Chapter 13
Integrated Management of Energy Resources in the Residential Sector Using Evolutionary Computation: A Review

Ana Soares
University of Coimbra, Portugal
Álvaro Gomes
University of Coimbra, Portugal
Carlos Henggeler Antunes
University of Coimbra, Portugal

ABSTRACT
The gradual transformation of electricity distribution networks to smart grids is expected to provide the technological infrastructure allowing demand to be treated as a responsive resource, enabling end-users to make optimized decisions concerning the integrated use of domestic energy resources (i.e. manageable loads, storage, and local generation systems). The support to this active use of demand asks for the development of optimization models of combinatorial nature, given the diversity of comfort requirements, technical constraints, appliances to be scheduled, etc. in a near real-time framework. Evolutionary algorithms have been used to cope with the combinatorial characteristics of models, large and irregular search spaces, and also multiple objectives of economic, environmental, quality of service, and technical nature. This chapter makes a review of the use of evolutionary algorithms to optimize the use of domestic energy resources, identifying the main characteristics of the approach, including decision variables, sets of constraints and objective functions, as well as the main algorithmic features to obtain usable solutions.

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INTRODUCTION

Two of the main features that make the difference between the traditional grid and smart grids are bidirectional communication and inclusion of computing, control and information technologies to increase the system’s overall efficiency, reliability, flexibility and sustainability (Kahrobaee, Asgarpoor, & Qiao, 2013). Bidirectional communications enable the adoption of dynamic pricing and hopefully encourage end-users to efficiently use their energy resources and decrease their energy bill through the adoption of a “load follows supply” strategy and simultaneous use of local generation (Katz, Culler, Sanders, Alspaugh, Chen, Dawson-Haggerty, Dutta, He, Jiang, Keys, Krioukov, Lutz, Ortiz, Mohan, Reutzel, Taneja, & Hsu, 2011). The combination of distributed generation, local storage, and a “load follows supply” strategy may change the way energy is consumed and produced (Molderink, Bakker, Bosman, Hurink, & Smit, 2010b), especially when using some type of decision support tool to automatically implement smart demand side management (DSM) actions.

DSM has re-emerged in the smart grids context as a tool that helps energy suppliers minimizing peak load demand while allowing end-users to reshape their energy consumption by making informed decisions regarding consumption and storage (Gomes, Soares, & Antunes, 2011). In this context, DSM can be seen as an alternative to build (or reinforce) power plants and network infrastructures since it contributes to increase the utilization of existing generation capacity and network assets by inducing end-users to modify their demand patterns according to real-time and estimated information concerning generation availability (namely renewables) and kWh prices (Salinas, Li, & Li, 2013). Similarly to already existing DSM strategies, the automated implementation of DSM actions requires system specific techniques and well-designed algorithms to be at the core of energy decision support tools.

From the domestic end-user’s point of view the main advantage of using decision support tools is the optimized management of his/her energy resources with the consequent decrease of the electricity bill while assuring the quality of the energy services provided. For prosumers (simultaneously producers and consumers), the objectives can also include maximizing the use of local renewable energy resources and minimizing the amount of power imported from the grid. As for the utility, the main goals lay on the maximization of profits, the minimization of the difference between generation and demand, and the maximization of savings in both capital and operational expenditures. For the grid operator, a major motivation is increasing the reliability of supply and the minimization of congestions in the electrical grid. Therefore, conflicting objectives are at stake and the adoption of a decision support tool in the form of an energy management system (EMS) requires the clear identification of the objectives to be pursued to adequately design and configure the embedded control algorithms.

With the expected changes in power systems towards smart grids and the deployment of smart meters and smart appliances, EMSs with adequate capabilities are necessary. EMSs commonly used in the services sector and even in the residential sector can also have their functionalities enhanced by including the option of automatically adapt demand to supply on behalf of the end-users (Miorandi & De Pellegrini, 2012).

In the smart grids context, it is also reasonable to expect the introduction of new products by utilities. In addition to energy supply, bundled up services and new contract options already including technologies and strategies for the implementation of DSM actions can be proposed (Logenthiran, Srinivasan, & Shun, 2012). Nevertheless, the investment payoff or the savings achieved are dependent on the end-users’ flexibility regarding the use of different energy sources and the amount of controllable loads engaged in load management programs. In the case of domestic users, the level of achievement is expected to be