Enhancing energy management in buildings through data analytics technologies

Original
Enhancing energy management in buildings through data analytics technologies / Piscitelli, Marco Savino. - (2020 Jul 08), pp. 1-219.

Availability:
This version is available at: 11583/2841164 since: 2020-07-22T19:46:25Z

Publisher:
Politecnico di Torino

Published
DOI:

Abstract

Advanced metering infrastructures are enabling the collection of large amounts of building-related data that are leading to a profound transformation of the energy management paradigm in buildings and energy grids. Building-related data are full of hidden knowledge that can enable significant energy savings when a proper knowledge discovery process is performed. To this purpose advanced Energy Management and Information Systems (EMIS) based on the application of powerful and novel data analytics techniques can be employed. The focus of this dissertation is on the specific segment of EMIS technologies called Decision Support Systems (DSS). DSS include Energy Information Systems (EIS) and Fault Detection and Diagnostic (FDD) systems and can be classified as enabling tools in the building energy management process. Differently from advanced control systems, DSS provide feedbacks to human users (e.g., energy manager, building owner, energy service company) assisting them in improving building performance during operation. The installation of such systems is characterized by a low investment cost and a high energy saving potential making them strategic technologies in the building sector. However, their penetration in the market is still not satisfactory.

In this dissertation four advanced and innovative data analytics based DSS tools (three EIS tools and one FDD tool) at both meter and system level are proposed with the aim of overcoming three main barriers that today thwart the full exploitation of such systems: (i) low level of user engagement, (ii) inadequate detail of the analysis and information provided, (iii) insufficient level of interpretability of the results obtained. For each scale of the analysis considered a novel methodological framework is employed for addressing the main tasks typically required to advanced EIS and FDD systems.

At system level, an EIS tool for the improvement of HVAC scheduling is developed for a town hall building. The tool can effectively reschedule the HVAC system leveraging on the analysis of building occupancy data. The results obtained for the considered case study show that the tool could lead to a potential monthly reduction of the electricity use for HVAC (space heating, space cooling, ventilation and air treatments) that ranges from 12.2% to 15.4% while the average energy saving for the whole analyzed period (4 months) amounts to 14%.

At whole building level, an EIS tool for the automatic detection of anomalous energy trends is developed for a town hall and a university campus. The results obtained for the two case studies demonstrated that the developed tool can predict the typical patterns of building energy consumption during specific periods of the day with an accuracy well over 80%. As a result of the high accuracy in identifying a typical/normal energy behavior, it is possible to achieve a strong anomaly detection capability of the tool when these patterns are violated over time during building operation.

At building portfolio level, an EIS tool for the identification of typical energy use patterns and the classification of energy customers is developed for a stock of 114 industrial buildings. The developed tool is capable to automatically extract from the building portfolio database, 5 groups of typical load profiles and estimate for a new unknown customer its membership to one of them. The tool is based on an evolutionary decision tree and achieves a classification accuracy of about 75% (6% higher than a reference classifier based on recursive partitioning decision tree).

At system component level, an FDD tool for the automatic detection and diagnosis of faults in HVAC systems with a focus on Air Handling Unit (AHU) components is introduced. The tool is developed on the ASHRAE-RP 1312 public dataset and it is capable of detecting up to 11 typical faults (related to valves, fans and dampers) in AHUs during the cooling mode with an overall accuracy of 90%.

All the developed tools leveraged on time series analytics and automated rule extraction techniques with the aim of maximizing the amount of information extracted from building data while maintaining a high level of feedback interpretability. The results obtained demonstrated the added value of data analytics in the process of building energy management and its effectiveness in extracting hidden, useful and actionable knowledge at different scales of analysis.

Findings and outcomes of the present research study are discussed providing a robust reasoning about the optimal design of data analytics processes according to specific mining purposes. Eventually, a wide overview on the lessons learned throughout this research study is proposed for clearly outlining the future application opportunities, and barriers of data analytics technologies in the energy and building sector.