STERG

SOLAR THERMAL ENERGY
RESEARCH GROUP

FEASIBILITY STUDY OF ONCE THROUGH COOLING FOR 50 MW SOLAR THERMAL POWER PLANT ON/NEAR THE LOWER ORANGE RIVER

Author: Abiola Kehinde

Supervisor: Dr. J. Hoffmann

Solar Thermal Energy Group (STERG)
Stellenbosch University

Introduction

Background information

- With the technology advancement in CSP plants, the once-through cooling system has been neglected, due to a large amount of water passing through the condenser during operation.

Introduction

Background information

- In South Africa, 8 % of water is used in large industries and power generations, 18 % of water for rural and urban use, and 62 % of water resources are used for agriculture and irrigation (Roux *et al.*, 2012).

Introduction

Problem statement

- Agriculture and irrigation sector in South Africa consume more water resources than other sector.
- Low thermal efficiency in CSP plant using air-cooled system

Introduction

Aims and objectives

- To analyze the possibility of diverting water that passed through a condenser to agricultural purposes or not.
- To compare the improved thermal efficiency against condenser fouling factor.

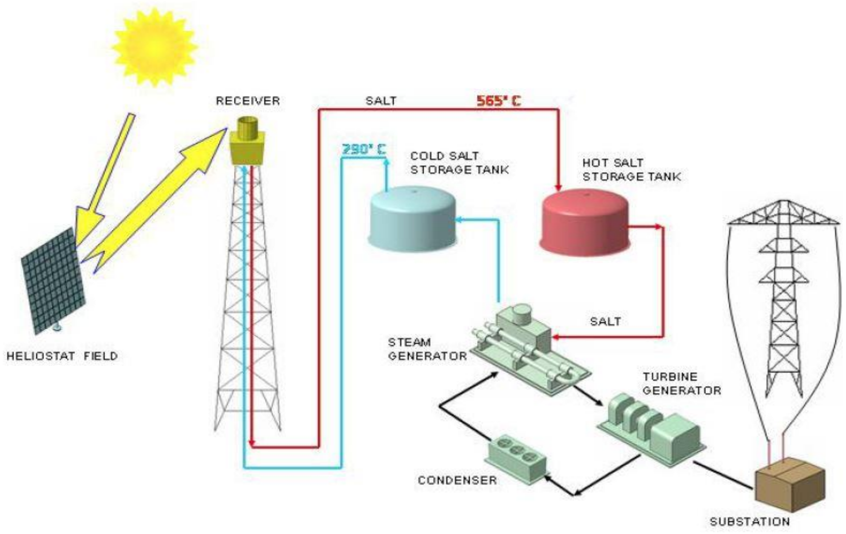
Introduction

Aims and objectives

- To compare the improved thermal efficiency against air-cooled efficiency.
- To identify the agricultural constraints.

