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Charge Management of Energy Storage Devices Considering Battery Wear in IoT-based Distribution Networks

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Abstract

This paper demonstrates how integrating energy storage resources into an energy management system can improve profitability and quality. By controlling the number of charging and discharging cycles, the service life of the storage devices is preserved. Additionally, the impact of consumer behavior and IoT on energy storage charge management is studied. The optimization process is performed using the YALMIP and MOSEK toolboxes, and applied to an IEEE standard 33-bus network. Results show significant improvements in technical and economic parameters with the presence of energy storage resources. Furthermore, the impact of storage resource longevity is considered in the comparison of results. In conclusion, IoT technology can offer significant benefits for network consumers and optimal consumption management.

Keyword: Internet of things, energy management, electrical energy storage, consumer behavior, distributed generation.

Nomenclatures

Symbol	Description
c_t^{DG}	production price of dg
$c_{t,wholesale}^{DG}$	major sell rate of dg production
c_t^{TOU}	Retail rate with term of use
$c_t^{TOU,wholesale}$	major sell rate market with term of use
$c_{min}^{TOU,wholesale}$	Lowest major sell rate market with term of use
$c_{max}^{TOU,wholesale}$	utmost major sell rate market with term of use
c_{min}^{TOU}	Lowest Retail sell rate market with term of use
c_{max}^{TOU}	utmost Retail sell rate market with term of use
d_{KL}	kullback leibler distance
$f_{customer}$	fitness function of consumer
$f_{discomfort}$	Inconvenience expenditure
$f_{Payment}$	Electricity payment expenditure
M	A biggish finite digit
$MUT^{\mathcal{L}}$	Minimum loading time
$N(\varepsilon_1^i)$	Number of consumers with the ε_1^i coefficient
L_t^{Total}	total load considering normal consumer behavior
PD_t^{total}	The whole power demand of the net
PD_n^t	Node load of n
$\mathcal{P}_n^{base}$	The node basis electricity of n
$\mathcal{P}_{Total}^{base}$	The general basis power of the net
$\mathcal{P}_t^{DG}$	retail electricity procure from dg
$\mathcal{P}_{t,wholesale}^{DG}$	major sell electricity procure from dg
$\underline{\mathcal{P}}_t^{DG}, \overline{\mathcal{P}}_t^{DG}$	Lowest / utmost range of dg
$\mathcal{P}_t^{Grid}$	electricity procure of the net
$\mathcal{P}_{i,t}^{Grid}$	electricity procure of the net by consumer i
$\underline{\mathcal{P}}_t^{Grid}, \overline{\mathcal{P}}_t^{Grid}$	Lowest / utmost range of the net power
$\mathcal{P}_t^{UpGrid}$	electricity procure of the upstream net
$\mathcal{P}_t^{\mathcal{L}}$	Electric power of Load
$\breve{\mathcal{P}}_t^{\mathcal{L}}$	Ideal Electric power of Load
$\hat{\mathcal{P}}_t^{\mathcal{L}}$	Nominal Electric power of Load
$\mathcal{P}_t^S$	electric storage charging
$\underline{\mathcal{P}}_t^S, \overline{\mathcal{P}}_t^S$	Lowest / utmost electric storage charging
$\Pr(\varepsilon_1^i)$	Possibility relevant to the ε_1^i
$\Pr(\chi)$	Possibility relevant to the χ
$Pr^{new}(\chi)$	New Possibility relevant to the χ
$t, \Delta t$	time distance and its duration
t_{ini}, t_{final}	Initial and final time
$\mathcal{T}$	collection of time splits
$t_{operation}^{\mathcal{L}}$	Operating time for each load
$t_{des}^{\mathcal{L}}$	eligible time to start the time flexible load
$\gamma_t^{\mathcal{L}}$	inconvenience rate of the load
$\delta_t^{\mathcal{L}}$	assumed Parameter indicates the importance of time flex load postponement
$\varepsilon_1, \varepsilon_2$	Coefficients Weighting of the consumer expenditure
ε_1^i	Weight Coefficient of the i[th] consumer expenditure
$\xi_t^{\mathcal{L}}$	changing load situation
$\tau_t^{\mathcal{L}}$	binary for turn on/turn off situation of the load
σ_{TOU}^2	Rate amount with term of use

$\sigma^2_{TOU,desired}$	eligible rate amount with term of use
Ω^{Bus},Ω^{DG}, Ω^{Line}	collection of DGs, lines ,nodes
Ω^{TFL},Ω^{PFL},Ω^{NFL}	collection of time flex, power flex and non-flex loads
Ω^{Load},$\Omega^{customers}$	collection of loads and consumers
$\Omega^{storage}$	collection of batteries
$U^{ch}_{i,h}$	Storage charge status
$\mathrm{U}^{\mathrm{dch}}_{\mathrm{i,h}}$	Storage discharge status
$SOC_{i,h}$	The amount of energy available during each time interval in each storage
$XC^{ch}_{i,h}$	Counter The number of times the storage is in charging mode
$XM^{ch}_{i,h}$	Indicates a binary variable that the storage has started charging at a specified
T	Time Scheduling time for storage
$XC^{dch}_{i,h}$	Counter The number of times the storage is in discharge mode
$XM^{dch}_{i,h}$	Indicates a binary variable that the storage has started discharging at a specified time
$XN^{ch}_{i,h}$	A binary variable that indicates when the storage has started to stop charging
$XN^{dch}_{i,h}$	A binary variable that indicates when the storage has started to stop discharging
Γ^{ch}_{i}	Indicates the minimum number of hours that the storage unit is continuously in charging mode
Γ^{dch}_{i}	Indicates the minimum number of hours the storage is continuously in discharge mode

