StorEnergy – A Review of Non-Imaging Optics and Thermal Storage as Tools to Improve Solar Generation

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Abstract

With the effect that the fossil fuels industry has had in the environment since its conception, and the dire state that we have reached in terms of pollution, as the international community has agreed upon, the rise of projects that aim to improve the current systems and technologies related to alternative energies and exploitation of renewable sources. StorEnergy's goal is to implement new concepts to Concentrated Solar Power generators to not only decrease their cost to a competitive level, but also revolutionize the industry in terms of generation and storage efficiency.

***Index Terms* – Solar generation, non-imaging optics, renewable energy, thermal storage.**

I. INTRODUCTION

Something that has defined the recent years of technologic advancements is the focus towards implementing systems and devices that mitigate the effect that over two centuries of industry have had in a number of aspects in our lives, out of which the most concerning is the state of the environment.

Since the early days of burning coal for heat, transportation and energy through the discovery and exploitation of fossil fuels, the levels of pollution, especially in the air, had increased at an alarming rate. It was until the signing of the Paris Agreement on 2016 that the overall focus shifted towards the development, widespread and improvement of new and existing forms of renewable technology, with aims of controlling the increase in global temperature below 2 °C above pre-industrial levels[1].

With this in mind, there has been a resurgence in the field of renewable energy to improve the cost-efficiency and accessibility of the required technology to build self-sufficient networks that take advantage of the natural resources available in different regions of the world. In this document, we will cover how StorEnergy, a project founded in 2015 in Serbia, aims to improve the current accepted systems of solar generation of electric energy by enhancing the collection and conversion of energy and the storage measures, in order to create an entire ecosystem of efficient and sustainable generation.

II. BACKGROUND

Solar generation is one of the least used systems of alternative energy in the world, but it has seen an incredible growth in the last few years. According to the Center for Sustainable Systems in the University of Michigan, as of last year, solar generation represented 9.1% of the total energy consumption in the U.S.[2], and a study by the BP Statistical Review of World Energy shows that the total solar generation in the world has increased by more than 700% in the last 20 years[3], becoming the third most used behind hydropower and wind.

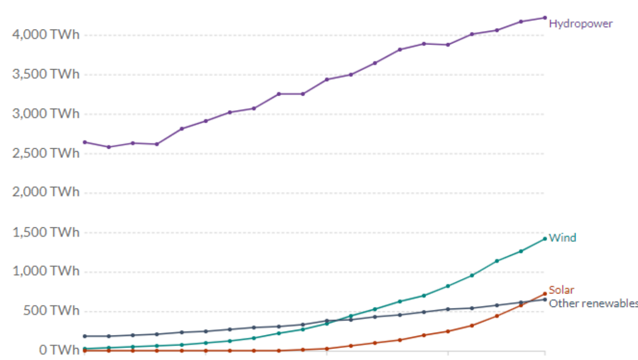

Figure 1. Renewable energy generation by source from 1990 to 2019.

The process to generate electricity usually falls in one of two categories: photovoltaic cells (PV) or concentrating solar power (CSP). The first one represents the image that is commonly associated with “solar generation”: large, dark-colored panels that use the light of the sun to separate electrons from a semiconducting material, which are then set to flow and an electric current is created, captured, transformed and distributed to power networks. The latter is, in theory, a simpler process. Using different configurations of mirror and other reflective surfaces, Concentrated Solar Power (CSP) systems convert the sun’s energy into a high-temperature heat, which is then used to heat water and power a steam turbine.

One of the main benefits of CSP is that it directly generates alternate current (AC), so it skips the step of conversion associated to photovoltaic cells than only generate direct current (DC). However, PV has a history of being cheaper than CSP, and its prices have dropped even more in recent years, which makes it the most attractive option for investors and organizations. This makes it so the current main goal for CSP projects is to increase the efficiency of this system, by either increasing the generation and storage capacity or reducing manufacturing and maintenance costs.

III. StorEnergy’s Proposal

Founded by physicist Marko Vuksanovic, StorEnergy aims to bring CSP technologies a step closer to PV systems by implementing concepts of non-imaging optics and developing new capturing and storage systems to not only increase the generation capacities of their system, but to also improve in terms of modularity, scalability and stability[4].

