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An Evaluation on Smart Energy Management Systems for Intelligent Buildings

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Abstract:
There is an essential necessity for technology to enhance the field energy to increase the efficiency since there is an increased rate of power consumption in the modern world. The building account for nearly a high amount of the total energy usage and efficient methods are required to manage the energy effectively. Thus, building energy management system (BEMS) can be described as a system with grouping of both smart and green building technology. This paper identifies multiple Building energy management systems and their efficiencies in optimizing the energy for higher savings rate. This paper also describes the different kind of energy management systems that are widely adopted and known for its optimization of energy savings.

Keywords: *BEMS, EMS, Smart Energy Management, Green Building Technology, Building Control System*

I. INTRODUCTION

Smart energy efficient buildings [1] are considered a large part of upcoming smart cities. Normally, when talking about intelligent buildings, what is meant are buildings which have a building management system (BMS) installed. BMS typically controls the heating, ventilation and air conditioning (HVAC) of bigger buildings based on some control strategies [2]. Moreover, BMSs are usually proprietary, closed systems provided as All-in-one solutions by one vendor and usually installed when a building is planned from scratch [3].

Intelligent residential buildings have become prominent in order to gain a high level of energy savings and net-Zero energy consumption.

According to the International Energy Agency, "the global electricity demand is expected to increase by more than two-thirds by the year 2035" [4]. In present day society, energy utilization is expanding drastically because of population growth, technological advancement, and steady acceleration of economic improvement. With the continuous rise in energy consumption and pollutant emissions, new energy resources are drawing attention. As deficiency of energy resources develops it leads to a national issue, the requirement for different investigations for the decrease and efficient utilization of energy is expanding. Precisely, buildings are considered as one of the world's highest energy utilizers. The energy consumed in buildings is over 40% of the world's energy and the carbon dioxide emissions represent more than onethird of the total [5]. Hence; these days, one of the difficulties concerns is the decrease of the carbon footprint in our urban areas. A major portion of this issue is devoured by heating, cooling and lighting of public and commercial buildings. Besides, European Union proclaimed that "Information and Communication Technologies have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy, in other words, in reducing emissions and contributes to sustainable growth" [6].

This paper aims to identify the best methods or strategies that could be applied in buildings to maximize the energy saving performance. The most basic objective of building development is to save energy and to reduce utilization. Building energy management system can assist in the development of a sensible plan for utilizing energy, reducing energy utilization per unit area, energy conservation and energy expenses and furthermore reducing CO2 emissions. Therefore, one of the fundamental goals in recent research is to expand the energy efficiency in Communal buildings and Spaces deprived of huge development works. Specific importance is given to historical buildings, which are not well optimized for efficient energy usage and in case of modifying the buildings structure for optimizing the energy usage, it might threaten the buildings structure which does not comply for extensive retrofitting. Hence, the present buildings should be transformed as much as possible into Smart Buildings, exploiting platforms, such as LivingLab approach, in direction to move onward towards the idea of the future Smart Cities.

This paper is organized as follows: Section II highlights the proposed methodology. In Section III, a detailed Literature review is provided. Conclusion is drawn in Section IV.

II. Methodology

A. *Problem Definition*

There are many factors which were taken into consideration by which the pre-defined keyword (Building energy efficient management) gets affected. One of the aspects / roles are proficiently treated, energy savings could be attained. There are significant number of energy management systems projected in order to identify the best energy saving algorithm/ techniques. While there are many scenarios to consider while implementing an efficient energy management technique to achieve a higher rate of energy savings. And there are many roles that affect the systems by minimizing the achievement rate of energy savings. This is portrayed in Fig 1for a more clarified view. The main objective of this paper is to identify the best methods or strategies that could be applied in buildings to maximize the energy saving performance. This paper reviews the different energy management systems and techniques that are applied on several kind of buildings.

