Continuous Renewable Energy Generation by Solar Radiation

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ABSTRACT

The world is seeing a changing trend from conventional cooking system to most reliable and predominant solar cooking system which is going wild commercially. This ideal attempts a heat energy storage for power generation in which a Molten Salt is proposed for Thermal Energy Storage for Concentrating Solar cooking systems. In the concept numerous large, flat, sun-tracking mirrors, known as *trough* are used which focuses sunlight onto a receiver at the top of a tall tower. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. The technology uses many large, sun-tracking mirrors commonly referred as heliostats to focus sunlight on a receiver at the top of a tower. The enormous amount of energy, coming out of the sun rays, concentrated at one point (the tower in the middle), produces temperatures of approximately 550°C to 650°C. The gained thermal energy can be used for molten salt, which saves the energy for later use. High temperature heated water converts to super heated steam, which is used to move the turbine-generator. This way thermal energy is converted into electricity.

Keywords— ***Concentration Solar Power (CSP), Heliostats, Molten Salt, Thermal Energy Storage Non pollutant power technology.***

I. INTRODUCTION

Solar technology has its own history which started from 7th Century B.C. The first commercial installation of solar-thermal water heater took place in the 1979 at the White House in USA by President Jimmy Carter.

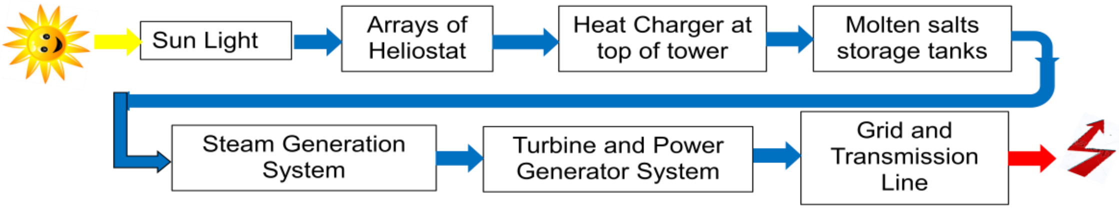

Fig. 1: Block diagram of thermal energy storage and power generation

However, higher fuel prices, and increased demand for energy independence, and a desire to mitigate the effects of greenhouse gases have led India and other countries to invest in solar power generation. The investment led to Today's solar-powered buildings to solar powered vehicles. The question of storing of the heat generated by sun's energy was solved by Molten-salt thermal energy storage in which liquid salt at 290ºC is pumped from a 'cold' storage tank through the receiver where it is heated to 565ºC and then on to a 'hot' tank for storage. When power is needed from the plant, hot salt is pumped to a steam generating system that produces superheated steam for a conventional Rankine cycle turbine/generator, the salt is returned to the cold tank where it is stored and eventually reheated in the receiver. Fig. 1 is a schematic diagram of the primary flow paths in a molten-salt solar power plant. Determining the optimum storage size to meet power-dispatch requirements is an important part of the system design process. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 15 hours.

The heliostat field that surrounds the tower is laid out to optimize the annual performance of the plant. The field and the receiver are also sized depending on the needs of the utility. In a typical installation, solar energy collection occurs at a rate that exceeds the maximum required to provide steam to the turbine. Consequently, the thermal storage system can be charged at the same time that the plant is producing power at full capacity. The ratio of the thermal power provided by the collector system (the heliostat field and receiver) to the peak thermal power required by the turbine generator is called the solar multiple.

Concentrating solar power (CSP) systems which use concentrated sunlight to run steam turbines have been receiving a lot of attention in recent years as a potential low cost alternative to photovoltaic cells. Like all solar technologies the power delivery profile of CSP depends on the availability of sunlight. Adding energy storage to such systems increases their power delivery flexibility. Unlike PV cells CSP systems can potentially store thermal energy rather than electrical energy giving them a cost advantage in this area because sensible heat storage has lower cost than electrical storage in batteries. This paper propose to use a mixture of nitrate salts as the thermal storage medium for power tower concepts using single-phase receiver fluids, the best of which was a 60% sodium nitrate 40% potassium nitrate molten salt.