III.a. Concentrator

The first great improvement that StorEnergy proposes to current CSP systems is the implementation of a field known as non-imaging optics to the mirror arranges in their concentrators. Unlike traditional optics, which are based in parabolic lenses to create a reliable image, non-imaging optics are solely focused

Figure 3. StorEnergy MK10 concentrator, located at a Siemens facility in Serbia.

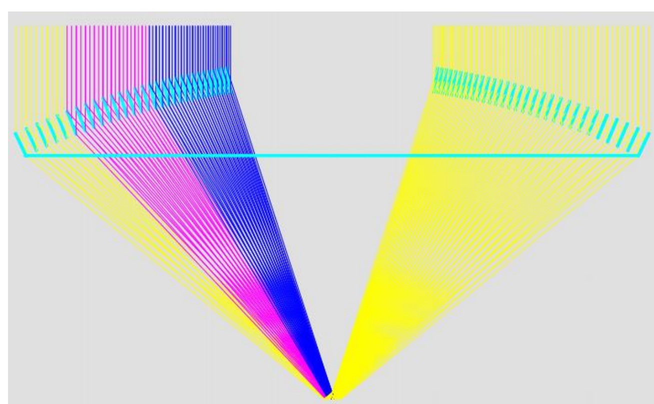

Figure 2. Approximate representation of non-imaging optics along a mirror used to concentrate solar radiation into a focus point.

on concentrating as much energy as possible, which brings a variety of advantages including[4]:

- Wider acceptance angles
- Less precise tracking
- Higher temperatures
- Lower thermal losses

All of these advantages translate directly into a more efficient and cost-effective system, while being mounted in a platform built with accessible materials that allows for easy tracking and implementing other features like self-cleaning mirrors and a modular design, turning StorEnergy's concentrators into a high-tech, state-of-the-art solution for solar generation that reaches temperatures up to 3 times higher than other CSM technologies.

III.b. Exergy Receiver

The second big development from StorEnergy is the creation of a new type of receiver, since the current technology does not reach a temperature high enough to take full advantage of their new storage system (explained below in section *III.c.*).

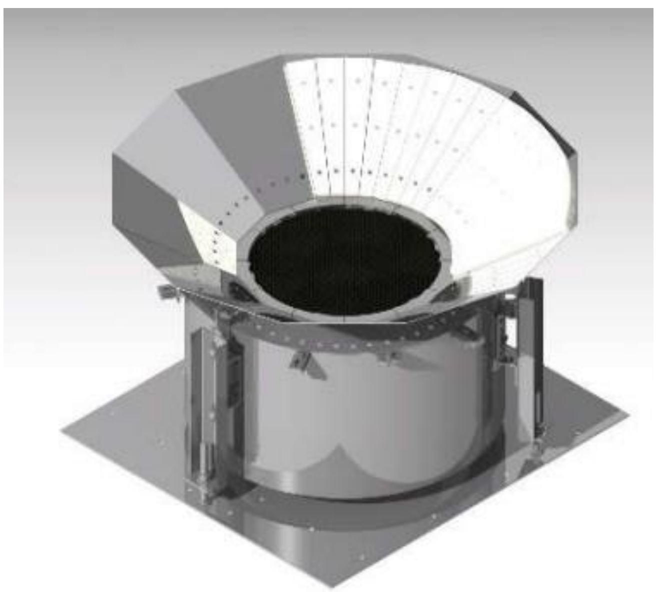

Figure 4. Digital representation of the Exergy Receiver. Note the ceramic array in the center and the conic design of the top further concentrates the rays coming from the structure.

This new model is built in a case of stainless steel and uses silicon carbide ceramics which absorb the radiation focused by the concentrator. Ambient air is then drawn into the receiver aperture and flows through the ceramics, absorbing the heat and achieving temperatures close to 1000 °C (1832 °F).

