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基于模糊神经网络的高加系统内部故障诊断方法

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摘　要: 论述了模糊神经网络的故障诊断方法在高加系统内部故障诊断中的应用, 实践证明该诊断模型具有很好的应用前景。

关　键　词: 故障诊断; 模糊神经网络; 高加系统
中图分类号: TP206. 3

1　概述

由于高压加热器系统所处的工作环境比较恶劣, 汽水参数都比较高, 因此, 火电厂回热系统的故障主要集中在高压加热器系统上。高压加热器的频发故障是影响大机组满发稳发的主要原因之一。深入研究高压加热器的故障分析与诊断方法对提高火电厂的安全经济运行具有重大的意义。

随着技术的进步, 故障诊断的方法也不断得到发展。最早是靠运行和维修人员的经验来判断故障的种类和部位, 不能及时准确地判断故障。随着模糊理论的建立, 模糊专家诊断系统成为一种新的方向。但是, 作为模糊诊断专家系统的核心"故障隶属度函数的确定"问题, 却一直是困扰模糊处理技术进一步推广的难题。而将具有自学习能力的人工神经网络与模糊诊断结合起来的模糊神经网络故障诊断技术能够克服这一难题, 因此受到广泛关注。

本文利用模糊神经网络模型, 根据对高加系统故障机理的研究, 建立的基于 BP 网络的模糊故障诊断系统能够及早、准确地发现高加系统内部故障。神经网络所具有的信息分布式存储、大规模自适应并行处理、很强的自学习能力以及极强的容错性等优点在该系统中能够得到体现和运用。

2　高加系统典型内部故障及其征兆[1]

引起高加系统故障的原因, 除了热工保护等原因之外, 还有高加外部系统的故障和内部的故障。对于由热工保护引起故障和外部故障比较容易诊断, 本文主要研究的是高加系统内部故障的诊断。高加系统在运行中可能发生的内部故障主要有如下几种: (1)管系泄漏, 在高加运行过程中, 如果发生管系泄漏, 汽水侧短路, 将引起进出口给水压差以及疏水温度的减小, 疏水水位升高或疏水调整门开度变大等现象。(2)传热特性不良, 当高加汽侧空间凝聚的不凝结气体较多或传热面结垢时, 高加传热特性不良, 热系数降低, 引起高加的疏水与给水端差增大。(3)给水水管路堵塞, 给水水管路堵塞将使得给水端差增加, 且给水进出口压差明显增大。(4)高加内进出水路短路, 当高加内部进出水路短路时, 则会出现给水温升下降、给水端差增加、给水进出口压差减小等现象。表 1 所示为故障征兆集和各征兆对应于各种故障的隶属度, A 代表故障, S 代表征兆。在征兆集中, 数据"1"表示该征兆存在, "0"表示该征兆不存在。

表 1　样本集

故障征兆							各故障的隶属度			
S1	S2	S3	S4	S5	S6	S7	A1	A2	A3	A4
1	0	0	1	0	1	0	1	0	0	0
0	1	0	1	0	1	0	1	0	0	0
0	0	1	0	1	0	0	0	1	0	0
0	0	0	0	1	0	1	0	0	1	0
0	0	0	1	1	1	0	0	0	0	1

A: 高加内部系统故障集
A1: 管系泄漏
A2: 传热特性不良
A3: 给水管束堵塞
A4: 高加内进、出水路短路
S: 故障征兆集
S1: 疏水水位高

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S2: 疏水调整门开度变大
S3: 疏水端差增大
S4: 进出口给水压差减小
S5: 给水端差增大
S6: 进出口给水温升下降
S7: 进出口给水压差增大

