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Research institution modernizes boiler controls for greater reliability, visibility and building automation integration.

Applied Control Engineering, Inc. designed a solution using the SIMATIC S7-1500 controller to resolve boiler operating issues that affected heating and steam generation at a major U.S. research institution.

White Paper

Abstract

After experiencing repeated failures of CompactLogix PLCs in its boiler control system due to excessively hot boiler-room temperatures, a major U.S. research institution contacted Applied Control Engineering, Inc., a Siemens Solution Partner, for a reliable, lasting solution. This case study describes the new boiler control system that was designed for use in ambient temperatures up to 158°F (70°C). Its core comprises a SIMATIC S7-1500 PLC and ruggedized Siemens SIPLUS extreme I/O, networked with a third-party HMI panel and other vendor components. The TIA Portal was used for software engineering, using functional blocks of both newly programmed code and code adapted from existing libraries. Beyond resolving the temperature issues, the new boiler control system also provided data to a Siemens APOGEE building automation system through a third-party communications gateway.

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When "one-size-fits-all" solutions don't work

Steam-generating boilers are used worldwide for a wide range of applications including water heating, central heating, power generation, sanitation, and cooking. The concept goes back more than 200 years with a basic design – similar to today's – that comprises a pressure vessel containing the water to be heated and a heating source burning some kind of fuel. Because water expands its volume 1,000 times when it becomes steam, boiler explosions have occurred throughout the technology's history, making safety a top concern.

Fortunately advancements in metallurgy and mechanical designs, plus strict inspection requirements, have made today's boilers much safer, whether used to heat water in homes for cooking and bathing or at nuclear energy plants to generate electricity. Another physical property of steam has made boilers useful for central heating in not only homes but also large facilities, such as office buildings, warehouses, and campuses: steam's huge volumetric expansion from water can send it down pipes at speeds exceeding 60 miles per hour.

Heating up research. Since 2006, this is how a major Mid-Atlantic research institution provided heating for a large number of campus buildings as well as steam used by scientists in its life sciences and medical research laboratories. Powered by propane or natural gas, depending on which costs less at any given time, two 1,500-horsepower (hp) boilers are engaged, each able to produce 51,750 pounds of steam per hour (pph). A third 900-hp boiler with 31,050 pph of capacity was used at times of lower loads, when the larger boilers weren't needed. These boilers were about 12 years old at the time Applied Control Engineering, Inc. was called.

While the boilers' burner management system (BMS) is not part of the boiler control system, the research institution's boiler room also includes what's called "balance of plant" or BOP mechanicals. Among the BOP infrastructure are eight variable frequency drives (VFDs) used to control six feed pumps and two transfer pumps. The BOP also includes two deaerators, devices designed to eliminate corrosive oxygen and other dissolved gases from the boiler feedwater. Oxygen can rust the walls of the system's piping, while carbon dioxide, if not removed, can form carbonic acid, which will further corrode the pipes. One deaerator provides protection against corrosion; the other provides clean steam for the research institution laboratories.

Cooling a fever. Problem was, the research institution's boiler controls worked only intermittently, due to poor ventilation in the boiler room that sent ambient temperatures to as high as 110°F (43°C). The heat was causing the CompactLogix PLCs that were core to the master control system to fail sporadically. This shut down the boilers – and shut off heat and steam to the research institution's buildings and labs.

While this did not affect the boilers' safe operation, it did require staff to manually operate the boilers and the ancillary equipment. They also had to record the boilers' operating data each hour by hand, as part of their standard operating procedures. But, if troubleshooting was needed, the boilers' hand-recorded data history offered no insights as to what might have gone wrong and needed fixing. At times, they even kept the boiler room's doors propped open, trying to improve ventilation and lower the room's temperature.

Hoping for a cure. The research institution contacted a local boiler engineering firm to upgrade their control system. The upgrade corrected the failing PLC control modules in the boiler controls, but not the BOP controls – nor little else. For example, it provided no communication between the BOP master control system and the boiler system, so the control room had no visibility of the boilers' operation. As a result, operators still had to walk down the hall to the boiler room to monitor the controls and record their data.

