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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: 9** **REPORT DATE: NOVEMBER 02, 2011**

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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 December 22, 2010 to October 31, 2011, and describes our progress on Milestone 9. Milestone 9 has been completed. Accomplishments in this reporting period include:

- Continued testing of the synchrophasor-based approaches. As part of the SEGIS project (not funded by RDF), a synchrophasor based method invented by NPPT was field- and laboratory-tested and performed very well.
- Performed extensive work on a little-explored family of passive, non-communications-based island detection methods. A set of methods was developed that exhibits high promise, but still has drawbacks relative to communications-based methods.
- Continued to participate in the IEEE 1547.8 development process.

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

TECHNICAL PROGRESS

Milestone #9 consisted of:

- Complete detailed report on synchrophasor-based and harmonic-based methods.
- Submit summary report on conclusions drawn regarding the feasibility of the two methods.

To understand the importance of this work and how the project got to where it is now, it is instructive to first consider how island detection is handled today. The industry standard approach by which distributed energy resources (DERs) detect islands today is through the use of positive feedback to destabilize an island, sometimes combined with a deliberately-added output perturbation. When an island is formed, the positive feedback and perturbation make it impossible for the island to hold a steady voltage and/or frequency (usually frequency is the target), and the island eventually reaches a frequency trip limit and shuts down. While generally effective in detecting and preventing unintentional islands, studies have shown (and it is intuitive) that this type of anti-islanding, when deployed on high penetrations of DERs, would have detrimental impacts on the operation and transient response of the larger system, although these impacts appear to be relatively minor. However, the real problem with today's active anti-islanding is that it conflicts with grid support functions: active anti-islanding relies on exacerbating abnormal voltages, whereas grid support functions work to mitigate abnormal voltages. As penetration levels of PV and other DERs rise, grid support functions become necessary, which in turn requires a new island detection approach.

The purpose of this Xcel RDF project is to work toward candidate alternative methods. The project originally focused on passive methods that relied on detection of harmonic patterns, to determine whether these could be feasible replacements for active anti-islanding. Later, a second approach was added, namely the synchrophasor-based approach. These two methods fall into two different categories of island detection method: synchrophasor-based approaches belong to the family of communications-based methods, while the harmonic-based methods are categorized as passive island detection.

During the course of the RDF project, it became clear that communications-based methods, including synchrophasors and power line carrier communications (PLCC), are probably the island detection methods of the future, because they have the potential to essentially eliminate concerns regarding islanding, for any combination of distributed energy resources (DERs) at any penetration level, while enabling DERs to provide grid support functions.

Synchrophasor-based island detection is proving highly effective. Our first paper on the subject, on the WAN method in particular, has already been published [1], and multiple additional publications are in the works at this time.

At the same time as the effectiveness of synchrophasor-based approaches began to become clear, it became similarly clear that passive approaches have one fundamental weakness: they necessarily involve a tradeoff between island detection effectiveness and false-trip immunity. Borrowing terminology that is more common across fields, for passive island detection it is difficult to obtain both *selectivity* and *sensitivity* simultaneously. One critical ramification of this problem is that it seems nearly impossible to conceive of a passive island detection method that will reliably pass the IEEE 1547 anti-islanding test in a laboratory, meaning that passive methods acting alone could probably not be UL-1741 listed because 1741 uses the same anti-islanding test. Figure 1 shows the configuration used for conducting this test. The PV system (or DER) under test is at the left, and the grid, or a grid simulator, is at the right, supplying real power P_{grid}

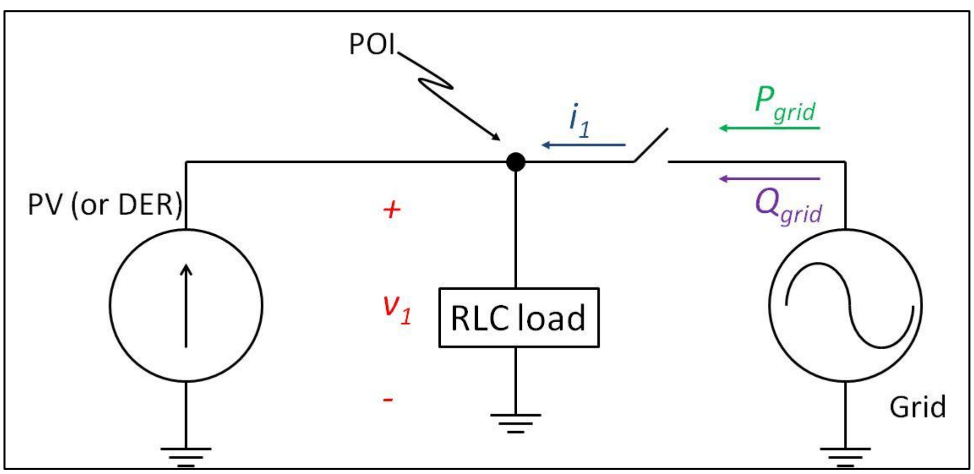

Figure 1. Simplified schematic of the IEEE 1547 anti-islanding test.

