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Thermal comfort evaluation in HVAC Demand Response control

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Abstract

A novel idea, the Daily Discomfort Score (DDS) is developed to assess Demand Response (DR) and thermal comfort in a University building. HVAC set-point control is exercised as a way to reduce the cost of energy and improve thermal comfort. The Daily Discomfort Score employs operative temperature as the key input parameter to take into account radiative and air temperature conditions in each thermal zone. A penalty mechanism is introduced to account for temperature deviation outside the comfort zone and consecutive hours of discomfort. Baseline and preconditioning scenarios are tested to demonstrate the effectiveness of the Daily Discomfort Score in evaluating thermal comfort and Demand Response HVAC control.

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Keywords: thermal comfort, demand response; adaptive comfort ;

1. Introduction

Demand Response (DR) refers to the technical, operational and market framework allowing consumers change their power demand in exchange for financial or other type of rewards. It provides the space for adding flexibility and smartness in the new era electrical power generation and distribution grid. In the smart grid, requirements for higher generation capabilities are lower and overall system efficiency is improved. In DR, consumers can become ‘prosumers’ and export energy to the grid in response to control signals aiming to accomplish an integrated harmonic

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performance of the overall electrical distribution power system. Since manageable loads are a valuable resource, consumers may employ various techniques related to the operation of their Distributed Energy Resources (DER) to shift their consumption in time, lower power peaks and overall reduce the cost of the energy they consume. At EU level considerable progress in implementing DR programs has been made including regulatory and statutory reforms. However, the EU DR market is at an early stage with investments targeted mainly at the rollout of smart metering and Advanced Metering Infrastructure (AMI) while barriers have not in most cases been fully removed to allow new business models such as aggregators establish their role and potential (1).

Advanced control of HVAC systems can be exploited to shift power peaks, reduce energy consumption and associated costs while adhering to indoor thermal comfort desired conditions. Specific techniques such as global temperature adjustment, passive thermal storage, fan variable frequency drive limit, supply air temperature adjustment etc. have been identified for commercial buildings and also can be applied depending on the installed systems in other building types (2). Passive thermal mass storage refers to the precooling or preheating of the building that can be used to reduce thermal loads in peak hours. In mild climates preconditioning strategies can result in total energy savings i.e. when free ventilation cooling is exploited. On the other hand, preconditioning may increase total energy consumption depending on weather conditions, building envelope and preconditioning schedule.

DR control strategies related to the operation of the HVAC system can be effectively implemented provided that indoor thermal comfort is not compromised. This is a crucial aspect of DR as indoor thermal comfort is related to users' health workplace satisfaction and productivity. This paper proposes a framework for analyzing DR preconditioning strategies in terms of financial performance and impact on thermal comfort.

1.1. Methodology

The Daily Discomfort Score (DDS) introduced hereafter is part of a wider framework for evaluating Demand Response HVAC control measures in smart buildings. The control measure tested in this case study refers to the time varying HVAC set-point temperature for heating and cooling. Set-point temperature control is a typical way to implement preconditioning of the building. In this case preconditioning is tested to evaluate whether it can be used to simultaneously establish cost of energy savings and thermal comfort improvements.

Moreover, preconditioning is a technique which may be exploited to minimize high power demand peaks by storing energy in the building's thermal mass. Stored energy in the building's thermal mass has as a result lower HVAC demand power required for desired indoor comfort temperatures to be reached during standard working hours. On the other hand, preconditioning could at the same time improve indoor comfort and avoid discomfort i.e. in early hours of HVAC operation during the day, when indoor temperature has not yet approached set point values.

The Daily Discomfort Score is developed to provide a decision support tool for assessing the impact of Demand Response HVAC operating strategies, modes or specific measures in indoor thermal comfort. The DDS can be used as a stand-alone indicator or in multi-criteria optimisation schemes. Evaluating DR cost savings is of limited practical value if the potential impact in terms of the thermal comfort is not taken into account. The Daily Discomfort Score aims to provide a valid criterion in evaluating the impact of a DR event in indoor thermal comfort conditions.

For verifying the DDS concept, the validated thermal model of K1 building of Technical University of Crete, developed as part of the Camp IT project (3), is exploited. In addition, a model of the existing cost of energy scheme (4) at Technical University of Crete is deployed to identify potential cost savings from implementing DR measures.

The methodological framework linked with this research work consists of the following steps:

1. Development of thermal dynamic simulation model of the building under study
2. Energy cost model implementation taking into account different energy tariff zones
3. HVAC DR control assessment based on the following criteria
 - a. Cost of annual energy consumption
 - b. Thermal comfort evaluation based on Daily Discomfort Score (DDS)

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