

Application of GA-BP model to fault diagnosis of hydro-turbine generating units

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Abstract: Hydro-turbine generating units play vital roles in safe and stable operation of the whole grid. Hydropower units may meet with some fault such as wear, decreasing productivity and increasing noise due to outside disturbance such as defects, vibration and so on after running for a certain period of time. These problems have to be settled in time to ensure operating safety. In this paper, 19 typical vibration faults and 16 features are proposed and analyzed in detail in order to prepare for the diagnosis model establishment from the aspects of hydraulic, electromagnetic and mechanical factors. An expert system of hydropower unit based on GA-BP is established considering the 19 typical vibration faults and 16 features mentioned above. The results show that the model is accurate and practical. It is seen that the GA-BP model is more rapid and effective than the BP model from the comparisons of the simulation results between the GA-BP and the BP network models.

1. Introduction

Hydro-turbine generating units bears the function of peak shaving, frequency modulation, pressure control and accident reserve, play a vital role to safe and stable operation of whole grid. Hydropower units, due to outside disturbance, such as defects, vibration and so on, may appear some fault such as unit part wear, productivity, increasing noise after running certain time, must maintain and repair in time, to ensure operating safety, stability and economic. August 17, 2009, SaYang-ShuShen scottie hydropower accident killed 75 people, 10 units were damaged with different degree, the hydropower factory building was destroyed, direct economic loss is 130 billion us dollars, repair need at least 400 billion rubles and five years [1-3]. It shows that safe operation of hydropower power plant cannot be ignored, it is very necessary to develop condition monitoring and fault diagnosis of hydropower equipment. In order to ensure security and stability of hydropower generating units in its life cycle, must constantly enhance monitoring and maintenance of hydropower units. Now, many researchers [3-7] studied artificial intelligence technology and try to apply in diagnosis hydraulic unit fault, such as expert system, immune system, Bayesian networks, fuzzy theory, artificial neural networks, support vector and the hybrid application of a variety of diagnostic methods.



In the past, the expert system is established based on fault trees. This system is so complicated that the model and rules are too hard to describe. ANN (Artificial Neural Network, ANN) is a new mathematical model which is composed of large numbers of simple elements. It is an information processing system based on the simulation of human brain structure and function. It can perform complex logic operations and nonlinear relationship operations. The ANN expert system can be easily established through the summary of relationships between faults and features, and the fault diagnosis of hydropower unit can be realized automatically.

In this paper, the hydropower fault cases were studied and analyzed, and built hydropower units fault diagnosis model based on neural network, which take fault symptoms as input, fault type as output, to realize the fault intelligence diagnosis of hydro-generating units. Genetic algorithm is used as a learning method of neural network instead of BP learning algorithm.

