

Identification of the Electric Spark Electromagnetic Waveform Based on SVM

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Abstract—Electromagnetic wave of electrical spark is a potential cause to electrical equipment failure. This research focused on identifying and comparative analyzing the different types of electromagnetic waveform generated by electrical equipment failure based on SVM. After analyzing and extracting the features the electromagnetic waveform, a model was built to identify the type of the electromagnetic waveform. The collected standard electromagnetic waveforms were used as the input of the train model and the model accuracy was improved by adjusting training parameters after analyzing the results. When inputting an unknown type of electromagnetic waveform, SVM may predict the output of the network according to the recognition rule. Then the types of electromagnetic waveforms were identified by using adjusted models. The result shows that the electromagnetic waveform can be effectively and feasibly identified based on SVM, which provides a theoretical support on prediction method of gas explosion caused by electrical sparks.

Keywords—SVM; features of electromagnetic waveform; waveform identification

I. INTRODUCTION

Under the influence of the power frequency electric field^[1], the electric spark is a phenomenon of breakdown discharge when strong electric field ionizes the gas in the contact gap because of a momentary strong electric field or quick close and disconnection, together with a series of light, heat and other phenomena^[2], which results the resistance cannot continue to maintain the insulation property. Electric spark exhibits a wide frequency band distribution over the entire frequency band of electromagnetic waves shown in the recent studies^[3].

II. THE EXTRACTION OF ELECTROMAGNETIC CHARACTERISTICS AND THE MODEL ESTABLISHMENT OF THE ELECTRIC SPARK WAVEFORMS

From the mechanism of the generation of electrical sparks, compared with the mechanism of static electricity and lightning lightning^[4], no matter what kind of spark discharge is used, there will be transient, high frequency, short rise time and short duration electromagnetic pulses in spark discharge. The electric spark is not generated by the static electric field generated by the initial accumulated electrostatic charge, but the electromagnetic pulse generated by the discharge is the same^[5]. The electric spark pulse electromagnetic field is the electromagnetic field generated by the discharge transient

current.

A. Electromagnetic Characteristics Extraction of the Electric Spark

First, confirm that you have the correct template for your paper size. This template has been tailored for output on the US-letter paper size. If you are using A4-sized paper, please close this file and download the file for “MSW_A4_format”. When the distance between the contact closure electrodes gradually decreases or a strong electric field occurs^[6], the current density gradually increases and produces high temperature ionization, then contact and electrode gas will be punctured. The moment of touch contaction or electric field reaching maximum leads to the discharge current reaches a peak, and then current decreases with exponential to zero^[7]. So, the relationship between the voltage across the capacitor and the breakdown voltage can be described as follow:

$$u_c = U_c e^{-\delta t} \left(\cos \omega t + \frac{\delta}{\omega} \sin \omega t \right) + \frac{u_0' e^{-\delta t}}{t - \frac{T_{RC}}{T_{LR}}} \cdot \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{\sin(2n-1)\omega t}{2n-1} \quad (1)$$

The electric current passed through electric spark can be described as follow:

$$I = C_o u_c' = \frac{U_c e^{-\delta t}}{L \omega} \sin \omega t - \frac{C u_0' e^{-\delta t}}{T_{LR} - T_{RC}} \cdot \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{\sin(2n-1)\omega t}{2n-1} \quad (2)$$

$$\text{Where } T_{LR} = \frac{2L}{R}, \quad \omega = \sqrt{T_{CR}^{-2} - T_{LR}^{-2}} = \sqrt{\frac{T_{LR}}{T_{RC}} - 1}, \quad \delta = \frac{R}{2L} = \frac{1}{T_{LR}}$$

The parameters of the electrical spark obtained by above formulas mainly include discharge voltage, discharge current, frequency, amplitude, energy, wavelength and rise time. Different types of discharge sparks have great differences in the four parameters^[8], namely amplitude, frequency, rise time, and discharge current. Therefore, the amplitude, frequency, rise time, discharge current, and discharge voltage are selected as the parameters of the electromagnetic wave, which are the object of the subsequent analysis.

B. Establishment of Electric Spark Magnetic Field Model Based on SVM

Using SVM to identify electrical spark electromagnetic waves, we first select the parameters obtained by the wavelet transform of electrical spark electromagnetic wave of known discharge type to form a training sample set, which was used as the input of the SVM training module. Then use the training sample data to train the SVM to get the support vector and the corresponding parameters, and thus establish the SVM model. If the result accuracy of model meets the expected requirements^[9], it is saved for use in the identification process of discharge spark electromagnetic waves. If the result accuracy of the model does not meet the expected requirements, the training parameters are readjusted and training is performed until the accuracy of the training error reaches the expected. Finally, the parameter data of the discharge spark electromagnetic wave to be tested is input into the established SVM model to obtain the spark spark type recognition result.

The flow chart of the entire training and testing process is shown in Figure I.

