Journal of Electrical Engineering and Automation (ISSN: 2582-3051)
www.irojournals.com/iroeea/

Smart Home Energy Monitoring and Energy Reduction Technique

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Abstract

The concept of Home Energy Management System (HEMS) is emerged from the development of smart homes, which connect humans and things to automate the manual operations. The smart homes users enjoy secured, pleasant, and autonomously managed lifestyle. Additionally, smart homes have the potential to generate revenue by vending clean and sustainable energy to the grid, thereby saving both energy and money. The proposed method efficiently reschedules and arranges the power flow among grid electricity, storage devices, and photovoltaic models to manage the energy requirements of smart home. Energy-management systems is highly preferred to economic benefits of smart homes while maintaining a comfortable living, maximizing connectivity and developing optimized operation of loads. The proposed system is finally implemented in a simulation environment, and further the obtained outcomes demonstrate the efficiency of the proposed method in terms of energy management from various sources.

Keywords: Home energy management system, Smart home, grid electricity, saving energy

1. Introduction

Home energy management (HEM) is a system developed with the support of renewable energy sources to reduce the overall energy consumption in a smart home environment. This concept was developed in later 1990s. Since around 20 years ago, the phrase "smart home" has been used frequently to refer to homes with managed energy systems. In particular, for disabled people or elderly, this automation technique provides a better lifestyle than traditional homes. The term "smart home" has recently been expanded to incorporate a variety of technological advances in a particular location. In order to lower the electricity costs and control peak load demand, renewable energy sources are considered as

DOI: https://doi.org/10.36548/jeea.2022.3.008
Received: 25.08.2022, received in revised form: 21.09.2022, accepted: 05.10.2022, published: 15.10.2022

the potential replacement for conventional energy sources. The need for efficient demand response is increased by the fact that these new energy sources are less predictable and controllable than traditional ones, where output can be more effectively matched to demand. Recent changes to domestic electrical tariffs by power grid authorities has been designed to promote a better capacity planning.

In order to reduce the dependency on power grid as well, it is highly required to build a cost-effective system. A smart energy-management technique used for smart home integrates the solar energy with the energy obtained from battery storage devices. Whenever a load requirement is minimal, the power grid may consume extra power from the planned system and, when demand is high, it can supply the energy to the load. Monitoring the performance of battery plays an important role if the output of the solar panels is inadequate to feed the load and if the amount of renewable energy sources is also not adequate during the periods of high load demand. This article highlights one of these challenges by recommending a combination of photovoltaic and storage devices with an energy management system, which provides additional power to the electrical grid while also consuming power in times of shortage.

1.1 Smart home architecture

Smart home: Any residential building that uses various communication protocols and optimization techniques to predict, analyse, improve, as well as control its own energy-consumption patterns in accordance with predefined user preferences in order to maximize economic benefits of home while maintaining predetermined standards of a comfort lifestyle is referred to as a "smart home."

Infrastructure: The main components of a smart home's infrastructure include control centres, electricity sources, smart metres, communication devices and so on.

Smart HEMS center: Collecting information from various meter, homeowner commands, as well as grid utility via an appropriate communication method are the key duties of the smart control center. In order to achieve the best outcome for predetermined objectives, it coordinates between various appliances and resources.

Renewable energy: The developed renewable sources of energy in current systems are solar and wind power facilities. Miniature wind turbines, Photovoltaic (PV) panels or thermal sun heaters are now present in many structures. Along with providing electricity, solar energy can also power a solar-powered solar cooler, solar dryer and water heater in smart homes.

Smart meter: Power companies send a demand-response signal to the smart metre, which the SHEMS system then uses as an input. Modern smart-metering infrastructures can now track a wide range of variables in homes, including electrical consumption, gas use, water use, and heating.

Home energy storage system: By enhancing grid stability and security, energy storage gives utilities the flexibility they need for modernized power generation and delivery. The grid storage systems that are currently available range in capacity and price.

Appliances: Schedulable versus non-schedulable loads are the two categories into which smart-home loads can be separated based on its functionality. In contrary to the organising loads, which predict operating patterns that are changed as well as controlled by SHEMS, non-schedulable loads, similarly printers, televisions, hairdryers, are occasionally operated by the end-user without satisfying any predetermined requirements.

