Hourly simulation models of thermodynamic solar plants

We present in this document the general principles governing the development of electro-solar plant hourly simulation software.

Solar facilities, even the most simple, are relatively complex and include at least one collection circuit, an energy distribution circuit, storage and various control systems (Figure 1). In these, both the load (demand) and availabilities vary continuously..

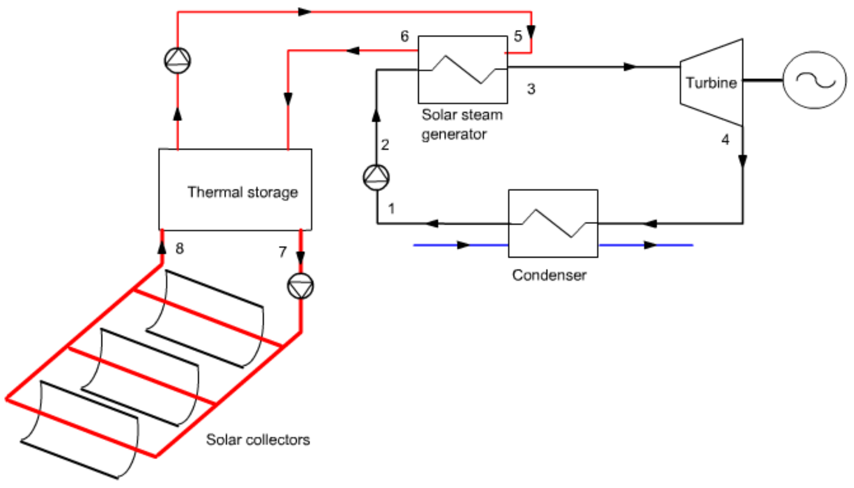

Figure 1: Schematic diagram of an electro-solar plant

Generally, systems with solar collectors do not behave as simply as it sounds, because of interactions between their components (collection, storage, distribution, free inputs, etc.) In particular, if it is possible to define unambiguously energy available at the outlet of a collector alone, the use of this concept becomes more delicate when it is integrated into a system: for the energy actually supplied by the system we can talk of useful energy.

That is why hourly (or sub-hourly) simulation methods are tools well suited for studying this type of installation.

The meteorological data input is usually outdoor temperature and horizontal global radiation Gh at the location.

Hourly values are most often derived from databases provided by national meteorological services or servers as SoDa[1]. These values are used to determine G, radiation received by a surface of any tilt α and orientation δ, as explained in section 11.2. Knowing the layout of the collector field and its surface, it is possible to determine the incident solar power. Thermal power supplied by the collectors can be deduced if one knows their operating temperatures and their characteristics.

This power is carried out by the fluid passing through the collectors, and directed to the storage tank, whose volume Vstock varies depending on the inputs and uses to feed the boiler steam cycle.

A possible model is to consider that the storage volume being limited by value Vmax, the power plant remains stopped as long as Vstock remains below a lower limit Vmin, and we simply store heat available if the solar radiation is sufficient for that. When the volume of stored fluid is greater than Vmin, the plant starts and continues to operate as long as Vstock> 0.

When the storage is full and the turbine in operation, and there is a surplus of solar power, the excess is discharged to the outside.

We can take into account storage thermal losses proportional to its surface and the difference between its temperature and the ambient air.

Such a simulation tool, which can be implemented in a spreadsheet, leads to results such as those presented in figure 2.

[1] http://www.soda-is.com/fr/index.html

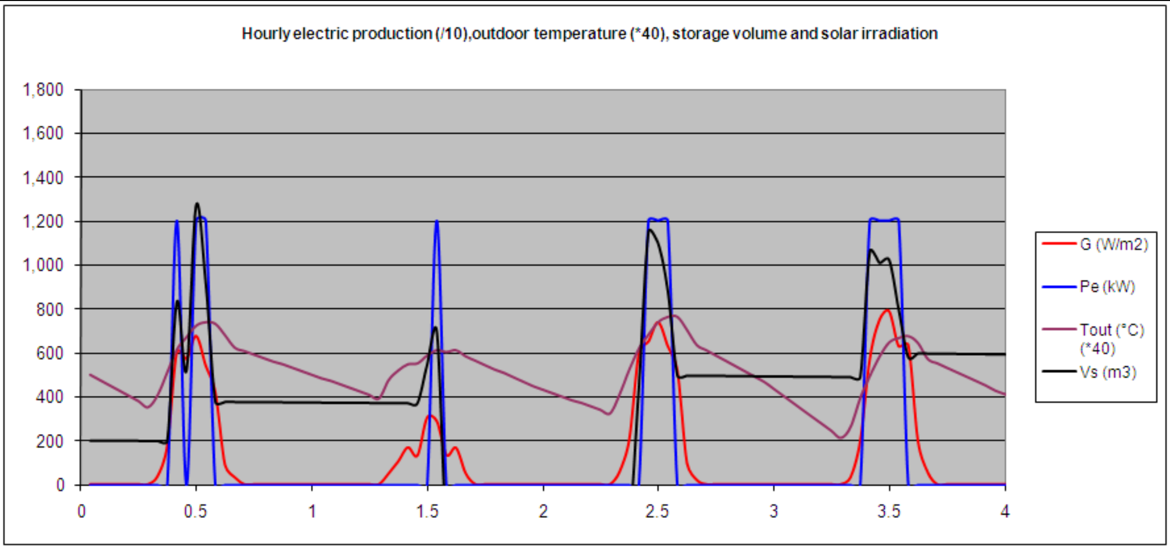

Figure 2: Climatic data and output of an electro-solar plant

This model is very simplified since it does not take into account the heating of the collector field in the morning (more precisely, it does not take it into account explicitly, but the collector heats up as the sun remains below the positive efficiency threshold).

In this model, we do not take into account the initial heating of the solar boiler, and we assume that the inlet and outlet collector temperatures remain constant as long as the field produces heat, which implicitly assumes the existence of a very efficient flow control. It is possible to refine these assumptions, establishing a fine model of the collector field and of the flow management strategy actually implemented.

The thermodynamic cycle efficiency can be assumed constant or variable depending on the one hand on the condensation conditions, which often depend on ambient temperature, and secondly on temperature and flow of the fluid entering the boiler. If one wishes to know the performance of the thermodynamic cycle when its boundary conditions vary, it is necessary to model it in off-design mode.

References

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