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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: 6** **REPORT DATE: AUGUST 30, 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 June 01, 2010 to August 27, 2010, and describes our progress on Milestone 6. Milestone 6 has been substantially completed. Accomplishments in this reporting period include:

- Completion and validation of the feeder models.
- Holding of our third on-site coordination meeting.

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

TECHNICAL PROGRESS

Milestone #6 consisted of: completion and validation of the feeder models, and holding of our third face-to-face coordination meeting with partner Enernex.

Completion and validation of feeder models

The reader may recall that three feeders were selected from across Xcel's system to represent "strong", "weak", and "median" feeders, with these terms being defined by the relative impedance of the feeder. Working with Xcel distribution engineers, data from Xcel's Synergee database for the three feeders were extracted and submitted to NPPT and Enernex. Using these data, EMTP-RV models of all three feeders were constructed. These models were validated by comparing load-flow data from Synergee against load-flow results from EMTP-RV. Slight differences are expected because of subtle differences in the way the two modeling programs represent system elements, and in how the solution is obtained. Nevertheless, these differences should amount to less than 1% error in any node voltage.

Screen shots of the three models are shown here as Figures 1, 2 and 3. These figures are included to give the reader an idea of the structure of the models and the scale of the process of creating them; a figure large enough to show any significant detail would not fit into this report.

