CASE STUDY: The Path to Recovery

Plant Rebuilds with NCS NET Concentrator System®

April 2009

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Installation of Moore Industries-International, Inc.'s Ethernet-based NCS NET Concentrator System® (NCS) by Dynalectric Company for Imperial Valley Resource Recovery Company, LLC located in Imperial, CA, USA.

The NCS NET Concentrator System® from Moore Industries is integral to rebuilding communications and controls at Imperial Valley Resource Recovery, a renewable energy plant.

BRIEF

Imperial Valley Resource Recovery (IVRR) is a biomass-to-electric power plant delivering more than 16MW power onto the grid. In the spring of 2004, during a maintenance shutdown, the electrical paralleling switchgear suffered a major electrical explosion that destroyed the electrical connection to the grid and adjacent control room electronics. As a result of the extensive damage, Dynalectric Company was contracted to provide design, installation, programming and support to update the prior electrical and process telemetry, and ultimately incorporate Ethernet-based MODBUS RTU communications and controls. The new Ethernet-based system has been in place for approximately one year with the generator again 'on-line' and with significant improvements adapting Ethernet-based I/O NCS NET Concentrator Systems from Moore Industries.

PROBLEM

You are in the Control Room area of the power plant. Suddenly, the adjacent AC power panel room lights up brilliantly white, accompanied by a loud boom. A plasma fireball is leaving the AC power panel main contactor area. It immediately vaporizes the paint off of the nearby steel power cabinets and melts the aluminum overhead cable trays along with all of your control room cable signals to/from the facility.

You prudently exit your workstation—after all, the melted cables have definitely shut down the facility. The fireball remains for a few seconds. There is no subsequent flame. All is contained properly within the metal walls of the AC contactor room. No one is injured. There is soot everywhere.

The fireball has destroyed a few AC cabinet panels, nearby cable trays, and contaminated all of your control room electronics with soot. The rest of the facility is undamaged. In the damaged control room, you had previously been using reliable twisted pair contact closure, thermocouples, and some additional analog signals and considerable relay logic. You now have the opportunity to upgrade to 21st century facility control and monitoring technology. You review your operation and your short and long term plans.

BACKGROUND

Design considerations for this facility have many common characteristics with other power plants and with all manufacturing facilities. IVRR's facility uses biomass raw materials—specifically wood chips. These chips arrive via truck, are unloaded and sent through conveyors. Workstations along the conveyors pre-process these chips to remove contaminants, re-chip the wood and sort raw material by size. Additional conveyors restack raw materials into holding areas. Stacker conveyor belt positioning is done using both manual control panels and the control room—positioning the stacker output to precise locations as desired. There are two such independent raw material preprocessing systems to enable redundancy. Each raw material system will be independently controlled both in the field and via the new Ethernet-based communication link with the control room.

Figure 1. Extensive damage to the control room at IVRR.

The furnace area has feed conveyors, forced air blowers to aid combustion, and thermocouple sensors. The control room provides precise monitoring and control of these functions.

Exhaust heat is collected via elevated temperature heat exchanger-collectors using circulating water. The collected superheated water creates high pressure steam to operate the turbine. The turbine shaft operates a three phase electric generator. Low pressure steam leaving the turbine is routed to a large condenser where it recovers the water to start the water flow process again. This heat to electricity conversion requires additional instrumentation and controls (thermocouples, pressure sensors, motor controls, condenser flows, etc.) to assure proper water flow rates and manifold switching. Manifold switching enables the switching in/out of pumps for maintenance, thus ensuring 100 percent operational time on the turbine generator. All of these processes are automatically monitored and controlled from the control room. Also, there are multiple manual gauges installed throughout the facility. However, these are not routinely used to control the automated processes.

Imperial Valley Resource Recovery (IVRR) is located in the Southern California desert near Baja California. Temperatures hover near 120°F (49°C) in the shade (hotter in the direct sun) during the summer months. This is a critical consideration for facility electronics. Field communications devices, sensors and actuators need to operate in this environment, and need to operate without any air conditioning. "We are in the power generation business, not the air conditioning maintenance business," says Mr. Jim Medland of Dynalectric. The only exception is an air conditioner in the operator control room.

