Installation of New Measurement Technologies at the Brunswick Nuclear Power Plant

Susan Tonkin
Coastal Environmental Systems
1000 1st Ave South #200, Seattle, WA 98134

Carolina Power and Light is in the process of replacing their meteorological system at their Brunswick plant. This is a 100 meter tower with extensive sensor suites and communication requirements, which in the past could only be instrumented using large, expensive, special-purpose, rack-mounted instrumentation (there were over 100 cables ***internal*** to the instrumentation!). The replacement system required two standard ZENO®-3200 data loggers -- the second providing complete redundancy. This state-of-the-art instrumentation provides the high accuracy, extensive communications capabilities, and processing power which allow Carolina Power and Light to take advantage of the high accuracy sensors and sophisticated computer models which are now available.

Sensors

The meteorological system has the following sensor suite:

- at 100 meters: AQ wind monitor and two aspirated temperature sensors;
- at 50 meters: AQ wind monitor, two aspirated temperature sensors and a humidity sensor;
- at 2 meters: Li-Cor solar radiation meter and tipping bucket.

NIST calibration is required for many of the sensors. The ZENO®-3200 data logger goes well beyond the existing instrumentation in taking advantage of the baseline sensor accuracy is in the temperature measurements -- rather than simply measuring delta-T to within 0.1°C accuracy, the logger's 18-bit resolution and corresponding accuracy allow the individual temperatures also to be measured to better than 0.1°C. (The industry standard is 12-bit accuracy.) The ZENO®-3200 also has the capability to connect to smart serial sensors, to a further 8 analog sensors (for a total of 16 analog), and to digital state and quadrature encoder sensors. The ZENO is often used to retro-fit existing instrumentation, and can be user-configured to handle much of the installed base of, often obsolete, sensors.

Outputs and communications

The outputs and communications requirements at Carolina Power and Light's Brunswick plant are four-fold:

- 5-second updates transmitted to a VAX, over a long-haul modem link, in a format defined by CP&L;
- a 14,400 baud phone modem, allowing both remote trouble-shooting and the capability for an independent auditor to dial in and download data;
- a local access port for terminal plug-in (***without*** unplugging anything);
- analog outputs driving a strip chart recorder.

With three independent UARTs (which can be multiplexed for a total of 6), the ZENO can provide all these communication capabilities. Again, this is part of the standard capabilities of the ZENO -- which include a wide variety of standard connections: RS-232, RS-485, RS-422, TTL, RF modem, and SDI-12 (a standard serial sensor protocol) at up to 19,200 baud.

The ZENO can be completely configured, using built-in, help-assisted, password-protected menus, either over a remote modem link or at the site. (They can also be made available over a two-way radio). The menus are accessed using any terminal emulation program such as the Windows Terminal, DOS Crosstalk or Macintosh MacTerminal.

Robustness and Redundancy: Hardware

A third major requirement of Carolina Power and Light's system is for robustness and redundancy. This was partly addressed through the provision of redundant ZENO data loggers (at the size of a small shoe-box, this becomes feasible). However, to a much greater extent, reliability of the system is ensured through the hardware and software design of the ZENO®-3200. The ZENO was originally designed for operation in extremely rugged and inaccessible locations, as diverse as the Arctic, the South China Sea, and the Middle East -- areas where service calls are expensive, if not impossible. The hardware design includes:

- 4 layer surface mount technology;
- an internal lithium battery which in the event of a power failure maintains the configuration, internal clock time, and logged data for up to 10 years;
- logging memory of up to 1 Mbyte, or 20 Mbytes with the optional PC MCIA card expansion board;
- extensive lightning protection.

The ZENO system monitors the external power voltage by two methods: one, by measuring the voltage directly, and two, by a power-fail interrupt signal generated by the system supervisory chip. If the external voltage falls below the threshold the system is held in a low-power reset state. It boots up again once power is re-established.

Additional software self-tests verify the performance of both the ZENO data logger, and its associated sensors.

Lightning Protection

Because the ZENO is based upon a surface mount board, it is inherently resistant to many surges and electrical spikes. However, components such as the microprocessor and the memory can be damaged by microjoule energy levels. Since lightning strikes typically produce megajoule energies, our ZENO installations include 4 layers of lightning diversion and protection. This is particularly important for a 100 meter tower installations. In our lightning protected systems, about 25% of the components are dedicated to lightning protection. More than a decade of experience in designing and maintaining products that survive in hostile environments where lightning is prevalent has shown that these techniques provide the most consistent and reliable protection possible.

