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Fault Detection of a Medium Voltage Cable Joint using Support Vector Machine Algorithm

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Abstract: Fault detection of the cable joints is one of significant problems in the electrical utilities and industrial companies to increase the network stability as the system interruption can make side effects for both power generation units, renewable energy generation units and other power sources beside of the costumers. In this paper, fault detection of a 20kV XLPE cable joint had been studied using the measured partial discharge (PD) signals and also support vector machine algorithm. In this study, the measured data had been classified based on proposed features as the indices of data classification and they had been used in the classifier algorithm to determine fault based on measured signals and the corresponding obtained features. The results show that the proposed features and applied algorithm could determine the faults in the cable joints with an appropriate range of accuracy. This study could develop the previous studies on a widely used cable joint. This research can be helpful for the electrical utilities to increase network stability.

Keywords: Partial Discharge, Cable Joint, Support Vector Machine

I.INTRODUCTION

Nowadays, XLPE cables play very important role in the distribution power networks and considering the network stability is an important challenge for the electrical utilities as the power lines are normally connected to different power sources i.e. the main power supply sources, solar farms and wind generation units on one side and have been linked to the costumers with various priorities on the other. Therefore, increasing the network stability is a significant issue in the energy management. Based on the annual reports from electrical utilities (electrical utilities of Iran, annual report, 2017), the cable joints is one of major fault sources that can make interruptions in the power supply. Moreover, fault occurrence in the power system can make side effects on the energy marketing plan of renewable sources. Therefore, reducing the fault occurrences can lead to increasing the network stability. One of important faults in the XLPE cable joints is due to partial discharges through formation of carbon trees at different layers of cable joints[1, 2].

These types of faults normally cannot be recognized in the first step of operating of networks and after few months start to make problem. In orders to evaluate the joint condition against these types of faults, the partial discharge (PD) tests have been carried out on the joints for different fault conditions and the results have been analyzed using different signal processing methods and extracted features[2, 3]. The obtained features will be stored in the data banks and they have been used in the classifier algorithms. Therefore, by using trained algorithm and getting PD signal for any other similar cable joints, the fault condition will be determined. Several studies had been done to evaluate different faults in the XLPE cable and also few other types of cable joints based on measured PD signals[3, 4]. In this study, a 20kV XLPE cable joint for the cable 1*185 millimeter square have been set as a case of study and after classifying different fault types in this kind of joint, the features have been estimated based on measure PD signals and the type of faults have been determined using support vector classification algorithm. This study can develop the previous studies on a widely used cable joint in the network and can be helpful for the electrical utilities to increase the network stability.

II.STRUCTURE OF CABLE JOINT

Figure 1 illustrates the structure of a Heat Shrinkable Cable Joint as it includes 5 main layers i.e. external layer to cover joint and isolate inside of joint from outside environment, stress control tube to prevent electrical stresses inside of joint, insulation layer to cover and isolate conductor form other internal layers, semi-conducting layer to conduct the leakage components and grounding and mechanical protection layer to maintain grounding in the external layer of joint as well as mechanical controlling of joint. It should be mentioned that a 20kV cable joint for 1*185(millimeter square) XLPE cables as a widely used joint in the Iranian distribution networks have been considered in this study.

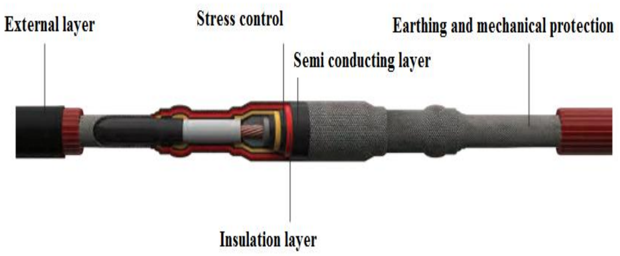

Fig. 1 Structure of 20kV cable joint

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III.CLASSIFICATION OF DIFFERENT FAULTS

In orders to classify the faults based on extracted features from measured PD signals, different smart algorithms had been used in the previous studies (for different cases of power equipment)[5-7] as Neural network, support vector machine, Decision tree algorithms had been widely used in the case of XLPE cables in previous researches[1, 3-5, 8, 9]. Figure 2 demonstrates the block diagram of this study as the considered faults in the joint are listed as follows;

