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CERTS MICROGRID LABORATORY TEST BED

CERTS Test Bed Design and Commissioning Lessons Learned Summary

APPENDIX H

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CERTS
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This document is intended to summarize some of the most important issues that were found during the design stage of the Testbed as well as during commissioning at the AEP site. The document includes a range of issues that go from safety, control, protection and data acquisition; the correspondent solutions implemented are also described. Safety Review recommendations were obtained via outside safety review of the design by Jim Daley, P.E., DGCP

1. **Zone Breakers:**

Initially, Molded-Case circuit breakers (ABB Isomax) were selected based on the CERTS Testbed criteria. However, due to the multiple fault testing that is expected for this project, these breakers were replaced in the design with Insulated-Case breakers (ABB Emax). Molded-Case breakers are not adequate for the following reasons:

a. They are not built to withstand repeated fault currents. Expected life would be 2 or 3 faults and they would have to be replaced. The molded-case design is not conducive to inspection and maintenance between test runs. Subsequent failures could be explosive and could damage other equipment.

b. Nuisance trips can be expected at ~10 times the continuous current rating due to the magnetic release mechanism in spite of the rapid static switch opening. This may interfere with testing the intended protection scheme. For example, in the current CERTS Tesbed design Strong Grid Case, the fault current in Zone 2 (just downstream of the Static Switch) was calculated to be ~8000A sym. Zone Breaker CB31 would require a continuous rating larger than 800A. ABB Isomax S7 would have meet that requirement (In=1200A; S6 would have been borderline In=800A); however, the CT ratings and microprocessor unit available in S7 would only allow for a minimum overload setting of 400A, which is much larger than the rated load in Zone 3 (~225A) so proper time-overcurrent protection wouldn't be possible. For CERTS Testbed testing this issue could be avoided by using the external protection CTs and SEL-351 Relays available at each zone, but for a commercial design or the next phase of CERTS testing (where these relays and CTs will not be present) careful evaluation of the rated load and fault currents of each zone breaker would be required to verify is Molded-Case breakers are appropriate.

Insulated-Case breakers were recommended for the following reasons:

a. They can handle much higher fault currents without damage

b. They can be more easily inspected and rebuilt.

c. They can stand much higher short time (6 to 18 cycles) currents without tripping, allowing the static switch time to act.

Other recommendations that were provided in the Safety Review include:

2. Other Safety Review Issues:

Fault contactors (K22, K32, K42, K52, K62): should be insulated-case circuit breakers with latching spring driven actuators. A common contactor may not be able to stay closed under fault currents due to high magnetic fields. This recommendation has been implemented in the CERTS Testbed.

Cable trays are preferred over conduit. The insulation on cable in conduit may be worn and may fail due to conductor whip under fault conditions and resulting magnetic forces. Conductors should be tied down on every rung of the cable trays. On the longer power cables, outbound conductor runs should be separated from returns to mitigate magnetic forces at fault current levels. Phase and neutral conductors should be tightly bundled.

AEP reviewed this safety comment and decided that significant forces are not expected, so in the present CERTS Testbed, conduit was used.

Power conductor termination lugs should be crimp type and not mechanical type. This recommendation has been implemented in the CERTS Testbed.

3. Energy Manager System

AEP made several recommendations that were implemented to the Energy Manager System (EMS) program that includes the following:

a. In the System Overview Display, status (Open/Closed) of all zone breakers was added to the already present information (Static Switch Status, power flows, etc).

b. Remote Operation of Breaker CB12 was added to the Energy Manager System; this breaker is used to backup the rest of the system and also its disconnection provides a testing condition for reverse power alarms. This option was added to avoid the operator from having to open CB12 locally.

c. Emergency Stop was added to the EMS. Every tab (window) in the EMS includes and E-Stop button that remotely shuts down every microsource and also opens CB12 to disconnect the microgrid from the utility.

4. Load Control Software and Zone/Fault Loads

a. The Load Control Labview Software initialization was modified so that upon initialization (Powering up computer/ Starting Program) all initial settings that are displayed in the screen are uploaded from the PLCs or DSP boards (this fix was also implemented in the EMS software). Before this correction, if the computers were restarted, the programs will be showing initial values that may not match the current controls, thus providing a confusing picture to the operator.

b. Remote Operation of Breaker CB12 was added to the Energy Manager System; this breaker is used to backup the rest of the system and also its disconnection provides a testing condition for reverse power alarms. This option was added to avoid the operator from having to open CB12 locally.

c. AEP recommended that an Emergency Stop be added to the EMS. Presently, every tab (window) in the EMS includes and E-Stop button that remotely shuts down every microsource and also opens CB12 to disconnect the microgrid from the utility.

d. A Load Bank as originally designed had temperature issues when running at full load. Post-Glover recommended the addition of ventilation on top of the load bank to improve the airflow.

