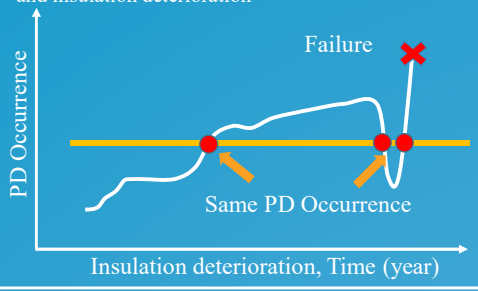
On-line PD Monitoring System (PDLOOK) for XLPE Cables

Shigeru Akaiwa[1]*, Koji Miyagawa[1], Takayuki Nakashima[1], Tatsuya Sakoda[2], Takuma Miyake[2], Akira Takayama[3]
1 Kyushu Electric Power Co., Inc.
2 Electric Power Lab, University of Miyazaki
3 Kyuden Business Solutions

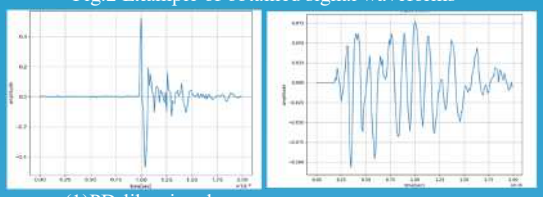
Introduction

Fig.1 Image of the relationship between PD occurrence and insulation deterioration



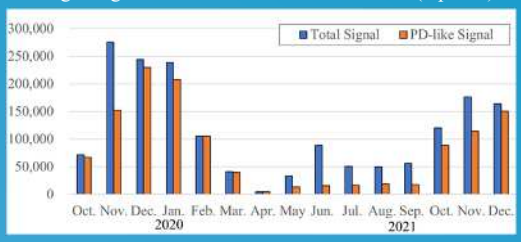
Necessary to monitor PD occurrence constantly to grasp the condition of insulation deterioration.

Fig.2 Example of obtained signal waveforms



(1)PD-like signal (2)Noise-like signal

Fig.3 Signal obtained on a substation cable (1 phase)

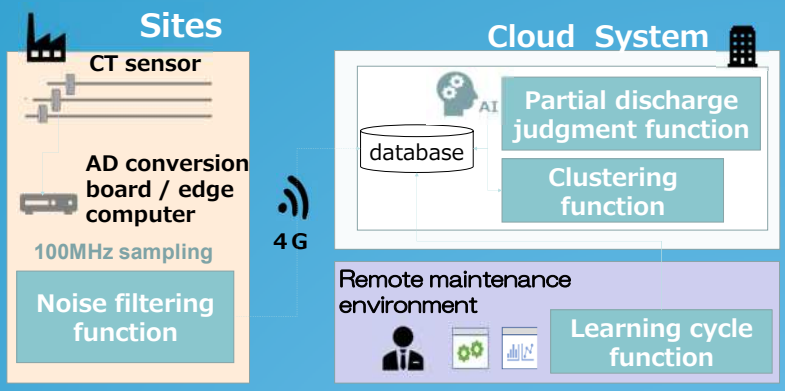


MASS DATA: Necessary to analyze every month: HARD WORK!

We have developed an Online Remote PD diagnosis system (PDLOOK) with Automatic Analysis Function taking advantage of AI.

PDLOOK system

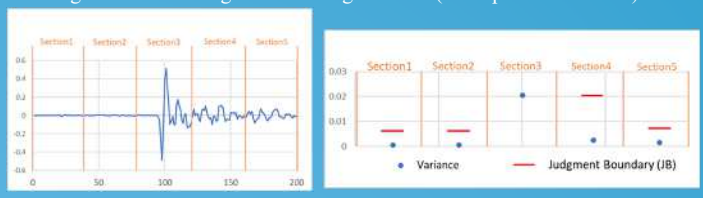
System Overview



- Noise filtering function reduces LTE traffic.
- AI PD judgement function enables real-time PD trend monitoring.

Noise Filtering Function

Fig.4 Noise Filtering method using variance (Example of 5 sections)



- Based on the variance of the peak section set the Judgment Boundary for other sections.
- If the variances of all sections are below the Judgment Boundary, the data is sent to the cloud system.

Table1. Performance of Noise filtering function

	Number of validation data	Number of data removed by the noise filter	Ratio
Noise	1,146,529	1,145,426	99.90%
PD	373,118	91	0.02%

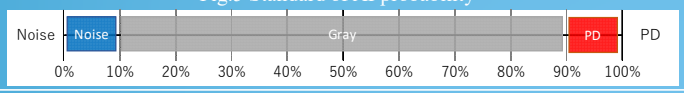
AI PD judgment Function

To reduce judgment omissions for the PD signals

- Set a "Gray" standard, which needs human judgment for the probability range where the AI judgment is ambiguous.
- Adopting ensemble learning using multiple AIs with different characteristics.

◆"Gray" standard

Fig.5 Standard of AI probability



PD probability based on AI judgment: "Noise" <10%, 90%=< "PD"
PD probability needed human judgment: 10% =< "Gray" <90%

◆Ensemble learning

- Adopt 3 judgment methods for 4 AI models.
- Implement them from [1] and end if "PD" result is reached.

[1] Priority: "PD", if any one of AI model judged as "PD"
[2] Majority: If majority AI models judged as "PD", "PD"
[3] Average value: Threshold judgment with the average value of the judgment probability of 3 models.

Table 2. Threshold for each judgment method

AI Model	[1] Priority	[2] Majority	[3] Average value
CNN	PD: 0.9 or higher	NA	PD:0.8 or higher Noise:0.2 or less
GRU	NA	PD:0.9 or higher Noise:0.1 or less	
Light GBM	NA		
Efficient GAN	PD: 0.038 or less	NA	NA

Table3. Judgment accuracy evaluation result of ensemble learning (evaluated with 718,335 data obtained from the field)

AI Model	Accuracy (without Gray)						PD probability		
	True Positive	True Negative	False Positive	False Negative	Precision (%)	Recall (%)	PD/ Noise	Gray	Gray ratio
CNN	332,164	383,845	185	181	99.944	99.946	716,375	1,960	0.27%
GRU	322,292	375,646	846	451	99.738	99.860	699,235	19,100	2.66%
Light GBM	205,722	340,564	4	69	99.998	99.966	546,359	171,976	23.94%
Ensemble learning	332,513	380,936	246	50	99.926	99.985	713,745	4,590	0.64%

AI		True Value: PD	True Value: Noise
	PD	True Positive	False Positive
	Noise	False Negative	True Negative

Precision：Low False Positives for PD
TP / (TP + FP)
Recall：Low False Negatives for PD
TP / (TP + FN)

Summery

- We have developed a continuous remote monitoring system for partial discharge, which consists of an AI judgment function and a noise filtering function, focusing on the waveform of the partial discharge signal. We're expanding services with this system in Japan.
- Accumulating big data from the system, we will try to clarify the correlation between cable lifetime and PD characteristics.