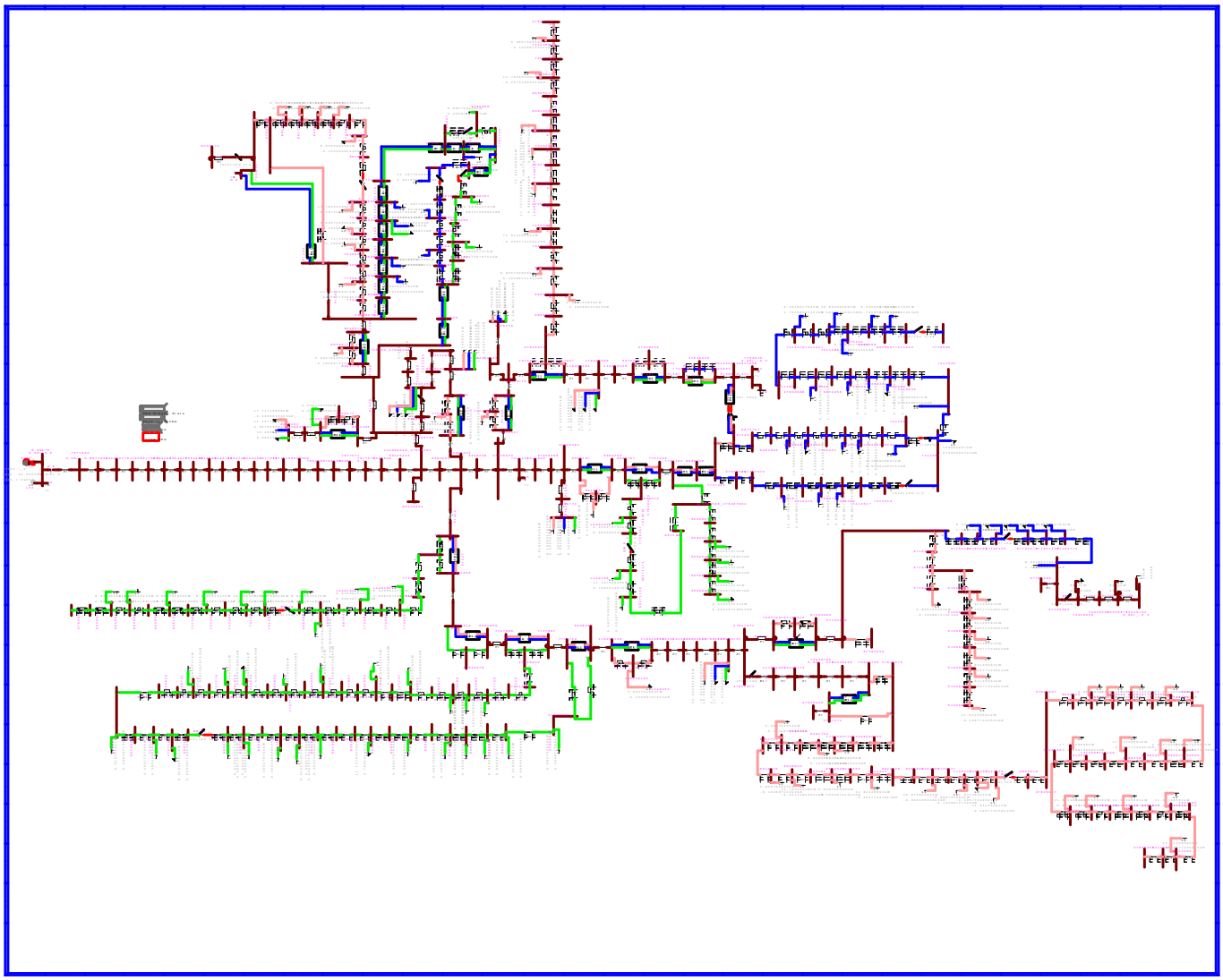

Figure 1. EMTP-RV model of "strong" feeder. This model contains just over 130 nodes.

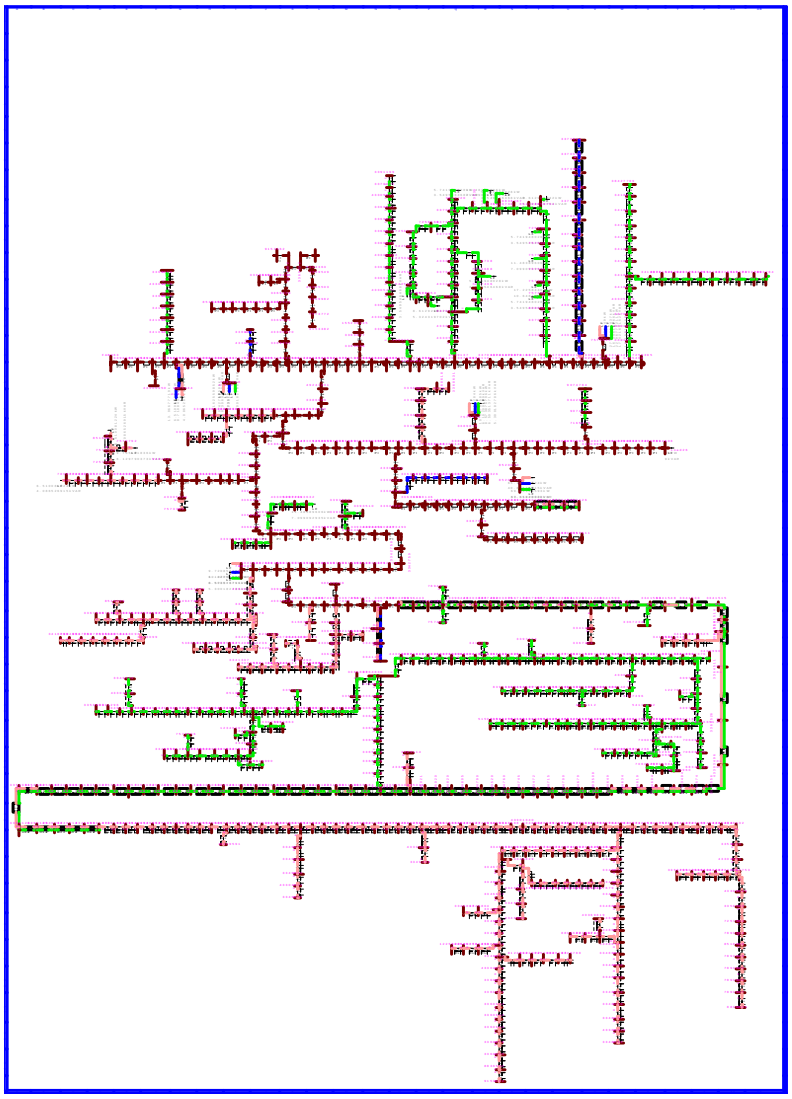

Figure 2. EMTP-RV model of "weak" feeder. This model contains more than 500 nodes.

