Chapter VII
Artificial Immune System in the Management of Complex Small Scale Cogeneration Systems

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ABSTRACT
The increasing cost of energy and the introduction of micro-generation facilities and the changes in energy production systems require new strategies to reach their optimal exploitation. Artificial Immune System (AIS) metaphor can be used to reach this aim. In this kind of management, the energy system can be seen as a living body which must react to external stimuli (cost of fuel, energy prices, fares, etc.) fulfilling its internal requirements (user loads, technical constraints, etc.). In this chapter, a developed procedure based on AIS is described and applied to this problem. Its performance is compared with the mixed integer linear programming on the same test. The result shows that AIS based method obtained better results, in terms of computational efficiency, compared with classical energy production management procedures based on Mixed Integer Linear Programming.

INTRODUCTION
Energy costs and concerns about its availability are an important issue at present. Recently, a growing interest in problems concerning energy distributed generation has emerged. This fact can be explained with two reasons: failures of centralized power grids with events of power delivery interruption, not always short, involving a large number of users (black-outs in USA and in Europe), and impact of energy market deregulation for industrial and civil uses. At the same time, the attention to a larger energy efficiency and to the environment contributes to the diffusion of renewable or combined energy sources to be used together with the energy furnished by the power stations connected to the grid has grown.
At present, many American and European institutions (U. S. Department of Energy, 2000, 2001; EU, 2003) are suggesting the realization of small distributed energy networks, usually called micro-ports, aiming at supplying, partially or totally, a small number of users. Thus they are able to operate in grid connected and standalone modes. Such a twofold possibility allows to be disconnected from the grid if power peaks requirements occur or, if an excess of energy is produced by the sources connected to the micro-grid, to sell this power to the network.

Designing and optimizing of the energy local network are quite different from those of the classical energy grid, because the micro-grid includes both sources and loads, so it is active in nature. A large number of small or medium size generators are often present in the grid: this makes their intermittent working during the day possible.

Another problem occurring in the micro-grid design stage is the sizing and sitting of the generators with respect to the loads, in order to reduce transmission losses and improve the dynamic response of the grid with respect to load power requirements. Moreover, very often loads need both electric and thermal power, so that the micro-grid must be of Combined Heat and Power (CHP) type.

One of the main peculiarities of these networks is that it often combines production of electric with thermal energy using in a positive way. The thermal energy is wasted in the thermodynamic cycle for thermal loads both in domestic or industrials. Since heat cannot be efficiently moved over long distances, its source must be located close to the load. In order to meet the specific needs of loads, the following factors, including generators with different nominal powers, reliability and pollution levels, the presence of storage units in conjunction with fuel cells and super-capacitors, must be taken into account in the micro-grid. These devices must be optimally controlled. And they add more degrees of freedom in the micro-grid management.

The high complexity of the micro-grid structure, the heterogeneity of sources, loads and backup units require an advanced management system. The use of new network strategies, for instance, can accumulate part of the energy produced in a given time instant. It needs to be exploited when favorable cost/price conditions are needed. Experience has taught us that decision making procedures, driven by low standards criteria, can lead to sub-optimal solutions both on the energy and operational standpoint.

The aim of maximizing performance indicators can be pursued by putting at the heart of the system. An energy manager (Energy Management System, EMS) which can optimally manage power flows inside the system and toward an external energy network. This management must be carried out by considering in each instant, the satisfaction of load requests, prices/costs of energy, operational constraints of the power units and optimizing different indicators, such as minimizing costs, minimizing emissions, keeping each power unit work at its best.

The interest of the research community toward this kind of problems is testified by several publications (Lasseter, 2002; Lasseter & Paigi, 2004; Georgakis, Papathanassiou, Hatzigryriod, Engle, & Hardt, 2004, Hernandez-Aramburu, Green, & Mugniot, 2005).

In the literature, micro grids optimization often concerns sizing and sitting of distributed energy sources with respect to loads (Vallem, & Mitra, 2005; Mardaneh, & Ghaehepetian, 2004; Carpinelli, Celli, Mocci, Pilo, & Russo, 2005; Celli, Ghiani, Mocci, & Pilo, 2005; Gandomkar, Vakilian, & Ehsan, 2005; El-Khattam, Bhattacharya, Hegazy, & Salama, 2004; El-Khattam, Hegazy, & Salama, 2005), but the system management is seldom faced. Heuristic software tools are often used for the optimization and work on a set of objective functions, including constraints expressing costs, reliability with respect to parametric uncertainties, probability of faults occurrence, distribution energy losses, voltage and power quality, harmonic distortion and so on. Simple analytic models of generators, transmission lines, storage units and loads are used to express objectives and constraints with respect to design parameters. The energy management problem of an energy system subjected to time-varying constraints is also interesting under the algorithmic point of view when it becomes the test field of different innovative optimization procedures.

In this state of the art, the use of innovative optimization algorithms can give an important boost to the energy system. AIS based procedures can be efficiently used in the solution of this problem. As testified by several decades of use optimization algorithms (Michalewitz, 2002), their efficiency in problem solving comes by the algorithm itself but, more often, by its intimate integration with the problem under analysis.

In the following section, the AIS procedure is integrated with an energetic system analysis. The energy management aspect is taken into account, while planning of the energy site, its optimal adaptation to the size of the