ANALYSIS OF THE IMPACTS OF LOAD SHIFTING DEPENDENT DSM STRATEGY IN A NEIGHBORING LOCALITY IN BANGLADESH

by

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CERTIFICATE OF APPROVAL

The thesis/project entitled as **"Analysis of the Impacts of Load shifting dependent DSM strategy in a neighboring locality in Bangladesh"** submitted by **Md. Shamiun Reza**, bearing Matric ID. **ET173055** and **Md. Ryhanul Islam**, bearing Matric ID. **ET173060** of session **Spring 21**, to the Department of Electrical and Electronic Engineering, International Islamic University Chittagong, has been accepted as satisfactory in partial fulfilment of the requirements for the degree of Bachelor of Science in Engineering and approved for the examination held on **22 JULY, 2022**.

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DECLARATION

It is hereby declared that this work has been done by us and no portion of the work contained in this thesis/project has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

In recent years, end users management of power usage has been given more importance to ensure efficient and effective use of electricity. One such tool, that can improve the end user power use scenario is Demand Side Management (DSM). The main theme of DSM is to reduce power wastage, improve efficiency and to reduce the price of electricity to the consumer. In this work,We have investigated the effects of residential customers' load shifting compared to their historical patterns of energy consumption. We have followed the data collection methodology of a similar study to take realistic load profile of the consumers. We have collected 10 individual house data from different locations to keep variety in the load profiles of the consumers and to find out an overall scenario. Initially, we have used an excel spreadsheet to take consumer data then we made simulink model for each user. The simulink model has been used to simulate the load shifting and its impacts. From the study we found that 6.7% of the total load can be shifted from peak electric hour to off peak hour. This study can make an important role in applying load shifting among mass consumer and to examine its impacts.

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LIST OF ABBREVIATIONS

DSM	Demand Side Management
GHG	Green House Gas
EC	Energy Conservation
EE	Energy Efficiency
DR	Demand Response
EECMP	Energy Efficiency & Conservation Master Plan
IEA	International Energy Agency
HEMS	Home Energy Management System
DLC	Direct Load Control

CHAPTER 1
BACKGROUND AND INTRODUCTION

1.1 Introduction

In the generation sector, renewable energy now accounts for 29% of the global total in 2020. If the current pace of 2% year-to-year improvement continues, renewable sources are predicted to provide one third of the overall generation within the next two to three years [7]. Even though the proportion of renewable energy in the generation sector is increasing, as of 2019, 42% of the total global CO_2 emissions are still produced by electricity and the heat that goes along with it [8]. The average amount of power used for homes accounts for over one-third of all the energy used worldwide [9], [10], which indicates that the residential sector is accountable for 14% of the CO_2 emissions brought on by the production of power. Beside this residential sector directly involves in emitting 6% of the global emission [8]. Together, the residential sector contributes 20% of world emissions. Since practically all peaking power plants burn gas, peak electricity demand plays another significant role in the electricity emission industry [11].

According to BPDB's annual report for 2020–2021, the residential sector accounts for an astounding 56.43 percent of all electricity usage in Bangladesh [12] which is much greater than the average for the world.As a result, Bangladesh's residential sector is indirectly to blame for the country's greater emissions related to energy generation. Reducing home consumption will make a big difference in the amount of emissions the electrical sector produces overall. End user management of power usage may be essential in lowering the proportion of the residential sector to overall electricity consumption. Demand-side management (DSM) is a term used to describe this end user management [13]. Three ideas are clarified by DSM: energy conservation (EC), energy efficiency (EE), and demand response (DR) [2]. Although these are the main DSM phases, the concepts are more straightforward and successful in achieving the goals of DSM. The possible benefits of DSM include lower GHG emissions, lower total electricity consumption, decreased peak demand, and cost savings [14]–[16].

