PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Innovations for Existing Plants

01/2009

APPLICATION OF PULSE SPARK DISCHARGES FOR SCALE PREVENTION AND CONTINUOUS FILTRATION METHODS IN COAL-FIRED POWER PLANT:

PROMIS/PROJECT NO.: DE-NT0005308

Background

Thermoelectric generation accounted for 39 percent (136 billion gallons per day [BGD]) of all freshwater withdrawals in the United States in 2000. While most of the water withdrawn is for the operation of once-through cooling systems, plants equipped with re-circulating (or closed-loop) cooling technology also withdraw significant volumes of freshwater. Makeup water is needed for these types of cooling systems primarily to account for evaporative loss in the plant's cooling tower. However, the concentration of mineral ions in circulating cooling water, such as calcium (Ca) and magnesium (Mg), increases with time as water evaporates to remove heat from condenser tubes in plant's cooling towers. When the mineral concentration in the circulating water becomes too high, precipitation of Ca/Mg carbonate salts occurs on the surfaces of the condenser tubes (commonly called scale build-up, or fouling), inhibiting heat transfer from the tubes to the cooling water and reducing the effectiveness of the cooling tower. In order to maintain a desired Ca level in the cooling water (i.e., a cycle of concentration [COC] of 3.5), power plants must continuously blowdown cooling water and replace it with fresh make-up water.

Description

This project deals with an innovative water treatment technology that utilizes spark discharges in water for scale prevention. The key issue is how to precipitate and remove dissolved Ca ions in recirculating cooling water so that the calcium carbonate ($CaCO_3$) scales can be avoided and COC can be increased. The project will utilize spark discharges in water to precipitate dissolved mineral ions in circulating cooling water in a simulated laboratory cooling tower and continuously remove precipitated mineral salts using a self-cleaning filter.

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PARTNERS

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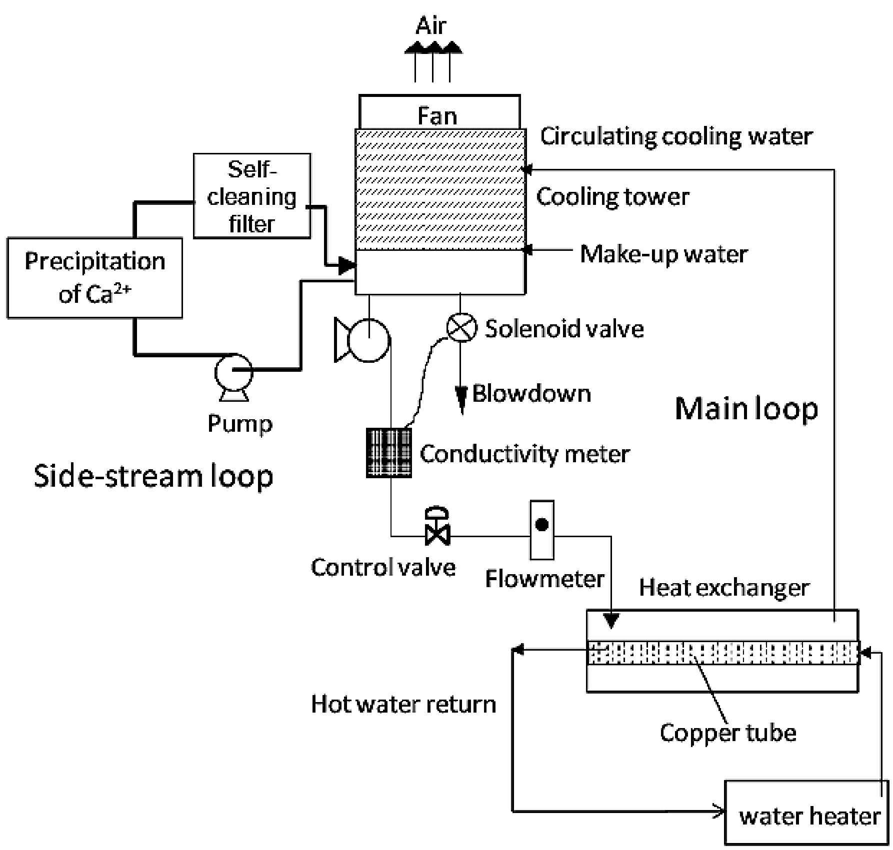
Primary Project Goal