1- Damage on the semiconductor layer(Type.1)

2- The presence of particle irons in the joint layers(Type.2)

3- The presence of air bubbles in the joint layers(Type.3)

In this study, fifty samples for each first type of above mentioned faults, second fault class and third kind of fault had been obtained through experimental work and the Mean, Variance, Skewness and Kurtosis features [10, 11]have been extracted from recorded and processed data. Next, 60% of the extracted features had been used for training of support vector machine as a machine learning method for classification of data [12]. Noted that the linear Kernel function had been applied in the SVM algorithm and the rest 40% of data have been used for evaluation and validation of algorithm performance.

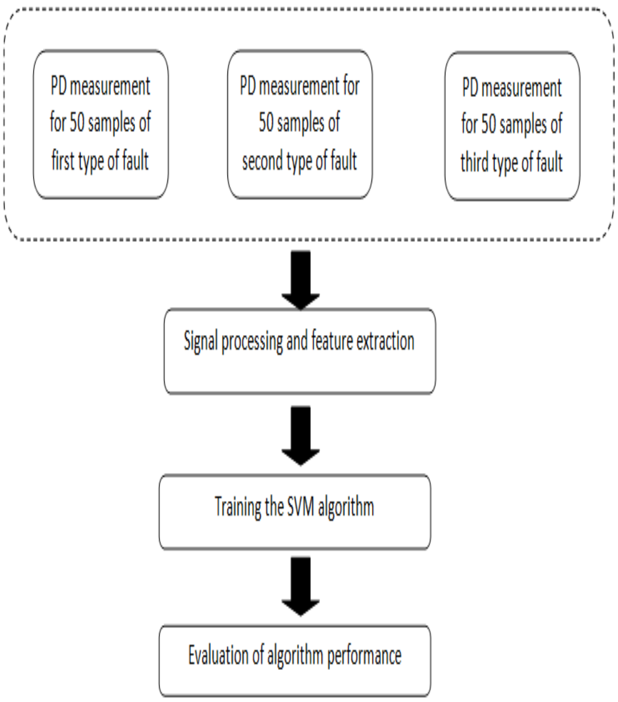

Fig. 2 Block diagram of study

In the first block of Figure 2, PD signals had been collected from different joint conditions. In the second block, the features had been extracted from measured signals and signal processing of data and in the third block, 60% of data had been used for training of SVM algorithm (randomly) [12] and in the last block, the rest 40% of data had been used for evaluation of classifier performance. It should be mentioned that in order to filter existing noises, the mother wavelet signal processing method (Daubechies-level 5) had been applied in this study[13].In this paper, the Mtronix MPD 600 had been used for PD measurement and duration of applied PD was 1min.

IV.RESULTS AND DISCUSSION

Figure 3 shows the extracted features from processed signal using mother wavelet for the case of joint with damage in the semiconductor layer (code 1). It should be mentioned that Hp is the number of PD vs. phase angle (pulse count distribution) from the positive half cycle of the voltage and Hpq is the average magnitude vs. the phase angle (the mean height pulse distribution) from the positive half cycle of the voltage. In this study, the above mentioned part of measured signal had been used for data extraction as it can sense the fault signature however other parts of measured signals can be studied in the future studies.

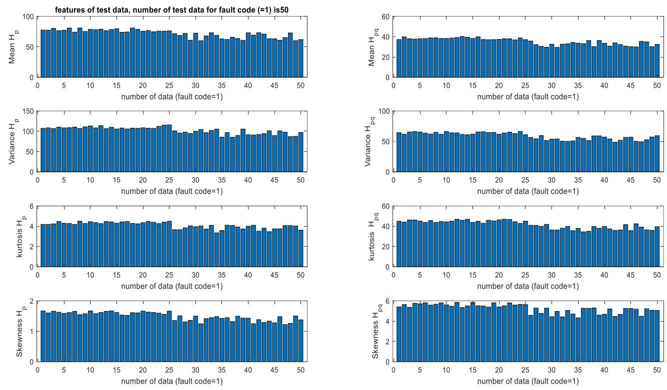

Fig. 3 Extracted features for fault type number 1 (Damage in the semiconductor layer)

Likewise, Figure 4 illustrates the extracted features from processed signal using mother wavelet for the case of presence of particle irons in the joint layers (code 2).

