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SOLAR THERMAL ENERGY SYSTEMS

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Abstract

Alternate energy sources are the buzz word in our resource starved world. Solar energy utilization is the prime consideration in research oriented towards alternate sources of energy. In order to remove its carbon footprint humanity is opting for renewable energy and among all renewable energy sources solar shows the most potential. The immense potential of solar power is a known fact; numerous techniques have been developed to harness this energy.

In this paper, concept of Thermal Energy Storage (TES), its analysis as compared to other available solar technologies and its scope in context of Pakistan are discussed. The concept comprises a heliostat field that uses the concentrated solar power (CSP) which is usually utilized to warm up a Phase Change Material (PCM) that can store the vitality for a long period of time. By utilizing exceedingly effective Stirling engine it can create on-demand power 24/7.

The framework as entirety is measured and can effectively be extended to meet the increasing demand. TES has shown great promise in terms of scalability and reliability for generating energy as compared to other solar technologies like solar photovoltaic (PV). In solar thermal available energy can be used directly by absorption of heat and converted into electrical energy through solar panels. Hence Solar thermal is most efficient solution to generate electricity eliminating the need of costly battery banks required in solar PV.

Keywords: energy; solar; photovoltaic; thermal; CSP

1. INTRODUCTION

Storing heat has significant benefits if compares to storing electricity that is less efficient and expensive method. The sun is producing unlimited amount of energy compared to our needs, but we are yet to harness that energy with complete efficiency. The fact is that sun is only available for a limited time at different locations. So the need to have storage capacity is an essential element of the system design. Summing up, it transpires that catering for the various elements of the solar power system the initial cost of the system is on the higher side and induction of battery banks further adds to the operating cost of the system.

For ideal and optimal choice for power on-demand through all hours of the day, Thermal Energy Storage (TES) works best in this case. Thermal solar system uses the solar light and focuses it onto a single point to generate high temperatures. A specially designed storage system which can retain this heat energy for long durations, helps to eliminate the costly battery banks, a comprehensive system design culminating into a compact electrical output is the hallmark of this system.

This paper is organized as follows: Concentrated Solar Power (CSP) technologies and TES concept are presented in Section 2. CSP TES comparison with other solar techniques is discussed in Section 3. Section 4 addresses the CSP system results analysis. Key issues, status and opportunities of CSP technology in context of Pakistan are presented in Section 5. Finally, conclusions regarding overall viability are presented in Section 6

2. Solar Thermal Technologies and Its Working

CSP plants offer a smart means for renewable power generation, near-term and utility-scale generation. In providing sustainable power generation, CSP innovations play a progressively critical part. Mostly all CSP based technologies consist of similar components which are solar based collectors, receivers, and thermal based conversion systems. Based on their collector/receiver geometries they are divided into two general types: point-focus and line-focus. The fundamental idea behind TES is to store solar energy in thermal form rather than directly converting it to electrical energy. One such system consists of using the Stirling engine. Stirling engine is a mechanical engine which converts thermal energy into mechanical energy, which may be used to power a turbine for electricity generation.

2.1 Solar Stirling Engines

The Stirling engines have a high thermal-to-mechanical conversion efficiency and nominally work at 800°C. Solar thermal electric power generating systems have three different design alternatives, as follows;

- Power tower: a solar furnace using a tower to collect the focused sunlight
- Parabolic trough collector: focus systems that concentrate sun rays onto tubes located along the focal line of a parabolic shaped trough.
- Parabolic dishes: focus systems where sun light is redirected into a receiver at the dishes focus Point.

Power tower and parabolic dish are point focus geometries while most commonly line focus geometry consist of parabolic trough design. The Power tower having a single receiver located at top of the tower bounded by fields of two-axis tracking mirrors also known as heliostats used to redirect and focused sunlight onto the receiver. The parabolic dish having a modular design with its two axis tracking system has a point-focus concentrator with a receiver/generator situated at its focal point. In case of parabolic trough design, single-axis based collector field with parabolic mirrors used to redirect and focus the sunlight to a focal line.