IVRR also has extended seasons of blowing desert dust and flying insects. Both require electrical panels to be NEMA 4 rated with no external ventilation openings. Therefore, electronics tightly packed within the NEMA 4 enclosures can only use internal air circulation fans—there is no outside air access.

Figure 2. Conveyors processing woodchips for renewable energy at IVRR's facility in Imperial, CA.

GUIDELINES

IVRR's management team, including Dynalectric and consultants, directed that the following guidelines be incorporated in the rebuild of their facility controls:

1. Rebuild what is necessary, not redesign the entire facility from scratch. Only implement changes that will be measurable improvements. There are only two adjacent damaged areas– the AC panel room and the control room. The rest of the facility is undamaged. IVRR wants to get back into normal production promptly.

2. Use technology that is proven, something that we are already familiar with, and is readily available.

3. Use technology that meets current and future plans. Strive for an open and flexible architecture. Do not get locked into a single vendor or a high maintenance technology.

Figure 3. AC Power Panel Room after plasma fireball destruction. Although there is incredible damage to the panel room and control center of IVRR, the rest of the plant is not compromised.

PLAN

The team decided as follows:

A. Delete multiple long cable runs of twisted pairs between sensors, actuators and controls. Replace them with field data concentrators to collect multiple sensor/control pairs near their point of installation

throughout the site. The data concentrators should be bidirectional. Communications for all channels need to be via a simple communications link. This will eliminate hundreds of pairs of previously installed twisted pairs and their maintenance. It also will eliminate the need for expensive A/D converters and control logic at the DCS location.

The team selected Moore Industries' NCS NET Concentrator System with a communications module plus up to sixteen (16) plug-in I/O modules. Each I/O module supports multiple discrete channels of inputs, or relay outputs, or analog inputs (voltage current loops) or low level sensors such as RTDs, thermocouples and potentiometers. The NCS is expandable as necessary by adding I/O modules as future growth occurs. The NCS readily handles temperature extremes of +185ºF (+85ºC) through –40ºF (–40ºC) to reliably handle all I/O and communications in the desert environment. All of the prior contact I/O pairs plus the analog and temperature pairs can now be routed very short distances from their various facility locations to the nearest NCS. The NCS retains its calibration for years under these temperature extremes, thereby minimizing maintenance.

The team selected the EIM Ethernet Interface Module as the communications module for the NCS. The NCS is available with either Ethernet (LAN-based) or RS-485 (twisted pair-based) communication modules. These both support MODBUS RTU and OPC communication protocols. However, the EIM supports an internal Web Page Server that is ideal for programming and maintenance. The EIM also provides its own internal data logger, and PLC-like programming using ISaGRAF (IEC611311-3 approved) languages.

B. Use a communication protocol that was already known with a recognized open architecture so that future growth and support would be readily available from any vendor at best performance for IVRR's needs.

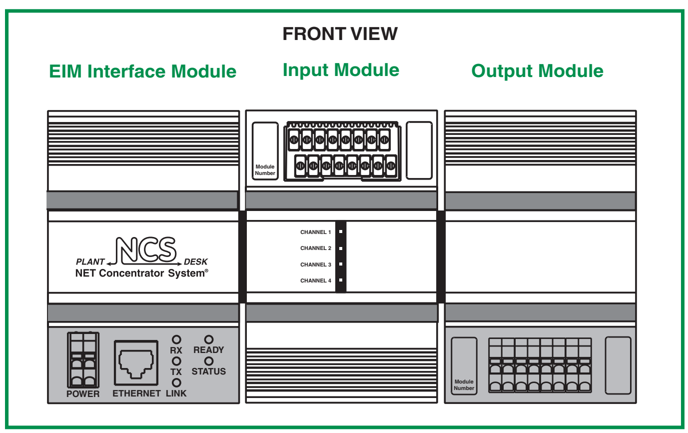
The team selected MODBUS RTU. This is the most popular protocol used by more than half of the process control industry. It is well suited to transfer the status of coils and analog signals. The communication is all digital. Thus analog and digital facility data is not degraded no matter where on the facility the information originates or is being directed.

C. The communications link technology needs to be flexible enough to use from anywhere on site to any remote location. Use a modern serial protocol that is readily available and reliable. Eliminate unnecessary pairs of wires where possible to simplify numbers of cables and associated maintenance.

