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PROJECT TITLE: ASSESSMENT OF THE UNIVERSAL FEASIBILITY OF USING POWER SYSTEM HARMONICS AS LOSS OF MAINS DETECTION FOR DISTRIBUTED ENERGY RESOURCES

CONTRACT NUMBER: RD3-21 **MILESTONE NUMBER: 5** **REPORT DATE: JUNE 24, 2010**

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MILESTONE REPORT

EXECUTIVE SUMMARY

The purpose of this project is to assess the universal applicability of harmonic signatures and/or synchrophasors as a means for detecting unintentional islanding of distributed generation equipment such as photovoltaics. This report covers the time period March 16, 2010 to June 01, 2010, and describes our progress on Milestone 5. Milestone 5 has been completed, and substantial progress has been made on Milestones 6 and 7. Substantial accomplishments in this reporting period include:

- Completion of the acquisition of a set of feeder data.
- Completion of definition of test cases.

Project funding is provided by customers of Xcel Energy through a grant from the Renewable Development Fund.

TECHNICAL PROGRESS

Milestone #5 consisted of: completion of acquisition of feeder data and test cases.

In selecting feeders, we desired to find examples that spanned, to the extent possible, the range of feeder conditions expected in the field. This undertaking must be interpreted within the context that there really is no such thing as a "typical" distribution feeder; feeders are as widely varied as the loads they serve and the territory they cross. However, as described in earlier reports, we sought cases that covered a range of cases like that seen in Table 1.

Table 1. Matrix of test cases.

System impedance (Z)→ System inertia (J)↓	**High Z**	**Medium Z**	**Low Z**
High J	HJ, HZ	HJ, MZ	HJ, LZ
Medium J	MJ, HZ	MJ, MZ	MJ, LZ
Low	LJ, HZ	LJ, MZ	LJ, LZ

In general system simulations, we can manipulate the system inertia, but in the field there is no practical way to do this. Thus, we have adopted a three-pronged approach that uses: generalized feeders in which all parameters can be manipulated; real-world feeders, with data provided by Xcel; and simulations using IEEE test distribution feeders, which are in some ways a cross between the first two approaches.

For the IEEE distribution feeders, we selected the 34-bus model. Details of this feeder model are available at http://ewh.ieee.org/soc/pes/dsacom/testfeeders/index.html.

For the real-world feeders, working with Xcel distribution engineers, we chose three feeders that represent "strong", "average", and "weak" parts of the system, as characterized by the system impedance or equivalently the short-circuit current capacity. Because the feeder data are classified as Critical Energy Infrastructure Information (CEII), the names and locations of those feeders are not disclosed here, but suffice it for present purposes to state that these are actual feeders on Xcel's system. Xcel's distribution engineer provided NPPT with data from these three feeders using the SynerGee software package, which produces a database that can in essence be read like a circuit netlist. Xcel's distribution engineers provided these database files under three loading conditions (minimum, maximum, and mean), and also provided a load-flow solution for use in validating the models.

The feeder databases are relatively large; they range in size from 143 to 370 load buses, and the smallest one has nearly 400 total nodes.

To produce the EMTP-RV models we need for simulation, the SynerGee database must be translated into something EMTP-RV can read. This, unfortunately, is an extremely tedious and time-consuming task. Project partners NPPT and Enernex have adopted a set of parallel approaches. Enernex has been working on automating the data conversion process. This multi-step approach that uses proprietary Excel spreadsheets and MATLAB code has had good, but not complete, success. To help with error checking and quality control of the automated process, NPPT has used the SynerGee database to draw out an electrical (not geographical) feeder map, which we then entered into EMTP-RV. Line impedances were calculated using in-house MATLAB software that uses Carson's equations.

As a final remark, NPPT and Enernex wish to acknowledge the responsiveness and professionalism of Xcel's distribution engineers. Their efforts and assistance in selecting feeders and securing feeder data will allow this study to have a much higher degree of real-world applicability than would be the case otherwise.

