analysis was applied to the risk cost defined in this paper, and the failure risk cost for each line was calculated using the average annual power consumption per region.

The failure risk cost relational expression defined in this study is shown in Equation (2).

$$\begin{aligned}\mathrm{Cost}_{\mathrm{failure}} = {} & \mathrm{Average\ Outage\ load\ loss(kW)} \times \mathrm{Cost\ of\ Power\ for\ Sale(won} \\ & \mathrm{/kWh)} \times \mathrm{Average\ Outage\ time(hour)} \times \mathrm{Probability\ of\ Failure}\end{aligned} \quad (2)$$

Equation (3) shows the method for calculating the failure risk cost score using the risk cost. Here, the failure risk cost score was based on 100 points.

$$\mathrm{Score}_{\mathrm{Failure}} = \frac{\mathrm{Cost}_{\mathrm{Failure}}(i)}{\mathrm{Maximum}(\mathrm{Cost}_{\mathrm{Failure}})} \times 100 \quad (3)$$

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The line replacement cost, defined as a risk factor in this study, was calculated using the KEPCO construction standard unit price and wire length as follows:

$$\mathrm{Cost}_{\mathrm{replacement}} = \mathrm{Replacement\ Construction\ Price} \times \mathrm{Span\ Length(km)} \quad (4)$$

The method for calculating the line replacement score using the line replacement cost is shown in Equation (5). Here, the line replacement score was based on 100 points.

$$\mathrm{Score}_{\mathrm{Replacement}} = \frac{\mathrm{Cost}_{\mathrm{Replacement}}(\mathrm{i})}{\mathrm{Maximum}(\mathrm{Cost}_{\mathrm{Replacement}})} \times 100 \quad (5)$$

Because power supply interruption and line replacement always accompany each other in the event of a failure, the health index of the total risk cost evaluation was calculated by defining the health index score of the failure risk cost and the health index score of the line replacement cost at a ratio of 0.5:0.5. This was calculated on a scale of 100 points.

$$\mathrm{Cost}_{\mathrm{Risk}} = \mathrm{Cost}_{\mathrm{failure}} + \mathrm{Cost}_{\mathrm{replacement}} \quad (6)$$

$$\mathrm{Score}_{\mathrm{Risk}} = \frac{\mathrm{Cost}_{\mathrm{risk}}(\mathrm{i})}{\mathrm{Maximum}(\mathrm{Cost}_{\mathrm{risk}})} \times 100 \quad (7)$$

Therefore, the overall health index assessment formula for the overhead line in this paper was calculated as shown in Equation (8).

$$\mathrm{Score}_{\mathrm{HI}} = 0.3 \times \mathrm{Score}_{\mathrm{Operating}} + 0.7 \times \mathrm{Score}_{\mathrm{Risk}} \quad (8)$$

4. Case Study

4.1. Health Index Weight

In this paper, the weights of the health index assessment were calculated using the data of about 4.7 million overhead lines installed in Korea. The average values for 2021 were used for the unit price and blackout time in the health index assessment items of risk cost, and the operation health index assessment items were defined as factors that affect the performance of the overhead lines for the operation health index assessment. The operation health index assessment items are listed in Table 5 [12].

Table 5. Evaluation factor.

Division	Evaluation factor	Note
Internal factors	Kind of overhead line, elapsed years	Internal characteristics of the lines, such as corrosion resistance and factors that can cause deterioration due to aging
External factors	Salt damage grade, number of lightning strike days, fatigue coefficient (wind tunnel impact factor)	Environmental factors that cause deterioration, corrosion, and abrasion of conductors

In evaluating the health index, the data types must be classified for each evaluation item and the maximum value must be selected for each evaluation item. For this purpose, the results of data type classification and bucket selection of evaluation items are shown in Table 6 [13].

Table 6. Data type classification.

	Data type	Bucket for analysis
Kind of overhead line	Static and plain categorical variable	ACSR-OC
Elapsed years	Continuous	18+ years
Salt damage grade	Static and plain categorical variable	Grade D

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Number of lightning strike days	Dynamic and continuous variable	more than 7 days
Fatigue coefficient	Dynamic and continuous variable	over 500

Table 7 shows the average life expectancy at the point where the survival probability is 0.995 using the analysis bucket for each evaluation item. Here, the life expectancy of each bucket is used only for weight calculation, where the failure rate for each evaluation item in the failure data was multiplied by the reciprocal of the average life. The final calculations for the weights for each evaluation item are shown in Table 7. Here, the sum of the weights was calculated out of 100 points.

Table 7. Life expectancy, failure rate, and weight results for each evaluation item bucket.

