Tutorial problems for "Solar Energy" lecture (23745), WS 2020/2021

Ulrich Paetzold & Bryce Richards

Tutorial Questions #4: PV System Design

1. PV System Design (adapted from exercise 20.1)

The Smith family has a small house in the countryside which is not connected to the grid. The place enjoys 3.5 equivalent sun hours. Therefore, Mr Smith has decided to install an off-grid PV system in the house to supply their electricity. He will be using PV modules with the following specifications: $P_{nom} = 100W_p$, $V_{MPP} = 16V$, $I_{MPP} = 6.25A$, $V_{OC} = 18V$, $I_{SC} = 7A$. We may assume that the combined efficiency of the cables, the charge controller and the battery system is 90% and that of the inverter is 96%. As the house is only used at the weekend, only two days of autonomy will be needed. In this case, batteries with the following specifications will be used: capacity 100Ah, voltage 12V, maximum allowed depth of discharge 50%. The daily house electricity requirements are summarized in Table 1.

Load	Quantity	Power per item (W)	Time of use (h)	Type
Light bulb	10	20	2	DC
TV	1	100	2	AC
DVD	1	40	2	AC
Laptop	1	100	2	AC

Table 1: Daily electricity requirements in the Smiths' house.

(a) Calculate the total daily electricity demand in Wh.
(b) What is the total power demanded by the DC loads?
(c) What is the total power demanded by the AC loads?
(d) How much energy in Wh must the panels generate in one day to cover the daily electricity demand of the family?
(e) Assume the panels work under MPP conditions. How many panels will be needed to produce that energy?
(f) The system is designed to use 24V as its operating voltage. What will be the minimum battery capacity required in Ah?
(g) How many of the specified batteries will be needed?

2. PV economics (adapted from: exercise 21.2 of textbook 'Solar Energy')

The Smith family are interested in buying a solar energy system. After some research on the Internet they have found two different systems that they are considering.

System A is a PV system based on multicrystalline silicon solar cells and system B is a PV system based on amorphous silicon solar cells. System A: The efficiency of the multicrystalline silicon module amounts to 15%. The dimensions of the solar modules are 0.5 m by 1.0 m. Each module has an output of 75 W_p. The modules cost €60 each.
System B: The amorphous silicon solar modules have an efficiency of 6%. The dimensions of the solar modules amount to 0.5 m by 1.0 m. The output of each module is 30 W_p. The modules cost €20 each. The advantage of the amorphous silicon solar modules is that they perform better on cloudy days when there is no direct sunlight. Installed in the Netherlands, this system gives, on an annual basis, 10% more output per installed W_p than the multicrystalline silicon modules.
Both systems are grid-connected using a 900 W_p inverter. The total price of the inverter, the cables, the installation and other costs amounts to €1,000. The solar modules are to be installed on a shed. The roof of the shed can only support 10 m^2 of solar modules. In the Netherlands a PV system using multicrystalline silicon modules generates on average 850 Wh per W_p in one year. The performance of both types of modules is guaranteed for 20 years. The price of electricity from the grid is €0.23/kWh. Assume that all the power produced by the PV system is completely consumed by the Smith family's.

a) How much (peak) power can be installed for system A given the peak power of the inverter and the area available on the shed?
b) How much (peak) power can be installed for system B given the peak power of the inverter and the area available on the shed?
c) What is the price of a kWh of electricity generated by system A?
d) What is the price of a kWh of electricity generated by system B?
e) The Smith family are eligible for a municipal subsidy for sustainable energy that amounts to 15% of the initial costs of the PV system. Using this subsidy, how many years does system A need to be operational, for them to recoup their share of the investment, assuming that the electricity price of €0.23/kWh does not change?
f) Using the same subsidy of 15% as the previous question, how many years would system B need to be operational, for them to recoup their share of the investment, assuming that the electricity price of €0.23/kWh does not change?