- The ***first layer*** of protection is a substantial vertical conductor, such as the tower, connected as directly as possible to an earth grounding system. The structure should be able to sustain the bulk of the lightning energy without serious damage. The sensor wires connected to the ZENO®-3200 will, however, acquire residual energy, primarily by induction.
- The ***second layer*** of protection is designed to divert the induced currents via the metallic electronics enclosure to earth ground. The required AWG10 grounding conductor, usually connected to a 6 foot grounding rod, is attached to a clamping ground terminal mounted on the ZENO®'s aluminum chassis. Protective voltage clamping devices shunt most of the induced currents from the point where sensor, power and communications wiring enters the electronics enclosure, via low reactance paths, back to the grounding terminal. This greatly reduces voltage and current levels reaching the sensitive electronic components inside the enclosure. The clamping devices are a combination of avalanche diodes (transorbs) and gas discharge surge arresters. Devices such as metal oxide varistors, known to degrade with accumulated lightning events, are not used in the ZENO®-3200.
- The ***third layer*** of protection uses a resistor-capacitor decoupling network, acting in combination with the fourth layer.
- The ***fourth layer*** is a resistor-diode network.

These networks are built into each line entering a sensitive semiconductor device; they reduce any residual energies below the microjoule thresholds required to avoid component failure or degradation.

Even with all this hardware protection, it is possible for electrical spikes to flip bits in the ZENO's working memory. To cope with such software glitches, the ZENO®-3200 has both hardware and software watchdog self-tests.

- The hardware watchdog timer is on the ZENO®-3200 surface mount board. The function of the hardware watchdog timer is to test the ZENO functioning on a regular basis. If it observes an error in the ZENO's operation, the hardware watchdog timer restarts the system -- the ZENO is rebooted using the protected stored code in EPROM and the protected settings in EEPROM to reboot.
- Each software task reports periodically to a central task mailbox. If a message is not received from each software task within a specific (task-dependent) period, the software watchdog timer resets the system automatically.
- All reads and writes to the EEPROM are verified when performed. Read operations are verified by first scanning the entire contents of the EEPROM, calculating a checksum, and comparing the calculated checksum to the checksum value read from the EEPROM itself. EEPROM write operations are immediately followed by a read verification and checksum recalculation. If a read or write error is detected, the fact is flagged in the output data stream.

When the system is reset -- either because of a watchdog time-out, or after loss of power -- sampling begins immediately, with no loss of configuration or data. This also means that the second, redundant ZENO system can be swapped in, if required, without any on-site configuration: the sensor and communication connectors simply need to be unplugged from one unit, and plugged into the other.

Robustness and Redundancy: Software

The capabilities described above are predicated upon the processing power of the 32-bit Motorola 68332 microcontroller. The ZENO®-3200 has leap-frogged the 8-bit microprocessor machines currently available. This power coupled with extensive (512 kbytes) program memory make data acquistion both easier and more robust. Almost unlimited signal processing and alarm capabilities are available.

As an example of its processing capabilities, the ZENO®-3200 adds an additional layer of robustness through its MET-EXPERT firmware, which checks for the physical reasonableness of the measurements obtained. This includes that sensor readings are within reasonable ranges, the rate of change is reasonable (neither too high, e.g., for barometric pressure, nor too low, for wind speeds). User-defined "null" values can be set up for serial sensors which fail to respond. These can all be user-configured, or included in the original configuration by Coastal's experts.

Size and Cost

The small size of the ZENO makes for much easier, and therefore cheaper, installation compared to previous rack-mounted systems. The ZENO is a single package, the size of a small shoe-box, rather than being a collection of different instrumentation devices. At Carolina Power and Light, the size of the instrumentation enclosure is now determined by their requirement to allow walk-in access -- not by the size of the equipment.

The fact that all the instrumentation is combined within a single package obviously makes for much simpler cabling diagrams (Carolina Power and Light were quoted several thousands of dollars for the as-built drawings). This also makes it possible to provide redundant systems.

The main cost saving, however, lies in the fact that the advanced ZENO®-3200 data acquisition system now provides, in a standard, off-the-shelf package, all (and more than all) of the capabilities which previously required extensive engineering and customization.