Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 7.056

IJCSMC, Vol. 10, Issue. 8, August 2021, pg.60 – 71

A Conceptual Framework for Minimizing Peak Load Electricity using Internet of Things

Amira Hassan Abed
Dept. of Information Systems Center,
Egyptian Organization for Standardization & Quality, Egypt
Email: mirahassan61286@gmail.com

Mona Nasr
Dept. of Information Systems,
Faculty of Computers & Artificial Intelligence, Helwan University, Egypt
Email: m.nasr@helwan.edu.eg

Laila Abd Elhamid
Dept. of Information Systems,
Faculty of Computers & Artificial Intelligence, Helwan University, Egypt
Email: Dr.laila.abdelhamed@gmail.com

DOI: 10.47760/ijcsmc.2021.v10i08.010

Abstract: Electricity load demand converts from time to time frequently in a day. Encountering time-varying demand particularly in peak times is considered a big challenge that faces electric utilities. Persistent growth in peak load increases the prospect of power failure and increases the electricity equipping marginal cost. Therefore, balancing production and consumption of electricity or addressing peak load has become a key attention of utilities. Most previous works and researches were focused on applying Shave/Shift peak load to solve energy scarcity. In this study, we introduce four significant technologies and techniques for achieving peak load shaving, namely "Internet of Things (IoT) in Energy System", "On-site Generation systems (Renewable Energy Resources)", "Demand Side Management (DSM)" applications of control center and "Energy Storage Systems (ESSs)". The impact of these four major methods for peak load shaving to the grid has been discussed in detail. Finally, we suggest a conceptual framework as guiding tool for illustrating the presented technologies of Shave/Shift peak load in energy systems.

***Keywords**: Internet of Things, Demand Side Management, On-site Generation systems, Energy Storage Systems, peak load reduction.*

1. Introduction

Rapid economic development has resulted in a power shortage all over the orb and this shortage is increasing seriously. Substantial numbers of energy deficiency situations occur according to the peak load events. Peak loads suffer a severe negative impact on many aspects including the grid capital, the grid operation costs, and pollution (CO2 emissions). During peak times on the grid, the prices of electricity consumption are high in comparison to the prices during the off-peak time; these high prices resulted from the utility requirements for larger generators and many other facilities and resources to nourishment the end-users' demand. In certainty, production and industrial sectors are the most consumers for electricity, and its consumption is estimated by 50% of all energy exhausted around the world [1]. According to that statics, we can explain the high negative influence on the societies by production and industrial factories, come from exhausting high amounts of energy that lead to peak load problem and increase in emissions (i.e., CO2). Manufacturing factories have a great role in decreasing electricity exhaustion and CO2 emissions that impact on electricity prices and weather change. Subsequently, the utility concern is to balance between the supply (electricity generation) and the consumption (electricity demanded) [2-4]. For reducing the peak power demand, little capacities of energy plants for example the gas energy plants are usually used. Diesel generators are also extremely based on them to supply peak demand is separated energy systems [5]. However, these types of power plants own costly processes and maintenance costs [6]. As peaking plants work just within rush loads times, also little efficacious plants are utilized for supporting these rush periods. The capital of these plants is considered low, but the processes and maintenance costs are high. Moreover, the electricity of the peaking plants becomes more expensive than that of any base-load plants to recover the capital costs as well as processes and maintenance costs within their lifespans [7]. Thus, most preceding studies pay attention to "Shaving peak loads" strategies for handling deficiency in energy. Peak load Shaving can be realized as "shifting the energy usage demand during the peak load to the off-peak load period with low energy demand."However, such methods wouldn't put an ideal solution for the peak load problem exactly, all quantities of electricity exhaustion in certainty not minimized, moreover shifting loads may lead to a new rush load hours. On other hand, there is a great effort all over the world that were taken for developing smart and green factories, besides, offering more efficient energy management approaches, minimizing energy shortage, minimizing peak load costs, and reducing the negative environmental impacts resulted from high-energy consumption.

For smart and green buildings and manufacturing, all over the world, the invention in consolidating communications technologies and information systems together with the tangible world has taken great attention by governments towards building smart and green constructions which are beneficial for our countries by enhancing energy management efficiency, save the societies and improve life fineness and goodness. Smart buildings in concise are defined as constructions that based on advanced technologies and networking, advanced sensors, in addition to hardware platforms for support convenient life [8]. IoT technology is undertaking for raising consciousness and sight on electricity exhaustion based on various advanced sensors in addition to a high number of smart meters equipped to machines, devices, and manufacturing lines at factories. According to [9], the IoT technology can locate as "the interplay of smart objects and smart communication networks."

On the other side, the traditional electric generation based on fossil fuel consumption is threatening humanity with global warming, climate-changing, and increased carbon emission. Thus, many strategies have focused on "*green and clean energy sources"* for minimizing these threatens, including promoting implementation for renewable power projects and promote heterodoxy and innovation in various technology fields. Indeed in recent years, there is a great focus on these renewable sources. Renewable energy resources are occupied great attention as they are considered the most sources supporting fuel (in comparison to nuclear energy) with the absence of serious risks, issues, and disasters.

In this study, we introduce four technologies, methods, and strategies that can be integrated within energy system for helping in achieve peak shaving to minimize the peak load periods, these technologies and strategies are as the following:

1) The utilization of IoT in Energy System
2) Building on-site power generation systems (Renewable Energy Systems)
3) Applying Platforms of "Demand Side Management (DSM)".
4) Integration of "Energy Storage Systems (ESSs)" in Energy System.