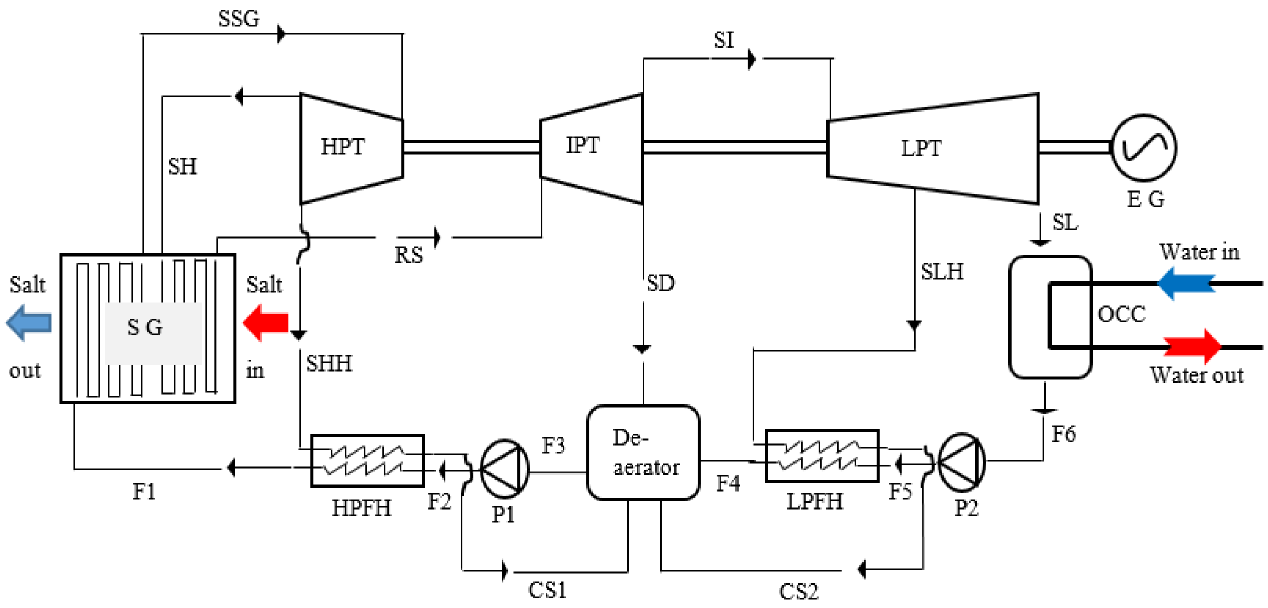
CSP Plant

Modelling



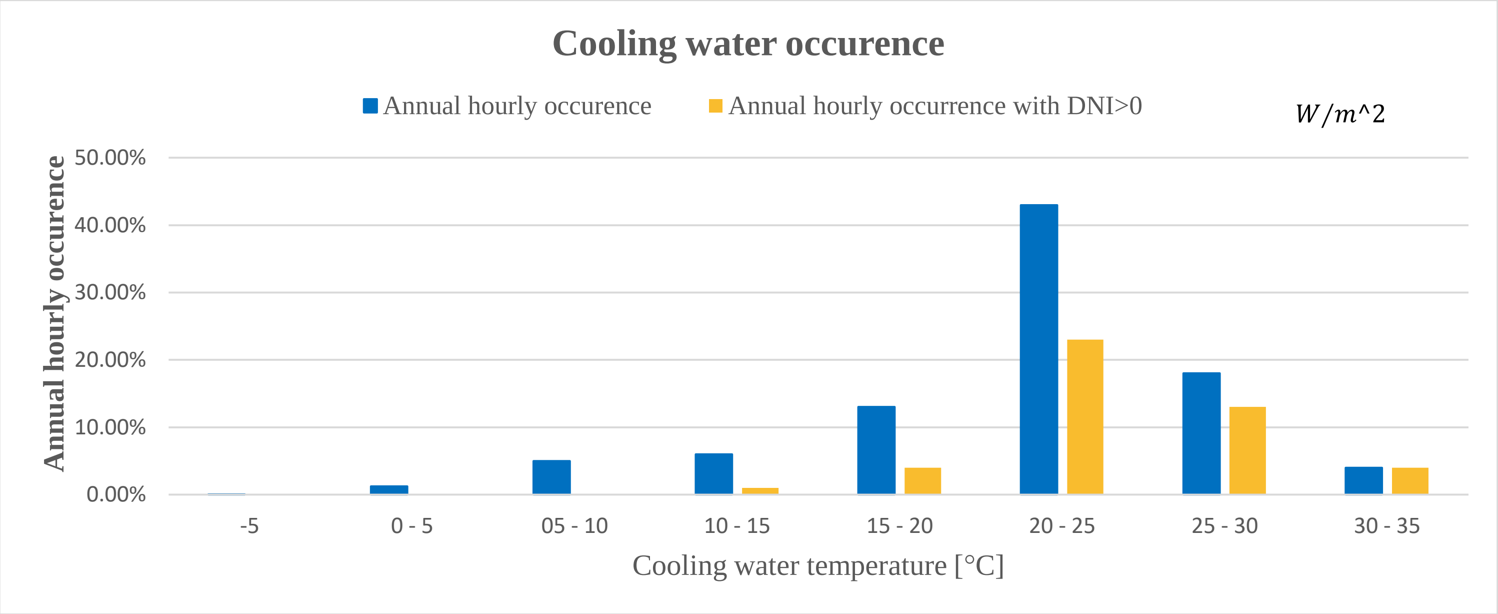
CSP Plant

Modelling



CSP Plant

Orange river temperature



CSP Plant

Modelling assumptions

- Steam pressure at outlet steam generator = 130 MPa
- Steam temperature at outlet steam generator = 540 ℃
- Reheat temperature = 540 ℃
- Electric Generator efficiency = 0.98
- Inlet cooling water temperature = 21.1 ℃

