EE 374
ELECTRICAL EQUIPMENT AND APPLICATIONS
2019-2020 SPRING
TERM PROJECT

1 INTRODUCTION

This document presents the project definition of the EE 374 Electrical Equipment and Applications course. Here are the important points about the project:

- This is not a group project. Each student must submit his/her own work.
- The project contains three phases. You will be given some tasks in the "Project Work" section of this document. Your code should accomplish these tasks. In Phase 1, you are expected to implement **a MATLAB function**. In Phase 2, **an improved MATLAB function** must be created. In Phase 3, you will submit both the **final version of MATLAB function** and a **report**.
- If you have a question concerning the project, contact the assistants via e-mail first.
- Late submissions will not be accepted.
- You must submit deliverables of all phases to get a passing grade from the course.

Important Dates:

- Phase-1 due date: April 5, 2020 until 23:55
- Phase-2 due date: May 10, 2020 until 23:55
- Phase-3 due date: May 29, 2020 until 23:55

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2 PROJECT INFORMATION

Electricity is generated in bulk and transmitted to consumption areas via HV overhead lines. Therefore, the selection of transmission line and tower plays an important role in transmission system planning. Geometry of the conductor positions plays an important role in the calculation of electrical parameters of a transmission line. In practice, there are many types of transmission towers.

Figure 1: 735 kV transmission lines carried on V-guyed towers, 4-bundle (Quebec, Canada)

Figure 2: Double circuit 6-bundle 765 kV transmission line

Figure 3: 380 kV transmission tower in Turkey during construction

Figure 4: Zhoushan Island overhead line with the tallest power pylon in the world with 380 m. (500 kV 4-bundle)

As it can be seen in figures, spacers are used in order to prevent the contact of conductors in a bundle. Those spacers have also an important role in the calculation of electrical parameters of transmission lines. The number of conductors in a bundle and the distance between them may vary as it can be seen in Figure 5 and Figure 6.

Figure 5: Spacer for a 6-bundle transmission line

Figure 6: Spacer for an 8-bundle transmission line, 1100 kV China

The distance between phases, circuits and bundles may vary. For example, in Figure 2 you can see a double circuit line, where the electrical parameters are strongly related to the distances between circuits.

There are many other specifications in transmission line and transmission tower design. However, the most important properties in terms of power system analysis are explained above. Some extra information is given below:

- The purpose of colorful spheres or cone shaped indicators in transmission lines are to inform helicopter pilots about transmission lines.
- The purpose of the shape of insulators is to make the surface flashover path longer.
- The purpose of ground wires is to protect the phase conductors from lightning strokes. Also, they provide a path for return currents.
- The higher the system voltage, the longer the insulator length.

As you expect, there are more parameters that can affect the design of a tower; however, those are out of scope of this course. In this project, you will need only basic parameters as input that are listed here:

- number of circuits
- number of bundle conductors, where bundles form a regular polygon
- bundle distance, which is the length of the edges of the polygon that a bundles forms (in m)
- length of the line (in km)
- name of the ACSR conductor
- location of the phases with respect to the origin
- a library of ACSR conductors and their parameters

Note that the library parameters will be given in Imperial Unit System and you should convert those values to SI units. Also, note that the system is **50 Hz**. With these raw input parameters, we expect students write a function to calculate the electrical parameters of a line. To compute these parameters, Geometric Mean Distance (GMD), Geometric Mean Radius (GMR) of the line are found first. You will be introduced with these concepts in the following weeks of the course. You are not required to know these information in the first phase of the project.

