NETL

Advanced Virtual Energy Simulation Training and Research (AVESTAR™) Center

Description

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has established world-class **Advanced Virtual Energy Simulation Training and Research (AVESTAR™) Center** dedicated to accelerating operational excellence for clean, electricity-producing power plants capable of carbon dioxide (CO_2) capture. Attaining operational excellence requires that energy companies maximize the efficiency and profitability from their operations through excellent control and drive maximum business value from all their plant assets, all while reducing negative environmental impact and improving safety. Driving people excellence via the development, training, and empowerment of a highly-skilled engineering and operations workforce is another critical component of operational excellence. The AVESTAR Center is addressing all of these goals by bringing together dynamic simulation-based technologies and state-of-the-art simulator facilities, managed by leading energy experts. Programs offer industry workforce training, engineering education, and collaborative internationally-recognized R&D focused on the safe, efficient, and reliable operation of clean energy plants.

Immersive 3-D virtual reality adds a dimension of realism to training scenarios

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U.S. DEPARTMENT OF
ENERGY

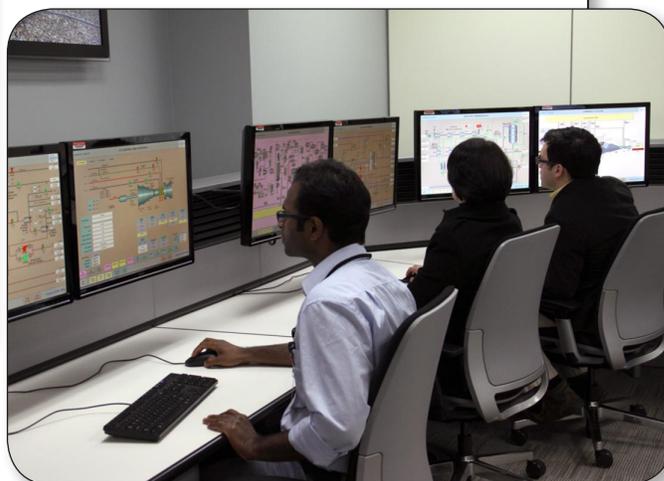*Dynamic Simulator / Operator Training System*

The AVESTAR Center is built around a portfolio of non-proprietary, high-fidelity, real-time dynamic simulators with operator training systems (OTSs) and 3-D virtual immersive training systems (ITSs) deployed in an integrated control room and energy plant environment. The full-scope dynamic OTSs enable engineers and operators to experience a wide range of operating scenarios, including normal full-load operation, plant startup, shutdown, cycling, power demand load following, and variable CO_2 capture rates. Users can also analyze an energy plant's response to disturbances (e.g., fluctuating feedstock composition), equipment malfunctions (e.g., pump failure), and abnormal situations (e.g., liquid and gas leaks).

The first-of-a-kind 3-D virtual ITS technology is used for energy plant familiarization and walkthrough, as well as interactive training of field operators. By fully integrating the real-time dynamic simulation-based OTS with the virtual reality-based ITS, the training scope covers both control room and field operators, providing hands-on experience with the plant's physical operation and illustrating how various pieces of equipment will operate under almost any scenario and condition. The benefits include more realistic training scenarios, improved communication and collaboration among work crews, off-line evaluations of plant procedures, and training for safety-critical tasks and rare abnormal situations.

Leveraging AVESTAR's simulation technology and facilities, the NETL has established an industry workforce training program in collaboration with its training partner, Fossil Consulting Services (FCS). The program offers a variety of integrated gasification combined cycle (IGCC) courses ranging from introductory to advanced, that merge classroom learning and simulator-based learning in a control-room operations environment. The AVESTAR team also works directly with clients to analyze their needs and goals for customized training programs. Target audiences include control room and field operators, as well as engineers and managers from electric utilities, engineering firms, and equipment vendors. The AVESTAR Center is developing a workforce well prepared to operate and control commercial-scale energy plants with CO_2 capture. Simulation-based training better prepares participants to manage the plant closer to economic constraints while minimizing or avoiding the impact of any potentially harmful, wasteful, or inefficient events.

