NIST's Testbed for Optimizing Building System Performance

BY MARY KATE MCGOWAN, ASSOCIATE EDITOR, NEWS

The National Institute of Standards and Technology's Intelligent Building Agents Laboratory (IBAL) is a "building in a laboratory," said Steven Bushby, Fellow ASHRAE. Actual buildings are not conducive environments for conducting reproducible research due to changing internal loads and outside weather conditions, so NIST created a testbed to remove those concerns.

The IBAL testbed is a controlled environment with reproducible weather and building loads that NIST uses to analyze real building mechanical systems. The testbed reflects the complex control optimization problems of real buildings, said Bushby, who is the leader of the Mechanical Systems and Controls Group of the Energy and Environment Division of NIST's Engineering Laboratory.

The IBAL demonstrates agent-based optimization and control approaches on real equipment and allows researchers to understand the challenges when moving out of simulation into reality, said Amanda Pertzborn, Ph.D., Associate Member ASHRAE, who is a mechanical engineer in NIST's Mechanical Systems and Controls Group.

Real HVAC equipment has dynamic operations and discontinuities that need to be considered in a real control system, but system models often neglect transient behavior and only model steady-state conditions, Pertzborn said. So a testbed allows researchers to develop data-driven models using machine learning that will be used in the optimization of system operations.

Bushby said the industry is skilled at local loop control of a single piece of equipment but generally uses heuristics to make supervisory control decisions that affect energy-efficiency, indoor environmental control of a building and campus-scale energy performance based on chilled-water setpoints.

"We think that the industry can do much better, and that the use of intelligent agents may be part of the solution. The IBAL is a research platform to test and demonstrate these potential solutions," said Bushby.

Most of the IBAL's optimization efforts so far have been focusing on minimizing energy consumption while still meeting comfort requirements, he said.

Finding the Best Ways to Meet Building Loads

The IBAL has the major types of equipment found in real commercial buildings: air handling units, variable

The IBAL has two chillers with capacities of about 35 kW (10 tons) and 25 kW (7 tons) when chilling a 30% propylene glycol mixture to 7.2°C (45°F).

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An AHU with a 68 kW (20 tons) cooling coil, 60 kW electric heater, and steam spray humidifier is used to create reproducible weather conditions.

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air volume units, multiple chillers with differing capacity, a simulated cooling tower and ice storage.

The systems allow the researchers to model complex operations and challenge a control system to determine the best way to meet a building load, said Pertzborn, adding that they define "best" in terms of cost, thermal comfort and energy efficiency.

"Unlike a real building, we have carefully determined the measurement uncertainty of all our measurements. We can test one optimization approach, and then change it or substitute another and run the tests again with the same internal loads and the same 'outdoor' weather to allow direct comparisons," said Bushby.

The IBAL's first order of business was exploring techniques for developing agent-based models of the mechanical equipment performance in the context of optimizing the use of thermal storage, said Pertzborn.

"…Our early results seem to confirm that there are potentially significant benefits to an agent-based approach," she said.

Challenges and Advantages

The IBAL presents challenges, just like real building projects, said Bushby. They have discovered some of the lab's design assumptions do not match the as-built systems.

"For example, I had anticipated that the chillers would operate over a range of loads without cycling, but in reality, they have a very limited range," he said

Because the IBAL is a lab and not a full-size building, the thermal mass of the water in the system is small. When a chiller cycles off, the temperature spikes rapidly, and the impact of cycling is more significant than it would be in a real building, according to Bushby.

Simplifying assumptions in models may mean things do not work as expected in a real system. Bushby said these challenges show the importance of evaluating new technologies on real equipment. Despite the challenges, dealing with non-ideal situations is a benefit to using real mechanical systems instead of simulation, he said.

"Real control systems must be able to adapt to these kinds of problems. We expect that, in the future, we will take techniques that are successful in this laboratory and test them in actual building systems," he said. "It will be important to prove the ideas in a variety of buildings."

Affecting Different Parts of the Industry

The IBAL is expected to help different industry professionals from design engineers to equipment manufacturers to facility operators, said Pertzborn.

For design engineers, the testbed should support the development of guidance on how advanced control algorithms can influence their designs, such as the sizing and selection of equipment. For researchers, the lab's results and data can help stimulate academic and corporate research to build industry knowledge and improve products.

Regarding equipment manufacturers, the lab is expected to provide strategies for developing data-driven models of real equipment and strategies for integrating agent-based intelligent control into building controllers.

"One level of complexity is that the data-driven models require data before they can be used, so the control algorithm will require a non-data-driven model to control the building in the short-term. The solution

The IBAL contains four simulated zones, stacked one above the other at the center of this image, that generate cooling loads for the water system. Each zone is connected to a VAV unit, shown at the left.

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An ice storage tank can be used to meet the cooling loads instead of the chillers or water side economizer. This system allows loads to be shifted to times of the day when electric rates are lower.

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to this problem is something we hope to define," said Pertzborn, adding that NIST hopes to work directly with HVAC equipment and controls manufacturers to test ideas on a common platform.

For facility operators, the testbed is expected to provide tools that track equipment performance, so operators can see if their equipment is degrading. Data-driven models will update over time and can alert the operators to significant changes from previous versions of the model, said Pertzborn. The testbed is also supposed to help facility operators automate decision making, so they can focus on other work.

Facility owners could benefit from the performance and cost benefits of a more optimized operation, said Bushby.

"We expect this research to inform the development of guidelines, standards, methods of test and possibly industry-run product or design certification programs," said Bushby.

Future Possibilities

The IBAL does not interact with NIST's other testbeds but could in the future.

Researchers have considered integrating it with the Virtual Cybernetic Building Testbed (VCBT) and the Smart Grid Testbed Facility, said Pertzborn. She said the testbed could help projects in NIST's Fault Detection and Diagnostics and commissioning work.

As NIST is involved in research and standards development related to a future smart electric grid, Bushby said progress in that area would require much more collaborative interactions between buildings and the grid.

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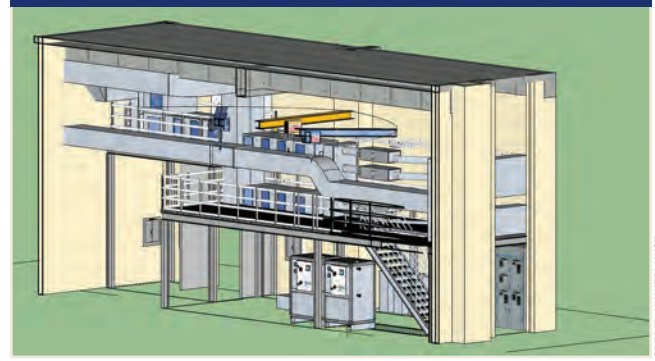

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"A smart grid environment complicates the optimization challenge because it introduces other opportunities and constraints. Linkage with the NIST Smart Grid Testbed in the future will create an opportunity to explore these building-to-grid interactions and how they impact system optimization," said Bushby, chair of ASHRAE's Smart Grid Application Guide Ad Hoc Committee.

NIST will engage collaborators from industry and academia to take full advantage of the capabilities of the IBAL. Data will also be posted on the lab's website.

"Researchers are always on the lookout for reliable data sets that can be used to advance their work. We have taken great care to understand and document our measurements. We plan to archive our experimental data along with meta information about what was being tested," said Bushby. ■