Aluminum Smelter Rectifier Control System
White Paper
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Abstract: Electrical power has been making the news recently with deregulation and price fluctuations. This is a concern for aluminum smelters, since their largest production cost is power. Many smelters have signed power contracts with penalties for using either more or less power than the contract amount in exchange for stable pricing. At one aluminum smelter a ControlLogix PLC system provides tight demand control while balancing load between thirty-six rectifiers supplying power to two pot lines. The control system also provides operator controls and a window into the system while automatically printing performance reports at specified times.

Keywords: Electrical Power, Demand Control, Aluminum Smelter, Programmable Logic Controller, ControlLogix, Operator Interface Terminal, RSView32, Metals Industry, Power Industry…

Customer Profile

Northwest Aluminum Company is an aluminum smelter located along the Columbia River. Electrical power in the form of DC current is an essential component of the smelting process.

Northwest Aluminum purchases their power from Bonneville Power Administration (BPA) and other energy suppliers at rates that have a specified hourly demand limit. Northwest Aluminum Company must declare contracted usage and demand limits prior to the beginning of a month and there is a heavy penalty if they should exceed the contract demand in any given hour or the usage for the entire month. Therefore, power demand control is critical to profitable operation.

Northwest Aluminum has two pot lines where the alumina powder is converted into molten aluminum. The smelting process electrical feed starts with three main transformers with corresponding load tap changers. Normally transformer 1 feeds pot line 1 and transformer 2 feeds pot line 2. Transformer 3 can be switched in to take the place of either of the other transformers when the normal unit needs service.

Each transformer feeds power to an electrical rectifier bank that in turn provides the DC current to one of the cell lines. The rectifier control and the tap changer settings control the power used by the smelter.

Customer's Business Problems / Issues

In 1985, Northwest Aluminum installed an automatic system to control the tap changers and rectifiers. This system had worked well over the years and provided better performance than manual operation. However, the hardware was obsolete and no longer supported by the manufacturer. In addition, the operator interface was a text based keyboard and printer system, providing only a limited ability to share production data with other areas of the plant. Northwest Aluminum wanted a new system that was reliable and would provide the following characteristics:

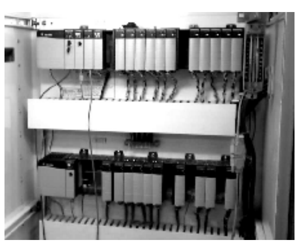
- PLC based controls
- Windows based Operator Interface Terminal (OIT) to support data sharing
- PLC controls continue with the OIT down
- Fail-safe PLC output to trigger a switch to manual controls on failure
- Duplicate old system functionality for control scheme

There are two primary considerations for the rectifier control system. First, the demand must never exceed the contract amount. Exceeding the contract could quadruple the cost of power. Second, the cell line current controls the aluminum production characteristics. Therefore, the system must control the line currents to match production desires when the plant is not up against the power demand constraint.

One challenge with duplicating the existing control scheme was that the system functionality had to be interpreted from existing assembly code language. Working with a combination of functional flow diagrams, interviews with operators and engineers based on their experience using the system, and some limited data retrieved and interpreted from the actual code the new system functionality was developed.

Solution Description

The new system design is based on an Allen-Bradley ControlLogix PLC with analog and digital I/O and support for several communications protocols. Two ControlLogix chassis hold the I/O modules, which provide direct replacement of the old control system I/O. These two chassis are linked using ControlNet. Selected feeder power data is collected on Allen-Bradley Power Monitor II meters and brought into the PLC over Remote I/O. Ethernet provides a wider bandwidth communication link to the Windows NT computer handling the PLC programming software and the Operator Interface Terminal functions.



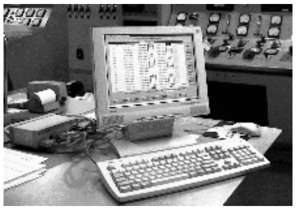
The OIT software used on this system is RSView32 from Rockwell Software. The computer is on the plant Ethernet so rectifier data is available elsewhere in the plant. Finally, a printer is connected to the OIT computer's parallel port for automatically and manually generated production reports.

