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Power Quality Detection of the Micro Grid based on Ensemble Neural Network Model

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Abstract: Micro grid's power quality is affected by many factors, Detection micro grid power quality accurately can help us to archive network environment improving and optimizing and effective management. In order not to miss the key information of the quality of the micro grid power, it is necessary to carry out more detailed from wave-based decomposition and calculation of the power signal to obtain more dimension information to fully describe it. At the same time, it is difficult to completely cover all the possible situations by the simulation or sampling from the micro grid. There is certain degree of deviation between simulation samples and real micro grid environment. The higher dimension and the deviation of the sample can easily lead to the over-fit of algorithm, thus in the actual operation process pattern recognition algorithms' ability will reduce. A Power Quality Detection of the Micro Grid based on Ensemble Neural Network Model (PQ-EMLP) is proposed in this paper, Through the integration of sub-model the input dimension of each sub model and generalization ability are improved. The experiment results show that PQ-EMLP has better detection ability than traditional method.

Keywords: Micro Grid, Power Quality, Neural Network, HTT, Ensemble Model.

1. Introduction

With the progress of social economy, people's requirements for energy production and use are higher and higher. Distributed generation and smart grid can more flexibly respond to the changes of power grid load, reduce investment, promote low-carbon environmental protection and energy conservation and emission reduction, which is a hot spot in the development of power technology [1-2]. In 2001, Robert et al. First proposed the concept of microgrid [3]. The emergence of microgrid technology provides new technical support for distributed generation and smart grid. The microgrid constructed by using a variety of small-scale distributed generation and load can weaken the impact and negative impact of distributed generation on the grid, and give full play to the benefits and value of distributed generation [4]. Accurate detection of microgrid power quality is very important for optimizing and improving microgrid environment, and for scientific and effective management.

Compared with the main grid, the microgrid is an intelligent controllable unit relative to the main grid in the system; relative to the users, the microgrid can meet the general or special needs of different types of local loads [5]. In the microgrid, the power quality is affected by many factors. On the one hand, the output power of wind power, photovoltaic power and other power sources has volatility, intermittence and uncertainty [6]. On the other hand, the use of electronic devices of a large number of high energy consuming devices (such as automobile charging devices) will cause harmonic vibration [7]; these will lead to current harmonics, voltage sag, voltage sudden rise, short-term voltage interruption and flicker Transformer and other problems, causing serious power quality problems [8]. Automatic power quality detection needs to go through two stages, the first stage is the power feature extraction stage, common methods include Fourier transform [9-10], wavelet transform [11], htt (Hilbert Huang Transform) [12], S transform [13]; the second stage is the intelligent algorithm pattern recognition stage, the methods used mainly include decision tree, neural network, support vector machine and other methods [14]. In order not to omit the key information of power quality of microgrid, it is necessary to decompose and calculate the power signal more carefully based on wave, so as to obtain more dimension information to fully describe it; at the same time, the samples obtained from simulation or sampling of microgrid are difficult to fully cover all possible situations, so simulation is used to collect samples and store the signal characteristics of microgrid to be detected In the presence of a certain degree of deviation. The samples with higher dimensions and biased samples are easy to cause transition fitting of classification algorithm, thus reducing the decision-making ability of pattern recognition algorithm in the actual operation process. Therefore, it is necessary to improve the existing methods to solve the problems of high dimension and bias, so as to improve the accuracy of power quality detection of microgrid.

This paper presents a power quality detection of the micro grid based on ensemble MLP model, Pq-em), on the basis of HHT transformation of power data, an integrated neural network classifier based pattern recognition method for power quality problems is introduced. By dividing the attribute set into several groups of independent subsets, the neural network model is trained respectively to improve the dimensionality reduction and generalization ability of the input data. Experimental results show that, compared with the traditional algorithm, the proposed method has a great improvement in power quality detection accuracy.

2. A Power Quality Detection Method for Microgrid Based on Integrated Neural Network Classifier

Aiming at the problems in the existing research, this paper proposes an integrated neural network classifier based power quality detection method for microgrid

