JURNAL PENDIDIKAN TEKNOLOGI KEJURUAN

Vol. 5, No. 4 November 2022 **P-ISSN: 2621-3273**
E-ISSN: 2621-1548

Health index analysis on asset management and the influence of electricity and environmental safety aspects on overhead transmission line 150 kV Anyer – Asahimas

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https://doi.org/10.24036/jptk.v5i4.29823

Abstract—The availability and reliability of electrical energy has become the backbone of society, so periodic maintenance needs to be carried out to avoid short breakdowns and technical malfunctions as well as to improve electrical and environmental safety. Overhead transmission line is an important part of the transmission network and their health status is an important foundation for ensuring the reliable supply of electricity to the power grid. The health index (HI) is a value that reflects the health status of high-voltage transmission lines obtained by combining the normalization of component ratings on certain parameters and calculation methods. This study shows that the condition of assets, electricity and the environment have an effect on determining the soundness index of the Anyer-Asahimas 150 kV overhead transmission line and can be a guide for its maintenance. The final health index value shows 92.8% meaning that the transmission is not only safe in terms of equipment but also safe in terms of electrical and environmental safety aspects.

Keyword: *Health Index, Overhead Transmission Line, Asset Management, Environmental, Electricity Safety*

I. INTRODUCTION

Transmission lines have become the backbone of the power system landscape. Maintaining it, extending the useful life of the line, improving the transmission ability of electrical energy, preventing failure, and ensuring the safety of employees and everyone are at the forefront of transmission line research and development (P. Thongchai et al, 2013). High voltage (HV) transmission lines are important for power transmission systems. HV transmission lines experience a decrease in quality over the period of use due to normal operating conditions and abnormal conditions such as the effects of lightning, corrosion due to pollution, and others. Failure of the HV transmission line and its components can affect the stability of the electric power system. Therefore, the transmission system needs to be properly maintained (I. Yongyee et al, 2018).

The health index (HI) of the overhead transmission line is a value that represents the health status of the overhead transmission line. It can be obtained by complex logic and mathematical operations based on key features. The health index has strong logical characteristics and is continuous in time. It can be used to determine if an overhead transmission line needs maintenance, and estimate the remaining life of an overhead transmission line (Y. Liu et al., 2019).

The overhead transmission line (OHL) 150 kV Anyer - Asahimas which has been in operation since April 2015 where the transmission line cuts the existing OHL's New Menes - Asahimas which has been in operation since June 1983. The life span of the SUTT project is generally between 50-80 years, but that depending on various conditions such as materials, quality of construction, climate, quality of maintenance, failure of HV transmission lines and their components can affect the stability of the power system (H. Manninen et al, 2018).

Therefore, the transmission system needs to be maintained properly. In this study, a method for assessing the condition of high-voltage transmission lines is proposed which will find out the condition of OHL, including the effect of the installation on electricity safety and the environment. The purpose of this study is to determine the conditions of the 150 kV Anyer - Asahimas high voltage overhead transmission line (OHL) installation and can also be an indicator for determining effective maintenance planning for the transmission line system.

II. METHODS

A. Steps and flowcharts

In this study, there are stages of designing high-voltage overhead transmission line assessment based on the Health Index method. The initial stage of this research is to determine the pattern of assessment of the research health index. The next stage is to determine the items and sub-items whose health index will be assessed, where at this stage it is also determined how to test each of these items and sub-items. The next step is to determine the standard of comparison from the test data that has been done. Standards are obtained from IEC Standards, IEEE Standards, PLN Standards and Electrical Standards that apply in Indonesia.