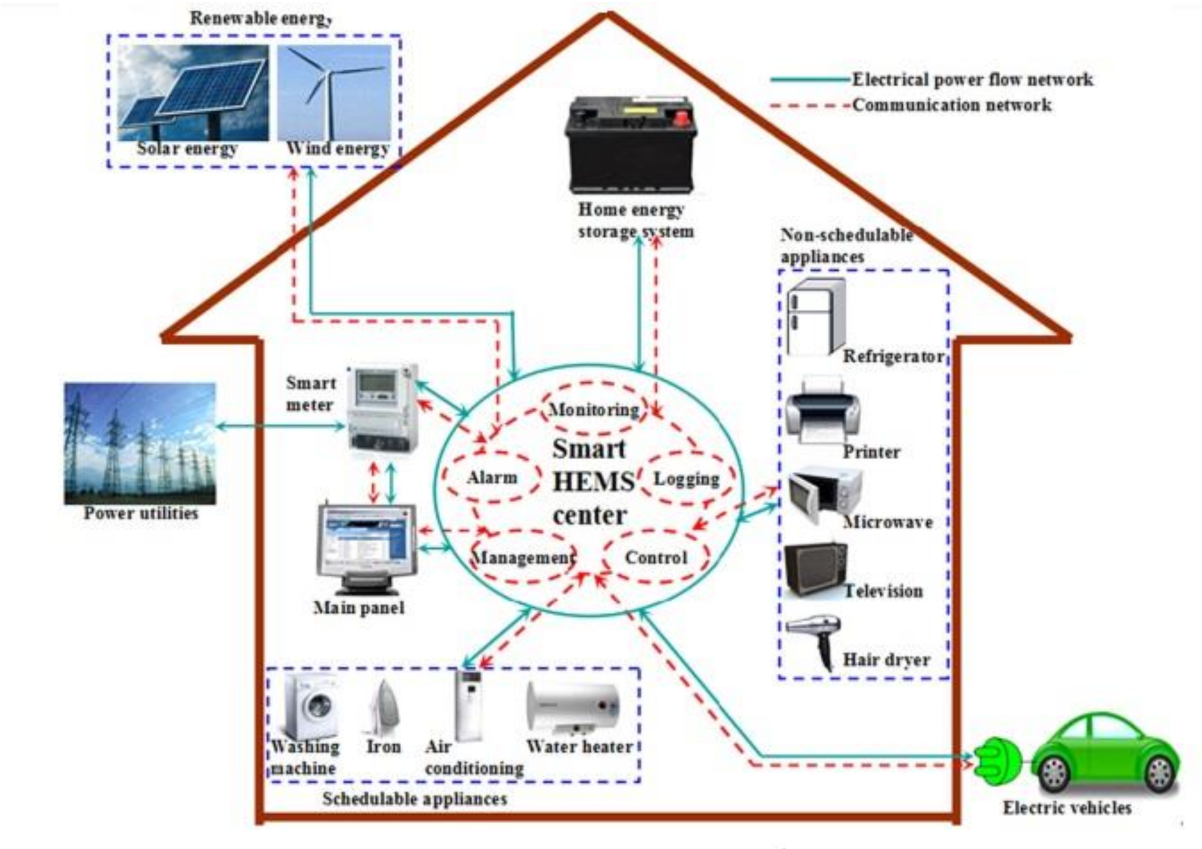


Figure 1. Overall architecture of Smart home energy monitoring and energy management [11]

2. Related Work

In this article, author analyses the effects of proposed control logic, which is designed for enabling an efficient use of electrical loads and air conditioning systems on residential structures. A Decision Support as well as Energy Management System created by the same authors makes it simple to deploy the control logics in both new and existing homes. The management practises allowed in residential areas are intended to limit system overloads brought by the contractual power as 3 kW. The measurement campaign conducted between June and September 2013 has given, demonstrating how the DSEMS functions. Control logics incorporated in the DSEMS have been tested in a real-time environment [2].

The introduction of energy hubs combine the conversion, energy production as well as storage technologies such as combined cooling, power grids, heating, batteries, renewable power resources and energy storages. The primary motive behind developing energy hubs is energy shortage and dynamic environmental considerations. The results show how the combination of demand request program, smart hybrid electric vehicle management, and TES affect the proposed energy hub model's ability to reduce energy costs [3].

The interface between users and their home appliances will be built in the smart home system by allowing the equipment to be controlled and managed either directly or remotely. These devices can therefore function autonomously, multi-functionally, and efficiently [4].

Power scheduling constraint in a smart home refers to the issue of managing home appliances at a proper time within a predetermined time horizon in compliance with a variable pricing scheme. In this article, power management algorithm is categorized as either precise or meta-heuristic algorithms. Single-based, population-based, as well as hybrid meta-heuristic algorithms are considered as the three major categories [5].