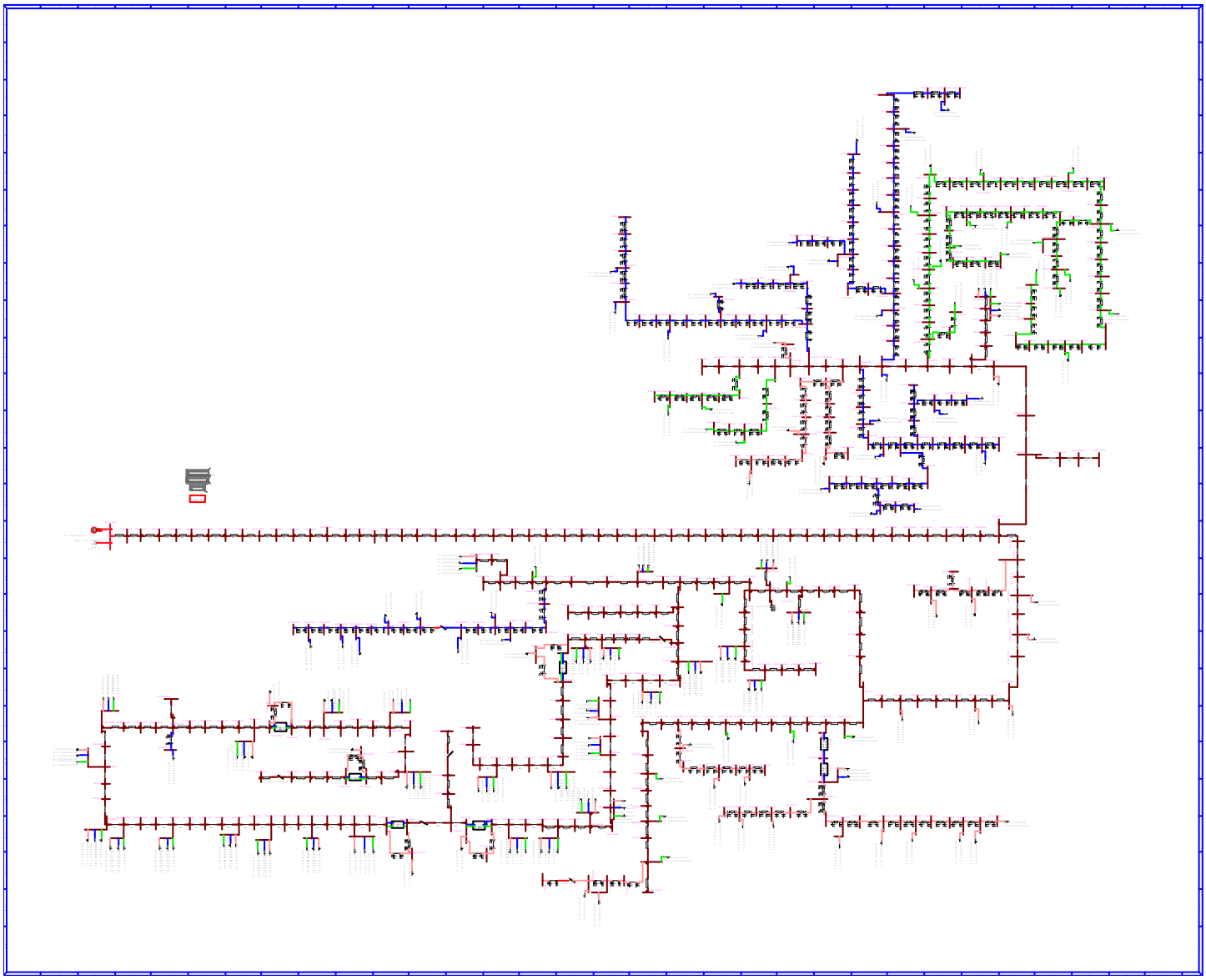

Figure 3. Model of "median" feeder. This model contains roughly 130 nodes.