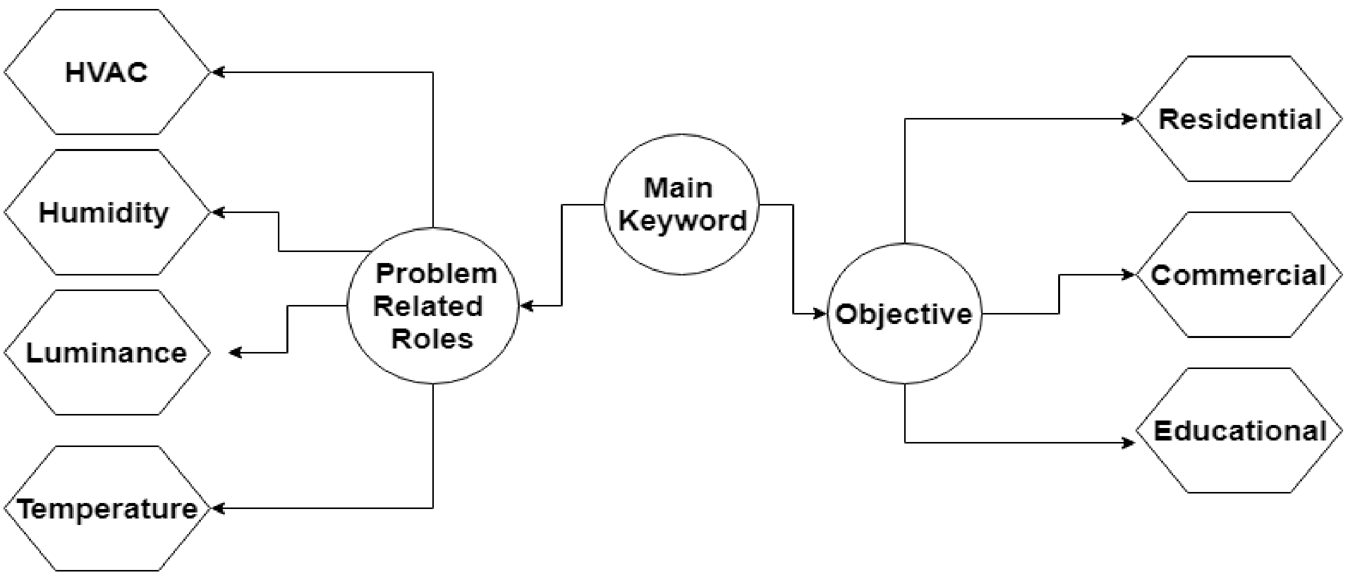

Fig. 1 Keyword Selection Process

B. *Strategy of collection of journal and conferences proceedings related papers*

In this paper, 4 digital libraries have been selected for papers' collection procedure. Cited papers are collected from conference proceedings and journals published by the publishers mentioned above. Journals are indexed by Scopus and WOS services within seventeen years from 2002 to 2019 are considered. Lastly, the criteria applied to whether the papers to be selected or not can be summarized as follows:

- Digital libraries used are: IEEEXplore, ScienceDirect, Emerald Insight, and ACM Digital Library.
- Paper date has been set to the periods 2002 to 2019.
- Types of papers collected: conference proceedings and journals' articles.

III. Literature Review

A. *Building Management Systems (BMS) Vs. Energy Management Systems (EMS)*

Present buildings are frequently outfitted with a Building Management System (BMS) to empower a stiff control of Heating Ventilation and Air Conditioning (HVAC) and lighting. Though, a Smart Building has needs to respond the real-time user behavior in order to deliver comfort and at the same time save energy as well. Another challenge is the design of BEMS, as it requires incorporation of the considerable number of the stakeholders and tenents could be one of the key elements to consider that could portray the user's necessities and desires. A broad meta-analysis of the distinctive enhanced control system is proposed by Shaikh and his scholars [7]. They had reviewed 121 works on the system thematic. In their examination on building energy management systems (BEMS), they reviewed the foremost specialized techniques to guarantee the internal building's comforts (related to thermal, humidity, indoor air quality and illumination levels). This proposal is useful, so as to have an ideal harmony between tenants' inclinations and electrical energy control and saving. These researchers likewise propose three important significant levels in planning a BEMS: (1) Building control system (BCS), (2) computational optimization methods and (3) simulation tools.

