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Original Article

Strategic Approaches for Water Conservation in Thermal Power Plants

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Abstract - *Thermal power plants are major consumers of water, essential for cooling and steam generation. With escalating concerns over water scarcity and environmental sustainability, optimizing water use in these facilities is critical. Advanced cooling technologies, such as dry and hybrid cooling systems, significantly reduce water consumption compared to traditional wet cooling towers. Implementing closed-loop water systems minimizes water loss through efficient recycling and reuse. High-efficiency boilers and turbines improve plant efficiency, reducing the water required per unit of electricity generated. Effective water management practices, including real-time monitoring and leak detection systems, are vital in identifying and mitigating water wastage. Treating and reusing wastewater within the plant can further decrease the need for freshwater withdrawal. Additionally, using alternative water sources, such as municipal wastewater and seawater, can ease the demand for freshwater resources. By incorporating these strategies, thermal power plants can markedly reduce their water footprint, thereby enhancing environmental responsibility and contributing to sustainable development.*

Keywords - *Thermal power plants, Water scarcity, Environmental sustainability, Water footprint.*

1. Introduction

Water conservation in thermal power plants is a critical aspect of modern environmental management and sustainability efforts. Thermal power plants, which generate electricity by converting heat energy, are significant consumers of water, primarily used for cooling and steam generation. With the growing global concern over water scarcity and the need for sustainable resource management, optimizing water usage in these plants has become imperative. The traditional methods employed in thermal power plants, such as wet cooling towers, are highly water-intensive, often leading to substantial water withdrawal and consumption. This not only strains local water resources but also poses environmental and operational challenges, especially in arid regions or during drought conditions [1]. As a result, there is an urgent need to implement more efficient water management practices.

Thermal power plants consume substantial water, causing environmental and economic challenges. Existing research lacks focus on innovative technologies, integrated water management, economic analyses, and practical case studies. Addressing these gaps is essential for developing sustainable, efficient water conservation strategies in the thermal power sector [2]. Innovative strategies, including advanced cooling technologies like dry and hybrid cooling systems, offer promising solutions to significantly reduce water usage. Additionally, the adoption of closed-loop water systems allows for the recycling and reuse of water, minimizing losses. High-efficiency boilers and turbines can improve the overall efficiency of power generation, thereby reducing the water required per unit of electricity produced[3,4]. Furthermore, incorporating real-time monitoring, leak detection systems, and wastewater treatment and reuse can further enhance water conservation efforts[5,6].

By focusing on these advanced methods and technologies, thermal power plants can significantly lower their water footprint, demonstrating a strong commitment to environmental responsibility and sustainable practices. This proactive approach not only helps conserve water but also ensures the long-term viability and efficiency of power generation operations. In this study, the emphasis is given to Innovative techniques such as advanced cooling systems, wastewater recycling, and dry cooling technologies focusing on reducing water loss in thermal power plants. Advanced cooling systems, such as hybrid cooling towers, significantly reduce water evaporation. Wastewater recycling involves treating and reusing water within the plant, minimizing freshwater intake [7]. Dry cooling technologies, including air-cooled condensers, eliminate water use for cooling by relying on air to dissipate heat. Additionally, membrane filtration technologies and zero liquid discharge (ZLD) systems ensure minimal water wastage and discharge. These innovations collectively enhance water efficiency, lower environmental impact, and contribute to the sustainable operation of thermal power plants.

2. Objectives and Motivations

To accomplish the study's aim, various references were reviewed. Key subjects included:

- Water Resources
- Distribution of Freshwater Resources
- Groundwater Hydrology
- Global Water Demand
- Depletion of Freshwater Resources
- Water and coal-based thermal power plant

This study promotes the dissemination of best practices in water conservation across industries, encouraging corporate adoption of sustainable water use [2]. It aims to raise awareness of water scarcity and quality issues, fostering discourse on sustainable water management amidst the growing depletion and pollution of water resources emphasizing the urgency of the matter [3].