The primary project goal is to precipitate and remove excess Ca ions in cooling water, which will prevent condenser-tube fouling and double COC at the same time, accomplishing one of the major U.S. Department of Energy (DOE) goals of reducing/minimizing freshwater withdrawal in thermoelectric power plants.

Objectives

The objective of this project is to reduce the amount of freshwater needed to achieve power plant cooling by preventing the buildup of mineral scale on condenser tubes, thereby increasing COC in the cooling water system from the present operational value of 3.5 to at least 8. This will be achieved through the development of scale-prevention technology that uses electrical pulse spark discharges to precipitate dissolved mineral ions, such as Ca and Mg, and remove them from the cooling water.



Schematic Diagram of Drexel University's Laboratory Cooling Tower Test Facility

Benefits

The potential benefits from this research include the ability to operate at a higher COC, which will reduce cooling tower blowdown water requirements and the amount of freshwater make-up needed. At the completion of the work, a new prototype hardware using pulse spark discharges will be available for scale-up with validating test results. It will be a true mechanical water softener that continuously converts hard water to soft water with little energy consumption.

Planned Activities

In the initial set of experiments, a high-voltage pulse (~40,000 volts [V]) will be applied for a short time period (e.g., 10-50 nanoseconds) to an electrode immersed in water to produce spark discharges at a frequency of 30-1,000 Hertz. The anticipated field strength at the tip of the electrode is approximately 1,000,000 V/centimeter. The spark discharge also produces an intense local heating around the tip of the electrode. The local heating can dissociate the bicarbonate (HCO_3-) ions and produce hydroxide (OH-) ions, a process which is critical to the precipitation reaction of $CaCO_3$. The parameters associated with the spark discharges (frequency, power level, pulse duration), electrode configuration (tip materials and geometry), and the cooling water (temperature, pH, level of supersaturation) will all be varied in order to identify the optimum conditions at which the $CaCO_3$ precipitation rate per unit of power consumption is maximized.

In the second set of experiments, the laboratory cooling tower will be operated at the optimum conditions to determine whether a COC of up to 8 can be sustained for a prolonged period. Both a Ca probe and an electric conductivity meter will be used to monitor COC in the circulating cooling water. In addition, chemical water analysis data (i.e., chloride ion concentration) will be used to confirm COC calculation.

Finally, a series of heat transfer fouling tests will be conducted using a condenser heat exchanger in the laboratory cooling tower. The fouling resistance will be experimentally determined by measuring the inlet and outlet temperatures at both the cooling-water side and hot-fluid side. The fouling resistance obtained with the proposed scale-prevention technology will be compared with the no-treatment case as well as the scale-free case.

PERIOD OF PERFORMANCE

10/01/08 to 09/30/11

COST

Total Project Value
$1,258,175

DOE/Non-DOE Share
$982,872 / $275,303

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The project will:

- Test whether the spark discharge can precipitate dissolved Ca ions by applying the spark to simulated cooling water and measuring the concentration of dissolved Ca ions in cooling water using a Ca ion probe.
- Test a laboratory cooling tower to determine if the technology can continuously precipitate Ca ions and whether the self-cleaning filter can continuously remove Ca ions at the same time so that the blowdown can be eliminated or significantly reduced.
- Verify that mineral scale buildup on condenser tubes can be reduced via the use of the proposed spark discharge technology.

by sequestering CO_2 while providing increased methane (CH_4) for home heating, industry, and other commercial uses. Working closely with the EPA has allowed DOE to better assess the role that non-CO_2 greenhouse gas emissions abatement can play in a nationwide strategy for reducing greenhouse gas intensity.