StorEnergy CSP with Storage	Other CSP with Storage
Cost estimate $3,700/kW (16-hour storage)	Cost estimate $4,500/ kW (16-hour storage)
Annual capacity up to 75%	Annual capacity 65%
Constant flat predictable output, guaranteed. Can be used as base load	Output can fluctuate with cloud cover and time of day
24/7 production, guaranteed	24/7 production with gas burners
Temperatures at focal point of 3000°C	Temperatures only up to 1000°C
Low build cost	High build cost
Modular design	Non modular
By-product of waste heat can be used for water desalination, cooling etc	No waste by-product
Self-cleaning mirrors	Manual cleaning
Can withstand high wind speeds	High wind speeds are a problem
Land coverage 25%	Land coverage between 15% - 20%
Lower maintenance costs	Higher maintenance costs

Table 1. Comparison between StorEnergy's CSP technology with other currently available CSP systems. Note the potential increases in annual capacity, operational temperatures, and land coverage, while cost estimates are reduced.

III.c. Thermal Storage

As a final point to improve compared to current CSP technologies, StorEnergy felt the necessity to develop a storage system that could make the best use of the higher temperatures reached by their new system. The solution came in the shape of a new iteration of Solid-State Thermal Storage (SSTS), a principle used in regenerators since the early days of the steel and glass industries.

Regenerators were first implemented for blast furnaces and patented in 1857 and have been used since then with little to no changes to their design. They function by exchanging heat continuously from a process fluid to a solid heat storage, which then transfers heat to a second process fluid[5]. By modifying the materials used to a modern system based on aluminum oxide, construction steel and rock wool, StorEnergy achieved the creation of a storage system that is not only cheaper than other alternatives (like molten salt storage or batteries), but also has a longer lifespan and represents little to no risks to workers' health or the environment in comparison.

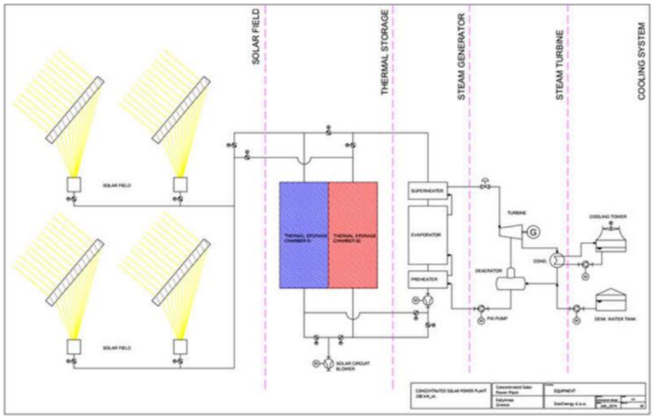

Figure 5. Diagram of the complete operational cycle of StorEnergy's proposed solution.

IV. Competitiveness

The previously mentioned characteristics turn StorEnergy's system into an alternative that can drive CSP to levels of efficiency and costs similar to those of not only PV systems, but also competitive with systems like natural gas reactors.

StorEnergy has already built two fully operational prototypes in Serbia, one for their smaller MK6 concentrator that currently operates in a swimming pool and spa complex in Belgrade replacing their connection to the main electricity network, and another for their larger MK10 concentrator, which replaced natural gas generators in a paint shop in Sobovica. This shows the potential of their product to cover the needs of a wide variety of clients, depending on their requirements of energy and the available extension of land.

With proven examples of the functionality of their product, and plans to develop a larger MK15 concentrator and to build a 200kW by 2021, with completed designs and designated lands for both projects, StorEnergy has the potential to become one of the most important names in the near future of solar energy, in a world that appears to need these alternatives more every day.

StorEnergy Storage	Molten Salt	Battery
Cost - $10 per kWh	$60 per kWh	$300 per kWh
Storage life >50 years	20 years	7 years
Nonhazardous	Corrosive and difficult to handle	Volatile, need to be maintained under specific climatic conditions
Air as transport fluid	Molten salt	
Solid state	Liquid	Solid
	Requires gas burners to keep the salt molten	

Table 2. Comparison between StorEnergy's storage system with two alternatives: molten salt and batteries. Note the increase in lifespan while both costs and risks are diminished.

VI. References

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