Chapter 9

CONCLUSIONS AND FUTURE RESEARCH

§ 9.1 Topology Error Summary and Future Work

In Chapter 3, a new robust methodology for detecting topology errors in a power systems network was derived and tested. The unknown quantities of interest (the state variables) were the true real and reactive power flows on each branch in the network, including short circuit lines. Power measurements that are taken off the network were modeled with a nonlinear function in terms of the unknown powers and nonlinear regression techniques were employed to solve for the state variables. The Huber estimator was used and advocated for its robustness to discordant measurements, its simplicity to implement, and its rapidity to estimate. The methodology was tested on a variation of the IEEE 118-bus system and the results were very successful. The topology estimator was able to identify topology errors as well as identify gross measurement errors, and correctly estimate the topology of the network. The estimator also does not suffer from the problem of leverage values in the model matrix, intrinsic in classical state estimation.

To complete the topology error study would involve investigating the *observability* of the network for this model. Saying the network is observable is equivalent to saying that the model matrix is of full rank. One obvious way to test whether a model matrix, X, is of full rank is to take a determinant of $X'X$ and compare it to zero. If it is nonzero, then the network is observable. Another way would be to invoke graph theory, since any matrix can be represented by an associated graph. Graph theory has two distinct advantages: 1) it is computationally faster than taking a determinant, which is of primary importance to power engineers, and 2) it is more informative than a determinant. Not only will graph theory show if a network is unobservable, but also will show which largest portion of the network is observable. For details on the observability of a network with the proposed topology error identification scheme, see Appendix E.

Statistically speaking, there is a concern using the asymptotic formulae when testing the sending end power estimates. Because of the low redundancy in the network, the applicability of small sample asymptotics is more appropriate. Thus it would be interesting to see how finite sample asymptotics would be implemented in power systems and then compared to the standard asymptotic formulae.

§ 9.2 Statistical Resistance Summary and Future Work

In Chapter 5 the maximum resistance to rejection (*MRR*) and the maximum resistance to acceptance (*MRA*) were derived and approximated for the Friedman test for the cases when the number of blocks, *b*, are an integer multiple of the number of treatments, *t*. The *MRR* is a decreasing function in *b*, and as *b* approaches infinity, the *MRR* approaches zero. The *MRA* is an increasing function in *b* and in the limit, the *MRA* approaches one-fourth. Chapter 6 reports the simulated expected resistance to rejection (*ERR*) as well as the expected resistance to acceptance (*ERA*) and comparisons were made. In Chapter 7 we derived a lower bound on the *MRR* for the Brown-Mood test and showed that the *MRR* of the Brown-Mood test is higher than for the Friedman test. The *MRA* of the Brown-Mood test was approximated and shown also to be higher than the *MRA* of the Friedman test. Finally, Chapter 8 displays the results of the simulated *ERR* and *ERA* of the Brown-Mood test and compares them with the Friedman test. It was shown that the Brown-Mood *ERR* is slightly higher than the Friedman, but the Friedman *ERA* was, for the most part, much higher than the Brown-Mood.

Further research in this area would include a more exhaustive study of some nonparametric tests for the two-way layout. Other candidate tests include a generalized sign test (Wormleighton, 1959), the two-way analysis of variance on the ranks (Kendall and Smith, 1939), or another internal rank correlation test, such as one proposed by Anderson (1959). In addition, a new test statistic could be invented based on high resistance (to rejection) properties, and its asymptotic distribution derived. Finally, one could investigate what test would achieve the highest possible resistance (to rejection) and define for a given *t* what the highest possible resistance is.