Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, October 30-31, 2014

Design of SMART waste heat removal dry cooling tower using solar energy

Young Jae Choi, Yong Hoon Jeong*
Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology,
291, Daehak-ro, Yuseong-gu, Daejeon, 305-701, Republic of Korea
**Corresponding author: jeongyh@kaist.ac.kr*

1. Introduction

Most of world power plant traditionally use the cooling with water, and the types of cooling system are different from each other. The 85% of cooling system are once-through cooling system and closed cycle wet cooling system. However, many countries are trying to reduce the power plant water requirement due to the water shortage and water pollution. Dry cooling system is investigated for water saving advantage. There are two dry cooling system which are direct and indirect cooling system. In direct type, turbine exhaust is directly cooled by air-cooled condenser. In indirect system, turbine steam is cooled by recirculating intermediate cooling water loop, then the loop is cooled by air-cooled heat exchanger in cooling tower. In this paper, the purpose is to remove SMART waste heat, 200MW by using newly designed tower. The possibility of enhancing cooling performance by solar energy is analyzed. [1]

2. Design and Result

Current indirect dry cooling is Heller system, which has a direct contact condenser with cold water spray instead of a steam surface condenser. The resultant hot condensate water mixture is pumped to air cooled heat exchanger. This Heller system has a number of advantages.[2]

In the paper, two new cooling towers which have 200MWt heat removal capacity are introduced. The first design looks like typical wet cooling tower. But the heat exchanger is in the bottom of chimney and ambient air flow cool down the hot water in Fig.1. The design uses the natural draft flow by the difference of air density between tower and ambient air. Second design is solar tower which has the glass roof collector in bottom side of cooling tower in Fig. 2. The heat exchanger is designed at entrance part of collector. Heat exchanger consist of simple long tube where heated water flow through. Two design have same tube and same heat exchanger area. Heat exchanger of Fig.1 cover whole side surface, but heat exchanger of Fig.2 cover only partial 4 side surface and the remainder entrance is blocked from ambient air to increase inlet air velocity. Also the collector is inclined toward centered from 10m to 20m height. Because height of HX is decreased 2times, the width increase 2 times but the side area of HX is same with Fig.1.

To compare two model, the height of chimney and radius of collector are obtained from MATLAB calculation. The basic dimensions of two tower is in Table 1.

Table 1: Basic Cooling tower configuration

Tower diameter(D_{chim})	70m
Heat exchanger height	20m→10m
Ambient air temperature(T1)	35°C
Inlet water temperature(Thin)	60°C
Outlet water temperature(Thout)	50°C

There are some assumptions to apply two cooling tower design.

1) The air follows the ideal gas law
2) The only the buoyancy force is considered in the chimney
3) Steady state condition
4) No heat loss in chimney wall

2.1 Simple Dry Cooling Tower

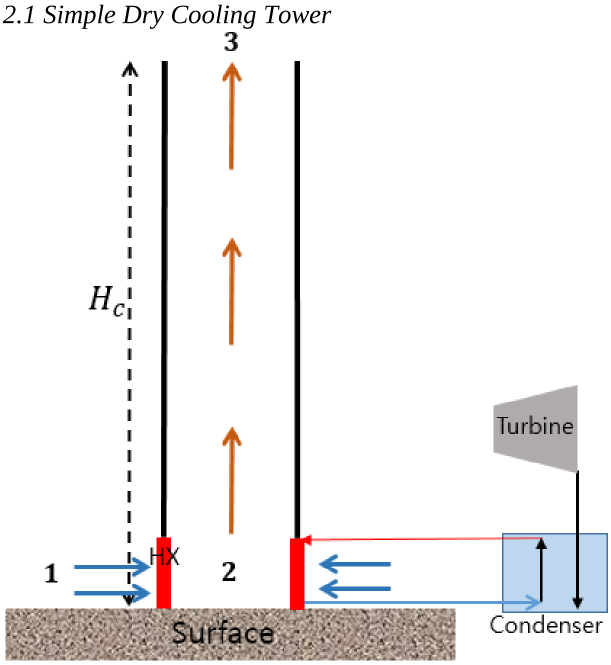

Fig. 1. Simple cooling tower

In two design, I had to remove 200MWt heated water in intermediate loop. Heat transfer and pressure drops in heat exchanger is obtained by calculating eq.(1)~ (3).

$$\dot{Q}_{HX} = U * A * \Delta T_{in} \quad (1)$$

$$\dot{Q}_{air} = \dot{m}_a * C_{p,a} * (T_2 - T_1) \quad (2)$$

$$\Delta P_{dyn} = (\rho_1 - \rho_2) g H_c - \Delta P_{fric} - \Delta P_{form} - \Delta P_{hx} = \frac{1}{2}\rho u^2 \quad (3)$$

,where U is overall heat transfer coefficient, A is heat transfer area in HX. The log mean temperature difference (LMTD) is used in heat exchanger. The density difference between 1 and 2 makes the natural air flow into chimney. But there are pressure drops by the heat exchanger, friction of chimney wall and inlet & outlet form loss, etc. From equation (3), the air velocity in entrance and overall chimney configuration is obtained. When the tower diameter is 70m, the height of chimney should be 360m high to remove 200MWt SMART waste heat.

