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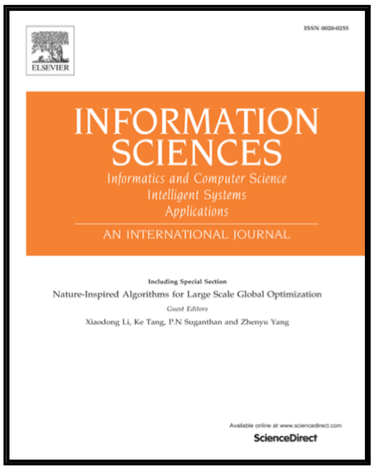

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Bi-level Particle Swarm Optimization and Evolutionary Algorithm Approaches for Residential Demand Response with Different User Profiles

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Abstract

The deregulation of electricity retail markets requires the development of new modeling approaches for the optimal setting of dynamic tariffs, in which consumers' responses according to their flexibility to schedule demand are considered. Retailers and consumers have conflicting goals: the former aim to maximize profits and the latter aim to reduce electricity bills. Also, there is a hierarchical relation between them, as retailers (upper-level decision makers) determine the pricing strategy and consumers (lower-level decision makers) react by scheduling their loads according to price signals and comfort requirements. This is a bi-level optimization problem. In this paper, typical residential loads are considered and three scenarios of feasible windows of appliance operation are established. Two new population-based approaches, an evolutionary algorithm and a particle swarm optimization algorithm, are developed to solve the bi-level problem. The results obtained are then compared with a hybrid algorithm that solves the lower-level problem exactly.

Keywords: Bi-level optimization; Particle swarm optimization; Evolutionary algorithms; Demand response; Electricity retail markets.

1. Introduction

In liberalized electricity markets, retailers procure energy in, for instance, intraday, day-ahead or future markets, with some dependence on purchase time and peak demand. Then retailers sell electricity to their clients who buy the necessary amount to satisfy demand, which may be adjusted according to budgetary constraints and comfort requirements. The further deregulation of the retail market requires the development of new modeling approaches for the optimal setting of dynamic tariffs, in which consumers' reactions in the framework of demand response (DR) programs are considered. Consumers aim to minimize their electricity bill by using their flexibility to schedule demand of shiftable appliances and the settings of thermostatically-controlled loads in the face of dynamic (time-of-use) tariffs established by the retailer.

Modern communication technologies play a central role in smart grids, which are characterized by bi-directional interaction between retailers and consumers. Smart grids provide the technological basis to implement effective DR programs, enabling consumers to react to price. The management of residential loads has many beneficial effects on the grid. It contributes to improving use efficiency of available infrastructure capacity, decreasing peak load demand, reducing GHG emissions levels (by increasing the share of supply from renewable energy sources under "load follows supply" strategies), providing ancillary services and enhancing overall grid sustainability.

Models using time-variant pricing schemes have been proposed to induce a shift in the peak load and smooth the load diagram, offering the system operator additional means for demand-supply balancing and constraint management purposes. A strategy often used is day-ahead pricing, in which the consumer receives tariff information one day or some hours before. The consumer may then react by scheduling load operation, i.e., changing the load profile by (optimally) deferring the use of some appliances, to set a trade-off between minimizing their electricity bill and maximizing their welfare in terms of comfort associated with the energy services provided (hot water, laundry, electric vehicle charging, etc.).