MIDDLE EAST TECHNICAL UNIVERSITY

ELECTRICAL AND ELECTRONICS ENGINEERING

EE374 Term Project Report

Prepared by

Rafet KAVAK

2166783

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1) Introduction

Electrical energy can be derived from the electrical potential energy or the kinetic energy i.e., it refers to the energy that has been converted from the electric potential energy. Moreover, electricity generation is the process that generation of the electrical energy from the other forms of energy. Electricity is usually generated at a power station by electromechanical generators or from the kinetic energy of flowing water and wind. There are many other techniques that can be used to generate electricity such as solar photovoltaics, geothermal power, etc. In order to transmit the generated electricity to the consumers, many transmission methods were in use for several purposes. In the transmission of the electricity from the generating substation to the distribution units, high voltage overhead transmission lines are used.

Figure 1 Example of Transmission Lines

In this project, we were given random transmission towers' specifications and we tried to model the given transmission lines. Firstly, the raw input data was extracted from the text file and prepared for the future calculations in MATLAB. Secondly, the resistance, reactance and susceptance of the transmission lines were calculated. Lastly, ABCD parameters of the transmission lines were calculated according to the medium length line and long length line assumptions by using the previous parameters. In this report, the methodology which was used for the modelling will be explained and the assumptions will be stated. Also, test method of the code will be explained in the manner of how can I prove accuracy of my code if the correct output is not given, and the observations will be introduced about the effects of the inputs on the line parameters. Lastly, the bonus part of the phase 3 will be stated.

2) The Method

There are many parameters that affect the design of the transmission towers. Some of them are included in the project and some of them are not. In this project, we are given

- Number of circuits (1 or 2)
- Number of bundles (Up to 8)
- Bundle distance (One edge of a polygon)
- Length of the line (In km)
- Name of the ACSR conductor
- Location of the phases with respect to origin

in a text file. Also, a library of ACSR conductors and their parameters is given as .csv file for the further phases. In the following part, the methodology that used each phase will be explained.

2.1) Phase 1

In the first phase, we were supposed to find a tool in order to preprocess the raw input data given in the text file into a useful format for the following phases. For this purpose, a function was written that reads the text file and extracts the necessary information about the transmission line.

The text file and the library have been scanned with the necessary MATLAB functions and conductor name was checked at the first step. If the conductor name was not correct, a warning was given, and the intended type was asked for the user. In the following step, number of circuit(s), number of bundles, bundle distance length of the line were assigned to the correct output formats. Finally, distances between the centers were calculated for the two types of circuits. When the number of circuit is one, the code was returned -1 for the second circuit values.

2.2) Phase 2

In the second phase, the electrical parameters of the line i.e., series resistance (R) in Ω/km, series reactance (X) in Ω/km and the shunt susceptance (B) in Ω^{-1}/km of the overhead line were calculated. In the calculation of the shunt capacitance calculations, the earth effect was also considered.

Firstly, according to the line type, necessary information was obtained from the library and this information were converted from imperial unit to SI unit. According to the circuit number, the resistance was calculated by dividing the strand resistance into the number of bundles. Thus, the resistance of the bundle has found. Then, if the circuit number was 2, then the resistance decreased by half as well.

Secondly, for the series reactance, GMR of the strand was extracted from the library according to the line type and converted from feet to meter. Then, considering the number of the bundles, bundle GMR was calculated for the eight cases. Each case was considered as a polygon and diagonals were calculated in this manner. Lastly, according to the number of circuits, GMD value, line inductance per km and reactance were calculated.

$$L = 2 * 10^{-7} \ln \frac{GMD}{GMR} \ \ in \ \frac{H}{m} \ per \ phase \tag{1}$$

$$X = 2\pi f L * 10^{3} \ in \frac{\Omega}{km} \tag{2}$$

Finally, equivalent radius of the bundle was calculated like in the previous case. Then for the earth effect, necessary lengths were calculated for the equations. For the single circuit case, it was relatively easy but for the double circuit case, it was a little bit challenging. (The formula of the capacitance is given without the earth effect)

$$C = \frac{2\pi\varepsilon_0}{\ln\frac{GMD}{GMR}} \ \ in \ \frac{F}{m} \ \ per\ phase \tag{3}$$

$$B = 2\pi f C * 10^3 \ in \frac{\Omega^{-1}}{km} \tag{4}$$

2.3) Phase 3

For the last phase, there was little work left to do. ABCD parameters of the transmission line which is defined in Equation 5 for the given length were calculated in the case of both medium length line and long length line assumptions.