The IEEE 34-bus feeder model in EMTP-RV has been completed; in fact, an early version of it containing thirteen three-phase PV systems was shown in Milestone Report #3 as Figure 12. That figure is repeated here as Figure 1 for convenience. We have also entered the first of the three Xcel feeder models (the "strong" feeder) and have checked it successfully against the power flow solution from Xcel; reporting on this and the other two Xcel feeder models will be the subject of Milestone Report #6.

PROJECT STATUS

We are making excellent progress. We continue to lag slightly behind schedule; Milestone Reports #5 and #6 were both due by June 1, and Report #6 will likely be at least two weeks out yet because we underestimated the difficulty in translating the feeder models from available data into EMTP-RV models. However, although we are beginning to sound like a broken record, we believe we will catch up because of progress already made on future milestones. We already have made significant progress on Milestones 7, 8, and 11. Working with the IEEE feeder model, we have produced some exciting preliminary results using synchrophasors, and through our SEGIS partnership (with which this Xcel project has a cost sharing relationship), we have some preliminary simulation and field results that will feed into Milestones 9 and 10. Thus, we have a strong basis to continue to assert that we will bring the project back onto schedule by Milestone Report #7.

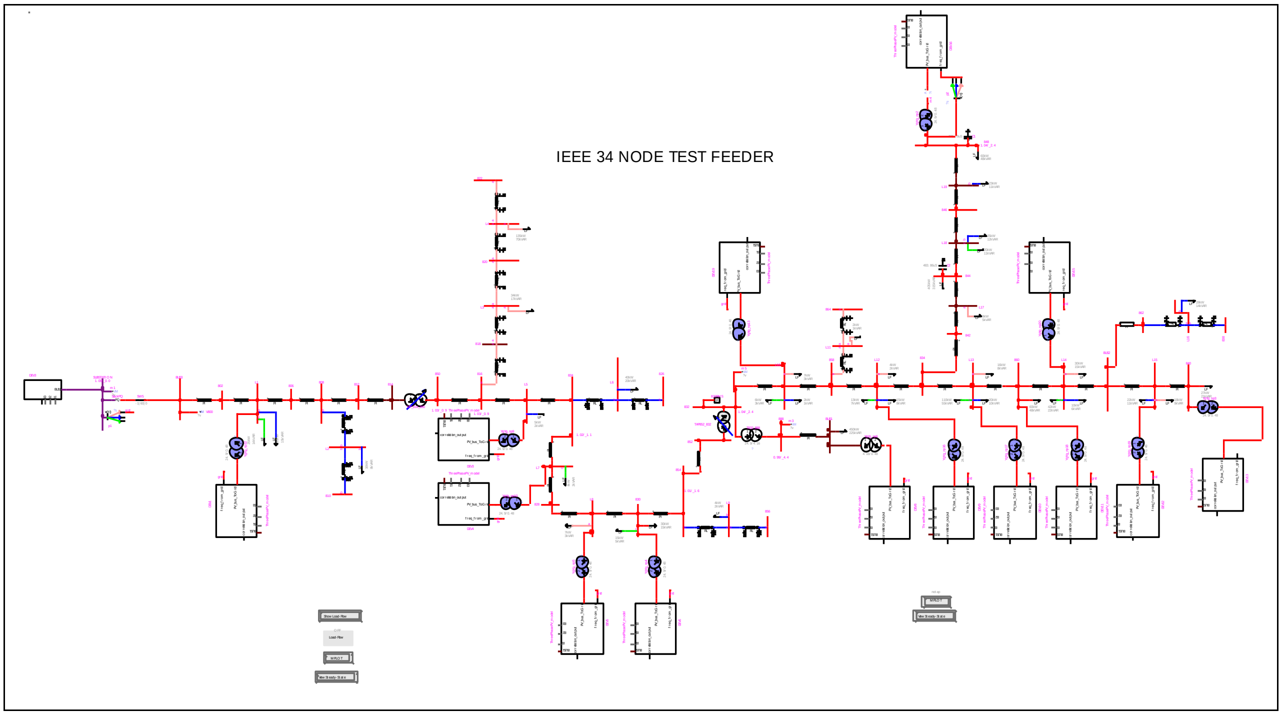

Figure 1. IEEE 34-bus distribution feeder with 13 PV systems added.

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