Remote Maintenance System of Industrial Ultra-Pure Water Based on Deep Learning

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Abstract. In order to meet the requirements of controlling the water quality of electric power, electronics and other manufacturing industries and reducing energy consumption through remote operation and maintenance system, an intelligent remote operation and maintenance system of ultra-pure water is constructed for ultra-pure water manufacturing in electronic industry. radial basis function neural network and generalized regression neural network are used to fit and predict the effluent quality of ultra-pure water. Through data analysis, the above algorithm is used to realize the accurate prediction of ultra-pure water system and intelligent adaptive control, which improves the accuracy and convergence speed of the algorithm. The results show that on the basis of the simulation of the model, the purpose of improving water production quality, saving energy and reducing consumption can be achieved through backwater utilization and frequency conversion speed regulation.

Keywords: Intelligent remote control, (TOC); radial basis function neural network (RBN), generalized regression neural network (GRNN) for organic carbon content in ultra-pure water.

1. Introduction

Ultra-pure water is needed in the production process of electronic manufacturing industry, such as integrated circuits, advanced semiconductor materials, flexible display devices and so on. It has a wide range of applications, including display devices, production of semiconductors, photovoltaic solar energy, integrated circuit chips and packaging, high-precision circuit boards, optoelectronic devices, various electronic devices and other large-scale ultra-pure water systems in the electronic industry. According to the different requirements of the process level and precision of electronic products, the demand for pure water quality and quantity is also different. the electronic grade water quality is divided into five grades: 18, 15, 10, 10, 2, 0. 5m Ω cm, ultra-pure water refers to pure water with resistivity above 18.2 M Ω cm [1].

At present, the domestic ultra-pure water preparation industry is in the stage of rapid development, but there is still a big gap compared with the development level of foreign countries. With the popularity
of domestic semiconductor production lines, the demand for ultra-pure water preparation equipment is increasing. At present, domestic semiconductor manufacturers mainly rely on foreign ultra-pure water preparation equipment and its management system. Therefore, the remote operation and maintenance of ultra-pure water still needs independent research and development [2].

Many literatures have studied the information system of ultra-pure water, including process selection, process design, equipment selection, structure design, control system selection, system processing integration and debugging.

2. Technological process of ultra-pure water system
To build the ultra-pure water remote operation and maintenance system, firstly, according to the technological process of the ultra-pure water system, the main data acquisition points and sensors are set as follows. Sensor position in the pretreatment system: raw water pump, multi-media filter, activated carbon filter. Sensor position in cationic bed, anion bed, decarbonization tower system (3B3T): Cationic bed, decarbonization tower, anion bed. The position of the sensor in the reverse osmosis system: mixed bed water supply pump, security filter, reverse osmosis water pump. The position of the sensor in the mixed bed system: mixed bed water supply pump, mixed ion exchange bed, degassing membrane device. Sensor position of polishing system: ultra-pure water pump, polishing mixed bed, terminal booster pump, terminal ultrafiltration.

3. Technological process of ultra-pure water system
The collected data is processed and transmitted to the cloud platform by the communication network for remote operation and maintenance information processing. The function blocks realized on the software and hardware platform of information processing are: equipment management, spare parts consumables management, maintenance management, safety management, fault diagnosis and prediction, data analysis. The specific functions contained in each function block are as follows:

1) equipment management: equipment running state management, equipment document management, equipment visualization based on virtual reality (VR);
2) spare parts consumables management: purchasing management, inventory management, replacement early warning prompt;
3) maintenance management: preventive maintenance, scheduling management, emergency scheduling, personnel training, remote expert support, patrol management.
4) Safety management: acid and alkali leakage alarm, nitrogen concentration detection, hydrogen area concentration detection, safety maintenance personnel management, basement wastewater transfer station leakage alarm, eye washer use monitoring, hazardous goods management;
5) Fault diagnosis and prediction: equipment health management, fault diagnosis and optimization, equipment failure time and type prediction.
6) data analysis: equipment health status analysis, consumables consumption / cost analysis, energy consumption / cost statistics, consumables margin analysis, spare parts consumption prediction, water quality index analysis, water production rate / recovery analysis, equipment operation statistical analysis, consumables and spare parts quality comprehensive ranking.

4. Intelligent remote operation and maintenance system architecture
The framework of intelligent remote operation and maintenance system is divided into intelligent perception and access communication layer, remote operation and maintenance service platform layer and remote operation and maintenance service application layer. The sensing unit installs sensors and data acquisition equipment according to the method shown in the figure to obtain the data of water quality, water quantity, energy consumption and process control of the ultra-pure water system.