The primary advantages of molten nitrate salt include a lower operating pressure and better heat transfer (and thus higher allowable incident flux) than a water/steam receiver. This translates into a smaller, more efficient, and lower cost receiver and support tower. In addition, the relatively inexpensive salt can be stored in large tanks at atmospheric pressure, allowing 1) economic and efficient storage of thermal power collected early in the day for use during peak demand periods; 2) increased plant capacity factor by over sizing of the collector and receiver systems with storage of the excess thermal energy for electricity generation in the evening; 3) isolation of the turbine-generator from solar energy transients; and 4) operation of the turbine at maximum efficiency. If necessary, a molten salt system can be hybridized with fossil fuel in a number of possible configurations to meet demand requirements when the sun is not shining.

The technical potential and the cost of renewable energy sources at different is illustrated in fig. 2. As can be seen, the focus was mainly put on power and heat.

A) Hydroelectric power B) Wind power C) Solar thermal power D) Geothermal Energy E) Solar photo-voltaic, PV F) Biomass G) Wave and tidal systems H) Others

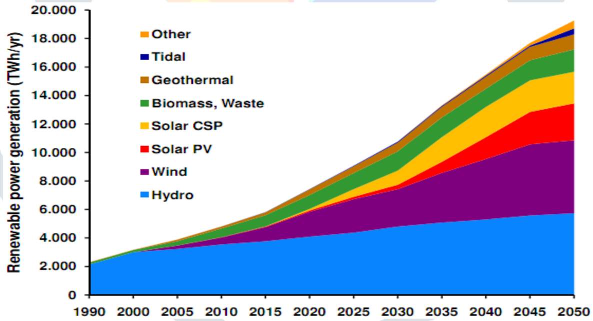

Figure 2 Growth of Renewable in the India and around the world.

surface vibrations, but passive method does not require external power, but this method requires a special geometric surface. The combination of both active and passive method technique is used in the compound method. Only passive techniques are discussed here. The passive method for heat transfer is based on two main strategies those are disturbing thermal barrier and creating turbulence flow. The destruction and restart of the boundary layer ensures that increase of heat transfer, making boundary layers instead of the constant limits. To do this Vortex generators can be used such as ribs, ridges, dimples or edges.

II. BACKGROUND AND SYSTEM DESCRIPTION

Solar power tower convert sunshine into clean electricity. The technology uses many large, sun-tracking mirrors commonly referred as heliostats to focus sunlight on a receiver at the top of a tower. The enormous amount of energy, coming out of the sun rays, concentrated at one point (the tower in the middle), produces temperatures of approx. 550°C to 1500°C. The gained thermal energy can be used for heating water or molten salt, which saves the energy for later use. Heated water converts to steam, which is used to move the turbine-generator. This way thermal energy is converted into electricity. Water is the oldest and simplest way for heat transfer. But the difference is that the method in which molten salt is used, allows storing the heat when the sun is behind clouds or even at night.

The 10-MWe Solar One Pilot Plant, which operated from 1982 to 1988 in Barstow, California, was the largest demonstration of first-generation power-tower technology (Radosevich,1988). During the operation of

Solar One and after its shutdown, significant progress was made in the U.S. on more advanced second-generation power-tower designs. The primary difference between first and second-generation systems was the choice of receiver heat-transfer fluid. Solar One used water/steam, and the second-generation designs in the U.S. used molten salt. The molten-salt power tower design decouples the solar collection from electricity generation better than water/steam systems and allows the incorporation of a cost-effective energy storage system.