The main objectives are:

- Formulate improved water resource allocation and management.
- Promote freshwater conservation in coal-based thermal power sectors.
- Document and disseminate best practices, facilitating information exchange.
- Promote innovative water-saving technologies like rainwater harvesting and desalination.
- Apply previous studies' knowledge to new water conservation scopes.
- Evaluate and redefine current practices for efficiency enhancement.

3. Methodology for Reduction of Water Consumption

3.1. Distribution of Freshwater Resources

The majority of precipitation not absorbed by plants or evaporated permeates the soil, replenishing groundwater. This groundwater flows through rock and sediment layers before ultimately discharging into rivers[4]. Water consumption in thermal power plants is primarily attributed to the following key areas:

3.1.1. Cooling Systems

The largest portion of water consumption in thermal power plants is typically associated with cooling systems. These systems are essential for dissipating heat generated during power generation processes. Water is circulated through cooling towers or other cooling mechanisms to remove excess heat from the plant's equipment.

3.1.2. Hybrid Cooling Towers

Thermal power plants combine wet and dry cooling methods, significantly reducing water consumption and improving efficiency, as shown in Figure 1. In wet mode, they use water evaporation to remove heat, which is ideal in high temperatures. In dry mode, air-cooled heat exchangers dissipate heat without water, suitable for cooler periods or water-scarce regions. These systems can switch between modes or operate both simultaneously, ensuring optimal performance while conserving water. This operational flexibility minimizes environmental impact, lowers operational costs, and supports compliance with regulations. Particularly beneficial in water-scarce areas, hybrid cooling towers help thermal power plants achieve efficient, sustainable, and responsible operation.

3.1.3. Steam Generation

Water is also consumed in significant quantities during the process of steam generation. This involves heating water to produce steam, which is then used to drive turbines for electricity generation.

3.1.4. Boiler Feed Water

Thermal power plants require a continuous supply of high-quality water to feed boilers. This water undergoes treatment to remove impurities before being heated to produce steam.

3.1.5. Wastewater Treatment

Water is consumed in the treatment of wastewater generated from various processes within the plant. This includes treating water used for cooling and steam generation before it is discharged back into the environment.

3.1.6. Auxiliary Processes

Water is used in various auxiliary processes within thermal power plants, such as cleaning and maintenance activities, as well as for personnel facilities.

Efforts to optimize water consumption in these areas can significantly reduce the overall environmental impact of thermal power plant operations.

4. Results and Discussion

A study on water consumption reduction techniques in thermal power plants would typically analyze the effectiveness of various strategies and their implications. Here's how it might be structured, as shown in Table 1.

- Implementation of Advanced Cooling Technologies: The impact of introducing advanced cooling technologies, such as dry or hybrid cooling systems, on water consumption reduction as shown in Figure 2. 34 % reduction in cooling water makeup due to hybrid cooling tower leads to a Cycle of Concentration (COC) enhancement achieved compared to traditional wet cooling towers as depicted in Table 1.

- Adoption of Closed-loop Water Systems: The effectiveness of closed-loop water systems in minimizing water loss by 25% through recycling and can be utilized for reuse.
- Integration of High-efficiency Boilers and Turbines: The efficiency improvements achieved through the integration of high-efficiency boilers and turbines. Quantify the reduction in water consumption per unit of electricity generated. An air cooling system (ACC) was found to save 30.5% of water in plants.
  Zero liquid discharge (ZLD) systems: The impact of water management practices was evaluated, such as real-time monitoring and leak detection systems, on identifying and mitigating water wastage. Zero liquid discharge (ZLD) systems save 28.2% of water.
- Wastewater treatment (WWT)
  The effectiveness of wastewater treatment and reuse systems in reducing freshwater demand. The volume of wastewater treated and reused within the plant. Wastewater Treatment and Reuse saves 45.3% of water.

