Solar Thermal Powered Steam Turbine Power Plant

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To

My Father and Mother

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❖ Introduction:

Solar power is one of the fastest growing sources of renewable power.**Concentrating solar power** (**CSP**) plants use mirrors which is called heliostats to concentrate the energy from the sun in a small place. From where the fluid gains the energy and drives to traditional steam turbines or engines that create mechanical energy which can be converted into electrical energy. The thermal energy can be stored through the liquid and used to produce electricity 24h when it is needed.

Basically we use fossil fuels and others to fuel the power plants. Here we are using solar energy which is vast and unlimited. That is why it is inexpensive, environmentally friendly and a flexible way to produce much electricity. For converting those solar energy, we are using here a traditional turbine which is being used in lots of power stations and a storage. Generally coal, oil and other fossil fuels are used to heat the water and turn into the steam, then the steam goes through the turbine and produce mechanical energy later on which can be converted into electrical energy. And here we gain that temperature from the solar heat transferring fluid instead of fuels which can create 500 degree centigrade temperature or above. So in this case we can easily achieve a huge amount of energy using the solar energy in an inexpensive way. But along this CSP has several boundaries to harden our way to gain such energy. It is needed to be built in a deserted area. So in that case we can build a large infrastructure to achieve more energy as we cannot have sunlight for whole day.

There is a concentrated solar thermal power plant near Seville, in Andalusia, **Spain** which is running based on this theory. Electricity can be produced there even when there is no sunlight.

Utilizing solar thermal energy is not a new concept. In 1970 Germany was granted as the first patent for the solar collector. After the oil crises of the 1970s in US they gave the significant effort to utilize sun as the major source of heat to generate power. Although no commercial plant appeared before 1980s since California established one in late 80s.But due to the domination of cheap and enormous natural gas as the source of energy in the market of the most developed country of the world, funding for development and deployment of solar thermal generation tailed off soon.

The good news is now solar thermal power technology has the attention of whole world and many investors are showing much interest in the development of it. The global warming, Greenhouse effect, price hike of oil and gas are the most concerned topic for the world scientists so that they

are trying to minimize the usage of natural resources like oil and gas and hence the coal, oil and natural gas based power plant are no more ecofriendly for the world. Investment is what

solar thermal power technology has lacked for most of the past 20 years is now accelerating rapidly. If there is sufficient investment no doubt that solar thermal power technology based generation of electricity will make the world not only greener but also transparent. The conditions are now seem right forit to progress. With several major projects proposed, under construction or recently entering service there is finally a strong chance thatthis electricity generating technology can become a part of the main stream, alongside wind, hydro and solar photovoltaic technologies, as the key source of renewable energy for the future.Beside using fossil fuels(oil, coal, gas), large hydro-power and nuclear power as the power in generation of electricity, there also some other sources of energybeing used in contribution of world's present energy demand although in a small way. For example energy sources like wind energy, small-hydro, photovoltaic conversion, bio-mass, tidal, geothermal energy and solar thermal power plants are used significantly. Solar thermal power based generation of electricity undoubtedly offers the most promising and viable option for future. The schematic views of solar power generation.
Methods are shown in Fig. 1.

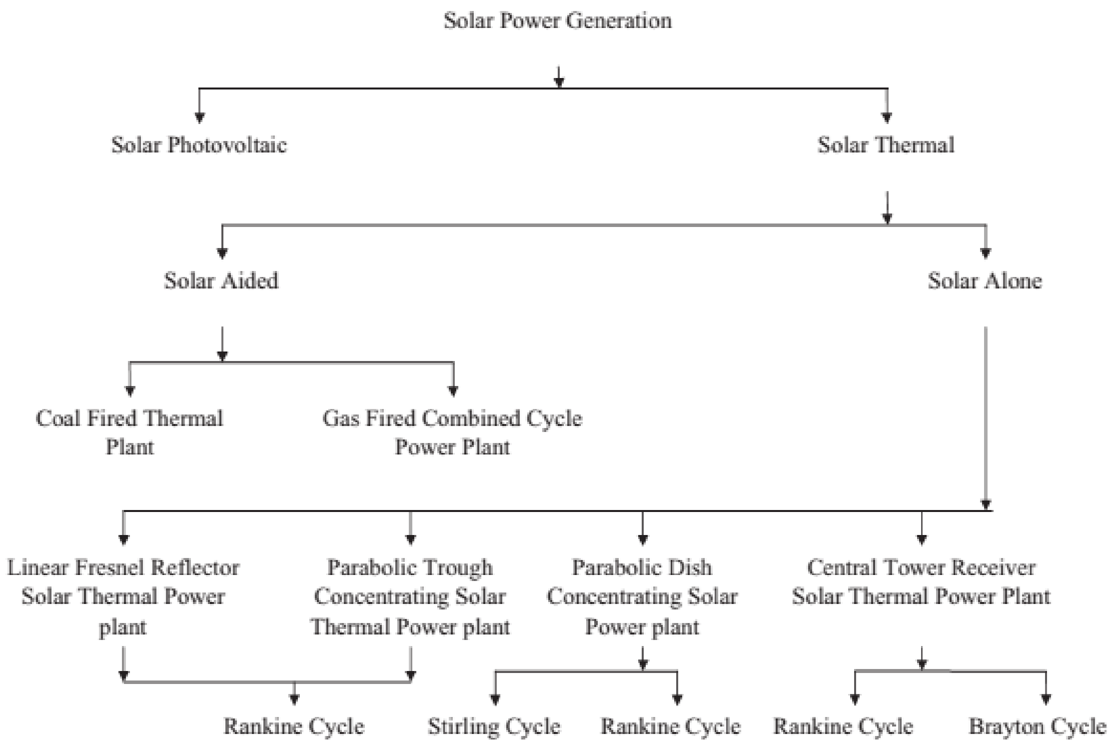

Fig. 1. Schematic view of solar power generation methods.

❖ Why concentrating solar power (CSP)?

Our world is getting warmer day by day and of course CO2 is responsible for this climate change. 90% of CO2 emits from burning of fossil fuel in power generation and vehicles. Recent studies shows that 80% of the CO2 emissions will be from current fuel system based industry by 2035.

If this continues in atmosphere, our world will face the temperature rise accentuation, the melting of the polar ice caps and the increase in extreme weather events.As a result, many people around the World, mainly in Africa, will face an increasing risk of hunger, water shortages, and desertification. On the other hand coastal countries like Bangladesh, Japan, Sri-lanka, Malaysia etc. will be flooded under sea as sea level will rise. Other severe environmental pollutions that are expected to cause about150,000 additional deaths every year.

Meanwhile, prices of natural gas and oil are projected to move forward in the next 22 years (from $130/barrel in 2011 to over $210/barrel in 2035).This is due to increased demand which set to grow by over 52%; from 87.5 mb/d in 2011 to 99.6mb/d in 2035.Consequently, energy-related Carbon dioxide emissions will then be more than double by the year 2050. Amount of pollution that produced by more than 7 billion people consuming far more fossil resources is much higher than that Earth can accommodate.[4] In the Mediterranean region energy consumption is raised by a factor of 3 between 1980 and 2005, and a further doubling is intended by 2020.

Due to Catastrophic events like those at the Fukushima Daiichi nuclear power plant, in March 2011, and the Turmoil in parts of the Middle East and North Africa (MENA), many countries around the world had to review their policies and retreat from nuclear power. This is also true for Germany.

