Continuous Commissioning for Energy Efficient Buildings

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Imperfect control algorithms waste energy in heating or cooling unoccupied spaces. Even an initially "optimal" system will not operate according to design specifications indefinitely as equipment degrades and building usage evolves.

This project aims to achieve optimal design and operation by employing Pareto optimization to design, retrofit, and operate a building. New optimization techniques improve every stage of building construction and design. New sensing technologies enable a fresh approach that provides "continuous commissioning" for buildings.

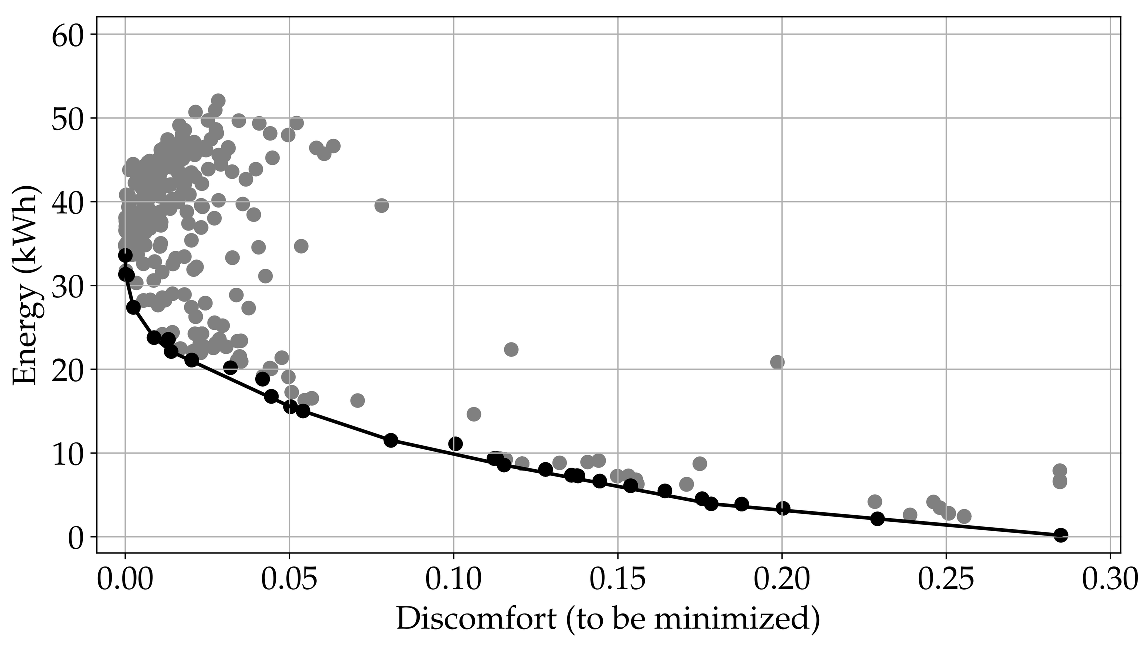

Fig. 1: Objective space for day-ahead simulation of a thermal system.

Pareto Optimization: Using computationally cheap thermal modelling, a Pareto surface summarizes the optimal or "best possible" operating points for a building energy system.