Due to higher thermal conversion efficiency and greater stored energy densities, Power towers in particular are thought to have more prominent potential for wide-scale implementation and usage. These both features exist due to their higher operating temperatures.

2.2 Stirling CSP System Design and Concept

Solar thermal solution consists of proven technology in combination with a storage innovation which is more efficient, less complex and reliable as compared to previous techniques. The basic mechanism of TES concentrated solar plant (CSP) is to direct and concentrate sunlight using a heliostat field, which is simply an arrangement of reflecting mirrors setup in the most optimal way, towards a power unit as shown in Figure.1.

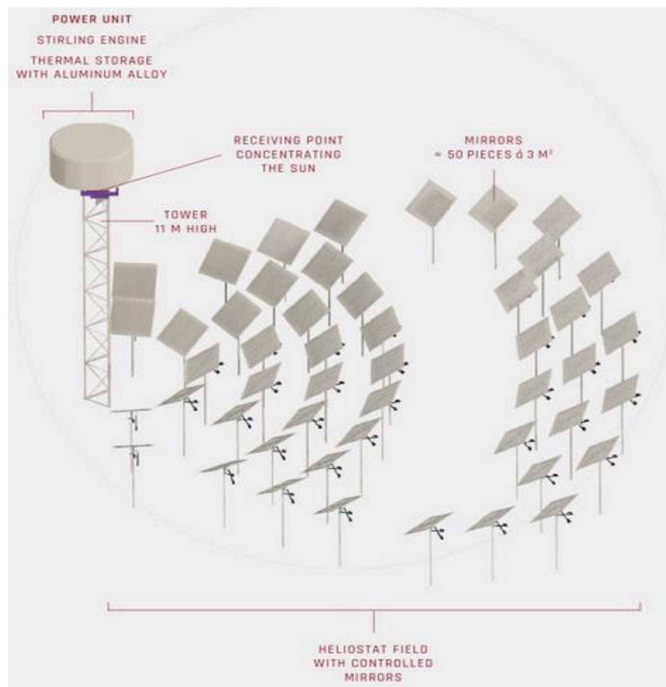

Fig.1. CSP Working Concept.

Framework is set up by a fan-shaped heliostat field having an average 50 controlled mirrors of 3m² which are fitted in up to nine columns. Depending on the local conditions their size can be readjusted and fine-tuned. The mirrors reflect sun beams up to the control unit which contains the heat storage and the Stirling engine system, positioned on eleven meters high tower. Power unit is responsible for both storing and converting the solar energy; it depends on two parts a phase changing material (PCM) and a Stirling engine. Figure.2 shows the two cylinder type Alpha Stirling engine fully optimized for target storage temperature with long service interval up-to 6000 hours.

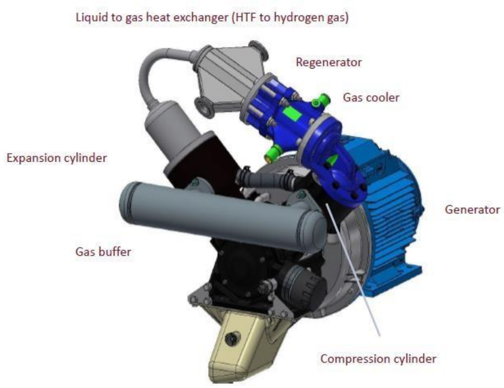

Fig.2. Stirling Engine.

The power unit is storing unit of the CSP, it is made up of a metal alloy (usually aluminum) which is molten by sunlight and retains the thermal energy in its molten form. The power unit is connected with the Stirling engine through an energy transferring mechanism as shown in Figure.3.

Fig.3. Power Unit.

With focused solar heat a Phase Change Material (PCM) is melted within the container with the direct illumination of the container wall. The heat is transferred from the PCM to a heat transfer fluid (HTF) during discharge. Heat from the thermal storage to the Stirling engine heat exchanger is transferred with HTF where working-gas in Stirling engine is heated and cooled off by ambient air, and by this means runs the engine. With its compact design it can fits in standard container and easy installation with integrated units. Unit can produce up to 13 kW electrical at nominal power. It is designed for 13h storage at nominal power enabling 24/7 capacity. With its long service interval of 6000h it keeps overall service costs low.

