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LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie

⑪ N° de publication : **LU506972**

⑫ **BREVET D'INVENTION** **B1**

㉑ N° de dépôt: LU506972

㉒ Date de dépôt: 19/04/2024

(51) Int. Cl.:
G01R 31/08, G01R 31/12, G01R 31/52

㉚ Priorité:

㊸ Date de mise à disposition du public: 21/10/2024

㊼ Date de délivrance: 21/10/2024

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(54) POWER CABLE STATUS DETECTION METHOD BASED ON CURRENT SIGNAL DISTORTION GRAPHIZATION, AND APPARATUS.

(57) Disclosed are a power cable status detection method based on current signal distortion graphization, and an apparatus, relating to the status detection field of electrical devices. The method includes: collecting a current signal of a to-be-detected power cable, to obtain to-be-detected current waveform data; determining a dynamic error two-dimensional scatter plot by adopting a Lorentz chaotic synchronous system according to current waveform data under a normal status and the to-be-detected current waveform data; and performing defect recognition on the dynamic error two-dimensional scatter plot by adopting a defect recognition model to determine a defect type of a to-be-detected power cable, where the defect recognition model is obtained in a manner that a training sample set is adopted in advance to train a target detection network, and the training sample set includes a plurality of sample dynamic error two-dimensional scatter plots and corresponding defect types thereof.

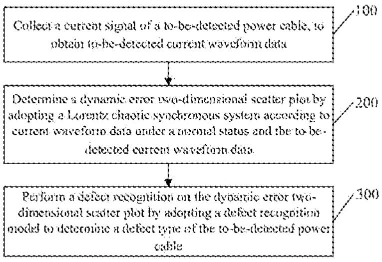


FIG. 1

POWER CABLE STATUS DETECTION METHOD BASED ON CURRENT SIGNAL DISTORTION GRAPHIZATION, AND APPARATUS

TECHNICAL FIELD

[0001] The present disclosure relates to the status detection field of electrical devices, and in particular to a power cable status detection method based on current signal distortion graphization, and an apparatus.

BACKGROUND

[0002] A grounding current method for power cable online monitoring mainly judges a running status of a system and a health condition of a cable by measuring a grounding current of the cable. The grounding current refers to the current that flows through the ground due to the loss of an insulation medium in a power system. When insulation aging or a local damage occurs to the cable, the grounding current does not present a good sinusoidal waveform any more, and will generate a corresponding fluctuation and form a harmonic distortion. A grounding current sensor is usually placed near the grounding point or the grounding pole of a cable system, and thus real-time and non-invasive monitoring performed on the cable grounding current is implemented. After grounding current waveform data is acquired, various time-frequency analysis methods are mainly adopted for harmonic decomposition, thus obtaining an amplitude, a phase position, a content rate and other information of each harmonic wave, and extracting richer multidimensional feature parameters as a data foundation for evaluating the cable status. However, this method still has some issues, such as complex and trivial feature extraction, existence of information omission and difficulty in feature fusion.

[0003] Few researches that master the cable grounding current distortion from an overall perspective are available currently, therefore the grounding current distortion is transformed into an intuitive image, and distorted component information is completely retained from a global perspective; and classification and recognition for a cable defect type are implemented through a further image recognition technology, to ensure the safe and stable running of the power cable, which is of important practical significance and research value.

SUMMARY

[0004] The objective of the present disclosure is to provide a power cable status detection method based on current signal distortion graphization, and an apparatus, which can improve the efficiency and precision for power cable status inspection.

[0005] A power cable status detection method based on current signal distortion graphization, including:

[0006] collecting a current signal of a to-be-detected power cable, to obtain to-be-detected current waveform data;

[0007] determining a dynamic error two-dimensional scatter plot by adopting a Lorentz chaotic synchronous system according to current waveform data under a normal status and the to-be-detected current waveform data; and

[0008] performing a defect recognition on the dynamic error two-dimensional scatter plot by adopting a defect recognition model to determine a defect type of the to-be-detected power cable, where the defect recognition model is obtained in a manner that a training sample set is adopted in advance to train a target detection network, and the training sample set includes a plurality of sample dynamic error two-dimensional scatter plots and corresponding defect types thereof.

[0009] A computer apparatus, including a memory, a processor and a computer program that is stored in the memory and can run on the processor, where while the processor executes the computer program, the steps for the above power cable status detection method based on current signal distortion graphization is implemented.

[0010] The present disclosure has the following technical effects: the present disclosure only needs to adopt the Lorentz chaotic synchronous system for performing one current signal distortion graphization operation before the detect recognition without requiring the complex multi-feature extraction, screening, fusion and other operations, the established dynamic error two-dimensional scatter plot includes all feature information of the current distortion, and the visualized current distortion is subjected to image feature extraction, fusion, classification and recognition by adopting the target detection network, to improve the precision of the power cable status detection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a flowchart of a power cable status detection method based on current signal distortion graphization provided by the present disclosure.

[0012] FIG. 2 is a denoising time domain waveform diagram of a power cable grounding current signal with a thermal aging defect.

[0013] FIG. 3 is a denoising time domain waveform diagram of a power cable grounding current signal with an inflowing and damp defect.

[0014] FIG. 4 is a denoising time domain waveform diagram of a power cable grounding current signal with an insulation scratch defect.

[0015] FIG. 5 is a denoising time domain waveform diagram of a power cable grounding current signal with an overbending defect.

[0016] FIG. 6 is a dynamic error two-dimensional scatter plot diagram of a power cable with a thermal aging defect.

[0017] FIG. 7 is a dynamic error two-dimensional scatter plot diagram of a power cable with an inflowing and damp defect.

[0018] FIG. 8 is a dynamic error two-dimensional scatter plot diagram of a power cable with an insulation scratch defect.

[0019] FIG. 9 is a dynamic error two-dimensional scatter plot diagram of a power cable with an overbending defect.

[0020] FIG. 10 is a schematic diagram of a test platform.

[0021] FIG. 11 is a structure frame diagram of a YOLOv5 network.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0022] As shown in FIG. 1, a power cable status detection method based on current signal distortion graphization provided by the present disclosure, including:

[0023] Step 100: Collecting a current signal of a to-be-detected power cable, to obtain to-be-detected current waveform data. In this embodiment, a current signal of the to-be-detected power cable is a grounding current signal.

[0024] The to-be-detected current waveform data is subjected to wavelet threshold denoising processing after obtaining the to-be-detected current waveform data.

[0025] The wavelet threshold denoising is a widely applied denoising algorithm, which is not only easy to understand, but also can select different threshold functions according to signal features, with a higher flexibility and a better denoising effect. The denoising effect thereof may be evaluated with a signal-to-noise ratio. The signal-to-noise ratio refers to an energy ratio between an original signal and a noise, labeled as SNR;

$$SNR = 10 \times \lg\left(\frac{\sum_{i=1}^{n} f_i^2}{\sum_{i=1}^{n}(f_i - y_i)^2}\right);$$

[0026] f_i is a i^{th} current value in the denoised to-be-detected current waveform data, y_i is a i^{th} current value in the to-be-detected current waveform data, and n is a length of the current waveform data.