To demonstrate the success of DSM, particularly in developing nations, numerous studies have been conducted using various DSM methodologies in different parts of the world. While EE & EC dependent DSM techniques can be applied on any grid, especially those in underdeveloped nations, advanced technology and smart grids are crucial factors for using DR dependent DSM strategies [2]. In this study, DR-dependent DSM approaches for HEMS [17]–[19]. Zizzo et al investigated how DSM affected the island of Lampedusa's residential sector and discovered that it may cut peak loads by 10.6% in the winter and 6.4% in the summer [20]. For smart grids and developed nations, price incentive and TOU dependent DSM techniques are also well suited [14]. The scarcity of data is a critical issue impeding the creation of appropriate DSM strategies in developing nations [21]. In light of these, EE & EC based DSMs are the most straightforward to implement in developing nations. Energy Efficiency and Conservation Master Plan up to 2030 is the name of the DSM method the Bangladeshi government adopted in 2015 [22]. Unfortunately, this master plan only takes EE-oriented strategies like swapping out wasteful loads for efficient ones into account. Whereas Bangladesh has a significant potential to adopt EC DSM techniques and achieve the DSM goals, EC-oriented approaches are not taken into consideration in this master plan.According to a study, Bangladesh may save 390 GWh of energy each month by changing people's behavior [23]. The author demonstrated [21] how energy conservation practices could result in a maximum 20.9% reduction in Bangladesh's electricity demand.

The main goal of this work is to present a novel approach to data collecting and load profile that can be utilized to precisely collect vast amounts of consumer data for the development of DSM policies in developing nations. This study also focuses on the implementation of the EECMP's missing EC methods, examining the effects and practicality in Bangladesh's residential sector. Load shifting and energy-usage behavior-based conservation are used to show the effects over the existing system.

1.2 Global energy situation

Electricity markets around the world faced unprecedented demand in 2021. Strong economic growth, paired with colder winters and warmer summers, increased worldwide electricity demand by more than 6%, the highest increase since the financial crisis ended in 2010. The rapid rise in overall energy demand put a pressure on coal and natural gas supply systems, driving up wholesale electricity costs. Despite the phenomenal growth of renewable energy, coal and gas-fired electricity output reached new highs. As a result, annual carbon dioxide emissions from the worldwide electrical industry jumped to a new all-time high after falling for the previous two years [24].The January 2022 issue of the IEA Electricity Market Report includes our estimates for demand, supply, and emissions in global electricity markets through 2024, based on our study of these recent events [22]. While renewables are expected to supply the great majority of the increase in global electricity demand in the next years, emissions from electricity generation are expected to plateau.An earlier estimate of future energy routes found that improving energy availability, air quality, and energy security while avoiding serious climate change is technically doable. In fact, many combinations of resources, technologies, and policies have been discovered to be capable of achieving these goals.Land, energy, and water are three of our most valuable resources, but how and to what extent they are used contributes to climate change. Meanwhile, the systems that supply these resources are extremely sensitive to climate change. Effective resource management is therefore critical, both for mitigation and adaptation purposes. Inconsistent strategies and inefficient resource utilization result from a lack of integration in resource assessments and policy-making [25]. This is insufficient for the electricity sector to play its crucial role as a driving factor in the global decarbonisation of economies.(https://www.iea.org/reports/electricity-market-report-january-2022) Following a minor decline in 2020, global electricity demand increased by 6% in 2021. It was the highest annual increase in absolute terms (nearly 1500 TWh) and in percentage terms since the financial crisis in 2010. China accounted for over half of worldwide growth, with demand increasing by 10% on average. A quick economic recovery, combined with more extreme weather conditions than in 2020, notably a colder-than-average winter, boosted global electricity demand [26]. The industrial sector, followed by the business and services sector, and finally the residential sector, contributed the most to demand increase **Fig. 1.1**.

More than half of the rise in world demand was satisfied by coal. Coal-fired electricity generation hit an all-time high, expanding by 9%, the fastest since 2011, fueled by high demand and coal's cost competitiveness in some markets vs gas. Despite the fact that growth was hampered by unfavorable weather conditions, renewables climbed by 6%. (in particular for hydropower). Gas-fired generation increased by 2%, while nuclear generation surged by 3.5 percent, approaching 2019 levels. CO2 emissions from electricity increased by about 7% in total, reaching a new high **Fig. 1.2**.

Scarcities and high energy prices arose from growing demand for fossil fuels paired with supply limits. Average wholesale power costs in the fourth quarter of 2021 were more

