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Studies on Solar Thermal Power Plant- A Review

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Abstract

Sun's energy is available in abundant quantity and also it is quite sustainable in its natural form hence forming a good alternative to match the ever-increasing demand for energy. The current solar power system efficiencies are relatively low as compared to the existing power systems running on fossil fuels which is a major hindrance to its global adoption .A thorough study is done on the current scenario in the power plants using the sun's energy is performed along with recent technological developments. New advancements in the materials capable of storing large amount of heat by changing phase at constant temperature (PCM) are also highlighted. Various hybrid modes of solar thermal power plants were compared based on parameters like Levelized cost of energy (LCOE) and found to be competitive with their conventional counterparts. The paper also highlights various algorithms and methodologies applicable for enhancing the efficiency of the plants using the sun's energy.

Keywords: *Optimization, Focused Energy, Thermal Energy, Solar Power plant.*

1. INTRODUCTION

As the world is realizing the limited availability and pollution caused by conventional fossil fuels the mass adoption of renewable energy is on the rise. The pollution caused by the burning of fossil fuels is adversely affecting the environment and the natural habitat of the earth. To arrest this degradation of the environment, mankind should focus on developing low-cost, sustainable, and clean renewable energy solutions. Among the diverse options available most abundant and promising alternative to conventional energy is solar energy.

The two primary technologies for harvesting solar energy are power generation by solar photovoltaic (PV) cells and by concentrating solar radiation at a point in a concentrated solar power (CSP) plant. The sun's concave energy trough collector is used in a CSP system to focus sunlight at a single point and generate a large amount of sun's energy and provide it to energy transporting liquid for power generation. The power plant which uses the sun's energy works on the Rankine cycle. Using focused solar radiation, energy transporting liquid is heated at a temperature of great value and then supplied inside a heat exchanger to produce

steam. This high enthalpy superheated gas is used to create electricity through a superheated gas turbine and this steam after undergoing expansion is fed to the condenser for condensation. Using an HTF pump, the cold HTF from the heat exchanger is re-circulated back into the sun's concave energy trough collector.

In a plant that uses focused sun's energy, to flatten out short-term fluctuations in solar energy and extend its operation long after daylight, a Thermal Energy Storage system (TES) is essential. For TES, several elements are being investigated, including phase-changing materials such as nitrates, molten salts, oil, and, most recently, steam as a heat transfer fluid. Necessary characteristics for HTFs are low viscosity, low freezing point, high heat capacity, high thermal stability, and non-corrosive nature. At a given temperature range, when we use the sun's energy for the state's changing substances while performing only the phase change process, we can provide much more storage capacity when compared to the simple heating process of substances. Because the heat capacity of the phase change process (constant temperature) is mostly determined by the heat released by the PCM during phase change, which is significantly larger (approximately 10 times) than the sensible heat, isothermal storage is an important feature. This allows for smaller and less expensive thermal storage systems.

2. STUDY OF SOLAR THERMAL POWER PLANT

Powel and Edgar [1] demonstrated that increasing storage capacity can result in a significant increase in solar share (defined as the fraction of energy supplied by solar means). On cloudy days, a relatively smaller gain in solar share was obtained. The ability to sustain a steady rate of energy produced by utilizing the collection tank in the form of a cushion when compared with the power demand along with available power is the fundamental benefit of thermal energy. By incorporating TES into the system delivers the invaluable benefit of turning an erratic source of energy into a consistent power supply.

Besarati and Goswami [2] suggested an innovative way of optimizing the conventional heliostat layout field. The shadowing and blocking potential of each heliostat causes unnecessary complexity in the calculation. This approach determines which heliostat has the greatest potential for shadowing and blocking, resulting in a considerable reduction in computation power. Numerical techniques were implemented by Peng et al. [3] to anticipate the component and melting point of a hypothetical molten salt. Using a solution theory called conformal ionic, we get the idea to mix fused salt in the quaternary system of reciprocals (Cl,No3, Na) as a heat transfer fluid was investigated. Simultaneously, testing results show

this type of mixture comes with a poor melting point. Furthermore, we recorded optimum stability up to 500-550 °C. However, the duration for which it can be used is limited as we approach higher temperatures. These characteristics result in molten salt with a wide operating range, allowing for efficient storage of thermal energy in PTC power plants. McGovern and Smith [4] investigated the possibility of an optimum degree of solar radiation concentration at which energy conversion efficiency is highest. It was discovered that an increase in the thermal resistance of condenser and receiver, as well as an increase in energy transportation, reduces Carnot heat engine efficiency.

