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Smart Energy in Home/Microgrid for Green Building

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Abstract*: This research aims to provide such conditions in smart home applications, which monitor and control energy resources, in addition to evaluating the microgrid system whose function depends on economic strategies. MATLAB Simulink was built to manage home energy using the microgrid system. Measurements of the three signals represent that there was a decrease in energy consumption after using the Microgrid system. Two scenarios or cases were used to make a comparison of the performance after the addition of the PV array to the system. The electrical load is distributed in the late night and morning when the cost of energy purchased is minimum. At the same time, the daily production of energy by the PV is approximately around 4 MW in the interval between 6 am and 5 pm. The excess energy is stored to be used in the greatest power need periods (peak period). Some power may overflow during the day, and it can be sold to the local network at a certain price (usually less than the purchase price). Energy may increase during the day and overflow; in this case, part of it is sold to local networks at less cost than the purchase. Also, there is a reduction in the cost in the two previously mentioned cases from 1008.56 to -39.42 € due to the comprehensive management of the smart energy software by scheduling the use of electrical loads in the time windows between the start time and the end time according to change in price to get the minimum cost. In view of the use of (PV) and battery storage system, expenditure costs are also decreased, and the customer benefits from the surplus energy by injecting 26.66 kW into the grid and selling the surplus kilowatt to the local network as well.

Keywords; Home Microgrids, photovoltaic (PV) panel, MATLAB Simulink, renewable energy, management of home energy..

I. INTRODUCTION

Recently, the idea behind the development of smart homes expanded all around the world, which began to be noticeable in the late 90s [1]. This development was the reason behind the initiation of the concept of home energy management. This system aims to provide the ability for users to manage electronic devices and operate technological devices through remote control or by a smart home application, or through any digital device [2]. The smart home application is the most common concept since it is more clearly known to users who use digital devices and interact [3]. Devices that provide interaction between humans and devices will be programmed in a way that helps users to operate them directly and sit away from them. A smart grid is the potential future of power systems [4]. Home Microgrids (H-MGs) are a new and vital technology that saves energy on a local scale by supplying energy to local networks. H-MGs are like conventional power systems, except that the difference is due to the difference in the ability to operate independently in island mode [2]. H-MGs are utilized to supply energy in two forms, either as a small-scale supply such as commercial buildings or residential buildings or as a large-scale supply such as supplying an entire city [5]. Since H-MGs are integrated with storage devices and renewable energy, a good management system is highly required. As a result, there is the important of having high-level supervision and control systems in relation to H-MGs; this increases work efficiency and provides a safe environment with the lowest possible cost.

H-MG may experience frequent shutdowns or shortages; therefore, H-MG requires a system that integrates its overall structure with Energy Management Systems (EMS). The integration of this design with environmental management enables it to operate in real-time. In addition to that, it is easy to adapt it to the different capacities and types of generation and its storage assets. The main reason why EMS power systems are widely used is to reduce emissions, increase the effectiveness of the environmental management system, maximize operational efficiency, and increase the life of the assets at hand. Energy management in terms of demand-side includes a number of strategies whose main objective is to reduce the number of utilities that depend on running energy in each household to reduce the carbon footprint of capacity, save money, and reduce air pollution [11][12]. To understand the reason behind the energy management demand-side is called in this term it depends on the way how energy flows from the source of production to the source of consumption [7].

- **Retort to demand**

To balance the economic conditions of the institution, the program pays the institutions and their users to reduce the energy used in order to reduce the burden in the event of an increase in the cost of fees for energy use or the event of pressure on the network. [13].

