P02-10 - DIESEL GENERATION CONTROL SYSTEM MODERNIZATION

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1. Abstract
The Programmable Logic Controller (PLC) SCADA upgrade for the Inuvik Power Station replaced an outdated SCADA system and incorporates automatic features of modern diesel generating stations. The modern PLC based control system provides many advantages:

- Reliable control system components;
- Industry standard hardware and software;
- A network infrastructure for future control scenarios;
- Computerized maintenance systems;
- Direct link between plant floor and head office.

This paper focuses on the PLC SCADA upgrade at Inuvik explaining the following:

- Why the project was taken on;
- Technical detail of the project;
- Features of the system.

2. Project Objectives
The Inuvik Power Station has been controlled by a 1970's vintage SCADA system. Over the years the product had become obsolete and the operation had been plagued with problems such as obtaining spare parts. As a result the reliability and performance had deteriorated. The primary objective was to replace the existing SCADA system with a modern system that will provide:

- Local and distributed control;
- A cost effective, non-proprietary solution;
- Special operation and maintenance features;
- Easy addition of future expansions;
- Continued vendor support;
- Integration into a fully operating plant.

3. System Overview
The PLC based control system provides five key advantages:

I. Replaces the outdated SCADA system.

II. Upgrades the control system on the gensets (generator and diesel engine).

III. Automates the Inuvik power plant.

IV. Increases reliability and productivity of the power station.
V. Provides a modern infrastructure for the control system and internetworking.

The system incorporates a PLC on every genset. These PLCs provide local, "stand-alone" control for each genset. Each genset, or piece of equipment, that has a local PLC is then controlled by the station PLC. The station PLC is responsible for supervisory control of the entire power plant. This PLC provides automatic station control with communication to the local PLCs, and main control room interface for the operators via a HMI (Human Machine Interface) system. This PLC is also a gateway to systems outside Inuvik that require access to the Inuvik power station control system.

The basic design of the PLC system allows for the addition and integration of other systems under a common PLC control system. For example, the facility in Inuvik also contains three boilers for town heating. PLC control systems are used to control the boiler systems, so it follows that any boiler control system upgrades can be done with similar PLC equipment that is easily integrated into the total control system.

4. Project Summary
The upgrade of the control system for the Inuvik Power Station began in March 1996 with serious evaluations of the equipment and philosophy that should be used. NWTPC Central Engineering Hay River, NWTPC Inuvik, and J. Kaehne and Associates Ltd. of Burnaby, BC jointly evaluated several designs and budgets until the project was officially accepted in August 1996. The control system upgrade consists of three phases. The project was divided this way to accommodate cash flow, operation issues, and the seasonal load variations.

4.1. Phase I
The first phase of the project concentrated on replacing all the existing hardwired controls on the five existing gensets in the Inuvik Power Station. The objective of this phase was to install a PLC based Local Engine Control Panel (LECP) on each genset. Each LECP was designed to provide local control of the genset, and contain the algorithms required for control from a supervisory system.

4.2. Phase II
The second phase concentrated on the installation of the station PLC (supervisory) system. The
station PLC system controls all the gensets as individual stand alone units, the power plant ancillary systems, and the switch-gear.

4.3. Phase III
The third phase was the installation of digital metering equipment. Digital metering was provided for all main feeders and each genset. Information from the metering was integrated into the HMI system.

5. Project Detail
5.1. Cost Advantages
Expenditures for control systems can be justified by cost savings due to increased efficiency of several areas of the operation. The following points identify areas that are improved by a modern control system:

- Decreased equipment maintenance costs and better maintenance through historical data collection, trending and data logging of maintenance criteria;
- decreased maintenance call-out cost or/and reduced call-outs (as simple as remotely closing a feeder);
- faster system trouble shooting because the system provides real time diagnostics;
- an increased ability for operators to anticipate load swings through trending and reporting;
- decreased blackouts, with increased recovery;
- automatic generation of reports.