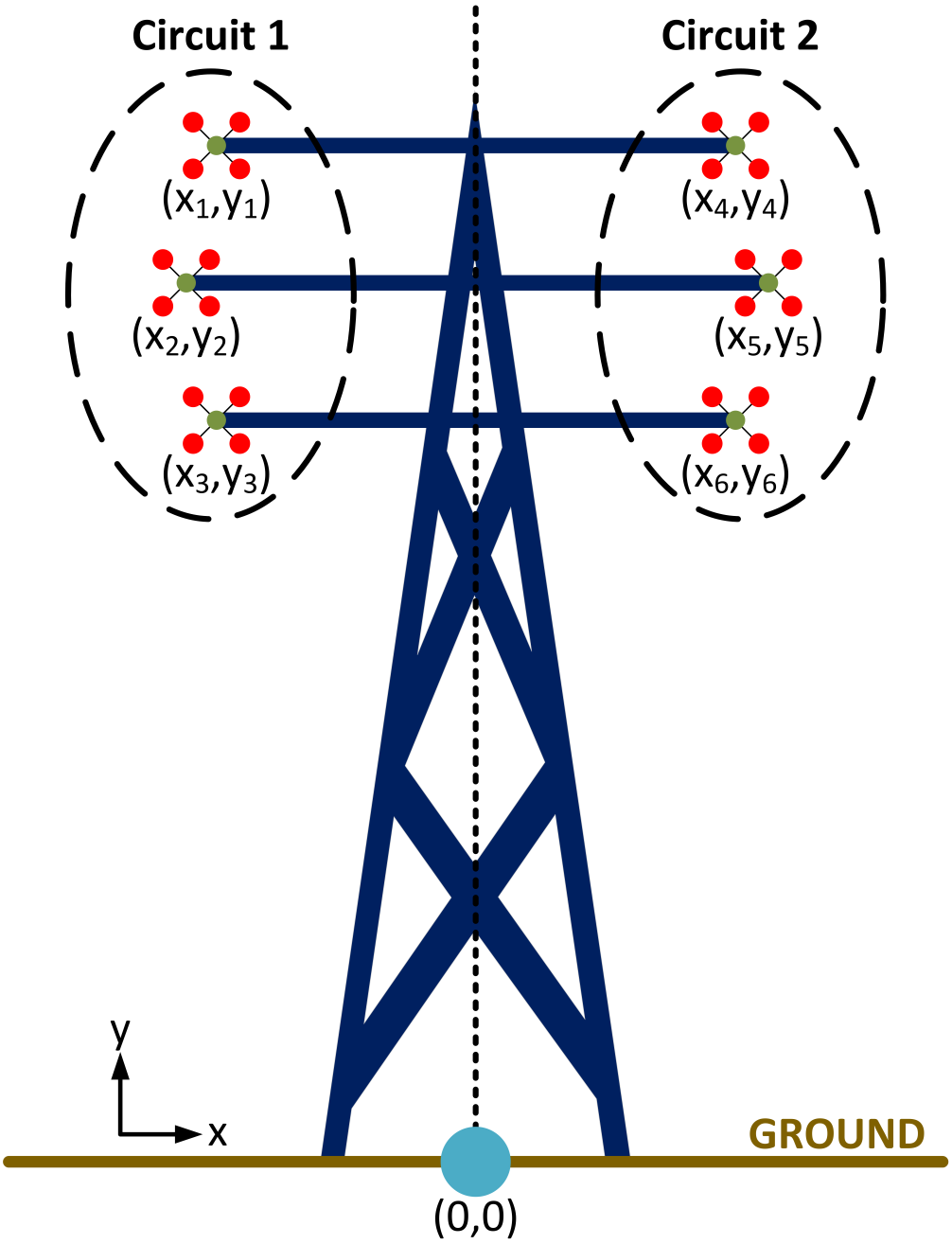

Figure 7: Definition of phase locations in input file

In your input file you will be given x and y coordinates of bundle centre for each phase, where distances are given in *meters* with respect to origin. The definition of these x and y coordinates are described in Figure 7, i.e. position of dark green circles. In Figure 7 red circles are representing the conductors and dark green circles are representing the centre of each bundle.

3 PROJECT WORK

In this project you will be given a random transmission tower's specifications in a text file. Also, you will be provided with a library of ACSR conductors that could be helpful for you. In Phase 1, you are supposed to find a tool to preprocess the raw input data given in text format into a useful format for Phase 2 and Phase 3 applications. In other words, you will create a function file that reads formatted data from text in MATLAB environment. In Phase 2, depending on these data your code should calculate the resistance (R), reactance (X) and susceptance (B) of the overhead line. Finally in Phase 3, your code should calculate the *ABCD* parameters of the line for the given length by using both long line and medium length line assumptions.

These information will be valid for the transmission line to be modeled:

- You will be given only 3-phase systems (no single-phase systems)
- All phases consist of the same bundle orientation and same type of conductors
- Lines are transposed
- If double circuits are used, they will have the same conductor types and length.

