Solutions

ENGR290: Renewable Energy

Midterm Exam

June 24, 2013

For this exam you must analyze the energy requirements of a particular application, calculate the costs of several options and decide which option is the best financial investment.

I am going to build a self-powered cabin in the mountains so that I have a quiet place to relax and get away from the stresses of teaching at SIPI.

Problem 1

I estimate that my average power consumption for the cabin will be as shown in Figure 1.

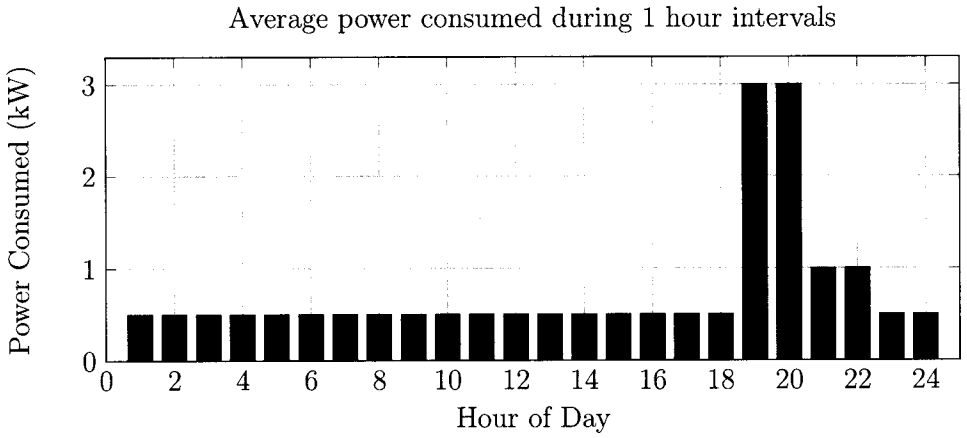


Figure 1: My (very simplified) household power consumption

1. How much energy does my cabin use per day (kWh/day)?

$0.5kw \cdot 20h + 3kw \cdot 2hr + 1kw \cdot 2hr = 18 \frac{kwh}{day}$

Problem 2

My first option is to power the cabin using solar power. Assume the solar power is constant for 6 hours each day. A solar power system costs \$4/W. The best available batteries are \$250 and provide 6 Volts and 400Ah and last 5 years.

1. How big does the solar array need to be (how much power does it need to produce) to provide my daily energy (kW)?

$\frac{18kwh}{day} \quad \frac{day}{6hr} = 3kw$

$\uparrow$ 1

6 hrs of sun per day

2. How much will the solar power system (not including batteries) cost ($)?

$3kW \cdot \frac{\$4}{W} \cdot \frac{1000W}{1kW} = \$12{,}000$

3. How much energy do I need to store in the batteries each day (kWh)?

$18kwh - 0.5kw \cdot 6hr = 15kwh$

don't store when sun is powering

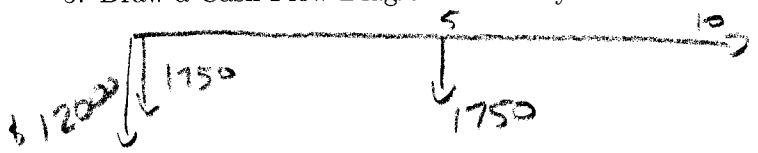
4. How many batteries do I need (bat)? 7 How much will they cost ($)? $1750

$1\ bat = 6V \cdot 400Ah = 2.4kwh$

$15kwh \frac{bat}{2.4kwh} = 6.25 \Rightarrow 7bat$

$7bat \frac{\$250}{bat} = \$1750$

5. Draw a Cash Flow Diagram over 10 years for the solar power system with batteries.



6. Calculate the Present value of the solar power system at 8% interest.

$PV = -12000 - 1750 - 1750\left(\frac{P}{F}\ 8\%\ 5yr\right) = \$14{,}900$

0.6806

Problem 3

My second option is to power the cabin using a generator. I found a $6kW$ diesel generator for $2400 which has a 10 year warranty. Diesel has an energy density of $40MJ/l$ and the generator is 30% efficient. Diesel costs $\$0.90/l$. Use the same batteries as in Problem 2.

1. How long must my generator run (at full power) each day($hours/day$)?

$\frac{18kwh}{day} \frac{1}{6kw} = 3\frac{hr}{day}$

2. How much diesel fuel will I burn each year ($l/year$)?

$\frac{18kwh}{day} \frac{3.6MJ}{1kwh} \frac{l}{40MJ \cdot 30\%} \frac{365day}{yr} = 1970\frac{l}{yr}$

3. How much money will I spend on diesel fuel each year($)?

$1970\frac{\ell}{yr} \quad \frac{\$0.9}{\ell} = \$1770\frac{}{yr}$

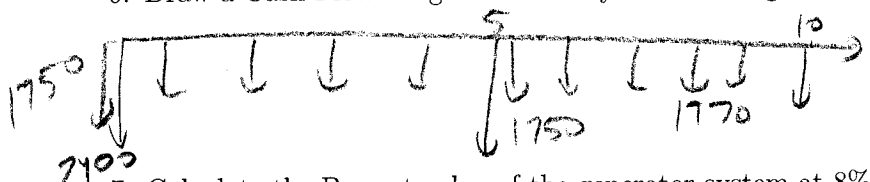
4. How much energy do I need to store in the batteries each day (assume the generator turns on at 6AM and runs as long as necessary) (kWh)?

$18kwh - 3hr \cdot 0.5kw = 16.5kwh$

5. How many batteries do I need (bat)? 7 How much will they cost ($)? 1750

$16.5kwh \quad \frac{bat}{2.4kwh} = 6.9 \Rightarrow 7\,bat \qquad 7bat \quad \frac{\$250}{bat} = \$1750$

6. Draw a Cash Flow Diagram over 10 years for the generator system with batteries.



7. Calculate the Present value of the generator system at 8% interest.

$PV = -1750 - 2400 - 1750\left(\frac{P}{F}\,8\%,5yr\right) - 1770\left(\frac{P}{A}\,8\%,10yr\right) = \$17200$

$\frac{P}{F}\,8\%,5yr \rightarrow 0.6806 \qquad \frac{P}{A}\,8\%,10yr \rightarrow 6.7101$

Problem 4: Extra Credit

1. Which system is better from a purely financial perspective?

generator is slightly better

2. Which system would you buy? Solar Why? No maintenance and fuel

3. For the generator system, what time of day would it be best to run the generator? 19-22hrs Why?

Best to run generator at highest load so you can store less energy. $18kwh - 3kw \cdot 2hrs - 1kw \cdot 1hr = 11kwh$

$11kwh \quad \frac{bat}{2.4kwh} = 5$ batteries instead of 7.