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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: 2** **REPORT DATE: SEPTEMBER 29, 2009**

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MILESTONE REPORT

EXECUTIVE SUMMARY

The purpose of this project is to assess the universal applicability of harmonic signatures as a means for detecting unintentional islanding of distributed generation equipment such as photovoltaics. This report covers the time period August 10, 2009, and September 29, 2009, and describes our progress on Milestones 2 and 3. Milestone 2 has been completed, and substantial progress has been made on Milestone 3.

TECHNICAL PROGRESS

Milestone #2 consisted of selecting and acquiring the software to be used in the project, and finalization of the system configuration to be simulated.

Selection and acquisition of software

We are using two software packages on this project. The primary tool will be EMTP-RV, selected because of its suitability for the type of modeling we will be performing, low cost, and the team's familiarity with it. Both NPPT and partner Enernex now have the needed numbers of EMTP-RV licenses in-house.

The other software package that will be used is MATLAB/Simulink, and the SimPowerSystems blockset that is part of Simulink.

Finalize selection of system to be modeled

We have chosen to move forward with a system like that shown in Figure 1 on the following page. This system will use a "synthetic source" in which the system's impedance and its dynamic characteristics (particularly its variation in frequency) are both realistically simulated. The diamond-shaped source is a controllable voltage source, and by feeding the correct frequency trajectory (discussed in more detail below) into a variable-frequency sine-wave generator and adding the correct Thevenin-equivalent impedance Z_{sys}, the grid as seen from any endpoint can be modeled simply, but with sufficient realism for this project. The simplicity of the system is advantageous not only for the obvious reasons, but also because it minimizes computational burden on the modeling computers, thus enabling the team to perform more simulation runs in less time.

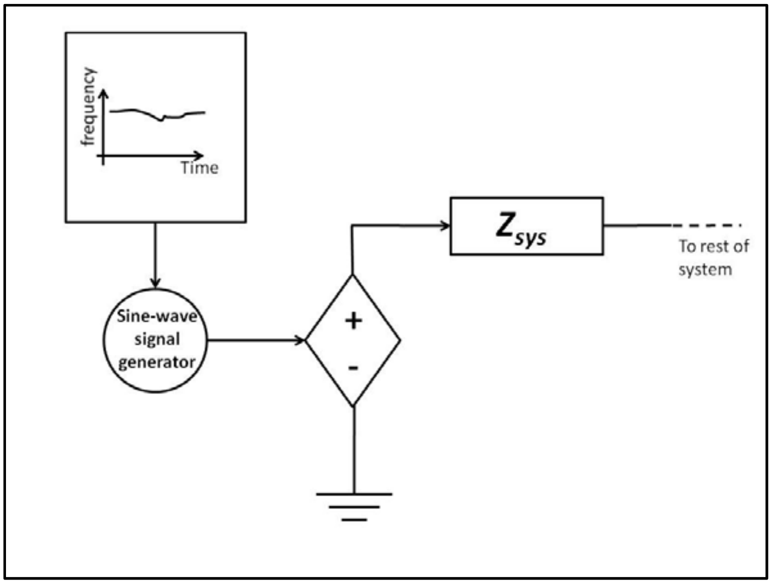

Figure 1. Schematic diagram of synthetic source to be used in the modeling work on this project.

As was noted in our previous Milestone Report, in both the harmonic and synchrophasor cases we intend to use the matrix of systems shown in Table 1.

Table 1. Matrix of systems to be simulated.

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

We will check each case in the matrix, and examine the effectiveness of both methods during transitions between elements of the matrix, to determine that no false trips occur during either steady-state or dynamic conditions. Then, for each system in the matrix, we will examine the appropriate system parameters as the system transitions from grid-tied to islanded mode and seek signatures that work in all cases, but do not produce false trips.