Tables 1, 2 and 3 give representative results from the comparison of load flow data between the two models for each feeder. For the strong feeder (Table 1), the agreement between the two models is very good. The agreement is acceptable for the median feeder (Table 3), although further investigation is warranted as to why the EMTP results seem to be biased high. For the weak feeder (Table 2), there is a small subset of nodes for which the voltages predicted by the two models deviates sufficiently to indicate a potential problem. This subset is shown in red in Table 2. The reason for the disagreement is being investigated. So far in the feeder model production process, this iterative validation procedure has allowed for the correction of several errors and minor problems in both the EMPT and Synergee models.

As a further quality check, project partner Enernex has worked out an automated process for generating EMTP feeder models from the Synergee data. The automation is obviously highly desirable because it saves a ***large*** amount of manual labor, but it also has a disadvantage in that it produces a form of the model in which it is very difficult to see relationships between components. This in turn impedes understanding of model results, and it also makes it difficult to properly design and implement test cases. The two models will likely be used in conjunction, especially for data entry validation.

Table 1. Comparison of load flow results between Synergee and EMTP; "strong" feeder case.

Section Id -	Volts - A, B, C -Xcel	Volts V Xcel	Volts V Emtp	% Error
8048474	122.58	11025.7501	11044.0412	0.165894
7724890	122.1	10982.56741	11007.7085	0.228918
8049290	122.23	10994.26057	11015.4432	0.19267
7412465	122.12	10984.36636	10998.3046	0.126892
7412261	122.06	10978.96952	11004.35	0.231174
7725052	122.44	11013.1495	11033.1679	0.181768
43769220	122.12	10984.36636	10998.08	0.124847
7410877	122.68	11034.73686	11036.7613	0.018346
7724730	122.55	11023.04371	11041.5007	0.16744
7725068	122.43	11012.25003	11031.7865	0.177407
7725246	122.05	10978.07005	11003.08799	0.22789
8048674	122.2	10991.56215	11012.9004	0.194133
9618027	122.14	10986.16531	11006.0624	0.18111
73328942	122.68	11034.73686	11006.996	-0.2514
73329306	122.66	11032.93791	11006.21602	-0.2422
7725230	122.09	10981.66794	11004.9995	0.212459
8048198	122.54	11022.14423	11040.7806	0.169081
8050897	122.67	11033.83739	11036.30985	0.022408
8361752	122.09	10981.66794	11004.6703	0.209461
8363770	122.14	10986.16531	11006.601	0.186013
8675298	122.42	11011.35056	11031.185	0.180127
67195082	122.65	11032.03844	11037.61	0.050503
8048182	122.66	11032.93791	11034.5035	0.01419
8050813	122.42	11011.35056	11031.1853	0.18013

Table 2. Comparison of load flow results between Synergee and EMTP; "weak" feeder case.