What's more, the upgraded control system could have linked those controls to the open architecture of the research institution's Siemens APOGEE building automation system (BAS), but didn't. It also didn't correct an irritating issue the research institution had with not owning its BOP and boiler control software code, which meant that any modifications and troubleshooting required an expensive service call from the vendor.

In retrospect, the research institution's initial installation of its boiler and BOP controls was a case of the integrator adapting what appeared to be a standardized solution without carefully evaluating the operating environment. Also, it seemed that little or no consulting with the research institution's facilities team was done, given the lack of effort to connect the upgraded master boiler and BOP control systems with the BAS – an obvious and not-too-difficult solution objective.

Providing a flexible yet highly integrated solution

To address all the shortcomings of the initial installation, a functional specification was developed. Especially important was to design a solution that would operate in ambient temperatures up to 158°F (70°C). This high-temperature requirement was more a measure of the research institution's frustration with the existing PLC failures due to the boiler room's typically oven-like environment than it was a concern that the room's actual temperature would ever rise that far.

The research institution also wanted to add a new deaerator, be able to reset the lead/lag timings of the three boilers to optimize energy efficiency and save fuel costs, and have a development station for viewing and modifying the control source code.

To this set of requirements was added two others, both with important benefits. One was to implement modular code, using function blocks for device logic and having the code segmented by the network segments of the boiler and BOP components. This would help the research institution manage the code much more efficiently and effectively over time. The other was to provide a comprehensive set of documentation, including the functional design, test protocols, and an operations manual, none of which existed before.

Master panel replacement. To start, a new master panel was designed around a Siemens SIMATIC S7-1500 PLC and SIPLUS extreme I/O. The ruggedized SIPLUS extreme line, which now includes Siemens advanced PLCs, is identical to the SIMATIC line, except for additional design, engineering, and manufacturing considerations to address harsh operating conditions. From a programming standpoint, the SIPLUS extreme version PLCs are identical to the standard S7-1500 PLCs – all software engineering is done using the Totally Integrated Automation (TIA) Portal.

Specifically, a SIMATIC S7 CPU-1513 PLC was selected for this application. To further assure the customer that ambient heat issues would be controlled, a small air conditioning unit was also to be installed to mitigate the boiler room's poor ventilation. Redundant power supplies were required to offer additional protection against heat. And the breakers had to be derated, as their amperages vary according to ambient temperature. For example, a breaker rated at 30 amps at 104°F (40°C) drops to 23.4 amps at 158°F (70°C), the solution's upward temperature limit.

The SIMATIC S7 CPU-1513 PLC was also chosen because it is among the latest and most advanced models in the Siemens S7 portfolio. Not only did this ensure the solution could take advantage of the newest PLC features and capabilities that Siemens offers, but it also could provide a design life cycle of at least 15 years, with upgradeability and support from Siemens along the way.

The SIMATIC S7 CPU-1513 PLC executes the user program located on the device's memory card, and the CPUs built in PROFINET interface enables simultaneous communication with other devices, including other controllers, HMIs, and systems. Integrated system diagnostics provide alerts and troubleshooting via the CPU's own display, an HMI or, thanks to an onboard web server, any remote device, including a PC, tablet, or even smart phone.

Open architecture helps. Given the SIMATIC S7 CPU-1513 PLC's open software architecture, both the boiler and BOP master control panels were able to manage the activities of many third-party devices. Although a Siemens Comfort Panel HMI was recommended as one of two options, the research institution chose a model from another manufacturer for its higher temperature rating. Although this other choice was not programmable in the TIA Portal, it was made to work with the SIMATIC S7 CPU-1513 PLC with extra effort. If anything, the exercise made the TIA Portal's time-saving benefits that much more appealing.

