(A) * Concentrating Solar Power (CSP) plants Exercise 1 *

→ 3.05

1/ * $\eta_{\text{solar to electricity}} = \frac{P_{EL\ EXP}}{Q_{SUN}} = \frac{Q_{TO\ RECEIVER}}{Q_{SUN}} \cdot \frac{Q_{TO\ HTF}}{Q_{TO\ RECEIVER}} \cdot \frac{Q_{TO\ ST/PB}}{Q_{TO\ HTF}} \cdot \frac{Q_{TO\ PB}}{Q_{TO\ ST/PB}} \cdot \frac{P_{EL\ GROSS}}{Q_{TO\ PB}} \cdot \frac{P_{NET\ SC}}{P_{EL\ GROSS}}$

$= \eta_{OPT} \cdot \eta_{TH} \cdot \eta_{pipping} \cdot \eta_{ST} \cdot \eta_{EL\ GROSS} \cdot \eta_{AUX\ SC} = \eta_{OPT} \cdot \eta_{FOVL}$

- $Q_{TO\ ST/PB}$: Storage to Powerblock
- $Q_{TO\ PB}$: Power Block
- η_{OPT}: steam cycle
- η_{TH}
- $\eta_{AUX\ SC}$: auxiliaries of steam cycle

- $\frac{P_{EL\ EXP}}{P_{NET\ SC}}$: exported
- $\eta_{AUX\ SF}$: auxiliaries of other part of the cycle

2/ * $P_{AUX\ SC} = (0.05) P_{EL\ GROSS}$ ✓

* $P_{NET\ SC} = P_{EL\ GROSS} - P_{AUX\ SC}$ ✓

* $\eta_{pipping} = \frac{Q_{to\ BT/PB}}{Q_{TO\ HTF}} = \frac{\dot{m}_{HTF} c_{p_{HTF}} (T_4 - T_1)}{\dot{m}_{HTF} c_{p_{HTF}} (T_3 - T_2)}$ ✓

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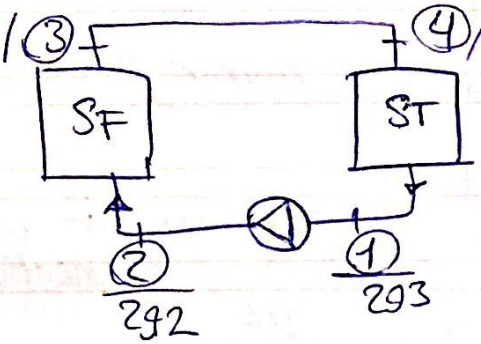


3/ * $Q_{TO\ PB} = \frac{P_{EL\ GROSS}}{\eta_{EL\ GROSS}}$ ✓

* $Q_{TO\ HTF} = \frac{Q_{TO\ PB}}{\eta_{pipping}}$ ✓ / 4/ * $\dot{m}_{HTF} = \frac{Q_{TO\ HTF}}{c_{p_{HTF}} (T_3 - T_2)}$ ✓

4/

$$\#\,\text{LOOPS} \rightarrow = \frac{\dot{m}_{LTF}}{\dot{m}_{max/LOOP}}$$ ✓

5/ $\dot{Q}_{TO\ HTF}\big|_{1\,LOOP} = \dot{m}_{HTF,1\,LOOP}\, C_{P_{HTF}} (T_3 - T_2) =$

$DNI \cdot \underbrace{L \cdot W}_{\text{Area of the mirror}} \cdot \eta_{OPT} \cdot \eta_{FOULING} - \dot{Q}_{TH\ Losses} \cdot L$ ✓

6/ $\rightarrow L = \frac{\dot{m}_{HTF,1\,LOOP}\, C_{P_{HTF}} (T_3 - T_2)}{DNI \cdot W \cdot \eta_{OPT} \cdot \eta_{FOUL} - \dot{Q}_{TH,Loss}}$ ✓

7/ $\rightarrow \eta_{TH} = \frac{\dot{m}_{HTF,1\,LOOP} \cdot C_{P\,HTF} (T_3 - T_2)}{Q_{receiver}}$ ✓ → ✗ W = receiver outer diameter ?