The team selected Ethernet communications. This is communications with the familiar LAN cable. While MODBUS RTU is the protocol for twisted pair wire, Ethernet uses MODBUS TCP. The MODBUS message is identical in both communications protocols. In MODBUS TCP (used with Ethernet LAN cables), the MODBUS data byte is prefixed by the LAN TCP addressing and suffixed by message error checks. Thus the originating and destination locations merely insert or extract the MODBUS data bytes from the overall message. The MODBUS TCP protocol communicates by using any common LAN cables, LAN switches, LAN fiber optic modems and goes 'anywhere' in the world. Thus communications within the IVRR facility is easily incorporated. Furthermore, the LAN nature of MODBUS TCP enables management, operators, and maintenance personnel to 'connect' to the communications link readily and transparently. Connection is via simple laptop computers to activate and monitor controls without the added expense of helpers or distracting the control operator. This is a significant step forward over any MODBUS RTU (RS-485) twisted wire pair solution.

While installing the new LAN cables throughout the facility, it was convenient to remove the hundreds of earlier, now unused, pairs of communications wires. The speed of the Ethernet approaches 10 MHz and higher, and carries all of the facility data in one cable. The data enters the DCS using one Ethernet card. The prior design required multiple pairs of wires each requiring an expensive interface card at the DCS. Thus the overall investment to go with Ethernet based NCS systems is a considerable cost saving over any consideration to replace piece-for-piece earlier technology.

Figure 4. NCS NET Concentrator System EIM Ethernet Interface Module with modular I/O modules.



D. The DCS Controller needs to be familiar and readily easy to use.

The team selected a brand of controller with which the programmers were already familiar. Additionally, it has a communication port to accept bidirectional Ethernet LAN communications, and thereby eliminates the need to have multiple scanners located at the DCS Workstation to collect sensor/contact signals and originate outgoing signals. Again, this saves wire pairs. Control and display are via readily available desktop computers and monitors. The control room is air conditioned—for the host computer workstation and operator, as well as the display panels and the operator.

The entire electrical room was demolished, and consequently, all power distribution equipment had to be removed. The damage was so extensive that all walls and roofing were also replaced.

The AC power panels were replaced as well. The burned cable pairs and melted cable trays in the power panel room were disposed of permanently. The overhead cable trays were replaced with a smaller tray—now requiring only a few twisted pair cables plus an Ethernet cable to do the same, if not better, job of communicating with the entire facility. Relay logic circuits are still used throughout the facility. However many of the communications links to the control room now ride on the Ethernet cable. Portions of the original cabinets make a good home for the new Ethernet based NCS electronics.

Figure 5. New Ethernet based NCS electronics in the original cabinets at IVRR.

The DCS Control Room was also cleared, cleaned of soot, repainted and new computers with monitors were installed. For convenience, five flat screen monitors provide entire graphic coverage of the system. An additional computer located in a nearby office, but still connected to the same LAN cable network, is used to monitor NCS activity and DCS programming.

Four new NCS units, some containing up to 16 I/O modules of multiple channels each, are installed into these old cabinets or into newly constructed cabinets throughout the facility. All cabinets are sealed to prevent dust and insect migration. Power, I/O pairs and an Ethernet LAN cable are all that enter the cabinet.

Lengthy sensor and control wire pairs that were cut just outside the AC panel room are now trimmed further back, thereby making even more space in the cable trays (and less maintenance). Sensor and control pairs are connected to the nearest NCS panel. Mapping diagrams are created to identify each sensor and control wire pair by Ethernet IP address, I/O module and channel number. Each NCS I/O channel is completely electrically isolated from every other channel, thereby enabling complete flexibility of thermocouple, RTD, potentiometer, current loop, dry contact closure, (and other) signals to have no adverse communications effect on each other. Furthermore, the isolation prevents ground loops in-between channels. This is important because sensors are widely separated with intervening large motors, and there are inherent ground loop concerns for low level sensor signals.

Each of the NCS analog input channels uses a 20 bit A/D converter and communicates this analog value as a digital number all of the way back to the DCS. Thus the DCS now is able to obtain a true WYSIWYG (What You See *at the sensor* Is What You Get) at the DCS with no data corruption regardless of sensor distance from the DCS. This enables the DCS to operate with better precision and higher stability from all sensors.

