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Research Paper

Operation of air cooled condensers for optimised back pressure at ambient wind ☆

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ABSTRACT

The traditional back pressure regulation of turbine is influenced more seriously by ambient wind and temperature, especially the hot air reflow and high temperature effect on the axial fans of the air-cooled condensers. This variation would result in the cooling capacity of the fans decreasing and the power consumption increasing. The grey difference incremental correlation method is proposed for considering the back pressure regulation problem from a single condenser cell perspective, and analyze the influence on the heat rejection when processing the speed regulation of the axial fans, then the relationship between the heat rejection increment and the influence of the back pressure will be obtained. The flow and temperature fields of the air-cooled condensers can be obtained by applying the CFD method, and the different back pressure in the different fan speed will be calculated. The results show that, larger the fans ventilation rates will not necessarily cause higher the heat rejection of the finned tube bundle. Reasonably improve the speed of the higher relational degree fans can effectively reduce the turbine back pressure and save energy.

1. Introduction

Due to the growing shortage of global water and the continuous concern over the water resource conservation, the remarkable water-saving technology of direct air cooling in thermal power plant has very important significance for the water shortage countries and regions. However, the complex environment meteorological conditions, including hot air reflow and summer high temperature, which are likely to cause the temperature increases at the inlet of air-cooled unit fans, so the heat exchange efficiency of the air-cooled condensers (ACCs) will be weakened, and in order to stabilize the turbine back pressure, the power consumption of the axial flow fans will be increased. Rooyen and Kroger [1] investigated the air-cooled performances at the ambient winds with the actuator disc model, concluded that the off-axis inflow results in poor performances of the fan and condenser. Yang et al. [2] studied the characteristics for the thermal performance of the ACCs at various ambient wind speeds and directions, which is of use for the fan performance and the A-type condenser cell geometric improvements. Bredel et al. [3] studied the effect of inlet flow distortions on the flow rate, pointed out that the installation of a walkway near the edge of the fan platform can significantly increase the flow rates. O'Donovan and Grimes [4] investigated the relationship between fan speed, condenser operating conditions, and turbine back pressure, which was suggested that the unique ability of the modular air-cooled condenser to continually vary fan speed could result in efficiency gains over a plant operating with existing state-of-the-art fixed speed ACCs.

Work efficiency of ACCs is directly affected by the axial flow fans cluster, researchers found that the performance of the fan group is affected by many different factors, which not only include the performance of each fan itself, but also include the complex meteorological environment and the layout of the fan group. Meyer and Kroger [5] investigated the air-cooled heat exchanger plenum chamber aerodynamic behavior for different fan performances by using CFD simulation. Butler and Grimes [6] investigated the effect of wind on the optimal design and performance of a modular air-cooled condenser. Duvenhage and Kroger [7] pointed out that the upwind condenser cells are mainly affected and the hot plume recirculation occurs at the side condenser cells when the crosswind blows along the longitudinal axis of air-cooled condensers. Yang et al. [8] studied the trapezoidal array of air-cooled condensers, which can restrain the adverse impacts of

☆ The main research direction: Modeling and control of direct air cooled condenser in thermal power plant.

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Nomenclature

C	k-ε model constant
p	pressure (Pa)
f_n	polynomial coefficient of the pressure rise of the fan
v	component of velocity (m s^{-1})
N	rotational speed of the fan (r min^{-1})
n	rated speed (r min^{-1})
r_n	polynomial coefficient of non-dimensional loss coefficient
h	air-side convection heat transfer coefficient (W m^{-2} k^{-1})
h_n	polynomial coefficient for the convection heat transfer coefficient
q	heat flux (W m^{-2})
k_L	non-dimensional loss coefficient
u_j	air velocity (m/s)
x_j	cartesian coordinate (m)
S_φ	source term
G	turbulence kinetic energy generation (m^2 s^{-2})
z	height above the ground (m)
T	temperature (K)
k	turbulence kinetic energy (m^2 s^{-2})
Q	heat rejection (w)
L	volumetric flow rate (kg s^{-1})
x	comparison sequence
r_i	correlation function
Ps	back pressure (kpa)
d_i	difference value
D	matrix of difference value
a_i	back pressure reduction (kpa)
A	matrix of back pressure reduction
b_i	micro – increment of heat transfer
B	heat transfer micro increase matrix
R	the array of the ACCs