$Q_{receiver} = DNI \cdot W \cdot L \cdot \eta_{OPT} \cdot \eta_{FOUL}$

8/ * $A_{MIRRORS} = \#\,LOOPS \cdot W \cdot L$ ✓

* $\underbrace{SM}_{\text{Solar Multiple}} = \frac{\dot{Q}_{ACTUAL\ TO\ PB/ST}}{\dot{Q}_{NOM\ PB}} = 2$ → mentioned in the question. (this formula is correct)

THIS IS η_{ST}, or SM?

* $A_{MIRRORS_{ACTUAL}} = A_{MIRRORS} \cdot SM$ ✓

* $A_{LAND} = A_{M,ACTUAL}\ (L/M)$ ✓

→ Land mirror area ratio

9/ * $\underbrace{\Delta P}_{\text{pressure drops}} = \Delta P_{distributed} + \underbrace{\Delta P_{concentrated}}_{\rightarrow \text{the sum of all mentioned}}$ ✓

$\rightarrow \Delta P_{DISTR} = f \cdot \frac{L}{D_{INT\,(INTERNAL)}} \cdot \rho_{HTF} \cdot \frac{v^2}{2}$ ✓

→ distributing pumps

* $v = \frac{\dot{m}_{HTF,1\,LOOP}}{\rho_{HTF} \cdot \pi \cdot D_{INT}^2/4}$ ✓ $\dot{m} = \rho v A$

* $P_{PUMP} = \frac{\dot{m}_{HTF} \cdot \Delta P}{\rho_{HTF} \cdot \eta_{PUMP}}$

* $P_{AUX\ SF} = P_{PUMP} + P_{OTHERS}$ ✓

* $P_{EL\ EXP} = P_{EL\ NET\ SC} - P_{AUX\ SF}$ ✓

* $\eta_{AUX\ SF} = \frac{P_{EL\ EXP}}{P_{EL\ NET\ SC}}$ (from part 1, $P_{EL\ gross} - P_{aux,\ SC}$) ✓

(B) * $\eta_{OPT} = \eta_{OPT,PEAK}\big|_{0^\circ} \cdot K(\theta) \cdot \eta_{shading} \cdot \eta_{END-LOSS}$

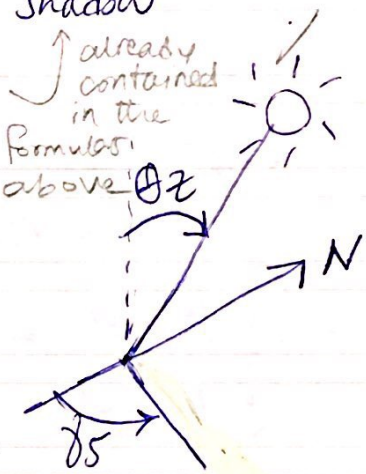
(0° = ZERO; shading = shadow)

→ $\eta_{OPT,PEAK}\big|_{0^\circ} = \rho_m \cdot \gamma \cdot \tau_G \cdot \alpha_C$ (already contained in the formulas above)

ρ_m: angle of the diagram

γ: transmisity!

α_C: absorbity!



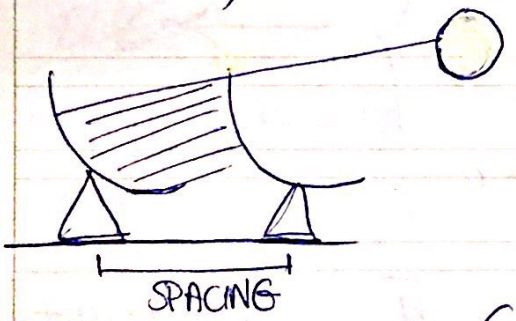
Excel datas are alst, Average?