Energy storage allows the solar electricity to be dispatched to the utility grid when the power is needed most, which increases the economic value of solar energy. In 1992, a team composed of utilities, private industries, and government agencies collaborated to demonstrate molten-salt power towers at the 10-MWe Solar Two plants, which were constructed by retrofitting Solar One with molten salt technology. The Solar One heliostat field, the tower, and the turbine/generator required only minimal modifications. Converting Solar One to Solar Two required a new molten salt heat transfer system (including the receiver, thermal storage, piping, and a steam generator) and a new control system. The major Solar Two systems and equipment are described below.

The original heliostats were reused from the Solar One project, but the facets of the inner rows of heliostats were recanted for the smaller Solar Two receiver. The Solar One heliostat field was modified at the boundary by moving north-side heliostats (which produced excessive flux on the north side of the receiver) to the sides of the field, and adding large area heliostats on the south boundary of the field shown in figure 2.

The use of molten nitrate salt has several advantages over more conventional heat transfer fluids. The heat transfer properties of the nitrate salt are such that incident fluxes on the solar receiver up to 1,000 kW/m2 can be safely tolerated; this was approximately twice the allowable flux levels for the water steam receiver at Solar One (Kelly, 2000). However, the main advantage is that molten nitrate salt can be used for thermal energy storage allowing overnight operation and uninterrupted operation. 3.3 million pounds of a nitrate salt mixture with a

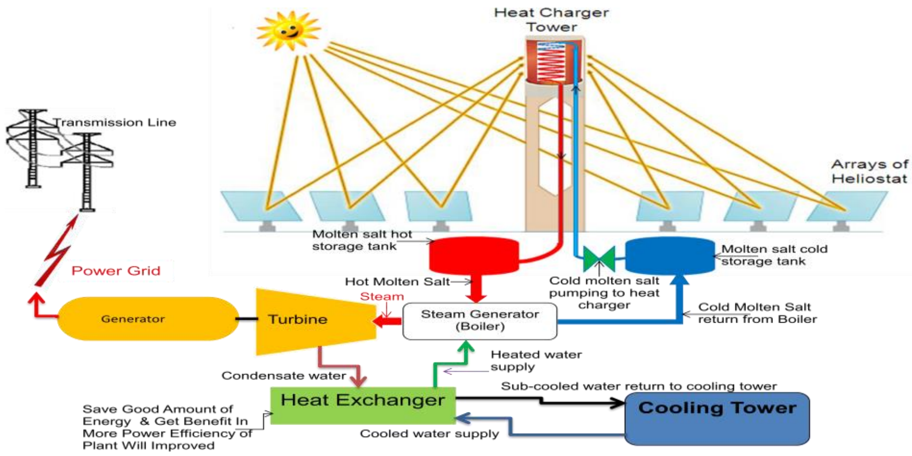

Fig. 2: The operating principle of a molten-salt power tower ‘‘Cold’’ molten salt is pumped to the heat charger where it is heated up to 565^{o}C to 580^{o}C.

composition of 60% sodium nitrate and 40% potassium nitrate were used in the Solar Two Project. The major processing units for molten nitrate salt and the construction materials for the units for the Solar

III. CENTRAL RECEİVER SYSTEMS FROM HELIOSTATS

A heliostat (from helios, the Greek word for *sun*, and *stat*, as in stationary) is a device that includes a mirror, usually a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky. The target may be a physical object, distant from the heliostat, or a direction in space. To do this, the reflective surface of the mirror is kept perpendicular to the bisector of the angle between the directions of the sun and the target as seen from the mirror. In almost every case, the target is stationary relative to the heliostat, so the light is reflected in a fixed direction.

The flat mirror surface can be made by metallization of float glass or flexible plastic sheets. In view of the life expectancy of plant (up to 30 years say), glass and plastic seem less appropriate because their optical and mechanical properties are liable to change with time. Float metalized with silver or aluminum provides reflectivities of 93% and 82% to 86% respectively, subject to cleaning [1].

