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Fault Diagnosis of Electronic Circuits Based on Matlab

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Abstract: The purpose of this paper is to develop an intelligent diagnosis method for three-phase inverters of electronic circuits, and select three-phase full-bridge inverters with wide application. Firstly, the working principle of the inverter is introduced, and the fault type of the inverter is analyzed. Secondly, we establish the model of the inverter in Matlab / Simulink environment and simulate the fault of the inverter, and then collect the corresponding fault data. Finally, BP neural network was trained by using the collected fault data, and then it was used to diagnose the fault. The BP neural network was proved to be effective for the prediction of the results.
Key words: inverter; BP neural network; fault diagnosis;

I. INTRODUCTION

With the rapid development of science and technology, power electronics technology has played an important role in China's national economy and it has been gradually integrated into all aspects of people's lives. However, there are some problems in power electronic equipment, which brings some trouble to our daily life. So, it is very necessary to predict the fault of electronic circuits. The main purpose of fault diagnosis: 1, predict the failure of electronic circuits to prevent the expansion of the accident; 2, saving manpower, material resources, financial resources; 3, improve the management level of the relevant equipment, to carry out automatic detection;

The current fault diagnosis of power electronics is mainly divided into the following methods: 1, based on the analytical model of the method; the method can be used to evaluate the whole system, but it is based on the accurate model, which is a certain obstacle to the fault diagnosis. 2, based on the signal processing method; spectrum analysis method [1-3] is the signal from the time domain to the frequency domain analysis, interception of the relevant data analysis. Wavelet transform method [4-5] is the most advanced method, although the time is short, but the efficiency is high. Its characteristic is that the signal quality request is low, the reaction is strong, and the computation is simple. 3, the method based on knowledge; this method is summarized in the long-term production experience, fault diagnosis by using gradually developed technology, the main methods include: 1) neural network method [6] 2); pattern recognition; 3)expert system; 4) artificial intelligence methods.

In this paper, by detecting the output voltage when the inverter is faulty, the collected fault data are numbered, and the fault detection is carried out by using BP neural network[7].

II. THEORY

2.1 inverter structure and working principle

Three-phase full-bridge inverter structure shown in Figure 2-1.

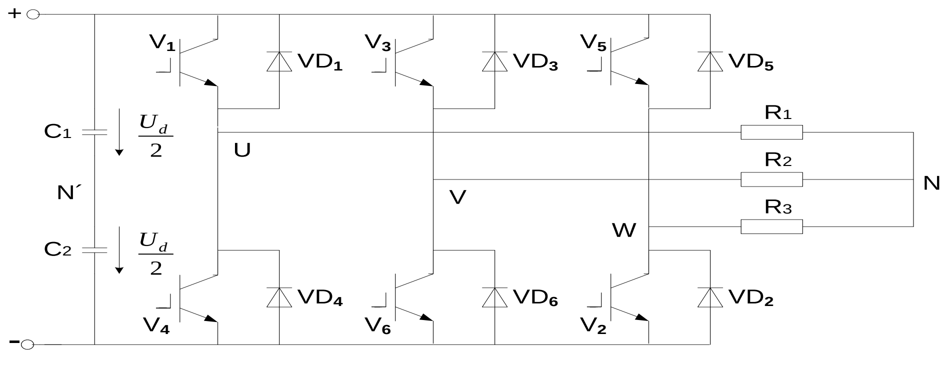


Figure 1-1 Three-phase full-bridge inverter structure

Three-phase full-bridge inverter circuit of the basic work process: 180 ° conduction mode and the upper and lower leg alternately turn on → each phase of each phase difference of 120 ° .

