Skolkovo Institute of Science and Technology
Center for Energy Science and Technology

Course: Fundamentals of Power Systems
Term 2: 2021
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# Homework 3: State Estimation

**General Instructions**: *The report should contain answers to the questions in the task and short description of every step in your code – in comments or Jupyter markdowns. The Jupyter notebook should be uploaded to canvas. The logic of the solution to the problem and all notations should be clear. The notebook must work correctly if one restarts and runs all cells. The report (.ipynb file) should be submitted by* ***November 22***

**Concepts Covered**: *State estimation, $\chi^2$ test, bad data identification, AC power flow, Data processing, Newton-Raphson method, JuMP package*

Name: _____

Consider the 2-bus power system in Fig. 1. You are given the files that contain measurements of some of this system's parameters. See *data/Measurements.csv*.

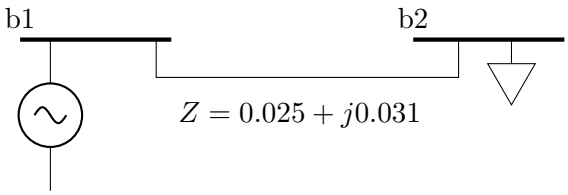


Figure 1: Power system

## Problem 1 [40 points]

(a) (**5 pt**) Read the data using the function from Computer Lab 2. Construct admittance matrix by yourself. For which buses we have measurements? Which power system parameters are provided with measurements?

(b) (**15 pt**) Obtain WLS estimator using Newton-Raphson method.

(c) (**15 pt**) Obtain WLS estimator using optimization framework (i.e., JuMP, Ipopt packages from Julia). Compare with results of (b).

(d) (**5 pt**) What are the estimates for $\delta_1,\ \delta_2$?

## Problem 2 [60 points]

(a) (**20 pt**) Assuming significance level $\alpha = 1 \cdot 10^{-2}$, test the following hypothesis using $\chi^2$ test: the given data describes the power system from previous problem. What is the number of degrees of freedom $n$?

(b) (**10 pt**) Explain the results from (a) using the CDF of $\chi^2(n)$, and the quantile of $\chi^2(n)$ at given significance level used in the test. Plot them in one figure.

(c) (**30 pt**) If the hypothesis has been rejected (there is bad data), find the bad measurement.

*Hint: there is a single bad measurement. May be you could exclude it?*