[0027] The greater the signal-to-noise ratio, the better the denoising effect is. More than 15 denoising waveform signal-to-noise ratio values are extracted from the original grounding current signal, and the wavelet denoising method has achieved good results. It may be seen from FIG. 2 to FIG. 5 that the wavelet threshold denoising method may retain the harmonic distortion feature including a defect cable grounding current signal while effectively filtering the background noise.

[0028] Step 200: Determining a dynamic error two-dimensional scatter plot by adopting a Lorentz chaotic synchronous system according to current waveform data under a normal status and the to-be-detected current waveform data.

[0029] As a non-linear dynamics system, the chaotic system has uncertainty and complexity. Due to the existence of singular attractors, signals generated by chaos produce seemingly random irregular motions, but in fact lead to aperiodic order motions. The chaotic synchronous system consists of a master system and a slave system. When the master system and the slave system have different signals, a dynamic deviation is formed between motion trails.

[0030] The master system and the slave system may be represented by two nonlinear functions:

$$\begin{cases} \dot{u}_1 = G_1(u_1, u_2, u_3, \ldots, u_k) \\ \dot{u}_2 = G_2(u_1, u_2, u_3, \ldots, u_k) \\ \vdots \\ \dot{u}_k = G_k(u_1, u_2, u_3, \ldots, u_k) \end{cases}, \quad \begin{cases} \dot{v}_1 = G_1(v_1, v_2, v_3, \ldots, v_k) \\ \dot{v}_2 = G_2(v_1, v_2, v_3, \ldots, v_k) \\ \vdots \\ \dot{v}_k = G_k(v_1, v_2, v_3, \ldots, v_k) \end{cases}.$$

[0031] $\dot{u}_1$ - $\dot{u}_k$ are function values of the master system, $\dot{v}_1$ - $\dot{v}_k$ are function values of the slave system, $G_1(\ )$ - $G_k(\ )$ are functions of the chaotic system, *k* is an equation quantity of the chaotic system, and an equation number of the system and parameters of various systems may be determined according to the system features. When the parameter setting ensures the existence of singular attractors, the motion trails form the deviation. Sequence deviation equations and dynamic deviation equations of the master system and the slave system may be represented as:

$$\begin{cases} e_1 = u_1 - v_1 \\ e_2 = u_2 - v_2 \\ \vdots \\ e_k = u_k - v_k \end{cases},$$

$$\begin{cases} \dot{e}_1 = G_1(u_1, u_2, u_3, \ldots, u_k) - G_1(v_1, v_2, v_3, \ldots, v_k) \\ \dot{e}_2 = G_2(u_1, u_2, u_3, \ldots, u_k) - G_2(v_1, v_2, v_3, \ldots, v_k) \\ \vdots \\ \dot{e}_k = G_k(u_1, u_2, u_3, \ldots, u_k) - G_k(v_1, v_2, v_3, \ldots, v_k) \end{cases}.$$

[0032] To ensure the existence of singular attractors, the Lorenz system proposed by Lorentz, an American mathematician, is selected in the present disclosure. The Lorentz chaotic synchronous system includes the master system and the slave system, with an equation number *k* of 3, including three system parameters of α, β and γ and empirical values of α=10, β=28 and γ=3/8.

[0033] Specifically, the step 200 includes: the current waveform data under the normal status is input into the master system and the to-be-detected current waveform data is input into the slave system such that the current waveform data under the normal status and the to-be-detected current waveform data are subjected to a dynamic deviation calculation, to obtain a first dynamic error sequence and a second dynamic error sequence.

[0034] When the Lorentz chaotic synchronous system is adopted, the master system and the slave system may be represented as:

$$\begin{cases} \dot{u}_1 = \alpha(u_2 - u_1) \\ \dot{u}_2 = \beta u_1 - u_1 u_3 - u_2 \\ \dot{u}_3 = u_1 u_2 - \gamma u_3 \end{cases}, \quad \begin{cases} \dot{v}_1 = \alpha(v_2 - v_1) \\ \dot{v}_2 = \beta v_1 - v_1 v_3 - v_2 \\ \dot{v}_3 = v_1 v_2 - \gamma v_3 \end{cases}.$$

[0035] The current waveform data under the normal status and the to-be-detected current waveform data are subjected to the dynamic deviation calculation by adopting the following formula:

$$\begin{bmatrix} \dot{e}_1 \\ \dot{e}_2 \\ \dot{e}_3 \end{bmatrix} = \begin{bmatrix} -\alpha & \alpha & 0 \\ \beta & -1 & 0 \\ 0 & 0 & -\gamma \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} + \begin{bmatrix} 0 \\ -u_1 u_3 + v_1 v_3 \\ u_1 u_2 - v_1 v_2 \end{bmatrix};$$

$$\begin{cases} e_1 = u_1 - v_1 \\ e_2 = u_2 - v_2 \\ e_3 = u_3 - v_3 \end{cases};$$

[0036] where $\dot{e}_1$ is a first dynamic error sequence, $\dot{e}_2$ is a second dynamic error sequence, $\dot{e}_3$ is a third dynamic error sequence, α is a first system parameter of the Lorentz chaotic synchronous system, β is a second system parameter of the Lorentz chaotic synchronous system,

γ is a third system parameter of the Lorentz chaotic synchronous system, e_1 is a first sequence deviation, e_2 is a second sequence deviation, e_3 is a third sequence deviation, u_1 is a first sequence of the current waveform data under the normal status, $u_1 = (x[1], x[2], \ldots, x[n-2])$, u_2 is a second sequence of the current waveform data under the normal status, $u_2 = (x[2], x[3], \ldots, x[n-1])$, u_3 is a third sequence of the current waveform data under the normal status, $u_3 = (x[3], x[4], \ldots, x[n])$, v_1 is a first sequence of the to-be-detected waveform data, $v_1 = (y[1], y[2], \ldots, y[n-2])$, v_2 is a second sequence of the to-be-detected waveform data, $v_2 = (y[2], y[3], \ldots, y[n-1])$, v_3 is a third sequence of the to-be-detected waveform data, $v_3 = (y[3], y[4], \ldots, y[n])$, x is current waveform data under the normal status, y is to-be-detected current waveform data, $x[1]$ is a first current value of the current waveform data under the normal status, $y[1]$ is a first current value of the to-be-detected current waveform data, and n is a length of the current waveform data.

[0037] Due to a relatively unapparent error in a $\dot{e}_3$ direction, the dynamic error two-dimensional scatter plot is drawn in the present disclosure with the first dynamic error sequence as an abscissa and the second dynamic error sequence as an ordinate, as shown in FIG. 6 to FIG. 9, the dynamic error two-dimensional scatter plot basically presents a bilateral symmetry. The dynamic error two-dimensional scatter plot corresponding to different defect cables is very different in the distribution pattern, which may serve as the valid basis for evaluating the cable defect.

