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Option: Renewable Energy and Environment

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Tutorial Session No. 5.

Exercise 1 :

A solar tower power plant uses a heat transfer fluid (molten salts) to transfer heat to the steam generator. The following information is given:

- Nominal electrical power of the plant: Pelectric=100 MW
- Desired operating time without sunlight: tstorage=6 hours
- Overall thermodynamic cycle efficiency: ηcycle=40%
- Average heat capacity of the heat transfer fluid: cp=1.5 kJ/kg \
- Fluid temperature range: Thigh=565∘C, Tlow=290∘C

Questions:

1. Calculate the **total electrical energy** to be supplied during the 6 hours of storage.
2. Calculate the **thermal energy** that needs to be stored in the heat transfer fluid, taking into account the conversion efficiency.
3. Determine the **mass of heat transfer fluid** required to store this energy.
4. If the storage is realized in two tanks (hot and cold), what is the **energy capacity of each tank**?
5. Discussion: How does **thermal storage** allow electricity production during periods without sunlight, and what are the main constraints (cost, volume, thermal losses)?

Exercise 2 :

We want to size a thermal storage tank using a Phase Change Material (PCM) for a small building heated by solar thermal panels.

- Daily thermal energy to be stored: Qstock=30 kWh/day
- PCM melting temperature: Tfusion=45∘C

- PCM specific heat capacity: $c_p = 2.0$ kJ/kg
- PCM latent heat of fusion: $L = 180$ kJ/kg
- Initial storage temperature: $T_i = 20^\circ C$ Final storage temperature: $T_f = 50^\circ C$

Questions:

1. Calculate the fraction of **sensible energy** stored due to heating the PCM:
2. Calculate the **energy stored during melting**:
3. Determine the **mass of PCM** required to store 30 kWh per day.
4. Verify whether the chosen PCM can provide heat at the desired temperature.
5. Discussion: Explain the **advantages and limitations** of using PCM for thermal energy storage in the building.

Exercise 3 :

A thermodynamic solar power plant feeds a Rankine steam cycle, with a **desired net electrical power of 50 MW** (net output at the generator). Operating parameters and assumptions are:

- Steam enthalpy at the turbine inlet: $h_1 = 3450$ kJ/kg
- Isentropic enthalpy at the turbine outlet: $h_{2s} = 2200$ kJ/kg
- Turbine isentropic efficiency: $\eta_t = 0.88$
- Pump work (approximate): $w_{pump} = 10$ kJ/kg
- Enthalpy of the fluid feeding the boiler (after pump / feedwater): $h_3 = 460$ kJ/kg (Neglect heat recovery for simplicity; use $q_{in} = h_1 - h_3$)
- Thermal energy storage (TES) is provided by molten salts ($NaNO_3$–KNO_3), with: $c_p = 1.50$ kJ/kg
    - Operating temperature range: $\Delta T = 290$ K (e.g., 290 → 580°C)
- Overall TES discharge efficiency (losses, heat exchangers, pumps): $\eta_{TES} = 0.90$ (90%)
- The plant must operate for **6 hours without sunlight** (night) at the same net power (50 MW).

Questions:

1. Calculate the **real specific turbine work** wt (kJ/kg), the **net specific work** wnet (kJ/kg), and the **thermal efficiency of the cycle**:
2. Determine the **mass flow rate of water/steam** $\dot{m}$ (kg/s) required to produce 50 MW.
3. Calculate the **total electrical energy required** during 6 hours (MWh) and the **thermal energy that must be withdrawn from the TES** (MWh), taking into account the cycle efficiency and storage losses (ηTES).
4. Calculate the **mass of molten salts required** (in tonnes) to store this energy;
5. Discuss the **feasibility (order of magnitude)** of this storage compared to real CSP plants.