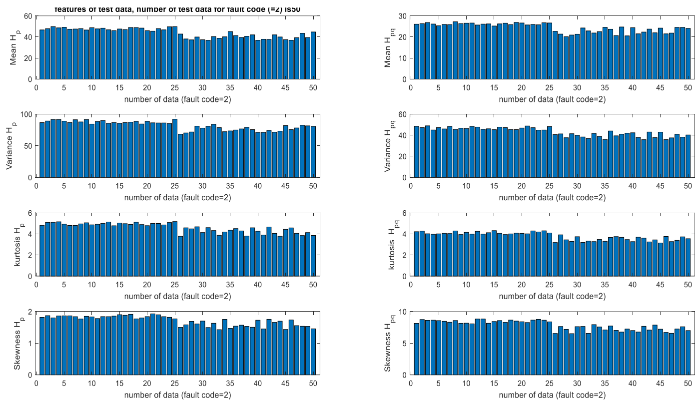

Fig. 4 Extracted features for fault type number 2 (Presence of particle irons in the joint layers)

Moreover, Figure 5 demonstrates the extracted features from processed signal using mother wavelet for the case of presence of air bubbles in the joint layers (code 3).

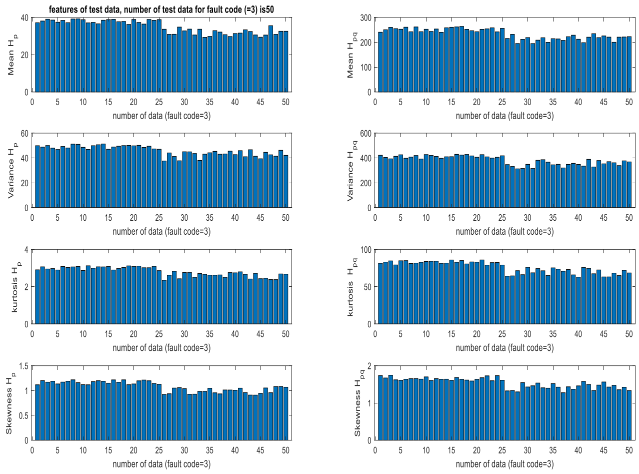

Fig. 5 Extracted features for fault type number 3 (Presence of air bubbles in the joint layers)

By using 60% of extracted features (Figures 3 to 5) for training of SVM algorithm based on linear Kernel function and evaluation of algorithm performance based on remained 40% of data(randomly), the results shows that the accuracy of classifier algorithm is 96.6% as demonstrated in Figure 6. Noted that codes 1 to 3 are for the faults in the semiconductor, particle iron and air bubbles, respectively.

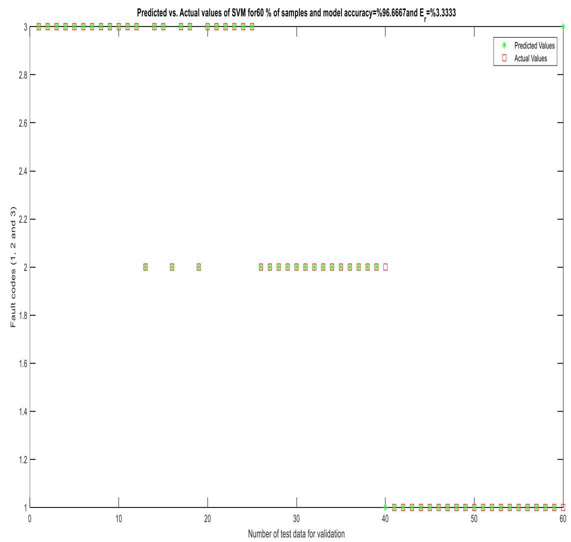

Fig. 6 Comparison between actual joint condition and the corresponding evaluated one obtained from proposed SVM algorithm

Figure 6 illustrates the comparison between actual fault condition and evaluated fault condition obtained from proposed SVM algorithm as the input parameters of trained algorithm are the features that have been presented in Figures 7 , 8 and 9 for first ,second and third fault types, respectively (based on remained 40% of data). Noted that 50 samples for each faults had been measured (total number of samples of three faults is 150) and 60% of measured data had been selected randomly and applied for training of algorithm (90 samples) and the rest 40% (60 samples) had been used for validation of proposed algorithm.