Montes and Linares [5] studied the solar thermal plant coupled with a CO2 cycle operating at supercritical conditions and proposed newly produced energy transfer system that transfers the energy of molten salt into the CO_2 when coupled in a cycle. Substances at constant temperature (phase change only) have low thermal conductivity. Agyenim et al. [6] analysed the various methods to improve the energy transportation from the substance at constant temperature (phase change only) to energy transportation liquids. It was observed that by blending particles with good thermal conducting properties with PCM or introducing metal fins, desired thermal conductivity can be achieved.

Shuangmao et al. [7] researched the heat interactions between HTFs and PCM. It was observed that when PCM is encased into several smaller spherical or cylindrical-shaped capsules, the available surface area for heat transfer of PCM increases manifold, resulting in much-improved energy transportation in energy transportation liquid as well as in the capsule bed. Michels and Paal [8] evaluated that using a storage unit having numerous cascaded PCMs (cascaded Latent heat storage) can provide a better application of the phase change phenomenon, in addition to improved exergy efficiency and a more stable Heat Transfer Fluid (HTF) output temperature.

Desai and Bandyopadhyay[9] analysed the effects of several parameters of a power plant using the sun's energy works similar to the Rankine cycle. It was determined that by increasing the inlet pressure of the turbine the moisture content at the turbine outlet increases, which causes a reduction in the efficiency (at constant entropy or reversible adiabatic process). When the turbine's inlet pressure increases, the input energy transportation to the HTF and the feed water pump rises along with an increment in the heat exchanger exit temperature. Also, pressure at the entrance grows in proportion to the plant size in our ideal turbine.

Suresh et al [10] used a case study to show that combining solar thermal and biomass systems is a potential way to solve resource intermittency and supply reliable electricity to the grid. The study emphasizing the plant sizing observed that a20-foldincrease in plant capacity improved the power blocks efficiency by 16%, reduced the required solar field area by 50%, and reduced the biomass requirement by 50%.

Araujo et al. [11] proposed an arrangement of the normal air standard cycle with the ideal air standard cycle along with a component (which is used for natural gas combustion) are inline attached. A mathematical simulation was executed to achieve all-around dimensional effectiveness for the given system by using the genetic algorithm that yielded a collection of optimum designs that were compared to a reference. Around 7% increment in 1st law, as well as 2nd law efficiency, was observed. An increase of 6.6 % from the base design in the average solar shares was observed. The impact of several variables on the LCOE is explored by Khajepour and Ameri [12], and the major aspects are introduced. The power plant which works on PV can't be used at night even though the value of LCOE is quite low when compared with power plants that work on the sun's energy. Finally, to reap the benefits of both types of plants and to obtain an optimum LCOE, when apower plant that works on the sun's energy is integrated into a PV processor control, then the impact on PV plant sizing in terms of a hybrid system are explored.

The research work by Praveen and Mouli [13] provides a fuzzy non-linear programming-based optimization strategy employing a Genetic algorithm that improves both working and efficiency of the PTC in the power plant that works solely by concentrating the sun's energy having heat storage ability. Unlike traditional methods, the suggested optimization strategy involved mainly three performance parameters that are LCOE, plant efficiency, and capacity factor to achieve optimal plant performance. When this algorithm was applied to a commercial PTC, it was observed that efficiency improved by 16.53 percent. The capacity factor also followed the same trend and was recorded as greater than 60%.

Zaaoumi et al. [14] in their study used three models to calculate the electricity production on an hourly basis for a PTC sun's energy-based power plant. Energy losses of(PTCs) are recorded in the 1st analytical model, while the thermal efficiency of PTCs is calculated in the 2nd analytical model. The 3rd approach is based on artificial intelligence techniques and uses artificial neural networks (ANN). Aseri et al. [15] researched the effect economic feasibility of the power plants which work on the sun's energy. They focused on the time that is used to store the sun's energy and the space required to store such a huge

amount of energy with proper care. They studied various types of the power plant which works on the sun's energy to determine which performs most efficiently according to the capacity required and the hours it is worked upon.

3. CONCLUSION

As a result, from the literature review discussed above the different areas that will be covered in this study are as follows

- A TES system significantly improves the fluctuations that arise from the intermittent nature of solar power.
- Substances transporting energy at constant temperature (phase change) and energy transporting fluid can be enhanced by the method of PCM (by encapsulation) or by introducing the thermally conductive particle in PCM.
- Solar power plants running in hybrid mode offer power at a cheaper price than their standalone counterparts.
- The performance of the PTC with TES can be enhanced significantly by implementing a genetic algorithm.
- Sizing helps in making a power plant using the sun's energy economically feasible.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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