DNI
θ, $K(\theta)$, shading, η_{opt}

* $\theta = \arcsin(\cos(\gamma) \cdot \sin(\theta_Z))$ ✓ & γ_S

→ $K(\theta) = \cos(\theta) - 5 \cdot 2 \ldots \theta + \ldots \theta^2$ ✓

everything should be in degrees, But excel calculater in radianse. Be careful!



* $\eta_{SHADING} = \min\left(\max\left(0; \frac{L_{SPACING}}{w} \cdot \frac{\cos(\theta_Z)}{\cos(\theta)}\right); 1\right)$ ✓

(the same L from last part?)

* $\eta_{OPT}(h) = K(\theta) \cdot \eta_{SHADING} \cdot \eta_{OPT,PEAK}\big|_{0^\circ}$ ✓ (h: hour angle; w.l.)

→ $\dot{Q}_{TO\ RECEIVER}(h) = \underbrace{DNI \cdot A_M}_{=\dot{Q}_{SUN}(h)} \cdot \eta_{OPT} \cdot \eta_{FOUL}$ ✓

⇒ $P_{EL\ EXP}(h) =$ ✓

average $\dot{Q}_{TO\ REC} \cdot \bar{\eta}_{TH} \cdot \bar{\eta}_{PIPINGS} \cdot \bar{\eta}_{NETPB} \cdot \bar{\eta}_{SFAUX}$ ✓

$$*\eta_{\text{SOLAR TO ELECTRIC}} = \frac{P_{EL EXP,Y}}{Q_{SUN,Y}}$$ ✓

(C) $*V_{ST} = 2 \cdot \pi \cdot D^2/4 \cdot H$ → Volume of 2 storages ✓ Storage cost

→ $TPC = C_{SF} \cdot A_M + C_{ST} \cdot V_{ST} + C_{PB} \cdot P_{GROSS}$ → Power Block cost
(total plant cost) ↳ found in A, Solarfield ↳ from above → data of the question ✓

→ $LCOE = \frac{TPC\,(1 + 0.14 + 0.15) \cdot LCC}{P_{EL EXP,Y}}$ → $\left(\frac{TPC \times LCC}{\text{Production}} = LCOE\right)$ PB unit ✓

✗ $P_{EL,EXP}$ found in A, but that one is not yearly! What do we do with BL: 30 years?

(D) $\eta_{TH} = \frac{Q_{TO\ HTF}}{Q_{TO\ RECEIVER}} = \frac{Q_{TO\ REC} - Q_{TH\ LOSS}}{Q_{TO\ REC}} =$ ✓

$1 - \frac{Q_{TH\ LOSS}}{Q_{TO\ REC}} = 1 - \frac{Q_{TH\ LOSS}}{\eta_{OPT} \cdot DNI \cdot W \cdot L} = 1 - \frac{q_{TH\ LOSS}\left[\frac{W}{m}\right]}{\eta_{OPT} \cdot DNI \cdot W}$ ✓

$Q_{TO\ REC} = Q_{SUN}$

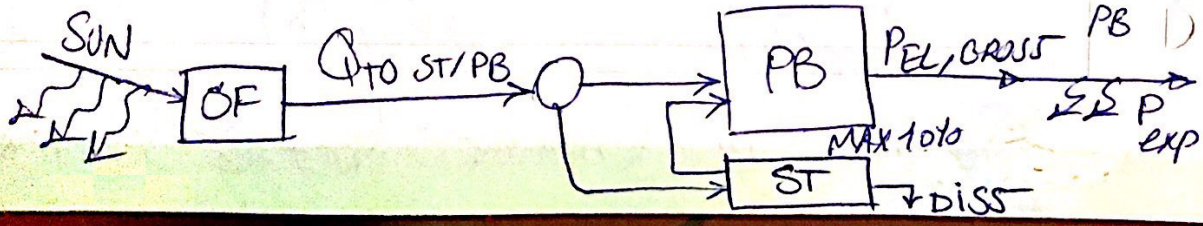
→ { if $DNI = 0 \rightarrow \eta_{TH} = 0$
if $\eta_{OPT} = 0 \rightarrow \eta_{TH} = 0$
if $\eta_{TH} < 0 \rightarrow \eta_{TH} = 0$ } ✓ →