	Life expectancy by bucket	Failure rate	Weight
Kind of overhead line	30	0.287537	31
Elapsed years	39	0.359176	30
Salt damage grade	20	0.15211	25
Number of lightning strike days	19	0.042198	7
Fatigue coefficient	30	0.07262	8

Here, the salt damage grade and kind of overhead line are categorical data. The weight calculated by multiplying the life expectancy and failure rate for each grade is shown in Table 8.

Table 8. Result of salt damage grade and kind of overhead line weight.

	Grade	Weight
Salt damage grade	A	8
	B	17
	C	23
	D	25
Kind of overhead line	ACSR/AW-TR/OC	2
	etc	11
	ACSR/AW-OC	20
	ACSR-OC	31

The final operation health index calculation formula using the calculated weight is shown in Equation (9).

$$\mathrm{Score}_{\mathrm{Operationg}} = \mathrm{F}_{\mathrm{chloride}} \times \mathrm{W}_{\mathrm{chloride}} + \mathrm{F}_{\mathrm{Type\ of\ line}} \times \mathrm{W}_{\mathrm{Type\ of\ line}} + 30 \times \mathrm{F}_{\mathrm{operating\ years}} + 19 \times \mathrm{F}_{\mathrm{light\ days}} + 30 \times \mathrm{F}_{\mathrm{fatigue}} \tag{9}$$

Here, in case of $\mathrm{F}_{\mathrm{chloride}} = \mathrm{A}$, $\mathrm{W}_{\mathrm{chloride}}$ 8 in case of $\mathrm{F}_{\mathrm{chloride}} = \mathrm{B}$, $\mathrm{W}_{\mathrm{chloride}}$ 17 in case of $\mathrm{F}_{\mathrm{chloride}} = \mathrm{C}$, $\mathrm{W}_{\mathrm{chloride}}$ 23 in case of $\mathrm{F}_{\mathrm{chloride}} = \mathrm{D}$, $\mathrm{W}_{\mathrm{chloride}}$ 25 in case of $\mathrm{F}_{\mathrm{Type\ of\ line}} =$, $\mathrm{W}_{\mathrm{Type\ of\ line}} = 2$ in case of $\mathrm{F}_{\mathrm{Type\ of\ line}} = \mathrm{etc}$, $\mathrm{W}_{\mathrm{Type\ of\ line}} = 11$ in case of = ACSR/AW − OC, $\mathrm{W}_{\mathrm{Type\ of\ line}} = 20$ in case of $\mathrm{F}_{\mathrm{Type\ of\ line}} = \mathrm{ACSR-OC}$, $\mathrm{W}_{\mathrm{Type\ of\ line}} = 31$

4.2. Result of Overhead Line Total Health Index

Currently, in Korea, health index ratings are distinguished in units of 20 points. The overall health index assessment results by grade are shown in Figure 3 and Table 9. The Gyeongbuk and Gangwon regions apparently have plenty of extremely poor supplies, whereas the Seoul and Namseoul Headquarters have a few.

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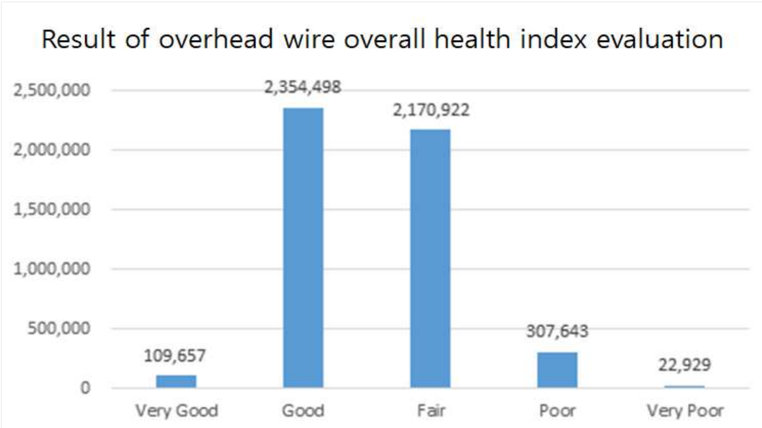

Figure 3. Result of the overall health index assessment of overhead lines by grade.

Table 9. Results of the overall health index assessment rating of overhead lines.