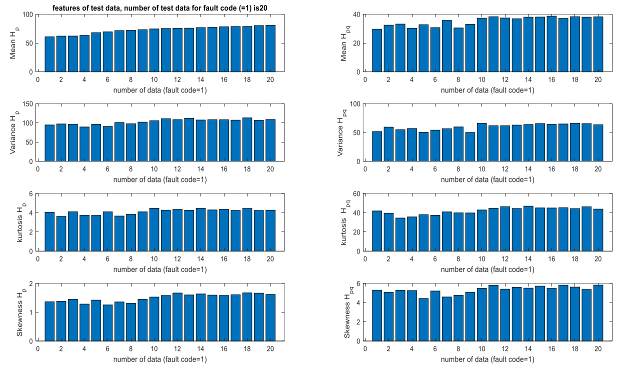

Fig. 7 Extracted features that had been used for algorithm performance for fault type number 1 (damage in the semiconductor layer)

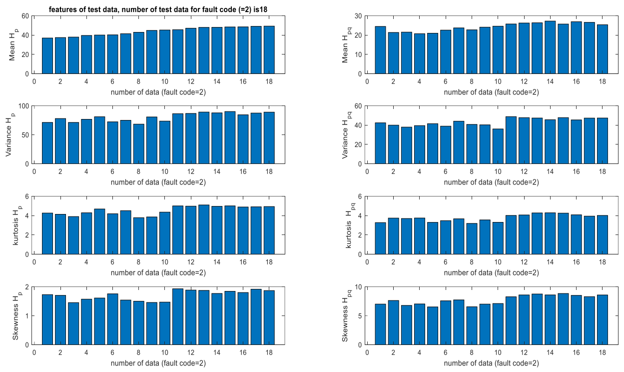

Fig. 8 Extracted features that had been used for algorithm performance for fault type number 2 (presence of particle irons in the joint layers)

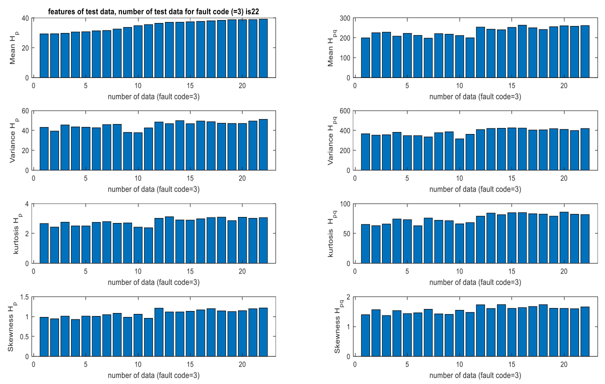

Fig. 9 Extracted features that had been used for algorithm performance for fault type number 3 (presence of air bubbles in the joint layers)

The results show that the proposed algorithm could evaluate tree major types of faults in the 20kV cable joint (1*185 XLPE cable) with an acceptable value of accuracy (96-99%) compared to the previous studies (in other power equipment) [1-2, 9]. This study could develop the fault diagnostic algorithms on the 20kV cable joint. The proposed method can be used in the electrical utilities to find faults before operation of network as some types of faults are hidden in the first stage and after few months from first operation, they can make network disturbance.

V.CONCLUSION

In this paper, fault detection of a 20kV cable joint (1*185 millimeter square) had been studied as it was based on extracted features obtained from measured PD signals. Moreover a SVM classifier algorithm had been employed to detect fault condition of this type of cable joint. The results showed that the applied method could reach to an acceptable rate of accuracy. The proposed method could develop the previous researches on the above mentioned type of cable joint and can be helpful for the electrical utilities to increase the network stability against hidden existing problems in the power networks.

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