Research Paper

Entransy dissipation based optimization of a large-scale dry cooling system

Huimin Wei, Xiaoze Du, Lijun Yang, Yongping Yang

Key Laboratory of Condition Monitoring and Control for Power Plant Equipment (North China Electric Power University), Ministry of Education, Beijing 102206, China
School of Energy and Power Engineering, Lanzhou University of Technology, Lanzhou 730050, China

Corresponding author at: Key Laboratory of Condition Monitoring and Control for Power Plant Equipment (North China Electric Power University), Ministry of Education, Beijing 102206, China.
E-mail address: duxz@ncepu.edu.cn (X. Du).

Correlation between tower loss and geometric parameters of dry cooling tower is investigated.
Entransy dissipation is applied to dry cooling system as constraints of optimization.
The minimization of annual cost is taken as the optimal objective with Lagrange multiplier method.
Total annual cost of dry cooling system can be deduced significantly by optimization.

A R T I C L E   I N F O

Article history:
Received 9 February 2017
Revised 14 June 2017
Accepted 22 June 2017
Available online 24 June 2017

Keywords:
Large-scale dry cooling tower
System optimization
Entransy dissipation
Annual cost

A B S T R A C T

The natural draft dry cooling tower (NDDCT) with heat exchangers accounts for about 10 percent of the total investment of a power plant, so it is meaningful to optimize the geometric parameters to explore the potential that matching the cooling load of a power generating unit in the most cost effective way. The entransy dissipation equations of two typical irreversible heat transfer processes, including that the ambient air heated by heat exchangers and circulating water heated by the exhausted steam of turbine, are derived in this paper. Combined with the force balance equation of NDDCT, all parameters that may affect the performance and annual cost of a cooling system are taken into consideration. Such constituted constraints are applied to the Lagrange multiplier optimization of such a system. Based on the mathematical relation and conditional extremum method, an optimization equation group aiming to obtain the minimum of total annual cost is constructed. Finally, a practical 600 MW power generating unit is taken as an example to illustrate the applications of entransy dissipation based optimization principle. The result indicates that total annual cost of the dry cooling system can drop from $6 420 643 to $5 665 660.

1. Introduction

Dry cooling that depends on natural convection and uses air as the cooling medium is preferable under certain conditions, especially for the insufficient water supplies in arid areas [1]. The high capital and operating costs of cooling system make it necessary to optimize the cost-performance trade-off.

Natural draft dry cooling tower (NDDCT) plays the most important role in the indirect dry cooling system. Since airflow in dry cooling systems is accomplished by natural draft, numerous investigations have concentrated on the influences of geometric parameters of (NDDCT) [2–5]. Huang et al. [2] investigated the cooling performance of NDDCT with variations of geometric parameters via theoretical prediction and experiments. Du Preez et al. [3] made use of scale model tests to study the flow characteristics inside NDDCT and regarded the overall loss dependent on structure. The 17th IAHR international conference on cooling tower [4] gave a brief review of the latest developments in cooling technologies, including the influence of geometric parameters. Jacques du Plessis [5] conducted experimental work and CFD models to develop novel collection trough and basin system design, and empirical loss coefficient relations were presented and discussed.

A larger tower brings more cooling air passing through the heat exchangers and improves the cooling performance with an increasing investment cost yet. Hence the optimal objective is to match the cooling load of a power plant in the most cost effective way. Some researchers have addressed this kind of problem with a detail economic analysis [6–12]. Cui et al. [6] gave a concrete analysis on the relation of total annual cost and different combination
Taking entransy dissipation as the optimization criteria, the method and a new physical quantity, entransy, was proposed. On the other hand, a new combination can reduce the number of variables and equations, moreover, simplify the Lagrange multiplier method calculations.

A global optimal design approach for the dry cooling system of the power generating unit is proposed in this paper. A modified draft equation of NDDCT and entransy balance equations of an indirect cooling system are firstly proposed in this paper. A modified draft equation of NDDCT and entransy balance equations of an indirect cooling system are firstly obtained. Combined the structural requirements, a mathematical model is established by the conditional extremum method, which takes all the parameters that may affect capital and operating costs into consideration. By solving all the equations, the minimum total annual cost of mathematical meaning is obtained comparing with that of heat conduction [14,15], heat convection [16,17], thermal radiation [18,19] and specially, heat exchangers similar to air cooling systems in power plants [20–22]. It can be found that the combination can reduce the number of variables and equations, moreover, simplify the Lagrange multiplier method calculations [23,24].

Based on the above-mentioned method, a global optimal design method can be applied in various heat transfer modes, including that of heat conduction [14,15], heat convection [16,17], thermal radiation [18,19] and specially, heat exchangers similar to air cooling systems in power plants [20–22]. It can be found that the combination can reduce the number of variables and equations, moreover, simplify the Lagrange multiplier method calculations [23,24].

Based on the above-mentioned method, a global optimal design approach for the dry cooling system of the power generating unit is proposed in this paper. A modified draft equation of NDDCT and entransy balance equations of an indirect cooling system are firstly obtained. Combined the structural requirements, a mathematical model is established by the conditional extremum method, which takes all the parameters that may affect capital and operating costs into consideration. By solving all the equations, the minimum annual cost of mathematical meaning is obtained comparing with the “try-and-error” method.

2. Physical model and control equations for indirect air cooling tower design

According to a typical dry cooling power generating unit, the physical model of dry cooling system including a hyperbolic tower with vertical heat exchanger bundles is shown in Fig. 1. The stagnant ambient air at the surrounding, 1, driven by the suction force generated by the temperature difference of the inlet.
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات