Challenges and Opportunities for Solar Tower Technology in India

by Sukanta Majhi, EE 4th Year

Solar Tower (ST) technology, which is also referred to as Central Receiver Technology, uses a large number of heliostats having a dual axis control system (one about the elevation axis and the other about the azimuthal axis). These heliostats reflect direct beam solar radiation (impinging on their surface) to a stationary receiver located at the top of a tower. In the receiver, Heat Transfer Fluid (HTF) gains heat and transfers this thermal energy to the power block to generate electric power. This technology has evolved over the past 20 years. Even though it dates back to the late 1980s, over the past decade, a considerable increase in the number of operational ST plants has been observed. The capacity of plants under construction indicates that the growth of ST technology is on par with that of Parabolic Trough (PT) technology.

Early designs used these focused rays to heat water, and used the resulting steam to power a turbine. Newer designs using liquid sodium have been demonstrated, and systems using molten salts (40% potassium nitrate, 60% sodium nitrate) as the working fluids are now in operation. These working fluids have high heat capacity, which can be used to store the energy before using it to boil water to drive turbines. These designs also allow power to be generated when the sun is not shining.

Components Used

The major components involved in ST systems are listed below:

- Heliostats
- Receivers
- Heat Transfer Fluid
- Power Cycle

Challenges for ST Technology Deployment in India

India has limited experience in the development of power tower systems. Apart from a couple of small scale demonstration plants, there have been no plants in the pipeline for India. ACME company in India have partnered with e-solar, USA in developing a 2.5 MWe (to be scaled up to 10 MWe) tower plant in Bikaner, Rajasthan. The heliostat field for the 2.5 MWe plant set up utilises small size flat mirrors of 1.16 m². The advantage of small size heliostats is that they are easy to handle and install but a major disadvantage is that they require more number of controllers for tracking. The plant of 2.5 MWe was commissioned in 2010. However it is not running to its full capacity. Some of the possible problems were attributed
to lack of sufficient Direct Normal Irradiance (DNI), difficulties in tracking and accumulation of dust on the mirror.

Sun Borne energy is setting up a 1 MWth ST system, with support from Ministry of New and Renewable Energy (MNRE), Government of India, at the National Institute of Solar Energy (NISE), Gurgaon. The primary aim of this demonstration plant is to devise a method to optimize the heliostat field (using Titan tracker heliostats) using volumetric air receiver while simultaneously having a provision for thermal storage. This plant is planned to be set up using regional indigenous resources for most of the system components.

The challenges for using ST technology in India are as follows:

- Dust on the heliostats reduces its life and efficiency. Most of the areas in India with abundant solar irradiation (for example, Gujarat and Rajasthan) are areas which are prone to very high dust factors. In these cases maintenance of each heliostat is of prime importance which is not an easy task in a field with thousands of mirrors.
- There are only three suppliers of molten salt HTF globally, namely, SQM, Haifa Chemicals and Durferrit Salts and Auxiliary Products. Lack of domestic suppliers of HTF is one of the main challenges in implementing ST plants with storage (as molten salt storage is the most efficient presently). This is due to the fact that the major cost contributor of any storage system is the storage medium.
- Absence of an established supply chain for the main ST components is also a major challenge. One of the most important components of ST technology, namely, the receiver, does not have even a single indigenous manufacturing unit in India. At the international level as well, there are only a handful of manufacturers resulting in extremely costly receivers.
- Unlike the parabolic trough which has a well-established supply chain and standards, ST, due to its variants in technology has seen limited suppliers as well as standards. Furthermore there is no benchmarking for reliability testing of ST components. Due to this, market acceptability of in-house manufactured components reduces. As a result of the lack of demand, even components for which a domestic market can be set up, the question of sustainability looms at large.
- There exists no policy support or incentive from the government for setting up of ST plants as well as promoting hybridization. This is also a huge challenge which currently hinders the implementation of ST plants in India.

Opportunities for ST Technology India

India is situated between 8°N to 37°N latitude and 70°E to 96°E longitude. For these geographical coordinates, the sun is in the southern side for a larger part of the year and on the northern side for a smaller duration annually for any particular location. Based on this geographical positioning, the opportunities for ST deployment in India are as follows:
High temperatures in the range of 300 to 565°C are possible with the use of suitable HTFs. The presence of higher operating temperatures results in a higher power cycle efficiency as well as number of hours of storage.

India has a good solar zone with high solar resource (DNI values) almost throughout the year which has the potential to be tapped. The best sites in India, receive around 2100 kWh/m²/annum which is at par with most of the existing tower plants. This sets the benchmark for commercial viability of this technology under Indian conditions.

The land requirement for ST plants can be fulfilled by utilising the huge wastelands present in India. Approximately 472200 km² of wasteland is available in India (55). Even if 1% of this land is utilised for solar projects the potential goes beyond India’s current installed capacity. Hence land constraint is not a deterrent to growth of ST technology in India.

Since ST technology does not require land of constant slope, terrains (of up to 5° difference) need not be filled in or levelled. This reduces the construction time and installation (set up) cost.

