Project Title: Investigation of water spray effects on thermal performance of power plant flat-tube air cooled condenser

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Project Necessity:

To the best of our knowledge, effects of water spray on thermal performance of air cooled condensers (ACC) has not been extensively and comprehensively studied. Before applying such an approach for ACC, it is strongly recommended to obtain sufficient data to make sure that this approach is effective enough and technically feasible. For that purpose, thermodynamic studies, CFD simulations and consequent analyses are necessary.

Project Goals:

Performance of condenser directly affects steam turbine back pressure and consequently plays a big role in power plant performance and power generation output. Air cooled condenser includes a number of tube-bundles. Steam exiting the turbine flow through tubes and is condensed. The released heat during condensation is rejected by air flow over finned tube-bundles. Forced convection of air over tube-bundles is made by ACC fan. In order to enhance heat transfer in ACCs and reducing steam turbine back pressure, particularly in summer hot air, on solution is to apply water spray to decrease the air temperature. In A-frame ACCs, an array of spray nozzles is located between fan and tube-bundles (closer to the fan) and spray water upward. Upward air draft made by the fan conveys water micro-droplets toward the tube-bundles. This project aims to perform thermodynamic studies as well as CFD simulations of droplet laden air flow between the fan and tube-bundles as well as that over tube-bundles.

Abstract:

As specified in the title of this project, this project aims to investigate effects of water spray on thermal performance of flat tube-bundle air cooled condensers of power plants. This work was performed in four stages. In stage one, in addition to studying principles of ACC function, a brief review of evaporative cooling, spray and atomization was performed. In the second stage, thermodynamic aspects together with mass and energy balance during water droplets evaporation were studied. Also, mapping of results on the psychrometric chart and corresponding analyses were carried out. In this stage, EES and Thermoflow softwares were utilized. In the next stage, numerical simulation of droplet-laden air flow under ACC (between fan and tube-bundles) were performed. DPM was used for modelling droplet. Hydrodynamics, evaporation and heat transfer within airflow was investigated in this stage. The main goal of this stage was to determine air flow properties (including temperature, humidity, amount of non-evaporated water, etc.) before entering the tube-bundles. The last stage was dedicated to CFD simulation of droplet-laden air flow over tube-bundles (i.e. within gaps between fins). Outputs of the third stage were used as inputs of the fourth stage.

As expected in the beginning of the project, this work made a better understanding of water spray effects on ACC performance. Another important achievement of this work was realization of various aspects of simulation and thermal design of air side of ACC. Moreover, a simulation setup was established which can be used further not only for ACC design purposes but also for any type of air cooled heat exchanger.

This project only focused of thermal aspects of ACC. However, for applying water spray to cool ACC inlet air some other aspects such as chemical compatibility of water with tube-bundle material as well as economic feasibility must be considered.

Steps and Methodologies:

This project included four steps as follows:

Stage #1: General studies

This stage was dedicated to introduction of ACC, evaporative cooling and spray and atomization.

Stage #2: Thermodynamic analyses

In this stage, assuming complete evaporation of sprayed droplets, variation of thermodynamic conditions (including temperature and humidity) and its effects of ACC performance were investigated. At this step, EES and Thermoflow softwares were utilized for calculations and simulations.

Stage #3: CFD simulation of droplet-laden air flow under ACC

CFD simulations of this stage was carried out by finite volume method and Ansys Fluent software. DPM was used for modelling suspended droplets in the air flow.

Stage #4: CFD simulation of droplet-laden air flow over tube-bundle

CFD simulations of this stage was also carried out by finite volume method and Ansys Fluent software. Again, DPM was used for modelling suspended droplets in the air flow.

Main Results (technical outputs, patents, papers, books, reports, etc.):

Achievements of this project include four technical reports.