IEooc_Methods1_Exercise1: Defining and locating indicators in a system definition

Sample Solution

Goal: *Establish a system definition to allocate quantitative information that is given as text. Define and calculate indicators base on the system definition.*

Problem setting

The following problem deals with energy flows of different forms (sunlight, electricity) in a photovoltaics installation.

Assume that the following information is given in the technical manual of the PV park, which is available on the homepage of the operator of the installation:

"The solar park is built with PV modules of an average conversion efficiency of 17%. It is equipped with DC/AC converters with a loss rate of 2%, resulting in an overall conversion efficiency of 16.7%. With additional grid and transformer losses of 8% the system efficiency is 15.3%."

A report on the PV plant in the local newspaper, which is based on the information supplied by the operator, gives the following information:

"With an overall conversion efficiency of 16.7%, solar park A clearly outperforms the other parks in the region. Electricity consumers rejoice as the system efficiency of the renewable energy grid is now more than 15%."

Clearly, the cited section of the newspaper article contains less quantitative info than the technical report. Information was lost when simplifying the description. In particular, the exact meaning of 'overall conversion efficiency' and 'system efficiency' remains unclear, as no definitions are provided (which cannot be expected from a newspaper article). The technical report cited above does not provide definitions either, but from the flow of the text and the numbers provided it becomes clear that the 'overall conversion efficiency' must be the ratio of electricity supplied to the grid and the incoming sunlight. It can be calculated as (1-0.02) * 0.17. This understanding of the meaning of the indicator gets lost in the transition to the newspaper article.

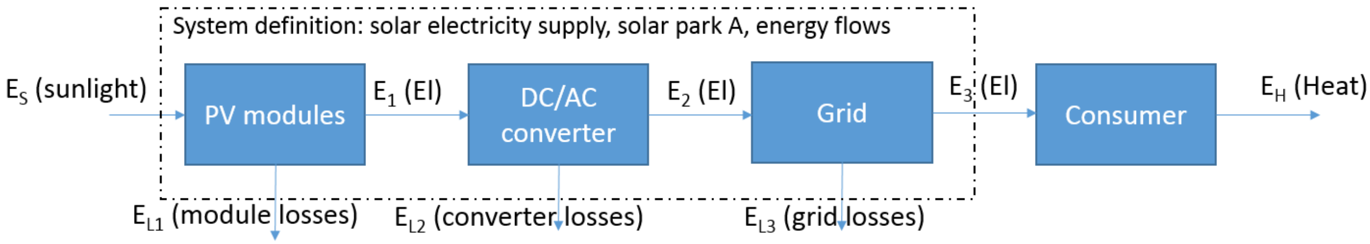
By providing explicit definitions of the efficiency indicators and using them consistently ambiguities can be removed. To formalize the knowledge provided in the technical report an explicit system definition shall be used to define and quantify indicators for this case:

Task

Draw a system describing the situation, define the system variables, define and calculate the efficiency indicators from the text above, and find more descriptive names for the different efficiencies!

Solution

The following system definition with the different energy flows is suggested (Fig. 1).



We define:

Average module conversion efficiency: $e_m := E_1 / E_S$

Sun-to-grid efficiency: $e_{sg} := E_2 / E_S$

Sun-to-consumer efficiency: $e_{sc} := E_3 / E_S$

Easy, clear, and unambiguous!

Figure 1: Suggested system definition of the sunlight-to-delivered-electricity supply chain.

We can then locate the different efficiency indicators that are provided in the text above in the system in Figure 1 and suggest some more descriptive names for them:

- The 'average conversion efficiency' is renamed into 'average module conversion efficiency', to make clear that it includes the modules only. It is then defined as

$$e_m := \frac{E_1}{E_S} = 0.17 = 17\%$$

- The Loss rate of the DC/AC converter is defined as

$$l_{DC/AC} := \frac{E_{L2}}{E_1} = 0.02 = 2\%$$

- The 'overall conversion efficiency' is renamed into 'sunlight-to-grid efficiency', to illustrate which processes in the system are spanned by this indicator, namely the PV modules and the DC/AC converter. It is defined and calculated as

$$e_{SG} := \frac{E_2}{E_S} = \frac{E_1 - E_{L2}}{E_S} = \frac{E_1}{E_S} \cdot \left(1 - \frac{E_{L2}}{E_1}\right) = em\left(1 - l_{DC/AC}\right) = 0.167 = 16.7\%$$

Here the energy balance of the DC/AC converter $\left(E_2 = E_1 - E_{L2}\right)$ was used.

- The ‘system efficiency’ is relabelled into ‘Sun-to-consumer efficiency’ and defined as

$$e_{SC} := \frac{E_3}{E_S} = 0.153 = 15.3\%$$

One can of course argue whether terms like ‘sun-to-consumer efficiency’ and ‘sunlight-to-grid efficiency’ are meaningful. The point made here is a different one, though:

By using an explicit system definition the different efficiency indicators can be explicitly defined as ratios of certain flows. When pointing to the explicit system definition experts and lay people no longer have to guess the meaning of an indicator from its name. Instead, they can point to a system description where it is properly defined.