[0038] Step 300: Performing a defect recognition on the dynamic error two-dimensional scatter plot by adopting a defect recognition model to determine a defect type of the to-be-detected power cable.

[0039] The defect recognition model is obtained in a manner that a training sample set is adopted in advance to train a target detection network, and the training sample set includes a plurality of sample dynamic error two-dimensional scatter plots and corresponding defect types thereof. The detect type includes zero defect, thermal aging, inflowing and damp, overbending and insulation scratch.

[0040] Further, the process for establishing the training sample set includes:

[0041] (1) Preparing cable samples with various defects.

[0042] In this embodiment, the cable samples with four typical defects including thermal aging, inflowing and damp, overbending and insulation scratch are prepared.

[0043] (2) Collecting the current waveform data of various cable samples through a test platform. Taking the grounding current signal as an example, the grounding current waveform data of the cables with different defects is acquired in a laboratory environment through the test platform. Then the collected grounding current waveform data is subjected to denoising processing.

[0044] As shown in FIG. 10, the test platform includes a power supply, a protective resistance 2, a copper foil measuring electrode 4, a sampling resistance 5 and a data acquisition card 6. The power supply is a high voltage power supply 1 that consists of a voltage regulator and a testing transformer, and outputs 8.7kV of testing voltage. An output end of the power supply is connected with the cable samples 3 through the protective resistance 2. The protective resistance 2 has a resistance value of 1MΩ, to prevent the possible overcurrent influence in a testing process. The copper foil measuring electrode 4 is arranged on the cable samples 3 and grounded by the sampling resistance 5. The sampling resistance 5 has a resistance value of 10kΩ, and is placed in a shielding box to reduce an electromagnetic interference. The data acquisition card 6 is connected with both ends of the sampling resistance 5, and current values of the cable samples 3 are collected, to obtain the current waveform data of the cable samples 3. The data acquisition card 6 has a sampling frequency of 20kHz. In addition, the test platform further includes a voltage divider 7, an oscilloscope 8 and a personal computer 9, the voltage divider 7 is connected with the oscilloscope 8 and grounded, and the personal computer 9 is connected with the data acquisition card 6.

[0045] (3) For any one cable sample, the dynamic error two-dimensional scatter plot of each cable sample is determined by adopting the Lorentz chaotic synchronous system according to the current waveform data under the normal status and the current waveform data of the cable sample, to obtain a plurality of sample dynamic error two-dimensional scatter plots and the corresponding defect types thereof.

[0046] Specifically, the current waveform data under the normal status and the current waveform data of the cable sample are separately input into the master system and the slave system, and the dynamic scatter plot is drawn by using a trail deviation caused by a signal difference, which serves as a basis for evaluating the power cable defect. Thereafter, a total of 300 sample dynamic error two-dimensional scatter plots of four typical cable defect types serve as the training sample set to establish the defect recognition model by using the YOLOv5 target detection algorithm.

[0047] YOLO is an advanced target detection algorithm, and the target detection can be completed in a short time by adopting a single forward propagation mode, to achieve the purpose of real-time detection. A target detection network in this embodiment is YOLOv5, has a network structure as shown in FIG. 11 and mainly includes four parts such as an input layer, a backbone network, a neck network and a prediction network, and each part has the function below:

[0048] (1) The input sample dynamic error two-dimensional scatter plots complete adaptive anchor frame calculation, adaptive scaling and other preprocessing operations first in the input layer. According to the features of an actual task and a data set, a suitable anchor frame is automatically calculated through the adaptive anchor frame calculation. In the follow-up training, the network outputs a prediction frame on the basis of the initial anchor frame, the prediction frame is compared with an actual frame to calculate a difference therebetween, and iterative network parameters are updated reversely. After the input images of different sizes are uniformly scaled to the standard size through adaptive pictures, the follow-up test is carried out again.

[0049] (2) The backbone network implements multi-layer feature extraction on the image by adopting the combinations of CBL (Conv+BN+LeakyRelu), CSP (Cryptographic Service Provider) and other modules. The features are sampled and extracted under a convolution operation, and in this embodiment, the input images are uniformly scaled to 640×640, and three size features of 20×20, 40×40 and 80×80 are obtained through multiple convolutions.

[0050] (3) The image features of different layers complete fusion in the neck network through a FPN+PAN (Feature Pyramid Network + Path Aggregation Network) pyramid structure. The FPN structure delivers high-layer feature information from top to bottom by an upper sampling mode, while the PAN structure delivers a strong positioning feature from bottom to top. The pyramid structure implements the feature fusion of different layers through a connecting operation.

[0051] (4) Finally, through a loss function, a non-maximum suppression and other processes, the feature image completes a defect type recognition corresponding to a scatter pattern in the prediction network.

CLAIMS

1. A power cable status detection method based on current signal distortion graphization, wherein the power cable status detection method based on current signal distortion graphization comprises:

collecting a current signal of a to-be-detected power cable, to obtain to-be-detected current waveform data;

the current signal of the to-be-detected power cable being a grounding current signal;

performing wavelet threshold denoising processing on the to-be-detected current waveform data;

determining a dynamic error two-dimensional scatter plot by adopting a Lorentz chaotic synchronous system according to current waveform data under a normal status and the to-be-detected current waveform data, wherein the Lorentz chaotic synchronous system comprises a master system and a slave system, the current waveform data under the normal status is input into the master system and the to-be-detected current waveform data is input into the slave system such that the current waveform data under the normal status and the to-be-detected current waveform data are subjected to a dynamic deviation calculation, to obtain a first dynamic error sequence and a second dynamic error sequence; and the dynamic error two-dimensional scatter plot is drawn with the first dynamic error sequence as an abscissa and the second dynamic error sequence as an ordinate;

performing a defect recognition on the dynamic error two-dimensional scatter plot by adopting a defect recognition model to determine a defect type of the to-be-detected power cable, wherein the defect recognition model is obtained in a manner that a training sample set is adopted in advance to train a target detection network, the target detection network is YOLOv5, and the training sample set comprises a plurality of sample dynamic error two-dimensional scatter plots and corresponding defect types thereof; and

the detect type comprises zero defect, thermal aging, inflowing and damp, overbending and insulation scratch.

2. A computer apparatus, comprising a memory, a processor and a computer program that is stored in the memory and capable of running on the processor, wherein while the processor executes the computer program, the steps for the power cable status detection method based on current signal distortion graphization according to claim 1 is implemented.

