Study Committee B1

Insulated Cables

10642_2022

Development and Site Application of Intelligent Partial Discharge and Condition Assessment System for Underground Transmission Lines

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Motivation

- As the maintenance method of power facilities is switched from TBM (Time Based Maintenance) to CBM (Condition Based Maintenance), accurate condition evaluation technology is required.
- Partial discharge diagnosis is the only diagnostic method for underground transmission lines in operation.
- Since 2018, an online partial discharge diagnosis system based on the IEC 61850 communication protocol has been introduced and operated in the 345kV underground transmission line.
- Standardized systems and data become the basis for the development of an intelligent partial discharge and condition assessment system for underground transmission lines(U-phas)

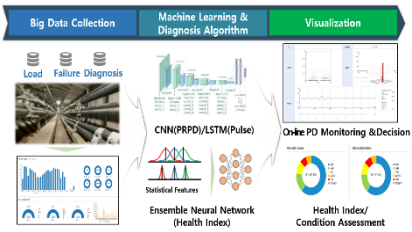

Figure 1. Overview of Intelligent Partial Discharge and Condition Assessment System for Underground Transmission Lines(U-phas)

Partial discharge decision algorithm

- Development of a two-step automatic decision algorithm to determine PRPD patterns and pulses using various artificial intelligence technologies
- PRPD patterns recognition

1) CNN(Convolution Neural Network) : Noise elimination and Learning PRPD images ⟍ accuracy 99.8%

2) SVM(Support Vector Machine) : Noise elimination and learning with 7 statistical features ⟍ accuracy 99.9%

- Pulse determination

1) LSTM(Long -Short Term Memory) : Time series data processing, PD ratio > 0.65 ⟍ 99.0%

- After continuous verification of field data, PRPD pattern recognition is selected by CNN and pulse determination is selected by LSTM method.

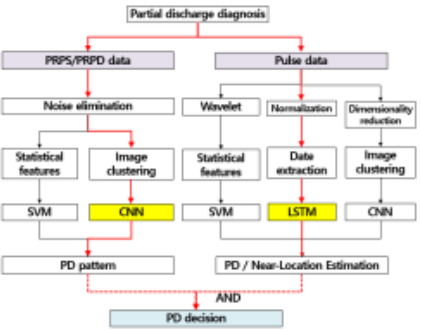

Figure 2. Two-step automatic decision process

Health index calculation algorithm

- Derivation of 8 input parameters through ANOVA and logistic analysis of the existing health index and new load.
- Development of health index calculation algorithm based on ensemble NN(neural network)
- Additional analysis in progress to secure the reliability of the improved health index

Table 1. Parameter Derivation for Health Index Calculation

Stress	Parameters
Thermal stress (4)	Operating period at Max load
	Annual maximum load
	Operating period
	Sheath circulating current
Electrical stress (3)	No. of lightning
	No. of outrage
	Maintenance history
Physical and environmental stress (6)	Record of hanging cable
	Pipe laying rate
	Non-sliding device
	Installation environment
	Manhole size
	Maintenance history for connection part overheating

Data	Parameters	
Operation (5)	No. of Joint box	New
	Damaged record of SVL	Existing
	Dismantled record of Joint box	Existing
	Pipe laying rate	Existing
	Score of operating period	New
Load (3)	Average of load	New
	Components of Correlation coefficient matrix	New
	ATR (Load variability)	New

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Condition assessment algorithm

- The improved Health Index and RI are used to determine the condition of underground transmission lines.
- RI(Risk Index) means a risk factor that requires immediate action according to the diagnosis result

→ PD decision result, EBG result of DGA, EBA result of DGA

- It will be used to determine the inspection interval of the underground transmission line by multiplying the improved Health Index (HI) and the Risk Index (RI) .

Figure 3. Calculation process of Condition assessment

System development

- The physical structure of U-phas is divided into big data server, AI server, DB server, and Was server, and each function is as follows.
- The big data server : collecting online PD diagnostic data and operational data from the field. All diagnostic and operational data linked to the system can be inquired, analyzed, and managed through the big data server.
- The AI server : re-learning PD algorithms and developing new learning models.
- The DB server : building the partial discharge determination result and the data received from the head office legacy as a database.
- The Was server : Users can access the system
- The UI of the system is divided into :

- General status
- Condition assessment
- Partial discharge decision
- Big data
- Artificial intelligence platform (Only administrator)
- System management (Only administrator)

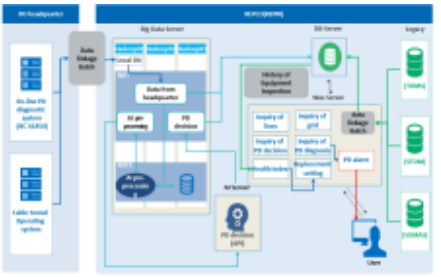

Figure 4. Configuration of U-phas

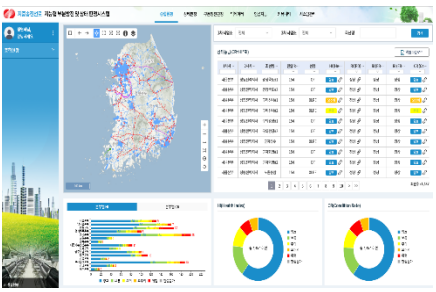

Figure 5. General status of Health index(HI) and Risk index(RI) in U-phas

Figure 6. Big data Management in U-phas

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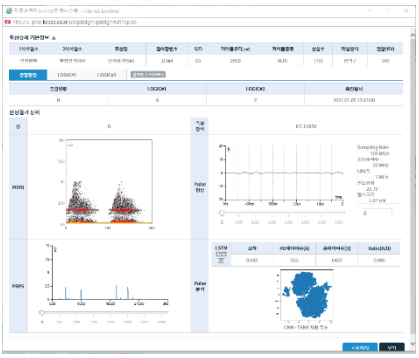

Figure 7. Result of PD analysis using AI algorithm in U-phas

Application

- U-phas was applied to 23 underground transmission lines in the field.

  - 14 lines (online partial discharge diagnosis system based on IEC 61850) : a two-step automatic decision algorithm

  - 9 lines(the existing system) : only PRPD

- After the existing systems are changed to the data structure based on IEC 61850, a two-step automated decision process will be applied.

Figure 8. Application of KEPCO's actual underground transmission lines

Conclusions

- KEPCO is working on data linkage and system improvement in order to expand and use U-phas to all headquarters.
- In addition, we are developing an algorithm that advances the two-step automatic decision algorithm by continuously collecting field data.
- U-phas will serve as a basis for establishing a preventive diagnosis system that can prevent breakdowns in underground transmission lines.