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## Development of solar-assisted coal-fired hybrid power systems: A review

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### Abstract

This review paper critically examines the development and optimization of solar-assisted coal-fired hybrid power systems, focusing on their potential to address the challenges of energy security, environmental sustainability, and economic viability. Through a comprehensive analysis of existing literature, technological advancements, and real-world case studies, this paper provides insights into the design, implementation, and performance optimization of these innovative energy solutions.

**Keywords:** Solar-assisted, coal-fired, hybrid power

### Introduction

The integration of solar energy with traditional coal-fired power generation represents a promising approach to enhancing energy sustainability while reducing greenhouse gas emissions. This paper provides an overview of the historical development, current state-of-the-art, and future prospects of solar-assisted coal-fired hybrid power systems. By examining the technical, economic, and environmental aspects of these systems, we aim to shed light on their role in the transition towards a low-carbon energy future.

### Main Objective

The primary objective of this review is to analyse the model of solar-assisted coal-fired hybrid power systems. This review based on the following steps:

1. To understand the deep Concepts and components of solar-Assisted Coal-Fired Hybrid Power Systems.
2. To outline the basic structure and importance of Solar-Assisted Coal-Fired Hybrid Power Systems.

### Concepts and components of Solar-Assisted Coal-Fired Hybrid Power Systems

#### Solar Collectors

Solar thermal collectors play a vital role in the development and optimization of solar-assisted coal-fired hybrid power systems. These collectors are pivotal components that facilitate the integration of solar energy into traditional coal-fired power plants. Their primary function is to capture sunlight and convert it into thermal energy. By harnessing solar energy, these collectors provide a supplemental heat source to the coal-fired power generation process. This additional heat reduces the reliance on coal as the sole fuel source, leading to decreased greenhouse gas emissions and fossil fuel consumption. Moreover, solar thermal collectors enhance the overall efficiency of the power plant by preheating the water or thermal oil that is fed into the boiler. This preheating process reduces the amount of coal required to produce the same amount of steam, resulting in improved thermal efficiency and reduced operating costs. Environmental benefits are another significant aspect of integrating solar thermal collectors into coal-fired power plants. By offsetting carbon emissions associated with burning coal, these collectors contribute to mitigating air pollution and reducing the environmental impact of power generation.

Furthermore, solar thermal collectors enhance the flexibility and reliability of coal-fired power plants. They provide a source of renewable energy that is available during daylight hours, thus improving the plant's ability to respond to fluctuations in energy supply and demand. In hybrid systems equipped with thermal energy storage, excess solar heat can be stored for later use, further enhancing the plant's flexibility and resilience. Continuous research and development in solar thermal collector technology drive the optimization of solar-assisted coal-fired hybrid power systems. Advancements in collector efficiency, durability, and cost-effectiveness contribute to improving the performance and viability of

these hybrid systems over time. In summary, solar thermal collectors play a critical role in enhancing the efficiency, environmental sustainability, and reliability of solar-assisted coal-fired hybrid power systems.



(Source: [https://en.wikipedia.org/wiki/Solar\\_thermal\\_collector](https://en.wikipedia.org/wiki/Solar_thermal_collector))

**Fig 1:** Solar thermal collector

### Integration System

In solar-assisted coal-fired hybrid power systems, the Integration System serves as a pivotal bridge between traditional coal-fired power generation and solar energy capture technologies. Its primary role is to seamlessly incorporate solar energy into the existing infrastructure of coal-fired power plants, ensuring efficient operation and maximum utilization of renewable resources. This system enables the integration of solar thermal collectors or photovoltaic panels with the power plant's equipment, such as boilers and turbines. It facilitates the transfer of solar-generated heat or electricity into the power generation process, augmenting the plant's overall energy output while reducing reliance on fossil fuels. Key components of the Integration System include piping, valves, and control mechanisms that regulate the flow of heat transfer fluids or electricity between the solar collectors and the power plant. Heat exchangers play a vital role in transferring thermal energy from solar collectors to the power plant's boiler, enhancing efficiency. Monitoring and control equipment ensure the system operates optimally, adjusting parameters as needed to maintain stability and reliability. By effectively integrating solar energy, the Integration System helps to mitigate environmental impacts associated with coal-fired power generation, such as greenhouse gas emissions and air pollution. It enhances the flexibility and resilience of the power plant by diversifying its energy sources, contributing to a more sustainable and reliable electricity supply. Overall, the Integration System plays a critical role in advancing the transition towards cleaner and more efficient energy generation in solar-assisted coal-fired hybrid power systems.