With support from the NETL-Regional University Alliance (NETL-RUA), the AVESTAR Center is also used to augment graduate and undergraduate engineering education in the areas of process simulation, dynamics, control, and safety. In addition, the AVESTAR team is reaching out to regional community and technical colleges with power plant training programs. Students and researchers gain
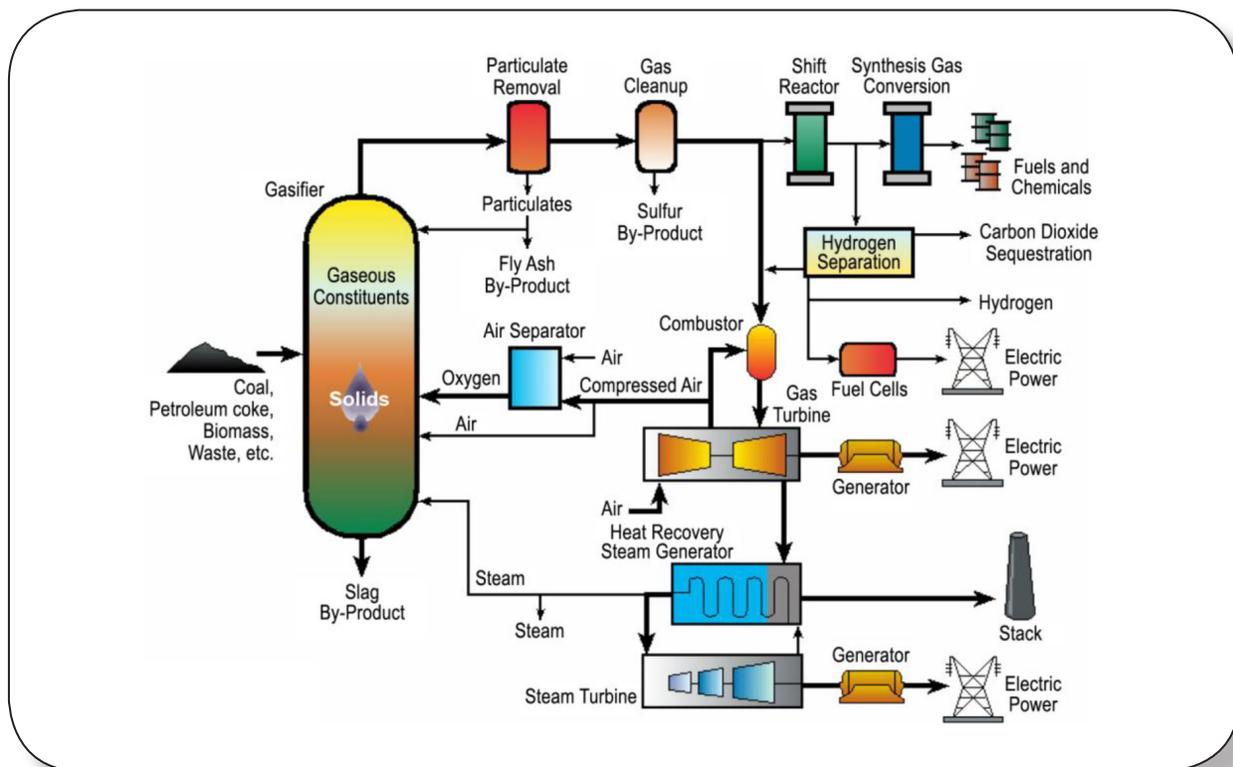
Integrated Gasification Combined Cycle Plant

hands-on simulator-based training experience and learn how the commercial-scale power plants respond dynamically to changes in manipulated inputs, such as coal feed flow rate and power demand. Students also analyze how the regulatory control system impacts power plant performance and stability. In addition, students practice start-up, shutdown, and malfunction scenarios. The 3D virtual ITSs are used for plant familiarization, walk-through, equipment animations, and safety scenarios.

Under the NETL's Advanced Research Sensors and Control program, AVESTAR team is pursuing an innovative and collaborative R&D program in the areas of coordinated plant-wide control, model predictive control, and optimal sensor placement. Other R&D focus areas include high-fidelity equipment modeling using partial differential equations, dynamic reduced order modeling, 3D virtual plant simulation, and modern grid applications. The AVESTAR Center also participates in smart manufacturing (SM) R&D and serves as a virtual energy plant test bed for SM technologies. AVESTAR's high-fidelity real-time dynamic simulators are used to test integration with SM software platforms and plug-and-play interoperability with customizable real-time data-driven applications in areas such as modeling and simulation, sensors and control, process monitoring and fault diagnosis, and decision-making analytics and enterprise-wide optimization.

The AVESTAR Center is operated by NETL with locations at NETL in Morgantown, WV and at West Virginia University's National Research Center for Coal and Energy, also in Morgantown.