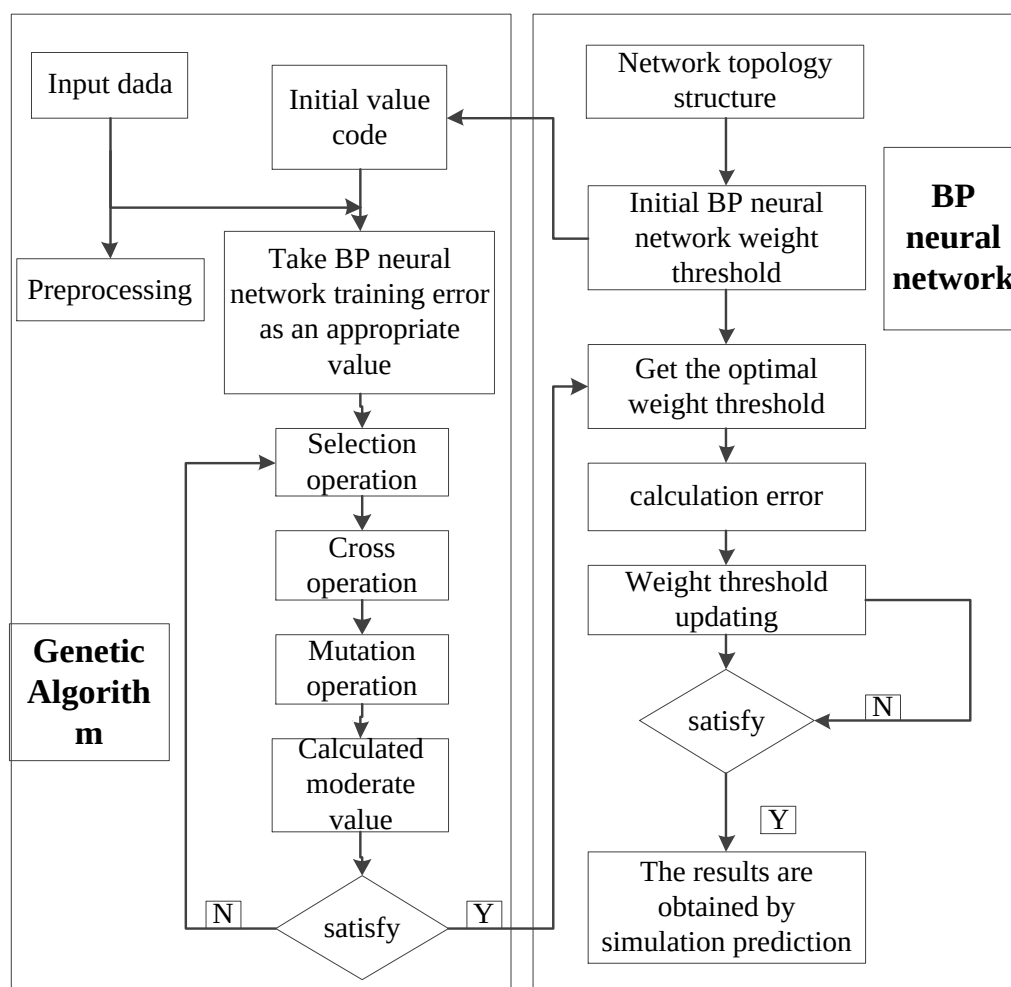


Figure 1. Flow chart of neural network model optimized by genetic algorithm

2. GA-BP mixture model

GA-BP is a hybrid model algorithm which combines BP neural network and genetic algorithm GA. The learning process of BP neural network is actually the process of finding the global optimal solution of nonlinear function, and because of the shortcoming of the process, it may only get a local optimum value. The advantage of genetic algorithm is the ability to grasp the overall search ability, but the disadvantage is that the local search ability is poor. The combination of genetic algorithm and BP neural network can complement each other, and become a new global search algorithm. Generally

speaking, the combination of GA and BP has the following three aspects: [8]:

- Evolution of network structure: The neural network structure design includes two aspects: topological structure and node transfer function.
- Evolution of learning rules: The evolution of learning rules includes the evolution of learning rule parameters and the evolution of learning rules method.
- Evolution of network weights: BP method training has some shortcoming, such as existence of local minimum in conventional BP neural network. Therefore, genetic algorithm is used as a learning method of neural network instead of BP learning algorithm. In the process of evolution, to obtain the optimal network connection weight, the network weights and thresholds is trained by GA and the global search is done by genetic algorithm on the basis of keeping the number of network nodes unchanged.

In this paper, the evolution of network weights is used to improve the BP network. figure 1 is the flow chart of the neural network weights optimized by genetic algorithm [9].