For these reasons, many countries assigned that a part of the electric power should be from renewable sources, in particular solar energy. 50% of the new power infrastructures must be based on clean-sustainable energies (According to IEA). As a result, renewable energy will be the world’s second-largest source of power generation by 2015; which will deliver about 30% of the electricity needed by the year 2035. Nowadays, concentrating solar power (CSP) technology implantation is growing faster than any other renewable technology.

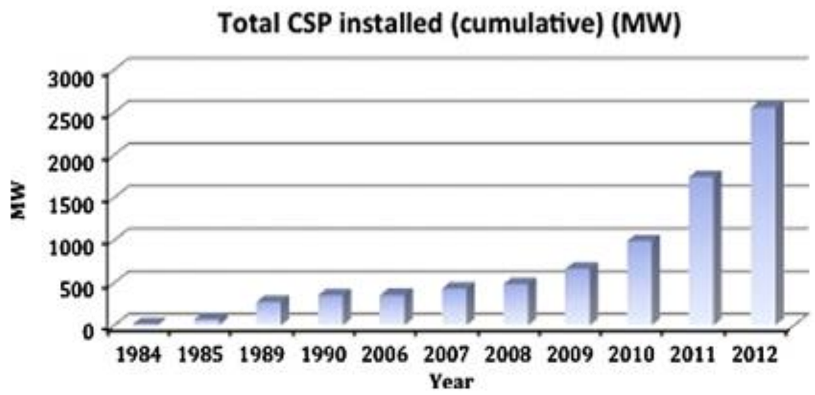

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Fig.2. Installed solar thermal plants since 1980s

As this technology is ecofriendly and has no impact on atmosphere moreover does not polluteour earth and the source is abundant so this is the best solution to the upcoming decade's global problems, i.e., climate change and limitation of untenable energy. For example, a 1 MW of CSP based plant can reduce the emission of CO2 by 688 Ton and 1360 Ton of CO2 compared to a combined cycle system and a coal/steam cycle power plant respectively. Each square mirror in the solar field produces 400 kW h of electricity per year, and avoids 12 Ton of CO2 emission contributing to a 2.5 Ton savings of fossil fuels during its 25-year operation lifetime.

❖ Available solar thermal power technologies:

The sun continuously emits electromagnetic waves into space which consist a large amount of solar energy and Earth receive these energy as a huge solar collector in various form like direct sunlight, heated air masses causing wind, evaporation of the oceans resulting in rain which can form rivers. It is a renewable source that is inexhaustible and locally available.Solar power that the earth is receiving annually is about 1000 W/m2, although availability varies with location and time of year. Concentrating sun rays requires equipment which are relatively costly initial.
However, considering the lifetime of the solar equipment, this systems can prove to be cost competitive, as compared to present untenable energy technologies.Mainly the solar thermal energy is divided into two markets-

1. The photovoltaic (PV) market and

2. The solar thermal market.

PV solar cells use the properties of particular semiconducting materials to convert sunlight energy directly into electricity. On the other hand the solar thermal technology uses the heat radiated from the sun, for purposes such as heating water or power generation. Again current solar thermal power technologies are divided into three techniques.

- Parabolic Trough Technology:

A parabolic trough is a long, trough-shaped reflector with a parabolic cross-section as indicated in Fig. 3. Principle of this system is that sunlight reflected within the trough is focused along a line running the length of the trough. In order to collect this heat, a pipe is placed along the length of the trough at its focus and a fluid is pumped through it. The fluid is used as the heat collector. The pipe (heat receiver) is designed in such way that it can absorb most of the heat focused onto it and able to withstand very high temperature raised by the concentrated solar rays. Generally this receivers are made of steel cylindrical pipecoated black and covered by glass to reduce heat loss due to radiation. For the betterment an anti-reflective coating may also added on the outer surface of the glass.This consist of several parallel rows of parabolic reflectors. The heat collecting fluid is typically molten salt, liquid metal, high pressure gas, silicon particle synthetic oil similar to engine oil etc. which are capable to operate in high temperature like between 300 °C and 400 °C. While passing through the collector tube fluid gains heat and then passed through a heat exchanger where the heat is extracted to produce steam in a separate sealed system and that steam is used to run typical steam turbine and produce electricity. After exchanging heat the cold fluid again cycled back through the collector to operate another heat exchange cycle.The dimensioning of the trough may be 5–6 m wide, 1 m or 2 m deep and up to 150 m in length (though an individual trough of this length will usually be constructed from modular sections).

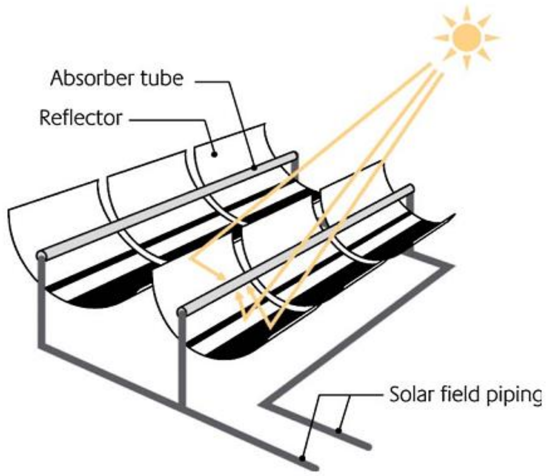


Fig.3. Principle of operation of parabolic trough system.

About the positioning system in parabolic solar troughs their long axis are aligned from north to south and mounted on supports that allow them to track the sun from east to west across the sky. Those supports may be made of steel or aluminum. At first 4 mm glass were used in commercial plane which were both expensive and heavy. But for maximum optimization it should cost less and weight less. So that instead of coated mirrors, industries started to use materials of polished aluminum. Since the energy conversion is the main motto the reflecting mirrors must be both accurately shaped positioned in order to get maximum efficiency. Then to receive maximum heat all over the day the tracking system is necessary.

- Parabolic trough with direct steam generation:

What if we use water instead of heat receiving fluid? The water will directly converted to steam while passing through the trough. This simplification shows that the produced steam immediately used to drive the turbine without using heat exchanger. This can reduce the cost significantly. But the disadvantage is this can either cause further more technical requirement which may lead to higher cost or just the efficiency will be lesser.

- Hybrid parabolic trough:

A major disadvantage of using solar energy is that this energy is depended on time, we cannot get the solar power 24h a day. But the turbine must be running continuously to meet the demand and supply. So either the plant has to use alternate source of energy like fossil fuel when there is no availability of sun or to store that solar power when the sun is available to keep running the plant. The combination of solar heat plant when available with fossil fuel power plant can reduce CO_2 emission and contribute in power generation.

Thus most suitable hybrid arrangement to be considered is building a solar thermal power plant based on parabolic troughs along with a combined cycle power plant. This arrangement is called an Integrated Solar Combined Cycle (ISCC) plant. In an ISCC plant the combined cycle plant is built in same old fashioned configuration with a gas turbine burning natural gas to generate electricity while the exhaust heat from the turbine is fed into a waste heat boiler, generating steam to drive a steam generator. In the hybrid plant, however, the heat from the solar collectors is used to supplement the heat from the gas turbine exhaust, increasing the output from the steam turbine section of the plant. Currently such plants are under construction in Morocco, Algeria and Egypt.

➤ Solar towers:

Solar towers are often called solar central receiver power plants. It is an alternative way of exploiting the solar power. Here the collector fieldis consist of an array of heliostats (mirrors) at the center of which is a tower as illustrated in Fig. 4. At the top of the tower there is a central receiver designed to collect the heat from the sun. Since tracking system is very important to continuously receive solar rays and concentrate into the receiver each individual heliostat has dual axis tracking system so that sun rays incident on each reflector and reflect in such a way that is directed towards receiver at the top of the central tower. As the sun moves across the sky, based on locality each mirror must be rotated accordingly too to gain maximum efficiency. The receiver works in such that it transfer that solar heat absorbed from sun to the fluid that is circulating continuously.

