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On the Improvement of the Process by Analyzing Precision Diagnosis of Deteriorated Railroad Communication Facilities

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Abstract

Railroad Systems, which are national infrastructure industries, cause unexpected property and human damage if they fail to function while operating. Accordingly, railroad facilities supporting the railroad system are areas where high reliability and safety are required. However, it is time for systematic and scientific maintenance to be taken away from the traditional maintenance methods, as the nation's railroad facilities are now aging seriously. The purpose of this study was to secure the safety and reliability of the aging railroad communication facilities and to improve their performance. The research subjects were selected as a precision diagnosis process for railroad communication facilities, and improvement points were derived through detailed precision diagnosis process analysis. It is deemed that this study can contribute based on securing stability, improving reliability, and continuous improvement of railroad communication facilities should be conducted in the operation of the entire railroad system.

Keywords: *Deteriorated Railroad Facility, Railroad Facility Maintenance, Communication Facility, Precision Diagnosis of Facility, Performance Evaluation of Facility*

1. Introduction

1.1. Background and Necessity of Research

Railroad systems, which are national infrastructure industries, cause unexpected property and human damage if they fail to function while operating. Accordingly, railroad facilities supporting the railroad system are areas where high reliability and safety are required. However, it is time for systematic and scientific maintenance to be taken away from the traditional maintenance methods, as the nation's railroad facilities are now aging seriously. Traditional facility maintenance methods have been based on Time-Based Maintenance (TBM) methods based on the number of years in use of the facility, which are relatively low reliability and safety because they rely on the results of the number of years in use. The current trend is changing from the existing TBM maintenance method to the improved Condition Based Maintenance (CBM) method, which

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shows relatively higher reliability and safety compared to the TBM maintenance method due to performance evaluation through regular inspection and precision diagnosis. In addition, the TBM method may be effective from a short-term economic perspective, but the CBM method is advantageous from a long-term economic perspective, considering major failures and accidents. The Ministry of Land, Infrastructure and Transport enacted the "Act on Railroad Construction and Facility Maintenance [2019.03.14]" for systematic maintenance of railroad facilities, required the state to establish and implement a railroad facility maintenance plan every year. Accordingly, local industry, school, and related agencies are reviewing and establishing detailed standards for precision diagnosis and performance evaluation, and the results of precision diagnosis and performance evaluation of railroad facilities will be used in the future.

1.2. Analysis of prior researches

Kang et al. conducted a survey on the maintenance requirements of eight urban railroad operating institutions [1] to optimize the maintenance of the subway power sector. As a result, the results were that temperature condition checks for transformers, AC and DC breakers should be checked first. Kim et al. recognized the problem that 60% of the maintenance budget is used for labor costs and presented the need for maintenance improvement through information service and automation [2]. In addition, maintenance operations cases were compared in France and the United Kingdom, and research was conducted to improve the efficiency of maintenance operations. Recognizing that maintenance does not reflect the weight of each route, Park et al. presented the need to derive scientific inspection cycles through systematic data construction and emphasized that data such as analysis/recording of old age, inspection follow-up measures should be included [3]. In addition, the need for automation of precision diagnosis of facilities was derived by introducing information and communication technology. Oh et al. conducted a study on the preparation of sustainable railroad industry policies from a long-term perspective, referring to the history of structural reform of railroads abroad [4]. In addition, the scale of each railroad investment project, the trend of maintenance cost increase and decrease, and the ratio of track use to maintenance cost were analyzed. As a result, it was emphasized that efficient maintenance procedures should be prepared by analyzing the overall system such as national transportation system, railroad industry structure, safety and environment rather than simple comparison with overseas cases. Park, etc. has been developing railroads since the opening of the Gyeongbu High Speed Railroad. Inappropriate, it was suggested that the railroad facility maintenance sector was in a state of limbo [5]. To improve this point, the government presented the need to build a database that encompasses information such as railroad facility history management at the national level. The target facilities were selected in consideration of items such as construction cost, train operation impact, other facilities impact, and frequency of failure, and basic items were prepared for performance evaluation. Na et al. conducted a development study of the performance evaluation index analysis program, recognizing that performance evaluation is complex and takes considerable time to calculate [6]. The results laid the foundation for efficient improvement in procedures such as complex, time-consuming weight calculations, and route-specific parameter calculations in performing future performance evaluations. Recognizing the problem of excessive time spent on data collection and analysis activities in existing performance evaluation procedures, Kang et al. conducted a study on the implementation of performance evaluation simulations using Virtual Reality (VR) [7]. To ensure the safety of railroad infrastructure, Kim et al. conducted research on the construction of railroad safety information systems and operational architecture development by analyzing technical related matters of reflecting/requirements for use and product characteristics [8]. Choi et al. conducted a quantitative risk assessment study of railroad safety facilities by classifying the personal risk category as passenger risk (general traveler, passenger crew), public thought risk (around railroad) and safety high equipment rate safe failure fraction (SFF) and diagnostic coverage (DC)[9]. Kim et al. conducted maintenance improvement research on the lack of standard evaluation methods for existing electric railroad facilities, quantitatively analyzed the importance of the facilities and the impact on train operation in the subway power field, and prepared items for safety, durability, and usability[10 − 13]. Kim et al. conducted a study on the selection of target facilities for signal control systems among railroad electrical facilities [14]. As a result of analyzing prior research, research on the selection of facilities subject to precise diagnosis/performance evaluation of subway power facilities and signal control facilities included in railway electrical facilities was confirmed. However, prior research on information and communication facilities is considered insufficient. Therefore, in this paper, we intend to analyze the precision diagnosis process to secure the reliability and safety of information and communication facilities and conduct a foundation study for the selection of target facilities and evaluation factor.