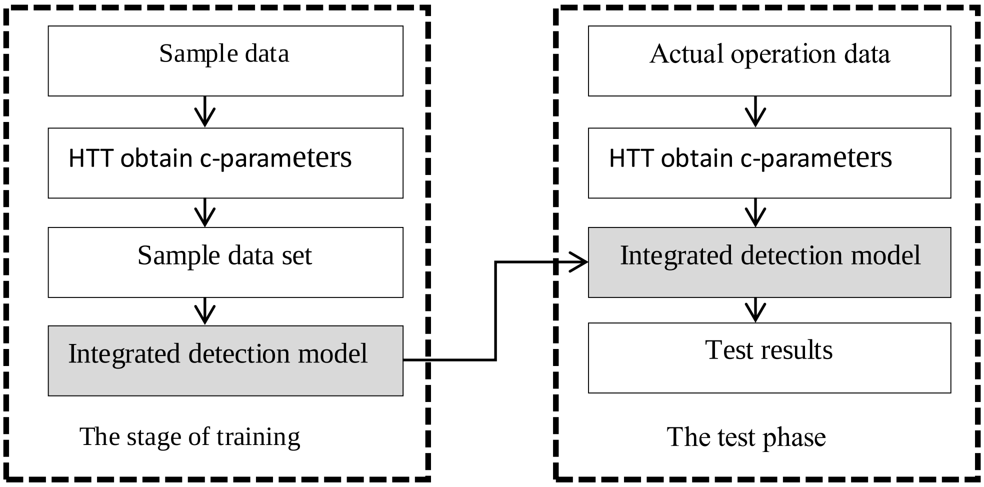

Fig. 1. Overall framework of the algorithm

As shown in the figure, the whole algorithm is divided into two stages: in the training stage, firstly, the microgrid samples are obtained for htt (Hilbert Huang) Transform) method is used to analyze and decompose to obtain the characteristic parameter values, and then the attribute set is divided to train the neural network classifier to obtain the integrated detection model, which can analyze and make decisions on the data in the microgrid; in the detection stage, several layers of detection models are directly used to make decisions on the actual operation data of the microgrid, and the detection results are obtained.

2.1 HTT Method

The basic idea of HTT is to use IMF solid Function (IMF) superposition to achieve a variety of signals expression, based on this idea proposed END (Empirical Mode Decomposition, END) can decompose a signal into a number of IMF signals and a residual component, can get the original signal data on the different time scales of local characteristic signals. The basic process of the END of a segment of signal x(t) is to first determine all local minima and local maxima of x(t), and then calculate the mean values of the upper envelope v1(t) and the lower envelope v2(t) :

$$m_i(t) = \frac{v_1(t) + v_2(t)}{2} \tag{1}$$

The original signal x (T) is subtracted by mt to obtain a new data sequence without low frequency data:

$$\theta_i(t) = x(t) - m_i(t) \tag{2}$$

In the formula, i=1…n represents the result of the i-th iteration. If the result meets the requirements of IMF, the decomposition shall be stopped. Otherwise, formula (1) and (2) shall be repeated until the requirements are met. The i imf component is separated from X (T)

$$r_i(t) = x(t) - I_i(t) \tag{3}$$

If the value is monotonous or less than a certain value, stop the END decomposition process, otherwise repeat the above values, and finally get I1(t), I2(t),…, In(t) is the IMF component after decomposition. After the signal is decomposed by EMD, Hilbert transformation is required for IMF components of each order:

$$H[I_k(t)] = \frac{1}{\pi} \int_{-\infty}^{+\infty} \frac{I_k(\tau)}{t - \tau} d\tau \tag{4}$$

The original analytic signal X (t) can be obtained by Hilbert transform:

$$x_k(t) = I_k(t) + jH[I_k(t)] \tag{5}$$

Based on the analytical signal, the amplitude and instantaneous phase can be obtained

$$a_k(t) = \sqrt{I_k^2(t) + H^2[I_k(t)]} \tag{6}$$

$$\theta_k(t) = \arctan\left(\frac{H[I_k(t)]}{I_k(t)}\right) \tag{7}$$

The corresponding instantaneous frequency is as follows:

$$f_i = \frac{1}{2\pi} \frac{d(\theta_k(t))}{dt} \tag{8}$$

2.2 Multilayer Neural Network

In this paper, MLP (multi layer perception) is used as the algorithm model of pattern recognition. The output of each layer is used as the input of the next layer. The structure of a three-layer neural network.

As shown in the figure, the neural network consists of three layers: the first layer is input layer, the second layer is hidden layer and one output layer. For each layer, the calculation is as follows

$$a^{(l+1)} = f(w^l a^l + b^l) \tag{9}$$

In the formula, f is the transfer function, l corresponds to the number of layers, the superscript of the formula represents the corresponding number of layers. For the first layer, wl is the weight, bl is the offset, and a(l+1) is the output obtained after transmission calculation. The transfer function can select sigmoid, softmax and relu functions for processing. For an input vector, the output h of the neural network can be obtained by calculating formula 9 for three rounds. For a set of samples x and its corresponding class target sign x, MLP can learn and obtain w and b, the objective function to measure the learning effect is as follows:

$$J(W,b;x,y)=\frac{1}{2}\left\|h_{w,b}(x)-y\right\|^{2} \quad (10)$$

Through continuous iteration, the gradient descent method is used to adjust W and b to make j reach the minimum value, and finally the classification model based on neural network is obtained.

