MEA1: TRANSMISSION LINE ANALYSIS

SCENARIO

In this scenario your team works for QUPower Consulting, specializing in energy distribution. The Toronto power failure in April 2014, caused by arcing between transmission lines and the local utility lines, made many municipalities concerned about transmission line sagging. Consequently the local city council put out a request for proposal (RFP) for an analysis of transmission line sag over a range of expected conditions for the weather norms and extremes of the selected place of interest. QUPower responded to the RFP, and won the contract with the city. Specific requests from the municipality are in the letter from the city council, document 1, below. QUPower's engineering director, Reginald Grover, has assigned the project to your team (as described in document 2, below). Some background information is also attached below, and presented as part of the in-studio activities.

Your team should pick a municipality (a hometown of one of your members, or other interesting location) to serve as the context for the problem. You should ensure that the location has some relevant information available (power line data, weather conditions, etc.). A starting point to determining locations of high voltage transmission lines is in the Hydro One Transmission map. Include satellite imagery and the street location nearest to the transmission line you have selected. It is recommended that you use Google Earth to both acquire the satellite imagery and determine the span of wire between two transmission towers.

Your investigation should include models of the sag of a transmission line in 1-in-50 year conditions to determine the effects of climatic conditions on the line, specifically due to thermal elongation in the summer, ice buildup in the winter and wind loading year round. Some helpful equations can be found on the D2L site under MEA1 content.

Please cite as: Frank, B., Woischwill, C., & Lucas, T. (2016). *Power line sag analysis*. Queen's University, Canada.

Team Roles

Your team will consist of three or four members. The major roles for each team member's contribution to the model are listed below, and each person will take the lead in one area of the tasks. Members should also contribute evenly to the entire project and work as a highly efficient team. When the assignment is submitted we will ask team members to evaluate the quality of work and effort of each of their team members. The course personnel will meet with teams that appear to have significantly uneven work distribution.

2.1 – Cable Specialist

The cable specialist team member is the lead on the cable selection and properties. This includes the research for determining the cables to be modeled as well as the writing the code for the model that calculated the temperature of the wire based on the electric current and ambient temperature.

2.2 – Climate Conditions Specialist

The climate conditions specialist is responsible for researching and reporting on the weather and climate for the selected region and how it will affect the model. This includes writing and modelling the total effective force acting on the cable from weather conditions such as wind or ice accumulation.

2.3 – Team lead and utility specialist

This team member's responsibility includes coordinating the team's activities. This person is responsible for information about the municipality selected, combining the ideas, and explaining the what are significant effects on sag.

2.4 – Electric Magnetic Field Specialist (if you have a team of 4 only)

As the EMF specialist, the team member will be responsible for modeling and reporting on the electrical magnetic field created by the transmission line. An investigation into the health risks and general concerns on EMFs should be included and analyzed in accordance to transmission lines.

Below you will find the two documents and instructions on creating the final document.

There are quite a few materials posted under Resources in the MEA1 section of the D2L course site that should be helpful. For support in writing the MEA1 document, we refer you to section 13.3 of the recommended course text, *Designing Engineers* by McCahan on the structure of engineering reports, in addition to the lecture material on written communication. Note that the instructions below are more specific than the text, so use that as general guidelines for report writing.

SCENARIO DOCUMENTS

Document 1: Award of Contract

From: {Your city name} City Council

To: Reginald Grover, Director of Engineering, QUPower Consulting

Date: October 1, 2014

Dear Reginald Grover,

This is to inform you that QUPower Consulting has been awarded the contract to conduct an analysis of transmission line sag in the high voltage lines feeding our city. We require a report providing analysis of possible transmission line sag that will allow our local utility's engineers to determine if local high voltage lines could sag sufficiently to create arcing with local power lines, trees, or other obstructions. It is our responsibility to protect the health and property of local citizens. Since the power failure event in Toronto in April 2014 many residents have expressed concern that the high voltage transmission lines could sag significantly over the year due to the extreme temperatures in the summer and ice storms in the winter, and the council is becoming increasingly worried that future changes in the climate may cause power lines in our community to sag much more than present day conditions.