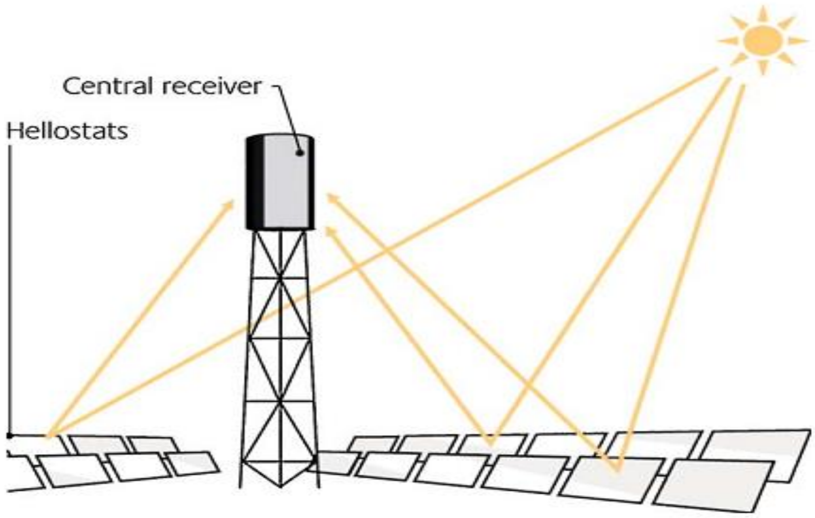


Fig.4. Principle of operation of solar tower system

Gaining heat from receiver the fluid then passed through a heat exchanger where using this heat steam is produced to run the steam turbine and hence generate electricity. The heat transfer fluid may be molten salt, water, high pressure air or synthetic oil etc. A thermal energy storage is required to generate electricity 24h a day especially when the sun is not available.

➢ Solar dishes:

Another way to collect solar thermal power is in a circular parabolic dish and bring it to the focus. Sun rays reflect on the concave surface of the dish. At the focus either a heat engine is placed to exploit the heat generated by the concentrated solar power to provide mechanical motion to drive a generatoror sometimes a receiver is placed to produce steam as like described in solar tower system. A special type of heat engine with extremely high efficiency called ‘Stirling engine’. This engines are limited to 25 kW so it’s suitable for smaller dishes. The dimensioning for dish is generally 5 m and 10 m in diameter and with reflective areas of 40–130 square meter though the largest reflector is 400 square meter. Dishes of this size range can provide up to 50 kW of power. Gas turbine heat engines based on micro-turbines can provide a higher output but they are significantly less efficient than ‘stirling engines’. Using a combination of solar power from solar dish and the heat from the combustion of natural gas and oil,hybridization of ‘stirling engine’ based system and gas turbine system is possible to get higher efficiency and lessen pollution compared to only gas-turbine based power system. But in this hybridization micro gas-turbine only can be used. Possibility of using large gas turbine is under experimentation. Till today solar dish with ‘Stirling engine’ have been built were able to produce 5kW to 25kW depending on the size.

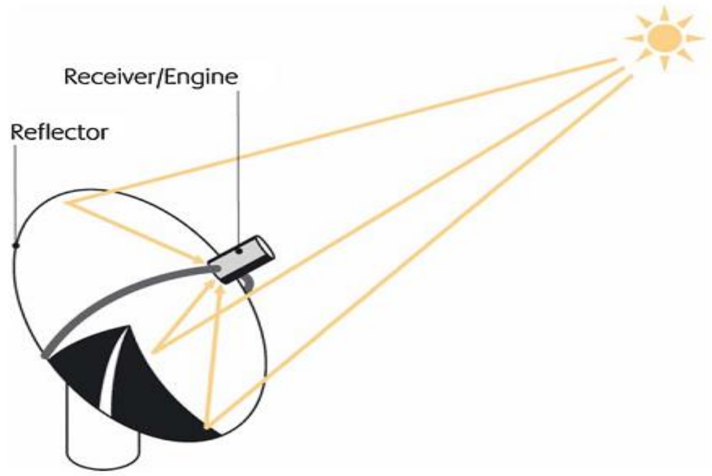


Fig.5. Principle of operation of solar dish system

Theoretically the energy conversion efficiency is about 40% although practically 30% efficiency were achieved. All these solar dish, parabolic trough, solar tower requires tracking system for the reflector as the sun moves over the sky from dawn to dusk. So a large part of costing goes for this tracking system and hence plays an important role in the economic system of solar thermal power system.

❖ Solar thermal power plants around the world:

Solar thermal power plant is not free of disadvantages. Still now it has so many difficulties and technical liability to make maximum efficiency. Commercially it still lack of desired profit after meeting the mass peoples demand and supply. It couldn't meet the optimum point of cost vs demand. It's because further progression is needed to develop and advance the materials and technical parts used in plant for better output with minimum cost. For example tracking system, thermal storage, heat transfer fluid, optimum temperature etc. all these when could make betterment then the total costing will be considerable comparing to long-term view. In this section, the available solar thermal power plants in operation and also under construction around the world will be discussed and reviewed as example.

➢ Solar thermal power plants in operation:

Solar Electric Generating System (SEGS) is the largest solar thermal power plant in the world consisting of nine solar plant together that generate 2700 kWh/m2 power annually. It is located at Mohave Desert, in California, USA. The total capacity of the plant is 354 MW,where each plant is able to produce 75 MW in average. It's actually a combined cycle power plant where the turbine is run by burning natural gas when the solar power is not available and hence it works 24h a day. The total area of reflective mirror is about 2 million square meter. The whole SEGS plants is on the area of 6,400,000 square meter. The parabolic reflecting mirrors might extend to 369 km. Actually the SEGS power plant is consist of parabolic trough system combined with natural gas-turbinebased power system to generate electricity. The good news is about 90% of the total electric power is produced by conversion of solar power. Natural gas is only burnt when the solar rays are very poor to produce sufficient electricity to meet the demand and supply for southern California. For absorption of heat synthetic oil is used as the heat transfer fluid which might be heatedup to 400 °C. That fluid release heat in heat exchanger to produce steam and that steam runs the turbine where the generation of electricity is under Rankine cycle.

- Nevada Solar One

Nevada Solar One solar thermal plant is located at the El Dorado Valley in Nevada, USA. It is based on the parabolic trough technology and the field is consist of 760 solar parabolic trough collectors, each with a reflective surface of 470 square meter. The whole plant is over 1,600,000 sq.m of land and total reflective area is 357,200 sq.Total production of the plant is 130 GWh per year (annual capacity factor of 23%), where the capacity of the steam turbine is 64 MW. Gas turbine is also available to run the plant 24h a day in case solar irradiation in not enough.

- PS10

PS10 is located in Sanlucar de Mayor in Sevilla, Spain and started operating in 2007. The plant is based on solar tower technology. It has covered a land of 600,000 m2 and is the first solar tower plant in the world to generate electricity commercially. The plant solar tower is 100 m high, and the heliostat has dual axis tracking system to track the moving sun, and concentrate the sun's irradiation to the focus (receiver) located on the tower. Those heliostat are total 624 in number having surface area of 120 sq.m each. So the total reflective surface area becomes 75,000 sq.m. Each heliostat has individual solar tracking system that directs solar radiation toward the receiver tower.

