Energy Management Systems by means of Computational Intelligence Algorithms

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I. Introduction

In a context of continuous increasing of energy costs and imperative need of CO_2 emission reductions, the solution is not only look for new clean energy sources, but the optimization of energy use is also one of the main ways to solve the problem. We can view the saved energy as clean energy available for others consumers. In addition, the saved energy has less associated costs (economic and human resources). Hence, the clean energy generation and smart energy use are two goals to have in mind to get a sustainable energy production system.

In that way, the interest in Energy Management (EM) is growing increasingly. Particularly in the field of industrial and building applications, the Energy Management Systems (EMS) now are an excellent option to get this capability and to improve the company competitiveness.

It is in this context that the Information and Communication Technologies (ICT) take a central role, and among them, the tools of Artificial Intelligence (AI) presents an excellent alternative to provide capabilities of intelligence, autonomy and support in making decisions for EMS, which has already been done in this area (and many others as is well known)

This work pretends to take advantage of powerful capabilities of computational intelligence to improve the actual features of modeling, prognosis, diagnosis and optimization of load demand for EMS.

This work gives a potent complement to the rising new paradigms about renewable energies, distributed generation, micro-grids and smart grids in general, which are in focusing in the optimization or improving of how the energy is generated and not how the energy is used.

II. Intelligent Energy Management System (iEMS)

In the industrial sector, Energy Management Systems have focused so far on the monitoring and “passive” management of energy, as outlined in [1]. Figure 1 presents a diagram that shows the basic structure of current management systems.

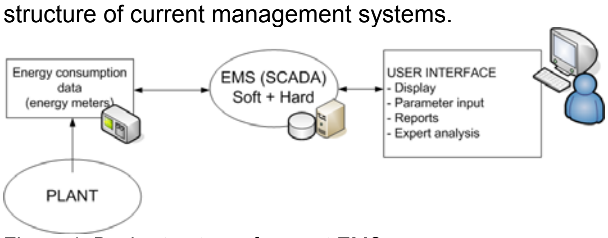

Figure 1. Basic structure of current EMS.

This typical EMS is based on the collection of information through energy meters (electricity, gas, water, etc.), which is taken by a SCADA system or another software for later information management, whose function is to collect the data, store them and presented them appropriately for the users. The software is able also to analyze data and generate reports to identify critical points of consumption.

The main advantage in these monitoring systems is to enable the user to control consumption and costs through energy audits that are supported by data collected continuously, improving the energy efficiency of the plant, its processes and devices.

In addition, these energy data could be used to build up models and get consumption trends. So in some recent works models based on linear regressions of energy consumption versus production scheduling are proposed [2]. These models could be used to forecast energy consumption for a given production volume, and this property has a number of useful applications, ranging from consumption energy prediction for production scheduling to predicting the possible energy saving if any proposed energy efficiency measure is taken.

However, the models used and the mechanisms of action are simple and not to use advanced analytical tools for prediction and control, which could improve the system performance without affect the production or comfort, and taking into account cost functions which help to the system to take optimal choices.

Under that context, this thesis proposes an iEMS (Fig. 2) running advanced algorithms of modeling, prognosis, optimization and diagnosis.

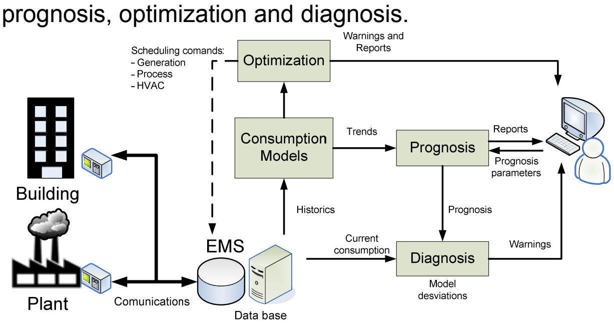

Figure 2. Block diagram of the proposed iEMS.

It can be seen in Fig. 2 an iEMS that access to information collected from the meters via field buses. It also has ability to interact with active systems in the building or factory plant to take actions with the objective of optimizing the demanded power.

The iEMS will take advantage of its ability to create advanced models of load profiles of consumptions from collected information (energy database) and information entered by users, which will generate consumptions models and consumptions prognosis. Based on the models the iEMS will schedule of power load demand in order to reduce of power peaks and contracted power. Moreover, diagnosis and detection of anomalies by detecting deviations from the models could be carried out.

In order to get these advanced features, the algorithms will be based on computational intelligent tools. For example, optimization algorithms will be based on evolutionary algorithms, game theory, among others. Neural networks, fuzzy systems and ANFIS with support of statistical analysis could be used for consumption’s models, forecasting, and diagnosis.

