MLE+: A Tool for Integrated Design and Deployment of Energy Efficient Building Controls

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ABSTRACT

Simulation engines for buildings can be realistic and accurate, but only provide basic control interfaces. Control engineers have developed robust and complex controls for energy-efficient building operation though such methods are often based on simplistic physical models. To address this issue, we developed MLE+, a tool for energy-efficient building automation design, co-simulation and analysis. This tool leverages the high-fidelity plant simulation capabilities of EnergyPlus building modeling software and the scientific computation and design capabilities of Matlab/Simulink for controller design. MLE+ facilitates integrated building simulation and controller formulation with integrated support for system identification, control design, optimization, simulation analysis and communication between software applications and building equipment. MLE+ has been successfully used to generate schedules for building HVAC control systems for peak power minimization.

1. INTRODUCTION

MLE+ (Fig. 1) is intended as a tool for building energy research and development for researchers familiar with Matlab that want to couple it to realistic building energy simulation software like EnergyPlus. EnergyPlus is one of the most robust and complete buidling energy analysis and thermal load simulation tools available and it has become the de facto whole building simluation of the U.S. Department of Energy. The following are the main features of MLE+:

1. **Simulation configuration**: The MLE+ front-end (Fig. 2) streamlines the co-simulation configuration process by linking the building model and the controllers. This reduces setup time and configuration problems.

2. **Controller design**: MLE+ provides a control development workflow and graphical front-ends for designing advanced control strategies.

3. **Simulation-based optimization**: MLE+ can be used to find optimal parameters or control sequences for building system simulations in EnergyPlus.

4. **Data analysis**: After a co-simulation run, the output data from EnergyPlus can be aggregated, analyzed and visualized in Matlab.

5. **Building Management System Interface**: MLE+ provides a BACnet interface for real-time deployment of green schedulig methods for building equipment.

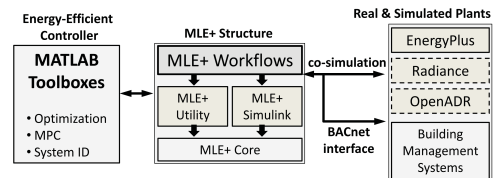6. **Matlab environment**: MLE+ allows complete access to the Matlab environment and toolboxes such

Figure 1: MLE+ interfaces control systems toolboxes with building models and systems
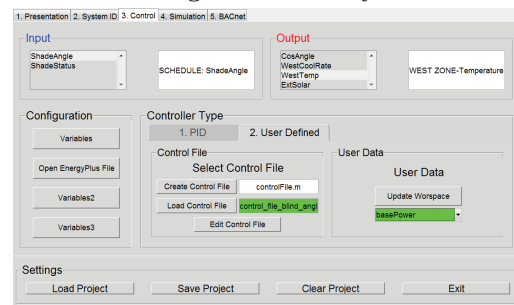

Figure 2: MLE+ tool interface

as Global Optimization Toolbox, System Identification Toolbox and Model Predictive Control Toolbox.

2. TEST CASES

We have implemented two test studies to showcase MLE+ capabilities. The objective of the first case is to generate energy-efficient HVAC schedules for a building simulated in EnergyPlus and to show the potential and ease of use of MLE+ in implementing and evaluating such controls. For the second case study, MLE+ is interfaced with a instrumented test-bed that simulates both the dynamics of a building and the behavior of BACnet devices. The test-bed consists of a scaled building with four zones with independent heating and cooling elements. Sensor nodes monitor the temperature and energy levels in different zones of the building. The test-cases are simple examples that pave the way for using MLE+ for modern energy-efficient control methods such as MPC.

3. CONCLUSION

MLE+ provides high fidelity simulation while allowing complete access to Matlab's built-in capabilities and computational power to design advanced building controls. Our current effort involves extentions to work with other building energy simulation tools like Radiance and OpenADR. Also, we aim at coupling it with other optimization and modeling tools.