2.3 Construction Mode of Integrated Detection Model

In this paper, an integrated detection model for microgrid power quality is proposed. The goal is to divide the multi-dimensional sample set s of microgrid power into several subsets according to the correlation degree of attributes, and each subset can accommodate more unrelated attributes as much as possible. The integrated detection model is composed of multiple MLPs trained by multiple subsets, and its structure is shown in the following figure

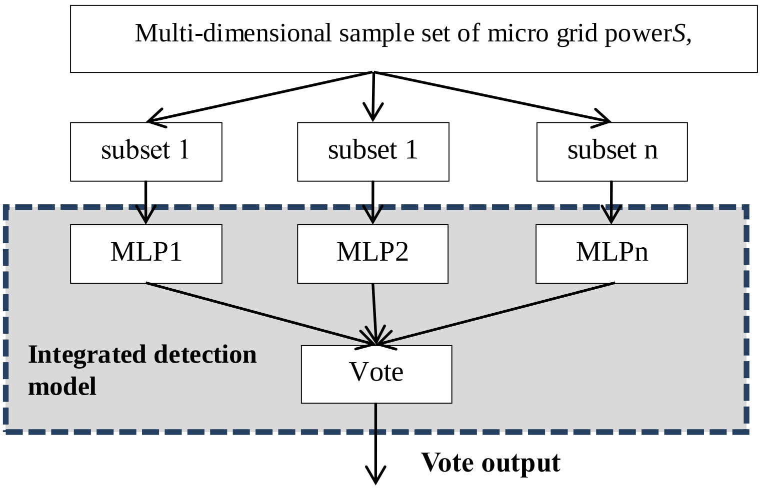

Fig 2. Structure of the integrated classifier

The algorithm of integrated classifier construction process is as follows:
ConstructEnsemble-Alg by integrating neural network classifier
Input: microgrid power multi-dimensional sample set S, group number m
Output: ensemble neural network model Ensemble Model
Begin

    EnsembleModel=Φ;
    FeathersSet=S All attributes

```
        num= FeathersSet .Count/m;
        for i=1..m {
                subset= FeathersSet[1];
                FeathersSet= FeathersSet- FeathersSet[1];
                while  sebset<num {
                        m= FeathersSet  Look for the attribute with the lowest degree related to Subset
                        FeathersSet=FeathersSet-m;
                        subset= subset∪m }
                subsample= Take out the Subset of S subset
                EnsembleModel= EnsembleModel∪ Train a neural network model using subsample
        }
End
```

MLP models with lower attribute dimensions can be integrated by ConstructEnsemble-Alg, and in power quality inspection, multiple model functions make decisions and vote on the results. On the one hand, the model reduces the dimension of a single MLP and prevents the transitional fitting phenomenon in the case of insufficient samples. On the other hand, due to the use of different groups of HHT results among MLPS, the way to measure the target in terms of frequency and amplitude is also different, which prevents the deviation of a single MLP for decision making and makes the result more stable.

3. Experiment and simulation

In this paper, all algorithms are implemented by MATLAB 2012b. In order to test the detection accuracy of pq-em, training sample set and test sample set are introduced respectively

Training sample set: the simulation generates 8 kinds of power quality problems signals including integral harmonic, inter harmonic, composite harmonic, voltage fluctuation and flicker, voltage sag, voltage sag, voltage sag, voltage interruption and transient oscillation. The signal-to-noise ratio (SNR) is 50, 40, 30 and 20dB, and 1000 waveform samples are randomly generated for each type, with a total of 8000 samples.

Actual test data: collect the actual operation data of microgrid including wind power and photovoltaic power generation. Each type of quality inspection data contains 100 samples, a total of 800 samples.

The method proposed in this paper is compared with single MLP, SVM and cart tree. Each model is trained by training sample set to obtain the detection model and detect the test data. The comparison of classification accuracy is as follows:

Table 1 Accuracy comparison of the four methods

Detection type	Classification accuracy（%）			
	PQ-EM	MLP	SVM	CART
Subharmonic	95	86	87	84
Harmonics	97	83	84	84
Compound harmonic	93	85	88	83
Voltage fluctuation and flicker	94	90	87	86
Voltage sag	96	92	94	90
voltage rise	97	96	97	93
Voltage interruption	100	100	100	100
Transient shock	98	90	92	90
Mean value	96.25	90.25	91.125	88.75

It can be seen from table 1 that the simulation data can not cover all the possible situations, which requires the model to have a high generalization ability to accurately detect the power quality problems of microgrid. Among the four methods, cart tree achieves the lowest classification accuracy, and the average detection accuracy is only 88.75%; SVM and MLP obtain higher classification accuracy than cart tree because of using spatial hyperplane to segment samples. SVM has higher generalization ability in other types of pattern recognition experiments. However, due to more dimensions in this experiment, simulation samples and actual samples have deviation So it has no obvious advantage over MLP. The proposed method achieves the highest detection accuracy of 96.25%, which shows that pq-emlp has higher generalization ability than other models, and can detect power grid quality more accurately in the process of actual data testing.

4. Conclusion

In the process of power quality detection of micro grid, the existing samples and samples collected by simulation are difficult to cover all the situations, which requires the pattern recognition algorithm to have high generalization ability. In this paper, a Power Quality Detection of the Micro Grid Based Ensemble MLP Classifier ((Power Quality Detection of the Micro Grid based Ensemble MLP Classifier, PQ-EMLP) is proposed. Based on the HHT transform of the Power data, the original attribute set is divided into several attribute subsets, and then each subset is utilized to train each neural network. Each neural network model is integrated to form an integrated neural network classifier. On the one hand, the model can reduce the dimension of input data; on the other hand, it can obtain higher generalization ability through the joint decision of multiple sub-classification models. Compared with MLP, SVM and CART tree, PQ-

EMLP has better detection capability than traditional methods.

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