(1) BCS can be divided in two subcategories: conventional and smart systems. Both are connected to a continuous monitoring and a control of the system. The most well-known model is constructed on predictive control, which are exceptionally exciting since they use meteor forecasts as well as human behavior as an entry data for the model.

(2) Computational optimization methods: optimization is required commonly in order to reduce (cost and energy consumption) or to maximize comfort. Genetic algorithms (GA) are the furthermost prominent methods.

(3) Simulation tools: supplement the enhancement approach. MATLAB in the review as the most widely recognized program for this solution.

Previous researches that was conducted led a broad number of studies on automate controls system and computational optimization tactics on the contrary, they likewise show a hole in the comprehension of the human part nourishing the system that incorporate inhabitant's behavior, activities and act as a significant criticism for smooth building automation" [8].

A major research which is in current trend is Building energy conservation (BEC). BEC has already become a focus, and there are many studies related to the management of building energy conservation [9-11]. Apart from BEC another major focus is the building automation systems (BASs) which are increasingly mainstream these days. They are commonly delegated as either proprietary (closed) or non-proprietary (open). Proprietary systems incorporate equipment and software developed only by the organization that develops the system, while non-proprietary BASs can incorporate equipment from different manufacturers and software platforms. They incorporate on a field level different sensors and actuators from the buildings infrastructure: lighting, heating, ventilation and air condition (HVAC), security, and so on. The BASs are utilized to form advanced building management systems (BMSs), giving users and infrastructure of the buildings with comfort and security. Lately an energy management as well as energy efficiency improvement questions are more frequently considered. So as to oversee energy in buildings, building energy management systems (BEMSs) are executed by the user [12].

Building energy system incorporates building energy supply system and energy use system. Buildings are typical utilizers of many different energy sources. In accordance with the energy utilization of buildings can be separated into electricity, natural gas, coal gas, oil, kerosene, coal, water, biomass, etc. Furthermore, the utility of energy can be separated into: power supply, gas supply, heating, steam supply, cooling, water supply, etc. Gas supply and water supply in building are commonly unified by gas companies and water companies, and this part centers around power system and heating system [13].

Another major term in Building energy system is Energy management systems (EMS) that serve as interfaces for building operators [14]. This system will enable the administrators to monitor sensor data and alter operational (set-point) conditions of air-handling units, thermostats, chillers, ice storage, etc. as external climate and price conditions change for the duration of the day so as to minimize energy costs and fulfill inhabitant comfort. An example is the Metasys system of Johnson Controls [15]. Current EMS systems are outfitted with essential controllers that track the set-points dictated by the administrator. In addition, the system likewise incorporates essential improvement capacities to minimize energy utilizing precooling and economizer control. Currently, the human operator must make the decisions in the building while monitoring proper equipment functioning. This approach can be wasteful on the grounds that climate and economic situations are profoundly powerful and human administrators ordinarily have access to only limited real-time data about both building energy consumption and market prices. The constraint of current EMS systems is that they are fundamentally reactive. As it were, they need components to precisely evaluate and envision the impact of climate, inhabitance, building design, and market prices on the building dynamic response, energy demands and costs, and comfort conditions. Theses deficiency of systematic knowledge restricts the participation of the building on electricity markets. For example, buildings are generally price-takers and share sporadically on demand response events during outrageous possibilities. This situation exposes buildings to high unpredictability in price and discourages investment in technologies such as metering, automation, and storage techniques. Moreover, the absence of systematic knowledge underestimates the advantage of using utilities to build active and passive storage resources, an independent system administrators (ISOs) and regional transmission administrators. [15].