Moreover, we suggest a framework that presents the integrations of the four mentioned techniques within the energy system in which end-users can adopt on-site power generation and energy storage facilities with great support from "IoT network" and "demand-side management" platforms and services. The main objectives of the suggested framework are to minimize peak load periods, electricity consumption prices, and carbon emissions.

In section 2, we present the potential benefits that can be obtained by applying the peak load shaving method. In the following sections, we extensively provide the four different techniques of peak load shaving that mainly based on the internet of things and renewable energy recourses. Moreover, in section 7, we present the conceptual framework's design that shows the integrations of the four peak shaving techniques within the energy system.

2. Why peak shaving

Peak loads periods are considered a precise element for the power systems and their grids. For supplying high demands during the peak loads times, a traditional approach in those cases is confirmed by supplying additional quantities of electricity. But, this traditional approach was not preferable from the economical side and it impacted negatively on the generators usage, as the electric utilities have to supply the required capacity of electricity enough for "few hours" [10]. Also, it resulted on many critical drawbacks, includes increasing CO2 emissions, high distribution, transmitting and maintenance costs, and early deterioration for many types of equipment and generators [11]. Thus, "peak load shaving" considers an effective method for avoiding the mentioned critical drawbacks. Also, peak shaving method can offer a lot of extensive benefits for power suppliers, grid operators, and electricity end-users [12]. Basically, these benefits are summarized in the following areas:

2.1 gains for "the grid operator"

One of the numerous progress challenges practiced by the utilities is to keep up a balance between electricity generation and required quantity [13]. In the case of the generation systems not able to meet exactly the predicted demand of electricity, many issues like instability or total blackout can probably take place, so affecting badly on the grid system [14]. Those problems will cause stress on generation mechanization and quality for provided power. Several previous kinds of research and studies had designed completely various "peak shaving methods" for mitigating the imbalance. Using shaving techniques notably led to the perfect demand profile, which can lead to enhance the quality of electricity [15].

2.2. Gains for "end-user"

By observing, for fulfilling the peak time's demands typically "less economical" generators are needed [16]. Thus, per kWh electricity production value will increase throughout the high request on electricity. Thus, the rising value of "per kWh" electricity production has affected negatively on the end-users throughout the rush hours [17, 18]. So, "peak-shaving" is a vital tool to electricity consumers. The end-users will reduce their bills of consumption by converting their consumption from "on-peak" to "off-peak" [19, 20]. "Peak shaving" additionally supports several non-financial edges to end-users like enhancing reliableness and quality of power.

2.3. Minimization for "Carbon emission"

For managing the huge request on electricity, power utilities need further "fuels". A lot of consumption of fuels will increase carbon emissions. Peak load shaving can guarantee a lot of economical processing of power plants and scale back variableness on "electricity loads". Also, it can scale back "carbon emissions" [21, 22].

3. Internet of Things (IoT) in the energy system

IoT has the potential to considerably remodel any sector such as industry and economic sectors. The McKinsey international Institute predicts that the whole impact of IoT development on economics is the amount for "the range of $3.9 trillion to $11.1 trillion each year by 2025" [23]. "General electrical (GE)" predicts that "$1.3 trillion" price valuable will gained within the "electricity value chain from 2016 to 2025" all over the world via adopting IoT [24]. Internet of Things (IoT) may be "an idea and a paradigm that considers pervasive presence within the atmosphere of a range of things/objects that interconnected smartly through wireless and wired connections and join forces with other things/objects to form new applications/services to finally reach to common goals" [24]. The key IoT objective is modifying "things" to be linked anywhere, to any smart object, and at any time exemplary victimization regardless of the utilized network and serving. IoT is considered as a significant revolution in the world of the web.

The “Institute of Electrical and Electronics Engineers (IEEE)” has granted the mission of revising the high numbers of IoT definitions that are located on many types of research and studies then it defined IoT as [23] “IoT may be a network that connects unambiguously classifiable ‘Things’ to the web.” According to this definition, the “Things” own “sensing/actuation” facilities and the ability to be programmed. Via the utilization of distinctive “identification and sensing”, information regarding the “Things” will be gathered; also “Things” status will be modified at any place, in every required time. The “Objects” make themselves distinguishable as they become smart via establishing the linked features as they'll connect info concerning them. They'll access to info that is gathered and collected effectively by different objects, and also these smart objects may become parts of advanced serving.

The “Smart cities” are advanced environs wherever high numbers of innovation things are meeting to considerably enhance “socioeconomic development” and “life quality”. The “Smart Grid (SG)”, the smart electricity system, might be realized as the biggest IoT network mental representation within the coming future, as shown in **figure 1**. The main objective of SG aims to keep the balance between “power generation and power consumption", via permitting perfect observance and management through a chain of abilities and smart objects including: “smart meters, smart appliances, sensors, actuators, etc”. IoT can support the smart grid for modifying a lot of data and property throughout the advanced infrastructure. Via IoT, end-users, makers moreover suppliers can set advanced strategies and smart paths for effectively managing devices, machines, and save cash via victimization “smart meters, home gateways, intelligent plugs, and connected appliances”.

IoT: The Promise and Potential

Electricity utilities: An advanced network equipped with smart grids, smart meters, and advanced machines and devices which endlessly communicate with one another to confirm load reconciliation and peak leveling for power consumption. These technologies conjointly provide utility corporations the flexibility to scale back consumption thanks to its ability to communicate directly with smart appliances and devices to forestall system overloads and optimize the total price of electricity production and consumption.

