EXERCISE SET # 4: MEETING ELECTRICAL DEMAND IN COMBINED WIND/GAS TURBINE SYSTEMS

JULIAN HAIMOVICH, JIEHUA CHEN, AND MATT ZEBIAK
ASSIGNMENTS WEBSITE

The purpose of this problem set is to analyze how variability in wind systems affects the need to install backup (in this case, gas turbines) to meet electricity demand. The metrics involved in these calculations, such as LOLP, LOLE, and ELCC, are crucial figures in energy planning. You will, again, be using demand data from NY State (nyload.txt) and systems of centrally located (nyturbinepower.xls) and optimally distributed (optturbinepower.xls) wind turbines in your calculations. All necessary data files are located in the Input(Data/Files) folder and should be copied into the MATLAB directory.

Problem 1

In a gas turbine system, there are three electricity-producing units:

- Turbine 1: 10^4 MW (Forced Outage Rate (FOR) = 0.1)
- Turbine 2: $2 * 10^4$ MW (FOR = 0.2)
- Turbine 3: $3 * 10^4$ MW(FOR= 0.1)

(1) Calculate the COPT (Capacity Outage Probability Table).
(2) Given the hourly electricity load in NY in 2005 (*nyload.txt*), calculate:
   - Hourly Loss Of Load Probability (LOLP).
   - Loss Of Load Expectation (LOLE) for 2005.
   - The Effective Load Carrying Capacity (ELCC) (Set the target LOLE to be 0.1).

(3) Add 10^4 wind turbines in NY into the generating system. Use the NY turbine power data (*nyturbinepower.xls*) for the power output of a single turbine, and assume all 10^4 turbines have the same behavior. Now redo the calculation in the previous problem. This problem will allow you to see how LOLP, LOLE, and ELCC change with the addition of a time-varying power source.
(4) Instead of putting all 10^4 turbines in one location, we observed that placing them optimally in 20 different locations has some advantages. Redo the calculation in the previous problem, using the 10^4 turbines, now distributed across 20 locations optimally from Assignment 3 into the generating system (*optturbinepower.xls* has the hourly power output of those 10^4 turbines).
(5) In this problem, we want to examine whether the addition of optimally placed wind turbines can allow one to retire some gas turbine capacity.

   Hence, instead of using three gas turbines as in the previous problems, we would like to consider retiring the first unit with a 10 GW capacity and a Forced Outage Rate of 0.1. Now, we are left with the following two gas turbines
   - Turbine 2: $2 * 10^4$ MW (FOR = 0.2);

Date: June 28, 2012.

- Turbine 3: $3 * 10^4$ MW (FOR= 0.1).

together with 10^4 optimally placed wind turbines in the 20 locations from Assignment 3 (*optturbinepower.xls* has the hourly power output of those 10^4 turbines). Now redo the calculation in the previous problems with this new system with only two gas turbines, and compare its results to the results of (2), where there are no wind turbines at all. Comment on your results.

Problem 2

When only the distribution of one turbine power is known (not the time series), we can use the approximation method to calculate the LOLP, provided the load time series is known.

Now assume the Cumulative Distribution Function (CDF) for the 1.5 MW wind turbine power output is given by:

$$f(x) = \begin{cases} 0.2 & \text{if } x = 0 \\ 1.2 - exp(-x) & \text{if } 0 < x < 1.5MW \\ 1 & \text{if } x = 1.5MW, \end{cases}$$

where x is the turbine power.

(1) Plot the CDF versus power output;
(2) If the wind turbine has Forced Outage Rate (FOR) equal to 10%, calculate the new CDF $f'(x)$, written as a function of the original CDF $f(x)$; Plot the new CDF on the same figure of the "old" CDF plot in the previous part.
(3) Calculate LOLP when the load is 1 MW.

Problem 3

When only the distribution of the turbine power, and the distribution of electricity load are known (no time series data available), we can still calculate LOLE and ELCC using the approximation method.

Assume the distribution of turbine power is the same as it is in the previous problem, and the distribution of the load is: 1/3 of the time load is 0.01 MW, and 2/3 of the time load is 0.1 MW.

Calculate the system LOLE and ELCC (target LOLE is 0.3), using the COPT function calculated in the previous part.

E-mail address: jc3288@columbia.edu, jsh2146@columbia.edu and msz2112@columbia.edu