Special Topics Course ME 5374 "APPLICATIONS OF CONCENTRATING SOLAR THERMAL TECHNOLOGIES"
Spring 2024

Assignment 2

Read Chapter 2.0 to 2.2. (pages 45-70) and the Reda, I and Andreas, A (2004) reference for the "SPA" algorithm, see pg. 48 of the text.

1) Summarize your thoughts concerning the comparisons of the different incident solar radiations in section 2.1.1 in terms of the solar/zenith angle and solar/azimuth angle and why these parameters are emphasized instead of the incident solar radiation flux. This is more a thought based question since the complete answer will be given after we complete Chapter 3.

2) You have been given the following single point design condition for direct incident solar radiation on the collector of 550 W/m^2 and a surrounding temperature of 18 C You can perform your analysis at steady state conditions. Determine the power output and first law efficiency of the concentrating solar power (CSP)system.

The CSP will heat the working fluid from a temperature of 32 C and has a concentration factor of 10,000. The concentration factor is the ratio of the incident solar radiation on the collector to the incident solar radiation area where it is absorbed. The optical efficiency of this system is 0.94 and the solar absorptivity of the receiver is 0.98. Note: that defining your system at the incident area will avoid needing the geometric optics information associated with the concentration factor. The concentrating collector has an opening of 5 m^2 and a heat transfer area of 0.05 m^2 for the receiver. The mass flow rate of the working fluid through the system is 0.009 Kg/s. For the purpose of this problem linearize the thermal radiation heat loss with at least one iteration. The convective heat transfer coefficient is 5.0 W/m^2 K from the receiver and its thermal emissivity is 0.2. The heat transfer from the collector can be considered to be at the average temperature of the working fluid, $(T_{in} + T_{out})/2$. The specific heat of the incompressible working fluid is 2,678 J/(Kg K). The useful energy from this collector system is the change in the enthalpy of the flow through the system. The working fluid enters a heat engine with an efficiency of 0.30 that is connected to a generator with an efficiency of 0.90. The generator operates isothermally.

a) Determine the power output for the system for the given collector area.
b) Determine the system efficiency based on power.
c) The given direct incident solar represents an average value for an average daylength of 9 hours per day over a year. Using this information determine the energy produced by this system for one year.
d) Is the system efficiency different based on the energy vs the power? Explain your answer.
e) Neglecting the effects of interest, degradation and usage factors, estimate the capital costs for this system if the produced electrical power cost is 75 USD/MWh over a 20 year lifetime.
f) If the peak direct incident solar radiation is 900 W/m2, determine the capacity factor for this system using the average information cited in part "c". The average production corresponds to the nominal system capacity.

NOTE: Many of the details that are involved in a CSP system have been removed from this problem, but it illustrates the reason for concentrating solar radiation to increase its flux and reduce the heat transfer area from the receiver. It is a system level analysis based on the First Law Energy Balance and heat transfer theories, builds on the material in Chapter 1 of the textbook and is intended to get you questioning about the details of the CSP systems.