and reactive power Q_{grid}. The resistive (R) part of the RLC load is adjusted until P_{grid} becomes zero, and then the reactive (L and C) components of the RLC load are adjusted so that Q_{grid} goes to zero, while maintaining the load's resonant frequency at 60 Hz. At this point, the current i_1 is also zero, and the generation and load within the island are in perfect balance. When the switch in Figure 1 is opened, it is not interrupting any current, and the island goes into a self-excitation mode in which the voltage v_1 very closely resembles the grid voltage. It is not difficult to see that under controlled laboratory conditions it is possible to match the local generation and load so closely that there is no change at all in v_1 when the switch opens, and thus there is nothing for a passive method to detect. Whatever parameter of the terminal voltage one may choose to monitor, it will be possible to match the generation sufficiently closely to the load that no detection criterion would work.

The NPPT team was about to abandon the original passive approach when a new situation came to light that changed our minds. We still believe that communications-based methods will be the first line of defense, and it appears that interest in broadband approaches like the synchrophasor-based approach is very high because of the potential value that can be added by the synchrophasors. However, communications-based methods have their own key weakness: they require a fallback method to which the inverters switch when communications are lost. This is not true for PLCC, in which loss of carrier signal is actually the island detection signal (and thus communications reliability is absolutely critical for PLCC), but for other candidate methods, communications reliability is a major barrier to acceptance. An instinctive approach would be to simply have the generation disconnect upon loss of communications, just as with PLCC, but utilities do not want large portions of their generation dropping offline any time there is a communications "glitch". Therefore, for these methods, some fallback method is needed that preserves as much islanding detection effectiveness as possible when communications are down. Positive feedback-based active anti-islanding might seem like a good candidate, until one recalls that the reason this method is being phased out is to enable grid support functions and to remove DER penetration limits. Clearly, utilities do not want to lose their grid support upon loss of communications; this could be as detrimental as, or even more detrimental than, a loss of generation in many cases.

Passive anti-islanding will be needed to fill this role. Passive anti-islanding preserves grid support functionality and enables generation to stay online during communications outages, but as discussed above, it will involve some loss of island detection effectiveness (the sensitivity vs. selectivity tradeoff). A lengthy discussion and educational process is likely needed to ensure that the needs of both utilities and DER owner/operators are met in the most optimal way.

It was in this environment that NPPT began earnest work on a type of passive anti-islanding that has received little attention, namely statistically-based analyses of the voltage at the point of interconnection. As has been reported previously, NPPT has been working for the past several months on what appears to be a particularly promising statistically-based passive method, both in terms of its island detection effectiveness and its ease of implementation. It is our intention to pursue publication of this method at the IEEE Power and Energy Society General Meeting in the summer of 2012, at which time details of the method will become publicly available.

NEXT STEPS

Our primary next steps to get to Milestone #10 involve the submission of two completed manuscripts, one on synchrophasor-based island detection and the other on passive methods, for publication and presentation at the IEEE Power and Energy Society General Meeting in July of 2012. The submission deadline is November 30, so we hope to have both manuscripts completed by then.

PROJECT STATUS

Although we have fallen far behind in our milestones, we believe we will be within one month of being on schedule by the end of this year. The reason is that, as evidenced by our progress on the two above-mentioned manuscripts, we are far along on Milestone #10, and our recent activity on the IEEE 1547.8 and IEEE 2030 committees has enabled us to nearly complete Milestone #11.

REFERENCES

[1] M. Mills-Price, M. Scharf, S. Hummel, M. Ropp, D. Joshi, G. Zweigle, K. G. Ravikumar, B. Flerchinger, "Solar Generation Control with Time-Synchronized Phasors", IEEE Western Protective Relaying Conference (IEEE WPRC), October 2010, 8 pgs.