Greek symbols

ε	turbulence dissipation rate (m^2 s^{-3})
ρ	density (kg m^{-3})
Γ	diffusion coefficient (kg m^{-1} s^{-1})
φ	scalar variable
P_r	turbulent Prandtl number
λ_i	comparison value
ξ_i	correlation coefficient
β	resolution factor

ambient winds in a power plant. Lei Chen et al. [9] investigated a novel vertical arrangement of air-cooled condensers to improve thermo-flow performances.

The adjustment of the fans operation mode is one of the most important approach to deal with the complex climate and environment. Cooling ability of each air-cooled cell would be different even though all of the fans at the same rotation speed. Efficient operation of the air-cooling unit will directly affect the turbine back-pressure and the economic operation of thermal power plant.

Grey relational analysis is an important part of grey system theory, it is a mathematical model to study the degree of correlation among the internal factors of the system [10], and this method has been applied and developed in many special fields [11,12].

Through the aforementioned research, it is found that most of the numerical simulation experiments are mainly focus on the design of ACCs, such as the walkway, windbreak wall and the arrangement of the condenser cells itself. Most of the studies only aim at improving the thermo-flow performances of ACCs in the same fans speed, this paper focus on the high efficiency operation of the condenser cells from these aspects, such as energy conservation, the relationship between variable speed of single fan and turbine back pressure. Because the back pressure of turbine is an important operation parameter, and the reasonable way of pressure regulation can save energy. The reduction of back pressure is beneficial to the improvement of the operation performance of thermal power units in the power plant, but sometimes it means the fans are operating at higher speeds and, thus, consuming more power.

In this paper, it mainly discusses how to make the turbine back pressure drop up to the least with the same amount of fans power consumption. A novel operation regulation mode of the fans is proposed, which based on the each condenser cell as a single unit through the research on the numerical simulation of the direct air-cooled unit. This approach utilizes the grey difference incremental correlation method which is the grey relational analysis method combined with the difference method to obtain the correlation degree between the heat rejection of the ACCs and the turbine back pressure, then takes the correlation coefficient as reference, and decides which the speed of the fans need to be increased. The traditional way to adjust the back pressure is compared with this reasonable adjustment method under the influence of flow field and temperature field, in order to prove this method can achieve the optimize energy-saving purposes.

2. Computational models

The layout of the air-cooled condensers, main buildings consisting of the boiler and turbine house in a typical 600 MW direct dry cooling power plant are schematically shown in Fig. 1. The distribution of 56 axial fans of condenser cells and the numbering rules for condenser cells are shown in Fig. 2. The air-cooled cells away from the boiler and turbine houses are set as the first row, and the corresponding fans are the first row axial fans. The computational domain is built as shown in Fig. 3, which is going to study the influence of the ambient wind direction on the cooling air flowing through the ACCs.

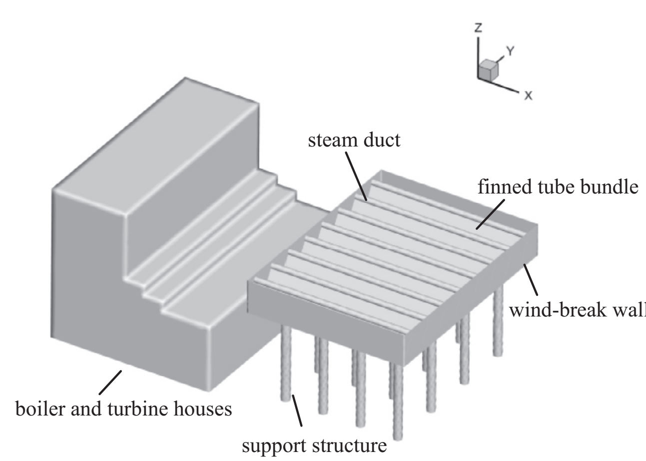

Fig. 1. Physical model of air-cooled island.