1.3. Current status of deterioration of railroad facilities

The performance evaluation of railroad facilities and facilities, including track, architecture, electricity, etc., is classified into A, B, C, D, E. Class A shall be rated "excellent" for defects, "low probability of lossless durability degradation", and Class B shall be rated "good" for "continuous observation of progress with minor defects". Class C is "ordinary", indicating "safety is not affected, but simple repair and reinforcement is required", and grade D is "insufficient", which means "urgent repair and reinforcement is required because performance does not meet the standards". Finally, Class E is a "defective" class, meaning "severe defects require immediate discontinuation of use, reinforcement, and renovation." As such, the performance evaluation is divided into five alphabetical classes. The Ministry of Land, Infrastructure and Transport announced the "first basic plan for railroad facility maintenance" in 2020. In this data, 54.7% of national railroads, 83.0% after 5 years, 93.4% after 10 years, 45.2% after 5 years, 85.6% after 10 years, 6.30% for private railroads, 25.6% after 5 years and 55.2% after 10 years. In addition, the performance change trend is expected to be 3.4 for national railroads, 2.77, after 10 years, 2.31 for urban railroads, 4.41, after 5 years, 2.94 for 10 years, 4.00 for private railroads, and 3.60 for 10 years. This indicates the expected ratio of rail facilities and facilities such as track, construction, and electricity below Class C and the trend of performance changes, and reminds us of the need for maintenance of future facilities and facilities. When evaluating the composite performance index of railroad facilities, it is expected to increase 0.11 (3.3%) from 2017 to 3.40 in 2020 and 3.29 in 2017, and 3.82 (3.1) from 2017 for urban railroads to 3.82 in 2020 and 3.94 in 2017. These figures are a comprehensive assessment of the structures, track facilities, buildings, subway power, signal control, and information and communication sectors comprising the railroad system, located in 3.0 to 4.0 (C to A) sections, or relatively higher sections. However, in terms of electric power, signal control, and information and communication sectors, which make up electricity facilities as of 2020, it was calculated as a performance index located in a relatively lower section with 2.99, signal control 2.87 and information and communication 2.79 respectively. In addition, the ratio of facilities below Class C was calculated as 76.9% for electric power, 51.4% for signal control, 66.4% for information and communication, 11.7% for electric power, 33.9% for signal control, and 25.0% for information and communication. In this context, it can be judged that the current aging of railroad facilities is serious, and in order to operate stable railroad systems, improvement studies are needed through detailed analysis of information and communication facilities.

1.4. Composition and flow of thesis

Based on the background presented, the aging of the railroad communication facilities was recognized, and therefore, this paper selected the railroad communication facilities for research. This section describes the composition and flow of the paper. The first is an introduction to the paper, which shows the background and necessity of research, prior research analysis related to railroad communication facilities, and the aging status of the facilities. In line with this background, a second overview of the precise diagnosis of railroad communication facilities is presented. The overview of precision diagnosis consists of major defects in communication facilities, facilities subject to precise diagnosis of communication facilities, and assessment items. Third, we present an analysis and improvement plan for precise diagnosis of railroad communication facilities. The detailed diagnosis and improvement plan of railroad communication facilities includes the analysis and improvement plan of railroad communication facilities. The fourth consists of the conclusions of this paper based on the content presented in the third.