The manufacture of low cost heliostats is possible as there is considerable availability of low iron content glass in India which is necessary for the fabrication of heliostats. Further, the structural designing and manufacture of heliostat support structure, the requisite drive mechanisms and tower can be accomplished in India at lower costs.

Establishment of an indigenous market for receiver technology, external cylindrical and cavity receivers can be done since for both these technologies, once the specifications are known, the manufacturing and fabrication process is relatively straightforward.

Due to availability of biomass resource in India hybridization with biomass can be achieved in order to increase the Plant Load Factor (PLF) of the plants.

The total capacity of grid connected solar projects in India currently stands at 2632 MW as on March 31st, 2014. The contribution from CSP in Phase-1 has been very less as compared to the contribution of Photovoltaic (PV) based systems. Some of the reasons for the slow deployment of CSP in India are: availability of solar resource data, delay in importing key components of the plant (mirrors, HTF etc.), obtaining financial closure etc. However, CSP is expected to play a significant role in the coming phases of the Jawaharlal Nehru National Solar Mission (JNNSM), given the mandate of 30% capacity addition from CSP. Assuming that 30% of the target could be tapped from solar thermal technologies, the CSP share will be around 6000 MW. Based on present maturity levels of ST technology, it is assumed that it can contribute around 30% of the CSP share resulting in approximately 1800 MW of installed capacity by 2022. Using a mix of cavity and external cylindrical receiver technologies, the approximate land required per MW is about three hectares resulting in a land requirement of 54 km² for the 1800 MW target.
# Existing Solar Tower in Different Countries

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Country</th>
<th>Developer</th>
<th>Capacity (MWe)</th>
<th>No of Heliostats</th>
<th>Heliostat Aperture Area (m²)</th>
<th>Tower Height (m)</th>
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<tr>
<td><strong>OPERATIONAL</strong></td>
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Table: Basic information on Existing Solar Tower Plants
Fig. 1: Heliostat Field at Gemasolar Plant, Spain

Fig. 2: Heliostat Field at Julich Plant, Germany

Fig. 3: Heliostat Field at Sierra Sun Tower, USA

Fig. 4: Heliostat Field for PS 10 and PS 20, Spain
Magneto Hydro Dynamic (MHD) Power Generation: The Future Power Generation

by Dibendu Patra, EE 4th Year

Since a decade the demand for electricity is increasing at alarming rate and the demand for power is running ahead of supply. The present day methods of power generation are not much efficient & it may not be sufficient or suitable to keep pace with ever increasing demand. The recent severe energy crisis has forced the world to rethink & develop the Magneto Hydro Dynamic (MHD) type power generation which remained unthinkable for several years after its discovery. It is a unique & highly efficient method of power generation with nearly zero pollution. It is the generation of electric power directly from thermal energy utilizing the high temperature conducting plasma moving through an intense magnetic field. In advanced countries this technique is already in use but in developing countries it’s still under construction. Efficiency matters the most for establishing a power plant. MHD power plants have an overall efficiency of 55-60% but it can be boosted up to 80% or more by using superconducting magnets in this process. Whereas the other non conventional methods of power generation such as solar, wind, geo-thermal, tidal have a highest efficiency not more than 35%. Hence by using MHD power generation method separately or by combined operation with thermal or nuclear plants we hope to bring down the energy crisis at a high rate.

History

- The conversion process in MHD was initially described by Michael Faraday in 1893. However the actual utilization of this concept remained unthinkable.
- The first known attempt to develop an MHD generator was made at Westing house research laboratory (USA) around 1938.
- The first MHD-steam power plant U-25 was put into operation was of 75MW unit in USSR of which 25MW is generated by MHD means in early 1970’s & this work has been progressing fruitfully.
- The first pilot plant was set up in Tiruchirapalli (by BARC). A five year plan was signed in February 1975 which included 22 spheres of applied science and technology connected with the MHD energy generation.
- The Japanese program in the late 1980s concentrated on closed-cycle MHD.
- In 1986, Professor Hugo Karl Messerle at The University of Sydney researched coal-fueled MHD.
- The Italian program began in 1989 with a budget of about 20 million $US, and had three main development areas:
  - MHD Modeling.
  - Superconducting magnet development.
**Principle**

MHD power generation process is governed by M. Faraday’s law of Electromagnetic Induction. (i.e. when the conductor moves through a magnetic field, it generates an electric field perpendicular to the magnetic field & direction of conductor). The flow of the conducting plasma through a magnetic field at high velocity causes a voltage to be generated across the electrodes, perpendicular to both the plasma flow and the magnetic field according to Flemings Right Hand Rule.

![Magnetohydrodynamic Power Generation (Principle)](image)

The Lorentz Force Law describes the effects of a charged particle moving in a constant magnetic field. The simplest form of this law is given by the vector equation.

\[ F = Q \cdot (V \times B) \]

where
- \( F \) is the force acting on the particle.
- \( Q \) is the charge of the particle,
- \( v \) is the velocity of the particle, and
- \( B \) is the magnetic field.

The vector \( F \) is perpendicular to both \( v \) and \( B \) according to the right hand rule.

