ENGR290: Renewable Energy

Homework 1: Power and Energy Units and Calculations

Assigned: Sept 19, 2013
Due: Sept 26, 2013

Notes:

Unit	Measure	Derivation	Description
Second (s)	Time	Fundamental	
Meter (m)	Distance	Fundamental	
kilogram (kg)	Mass	Fundamental	amount of matter in an object
Newton (N)	Force	$kg * m/s^2$	Force required to accelerate 1 kg $1m/s^2$
Joule (J)	Energy	$N * m$	Energy expended pushing 1 N of force for 1 meter
Watt (W)	Power	J/s	Rate of consuming (or delivering power)
kilowatt-hour (kWh)	Energy	kW*h	Energy expended consuming 1000W for 1 hour

Table 1: Common Energy-Related SI Units

Energy is a measure of the capacity of a system to do work. Energy is always conserved, it cannot be created or destroyed, it can only be transferred from one object to another, or changed from one type to another such as electricity into heat, kinetic energy of the wind into electrical energy in a turbine and electro-magnetic radiation energy into electricity in a PV cell.

Power is the rate of change of energy in a system. Power is an instantaneous value. It is how much energy is being put into (or removed from) a system at one instant in time.

To calculate the change in energy in a system you must integrate the power over a time. For example, if a 1200 Watt microwave oven heats your food for 10 minutes then it transfers $1200W * (10min * 60sec) = 720000J = 0.2kWh$ of energy from the electrical supply into the food.

According to recent government studies,[1] the average American household consumes 940 kWh per month. According to our text book (see chart on page 7), the world consumes 451 EJ (1 exajoule = $10^{18}J$) or $1.25 * 10^{14}kWh$ of energy per year of which only 18.4% can be considered renewable and only 0.21% is from solar power.

Problem 1

Consider your house or apartment on an average day. Identify the energy consuming devices that you use during the day and estimate the amount of time each one is used. Don't forget appliances that you do not interact with directly such as the refrigerator and water heater. Make a table similar to Table 2 for your house and calculate:

1. The total daily energy consumed by your house
2. The peak power required by your house (depends on how many loads are on at the same time)

[1] http://www.eia.gov/tools

answer depends on your house.

3. The average daily power consumed by your house
4. How does your house compare to the national average?

Appliance	Power	Time Used	Energy Consumed
TV			
Computer			
Stove or microwave			
Air Conditioner			
Refrigerator			
Ceiling Fan			
etc...			

Table 2: Energy Consumption Table

Problem 2a

Say you live in a particularly windy location and you decide to put a wind turbine on your roof. The power produced by the turbine in one 24 hour period is as shown in Figure 1. Calculate:

1. The total energy generated by the turbine in one day 15kWh
2. The peak power generated by the turbine during the day 1kW
3. The average power generated by the turbine during the day 0.625 kW

Compare the total energy generated by the turbine with your answer from problem 1. Could this turbine power your home?

Problem 2b

Now consider the sample household consumption shown in Figure 2. Assume the peaks in the morning are the water heater for your shower, the peak at noon is you heating your lunch and turning on the air conditioner and the peaks in the evening are you cooking dinner, watching TV, using the lights and running the dishwasher and some laundry. On this household, calculate:

1. The total energy consumed by the house in the day 15 kWh
2. The peak power consumed by the house 2.2 kW
3. The average power consumed by the house 0.625 kW

Could this household be powered by the wind turbine?

