U.S. DEPARTMENT OF ENERGY

UK-US Collaboration on Fossil Energy R&D

Virtual Plant Simulations

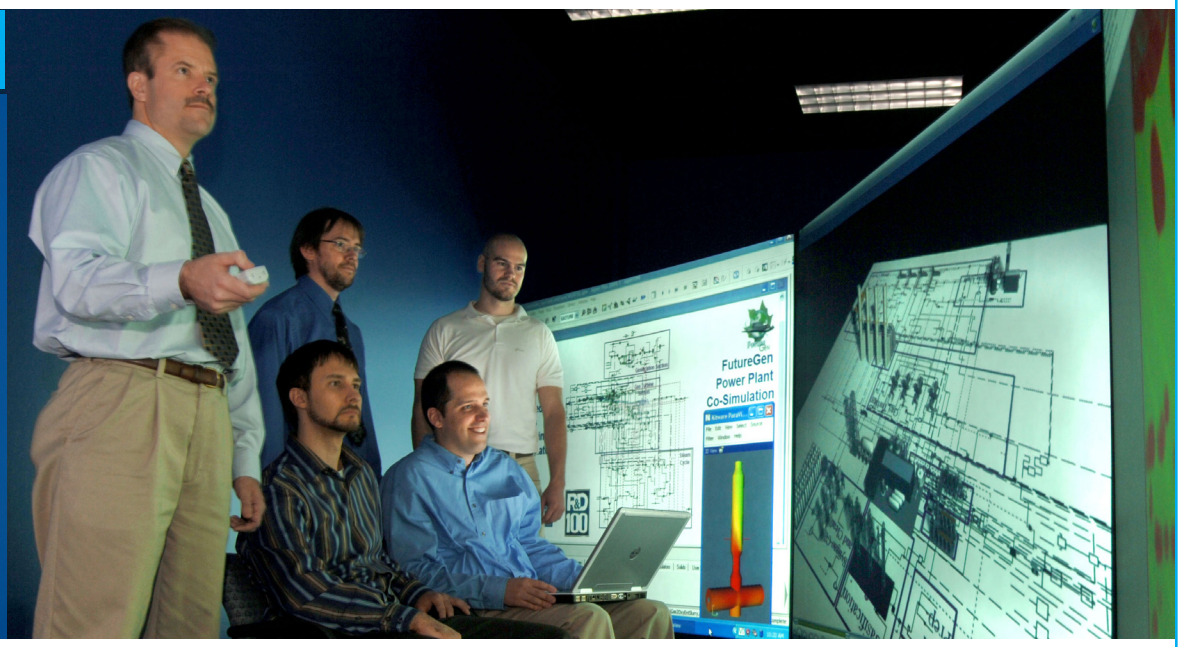
DEPARTMENT OF ENERGY & CLIMATE CHANGE

project duration
October 2004 - September 2007

project partners

UK:
K-S Technology Ltd.
Process Systems Ltd.
Enterprise Ltd.
Alstom Power
Engineous Software, Ltd.
Fluent Europe Ltd.
RWE nPower
Doosan Babcock Energy Ltd.
University of Ulster

US:
National Energy Tech. Lab.
Ansys Inc.
Aspen Technolgy, Inc.
Carnegie Mellon University
Iowa State University
West Virginia University
Vishwamitra Research Institute



background

Under the auspices of the U.S.-U.K. Memorandum of Understanding and Implementing Arrangement for Fossil Energy Research and Technology Development, the U.S. Department of Energy's (DOE) Office of Fossil Energy participated in a three-year collaboration on virtual plant simulation with a project team supported by the Department of Energy and Climate Change in the United Kingdom. Virtual plant simulation will help the U.S. and U.K. fossil energy industries to develop new and cleaner power generation systems with lower cost, shorter time-to-deployment, and reduced technical and commercial risk.

The U.S.-U.K. collaboration leveraged the strengths and synergies of the ongoing NETL Advanced Process Engineering Co-Simulator (APECS) project and the recently completed U.K. Virtual Plant Demonstration Model project. The R&D100 award-winning APECS system is an innovative software tool that uses the process industry CAPE-OPEN (CO) software standard to combine best-in-class process simulation, computational fluid dynamics (CFD), and virtual engineering software. At NETL, APECS provides high-fidelity process/CFD co-simulation capabilities for the design of sophisticated, highly-integrated plants such as the DOE's FutureGen power and hydrogen generation system with carbon capture and storage. Collaborative R&D partners on the APECS project include NETL; ANSYS Inc., the world's leading supplier of CFD software and services; Aspen Technology, Inc., a major supplier of process simulation software; Carnegie Mellon University; Iowa State University; West Virginia University; Vishwamitra Research Institute; and Alstom Power, a major worldwide industrial player in equipment and services for power generation.