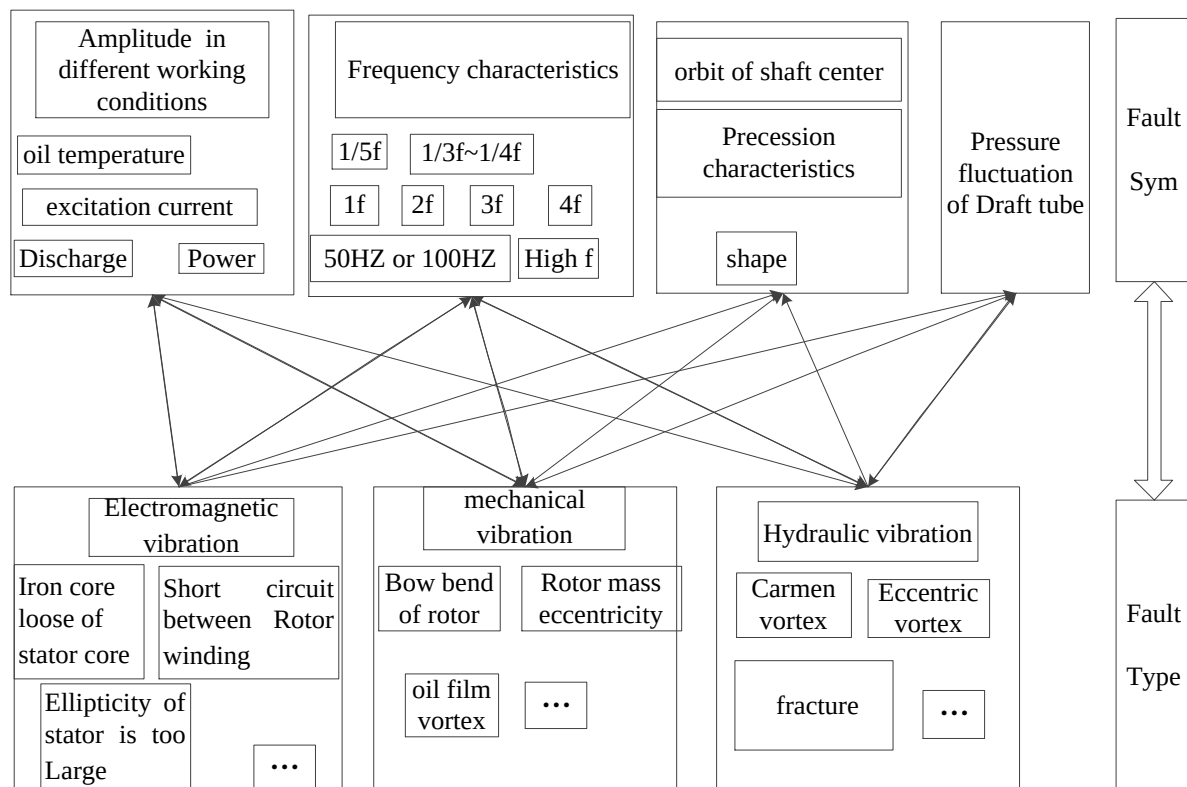


Figure 2. Relation diagram of fault symptom and fault type

Figure 2 shows the relationship between fault symptom and fault type, if the relationship between symptoms and faults is clear, through feature data from condition monitoring or field test, we can infer the fault occurred, what fault was happened, so as to realize judge which fault type by fault symptom; when the new fault appeared, collect and analyze fault extraction feature, added the feature information into the symptom set, so as to realize extract fault symptom from fault, if when the same fault appeared again, thus the system can determine the fault type. However, the type of fault and the characteristics of fault are not one-to-one correspondence, usually one kind fault will have multiple symptoms, and one kind symptom can't determine an exact fault. The relationship between symptoms and fault types is interlaced.

Table 1. Symptom set

Code	symptom	Code	symptom
S1	(1/2~1/6)rotating frequency	S9	The pressure fluctuation of tail water is obvious
S2	1 time rotating frequency	S10	Rotating speed
S3	2 times rotating frequency	S11	power
S4	3 time3 rotating frequency	S12	discharge
S5	50Hz or 100Hz	S13	excitation voltage
S6	High frequency	S14	excitation current
S7	$f=(0.18\sim 0.2)*W_2/b)$	S15	Frequency related to magnetic pole $f=f_1*P$
S8	orbit of shaft center	S16	Guide vane number X rotating frequency

Note: W_2 - relative velocity of outlet of blade b-relative thickness of blade outlet;

P-generator poles;Orbit of shaft center number: 1-ellipse; 2-banana shape or outer "8" glyph; 3-regular or irregular petal shape;4 -"8" glyph;5- two independent ellipses;6- with protruding burr;0-unknown

Table 2. Fault set

fault type	Code	fault
mechanical vibration	F1	Rotor mass eccentricity
	F2	Bow bend of rotor
	F3	Misalignment of rotor
	F4	Rotating parts defects
	F5	oil film vortex
	F6	Bistability
	F7	component friction Static between and dynamic
Hydraulic vibration	F8	Eccentric vortex in draft tube
	F9	Uneven clearance of Stop leak ring
	F10	Bad shape of runner blade
	F11	Runner blade fracture
	F12	Uneven guide vane or blade opening
	F13	Carmen vortex at blade exit
	F14	Cavitation
Electromagnetic vibration	F15	Iron core loose of stator core
	F16	Short circuit between Rotor winding
	F17	Magnetic pole Uneven in the bore of the stator
	F18	Elasticity of stator is too Large
	F19	Unbalance of three phase load

The fault symptom sets and fault sets of hydropower units are classified as table1, table2, which correspond to the symptoms and faults of hydropower units.