III. Smart Use of Energy

Using intelligently the energy according to this work has three main pillars, which are the expected results of this work. These are:

III.A. Modeling and prognosis

Building up advanced algorithms of modeling and prognosis in different levels in an industrial plant or office building. In the Fig. 3, we can see an example of a load profile model in function of daily production and maximum temperature. In the Fig 4, the example of a power load profile or prognosis.

The modeling part is the base of the proposed iEMS. If we can know how the load demand will be, we can take actions to change it.

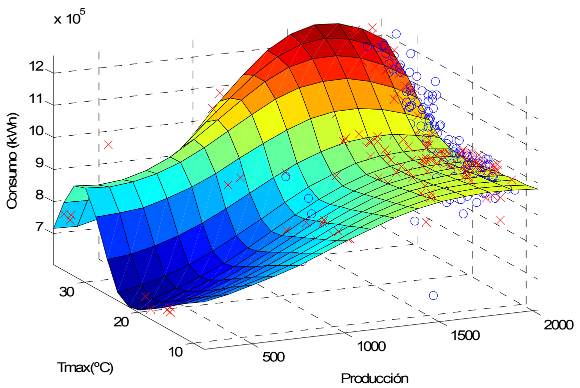

Figure 3. Load profile modeling in function of maximum temperature and production in an industrial plant.

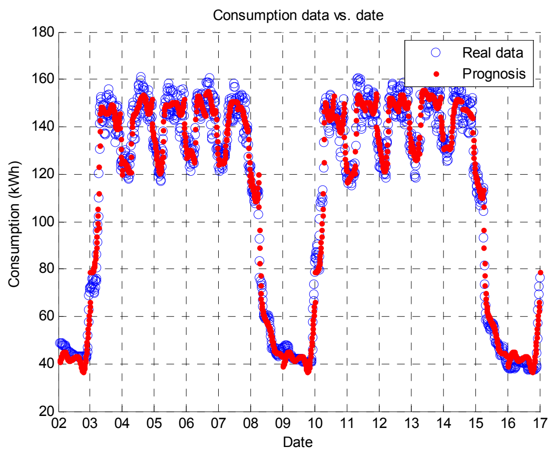

Figure 4. Load profile prognosis in an industrial plant.

III.B. Advanced demand management

Implement algorithms of optimization and diagnosis, taking the former modeling and prognosis algorithms as base. The Fig. 5 shows an example the demand optimization where the maximum demanded power has been reduced by means of a genetic algorithm [3, 4], which look for the optimum scheduling of consumptions to avoid peaks and use the same or less energy in the affected process. The upper graphic in the Fig. 5 is the load profile without load demand scheduling. The bottom graphic is the load demand after to apply the scheduling that has been obtained by the genetic algorithm.

III.C. Real world Integration

To provide for the EMS a true demand management and diagnosis system in the field of industrial and building consumptions. For this reason, it is important that the proposed algorithms will be easily integrated with real EMS. In that sense the current algorithms are been tested in real industrial plants.

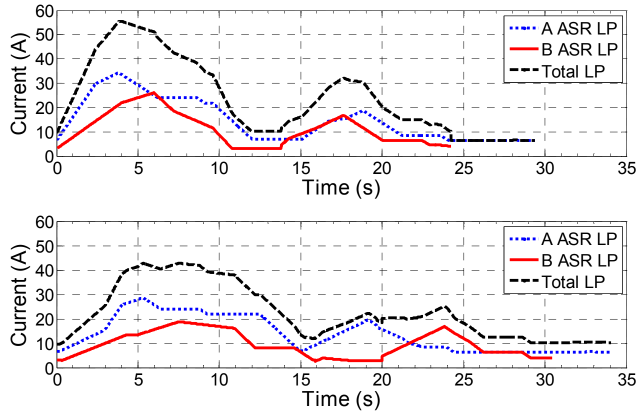

Figure 5. Power demand optimization in an automated warehouse.

IV. Conclusions

This thesis project presents an iEMS framework, which is blessed with advanced algorithms of modeling, prognosis, optimization and diagnosis. These characteristics are aimed to improve the use of energy in factories and buildings.

The algorithms of computational intelligence are thought to be one of the best alternatives to implement the former characteristics.

Some results in modeling and scheduling optimization have been obtained. The base algorithms have been the ANFIS for modeling and GA for optimization. Finally, real data have been used to test the proposed algorithms in both cases, getting the expected results.

V. Acknowledgments

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VI. References

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