The actual heliostat field does not however completely surround the receiver tower. In the northern hemisphere, the heliostat field is located on the north side of the tower to optimize the amount of solar radiation collected while minimizing heat loss. The receiver is located in the upper section of the tower. It is a ‘‘cavity’’ receiver and is comprised of four vertical panels that are 5.5 m wide and 12 m tall. The panels are arranged in a semi-cylindrical configuration and housed in a square opening 11 m per each side. The annual generation of the plant is 24.3GWh of electricity (annual capacity factor of 25%) with solar potential of 2100 kWh/m2. The installed capacity of the plant is 11 MW.

In the thermal storage the steam is stored at pressure of 50 bar and temperature of 285 °C. The steam then condenses flashed back to steam when the pressure is lowered. When the solar radiation is low the plant is able to supply 12–15% of its total power by burning natural gas. The total efficiency of the plant is, (conversion of solar irradiation to electricity) about 17%. This is of course a high number considering that the efficiency of general steam cycle alone is approximately 27%.

- Andasol 1 and 2

Andasol 1 and 2 are two solar thermal plants that will begin operation very soon and will be the first solar thermal power plants to operate in Europe. They are based on parabolic trough system and the capacity is 50MW. These plants are located in Andalucia, Spain. The Andasol 1 solar thermal plant consists of three basic parts: (a) the solar field, (b) the storage tanks and (c) the power generation block. 624 parabolic mirrors are used in each of the plant and arranged in 156 loops hence it makes total reflective area of 510,120 sq.m. The total land cover for these reflection is 2,000,000 sq.m. Andasol 1 might generate 179GHh of power annually with solar thermal potential of 2201 KWh/sq.m. The annual average efficiency is about 46% (conversion of solar irradiance to steam) where only steam cycle gives a number of 38.1% and hence the overall efficiency of the Andasol 1 is around 16%. Two thermal heat storage is used to store heat by molten salt when solar power is low or not available. Converted heat from solar radiation is stored at that storage especially at midday when irradiance is maximum at the same time electricity is produced. But when irradiation is low or not available that storage contribute power stored at midday. Actually it works like a battery but not typical electric battery where charge is stored. Instead of storing Charge as electricity the heat storage store heat to utilize later. The heat transfer fluid does this storing system passing through the solar tower, absorbing heat and then circulated through the storage and exchange the heat, become cold and again circulate through solar tower in order to complete cycle. There are two tanks used, one is for cold salt another one is for hot molten salt. Dual molten salt storage tank system increases the running time of solar thermal power plant. It might increase equivalent time of 3500h annually. The dimensioning for the both cold ant hot tank is of 64m in diameter and 14m high. They consist of storage capacity of 705h at 50MW with 28,500 ton of molten salt. The temperature of hot and cold tank while operate is 384°C and 291°C respectively.

❖ Solar thermal power plants under construction:

- Solnova 1

Solnova 1 is located in Sanlucar de Mayor, Seville, Spain and will began operation very soon. This plant is based on parabolic trough technology and uses synthetic oil as heat transfer fluid. Total 90 rows each consisting 4 trough positioned north-south along their long axis to track sun moving east-west that makes total 360 troughs where each trough has the diameter of 12.5m long and 5.75m wide. Total reflective area will be approximately 260,000 sq.m and total land covered by the plant will be about 1,200,000 sq.m. The annual generation of this plant is 114.6GWh (factor of 26%) of electricity that has installed capacity of 50MW. The plant is able to contribute 12-15% of total generation by burning natural gas at low irradiance. The maximum efficiency when solar power is fully available is about 57% hence in combined the total efficiency becomes 19%.

- PS20

PS20 is under construction that has the capacity of 20MW. It is similar to PS10 and the capacity is double of that.This solar power plant will consist of 1255 heliostat each of reflective area of 120 sq.m along with dual axis tracking system. The plant is actually based on solar tower technology where the height of the tower is 160 m long. Annual expectation of the plant is that it will generate 4606GWh and contribute 15% of power at low irradiance.

❖ Optimization

Sun is the ultimate source of our energy in our world. It produces 350,000,000,000,000,000,000,000,000 watts of energy every second and we believe that it will provide us with this energy for another 5.2 billion years. All around the world there are many resources for producing energy such as fossil fuels, biomass, photo-biological fuel cells etc. But they all are limited and perishable and some of them are such as fossil fuel though cost effective but they are harmful for our environment. But on other side Sun is the most sustainable and easily available energy we can ever imagine in our world. It is the most reliable and viable energy in our world.

As we mentioned earlier that coal power is the most common and less expensive source of producing energy. Solar thermal power energy now leads it way to beat all other energy and it becomes the most reliable energy source now. So if we maintain this sustainable energy and gain the maximum output by using this energy so we need to concentrate to optimize its procedure. So we can get maximum outputs for a long time. Many companies who work with solar thermal power production have already beaten PV and other renewable energy sources on the basis of price. Now they are aiming for beating the coal powered energy resources. Day by day we are advancing our way to the modern era and in that case new technologies are being invented daily. Every day we are being introduced with new, optimized, efficient and cost effective technologies what is making our life easier gradually. And in our life energy is one of the necessary components what we must need in our daily life. So we have to think also not about technological optimization but also economical optimization for solar thermal power plants. The issue is how to make these technology more economically beneficial and advanced.

We discussed it earlier that there are several ways to use solar power coming from sun. But basically to produce huge amount of electricity or energy or to run a power plant we need such huge setup to maintain it. In that case we can follow two ways. The first way is gathering solar power through parabolic trough.

The mechanism of parabolic trough collector is that number of long, U-shaped mirrors focus the sunrays to a straight absorber. The mirrors follow the sun on a linear axis. It tracks the sun from north to south whole daylight. The pipe is placed above the mirror in the center along the focal line. It should be placed in a perfect place otherwise if it fails to focus the sunrays in the pipe then the whole trough will be useless and it has a heat absorbent medium into the pipe. There are several choices for heat transfer fluids. Such as mineral oil, synthetic oil, molten salt, Sulphur etc. and has a heat-absorbent medium running in it. The sun's energy heats up the medium. Then this medium carries the thermal energy to the water. Through a heat exchanger the water in the boiler gets the heat, where it can obtain temperature about 400°C. Then the heated water goes into the turbine and runs through the turbine and produce energy from which we can easily get electrical energy.