Introduction

Today, the use of renewable energy sources in networks Power to generate electricity due to new trends in energy supply Global and environmental concerns arising from products based on Fossil fuels have been undeniable [1]. So today the rate of the use of energy sources based on solar power is increasing And this increase in their use leads to a reduction in their installation costs Has been [2]. Energy storage management is crucial to increase the safety, reliability, and performance of energy storage systems. This paper presents a cloud storage management system for energy storage systems to improve the computing power and data storage capability of cloud computing. With the IoT, all storage data is measured and transmitted seamlessly to the cloud [3]. Use of solar power generation sources Can be installed on rooftops in low-pressure distribution networks and Capacities of less than 10 kW by consumers across the world. The reason for this can also be found in the intensity of sunlight in different areas, cost savings, incentives, and subsidies that are given in this field. Utilizing solar power-based production resources has advantages These include reducing network dependence on Global electricity to supply electricity, improving voltage profiles, and reducing losses The network pointed out [4]. However, the presence of these renewables at the level of distribution networks has not been without problems. When the volume of the presence of These resources goes up in distribution networks and at times when generated from Increased load consumption causes reverse load distribution in the network [5]. Reverse load playback on the network also in turn increases Harmonics in the network, increase voltage in the nodes, cause errors in performance Network protection systems, increase network losses and finally, Reliability will be reduced. To control the negative effects of the significant presence of production-based resources There are two main solutions to solar power in modern distribution networks. The first method is to use the old methods that can be used for Momentary change of the pointed load and another way of utilizing technologies New that can be used to control reactive power Inverter solar power-based production resources, the use of tools Flexible AC at the level of distribution networks and the use of Stored technology at the local level noted. Utilizing storage technology can be significantly reduced the negative effects of the presence of solar sources in the network. For this purpose, today there are various papers in the field of planning management Batteries and how to determine their optimal size are provided [6,7]. In [8], the authors describe the optimal size of batteries in power distribution networks That are equipped with solar power, sources to control the voltage Network specified. Authors in the paper [9] of the compensator Static synchronous parallel to the storage in the direction of control Increased voltage in the network have benefited but in this paper evaluation, The economy is not done. Energy storage technologies, including storage types, categories, and comparisons, are critically reviewed. Most energy storage technologies are considered. This reference also includes new types of energy storage as well as the most important advances and developments in energy storage [10]. The authors in the paper [11] according to the importance of buying and selling optimal electricity, reducing network losses, and Power generation at peak times economic evaluation to use Storage devices have been done in the power grid, but in this paper, there are restrictions Exploitation is not Considered. In paper [12] of time control method Real to debug and smooth the load profile in the distribution network Have used. also in this work of storage capabilities Used. But the point that needs to be noted is that this paper does not address economic issues and only Storage devices have been used for decoding. The authors in the paper [13] consider the size and location of storage devices in the network They have highlighted the importance of network losses, voltage control, and load management. The authors in the paper [14] of the simultaneous collaboration of old methods such as Utilizing voltage regulators along with storage sources, they used energy to control the voltage in the network. Authors in Paper [15] also to de-network in the network and prevent increase Network voltage from storage sources for optimal operation of networks Have used distribution. The authors in the paper [16] also consider the problem of voltage in the network of storage devices in line with economic goals, they have used reverse load reduction and volume reduction. The authors control the number of voltage fluctuations in the shadow of changes Sudden power output of solar production sources from storage sources Have used. How to charge and discharge them without any optimization Provided. Expansion of storage at the level of distribution networks only Based on the cost of their investment and the land used in the paper has been done but in this paper the benefits of [17]. The presence of these new technologies has not been studied. In the paper [18] also the authors of optimal programming for storage devices in the level of distribution networks have provided the goal of reducing losses It is a network, but it does not take into account environmental issues Is. Similarly, in the paper [19] the authors aimed to reduce costs Network and network losses from storage resources at the distribution network level Used. This paper introduces a new approach to battery pack modeling by combining several previously published models into a comprehensive framework. This describes how the sub-models are connected, their basic principles, what configurations, and what new parameters are required. Is to be introduced [20]. With the advent of IoT technology, traditional energy management systems have been transformed into new responsive embedded systems that reflect consumer preferences in their energy supply process [21]. The concept of IoT is somewhat simple, while its practical implementation requires various infrastructures such as communication systems, tools, sensors, actuators, control, and protection systems [22-23]. Two-way customer communication with the smart grid operator leads to several technical and economic benefits for each part of the system, such as consumers, distribution system operators, and central control units (e.g., government agencies) [24] In the modern energy management system, the share of IoT in smart grids has gained a way to connect everything in every part of society with high potential due to various advantages in various fields. This paper reviews the most important research work focusing on the use of the Internet of Things in smart grids [25]. The potential of the US grid to run the IoT system has been explored in [26]. The study of smart cities that work with the Internet is presented in [27]. Several advantages of the IoT-based system have been investigated in research [28]. Also, some technical benefits such as flattening the load profile, shaving peak, minimizing drop, optimizing voltage deviation, etc. can be achieved with IoT technology. Here, we focus on how to achieve these benefits by properly modeling IoT-based energy management systems. How to effectively integrate distributed (renewable) energy sources and energy storage to meet the energy service needs of consumers, while minimizing power generation and transmission costs [29]. New technologies in all activities of daily life reinforce the belief that for every new social challenge there is always an ICT solution that can be successfully overcome. Recently, the solution that has been proposed almost all the time is the Internet of Things (IoT). Meanwhile, industry activists are taking advantage of the popularity of the Internet of Things and using it as a very popular brand for consumer-oriented technology solutions. The purpose of this paper is to present the evolutionary steps, that is the generations that have marked the development of IoT along with the motivations for its creation [30]. One of the most important things in a smart grid is its increased vulnerability to cyber threats. A bibliographic review of research papers focusing on the security aspects of IoT [31]. Using IoT technology, the role of advanced sensing systems in the future electrical network is described. Using the potentials of this technology, sensing systems can be used to effectively monitor the flow of energy between nodes in an electrical network [32]. the only basic portion of intelligent towns is advanced internet of things-based ingenious measurements of two-way energy flow measurement systems, which are described in [33]. With the development of emerging technologies (IoT), it is possible to implement applications in the smart grid. Advanced sensing systems and smart converters are used to improve the performance of electricity networks and municipal services [34]. In this paper, a bi-level power management strategy for an active distribution network (ADN) in the presence of a virtual power plant (VPP) is presented. In the proposed strategy, the VPP includes a renewable energy source (RES) parking lot, an energy storage system (ESS), and an electric vehicle (EV) that is coordinated with the VPP operator (VPPO) and a coordinated framework between the VPPO and the distribution system operator [35]. As reviewed, in most of the work done, the goal is to set the optimal size and location of storage resources in distribution networks. The important thing in this regard is to be examined to what extent are energy storage resources in distribution networks managed. Optimally these networks can be effective overnight rather than Check whether there is a value for the investment. The issue of longevity of storage resources should also be considered in the operation of new distribution networks Consider the frequent increase in the number of charges and discharge cycles of batteries This will reduce their lifespan from their average value Which will incur additional costs. It is, therefore, necessary in productivity Optimized restructured energy distribution networks to the importance of the issue Consider the lifespan of storage devices. In this paper, the quantitative evaluation of IoT-based energy management systems in the distribution system is analyzed. A useful and simple framework is provided that facilitates IoT-based system control and simultaneously considers both the customer and the electrical energy storage. In addition, in this paper, accurate modeling of storage devices is done during a day and night Until their charge and discharge rate is properly controlled from to reduce their lifespan is prevented Several analyzes have been proposed to demonstrate the effect of TOU and customer satisfaction on economic parameters (eg total cost and cost of customer discomfort) or technical parameters (such as peak load, average load, and load factor). In this paper, the purpose is to evaluate the presence of energy storage resources from the economic and technical point of view by considering the behavior of IoT-based consumers at the level of distribution networks that have a significant volume of solar power generation resources. The results show that the use of IoT technology in the smart grid causes more benefits than the smart grid without this structure. So far, the analysis of charging management of energy storage devices by considering consumer behavior in IoT-based distribution networks has not been done in any research. Therefore, this paper focuses on the efficient analysis of consumer behavior by considering this structure. The innovation of this paper is as follows: 1.IoT application for home energy management based on time-of use. 2. The total load profile extracted for the benefit of the consumer follows the normal distribution function. 3. Implement IoT-based storage charge management. 4.Using Kulback-Leiber (KL) distance convergence, the difference between the actual total distribution function of the consumer and the normal distribution function is shown. 5. Consider the issue of storage wear due to intermittent charging and discharging to avoid reducing their service life. Model Description The mathematical model of problem optimization is fully described here. The control system type is a combination of decentralized and centralized control. The home energy management department is managed locally based on its interests and based on the information that is transferred to it from the central server, and the necessary analyzes are performed in it and the results are sent to the central server again. According to the information received in the central server, decisions are made to change or not change the price of electricity based on the interests of the central server, and these changes are sent to the home energy management units and the results are sent alternately until the best decision is made. After that, the information is provided on the web and sent to the consumer s' application so that they can consume electricity accordingly. The Internet of Things provides a structure for communicating and managing various parts of the distribution system. There are many benefits to consumers and the electricity market from using the Internet of Things. Decisions can be made based on the constraints, benefits, and information received from the IoT Central Unit and the new information sent to the Central Unit for each unit. Data analysis is then performed in the center to gather information for the final optimization decision. Figure (1) shows the structure of the Internet of Things. In this structure, consumers and the electricity market are connected to the center through communications.