In this article, an effective interface with the ultimate user is created, electrical smart metres, together along with heat, gas as well as water metres, are networked in a wide network presenting a future benefits to execute power energy efficiency and other related services. By putting forth the description of a neighbourhood interface for smart metres, by examining the technical solutions in the market and at last by putting forth specific model for an appropriate consumer-support execution of a smart metre [6].

The maximum power point tracking (MPPT) technique enables the photovoltaic array operating point to be set at the maximum power point (MPP) or very near it, regardless of the surrounding conditions. The most widely used algorithm is the conventional incremental conductance (INC) algorithm. To improve the response time, a new MPPT method is suggested. It has two stages: the first is the computing stage, and the second is the regulating step. The simulation results demonstrate that the suggested method has a higher efficiency and responds to certain scenarios 4.6 times faster than the INC [7].

The dynamic power management of a smart home with a solar array and battery storage of PEV (plug-in electric vehicle) is the key focus of this article. It is driven by the difficulties in obtaining sustainable energy sources and the chance for regional energy storage offered by the electrification of vehicles. Therefore, compared to the case when there is no optimal control, the electric cost for a Model S from Tesla with optimum stochastic dynamic programming (SDP) control is 493.6% lower and is 175.89% lower for a Nissan Leaf [8].

A two-stage photovoltaic system consist of a boost converter with proposal of a modified MPPT technique, with constant output voltage using a predetermined control strategy, to guide the photovoltaic or other controller design based on change of load, as well as connected photovoltaic diode rectifier with single-phase grid as well as PFC controller for reducing the voltage of DC link as well as bridge rectifier current waveform with a fine track of the MPP are presented in this paper. It provides good performance in terms of rapid convergence to the necessary operating current as well as voltage variables together with the waveforms' stability under diverse environmental and operational circumstances with little tracking time [9].

Synchronised control of low-voltage energy router-based smart home energy management system (HEMS) design, analysis, and implementation. The main contribution of this research work is to develop novel energy routers, which remain technically feasible and usable in HEMS to fully utilize RESs while still being "operationally friendly and advantageous" to the power grid [10-14]. The proposed approach preserves the overall system's operational stability and works with respect to power grid to reduce the effects of output RES fluctuations and variations in load consumption.

3. Proposed Work

One of the main objectives of a sustainable energy system is the utilization of renewable energy to offer sustainable, affordable, and accessible energy with effective energy storage without compromising the sustainability. This approach demonstrates the working of current HEM concept combined with sustainable energy sources as well as battery storage systems. The fundamental solution to successfully integrate high proportions of wind and solar energy renewable in power systems are the development of battery storage systems. The MPPT control method that extracts maximum power under fluctuating system conditions has been utilised to track the maximum power point.

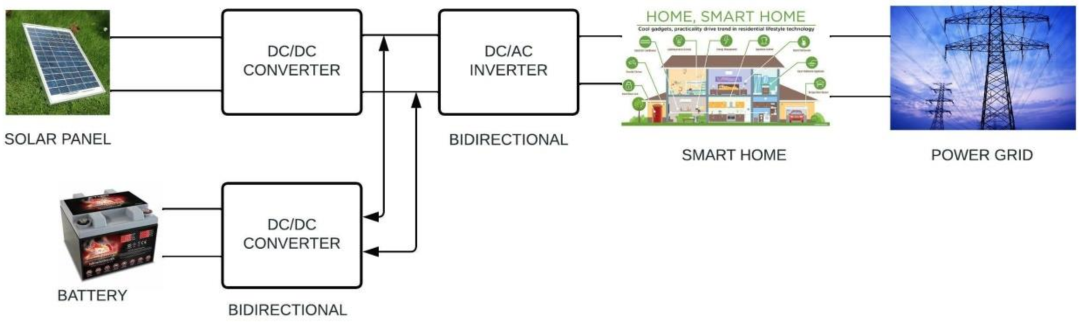


Figure 2. Proposed model architecture

3.1 Solar Photovoltaic System

In the aforementioned system, solar photovoltaic (PV) cells are used to generate electricity. PV or solar cells are devices that directly convert sunlight to electricity. The amount of sunlight has a significant impact on the solar energy produced. Maximum generation is often attained during the day's peak hours. If sufficient, excess power is conserved during off-peak hours, which are typically early in the morning and late at night in energy storage system, including lithium-ion batteries. Modified MPPT technology controls the controller parameters of the array, which has been used to track the solar panel's maximum output power.

