



## Application of load monitoring in appliances' energy management – A review



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### ABSTRACT

Energy monitoring is one of the important aspects of the energy management, as such there is a need to monitor the power consumption of a premises before planning some of the technical measures to minimize the energy consumption. This paper presents the current state of art of appliances' energy management through Intrusive Load Monitoring (ILM) and Non-intrusive Load Monitoring (NILM), ILM is referred to as distributive sensing and NILM is based on single point sensing. In an effort to explore the recent trend in Energy Management for researchers in the area, various techniques of Home Energy Management (HEM) using ILM and NILM have been analyzed and categorized. Different contributions made by the researchers have been highlighted together with some techniques of reducing power consumption of a building for cost saving and greener environment. This study reveal that there are issues concerning load monitoring and load management that need the attention; issues such as more accurate recognition and the need for monitoring system that can recognize as many kind of loads as possible. More efforts to apply NILM in appliances' energy management is also required. Finally there is need for promoting the energy management culture among the electricity consumers whether in homes, offices or industries. The study will help the researchers in the area to have a clear vision of the recent trends in the area.

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## 1. Introduction

The operating condition of appliances cannot be well ascertained without the proper monitoring of the system. The purpose of every load monitoring is mostly to facilitate the conservation of the energy by taking energy efficiency measures like using less energy consumption devices, appropriate timing of the appliance usage and eliminating energy unwanted activities [1]. Recently there is increase in the micro grids and steady increase in the installation of renewable energy, hence to add quality to these efforts, more energy sustainability measures need to be taken to monitor, control and hence manage the power system [2]. Home energy monitoring and automation can motivate the consumers to use the energy more efficiently and wisely by having the overview of their appliances' consumptions [3,4]. Researchers in the field of energy pointed out that due to globalization and urbanization of the rural areas the energy demand is mysteriously increasing and it can be contained only by appropriate and efficient management [1,5]. The residential and commercial settings, where load management is of vital importance consumed a significant percentage of the total energy generated. This percentage depends on the level of industrialization of a country, hence the focus on energy monitoring and management is equally important [6–10].

Majority of the global electrical energy comes from fossil fuel which is perishable and hence decreasing in reserve every time. Energy crises, global warming and cost of electricity are all present and future challenges of the power sector. The critical inefficiencies in the power system can be detected and taken care of, at low cost using the load monitoring devices especially the non-intrusive load monitoring [8]. Advances in computer technology, measurement instrumentation and new communication facilities make it possible to perform monitoring of a large number of utility consumers both economically and accurately [11]. Different methods of load monitoring are applied to facilitate the application of optimization and management to minimize the problems of electricity crises, possibly by an electricity management system that can be used globally [12].

Energy management system has reached a level of advancement that it has been developed by so many Electrical and Electronics market players, such as Siemens, Samsung Electronics ABB, LG, Rogers, Apple etc. it is estimated that better demand management and tariff innovations could save a utility company with about 5 million customers roughly \$10 million per annum, with a possible additional \$6 million through customer usage information [13]. The cpmPlus Energy Manager produced by ABB Inc. [14]

is a software product that helps consumers to monitor, manage and optimize for obtaining maximum efficiency and cost saving. The LG Environmental Control Manager (EMC) is a controller specifically designed by LG for unpredicted energy savings. It is designed to work with either wired or wireless communication and it comes with integrated occupancy sensor that provides 100% accurate occupancy detection [15]. The Sunny Home Manager produced by SMA, offers a plant monitoring, smart energy management and integrated energy management solution for SMA based solar system. It provides an overview of all important energy flows in the house, automatic control and storage system integration.

The energy management is a very important area in the electrical power system. Recently there are a lot of review articles in the area more especially the HEMS. Table 1 is a highlight of some of the most recent review articles in energy management with some of their key findings.

The major aim of this article is to review the state of art of load monitoring applications in electricity management and automation with the view of helping the researchers in the area to have a clear vision of the load monitoring applications and know the recent trend in the area. Home and offices appliances are one of the major targets of energy managements, as there are a lot of mismanagement happening in the sectors. Researches have estimated that the residential setting can waste one-third of their energy consumption due to unaware activities of various appliances [1]. Section 2 of the paper described the concepts of load monitoring system and Energy monitoring devices are relatively covered in Section 3, while Sections 4 and 5 gives the load management approaches based on intrusive and non-intrusive monitoring respectively. Section 6 gives a highlight on the global greenhouse gas (GHG) emission and the techniques for minimizing power consumption in the utility are provided in Section 7. Finally future research works is given in Section 8 before concluding in Section 9.

## 2. The load monitoring concept

The load monitoring in general is a process of identifying and acquiring the load measurement in a power system. These load measurements will determine the energy consumption and the appliances' status for understanding energy consumption of the individual loads in the system. Depending on the approach used in the appliance monitoring the load monitoring can be Intrusive

**Table 1**  
Some recent review articles in energy management.

Study	Year published	Review focus	Key findings
[16]	2016	The study analyzed the management performance of 305 energy management systems from 1976 to 2014. It also investigate the saving effects of the published articles related to Building Energy Management Systems (BEMS), Industrial, Company and Factory EMS (I/C/F EMS), air-conditioning, artificial lighting etc.	The BEMS is increasing by 11.39–16.22% annually I/C/F EMS decrease by 18.89–10.35% with the artificial lighting having highest saving effects of 39.5%
[17]	2016	It provide a systematic review of the academic journals on EMS that covered 44 selected scientific journals.	The work identified five essential key elements of EM. They also set up a conceptual frame work for EMS to exploit the existing energy efficiency potentials.
[18]	2016	It provides a review of the most relevant works tackling the safe and effective management of distributed electricity networks with autonomous software agents that negotiate on behalf of the consumer.	The work concluded that the Supply Demand Matching (SDM) model is a valid mechanism for managing Distributed Electricity Networks (DENs).
[19]	2015	A literature review of energy management system scheduling, control, real-time automation and communication.	The study suggested a better approach for smart home energy management in a future energy efficient environment.
[20]	2015	The article studied around eighty management models, analyzing their main advances and contributions.	It came out with a preliminary model for implementation of the Management System.
[21]	2015	A comprehensive review of PSO applications for HEMS and Economic Dispatch.	The PSO optimization will allow the system to cope with the objectives of energy management in smart grid.

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