Today, the use of renewable energy sources in power networks to generate electricity due to new trends in energy supply and global environmental concerns arising from products based on fossil fuels has been undeniable [1]. Therefore, the rate of the use of energy sources based on solar power is increasing, and this increase in their use leads to a reduction in their installation costs [2]. Energy storage management is crucial to increase the safety, reliability, and performance of energy storage systems. This paper presents a cloud storage management system for energy storage systems to improve the computing power and data storage capability of cloud computing. With the Internet of Things (IoT), all storage data is measured and transmitted seamlessly to the cloud [3].

The use of solar power generation sources can be installed on rooftops in low-pressure distribution networks and capacities of less than 10 kW by consumers worldwide. The reason for this can also be found in the intensity of sunlight in different areas, cost savings, incentives, and subsidies that are given in this field. Utilizing solar power-based production resources has advantages. These include reducing network dependence on global electricity to supply electricity, improving voltage profiles, and reducing losses in the network [4]. However, the presence of these renewables at the level of distribution networks has not been without problems. When the volume of the presence of these resources goes up in distribution networks and at times when generated from increased load consumption, it causes reverse load distribution in the network [5]. Reverse load playback on the network also increases harmonics in the network, increases voltage in the nodes, causes errors in performance network protection systems, increases network losses and finally, reliability will be reduced.

To control the negative effects of the significant presence of production-based resources, there are two main solutions to solar power in modern distribution networks. The first method is to use the old methods that can be used for momentary changes of the pointed load, and another way of utilizing technologies is new that can be used to control reactive power inverter solar power-based production resources, the use of tools Flexible AC at the level of distribution networks and the use of stored technology at the local level noted. Utilizing storage technology can significantly reduce the negative effects of the presence of solar sources in the network. For this purpose, today, various papers in the field of planning management batteries and how to determine their optimal size are provided [6, 7]. In [8], the authors describe the optimal size of batteries in power distribution networks that are equipped with solar power sources to control the voltage network specified. The authors in the paper [9] of the compensator Static synchronous parallel to the storage in the direction of control increased voltage in the network have benefited but, in this paper, evaluation, the economy is not done.

Energy storage technologies, including storage types, categories, and comparisons, are critically reviewed. Most energy storage technologies are considered. This reference also includes new types of energy storage as well as the most important advances and developments in energy storage [10]. The authors in the paper [11] according to the importance of buying and selling optimal electricity, reducing network losses, and power generation at peak times, an economic evaluation to use storage devices has been done in the power grid, but in this paper, there are restrictions exploitation is not considered. In paper [12], the time control method Real to debug and smooth the load profile in the distribution network has used. Also, in this work of storage capabilities, used. But the point that needs to be noted is that this paper does not address economic issues, and only storage devices have been used for decoding. The authors in the paper [13] consider the size and location of storage devices in the network. They have highlighted the importance of network losses, voltage control, and load management. The authors in the paper [14] of the simultaneous Collaborating with old methods such as utilizing voltage regulators along with storage sources enabled the authors in Paper [14] to control the voltage in the network through energy management. Paper [15] aimed to prevent an increase in network voltage from storage sources for optimal operation of networks by using distribution to de-network in the network. The authors in Paper [16] also considered voltage problems in the network of storage devices in line with economic goals and used reverse load reduction and volume reduction. They controlled the number of voltage fluctuations in the shadow of sudden changes in the power output of solar production sources from storage sources. However, charging and discharging them without any optimization were provided. Expansion of storage at the distribution network level based only on the cost of investment and land used has been done in a previous paper but did not consider the benefits of new technologies [17]. In Paper [18], the authors provided optimal programming for storage devices in the level of distribution networks to reduce the network losses, but environmental issues were not taken into account. Similarly, in Paper [19], the authors aimed to reduce network costs and network losses from storage resources at the distribution network level. This paper proposes a new approach to battery pack modeling by combining several previously published models into a comprehensive framework [20]. It describes how the sub-models are connected, their basic principles, possible configurations, and the new parameters required for optimal efficiency. With the advent of IoT technology, traditional energy management systems have transformed into new responsive embedded systems that reflect consumer preferences in their energy supply process. IoT technology has various infrastructures such as communication systems, tools, sensors, actuators, control, and protection systems [21]. The concept of IoT is relatively simple, but its practical implementation requires various infrastructures such as communication systems, tools, sensors, actuators, control, and protection systems [22-23]. Two-way communication between customers and smart grid operators leads to several technical and economic benefits for everyone involved in the grid, including consumers, distribution system operators, and central control units such as government agencies [24]. In the modern energy management system, the incorporation of IoT in smart grids provides a way to connect everything in society with high potential due to various advantages in various fields. This paper reviews the most important research work focusing on the use of IoT in smart grids [25]. The potential of the US grid to run IoT systems has been explored in [26], and the study of smart cities that work with the Internet is presented in [27]. Several advantages of IoT-based systems have been investigated in research [28]. Technical benefits such as flattening the load profile, shaving peak, minimizing drop, and optimizing voltage deviation can be achieved with IoT technology. This paper focuses on achieving these benefits by effectively modeling IoT-based energy management systems and integrating distributed (renewable) energy sources and energy storage to meet consumers' energy service needs while minimizing power generation and transmission costs [29]. New technologies in daily activities reinforce the belief that every social challenge can be successfully overcome with an ICT solution. The proposed solution for numerous challenges is the Internet of Things (IoT). The usage of IoT for consumer-oriented technology solutions is quite popular among industry activists. This paper aims to present the evolutionary steps and motivations for IoT's creation [30]. One of the most significant factors in a smart grid is its increased vulnerability to cyber threats. Research papers with a focus on the security aspects of IoT were reviewed in a bibliographic analysis [31]. The role of advanced sensing systems in future electrical networks is described using IoT technology. Sensing systems can monitor the flow of energy between electrical network nodes effectively [32]. Advanced internet of things-based ingenious measurements of two-way energy flow measurement systems are the basic components of intelligent towns, as described in [33]. Emerging technologies such as IoT can improve the performance of electricity networks and municipal services using advanced sensing systems and smart converters [34].