3.2 Modified MPPT Technology

In order to overcome the low converging speed challenges, modified MPPT algorithm is used. In the computing stage, both coarse and fine positioning operations are considered. The features of DC-DC converter as well as the parameters of the curve are used in the calculation stage to obtain a starting value for duty cycle. The regulating stage uses a modest step size to adjust the duty cycle. So, by guaranteeing that the system response is on the MPP or very near it, the regulating step can increase efficiency. Additionally, the computing stage might speed up the response time. The following factors determine the energy production or energy delivered for solar systems:

ISSN: 2582-3051

$$Ep=A\ P\alpha\ Gr+(1-\Omega p)(1-\Omega c)$$

A-array area

$P\alpha$-efficiency of an array

Gr-Global radiation

Ωp-Panel loss

Ωc- condition power loss.

The grid's power consumption can be described as follows:

*Pgrid=Inverter efficiency*panel energy absorption*energy produced by PV.*

The output shown by the panel which is around 7000 watts

3.3 Battery Energy Storage

During power surge transitions, the load power determines how quickly a battery energy storage unit empties. As a result, the grid's electricity demand is constant. The energy demand from grid is more steadily met by solar hybrid systems. Energy storage systems offset the grid's power stresses. The solar system, through which the Photovoltaic panels were connected to the power grid, was expanded to include the battery group, and the outcomes were studied. The PV panels now have a lead-acid battery group with a 24 V, 30 Ah, and 1,200 Wh power capacity. As a result, a system for energy storage was added to a solar hybrid construction.

4. Results and Discussion

4.1 Steps of simulation

The modified Maximum power point control technique was used to provide a power output from the panel that was nearly constant at 7 kW.

Case 1: When one of the two 7 kW loads was activated, it is analysed that load greater than 50 % of solar panel power. As a validation, extra electricity was once again sent to solar grid.

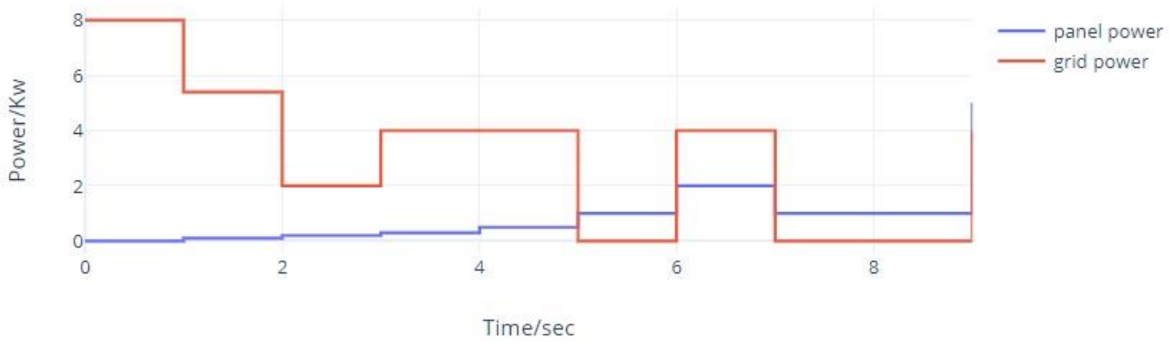
Case 2: If the two loads are turned on, total power consumption is 8 kW, therefore the solar panel is insufficient and the grid was used to supply the energy.

Case 3: The loads have been disconnected once more, the battery has been connected to ensure that the overall power will be enough to satisfy the requirement of the load, when the loads are reconnected to the system in identical way before. At t=1 sec, demand for the load is to be 8 KW,t=2 sec the loads are Off.

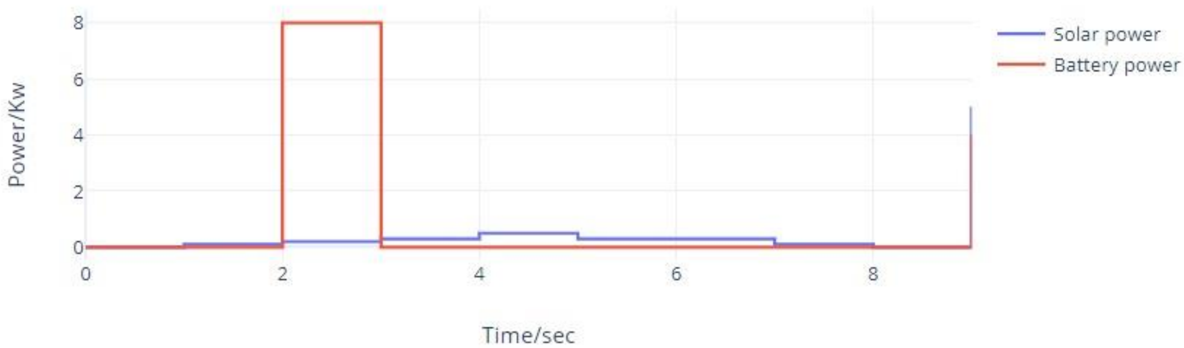
The real power figure illustrates the electricity delivered and consumed by the grid in the event of changing load circumstances.

