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Dominion's 1,346-MW Warren County Generating Station in Virginia uses a 3-on-1 configuration with Mitsubishi Hitachi Power Systems America 501GAC combustion turbines. High-efficiency, combined-cycle, natural gas-fired plants such as this can benefit from high-fidelity plant simulations that allow for virtual training and testing before execution in the real world.

A Cutting-Edge Approach to Combined-Cycle Plant Simulation

BY KEITH NELSON AND BILLY MOORE

High-fidelity plant simulators are a cornerstone for robust operator training, event replay and analysis, engineering development, and 'what if' analysis. They are beneficial tools to help today's combined-cycle power plants address operator turnover, complex operational demands, and ensured reliability. However, it can be very challenging to manage traditional simulators, given the specialized expertise required to develop and maintain custom plant models, and the complexity of maintaining two simulator software platforms—both the simulated process models platform and the simulated control system platform.

At its Mississippi Power Daniel plant, Southern Company is now implementing a first-of-its-kind, high-fidelity, combined-cycle simulator that uses leading-edge technology to overcome these traditional simulator issues. Working in conjunction with Emerson Process Management, Southern Company implemented a unique phased simulator approach that provides all the benefits of a traditional plant simulator with a significantly reduced maintenance burden and improved long-term sustainability.

Unit 3 of Southern Company's Daniel Electric Generating Plant is a 2-on-1 combined-cycle facility with a capacity of 530 MW. As is the case with many of the generating plants in the United States, staff turnover has been driving the need for efficient and effective training of control room personnel. In addition, due to market conditions, reduced cycling and load following have dramatically reduced opportunities for on-the-job training. To address the risks posed by this situation, plant management decided to procure a unit simulator.

Southern Company had a good deal of experience with multiple simulator suppliers and was familiar with the technical challenges associated with their existing simulators. They came to the project with well-defined goals to better serve the needs of both the operations and engineering staff, including improved ease of use and decreased maintenance requirements. Because they understood the challenges associated with duplicating the actions of the so-called 'black-box' controls (e.g. OEM-provided turbine controls), they knew they wanted a simulator designed and configured by a company with expertise in all power plant system controls.

PROJECT GOALS

The project sought to develop a system that would:

1. Include an operator training simulator with quick implementation—12 months or less
2. Include high-fidelity plant equipment models to provide realistic dynamic response to operator actions and simulated abnormal conditions
3. Effectively duplicate/emulate third-party control system graphics and hard-panel control stations
4. Ensure that the controls and plant models could be easily updated and kept in step with the plant configuration
5. Support usage of simulator as a test bed (offline engineering tool with process simulation) to enable modeling, control, and plant equipment changes without affecting operations

Southern Company specified that the simulator should be of the 'high-fidelity' type. The thermodynamic performance and dynamic response of the simulated plant equipment and systems were to be based as much as possible on first-principles engineering/physical models. Recognizing that the OEM-supplied turbine control systems were already predominantly black-box in nature, the action and response of those control systems were permitted to be 'emulated'; their behavior could be simulated based on measurements of the operating control systems' characteristics.

All modeling and control logic of the simulator was expected to be open and available for inspection, tuning and modification (including the emulated empirical models), and controls of black-box systems.

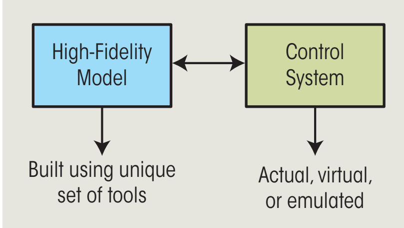
EMBEDDED SIMULATION TECHNOLOGY

Control System and Equipment Models Integrated on One Platform

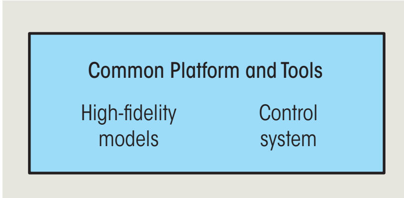
One of the historical challenges of building high-fidelity simulators has been that the first principles models of the plant equipment and the plant control systems were supplied by different companies on different platforms. This has exacerbated the difficulty of producing realistic plant responses to control system actions or to unexpected events like plant equipment failures. In addition, having two systems on two platforms has meant that modifications had to be accounted for on both platforms by two different sets of subject matter experts, and the dynamic response of the modified system had to be re-tuned to restore its realism.