2. Analysis of precision diagnosis for communication facilities

2.1. Introduction of precision diagnosis

Railroad communication facilities shall be regularly inspected in accordance with the Act on the Construction and Maintenance of Railroad Facilities, which aims to secure public safety by prescribing matters concerning railroad construction and maintenance. In addition, target facilities and assessment items shall be carried out in consideration of the safety, durability and usability of railroad communication facilities. Safety means "performance to prevent casualties, damage and loss of railroad facilities under the requirements of railroad facilities", durability means "performance of railroad facilities to maintain the functions required during the service life", and usability means "performance to provide appropriate convenience and functionality" in terms of railroad facilities. In addition, precision diagnosis means "an activity that investigates, measures, and evaluates the causes of physical safety and performance degradation to detect physical and functional defects in railroad facilities and take prompt and appropriate measures." The function and performance diagnosis of aging railroad communication facilities can be performed in three ways. The first is to inspect the module, and the second is to utilize the Network Management System (NMS)/Element Management System (EMS). The third measurement is the BER (Bit Error Rate).

2.2. Module diagnosis

Module inspection checks the normal operation of the module functions as shown in Table 1, and for redundant modules, determine whether the module is operating normally before switching, during the module switching process, and after switching the module. In addition, the normal operation verification targets should include modules and associated links.

Table 1. Carry out and evaluate module inspection diagnostics

Sortation	Diagnostics content	Evaluation score
A	Switching target module functionality is OK	5
B	One of the switching target modules is abnormal (for Simplification, functionality is OK)	3
C	When continuous switching is performed, it fails to return to normal (initial) state (simplification, dysfunctional)	1

The PCB module diagnostic method using thermal imaging camera has a method of measuring the temperature of PCB using thermal imaging camera, and determines the aging level by analyzing the temperature difference measured by the same PCB. In general, when a part ages due to the temperature, the life span of the part is doubled as the temperature of the environment increases by 10°C. The sequence of thermal imaging measurements is 1. Turn off the power of the module and detach the module under diagnosis. 2. Connect the interface card to the module under diagnosis. 3. Connect the disconnected original card to the connected interface card. 4. With the module on, check if the target is operating properly. 5. Adjust the focus of the thermal imaging camera to the hotspot and measure it. Table 2 shows the diagnostic/evaluation method of the PCB module utilized for thermal imaging measurements. In addition, Figure 1 is the process of thermal imaging of real PCB modules.

Table 2. Diagnosis of PCB modules with thermal imaging measurements

Sortation	Temperature difference	Diagnosis contents	Evaluation score
A	-	Normal functional facilities	5
B	Less than 1℃	No possibility of degradation	4
C	1 ~ 10℃	Possible degradation	3
D	11 ~ 20℃	degradation progression	2
E	21 ~ 40℃	Possible to advance to a later defect	1

Figure 1. process of thermal imaging of real PCB modules

2.3. NMS/EMS diagnosis

NMS/EMS is a system for efficient operation and management of network equipment in accordance with the service area, and in the case of wired networks, the network engineer often sets up routers, switches, etc. directly and monitors them with NMS. EMS is a system for monitoring and controlling network equipment over a network, which is a sub-component of NMS, and for mobile networks, NMS and EMS are essential. Various equipment is required to perform mobile communication services such as LTE(Long Term Evolution) and 5G(5th Generation Mobile Telecommunication), and to operate these equipment, each network management center or base station in each region must monitor each network equipment for failures, various settings, and statistics. It is the NMS and EMS, the equipment systems responsible for these functions. Railroad communication facilities collect and analyze utilization rates of facilities and the number of failures/disorders in the period using the functions of the NMS/EMS system that manages the aforementioned communication facilities. As an evaluation metric and formula, CPU utilization means "the ratio of CPU usage to total CPU capacity measured [%], memory utilization means "the ratio of memory usage to total physical memory capacity of the server [%]", and disk utilization means "the ratio of disk usage to physical total capacity". Table 3 shows the contents of this.

Table 3. Diagnosis and calculation formula for facility utilization

Classification	Detailed classification	Definition [%]	Calculation formula
Server resource efficiency	CPU utilization	Ratio of CPU usage to total CPU capacity measured	(CPU Capacity Used/ CPU Full Capacity) X 100
	Memory utilization	Memory utilization is the ratio of memory usage to the total physical memory capacity of the server	(Memory Capacity Used/ Full Memory) X 100
	Disk utilization	Ratio of disk usage to physical total capacity of disk	(Disk Capacity/ Disk Total Capacity) X 100

Table 4 shows the evaluation methods for Table 2. For Class A failures, all services provided to users of an information communication system, such as Main Network and Database Management System (DBMS), for Class B failures, some services provided to users of an information communication system are unavailable, for Class C failures. Finally, in the case of Class D disability, it means a condition beyond the control or force majeure, such as a natural disaster

Table 4. Evaluation of Facility Utilization

Sortation	Diagnosis contents			Evaluation score
A	CPU	Central control facility	Not more than 30%	5
		Etc.	Not more than 20%	
	Memory			
	Disk			
B	CPU	Central control facility	30% over 80%	3
		Etc.	20% over 70%	
	Memory		20% over 80%	
	Disk			
C	CPU	Central control facility	More than 80%	1
		Etc.	More than 70%	
	Memory		More than 80%	
	Disk			

Table 5 shows the disability measurement techniques. The measurement tool is the NMS and the fault history information is entered. The measurement is derived by multiplying the combined number of failures of Class A and Class B by 0.7. Here, Class C and Class D disorders are not included. The data collection period utilizes data from 1 to 3 months in advance when performing a precision diagnosis.