3. Comparative Analysis of Solar PV Vs Solar Thermal

TES has several advantages over a photovoltaic (PV) system. The Stirling engine operates at almost twice the efficiency of a PV cell. As compared to conventional CSP system, Stirling engine based systems conversion rate to electricity is considerably higher. Maintenance is kept to a minimum with its reliable and highly robust design. The TES is cheaper than a PV system as the components do not require highly complex and sophisticated methods to be manufactured. The maintenance is also negligible compared to a PV system. As TES operates by healing up the PCM and then converting it to electrical energy; we get a stable energy supply, whereas a PV system converts energy on the spot and depends on the intensity of sunlight we get a ragged energy supply. And lastly the storage system is also more reliable and efficient as a solar battery losses its storage capacity over time TES's does not. This system doesn't rely on any continuous supply of a storage media like salt or water unlike other solutions. They only need solar energy when system installation is done.

4. Stirling CSP System Analysis

CSP plants provide saleable utility and dispatch able electricity to the power grid which makes them unique among other renewable technologies. By dispatch able delivery it means to meet the utility load demand, power is reliably available when it's needed. This feature occurs due to the integration of TES into the power plants. For longer time scales, these power plants are more cost effective as TES allows CSP plants to generate electricity well into the evening hours when electricity is highly valued. TES permits more noteworthy utilization of turbine and other power-block components. These features give economic and financial incentive for the expansion of TES. Without TES, CSP solar power becomes an irregular/intermittent power resource which depends on daylight availability. In expansion to improving CSP dispatch ability, TES allows increased deployment of renewables in general by adding flexibility to a grid with photovoltaic and wind power systems.

5. Solar Thermal Scope in Pakistan

Pakistan future economic growth puts high demand on the grid. The industrial activities cannot sustain electrical outages and private sector invests in back-up generation. Two third of rural population do not have access to grid electricity supply. Pakistan is ideal place for solar energy with strong solar radiation reaching 2500 kWh/m2/year. But the question arises what’s the scope of solar thermal in context of Pakistan directing the attention is TES eligible in Pakistan?

Well the answer is yes it is, Pakistan just happens to be among the most thermogenic countries, and Pakistan is also full of places eligible for thermal systems for example most of Baluchistan, sizeable region of Sindh and southern Punjab even the northern more cooler areas can produce a sufficient amount of energy. Plus, almost entire of Pakistan is a market for TES system from residential to industrial sector, because currently Pakistan is entirely dependent on fuel imports to meet its energy requirements and this in turn creates fluctuating energy rates, thermal systems shall not only stabilize and possibly cheapen energy rates but also reduce the country’s pollution.

One might ask if thermal systems a so great for Pakistan then why aren’t there any such systems yet? Well there are three main factors political, educational and economical. Investors have a higher risk in Pakistan; therefore want more returns than usual, thus higher tariffs. But all of this is concerned with PV-systems not thermal systems. This is where politics comes into play due to the failure of the bigger solar projects like 100MW Bahawalpur plant the government’s policy on investing in the renewable sector has changed. But despite the entire obstacle Pakistan must in the near future opt for renewable energy and TES would be its best choice. Government of Pakistan has to take strong policy and marketability measures that will establish and strengthen this environment friendly technology in the country.

6. CONCLUSIONS

CSP technologies need to make significant cost and performance improvements to keep the initiative cost at reliable rate. In addition, TES plants will need to deliver reliable, consistent power during daylight hours and into the evening which makes them an essential component of next-generation power plants. Meeting the cost target will require significant performance improvements and cost reductions for all components and subsystems that make up a CSP plant. Also with respect to TES, new heat-transfer fluids and storage materials will be required which works efficiently at higher temperature and have a capability of high stored energy density due to their high heat capacities and multiple phase changes. Thermochemical storage may provide the ultimate solution to the TES challenge if a suitable system can be identified and developed for high-temperature CSP applications. Efforts will be made to highlight the intricacies involved in the thermal solar system. At present the system is new to Pakistan and a concerted effort will be made to have the dissipation of the knowledge regarding this technology.

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