Research progress of control of condensate depression for condenser

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Abstract. It is introduced that significance and structure of the condensate depression control system. In accordance with controller devised procedure, we analyze and elaborate how to construct the lumped parameter and dynamic mathematical model which possesses distinct physics significance. Neural network model being called black-box model is also introduced. We analyze and contrast the control technique of condensate depression as conventional PI control, fuzzy PI control and fuzzy control. It is indicated that if the controller of condensate depression were devised inappropriate, while the steam discharge d of turbine varying by a large margin, would result in the rotation rate of cooling water circulating pump accelerating at a great lick even to trigger the galloping danger which is less impressive for the units operating safely.

1. Introduction
The condenser is a significant portion of steam turboset. The thermal economy of the whole of set is influenced immediately by condenser, the same as operational reliability. And the condensate depression is a significant economic indicator to evaluate the condenser [1]. If the condensate depression exceeded that would bring about increase dissolved oxygen of condensation water. And that would exacerbate the corrosion of low tension regenerative system. On the contrary, minor condensate depression stand for cold source is minor, and the thermal economy of the set is better [2]. Nonetheless, condensate depression cannot be too small. If condensate depression is lesser than 0°C would result in supercharged jet pump coming into cavitation erosion.

Therefore, it is extremely necessary to control condensate depression. The control method of condensate depression must be chose felicitously which is of momentous significance.
The function of condensate depression control system is as followed. On the premise of ensuring the vacuum of condenser, to enable the degree of condensed water approach the saturated temperature of current pressure. Condensate depression control system dominates cooling quantity of condensed water by adjusting the rotation rate of cooling water circulating pump. And it dominates exhaust steam heating condensed water by manipulating the opening of the bubbling oxygen deprivation valve. The rotation rate of circulating pump is regulated by adjusting the opening of the inlet valve. The structure chart of condensate depression control system is as Fig.1.

2. Mathematical Research in Modeling During the Controller of Condensate Depression Designed

There are various types of analysis methods for condensate depression control system. It is researched mainly on account of different mathematical model of condenser.

Condensate depression is defined as the magnitude of condensed water over cooling in condenser’s hot well. Under the absolute static pressure in condenser shell, it is the difference between condensed water temperature $t_{cw}$ and the saturation temperature of steam in condenser $t_s$ [3]. As followed:

$$\Delta t = t_s - t_{cw}$$  \hspace{0.5em} (1)

The mathematical model of condenser is founded on principle of condenser devices. And it is the pivotal factor for researching and simulating the controlling means of condensate depression. As to design the controller of condensate depression, it is extremely essential to establish the lumped parameter and dynamic model of condenser. There are quiet a few elements affect the function of system. As an example, bubbling oxygen deprivation, steam resistance, leakage of condenser, flash evaporation of hot well water and swept volume of air ejector can be chose to take into consideration. And it should be made its choice on the basis of actually condition.

But for the sake of founding the mathematical model of condenser explicitly, quiet a few matters are assumed on the basis of simplification principle of mathematical model [4].

(1) The steam and non-condensed gas can be regarded as ideal gas as a result of the low pressure and density in condenser conform to the requirement of ideal gas.

(2) The system simulation takes the main parameters of condenser into consideration. The internal microcosmic variation is not keynote of research. Hence we can presume that working medium in shell-side is in equilibrium and saturation state except condensed water in condenser’s hot well. Parameters of working medium are selected amongst saturation value, and the equation is built at equilibrium point ignoring the air content.

(3) Circulating cooling water is flowing at pipe-shell, and its velocity distribution is a parabola. In the process of simulation, we adopt its average velocity and suppose its current velocity and mass flow rate distributing uniformly.
(4) The temperature variation of circulating cooling water is calculated on the basis of its average temperature, and we presume it is uniformly.

(5) We presume that the mass of metal of circulating cooling water tube is distributed uniformly, same as its specific heat capacity and temperature gradient.

There are numerous researches of lumped parameter and dynamic model of condenser. Xue Ruojun [5] presented a real-time model describing the dynamic behavior of a nuclear power shell-and-tube condenser. Normal condition and accident condition are simulated on simulation platform, and it is appropriate for the whole simulation range. DING Yan et. [6] Described the working process of the condenser by a series of differential equations, thus presenting the dynamic mathematical model of the condenser. And several simulation result of different condition of condenser in 300MW are analyzed. That presents a more intuitive analysis of the problem, but no solution is given. WANG Wu-Chao [7] employed a new moving boundary method to develop the dynamic simulation mathematical model of condenser. The simulation model reflects the variation of length of different phase region condenser during working, and could be simplified to a set of ordinary derivative equation finally. It could be solved more easily, both the efficiency and accuracy. The model can provide detailed performance parameters of the condenser. It studied the dynamic response of condenser in the step change of different control parameters. ZHANG Yong-sheng [8] presented the simplified lumped parameter mathematic model of a marine condenser according to its structure and its working principle in order to effectively control the vacuum and condensate depression of the condenser. The control system of the vacuum and condensate depression for the condenser is designed. Matlab /Simulink software is used for the simulation of the control system. The operating condition of decreasing load is calculated. With the support of general simulation platform Minis, NI He et. [9] Established a dynamic mathematical model of condenser by a series of difference equations on basic principium of mass and energy conservation. And the model possesses a better static accuracy.