Your investigation should include models of the sag of a transmission line over the next 50 years to determine the effects of climatic conditions on the line, specifically including thermal elongation in the summer and ice buildup in the winter. The council has requested that your investigation addresses scenarios including extreme heat environments, high current draw, extreme cold conditions, ice buildup, and any other conditions that could cause sag. We require a report that includes information we could use to reproduce your analysis, and your conclusions. Note that on submission to council this report will be made available to the public.

The council is also interested in seeing the effects of different diameter cables has on the sag of the wire. Clearly state which conductors you are modeling and justify why your selections are appropriate.

One of our local advocacy groups has been claiming that electric and magnetic fields (EMFs) radiating from the high-voltage transmission lines are a risk to human health. The council would like you to investigate the validity of these claims and report on if sag of transmission lines will have any effect on these EMFs.

Sincerely,

Phoebe Williams

Phoebe Williams, Council Secretary

On Behalf of (Your city name) City Council

Document 2: QUPower Memo

QUPower Consulting

From: Reginald Grover, Director of Engineering, QUPower Consulting

To: {Your team}

Date: September 16, 2014

Hi Team,

We got the power transmission line analysis contract! This is to let you know that your team has been assigned to complete the report. Note that you are all responsible for your other projects, so you'll need to manage your time efficiently. This work should correspond to the equivalent of around 5 hours a week for each of your team members.

Cheers,

Reg

REPORT INSTRUCTIONS

Specific expectations are outlined below and in the rubric – ensure you read both!

Some general principles:

- Engineering problem solving can be approached as a structured process that involves problem definition, information, modeling, idea generation, decision-making, implementing, check/testing, communicating, and self-evaluation. Many of those elements are explicitly in the document sections, but you should ensure that you consider all those elements in solving the problem.
- You should support your recommendations and conclusions by considering relevant technical, social, environmental, legal, and ethical factors.
- Arguments should be supported. Recall, as a framework that arguments consist of *claims, evidence, justification, qualifier, and rebuttal*.
- You need to support your choice of information sources critical to your model and conclusions. Recall the information evaluation considerations include *currency, relevance, authority, accuracy, and purpose*.

The deliverable is a report addressed to the city council detailing your investigative research, model, and conclusions. The document should be written in an easily readable font (e.g. Times New Roman 11 pt), following principles for effective technical communication (section headings, figure captions, citations, cross-references, numbered equations, etc. You should use the guidelines for technical report writing presented in the Word/Excel assignment that you submitted in week 1). The main body of your report (i.e. excluding title page, executive summary, table of contents, and appendices) should be no more than 10 pages long. *Marks will be deducted for report bodies exceeding 10 pages in length*.

The structure of your report should be as follows:

- Title Page, listing team members, student numbers, and a statement that all work in the report is by the listed authors, with the exception of properly cited material.
- Executive Summary
- Table of Contents
- Problem Definition
- Models and analysis (with one subsection for each team member)
- Conclusions
- Appendix I – Team contract and work distribution
- Appendix II – Team self-assessment
- Appendix II – MATLAB code

Specific instructions about the content of the sections are below.

Executive Summary

The Executive Summary is an objective, abbreviated statement of the primary information in your report using language understandable by a non-technical reader. It should include a brief summary of the problem, your approach, model, result, and recommendations. A reader who reviews only the content of

the executive summary should understand the problem and your recommendation. The Executive Summary should be no more than one page long, and appear directly following the title page and prior to the table of contents. The Executive Summary should be on its own page and not contain any new information that is not presented in report.

Problem Definition

Briefly describe the situation and define the problem(s) that you are solving, including a description of required function, attributes, and constraints of the solution, and stakeholders involved in the problem.