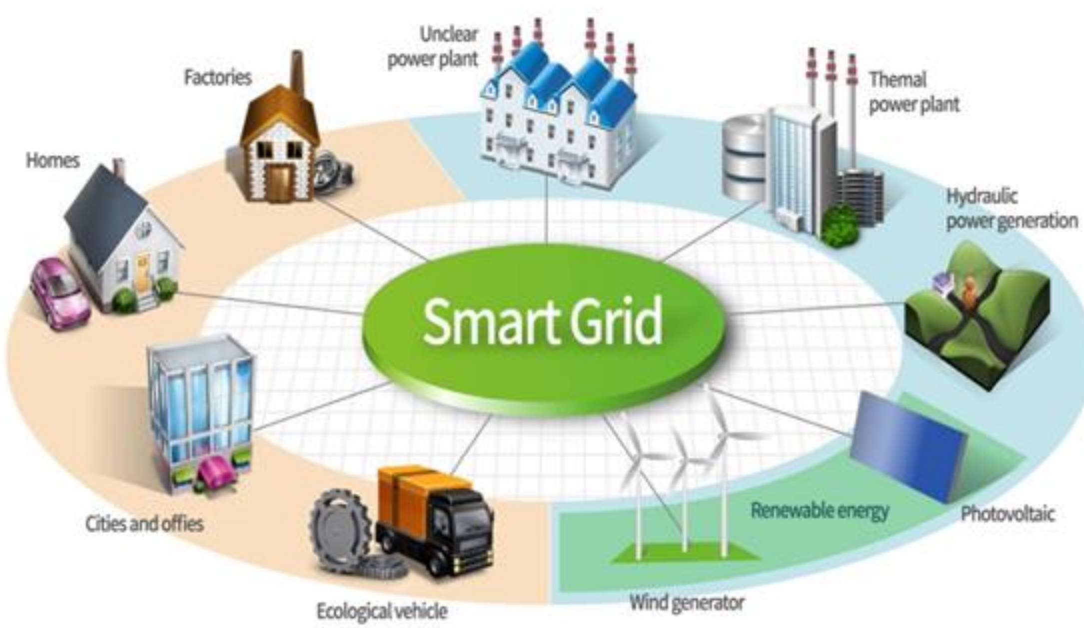

Fig. 1: Smart Grid as a representation of the IoT network

Controls optimization: electricity is considered the highest contributor that effect on industrial sector costs overhead. Many initiatives are current to scale back electricity usage and a number of that embody advice the employment of alternate energy sources. IoT technologies and automation of environmental monitoring and control devices, corresponding to HVAC and electricity, will save high costs for manufacturers. Bound IoT-enabled HVAC applications conjointly supply accurate weather knowledge and prediction analysis to assist makers to perceive expenses and arrange power consumption.

Plant floor management automation: the collected data via IoT and intelligent network supports interconnectivity between the top floor and shop floor that allows the processes automation and decrease the human recourses intervention needed to handle problems or deviations. Moreover, smart sensors will frequently live operational measurements corresponding to temperature, pressure, thickness at a production level and send these records of data to a far off controller.

4. On-Site Generation (Renewable Energy) systems

By increasing the trend of "*environmental protection and climate changes"* all over the world, the "renewable sources" integration within the power network has taken great attention from governments, utilities, researchers, and engineers. This growth is anticipated to be still and conti.1n4ues for many years, and it expected that these sources can count about eightieth of all power production quantity within the United States in 2050 [25]. Replenished energy is known as renewable energy that is planning to become the long-run energy sources all over the world. Renewable energy depends on sources that are come from infinitely replenished or frequently replenished sources, by nature—the sun, the wind, and water. Renewable energy technologies flip these fuels into usable kinds of energy—most typically electricity, however conjointly heat, chemicals, or mechanical power. Renewable energy resources are extremely contrasted with non-renewable fossil fuels. Also, these energy systems are regularly known as clean or green sources owing to turning out few or no pollutants. Soon, the supplement of energy will base mostly on varied clean and green renewable resources and technologies. One of the necessary achievements for "renewable energy sources" is the development of "onsite generation systems" for reducing pressure on the utility grid. The onsite generation systems can process whereas any failure occurs on the traditional electricity network and can enhance "reliableness", "affordability", and securing electricity delivery for consumers. What is more, the gas emissions are often reduced and therefore the pressures on distribution network are often decreased. Therefore, a few numbers of pioneer onsite generation systems were developed in housing cases, appreciate medical centers, monetary firms, and military bases.

For the manufacturing sector, it's not possible to perform any production activity within the power absence; even a brief equipment failure will cause damage in production lines. Reports indicated that producing considered the greatest influenced sector from the electricity shortage issues. The outage will affect seriously on production lines as a result of machines halt. Developed elasticity via building "onsite generation systems" depends on "renewable energy sources" that can significantly scale back these issues. Various "on-site energy generation systems" can be distinctive and vary on many features like availableness and accessibility. On-the-scene renewable energy production will turn out electrical power in addition to environmental and economic benefits by serving it to native governments and communities:

- **Reducing gas emissions and pollutants:** using renewable sources instead of traditional power would greatly minimize gas infectious and pollutants as negative outputs of manufacturing activities. Many governments all over the world have planned a high number of projects, procedures, and goals for reducing gas emissions. By producing on-site energy, local governments, manufacturing, and industrial sectors are interpreting for its electors that they demarche perfectly for matching specified objectives.
- **Supporting economic growth:** building on-site renewable energy production projects and Investing in them help in enhancing local economies. The "On-site renewable energy" projects production structures need to buy big "raw materials" quantities, and transporting them from companies will positively impact on local manufacturing employment. Also, requests for building, installation, and regular conservation for these projects will require a high number of assignments for many workers [26].
- **Enhancing power quality:** Electricity power owes great consistently "power quality" without variation during the demanded electricity is supplied for the end-users. According to, the complex interconnections of the grid power system (as it involving various phases: the generation, transmission, and distribution), the power network faces provisional modulation on supplied electricity features. However, the distributed structures of renewable energy systems own just a few network interconnections (such as transmission substations), so electricity from these systems own better "electricity quality" in comparison to "electricity supplied via the traditional grid" [26].