This paper presents a bi-level power management strategy for an active distribution network (ADN) in the presence of a virtual power plant (VPP) [35]. The VPP comprises a renewable energy source (RES) parking lot, an energy storage system (ESS), and an electric vehicle (EV) that is coordinated with the VPP operator (VPPO) in a coordinated framework between VPPO and the distribution system operator.

In most of the previous work, the objective was to optimize the size and location of storage resources in distribution networks. However, it is essential to examine to what extent energy storage resources in distribution networks are managed optimally. These networks can be effective overnight rather than only the cost invested. The longevity of storage resources should also be considered in the operation of new distribution networks. The frequent increase in the number of charges and discharge cycles of batteries can reduce their lifespan from their average value, which incurs additional costs. It is therefore necessary to consider the importance of the lifespan of storage devices in optimized restructured energy distribution networks.

In this paper, a quantitative assessment of IoT-based energy management systems in the distribution system is conducted. A useful and straightforward framework has been provided to facilitate IoT-based system control while considering both the customer and the electrical energy storage. Additionally, accurate modeling of storage devices is done during the day and night to properly control their charge and discharge rate to prevent reducing their lifespan. Several analyses have been proposed to demonstrate the effect of time-of-use (TOU) and customer satisfaction on economic parameters, such as the total cost and cost of customer discomfort, or technical parameters such as peak load, average load, and load factor.

The objective of this paper is to evaluate the economic and technical impact of the presence of energy storage resources in IoT-based distribution networks that have a significant volume of solar power generation resources while considering consumer behavior. The results show that using IoT technology in the smart grid yields more benefits than a smart grid without this structure. Notably, the analysis of charging management of energy storage devices considering consumer behavior in IoT-based distribution networks has not been done in any research yet. Therefore, this paper focuses on the efficient analysis of consumer behavior by integrating IoT technology. The following are the innovations of this paper:

1. IoT application for home energy management based on time-of-use.
2. The total load profile extracted for the benefit of the consumer follows the normal distribution function.
3. Implementation of IoT-based storage charge management.
4. Utilization of the Kulback-Leiber distance convergence to demonstrate the difference between the actual total distribution function of the consumer and the normal distribution function.
5. Consideration of the issue of storage wear due to intermittent charging and discharging to avoid reducing their service life.

Model Description

The mathematical model of problem optimization is fully described here. The control system type is a combination of decentralized and centralized control. The home energy management department is managed locally based on its interests and based on the information that is transferred to it from the central server, and the necessary analyzes are performed in it and the results are sent to the central server again. According to the information received in the central server, decisions are made to change or not change the price of electricity based on the interests of the central server, and these changes are sent to the home energy management units and the results are sent alternately until the best decision is made. After that, the information is provided on the web and sent to the consumer s' application so that they can consume electricity accordingly. The Internet of Things provides a structure for communicating and managing various parts of the distribution system. There are many benefits to consumers and the electricity market from using the Internet of Things. Decisions can be made based on the constraints, benefits, and information received from the IoT Central Unit and the new information sent to the Central Unit for each unit. Data analysis is then performed in the center to gather information for the final optimization decision. Figure (1) shows the structure of the Internet of Things. In this structure, consumers and the electricity market are connected to the center through communications.

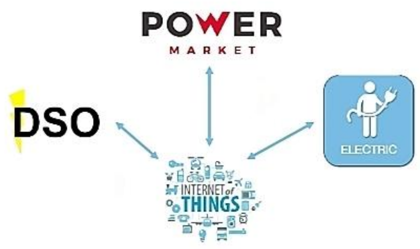

Fig. 1 . Schematic of Proposed IoT-Based Infrastructure

Electricity consumers receive time-based tariff prices from the center and send their load profile (power purchased from the grid) for big data analysis. The electricity procured from the upstream network is also sent to the center. To achieve optimal time consumption and wholesale tariff, the amount of power purchased from wholesale and consumer markets is sent to the electricity market. These prices are then sent to the center, and this process is repeated until the best price is reached.

MILP Model of Customers Behavior

The home energy management system finds information about the home's electrical equipment as well as the number of common desires and optimizes the home's electricity consumption based on the price of electricity received from the central server. In general, loads of a home can be divided into three categories: none flexible loads (NFL), time flexible loads (TFL), and power flexible loads (PFL). none flexible loads are immutable and are operated at the desired time and with a certain power. time Flexible loads are loads that can shift time and the consumer can change the operating time according to his interests. The third category is flexible loads that have a specific operating time but can be increased or decreased depending on the conditions. It is also assumed that each home is equipped with renewable resources and storage. The use of renewable resources is also included in the cost, and the user can choose to supply a few percent of his energy from renewable sources and a few percent from municipal electricity, depending on the cost of using renewable products or the price of electricity.In this study, the purpose of the energy management system is to minimize the weight of the costs paid and the extent of their dissatisfaction. Therefore, the objective function of the energy management system will be equal to:

$$f_{Customer} = \varepsilon_1 f_{Payment} + \varepsilon_2 f_{discomfort} \quad (1)$$

Where $\varepsilon_1, \varepsilon_2$ are constant coefficients selected as:

$$\varepsilon_1 + \varepsilon_2 = 1, \quad \varepsilon_1, \varepsilon_2 \geq 0 \quad (2)$$

The selection of these coefficients is completely on the consumer's basis and based on their selection, the analysis and studies of home energy management are done. Therefore, each consumer has full control over the choice of their interests. It should be noted that the vector of home energy management decision variables is equal to the:

$$X \equiv \left[P_t^{L}, \tau^{L}, \ldots, P_t^{S}, E_t^{S} \ldots, P_t^{DG} \right], \quad L \in \Omega^{load}, DG \in \Omega^{DG}, S \in \Omega^{strg}, t \in T \quad (3)$$

Which includes the power of each load, their latency, the power of energy storage and the power of distributed generation sources, and the energy level of the storage. All variables in this program are real numbers. Also, fdiscomfort and fpayment represent the cost of payment and total consumer discomfort, respectively, which can be computed as follows:

$$f_{Payment} = \sum_{t \in T} \left(\underbrace{c_t^{TOU} P_t^{Grid}}_{From Grid} + \underbrace{c_t^{DG} P_t^{DG}}_{From DG} \right) \quad (4)$$

$$f_{discomfort} = \sum_{t \in T} \sum_{L \in \Omega^{PFL}} \gamma_t^{L} \left(\breve{P}_t^{L} - P_t^{L} \right) + \sum_{t \in T} \sum_{L \in \Omega^{TFL}} \gamma_t^{L} \delta_t^{L} \tau_t^{L} \quad (5)$$

