

Professional Certificate in Concentrated Solar Power Technology

Thermal Energy Storage Systems

Thermal Energy Storage Systems play a crucial role in Concentrated Solar Power (CSP) technology, allowing for the efficient storage and utilization of solar energy. These systems enable the generation of electricity even when the sun is not shining, providing a reliable and sustainable source of power. In this course, we will explore the key terms and vocabulary related to Thermal Energy Storage Systems in CSP technology.

1. **Thermal Energy Storage (TES)**:

- **Definition**: Thermal energy storage is a technology that stores excess thermal energy for later use. In CSP systems, thermal energy is stored during peak sunlight hours and used to generate electricity when needed.
- **Types**: There are three main types of TES systems: sensible heat storage, latent heat storage, and thermochemical storage.

2. **Concentrated Solar Power (CSP)**:

- **Definition**: CSP is a technology that uses mirrors or lenses to concentrate a large area of sunlight onto a small area, typically a receiver, to produce heat.
- **Applications**: CSP is used to generate electricity, heat, and even cooling in some cases.
- **Advantages**: CSP is a renewable energy source that can provide power even when the sun is not shining, making it a reliable source of energy.

3. **Receiver**:

- **Definition**: The receiver is a key component of a CSP system where concentrated sunlight is absorbed and converted into heat.
- **Types**: Receivers can be tubular, flat-plate, or volumetric, depending on the design of the CSP system.

4. **Heat Transfer Fluid (HTF)**:

- **Definition**: The heat transfer fluid is a medium that transfers heat from the solar collector to the thermal energy storage system or power block.
- **Common fluids**: Water/steam, molten salt, and synthetic oils are commonly used as heat transfer fluids in CSP systems.

5. **Molten Salt**:

- **Definition**: Molten salt is a mixture of salts that remain in a liquid state at high temperatures, making it an ideal heat transfer fluid and thermal energy storage medium.
- **Advantages**: Molten salt has a high specific heat capacity and can retain thermal energy for long periods, making it an efficient storage medium.

6. **Sensible Heat Storage**:

- **Definition**: Sensible heat storage is a type of thermal energy storage where heat is stored or released by changing the temperature of a material without undergoing a phase change.
- **Examples**: Water tanks, rocks, and concrete are commonly used as sensible heat storage materials in CSP systems.

7. **Latent Heat Storage**:

- **Definition**: Latent heat storage is a type of thermal energy storage where heat is stored or released by changing the phase of a material, such as melting or freezing.
- **Advantages**: Latent heat storage materials have a high energy density and can store large amounts of thermal energy in a small volume.

8. **Thermochemical Storage**:

- **Definition**: Thermochemical storage is a type of thermal energy storage where chemical reactions are used to store and release heat.
- **Principles**: Thermochemical storage systems utilize reversible reactions to store and release thermal energy efficiently.

9. **Heat Exchanger**:

- **Definition**: A heat exchanger is a device that transfers heat between two fluids at different temperatures.
- **Types**: Shell-and-tube, plate, and finned-tube heat exchangers are commonly used in CSP systems for heat transfer between the heat transfer fluid and storage medium.

10. **Power Block**:

- **Definition**: The power block is the section of a CSP plant where the thermal energy stored in the TES system is converted into electricity.
- **Components**: Turbines, generators, and heat exchangers are key components of the power block in a CSP plant.

11. **Dispatchability**:

- **Definition**: Dispatchability refers to the ability of a power plant to generate electricity on demand.
- **Importance**: CSP plants with TES systems are dispatchable, meaning they can produce electricity when needed, providing grid stability and reliability.

12. **Round-Trip Efficiency**:

- **Definition**: Round-trip efficiency is a measure of the efficiency of a TES system in storing and retrieving thermal energy.
- **Calculation**: It is calculated as the ratio of the energy output to the energy input during the charging and discharging cycles of the TES system.

13. **Cycling Capacity**:

- **Definition**: Cycling capacity refers to the number of charge-discharge cycles a TES system can undergo without significant degradation in performance.

- **Factors**: The choice of storage material, operating temperature, and cycling strategy affect the cycling capacity of a TES system.

14. **Thermal Energy Storage Tank**:

- **Definition**: A thermal energy storage tank is a container where thermal energy is stored in the form of hot or cold fluid.

- **Materials**: Steel, concrete, and composite materials are commonly used to construct thermal energy storage tanks in CSP systems.

