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Energy Management System for Domestic Applications

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Abstract

The power grid is amid the period of transformation. Consumers are interested in taking on a dual role as producers and consumers, or prosumers, in the operation of the electric grid. Renewable energy sources are increasingly being used in the residential sector, which has environmental advantages but also presents issues in terms of energy management. Misleading patterns may result, for instance from the energy usage of common household equipment. Energy prices are a further obstacle because of the potential for economic loss to the user as a result of inefficient systems or imbalanced energy management. The Home Energy Management Systems (HEMS) are a recent innovation that aim to address this issue. When properly implemented, the Smart HEMS uses a Hidden Markov Model-based method to calculate the likelihood that a given state of the house really exists. The suggested system makes use of GSM technology for outside communication and WiFi for interior data transfer. Tests show that the suggested approach and algorithm are effective, and that they have reduced the energy use by 18%.

Keywords: Home energy management, optimization, smart grid, decision making, Hidden Markov Model

1. Introduction

It's no secret that smart home technologies that allow for the remote control or automation of appliances are on the rise. Traditional home equipment like thermostats and refrigerators may be retrofitted with sensing, communication, and actuation features, and whole new goods can be introduced to facilitate novel user interactions inside the dwelling. People are becoming increasingly reliant on energy, which in turn has increased CO_2 emissions from power plants, due to the increasing pace of human existence, the proliferation

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of information technology, and the increasing usage of household devices, contemporary appliances, and electric automobiles. How to save energy in order to slow global warming is a pressing concern today [1-5].

With the help of this study, a Smart House Energy Management System (HEMS) has been created to ensure that electrical devices in the home are always running at peak efficiency. These days, energy is one of humanity's most basic need. Recent technical advancements and the widespread use of electric vehicles have led to a steady rise in everyday energy usage. Consequently, the worldwide gap between energy demand and supply is widening. Thus, energy should be seen as one of the most significant components of economic development and a critical factor in determining a state's or nation's success [6].

1.1 Energy Management

While the phrase "energy management" covers a wider range of contexts, the focus of this work is on that which pertains to reducing energy use in institutional settings such as households, governments, and enterprises. Energy management in this context refers to the processes of observing, regulating, and saving energy within a certain institution or structure [7,8]. In a smart grid, where users may create local energy from many distributed generating units and where there is a lot of room for varied pricing systems, many academics have pointed out the necessity for energy management programmes. Evidence from before suggests that including food in energy management programmes leads to greater cost savings than doing so without. The discrepancy between the theoretical energy need and the observed energy demand is known as the energy performance gap. This problem is resolved by using up-to-date off-site construction techniques, doing additional inspections on-site, and analysing the structure's performance after it has been put into service [9-11].

Building owners and occupants who are energy efficient also get non-energy related advantages. Some property owners are integrating smart technology to attract and maintain tenants by meeting their growing desire for flexible, customizable workplaces. The ability to regulate the temperature and the air quality may have a positive effect on worker output.

1.2 Energy Usage

A more demand-focused feedback system linking consumer behaviour to energy usage is necessary in light of the extensive amount reduction from previous energy usage. Sustainable lifestyles and long-term fuel security need a shift toward a reduced reliance on

grid-supplied energy and gas. Innovative metering technology has shown the importance of behavioral modification in lowering carbon dioxide emissions from buildings [12]. These buildings are home, hotel / shop, small scale industry, office, and hospital. The energy savings from smart technology for the above said building region based on size is detailed in table 1.

1.3 Motivation

Retailers, utility programme managers, and policymakers may all utilise this framework, to educate and inspire customers to use cutting-edge home devices for energy management, by providing them with the information and resources they require, to make informed decisions.

2. Literature Survey

This paper's foundation is based on a comprehensive study of HEM technology completed for Pacific Gas & Electric Company. The study included a stakeholder analysis, consumer research, and a technology evaluation (an inventory and analysis of existing HEM technologies). The foundation for HEM use case structure was laid by the results of a technological analysis and insights from consumer research. The synopses of several studies whose results assisted this study have been provided [13].

Finding the energy savings and demand response potential of the items evaluated was challenging. The advantages and cost reductions that may be realised by using various HEM products are generally outlined in the product's technical literature. Inconsistent findings are common in studies that use energy simulations because researchers often make oversimplified assumptions [14].

