Assignment 1: Solution

April 8, 2018

Data Processing

- H is the partial derivative of h with respect to x and has size $m \times n$, where m is the number of measurements and n is the number of unknown states. Unknown states are all voltage magnitudes and all voltage angles except one, which is the angle at the reference bus.
- h has size $m \times 1$.

Task 1

Table 1: 14-Bus system

	Inverse		Cholesky		QR		Hybrid	
	sparse	full	sparse	full	sparse	full	sparse	full
time, s	0.0028	0.009	0.0021	0.0024	0.0052	0.0057	0.0071	0.0314
N_iter	4	4	4	4	4	4	4	4

Table 2: 1354-Bus system

	Inverse		Cholesky		QR		Hybrid	
	sparse	full	sparse	full	sparse	full	sparse	full
time, s	12.727	22.918	0.1146	19.778	76.5	155.71	0.1411	321.725
N_{iter}	5	5	5	5	5	5	5	5

- The only thing that is changed is the method and efficiency of inverting the matrix G, which is used to compute the update on the unknown state variables. Therefore the vector of updates will always have the same size and the number of iterations will stay the same, regardless of sparsity/non-sparsity and the solution method.
- Sparsity makes matrix operations faster, because the zero entries are simply skipped. The bigger the matrix, the more noticeable this effect becomes because the density of and admittance matrix of a power system decrease as the size of the power system grows.
- The fastest solution methods are Hybrid method and Cholesky decomposition. This is the case because these methods are are computationally less expensive than other decomposition methods.

Task 2

Table 3: Densitiy and Condition of important Matrices

	H	G	G^{-1}	L	Q	R
density	0.16	0.77	100	0.63	5.01	0.69
condition	$2.158 * 10^4$	$4.655 * 10^8$	-	-	-	$2.158 * 10^4$

- The direct inversion method does not preserve density at all, in fact the density is 100% meaning that all elements are non-zero. The L Matrix of the Cholesky decomposition is slightly less dense than the R Matrix from the QR decomposition but a lot less dense than the Q matrix from the same decomposition method. As can be seen from the results of Task 1, density factors are the main reason for the computational efficiency/inefficiency of a particular method.

- The condition number of G is of magnitude much larger than the one of H. Since the QR-decompostion uses matrix H and the Cholesky decomposition uses matrix G, the QR method is numerically more stable.

- Since the hybrid method combines the efficiency of the Cholesky method with the numerical stability of the QR method, it can be a preferred method for the state estimation program.

Task 3 [1]

- Since in the fast decoupled method the measurement Jacobian is approximated based on several assumptions, it takes more iterations to converge, however each iteration is much faster because matrix G can be factorized only once.

Task 4

- Based on the normalized residuals plot, measurement data sets B & C have faulty redundant measurements. Since data set A has a warning from the SCADA system it has an error in a critical measurement. This leaves data set D being a good data set.

- A critical measurement is a measurement which can't be removed from the data set being analyzed for state estimation because otherwise parts of the grid are not observable anymore. This means that a critical measurement is the only measurement giving information on grid properties in the corresponding area area. A redundant measurement on the other hand is one that is not necessarily needed, since its state could also be computed by other measurements which have been done.

- Let us consider the following critical measurement: the active power flow $P_{11,10}$. If the voltage at bus 10 is measured, $P_{11,10}$ is no longer a critical measurement.

[1] The code for this task will not be distributed.

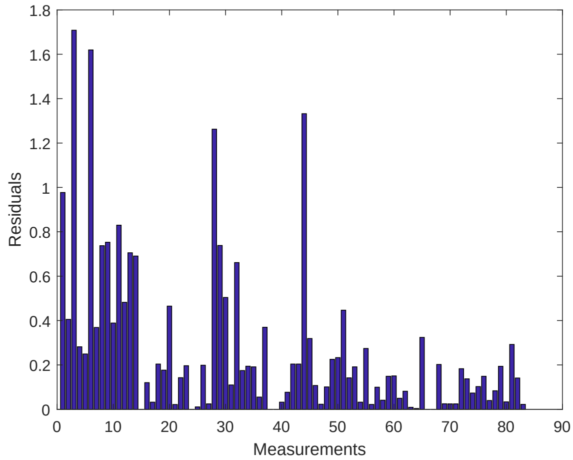

Figure 1: Normalized residuals for dataset A.

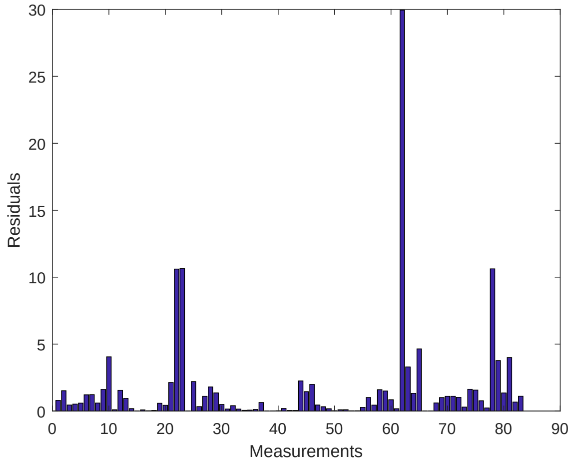

Figure 2: Normalized residuals for dataset B.