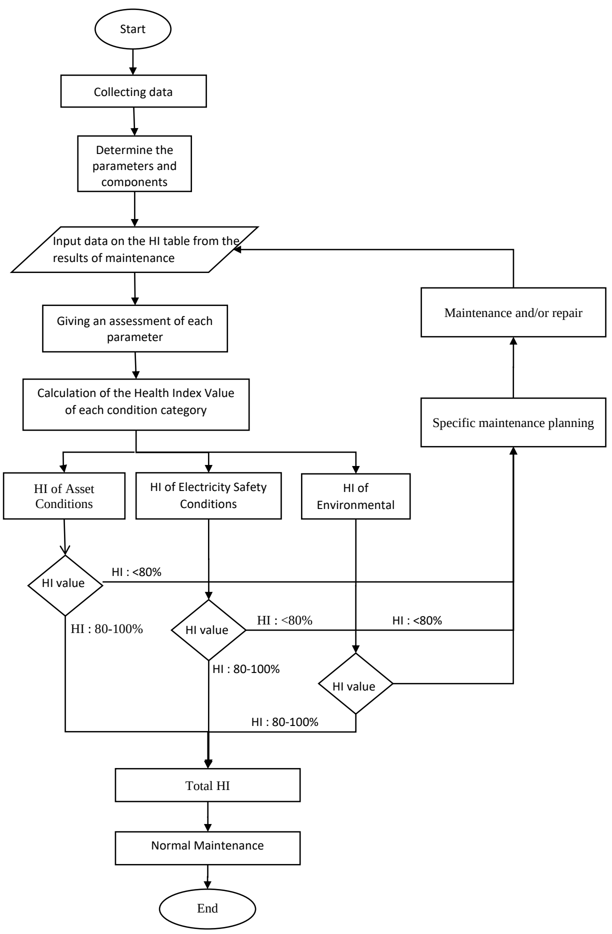

Figure 1. Flowchart of the influence of the overhead transmission line health index on several conditions

The next stage is the weighting and assessment stage where at this stage each item and sub item has been determined how to carry out the test and the standard is given the appropriate weight. The criteria obtained are in accordance with the first stage in this study. In the final stage, an analysis of the health index value and the total health index of each condition category was.

B. Transmission line overhead components and sub-components

Before conducting a health index analysis, it is necessary to determine its components and sub-components. According to Yongyee, high voltage transmission line components are classified into eight groups namely conductors, conductor accessories, insulators, steel structures, foundations, lightning rods, tower accessories and right of way. According to Thongchai, the design criteria for an overhead transmission line system can be categorized into four components: i) concrete piles, ii) insulators, iii) conductors and iv) grounding/lightning systems (I. Yongyee, 2018).

In this study the components and sub-components of high-voltage overhead transmission line were referred to from previous studies and several items were added which were referred to from the Regulation of the Minister of Energy and Mineral Resources of the republic of Indonesia No. 12 of 2021. So that in this study it is proposed that the transmission components and sub-components be categorized into three parts consisting of asset conditions, electricity safety conditions and environmental conditions (Ministry of Energy & Mineral Resources, 2021).

Table 1. Components and sub-components on asset condition

Component	Sub - Component
1.1 Tower	Stub
	Chimney Structure /member /brasing
	Ladder/climbing bolt
	Tower alignment
1.2 Conductor	Conductor
1.3 Insulator	Insulator
1.4 Accessories	Vibration Damper
	Spacer
	Suspension set
	Tension set

Table 2. Components and sub-components on Electricity Safety Conditions

Electricity Safety Conditions	
Component	**Sub - Component**
2.1 Sagging	Sagging
2.2. Clearance	Vertical
	Horizontal
2.3. Electrical safety equipment	Danger Sign
	Phase Plate
	Number Plate
	Anti-climbing device (ACD)
2.4 Grounding System	Mounting System
	Earth Resistance
2.5 Measurement of temperature after loading	Temperature after loading

Table 3. Components and sub-components on Environmental conditions

Environmental conditions	
Component	**Sub - Component**
3.1 Noise level	Noise level
3.2 Electromagnetic field level	Magnetic field
	Electric field

C. Inspection methods and test results criteria

Determine the standard of test results to be determined as the criteria of the condition ratio. The standard of the condition ratio criterion was obtained from previous research and based on PT. PLN (Persero) SPLN T6.003-2: 2021 regarding the Commissioning of High Voltage and Extra High Voltage overhead transmission line (State Electricity Company, 2021).

In the inspection method to provide a different value for the condition of the sub-components of high-voltage overhead transmission line in the 3 groups of categories previously mentioned. Where line patrol officers must investigate the condition of the transmission line and complete detailed inspections and make repairs later on an ongoing basis. In this study, investigations on the sub-components of each group were carried out during the periodic maintenance of the transmission line.