Table 1. Assessment of water consumption

Sl, No.	Areas identified	Yearly Savings (Rs Lacs)	Investment (Rs Lacs)	RoI %	Payback (months)
1	Rooftop rainwater harvesting system for Turbine building	1.96	5.70	34.3	35
2	Recovery water line connectivity to CT for use during monsoon.	2.25	5.70	39.4	30
3	Once through cooling system of the Air Conditioning Plant and Ash Plant is to be replaced with Air Cooled Condenser/Conventional cooling tower.	29.69	30.0	99.0	12
4	Optimization of COC (Cycle of Concentration) of cooling water	27.81	0.00	NA	NA
5	Re-Utilization of SSF backwash water for bottom de-ashing	11.00	3.00	366.6	3

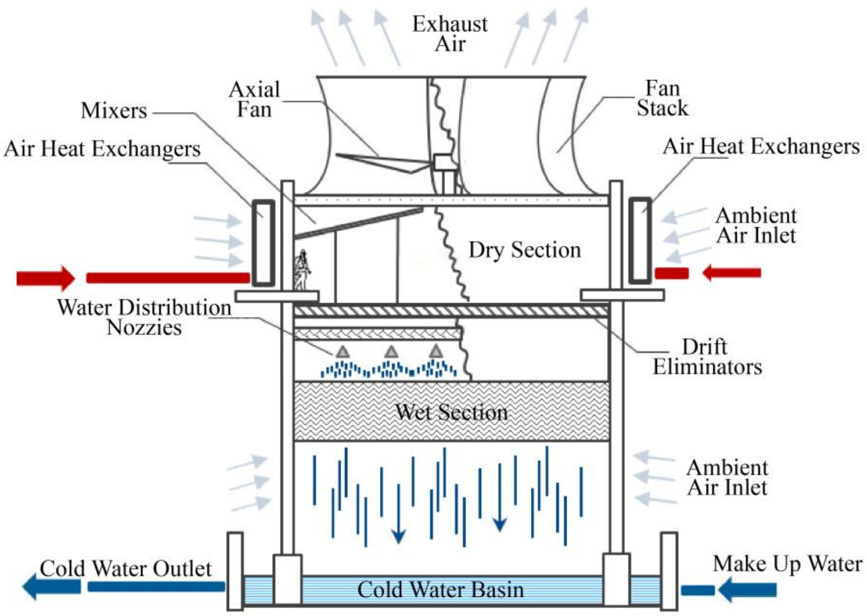

Fig. 1 Schematic diagram of hybrid cooling tower

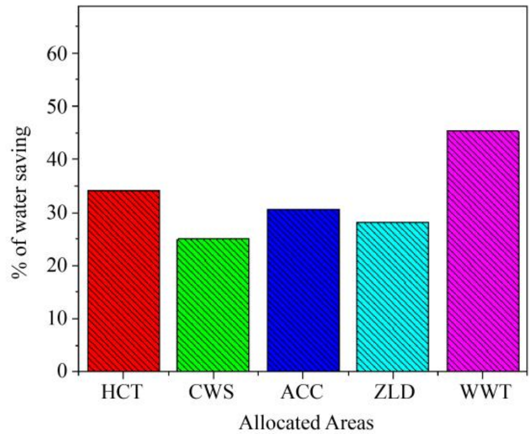

Fig. 2 Different strategies for saving water in PP
(HCT: Hybrid cooling Tower, CWS: Closed-loop Water Systems, ACC: Air Cooled Condenser, ZLD: zero liquid discharge Systems, WWT: Wastewater treatment)

5. Conclusion

Analysis reveals a shift towards multidisciplinary water management in thermal power plants, utilizing unconventional water sources and advancing wastewater treatment for zero discharge. Future water management should prioritize meticulous treatment, enhanced financial support, improved incentives, and prompt policy implementation. Strengthening water resource planning ensures regional water and energy sustainability.

As freshwater scarcity and regulations intensify, freshwater costs will likely rise, emphasizing the need for water conservation in power plants. Despite challenges, various technologies offer opportunities for water conservation within the sector.

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