The points listed above can be realized over a short term. The long-term advantages of a modern control system are difficult to accurately measure since this depends on how well the system is integrated into the company. This type of control system provides an infrastructure for integrating remote plants on a common network. Nodes of this network can exist on the plant floor or on the desk of the CEO and provide real-time information. The advantages provided by a system of this magnitude are beyond the scope of this paper, but are bound only by the imagination of the system owner.

5.2. Genset Available.
A determining factor for the station PLC to use a genset is whether that genset is available for use. This is a fundamental condition that is used throughout the system and is referred to as the genset being AVAILABLE or NOT AVAILABLE. The genset decides locally if it is AVAILABLE and informs the station PLC via the network. The genset can become NOT AVAILABLE from several conditions, major ones being:
- Genset mode is selected in MAINTENANCE;
- there are critical alarms;
- there are operational alarms;
- communication problems with the PLCs;
- the engine is not pre-heated;
- the operator has selected the genset to be NOT AVAILABLE.

5.3. Genset Stacking and Auto Dispatch.
The station PLC automatically starts and stops gensets with respect to the load. The order in which the gensets are used is called the stacking order (dispatch priority). With the stacking order established, the control system evaluates the load, and automatically dispatches the AVAILABLE gensets. The variables used to seed the automation program for automatic dispatch are entered in two tables. The tables provide information for:
- Loading characteristics of each genset;
- stacking orders for the gensets in the system.

The control system administrator must provide these seed values for these two tables. Table 1 establishes the loading, in kilowatts, for the respective Genset. Table 2 establishes the stacking order of the system. The stacking order sets the combination and order that the gensets will run.

From these two tables the station PLC has enough information to generate power ranges and associated stacking order numbers. When compared to the load, these values provide the start and stop information for the AVAILABLE gensets.

The automatic dispatch is tuned by two parameters;
- Time between each load change calculation;
- the size of the load change before an action is taken.

The events in a typical automatic dispatch are described in detail by the following points:

a) The system is continually checking the load from the feeder metering, it is stored for calculations and is called "current load".

b) The current load is compared with the last load reading that was taken. The time between calculations is a tunable parameter which is set to best fit the system. In this example the time period is set for ten seconds.

c) If the load has not changed more than 50 kW the system waits another ten seconds,
recalculates the current load and compares with the old load. The load change is a tunable parameter which is set to best fit the system.

d) With decreasing load a 50 KW load change will be recognized and the system evaluates that there has been a load decrease.

e) The system now must decide if a new stacking order is warranted so the current load is compared with the stacking order ranges to see if the new value falls in a new stacking order.

f) The new current load has not moved out of the range represented, so nothing is done.

g) The system identifies that the load is changing and stores the current load as the last load, waits ten seconds, calculates a new current load and begins the comparison cycle over again.

h) Load continues to decrease. The system sees that the load has changed to require a new stacking number. The new stacking order is assigned and the system begins starting and stopping gensets.

i) On completion of the stacking order change the system goes back to monitoring load change as described above.

At any time during this process a genset can become NOT AVAILABLE. The stacking order is only calculated with AVAILABLE gensets. The system automatically calculates the stacking order load ranges from the AVAILABLE gensets, so each time the availability of a genset changes new stacking order range values are calculated. It follows that if the stacking order ranges change the system must re-evaluate the stacking number that best represents the load. During the load checking process described above the system can be interrupted to adjust the stacking order if genset availability changes.

5.4. Black Start.
In the event of a black-out the system can provide a first attempt at restoring the power. The control system must have reliable uninterrupted power during the black start procedure. The following description details a black start scenario.

a) A dead bus is detected.

b) All feeders are automatically opened.

c) All genset feeders are automatically opened.

d) Automatic dispatch procedure is suspended.

e) All available gensets are started.

g) The system waits for the selected black start genset to be ready for load and closes the associated breaker.

h) One critical feeder is closed.

i) Gensets of the previous stacking order are synchronized on the bus.

j) Remaining feeders are closed.

k) Automatic dispatch system is enabled for normal operation.