5. Demand-Side Management (DSM) **techniques**

DSM associates in nursing initiative enforced by energy utility through promoting end-users to apply extensive practices and proceedings which returns a wide range of benefits to each party [27]. That practices embrace any activity aiming to alter the load curve by positively affect end-users behavior to reduce their electricity consumption [28]. On the other side, the DSM adoption will increase the complexness of existing grids network owing to the effective DSM performance needs regularly observation power network loads and efficient generators [29]. However, the benefits of DSM is greater than its disadvantage of inflated grid price. Consider **Figure 2,** we show that DSM consists of energy efficiency and demand response, as the following:

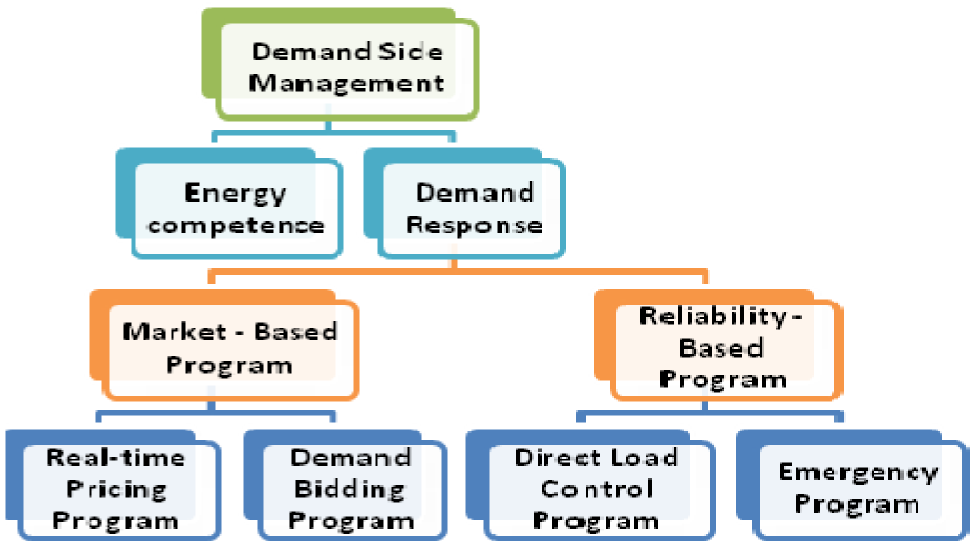

Fig. 2: Demand-side management techniques

5.1. Electricity competence management

Competence defines as "a long conservation strategy objects to avoid wasting energy and cut back demand through energy-efficient processes." Electricity competence platforms embrace "house-appliance" competence improvement addition to "weatherization". "Weatherization" basically aims to protect houses against outside parts, wind reminiscent and daylight, and promotion buildings for reducing power exhaustion. Electricity competence platforms implementation will help significantly in minimizing energy demand at rush electricity periods and electricity prices, also as delay the necessity to expand power grid capability.

5.2. Demand response (DR)

DR is a short load processing program object to positively affect end-users behaviors for energy consumption. Demand response is defined as "the electrical usage changing by end-use shoppers from traditional consumption patterns according to changes occur on the electricity prices over time" [30]. Providing one of the "Demand Response" benefits is its impacts on loads in a direct manner, in comparison to other DSM techniques. Nowadays, other DSM methods are replacing with the "Demand Response" platform and services within the advanced energy marketplace [31]. As represented in **figure 2**, the "Demand Response" platform consists of two kinds of programs: "reliability-based DR program" and "market-based DR program."

5.2.1 reliability-based DR programs

By using these programs end-users can reduce their loads or voluntarily take part in controlled appliance utilize. As sending immediately power costs, "market-based DR programs" give end-users choices to regulate consuming power.

"Reliability-based DR programs" contains:

- **Direct load control platform**: by it, the electricity utilities are authorized to immediately minimize supplements of end-user electricity through rush hours subsequent sending alarm for consumers to notice them [30].
- **Emergency program:** end-users are incentives to decrease their consumption during system peaking. Contrasting for intermittent loads, and not involves benefits in case of a consumer's not participating.

5.2.2 "Market-based DR" services platforms:

- **"Demand bidding program":** This **platform** permits large numbers of consumers to bid to specific load power curtailments. Customers occupy a fixed proportion and pay a lot of costs once the power consumption became huge [32].
- **"Real-time pricing program":** power generation prices change frequently and power prices are fixed while not taking on account the power badness, notably to giant industrial or house customers. For handling the mention problems, the pricing service has immediately supported and enforced [33].

6. Electrical Storage Systems (ESSs)

ESSs indicate a method of transferring electricity from an influence source to a type that may be saved for transferring electricity back once it requested [34]. Such a method permits charging electricity at a time of a request on electricity is low, or consumption electricity price is low or existence of alternative energy sources and permits supplying electricity at a time of a request on electricity is high, consumption electricity price is high or no existence of alternative generation means. EES owns various applications as well as transportable apparatus and steady power expedience. Recently, the governments of the USA, the EU, Japan, and Australia all have developed and adopted their national projects and programs depend on EES. It is predicted that the anticipated storage level will extend by 10% to 15% of the inventory supplied for the USA and European countries and maybe greater for Japan within the future [35].