IGCC Dynamic Simulator and Immersive Training System

The first dynamic simulator and ITS deployed at the AVESTAR Center is a next-generation, IGCC plant with CO_2 capture. The IGCC reference plant is a modified version of an IGCC system presented in NETL's report "Cost and Performance Comparison of Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Final Report (DOE/NETL-2010/1397), Rev. 2, November 2010." The coal, biomass, and/or petroleum coke-fired IGCC plant areas include air separation unit; entrained down-flow gasifier with radiant syngas cooler; two-stage water gas shift; dual-stage acid gas removal process where the second stage captures CO_2; Claus plant for sulfur recovery; combined cycle including gas turbines, heat recovery steam generator, and steam turbine cycle with three pressure levels; and electrical system.

The highly flexible OTS software and hardware configuration allows concurrent training on separate gasification and combined cycle simulators, or up to two IGCC simulation sessions at the same time. The dynamic simulator is combined with a plant-wide ITS to create an accurate, 3-D virtual experience of the IGCC system.

Primary Project Goals

• Accelerate progress toward achieving operational excellence for advanced near-zero emission energy plants.

• Develop and deploy a portfolio of non-proprietary, full-scope, high-fidelity, real-time dynamic simulators with 3D virtual immersive training systems for a wide variety of advanced energy plants, starting with an IGCC system with carbon capture. Future dynamic simulators are under development for a supercritical once-through (SCOT) pulverized coal power plant and a natural gas combined cycle (NGCC) power plant. These two new high-fidelity, real-time dynamic simulators will provide training, education, and research on plant operations and control for SCOT and NGCC systems, as well as processes for post-combustion carbon capture, utilization, and compression.

• Offer comprehensive simulation-based training, enhanced engineering education, and collaborative internationally recognized R&D programs on the operation and control of clean energy plants.

• Use experiential learning to develop a workforce well prepared to operate commercial-scale power plants with CO_2 capture.

• Enhance engineering education in the areas of process simulation, dynamics, control, and safety.

• Implement strategic R&D collaborations with the process and energy industries, engineering and construction firms, technology suppliers, government labs, universities, and simulator software and service providers.

• Conduct leading-edge R&D in the areas of high-fidelity, real-time dynamic simulation, reduced order modeling, model predictive control, sensor placement, risk and safety analysis, virtual engineering, modern grid, and smart manufacturing.

Key Dynamic Simulator Features

• High-fidelity, real-time dynamic models for generic, commercial-scale energy plants with carbon capture.

• Full-scope dynamic simulator capabilities including complete cold, warm, and hot start-ups; shutdowns; cycling and load changes; normal, abnormal, and emergency operating conditions; control strategy analysis; malfunctions/trips and alarms; scenarios, trending, and snapshots; data historian; and trainee performance monitoring.

• Extendable to incorporate carbon capture, compression, and utilization technologies.
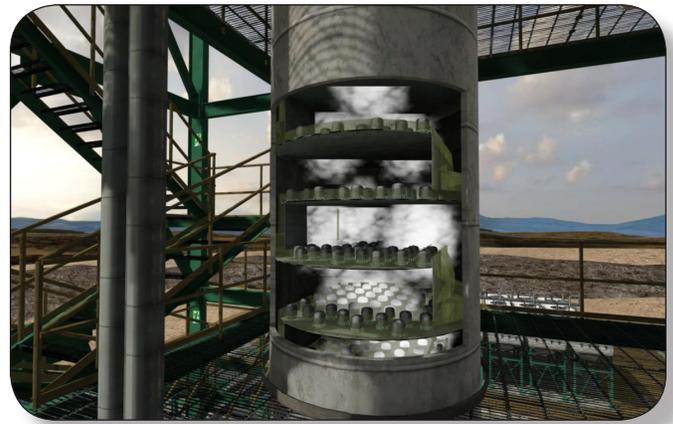
3-D Virtual Immersive Training System

Benefits

The AVESTAR Center provides the following impact and benefits:

• Provides users with world-class simulation tools for research, training, and education.

• Demonstrates key energy plant technologies including gasification, combustion, carbon capture, and combined-cycle power generation.

• Provides virtual test bed for optimizing the operation and control of carbon-capture, -utilization, and -compression technologies.

• Enables combined control room and plant crew training in an immersive 3-D plant walk-through environment.

• Develops and trains the existing workforce and a new generation of engineers, thereby satisfying the growing industry demand for expertise and experience with the analysis, operation, and control of commercial-scale energy plants with carbon capture.

• Serves as a focal point for collaborative R&D with universities, research organizations, government labs, software and service providers, and the power and energy industries.

• Delivers better preparation for actual operating scenarios and emergencies, which improves the safety, environmental impact and overall efficiency of energy plants.

• Accelerates the application of advanced dynamic simulation technology to better achieve the aggressive design, operability, and controllability goals for high-efficiency, zero-emission power plants.

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