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Discrete demand side control performance under dynamic building simulation: A heat pump application

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ABSTRACT

This study presents the findings of applying a Discrete Demand Side Control (DDSC) approach to the space heating of two case study buildings. High and low tolerance scenarios are implemented on the space heating controller to assess the impact of DDSC upon buildings with different thermal capacitances, light-weight and heavy-weight construction. Space heating is provided by an electric heat pump powered from a wind turbine, with a back-up electrical network connection in the event of insufficient wind being available when a demand occurs. Findings highlight that thermal comfort is maintained within an acceptable range while the DDSC controller maintains the demand/supply balance. Whilst it is noted that energy demand increases slightly, as this is mostly supplied from the wind turbine, this is of little significance and hence a reduction in operating costs and carbon emissions is still attained.

1. Introduction

Demand Side Management (DSM) applications make use of centralised controllers and two-way metering systems to shift electric loads, switch off appliances and delay itemised consumption. DSM applications using low-carbon electricity sources can bring about economic and environmental benefits in the form of improved demand–supply matching, maintain or improve thermal comfort, reduced operating costs and lower carbon emissions. From the consumer perspective, the combination of DSM control systems alternating grid electricity and intermittent energy from clean/renewable sources can reduce heating bills and improve the service whilst maintaining acceptable levels of comfort.

DSM programs typically work upon the condition that either the demand side can respond to price signals at peak times or other enablers allow load shifts i.e. variations in supply frequency. The inelasticity of the demand curve for electricity suggests that the economic leverage of some of the DSM programs involving active consumer participation is often insufficient to encourage the consumer to shift loads [1]. Discrete Demand Side Control (DDSC) through intelligent algorithms is an alternative to consumer-driven load shifting. In the wide spectrum of DSM programs, including real-time pricing, time-of-use pricing, demand bidding, interruptible programs, and direct load control, these impact on the consumer by making them aware of load management being implemented and therefore a reduction in load functionality or comfort being experienced. The application of this bottom-up approach to demand control using DDSC results in automated load control being implemented so long as the service provision each load is providing is within upper and lower limits of acceptability. This approach offers one solution to integrate intermittent micro-generation systems within the built environment.

This paper reports the use of a detailed building simulation platform to assess the impact of applying Discrete Demand Side Control on a heat pump based space heating system used to supply heating to both a light-weight and a heavy-weight building. The controller tolerance, in terms of time variance of supply, makes it possible to combine a wind turbine as the primary electricity supply with the electrical network. This paper compares the performance of the Discrete Demand Controller in terms of: the match between demand and supply in high tolerance and low tolerance scenarios; its impact upon the built environment as to thermal comfort; the amount of energy utilised from intermittent sources – a wind turbine; and the consequent reductions in operating costs and carbon emissions.

This paper commences by reviewing existing DSM applications making use of demand control systems (Section 2). It explores the issues and challenges associated with energy utilisation from micro-generation systems (Section 3). It introduces a Discrete Demand Side Control algorithm (Section 4) and implements it within dynamic building simulation software (Section 5). The

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controller is applied to a heat pump system powered by a 6.5 kW wind turbine, with support from the grid; and assessed in high and low tolerance scenarios as to demand/supply match, thermal comfort, and avoided operating costs (Section 6).

2. Existing DSM applications using demand control systems

Several technological attempts have been made to implement controllers for DSM purposes. This section reviews some recent DSM applications which made use of different typologies of demand control systems.

Moholkar [2] carried out trials on a Computer-Aided Home Energy Management (CAHEM) system which enables the implementation of price-responsive load management for the residential sector. This consists of a computerised load control implemented with the help of X10 appliance controllers, the oldest home networking protocol that communicates over the power line within the house. The main drawback of using the X10 power line carrier is its low signal strength which can be subject to failures due to noise on the power line. Extra devices, such as noise filters and phase couplers, are needed to resolve the problem, adding significantly to the costs of the system.

Low cost, flexible and powerful monitoring and control systems are required in this field. The structural elements of possible systems for residential energy consumers could include: wired or wireless network architecture/protocols, sensors, actuators and software systems to monitor and control home devices.