- **Management of Demand**

Management of demand contributes to improving the way how energy is used. Suppose any institution uses energy efficiency projects, whether it is currently operating or will be completed in the future. In that case, the energy efficiency plan reduces the cost to the institution's potential to encourage it to use energy efficiency. One of the issues related to demand management is working to reduce total energy costs and reducing energy volume during system loads reach their maximum [14][15-17]. Recent developments,

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especially with the emergence of smart networks,
will completely change energy consumption or the use of energy methods in infrastructure, home networks, or energy storage plans. In maintainable smart grids, smart homes with Home Energy Management System (HEMS) have an important role in enhancing the power distribution system's efficiency, economy, reliability, and energy savings. HEMS includes an entire framework that uses production, conveyance, and distribution systems to distribute electrical power throughout the grid [5]. This system includes many applications such as data acquisition and supervisory with full power management system functions. It is an important invention for customers residing worldwide since it helps them monitor their daily, weekly, or annual energy consumption and helps them conserve energy sources for their efficient use within the environment [6]. Many studies encourage the use of advanced infrastructure for measurement and smart meters (AMI) to contribute to the effective management and control of energy use within households. Users are alerted in the event of an increase in energy use, and in the event of excessive energy use, fines and additional amounts are paid. In order to avoid such occurrences, users will be encouraged to manage the use of energy sources. This regular meter readings and careful monitoring will ensure that the energy sources are not misused in any way. With the tremendous speed in the development of technology innovations over time, smart home applications will be developed by integrating technologies and methods in these applications so that they alert users directly regarding their energy use. So that the applications used to monitor the meter are compatible with the applications used. The application of the HEMS is similar to the work of the smart home application, as it works to use energy efficiently by reducing the use of energy at peak times, and this leads to a relative decrease in the monthly bills of the users. HEMS application uses effective data management techniques to align the work of home appliances within the user's required requirements. The application includes four basic stages used in data processing and, therefore, its interaction with the end-user [7].

- Collection of data
- Processing of data
- Representation of data
- Set up an interactive operation with the user

The applications of smart homes effectively use the data management systems that have enabled users to make good use of them to operate their home appliances and other electronic devices. This can effectively conserve energy in homes and makes users more responsible about their usage of their home appliances [8]. Usually, users overuse household appliances due to their daily use, and therefore the purpose for which they were found is neglected. Excessive use of household appliances harms the surrounding environment and reduces the life of these appliances relatively now. There are consequences to the excessive use of household appliances, such as harm to the environment in addition to reducing the relative life of these appliances. These applications will contribute to providing information on the daily, weekly, or monthly use of the devices [9] extensive review and analysis of step-by-step HEMS home-based applications and infrastructure. The Microgrid is considered an independent energy mechanism that includes the distribution of energy such as (the management of demand, production, and storage) and loads, Which can be run with the leading network to work either in parallel or independently, and the main objective of this is to contribute to providing the local community, whether rural or urban, with the safest and most cost-effective energy, as shown in Figure 6. By providing solutions to federal, commercial, and industrial consumers, benefiting society at large by reducing pressure on energy transmission and distribution as well as lowering greenhouse gas (GHG) emissions. Micrograms are considered smaller versions than traditional micrograms, such as power distribution, current grids, regulation of voltage, power generation, and control devices such as key gears. Although there is a variation between microgrids and traditional grids, they are closer to each other [18]. In addition, it is integrated with renewable sources of energy such as wind energy, micro-shell energy, geothermal energy, solar energy, waste energy, micro-hydro energy, as well as combined thermal and energy mechanisms (CHP), and this reduces the transfer between the use of electricity and energy production and thus increase efficiency. The microgrid mechanism facilitates remote applications and agrees to pollution-free connection to energy, accelerating the use of renewable energy. In addition, microgrids are considered one of the essential alternatives in case of network disappointment. Microgrids are expected to be a member in the development of the following power mechanism, not only in rural and remote areas but also in city groups; microgrids are expected with conventional networks (e.g., in traditional healing techniques, such as district heating mechanisms). The planning process must be economically viable to ensure stability in the long term; Planning for small networks includes more than one aspect due to existing substitutions, goal situations, limitations, and uncertainties [19]. Various studies contain a conclusive review for improving skills associated with microgrids, such as renewable energy, hydropower, solar, bioenergy, wind, and geothermal energy, and optimization methods for cross mechanisms [20][21]. Hybrid Mechanism-based energy is provided as a general list of renewables in the General Distribution Sources, Constraints lists, Output, and Target. It also provides a list of optimization tools and techniques, a conflicting objective matrix. Various optimization planning techniques are applied to renewable energy, but energy community mechanisms, such as the district boiler, are also applied. Thus, it is essential to develop and restore a microgrid energy management system (MEMS) to counteract the integration of distributed generators (DG). The essential architecture and functions of MEMS are analyzed, and the main application areas, objectives, meanings, and ways of development are analyzed in the Distributed Energy Management System (DEMS) and the Central Energy Management System (CEMS), respectively. The functions of the Microgrid power management system are represented by the application to the actual Microgrid, which checks the accuracy and efficiency of the process strategy in the pattern of the planned microgrid power management system [22][23][24]. The dispersed generation and charging system develop new skills in the context of the erratic electricity market.

