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A PHYSICALLY BASED LOAD MODEL OF RESIDENTIAL ELECTRIC THERMAL STORAGE: APPLICATION TO LM PROGRAMS

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Abstract

This paper describes and assesses a physically based load model of residential Electric Thermal Storage (ETS) devices, for both static and dynamic loads. This load model is based on an energy balance between the indoor environment, the dwelling constructive parameters, the ETS device, and the internal mass through a discrete state-space equation system. Therefore, detailed information about several physical magnitudes of the whole system are given along the time: ceramic brick temperature, electrical demand, heat fluxes, and indoor temperature. The main application of this load model has been oriented towards the simulation of the ETS device performances, in order to assess load management (LM) programs. The proposed model has been implemented and validated using data collected for the last two years in residential areas, in order to evaluate its accuracy and flexibility. Finally, a simulation case study is presented to show the possibilities of limiting and reducing the actual winter-peak by means of an LM program, proposed by the authors, that takes into account customer minimum comfort levels and the experimental data of residential load curve profiles.

Key Words

Electric thermal storage, residential heating, load models, demand side, sustainable development

1. Introduction

Two different approaches have been used to solve the continuous growth experienced in the demand of electrical energy systems. The first one focuses on adding new resources and expanding the power system so that the new energy requirements can be met, this is called supply-side management (SSM). The second tries to influence customers to reduce their demand peaks and/or modify their habits. Thus, demand-side management (DSM) technologies—and specifically load management (LM) programs—have been applied in the United States and the European Union countries over the last two decades. The success of these LM programs depends on the degree to which any load can be controlled during periods of system capacity shortages, high generation, or unacceptable environmental costs.

Unfortunately, customers have considered most of the developed control policies unacceptable, mainly because the models of the loads involved in these control strategies—heating, ventilation, and air conditioning (HVAC) residential loads—were incomplete and/or inaccurate. From the utility side, it should be pointed out that a possible side-effect of LM direct control policies is the increase of load peaks at residential level, due to the loss of diversity after each control period; this effect is known as *payback*. This effect might cause the need for reinforcing or upgrading the distribution system network. Intelligent control strategies can partially mitigate this problem, but only through the use of detailed models, which would allow an accurate prediction of the controlled load response, can this problem be solved.

In Spain and other EU countries, around 20—25% of the annual electric energy demand is attributable to residential loads. Specifically, over 75% of the residential electric energy use is for air conditioner, space heating, and water heater loads. Moreover, these loads bear great responsibility for power system peaks, during both winter and summer peak. Direct load control (DLC) and other technologies such as heat/cool storage have the greatest potential to meet DSM objectives, as well as utility and customer needs.

This article describes and assesses a physically based load model of residential electric thermal storage (ETS) heaters, analyzing the possibilities of modifying customer demand profiles, maintaining their comfort levels, and improving the efficiency of electrical delivery network by means of adequate LM programs.

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