5.5. Feeder Re-closure
The system provides a first attempt at re-closing tripped feeders. Feeder re-closure is a very critical operation and, in some cases not well suited to be done by this type of control system. The following description explains a typical PLC feeder re-closure scenario.

a) A feeder trip is detected by the system.

b) The system determines if an operator initiated the trip. If so, the system does not try to re-close the feeder.

c) The system determines if more than one feeder has tripped. If so, the system does not try to re-close any of the tripped feeders.

d) If interlocks are satisfied the system will try to re-close the feeder.

If the feeder does not stay closed after two tries the system leaves it open and advises the operator.

e) The system will try to close the feeder two times, waiting ten seconds (or any pre-programmed time) before each re-close attempt.

5.6. Load Sharing
The system is designed to run the gensets in a load share mode. The automatic dispatching program can be optimized by the operator to provide the best loading characteristics for the gensets. Gensets can also be selected in base load with their generation accounted for in the stacking order.

5.7. Modular System Design
The entire system is designed in a modular fashion. Any genset from the Inuvik Power Station can be removed and re-installed, complete with the local control system, at another location. The station PLC system can run without the missing genset by simply setting that genset NOT-AVAILABLE. Integrating with the same control system philosophy can easily accommodate additional gensets. Some additional programming on the station PLC is required to add the new genset to the stacking order system.
6. Control System Networks

6.1. Local Genset.
This network refers to the control level which carries all the local genset data. The key element of this network is that it must be isolated from other systems in the station. The genset must be able to run in the absence of the station network.

6.2. Power Station.
This network runs throughout the Inuvik Power Station to connect all power generating and power consuming devices. The station PLC ties the station control network together. It controls all plant ancillary equipment and provides a node on the Ethernet TCP/IP network. The station control network provides the backbone for the communication required to control the entire station. The station PLC uses this network to accomplish the following fundamental tasks:
- Collect data from the genset unit control PLCs and store it in standard data tables;
- Collect data from the station's ancillary equipment (power meters, protective relays) and store the data in standard data tables;
- Analyze the data read from the gensets and make station control decisions;
- Provide data tables of all station data that are available to the Local Area Network (LAN);
- Provide a node on the (LAN) which will interface to the main operator control administration stations.

6.3. Local and Wide Area Network.
The local area network (LAN) provides two main functions:
- An isolated control network for computer based operator stations (HMIs);
- A node on the wide area network (WAN) to provide real-time, local generating data for remote monitoring.

An Ethernet system is used for this network. The Ethernet port on the station PLC provides a gateway through which plant floor data can be read at high speed (10 Mbps).

Since Ethernet TCP/IP is used as a networking system connection to other types of networks is easy (inter-networking ready). This remote Power Plant can now be integrated into NWTPC's WAN. The control system provides real time operation information to three key levels:
I. Operations - the plant floor operator.
II. Plant Management and Maintenance - the plant personnel responsible for an efficient running system.

III. Head Office - the company's directors and managers.

Most important with this high level of networking is the ability to tie together power stations that are remote to each other. On remote power stations operating on a common grid the owner can easily achieve a low cost, reliable, central control system. Where power stations do not share a common grid the owner obtains real time, accurate operation data of his utility.

Once the control system and communication infrastructure is in place and tested the levels of control can vary from monitoring only, to complete unmanned control of the remote generating station.

7. Conclusion.
Control system upgrades similar to the Inuvik SCADA system, or new control systems applied to new systems provide a cost effective and powerful solution. This control philosophy should be embraced for reasons summarized here.

Cost savings are realized by:
- Improved maintenance and reduced or faster maintenance call outs;
- Increased power availability to the customers;
- Load and generation optimization.

Company improvements and future savings are:
- Standardized data logging of generation and consumption;
- Standardized data logging of faults and interruptions;
- Automated reporting features to satisfy regulatory boards;
- Integrated wide area networking with plant floor operation to head office;
- Remote access of real-time generation or consumption data.

The control system hardware selections have the following strengths:
- Industry standard;
- Easily configured and programmed;
- Well supported by the industry;
- Product expertise is widely available;
- Easy integration with other systems.