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II. METHODOLOGY

A. Design of Microgrid Energy Management Network

In this section, two types of design problems have been issued. The first one is the engineering challenges. The second one is the basic requirements for these networks, which are necessary to make the system work in a proper manner within the environment of the emerging Microgrid.

B. System Architecture

In Resource-Oriented Architecture in MP has been applied [10], each resource executes a defined interface which is well and enables the MP to play and plug the loads. This architecture owns some advantages over the service architecture. It is linked with energy sources; therefore, it increases the effectiveness of interactivity within the EMS. Further, this architecture is relatively lightly weighted since it comes without a complex interface.

C. Facility- Interoperation Energy Services

A microgrid plays the role of the service provider; the prediction of the facility side can be recognized by it in order to assist the grid in understanding the behaviors of the energy in an accurate manner. The MP gives the data service, which most the EMSs could do. Historical energy data is also consisted of within the EMSs. The acceptance command message can be shown in MP, which makes management for the internal energy sources; this match with a direct load can control the service. Various future expectations will also be offered, consisting of demand forecast and the generated power.

D. System Design

Any microgrid EMS has to be executed and designed to satisfy all of the functional requirements. Some tasks would be undertaken in order to achieve them to respond to the orthogonal issues. However, an EMS would be designed, but it is necessary to keep in mind the possible challenges that may be met and the functional requirements. Various systems of energy management will be directed into one element. The EMS must be flexible to accommodate the new application easily; for instance, a user can create an application from a smartphone and then sell it to various APP stores. On the other hand, any system that focuses on computer systems and communications will normally use specialized scheduling and control algorithms. Hence, to incorporate new technology, a configuration must be customized, and the corresponding system must be recreated. Also, the challenge could be met by designing the MP where a variety of models like algorithm module and communication module, a model for power generation could be used and added within a current optimization module. In this way, the responses to the challenges and the functional requirements for the MP are facilitated. A design for the EMS microgrid is shown in Figure 7.

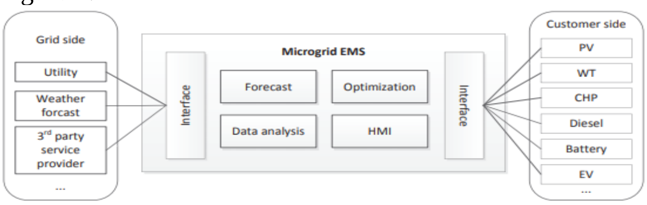

Figure 1: Energy Management System Design for a microgrid.

The main problem is to detect how to run or design a scheduling algorithm. Each Microgrid consists of some intrinsic features, unlike the simulation. Therefore, an algorithm that is predefined may not be worked well within the configuration of the Microgrid. Two algorithms would be used in MP, and those algorithms support the operation of the ideal Microgrid, which are energy scheduling and demand response (DR) algorithms. A formulation for the microgrid system model and the energy scheduling with the demand response has been implemented and considered as an optimization problem. Assume that the microgrid system own a number of distribution generation units (DG) which have the symbols $G := \{g_1, g_2, \ldots, g_G\}$, and distribution storage which have the symbols $S := \{S_1, S_2, \ldots, S_B\}$, and some controllable loads which have the symbols $L := \{l_1, l_2, \ldots, l_L\}$. Keep in mind that the model of discrete-time with the finite horizon has been utilized here.

