

GridPACK Validation Report on State Estimation

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This documentation has been prepared to validate the GridPACK state estimation (SE) module. Because a commercial SE tool is not available to validate against, the validation was conducted by comparing the SE outputs against measurements obtained from a powerflow solution. Using this strategy, the SE results are expected to self-consistently match the powerflow solution. If the maximum absolute difference between SE estimates and the measurements is smaller than a preset tolerance, the SE application is considered to meet the validation requirements.

During the validation, three power systems, the IEEE 118-bus network, a 3,000-bus network, and a 20,000-bus network representing the Western Electricity Coordinating Council (WECC), were used to represent small, medium, and large systems. Power flow solutions for each test system are used as measurements. The types of measurements include bus voltage magnitude (V_M), real power injection (P_I), reactive power injection (Q_I), real power flow in both directions (P_{IJ} and P_{JI}), and reactive power flow in both directions (Q_{IJ} and Q_{JI}). Table 1 contains the details of measurement type and the associated measurement deviation.

Type of measurements	Deviation
V_M	0.015
P_I	0.015
Q_I	0.015
P_{IJ}	0.01
P_{JI}	0.01
Q_{IJ}	0.01
Q_{JI}	0.01

Table 1: Type of measurements and measurement deviations used in State Estimation Validation.

The SE validation is based on comparing the maximum absolute differences between measurements and SE estimates against SE tolerance. The histogram of these differences for each test systems are provided below.

1 IEEE 118-bus test system

712 measurements based on the power flow solution were applied to the 118-bus test system with a tolerance of 10^{-4} . The largest difference between SE output and the power flow solution is $6.0 * 10^{-5}$, which is smaller than the tolerance. The histogram of the absolute differences between measurements and estimates is shown in Figure 1. Table 2 summarizes the validation results.

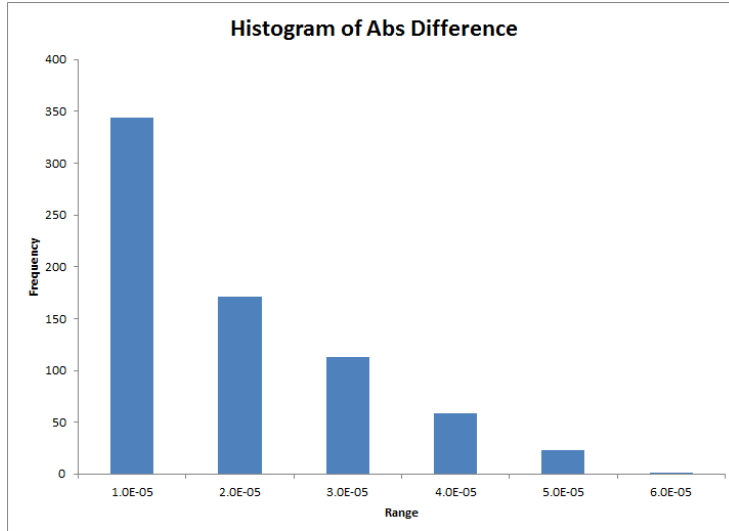


Figure 1: The histogram of the absolute differences between measurements and estimates for the IEEE 118-bus test system .

Properties	Values
The number of measurements	712
Solution tolerance	10^{-4}
max difference	$6.0 * 10^{-5}$

Table 2: Validation results for IEEE 118-bus test system.

2 3000-bus test system

For the 3,000-bus system, 24,105 measurements were applied to test the SE. As shown in Figure 2 , most state estimates are close to the measurement values. The largest difference between measurements and estimates is 8.0×10^{-5} , smaller than the tolerance. Table 3 summarizes the validation results.

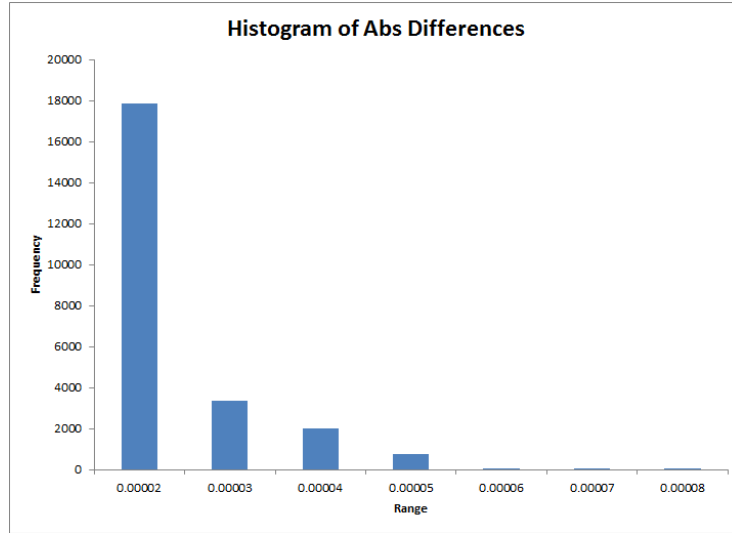


Figure 2: The histogram of the absolute differences between measurements and estimates for the 3,000-bus test system .

Properties	Values
The number of measurements	24,105
Solution tolerance	10^{-4}
max difference	8.0×10^{-5}

Table 3: Validation results for the 3000-bus test system.

3 20,000-bus test system

The 20,000-bus system represents a western United State power grid (WECC system). The number of measurements is 74,747. As shown in Figure 3, the largest absolute difference between measurements and estimates is $9.0 * 10^{-5}$, smaller than the tolerance. Table 4 summaries validation results.

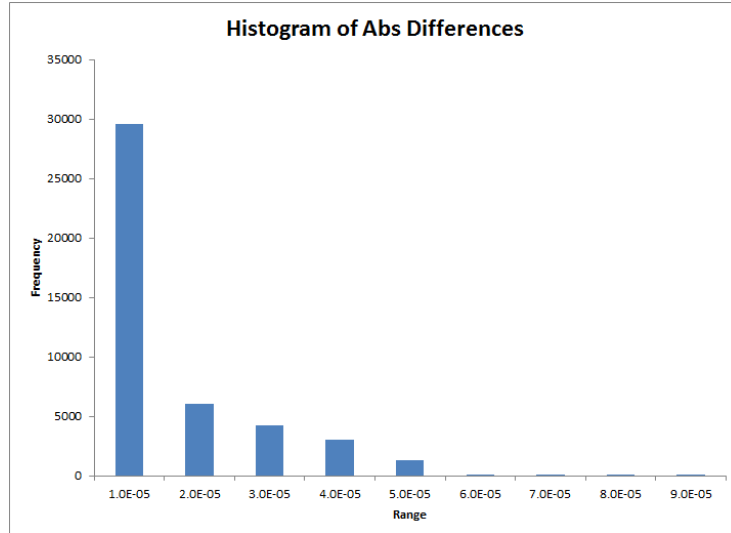


Figure 3: The histogram of the absolute differences between measurements and estimates for the 20,000-bus test system.

Properties	Values
The number of measurements	74,747
Solution tolerance	10^{-2}
max difference	$9.0 * 10^{-5}$

Table 4: Validation results for the 20,000-bus test system.

In summary, all the test results above have shown that GridPACK SE meets the validation requirements.