15. **Hybrid Systems**:

- **Definition**: Hybrid systems combine different types of energy storage technologies, such as TES and batteries, to optimize energy production and storage in CSP plants.

- **Benefits**: Hybrid systems can improve the overall efficiency and reliability of CSP plants by combining the strengths of different storage technologies.

16. **Entropy**:

- **Definition**: Entropy is a measure of the randomness or disorder in a system and is a key concept in thermodynamics.

- **Role**: Entropy affects the efficiency of energy conversion processes in CSP systems and TES systems.

17. **Thermal Efficiency**:

- **Definition**: Thermal efficiency is a measure of how well a system converts thermal energy into mechanical or electrical energy.

- **Calculation**: It is calculated as the ratio of the useful energy output to the energy input in a system.

18. **Parabolic Trough**:

- **Definition**: A parabolic trough is a type of solar collector used in CSP systems to concentrate sunlight onto a receiver tube.

- **Design**: The parabolic shape of the trough focuses sunlight onto the receiver, where the heat transfer fluid is heated.

19. **Solar Power Tower**:

- **Definition**: A solar power tower is a type of CSP system where a field of mirrors reflects sunlight onto a central receiver located at the top of a tower.

- **Operation**: The concentrated sunlight heats the heat transfer fluid in the receiver, which is then used to generate electricity.

20. **CSP Plant Layout**:

- **Components**: A typical CSP plant consists of solar collectors, thermal energy storage systems, power blocks, and auxiliary systems such as cooling towers and water treatment facilities.

- **Configuration**: The layout of a CSP plant is designed to maximize energy capture, storage, and conversion efficiency.

21. **Degradation**:

- **Definition**: Degradation refers to the loss of performance or efficiency of a component or system over time.

- **Challenges**: Degradation of TES materials and components can affect the overall efficiency and reliability of a CSP plant.

22. **Thermal Stratification**:

- **Definition**: Thermal stratification occurs when different layers of temperature form within a thermal energy storage tank, affecting the efficiency of heat transfer.

- **Mitigation**: Proper mixing and circulation of the heat transfer fluid can help reduce thermal stratification in TES systems.

23. **Cost Analysis**:

- **Importance**: Cost analysis is essential in evaluating the economic feasibility of CSP plants with TES systems.

- **Factors**: The cost of materials, construction, operation, and maintenance all contribute to the overall cost of a CSP plant.

24. **Grid Integration**:

- **Definition**: Grid integration refers to the process of connecting a CSP plant to the electrical grid and managing the supply of electricity to meet demand.

- **Challenges**: Grid integration of CSP plants with TES systems requires proper planning and coordination to ensure grid stability and reliability.

25. **Thermal Storage Capacity**:

- **Definition**: Thermal storage capacity is the amount of thermal energy that can be stored in a TES system.

- **Calculations**: It is typically measured in kilowatt-hours or megawatt-hours and depends on the size and design of the TES system.

26. **Thermal Cycling**:

- **Definition**: Thermal cycling refers to the repeated heating and cooling of a TES system during charge-discharge cycles.

- **Effects**: Thermal cycling can lead to material fatigue and degradation, affecting the performance and longevity of the TES system.

27. **Hydrogen Storage**:

- **Definition**: Hydrogen storage is a type of thermochemical storage where hydrogen is used as a medium to store and release heat.

- **Advantages**: Hydrogen storage can provide high energy density and efficient heat transfer in TES systems.

28. **Thermal Efficiency Enhancement**:

- **Strategies**: Various strategies such as insulation, heat recovery, and advanced materials are used to enhance the thermal efficiency of TES systems in CSP plants.

- **Benefits**: Improving thermal efficiency can increase the overall performance and cost-effectiveness of CSP plants.

29. **Heat Losses**:

- **Causes**: Heat losses in TES systems can occur due to conduction, convection, radiation, and thermal stratification.

- **Mitigation**: Proper insulation, heat exchanger design, and operational strategies can help minimize heat losses in TES systems.

30. **Energy Density**:

- **Definition**: Energy density is the amount of energy stored per unit volume or mass in a TES system.

- **Factors**: The choice of storage material and design of the TES system affect the energy density and storage capacity.

In conclusion, understanding the key terms and vocabulary related to Thermal Energy Storage Systems in Concentrated Solar Power technology is essential for designing, operating, and optimizing CSP plants for efficient and sustainable energy production. By familiarizing ourselves with these concepts, we can address challenges, improve performance, and promote the widespread adoption of CSP technology for a clean energy future.