The system switch over schedule was important since the rectifiers would be operated manually during the transition. The old control system was contained in two enclosures, one with the controls and the other with the I/O terminations. We were able to build the new control system in an enclosure that matched the profile of the existing I/O enclosure. This was located on the opposite side of the I/O termination cabinet from the old control enclosure. This enabled the customer to set the new control enclosure and prepare the interconnections before turning off the old control system.

The control scheme was segregated into functional sections to facilitate troubleshooting and minimize any inherent interactions. First, the tap changer controls regulated the voltage support to the rectifiers. This control also detects which transformer set is feeding each line so the correct tap changer can be adjusted. Next, the plant hourly (cumulative) demand is regulated to match the contract amount. Demand is measured by pulses which are a measure of KWH per hour demand. For a given contract amount, the operators set the demand target to just under the contract amount, usually ½ pulse per hour less than the target demand pulse count. The demand control uses a time slice approach to track the power usage and make adjustments throughout the hour. This control outputs an instantaneous demand set point that is then divided between the two cell lines.

In theory, the instantaneous demand (kW) will equal the kWh set point value for the hour. In reality, process fluctuations such as anode effects and line shutdowns require adjustments over the course of the hour. As part of the cell-line instantaneous demand division, the control calculates the maximum allowable cell line current that will keep power usage within the plant demand allowance. The cell line current reference is set to the lower value between this calculation and the cell line current limit entered by the operator. PID loops control the actual current to each line using this reference and the line current feedback from an analog sensor. Finally, these controlled line currents are proportioned among the eighteen rectifiers on each line according to the rectifier current limits entered by the operator. These rectifier current references are delivered as analog outputs to the existing analog rectifier control systems.

The OIT system included screens displaying an overview of the AC and DC power, operator configuration, rectifier set-up, trending, and production reporting. The new operator interface is very different from the old system. The old system was based on a Texas Instrument Silent Sentinel Keyboard printer for entering operator commands. The operator entered keyboard codes and then waited for the status response to print out. The new system is a Personal Computer with Windows NT and RSView 32 using full Windows GUI capabilities. Although there was a period when the operators were adjusting to the changes, as they became accustomed to the new system, they found the real time data displays easier to use than the old system.



Business Benefits

Once the rectifier controls system got past the start-up adjustments and operator unfamiliarity, it has provided consistent power control. The desire for active support on the hardware and software were immediately realized. One advantage from selecting the ControlLogix platform is it is a relatively new Allen-Bradley product and should have a long support life ahead.

The functionality of the old system was essentially duplicated. There were several unexpected benefits where the system operated better than its predecessor. These included smoother control of the line current when not up against the demand set point, which is the most common operating condition. The new system makes the transition from manual to PLC control and PLC to manual control modes more smoothly than the old system. In addition, a periodic maintenance procedure for calibrating the analog rectifier controls proved much faster and easier with the new operator interface providing real time rectifier current feedback for comparison to the analog meters.

The new ControlLogix and RSView32 control system has maintained the line current or demand set point with and without the operator terminal on line. It provides clearer and immediate information to the operators. And as part of making production information available anywhere in the plant, an engineer at Northwest Aluminum has used Windows capabilities to post the daily production report on the plant internal web site.

Biography

Jim Michaelis grew up in northern California. He is a member of IEEE (S' 1979, M' 1984) and ISA (SR' 1994). Jim earned his BSEE from the University of Nevada - Reno in 1984. In 1990 he passed the Professional Engineers exam for Electrical Engineering in California while working as a Control Engineer for Reliance Electric Industrial Company. Jim joined PCS UtiliData in 1994 as a Control Engineer with a Drive Systems specialty. PCS UtiliData is a Spokane, Washington based control system integration firm specializing in the metals industry and power system automation using PLCs.

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