The transmission network can choose wired and wireless networks with the transmission capability of the Internet of things. The data transmitted by the transmission network corresponding to the infrastructure service layer of the industrial Internet of things model (IaaS), belongs to multi-source and heterogeneous data, which needs to be processed by the gateway and converted into a unified system-
recognizable format. The remote operation and maintenance service platform layer are equivalent to the platform service layer of the industrial Internet model, (PaaS), which is divided into two sub-layers. The remote operation and maintenance service application layer corresponds to the industrial Internet application layer. Among them, the user interface layer can be implemented by Bamp S structure, which provides interfaces for managers, operators, terminal equipment, suppliers and organizations, as well as interfaces and interfaces for specific functions.

5. RBF algorithm Measurement of Ultra-Pure Water Control

At present, the purity of ultra-pure water is close to the theoretical value of 18.2 M \(\Omega\) cm, so other auxiliary indexes such as total organic carbon content (Total Organic Carbon, TOC) are taken as the measurement goal of ultra-pure water control, on the basis of which the energy consumption and cost are reduced. The main cost of ultra-pure water operation and maintenance includes five items: energy consumption (tap water and electricity); labor cost; medicament consumption; consumables replacement cost; equipment depreciation cost.

In this paper, a three-layer network structure is adopted by using radial basis function (Radical Basis Function, RBF). The input layer is composed of three parameters: inflow TOC, inflow flow and backwater flow, and the output layer is TOC. In view of the above shortcomings of RBF, the generalized regression neural network (GRNN) is used to optimize. In the monitoring of ultra-pure water quality, GRNN consists of a radial network layer and a linear network layer. Taking the sample data as a posteriori condition, the non-parametric estimation is carried out, and each of the three independent variables uses a smoothing factor. For the samples participating in the training, one-dimensional optimization is carried out to obtain the smoothing factor by the way of lack of cross-verification. the specific steps are as follows.

1) set a smoothing factor value \(\sigma\).

2) one measurement sample is taken from the sample, and the rest are used as training samples to build the network.

3) the sample is tested with the constructed network, and the absolute error value is obtained.

4) repeat steps 2) and 3) until all samples have been set as test samples, define the objective function and calculate the average error:

\[
J_{cost}(t) = \frac{1}{n} \sum_{i=1}^{n} |y^*(x_i) - y(x_i)|
\]

6. System simulation experiment

According to the experimental parameters of reference [8], 20 groups of data from the database of ultra-pure water system are randomly selected as simulated test samples, and RBF and GRNN are used to approximate the function of TOC of ultra-pure water quality.

The ultra-pure water system uses PLC and sensors to collect data and record them in the database. The original test data applied to the neural network include: inflow TOC, inflow flow rate, backwater flow rate, water production TOC. Taking the water production TOC as the training sequence, it was recorded as: \(X_k=\begin{bmatrix}3.26 & 6.11 & 7.17 & 6.67 & 9.46 & 5.27 & 3.06 & 2.83 & 0.9 & 3.54 & 3.67 & 2.36 & 2.36 & 4.79 & 10 & 8.42 & 1.25\end{bmatrix} \text{(ppb)}\). By calculating the relative error between the predicted value and the target value, the number of neurons in the hidden layer is 7, and the average relative error is 9.05%, which is better than the existing results. It can be seen that the prediction results obtained by the radial neural network algorithm are in good agreement with the actual values. The biggest relative error occurs when the TOC value is 0.9ppb, which is because it is easy to produce a large relative error when the target value is small. The error produced in the first half of figure 1 is large, and then converges step by step, indicating that the prediction accuracy can be improved by the training of neural network. The artificial neural network algorithm is used to predict whether the TOC of produced water is too high, and the RBF model can meet this function.
The TOC of water production can be accurately predicted by directly calling the relevant function of MATLAB generalized neural network GRNN. The comparison between RBF network and GRNN network of effluent TOC is shown in figure 2.

From the above simulation results, the use of RBF network and GRNN network overcomes the shortcomings of BP neural network, which is sensitive to training sample size, hidden layer nodes and expected error, and has faster convergence speed and higher accuracy. GRNN has better characteristics of nonlinear function approximation. We can consider the influence of resin and UV lamp loss on the TOC of water production, model with RBF or GRNN, realize real-time on-line simulation and monitoring of ultra-pure water system, and adaptively adjust the network structure. To improve the efficiency of the system, intelligent control is needed through the above RBF or GRNN algorithm, that is, the backwater flow is automatically adjusted according to the predicted value of water production TOC by neural network, so as to achieve the purpose of reducing raw water consumption and energy consumption [3].
7. Conclusions
In this paper, the functions of remote operation and maintenance are analyzed through the technological process of ultra-pure water system in electronic factory, and the three-tier architecture of intelligent remote operation and maintenance system is designed. Because of the nonlinear, large lag and time-varying characteristics of ultra-pure water system, the intelligent algorithms of radial basis function neural network and generalized regression neural network are applied to water quality (TOC) detection. On this basis, the model is simulated and analyzed, and the best neural network algorithm is selected. The model is applied to the ultra-pure water system, early warning is given in time when the water production TOC of the prediction system does not meet the standard, and the best return water quantity is selected to achieve the purpose of optimal control.

References
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