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Load Demand Disaggregation based on Simple Load Signature and User's Feedback

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Abstract

A detailed and on-line knowledge of the electrical load demand by the users is a critical issue for an effective and responsive deployment of home/building energy management. An approach based on the application of Non Intrusive Appliance Load Monitoring (NIALM) techniques copes with the goal of disaggregating composite loads; but to get a high level of precision, NIALM algorithms need a complete load signature and complex optimization algorithms to find the right combination of single loads that fits the real electrical measurements. On the other hand, it is practically impossible to get the detailed signature of all appliances inside a house/building and sophisticated optimization algorithm are not suitable for on-line applications. To overcome such problems a straightforward NIALM algorithm is proposed, it is based on both a simple load signature, rated active and reactive power and a heuristic disaggregation algorithm. Of course, it is expected that on real applications, this approach cannot reach very high performances; this is the reason why an active involvement of users is considered. The users' feedback aims to: correct the load signatures, reduce the error of disaggregation algorithm and increase the active participation of users in saving energy politics. The NIALM algorithm has been accurately tested numerically using as input load curves generated randomly but under given constraints. In this way, the causes of inefficiency of the proposed approach are quantitatively analyzed both separately and in different combinations. Finally, the increase of the efficiency of the NIALM algorithm due to the application of different feedback actions is evaluated and discussed.

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Keywords: Energy Disaggregation, Feedback, Nialm

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1. Introduction

In recent years there has been a radical change of the energy market due to the presence in distribution networks of renewable energy sources such as, for example, photovoltaic systems or wind turbines. The energy flows, not only from large power plants to end users, but is produced in discontinuous manner, by a large number of generators located in different places. For this reason, the management of energy flows becomes even more critical in order to ensure the efficiency of the electricity grid and to maintain a proper balance between production and consumption.

At the same time, a further revolution has interested the evolution of the traditional network of the energy that is the so-called “Smart Grid”. A Smart Grid is a smart network that combines the use of traditional technology with innovative digital solutions, making the management of the electricity grid more flexible thanks to a more effective exchange of information. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce the energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. In this new energy scenario, residential users are expected to play a key role in improving efficiency of the network, through the adoption of mechanisms intelligent management of energy demand. In the new smart grid, in fact, an huge amount of data is made available to users such as, for example, information provided in real-time or on the economic value of the energy consumption home devices.

There are different approaches for implementing energy efficiency programs, and basically two types of actions can be taken: by changing the behaviour and habits of the customers in what concerns the use of home appliances or by making investments in energy-efficient technologies. Many times, in order to achieve a significant improvement in energy savings, these two actions must be implemented simultaneously. The development of innovative digital technology allows the monitoring of the entire network to act promptly on faults and ensure optimum supply of electricity. In this system, in constant evolution, the user becomes the protagonist using electronic devices that make transparent consumption, encourage its active participation in the energy market, and promote rational use of energy. Know and understand his own habits in terms of consumption is the first step to a more efficient use of electricity and it allows identifying potential savings in the bill respecting the environment.

In order to achieve the National and European targets about emission reduction, economic competitiveness and energy security, a crucial role is assigned to the consumers, they also have to behave more and more efficiency-oriented.

Today they can have the opportunity to participate actively in energy markets and in the next future, the customers would be involved in the management of the smart grids by means of the optimal management of loads, local generation (e.g. photovoltaic systems) and storage system.

In such a dynamic context, the improvement of the energy awareness at household level is one of the major issues in future energy research [1].

Nowadays commercial solutions to improve the management of energy demand have centred on the deployment of smart meters and in-home energy displays with an interface user friendly.

Based on this hardware, the energy disaggregation or Non-Intrusive Appliance Load Monitoring (NIALM) systems are under rapid development. A NIALM system reads real-time data from a smart meter, usually positioned at the point on the public electricity network at which the customers is connected, and uses algorithms not only to quantify how much energy is used in the home, but also to determine what main devices are being operated.

In literature many NIALM algorithms are proposed, they can be classified into two main approaches, namely: supervised and unsupervised learning algorithm ([2], [3]).

In [4] and [5] a wide variety of optimization strategies, such as integer linear programming and pattern recognition methods like artificial neural networks are described.

The general technique starts from learning input data, in the form of examples, to realize systems for the synthesis of new knowledge through classifications and generalizations. Its aim is to exploit the enormous computing power available in the computer to explore all the ways in which learning can take place automatically and statistical methods and computational techniques are used to achieve the results.

In [6] the following requirements, that contribute positively to define a good NIALM approach are described:

1) feature selection: the feature that characterize the appliances should be sample at 1 Hz;
2) accuracy: the minimum acceptable accuracy of the disaggregation algorithm is 80%-90%;
3) no training: no training algorithm should be necessary;
4) near real-time capabilities: the algorithm should perform in real time;
5) scalability: the algorithm should be scalable if the number of used appliances increase from 10 to 20;