If winters get colder and people require more heating to remain warm, or if summers get hotter and people need more mechanical cooling to be comfortable, then environmental concerns may no longer be a reasonable justification for individuals to consume less energy at home.

There’s a chance that your home’s gas and electricity are operating on an unconscious level. Thomas et al., presented that, consumers were relatively helpless in this regard, with the blame for high or low consumption levels consistently placed on the dwelling's physical characteristics. The best approach to save costs was thought to be, to change providers [15].

The purpose of this research is to examine the technical and computational challenges inherent to HEMS and their many applications, so that new approaches may be developed. Kitchenham's et al., recommendations for systematic reviews served as the basis for this analysis. Pre-review, as outlined in these rules, calls for the formulation of research questions and the development of a review protocol, the blueprint from which subsequent review steps may be derived. Therefore, the research questions aren't the only thing that needs to be defined in the review stage's planning phase. The next step is performing the review, which entails gathering and analysing relevant data. The last section presents the outcomes, which are extensive evaluations of the currently active publications [16].

2.1 Summary of the Problem Statement

When properly implemented, demand-side management may help with pollution reduction, power reliability, and energy prices. Commercial and industrial facilities, among other grid users, may participate in demand-side management initiatives. In contrast, there is no similar programme for residential users owing to insufficient channels of communication, automation tools, and sensors. Second, there is a disproportion between the expenditures of implementing demand response systems and the benefits they provide. Smart grid technologies such as intelligent loads, cheap sensors, smart meters, and ICT provide an opportunity for residential energy management programmes [17].

2.2 Research Questions

Determining what needs to be reviewed is a crucial step in accomplishing the review's goals. So-called research questions are what make this feasible. The formally specified research topics for this review are as follows.

How have optimization methods for HEMS evolved over the last several years?

To what extent do technical and computational factors rank among the most important, to think about, while creating HEMS?

Question 1 was addressed by doing a systematic review of the most common approaches used while creating HEMS through some advanced optimized algorithm with better decision-making procedure.

To answer the second question, a thorough analysis of the technical and computational factors that went into creating HEMS was conducted. Size, difficulty,

timeframe, and incremental timing are all factors considered. User behaviour, demand-side management, unpredictability, and multi-objective issues are other crucial factors to think about.

3. Energy Efficient HEMS

3.1 Decision Maker

Considering the complexity of HEMS, the decision maker must take into account the system's modelling as well as the methods for resolving the problem at hand while making plans for the system's operation. The challenge of operational planning for complex systems, like a house, is often a non-linear one with many restrictions and variables. However, by using function linearization methods, it is feasible to generate approximations that transform the situation into a linear issue. In recent years, several different approaches have been used using HEMS. The specifics of the issue are what should guide the design decision. Traditional approaches, predictive model control, heuristics and metaheuristics, and other techniques are employed to further categorise these methods in this study [18]. Figure 1 shows advanced smart HEMS employment protocol.

Figure 1. Advanced smart HEMS employment protocol

3.2 Efficient - Smart Management System (E-SMS)

Management systems for the electricity grid have traditionally been developed with the needs of energy producers, distributors, and retailers in mind. In recent years, ICTs have played a pivotal role in the energy industry [19], paving the way for the creation. The users of energy have gone from being spectators to participants in this space during the last several years [20]. The original goal was to help people control their energy usage at home. Thus, the term "home energy management systems" was coined to describe these devices.

Table 1. Energy saving from smart technology

S.No.	Building Area Region	Smart Technology connection	Average Energy Consumption (kWh/year)	Percentage of Saving
1	Home	Many devices connected	72,000	10%
2	Hotel / Shop	Medium number of devices connected	8,50,000	7%
3	Small Scale Office	Less number of devices connected	9,900	2%
4	Hospital	Many smart sensor devices connected	7,900,000	18%