Most modern heliostats are controlled by computers. The computer is given the latitude and longitude of the heliostat's position on the earth and the time and date. Then, given the direction of the target, the computer calculates the direction of the required angle-bisector, and sends control signals to motors, often stepper motors, so they turn the mirror to the correct alignment shown in fig. 3. This sequence of operations is repeated frequently to keep the mirror properly oriented. Large installations such as solar-thermal power stations include fields of heliostats comprising many mirrors

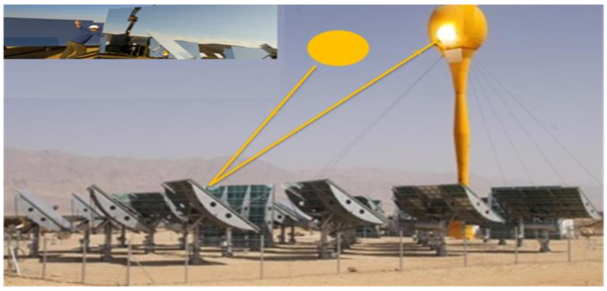

Fig. 3: Two axis type heliostat, with horizontal and azimuth (up and down) freedom of movement.

IV. THE PRINCIPLE OF MOLTEN-SALT STORAGE

The most important characteristics thermal storage system is its very high efficiency of the storage, with a possibility of annual efficiency of 99% for commercial plants. The only losses come from slow heat loss through the tank walls, which is kept to a minimum via insulation.

The heat exchange process between mediums, i. e. salt to steam for towers, or oil to salt, salt to oil, and then to steam, in the case of a trough system. When these steams is converted to electricity, the typical net steam (Rankine) cycle efficiency for a superheat plus reheat system at 565^{0}C and 100 bar is 38%. As with any thermal power generation (including coal and gas), the conversion from heat to electricity gives the largest energy loss in the system. However, in a thermal storage system, the energy is stored as heat prior to conversion to electricity through the Rankine cycle thus these conversion losses do not affect the efficiency of the storage.

Because the energy generation system is completely independent of the energy collection system, a steady flow of power can be produced regardless of whether the sun is shining at full strength, or partial strength, or whether it is cloudy, or nighttime as long as there is sufficient energy stored in the hot salt tank. The mirror fields are oversized to allow the storage tanks to be filled during the day while electric power is generated simultaneously. The exact balance of mirror field size, to turbine size, to storage size can be optimized depending on the desired performance of the CSP plant. For example, a plant with upwards of 20h of storage can act as a base-load power plant, while a plant with 10 to12 h of storage but a larger turbine can meet the afternoon evening peak power demand shown in fig. 4.

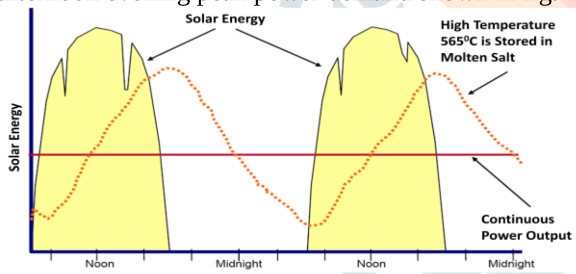

Fig. 4: Daytime and night time operation of a solar power tower with thermal energy is storage in molten salt.

Fig. 5 (a) & (b): Potassium and sodium nitrate prior to the melting process. In the liquid state, it is clear with a yellow tinge, like beer.

V. MOLTEN-SALT PROPERTIES

Currently, both trough and tower plants use the same molten-salt mix for storage a 60 wt% to 40 wt% mix of sodium and potassium nitrate know as Solar Salt, illustrated in Fig. 5 (a) & (b). At room temperature, Solar Salt is a white crystalline solid. Therefore, during plant commissioning, it is necessary to melt the entire salt inventory. The salt inventory then remains in the liquid state for the operating life of the plant.

