

Popular Abstract

Energy production is one of the main activities causing environmental harm and climate change. For this reason, in the recent past, most government bodies and public and private institutions set ambitious goals for reduction in energy consumption and increase in energy efficiency. The buildings sector is one of the main actors in the energy usage scheme. It is estimated that buildings account for over one third of global energy consumption, and that they are responsible for a large amount of greenhouse gas emissions, which have major effect on climate change. Therefore, many policies and regulations for buildings energy efficiency have been issued, and many institutions have defined classes of highly energy efficient buildings.

However, a large difference between design goals and actual energy performance has been observed in many buildings, especially long time after construction. One of the main causes for this gap is due to building faults. Modern buildings have complex engineering designs, made up of several subsystems, which, in turns, are composed of many components. Several kinds of faults can affect all of these components, such as sensors faults, mechanical components failures, time wear or misconfiguration. Faults impact both occupants comfort and energy consumption, causing often significant energy waste.

Fault detection and diagnostics techniques have been successfully developed and used in many fields, such as avionics and process engineering, for many decades, however, their application on buildings is relatively recent. Many proposed methods were only tested on isolated or simulated components, since real data is scarce and not publicly available. The few available commercial solutions are still simplistic, and can only detect a small subset of possible faults. Moreover, while many individual techniques have been proposed, there are no common and widespread approaches for overall fault detection and diagnostics.

In this thesis, a top-down approach for fault detection and diagnostics in buildings is proposed, where building systems are stacked in a hierarchy. In the first step, building data is validated. All building applications, including fault detection and diagnostics, require sane and validated data to operate correctly. Afterwards, using the building's energy distribution tree, the overall performance of the building is evaluated, and potential underperforming subsystems are identified. Once the scope is restricted, specialized methods are used for fault detection and diagnostics on the specific subsystems.

Ventilation systems are one of the most critical systems in buildings, and are responsible for a large share of energy consumption. Therefore, special focus was devoted to them, and they were considered as case study for three specialized fault detection and diagnostics methods. In the first, virtual redundancy was introduced inside a ventilation unit by exploiting physical relations between different measurement. In the second, consensus among multiple similar components was used to identify outliers in the air distribution system. Finally, a technical report of faults impact was prepared through simulating healthy and faulty conditions using a dynamic energy model of a building.

All techniques developed in this thesis were deployed and tested on a real building at the University of Southern Denmark. The building, built in 2015 and used for teaching and office work, is fully equipped with sensors and meters, and acts as a living lab for the university. When deployed, the techniques helped identifying faults and anomalous conditions in the building, such as uncalibrated CO₂ sensors which lead to reduced indoor air quality, oscillating temperature readings inside ventilation units, and rooms with anomalous air distribution patterns.

Finally, in the proposed techniques, all main classes of fault detection and diagnostics methods present in literature have been explored, rule-based methods, model-based methods and data-driven methods.