ENGR290: Renewable Energy

Midterm Review

Oct 22, 2013

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 energy)
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. Power is the instantaneous rate of change of energy in a system.

To calculate the change in energy in a system you must integrate the power over a time.

Time Value of Money

The Present Value Analysis procedure is a way to compare the monetary value of several alternatives by converting all the expenses or incomes of a project over a time period into their *Present Day* value.

The Cash Flow Diagram is a timeline that shows positive (income) and negative (expenses) cash flow on the year in which that cash flow occurs. For example Figure 1 shows a cash flow where you buy a solar system today for $10,000 and it offsets $1200 per year of your electric bill, but you have to replace the inverter for $2,000 after 5 years.

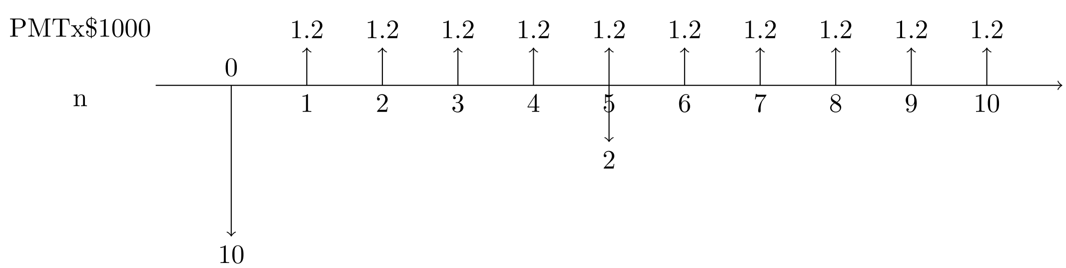

Figure 1: Cash flow for a simple PV system

Calculating the Present Value of a project can be done in the following simple steps:

1. Identify the interest rate and number of years to be used in the calculations. If none is given, assume 8% and 10 years.

2. Convert all annual payment series (the same value every year) to a present day value

(a) Look up A/P factor based on the interest rate and number of payments in the "Present to Annual" chart (handout)

(b) Divide the annual payment amount by the A/P factor. This is the present value of that annual series so write this value at time 0 on the cash flow.

3. Convert all future payments into present day values

   (a) Look up P/F factor based on the interest rate and number of years in the "Future to Present" chart (handout)

   (b) Multiply the future value amount by the P/F factor. This is the present value of that future payment so write this value at time 0 on the cash flow.

4. Add up all of the cash flow at time 0. This is the Present day value of all of the cash flow.

For example, calculate the Present Value of the cash flow in Figure 1.

1. Convert the annual income of \$1200 over 10 years by finding the A/P factor in the table under 8% and 10 years = 0.1490. So the Present value of the series is \$1200/0.1490 = \$8053.

2. Now consider the present value of the cost to replace the inverter. It is a Future value of \$2000 in 5 years, so look up the P/F factor in the F to P table = 0.6806. So multiply $-\$2000 * 0.6806 = -\$1361$.

3. Now you have all values in the present, so sum them up: $-\$10000 + \$8053 - \$1361 = -\$3308$.

So, as an investment, this would lose \$3308 and is therefore not a good investment from a purely financial perspective.

A final note: If you get confused whether you should multiply or divide by the factor in the table, remember that money *ALWAYS* grows with time if the interest rate is positive. So if you move a Future value to the present it must get smaller. The Present value of an Annual series must be greater than the payment.

Energy Density of Fuels

Energy density is the amount of energy a particular fuel contains per unit of mass or volume. The class handout (or a quick internet search) shows the energy density of several common fuels such as Gasoline = 46MJ/kg. This means that if you completely burn 1 kg of gas, it will release 46MJ.

Efficiency

Efficiency is $\frac{Output}{Input}$. Efficiencies multiply, so if there are 3 devices in series you must multiply their efficiencies to find the overall efficiency. For our purposes it is essential to include in all calculations because everything runs at < 100% efficiency.

- For example, a good quality gasoline engine may reach 30% efficiency. A rotary electric generator may be 90% efficient. So of the 46MJ of energy stored in one kg of gasoline, you will only get $46MJ * 0.3 * 0.9 = 12.4MJ$ of electricity from a gas powered generator.

- Another example: we know that solar radiation delivers $1kW/m^2$ to the earth's surface. But a typical PV panel is around 18% efficient and the power inverter is probably about 90% efficient, so of the 1kW you should get out of a $1m^2$ panel, you will only see $1000W * 0.18 * 0.9 = 162W$ out if it.

Solar Thermal (book chapter 2)

Thermal collection systems depend on the *specific heat* of a substance. The specific heat is the energy required to raise the temperature of one kg (or liter) of a substance 1 °C. The specific heat of water is $4.2\frac{kJ}{l*°C}$.

For example to heat 80 liters of water from 12°C to 60°C requires $80l*4.2\frac{kJ}{l*°C}*48°C = 16MJ = 4.5kWh$.

The standard solar power influx is about $1\frac{kW}{m^2}$.

Photovoltaics basics (book chapter 3)

PV systems convert solar radiation directly into electrical power. Most silicon cells produce a voltage of 0.7V and from 5 to 7A of current. In order to get useful voltage levels from the cells, they are wired in series into *strings*.

The voltages of cells wired in series add together, so to get up to 14V would require $14V * \frac{1cell}{0.7V} = 20cells$. If each cell produces 7A (cells in series all carry the same current) then a 20 cell *string* would produce $14V * 7A = 98W$.

In order to produce more power at a specific voltage, strings are connected in parallel which adds the currents together. So two 20 cell strings in parallel will provide 14V @ 14A or 196W.

Silicon cells are very expensive so it is possible to reduce the size of the required cells by using concentrators. Concentrators are simply lenses or mirrors used to focus a large area of sunlight onto a small cell. This is very attractive for the reduction in cell area, but it can become expensive due to the high heat generated on the cell and the need for very precise tracking to keep the focused energy on the cell.

It is also possible to increase the production of a PV panel by tracking the sun as it moves across the sky. According to our Photovoltaics book, in Albuquerque a tracking system can increase the output of an array as shown in Table 2.

Array orientation:	Fixed at Latitude	Single Axis	Dual Axis
Solar Energy Received ($\frac{kWh}{m^2*day}$)	6.4	8.5	8.8
Improvement over Fixed		+33%	+38%

Table 2: Average Daily Solar energy in Albuquerque

PV systems produce *DC* power which must be converted to AC if it is to be used by normal household appliances or be connected to the electrical grid. An inverter converts DC to AC power and represents a large part of the cost of a PV system.