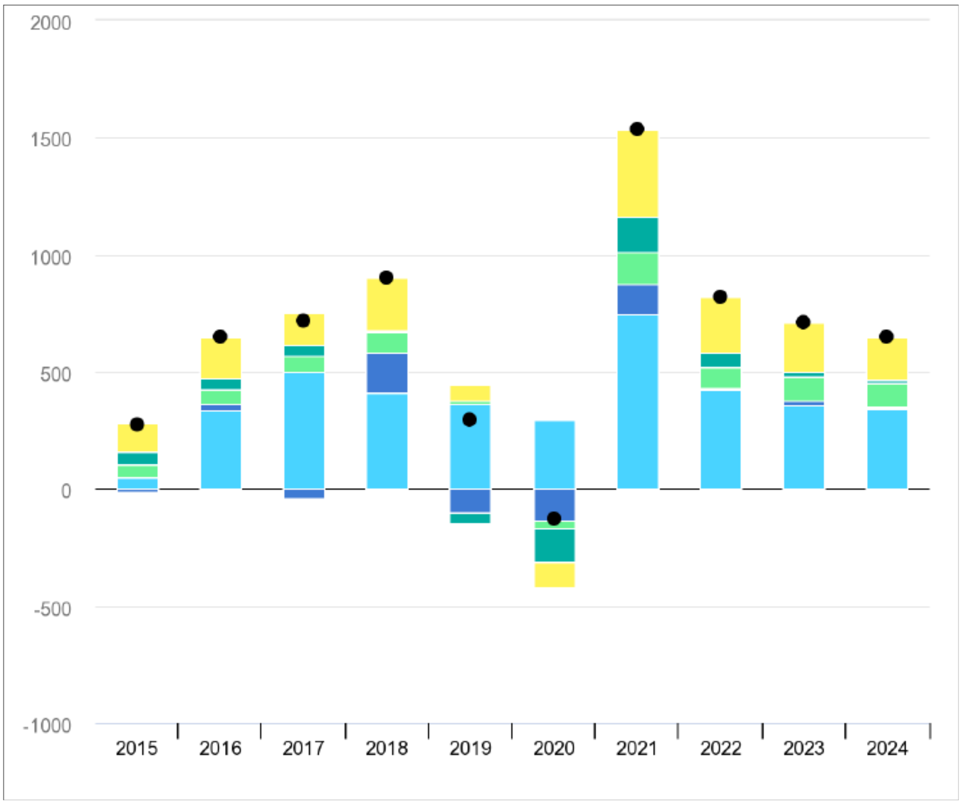


Fig. 1.1 Global changes in electricity demand, 2015-2024 [1]

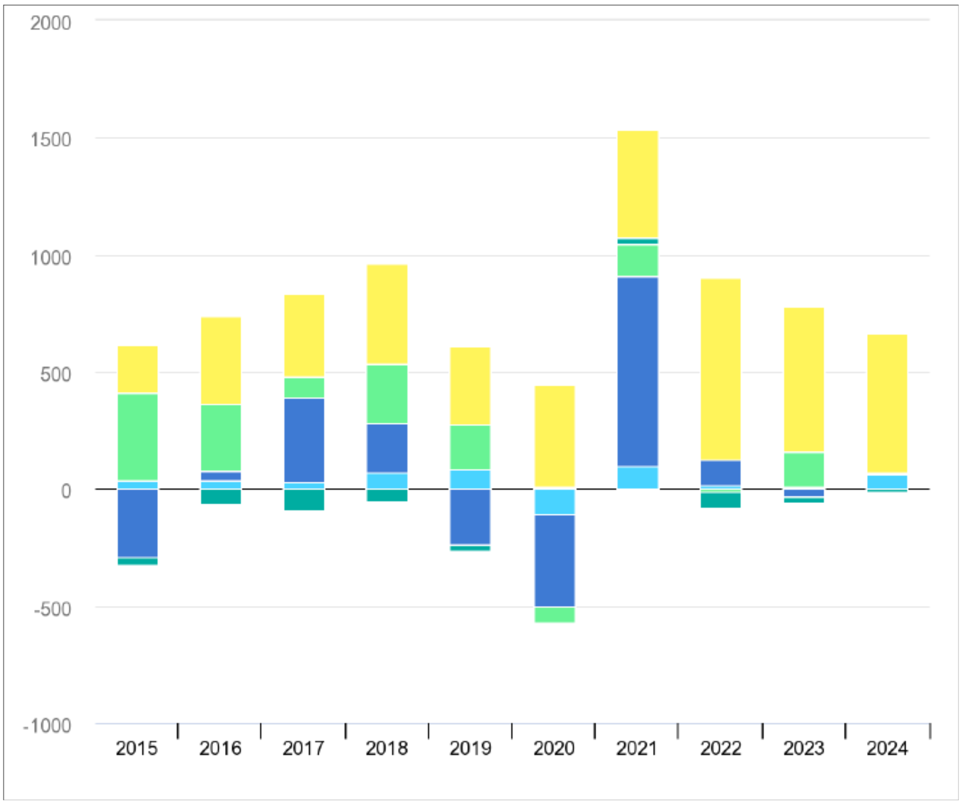


Fig. 1.2 Global changes in electricity generation, 2015-2024 [1]

than four times higher than the 2015-2020 average, owing to notably high gas prices in Europe and its 20% proportion of the generating mix. **Fig. 1.3**