According to the work process can be the following formula, the load line voltage u_{UV} 、u_{VW} 、u_{WU} , then:

$$u_{UV} = u_{UN'} - u_{VN'} \quad (2\text{-}1)$$

$$u_{VW} = u_{VN'} - u_{WN'} \quad (2\text{-}2)$$

$$u_{WU} = u_{WN'} - u_{UN'} \quad (2\text{-}3)$$

The voltage between the midpoint of load N and the midpoint of the design is $u_{NN'}$, then:

$$u_{UN} = u_{UN'} - u_{NN'} \quad (2\text{-}4)$$

$$u_{VN} = u_{VN'} - u_{NN'} \quad (2\text{-}5)$$

$$u_{WN} = u_{WN'} - u_{NN'} \quad (2\text{-}6)$$

Then: $$u_{NN'} = \frac{1}{3}(u_{UN'} + u_{VN'} + u_{WN'}) - \frac{1}{3}(u_{UN} + u_{VN} + u_{WN}) \quad (2\text{-}7)$$

Also $u_{UN} + u_{VN} + u_{WN} = 0$

then: $$u_{NN'} = \frac{1}{3}(u_{UN'} + u_{VN'} + u_{WN'}) \quad (2\text{-}8)$$

2.2 Inverter fault type

Fault type of inverter: short circuit fault and open circuit fault, this paper mainly analyzes the open circuit fault. In accordance with the actual operation, it is assumed that at the same time there are 2 IGBTs (insulated gate bipolar transistor) occurs open circuit, the fault type can be divided into 3 categories:

1: normal operation, 6 IGBTs can be switched on;

2: only one IGBT open circuit fault, a total of 6 (V1, V2, V3, V4, V5, V6);

3: there are two IGBTs open circuit fault, a total of 15 (V1V2, V1V3, V1V4, V1V5, V1V6, V2V3, V2V4, V2V5, V2V6, V3V4, V3V5, V3V6, V4V5, V4V6, V5V6);

III. Software and methods

3.1 Inverter simulation

According to the circuit structure and working principle of the three-phase full-bridge inverter, the model of the inverter is established in Matlab, and the system structure is shown in figure 3-1:

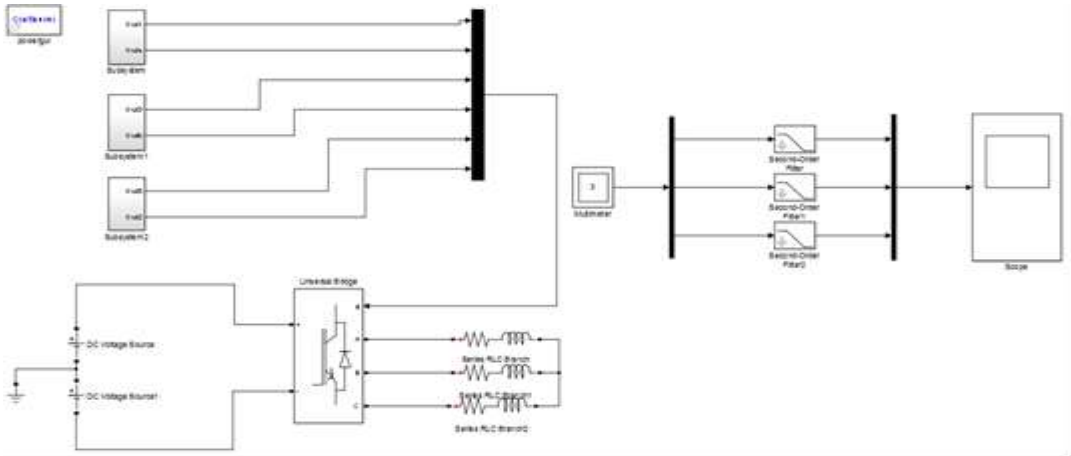


Figure 3-1 Three-phase full-bridge inverter system structure model

Figure 3-1 the trigger pulse module expansion diagram, as shown in figure 3-2.

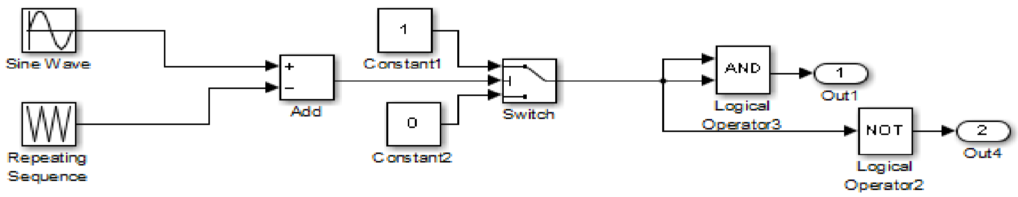


Figure 3-2 pulse signal circuit

3.2 Inverter fault simulation and data acquisition

In this paper, the simulation model has been established to test, by removing the drive signal to achieve IGBT fault.