Values for condition parameters are determined using condition criteria. The condition criterion is the scale used to determine asset values for certain parameters (Y. Tsimberg et al, 2014). The transmission line can be classified as n components, each of which has a mode value Mi. Physical condition can be assessed in three levels: G (Good, condition value C = 1), N (Normal, condition value C = 0.5, and P (Poor, condition value C = 0) (P. Thongchai et al, 2003)

Table 4. Inspection method and condition criterion on asset conditions

Asset Condition				
Sub - Component	**Inspection Method**	**The condition criterion**		
		G	**N**	**P**
Stub	Visual Inspection	Normal	There are drawbacks	Abnormal
Chimney Structure /member /brasing	Visual Inspection	Normal	There are drawbacks	Abnormal
Ladder/climbing bolt	Visual Inspection	Normal	There are drawbacks	Abnormal
Tower alignment	Visual Inspection	Normal	There are drawbacks	Abnormal
Conductor	Visual Inspection	Normal	There are drawbacks	hack/bloom
Insulator	Visual Inspection	Normal	There are drawbacks	Abnormal
Vibration Damper	Visual Inspection	Normal	There are drawbacks	Abnormal
Spacer	Visual Inspection	Normal	There are drawbacks	Abnormal
Suspension set	Visual Inspection	Normal	There are drawbacks	Abnormal
Tension set	Visual Inspection	Normal	There are drawbacks	Abnormal

Table 5. Inspection method and condition criterion on electricity safety conditions

Electricity Safety Conditions				
Sub - Component	**Inspection Method**	**The condition criterion**		
		G	**N**	**P**
Sagging	Visual Inspection	Normal		Abnormal
Vertical	Clearance Length	≥ 8,5 m	5,0-8,4 m	< 5,0 m
Horizontal	Clearance Length	≥ 10,0 m	9,11-9,9 m	< 9,11 m
Danger Sign	Visual Inspection	Normal	Dirty/ unclear	Abnormal
Phase Plate	Visual Inspection	Normal	Dirty/ unclear	Abnormal
Number Plate	Visual Inspection	Normal	Dirty/ unclear	Abnormal
Anti-climbing device (ACD)	Visual Inspection	Normal	There are drawbacks	Abnormal
Mounting System	Visual Inspection	Normal	There are drawbacks	Abnormal

Electricity Safety Conditions				
Sub - Component	Inspection Method	The condition criterion		
		G	N	P
Earth Resistance	Measurement of grounding resistance	≤3 Ω	≤10 Ω	>10 Ω
Temperature after loading	Measures the difference between the measured point and the ambient temperature	≤ 5°C	6-10° C.	> 10°C

Table 6. Inspection method and condition criterion on Environmental conditions

Environmental conditions				
Sub - Component	Inspection Method	The condition criterion		
		G	N	P
Noise level	Noise level measurement	≤ 60 dB	60-70 dB	> 70 dB
Magnetic field	Magnetic field measurement	0,1 mT	0,1 - 1 mT	> 1 mT
Electr.ic field	Electric field measurement	5 kV/m	5-10 kV/m	> 10 kV/m

D. Weighting and scoring

In this study, on the condition of the assets, the weighting is calculated based on the portion of the initial construction cost of the high-voltage transmission line. According to Manninen, values for weighting factors calculated on the proportion of component costs selected for high-voltage overhead lines are generally based on Estonian practice (country where transmission lines are built) (H. Manninen et al, 2018). This provides an opportunity to estimate the cost of replacing the overhead transmission components as they are and therefore not focus too much on each component separately. The weight of component asset of condition is tower 66.1%, Conductor 21.8%, insulator 4.1% and Accessories 8.1%. As for the conditions of electricity safety and environmental conditions, the weighting is divided equally for each component parameter because it is assumed that each part has the same effect on electricity safety and on environmental matters.

The Health Index for each component, HI can be calculated as in equation (1).

$$HI = \sum_{i=1}^{m} I_i C_i \qquad (1)$$

Where I is the item, C value is the condition, M value is the total number of items.

From each component where HI is calculated based on (1), the total health index (THI) can be determined by equation (2).

$$\%THI = \sum_{i=1}^{n} \frac{HI_i \times M_i}{100} \qquad (2)$$

Where HI is the health index of the component M is the mode value n is the total number of components (P. Thongchai et al, 2013). From equation (2) HI shows the condition of each category. The relative range is in the form of a percentage of conditions where HI > 80% means good conditions that do not require maintenance or just regular maintenance, HI < 80% means conditions need to be repaired or material replaced.

Table 7. Proposed health index value

% Total Health Index Interval	Category	requirements
80 ≤HI≤100	Safe	Normal Maintenance
50 ≤HI≤80	Alert	Improve Diagnostic Testing
0.0 ≤HI≤50	Critical	Begin the Planning Process for Replace/Rebuild

III. RESULTS

Based on the weighting and scoring calculations that have been carried out on the Anyer - Asahimas overhead transmission line of 58 towers, the results are as follows.