Additional Milestones

Creation of the synthetic source

This is not specifically a milestone item, but from the foregoing discussion it may be clear to the reader that our team will need to create in our modeling tools an electrical source that has a programmable frequency, and the correct Thevenin-equivalent impedance. The key lies in developing the signal source that creates the correct signal to drive the controllable voltage source.

As a bit of background, early attempts at producing a variable-frequency system used "real" power system models that included the generator models available in EMTP-RV and a simple power system model used to set the impedance. At first glance, this type of model seems more attractive than the simplified one in Figure 1 because it seems more "real". However, it actually ends up being less realistic because of the fact that frequency control is done by manipulating the generator inertias and governor parameters, and relating these directly to the system frequency trajectory is not straightforward. Thus, one usually ends up with an unrealistic frequency trajectory. Setting Z_{sys} is similarly difficult.

Thus, we have adopted the approach in Figure 1. All of the blocks needed to implement this model are available in EMTP-RV except one: the frequency-controlled sine-wave generator. To create that block, we are working on two parallel procedures. One involves coding an entirely new block in C, which is something of a "brute force" approach and is considered a fallback at this point. The other adapts a procedure borrowed from a common method for modeling phase-locked loops. The desired frequency trajectory will be entered as a lookup table or function. This function will be integrated over time, and then we will take the modulo of the integration result with $2 \times \pi$ ("modulo" is basically a division, but then we keep only the remainder; the integer part of the division is not used). The result will be a sawtooth wave with a frequency directly controlled by the frequency trajectory function, with amplitude between zero and 2π. We can then take the sine of this sawtooth wave and obtain our desired frequency-controlled sine wave. The series impedance can then be added easily.

To obtain realistic values for the frequency trajectory and Z_{sys}, we have been given a technical point of contact within Xcel and have begun with him a conversation regarding what parameter values we need and how to obtain them.

<u>Complete development of models for wind turbines and PV (Milestone #3)</u>

We noted in Milestone Report #1 that considerable progress was made on this deliverable. The photovoltaic (PV) model as presently implemented in both EMTP-RV and MATLAB/Simulink includes several traditional anti-islanding methods, to serve as baselines and also for inclusion in the study (because the methods being studied here will need to work in the presence of legacy anti-islanding methods as well), a realistic maximum power point tracker, a PV array model, and an averaged model of the power stage. These components have been tested and are working well. At this time, we have both single- and three-phase PV models that include all of the components needed to do the synchrophasor modeling. We have not yet begun work on the needed components to perform the harmonic modeling, but our current concept, that of using "subharmonics" (really, low-frequency transients), will use many of the same signal processing and mathematics blocks as the synchrophasor work.

Enernex has begun development of the wind turbine model. We have opted to model primarily smaller turbines for this work, because these are the most likely to be deployed in a distributed mode in which generalized loss-of-mains detection like that being studied here is needed. For large "utility scale" turbines (1 MW and larger), in most cases deployment will include dedicated protection systems that tie in to existing utility SCADA and other communications systems, so that this type of islanding detection is not needed. Enernex is leveraging its considerable experience in this area to create a realistic model of appropriate turbines in EMTP-RV.

<u>Complete acquisition of all feeder data and test cases (Milestone #5)</u>

We have begun the process of collecting the information we will need to be able to create the synthetic source. As noted above, we now have a technical point of contact within Xcel that is assisting us in obtaining reasonable frequency trajectory and impedance values for the synthetic source. We hope to obtain values from other utility systems as well, as time and availability permit.

<u>Begin testing and evaluation of synchrophasor and harmonic models (Milestone #7)</u>

We have begun early testing and validation of our models, as well as early evaluation of the synchrophasor method of loss-of-mains detection. Although it is too early to include results in this report, we are highly encouraged by what we are seeing thus far.

<u>PROJECT STATUS</u>

This report is approximately two months behind its scheduled date of August 1. However, we remain optimistic because of the progress we have made in future Milestone items, and we believe we can bring the project back onto schedule by the next report, which is due in November. Monetary spending has so far progressed as planned in the Budget.

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