No. Peak is too high, timing is not right

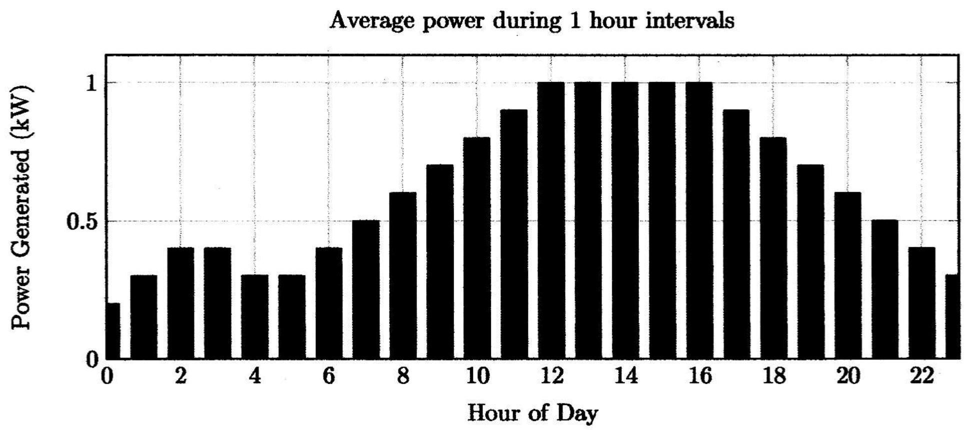

Figure 1: Wind turbine power for one day

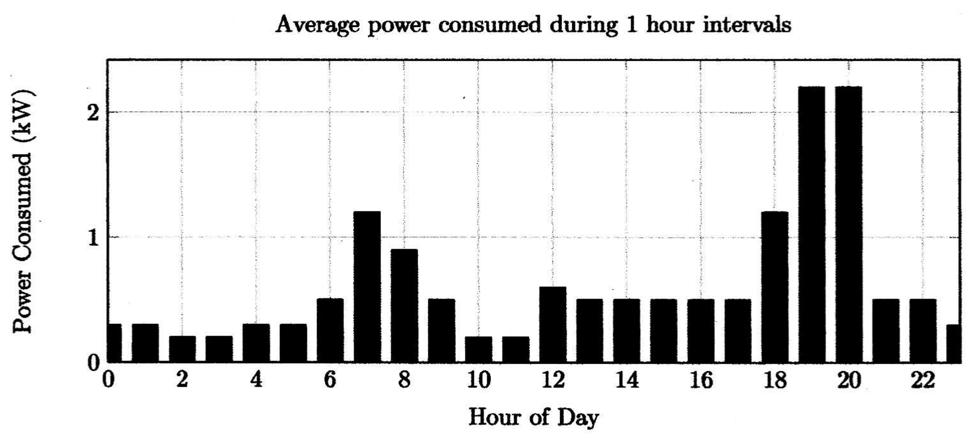

Figure 2: Example household power consumption

Problem 3a (extra credit)

Alas, we live in Albuquerque and we have no good wind here, but we have a lot of sun! So instead of the wind turbine, we install a 10kW PV array on our roof. The PV power production for a sunny day in June is shown in Figure 3. Calculate:

1. The total energy consumed by the house in the day using *integration* of the cosine function **20kWh**
2. The peak power produced **10kW peak**
3. The average power produced $\frac{20}{24}$ kW = .83kW Avg

$$\text{energy} = \int_7^{19} 10\cos\left(\frac{(t-13)\pi}{12}\right) dt$$

$$= 10\int_{-6}^{6} \cos\left(t\frac{\pi}{12}\right) dt$$ ← time shift does not change area under curve.

$$= 10\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos\theta \, d\theta$$ ← change of variables

$$= 10\left(\sin\frac{\pi}{2} - \sin -\frac{\pi}{2}\right) = 10 \cdot 2 = 20 \text{ kwh}$$

Could this power the house in Problem 2b (Figure 2)? No, timing requires storage.

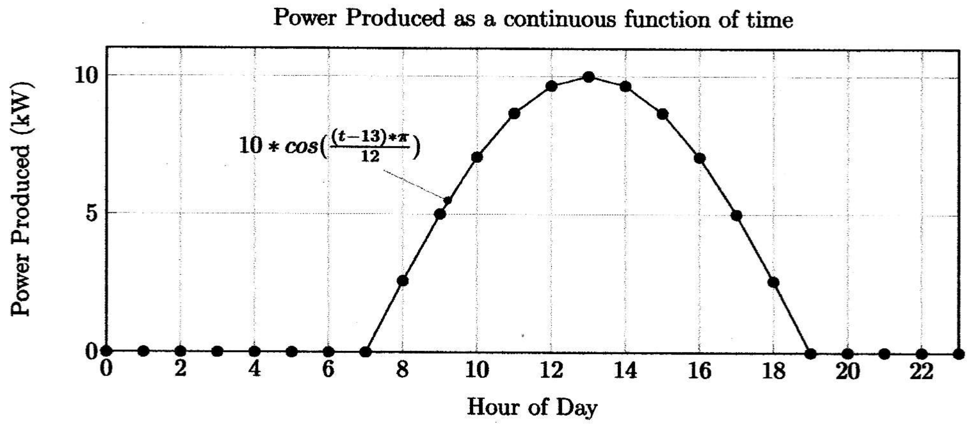

Figure 3: PV system power production

Problem 3b (extra credit)

If the Solar cells are 15% efficient and the solar influx in Albuquerque is $1\frac{kW}{m^2}$ then how big (in m^2) does the array need to be to produce 10kW peak.

$$1 \frac{kW}{m^2} \times 0.15 = 0.15 \frac{kW}{m^2}$$

For 10kW:

$$10kW \frac{m^2}{0.15 kW} \Rightarrow 67 m^2 \text{ of panels}$$