The MODBUS TCP protocol provides simple and successful communication between the remote NCS and the DCS. The DCS costs less because it no longer requires multiple manufacturers' unique I/O cards at the DCS to collect and send information. Communication for the entire facility is via one Ethernet card and one LAN cable. The LAN cable is split using standard industrial grade LAN switches. No particular setup is required on the LAN switches since the entire system is co-located at one facility and no 'outside' LANs are connected to the process control LAN system. If desired, the LAN switches may be configured to communicate with selected 'outside' virtual workstations so programmers and maintenance staff may securely check performance of the system from anywhere—even off-site by using any Ethernet port for access. The NCS has a built-in Ethernet Web Server providing an HMI (Human Machine Interface) with security for this purpose, both on- and off-site with connected laptop computers.

IMPLEMENTATION DETAILS

These new improvements did require some extra efforts including:

I. Unused relay logic and many interposing relays were removed from earlier cabinets to make room for the new NCS electronics—a good cost savings. The NCS electronics replaces the cable pair bundles and provides up to 16 sets of I/O modules. Each input and output is isolated thereby diminishing the need for the former interposing relays. It also simplifies maintenance. Input signals arrive on one side of the NCS I/O modules. Outputs are on the other side. This makes for high density wiring to the terminals since I/O modules typically have up to 16 wire terminals per I/O module base. This can be awkward access in tight quarters. However, each I/O module's electronics is quickly detachable from its own terminal base as a maintenance feature for 'hot swaps'. Removing the electronics portion (press two side clips, and pull) of the I/O module provides more access room to the terminals. Reinstallation of the I/O module electronics is just as fast.

II. On literally the 'sunny' side of the enclosures, the desert summer sun can easily raise the temperature of the enclosure several degrees. Since the enclosures are sealed, Dynalectric chose to add two air circulation fans inside certain enclosures exposed directly to the sun. This moves the inside air sufficiently to assure inside temperature does not exceed +185°F (85°C). The decision to go with the Moore Industries' NCS and its higher operating temperature is a benefit that has resulted in a "no maintenance concern," which is just about the best compliment that maintenance personnel can give to a piece of electronics.

III. Previous relay logic panels distributed throughout the facility are replaced with computer programs within the DCS. These new programs duplicate the prior relay logic and sometimes complex interlock function algorithms. Programming is a time consuming task, but is now successfully accomplished. Now fine tuning of functions is readily monitored and improved by this upgrade. Many of the facility's manual push-button panels have their contacts duplicated and sent to the DCS via the NCS and MODBUS TCP. The DCS can 'see' these actions, display them and can even perform the same actions as the manual controls without the need for personnel to be sent outside to do these same tasks. These are a sample of the new flexibility of a DCS with flexible programming and using the Ethernet to fetch and send sensor data and control information. What was previously a physical re-wiring of a task in the field is now a computer subroutine and communication with IP addresses on the Ethernet.

IV. The exhaust gas exiting the furnace via the super heated water coil exchanger is a waste product. The gas is quite clean but it needs to be scrubbed and the fine ashes and large particulates removed prior to being sent to the chimney. This scrubbing includes a 'bagging' process. Imagine a series of bags whose fabric allows gasses of up to 500°+F (260°C) to pass through freely but catches dust particles as fine as one micron (that is much smaller than the diameter of a human hair). As ashes collect on the bag's inner surface, the bag's differential pressure (inlet versus outlet) increases. This pressure difference is measured by pressure sensors and reported via MODBUS TCP to the DCS. At a given threshold, the DCS runs a subroutine to send a very brief ON/OFF pulse burst in a precise sequence to valves on an air manifold. The parameters are proprietary. The air pulse for each bag knocks the accumulated dust particles downward out of the bag onto a screw drive conveyor and ash is removed from the system. The DCS-MODBUS TCP-NCS-Manifold valve process is a somewhat lengthy communications distance, but was necessary to fine tune the process for optimization.

As a future alternative to the above DCS-MODBUS TCP-NCS-Manifold valve communication link process, the

Figure 6. The baggers at the plant collecting the fine ashes and large particles from the gas waste product the process produces.

programmer can take this same DCS algorithm, rewrite it using [ISaGRAF Control Engine Software] and install it within the NCS EIM module located at the scrubber/bagging system. The NCS has a 'built in' PLC capability using an ISaGRAF run time module. When the programmer's algorithm is downloaded into the NCS EIM module via the Ethernet, the NCS runs and performs the identical task as the DCS without the need for the DCS or the Ethernet to participate. The pressure sensors may be measured directly by the NCS and then trigger the NCS to perform the correct valve sequence. This same NCS algorithm may also be triggered or inhibited by the DCS, as desired, for more flexibility.