Section Id -	Volts - A, B, C -Xcel	Volts V Xcel	Volts V Emtp	% Error
7575041	124.82	11250.5119	11191.64	0.523281969
3369193	124.56	11227.07709	11181.18	0.408807109
3369404	124.39	11211.75433	11155.85	0.498622487
3386555	124.31	11204.54362	11150.13	0.485638855
43305411	124.57	11227.97843	11182.55	0.404600244
7573749	124.4	11212.65567	11155.68	0.508137134
147198492	124.33	11206.3463	11150.88	0.494954319
3369100	124.29	11202.74094	11146.5	0.502028386
3369261	124.55	11226.17575	11180.46	0.40722461
3369616	124.37	11209.95165	11340.57	1.165199936
3370370	124.18	11192.82621	11193.61	0.007002594
3386640	124.28	11201.8396	11146.75	0.491790658
3390916	124.24	11198.23425	11101.81	0.861066513
3390979	124.36	11209.05031	11325.74	1.041030998
3369817	124.22	11196.43157	11314.1	1.050945848
51635487	124.31	11204.54362	11147.06	0.513038453
7258764	124.03	11179.30613	11167.08	0.109363931
7575213	124.21	11195.53023	11197.53	0.017862231
3369914	123.83	11161.27935	11118.52	0.383104389
7257402	123.79	11157.674	11115.2	0.380670698
43310201	122.66	11055.8227	11058.26	0.022045378
153304931	121.56	10956.67543	11038.69	0.748535222
7258700	122.51	11042.30262	11044.9	0.023522097
8837757	122.46	11037.79592	11041.1	0.029934196
63306638	123.76	11154.96998	11025	1.165130692
43303612	120.02	10817.86924	10895.77	0.720111886
3357509	116.78	10525.83544	10883.99	3.402623586
3349857	116.73	10521.32875	10880.12	3.410132526
51455415	115.53	10413.16808	10765.23	3.380929959
3397111	115.98	10453.72833	10810.56	3.413439287
51455688	115.44	10405.05603	10758.66	3.398386018
3348963	117.76	10614.16665	10721.87	1.014713191
102476777	117.15	10559.18498	10529.04	0.285485852
122540821	117.05	10550.17159	10476.89	0.694600934
3346785	117.04	10549.27025	10471.41	0.738062915

Table 3. Comparison of load flow results between Synergee and EMTP; "median" feeder case.

Section Id -	Volts - A, B, C -Xcel	Volts V Xcel	Volts V Emtp	% Error
4739933	119.62	10957.12976	11120.9	1.49464545
7476892	119.59	10954.38177	11115.98	1.47519257
4740003	119.56	10951.63379	11113.04	1.47380942
4735555	119.57	10952.54978	11114.66	1.48011393
58055545	119.23	10921.40596	11052.93	1.20427753
4746499	119.36	10933.31389	11094.66	1.4757292
8296952	119.16	10914.994	11046.41	1.20399518
4740133	119.34	10931.4819	11087.46	1.42687055
4739861	119.27	10925.06994	11056.42	1.20228117
9237322	118.95	10895.75811	11056.62	1.47637173
4739731	119.11	10910.41402	11064.9	1.41594971
4746065	119.02	10902.17007	11063.34	1.47832888
7979755	119	10900.33808	11062.07	1.48373305
7981213	118.77	10879.2702	11020.64	1.29944193
106697558	118.51	10855.45434	11014.65	1.46650392
57702850	118.38	10843.5464	11005.74	1.49576153
7656769	118.4	10845.37839	11009.84	1.5164211
9068191	118.44	10849.04237	11009.86	1.48232094
8601588	118.43	10848.12638	11008.97	1.48268573
9093279	117.95	10804.15863	10976.22	1.59254763
7978493	118.37	10842.63041	11007.84	1.52370398
44091798	117.93	10802.32664	10973.19	1.58172742
7488536	118.37	10842.63041	11007.69	1.52232055
7981249	117.91	10800.49465	10970.65	1.57544036

Third face-to-face coordination meeting

The project partners held our third face-to-face coordination meeting at Enernex' headquarters in Knoxville on May 28, 2010. The meeting was relatively brief, and consisted primarily of updates on the status of feeder model development and next steps. Enernex personnel detailed the automation process under development, showing progress and status and walking NPPT personnel through the steps in the procedure. Data needs were also discussed. The team's next two face-to-face meetings will be on or about December 1, 2010, in Knoxville, and on or about June 1, 2011, in Brookings.

PROJECT STATUS

Unfortunately, this report is approximately three months late; fortunately, we have already made significant progress on Milestone #7, and we hope to be able to submit that report within two to three weeks. We further anticipate submitting report #8 on schedule.

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