Where $\delta_t^{\mathcal{L}}$ as a hypothetical vector that shows the effect of time delay on TFL loads and is expressed as follows:

$$\delta_t^{L} = \begin{cases} 0 & t \leq t_{des}^{L} \\ t - t_{des}^{L} & t > t_{des}^{L} \end{cases} \quad (6)$$

Also, $\tau_t^{\mathcal{L}}$ is a fixed fine for Any kind of load and $\breve{\mathcal{P}}_t^{\mathcal{L}}$ is the shape of the desired load for each power flexible load. It can be determined conforming consumers as follows:

$$\breve{P}_t^{L} = \begin{cases} \hat{P}_t^{L} & t \in t_{operation}^{L} \\ 0 & t \notin t_{operation}^{L} \end{cases} \quad (7)$$

Equation (7) states that ideal PFL loads must operate at rated power at the allowable period distance and shall be OFF at other times. Assuming relationships (1) to (7), the priorities of the consumer objective function can be called linear. Additionally, the electricity consumption of PFL loads is a continuous variable, and the execution time of TFL loads is a binary variable. Home energy management should be done in such a way that the boundary conditions of the problem are observed. To attain a passable method, which is listed below, various boundary constraints shall be met:

$$\sum_{L \in \Omega^{Load}} P_t^{L} + \sum_{S \in \Omega^{Storage}} P_t^{S} = \sum_{DG \in \Omega^{DG}} P_t^{DG} + P_t^{Grid} \quad (8)$$

$$\sum_{L \in \Omega^{Load}} P_t^{L} = \sum_{L \in \Omega^{PFL}} P_t^{L} + \sum_{L \in \Omega^{TFL}} P_t^{L} + \sum_{L \in \Omega^{NFL}} P_t^{L} \quad (9)$$

$$0 \leq P_t^{L} \leq \breve{P}_t^{L}, \quad \forall L \in \Omega^{FPL}, t \in T \quad (10)$$

$$P_t^{L} \equiv \tau_t^{L} \hat{P}_t^{L}, \quad \forall L \in \Omega^{FTL}, t \in T \quad (11)$$

$$P_t^{L} \equiv \breve{P}_t^{L}, \quad \forall L \in \Omega^{NFL}, t \in T \quad (12)$$

$$\underline{P}_t^{DG} \leq P_t^{DG} \leq \bar{P}_t^{DG}, \quad \forall DG \in \Omega^{DG}, t \in T \quad (13)$$

$$\underline{P}_t^{Grid} \leq P_t^{Grid} \leq \bar{P}_t^{Grid}, \quad \forall t \in T \quad (14)$$

$$\tau_t^{L} \in \{0,1\}, \quad \forall L \in \Omega^{FTL}, t \in T \quad (15)$$

$$\xi_t^{L} \equiv \tau_t^{L} - \tau_{t-1}^{L}, \quad \forall L \in \Omega^{FTL}, t \in T \quad (16)$$

$$\tau_{t_i}^{L} \geq \xi_t^{L} ; \forall L \in \Omega^{FTL}, t_i \in [t, t + MUT^{L} - 1] \quad (17)$$

Equation (8) shows the total power distributed generation and electricity procured from the net, which should be equal to the power consumption of the load and the charging power of the energy storage. Equation (9) shows that the sum of the three types of load (PFL, TFL, NFL) is equal to the total network load. Flexible power loads turn on and off at certain times that cannot be changed, and only their rated power in this range can change between zero (off) and their ideal level. According to Equation (10), other types of loads are flexible when their on and off times can be moved, but no change can be made in the value, and only the entire ideal customer curve can be shifted in the time domain. Relationship (11) notes that the known data is a problem and is determined by the consumers based on the ideal waveform of power consumption of each home appliance. In the simulation section, this information will be expressed. Inflexible loads are also always unchanged, according to Equation (12). The power level harvested from each of the distributed generations should be in the range of minimum (usually zero) to maximum (available renewable power), and the electricity purchase from the upstream network must be in the minimum and maximum range, as stated in Equations (13,14). Equations (15-17) show the constraints of a binary variable. Upon receipt of TOU price data from the center, each consumer proceeds to plan the load according to their interest. The customer can choose the weight of ε1 to show their demands between reducing electricity bills and inconvenience costs. Additionally, energy storage provides the option to preserve energy at low-cost periods and discharge energy at higher-priced periods. NFL loads cannot exceed their predefined standard, but time-flex loads can vary their operating time, and power-flex loads can regulate their electrical power at work to provide favorable cost and discomfort. After planning, the total net hourly consumption information of each consumer is sent to the center to be utilized in data disintegration [32].

Modeling of energy storage resources

In this section, the goal is to establish relationships related to resource utilization, specifically energy storage in distribution networks. It is important to note that the paper introduces additional constraints for the intermittent charging and discharging of storage resources. These resources are now controlled in a more effective and efficient manner. Why so

$$U_{i,h}^{ch}P_{ESS}^{min} \leq P_{i,h}^{ch} \leq U_{i,h}^{ch}P_{ESS}^{max} \quad (18)$$

$$\mathrm{U_{i,h}^{dch}P_{ESS}^{min} \leq P_{i,h}^{dch} \leq U_{i,h}^{dch}P_{ESS}^{max}} \quad (19)$$

$$U_{i,h}^{ch} + U_{i,h}^{dch} \leq 1 \quad (20)$$

$$SOC_{i,h} = SOC_{i,h-1} + (\eta_i^{ch}P_{i,h}^{ch} - P_{i,h}^{dch}/\eta_i^{dch})\Delta t \quad (21)$$

$$SOC_i^{min} \leq SOC_{i,h} \leq SOC_i^{max} \quad (22)$$

$$0 \leq XC_{i,h}^{ch} \leq TU_{i,h}^{ch} \quad (23)$$

$$0 \leq XC_{i,h}^{dch} \leq TU_{i,h}^{dch} \quad (24)$$

$$(T+1)U_{i,h}^{ch} - T \leq XC_{i,h+1}^{ch} - XC_{i,h}^{ch} \leq 1 \quad (25)$$

$$(T+1)U_{i,h}^{dch} - T \leq XC_{i,h+1}^{dch} - XC_{i,h}^{dch} \leq 1 \quad (26)$$

