Solar Thermal Power Generation

Introduction

- Solar thermal power plant comprises of power plants which first convert solar radiation into heat. The resulting thermal energy is subsequently transformed into mechanical energy by a thermal engine, and then converted into electricity.

Introduction

- For thermodynamic reasons high temperatures are required to achieve the utmost efficiency. Such high temperatures are reached by increasing the energy flux density of the solar radiation incident on a collector.
- Concentrated radiation or concentrating collectors.
- Considerably reduced costs may be desired in some cases (use of large-surface cost-efficient collectors).

Types

Solar thermal power plants are subdivided into:

1. Concentrating (point and line focusing systems)
2. Non-concentrating systems.

Classification can be further made according to:

3. Type of receiver of the solar radiation.
4. The heat transfer media and the heat storage system.
5. Additional firing based on fossil fuel energy.

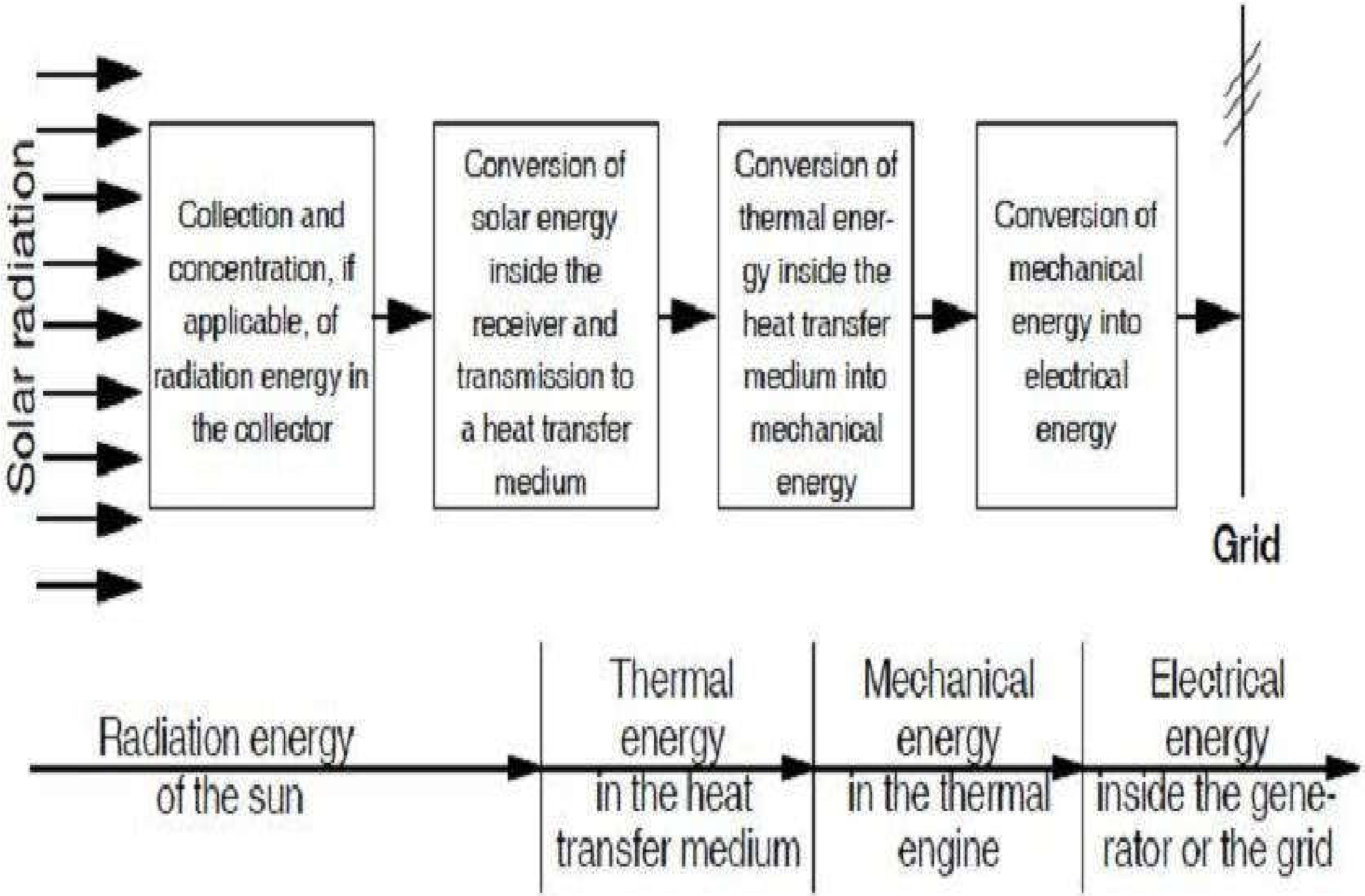
Concentrating Systems

- **Solar tower power plants** (i.e. central receiver systems) as point focusing power plants.
- **Dish/ Stirling systems** as point focusing power plants.
- **Parabolic trough and Fresnel trough power plants** as line focusing power plants.
- Concentrating collectors can reach temperature levels similar to that of existing fossil-fuel fired thermal power stations (e.g. power plants fired with coal or natural gas)