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \tag{5}$$

Firstly, the total series impedance and the total shunt admittance were calculated as follows. (l in meters)

$$Z = zl = (R + jX)l \tag{6}$$

$$Y = yl = jBl \tag{7}$$

Secondly, for the medium length line assumption, ABCD parameters were found as

$$A = D = 1 + \frac{ZY}{2} \tag{8}$$

$$B = Z \ in\ ohm \tag{9}$$

$$C = Y\left(1 + \frac{ZY}{4}\right) in\ mho \tag{10}$$

Finally, for the long length line assumption, ABCD parameters were found as

$$A = D = \cosh \gamma l \tag{11}$$

$$B = Z_0 \sinh \gamma l \ in\ ohm \tag{12}$$

$$C = \frac{\sinh \gamma l}{Z_0} \ in\ mho \tag{13}$$

where Z_0 is the characteristic impedance of the line and gamma is the propagation constant

$$Z_0 = \sqrt{\frac{z}{y}}\ , \qquad \gamma = \sqrt{zy} \tag{14}$$

3) Assumptions

In this project, many assumptions slip beneath the radar and I want to mention them. Firstly, we assumed that the all bundles are regular polygon but, in the reality, it would be very rare condition. Also, the position of the centers cannot be as accurate as in reality again. Because of the bundle distances, GMR values and radius of the bundle also will be deviated in practical applications. Correspondingly, the series reactance and the shunt susceptance will be deviated.

Furthermore, in our calculations, we assumed that all parameters are linear but in reality, almost everything is nonlinear. For instance, the resistance will be differed for the different temperature and environment conditions.

For the ABCD parameters, shunt resistance was also neglected for the sake of simplicity. Also, sagging is not included in the calculations.

There are also a lot of issues like skin effect, proximity effect, hysteresis loss, etc. and we did not consider any of them.

4) Test Results

The results of the code can be checked with the hand calculation of the parameters at the first glance if the expected outputs are not present. For the first phase, it is easy to check whether the outputs are true or not. All you need to do is just comparing the input(text) file to the output of the MATLAB function. For the second and third phase, according to the library data, all values can be calculated by hand and can be compared with the outputs again.

Moreover, based on the observations, by changing the parameters of the input files, one can observe the changes on the parameters and decides whether the code is working correctly or not intuitively.

5) Observations

For the ACSR conductors, from Waxwing to Bluebird, Aluminum area, stranding, outside diameter and GMR are increasing, and DC&AC resistance are decreasing as well. As a result of the two example input files inductance and capacitance of Pheasant type is higher than the Rail type because GMR and the bundle radius of Pheasant is higher than the Rail.

Moreover, the length of the transmission lines has direct impact on the ABCD parameters and as the length of the lines increased Y and Z also were increased and the ABCD parameters were also increased.

6) Bonus Part

Sag can be defined as the level different between points of supports and the lowest point of the conductor. It can be seen in the Figure 2 below.

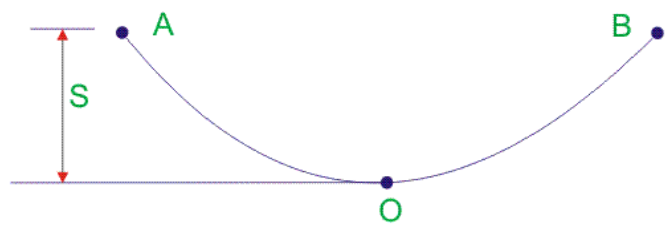

Figure 2 Illustration of the Sagging where AOB is the transmission line

Sag is very crucial in transmission lines because it provides suspension to the lines in the case of wind or weather conditions. Actually, we are seeing effects of the sagging on the transmission lines since our childhood. In the summers, transmission lines are tightened, and in the winters, they were bended, because temperature has a lot of impact on the sagging. The calculation must be done precisely because if the lines sag too much, they can violate the safety rules and if they were stretched too much, some of break off might be occurred.

7) Conclusion

This project is very comprehensive for the course and the transmission lines. I have researched many things about electricity, generators, etc. Also, thanks to this project, I have seen the physical representation of spacers, bundles, several transmission lines, etc. Moreover, learning of some general knowledge issues like purposes of the colorful spheres was very enjoyable. It is been very nice to seeing the practical implications of the theoretical knowledge and modelling them in MATLAB provided a lot of insight about them.

Lastly, I would like to thank our course assistants İven GÜZEL and M. Erdem SEZGİN for sharing their knowledge and for their support, patience and guidance.

8) References

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