Set the data: Frequency: 50Hz; Cycle: 0.02s; Simulation time: 0.05s → Simulation begins.

Select part of the output waveform shown in Figure 3-3, Figure 3-4:

① Normal output waveform

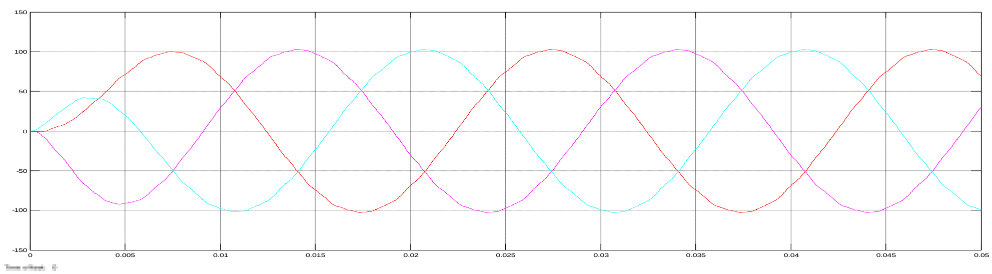


Figure 3-3 Output waveform of the inverter under normal condition

② One of the power tubes of the upper leg has failed.

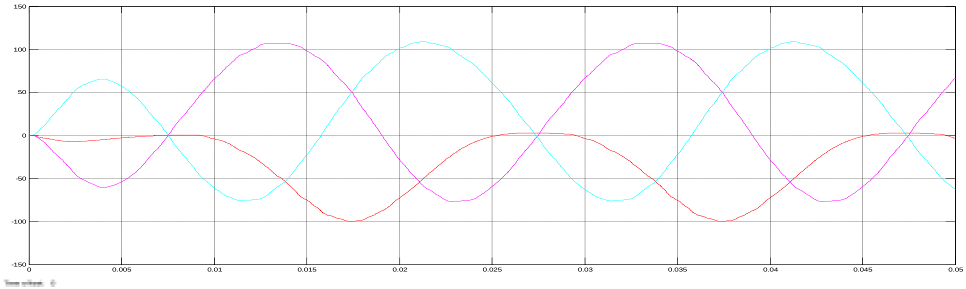
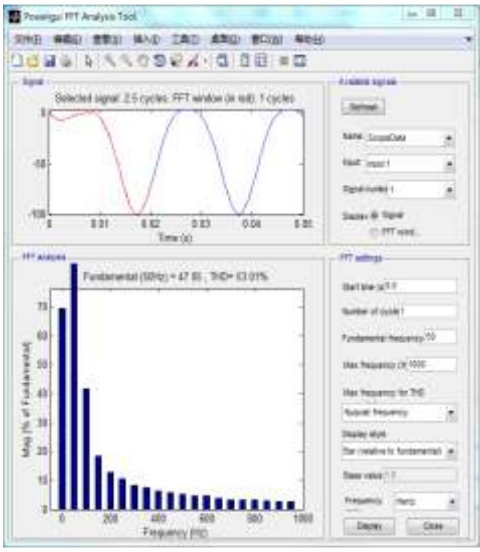


Figure 3-4 Output waveform of the inverter under V1 fault condition

Because the time domain signal is more complex, we can use the Fourier transform to transform it into frequency domain. In the experiment, we set the frequency to 50Hz, through the Powergui module of Matlab to analyze the voltage waveform, get the characteristic parameters of the occurrence of the fault waveform. Taking V1 as an example, its column analysis diagram and waveform list diagram are shown in Figure 3-5 and figure 3-6:



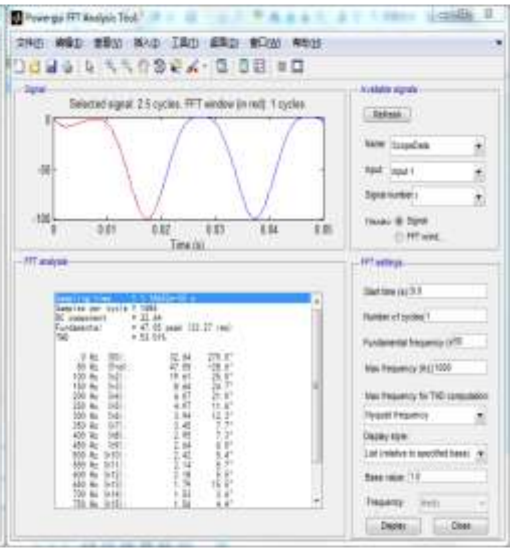


Figure 3-5 Histogram in V1 Fault State　　Figure 3-6 List of V1 Fault Conditions

As can be seen in the above figure, the DC component and the fundamental amplitude of the two basic components can basically represent the waveform characteristics. In order to be more accurate, we choose the DC component of the voltage D, the fundamental amplitude A, the fundamental phase angle ϕ_1, and the second harmonic phase angle ϕ_2 as the characteristic parameters, we can get the characteristic parameters of each fault state, as shown in Table 3-1.

Table 3-1 Fault waveform eigenvalue table

Serial number	Fault management	enter				Output encoding					
		D	A	ϕ_1	ϕ_2						
1	none	4.78	96.34	-36.6	45	0	0	0	0	0	0
2	V1	31.33	46.04	-27.9	26	0	0	1	0	0	1

3	V2	15.3	90.07	-21.9	39.8	0	0	1	0	1	0
4	V3	25.13	87.77	-50.9	17	0	0	1	0	1	1
5	V4	38.33	50.9	-46.1	178.7	0	0	1	1	0	0
6	V5	17.21	91.08	-31.3	83	0	0	1	1	0	1
7	V6	10.09	88.57	-43	54.7	0	0	1	1	1	1
8	V1V2	38.34	54.71	-23.3	39.7	0	1	0	0	0	0
9	V1V3	19.01	29.33	-48.7	-2.8	0	1	0	0	0	1
10	V1V4	0.02	0.01	-36.8	50.11	0	1	0	0	1	0
11	V1V5	21.34	35.43	-15.1	48.9	0	1	0	0	1	1
12	V1V6	34.78	50.31	-31.4	17.8	0	1	0	1	0	0
13	V2V3	4.94	63.24	-37	-54.7	0	1	0	1	0	1
14	V2V4	23.07	37.64	-27.5	197	0	1	0	1	1	0
15	V2V5	1.78	81.19	-16	134.5	0	1	0	1	1	1
16	V2V6	44	56.12	-25	32.7	1	1	0	0	0	0
17	V3V4	45.49	57.5	-53.3	143.2	1	1	0	0	0	1
18	V3V5	46.75	65.2	-46.6	179.1	1	1	0	0	1	0
19	V3V6	8.43	75.21	-67.9	35.4	1	1	0	0	1	1
20	V4V5	41.86	56.63	-37.3	266.5	1	1	0	1	0	0
21	V4V6	24.26	37.54	-65.6	133.9	1	1	0	1	0	1
22	V5V6	0.93	66.43	-41.87	85.3	1	1	0	1	1	0

IV. ANALYSIS

4.1 BP neural network structure and working principle [8]

In a basic artificial neural network model, the network output can be expressed as:

$$a = f(\mathrm{wp} + \mathrm{b}) \qquad (4\text{-}1)$$

a as the network output, f as the input-output relationship for the transfer function, w as the weight, p as input, b as the threshold.