The U.K.'s Virtual Plant Demonstration Model (VPDM) framework also exploits CO-compliant integration technology to deliver virtual plant co-simulation capabilities, with special emphasis on allowing secure web-based execution of distributed, heterogeneous equipment models. In the recently completed VPDM project, R&D partners included: Alstom Power Ltd, Engineous Software Ltd, Fluent Europe Ltd, RWE npower plc, K-S Tech Ltd, Doosan Babcock Energy Ltd, Process Systems Enterprise Ltd, and the University of Ulster.

objectives

The key objective of the U.S.-U.K. collaboration was to develop compatible virtual plant co-simulation software platforms for application to advanced fossil-energy power generation systems. Other important objectives included:

- Improving the focus and efficiency of APECS and VPDM project activities through information exchange and dissemination
- Providing plug-and-play interoperability for power plant equipment models (e.g., combustors, gasifiers, heat exchangers, gas and steam turbines, and fuel cells)
- Increasing leverage for cooperation with process simulation and CFD software vendors and open-standards organizations
- Developing potential for long-term cooperation in virtual plant simulation from experience gained during project collaborations

technical approach and accomplishments

The technical approach focused on the following four key collaborative tasks:

Task 1: Implement CAPE-OPEN software standard for interoperability of equipment models.

CAPE-OPEN (CO) is the de facto standard for plug-and-play equipment model interoperability for process simulation software. The CO standard is managed, tested, and disseminated by the internationally recognized, user-driven organization, CAPE-OPEN Laboratories Network (CO-LaN, www.colan.org), representing more than 50 member organizations from the process industries, academic institutions, research entities, and software vendors.

Accomplishments

- Adopted CO software standard for model integration in the APECS and VPDM frameworks
- Verified CO-compliant interoperability between U.S. equipment models and the VPDM framework, as well as between U.K. equipment models and NETL's APECS system
- Tested running CO-compliant FLUENT® CFD equipment models within VPDM using APECS technology
- Demonstrated a process/CFD co-simulation of RWE npower's Didcot A conventional coal-fired power station using APECS technology to couple a detailed CFD furnace simulation with a VPDM process simulation of the power plant

Task 2: Evaluate reduced-order models to enhance speed of process/CFD co-simulation

A potential barrier to the widespread use of process/CFD co-simulation is that the integration of high-fidelity equipment models may lead to unacceptable co-simulation turnaround times, especially for cases in which one or more CFD models are embedded in the iterative process flowsheet-solution procedure. One promising solution is the use of reduced-order models (ROMs) that approximate the CFD-based equipment simulations, while keeping the computational cost manageable.

Accomplishments

- Evaluated order reduction techniques for application to CFD-based equipment models
- Exchanged information on speed, accuracy, and applicability of ROMs as implemented in APECS and VPDM
- Demonstrated the use of an APECS neural network-based ROM in VPDM

Task 3: Adopt common specification for Internet security and communication

By adopting a common specification for secure, web-based execution over the Internet, virtual plant simulations can use the best equipment models available in the U.S. and U.K. while ensuring that the intellectual property contained within these models is fully protected.

Accomplishments

- Addressed issues such as model compatibility, operability over the Internet, secure communications between companies, and security of models at host sites so that companies will be comfortable in offering other parties the use of their in-house equipment models

Task 4: Define requirements for CAPE-OPEN dynamic simulation

Both the U.S. and U.K. virtual power plant simulation programs are planning to pursue dynamic co-simulation, especially for use in process control applications. The CO standard for dynamic model interoperability is under development by CO-LaN and its member organizations.

Accomplishments

- Identified the dynamic simulation requirements for power plant applications
- Worked with CO-LaN to ensure that the CAPE-OPEN standard for dynamic simulation satisfies the requirements for the APECS and VPDM projects

benefits

Virtual plant simulation benefits the U.S. and U.K. fossil energy industries in the following ways:

- Helps engineers to better understand and analyze the coupled fluid flow, heat and mass transfer, and chemical reactions that impact overall power plant design and operation
- Presents detailed equipment models in the context of plant-wide simulations, with recycle loops, heat integration, and water management
- Enables rigorous analysis and optimization of entire power plants with respect to CFD-related equipment model parameters
- Speeds technology development by reducing the pilot- and demo-scale facility design time and operating campaigns
- Offers opportunities to achieve the aggressive environmental, performance, and economic goals for advanced fossil energy power generation systems

Continued U.S.-U.K. collaboration on virtual plant simulation will accelerate the development of competitive power plant solutions and ultimately zero-emission technologies with significantly reduced development costs and technical risk.