Table 1. Simulation parameters of the proposed method

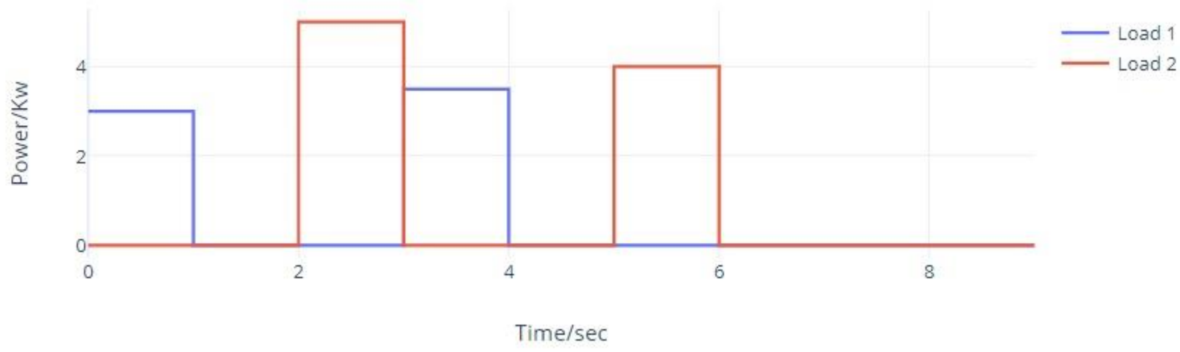
Solar panel	7Kw
System load1	5Kw
System load2	8Kw
Switching frequency	10Khz
Reference voltage	420 v
Power grid	66Kv



(a)



(b)



(c)

Figure 3. Power flow with respect to the three cases

Figure 3 (a) displays the utilized power by power grid also the power that is delivered when load circumstances and the state of the power supply changes. Figure(b) demonstrates how battery power fluctuates and how much solar power is required to keep the load running case of increased demand of the load. Figure3 (c) displays the switching pattern of the load, which demonstrates highest as well as the lowest load demands over the whole time period.

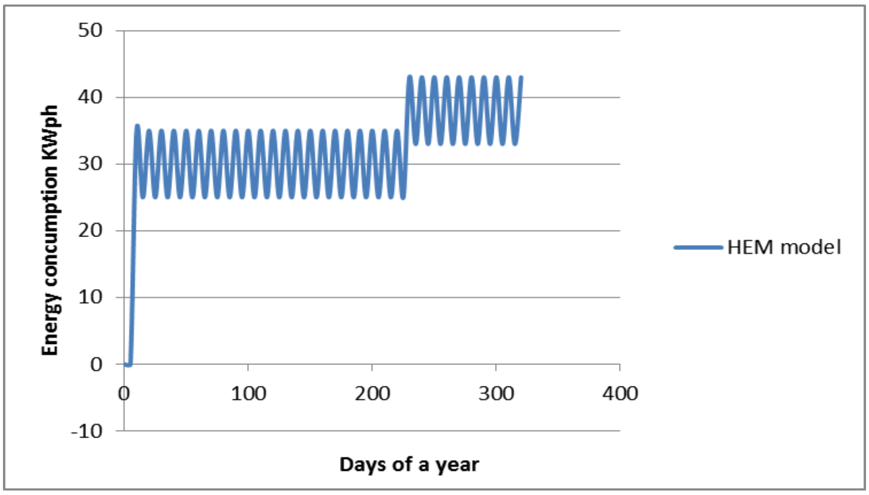


Figure 4. Energy consumption over a year with the proposed model

The energy consumption with respect to the implemented algorithm of power management is shown in the above figure 4.

5. Conclusion

An effective power management system is required to coordinate between available sources, loads, and user preferences in significant portions of the energy management system.

This article incorporates renewable energy sources into the supply to regulate load during base and peak load periods of demand. It consists of numerous energy-consuming objects known as loads as well as various energy-generating sources such as batteries and solar storage systems. Switching between several energy sources is carried out for energy saving, and finally the simulated results are obtained. As a result, developing smart HEMS is now a top priority on global scale to assist the drive towards more dependable and sustainable green power production for smart grids.

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