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Experimental analysis of simulated reinforcement learning control for active and passive building thermal storage inventory Part 2: Results and analysis

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Abstract

This paper is the second part of a two-part investigation of a novel approach to optimally control commercial building passive and active thermal storage inventory. The proposed building control approach is based on simulated reinforcement learning, which is a hybrid control scheme that combines features of model-based optimal control and model-free learning control. An experimental study was carried out to analyze the performance of a hybrid controller installed in a full-scale laboratory facility. The first paper introduced the theoretical foundation of this investigation including the fundamental theory of reinforcement learning control. This companion paper presents a discussion and analysis of the experiment results. The results confirm the feasibility of the proposed control approach. Operating cost savings were attained with the proposed control approach compared with conventional building control; however, the savings are lower than for the case of model-based predictive optimal control As for the case of model-based predictive control, the performance of the hybrid controller is largely affected by the quality of the training model, and extensive real-time learning is required for the learning controller to eliminate any false cues it receives during the initial training period. Nevertheless, compared with standard reinforcement learning, the proposed hybrid controller is much more readily implemented in a commercial building.

Keywords: Load shifting; Thermal Energy Storage (TES); Optimal control; Learning control; Reinforcement learning

1. Introduction

As the first part of the report of this research, the companion paper [1] has presented a brief introduction to the general background of this project. The fundamental theory of classic reinforcement learning and its variation, simulated reinforcement learning has been introduced. The hybrid learning controller was developed based on the architecture of simulated reinforcement learning. In order to validate the feasibility and evaluate the performance of the hybrid control approach, an experiment was conducted at a full-scale laboratory facility called Energy Resource Station (ERS) at the Iowa Energy Center in Ankeny, IA. A detailed discussion and analysis of the experiment and its results are presented in the following sections.

2. Description of experimental study

2.1. Introduction to the experimental facility

The experiment was carried out in the Energy Resource Station, operated by the Iowa Energy Center (IEC). The ERS is a unique demonstration and test facility, where laboratory-testing capabilities are combined with real building characteristics. The ERS is capable of simultaneously testing two full-scale commercial building systems side-by-side with identical thermal loading. The ERS building, a

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single-story structure with a concrete slab-on-grade, has a height of 4.6 m and a total floor area of 855 m^2. The building is divided into a general area (office space, service rooms, media center, two classrooms, etc.), and two sets of identical test rooms, labeled A and B, adjacent to the general area. The eight test rooms are organized in pairs with three sets of zones having one exterior wall (east, south, and west) and one set that is internal. Fig. 1 presents a layout of the ERS including the four sets of identical test rooms used for the experiment.

The test facility has a central heating plant, consisting of a natural gas-fired boiler, and a cooling plant with three nominal 35 kW air-cooled chillers that operate in both chilled-water and ice-making modes. The chilled-water loop is filled with 22% propylene glycol water solution. In addition, the building includes a 440 kW h internal melt ice-on-tube thermal energy storage tank as well as pumps and auxiliary equipment needed to provide cooling. Hence, several modes of operation between these sources of cooling are possible in order to supply chilled-water to the air-handling units (AHUs).

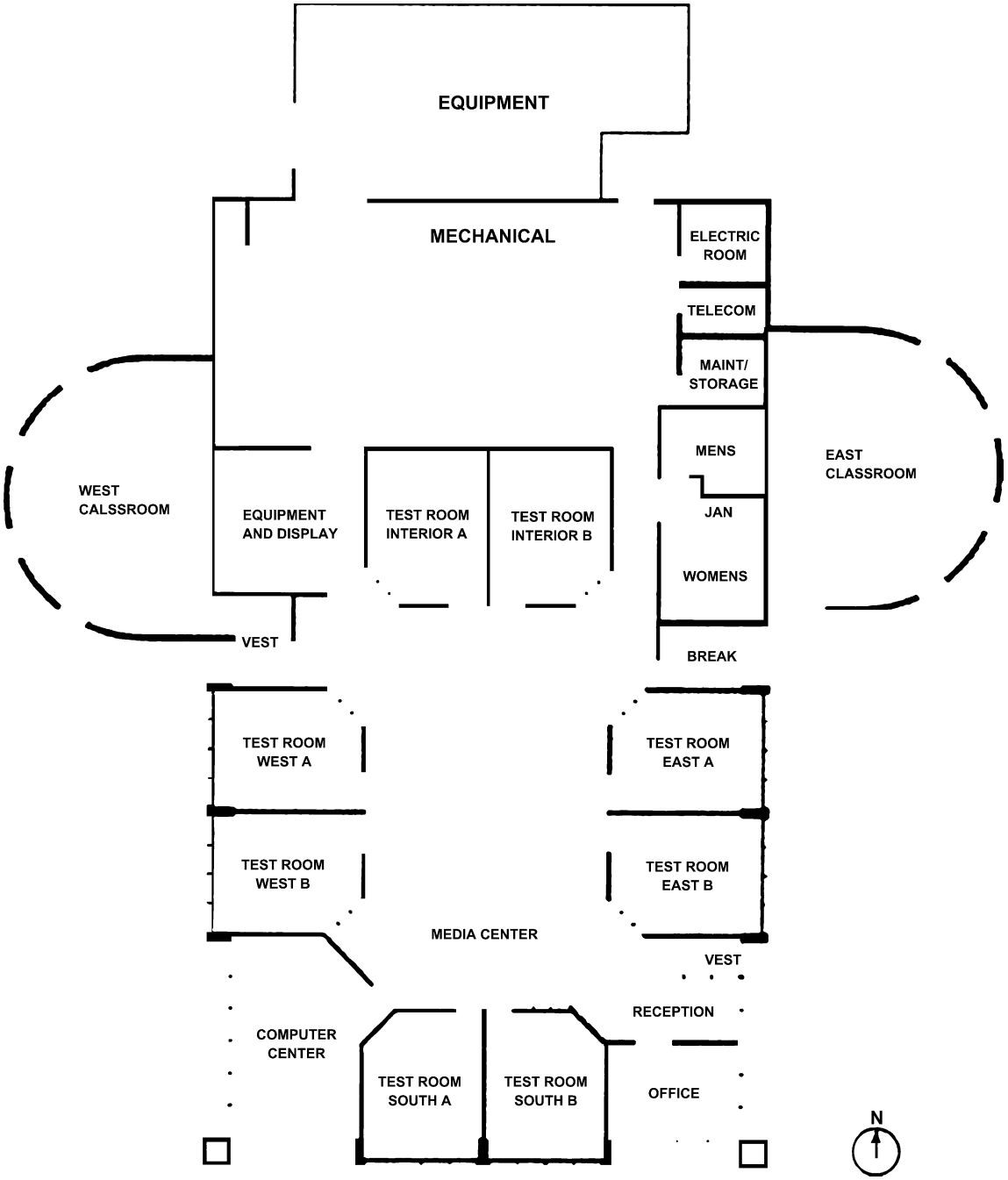

Fig. 1. Layout of the test facility at the Energy Resource Station (ERS), Ankeny, IA.