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Implementation and assessment of physically based electrical load models: application to direct load control residential programmes

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Abstract: The purpose of the paper is to describe physically based electrical models of heating, ventillation and air conditioning residential loads. These models are based on energy balances between the internal air, the dwelling constructive elements, the conditioner appliances and the external environment through a discrete state-space equation system. The main objective of these dynamic models is to evaluate load management programmes, above all direct load control actions. The models have been implemented and tested to assess their accuracy and suitability in this specific kind of applications. In this way, simulated results have been compared with data collected over a period of one year in different cities and for different load performances—steady state as well as response to remote control actions. The advantages of the models proposed here are also compared with models previously developed and described in the literature.

1 Introduction

Demand-side management (DSM) technologies and specifically load management (LM) programmes have been widely applied in the USA and European Union (EU) countries for the last two decades. The main objective of these programmes has been to modify the load curve shape of customers by deliberate utility intervention [1], in order to achieve several objectives, such as minimising peak demand, improving system operation or maximising quality of service. The most common programme is known as direct load control (DLC) in which portions of the load — heating, ventilation and air conditioning (HVAC), water heating devices — are under the direct operational control of the utility, taking into account several constraints fixed previously between the customers and the utility. Due to the special characteristics of this kind of action, they require a preliminary study and evaluation of the load dynamic response during control periods and after them in order to offer correct assessment of the impact of each LM programme on the power system performance. Hence, having a means of anticipating LM effects is a goal from two points of view: system load curve modifications and customer expectations — and the cost-effectiveness and quality of supply. The precision of these evaluations depends on several aspects, one of the most important being the load model used. Discrepancies between real effects on the load demand curve and preliminary results are mainly due to the incorrect modelling of loads involved in these control strategies. In this paper, physically based electrical load models are described and implemented. These models are also validated, and applied to several direct load control programmes to show their suitability for this kind of application and the sensitivity to several parameters which have been neglected in previous load models.

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2 Literature review

Modelling residential appliance loads for use in DSM programmes, specially in direct load control, has been of concern for the last two decades [2]. Models based only on historical data have been developed [3, 4], but they do not offer results of sufficient accuracy: on the one hand, model parameters are obtained during the normal state of the power system, which is altered by LM actions; and on the other hand, these parameter values are different for each power system, so that it is not possible to apply a specific load model on any other Power System. Walker and Pokoski [5] suggested an empirical model based on historical data and lifestyle, but weather fluctuations were neglected and thus results were not as accurate as was expected.

Physically based load modelling methodologies have been widely used, because they are able to predict the individual load dynamic response and allow one to obtain the aggregated response of these loads efficiently. Therefore, the problem can be decomposed into two subproblems: modelling individual loads at the elemental level, and subsequently devising schemes to aggregate these elemental load models. A great number of models based on this methology have been developed and used, but, in the authors opinion, they have not generally given the results expected by the utilities, due to the hypotheses and simplifications that have normally been assumed. The main parameters which have been neglected are the following. Solar radiation [2, 6–8], which can be an important internal load contribution and should be taken into account, specially the portion of solar radiation which is introduced through glazed surfaces and is converted into internal load immediately. Duty cycle and consumption of HVAC