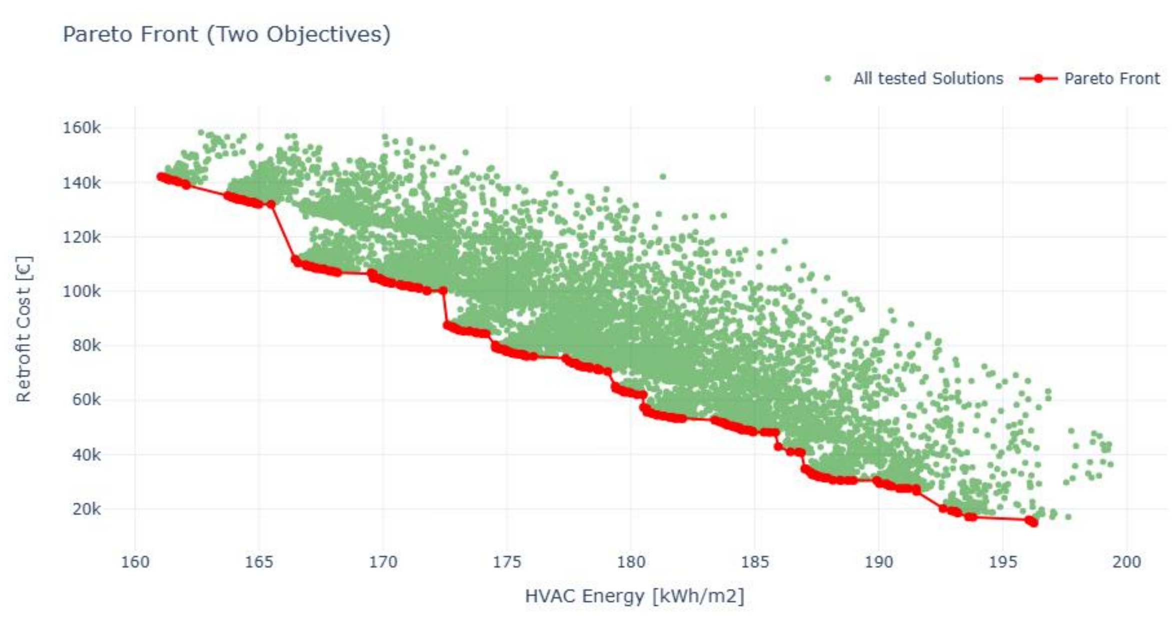

Fig. 2: Objective space for simulating annual energy use and retrofit costs for various building retrofits, such as wall and window retrofits.

A surrogate model predicts EnergyPlus simulations of annual energy use for different retrofit combinations of the MIT building. A Pareto surface shows the best tradeoffs between retrofit costs and energy consumption. Current work is evaluating the effect of retrofits on day-ahead operation of building HVAC systems.

