Research on Gas Pipeline Leakage Detection and Localization Based on Diagonal Recurrent Neural Network

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Abstract: A new method is put forward to detect and locate the gas pipeline leakage, which designed a dynamic network model DRNN. The samples of the network are composed of pressure and flowrate data of all kinds of working conditions. The experiment results verify that the model can describe the gas flow-characteristic in the pipeline, as well as detect the leakage and locate the leakage position.

Key words: pipeline leakage; detection & localization; DRNN
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In this paper a new method to detect and locate the leakage in the gas pipeline is put forward on the basis of dynamic network DRNN (Diagonal Recurrent Neural Network), which is different from the method based on the model of pipeline. It uses its self-adaptation ability to learn the characteristics of all kinds of working conditions of the pipeline, and then classify these working conditions. Experiment verifies this method is effective and sensitive.

1 Principle of pipeline leakage detection and localization based on DRNN

When the leakage happens, the pressure of the leakage position will decrease, which will make the pressure along pipeline vary. Meanwhile, the flowrate of the inlet and the outlet will vary too. References[1] put forward using the traditional ANN to detect and locate the leakage with pressure and flowrate data of pipeline as input. Traditional BP network are static in essence which can only realize nonlinear static mapping. It runs on the base of the stable state of the pipeline. While the pipeline transform from one stable state into another stable state attributed to leakage or sudden variations of boundary conditions, it will be difficult for the system to work normally.

DRNN can describe the dynamic process of the system. In this paper, we use DRNN to diagnose the pipeline leakage through learning the dynamic data of the pipeline. When the pipeline data are input into the network, the network will detect whether the pipeline leaks or not and locate the leak location. For an actual pipeline, these data include the pressure and flowrate of the start and end segment of the pipeline. The sample data for training the network include all working conditions of the pipeline.

2 Structure and algorithm of DRNN

DRNN is a simplified form of Elman network. In DRNN, each neuron of the hidden layer only accepts the output feedback of its own and has no connection with another neuron. The topology structure of DRNN is depicted in Figure 1. The mathematical description of the relationship and learning algorithm of DRNN are discussed as follows.

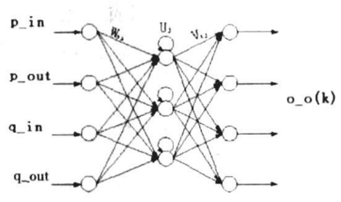

Fig. 1 The topology structure

The input vector of the classifier is

$$x(k) = [p\_in, p\_out, q\_in, q\_out]$$

The output of the hidden layer is

$$O\_H_j(k) = f[net_j(k)] = f[u_j(k) * O\_H(K-1) + \sum_{i=1}^{N\_in} w_{ji}(k) x_i(k)]$$

Where

$$net_j(k) = I\_H_j(k) = u_j(k) * O\_H(K-1)$$

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$$+\sum_{i=1}^{N\_in} w_{ji}(k)\, x_{ji}(k)$$

The output of the output layer is

$$O\_O_l(K) = \sum_{j=1}^{N\_hide} v_{lj}(k) * O\_H_j(k)$$

In training, the improved self-adapt momentum factor is adopted for improving convergence rate. If the current error is less than the last error, the momentum factor will be increased. Otherwise, it will be decreased.

3 Design of experiment

According to the method we design the experiment. As shown in figure 2, we choose the rigid steel pipeline, the length of the experimental pipeline is 84 m, the diameter is 0.01 m. We divide the pipeline into 8 segments, and at the 2, 3, 4, 5, 6, 8 segment we set throttle for simulated leakage.

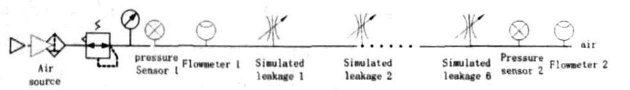

Fig. 2 The scheme of the experiment

In the design of the network DRNN, we set 4 output nodes, which produce 4 bits binary number to denote the different state of the pipeline (for example, 0000 denotes that no leakage happen, 0001 denotes that leakage lies at the 1st segment and so on).

4 Result and analysis

According to the method described above, we train and then test the network, the following table shows the test result of the experimental pipeline.

Pipeline Leak Detection and Localization Test Result

No.	Test result				location	T/f
1	1.0000	0.0000	0.0005	0.0000	8	T
2	1.0000	0.0000	0.0006	0.0000	8	T
3	0.0000	0.0000	0.0004	1.0000	1(no leak)	F
4	0.0034	1.0000	0.9845	0.0171	6	T
5	0.0025	1.0000	0.9995	0.0032	6	T
6	0.0025	1.0000	0.9996	0.0027	6	T
7	0.0025	0.0000	0.9996	0.9029	3	T
8	0.0025	1.0000	0.9995	0.0032	6	T
9	0.0001	1.0000	0.0000	0.9874	5	T
10	0.0020	1.0000	0.0459	0.9934	5	T
11	0.0018	0.0000	0.9473	0.3945	2	T
12	0.0019	1.0000	0.0488	0.9942	5	T
13	0.0013	1.0000	0.0796	0.9966	5	T
14	0.0020	1.0000	0.0385	0.9941	5	T
15	0.0043	0.9795	0.0000	0.0000	4	T
16	0.0022	0.8665	0.0000	0.0000	4	T
17	0.0001	0.8822	0.0461	0.1858	4	T
18	0.0001	0.9124	0.0330	0.1874	4	T
19	0.0000	0.1307	0.9867	0.4495	2(3)	T
20	0.0002	1.0000	0.0000	0.6962	4	T

As shown in the table, the system can describe the dynamic characteristic of the gas pipeline and can detect & locate the leakage. For the sample is not very rich, some error still exist. But compared with the static network model, test precision of the method in this paper increased greatly despite the longer train time.

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基于对角递归网络的气体管道泄漏检测与定位的研究

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摘 要：利用对角递归网络能够描述非线性动态系统的特点，设计了用于气体管道泄漏检测定位的动态网络模型。网络的训练样本由管道各种工况下的压力、流量数据组成。试验结果表明，与传统的静态前馈神经网络模型相比，本研究建立的网络能更好的反映气体在管道中的流动特性，实现气体管道的泄漏检测与定位。

关键词：管道泄漏；检测与定位；DRNN
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