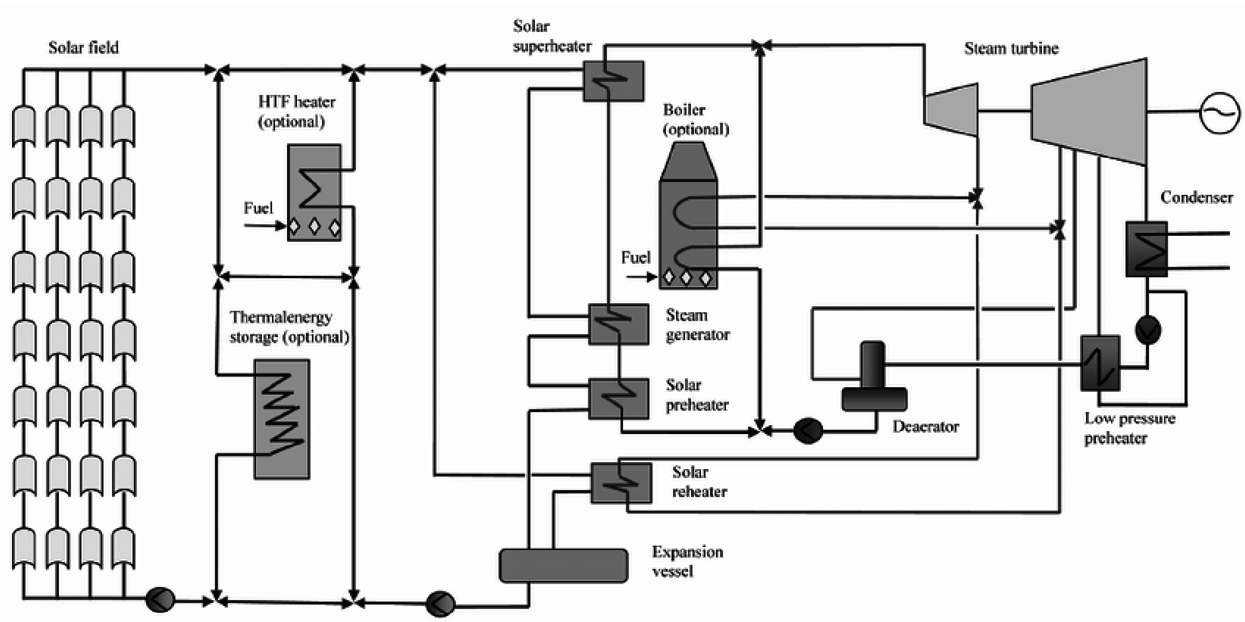
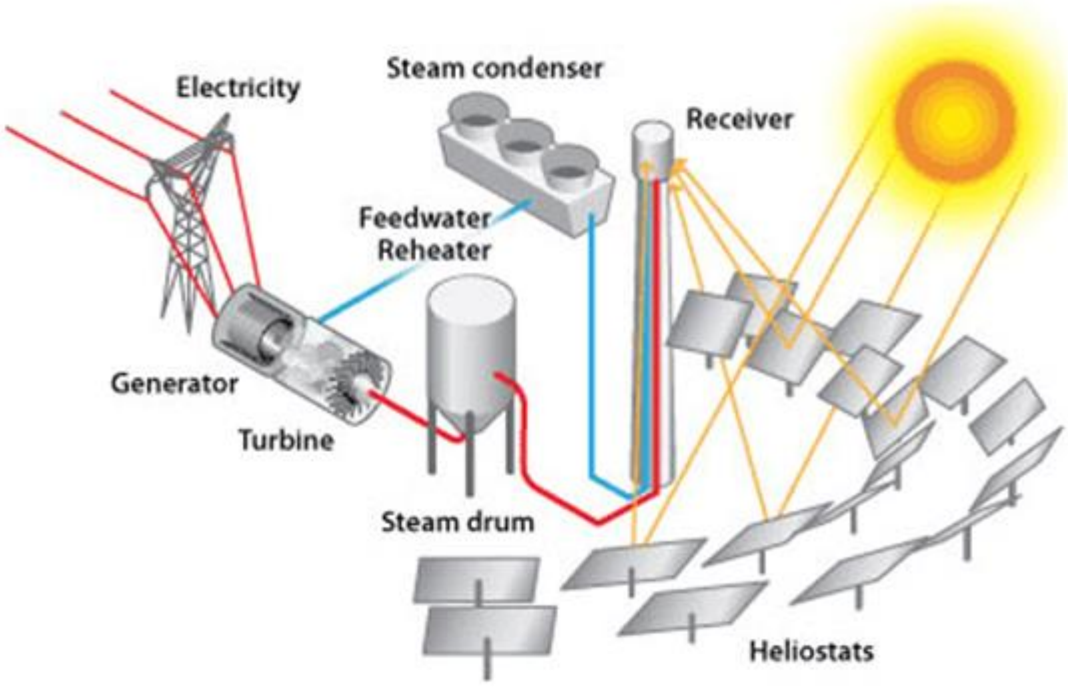


Figure: Parabolic trough solar power plant

Another one is point focus system, what we discussed earlier and it is basically maintained with a solar tower. And there are huge amount of mirrors, which are called heliostat. Heliostat are mainly parabola shaped mirror surrounding the solar tower. Point focus system is these heliostats focus sunray in particular point in that tower. They rotate on a single axis throughout the whole day to track the sun. It is a lot complex process than parabolic trough system and in many ways it is more expensive than trough system. But there are certain reasons to use this concentrated solar power system. We need a huge land to setup this system but moreover we can get huge amount of energy from this concentrated solar power system. From comparision we get that it can reach upto 500° C, where generally trough system can give us 250° C. So when this much output comes out in that case obviously it is more efficient than parabolic trough solar power system.

Then this heated fluid goes through the turbine and produce mechanical energy. And there is a generator which converts those mechanical energy into the electrical energy. And through the grid line the electricity is being supplied to the main power station. And this how Concentrated Solar Power (CSP) does produce electricity. Though in this process there are many issues like land acquisition etc. but so far it is the best process to produce huge amount of energy through solar thermal energy.



<u>Figure: Concentrated Solar Thermal Power Plant</u>

So we have to keep our focus on advancing these thermal system. As they are one of the most sustainable energy what we get for an unlimited time. Without optimization and utilization these technologies can't give us desired output. We have to augment the system, update the components.

Here are some optimized techniques have been used in solar thermal power generation.

- ## Heat Transfer Fluids (HTF):

There are some criteria which is needed to be fulfilled to be an optimized and flexible Heat transfer fluid:

- It shall allow for a simple and safe system operation
- It shall allow for a simple storage concept
- It shall not be toxic or flammable
- It shall be cheap

The main HTF used today in CRSs is Hitec. The issue with Hitec (53% KNO_3 + 40% $NaNO_2$ + 7% $NaNO_3$) is that it has a melting point of 142° Cand is only usable up to about 535° C. Another HTF used is the binary salt 60%$NaNO_3$ and 40%KNO_3 commonly known as solar salt.This salt has similar properties to Hitec but is comparatively cheaper and is usable up to about 585° C, however it has a much higher melting point of 220° C.

In recent years, two competing technologies have emerged to achieve higher temperatures, namely molten-salt and direct steam generation towers [12], which have successfully demonstrated higher efficiencies and lower costs. Despite this, both technologies have their associated drawbacks.

Though in parabolic trough system still it operates with synthetic aroma fluid as heat transfer fluid. It is an organic based, more specifically Benzene based. But this organic heat transfer fluid can reach upto 400ºC with its best performance. Because of its inclination into unused components at high temperatures. When it reaches more than 400ºC, this fluid can’t operate anymore in the system. This limitation can degrade a lot efficiency. So we need to think of an optimization which can give us an ultimate solution and provide us a better efficiency.

In order to solve this issue, researchers have been working and they advise to focus on molten salt instead of organic oil. They are thinking of using this as an alternative fuel for solar thermal technology.

Now if we analyze why they preferred molten salt over organic oil, which is now used as a heat storage medium in solar thermal power plant. It can also work as a heat transfer fluid without the organic oil which we used earlier as a heat transfer fluid. Molten salt gives us a whole new configuration which can do lot saving in several portions.

1) We don't need heat exchanger in this system at all in this system, as we are sending same fluid in turbine which carries thermal energy from tower.

2) When it operates its cycle in higher temperatures, volume of molten salt gets reduced. And the reduction can be by 1.5 which also occurs declination of storage tank size. It also impact in economical factor such as 30% cost can be saved by using these molten salt. These savings make impact on total cost of solar thermal power plant. When cost analysis of these solar thermal power plant is compared with other oil generated power plants it shows 20% total plant cost reduction. Also because of higher temperature efficiency of the plant can be increased up to 6%.