3 高加内部故障诊断系统模型与拓扑结构

本文所采用的基于模糊神经网络的高加内部系统故障诊断系统由模糊化层 FL、神经网络层和非模糊化层 DFL 组成(如图 1 所示)。FL 层将前提条件中模糊变量的状态转化为其基本状态; 神经网络层输出的是发生某一故障的隶属度; DFL 层是根据一定的规则将网络层的输出转化为系统的确定输出。其中, 神经网络层是计算量最大的部分, 因此, 网络类型的选择是非常重要的问题。前馈型 BP 网即误差逆传播神经网络是目前研究得比较深入, 实际应用较多的一种网络。根据文献[2] 在理论上证明的论述: 对于前馈型神经网络而言, 即使该网络只有单隐层, 只要节点数目足够多, 节点激活函数不是常数且有界, 那么该网络可以近似输入输出间的任意非线性映射。因此, 在本系统中选择 BP 网络, 它共有 $m = 7$ 个输入结点, 分别代表高加系统内部故障的七种征兆, 输出层结点数为 $n = 4$ 个, 分别对应高加系统常见的四种内部故障, 隐含层结点数根据公式

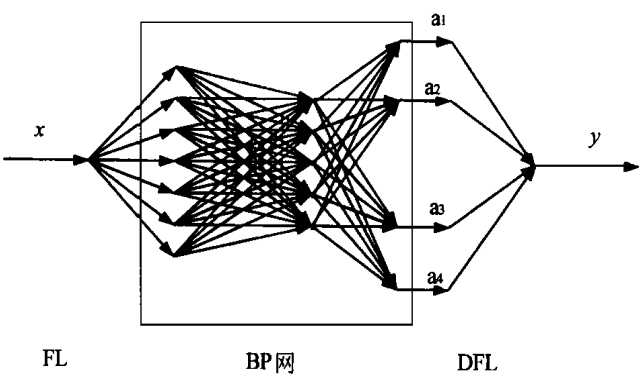

图 1 高加内部故障诊断系统网络拓扑结构图

$h = \sqrt{m + n} + \alpha$ 来选取, α 为 1 ~ 10 之间的常数, 这里取 $h = 5$。结点激励函数采用 Sigmoid 函数, 其表达式为: $f(x) = 1/(1 + e^{-x})$。整个系统的拓扑结构示于图 1。

高加内部故障诊断系统的运行分两个阶段: 第一阶段为学习阶段, 将表 1 中的样本集输入 BP 网络, 对网络进行训练。网络经过多次迭代后, 其权值与阀值逐渐稳定, 网络也逐渐向训练样本靠近。但训练次数越多, 训练时间也越长。考虑到训练精度与训练次数并非呈线性关系, 根据诊断要求, 本网络在学习率 $\eta = 0.75$ 时, 经 243 次迭代后训练精度达到 $Em < 0.002$。训练后的网络通过记忆各个结点的权值与阀值得到隐含在网络内部的故障隶属函数。第二阶段是运用阶段, 它是系统在外界的激发下实现已记忆信息的转换操作, 对系统输入作出响应, 从而对故障作出诊断。

4 诊断实例

例如某机组运行时, 出现下列症状: 疏水水位高, 进出口给水压差减小, 给水端差增大, 进出口给水温升下降, 其它一切基本正常。经过模糊化处理后, 输入 BP 网的是: (1, 0, 0, 1, 1, 1, 0), 经 BP 神经网络计算后, 输出该征兆相对于各故障的隶属度(见表 2)。在非模糊化层 DFL 层, 根据最大隶属原则, 且取门限值为 0.1 时, 诊断出故障序号为 A4, A1。即在运行可能的故障是高加内进出水路短路和管系泄漏。

表 2 故障诊断结果

故障序号	A1	A2	A3	A4
隶属度	0.2938	3.273×10^{-3}	3.741×10^{-3}	0.6804

5 结论

基于模糊神经网络的高加内部故障诊断系统不必事先给出故障隶属度函数, 它借助于本身所具有的学习能力, 从对故障事例的学习中自动获取故障隶属函数, 因而具有广阔的应用前景。在实际应用中, 应尽可能多地收集故障事例, 使训练样本覆盖整个故障空间。这样, 经过适当选择的网络就能够快速准确地作出故障诊断。

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(渠 源 编辑)

ing method for the system can reduce the influence of quantization error of A/D converter, thereby increasing the measurement accuracy of the temperature-rise rate and enhancing the accuracy of thermal stress calculation. In addition, the system on the basis of a measured thermal stress gives an output in the form of 4 - 20 mA to other systems for analysis, accumulating relevant data for computing turbine service life later on. **Key words**: rotor thermal stress, real-time monitoring, difference measuring method, accuracy