CSP Plant

Modelling assumptions

- Feed-water heater at inlet steam generator = 130 MPa
- Feed-water heater temperature at inlet steam generator = 220 ℃
- Temperature rise across each feed-water heater are equal

CSP Plant

Modelling assumptions

- Total power output at the electric generator = 50 MW_e
- Exit pressure pump (P2) is equal to the Deaerator pressure
- Exit pressure pump (P2) is equal to the inlet pressure at the steam generator

CSP Plant

Modelling assumptions

- The efficiency of high pressure turbine = 0.90
- The efficiency of intermediate pressure turbine = 0.85
- The efficiency of low pressure turbine = 0.82

CSP Plant

Modelling

- Steam generator

$$\mathbb{Q}_{SG} = \dot{m}_{F1}(h_{SSG} - h_{F1}) \quad \mathbb{Q}_{RH} = \dot{m}_{SSG}(h_{RS} - h_{SH})$$

$$\dot{m}_s\, \bar{C}_{ps}(T_{is} - T_{os}) = \dot{m}_{F1}(h_{SSG} - h_{F1}) + \dot{m}_{SH}(h_{RS} - h_{SH})$$

- Turbine

$$w_{HPT} = \dot{m}_{SH}(h_{SSG} - h_{SH}) + \dot{m}_{SHH}\,(h_{SSG} - h_{SHH})$$

$$w_{IPT} = \dot{m}_{SI}(h_{RS} - h_{SI}) + \dot{m}_{SD}\,(h_{RS} - h_{SD})$$

$$w_{LPT} = \dot{m}_{SL}(h_{SI} - h_{SL}) + \dot{m}_{SLH}\,(h_{SI} - h_{SLH})$$

- Feed pump

$$w_{P1} = \dot{m}_{F3}(h_{F2} - h_{F3})$$

$$w_{P2} = \dot{m}_{F6}(h_{F5} - h_{F6})$$

CSP Plant

Modelling

- Feed-water heater

$$T_r = \frac{T_{F1} - T_{F5}}{N_{fwh}} \qquad \dot{m}_{SHH}\,(h_{SHH} - h_{CS1}) = \dot{m}_{F2}(h_{F1} - h_{F2})$$

$$\dot{m}_{F3}(h_{F3}) = \dot{m}_{F4}(h_{F5}) + \dot{m}_{CS1}(h_{CS1}) + \dot{m}_{CS2}(h_{CS2}) + \dot{m}_{SD}(h_{SD})$$

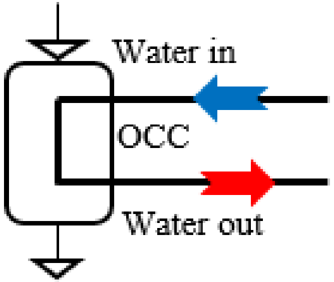
$$\dot{m}_{SLH}\,(h_{SLH} - h_{CS2}) = \dot{m}_{F5}(h_{F4} - h_{F5})$$