5. Data Acquisition System:

a. PML ION 7650 Meters are used as the data acquisition equipment at every important location of the Testbed (Zones, Loads, Static Switch). These meters have fast sampling (up to 3 cycles 1024 samples/cycle; 96 cycles at 16 samples/cycles). It also includes a 1cycle-RMS calculation for the variables that are required to be monitored in CERTS (Real Power, Reactive Power, Voltage, Current, Frequency). Initially during commissioning, several data collection tests were performed with waveform resolution of 128 samples/cycle and 10-second duration RMS calculations at 1cycle sampling. The waveform collection was optimum; however, the RMS collection had issues because the ION 7650 does not include a pre-trigger option for this type of calculation (which the waveform collection does). This is an important requirement since it is useful to know the initial state of the system before step loads or switch transitions occur in order to understand the response of the inverter-gensets. Several solutions were attempted, such as implementing pre-triggering signals directly from the EMS-DAS Labview programs, however, this provided mismatching between the starting times of the waveform and RMS data, which added confusion in interpreting the data. Also, with this strategy, a Software “Manual Trigger” from the operator would have been required, thus adding further complication to the system.

b. To eliminate this problem, the approach taken was to use the meters only as a front-end data acquisition system (waveform data collection) and allow external software to download the data and process it and perform the RMS calculation. By taking this approach, any pre-triggering mismatches are eliminated (every meter gets the same trigger signal, and each meter has a #cycles pre-trigger setting). PQView, software developed by Electrotek Concepts, will be used as the processing tool and also as a Database Management System to share data in the internet (PQWeb). Setup of PQ View is currently under way.

6. Protection:

a. In the original design, neutral point the Y-side of every microsource transformer was connected to a ground-conductor that will run from the neutral point of the microgrid main transformer (T11) through the length of all feeders. However, due to a safety recommendation from AEP, the microsource transformers Y-side neutral is now tied to a neutral conductor that runs back to the neutral point of T11, where it is solidly grounded. These change affected the original intent of the differential current (CT around phase and neutral conductors) scheme; now, this scheme will only detect ground faults that are downstream of the microsource (rather than independent on location). Professor Lasseter investigated and provided recommendations to implement additional zero-sequence and negative sequence current elements to the protection scheme. The addition of these elements is possible due to the flexibility provided by the SEL-351 Relays.

7. S&C Power Electronic Switch (PES)

During Low-Power Testing of the Static Switch (at NPS Lab), some issues were found with nuisance alarms from the S&C PES (power electronic switch) local controls:

a. When the Switch was commanded to Open, with a source only on the “Input” (Grid) side, the system will “Stop”, opening the input CB. The reasoning behind was that control power is usually taken from the "Output" (DG) side, thus when the switch opens, control power is lost temporarily, which sent the system "Stop". This issue was verified by performing a similar test but with the source connected to the "output" side, so control power was always available; during this test, the problem disappear. Roger Troyer from S&C visited the AEP Dolan Lab and performed modifications to the control power circuit of the S&C to eliminate this problem.

b. The PES also includes a "Fail to Open" Alarm, which will Stop the system (open the input breaker) in the switch if the switch is still closed (measured >15Vpk across any phase of the SCR switch) after 2-cycles of being commanded open. This issue was found sporadically during low power testing at NPS, and was replicated during the first visit of Roger Troyer to the AEP site. This issue occurs because this method of detection is not design to account for having sources of approximately the same frequency on both sides of the switch (if this is the case, then voltage will not develop, or will take time to develop, across the switch when it has opened). Based on the CERTS microsource control, this situation will occur when the power across the switch is zero or very low (there is usually at least some real power taken by the PES controls). To fix this issue, Roger Troyer provided a modification in the PES code so the "Fail to Open" detection will only occur if the current across the switch has fallen below ~20A after 2 cycles.

8. TECOGEN Engine Control-Communications

During the commissioning process, it was noticed that communications between the EMS computer and the TECOGEN inverter controls was very slow; commands for frequency-voltage-power were modified from the EMS computer, and it will take approximately 20 seconds until values were updated on the Engine Control side.

Modifications to the communications between gensets and EMS computer were required. Initially, the gensets were connected together (2-wire duplex) using RS-485 connection to the EMS.

This setup was replaced with an Ethernet connection from the EMS to the gensets; on the genset side, an Ethernet serial switch is used to split the Ethernet link into 4 COM ports; three of these are used to communicate with each genset, using RS-232. With this setup, each generator will be polled individually, thus speeding up communications.