Model of concentrating solar collector

To reach high temperatures (above 120 ° C), it is necessary to concentrate sunlight by suitable sets of reflective elements (mirrors) or lenses. The main constraint, apart from the cost of the devices higher than flat plate collectors, is the tracking system for tracking the sun in its course. A series of concentrator mirrors has been proposed and developed, the choice of parabolic trough represents the best technical-economic compromise for the Mojave Desert power plants.

The solar flux received by the collector is first reflected on the concentrator mirrors and goes then through the glazing material thermally insulating the receiver where it is absorbed by a suitable surface. Reflection, transmission through the glazing, and absorption result in optical losses, generally characterized by an effectiveness τ. In high concentration collectors, only the direct component of solar radiation can be directed to the receiver, as the diffuse component cannot be concentrated.

The absorber heats up and loses heat to the outside mainly in the form of radiation and convection. This loss can be characterized by a coefficient of thermal losses U. A thermal fluid cools the absorber, taking useful heat that is then converted or transferred for different uses.

The model parameters are:

- glazing transmittivity τ;
- thermal loss coefficient U ($W/m^2/K$);
- incident solar flux G (W/m^2) ;
- collector surface A (m^2) ;
- possibly the absorber surface S_a (m^2)
- outside temperature T_{ext} (°C).

The model input data are as follows (provided by other system components):

- the thermal fluid temperature at the collector inlet T_e (°C);
- the flow $\dot{m}$ of the thermal fluid (kg/s).

The outputs are:

- the thermal fluid temperature at the collector outlet T_s (°C);
- the thermal power received by the thermal fluid Q_{ex} (W/m^2);
- the collector effectiveness.

Two calculation methods are possible: determine the state of the inlet point knowing the collector and absorber surfaces, or determine these two surfaces (with the assumption that their ratio is set) knowing the state of the outlet point.

With the previous notations, and assuming a linear distribution of temperatures in the collector, assumption only valid if the flow is not too low, which is often the case in practice, the model equation is as follows, T_m being the average absorber temperature, and S_c and S_a being respectively the collector and absorber surfaces:

$$Q_{ex} = \dot{m}\, Cp\, (T_s - T_e) = \tau\, Es\, S_c - S_a\, (U_0 + U_1\, (T_m - T_{ext}))\, (T_m - T_{ext})$$

Heat loss of a concentration collector generally following a parabolic law, the loss coefficient U can often be well represented by a linear function of the temperature difference between absorber and ambient air:

$$U = U_0 + U_1\, (T_m - T_{ext})$$

It would be possible to generalize the relation giving Q_{ex} to obtain the differential equation of the high temperature collector, but its integration would be a bit more difficult (it requires to factorize the degree 2 polynomial in T).

The table below gives values of coefficients valid for three types of concentrating collectors, among which two parabolic trough used in Luz SEGS power plants.

	Luz 2	Luz 3	trough	Fresnel
τ	0.737	0.8	0.7	0.66
S_c/S_a	22.6	26.1	500	20
U_0	-0.0223	-0.0725	0.21	-0.031
U_1	0.000803	0.00089	0.000134	0.00061

By dividing the heat collected by the product of the collector surface by the irradiation received G, we can express the efficiency in the form:

$$\eta = \tau - U \frac{(T_m - T_{ext})}{G}$$