3.1 Phase 1

Tasks:

- Create a MATLAB function that reads the raw input data, which are listed in the previous section, given in the text file.
- Your function must give the outputs in SI Units, i.e. all lengths in meters.
- The code must find the conductor name that is given in the input text file in the library and extract the necessary information from there.
- If the conductor name in the text file is not included in the library (due to a spelling mistake, or else) the code must give a warning and let the user try another conductor name.
- Your function must take the input file path in string format as the input of function.

Evaluation:

- You must parse all the raw input data correctly and in correct format (string for line type, double for other parameters).
- You must submit your function in this format. Note that the order of output variables is important (-10 Points for wrong function format):

$$[N_{circuit}, N_{bundle}, d_{bundle}, length, line\_type,$$
$$D_{1,AB}, D_{1,AC}, D_{1,BC}, D_{2,AB}, D_{2,AC}, D_{2,BC}] = e123456\_surname(text\_path, library\_path)$$

- If $N_{circuit} = 1$, then you must return $D_{2,AB} = D_{2,AC} = D_{2,BC} = -1$
- Upload m-file of your code to ODTUCLASS directly, first.
- Then, publish and upload the PDF format of your function on ODTUCLASS as Turnitin assignment. Uploaded m-files and PDFs must be the same! Do not change your code after your Turnitin upload.

3.2 Phase 2

In this part, you are expected to submit a MATLAB function. Your code must execute all the tasks in Phase 1, so refine your code.

Tasks:

- Your MATLAB function should calculate the electrical parameters of the line, i.e., series resistance & reactance (Ω/km), and shunt susceptance ($\mho/km$). (Include the effect of earth on shunt capacitance calculations.)
- **(BONUS)** Transmission lines usually have bundled structures. Phase conductors can be referred as bundles in such cases. To find the distance of one phase conductor to another, the geometric mean of the distances of each conductor in a bundle to the conductors in the other bundle must be calculated. However, this value is approximated as the distance between the bundle centers, or in other words phase conductor centers. Because conductors in a bundle are so closer to each other comparing to the distance between phase conductor centers that bundles can be considered as points. To give an example, for transmission lines with bundled structures, GMD is calculated as the geometric mean of distances between the centers of phase conductors. However, this is just an approximation. In fact, GMD is the geometric mean of the distances between the center of each conductor in a bundle of each phase with the conductors of the other phases.

  For the bonus part of the project, you should calculate the series reactance and shunt capacitance using the more accurate method to find the distances between phase conductors. **Hint:** Where else do you need to find the distance between two phase conductors except GMD calculation?

Evaluation:

- You must submit your function in this format where the data type of the output variables is double (-10 Points for wrong function format):

$$[R, X, B, X_{Bonus}, B_{Bonus}] = e123456\_surname(text\_path, library\_path)$$

  If you will not do **BONUS** part, you can return −1 for the corresponding variables.

- Upload m-file of your code to ODTUCLASS.
- Then, publish and upload the PDF format of your function on ODTUCLASS as Turnitin assignment. Do not change your code after your Turnitin upload.

3.3 Phase 3

Tasks:

- In this part of the project, you need to find the *ABCD* parameters of the line, which is defined in (1), for the given length in the text file by using both long line and medium length line assumptions.

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \tag{1}$$

- You must return output variables in given units: $A_m = A_l = D_m = D_l$ are unitless. $B_m = B_l$ are in Ω, $C_m = C_l$ are in $\mho$. $length$ is in $meters$.

Evaluation:

- You must submit your function in this format where the data type of the output variables is double (-10 Points for wrong function format):

$$[A_m, B_m, C_m, D_m, A_l, B_l, C_l, D_l, length] = e123456\_surname(text\_path, library\_path)$$

- The report should not include explanation of your code rather it should include the following:

  The employed method, why and how you used it.

  Any method/assumption/etc. you used to improve accuracy performance.

  Test results.

  Your observations on how changing the inputs in the text file affects the line parameters.

- **(BONUS)** We did not ask you to include the sagging in lines into your calculations. In reality, there is a certain line sag which depends strongly on the ambient temperature. Also, resistance of a line has a strong relationship with temperature as well. Research on how effects of these phenomena are modeled and include your findings in your report.
- Upload m-file of your code to ODTUCLASS.
- Then, publish and upload the PDF format of your function on ODTUCLASS as Turnitin assignment. Do not change your code after your Turnitin upload.
- Upload your report on ODTUCLASS as Turnitin assignmnt.