3) It works as a sole fluid in whole system, there is no need of any other fluids.

4) Smaller thermal storage due to molten salt surely meet the demand of solar discontinuity.

Molten salt was used as a heat transfer fluid in the American Solar-Two power tower project. Due to its simple storage concept it is also suggested for use in parabolic trough plants. Different potential molten salts have been investigated in various solar thermal power plants. It showed maximum operation temperature of 600°C. In ionic liquids are proposed as HTF with a maximum operation temperature of 459°C. Ionic liquids are a specific class of molten salts with a low melting point of less than 100°C.

Molten salts have been used as heat transfer fluids in solar towers in a number of concentrated power plants around the world. Their use in solar towers has been quite established though at the same time it makes the electricity generated from such solar towers expensive. Further, since solar plants are operated intermittently, keeping the salts in molten state is a big engineering and economic challenge. However, salts offer an added advantage of being used as a thermal energy storage (TES) medium as well [14-17].

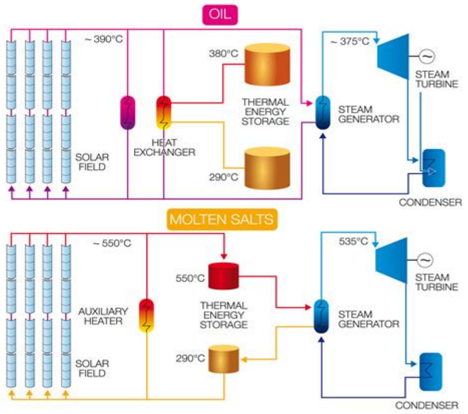


Figure: Molten Salt as HTF

Though molten salt is an optimization for heat transfer fluid, but synthetic oil is not a bad choice. If we compare synthetic oil to other heat transfer fluids it has a better characteristics and heat transfer capacity. It has minimum viscosities and operating temperatures of up to 400°C. All plants built so far employ synthetic oil as HTF in the collector field. This HTF is Therminol VP-1 which is a eutectic mixture of Biphenyl and Diphenyl-oxide. Although its temperature is limited to 395°C. It is still considered for near term power plant projects. This oil is used as a reference in this study. Since steam is used in the Rankine cycle of the power plants. Using these synthetic organic oils in solar collectors as a heat transfer fluid is one of the most convenient ways in terms of operation and maintenance, but when it comes in term of producing a huge energy it is not the best choice because when it crosses 400°C then it vaporizes easily.

But we need to optimize and come out with a better results. Researchers are also working to prove the feasibility for different kind of materials to use as a heat transfer fluid. They also think of substituted poly-aromatic hydrocarbons such as phenyl naphthalene for solar heat transfer application. These substances have some favorable thermo-physical characteristics. And what makes them more suitable for utilizing as a heat transfer fluid is their ability to adopt in 500°C or above and can be derived as the byproducts of refining of clean-diesel. Thermo-physical properties like low vapor pressure and high resistance to thermal decomposition may make poly-aromatic hydrocarbons such as phenyl naphthalene suitable for heat transfer applications in parabolic solar collectors. Since they are liquids at room temperatures and at the same time can withstand high temperatures of above 500°C, Phenyl naphthalene can potentially replace high temperature inorganic salts in solar CSP application.

Marton proposed to use Sulphur as HTF. In his approach Sulphur is evaporated and superheated in a parabolic trough. The heat is transferred in a heat exchanger to a conventional Rankine cycle. Rubbia recommends to use CO2 as HTF in the collector field. The heat from the collector field is transferred to an intermediate molten salt loop via heat exchangers. The molten salt loop is used for the transport of heat from the distributed collector field to the power block and for heat storage

CSP Technology	**Operating Pressures (Bar)**	**Operating Temperatures (°C)**	**HTF Commonly Used**
Trough	15	400	Synthetic hydrocarbon oils
Trough	40	270	Saturated steam
Trough	50-100	400-500	Superheated steam
Tower/Trough	1	500-600	Molten Salts
Tower	1	700-1000	Air
Tower	15	800-900	Air

Table 5: Indicative list of choice of CSP technology versus heat transfer fluids employed.

	Unit	Sodium salt	Sodium potassium salt	Potassium salt	Salt Hitec XL	Salt Hitec	Salt grade Hitec Solar salt	Solar grade HTF (oil)
Melting point	°C	97.82	-12.6	63.2	120	142	240	15
Boiling point or maximum operating temperature	°C	881.4	785	756.5	500	538	567 (bp 593)	400
Density	Kg/m^3	820	749	715	1640	1762	1794	1056
Specific heat capacity	KJ/KG.K	1.256	0.937	0.782	1.9	1.56	1.214	2.5
Viscosity	Pa.s	0.00015	0.00018	0.00017	0.0063	0.003	0.0022	0.0002
Thermal conductivity	W/m.K	119.3	26.2	30.7	Na	0.363	0.536	0.093
Prandtl number		0.0016	0.0063	0.0043		12.89	4.98	5.38

Table 6: Comparison of the various properties of commonly used thermos fluids used in high temperature solar collectors.

That's how more results and proposal come out and evaluated but what is perfect HTF it does matter on environment and installment. And we should choose our HTF for solar thermal power plants by keeping a balance with our demands. If our demand is for huge energy production we shouldn't use synthetic oil. Instead we should use molten salt. This statistical data shows us the capabilities of various heat transfer fluids.

- ## Heliostats:

Though we know heliostats are mirror pieces compiled in a shed and surrounds the solar tower. Its only job is to focus the sun rays in a specific point in the tower. There are many optimization processes what can save is economically and technologically.

Noone et al. Have proposed a new Polly taxis spiral field layout based on heliostats discretization approach. They have compared the results of the proposed layout approach with current PS10 field arranged in a radially staggered configuration, as well as, with the simulated results of Wei et al. They concluded that the spiral layout allow placing heliostats in high efficiency field positions, and thus, offers higher optical efficiency and significantly reduce land area and leveled Energy Cost LEC.

Leonardi and Aguanno have developed a code named CRS4-2 to evaluate the optical performance of solar field made up of both square and circular heliostats of diverse geometrical parameters. They have then introduced a new factor called the characteristic function that depends on the zenith and the azimuth angles. This factor has been applied to estimate the total energy collected by the field; while the shading-blocking effects have been determined by a tessellation of the heliostats. In addition to the comparisons of concentrating solar thermal systems, the code going to be extended to the analysis of Multi- Tower configuration, Beam-Down and Multi-Apertures concepts.

Danielli et al have introduced a new concept named Concatenated Micro-Tower CMT. They have compared its performance with that of larger configuration and have revealed that CMT with a dynamic receiver allocation can improve the annual optical efficiency by12–19%.

Pitz-Paal et al have coupled genetic algorithm with Nelder–Mead algorithm to design heliostat field for high temperature thermo-chemical processes for fuels production. They have found that the selected chemical process has a strong impact on the field design and performance.