REVENDICATIONS

1. Procédé de détection d'un état d'un câble électrique basé sur la dessination de distorsion d'un signal de courant, caractérisé en ce que le procédé de détection d'un état d'un câble électrique basé sur la dessination de distorsion d'un signal de courant comprend :

acquérir un signal de courant d'un câble électrique à détecter et obtenir des données de forme d'onde d'un courant à détecter ;

le signal de courant du câble électrique à détecter est un signal de courant de mise à la terre ;

effectuer un débruitage à seuil d'ondelettes sur les données de forme d'onde du courant à détecter ;

déterminer, en fonction des données de forme d'onde d'un coutant à l'état normal et des données de forme d'onde du coutant à détecter, un nuage à points bidimensionnels d'erreur dynamique à l'aide d'un système de synchronisation chaotique Lorentz ; le système de synchronisation chaotique Lorentz comprenant un système maître et un système esclave ; saisir les données de forme d'onde du courant à l'état normal dans le système principal, et saisir les données de forme d'onde du courant à détecter dans le système esclave, calculer des déviations dynamiques sur les données de forme d'onde du courant à l'état normal et les données de forme d'onde du courant à détecter et obtenir une première séquence d'erreur dynamique et une deuxième séquence d'erreur dynamique ; et dessiner un nuage à points bidimensionnels d'erreur dynamique en prenant la première séquence d'erreur dynamique comme abscisse et la deuxième séquence d'erreur dynamique comme ordonnée ;

identifier des défauts dans le nuage à points bidimensionnels d'erreur dynamique à l'aide d'un modèle d'identification de défauts, afin d'identifier un type de défaut du câble électrique à détecter ; le modèle d'identification de défauts étant obtenu en entraînant à l'avance un réseau de détection cible à l'aide d'un ensemble d'échantillons d'entraînement, le réseau de détection cible étant YOLOv5, et l'ensemble d'échantillons d'entraînement comprenant une pluralité de nuages à points bidimensionnels d'erreur dynamique d'échantillon et des types de défaut correspondants ;

les types de défaut comprenant l'absence de défauts, le vieillissement thermique, l'humidité due à la pénétration d'eau, la flexion excessive et les rayures d'isolateur.

2. Dispositif informatique, comprenant : une mémoire, un processeur et un programme informatique stocké sur le processeur et exécutable sur le processeur, caractérisé en ce que le processeur exécute le programme informatique pour mettre en œuvre les étapes du procédé de détection d'un état d'un câble électrique basé sur la dessination de distorsion d'un signal de courant selon la revendication 1.

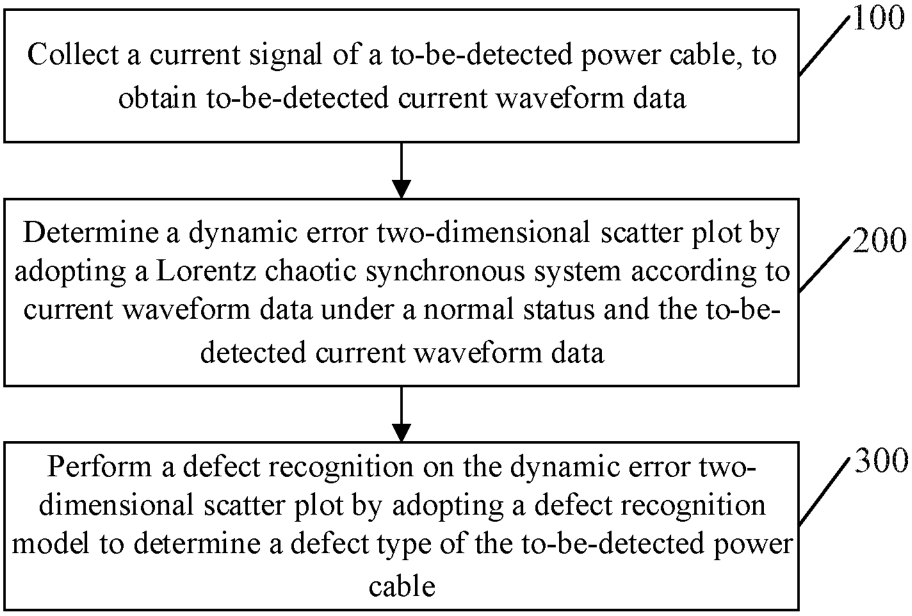
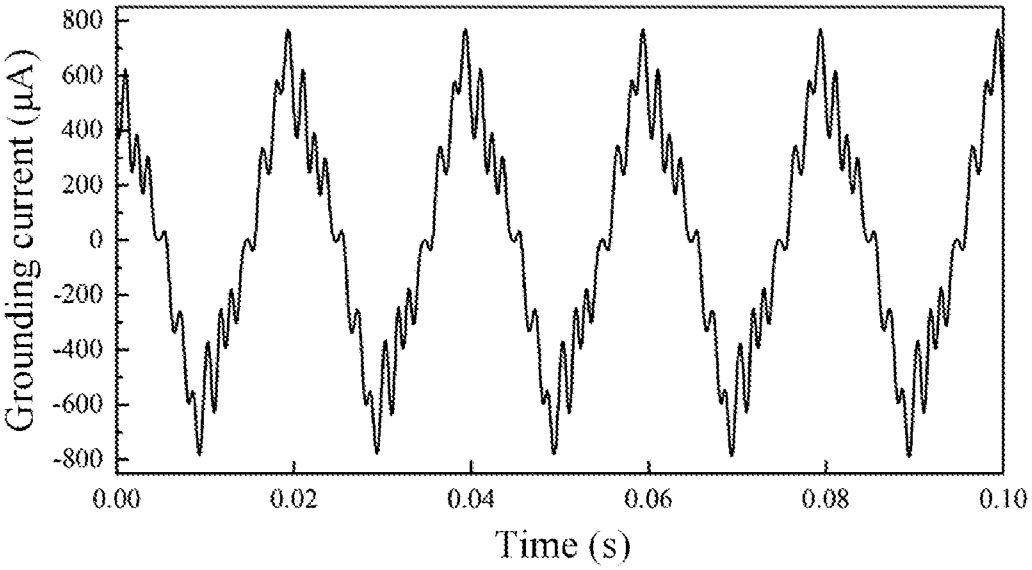

Collect a current signal of a to-be-detected power cable, to obtain to-be-detected current waveform data
100
Determine a dynamic error two-dimensional scatter plot by adopting a Lorentz chaotic synchronous system according to current waveform data under a normal status and the to-be-detected current waveform data
200
Perform a defect recognition on the dynamic error two-dimensional scatter plot by adopting a defect recognition model to determine a defect type of the to-be-detected power cable
300