Model and analysis (with 1 subsection per team member)

This section should have four subsections, one for each of the four roles on the project (utility, cable, climate, and electromagnetic fields). Each of the four sections should be primarily authored by the team member responsible for that area, and include that person's name (e.g. one of the subsections would be "Climate Conditions (team lead: Sam Smith)"). Even though one person is primarily responsible for each of the subsections, the entire team should edit and ensure consistency throughout the document.

Each subsection should include the following elements (*Note: recall that we talked about five elements of an effective model in week 4 – four of those elements should be in this section, and the last element is in the Conclusions section*):

- a description of the physical system, including all relevant information needed for modelling and analysis of the problem. This can include drawings, photos, diagrams as appropriate. You should also *include an evaluation of the information sources used* (i.e. the currency, authority, accuracy, etc. of the information sources). You should include information about the local region you selected for the problem, characteristics of the transmission lines, weather conditions, and electrical voltage and power on the transmission lines in the appropriate subsections. You are free to summarize key quantitative values in a table. Ensure that you state any assumptions and approximations you use in your model and analysis in the next section.
- Describe how the physical system was modeled, including what characteristics of the physical system are parts of the model, and what is neglected or assumed. Describe the analytical equations that model the system, including variables and constants, etc.
- Show the output of the simulations using the model, generally using by plots or tables. Your results should be formatted either graphically or in tables where appropriate. Your MATLAB code should *not* be included in this section, as you will include your published MATLAB code and output as an appendix to your report. NOTE that you should **evaluate** the model in your Conclusions section below.
- A description of how the output relates to the real system, and prediction of real behaviour, including possible variations from the simulation due to uncertainty and assumptions

Conclusions

Based on your models make some preliminary conclusions about the maximum sag your selected transmission line is projected to experience. Describe the model's accuracy, limitations, and a comparison with measured data or other accepted models. Assess uncertainties or potential errors in your conclusions

based on approximations and assumptions made. If you have found incorrect or misleading information in your research, identify it and describe how you dealt with it.

APPENDIX I – Team contract and work distribution

In this section the team should describe the team contract established early in the team's formation. Ensure you also summarize the individual contributions of each team member to the code, modeling, analysis and write-up of the team section of the report.

APPENDIX II - Self-Assessment

Critically assess the team report. The following questions should be answered in your assessment:

- Is the report ***fair*** (i.e. balanced, considering multiple perspectives)? Would someone from a difference perspective draw different conclusions?
- Is the information used and conclusions drawn ***accurate*** for the required purpose? Are your assumptions supportable? Under what conditions do the conclusions hold? Would a reader have confidence in the information used? Note that this section is not intended for you to defend your work, but rather to ***realistically identify any lack of information or knowledge*** that limits the accuracy of your results and conclusions.
- Is the information used, and conclusions drawn, ***precise***? Is the report as specific as possible? Is information quantified where possible (e.g. where possible give a range of an object's mass rather than saying it is "heavy")? If there is uncertainty around the value of variables used in the model, what is the potential range of values predicted by the model, and how could this be improved?
- What prior experiences, and learning in other courses/programs, were useful to solve this problem? How did you integrate these concepts to solve the two problems?
- How efficient was your process in solving this problem? What could you do next time to be more efficient and accurate?

As part of your self-assessment you should also self-evaluate your submission using the grading rubric below (i.e. what score would you give your team or yourself for each row on the rubric?).

APPENDIX III – MATLAB code

Integrate all the contributions from the team members into one commented MATLAB script. Ensure that the script generates all necessary numeric values and figures used in your report. Ensure that you have used descriptive headings in your code like *%% Conductor Properties* that will be published as section headings. Paste the published MATLAB script and output of your code by publishing it as a Word document. The instructions for publishing code were described in the Week 2 studio, and are described in the course D2L page. You must **not** make any modifications to the published output – simply paste it into the appendix.