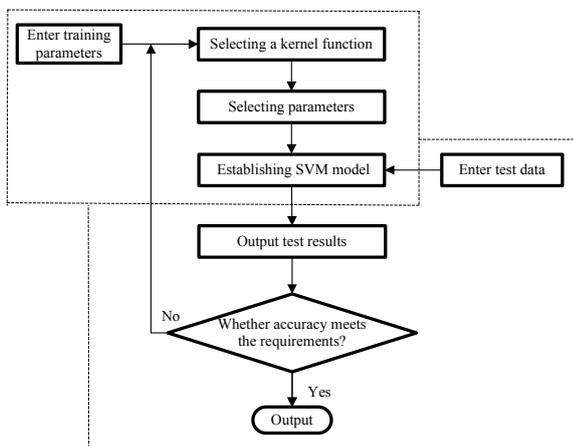


FIGURE I. SVM TRAINING AND TESTING FLOW

Support vector machine (SVM) model sample selection of three discharge types: low-voltage discharge sparks, high-voltage discharge sparks and glow discharge sparks. After wavelet analysis of electromagnetic wave data, amplitude, frequency, rise time, discharge Voltage and discharge current were selected. Due to the different dimensions of the five parameters, before the model training, the sample data need to be normalized to eliminate the influence of different dimensions and differences in the size of the different indicators on the recognition results^[10]. Use the svdatanorm command in MATLAB to normalize the sample data.

The support vector machine uses the binary tree method to identify the type of discharge sparks^[11]. In fact, the discriminant function f_1 is calculated from the root node, and the discharge spark type 1 and other types of discharge sparks are distinguished based on the value of f_1 . If $f_1=-1$, then the input spark is type 1. if $f_1=1$, then f_2 is calculated, and so on. Until the state combination of the discriminant functions f_1, f_2, f_3 . Complete the identification of discharge spark electromagnetic waves, as shown in Table I.

TABLE I. SVM DECISION RULES TO RECOGNIZE MULTI-HEADSTREAMS

Types of Electric Spark	f_1	f_2
1 High-voltage discharge spark	-1	+1
2 Low-voltage discharge spark	+1	-1
3 Glow discharge spark	+1	+1

Finally, MATLAB was used to program in SVM toolbox^[12], support vector machine and training function svc were used to design for SVM classifier design and train samples.

III. THE PROCESSING AND ANALYSIS OF DATA

Using the SVM model that has been trained, the actual output of the spark discharge spark sample is used to complete the identification work and compared with the actual situation. As shown in Table II, HV-discharge spark represents High-voltage discharge spark, LV-discharge spark represents Low-voltage discharge spark, and G-discharge spark represents Glow discharge spark. the SVM model is used to identify 25 samples, the number of correct data is 23, the correct rate was 92%. It can be seen that using the binary tree SVM model to identify the type of discharge sparks has a higher correct rate.

TABLE II. RECOGNITION RESULTS OF SVM

No.	f_1	f_2	Recognition result of SVM	The actual situation
1	-1	+1	HV-discharge spark	HV-discharge spark
2	-1	+1	HV-discharge spark	HV-discharge spark
3	-1	+1	HV-discharge spark	HV-discharge spark
4	-1	+1	HV-discharge spark	HV-discharge spark
5	-1	+1	HV-discharge spark	HV-discharge spark
6	-1	+1	HV-discharge spark	HV-discharge spark
7	-1	+1	HV-discharge spark	HV-discharge spark
8	-1	+1	HV-discharge spark	HV-discharge spark
9	+1	-1	LV-discharge spark	LV-discharge spark
10	+1	-1	LV-discharge spark	LV-discharge spark
11	+1	-1	LV-discharge spark	LV-discharge spark
12	+1	-1	LV-discharge spark	LV-discharge spark
13	+1	-1	LV-discharge spark	LV-discharge spark
14	+1	+1	G-discharge spark*	LV-discharge spark
15	+1	-1	LV-discharge spark	LV-discharge spark
16	+1	-1	LV-discharge spark	LV-discharge spark
17	+1	-1	LV-discharge spark	LV-discharge spark
18	+1	+1	G-discharge spark	G-discharge spark
19	+1	+1	G-discharge spark	G-discharge spark
20	+1	+1	G-discharge spark	G-discharge spark
21	-1	-1	HV-discharge spark*	G-discharge spark
22	+1	+1	G-discharge spark	G-discharge spark
23	+1	+1	G-discharge spark	G-discharge spark
24	+1	+1	G-discharge spark	G-discharge spark
25	+1	+1	G-discharge spark	G-discharge spark

IV. CONCLUSION

Based on the SVM, the network model of the discharge spark electromagnetic wave was established and trained. In the case of the insufficient number of spark spark samples, it can also play a good classification and recognition role. Through

the trained network, 25 groups of spark samples are identified, the recognition rate is high and the training algorithm time is very short. It solves practical problems such as small sample, nonlinear and high-dimensional pattern recognition, and determines the SVM discharge. The effectiveness and feasibility of spark electromagnetic wave recognition make the recognition model have good generalization performance.

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