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SOLAR THERMAL HYBRID FOR CUMBUSTION POWER PLANT

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Abstract :- A solar thermal hybrid system integrated with a combustion power plant offers a promising approach to significantly reduce carbon emissions by utilizing concentrated solar thermal energy to partially replace fossil fuel combustion, resulting in decreased fuel consumption while maintaining grid stability; this hybrid design leverages existing power plant infrastructure by incorporating solar receivers to preheat combustion air or generate steam, thereby enhancing overall plant efficiency and providing a pathway towards cleaner electricity generation with potential for further optimization through thermal energy storage integration. The development of technologies to hybridise concentrating solar thermal energy (CST) and combustion technologies, is driven by the potential to provide both cost-effective CO2 mitigation and firm supply. Hybridisation, which involves combining the two energy sources within a single plant, offers these benefits over the stand-alone counterparts through the use of shared infrastructure and increased efficiency. In the near-term, hybrids between solar and fossil fuelled systems without carbon capture offer potential to lower the use of fossil fuels, while in the longer term they offer potential for low-cost carbon-neutral or carbon-negative energy. The integration of CST into CO2 capture technologies such as oxy-fuel combustion and chemical looping combustion is potentially attractive because the same components can be used for both CO2 capture and the storage of solar energy, to reduce total infrastructure and cost. The use of these hybrids with biomass and/or renewable fuels, offers the additional potential for carbon-negative energy with relatively low cost. In addition to reviewing these technologies, we propose a methodology for classifying solar-combustion hybrid technologies and assess the progress and challenges of each. Particular attention is paid to "direct hybrids", which harness the two energy sources in a common solar receiver or reactor to reduce total infrastructure and losses.

***Keywords** – Hybrid integration: Combines solar thermal collectors with a conventional combustion power plant to supplement fossil fuel heat with solar energy, Concentrated solar thermal energy, Hybrid systems, Carbon capture, Energy storage, Firm supply.*

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1 INTRODUCTION

A "solar thermal hybrid for a combustion power plant" refers to a system where a conventional combustion power plant is integrated with a solar thermal energy system, allowing the solar heat to partially replace the heat generated by burning fossil fuels, thereby reducing greenhouse gas emissions while still maintaining reliable power generation, especially during peak sunlight hours; essentially, the solar heat is used to preheat the combustion air or directly contribute to steam generation within the existing power plant cycle, providing a hybrid energy source with reduced carbon footprint. Concentrating solar thermal energy (CST) technologies make use of the entire solar spectrum to provide a source of high-temperature process heat in the range 500–2000 °C, which is compatible with temperatures generated by combustion, to produce power, fuels, and materials [1]. CST technology is commercially available at the lower end of this temperature range for power production, while higher temperatures in a wide range of applications presently performed by combustion have been demonstrated at lab or pilot-scale using CST [1], [2], [3]. Another driver for CST is its compatibility with thermal energy storage, which is a very low-cost method of storage. Nevertheless, its reliance on the intermittent and variable direct solar radiation resource makes it complimentary with combustion, which utilizes the energy-dense source of stored energy in fuels. This, combined with the strong temperature compatibility, provides a strong driver to integrate them to achieve one continuous process rather than two variable ones. This combination is hereafter termed "CST-hybrids" for brevity." "CST-Hybrids offer both low net CO2 emissions and firm supply, providing greater security of supply than is possible with only "dispatchability". Firm supply is increasingly sought in OECD nations because the growth in intermittent renewables is leading to the increased curtailment of their output, while the strong growth in total demand in non-OECD nations is providing strong incentive to install new plants that cannot provide firm supply [4]. In addition to the capacity to provide firm supply, CST-hybrids offer more cost effective power generation than is possible with the equivalent stand-alone solar thermal and combustion power plants because of the opportunities for infrastructure sharing, increases in efficiency, and greater capital utilisation [5], [6]. For example, Spelling and Laumert [7] found that hybridising the topping cycle of a Gas Turbine Combined Cycle (GTCC) is more economic under most conditions than "hybridising" with solar photovoltaic (PV) energy behind the meter (to share electrical infrastructure), which results in the gas turbine being turned down to operate at lower efficiency to accommodate the solar resource. However, many other possible hybrid configurations are also possible and no systematic review is available of their relative merits. The overall aim of the present review is to meet this need. Given the wide range of technologies under development for both concentrating solar thermal and combustion technologies in isolation, the number of potential combinations of hybrids between them is even greater. It includes those that harness a relatively small fraction of solar energy into commercially available combustion plant without carbon-capture, such as the low temperature solar heating of the feedwater to a steam boiler.