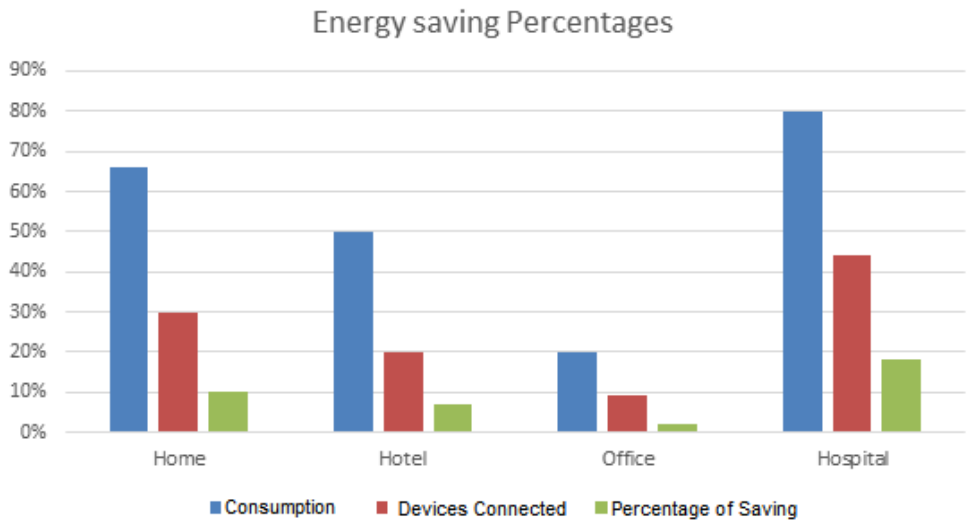

Figure 2. Energy saving percentages at various regions

As of now, end-users with a HEMS, care most about one thing: lowering the value of their power bill. The second phase, however, saw end users concerned not just with lowering

their power bills, but also with increasing their energy efficiency and perhaps generating. As a result, HEMS is now a genuine energy center, allowing for the control of both production and consumption of energy whose mission is to develop and disseminate ever-better management tools that include cutting-edge methods for more effective administration [21]. The table 1 proves maximum percentage of saving (18%) during maximum number of smart devices connected. In the office sector, a minimum number of smart sensor devices are used and connected. In short, when maximum number of smart sensors are connected, maximum are the devices connected through Wi-Fi. This proves the energy can be used in an efficient way. Figure 2 shows chart graph for table 1.

3.3 Advanced Smart grid

A smart grid may be used at all stages of the electricity supply chain, from generation to distribution to consumption. Distributed power production, made possible by advances in grid technology, allows for electricity to be produced at several locations, used locally, and then sold to the utility company for use elsewhere. In [22], sensor networks in the smart grid have been used to implement a power quality monitoring method (transmission and distribution application). Efficient use of power is another area where the smart grid may help. The effective use of electrical power has been shown to have positive economic and societal effects. Managing energy use at home may reduce costs, peak demand, and carbon emissions.

4. Future Direction

Additional research is required into consumption-related lifestyles in which domestic energy usage is integrated into broader efforts to improve household behaviour and well-being. Further research in this area might benefit from the use of ethnographic techniques, which could provide further nuance to the aforementioned results and investigate if the observed shifts in behaviour are sensitive to other archetypal, demographic, financial, or other constraints. The advanced smart system cannot be measured using the social science methods available for this sort of investigation. Kids who were four when the trial began were seven when it was over. The spread of energy-saving habits from the classroom to the household might have far-reaching consequences. It's common knowledge that adding a new family member may alter a home's energy consumption patterns, but less is known about how that pattern changes as children age [24 - 27].

4.1 Recent Development Research

Inadequate coverage of microgrids and energy communities is another shortcoming. The connection between HEMS, energy communities, and microgrids is briefly described. It is believed that energy community management systems will soon become the norm, rather than the current exception. This is because prosumers, armed with more information and the ability to make more informed decisions, will band together to take charge of their energy use, opening the door for new entrants in the shape of clean energy aggregators. Because of the volume of data and the urgency with which it must be handled, big data platforms are infeasible when collecting information on a large number of buildings simultaneously.

5. Conclusion

Saving energy with the help of a home management system is possible without installing pricey new appliances or bothering the occupants in any way. In a lot of places throughout the world, people are still tethered to unreliable and inflexible traditional national grids that can't handle the load of modern homes. This study determines that smart home energy management may be an effective means of implementing an adaptive approach for reducing energy use by up to 18%. The system's architecture is straightforward, and it makes use of the latest, least expensive technologies available. The suggested intelligent home monitoring system allows the homeowner to get updates on the status of his or her appliances through text message from anywhere. In this way, it helps kids feel safer. When the homeowners are away, the suggested algorithm may be modified to include a new feature that can identify potential security breaches inside the home. However, in the not-so-distant future, this may be something that the cutting-edge home energy management system handles.

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