Nonetheless, BEMS are regularly mistakenly viewed as a fit and forget system. A proficient BEMS can transform into an unproductive platform deprived of a repetitive maintenance and system upgrade [16]. In this way, it is the interest of effective EMS to be updated After a certain period of time to keep up consistency in performance [17]. This technical improvement of BEMS must comply with Energy Management Control (EMC) regulation and significantly, Keep pace with any structural adjustments. To assess the viability of any EMS and its prevailing tactics, it is very imperative to efficiency in energy consumption, examine building environment indoors and explore current working strategies [18].

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B. *Building Energy Management Systems*

Building Energy Management Systems (BEMS) is a decision support system that can improve quality of living for the inhabitants and conservation of energy in buildings. The system ought to contain knowledge and distinguish the abnormality to the set standard values. various sources of information can be used to collect indoor and outdoor sensors (temperature, air quality, humidity, movement, luminance and others) [19]. BEMS is intended and created for particular building settings for particular facilities manually operated and regulated by system operators or energy professionals [20]. A building information model (BIM) stores the building geometric statistics, physical characteristics, and component information that can be used to calculate lighting energy and thermal efficiency of a building. By generating set points for the reference energy model, the energy efficiency of the building can be measured. Taking into account the energy utilization and Analysis of cost benefits [21]. Energy efficiency and energy saving can be optimized with the methodological framework for BEMs. A conceptual framework has been proposed for BEMs, as shown in Fig. 2 [22].

