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Energy savings by energy management systems: A review

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ABSTRACT

This study investigated energy saving effects of published papers related to energy management system (EMS), building energy management system (BEMS), industrial, company and factory energy management system (I/C/F/EMS); and EMS for heating, ventilation, air conditioning (HVAC) and refrigerating equipment, artificial lighting systems, motors and others (EMS for equipment). From 1976 to 2014, management performance reported by 305 EMS cases (105 BEMS cases, 103 I/C/F EMS cases and 97 cases of EMS for equipment) is analyzed to evaluate varied energy saving effects. Statistical results show that saving effects of BEMS increased from 11.39% to 16.22% yearly. Inversely, saving effects of I/C/F EMS decreased from 18.89% to 10.35%. Regarding to EMS for equipment, there is no obvious trend but only the averaged saving effect can be reported. EMS for artificial lighting systems has the highest saving effect up to 39.5% in average. For HVAC and other equipment, energy saving effects are around 14.07% and 16.66% respectively. These energy saving performances are correlated with developed EMS functions. The key EMS functions could be identified from their developing progress for effective energy savings. Based on the quantitative analysis, the future trends of EMS are discussed.

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1. Introduction

Energy management system (EMS) has been extensively studied for almost 40 years. According to the database of the Science

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Nomenclature

AI	Artificial intelligence
BEMS	Building energy management system
CRM	Customer relationship management
EMS	Energy management system
HVAC	Heating, ventilation and air conditioning
IAQ	Indoor air quality
I/C/F EMS	Industrial, company and factory energy management system
IEL Online	IEEE Xplore database
IR	Infra-red
OA	Office automation
SDOL	Science direct on line
MES	Manufacturing execution system

Direct on Line (SDOL), there are 357,030 published papers from 1982 to 2014. Regarding to the IEEE Xplore (IEL Online), mainly on the electrical and power electronic fields, there are 26,767 published papers from 1907 to 2014. Among the huge number of publications, a part of papers are picked up for studying energy savings by EMS. Selecting criterions include:

- Selected papers report quantitative energy saving data obtained from real case studies.
- Research works provides detailed descriptions of energy management sites or technical specifications of managed equipment.
- Researches related to building energy management system (BEMS)
- Researches related to industrial/company/factory EMS (I/C/F EMS)
- EMSs applied to equipment include heating, ventilation, air conditioning (HVAC), refrigerating and other equipment; artificial lighting systems; motors and other equipment (EMS for equipment).

Through reviewing selected papers, this study aims at

- Analyze energy saving performances achieved by different kinds of EMSs.
- Identify the key EMS functions for effective energy savings.
- Explore the future of EMS development.

2. Study cases of EMS

Due to the global warming and energy shortage, EMS became one of the popular research topics. A computerized EMS was reported in 1976 [1]. Afterward, The EMS has been developed around 40 years. These computerized systems could manage and control the energy usage of building, industry, company, factory and equipment automatically or semi-automatically according to various control logics or developed functions. However, the diversity of managing and controlling functions increased the complexity of EMS. What's the main function for effective energy saving is still under investigation.

In this review paper, the reviewing points would be focused on the energy managements and saving effects of EMS study cases on whole site, including BEMS, I/C/F EMS, and single facility, such as HVAC systems. The main purpose is to identify the key EMS functions for effective energy savings. The cases study of BEMS, I/C/F EMS and equipment would be introduced in the following sections.

2.1. BEMS cases

The published year, case description and referencing number of BEMS case are listed in Table 1.

In totality, there are 105 BEMS cases discussing about the whole building management. The distribution of these 105 cases is illustrated as follows:

(1) Residential building: 34%;
(2) Complex building: 25%, including commercial departments and residential house, schools;
(3) University: 10.5%;
(4) Commercial building: 16%;
(5) Office building: 9.5%;
(6) Others: 2% for hospitals and 3% for hotels.

The locations of these BEMS cases are: 33.3% in Northern America, 30.5% in Europe, 29.5% in Asia, 4.8% in Africa; just one case in Australia.

2.2. I/C/F EMS cases

The types of I/C/F EMS cases include application of EMS for industrial process management, entire company, and factory. The published year, case description and referencing number of I/C/F EMS cases are listed in Table 2.

In Table 2, totally 103 cases located in the following areas: 45% in Europe; 25% in Asia; and 12% in North America. The 18% other cases are the companies or factories in various countries or areas integrated together through worldwide EMS communication. They can't be counted actually in one single country or area.

Based on the applications, these 103 I/C/F EMS cases are divided into:

(1) Industrial process energy saving: 50%, i.e. among the cases of Table 2, there are 52 cases with the main energy consumption instruments include motors, heaters and other power facilities;
(2) Company energy management: 21%, the main energy consumption instruments are HVAC systems, artificial lighting systems and office automation equipment;
(3) Factory energy management: 29%, the main energy consumption instruments combine those mentioned in industrial process and company divisions.

2.3. Equipment energy saving cases

The research papers of applying EMS on the management of single facility, including HVAC systems, artificial lighting systems, motors and other equipment, are listed in Tables 3–5.

In Table 3, there are 52 cases applying EMS on the HVAC systems and refrigerating equipment. The energy management cases of adopting HVAC system for heating function in America and Europe are 46% of the whole cases. Those for cooling function in Asia and the energy management cases are in the same ratio.

Based on the type of equipment, the case ratios of various equipment are: large HVAC facility (chiller) 71%, small type air conditioner 21%, refrigerator 8%.

In Table 4, there are 22 cases applying EMS on the artificial lighting system. Among them, 81% of cases are located in North America or Europe, which are at high latitude and less sunshine