V. The Ethernet link enables the DCS operator and field technician to connect a laptop anywhere there is a LAN connection at the facility. Via any Ethernet port on the LAN, all of the NCS I/O modules may be monitored using the NCS built-in Web Server. Thus the NCS has an HMI (Human Machine Interface) panel, and there is no software to purchase for this ability. Similarly, the configuration of any of the NCS I/O channel setups may be accomplished from the same Ethernet connection. A security password prevents unauthorized editing of the system. A data logger on-board each NCS allows the last 64,000 transactions to be recorded on any selected channels. The data logger configuration and log file are also available via Ethernet. Thus the maintenance technician can see and exercise valve positions, actuators, temperatures, etc at any point without the need to have the DCS operator or an 'extra' helper for these tasks.

CONCLUSION

IVRR is up and operating now with their well planned Ethernet based system. It is current technology that enables programmers to rapidly incorporate performance enhancements and/or adjustments to peak process performance. These decisions reduce maintenance costs and the need for extra maintenance personnel as compared to the earlier control system. IVRR is confident they are already reaping the benefits of this new and reliable platform to be competitive for the future.

Figure 7. The network communications structure after the new Ethernet-based NCS I/O system was installed.

Each NCS supports multiple analog and discrete channels to fully capture the resolution of any remote sensor, switch, actuator and display. The NCS digitally communicates these to another NCS and/or to the DCS. The use of digital communication with error correction and a high speed Ethernet LAN cable assures no signal degradation.

The LAN cable is split to provide redundant communications via LAN 1 and LAN 2 cable paths. This guarantees digital communications during LAN maintenance. Also, the DCS supports a separate legacy hardwired twisted pair link for safety critical tasks.

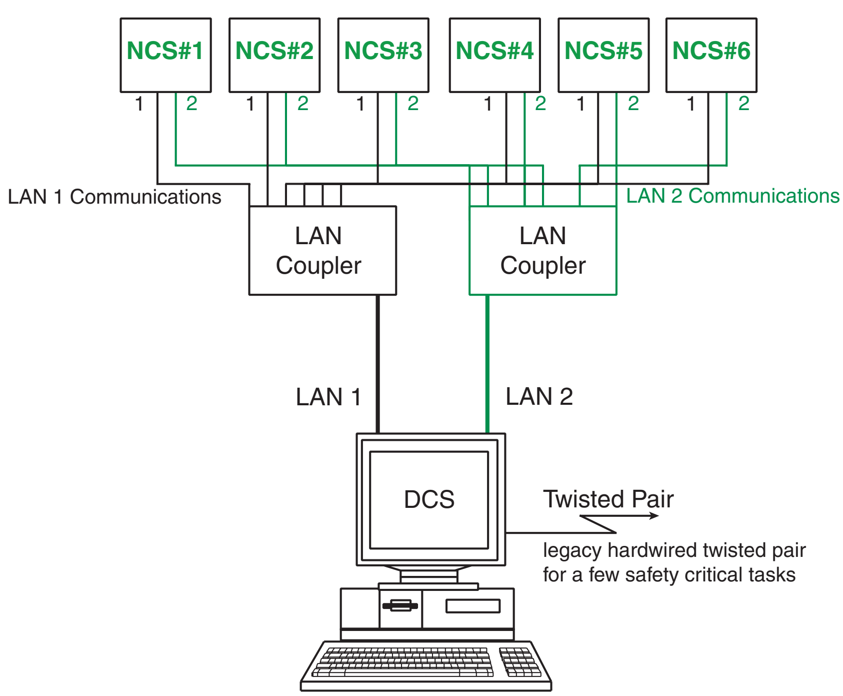


Figure 8. Physical process and distributed I/O layout.

Multiple I/O data points are collected throughout IVRR's process. A total of 6 NCS cabinets communicate and provide control for several complex sub-processes. ***Mouse over each NCS station's check mark to get a detailed look at the sub-processes and the multifaceted I/O communications.***