A Study on Partial Discharge Diagnosis Technology in Power Distribution Field Using Deep Learning Technology

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A Study on the Diagnosis of Partial Discharge using Deep Learning Model in the Power Distribution Grid

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summary

Accident prevention and recovery costs increase due to aging of distribution power facilities, and efficient management of these facilities is required. Recently, in consideration of these points, research on automatic diagnosis of partial discharge through deep learning technology has been actively conducted. Therefore, in this paper, research on diagnosing partial discharge in the distribution field using deep learning technology, mentioning the issues of diagnosing partial discharge in the distribution network, and suggesting countermeasures to ultimately improve the safety and efficient operation of distribution facilities. want to contribute

I. Introduction

Accident prevention costs and accident recovery costs are increasing day by day due to the aging of distribution power facilities. In addition, an efficient management system is required according to the increase in aging facilities. In addition, it is necessary to maximize the value of equipment investment by operating equipment until the end of its lifespan, and it is necessary to prevent safety accidents of defective equipment through partial discharge diagnosis management. Currently, these points are solving the above-mentioned problems through partial discharge diagnosis. Existing partial discharge diagnosis methods in the power distribution field can diagnose partial discharge in an oblique state through a tan delta diagnosis method and a VLF PD diagnosis method. However, since this diagnosis method requires human intervention, the diagnosis may not be consistent unless a partial discharge expert is involved, and the diagnosis may be slow because the automation of the partial discharge system capable of diagnosis in a live state is not achieved.

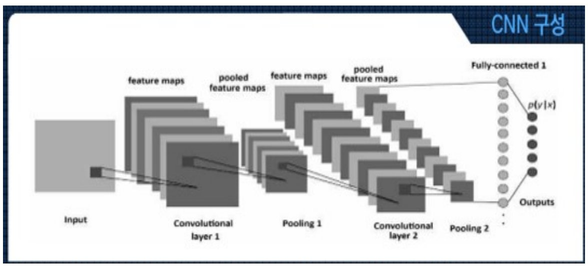
Recently, deep learning technology has been used in the diagnostic field to produce remarkable results in the field of partial discharge diagnosis [1]. Considering this point, it is necessary to research a technology that can automatically judge and classify partial discharge in a live wire state without human intervention through deep learning technology, which is a data-based learning model, even in the power distribution field. Therefore, this paper introduces deep learning technology that can diagnose partial discharge using data learning-based deep learning technology while minimizing human intervention, and concludes by mentioning issues and countermeasures for diagnosing partial discharge in distribution power grids. .

II. Main subject

Basically, since the deep learning model is a data-based learning model, partial discharge input data is required to determine partial discharge. Typically, the distribution pattern of the partial discharge signal relative to the reference phase is input data. Phase-resolved partial discharge (PRPD) data in the form of phase-resolved partial discharge (PRPD) is widely used as input data.

Deep learning models recently used for partial discharge diagnosis can be largely summarized into four models. First, there is a convolutional neural network (CNN) model widely known as an image recognition technology, and a long short-term memory (LSTM) model used to handle time-series data. As a third model, there is an autoencoder, which is an unsupervised learning model, and a generative adversarial networks (GAN) model, which is also an unsupervised learning model, is used for partial discharge diagnosis technology.

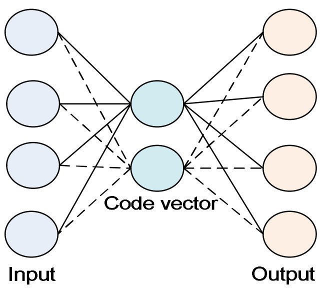
As shown in Figure 1, the CNN model is an image recognition deep learning model, which uses PRPD data, which is input data, to convert into digitized partial discharge image pattern input data and apply it to the model [2]. Finally, partial discharge can be judged and classified in the form of an image. Combination models of CNN models and other deep learning models are also presented. As an example, there is a model that decomposes partial discharge signals with a CNN hybrid model, applies them as input data for each CNN model, and finally classifies partial discharge types with an LSTM model [1].