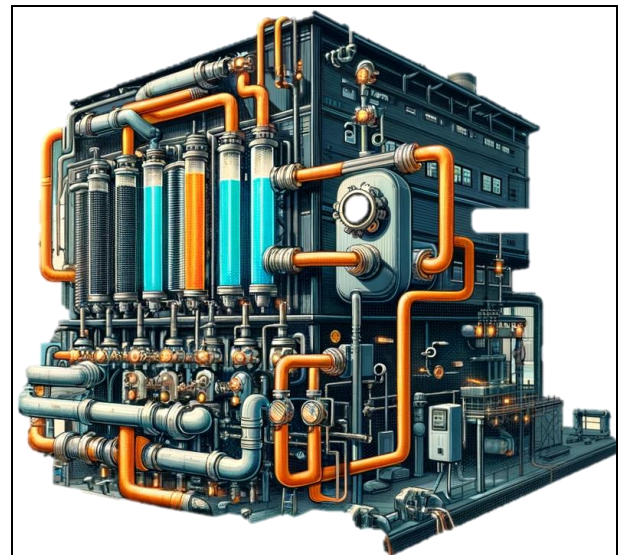
### Heat Transfer Fluid

In these hybrid systems, the HTF acts as a medium for capturing solar energy efficiently. Solar collectors heat the HTF to high temperatures, which can then be used to preheat water in the power plant's boiler. This preheated water requires less energy from coal to reach the necessary steam production levels, thus reducing the overall coal consumption and improving the plant's efficiency. Additionally, the HTF enhances the flexibility and reliability of the hybrid system. It allows for the storage of

excess solar heat during periods of high solar radiation, which can be utilized later when solar energy is not available, such as during night time or cloudy days. This thermal energy storage capability helps to stabilize the power output of the hybrid system and ensures a consistent electricity supply to the grid. The HTF serves as a vital intermediary in solar-assisted coal-fired hybrid power systems, enabling efficient utilization of solar energy and enhancing the sustainability and reliability of power generation processes.

### Heat Exchangers

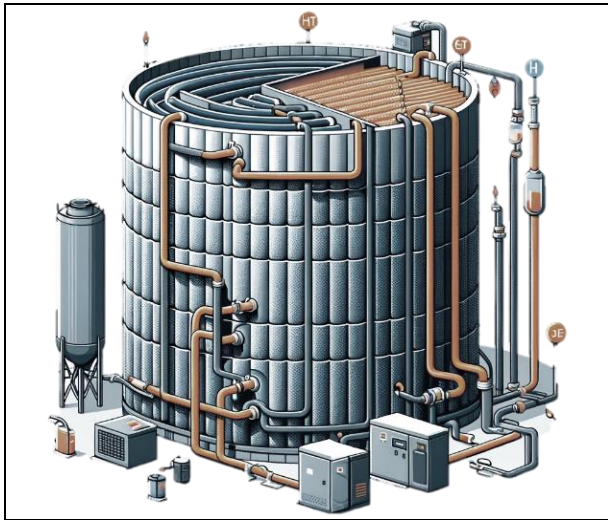
Heat exchangers enable the efficient transfer of heat from the HTF, which has been heated by solar collectors, to the water or steam in the power plant's boiler. This process preheats the water, reducing the amount of coal needed to reach the desired steam production levels. As a result, the overall efficiency of the power plant is improved, leading to lower fuel consumption and reduced greenhouse gas emissions per unit of electricity generated. Moreover, heat exchangers contribute to the flexibility and reliability of solar-assisted coal-fired hybrid power systems. They allow for the smooth integration of solar energy into the power generation process, enabling the plant to adjust its output based on fluctuations in solar radiation levels. Additionally, heat exchangers can be incorporated into thermal energy storage systems, allowing excess solar heat to be stored and utilized later during periods of low solar radiation or increased energy demand. Heat exchangers are critical components that optimize the performance of solar-assisted coal-fired hybrid power systems by facilitating efficient heat transfer and enhancing the sustainability and reliability of power generation processes.



**Fig 2:** Heat Exchangers in Hybrid Power Systems

### Storage Systems

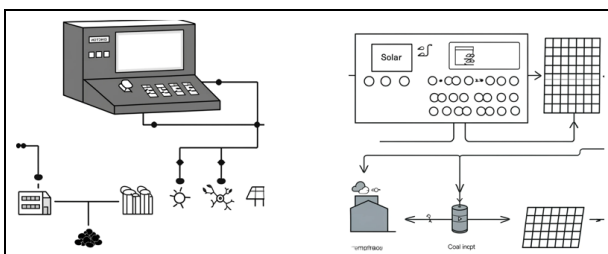
The stored thermal energy can be utilized to preheat water in the power plant's boiler, reducing the reliance on coal and improving overall efficiency. This not only decreases greenhouse gas emissions but also enhances the economic viability of the power plant by reducing fuel consumption. Moreover, storage systems contribute to the stability of the power grid by providing a reliable source of energy that can be dispatched as needed. By buffering fluctuations in solar energy output, they help to ensure a consistent electricity supply, mitigating the intermittency associated with renewable energy sources.