EESs are desperately required by the standard electricity-generating trade [36]. Not like the other sure-fire products or goods, standard power generation utilities own very few or in many cases may have not "storage systems". The power transportation in addition to distribution network structures has been processed for "simple" directed unidirectional power transmission from distant utilities. The mentioned reasons imply that end-users should permanently utilize the power once it generated. However, the request and need to power changes hourly, seasonally, or daily; the most requested electricity might solely go on just for some hours every year. This ends up in not efficient and costly factories.

ESSs permit electricity generation to dissociate from whether their supplies or on-site generation systems. Through existing long- term energy storage capabilities offered at rush hours, investigate **Figure 3,** systems' organizers and planners would want to make solely spare generating capability to fulfil average electrical needed instead of peak requirements on electricity [37]. This can be notably vital to giant utility generation systems, e.g. atomic energy plants that should operate close to full facilities and capabilities for many economic reasons. Thus, ESSs will give great advantages such as peaking electricity, grant frequent load, and standby backup.

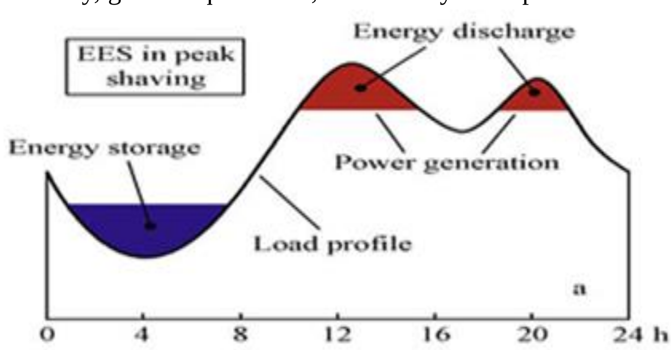

Fig. 3: EES in Peak Shaving

Furthermore, EES is thought to be an indispensable technology of "the distributed energy resource (DER) systems". postponed from the standard installation electricity systems that own massive "centralized units, DERs" are sometimes set up in at the distribution base, on the point of the place of utilization, and produce electricity generally within the tiny vary of a couple of power unit to a couple of MW. A DER is thought to be effective, property, trustworthy, and friendly for the environment variable for the standard power systems. Additional desperately, EES systems are vital to "intermittent renewable energy delivery systems" akin to "solar photovoltaic, wind turbine and wave". So, the combines of ESSs and renewable resources might dig out huge quantities of power made via massive standard factories soon.

7. The Suggested framework for minimizing peak load using IoT

Now, we present the energy system framework as a novel attempt to integrate advanced technologies and techniques that are utilized for achieve peak shaving. As we mentioned before, the peak shaving approach is considered the most vital approach to minimize the peak load problem. The counselled framework involves the whole power system (energy generation – distribution – storage systems – monitoring & controlling – consumers) with the integration of new energies sources and internet-based infrastructure for supply and distribute electricity. As supported in **figure 4**, the conceptual energy system framework composed of the subsequent parties:

1. Conventional (Centralized) energy- generation systems: are long-scale electricity-production capabilities of huge electricity utilities.
2. On-site energy- generation systems: consist of the different renewable energy systems such as "photovoltaic (PV)" and "wind farms" owned by end-users themselves.
3. Energy storage systems (ESSs): ESSs are facilities owned by end-users to supply electricity for end-users during on-peak time. Depending on electricity consumption data collected from consumers and then supplied for the applications of "control center", the energy storage systems are charged and discharged according to appropriate periods.
4. "IoT Technologies": thanks to the development of IoT, the different energy generation sources whether renewable or non-renewable resources are connected collectively based on the Internet and various advanced sensors, so that the generation, distribution, and storing of energy can be monitored and controlled smartly.
5. "Demand-side management application": handle customers' power requests, and announce them for intending "electricity charging and discharging operations" via utilizing their electricity storage systems.
6. "Distribution grid": it links high numbers of customers within the power system. Thus, via the distribution grid consumers can consume electricity supplied from all electricity-production sources on the power system.
7. "The end-users": every consumer owns particular "distributed" on-site energy generation facility and energy storage facility, thus he plays the both roles of energy producer and consumer.

The suggested framework aims to increasing the electricity utilization rate, enhancing the ratio of applying renewable energy sources, and utilizing energy storage facilities within the energy system to supply electricity demand. Thus, we can consider that our framework introduces a significant solution for minimizing peak load. The key reasons why the electricity shortage problem occurs during peak load times are 1) the full consumed electricity overrides the total quantity of electricity that can be furnished via the power system, 2) reduction on fuels that are a user on the operation of generating electricity in traditional power stations. "Shaving peak load" in power grids able to efficiently deal with electricity shortage facilities, and therefore it has attracted numerous interests from different areas. In general, "peak load Shaving is a process of creating the weight curve flattens with the aid of lowering the height quantity of load and shifting it to times of lower load". In our counselled framework, four exceptional techniques of "peak load shaving" were integrated, that is: applying IoT networks in power system, the development of on-site energy- generation structures, utilization of demand-side management applications of the control center, and integration of energy storage facilities.

As presented in our designed structure in **Figure 4** The **traditional electrical grid** supplied a centralized electricity production and is a network with a one direction energy stream (firstly, energy production then energy distribution, and finally supplied for consumers). The electricity era suppliers undertake the power generation according to the estimated electricity demand from the consumers. The second energy generation sources within the framework are "**Renewable Energy Sources**" (on-site structures). Renewable power systems are derived from assets that can be infinitely replenished, or constantly replenished through nature—the sun, the wind, the Earth's heat, and vegetation. Greater renewable sources incorporation within power structure is the key to reducing peak load on the grids. The power produced from conventional grids and dispensed on-site generation systems can be charged effectively in Energy storage facilities. Thus, we integrate the **energy storage systems** (**ESSs**) into our electrical systems as the maximum potential method of peak shaving. The features of ESSs can offer financial benefits because it minimizes the need to produce costly rush hours electricity. Between extraordinary storage systems, the **"Battery Energy Storage System" BESS** is considered to supply top loads shave serving (maximum for a few hours). Basically, the ESSs is charging from the conventional power grid during the electricity consumption price is "low" (during the off-peak period / the night) and is discharging during the electricity consumption price is "high" (during the on-peak period / the daily hours). Moreover, they are charging and storing large amounts of renewable energy generated from on-site generation systems (many megawatt-hours) for use later during the on-peak period.

