Engin 112 – Fall 2022
Homework 6: Power Systems
Due: 5:00 pm, Tuesday, November 1

1.) General concepts about power: Answer the following questions about power, voltage, and current.
   a) Assume you measure a current of 6.7 mA on a circuit powered by a 3 V battery. What is the power consumption of the load on this circuit?
   b) Assume you connect a space heater that creates a load of 1100 W to a power outlet in the U.S. How much is the current that goes through the cable to the space heater?
   c) Consider AA batteries, which have a rating of 1.2 V and 2200 mA-h (milliamp-hours). Assume you have a circuit that uses four (4) of these batteries as its source. The power consumption of the circuit is 9 W. How long, in units of hours, can the circuit operate before the batteries are drained?

2.) Solar panels: In class we calculated the solar power radiation intensity incident on Mars
   a) If the Mars rover requires 200 W of peak power for driving, for maintaining heat, charging batteries and other systems, what area solar panels would be required to maintain the rover if the panels were 20% efficient?
   b) Over time, dust and other factors will degrade the performance of the solar panels. If the effects of this degradation are 95% of the efficiency of the previous year, if we begin at 20% efficiency, what will be the total solar power output after 5 years of operation? (provide your answer in percentage efficiency and in total Watts).
   c) If we were to orbit a satellite that required 200 W of power around Saturn, calculate the area of 20% efficient solar panels that would be necessary to provide power to the satellite. Note: for this problem, you will have to look up the distance that Saturn is from the sun.

3.) Use GoogleEarth to identify a "Solar Panel Farm" near your home. Using the "ruler" icon at the top of Google Earth, and the "Polygon" option that shows up in the popup winder, estimate the total area in Square Meters that the solar farm occupies. Assuming a 25% efficiency for the panels (that takes into account the illumination angle of the sun, and the inherent efficiency of the panels themselves), calculate the power (in units of kW) generated by the solar farm. If a single family uses 3.6 kW of power, calculate the number of families that the solar farm supports when it is running at maximum power (i.e. the Sun is overhead). Comment on whether this number is realistic and on how other factors such as weather, time of year, and the use of fuel oil may alter these calculations. In your submission, provide a screenshot of the GoogleEarth solar farm and the pop-up window that shows the area of the farm.

4.) Power generation: Go to the ISO-New England website (https://www.iso-ne.com/). Go to "Markets and Operations", then "ISO Express", then "Energy, Load, and Demand Reports." Under "Five-Minute System Demand", click "More" and use the "Search Historical Data" button to download the reports for August 7, 2022, which was a particularly warm summer day.

Answer the following questions from the data files you have downloaded:

a) Looking at the real-time system load (5-minute intervals) of 8/7/2022, at what time was the highest Total Load on the system and how much was that load?

b) Looking at the real-time system load (5-minute intervals) of 8/7/2022, at what time was the lowest Total Load on the system and how much was that load?

c) Compare the values obtained from (a) and (b) with the highest and lowest loads for the current day (or yesterday if you are answering this problem before 8 p.m.)? (You can find current data under 'Markets and Operations", then "ISO Express", then "Real-Time Maps and Charts.") Discuss what differences you observe.

d) Assuming that at the point of daily maximum is entirely due to the power consumption of air conditioning, and using 1500 W as a typical power consumption for a window-mounted air conditioner, calculate the number of *additional* air conditioning units that are working on 8/7/22 compared to the usage that you found from part c.

e) Using Excel, Matlab, or similar, create a plot that has both the "current day" power output from part c with the data from 8/7/2022. Label the horizontal axis to be "time of day (hours)" and the vertical axis to be "Total load (MW)". Create a title for the plot that says "Total Power Generation from ISO-New England for (current day date) and 8/7/2022". This will take some care to create the hours axis of the plot and to put both sets of data on the same axis. The plot should show the information for the span from the beginning of the day to the end of day (midnight to midnight).

5.) Power Transmission: High tension lines are used to send electricity from one location to another. A common length for a high-tension line is 300 miles. The voltage on such a line can be 500,000 Volts, with the voltage between any two lines being $500{,}000*(1 - \cos(120^o))$, or 750,000 Volts for a three-phase line.

a) If the distance between wires is 80 feet, calculate the Voltage gradient (voltage difference divided by the distance; in units of kV/m) between any two adjacent lines. Compare this value to the breakdown voltage of dry air (look it up on the internet).

b) How close would two of the power lines have to get to one another before the air between them broke down and arced?

c) If 500 kW of power is transmitted over 100 miles using 1 cm diameter Copper cables, use Ohm's Law, the equation for Power, and the resistivity of Copper to calculate the Current and Power Loss if the voltage on the line was 10 kV, 138 kV or 500 kV.

6.) Energy Storage:

a) If a water tower is 185 feet tall and holds 25,000 gallons of water, calculate the total storage capacity (in Joules) of the water tower.
b) If an automobile gas tank holds approximately 20 gallons of gasoline calculate the storage capacity of gas tank in units of Joules. What is the weight of the gasoline in kg?
c) Based on the lecture notes, calculate the weight of Lithium Ion batteries (in kg) that would be required to provide this same capacity.
d) If the car, without fuel (or batteries) weighs 1000 kg, calculate the percent weight from parts b and c of this problem that the fuel occupies.