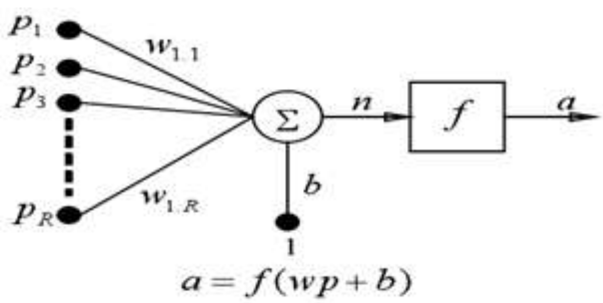


Figure 4-1 Artificial neural network model

In the BP neural network, the output of each neuron in the first layer is sent to the neurons in the second layer ... and so on until the output of the network. Its structure is shown in Figure 4-2:

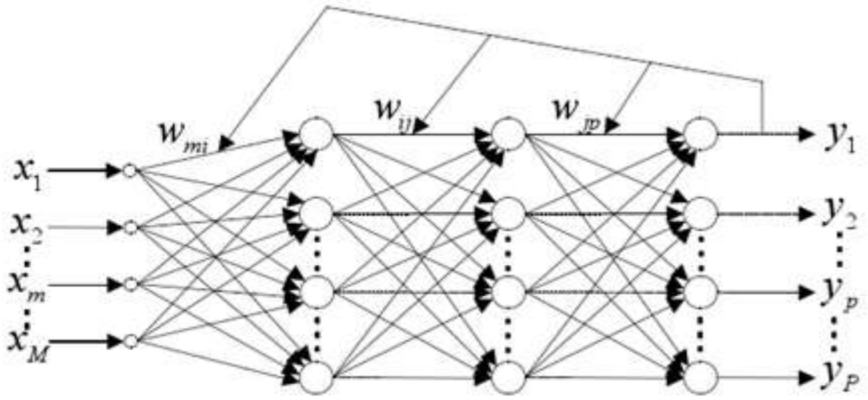


Figure 4-2 BP network structure

4.2 Based on BP neural network fault algorithm

The normalization of the eigenvalue is to speed up the learning speed of the network. In this paper, the normalization of the linear function is used to deal with the data:

$$y = (\mathrm{x} - \mathrm{MinValue}) / (\mathrm{MaxValue} - \mathrm{MinValue}) \qquad (4\text{-}2)$$

After the normalization of the fault data, this paper uses Simulink to predict, the result and the expected output as shown in table 4-1：

Table 4-1 Comparison between actual output and expected output

number	Fault management	Expected output	Actual output					
1	None	000000	0.0000	0.0000	0.0003	0.0000	0.0143	0.0000
2	V1	001001	0.0000	0.0000	1.0000	0.0000	0.2126	0.9992
3	V2	001010	0.0033	0.2022	0.9999	0.0000	0.9956	0.0000
4	V3	001011	0.0000	0.0008	0.9985	0.0000	1.0000	0.9999
5	V4	001100	0.0314	0.0000	1.0000	1.0000	0.0000	0.0000
6	V5	001101	0.1858	0.0000	1.0000	1.0000	0.0000	1.0000
7	V6	001111	0.0005	0.0000	1.0000	0.9997	1.0000	1.0000
8	V1V2	010000	0.0000	0.9321	0.0000	0.0000	0.0545	0.0026
9	V1V3	010001	0.3625	1.0000	0.0000	0.0000	0.0000	1.0000
10	V1V4	010010	0.0000	1.0000	0.0000	0.0000	0.7346	0.0000
11	V1V5	010011	0.0000	1.0000	1.0000	0.0000	0.0159	1.0000
12	V1V6	010100	0.0000	1.0000	0.0000	1.0000	0.0000	0.3625
13	V2V3	010101	0.0000	0.9995	0.0000	1.0000	0.0000	1.0000
14	V2V4	010110	0.0000	1.0000	0.0000	1.0000	1.0000	0.0000
15	V2V5	010111	0.0000	1.0000	0.0000	1.0000	1.0000	1.0000
16	V2V6	110000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000
17	V3V4	110001	1.0000	1.0000	0.0000	0.0000	0.2459	0.8795
18	V3V5	110010	0.7414	0.8420	0.1440	0.4271	0.9540	0.2409
19	V3V6	110011	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000
20	V4V5	110100	1.0000	1.0000	0.0000	1.0000	0.0000	0.0000