FIG. 1


Grounding current (μA)
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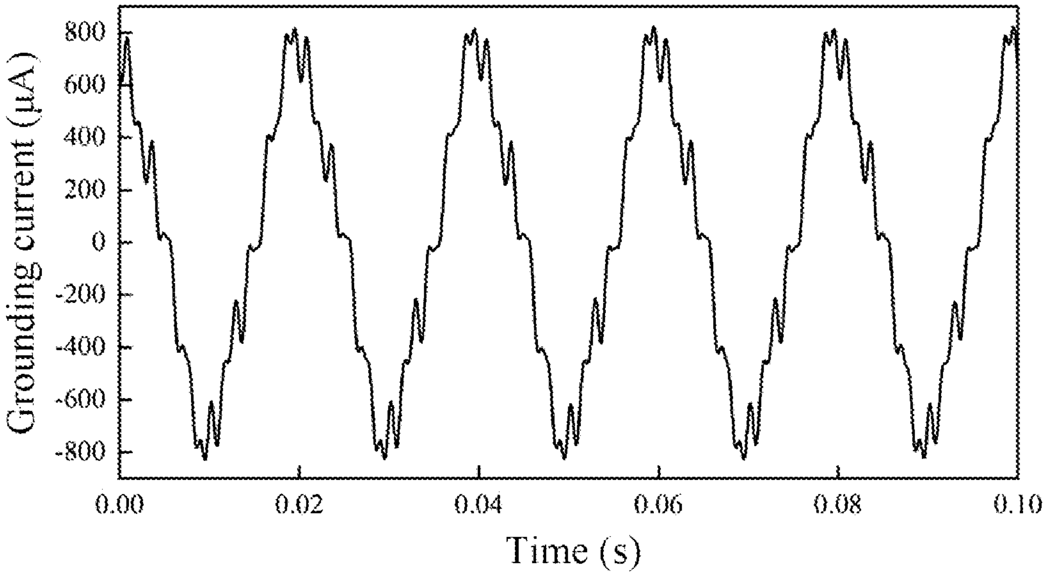
0.06
0.08
0.10
Time (s)

FIG. 2


Grounding current (μA)
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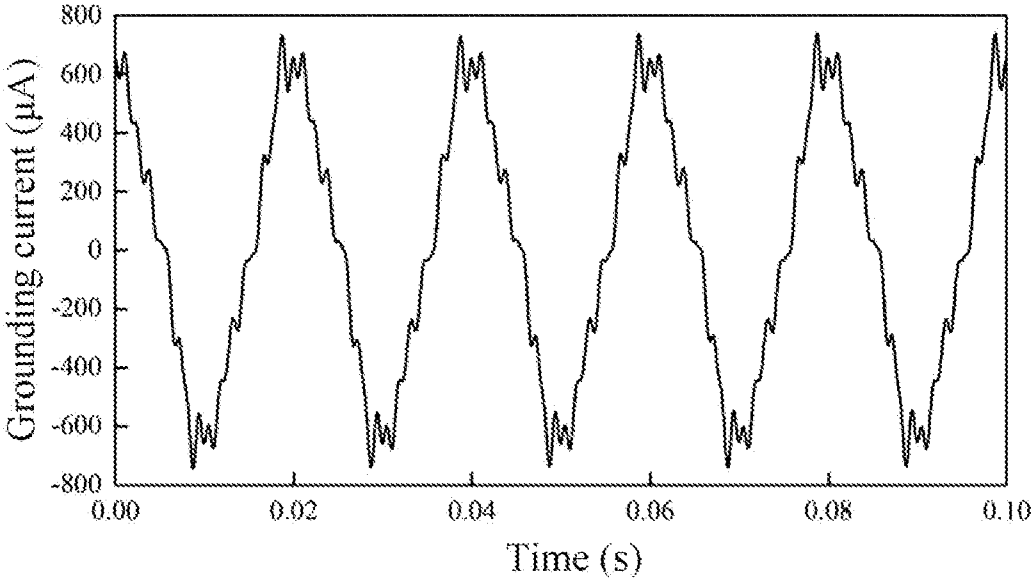
-600
-800
0.00
0.02
0.04
0.06
0.08
0.10
Time (s)

FIG. 3


Grounding current (μA)
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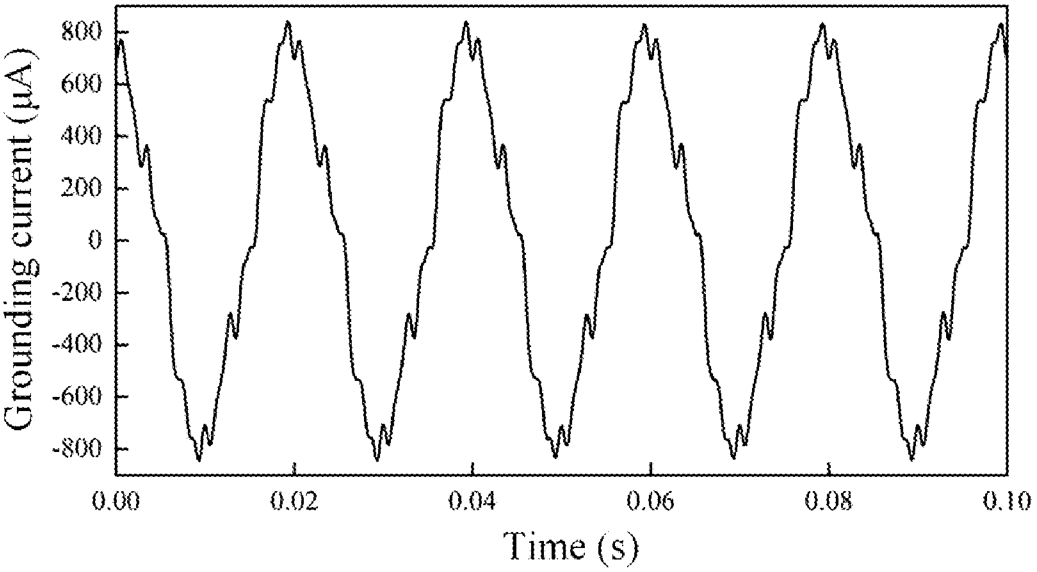
0.10
Time (s)

