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A generic data driven approach for low sampling load disaggregation

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ABSTRACT

Non-intrusive load monitoring (NILM) deals with the disaggregation of individual appliances from the total reading at the power meter. This work proposes an industrial scale solution which uses a specific modeling technique for appliance detection, trained and tested on two distinct databases extracted from actual customers readings. The proposed method is tested for different household categories to address its robustness. The validation of the implemented solution is done over a period of one month with a sampling rate of 10 s. The results indicate that high energy consuming appliance can be correctly detected (>80% of accuracy). In addition, general cases of errors are analyzed, paving the way of the next step in the development of a commercial application of the proposed method.

1. Context

1.1. Smart meters in the context of smart grids

Smart meters are getting deployed worldwide on a large scale. This large scale generation of digital energy data mandates a deeper look inside the consumption patterns of different appliances present inside buildings.

In the context of smart grids, insights on the energy consumption patterns through appliances usages could help system operators to better manage the energy distribution [1,2], especially regarding the integration of more fluctuating energy sources (i.e. renewables). Strategies commonly employed to that end are usually known as *demand response* [3,4]. Through these strategies, it is possible to reduce peaks demands by eliminating consumption, or by shifting it to non-peak times. For example, the *time of use pricing* has been successfully employed to this end [2].

From the point of view of energy consumers, load identification can play an important role in the prediction of future usages of particular appliances where the process of historical data collection is made as less intrusive as possible [5]. The current technology of smart meters allow reporting the total electrical consumption of a building. But to further develop energy management strategies, appliances usages insights need to be provided. A fourth part system will very likely be used for that purpose, in addition to the end user, the energy provider and the energy distributor.

For that reason, an increasing number of innovative industrial solutions are being under development. The appliances in residential or tertiary buildings could be directly monitored but both the associated costs and inconveniences to the users represent a significant limitation to a correct gross on the market for such implementations.

In that context, this paper focuses on the implementation of a generic solution, based on real-life data acquired in commercial contracts by the start-up *Greeniant B.V.* with which algorithms derived from laboratory developments have been run. The objective is to determine the level of accuracy that can be reached within strict limits of industrial feasibility, privacy concerns and costs.

1.2. Data analytics and data usage

Non-intrusive methods propose an attractive alternative to in-house load monitoring with reduced costs and manual overheads. To achieve this goal, new data analysis mechanisms have to be proposed to inhabitants for their satisfaction and possible energy costs reduction. Note that just a transfer from an analog to a digital system is not good enough for the customers. Indeed, a

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comprehensive and qualitative data analysis mechanism has to be coupled with the subsequent load management strategies to present enough interest.

Next to the necessary efforts on the data-acquisition side, it is equally important to develop insights in consumers' needs. Typically, an additional context, through analysis on the end-users, would benefit significantly to the performances of such systems. Customers could be residential consumers, small-business owners, farmers etc. Mapping a daily/weekly routine in a so-called "customer journey map" gives insights in jobs-to-do for these end-users and the pros and cons of using a local energy management system.

1.3. From research to industrial development

As nowadays energy supports most of the indoor activities in buildings, all these jobs-to-do have a relationship to and/or an impact on the overall energy consumption of the buildings. As an example, a customer survey was conducted by *Greeniant B.V.* to question users on their experiences with their equipment. When asked if they would like to know their energy consumption per time used, usually the answer of customers was negative. The same answer came regarding the associated costs as a function of the time of use. However, a typical behavior of the energy management system that would be welcomed as interesting without being too intrusive is to send warnings at particular times, depending on pre-defined thresholds for example. We can easily relate these warnings regarding the energy consumption to similar signals already proposed in a regular household for the daily operation of typical appliances, for example to clean some machine, or to replace some filter, etc.

The results of these surveys show that an adequate accuracy and confidence to support an early-warning system is the key to insure that this system is being widely adopted. A thorough analysis could surface ample applications of given technologies in a unique, tailored made proposition for energy utilities and customers.