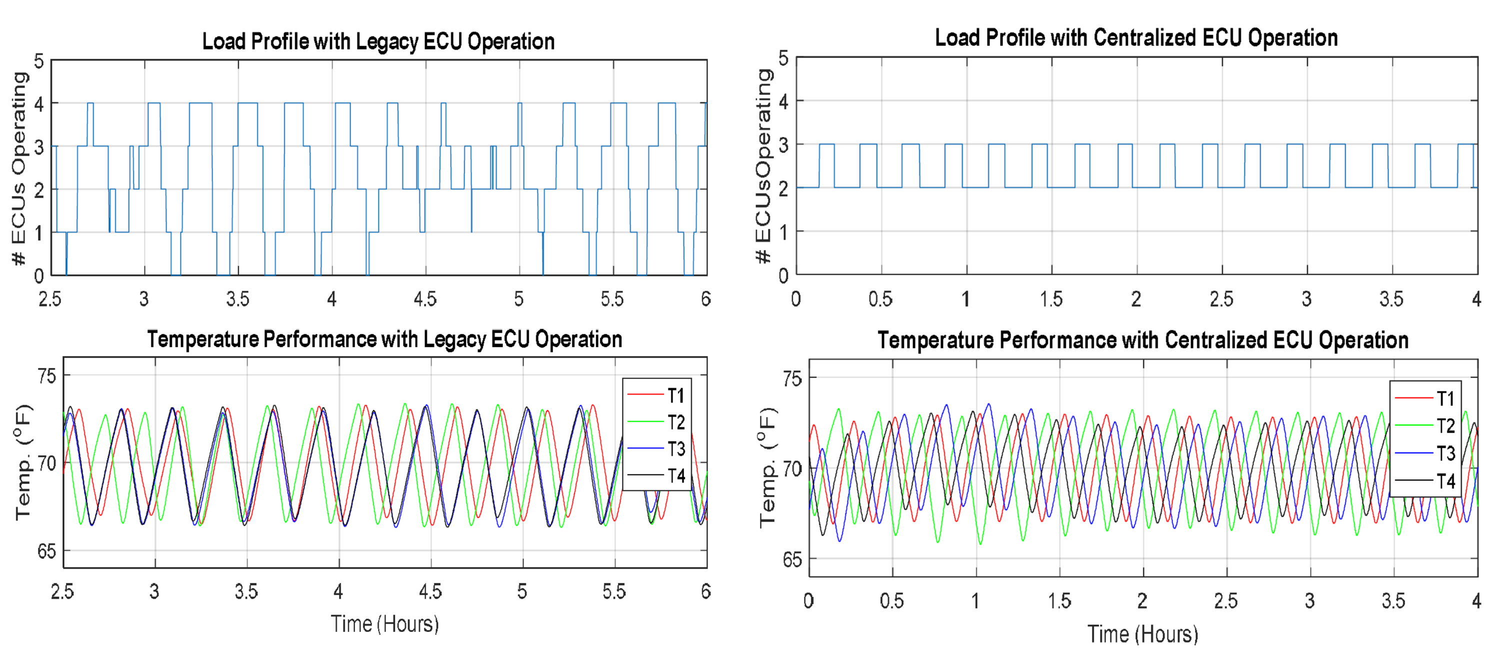

Fig. 3: Comparison of ECU operating schedules with legacy and coordinated control schemes.

Grid-friendly Operation: The above figures show the schedule of environmental control units (ECUs) and the corresponding temperature profile. Under legacy operation, the grid is strained by uncoordinated ECU operation.

Under centralized operation, ECU operation is managed such that at most 3 ECUs are allowed to operate, without compromising occupant comfort.

Coordination is made possible by a central grid observer (such as a NILM), or by intelligent power electronic front-end on modern HVAC equipment.

Main objectives:

- Develop a real-time building monitoring and control framework that provides actionable information to operators.
- Help operators better maintain existing equipment and perform retrofit installations with low-cost and scalable solutions.
- Operate system at peak efficiency with a minimum strain applied to the grid.

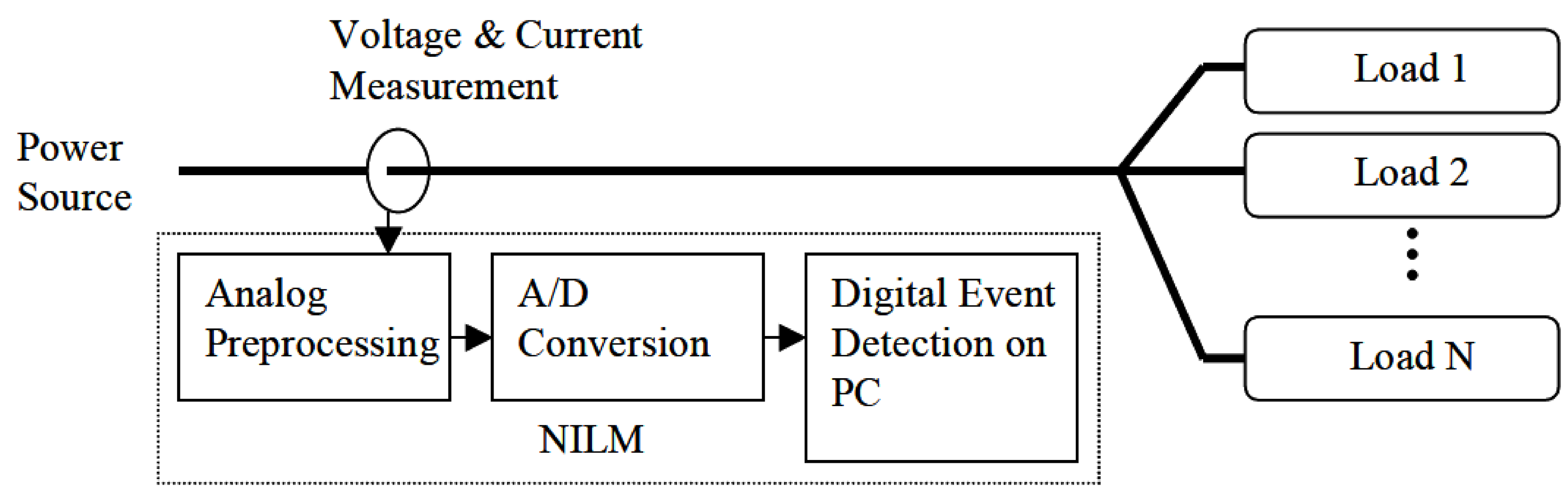

Fig. 4: Nonintrusive load monitor (NILM) block diagram.

Nonintrusive Monitoring: Conventional sub-metering of individual loads is costly and inconvenient. Obtaining useful information from embedded control and monitoring systems requires collation and interpretation of a vast amount of data.