FIG. 4


Grounding current (μA)
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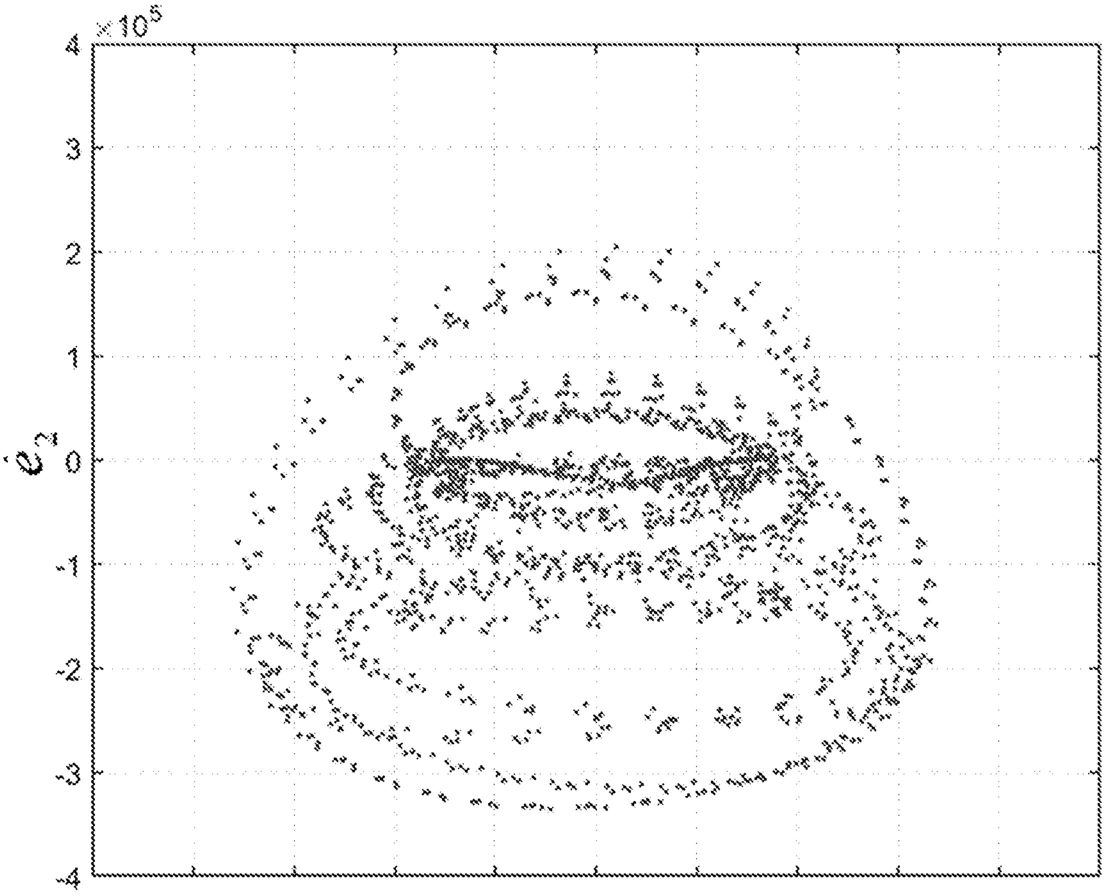
-600
-800
0.00
0.02
0.04
0.06
0.08
0.10
Time (s)

FIG. 5


×10^5
4
3
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-1
-2
-3
-4
$\dot{e}_2$
-500
-400
-300
-200
-100
0
100
200
300
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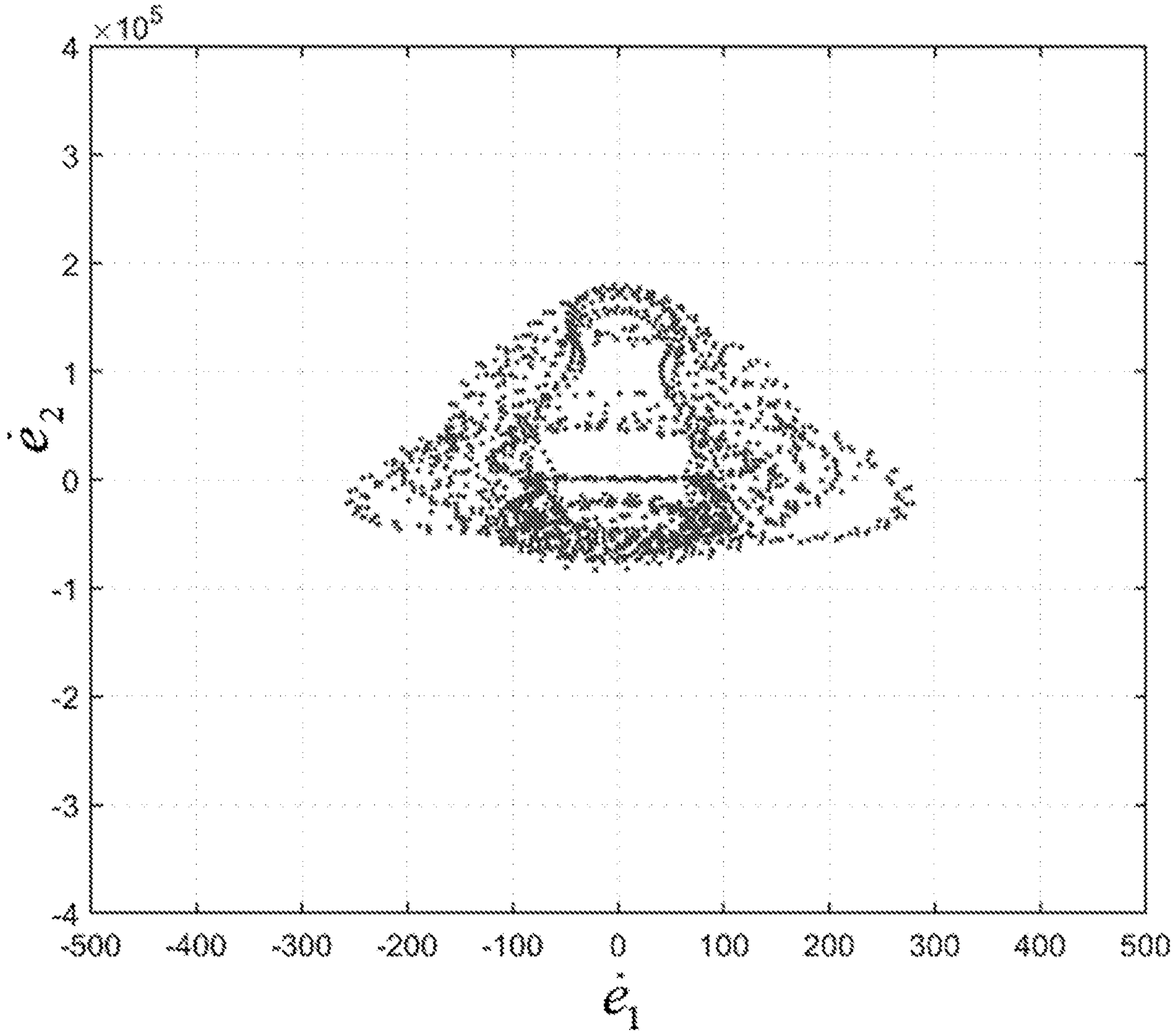
500
$\dot{e}_1$