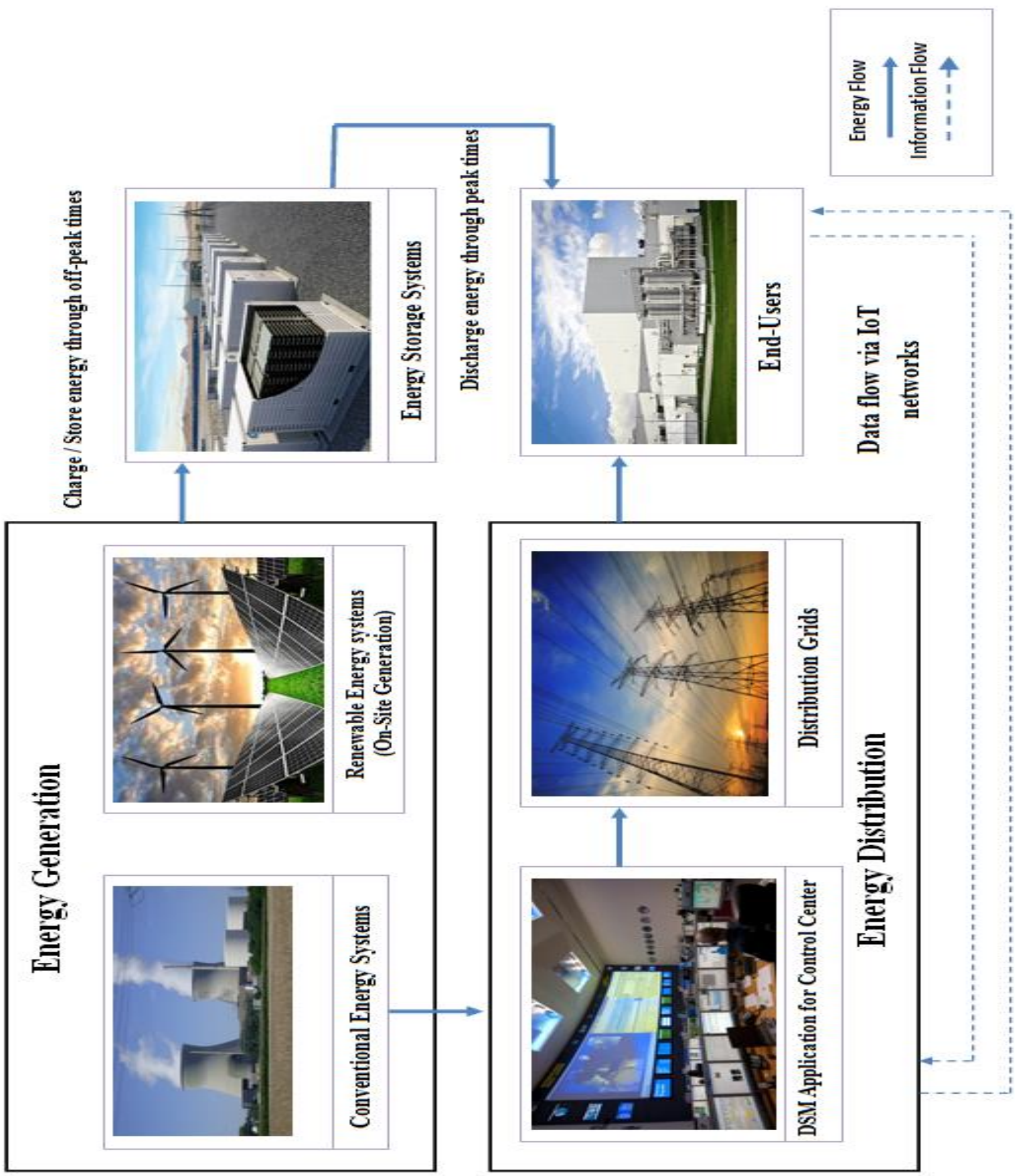

Fig. 4: the conceptual framework of peak shaving technologies & techniques to minimize peak load

Then, the **electricity distribution** includes the **demand-side management (DSM) application** for **control center** and electricity distribution networks, in which "the demand side control application" define exactly a way for allocating electricity inside each specific area, after that the distribution network supply the estimated demand of electricity for consumers. DSM allows grid customers to take part in grid operation by lowering or shifting loads at some points during the peak times. The **End-users** are the **electricity consumers**, in which they consume electricity according to their demands. Every consumer inside the electricity system on this framework possesses respective on-site electricity-producing systems in addition to warehouse structures for saving energy (ESS), is able to take roles of electricity consumers and producers. This return to his ability to generate electricity using his own on-site generation systems and he usually save this production using own energy storage facilities. The framework consolidates the idea of applying the "Internet" within the electricity and power area via the utilization of **IoT networks and communications**. With the IoT, energies can be transported bi-directionally within the grid (power flow and data flow), and the supply and demand for electricity can be dynamically balanced. IoT networks guarantees consciousness for power consumption, via various advanced sensors addition to **smart meters** equipped in the smart buildings and homes. Smart meter produce huge amount of data about end-users electricity consumption and device level usage. End-users' power consumption data is collected by smart meters, and these data records are sent through the IoT networks and communications to the DSM application of the control center (the data records flow, as shown in **figure 4**). The "control center" will supply a demand of electricity for distribution grid based on this information. In the case of "the control center" is informed that the grid is in the off-rush load time state, "the control center" will send the notification for consumers to allow them to charge the needed electricity. In this case customers are able to consume this lower-cost electricity throughout this off-peak load period and also, to be saved in their own ESSs for later use throughout top load periods. However, if the control center is aware that the grid is during the rush hour loads; "*the control center*" is going to send a notification for consumers to alarm them to charge electricity. And, in this case the customers can consume electricity from their own ESSs to avoid high electricity consumption expenses during this peak times and mitigate loads on the grid.