Non-concentrating Systems

- **Solar updraft tower power plants**
- **Solar pond power plants**

Solar Thermal Generation Process



Solar Thermal Generation Process

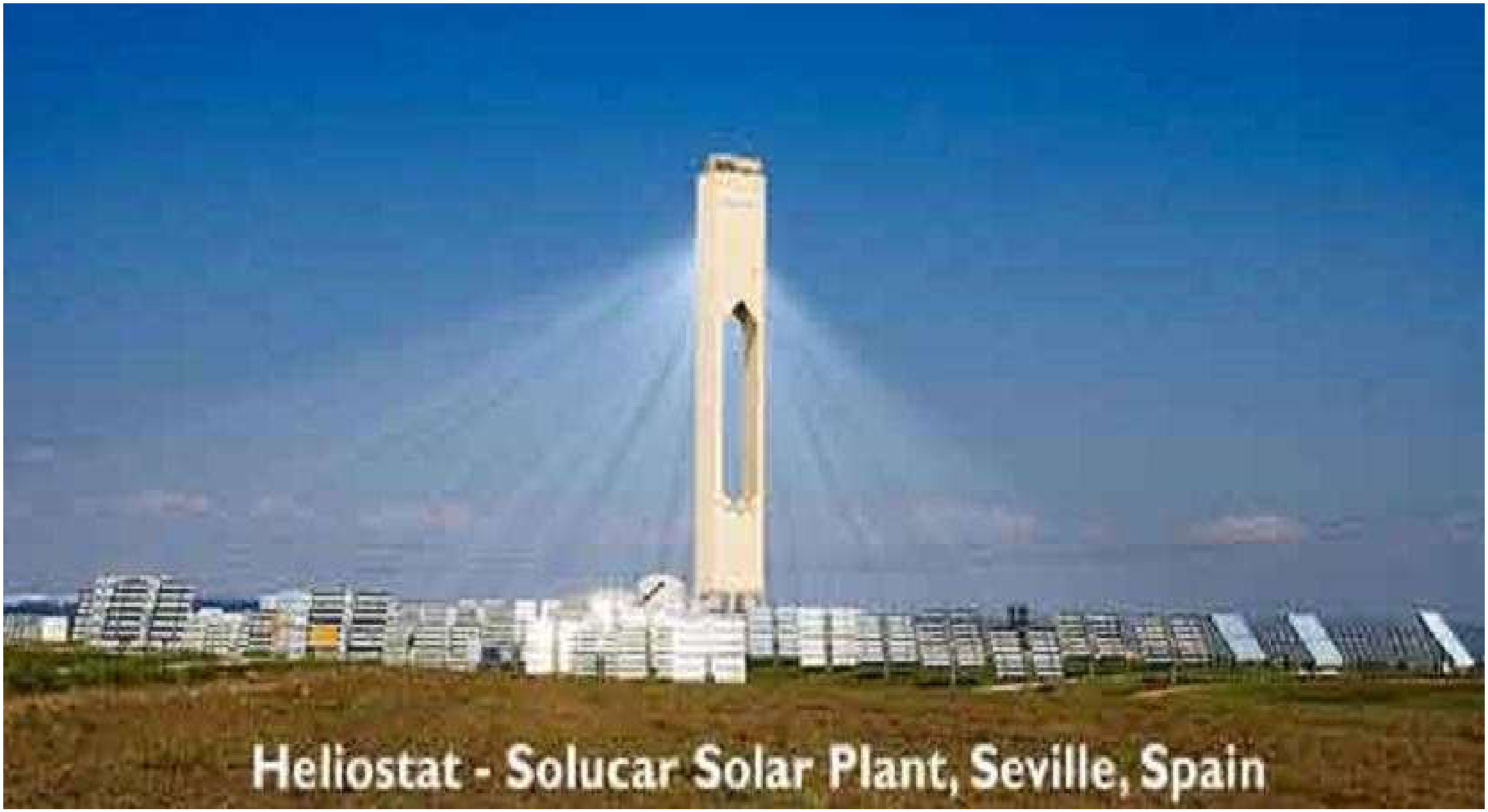
- Concentrating solar radiation by means of a collector system.
- Increasing radiation flux density (i.e. concentrating of the solar radiation onto a receiver), if applicable.
- Absorption of the solar radiation (i.e. conversion of the radiation energy into thermal energy (i.e. heat) inside the receiver).
- Transfer of thermal energy to an energy conversion unit.
- Conversion of thermal energy into mechanical energy using a thermal engine (e.g. steam turbine).
- Conversion of mechanical energy into electrical energy using a generator.