Collado has developed as amplified radial staggered method for surrounded heliostat field that uses only two parameters for the optimization, i.e., a blocking factor and an additional security distance, required for installation and maintenance. He has confirmed that the Houston cell wisemethod (UHC-RCELL) needs some improvements to find optimum mean radial and azimuth spacing of the heliostat field. Collado and Guallarhave partially described a new code, called campo. This code is meant to be used to solve the complex problem of the optimized design of heliostat field layouts, by performing accurate evaluation of the shadowing and blocking factor for heliostats placed in radial staggered configuration. They have compared the resulting optimized layout to that of the Gemasolar plant with good agreement

Wei et al have developed a new method and a faster code called HFLD (Heliostat Field Layout Design) for heliostats layout. In this method the heliostat field optimization is based on the receiver geometrical aperture and an efficiency factor. Applying their technique to the PS10 power plant, they proposed a new layout for PS10 field as good as that is already implanted.

- Solar Tracking System:

In the solar field, each heliostat tracks the sun to minimize the cosine effect, and therefore maximize the solar energy collection through positioning its surface normal to the bisection of the angle subtended by sun and the solar receiver. Heliostat sun tracking can be classified either as Open loop system or as closed loop system. The open loop system is based on astronomic formulae relating the sun's position to the system geometry. This system is reliable-low cost and it is recommended for larger solar field because the heliostat is under computer control. On the other hand, the closed loop system uses sensor to track the sun. This system is then more accurate and very useful for small heliostat fields.

Arqueros et al have suggested the use of star reflection on the mirror at night to move the heliostat in order to get enough information for determining the local surface normal at various points on the reflector.

Berenguel et al have used artificial vision technique and a B/W CCD camera to correct and control heliostat positioning offset in an automatic way. The proposed control system allows the elimination of the manual regulation.

Mehrabian and Aseman have developed a computer programming algorithm for evaluating the typical angles of individual heliostats. The algorithm can be used for open loop control and to predict blocking and shading effect of the heliostat field.

Bonilla et al have coupled the hybrid heliostat field model and a wrapped model to handles the real-time simulation and communication between the heliostat field simulator and Heliostat Field Control software HelFiCo. The Authors has also reported some techniques to improve simulation performance.

Roca et al have designed, simulated and tested an automatic controller that employs the mean hydrogen reactor temperature as feedback and selects the heliostats to be focused or taken out of focus, to make the CRS-hydrogen reactor within the margins of safety and for eliminating the manual control of heliostats. The ensuing experimental results of Hydrosol facility at CIEMAT–PSA have been very promising.

- Solar Receiver:

In a CRS, the solar receiver is the heat exchanger where the solar radiation is absorbed and transformed into thermal energy useful in power conversion systems. There are different classification criteria for solar receivers, depending on the geometrical configuration and the absorber materials used to transfer the energy to the working fluid. In this survey, receivers are classified into three groups widely employed in central receiver system, i.e., volumetric receivers, cavity receivers and particle receivers. The results of numerous articles concerned with receivers design, experiments and improvements are presented in this part

Lenert and Wang have presented a combined modeling and experimental study to optimize the performance of a cylindrical Nano-fluid volumetric receiver. Their results suggest that optimized Nano-fluids have significant potential as receivers for CSP systems because their efficiencies are expected to exceed 35% when coupled to a power conversion cycle.

Cheng et al have developed a general numerical modelling method and homemade unified code with the MCRT to simulate the thermal conversion process of REFOS-SOLGATE pressurized volumetric receiver. They have pointed out to the fact that the non-uniformity of the radiation flux density distribution is very significant; it could reach the maximum at the center-left area near the symmetry axis, and the minimum near the pressure vessel wall, with the order of magnitude of 8 and 3, respectively. The proposed design simulation tool is very powerful for simulating other CSP systems and it is capable of providing behavior information on many parameters and phenomena difficult to study experimentally.

Cheng et al have combined the Finite Volume Method (FVM) and the Monte Carlo Ray Tracing (MCRT) method to examine the effects of geometric parameters of the compound parabolic concentrator (CPC) and the properties of the porous absorber on the performance of solar conversion process in pressurized volumetric receiver (PVR). He has concluded that CPC exit aperture has much larger effects on the characteristics and the performance of the PVR than that of the CPC entry aperture with a constant acceptance angle.

- ## Solar thermal storage:

Solar thermal power plant is used for dynamic heat integration with thermal energy storage. Findings show that thermal energy storage gives the system the ability to make the power dispatchable. Additionally, by solving a 24-hour dynamic optimization problem where the plant temperatures and power output are variable allows the system to capture and harvest a higher percentage of solar energy, with the most benefit occurring on mostly cloudy days. The solar energy captured increases 64% from 4.75 MWh to 7.80 MWh using this scheme. Hybrid plant operation and the ability to bypass the storage tanks further improve the system performance

There are several optimized process to store the energy. And we can use them to store energy and produce electricity or energy whenever we want. Such as Electro-mechanical electrical energy is used to do mechanical work in thermal storage.

Pumped hydro systems(PHS) water from a lower level reservoir lake is pumped up to the higher reservoir for later usage in the generation of energy.

Compressed Air Energy Storage (CAES) natural air tight caverns are pumped withcompressed air for later energy recovery via decompression to atmospheric pressure.

Flywheel Energy Storage Systems (FESS) a flywheel is spun-up to store energy and thisincrease in rotational momentum is then harvested to recoup the energy. Electro-chemical energy is stored via changing the level of ionization of a chemical electrolyte, Battery Energy Storage Systems (BESS) there is a wide variety of battery technologies both in production and as topics of research. The main challenges with battery storage relate to limited useful life and the trade-off between the amount of storage used vs: battery life as is typical with Lead Acid batteries where the greater the Depth of Discharge (DoD) in any one cycle, the shorter the expected lifespan of the battery as a whole (expressed as the expected number of charge-discharge cycles. Batteries offer large good energy storage capacity but are limited in the amount of power they can deliver. Key parameters for batteries are useful life (of the order of 1000s of cycles), capacity, maximum charge and discharge rates and the impact of DOD on useful life.

- **Optimization of Kalina Cycle:**

Though we know that in solar thermal power generation system Rankine cycle is basically used in every parameters but recently optimization issues for solar thermal power plants come up on the table then researchers suggest to experiment Kalina cycle instead of Rankine cycle. In Kalina cycle the main substances are Ammonia and water mixture. This mixture evaporates and condenses with a constant temperature.

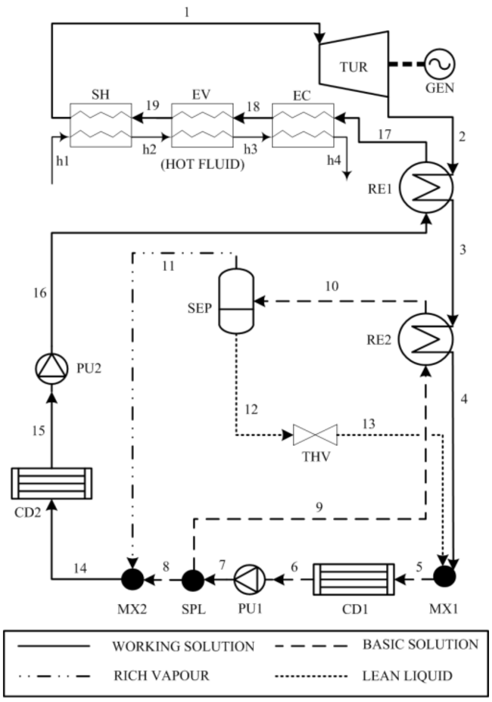


Figure: Kalina Cycle

Researchers compare between Kalina cycle and Rankine cycle on the basis of total capital investment cost for use in a trough system. They found that the Kalina cycle produces 18 % more power than the ORC with 37 % less mass flow rate. In addition, the Kalina cycle had 17.8 % lower leveled electricity costs than the ORC.