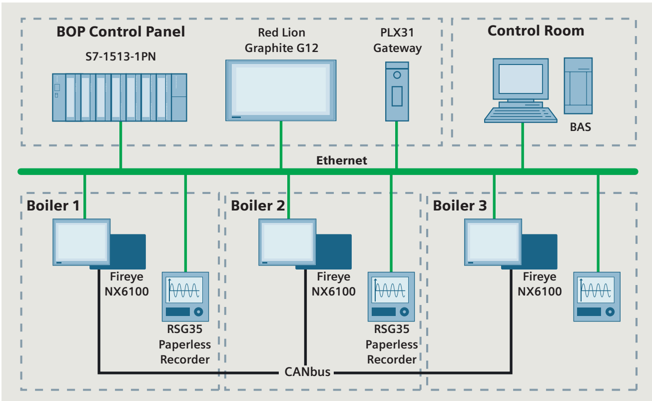

Figure 1. Upgraded architecture of boiler and BOP solution

To facilitate communications and control between the SIMATIC S7 CPU-1513 PLC and each boiler's third-party controller and paperless data recorder, a third-party, bi-directional communications gateway was used. It enables a combination of Siemens Industrial Ethernet (SIE) to operate on a network backplane along with Modbus TCP/IP extensions to the device level.

While the former supports 20 clients, reading and writing to a number of S7 databases, the latter supports 10 read/write clients and five servers for up to five different data sets. The gateway also linked the SIMATIC S7 CPU-1513 PLC and master boiler and BOP controls to the Siemens APOGEE BAS. Setting it all up to communicate with test boiler controllers was relatively easy, taking just two hours, including wiring the power supply.

Time-saving code reuse. The TIA Portal and function block programming were used to engineer the solution's software to the greatest extent possible, given the limitations of the various third-party devices, which required programming outside the TIA Portal. However, after writing the code for connecting the third-party devices into the solution, it was stored in the project's TIA Portal library for easy management during implementation.

Where possible, existing function block code was adapted for use, which helped save days, if not weeks, of time. For example, Modbus function blocks used to facilitate inter-device communications and already proven in other customer solutions were adapted for use. Conversely, function blocks developed for this solution will be stored in TIA Portal libraries for use with future customers. For systems integrators, code reuse is a critically important key to delivering profitable solutions on time and on budget.

A lasting solution, with no system failures after more than a year of operation

The research institution's facilities staff, especially its boiler operators, are delighted with the solution that the Siemens SIMATIC S7-1500 PLC has enabled. A year after deployment, they have reported no failures of any control components – neither the Siemens PLC nor the third-party ones operating at the boiler level – across the solution's upgraded boiler control panels.

In addition to greater reliability, they also have much more control over the lead/lag operations of the three boilers. This enables them to fine-tune which boilers are used, in what order, and when. The benefit is improved heating and steam delivery, plus more energy-efficiency and fuel savings.

Greater visibility. With the upgraded boiler control panels, now integrated with the Siemens APOGEE BAS, the staff has much greater visibility of their entire boiler operation. The BAS integration offers real-time and historical insights into how the boilers are operating within the greater context of the research institution's buildings as a whole. If boiler or BOP troubleshooting is needed, operators are notified along with sufficient diagnostic data to provide them the means to respond much more quickly than before, even remotely if necessary.

Finally, the research institution now owns the code, so its staff can use the development workstation to modify the solution's software and configurations as desired. The function block code is fully commented to make it easier for anyone unfamiliar with the code to understand and isolate whatever functions they need to work on. Also, the comprehensive set of documentation provides further support and autonomy. No longer will they have to call the vendor and pay for modifications they can do themselves. Of course, Applied Control Engineering, Inc. and Siemens will always be available for escalated support, if needed.

Lesson learned. Today the research institution has a lasting, highly functional set of boiler and BOP master controls that will serve them reliably for many years to come. That the road to this point was initially so painful is a cautionary story for prospective end-users of any automation and control solution: avoid adaptive, one-size-fits-all approaches, and seek an integrator that first strives to fully understand the context of a problem and then designs a solution to address it.

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