Table 5.1 Concentration factors and technical parameters of selected solar thermal power generation technologies

	Solar tower	Dish/Stirling	Parabolic trough	Fresnel reflector	Solar pond	Solar up-draft tower
Typical capacity in MW	30 – 200	0.01 – 1[a]	10 – 200[c]	10 – 200[c]	0.2 – 5	30 – 200[c]
Real capacity in MW	10	0.025	80	0.3[d]	5	0.05
Concentration factor	600 – 1,000	up to 3,000	50 – 90	25 – 50	1	1
Efficiency[b] in %	10 – 28	15 – 25	10 – 23	9 – 17[d]	1	0.7 – 1.2
Operation mode	grid	grid/island	grid	grid	grid	grid
Development status[e]	+	+	++	0	+	+

[a] by interconnection of many individual plants within a farm; [b] conversion of radiation energy into electrical energy, annual average is site-specific; [c] assuming a solar multiple of 1.0; [d] incorporated into a conventional power station; [e] 0 successful operation of demonstration plants, + successful continuous operation of demonstration plants, ++ commercial plants in operation.

Solar Tower Power Station



Principals and components

Main principals and components:

- Central receiver systems in the tower
- Mirrors tracking the course of the sun in two axes (Heliostats)
- Heliostats reflect the direct solar radiation onto a receiver, centrally positioned on a tower.
- In the receiver, radiation energy is converted into heat and transferred to a heat transfer medium (e.g. air, liquid salt, water/steam).
- This heat drives a conventional thermal engine.
- To ensure constant parameters and a constant flow of the working medium also at times of varying solar radiation, either a heat storage can be incorporated into the system or additional firing using e.g. fossil fuels (like natural gas) or renewable energy (like biofuels) can be used.

Heliostats

- Heliostats are **reflecting surfaces** provided with a two-axis tracking system which ensures that the incident sunlight is reflected towards a certain target point throughout the day.

- Heliostats commonly concentrate sunlight by means of a curved surface or an appropriate orientation of partial areas, so that radiation flux density is increased.

Heliostats

Faceted glass/metal heliostat

metal membrane heliostat

Heliostats

Heliostats consist of:

- The reflector surface (e.g. mirrors, mirror facets, other sunlight-reflecting surfaces)
- A sun-tracking system provided with drive motors
- foundations and control electronics.

The **individual heliostat's orientation** is commonly calculated on the basis of:

- The current position of the sun
- The spatial position of the heliostats
- The target point.

Contd….

- The target value is communicated electronically to the respective drive motors via a communication line. This information is updated every few seconds.
- The concentrator surface size of currently available *heliostats varies between 20 and 150 m^2; to date, the largest heliostat surface amounts to 200 m^2*.

Contd….

- The **heliostat field** accounts for about half the cost of the solar components of such a power plant.
- This is why tremendous efforts have been made to develop heliostats of good optical quality, high reliability, long technical life and low specific costs.
- Due to economic considerations there is a tendency to manufacture heliostats with surfaces ranging between 100 and 200 m^2 and possibly beyond.
- However, there are also approaches to manufacture smaller heliostats to reduce costs by efficient mass-production.

Contd…

Controller:

- Heliostats are usually centrally controlled and centrally supplied with electrical energy.
- As an alternative, autonomous heliostats have been developed which are controlled locally.
- There, the energy required for the control processor and the drives is provided by photovoltaic cells mounted parallel to the reflector surface.

Heliostat fields

- The layout of a heliostat field is determined by technical and economic optimization.
- Heliostats located closest to the tower present the lowest shading.
- Heliostats placed north on the northern hemisphere (or south on the southern hemisphere) show the lowest cosine losses.
- Heliostats placed far off the tower, by contrast, require highly precise tracking and, depending on the geographic location, have to be placed farer from the neighboring heliostats.
- Cosine losses: representing the difference between the amount of energy falling on a surface pointing at the sun, and a surface parallel to the surface of the earth.

Tower

- The height of the tower, on which the receiver is mounted, is also determined by technical and economic optimization.
- Higher towers are generally more favorable, since bigger and denser heliostat fields presenting lower shading losses may be applied.
- However, this advantage is counteracted by the high requirements in terms of tracking precision placed on the individual heliostats, tower and piping costs as well as pumping and heat losses.
- Common towers have a height of 80 to 100 m.
- Lattice as well as concrete towers are applied.

Receiver

- Receivers of solar tower power stations serve to transform **the radiation energy, diverted and concentrated by the heliostat field**, into technical useful energy.
- Nowadays, common radiation flux densities vary between 600 and 1,000 kW/m2.
- Receivers classification according to:
- the applied heat transfer medium (e.g. air, molten salt, water/steam, liquid metal)
- the receiver geometry (e.g. even, cavity, cylindrical or cone-shaped receivers)

Types

- According to heat transfer medium:
  - *Water/steam receiver*
  - *Salt receiver*
  - *Open volumetric air receiver*
  - *Closed (pressurized) air receivers*