Wang et al presented a parametric analysis and optimization of a Kalina cycle driven by solar energy. They found that the net power output and the system efficiency are less sensitive to the turbine inlet temperature under given conditions and that there exists an optimal turbine inlet pressure which results in maximum net power output. Coskun et al. presented a comparison between different power cycles for a medium temperature geothermal resource.

The total investment cost of the plant per kW of net electrical power output and other key results from the Kalina cycle optimization are shown in Table.

Turbine inlet ammonia mass fraction	Working solution (stream 1) mass flow rate (kg/s)	Separator inlet temperature T_{10} (°C)	Turbine outlet pressure p_2 (bar)	Total investment cost per kW of net electrical power output (USD/kW)
0.5	31.4	70.3	1.43	5851.2
0.6	33.7	82.9	2.23	6009.7
0.7	37.6	53.7	3.87	6159.0
0.8	43.0	47.5	6.76	6070.4

For the Rankine cycle, the total plant capital investment cost was 7625.1 USD/kW. Fig. 2 shows the capital cost breakdown for the steam Rankine cycle ('SRC' in the figure) and the Kalina cycle for different turbine inlet ammonia mass fractions (0.5 to 0.8). The costs shown are only for power cycle equipment, i.e. not including the solar field, land and other costs.

❖ Solar thermal vs photovoltaic cells:

Solar thermal works by using mirrors to concentrate sunlight. The concentrated sunlight is then used either directly as a source of heat, as in solar water heating, or to drive a heat cycle such as a sterling engine. Additionally, since solar thermal only directly produces heat, it can store thermal energy various mediums. Some plants, in fact, can store enough energy for 7.5 hours of generation in lieu of sunlight. Therefore, solar thermal can potentially generate power 24 hours a day.

Solar thermal electric energy generation concentrates the light from the sun to create heat, and that heat is used to run a heat engine, which turns a generator to make electricity. The working fluid that is heated by the concentrated sunlight can be a liquid or a gas. Different working fluids include water, oil, salts, air, nitrogen, helium, etc. Different engine types include steam engines, gas turbines, Stirling engines, etc. All of these engines can be quite efficient, often between 30% and 40%, and are capable of producing 10's to 100's of megawatts of power.

There is a long history of utility scale solar thermal generation. Plants were built in the American Southwest throughout the last 30 years. As of 2004 there is 418 MW of installed solar thermal power capacity installed in the US. All told, solar thermal energy costs between 19-35 cents per KWh.

Both photovoltaic and solar thermal are the two established solar power technologies. For decades both of them are used for advancing solar thermal technologies. If we analyze their working procedures then we see that Photovoltaics is a direct conversion of sunlight to electricity. It actually works based on the photoelectric effect that is some materials have characteristics that they release electron when they absorb photon of light. In photovoltaic cell we see that when sunlight strikes into the cell it follows the photoelectric effect and absorb the photon of light and release the electrons. There is a positive and a negative side where the electron conductor is attached which forms an electrical circuit. And the released electrons can be captured in the form of electricity. Photovoltaic cell basically uses semi-conductor technology to directly convert sunlight into electricity. These cells are made of semiconductor materials such as Copper. It only operates when the sun is shining, and must be connected with other power generation mechanisms to ensure a constant supply of electricity.

Photovoltaics are a popular energy source both on the utilities side and for residential home use. Photovoltaic capacity has blown past solar thermal power generation capacity. As of 2008, there was 800 MW of grid-connected photovoltaic capacity, or nearly double the amount of solar thermal generation capacity. Cost per watt for this technology is currently 18-43 cents per KWh.

Currently, there is little price difference between photovoltaic and solar thermal energy. Photovoltaics may become more affordable as more photovoltaics move to utility scale installations. Solar thermal power, however, still has the advantage that it can store power.

The technology differences are moot, however, since both solar technologies are currently much more expensive than other sources of renewable energy. Therefore, at present, solar energy is not a cost-effective power generation system.

❖ Economic advantages due to Solar energy:

According to statistical data and information, in 2010 the world produced 38,000 megawatts of energy directly from the sun, 14,000 megawatts more than last decades. If we compare this growth it will be equivalent to 14 coal powered plants. In comparison, in 1997 global demand for solar photovoltaic equipment was just 125 megawatts. Sales of photovoltaic cells and panels will reach $24 billion in 2010

And a huge amount of employment is happening all around the world to establish resources for solar thermal plants. If we take Ohio City as an example there are 13,400 residents, is building a $175 million, 162,000-square-foot solar materials plant that will employ 70 people. Hemlock Semiconductor is completing a $1 billion polycrystalline silicon plant to supply a basic raw material in the manufacture of solar photovoltaic cells, which convert sunlight to electricity. It will be built near Midland, about 320 mile north from Ohio.

On this issue global business director for DuPont Photovoltaic fluoro materials plant, John Odom said that, ***"Frankly, an even bigger challenge we've had is to invest quickly enough to keep up with market demand,"***

National census of solar industry employment released a statistical data last month the Solar Foundation found that there were 6300 jobs were available in Michigan. Even with this statistics Michigan ranked fourth in solar sector jobs after California, Pennsylvania and Texas. In Saginaw Valley, Michigan, a solar energy center is proposed to be built around the Hemlock Semiconductor's polycrystalline silicon plant, which involves constructing multiple facilities on a 500-acre site.

Ohio has become a center for the production of flexible sheets of photovoltaic cells. It is called thin film. Those were developed from research programs at the University of Toledo. The sheets combine layers of hair-thin semiconductors with non-silicon materials to generate power. The Ohio Department of Development assumes 1,500 jobs in its manufacturing sector.

Basically this advancement in solar energy is occurring in United States, Europe and Asia. As we mentioned about Ohio, the DuPont plant has received 50.1 million US dollars to organize its manufacturing and implementation sector. It also received 7 million US dollars from aid. Like this Michigan has also requested the 2009 federal stimulus bill and other public aid to produce $4.1 billion in public and private investment in the state.The Willard & Kelsey Solar Group planned to start production in a 280,000-square-foot, $250 million thin-film plant in Perrysburg that would employ 100 people and that was built with nearly $20 million in state support.

This is how the huge amount employment is happening all around the world for advancement of solar thermal energy and which not only develops the solar thermal sector but also benefits in world’s economic growth.

❖ Conclusion:

As the world population is growing at a faster rate so day by day the demand for energy will rise higher to maintain a sustainable life. To produce, develop, and manufacture the quest for energy is everlasting. And in this modern age we can’t think of a vast project like solar energy with single purpose. The purpose of this sector is not only producing energy. Many factors comes up when this sector runs its procedure. If production of energy turns out to be a harmful one for our environment then that production won’t help us in a long run. As well as we also have to think about economic aspects and obviously that is not an avoidable issue. And after analyzing the statistical reports, comments and reviews that Solar thermal sector is contributing a lot in Worlds economy by establishing a lot of employment and a market. But is the techno economical aspects are such convenient to encourage the investors in this sectors?

There is no doubt that untenable energy like fossil fuels is limited in our earth and of course someday there will be no gas or oil or coal left to use. Again using these fuel is the major threat for our mankind as burning them produces CO_2, SO_2 and many other toxics that not only pollute our earth but also hazardous for our climate. So for the sake of mankind and to gift our children a healthy and greener world we should think of alternative source of energy and of course that is solar power. CSP is yet the most suitable option. We must not only have to choose solar power as the only source of energy but using solar power at least as contribution in present fossil fuel based power generation system would help to reduce the greenhouse gas emission and our earth would have a little longer life.

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