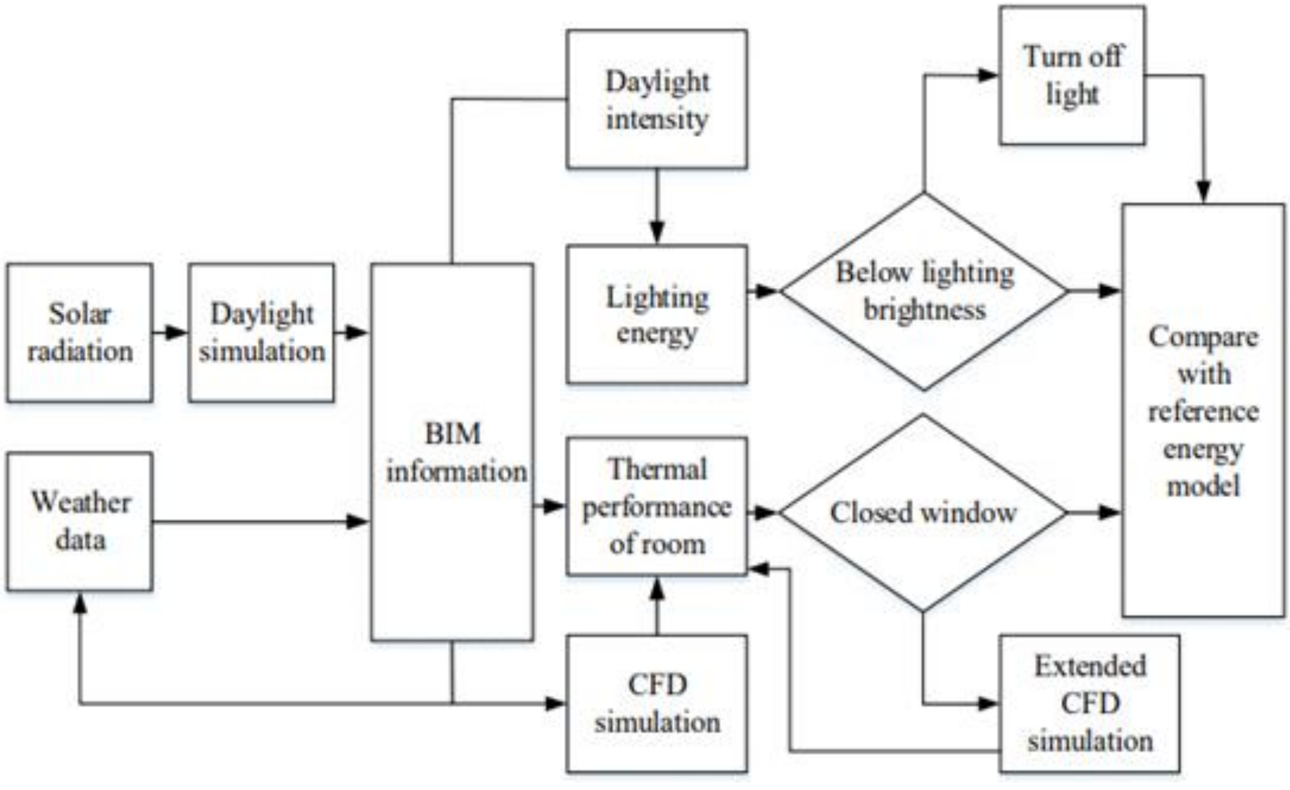

Fig. 3 Conceptual Framework of smart BEMs [2]

C. *Intelligent BEMS*

Another approach is the Intelligent BEMS (iBEMS), The proposed style of iBEMS comprises of a centralized system that uses open communication protocols for buildings to communicate with each subsystem and trade data in real time. [23] iBEMS can help essentially in the outline and control of all the sub-systems associated with it. The iBEMS approach solves the problem of intercommunication among many sub-systems inside a close loop network since all the statistics are collected on an advanced level and circulated in all essential station. Also, the scholar clarifies that Since common sensors are used and connected in one system, the cost of capital is reduced. [23].

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D. *Two stage optimization for building energy management*

Two stage optimization for building energy management is an approach proposed by the author in [22], A management of building energy was presented based on a novel two-stage optimization under consideration of the energy system's physical requirements. The problems of optimization include both continuous and discrete variables of decision and can be communicated as linear mixed number programs. The proposed advancement technique can be coordinated into a building management system in order to improve energy management. In two progressive steps, the ideal forecast for the different parts of the energy system is progressed.

The initial step is to solve a medium-term optimization with a sampling time of one hour over a one-day horizon. In the next step, with the sampling time of 5 minutes, the planning for certain segments of the energy system is refined for the next hour. The proposed two-stage approach provides an opportunity to determine the optimum schedule for a long horizon (at some point) and a little sampling time (five minutes) by solving two generally low computational complexity optimization issues. [24].

E. *Cloud Enabled building energy management system*

There are a few advantages to using cloud computing for buildings' energy management. s more information is accumulated from various associated buildings for analysis; storing, processing, and comprehension of this information will require colossal calculation and storage resources and advanced software to implement innovative algorithms for accurate analysis and management of energy consumption. This can be extremely expensive for property owners. Cloud Computing can give versatile and cost-effective solutions for such needs. In spite of the fact that incorporating with cloud computing can give numerous features for building energy management, there are a few provokes that should be tended to before certain advantages can be picked up from these features. One of the difficulties is security and privacy. As CE-BEMS will be associated to the cloud through the Internet, the system of the participating intelligent buildings can be defenseless for some security attacks [25].

Though, there are numerous security components created for the cloud to avoid many attacks. One major advantage of the cloud enabled BEMS is that the energy management system that is fit for smoothing the all-out pinnacle request of a building, lessening the total demand during most likely triad hours and empower a building supervisor to increment or reduction of the total energy demand by making a charging/discharging timetable for all associated electric vehicles. The local energy management system utilized the CometCloud framework that empowers a building supervisor to scale up the algorithm to simultaneously carry out parallel simulation to identify the most efficient and cost-effective configuration. The framework also empowers the analysis algorithm being utilized to scale up effectively when numerous buildings are considered [26].

IV. CONCLUSION

BEMS can play a vital role in managing the building energy efficiently, as these systems are intelligent systems that can alter the system based on the external factors which include the indoor and outdoor factors such as humidity, Temperature, HVAC and others. The paper has reviewed various tools and techniques designed to test and manage the building energy efficiency especially in existing buildings. This paper discovers that each of the strategies here which manage energy efficiently have its own variables and external factors which affect their performance such as indoor and outdoor factors. Future works that are needed to enhance the energy savings for a smart and green environment, it is advisable to have Zero energy intelligent buildings.

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