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A review disaggregation method in Non-intrusive Appliance Load Monitoring

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ABSTRACT

The development of home energy management have increased due to energy saving. Instead of Intrusive Load Monitoring (IALM) which requires individual sensor for each appliance, Non-Intrusive Appliance Load Monitoring (NIALM) is an advanced low-cost system that requires fewer sensors and disaggregates load data in a different way. NIALM is a study to determine energy consumption of individual appliances measured at a single power source point. This system disaggregates data from a total power load and analyses power consumption of an appliance so that consumer can monitor the total power usage of a building. This paper reviews several feature extractions, state-of-the-art load signatures and disaggregation algorithms used for appliance recognition in NIALM method.

Contents

Abbreviations: NIALM, Non-Intrusive Appliance Load Monitoring; IALM, Intrusive Load Monitoring; EPU, Economic Planning Unit; MIT, Massachusetts Institute of Technology; FSM, Finite State Machines; US, United State; HMM, Hidden Markov Model; FHMM, Factorial Hidden Markov Model; LCD, Liquid-Crystal Display; PF, Power Factor; HELP, Heuristic End-Use Load Profiler; UEC, unit energy consumption; CU, Concordia University; FFT, Fast Fourier Transform; NN, Neural-Network; CPU, Central Processor Unit; RBF, radial basis function; MLP, multilayer perceptron; SVM, support vector machines; EMI, electromagnetic interference; SMPS, switch mode power supplies; DSP, Digital Signal Processing; RECAP, Recognition of electrical Appliances and Profiling in real-time; ANNOT, Automated Electricity Data Annotation Using Wireless Sensor Networks; ROC, Receiver Operating Characteristic

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Nomenclature

CO_2	carbon dioxide
$P_{norm}(t)$	normalization power
$V(t)$	voltage
$P(t)$	power
P_{std}	standard Deviation Power
A	amplitude
μ	mean
σ	variance
V_{rms}	root mean square voltage
I_{rms}	root mean square current
I_{peak}	peak current
I_{avg}	average current
P-Q	real - reactive power
V-I	voltage – current
ms	milliseconds

1. Introduction

Primary energy has grown by 49% since the last two decades (1984–2004) with an average annual increment of 2%. This has led to 43% of CO_2 emission with an average annual increment of 1.8% [1]. The electricity growth forecast in Malaysia by the Economic Planning Unit (EPU) has shown an increase to 3.52% in 2012 compared to 3.48% in 2011. The growth in commercial and domestic sectors are the factors that have driven this strong growth in electricity demand [2].

Wastes and improper use of energy can be reduced by providing a direct and real-time feed-back on the appliances consumptions to the end users. Demand side management is a major development nowadays to study how consumers can manage energy usage and increase energy efficiency at the same time. The key feature of demand is the diversity in appliance usage. If the consumer wants to reduce their power load, they can directly control their domestic appliances to change the shape of the system load. Therefore, they will need to manage the process of load reduction and load recovery to achieve the desired effects [3]. It is an approach for electrical power companies to predict electrical power demands and to operate electric power facilities efficiently. Thus, the operating conditions of electrical appliance in houses or offices are valuable information to them.

On the other hand, Intrusive Appliance Load Monitoring (IALM) is based on predicting the operating condition by using sensors that are attached to every appliance in the house. This method can predict the operating condition precisely [4]. There is also a system in which each microprocessor-based smart meter acts as a home gateway. This meter directly interacts with intelligent appliances and total electricity energy consumption will be broken down. However, the installation cost to set up many sensors for each appliance is very high [5]. Besides, there are a few disadvantages that limit their practical use including multiple sensor configuration and huge installation efforts when the monitoring scenario involves many appliances. Intrusive Load Monitoring practice is shown in Fig. 1 by installing smart meter on each appliance so that individual data consumption obtained can be merged into an aggregated data. A survey on Intrusive Load Monitoring is briefly explained in [6] which discussed recent work in Intrusive Load Monitoring.

As opposed to IALM, Non-Intrusive Appliance Load Monitoring (NIALM) was first introduced by G. W. Hart is an alternative method where an electrical circuit that contains a number of devices which are switched on and off independently - can be monitored. This method neither requires access to install sensors on individual components, nor taking measurements. By using an advanced analysis of current and voltage waveforms applied to a total load consumption, NIALM estimates the number and nature of the individual load, individual energy consumption and other relevant statistic [7]. Figs. 2 and 3 shows the overview on NIALM process where individual appliance consumption is extracted from the total data consumption.

NIALM technology has been rapidly improved by worldwide researchers as a method to conserve our energy consumption. By using NIALM, users can manage their financial costs and pattern of appliances usage [9]. Various methods have been investigated using various types of approach including different algorithms and smart devices. Review of challenge and recent researches on state-of-the-art NIALM algorithms have been extensively explored in [10,11]. In this paper, a different method will be reviewed to choose the best and accurate method for total power load disaggregation. The objective of the review is to observe different features implemented in various Non-intrusive Appliance Load Monitoring method. In addition, this paper overviews the trend of different load identification and monitoring method focusing on Non-intrusive Appliance Load Monitoring.

2. Literature review

This paper focuses on literature review of various feature extraction as an input to disaggregation algorithm with different NIALM method. Based on the review by M. Zeifman, NIALM method is divided into two categories which are Low-Frequency Hardware Installation and High-Frequency Sampling Hardware [12]. Low-Frequency Hardware Installation is a cluster of method, monitor the changes in power draw while Higher-Frequency Sampling Hardware focus on harmonics and waveforms study.

2.1. Low-frequency hardware installation

In low frequency section, macroscopic features are applied due to fundamental period that is 1/60 s or 1/50 s by using inexpensive system. So this section will provide a study of different method which is consider on power changes only.

2.1.1. Real power and reactive power changes

2.1.1.1. Massachusetts Institute of Technology (MIT) original NIALM method. Instead of IALM, NIALM did not require sub-metering and interior wiring. This permits easy installation, removal and low maintenance. The traditional load research instrumentation [13] requires simple software but involves complex data-gathering

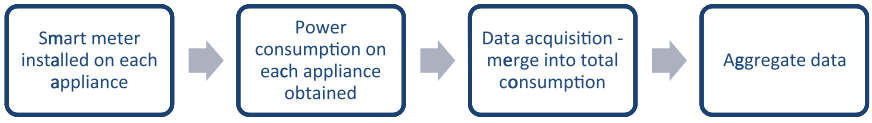

Fig. 1. Intrusive Load Monitoring process using smart meter by measuring individual appliance power consumption.