FIG. 6


×10^5
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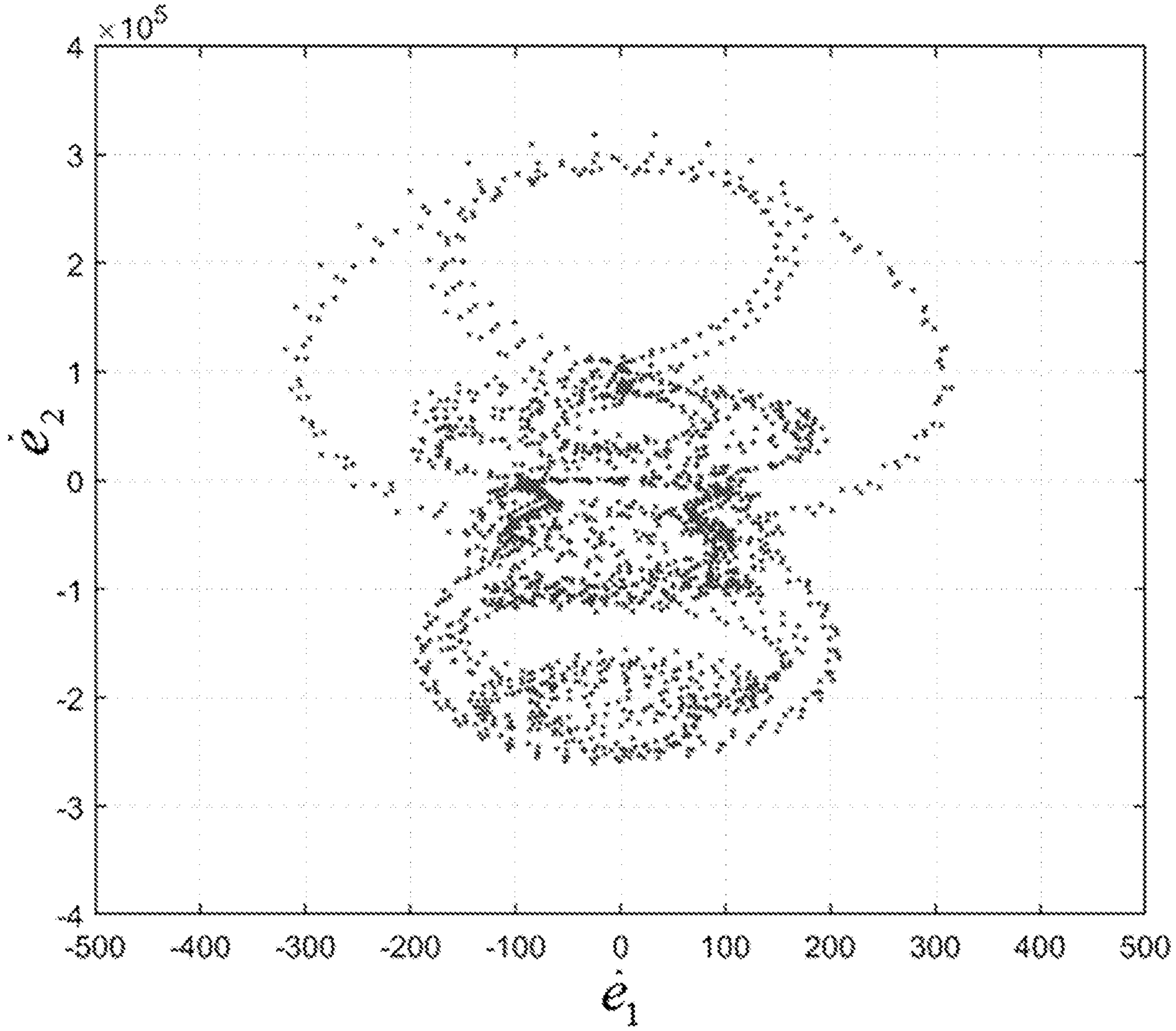
$\dot{e}_1$

FIG. 7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400
500
$\dot{e}_1$

FIG. 8

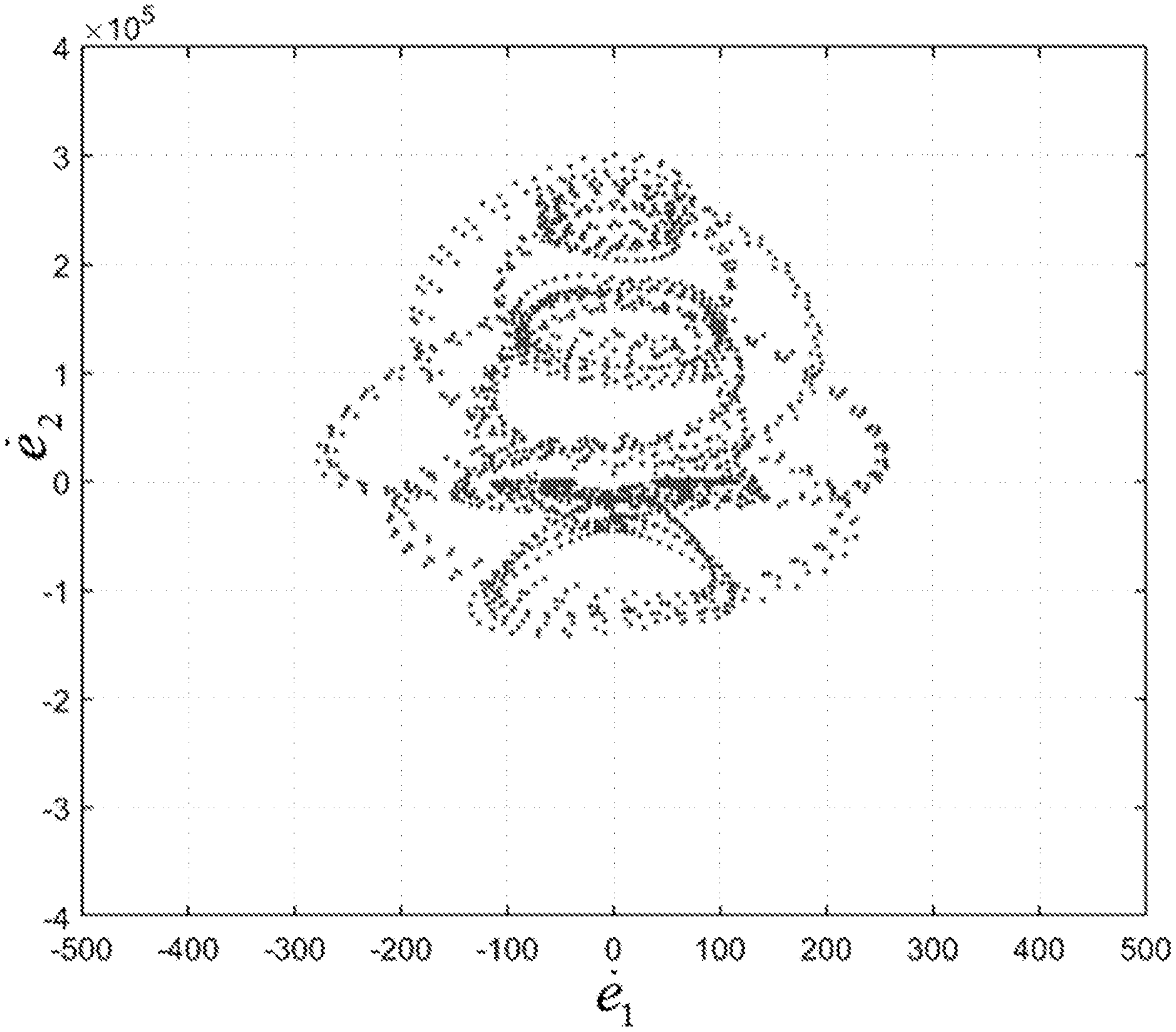
$\times 10^5$
4
3
2
1
0
-1
-2
-3
-4
-500
-400
-300
-200
-100
0
100
200
300
400
500
$\dot{e}_2$
$\dot{e}_1$