Headquarters	Grade				
	Very Good	Good	Fair	Poor	Very Poor
Seoul	2,280	43,582	25,078	1,474	**64**
Namseoul	2,371	40,544	25,121	1,661	**36**
Incheon	3,361	77,184	88,059	16,339	250
Northern Gyeonggi	3,551	131,494	141,668	20,947	882
Gyeonggi	17,210	234,831	200,601	25,706	763
Gangwon	5,892	160,287	190,444	32,809	**4,363**
Chungbuk	3,241	108,805	131,852	32,235	**3,758**
Daejeon Sejong Chungnam	12,844	254,623	255,106	41,839	2,297
Jeonbuk	7,571	196,672	174,226	21,153	1,105
Gwangju Jeonnam	15,762	327,569	280,552	28,205	1,876
Daegu	8,635	210,686	166,195	12,330	683
Gyeongbuk	5,286	186,429	160,331	33,887	5,444
Busan Ulsan	10,900	122,249	100,529	11,221	301
Gyeongnam	9,233	224,809	184,719	16,667	914
Jeju	1,520	34,734	46,441	11,170	193
Total	109,657	2,354,498	2,170,922	307,643	22,929

Tables 10 and Tables 11 show that the forest rates in the Gangwon and North Gyeongsang regions were higher than those in other regions, whereas the underground rate was low [14]. Given the many long-span lines in mountainous areas and because the construction cost for replacing them is high, these characteristics are reflected by the large number of replacement items of the health index.

Table 10. Forest rate by administrative district.

Administrative district	2020		
	National land area	Forest area	Forest rate
Nationwide	10,041,260	6,298,134	62.72
Seoul	60,523	15,323	25.32
Busan	77,007	34,926	45.35
Daegu	88,349	48,338	54.71

Incheon	106,523	39,373	36.96
Gwangju	50,113	18,944	37.8
Daejeon	53,966	29,764	55.15
Ulsan	106,209	68,001	64.03
Sejong	46,491	24,849	53.45
Gyeonggido	1,019,527	512,105	50.23
Gangwondo	**1,682,968**	**1,366,644**	**81.20**
Chung-cheong bukdo	740,695	488,337	65.93
Chungcheongnam-do	824,617	404,097	49
Jeollabuk do	806,984	440,746	54.62
Jeollanam-do	1,234,809	686,852	55.62
Gyeongsangbuk-do	**1,903,403**	**1,333,691**	**70.07**
Gyeongsangnam-do	1,054,055	698,810	66.3
Jeju	185,021	87,334	47.2

Table 11. Underground rate of national headquarters.

Headquarters	Underground rate
Seoul	57.87%
Namseoul	64.58%
Incheon	46.72%
Northern Gyeonggi	24.89%
Gyeonggi	32.67%
Gangwon	**10.63%**
Chungbuk	12.33%
Daejeon Sejong Chungnam	19.34%
Jeonbuk	11.94%
Gwangju Jeonnam	11.95%
Daegu	16.10%
Gyeongbuk	**5.63%**
Busan Ulsan	35.42%
Gyeongnam	10.33%
Jeju	20.52%
Total	20.67%

Analyzing the number of actual spans for each level of health index and its ratio to the total number of spans, as shown in Table 12, there were many lines with an actual span of 50 m or more in the Gangwon, Chungbuk, and Gyeongbuk regions. In particular, the number of spans in Gangwon and Gyeongbuk was higher than that in other regions; therefore, the number of spans with an actual span of 50 m or more was the highest in Gangwon and Gyeongbuk. This proves that the replacement cost of overhead cables is high because the underground rate is low and there are many long-span sections in the forest area.

Table 12. Number of spans over 50 m for each level of the health index.

	Very Good	Good	Fair	Poor	Very Poor	Percentage of the total span
Seoul	0	861	1,277	694	120	4.07%
Namseoul	0	1,309	968	723	66	4.40%
Incheon	0	8,904	4,522	4,279	256	9.70%
Northern Gyeonggi	0	29,365	15,256	14,158	1,373	20.15%

Gyeonggi	0	35,954	14,581	15,558	1,030	14.01%
Gangwon	**0**	**43,141**	**29,780**	**22,314**	**7,105**	**25.99%**
Chungbuk	**0**	**38,602**	**26,801**	**20,842**	**6,013**	**32.96%**
Daejeon Sejong Chungnam	0	71,110	33,440	25,612	3,901	23.66%
Jeonbuk	0	50,283	23,392	15,032	2,093	22.66%
Gwangju Jeonnam	0	72,229	29,524	20,487	3,343	19.20%
Daegu	0	27,912	13,462	8,281	1,233	12.77%
Gyeongbuk	**0**	**49,351**	**25,906**	**19,853**	**9,237**	**26.66%**
Busan Ulsan	0	8,070	5,582	5,516	517	8.03%
Gyeongnam	0	45,781	21,448	10,994	1,905	18.36%
Jeju	0	6,885	2,484	3,796	387	14.41%
Total	0	489,757	248,423	188,139	38,579	19.43%

In Seoul and South Seoul Headquarters, the Very Poor quantity was calculated to be significantly less. This means the overhead cable operating environment was good because the number of overhead cables was low in the downtown area, the pollution level was good, and the wind speed was not as strong as those in other areas. In the past, we used the replacement method of overhead wires that relied only on instantaneous/diagnostic extraction. However, according to the health evaluation method developed in this paper, a risk-based replacement can prevent consumer life/property damage through a stable power supply and prevent power facility accidents.