$*Q_{TO\ HTF} = Q_{TO\ REC} \cdot \eta_{TH}$, $\bar{\eta}_{TH} = \frac{\sum Q_{TO\ HTF}}{\sum Q_{TO\ REC}}$ ✓

almost equal to the one we considered before

Turn down means minimum allowed inlet

$*Q_{TO\ ST/PB} = \eta_{PIPING} \cdot Q_{TO\ HTF}$ { MAX IN: $Q_{NOM,PB}$; MIN IN: $0,4 \cdot Q_{NOM,PB}$ }



$\Rightarrow$ $Q_{SF \rightarrow PB}$
$Q_{SF \rightarrow ST}$
$Q_{ST \rightarrow PB}$
$Q_{IN\,ST}$
Q_{DISS}

$Q_{SF \rightarrow PB}$

IF $Q_{SF \rightarrow PB}(h) + Q_{IN\,ST}(h-1) \geq Q_{NOM,PB} \cdot 0.4$

IF $Q_{SF \rightarrow PB}(h) \leq Q_{NOM,PB} \rightarrow$

$Q_{SF \rightarrow PB}(h) = Q_{SF \rightarrow}(h)$

Should'nt we consider the current coming from storage like water ?

ELSE

$Q_{SF \rightarrow PB}(h) = Q_{NOM,PB}$

END

ELSE

$Q_{SF \rightarrow PB}(h) = 0$

END

$Q_{SF \rightarrow ST}$

IF "LIKE ABOVE"

IF "LIKE ABOVE"

$Q_{SF \rightarrow ST}(h) = 0$

ELSE

$Q_{SF \rightarrow ST}(h) = Q_{SF \rightarrow}(h) - Q_{NOM,PB}$

END

ELSE

$Q_{SF \rightarrow ST}(h) = Q_{SF \rightarrow}(h)$

END

$Q_{ST \rightarrow PB}$

IF $(Q_{SF \rightarrow}(h) + Q_{IN\ ST}(h-1)) \geq Q_{NOM\ PB} \cdot 0.4$

IF $(Q_{SF \rightarrow ST}(h) = 0)$ AND $(Q_{IN\ ST}(h-1) > 0)$

$Q_{ST \rightarrow PB}(h) = \min\left(E_{IN\ ST}(h-1);\ Q_{NOM\ PB} - Q_{SF \rightarrow PB}\right)$

ELSE

$Q_{ST \rightarrow PB}(h) = 0$

END

ELSE

$Q_{ST \rightarrow PB}(h) = 0$

$Q_{IN\ ST}$

IF $\left[\left(Q_{IN\ ST}(h-1) + Q_{SF \rightarrow ST}(h) - Q_{ST \rightarrow PB}(h)\right) > 0\right]$ AND

$[(\text{—}) < Q_{ST_{MAX}}]$

$Q_{IN\ ST}(h) = Q_{IN\ ST}(h-1) + Q_{SF \rightarrow ST}(h) - Q_{ST \rightarrow PB}(h)$