How it works:

Solar collectors concentrate sunlight to heat a fluid (like molten salt) which is then used to transfer heat to the combustion process, either by preheating the combustion air or directly heating boiler water, effectively reducing the amount of fossil fuel needed to reach the desired temperature for steam generation.

Benefits:

- Reduced emissions: By utilizing solar energy, the system can significantly decrease greenhouse gas emissions from the power plant.
- Improved efficiency: Preheating the combustion air with solar heat can enhance the overall efficiency of the combustion process.
- Flexibility: The solar component can be scaled to suit the needs of the existing power plant, and can be adjusted based on solar availability.

II TECHNICAL CHALLENGES

Energy storage: Solar energy is intermittent, so integrating energy storage systems is crucial to ensure consistent power output.

Cost considerations: Initial investment in solar thermal collectors and integration systems may be high.

Common types of solar thermal hybrid systems for combustion power #plants:

Integrated Solar Combined Cycle (ISCC):

This system uses solar thermal energy to preheat the combustion air in a gas turbine combined cycle power plant.

Solar-assisted steam #generation:

Solar collectors are used to heat boiler feedwater, reducing the amount of fossil fuel needed to generate steam.

Key points about solar thermal hybrids in combustion power plants:

III FUNCTION

Solar collectors concentrate sunlight to generate high-temperature heat, which is then transferred to the existing power plant steam cycle, either by preheating the boiler feedwater or directly injecting steam into the system depending on the design.

Benefits:

Reduced emissions: By utilizing solar energy, the reliance on fossil fuels is decreased, leading to lower CO2 emissions.

Improved efficiency: Solar heat can be used to boost the overall efficiency of the power plant cycle.

Grid stability: Can provide a reliable source of renewable energy during peak sunlight hours, helping to balance the grid.

Technology types:

Parabolic trough collectors: Most commonly used, concentrating sunlight onto an absorber tube filled with a heat transfer fluid.

Solar tower: Sunlight is reflected onto a central receiver tower where the heat transfer fluid is heated.

Challenges:

Integration complexity: Integrating solar thermal with existing combustion systems requires careful design considerations to ensure optimal performance and avoid disruptions.

Storage limitations: Solar thermal energy storage systems are needed to provide power during periods of low sunlight, which can add cost and complexity

Advantages:

Cost-effective power generation

- Uses abundant and economical fuel
- Can be set up irrespective of geographical requirements
- Requires less area compared to other power plants

Disadvantages:

- Fossil fuel use depletes resources
- Requires a large quantity of water [Image].
- Low efficiency and lifespan [Image].
- High maintenance cost Image]

Potential Advantages:

- Saves money on electric bills.
- Increases home value.
- Offsets rising electricity costs.
- Lowers carbon footprint.

Advances clean energy technology.

- Supports the local economy.
- Boosts clean energy in the grid.
- Long lifespan with low maintenance.
- Offers low-cost purchase and payment options.
- Earns credits toward electric bill.

Potential Challenges:

- High initial investment.
- Requires ample roof space.
- Difficult to forecast net savings.
- Difficult to DIY.
- Not compatible with all roof types.
- Installation isn't immediate
- Difficult to move once installed.
- Hard to find quality installers and technicians.
- Panels don't generate power at night.
- Production not 100% environmentally friendly.

IV CONCLUSION

A solar thermal hybrid system integrated with a combustion power plant offers a significant opportunity to reduce fossil fuel reliance and greenhouse gas emissions by utilizing solar energy to preheat the combustion process, resulting in lower fuel consumption and increased overall system efficiency, making it a promising approach for transitioning towards cleaner energy production while maintaining grid stability; however, careful consideration of factors like solar availability, thermal storage integration, and system design optimization are crucial for achieving optimal performance and cost-effectiveness.

Reduced fossil fuel use:

By utilizing solar energy for preheating, the combustion process requires less fossil fuel, leading to lower CO2 emissions.

Improved efficiency:

Integrating solar thermal energy can boost the overall efficiency of the power plant by utilizing the additional heat source from the sun.

Flexibility:

Depending on the design, the system can adjust to variable solar radiation by utilizing thermal storage systems to maintain consistent power output.

Potential for cost savings:

While initial investment may be higher, the reduced fuel consumption can lead to long-term cost savings.

Challenges to consider:

High initial cost:

Implementing a solar thermal hybrid system may require significant upfront investment for the solar collectors and necessary infrastructure.

Solar variability:

Reliance on sunlight means the system's output fluctuates based on weather conditions.

Integration complexity:

Integrating solar thermal energy into an existing combustion power plant requires careful design and engineering considerations.

Overall, integrating solar thermal technology into a combustion power plant presents a viable path towards cleaner energy generation by leveraging the sun's energy to supplement fossil fuel combustion, contributing to a more sustainable energy mix.

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