A nonintrusive load monitor (NILM) provides a flexible, inexpensive metering solution that can determine the electrical operating schedule of individual loads using only a single set of sensors.

As an example, one NILM can inform operators whether the building energy system is operating optimally (on the Pareto surface) or sub-optimally.

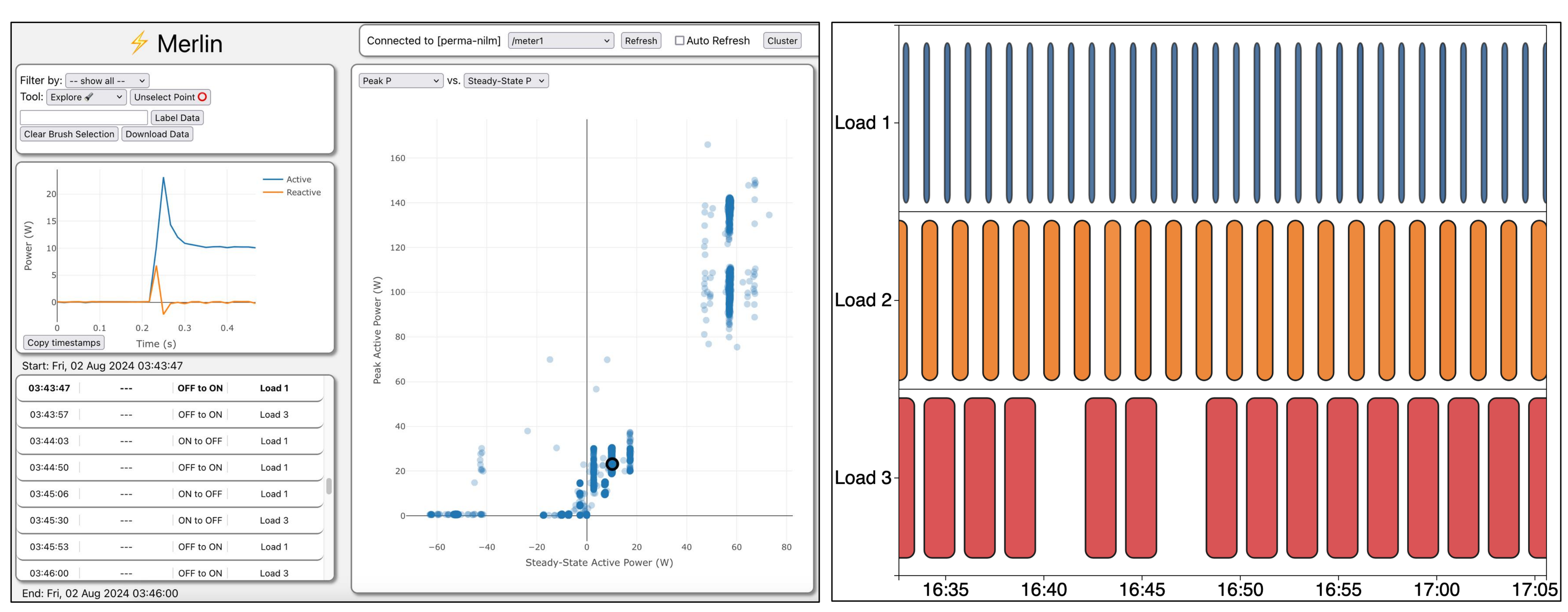

Fig. 5: MERLIN visualization platform prototype (left) and load schedule timeline (right).

Upcoming Work: State-of-the-art NILM diagnostic and prognostic techniques require a well characterized electrical system. However, when retrofitting a NILM on a legacy building electrical system there may not be such a characterization.

A project codenamed MERLIN (Microgrid Event Recognition and Load Identification Network) is currently underway to develop unsupervised and semi-supervised techniques for load identification and learning operating schedules.

MERLIN automates the currently manual process of setting up and training a new NILM installation in a facility. A data visualization platform (Fig. 5, left image) facilitates easy system characterization. Automatic tools identify clusters of similar electrical events for labelling by a human operator or machine learning system.

Once MERLIN identifies loads, their operating schedule is presented in an interactive timeline (Fig. 5, right image). Abnormal load duty cycles or missing load operation is made obvious to human watchstanders.

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