**Fig 3:** Storage system of hybrid solar power system

### Control Systems and Monitoring Equipment

In solar-assisted coal-fired hybrid power systems, control systems are used to regulate the flow of energy from both solar and coal sources, ensuring a smooth transition between them based on factors such as solar radiation levels, grid demand, and operational requirements. They manage the operation of components such as solar collectors, heat exchangers, boilers, and turbines, optimizing energy production while minimizing environmental impact. Monitoring equipment is essential for continuously monitoring various parameters such as temperature, pressure, flow rates, and energy output throughout the hybrid system. This real-time data allows operators to assess system performance, identify potential issues, and make necessary adjustments to maintain optimal operation. Control systems and monitoring equipment enable the implementation of advanced control strategies to maximize the efficiency and flexibility of solar-assisted coal-fired hybrid power systems. These strategies may include predictive analytics, feedback control loops, and demand response mechanisms to optimize energy production, reduce operating costs, and ensure grid stability.



**Fig 4:** Control Systems and Monitoring Equipment

### Grid Connection

One of the primary roles of the grid connection is to ensure the reliable and efficient delivery of electricity from the hybrid power system to the grid. It involves the installation of transformers, switchgear, and other infrastructure to regulate voltage levels, manage power flow, and ensure grid stability. The grid connection enables the hybrid power system to contribute to grid balancing and stability. By feeding surplus electricity into the grid during periods of high generation and drawing power from the grid during periods of low generation, the hybrid system helps to balance supply and demand, thereby enhancing grid reliability and resilience.

Moreover, the grid connection allows for the monetization of excess energy generated by the hybrid power system. Through net metering or feed-in tariffs, surplus electricity produced by the system can be sold back to the grid, providing a source of revenue for system operators and incentivizing renewable energy production. The grid connection enables the hybrid power system to benefit from grid services such as frequency regulation, voltage control, and demand response. These services help to optimize system operation, improve grid efficiency, and support the integration of renewable energy resources.

### Solar-Assisted Coal-Fired Hybrid Power Systems

Solar-assisted coal-fired hybrid power systems integrate solar energy technologies into traditional coal-fired power plants to enhance their efficiency and reduce their environmental impact. These systems leverage the reliability of coal-fired generation while harnessing the sustainability of solar power. Let's delve into the key concepts and components of these hybrid systems. Solar collectors are fundamental components responsible for capturing solar energy. They come in various types, including flat-plate collectors, concentrating collectors like parabolic troughs or solar towers, and photovoltaic panels. The selection of collectors depends on factors such as geographical location, available space, and desired efficiency.

Integration systems connect the solar collectors to the existing coal-fired power plant infrastructure. They consist of piping, valves, pumps, and control systems to regulate the flow of solar-heated fluids (Such as water or thermal oil) into the power generation process.

A crucial element of these systems is the heat transfer fluid, which absorbs solar energy and transfers it to the coal-fired power plant's boiler. Typically water or thermal oil, this fluid is heated by the solar collectors and then circulated to transfer its heat to the water in the boiler.

Heat exchangers facilitate efficient heat transfer between the solar collector fluid and the water in the power plant's boiler. They employ pipes or plates designed to optimize heat exchange while maintaining physical separation between the two fluids.

Some solar-assisted coal-fired power plants incorporate thermal energy storage systems. These systems store excess heat generated during peak solar radiation periods for later use, enhancing the plant's flexibility and reliability by providing supplemental power during low solar radiation or night time hours.

Control systems and monitoring equipment are essential for overseeing the operation of the hybrid power plant. They include sensors, actuators, and control algorithms that optimize the utilization of solar energy while ensuring stable and efficient operation of the plant.

Environmental controls are necessary to minimize emissions of pollutants such as sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and particulate matter from the coal-fired portion of the plant. Integrating solar energy can help reduce overall emissions by decreasing the amount of coal burned per unit of electricity generated.

Finally, grid connection equipment enables the power generated by the hybrid system to be fed into the electrical grid for distribution to consumers. This equipment includes transformers, switchgear, and transmission lines, ensuring the safe and reliable connection of the power plant to the grid.

### Conclusion

In conclusion, the future prospects for solar-assisted coal-

fired hybrid power systems are promising, with significant potential to contribute to a more sustainable and resilient energy landscape. As global energy demand continues to rise and the need for carbon emissions reduction becomes increasingly urgent, these hybrid systems offer a viable pathway to address both challenges simultaneously. Looking ahead, advancements in technology, policy support, and market incentives are expected to drive further innovation and adoption of solar-assisted coal-fired hybrid power systems. Continued research and development efforts will focus on improving the efficiency, reliability, and cost-effectiveness of hybrid power generation technologies, making them increasingly competitive with traditional fossil fuel-based generation. Moreover, the transition towards renewable energy sources is expected to accelerate, creating favorable conditions for the integration of solar energy into coal-fired power plants. As renewable energy costs continue to decline and environmental regulations become more stringent, hybrid systems will become increasingly attractive options for power generation. Furthermore, the flexibility and resilience offered by hybrid power systems make them well-suited to meet the evolving needs of modern electricity grids. By providing a reliable and stable power supply while reducing greenhouse gas emissions, these systems can play a crucial role in supporting the transition towards a low-carbon energy future.

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