In that context, this paper proposes a solution mainly validated on residential buildings but the tools and methodology are fully applicable to any other kind of building (tertiary, etc.). It is to be noted that this work has been conducted as a collaboration between an innovative start-up proposing a solution for energy management in residential households and a research laboratory working, among other topics, on the grid integration of smart buildings as non-conventional loads.

2. Problem statement

This work focuses on the power meter readings. The added capacity to automatically monitor and report these measurements make a classical power meter a smart meter. In that context, non-intrusive load monitoring (NILM) deals with the disaggregation of individual appliances, directly from the total load monitored at the power meter.

If a load curve, considered as a time series L and monitored at a power meter is the sum of three loads whose consumption is respectively the time series L_1, L_2 and L_3, then the task is to determine the state of L_1, L_2 and L_3 individually with the only knowledge of L, as summarized in Fig. 1. Of course, a way to improve the load identification is to add to the only knowledge of L other useful information, like the weather, historical data, non-technical data, etc.

The application of that principle in a household will decompose its overall energy consumption into its significant components, as depicted in Fig. 2.

The only interesting ones are loads consuming a significant part of the overall energy consumption of the building. Indeed, such loads need to be seen either from the grid point of view as a potential flexibility lever, or from the user point of view, as a potential appliance that could participate in the reduction of their energy consumption, and then directly their energy bill.

From the industrial point of view, it is important to identify periods during which the appliances were used. A typical example of support for identification is proposed in Fig. 3, directly extracted from the readings of a smart meter, for one full day. The shown data is then just monitored and not processed in the identifier yet. This is a time-line representation and the appliances are emphasized by colors. The blue line represents the total consumption. On that curve, two loads are identified: the clothes dryer and the dish washer.

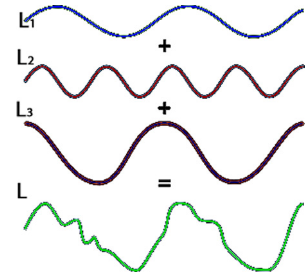

Fig. 1. The principle of signal separation, leading to load identification.

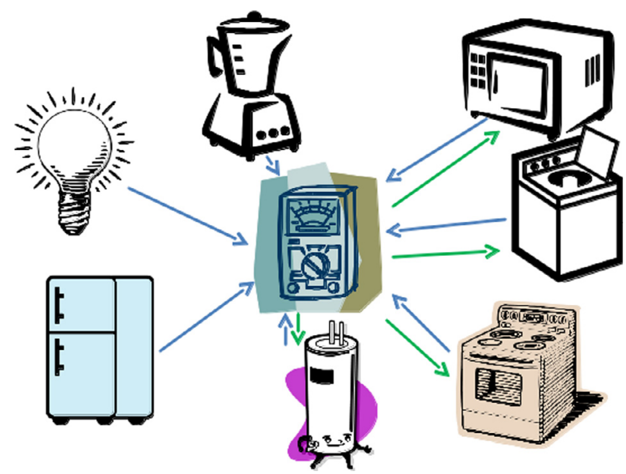

Fig. 2. Identification and management of appliances through the power meter.

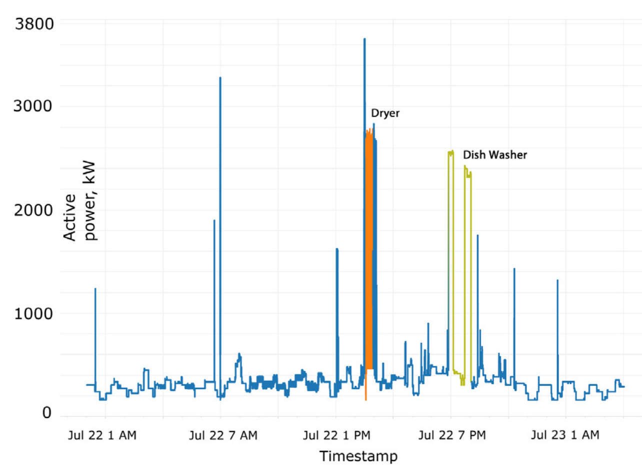

Fig. 3. Illustration of periods of usage of appliance (without data-mining involved). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)