ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

EE 374

FUNDAMENTALS OF POWER SYSTEMS AND ELECTRICAL EQUIPMENT

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TERM PROJECT REPORT

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Introduction

In this project it is asked to write a MATLAB code to that calculates series resistance, series reactance and shunt susceptance. In phase 1, it is asked to write a function that reads an input text file from the given path and extract the desired information (like the conductor type, outside diameter, AC resistance at 20°C, GMR of the conductor etc.). Also, the function needs to convert these parameters to SI units. In phase 2, the written function must be improved to calculate series resistance & reactance and shunt susceptance in per unit quantities.

Methods

1. Series Resistance Calculation

The length of the transmission line, the number of circuits in the bundle, and the AC resistance of the conductor affect the transmission line's series resistance.

$$R = \frac{length * R_{AC}}{N_{Bundle} * N_{Circuit}}$$

2. Series Reactance Calculation

We must first calculate GMD, GMR, and equivalent resistance of overhead line so we can compute series reactance and shunt susceptance. Where GMD is geometric mean distance between phases and GMR is geometric mean radius of each phase.

$$GMD = \sqrt[3]{GMD_{AB} GMD_{AC} GMD_{BC}} \qquad GMD_{AB} = \sqrt[4]{\prod red\ colored\ lines}$$

One Circuit Case

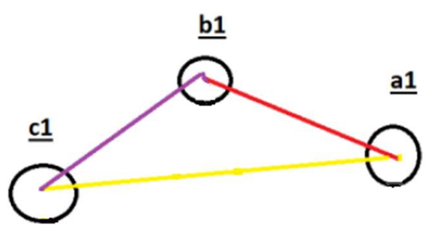

Figure 1: Phase locations in single circuit case

Double Circuit Case

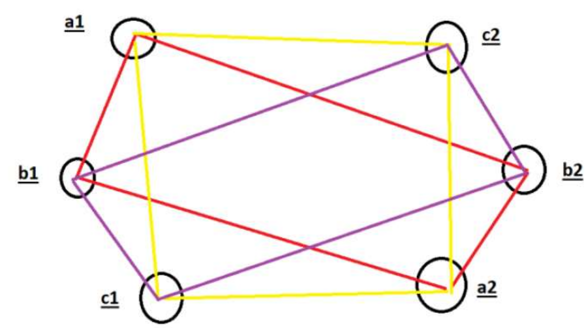

Figure 2: Phase locations in double circuit case

Single Circuit GMR Calculation

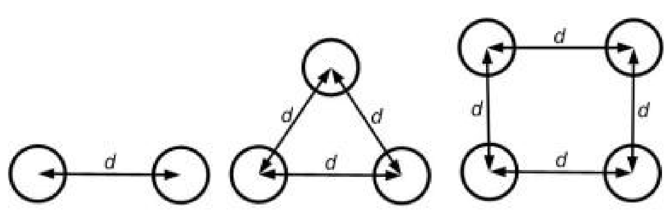

Figure 3: Conductor locations for 2-3 and 4 number of conductor cases

For 2 conductor bundle,

$$GMR_{bundle} = \sqrt{GMR_{conductor} * d},$$

For 3 conductor bundle,

$$GMR_{bundle} = \sqrt[3]{GMR_{conductor} * d * d}$$

For 4 conductor bundle,

$$GMR_{bundle} = \sqrt[4]{GMR_{conductor} * d * d * d\sqrt{2}}$$

The same pattern applies for the 5-6-7-8 conductor bundle cases. Geometric mean of the one conductor's all diagonals is GMR_{bundle}.

Double Circuit GMR Calculation

For the double circuit case, we need to calculate following expression in addition to previous GMR_{bundle} calculation.

$$GMR = \sqrt[3]{GMR_{AA} GMR_{BB} GMR_{CC}} \qquad GMR_{AA} = \sqrt{GMR_{bundle} \times red\ line}$$

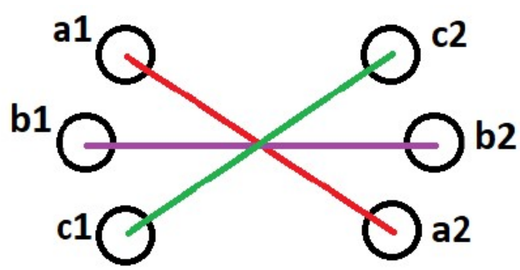

Figure 4: Phase locations in double circuit case

$$X = w * L * length = 2\pi * f * 2 * 10^{-7} * \ln\left(\frac{GMD}{GMR}\right) * length$$

Also, equivalent resistance is calculated with the same method with GMR.

3. Shunt Susceptance Calculation

$$C_n = \frac{2 \times \pi \times \epsilon}{\ln\left(\frac{GMD}{r_{eq}}\right) - \ln\left(\frac{\sqrt[3]{H_{12} H_{13} H_{23}}}{\sqrt[3]{H_1 H_2 H_3}}\right)}$$