Assume that a time (T) will be divided into a number of equal intervals (Δt) such that; $T := \{0, 1, \ldots, T-1\}$, and t_0 is known as the starting time. However, for each DG g ∈ G, the corresponding formula must be met, which defines the loser and the upper bounds regarding its power [6]:

$$p_g^{min}(t) \leq p_g(t) \leq p_g^{max}(t), \forall t \in T \quad (1)[6]$$

The minimum output power and the maximum output power are denoted by $p_g^{min}(t)$ and $p_g^{max}(t)$, respectively. In general, the DG includes wind turbines, photovoltaic, diesel, or a combination of power and heat generators. There will not be a certain model of generators considered in order to be able to integrate and therefore reach the desired optimization for this problem. Some of the DG could not be dispatchable like the wind turbines and the photovoltaic or dispatchable like the diesel. The essential difference between them is that the dispatchable units have a non-fixed amount of the outpour power $p_g(t)$. On the other hand, the non-dispatchable units have a fixed amount of output power that is equal to the approximated value (i.e., $p_g^{max}(t)$, = $p_g^{min}(t)$, = $p_g^{f}(t)$, where $p_g^{f}(t)$is the forecasted power at time t) and cannot be varying.

Assuming that the cost of the DG is denoted by $C_g(p_g(t))$, while the cost of the generation for the renewable (wind turbine of photovoltaic) units is zero.

Assume that some batteries like DS units are owned by the MP. Let the output power them is $p_b(t)$, which has a negative sign within the discharging process and a positive charge within the charging process. Further, let the stored energy within the batteries during the time t denoted by Eb (t).

The corresponding model battery could be calculated through:

$$E_b(t+1) = \eta_b E_b(t) + p_b(t)\Delta t, \quad \forall t \in T, (2)\ [6]$$

$$E_b^{min} \leq E_b(t) \leq E_b^{max}, \forall t \in T, \quad (3)\ [6]$$

Where the symbol $\eta_b$represents the efficiency of the battery. While the minimum and the maximum energy which is stored within the batteries are denoted by E_b^{min}, and E_b^{max}. When αb > βb, then the above-mentioned function is convex.

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The damages which occur to the battery can be captured through the cost function by the discharging and charging operation.

A model for the Load in MP is as:

$$p_l^{min}(t) \leq p_l(t) \leq p_l^{max}(t), \qquad \forall t \in T. (4) [6]$$

Where the minimum and the maximum power for load 1are represented by $p_l^{max}(t)$, $p_l^{min}(t)$. And the cumulative consumed energy for all the MP loads can be found by applying the following formula:

$$E_l^{min} \leq \sum_{t \in T} p_l(t)\Delta t \leq E_l^{max}. \qquad (5) [6]$$

Where the minimum energy for MP load which is required in order to finish the required tasks is denoted by E_l^{min}. While the symbol E_l^{max} represents the MP maximum overall energy for the loads. Further, the cost of the loads regarding the consumed power is denoted by C_l (p_l), and to make a match between the MP supply demand, the following formula has to be applied in order to calculate the net demand for the Microgrid:

$$P(t) = \sum_{l \in L} p_l(t) + \sum_{b \in B} p_b(t) - \sum_{g \in G} p_g(t), \qquad \forall t \in T. (6) [6]$$

Where $\sum_{\in L} p_l(t)$ represents the overall demand power, while $\sum_{g \in G} p_g(t)$ represents the overall generated power. However, when the MP works within an island mode, the corresponding p(t) will become zero, but when MP works within a grid-connected mode, the corresponding p(t) will be traded between the main grid and the traded grid. The cost of the energy purchase from the main grid could be calculated through:

$$C_0(t, P(t)) = \rho(t) P(t) \Delta t, \quad (7) [6]$$

Where p(t) represents the price of the market energy.

1. Energy Scheduling

The aim here is to plan the day-ahead operation for the DERs with the loads in the following way:

1) Achieve the goal of minimizing costs for energy purchase, energy storage, generation, and load.
2) Satisfy the load constraints, DER, and attain the matching of supply-demand.