稠密气固两相流的直接数值模拟＝**Direct Numerical Simulation of Dense Gas-solid Two-phase Flows** [刊, 中] /Yuan Zhulin (Thermal Energy Research Institute under the Southeastern University) //Journal of Engineering for Thermal Energy & Power. —1999, 14(6). —465 ~ 466

Gas-phase field and discrete particle field are treated respectively by a Eulerian method and a Lagrangian one. During the treatment of a particle field the effect of particle diameter, specific weight, rigidity of material and friction factor, etc on particle movement has been taken into account. A direct simulation method was employed to simulate funnel flow, the particle movement in a ball mill and a stouted bed. Moreover, tests were conducted to verify the simulation results obtained on the stouted bed. **Key words**: gas-solid two-phase flow, direct numerical simulation

换热系统变工况分析＝**Off-design Performance Analysis of a Heat Exchange System** [刊, 中] /Bao Demei, Fan Deshan, Xu Zhigao (Southeastern University) //Journal of Engineering for Thermal Energy & Power. —1999, 14(6). —467 ~ 470

A new method for analyzing a heat exchange system performance variation is proposed along with the establishment of a relevant linear mathematical model. The proposed method can not only analyze the performance of the heat exchange system as a whole during a change in operating conditions, but also reflect the thermal excursion and temperature changes of each heat exchanger within the system and also the efficiency of the heat exchanger itself. Finally, by taking the boiler heating surface soot-blowing as an example the results obtained from the model and those from a simulated model are compared. It is shown that the proposed method features both simplicity and real-time properties. **Key words**: heat exchange system, off-design operating conditions, thermal efficiency, heat transfer unit, soot-blowing

基于模糊神经网络的高加系统内部故障诊断方法＝**A Method for the Diagnosis of Internal Malfunctions of a High-pressure Heater System Based on a Fuzzy Neural Network** [刊, 中] /Qin Zaicong, Xu Zhigao (Southeastern University), Lu Songlin (Jiangsu Provincial Electrical Power Test Research Institute) //Journal of Engineering for Thermal Energy & Power. —1999, 14(6). —471 ~ 472

The authors expound the application of a fuzzy neural network for the diagnosis of internal malfunctions in a high-pressure heater system. Practice has shown that the diagnosis model under discussion has broad prospects for engineering applications. **Key words**: failure diagnosis, fuzzy neural network, high-pressure heater system

双列调节级的变工况热力计算方法及应用＝**A Method of Thermodynamic Calculation for Off-design Conditions of a Turbine Dual-row Governing Stage and Its Application** [刊, 中] /Fu Lin, Jiang Yi (Qinghua University) //Journal of Engineering for Thermal Energy & Power. —1999, 14(6). —473 ~ 476

The authors have come up with a thermodynamic calculation method for a turbine dual-row governing stage. Under this method the thermodynamic properties of the governing stage, including post-stage steam enthalpy, can be speedily identified when made known are only such parameters as the relevant geometric characteristics of the stage. The method can be employed for the simplified thermodynamic calculation of heat supply units. **Key words**: dual-row governing stage, algorithm, steam extraction unit

矩阵法和偏微分理论在机组热经济性分析中的应用＝**The Use of Matrix Method and Partial Differential Theory for the Analysis of a Reheat Unit Economic Performance** [刊, 中] /Zheng Xiuping, Zheng Luying, Cai Tianyou (Northeastern University) //Journal of Engineering for Thermal Energy & Power. —1999, 14(6). —477 ~ 480

A general analysis is performed of a power plant reheat-regeneration thermodynamic system with the use of a matrix method and partial differential theory. Given are the calculation results of thermo-economic analytical parameters H_j^o and η_j^o. The proposed method is applicable for both reheat units and non-reheat ones. **Key words**: thermal system, matrix method, partial differential theory, economic performance analysis

弹性转子磁气轴承系统的 H_∞ 控制＝**H_∞ Control of the Magnetic Bearing System of a Flexible Rotor** [刊,