8. Contribution

At this study, extensive review of peak load shaving technologies and techniques has been discussed. The review discovered the integration and adoption of four major techniques and technologies in energy systems to minimize the problem of peak load periods, namely integration of IoT in power system, integration of on-site energy generation systems, DSM applications and techniques of control centers, instillation of ESS. On the other side, this work has just suggested a framework to clarify the techniques and strategies reviewed through this study aiming to address the problem of peak load within an energy system which affected negatively on electricity utilities and electricity consumers. This work is one of the first attempts to suggest peak load shaving framework using IoT in the energy system of grid power, renewable energies and energy storage capabilities. The framework integrated the IoT technologies and other technologies and strategies for achieving peak shaving. Thanks to adoption of IoT technologies, the data records of electricity suppliers and consumers can be collected immediately and accurately to demand side management application of control center for organizing energy distribution. Also, the framework significantly bases on on-sie renewable energies production systems and distributed energy storage capabilities in the power system. End-users can not only consume the energy from conventional electrical grids, but also have choice to switch to consume from other on-site renewable energies and energy storage systems especially during on-peak periods, to mitigate the power-generating pressure of grid suppliers, Minimize operating costs, reduce pollution and minimize the total electricity consumption cost of end-users, especially industrial and manufacturing consumers.

9. Conclusion

In this study, extensive investigation on rush hours loads shaving technologies and techniques has debated. The review discovered the integration and adoption of four major techniques and technologies in energy systems to minimize the problem of peak load periods, namely the utilization of IoT networks in energy system, building on-site energy generation systems, utilizing DSM applications of the control center and the instillation of ESSs. On the other side, this work has just suggested the internet of energy framework to clarify how to apply the presented techniques and strategies reviewed through this study into the energy system. As, we aim to overcome peak loads problems which affected negatively on electric utilities and electricity consumer. As we support, the framework integrate the IoT technology, other technologies and strategies for achieving peak shaving. Thanks to the adoption of IoT networks, records' data related to electricity consumption are instantly and accurately collected for supporting demand-side management application of the control center to be able for organizing energy distribution. Also, the framework significantly bases on on-site energies production systems and distributed energy storage capabilities in the power system. Thus, the end-users are able to consume electricity from ordinary grids, and have chosen to freely switch to on-site sources of electricity (renewable systems) and energy storage systems especially during on-peak periods, to mitigate the power-generating pressure of grid suppliers, Minimize operating costs, reduce pollution and minimize the total electricity consumption cost for end-users, and minimize peak load periods. In the future, we will conduct a comprehensive experimental analysis of the suggested framework.

References

[1] BP. BP world statistical Energy Outlook review, 2021 edition. London, United Kingdom (2021). https://www.google.com/urlsa=t&source=web&rct=j&url=https://www.pb.com/content/dam/bp/business-sites/en/global/corporate/pdfs

[2] Rahimi A, Zarghami M, Vaziri M, & Vadhva S. (2021). A simple and effective approach for peak load shaving using Battery Storage Systems. In: Proceedings of the North American Power Symposium, IEEE. 1-5.

[3] Chua KH., Lim Y., & Morris S. (2019). Energy storage system for peak shaving. International Journal of Energy Section Management; vol.10, pp:3–18.

[4] Sinha S., & Chandel S. (2020). Review of software tools for hybrid renewable energy systems. Renew Sustain Energy Rev; vol.32, pp:192–205.

[5] Palamar A, Pettai E, & Beldjajev V. (2018). Control system for a diesel generator and ups based microgrid. Sci J Riga Tech Univ Power Electr Eng; vol.26, pp:48–53.

[6] Chua KH, Lim YS, & Morris S. (2021). Battery energy storage system for peak shaving and voltage unbalance mitigation. Int J Smart Grid Clean Energy; vol.514, pp:357–363.

[7] Van den B., & Delarue E. (2020). Cycling of conventional power plants: technical limits and actual costs. Energy Convers Manag; vol.97, pp:70–79.

[8] Zanella A., Bui N., Castellani A., Vangelista L. & Zorzi, M. (2021). Internet of Things for Smart Cities. IEEE Intern. Things J., pp: 22–32.

[9] Sheng Z., Yang S., Yu Y., Vasilakos A. & Leung K. (2017). A survey on the IETF protocol suite for the internet of things: Standards, challenges, and opportunities. IEEE Wirel. Commun., vol.20, , pp:91–98.

[10] Mishra S, Palanisamy P, & Hemamalini S. Efficient power flow management and peak shaving in a microgrid-PV system. In: Proceedings of the international conference on renewable energy and sustainable development; 2021.

[11] Mishra A, Irwin D, Shenoy P, & Zhu T. (2020). Scaling distributed energy storage for grid peak reduction. In: Proceedings of the fourth international conference on Future energy systems.
Association for Computing Machinery, pp: 3-14.