Heat transfer salt	Melting point (^{0}C)	Thermal stability limit(^{0}C)	Density at 300^{0}C (kg/m^3)	Velocity at 300^{0}C (Pa. s)	Heat capacity at 300^{0}C (J/kg. K)	Thermal conductivity (W/(m K))
Solar salt (60:40 Na:K nitrate)	220	600	1899	0.00	1495	0,55 (at 400^{0}C)
Hitec (7:53 Na:K nitrate, 40 Na nitrate)	142	535	1640	0.00316	1560	
HitecXL (7:45:48 Na:K: Ca nitrate)	120	500	1992	0.00637	1447	

Solar Salt is a eutectic mixture, meaning that this particular composition melts at a lower temperature than any other ratio of the two salts, and that at this ratio; both of the salts begin melting at the same temperature. Solar

Salt was chosen for use with molten-salt power towers because its upper stability temperature limit (6000C) allows high-efficiency Rankine cycle turbines to be used [19], for example, a superheat plus reheat system, or potentially a supercritical plus reheat system.

Freezing of the salt was also encountered in the evaporator at the Solar Two facility the heat exchanger between the salt and water, in which saturated steam was produced. This freezing was due to cold water being passed through the evaporator during startup, and as few as four freeze/thaw cycles could cause tube rupture. To address this issue, a feed water heater was installed for use during startup, and the feed water flow path was altered.

Table 2 lists the compositions and properties of a variety of salt mixtures used as heat transfer fluids. In addition to Solar Salt, both Hitec and HitecXL are commercially available. Hitec and HitecXL have lower melting points than Solar Salt. Hitec, containing a nitrite salt, requires an N2 cover at atmospheric pressure in the thermal storage tanks to prevent conversion to nitrate

VI. CALCULATİONS OF SOLAR ENERGY

Heat from a solar collector may be used to drive a heat engine operating in a cycle to produce work. A heat engine may be used for such applications as water pumping and generating electricity. The thermal output Q_{out} of a concentrating collector operating at temperature 'T' is given by

Q_{out} = F'[*Gamma*.$a_{in}q_{in}$ - L.$a_{rec}(T - T_{amb})$] where,

a_{in} : the area of the incident solar radiation (m^2).

a_{rec} : the area of the receiver (m^2)

Gamma:optical efficiency

q_{in} : the incident solar irradiation (W/m^2)

T_{amb} :the ambient temperature (°C)

L :the heat loss coefficient (W/m^2k)

F' :collector efficiency factor

The quantity a_{in}/a_{rec} is called the concentration ratio. High concentration ratios are obtained by making a_{in} the area of a system of mirrors designed to concentrate the solar radiation received onto a small receiver of area a_{rec}. Heat losses from the receiver are reduced by the smaller size of the receiver. Consequently, high concentration ratios give high collector temperatures. The stagnation temperature T_{max} is given by:

Gamma.$a_{in}q_{in}$ = L.$a_{rec}(T_{max} - T_a)$.

For example, if the optical efficiency is *Gamma* = 0.8, the incident solar irradiation is q_{in} = 800W/m^2, the ambient temperature is T_a = 30°C, and the heat loss coefficient is L= 10W/m^2k, then a concentration ratio a_{in}/a_{rec} = 1 (no concentration) gives T_{max} = 94°C, and a concentration ratio a_{in}/a_{rec} = 10 gives T_{max} = 670°C.

The collector efficiency Eta_c at operating temperature T is

Eta_c=$Q_{out}/a_{in}q_{in}$ = F'[G*amma*-U.$a_{rec}(T - T_a)/A_{in}q_{in}$]= F'G*amma*$(T_{max} - T)/(T_{max} - T_a)$.

The available mechanical power from the thermal power output of the collector that would be obtained using a Carnot cycle is $Q_{out}(1 - T_a/T)$, where the temperatures are absolute temperatures.

The second law efficiency E*ta*$_2$ of a heat engine is defined by

Eta$_2$=(mechanical power delivered)/(available mechanical power).