Assuming that the period T is one day and assume that p_g is ($p_g(t)$, t ∈ T), p_b is (p_b (t), t ∈ T), p_l is (p_l (t), t ∈ T), and $C_g(p_g)$ is $\sum_{t \in T} C_g(p_g(t))$. Therefore, the energy in MP could be scheduled as:

$$min_{pg,pb,pl} \; \xi_g \sum_{g \in G} C_g(p_g) + \xi_b \sum_{b \in B} C_b(p_b) + \xi_l \sum_{l \in L} C_l(p_l) + \xi_0 \sum_{t \in T} C_0(t, p(t)) \; [6]$$

Where the parameters ξ_l, ξ_g, ξ_b, and ξ_0 are trade-offs to minimize the cost and maximize the utility. After solving this problem, the ideal schedules would be calculated, including the load schedules p_l, the generation schedules p_g, and the battery.

2. Demand Response (DR)

Demand Response could be described in time period T, which has started and ended time, and the demand limit is denoted by $P_{max}(t)$. Further, the constraint of DR could be calculated as:

$$P(t) \leq P_{max}(t), \forall t \in T \quad [6]$$

And the problem of Demand Response could be calculated by:

$$min_{pg,pb,pl} \; \xi_g \sum_{g \in G} C_g(p_g) + \xi_b \sum_{b \in B} C_b(p_b) + \xi_l \sum_{l \in L} U_l(p_l) \qquad [6]$$

III. RESULTS AND DISCUSSION

A. Case studies execution

A noteworthy reduction in the cost of electricity has been performed by studying two various cases. Further, the efficiency of the suggested system also has been studied. In the beginning, the time will be the key which will represent the horizontal axis which is for 24 hours. Case number 1: it is the simplest case that demonstrates a customer paying for electricity from only the national grid. Case number two: This case demonstrates the situation of a customer who imports electricity from two sources: the national grid and a photovoltaic system that produces electricity from solar radiation. It is necessary to bear in mind the response to demand. The following table shows the total demand which both customers require. The listed data were extracted from [25].

Table 1: The required energy.

Number	Appliance	(Duration in hours)	Consumed power (in kW)
1	Illuminations	5	0.5
2	Desktop	5	0.3
3	Heater	2	1.7
4	TV	5	0.3
5	Microwave	1	1.7
6	Washing machine	2	1.8
7	Iron	2	2.7
8	Air conditioner	12	1.15
9	Dishwasher	1	1.7

The cost of the electricity that was imported into the grid was 0.10 €/kWh, while the cost of the purchased electricity was altered during the day, as shown in [26]

B. Results of Calculations and Discussions

The following figure illustrates the power as well as load demand in case number 1 within a day, which means for 24 hours.

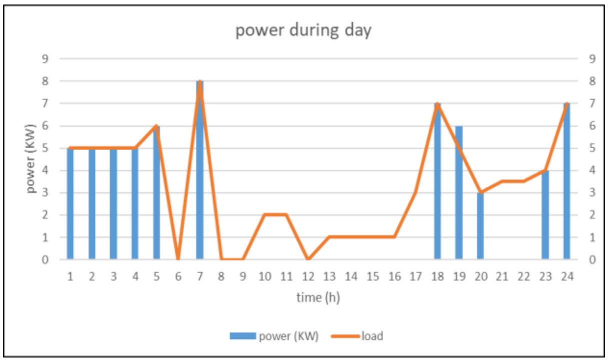

Figure 2: Load and power demand during 24 hours for case number 1.

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As illustrated afore, the electricity is purchased in case number 1 from the national grid. The power consumed by the load is changed during the day by the home applications based on the possibility of a human's presence in the house. It is known that the peak time of electricity consumption occurs from the afternoon until 11: 00 PM since it is the time of leaving the work. The physical meaning of increment in electrical load indicates greater electrical energy will be required. Consequently, a higher cost will also be required.