![Magnetohydrodynamic (MHD) Electricity Generation](image)
Advantages

➢ The on and off time is about second.
➢ There are no moving parts, it is very reliable to use.
➢ The MHD generator has high thermal efficiency.
➢ It is a direct conversion device.
➢ They have a better fuel utilization
➢ It can produce large amount of power.
➢ The size of the plant is small.

Disadvantages

➢ They need high pure superconductor.
➢ Working temperature is very high as about 200°K to 2400°K.
➢ The loss of power if very high
➢ The components get high corrosion due to high working temperature.

Application

➢ The MHD generators are used to power submarines and aircrafts.
➢ Electrical power production for domestic applications.
➢ They are used in a pulsed detonation rocket engine (PDRE) for space application.
➢ They can be used as power plants in industry and uninterrupted power supply Systems.
Nano Technology Fuel Cells
by Twinkle Hazra, EE 4th Year

A fuel cell is a device which converts a fuel directly into electricity in an electrochemical reaction. This is in contrast to most methods of generating electricity, which use the heat from burning fuel to generate electricity mechanically. Fuel cells have the potential to be an incredibly efficient power source. They can theoretically operate on a wide range of fuels, and the technology can be scaled from portable fuel cells in laptops, up to huge stationary installations to power data centres. There are many limitations preventing fuel cells from reaching widespread commercial use, however. Expensive materials such as platinum are needed for the electrode catalysts. Fuels other than hydrogen can cause fouling of the electrodes, and hydrogen is costly to produce and difficult to store. The most efficient types of fuel cell operate at very high temperatures, which reduce their lifespan due to corrosion of the fuel cell components. Nanotechnology may be able to ease many of these problems. Recent nanotechnology research has produced a number of promising nanomaterials which could make fuel cells cheaper, lighter and more efficient. Fuel cell provides a clean source of power in comparison to other sources like hydro, thermal, nuclear etc. It is known as cell because of some similarities with primary cell. It has two electrodes and an electrolyte between them which produces dc power. However, active materials are supplied from outside unlike conventional cell. A static device which converts the chemical energy of fuels into electrical energy. First crude fuel cell was developed in 1839. It was developed by welsh physicist William Grove. First commercial use of fuel cells was in NASA space programs to generate power for probes, satellites and space capsules.

Fuel Cell

- A fuel cell is an electrochemical conversion device. It produces electricity from fuel (on the anode side) and an oxidant (on the cathode side), which react in the presence of an electrolyte.
- In a fuel cell the fuel is also oxidized but the resulting energy takes the form electricity.

Anode side: \(2\text{H}_2 \rightarrow 4\text{H}^+ + 4\text{e}^-\)

Cathode side: \(\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}\)

Net reaction: \(2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}\)
Carbon Nanotubes

- Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure.
- Since the diameter of a nanotube is on the order of a few nanometers (approximately 1/50,000th of the width of a human hair)
- The chemical bonding of nanotubes is composed entirely of sp2 bonds, similar to those of graphite.
- It also makes the onboard hydrogen storage easier.

![Fig. 1: Carbon Nanotube](image)

Working

- Hydrogen from carbon nanotube is entered into the fuel cell.
- Hydrogen reacts with oxygen in polymer electrolyte membrane and the chemical energy is produced.
- In fuel cell, chemical energy is converted into electrical energy.
  \[
  \text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}
  \]
  \[
  2\text{H}_2 \rightarrow 4\text{H}^+ + 4\text{e}^- 
  \]
- Electrolysis of water is the decomposition of water (H\textsubscript{2}O) into oxygen (O\textsubscript{2}) and hydrogen gas (H\textsubscript{2}) due to an electric current being passed through the water.
- Water is obtained from the reaction.
- The byproduct water is used to regenerate the hydrogen by the process of electrolysis.
- 2\text{H}_2\text{O}(l) \rightarrow 2\text{H}_2(g) + \text{O}_2(g) Therefore, we plan to modify the existing design to enhance the efficiency.
Methods

Scheme 1

\[
\text{Multi-Wall Carbon Nanotube (MWCNT)} + \text{Nano Catalysts (Ag, Au, Pt, Pd and Cd)} = \text{Multi-Wall Carbon Nanotube (MWCNT)}
\]

Scheme 2

\[
\text{MWCNT+Graphene (9:1 Ratio)} + \text{Nano Catalysts (Ag, Au, Pt, Pd and Cd)} = \text{Multi-Wall Carbon Nanotube (MWCNT)}
\]
Merits

- It is eco-friendly, noiseless and has no rotating part.
- It is a decentralized plant.
- Because of modular nature, any voltage/current level can be realized.
- High efficiency up to 60% as compared to conventional which has 30%.
- No transmission and distribution losses.
- Wide choice of fuel for fuel cell.
- In addition to electric power, fuel cell plant also supply hot water, space heat and steam.
- Requires less space.

Demerits

- Cost to implement a fuel cell system exceeds $4,000 per KW.
- Feasible way to produce, ship, and distribute hydrogen.
- Lack of Hydrogen Infrastructure.
- Low lifetime of fuel cell.