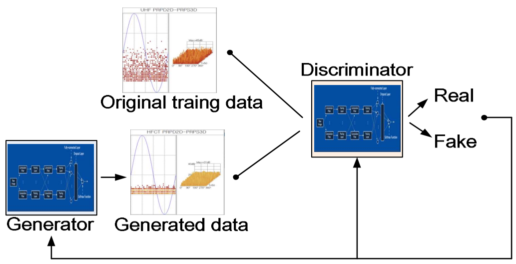
<Figure 1. Example of CNN architecture>

The LSTM model, a time-series deep learning model, can also be used to classify partial discharge patterns. PRPD data is input in the form of time-series data to finally classify partial discharges. As an LSTM hybrid model, there is also a case in which a CNN-LSTM model using partial discharge input data acquired through various partial discharge acquisition sensors is presented [1].

An autoencoder model, an unsupervised learning model, can also be used to determine and classify partial discharge. As shown in Figure 2, as an example of partial discharge determination, partial discharge outliers can be detected if the code vector for normal input data without partial discharge is different from the feature vector for outlier input data with partial discharge. Partial discharge can be classified by using a stochastic classifier (Softmax classifier) in the output stage [3].



<Figure 2. Autoencoder architecture example>



<Figure 3. Example of partial discharge data multiplication using GAN>

Finally, the input data of partial discharge can be augmented by using the GAN model. Figure 3 shows an example of multiplying partial discharge data using a GAN model. Fake partial discharge data is generated in the generator and input to the discriminator, and through repetitive learning, the discriminator and the generator model recognize and develop each other as hostile competitors. Data to the extent that it is indistinguishable from false data is generated. At this time, the generated fake data can be used as partial discharge input data. There is a case of multiplying partial discharge data using GAN [4].

In the field of power distribution, when partial discharge is diagnosed using deep learning technology, two major limitations may exist. First, actual data determined as partial discharge are insufficient. In addition, there is a significant difference in the number of samples for each type of partial discharge in classifying partial discharge, and these points may have limitations in increasing the precision and accuracy of the deep learning model. As a countermeasure, GAN can be used to multiply similarity-based data. Partial discharge data can be additionally obtained in a simulated environment by utilizing an IEC60270-based partial discharge generation system [2].

The second limitation is that it is not easy to obtain reliable data from the distribution grid. Basically, the locations of distribution transformers/switches and manholes do not exist at regular intervals and are scattered, making it difficult to acquire data. In addition, when data is acquired wirelessly in consideration of economic feasibility, the resultant increase in noise, data loss, or a change in the phase of the partial discharge signal compared to the PRPD reference phase may occur, which may reduce the accuracy of the judgment and classification of the deep learning model. As a countermeasure, it is possible to configure the fastest network without maintaining a fixed network by utilizing Ad-hoc technology [5], which is a self-configuration technology for wireless transmission paths, to secure data with low loss. Also, a method of minimizing deformation of the received partial discharge signal through a signal processing technique may be considered. That is, there is a method of applying a noise removal technique or a partial discharge signal phase correction technique.

In the future, it is expected that the demand for partial discharge technology will increase in order to maintain an efficient management system of distribution facilities and maximize the life of facilities. Therefore, it is judged that the research results of partial discharge diagnosis technology based on deep learning technology can contribute to improving the safety and economic feasibility of distribution power facilities by automatically diagnosing partial discharge in a live wire state without human intervention.

III. conclusion

In this paper, we introduced a deep learning technology that can diagnose partial discharge. Four major deep learning models were used for partial discharge diagnosis technology, and partial discharge diagnosis issues in the current distribution power grid were mentioned. In the future, deep learning-based partial discharge diagnosis technology is expected to improve the safety of distribution power facilities and improve economic feasibility through efficient facility operation.

references

[1] S. Barrios et al., "Partial discharge classification using deep learning methods-survey of recent progress," *Energies*, Vol. 12, 2019.

[2] X. Peng et al., "A convolutional neural network-based deep learning methodology for recognition of partial discharge patterns from high-voltage cables,"*IEEE Transactions on Power Delivery,*Vol. 34, pp. 1460–1469, 2019.

[3] L. Duan et al., "Identification of partial discharge defects based on deep learning method,"*IEEE Transactions on Power Delivery,*Vol. 34, pp. 1557-1568, 2019.

[4] Y. Wu et al., "Partial discharge data augmentation of high voltage cables based on the variable noise superposition and generative adversarial network,"*In Proceedings of the 2018 International Conference on Power System Technology (POWERCON), Guangzhou, China*, pp. 3855–3859, 2018.

[5] B. Kim et al., "Dynamic timer based on expected link duration in mobile ad hoc networks,"*Proceedings - 2019 IEEE 16th international conference on mobile ad hoc and smart systems workshops,*pp. 158-159, 2019.