[12] Pollitt MG, Davies S, Price CW, Haucap J, Mulder M, Shestalova V, et al. (2020), "Vertical unbundling in the EU electricity sector." Intereconomics; vol.42, pp:292–310.

[13] Joshi KA, Pindoriya NM. (2021). Day-ahead dispatch of Battery Energy Storage System for peak load shaving and load leveling in low voltage unbalance distribution networks. In: Proceedings of the IEEE power & energy society general meeting, IEEE; p. 1-5.

[14] Gajduk A, Todorovski M, Kocarev L. (2019). Stability of power grids: an overview. Eur Phys J. Spec Top; vol.223, pp:2387–2409.

[15] Thompson CC, Oikonomou PK, Etemadi AH, Sorger VJ. (2021). Optimization of data center battery storage investments for microgrid cost savings, emissions reduction, and reliability enhancement. IEEE Trans Ind Appl. vol.52, pp: 2053 – 2060.

[16] Malinowski J, Kaderly K. Peak shaving-a method to reduce utility costs. In: Region 5 Conference: Annual Technical and Leadership Workshop, IEEE; 2021. p. 41-4.

[17] Bradley P, Leach M, Torriti J. (2020). A review of the costs and benefits of demand response for electricity in the UK. Energy Policy. vol.52, pp:312–327.

[18] Chua KH, Lim YS, Morris S. A novel fuzzy control algorithm for Reducing the peak demands using energy storage system. Energy 2017.

[19] Zheng M, Meinrenken CJ, & Lackner KS. (2018). Smart households: dispatch strategies and economic analysis of distributed energy storage for residential peak shaving. Appl Energy. vol.127, pp:246–257.

[20] Kohansal M, Mohsenian-Rad H. (2020). Price-maker economic bidding in two-settlement pool-based markets: the case of time-shiftable loads. IEEE Trans Power Syst. vol.31, pp:695–705.

[21] Koh SL, Lim YS. (2021). Evaluating the economic benefits of peak load shifting for building owners and grid operator. In: Proceedings of the international conference on smart grid and clean energy technologies, IEEE; 2019. p. 30-4.

[22] Sardi J, Mithulananthan N, Gallagher M, Hung DQ. (2019). Multiple community energy storage planning in distribution networks using a cost-benefit analysis. Appl Energy. 190:453–463.

[23] McKinsey Global Institute. (2021). The Internet of Things: Mapping the Value beyond the Hype. https://www.mckinsey.de/files/unlocking_the_potential_of_the_internet_of_things_full_report.pdf

[24] World Economic Forum. (2021). World Economic Forum White Paper: Digital Transformation of Industries: Electricity—prepared in collaboration with Accenture. https://www.accenture.com /t20170116T084450__w__/usen/_acnmedia/Accenture/Conversion-Assets/WEF/PDF/Accenture-Electricity-Industry.pdf

[25] Union of Concerned Scientists (2021). Renewable Energy Can Provide 80 Percent of U.S. Electricity by 2050. http://www.ucsusa.org/clean_energy/smart-energy-solutions/increase-renewables/renewable -energy-80-percent-us-electricity.html

[26] NREL. (2021). Preliminary Analysis of the Jobs and Economic Impacts of Renewable Energy Projects Supported by the §1603 Treasury Grant Program. Available: http://www.nrel.gov/docs/fy12osti/52739.pdf.

[27] Gellings C. (2020). Evolving practice of demand-side management. J. Mod. Power Syst. Clean Energy. vol.5, pp: 1–9.

[28] Limaye D. (2018). Implementation of demand-side management programs. Proc. IEEE . vol.73, pp:1503–1512.

[29] Sim S. (2020). Electric Utility Resource Planning: Economics, Reliability, and Decision-Making; CRC Press: Boca Raton, FL, USA. p. 332.

[30] Qdr Q. Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them; U.S. Department of Energy: Washington, DC, USA, 2021.

[31] Walawalkar R., Fernands, S., Thakur, N., & Chevva, K.R. (2020). Evolution and current status of demand response (DR) in electricity markets: Insights from PJM and NYISO. Energy 2020, vol.35, pp: 1553–1560.

[32] Juaidi A., Montoya F., Gázquez J. & Manzano-Agugliaro F. (2019). An overview of energy balance compared to sustainable energy in United Arab Emirates. Renew. Sustain. Energy Rev. vol.55, pp: 1195–1209.

[33] York D. & Kushler, M. (2020). Exploring the Relationship between Demand Response and Energy Efficiency: A Review of Experience and Discussion of Key Issues; American Council for an Energy-Efficient Economy: Washington, DC, USA, 2020.

[34] Dti Report. Status of electrical energy storage systems. DG/DTI/00050/00/00, URN NUMBER 04/1878, UK Department of Trade and Industry; 2021, pp. 1–24.

[35] Ahearne J. (2019). Storage of electric energy, Report on research and development of energy technologies. International Union of Pure and Applied Physics. pp. 76–86. Available online http://www.iupap. org/wg/energy/report-a.pdf.

[36] Walawalkar R., Apt J. & Mancini R. (2007). Economics of electric energy storage for energy arbitrage and regulation. Energy Policy. 5:2558–68.

[37] Linden S. (2006). Bulk energy storage potential in the USA, current developments and future prospects. Energy. 31:3446–57.

[38] Chen L., Zheng J. & Sun F. (2003). Power, power density and efficiency optimization for a closed cycle helium turbine nuclear power plant. Energ Convers Manage. 44:2393–401.

[39] Maclay J., Brouwer J. & Samuelsen G. (2007). Dynamic modeling of hybrid energy storage systems coupled to photovoltaic generation in residential applications. J Power Sources. 163:916–25.