A mixed-technology web-based monitoring and control system was used in a pilot study between Intel Folsom Innovation Centre

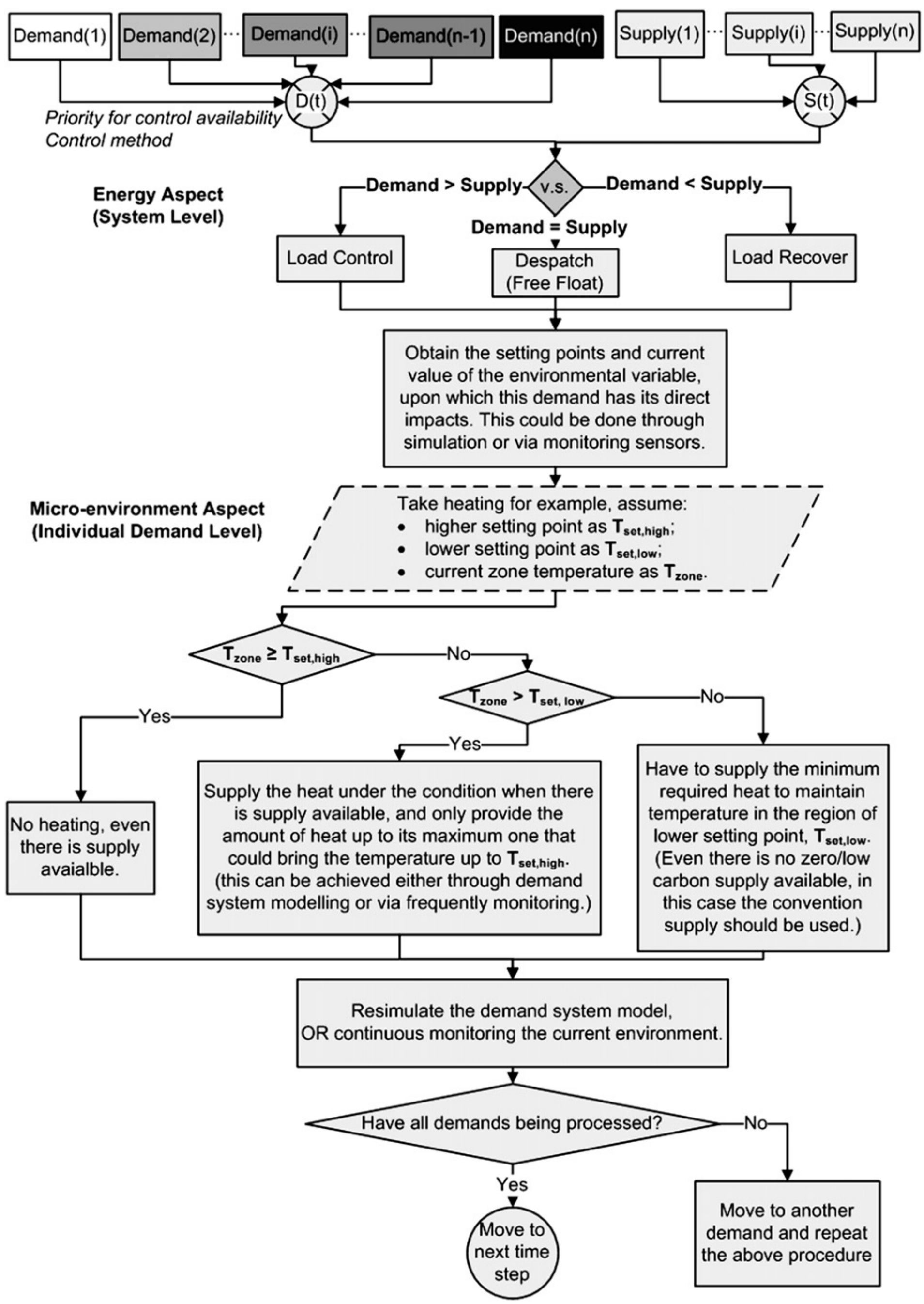

Fig. 1. Flowchart for discrete demand side control algorithm.