Although those models using different methods and emphasis, basically is to start a research on the basis of the working principle of the condenser.

### 3. Research into Control Method

There are a multitude of control methods of condensate depression, for instance, conventional PI control, fuzzy PI control, fuzzy control et.

On the basis of improving traditional controller, the conventional PI control, SUN Jian-hua [10] used the neural network method to establish the model of the condenser. The local hierarchical fuzzy control system is also designed. The effectiveness of the control system is verified by the simulation result. WAN Hua-qing [3] presented humanoid logical control and fuzzy control of condenser vacuum and condensate depression, on the basis of analysis the mechanism of condensate depression. The simulation results prove the validity of the control. LIU Wei-ting [11] studied condenser vacuum and condensate depression control system in an incisive way, and elaborated design principles, design model and realization method. Digital signal processing chip is adopted by the system hardware for ensuring the real-time of system. The fuzzy-neural network algorithm is adopted by the system software for conquering the no determinacy of system model. Results show that the designed system work stable and reliable, and possesses strong robustness.
3.1. Conventional PI control system

![Diagram of Conventional PI Control System]

Figure 2. The functional block diagram of condensate depression control system

The functional block diagram of condensate depression control system is shown in Fig.2. The figure shows that the controller measures the temperature of condensed water though the temperature sensor. We can calculate the condensate depression of the condenser and then to compare it with its set value. The circulating pump of circulating water is dominated by D-value signal to modify the flow of circulating water. That can make the condensate depression of the condenser in a certain range [8].

3.2. Fuzzy PI control System

The fuzzy PI control system is the incorporation of fuzzy control and traditional PI control. Its design philosophy is to find out the fuzzy control relation between parameters of the PI controller and deviation $E$ & deviation change rate $EC$. The parameters $E$ and $EC$ are constantly testing in the process of operation. And the parameters $K_p$ and $K_i$ are real-time modified according to the principle of fuzzy control. Thus, that could content the diverse demand of different $E$ & $EC$ to the controller parameters. Finally the controlled object possesses a positive dynamic and static performance [12]. The structure of control system is shown in Fig.3.

![Diagram of Fuzzy PI Control System]

Figure 3. The structure of fuzzy PI control system

According to the design philosophy of the fuzzy PI control system, first of all we should define that the deviation $E$ and the deviation change rate $EC$ between the expected value of condensate depression and the actual value of condensate depression are input parameters. The output parameters are $\Delta K_p$ and $\Delta K_i$, the correction of control parameters of PI controller $K_p$ and $K_i$. After that the universe of fuzzy sets of input and output value are defined. In the test the control effect of condensate depression of the fuzzy PI controller is better than the conventional PI controller. The concrete performances are less volatile and shorter setting time. As the condenser operate in changing different...
condition changing, the control performance of the fuzzy PI controller is better than the conventional PI controller. That can content the control requirement across the condensate depression control while the steam discharged of turbine varying by a large margin, but the improving is not well.

3.3. Fuzzy Control System
The fuzzy control is been used to design the controller as for condensate depression control system. It is the fuzzy controller that been designed as a combined fuzzy controller. It can be seen as the integration of traditional digital controller and fuzzy controller.

As shown in Fig.4, the system can switch between the fuzzy controller and the conventional PI controller based on the changed working condition of turbine. When the perturbation varying drastically, the fuzzy controller will be disconnected and switch to traditional controller. And then the rotation rate of circulating pump and the opening of the oxygen deprivation valve of exhaust steam will be adjusted according to the working condition of steam turbine corresponding experience. When condensate depression basically stable near the experience value, the traditional controller should be disconnected and switch to the fuzzy controller. After that, the fuzzy controller will be fine-tuned according to the vacuum error \( e \), the vacuum error derivative \( ec \), the condensate depression before bubbling oxygen deprivation and the condensate depression before bubbling oxygen deprivation. Finally, the condensate depression will reach regulation control performance index requirements.

![Diagram](image)

**Figure 4.** The functional block diagram of the condensate depression fuzzy control system

4. Conclusion
The condensate depression control is a significant portion of condenser, and to construct the lumped parameter and dynamic mathematical model which possesses distinct physics significance is the foundation in designing the condensate depression controller of the condenser. It is worth taking care that if the controller of condensate depression were devised inappropriate, while the steam discharged of turbine varying by a large margin, would result in the rotation rate of cooling water circulating pump accelerating at a great lick even to trigger the galloping danger which is less impressive for the units operating safely. It is central to study of condensate depression control method which has important practical significance according to the different condensing system operating characteristics.
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