Plant management chose to implement Emerson's Ovation™ simulator with *embedded simulation*, to meet their goals. Embedded simulation means that the first principles models of plant equipment are embedded

Traditional High-Fidelity Simulator 1



Control System-Embedded Simulation Solutions 2



in the control system computing platform. The Emerson simulator includes a complete suite of plant equipment models (algorithms) that are connected in a flow diagram-type structure, modeling plant systems in a hierarchical manner and ensuring continuous adherence to the laws of thermodynamics, fundamentals of heat transfer, and fundamentals of fluid mechanics. Ultimately, this results in a high-fidelity model of the plant.

Ease of Maintenance

With embedded simulation, standard control system engineering tools are used to construct the plant system models in exactly the same way they are used to construct control logic systems. Modifications to plant equipment or controls are accounted for in one place using one set of tools, making updates and maintenance of the simulator much more straightforward than was possible with traditional simulator architectures.

This supports Daniel Plant management's goals of simplified maintenance that can be performed

Fidelity Flexibility

TABLE 1

	New Control System-Embedded Plant Models	Traditional Simulator Plant Models
Model Location	Embedded in virtual controllers	Resident on separate hardware platform
Environment for Simulation and Control	Single platform - same system	Multiple platforms
Engineering Tools	Standard control system engineering tools	Uses separate engineering tools that require specialized programming knowledge
Instructor Station	Allows monitoring, scenarios, and trainee evaluation with a next-gen interface	Antiquated user interface, have same tools but often never used
Virtual Configuration	Yes	Yes
Model Fidelity Capability	High based on first-principle	High based on first-principle
Mixed Fidelity	Yes	No
Sourcing	Singe party	Various
Services	Comprehensive set for both simulation and controls	Simulation only

by Southern Company engineers, providing a lower total cost of ownership over the life of the simulator.

Fidelity Flexibility

With the controls and models being programmed in the same environment, there are no obstacles to mixing simulation models of varying fidelities. This provides practically unlimited ability to balance fidelity with budget and allows a simulator buyer/owner to acquire a simulator with relatively small investment/low fidelity, and then piecewise upgrade the fidelity as budget and/or engineering time becomes available.

HMI AND INSTRUCTOR STATION

It was important to ensure that the simulator Human Machine Interface (HMI) was as realistic as possible, so that student operators could seamlessly transfer their experience from simulator training sessions to the plant control room. At Daniel, simulator workstation arrangements mimic the actual plant control room, so that operators are more likely to internalize the actions necessary to perform control functions located in different areas of the control room. Hard panel control stations are emulated on the simulator's computer screens via digital photographs of the actual panel stations, with embedded active components such as push buttons, pistol grip switches, analog gauges, etc. Instructor Station screens and tools were designed with significant input from Southern Company, making the instructor's efforts much more effective and significantly increasing the ease with which abnormal operating scenarios can be simulated.

PROJECT EXECUTION

Daniel Unit 3 was in urgent need of an operator training simulator. At the outset of the project, Emerson had not yet developed models that accurately simulated the operation of the combustion turbines (CT) and the selective catalytic reduction (SCR) unit, or the interplay between these two. It was decided the project would be executed in two phases.

Phase 1, completed in Spring 2015, included:

- Final high-fidelity models for all the plant equipment and systems, except the CTs and the SCR
- Empirical models for the CTs and SCR
- Final control logic for the Ovation™ control system and emulations of the third-party supplied controls
- Software-emulated hard panels and third-party control graphics
- All required simulator hardware

To compress the project schedule, simulator software configuration was performed in an environment with remote connectivity, concurrent with engineering, ordering and assembling the project hardware and configuring the software platform on that hardware. Southern Company's engineers and operators were able to remotely participate in system testing and tuning through a virtual private network (VPN) connection, ensuring the accuracy and realism of the simulation while drastically cutting travel time and costs.

Phase 1 results provide proof of concept for mixed-fidelity simulation, where high-fidelity and empirical simulation of major plant systems can be combined seamlessly on the same simulator. The mixed-fidelity approach can be used to control costs and compress project schedule while achieving desired functionality.

Phase 2 includes upgrading the Daniel 3 empirical models for the CTs and SCR to high-fidelity models.

CONCLUSION

Southern Company has been using

the Phase 1 simulator since delivery and is very satisfied with its utility as a training simulator, both from a student and instructor perspective. The mixed-fidelity capability of embedded simulation was successfully leveraged to support a phased implementation schedule. This allowed expedited delivery of a realistic and pragmatic operator training tool that covers normal operations, startups, and upset conditions. The physical models embedded in the control system platform make every physical model and control algorithm accessible to Southern Company engineers via the standard control system engineering tools. This facilitates upkeep and gives engineers expanded flexibility to perform maintenance via in-house personnel. Engineers also have cross-functional use of the simulator as an engineering test bed, enabling trials of changes to both plant equipment parameters and control techniques in a harmless virtual environment prior to implementation in the real world. pe

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