$$XC_{i,h}^{ch} \geq \Gamma_i^{ch}XC_{i,h}^{ch} \quad (27)$$

$$XC_{i,h}^{dch} \geq \Gamma_i^{dch}XC_{i,h}^{dch} \quad (28)$$

$$U_{i,h}^{ch} - U_{i,h-1}^{ch} = XM_{i,h}^{ch} - XN_{i,h}^{ch} \quad (29)$$

$$U_{i,h}^{dch} - U_{i,h-1}^{dch} = XM_{i,h}^{dch} - XN_{i,h}^{dch} \quad (30)$$

$$XM_{i,h}^{ch} + XN_{i,h}^{ch} \leq 1 \quad (31)$$

$$XM_{i,h}^{dch} + XN_{i,h}^{dch} \leq 1 \quad (32)$$

$$XM_{i,h}^{dch} + XM_{i,h}^{ch} \leq 1 \quad (33)$$

$$XN_{i,h}^{dch} + XN_{i,h}^{ch} \leq 1 \quad (34)$$

By increasing the frequency of intermittent charging and discharging cycles of batteries in the network, the useful life of these resources is reduced. This causes the batteries to wear out sooner than expected, and failure to address this issue can result in additional costs to the network. Therefore, it is necessary to restructure distribution networks and pay attention to energy consumption management to address this issue. In addition to discussing the importance of battery longevity, it is also necessary to consider more complete specifications and restrictions of storage resources. The following relationships show how to accurately model these resources and optimize energy savings. In the above relations, $U_{i,h}^{ch}$, $\mathrm{U_{i,h}^{dch}}$ they show the binary variables and the charge and discharge mode of the storage, respectively. If the size of these variables is equal to 1, it means that the storage is in charge or discharge mode. The amount of energy available during each time interval in each storage is expressed $SOC_{i,h}$using a variable. T refers to the planning time, which in this paper is equal to 24 hours. And, $XC_{i,h}^{ch}$, $XC_{i,h}^{dch}$ counters are the number of times the storage is in charge or discharge mode. $XM_{i,h}^{ch}$, $XM_{i,h}^{dch}$ Binary variables indicate that the storage device has started charging or discharging at a specified time. Also, $XN_{i,h}^{ch}$, $XN_{i,h}^{dch}$ binary variables will be equal to 1 when the storage device has started charging or discharging. The parameters Γ_i^{ch} , Γ_i^{dch}also indicate the minimum number of hours that the storage must be continuously charged or discharged. Equations (18) and (19) show the acceptable range for the amount of storage power received or delivered per hour, respectively. Equation (20) shows that charging and discharging the storage can not be done simultaneously in a particular hour. Equations (21) and (22) show the amount of energy available in the storage at any given time along with the allowable amount to be stored. However, in this paper, relations (23) to (34) have also been added to the operating restrictions of the storage devices, so that the issue of managing the frequency of recharging and discharging the storage devices has been considered. This control is performed using related binary variables to prevent shortening of storage life or storage failure. Equations (23) and (24) state that the number of charges and discharge counters should be positive and less than the normal operating time. Constraints (25) and (26) state, respectively, that if the storage is in charge or discharge mode, one unit should be added to the charge or discharge of the said number of counters. Equations (27) and (28) for charge and discharge modes, respectively, emphasize that the minimum when the storage must remain in the same mod cannot be less than the Preset value (for charge mode) and (for discharge mode). Equations (29) and (30) for charge and discharge mode, respectively, emphasize that the binary variables (for charge mode) and (for discharge mode) will be activated when the storage status changes from one mode to another. Equations (31) and (32) also emphasize that the storage device can not have both start-up and start-up modes at the same time in any of its working situations. Relationships (33) and (34) also emphasize the same asymmetry between two different storage modes.

Impact of price tariff (TOU) on consumer behavior

First, the role of pricing tariffs on various parameters of a smart home is evaluated. It is assumed that the price of electricity follows the tariff of consumption time, and the hours of the day are divided into three parts: low load, medium load, and high load, which are shown in Table 1. In this paper, the price of power consumption time (TOU) will be optimized to meet the goals of the central server. The price of electricity generated by distributed generation sources is considered equal to the unit, and the price of electricity in each hour will be expressed as a proportion of this unit price [36].

Table 1. Network electricity consumption hours[36]

Peak load	Mid load	No load	
19pm-22pm(4hr)	7am-19pm(12hr)	11pm-7am(8 hr)	**Time**
0-3pu	0-3pu	0-3pu	**price**

To investigate the effect of price fluctuations on the issue, different scenarios have been considered. In these scenarios, it is assumed that the average consumption time tariff is equal to the unit value of a per unit (PU) to create a competitive environment between renewable products and the electricity distribution network. If the average price of the electricity tariff is higher than that of renewable generation, the consumer will have a strong desire for renewable production, and if the average price of this tariff is less than that of distributed generation, the consumer will prefer to consume all their consumption from the supply network. To balance this, it is assumed that the average tariff is equal to the price of distributed production, i.e. a per unit (PU). However, to model price fluctuations, a parameter called the standard deviation of price has been used. The common (consumer) reaction to price changes (TOU) is important. Undoubtedly, changing the price variance (TOU) can affect consumer behavior. Therefore, a model for determining the consumption hour tariff based on the standard deviation and the average tariff is formed as follows: the purpose of which is to find the tariff related to each hour of the day and night. The times of no-load, medium load, and peak load are quite clear, and the mean and standard deviation of the price are also considered as certain input parameters of the problem, the allowable limits of which are based on Table (1). The price of electricity is related to the periods of no-load, medium load, and peak load as an unknown.

Data solving for load collecting

Upon acquiring the load of each consumer, data solving is executed in the center to compute the total load profile in the distribution network. For further simplification in computations, the load profile of the entire distribution system is obtained by adding the information of each consumer (according to relation (35)). Then, the accumulated load on all buses is distributed according to the load of the nominal basis of each bus (according to relations (36) - (37)). When to get:

$$PD_t^{Total} = \sum_{i\in\Omega^{customers}} P_{i,t}^{Grid}\left(\varepsilon_1, c_t^{TOU}\right) \quad (35)$$

$$PD_n^t = \frac{P_n^{base}}{P_{Total}^{base}} PD_t^{Total} \quad (36)$$

$$P_{Total}^{base} = \sum_{n\in\Omega^{bus}} P_n^{base} \quad (37)$$

Where $\mathcal{P}_{i,t}^{Grid}$ Refers to the purchased electricity of the consumer i from the net. In this paper, to show the relationship between the effect of two parameters and without considering the total losses, several valuable curves have been extracted, and also a probability distribution function has been considered selecting all consumers with the parameter. Therefore, the relationship (35) is:

$$L_t^{Total} = \sum_{\varepsilon_1^i} N\left(\varepsilon_1^i\right) \Pr\left(\varepsilon_1^i\right) P_t^{Grid}\left(\varepsilon_1^i, c_t^{TOU}\right) \quad (38)$$

Considering the law of probability for each density function as follows:

$$\sum_{\varepsilon_1^i} \Pr\left(\varepsilon_1^i\right) = 1 \quad (39)$$

This paper aims to obtain the load profile of the entire distribution system for each price using the standard normal probability density function and evaluate the impact of changes in the distribution function. The parameter (KL) is applied as a convergence to display the interval by the probability distribution function to and is:

$$d_{KL} = \sum_{\chi} \left(\Pr(\chi) \log \frac{\Pr(\chi)}{\Pr^{new}(\chi)} \right) \quad (40)$$

Thus, the different effects of the normal distribution function can be demonstrated for each parameter. The results showed that a greater deviation from the standard normal distribution function resulted in more frequent maximum and minimum peaks in the load profile curve.