ELSE

IF $(\text{—}) \geq Q_{ST\ MAX}$

$Q_{IN\ ST}(h) = Q_{ST\ MAX}$

ELSE

$Q_{IN\ ST}(h) = 0$

END

END

Q_{DISS}

IF $Q_{IN\ ST}(h) < Q_{ST\ MAX}$

$Q_{DISS}(h) = 0$

ELSE

$Q_{DISS}(h) = Q_{IN\ ST}(h-1) + Q_{SF \rightarrow ST}(h) - Q_{IN\ ST}^{(h)}$

END

$\equiv Q_{ST\ MAX}$

→ $\dot{Q}_{TO\ PB}(h) = \dot{Q}_{SF \rightarrow PB}(h) + \dot{Q}_{ST \rightarrow PB}(h)$ ✓

- $\%\ LOAD(h) = \frac{\dot{Q}_{TO\ PB}(h)}{\dot{Q}_{NOM\ PB}}$ ✓

* $\eta_{Storage} = \frac{\Sigma \dot{Q}_{TO\ PB}}{\Sigma \dot{Q}_{SF \rightarrow}}$ ✓

* $\eta_{GROSS\ EL} = \eta_{GROSS}|_{NOM} \cdot \eta_{PARTIAL\ LOAD}$ ✓

* $P_{EL\ GROSS}(h) = \dot{Q}_{TO\ PB}(h) \cdot \eta_{EL\ GROSS}$ ✓

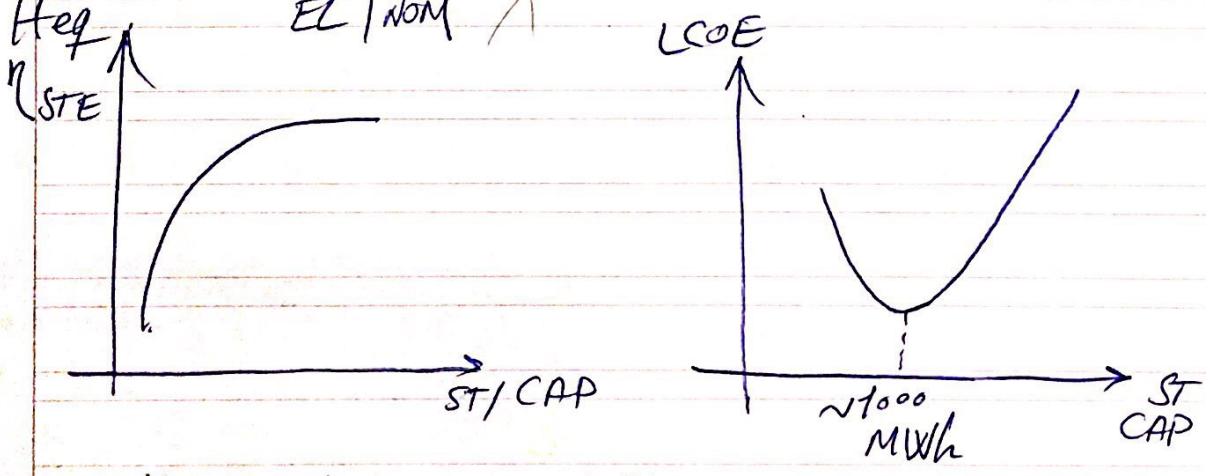
- → $\eta_{MAX\ SC} = 0.95$ (0.05 Aux consumption) / $P_{NET\ SC} = P_{EL\ GROSS} \cdot \eta_{AUX\ SC}$ ✓ consumption of auxiliaries of SC

* $P_{AUX\ SF} = \max(P_{EL\ NET\ SC}(1 - \eta_{AUX\ SF}); 1MW)$ ✓

→ $P_{EXP\ EL}(h) = P_{EL\ NET\ SC} - P_{AUX\ SF}$ ✓ → * $\eta_{S-T-E} = \frac{\Sigma P_{EXP\ EL}}{\Sigma \dot{Q}_{SUN}}$

* $H_{eq} = \frac{\Sigma P_{EXP\ EL}}{P_{EXP\ EL}|_{NOM}}$ ✓

- ✗ → where did we get this from?



✗ sensitivity Analysis?!

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