Proactive Building Energy Management based on Fuzzy Logic and Expert Intelligence

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Abstract

The main goal of this project is to develop expert intelligence tools to be incorporated in commercial energy management platforms for proactive energy management in buildings to further optimize energy savings. To this end, three (3) fuzzy logic powered tools will be deployed to be incorporated in well-known SaaS platforms used for energy management to further improve decision making related to smart fault detection and diagnostics as well as intelligent predictive maintenance of basic building equipment. The first tool, the so-called expert FDD analyser, will be a core fault detection and diagnostics tool related to common building equipment, such as HVACs, PV plants, pumps, etc., enhancing ongoing monitoring-based performance management of building systems to save energy and extend equipment life. The second tool, the so-called HVAC system optimizer, will be based on a fuzzy inference engine for optimizing HVAC system operation in order to increase comfort, reduce energy costs and shift peak demand. Finally, the third tool, the so-called maintenance expert, will be a cost-effective maintenance tool to predict future maintenance needs on basic building equipment with the view of further optimizing its operation across time.

Introduction

Studies all around the world indicate that commercial building owners spend 30% of their operating budget on energy. Costs can be reduced with improved building energy management practices. Optimising building performance reduces demand for energy from the grid and fuels burned on site, while on the same time minimizes carbon emissions from electricity generation, and improves occupant comfort.

Advanced information technology has expanded the volume, velocity and variety of data, or “big data” that can be collected. Today, more detailed and more regular intervals of data can be collected to complete analyses on the performance of specific building systems. With more accurate, complete, and consistent data and analysis, energy management decisions related to specific building systems can be made proactively to run systems efficiently, lowering operating costs, extending equipment life, and improving occupant comfort. With this level of data collected from the utility, a building automation or BEMS, and smart meters, several analyses can be completed to learn what equipment is running sub-optimally and to identify the types of energy efficiency projects in which to invest, at what level of investment. Analytical results should be shared consistently with building management staff to inform decision-making on building systems, like lighting, heating, and cooling, and to support choices of energy efficiency projects.

Fuzzy logic ensures to endow current BEMSs with built-in intelligence capable of improving their performance in managing complex infrastructures consisting of HVACs, refrigerators, PV plants, pumps, etc. These tools intend to replace human data analysis and interpretation with software that attempts to mimic human analytical procedures through expert rules by detecting and diagnosing problems without user intervention as well as predicting future maintenance needs through and medium-term energy consumption data, logging conditions, reports, prior FDD analysis and others.

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The main goal of the Fuzzy Experts project is to develop expert intelligence tools to be incorporated in commercial energy management platforms for proactive energy management and optimization of energy use. To this end, three (3) fuzzy logic powered tools will be deployed and incorporated in well-known SaaS platforms used for energy management to further improve decision making related to smart fault detection and diagnostics as well as intelligent predictive maintenance of basic equipment.

Goals of the Project

As mentioned in the introduction section the tree fuzzy logic combined with machine learning controllers will be developed.
The first tool, the so-called expert Fault Detection and Diagnosis (FDD) analyzer, will be a tool related to common building equipment, such as Heating Ventilation and Air Conditioning systems (HVACs), lighting, machines, Photovoltaic (PV) plants, pumps, etc., enhancing ongoing monitoring-based performance management of building systems to save energy and extend equipment life.
The second tool, the so-called HVAC system optimizer, will be based on a fuzzy inference engine for optimizing HVAC system operation in order to increase comfort, reduce energy costs and shift peak demand.
The third tool, the so-called maintenance expert, will be a cost-effective maintenance tool to predict future maintenance needs on basic building equipment with the view of further optimizing its operation across time.

Fuzzy Experts Project Structure and Analysis

This project is based on a Greek Israeli cooperation. The partners of the project are two companies Meazon and Green Power Management (GPM) and Laboratory for Automation Robotics (LAR) for the University of Patras.

The cooperating companies, Meazon and GPM, use their energy monitoring and analytics platforms to provide LAR with historical raw energy measurements of basic building equipment. Both companies will exchange knowhow and utilize their advanced own products (i.e., gateways and units) for measurements in this project. Furthermore, on the one hand, Meazon and LAR will collaborate to deliver an expert FDD analyser to detect and diagnose faults related to common building equipment and to propose fixes and workarounds, and on the other hand, GPM and LAR will fruitfully cooperate to deliver an HVAC system optimizer to increase comfort, reduce energy costs and shift peak demand. Finally, all partners together will join forces to deliver a maintenance expert system to predict future maintenance needs on basic building equipment with the view of further optimizing its operation across time.

Then, all partners will cooperate to carry out a requirement analysis of the intended smart built-in tools taking into consideration, indicatively, the following issues:

1) companies' knowhow exchange and products to be utilized for measurements (i.e., energy meters and sensors, gateways, thermostats, etc.),
2) interfaces of companies' commercial SaaS energy management platforms,
   specifications of cloud based historical energy measurements,
3) standards for energy data exportation from the above platforms for off-line processing in Excel or Business Intelligence systems,
4) selection of basic building equipment (e.g., HVAC systems, PV plants, refrigerators, etc.) for monitoring, controlling and testing,
5) normal and/or eco operation of the selected building equipment,
6) fuzzy logic toolkit, simulations and programming languages,
7) definition of faults and problems of the selected building equipment to be detected with FDD analyser (e.g., HVAC systems that improperly simultaneously heat and cool, under-utilised free cooling potential, systems with the wrong set points and operating schedules, lack of energy-saving control sequences, excessive building peak electrical demand, etc.),
8) input parameters of the proposed fuzzy logic controller (FLC) for the selected HVAC system optimization (e.g., temperature difference between the internal environment and set point, the change rate of the temperature difference, the relative humidity, etc.),

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9) output parameters of the proposed FLC for the selected HVAC system optimisation (e.g., fan speed, compressor's motor speed, etc.),

Finally, the academic partner devise fuzzy techniques for disaggregation of cloud-based energy loads into high level consumption categories (e.g., lighting loads, HVAC system loads, PV plants loads, refrigerator loads, etc.) with the view of off-line processing and exploiting them in the next phase of the project.

After implementing the tools, they will be integrated with Meazon and GPM commercial SaaS energy platforms. In particularly, the Expert FDD Analyser and the Maintenance Expert will be incorporated in Meazon SaaS platform, while the HVAC System Optimizer and the Maintenance Expert will be embodied in GPM SaaS platform. Performance of the tools in real operational conditions will be compared against simulation scenarios and according to their specifications and requirements. The obtained results will be analyzed by the academic partner to detect possible divergences from theoretical (or expected) performance and fine-tune them in order to improve their overall performance.

Conclusions

The Fuzzy Experts is a very promising project which aims to offer alternative solutions in combining efficiently the existent building automation in order to reduce the energy consumption of the building sector. The partners of the project also aim to develop high end tools in order to prolong the life span of the building equipment. In conclusion, the partnership strongly believes that all successful outcomes of this project and, mainly, the implementation of the three fuzzy logic powered tools will transform the way buildings are managed in the future and enable facility managers to have a more proactive role in increasing building efficiency and occupant comfort.

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