4.3. Analysis of Economic Effects

The expected replacement quantity of extra-high-voltage overhead wires in the future was calculated to analyze the economic effects of the health index assessment model proposed in this study. As for the lifetime of the overhead wires, the manufacturer's warranty period of 30 years was applied. Table 13 shows the calculation of the quantity of extra-high-voltage overhead wires over 30 years for the next 3 years and the analysis of such replacement quantity using the method proposed in this study.

Table 13. Estimated replacement quantity of extra-high voltage overhead wires for the next 3 years.

Classification	2022.12	2023.12	2024.12	2025.12
Quantity of wires over 30 years	64,550	8,047	10,397	18,549
The health index model in this study Very Poor quantity	22,929	1,001	991	817

As shown in the above results, it is necessary to replace a much smaller quantity when replacing extra-high-voltage overhead wires using the method proposed in this paper than when replacing a simple old overhead wire. This can reduce the annual replacement cost by more than 400 million won and can increase the accuracy of failure prevention by investing in activities such as precise diagnosis of overhead wires with reduced costs.

5. Conclusion

In this paper, a method for evaluating the health index of overhead wires was proposed to establish criteria for the efficient replacement of power distribution facilities.

For major power distribution facilities, there is an old replacement standard called health index assessment, but there is no old replacement standard for about 4.7 million power distribution overhead wires based on span, which were replaced only through diagnoses and visual inspections. This resulted in excessive diagnostic costs. In addition, by preemptively replacing overhead wires to prevent failure, excessive facility investment has been executed due to preemptive replacement even though the durability of the overhead wires remains. Thus, in this paper, a health index assessment model was proposed to establish cost-effective power distribution facility operating costs and facility replacement standards for overhead cables.

In future works, we plan to apply the algorithm developed in this study to an actual operating environment, perform replacements for more than 1 year, analyze statistical data on failure occurrence and old demolition, and consider machine learning-based algorithm accuracy verification results and expert opinions. In addition, we plan to increase the accuracy of equipment condition estimation by adjusting the weights of operation health and risk cost health using an analytic hierarchy process and calculating the optimal overall health weight.

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Reference

1. Dong-Jin Kwon, 2018, “Technology Trends for Asset Management System of Power Facilities”, The Korean Institute of Electrical Engineers, 67(1), pp. 30-33
2. TB309, 2006, “Asset Management of Transmission Systems and Associated CIGRE Activities”
3. TB422, 2010, “Transmission Asset Risk Management”
4. TB541, 2013, “Asset Management Decision Making using different Risk Assessment Methodologies”
5. N.S. Arunraj, J. Maiti, 2007, “Risk-based maintenance—Techniques and applications”, Journal of Hazardous Materials, 142(3), pp. 653-661
6. Hong-Seok Lee, 2021, "RISK Assessment of Asset Management System for Distribution Transformer", Ph.D. Thesis, Korea National University of Transportation, Republic of Korea.
7. Yahaya, M.S.; Azis, N.; Ab Kadir, M.Z.A.; Jasni, J.; Hairi, M.H.; Talib, M.A. Estimation of Transformers Health Index Based on the Markov Chain. Energies 2017, 10, 1824.
8. Kadim, E.J.; Azis, N.; Jasni, J.; Ahmad, S.A.; Talib, M.A. Transformers Health Index Assessment Based on Neural-Fuzzy Network. Energies 2018, 11, 710.
9. Kim Yu Min, Kim Myungchin, 2021, “Asset Management System Technology Trend Analysis of Power Facilities” Proceedings of Symposium of the Korean Institute of communications and Information Sciences, pp. 13-14
10. KEPCO, 2022, “The Monthly Report on Major Electric Power Statistic(2022)”, Korea Electric Power Corp.
11. KEPCO, 2022, “Statistics of Electric Power in Korea”, Vol.91, KEPCO
12. KEPCO Operation Office, 2022, “Standard of Distribution line inspection”, KEPCO
13. KEPCO, 2022, “Statistics of inspection and diagnosis”, KEPCO
14. Korea Forest Service, 2021, “Statistics of forest”, Korea Forest Service