$$Y = w * C_n * length$$

One Circuit Case

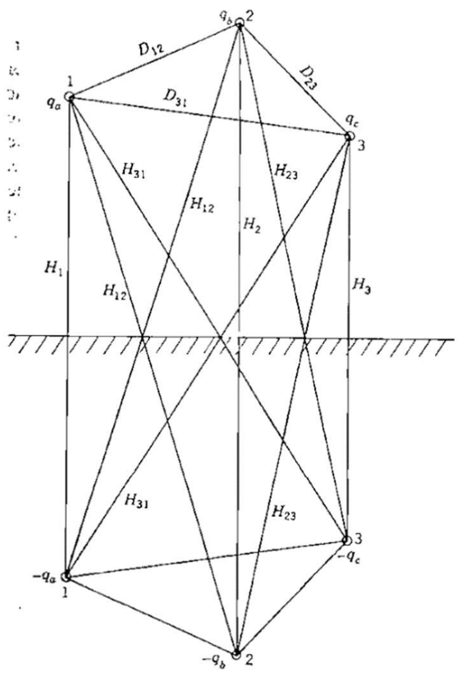

Figure 5: Phase locations in single circuit case

Double Circuit Case

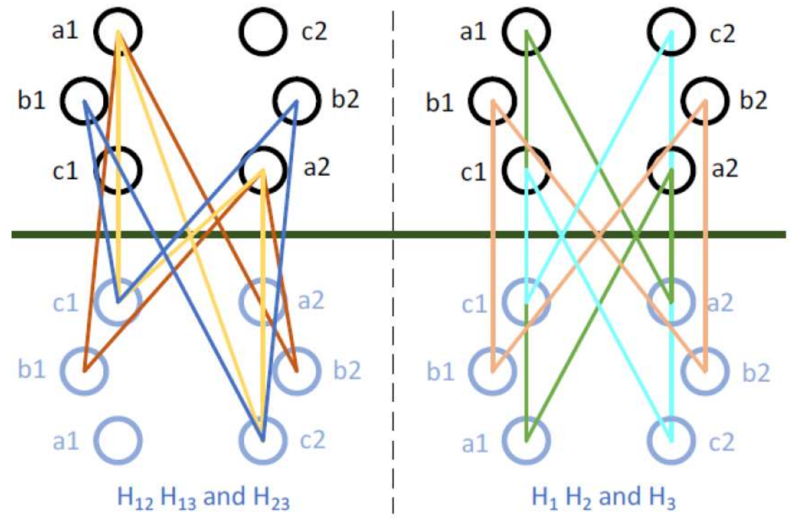

Figure 6: Phase locations in double circuit case

Assumptions

In this project, the following statements are assumed in order to reduce complexity:

- The given system is **balanced 3-phase** system.
- **Same type of conductor** is used for whole system.
- **Same type of bundle orientation** is applied for whole system.
- **Lines are transposed** as shown in the figure:

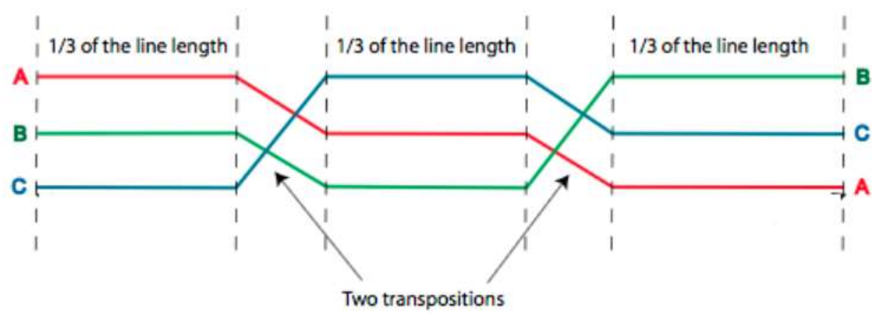

Figure 7: Transposed HV overhead lines

Observations

The quality of energy generated in bulk and delivered to consumers through high-voltage overhead lines strongly depends on the transmission line characteristics and design. As a result, transmission line and tower selection are critical for transmission system planning. When calculating the electrical properties of a transmission line, the geometry of the conductor positions is crucial (given in the input text file). As a simple example, as the number of bundles increases, the resistance decreases. The results are affected by the following parameters as discussed in the project manual:

	The parameter (given at the left side)	**R_pu**	**X_pu**	**B_pu**
Sbase (MVA)	↑	↑	↑	↓
	↓	↓	↓	↑
Vbase (kV)	↑	↓	↓	↑
	↓	↑	↑	↓
number of circuits	↑	↓	↓	↓
	↓	↑	↑	↑
the number of bundle conductors, where bundles form a regular polygon.	↑	↓	↓	↑
	↓	↑	↑	↓
bundle distance, which is the length of the polygon edges that bundles form (in m)	↑	---	↓	↓
	↓	---	↑	↑
length of the line (in km)	↑	↑	↑	↑
	↓	↓	↓	↓
name of the ACSR conductor	Not applicable			
location of the phases with respect to the origin	Not applicable			
a library of ACSR conductors and their parameters	Not applicable			

increase: ↑ decrease: ↓ no change: ---

Test Results

All the results converted to pu quantities at the end as follows:

$$Y_{base} = \frac{1}{Z_{base}} \qquad B_{PU} = \frac{B'}{Y_B} \qquad R_{PU} = \frac{R'}{Z_B} \qquad X_{PU} = \frac{X'}{Z_B}$$

	Input 1	**Input 2**
R_pu	0.003265246133622	0.004099297636828
X_pu	0.040688719098887	0.086281924737058
B_pu	0.275069074509593	0.202092791081598

Summary

As a summary, series resistance & reactance and shunt susceptance values of an HV overhead line is calculated in MATLAB with the given parameters like; S_{base}, V_{base}, number of circuits and bundle conductors, bundle distance conductor type length and the positions of the bundles. Making calculations by applying MATLAB code for similar structures decreases the engineer's workload significantly.