Suppose a heat engine with second law efficiency E*ta*$_2$ uses as input the thermal power Q_{out} from the solar collector. The first law efficiency of the engine is

Eta$_1$ = (mechanical power delivered)/Q_{out} = *Eta*$_2(1 - T_a/T)$,

where T_{max} depends on the design of the collector and on the solar radiation input q_{in}. Now, given F', G*amma*, *Eta*$_2$, T_a, and T_{max}, we can find the maximum efficiency obtainable, and the optimum operating temperature T_{opt} from the condition d(E*ta*)/dT = 0. This occurs at the optimum temperature

$T_{opt} = [T_{max}T_a]$, and the maximum efficiency is obtained by putting

$T = T_{opt}$ in the equation

Eta = *Eta*$_c$.E*ta*$_1$.

For example, putting F' = 0.9, *Gamma* = 0.8, E*ta*$_2$ = 0.6, T_a = 30°C = 303K, we get the efficiencies Eta_{max} for different degrees of concentration. Very low overall efficiencies are obtained unless operating temperatures greater than 500°C are used. Expensive concentrating systems are needed to reach these high temperatures, so commercial viability is difficult

VII. ECONOMİC AND ENVİRONMENTAL CONSİDERATİONS

The economical factor driving the solar energy system design process is shown in fig. 6. Although there are factors other than economics that enter into a decision of when to use solar energy; i.e. no pollution, no greenhouse gas generation, security of the energy resource etc., design decisions are almost exclusively dominated by the 'levelized energy cost'. This or some similar economic parameter, gives the expected cost of the energy produced by the solar energy system, averaged over the lifetime of the system. Commercial applications from a few kilowatts to hundreds of megawatts are now feasible, and plants totaling 354 MW have been in operation in throught world since the 1980s. Plants can function in dispatchable, grid-connected markets or in distributed, stand-alone applications. They are suitable for fossil-hybrid operation or can include cost-effective storage to meet dispatchability requirements. They can operate worldwide in regions having high beam-normal insolation, including large areas of the southwestern United States, and Central and South America, Africa, Australia, China, India, the Mediterranean region, and the Middle East.

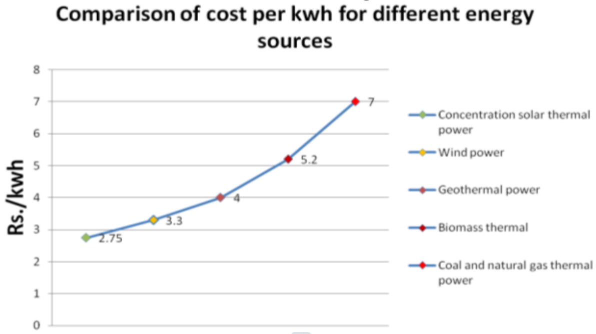

Fig. 6: Comperison of cost Rs. Per kwh of different energy sources.

VIII. CONCLUSION

Utilities are showing increasing interest in the deployment of concentrating solar power plants to meet the requirements of state renewable energy electricity standards. Concentration solar power is a reliable, proven renewable technology for generating electricity. Based in the sunny regions of the World, like India, Southern Europe and the Middle East and North Africa (MENA) region in particular, it can potentially make a substantial contribution to mitigating greenhouse gas emissions and establishing a sustainable energy system.

Advantages of the molten-salt power tower storage system include a lower salt requirement, higher steam cycle efficiency, better compatibility with air cooling, improved winter performance, and simplified piping schemes. Near-term advances in molten-salt power tower technology include improvements to the thermal properties of molten salts and the development of storage solutions in a single tank.

It is very efficient system and the efficiency can be increased by hybridizing it with the other conventional plants. It is Very economical excluding initial cost; molten salt has the best Heat capacity. It is Non pollutant power technology and it will be very important power source for developing countries.

FUTURE SCOPE

Saudi Arabian Govt. has raised the bar for its renewable energy program, taking its target from the previously announced 41GW to an even more ambitious 54GW by 2032. The kingdom has now taken action by formulating a preliminary procurement process for industry feedback. What can Concentration solar power developers expect in terms of challenges and incentives?

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