- Thermal efficiency

$$W_{net} = w_T - w_{TP} \qquad \eta_t = \frac{W_{net}}{\mathbb{Q}_T}$$

CSP Plant

Condenser modelling



$$T_{cwo} = \frac{\mathbb{Q}_{max}}{\dot{m}_{cw} c_{p,cw}} + T_{cwi}$$

$$\Delta T_{C,w} = T_{cwo} - T_{cwi}$$

$$TTD = T_s - T_{cwo}$$

$$ITD = T_s - T_{cwi}$$

Cooling water output temperature = 28.1 °C

Change in cooling water temperature = 7 °C

Terminal temperature difference = 5 °C

$$R''_{fc} = \pi d_1 L_{eff} \left[\frac{(T_{C,si} - T_{C,wo}) - (T_{C,so} - T_{C,wi})}{\mathbb{Q}_{C,m} \ln\left(\frac{T_{C,si} - T_{C,wo}}{T_{C,so} - T_{C,wi}}\right)} - \left(\frac{\pi d_2 L_{eff} k_{fs}}{d_3 - d_2} Nu_s\right)^{-1} - \frac{\ln\left(\frac{d_2}{d_1}\right)}{2\pi k_t L_{eff}} - \left(\pi L_{eff} k_{fw} \frac{\left(\frac{f_D}{8} Re_w Pr_w\right)}{1 + 12.7\left(\frac{f_D}{8}\right)^{0.5} (Pr^{2/3} - 1)}\right)^{-1} \right]$$

CSP Plant

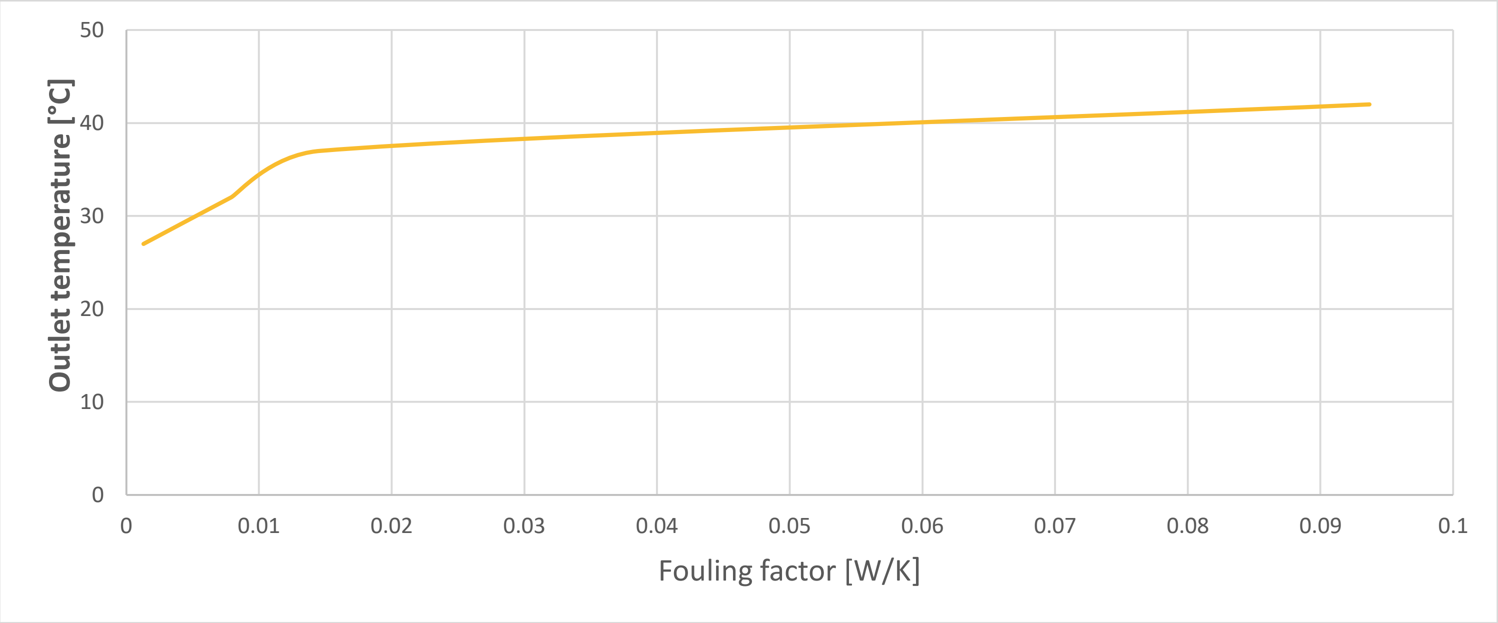
Results

	Units	Once-through cooling	Air-cooled
Energy supplied to steam generator	kJ/kg	104719.3	111555.2
Efficiency	%	47.7	44.8
Mass flow rate	kg/s	35.54	37.86
Power output	MW_e	50	50