Table 8. Inspection method and condition criterion on asset conditions

Sub - Component	Item Score	Condition Ratio	Condition Score
Stub	16.5%	G	1.0
Chimney Structure /member /brasing	16.5%	G	1.0
Ladder/climbing bolt	16.5%	G	1.0
Tower alignment	16.5%	G	1.0
Conductor	21.8%	G	1.0
Insulator	4.1%	G	1.0
Vibration Damper	2.0%	G	1.0
Spacer	2.0%	G	1.0
Suspension	2.0%	G	1.0
Tension	2.0%	G	1.0

The HI of asset condition obtained is 100% which indicates a safe transmission line.

Table 9. Inspection method and condition criterion on electricity safety conditions

Sub – Component	Item Score	Condition Ratio	Condition Score
Sagging	10.0%	G	1.0
Vertical	10.0%	G	1.0
Horizontal	10.0%	G	1.0
Danger Sign	10.0%	G	1.0
Phase Plate	10.0%	G	1.0
Number Plate	10.0%	N	0.5
Anti-climbing device (ACD)	10.0%	G	1.0
Mounting System	10.0%	G	1.0
Earth Resistance	10.0%	G	1.0
Temperature after loading	10.0%	G	1.0

The HI of electricity safety conditions obtained is 95% which indicates a safe transmission line.

Table 10. Inspection method and condition criterion on Environmental conditions

Sub - Component	Item Score	Condition Ratio	Condition Score
Noise level	33.3%	N	0.5
Magnetic field	33.3%	G	1.0
Electric field	33.3%	G	1.0

The HI of Environmental conditions obtained is 83.3% which indicates a safe transmission line. From the results of the health index for each condition category, it is known that then it is necessary to know the results of the effect of the condition of the transmission line assets on other categories of conditions

Table 11. Effect of health index results on asset and electricity safety condition

Category Group	Mode Score	HI	Total HI
Asset condition	50.0%	100	97.5%
Electricity safety conditions	50.0%	95	

The effect of electrical safety conditions on asset conditions to the total health index shows a change to 97.5%

Table 12. Effect of health index results on asset and Environmental conditions

Category Group	Mode Score	HI	Total HI
Asset condition	50.0%	100	91.7%
Environmental conditions	50.0%	83.3	

The effect of environmental conditions on asset conditions to the total health index shows a change to 91.7%.

Table 13. Effect of health index results on asset, electricity safety and Environmental conditions

Category Group	Mode Score	HI	Total HI
Asset condition	33.3%	100	92.8%
Electricity safety conditions	33.3%	95	
Environmental conditions	33.3%	83.3	

The effect of environmental conditions and electrical safety conditions on asset conditions to the total health index shows a change to 92.8%.

IV. DISCUSSION

From the results of the research that has been done, it is found that the results of the health index on the condition of the assets show a perfect value, which means that the physical condition of the installation still meets all eligibility criteria and standards for each of the main components of the overhead transmission line. whereas in the electricity safety condition it shows an HI value of 95% because there is a sub-component which show the condition of the N ratio indicating that it is not so perfect but is still classified as feasible to operate. Finally, in environmental conditions with an HI value of 83.3% because there is a sub-component that should have a more perfect value even though the current value meets the standard.

Furthermore, the health index value based on asset condition is combined with the HI value for electrical and environmental safety conditions to obtain a total value of 92.8%, which is decreased when compared to the previous total value. This decrease in the value of the health index reinforces the opinion that transmission installations that are safe from a physical point of view are not necessarily safe from an electrical and environmental safety point of view. However, the final results show that all air transmission channels are classified as safe.

V. CONCLUSION

The results of the research conducted show the effect of the health index value on the condition of assets in two other condition categories, namely electrical safety conditions and environmental conditions. There was a decrease in the total value of HI from 100% calculation based on asset condition only, to 97.5% due to the influence of electrical safety conditions. Furthermore, the total HI value becomes 92.8% if the two previous conditions are recalculated with environmental condition parameters. From this study it was concluded that the condition parameters in the form of assets, electricity safety and the environment can make the overhead transmission line health index assessment more specific dan can be stated that entire the overhead transmission line 150 kV Anyer – Asahimas is still classified as safe and feasible to operate. The results of this health index can also be an indicator for the next periodic maintenance with normal maintenance.

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