21	V4V6	110101	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000
22	V5V6	110110	0.9999	1.0000	0.0000	1.0000	1.0000	0.0122

In the actual output shown in the table, the actual output of the numerical limit of 0.5, The actual output is denoted by $X_i(i=1\sim 6)$, when $X_i > 0.5, X_i = 1$; when $X_i < 0.5, X_i = 0$. It can be seen that the actual value is almost identical with the expected value, and the accuracy of fault diagnosis using BP neural network trained by us is quite high. Figure 4-3 shows the BP neural network to predict the operation of the schematic, the output of its prediction results displayed in the MATLAB command window. From the graph, we can clearly see that the input node of the BP network is 4, the hidden layer node is 25, and the output node is 6.

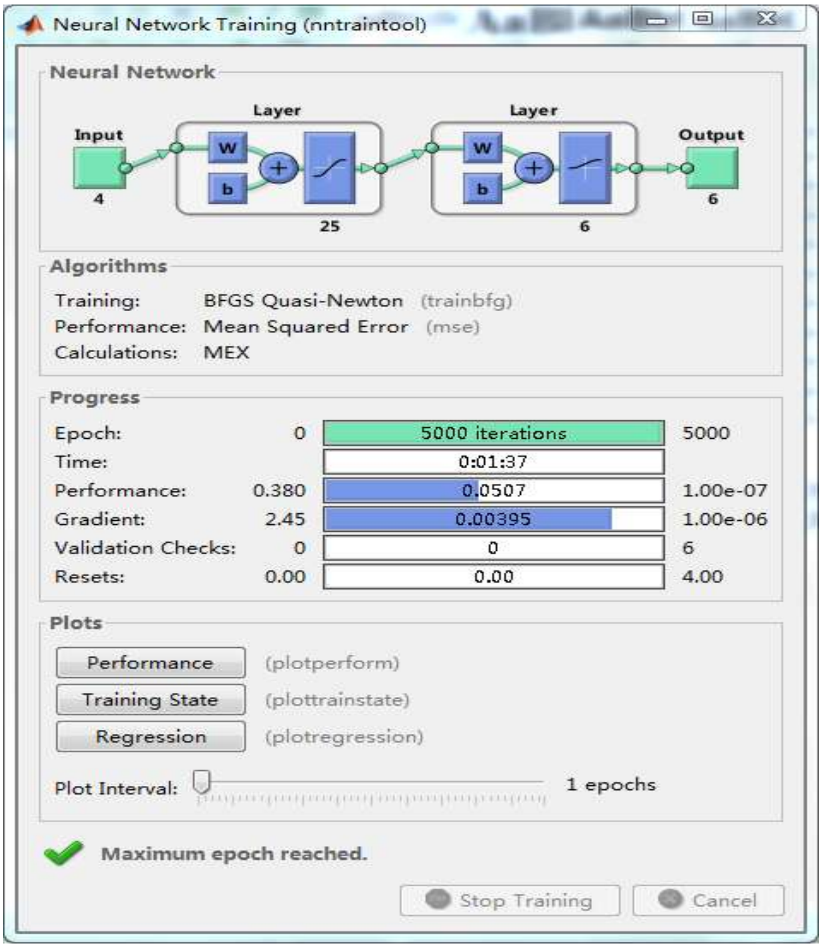


Figure 4-3 BP neural network operation diagram

V. CONCLUSION

The intelligent fault diagnosis of three-phase full bridge inverter is made in this paper. Firstly, the structure of the inverter is simulated by using Matlab simulation software, and the working principle of the inverter is analyzed; Secondly, we establish the model of the inverter in Matlab / Simulink environment and simulate the fault of the inverter, and then collect the corresponding fault data. Finally, BP neural network was trained by using the collected fault data, and then it was used to diagnose the fault. The BP neural network was proved to be effective for the prediction of the results. So it is feasible to use BP neural network for fault diagnosis of electronic circuits.

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