While case number two uses a smart microgrid system of energy management, the benefit of this type is that it makes a distribution for the electrical load, which is where the home applications within the 24 hours. This system uses the sun's renewable energy source to produce electricity from the photovoltaic technique, and the energy will be stored in batteries. Figure 16 illustrates the total energy distribution for case number two, especially when the home uses smart energy management for 24 hours.

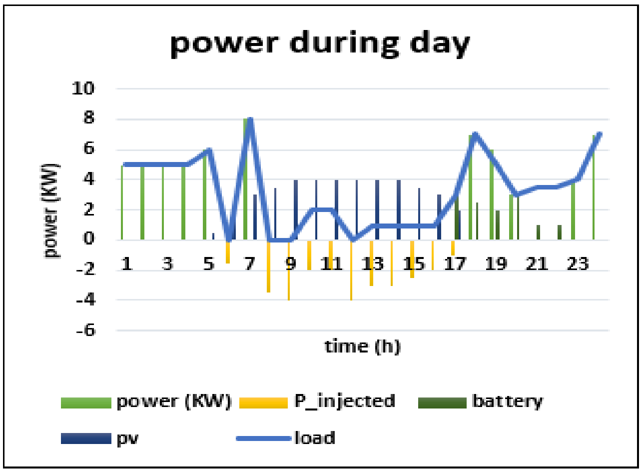

Figure 3: power distribution of case number two during the 24 hours.

As represented in Figure 16, which is the distribution of the energy for the second case within a day, it can be observed that the distribution of the electrical load occurs late at night as well as in the morning when the cost of purchased energy is at the lowest value. These days, the PV strategy produces n amount of daily energy, which is almost 4 W between the period from 6 am and 5 pm, and if an amount of extra energy was produced, it would be stored in batteries in order to be used next time in the peak periods. During the day, some energy may overflow, and this energy could be sold for the local grid at a suitable price, but it is commonly less than the purchases price. The intelligent energy management system aims to distribute the electricity into the loads within a day and save the cost of purchased energy. Further, this system produces a special type of clean energy by using the renewable energy system. Table 2 shows the economic differences between both cases (the first and second cases) by making a simulation for the model system that considers some specifications.

Table 2: Differences in cost and the power for the two cases

Case number	Solar power generation in kW	Purchased power in kW	Total costs (€)
Case number one	-------	64.7 kW	1008.56
Case number two	26.66	45.33	-39.42

Based on the previous table, the cost between the two situations is decreased from 1008.56 to -39.42 € as a result of the implementation of the smart energy program. So, the usage of the PV technique with battery storage leads to reducing the electricity bill. Further, when a surplus amount of energy is produced by the PV, it will be transmitted into the national grid and then sold it overflow kW for the local grid.

IV. CONCLUSION

It is very necessary to improve some services and products which are considered eco-friendly. Hence, some implementation and regulations are inserted to achieve this goal. The available applications for the smart home have a special system for managing and monitoring the energy capabilities in order to assure that the user will not waste the energy. It was found that by making this management and monitoring for the resources of energy, the efficient utilize for the home applications not only the thing that will be resulted. But the attitudes and the behavior of the users will also be considered as the saving of energy. Some outcomes from this research highlighted that when the behavior of the user is changed for the household applications, saving in energy will be observed with a percentage of almost 30% or more than this percentage.

- A microgrid network was built by MATLAB software to be used in home energy management.
- A system of PV produces an amount of energy which is almost 4 MW in the period between 6 am and 5 pm, and if an extra amount of energy is produced, it will be delivered for the national grid to be sold at a certain price or stored in batteries to be used next times.
- Purchased energy can be distributed and saved by the smart management of energy in a smart manner. Further, it produces clean energy by using renewable energy.
- The cost of electricity decreased in case number 2 compared with case number 1 from 1008.56 to -39.42 € as a result of smart microgrid integration.

The cost of electricity bills was reduced in an obvious manner because of using the solar system (PV) and the battery. It was found that in case number 2, the surplus energy which was injected into the grid was 26.66 kW.

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