	Units	Once-through cooling	Air-cooled
Energy supplied to steam generator	kJ/kg	104719.3	104719.3
Efficiency	%	47.7	44.8
Mass flow rate	kg/s	38.98	38.98
Power output	MW_e	50	47

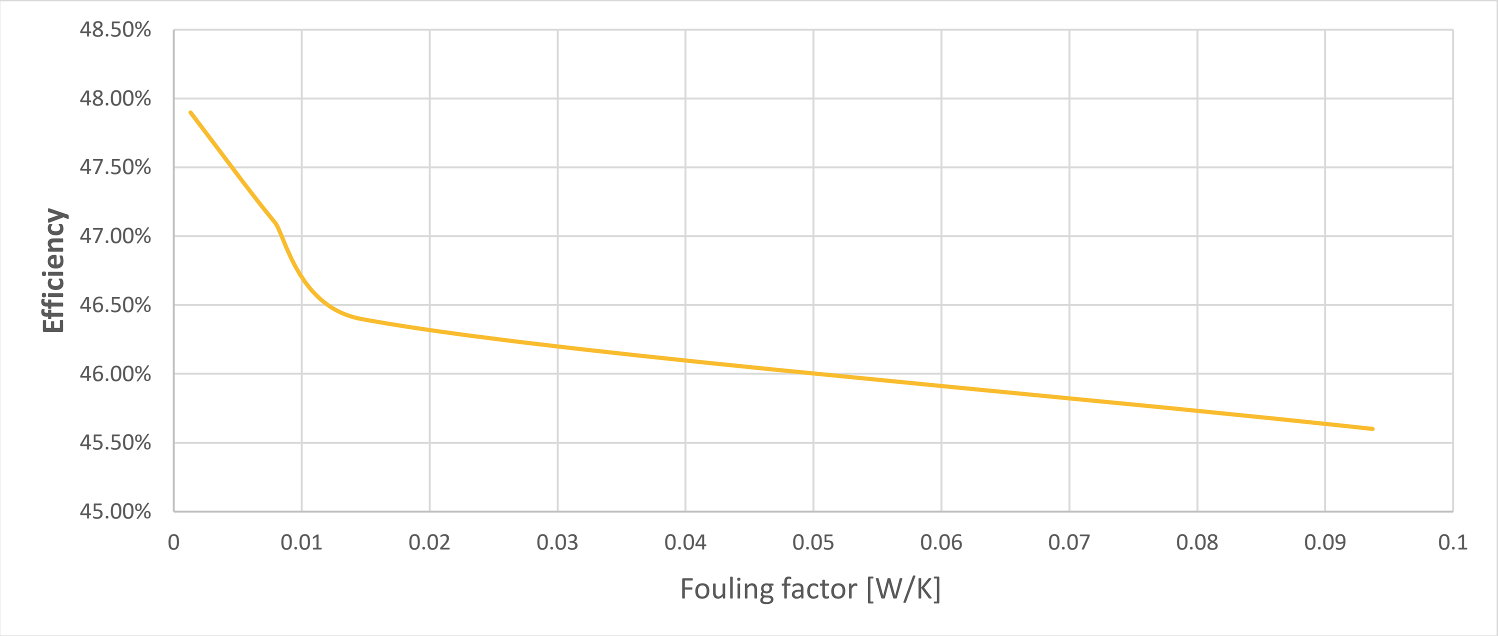
CSP Plant

Results



CSP Plant

Results



CSP Plant

Agricultural Constraint and environmental effect

- Agricultural constraint includes government policy, water demand and water temperature
- Environment impact includes water quality, and water quantity.

CSP Plant

Conclusion

- Once through cooling could be used to increase the CSP plant performance and at the same use the discharge water for agricultural purposes.

THANK YOU

ACKNOWLEDGEMENTS:

Dr. J. Hoffmann.

STERG

CRSES

Questions?

CONTACT DETAILS:

Abiola G. Kehinde

Solar Thermal Energy Research Group (STERG)
Stellenbosch University
South Africa

20851634@sun.ac.za
+27 (0)61 655 1152

visit us: concentrating.sun.ac.za