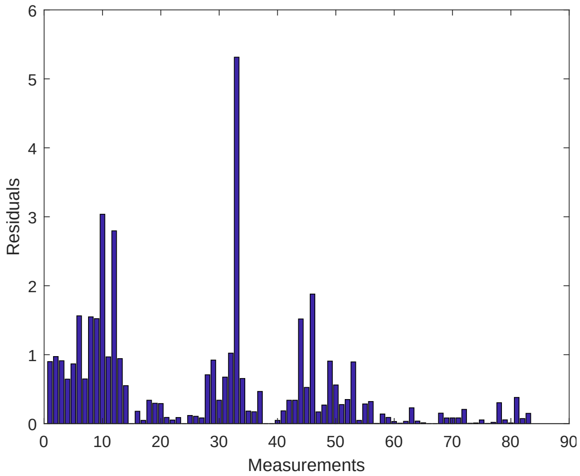

Figure 3: Normalized residuals for dataset C.

Task 5

- If a critical measurement is removed from the data set, a part of the system becomes unobservable.

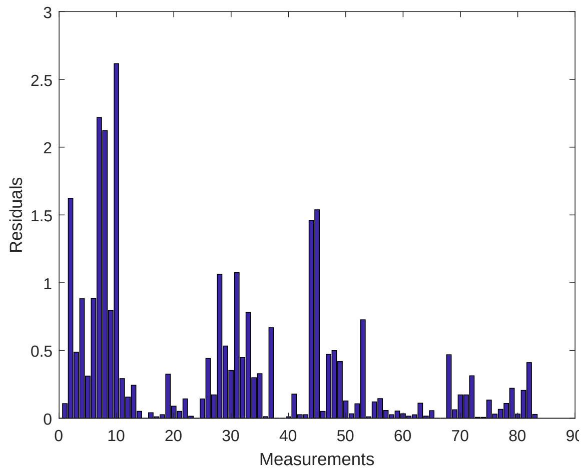

Figure 4: Normalized residuals for dataset D.

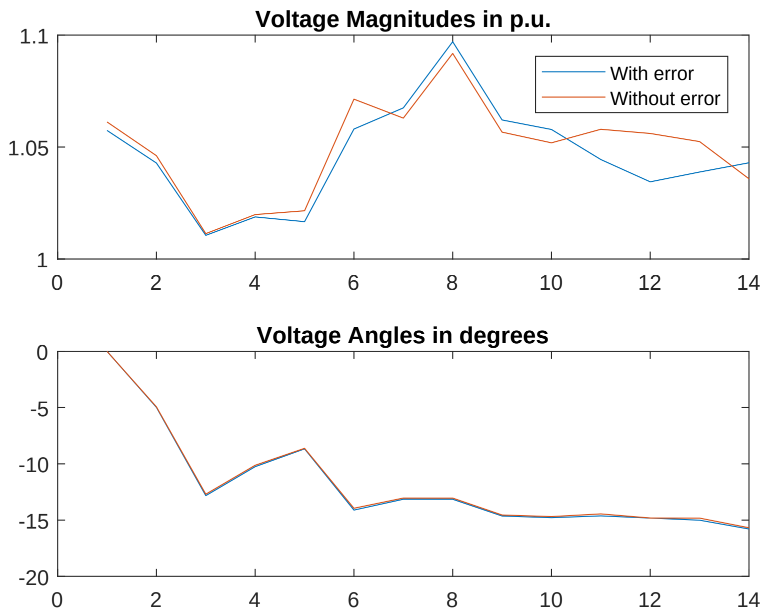

Figure 5: Voltage magnitudes and angles in dataset C before and after correction.

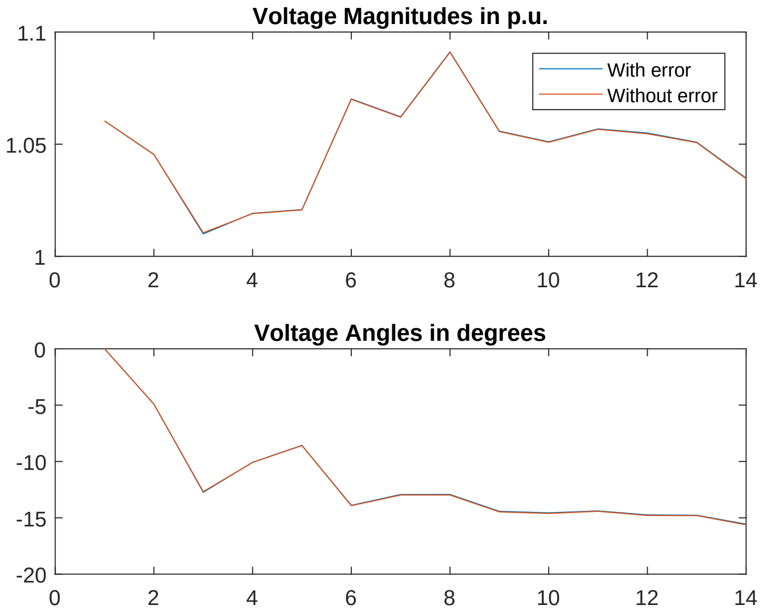

Figure 6: Voltage magnitudes and angles in dataset D before and after correction.