Table 5. Evaluation of measurements

Sortation	Measurement judgment	Evaluation score
A	Measurements from 0 to 1	5
B	Measurements from 2 to 3	3
C	Measurement value 4 or higher	1

2.4. BER measurement

The BER measurements measure the light transmission level and the performance threshold value of the facility to determine the performance of the light transmission unit and the optical cable. Here, Errored Seconds (ES) is the sum of the periods in which one or more errors occurred during each cycle in a one-second cycle. Table 6 shows the contents of this.

Table 6. Evaluation by BER measurement

Sortation	ES(Errored Seconds)	Evaluation score
A	ES = 0	5
B	1 ~ 10	4
C	11 ~ 66	3
D	More than 67	2
E	-	1

3. Presentation of improvement points through precision diagnosis analysis results

3.1. Presentation of improvement points for module inspection precision diagnosis

It is deemed necessary to diagnose the condition of the motor under Power On/Off conditions as a way to substantially improve the safety of the communication infrastructure, reflecting the characteristics of the communication facility with a relatively short life cycle compared to other facilities. In addition, for the economic feasibility of precision diagnosis, it is deemed necessary to review the items of target facilities that require module inspection. Module Inspection Functional Inspection and Switching of Digital Units (DU) and Radio Units (RU) related to LTE-R, eNB facilities are presented at least once a half-year.

3.2. Presentation of improvement points for NMS/EMS precision diagnosis

Normally, NMS and EMS were performed with BER measurements, but as an independent item of precision diagnosis, NMS/EMS should be performed. For LTE-R central control facility facilities, NMS/EMS is proposed to diagnose the state of the acquisition/operation/DB server more than once a month. This may contribute to securing safety and improving reliability of the entire railroad communication facilities.

3.3. Present improvement points of BER measurement

As with the NMS/EMS mentioned earlier, NMS/EMS shall be performed independently of the BER measurement items. This allows the measurement of BER entirely. For LTE-R central control facilities, BER measurements are presented at least once a year. In addition, the organization performing BER measurements is presented to have a BER measuring instrument that can support Operations in units of protocol in Protocol mode. In addition, for Network Analyzer, it is suggested that equipment with performance above Frequency range: 300KHz to 8GHz, Measurement level: -60 dBm to +5 dBm is essential.

4. Conclusion

Currently, the aging of railroad facilities in Korea is in serious condition, and measures are needed to prepare for it. As a result of the preliminary research analysis, it was determined that there was a lack of precision diagnosis research on information and communication facilities among railway electrical facilities. therefore, The purpose of this study was to secure the safety and reliability of the aging railroad communication facilities and to improve their performance. The research subjects were selected as a precision diagnosis process for railroad communication facilities, and improvement points were derived through detailed precision diagnosis process analysis. In the case of precision diagnosis of module inspection, it is deemed necessary to diagnose the condition of the motor in the Power On/Off state. In addition, for the economic feasibility of precision diagnosis, it is deemed necessary to review the items of target facilities that require module inspection. Module Inspection Functional Inspection and Switching of Digital Units (DU) and Radio Units (RU) related to LTE-R, eNB facilities are presented at least once a half-year. for NMS/EMS precision diagnosis, NMS and EMS were normally performed with BER measurements, but as an independent item of precision diagnosis, NMS/EMS should be performed. For LTE-R central control facility facilities, NMS/EMS is proposed to diagnose the state of the acquisition/operation/DB server more than once a month. For BER measurements, NMS/EMS shall be performed independently of the BER measurement items, as with the previously mentioned NMS/EMS. This allows the measurement of BER entirely. For LTE-R central control facilities, BER measurements are presented at least once a year. In addition, the organization performing BER measurements is presented to have a BER measuring instrument that can support Operations in units of protocol in Protocol mode. In addition, for Network Analyzer, it is suggested that equipment with performance above Frequency range: 300KHz to 8GHz, Measurement level: -60 dBm to +5 dBm is essential. The results presented in this study can be applied in a significant sense in that, as the legislation is amended, it can contribute to the selection of target facilities/evaluation items for future precision diagnosis processes. also, It is deemed that this study can contribute based on securing stability, improving reliability, and continuous improvement of railroad communication facilities should be conducted in the operation of the entire railroad system.

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