Market Preferences

Decisions in the electricity market are typically adjusted according to Time-of-Use (TOU) prices to maximize the total supply profile. The distribution system's profile is obtained from the difference between the cost of procuring electrical energy from the upstream network and the revenue generated from the sale of electricity to consumers and is expressed as follows:

$$\max benefit = \sum_{t\in\tau} (C_{t,wholesale}^{TOU} \ P_t^{UPGRID} - C_t^{TOU} PD_t^{TOTAL}) \quad (41)$$

Some of the boundary constraints that should be considered to promote contestation between distributed generations are as follows:

1.The average price (TOU) should be equivalent to the average price of distributed generation units (according to relations (42) and (43)).

2.The amount of prices (TOU) should be within their prescribed range (according to relations (44) and (45)).

3.Price variance (TOU) can be selectively used to show the effect of price changes on consumer behavior (according to relations (46) and (47)).

$$\sum_{t\in T} c_t^{TOU} = \sum_{t\in T} c_t^{DG} \tag{42}$$

$$\sum_{t\in T} c_{t,wholesale}^{TOU} = \sum_{t\in T} c_{t,wholesale}^{DG} \tag{43}$$

$$c_{\min}^{TOU} \le c_t^{TOU} \le c_{\max}^{TOU} \tag{44}$$

$$c_{\min}^{TOU,wholesale} \le c_t^{TOU,wholesale} \le c_{\max}^{TOU,wholesale} \tag{45}$$

$$\mathrm{var}\left(\sum_{t\in T} c_t^{TOU}\right) = \sigma_{TOU,desired}^2 \tag{46}$$

$$\mathrm{var}\left(\sum_{t\in T} c_t^{TOU}\right) = \sigma_{TOU,wholesale,desired}^2 \tag{47}$$

Simulation Results

This section examines various aspects of distribution network reconfiguration in the presence of the Internet of Things. Firstly, the energy management system of a home is studied, and then the role of network consumers in the load profile of each home and their purchased electricity is examined. Assuming that the network consumption criterion follows a normal distribution function, the network load profile is obtained. The paper then examines how electricity pricing can affect grid load profiles and electricity costs. Finally, network load profiles are displayed at different pricing points. Assuming that the load profile distribution in the network buses follows a uniform function, the load of each network bus is obtained.

Table .2. Information of all types of customer load [36]

Type	Name	Time (h)	kW	γ_t^L ($/kWh)
Time Flex	Wash-machine	2hr working duration	0.7	1
Power Flex	Light	11-17	0-0.8	0.8
	Air conditioner	Full time	0-1.4	1.4
Non Flex	Kettle	8-9,17-18, 20-21	0.3	0
	Toaster	8-9	0.2	0
	Refrigerator	Full time	0.2	0

Table 3. Technical and economic data of the distribution network [36]

Item	Value	Item	Value
DG unit location	Bus 6, 7, 13, 18, 28, 33	$c_{t,min}^{TOU}$	0 pu
DG unit capacity	500,1200,1350,1350,1200,500kW	$c_{t,max}^{TOU}$	3 pu
DG power factor	1,0.8, 0.9, 0.9, 0.8, 1	No Load interval	0-7
Voltage Limits	0.95-1.05 pu	Mid interval	7-19
$c_{t,wholesale}^{DG}$, c_t^{DG}	1 pu	Peak interval	19-24

This paper includes a standard 33-bus network (IEEE) with 2,000 consumers, with the same features as classified in Table (2). Every consumer uses a 1 kW/3 kWh battery, and additionally, a 2 kW ceiling photovoltaic system is provided for each consumer. Research intervals are 24 hours. The difference between consumers is based solely on their benefit factors. Some technological and economical data of the distribution network are shown in Table (3). The energy storage is a 1.5 kW/3 kWh battery that is charged or discharged without wasting energy. The cost of time-flexible load and power-flexible load are considered 0.001 per unit per hour and 1 per unit per kilowatt-hour, respectively. The results of IoT-based EMS optimization are given in Figure 2. This indicates a situation where the customer tends to minimize their discomfort regardless of the cost. Therefore, PowerFlex loads operate at their maximum rating, and time-flexible loads are launched exactly at the desired time and without delay.

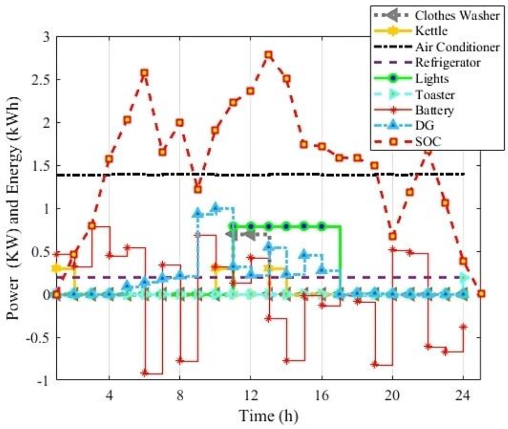

Fig. 2 . Energy management system results for $\sigma^2 = 1$ and $\varepsilon = 0$

Table (4) shows that as consumer weight ε_1 increases, the cost of payment decreases while discomfort, peak load, and average load decrease.

Table 4. The results several pricing strategies used for market decision making

Mid loa	Peak load	discomfort	cost	ε_1
1.7164	3.0317	0.0174	45.1201	0
1.7481	3.7532	0.0873	44.1113	0.1
1.5929	2.4608	0.4483	42.0398	0.2
1.5098	2.4699	1.3417	39.3618	0.3
1.2913	2.5572	3.3390	35.7096	0.4
1.0849	1.9115	7.3074	30.8990	0.5
0.8631	1.6400	15.3327	24.3335	0.6
0.4125	1.5844	34.3327	14.2211	0.7
0.2308	1.7644	47.4616	9.1808	0.8
0.2125	1.0729	47.4851	9.1333	0.9
0.1943	1.4466	47.214	9.2647	1

The effect of the presence and absence of energy storage devices on the technical parameters

Table (5) shows the voltage measurements on the buses to which the DG is connected during the peak hours of DG sources, specifically at 14 and 15 hours. Therefore, based on Table (5), without storage resources, the network voltage increases due to the high volume of DG resources present, which creates a problem at the distribution network level. However, the presence of storage sources is observed to reduce the voltage level and maintain the mains voltage within an acceptable range. Thus, it can be concluded that the presence of storage resources has a positive effect on reducing network voltage. To avoid intermittent charging and discharging, the minimum time that energy storage sources can remain in a working mode (charging, discharging, or out of circuit) is equal to 2 hours for each source. Since the amount of DG production is proportional to the sunlight, and the sunlight varies throughout the day, Figure (3) illustrates the output power of each DG based on solar power during the day and night as a percentage of its maximum power. The figure also shows the price of electricity over 24 hours.