The established ANN model take 16 features as inputs and 19 types of faults as outputs. Taking the vibration signals of a domestic power plant as example [10] ([0.9 0.12 0.01 0.03 0.02 0.15 0.02 3 0.95 0.92 0.2 0.15 0.0 0.0 0.0 0.0]), after 1000 steps, the error precision of BP neural network is 0.0094, and

the error precision of GA-BP neural network is 0.0039.

All the results of two models show that the eighth output is the maximum, close to 1, the rest is too small. So it can be concluded that the vibration is caused by F8 (eccentric vortex tube). The model is accurate and practical. Compare the accuracy and simulation results of GA-BP and BP network models, it can be concluded that the GA-BP model is more rapid and effective.

Table 3. Fault symptom of hydropower unit

Fault type	Fault symptoms															
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
F1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0
F2	0	1	0.8	0	0	0	0	1	0	0	0	1	0	0	0	0
F3	0	0.8	1	0.8	0	0	0	2	0	1	0	1	0	0	0	0
F4	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0
F5	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
F6	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
F8	1	0	0	0	0	0	0	3	1	1	0	0	0	0	0	0
F9	0	1	0	0	0	0	0	3	0	1	1	0	0	0	0	0
F10	0	1	0	0	0	0	0	3	0	0	1	0	0	0	0	0
F11	0	0	0	0	0	0.8	0	3	0	1	0	0	0	0	0	0
F12	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	1
F13	0	0	0	0	0	0	1	3	0	0	1	0	0	0	0	0
F14	0	0	0	0	0	1	0	3	0	1	0	0	0	0	0	0
F15	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
F16	0	1	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0
F17	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
F18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F19	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. Results output of Test sample

BP Test result	0.11	0.05	-0.08	-0.01	-0.10	0.15	0.07
	0.91	0.14	-0.02	-0.02	-0.01	-0.07	0.01
	-0.02	-0.04	-0.07	0.03	0.01		
GA-BP Test result	0.06	0.02	0.00	-0.08	-0.01	-0.10	0.00
	0.97	0.02	0.08	-0.14	-0.01	0.01	0.15
	-0.02	-0.08	-0.03	0.02	0.00		

Though 1000 calculate steps, the error precision dimension of the BP neural is 0.0094, and the GA-BP neural network achieve to 0.0039 accuracy. The calculated results of the two models are showed in table4. The results of the two models are that the output value of the eighth units is the maximum, close to 1, and the other values are relatively small, so the fault can be judged as the F8 which is eccentric vortex of the draft tube. It shows that both two models are accurate and practical. By comparing the convergence accuracy and simulation results of the two models, it can be concluded that the GA-BP neural network has faster convergence rate and higher prediction accuracy than the BP neural network.

3. Conclusion

The types and features of different vibration faults are summarized in this paper, and the expert system of hydropower unit based on GA-BP is completed. The main contents and conclusions of this chapter are as follows:

- 19 typical vibration faults and 16 features are proposed and analyzed in detail in order to prepare for the diagnosis model establishment from the aspects of hydraulic, electromagnetic and mechanical factors;
- Taking 19 typical vibration faults and 16 features as example, the expert system of hydropower unit based on GA-BP is completed. The results show that the model is accurate and practical. Compare the accuracy and simulation results of GA-BP and BP network models, it can be concluded that the GA-BP model is more rapid and effective.

Acknowledgments

The research work was supported by the following funding: the Central Universities fundamental research funds (2015B02814).& the National Natural Science Foundation of China (51339005) & the Open Research Subject of Key Laboratory of Fluid and Power Machinery, Ministry of Education , Xihua University”(szjj2015-042). & the Key Project of Yunnan Power Grid Co. Ltd. (YNYJ2016043).

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