FIG. 9

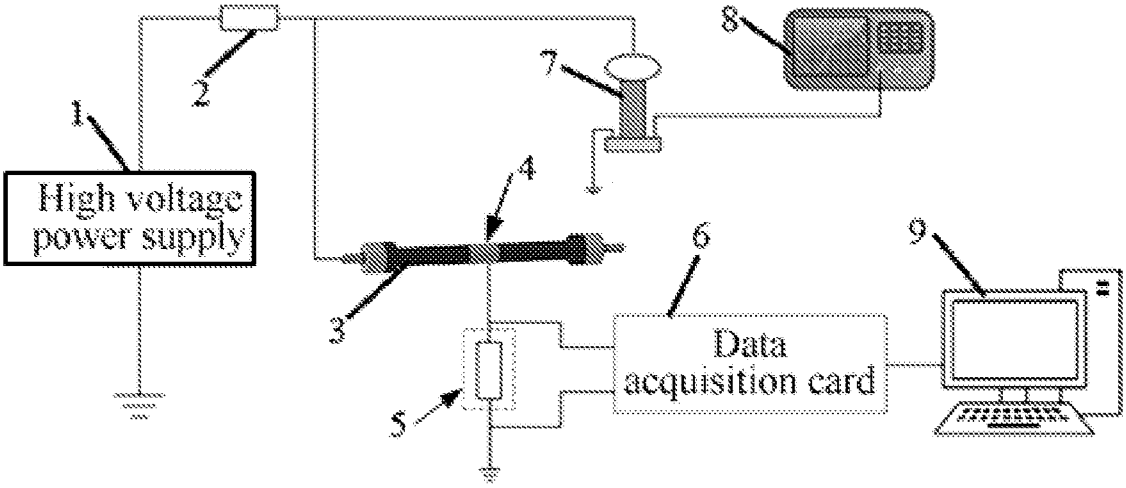
1
2
3
4
5
6
7
8
9
High voltage power supply
Data acquisition card

FIG. 10

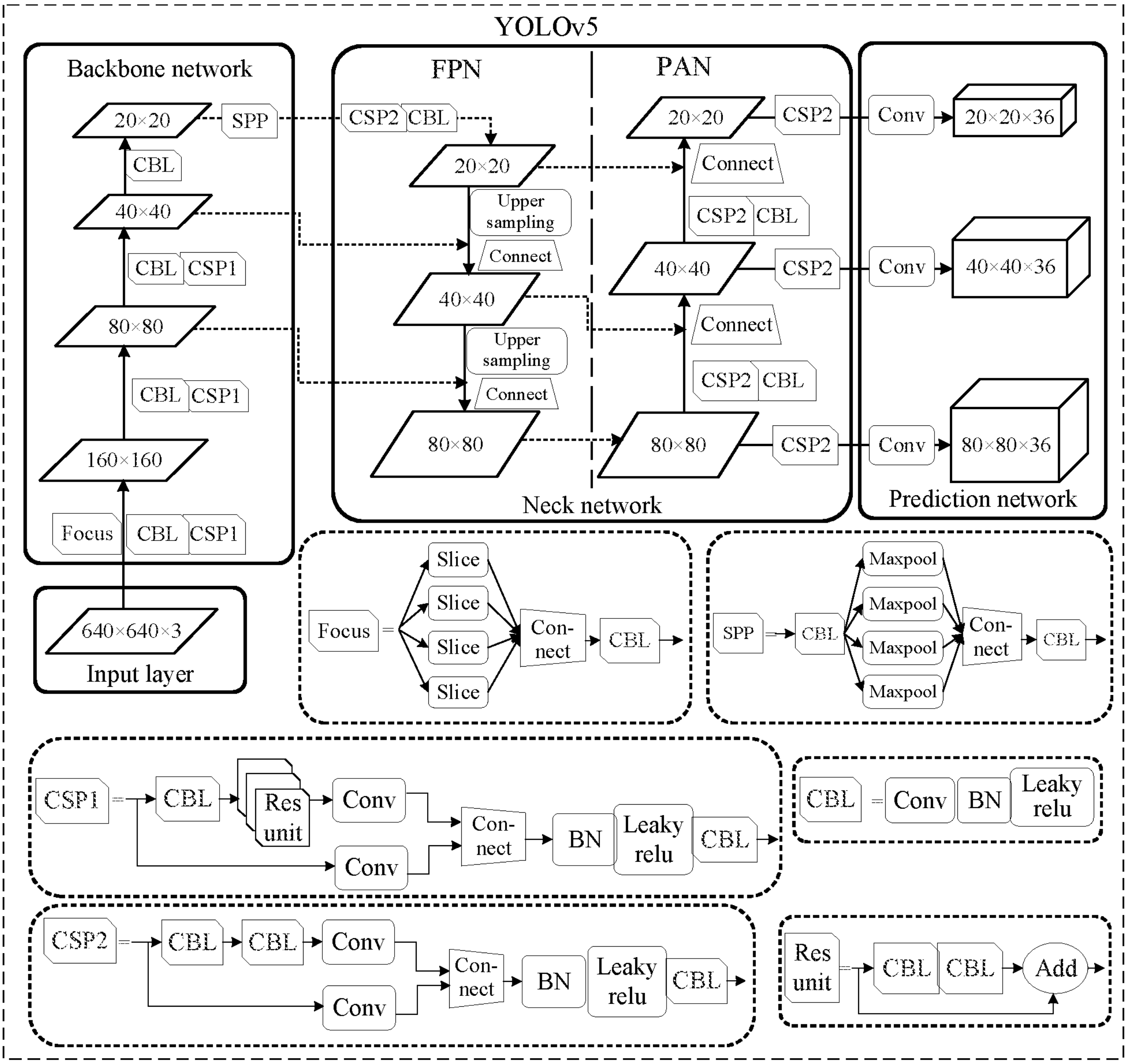
YOLOv5
Backbone network
20×20
SPP
CBL
40×40
CBL CSP1
80×80
CBL CSP1
160×160
Focus
CBL CSP1
640×640×3
Input layer
FPN
CSP2 CBL
20×20
Upper sampling
Connect
40×40
Upper sampling
Connect
80×80
PAN
20×20
CSP2
Connect
CSP2 CBL
40×40
CSP2
Connect
CSP2 CBL
80×80
CSP2
Neck network
Conv
20×20×36
Conv
40×40×36
Conv
80×80×36
Prediction network
Focus =
Slice
Slice
Slice
Slice
Con-nect
CBL
SPP =
CBL
Maxpool
Maxpool
Maxpool
Maxpool
Con-nect
CBL
CSP1 =
CBL
Res unit
Conv
Conv
Con-nect
BN
Leaky relu
CBL
CBL = Conv BN Leaky relu
CSP2 =
CBL
CBL
Conv
Conv
Con-nect
BN
Leaky relu
CBL
Res unit =
CBL CBL
Add

FIG. 11