Table 5. The result of changing consumers' interests on their behavior

bus	14pm		15pm	
	Without storage	With storage	Without storage	With storage
6	1.099	0.978	1.088	0.973
7	1.097	0,989	1.095	0.980
28	1.095	0.977	1.093	0.974
13	1.094	0.983	1.093	0.978
18	1.091	0.990	1.088	0.975

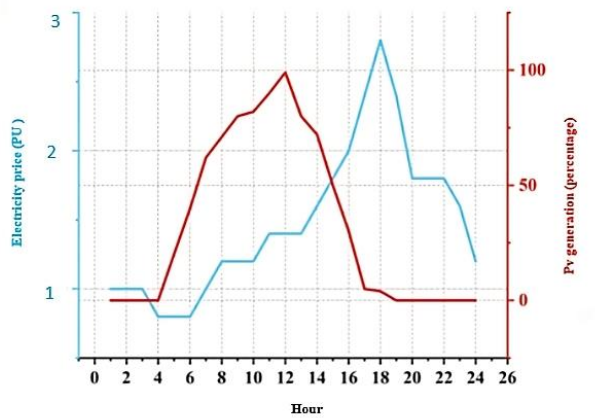

Fig. 3 . DG production profiles within 24 hours and electricity prices

In Table 6, the cost of energy management has been examined for three cases: without the presence of storage resources, with the presence of these resources and without considering the importance of longevity, and with the presence of these resources and considering the importance of longevity. According to this table, the presence of storage has ultimately reduced operating costs, which is very important from an economic point of view. Considering the importance of the issue of storage life, the cost of energy management has increased somewhat, but still, compared to the absence of these resources, it has reduced the cost of ideal network operation. The reason for this cost reduction can be attributed to the positive impact of these resources on the optimal management of purchasing and selling power from the upstream network. Figure 4 better illustrates how power is exchanged with the network.

Table 6. Voltage magnitude in DG buses with and without energy

Without storage	With the presence of storage and without regard to the importance of longevity	With the presence of storage and considering the importance to longevity
4057.818	3474.373	3687.405
Percentage reduction	14.37%	9.12%

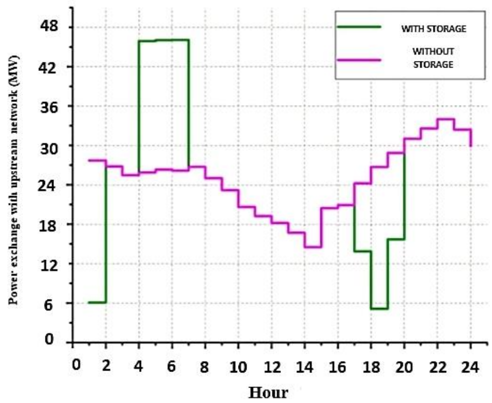

Fig. 4 . Power exchange rate with upstream network during 24 hours

According to Figure (4), the amount of power purchased during hours when the price of electricity was low increased with the presence of energy storage sources, while during hours when the price of electricity was high, the amount of power purchased from the upstream network decreased. This shortage is met by power injection and discharge of storage devices. Therefore, the same transfer of power and the change in the buying and selling mechanism can be the reasons why the presence of energy storage resources has reduced operating costs because they have increased the flexibility in the network for buying and selling. It is observed that the presence of these resources not only technically improves the network voltage but also ultimately reduces the cost of optimal operation of the network, which will be economically profitable for the network with the presence of these resources. Figure (5) shows the amount of energy of the storage devices connected to bus 23 and its charging and discharging modes in two different scenarios. The first scenario addresses the issue of storage depletion and resource management constraints, while the second scenario refers to conditions without considering the issue of storage source depletion.

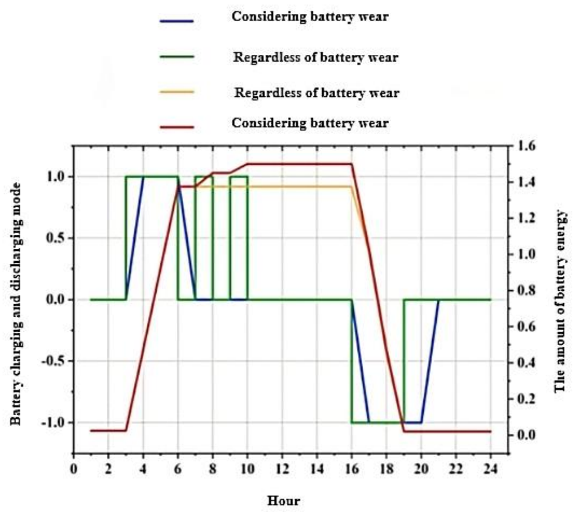

Fig. 5. Energy level and charging and discharging modes of energy storage sources connected to bus 23 in two different scenarios

Figure (5) shows that for both scenarios, during periods when the price of electricity in the upstream network was low, the storage was in charge mode and consequently increased the energy level of the source (to a maximum). The energy level of the storage devices is assumed to be 1.5 priorities. However, during periods when the price of electricity was high, the storage source was in discharge mode and injected power into the grid. Therefore, its energy level decreased. In the scenario where storage wear is considered, the number of charge cycles is relatively less than the scenario where it is not considered. As assumed, the minimum interval between which the storage on the bass should remain in working mode was 2 hours. As a result, in the first scenario, due to the wear and tear management constraints, the storage did not start charging again at 7 and 9 (am). On the other hand, not considering the wear and tear constraints caused the storage to change back to charging mode during these periods (Scenario 2). Regarding the energy level, it can be seen that not considering the wear and tear of the storage source resulted in a higher energy level than in the first scenario.

Conclusion

In this paper, an analysis of charging management of energy storage devices considering consumer behavior in IoT-based distribution networks is presented. With two-way communication between the IoT center and other parts of the system, all network goals can be achieved efficiently. The IoT can be managed in one way, by controlling the desired benefit through controlling consumer revenue and constructing the cost of electrical energy by selecting a suitable price for retail and wholesale prices (TOU) from the upstream grid. There are various choices for consumers in the IoT system. In this structure, all the various demands of consumers are considered. Data analysis is also applied to compute the cumulative load. The standard normal distribution is used for the consumer consent coefficient. Based on the data, the electricity market can specify a pricing method to acquire maximum benefit. The main purpose of this paper was to examine how the presence of energy storage sources in distribution networks can have negative effects that create sources of distributed solar generation in grid quality, preventing the reduction of their service life. An important point in this paper was the consideration given to the issue of longevity of storage resources. This paper provides additional insights into the operation of this equipment in question. Optimization was added to reduce the intermittent charge and discharge rate of this equipment to avoid reducing its service life. Although adding these restrictions increased the cost of grid energy management, it is mentioned that this is important despite the small increase in cost, as it prevents the reduction of the life of this equipment. The results showed that the presence of energy storage resources in distribution networks that disperse an acceptable volume of production resources having the sun in them is essential and has a positive effect on the network. These sources are technically the same as voltage size control, which during periods of high electricity prices leads to a reduction in the cost of energy management overnight.

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