2.2 Cooling Tower using Solar Energy

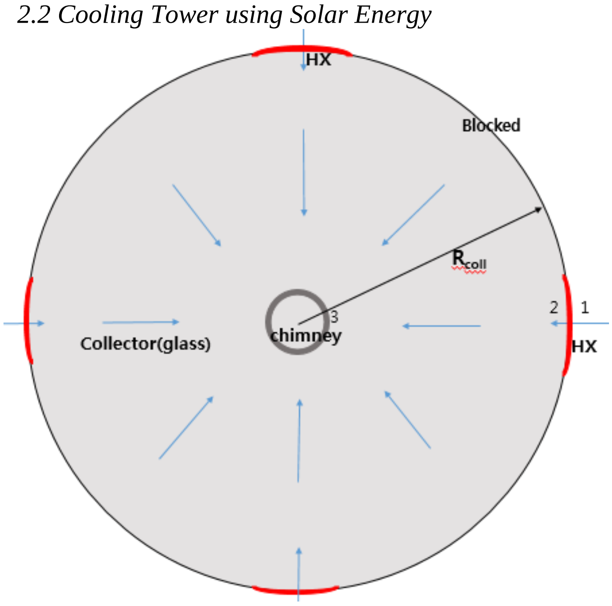

Fig. 2 Top view of cooling tower using solar energy

The air in collector is heated by the solar energy and the air temperature increase toward center of tower in Fig.2. It makes the inner air density lower, then this phenomenon makes pressure difference between tower and ambient air.

In the design, HX cover only partial 4 side surface and the remainder entrance is blocked from ambient air to increase inlet air velocity. The heat transfer equation is calculated by eq. (1),(2) and (5). The air temperature increase in collector is obtained by eq. (4). [3][4]

$$T_3 = T_2 + \frac{\alpha * G}{\frac{\dot{m}_a * C_p}{A_r} + U} \quad (4)$$

$$\Delta P_{dyn} = (\rho_1 - \rho_3) g H_c - \Delta P_{fric} - \Delta P_{form} - \Delta P_{hx} = \frac{1}{2}\rho u^2 \quad (5)$$

where G is global solar radiation, α is collector absorption coefficient and U is collector loss coefficient and A_r is total collector area. Finally, tower height (H_c) is obtained by changing collector radial length (R_{coll}) to meet the purpose of removing 200MW heat. In second design, the collector radius should be larger than about 100m to take advantage of the solar energy. Fig. 3 show that the tower height of first design is 360m when tower diameter is 70m. When solar tower diameter is 70m, the tower height is decreased from 360m to 180m as collector radius increase from 100m to 500m.

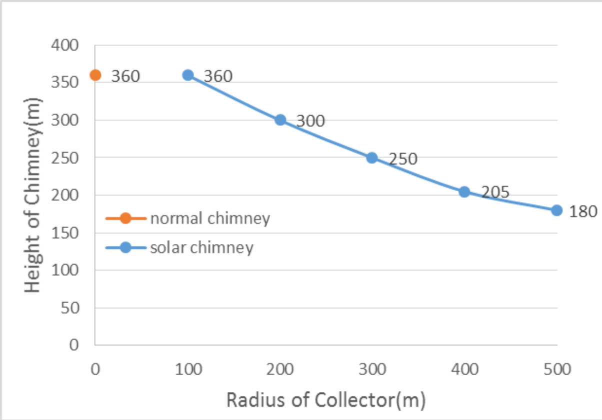

Fig. 3. Tower height dependent on collector radius

3. Conclusion

The simple cooling tower and solar energy cooling tower are presented and two design should meet the purpose of removing SMART waste heat, 200MW. In first design, when tower diameter is 70m, the height of tower should be 360m high. In second design, the chimney height decrease from 360m to 180m as collector radius increase from 100m to 500m due to collector temperature enhancement by solar energy,

To analyze solar cooling tower further, consideration of solar energy performance at night should be analyzed. Also detailed investigation of each component should be supplemented. Finally the economic capital cost should be estimated adequately.

REFERENCES

[1] John L. Tsou, John L. Power Plant Cooling System Overview for Researchers and Technology Developers, May 2013 Tsou Consulting Services, John Maulbetsch, Maulbetsch Consulting, Jessica Shi, EPRI

[2] Zoltán S, Attila G, Zoltán M, Water Conservation Type Cooling Systems for Nuclear Power Plants, Paper for 3rd Annual Meeting of ACC Users Group September 19-21, 2011, San Francisco, CA

[3] Zhou X, Yang J, Xiao B, Hou G, Xing F. Analysis of chimney height for solar chimney power plant. Appl Therm Eng 2009; 29:178–85.

[4] Koonsrisuk A, Chitsomboon T. Mathematical modeling of solar chimney power plants. 2013, Energy 51,314-322.