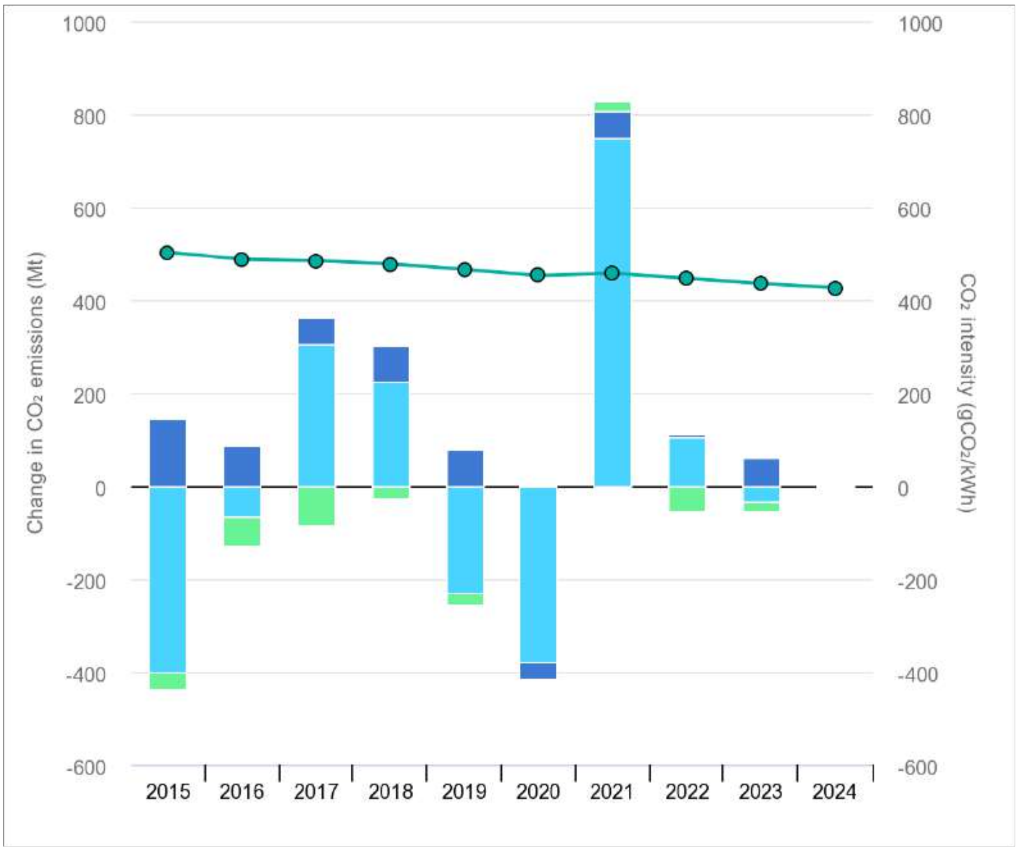


Fig. 1.3 Emissions intensity and change in electricity generation emissions, 2015-2024 [1]

We estimate fast expanding renewables to virtually match moderate demand growth between 2022 and 2024. We forecast a 2.7 percent yearly increase in electricity demand, but the Covid-19 epidemic and high energy prices add to the uncertainty. During this time, record-breaking renewables growth (rising 8% per year on average) is expected to meet more than 90% of net demand growth. During the same time span, we anticipate a 1% annual increase in nuclear power generation (meeting 4 percent of global demand growth).Over the next three years, fossil fuel production is expected to remain flat. Fossil fuel-based generation is expected to be generally flat in the next years as a result of decreasing energy demand growth and significant additions of renewable power capacity. We estimate coal-fired production to decline marginally as phase-outs and deteriorating competitiveness in regions such as the United States and Europe are offset by growth in China and India. Annual growth in gas-fired generation is expected to be around 1%.The policies in place now are insufficient to reduce emissions. To reach the

IEA's Net Zero Emissions by 2050 Scenario, power sector emissions are expected to stay around the same level from 2021 to 2024, according to our prediction. This emphasizes the significant changes in energy efficiency and low-carbon supply that are required for the electricity sector to play its vital role in decarbonizing the broader energy system. **Fig. 1.4**

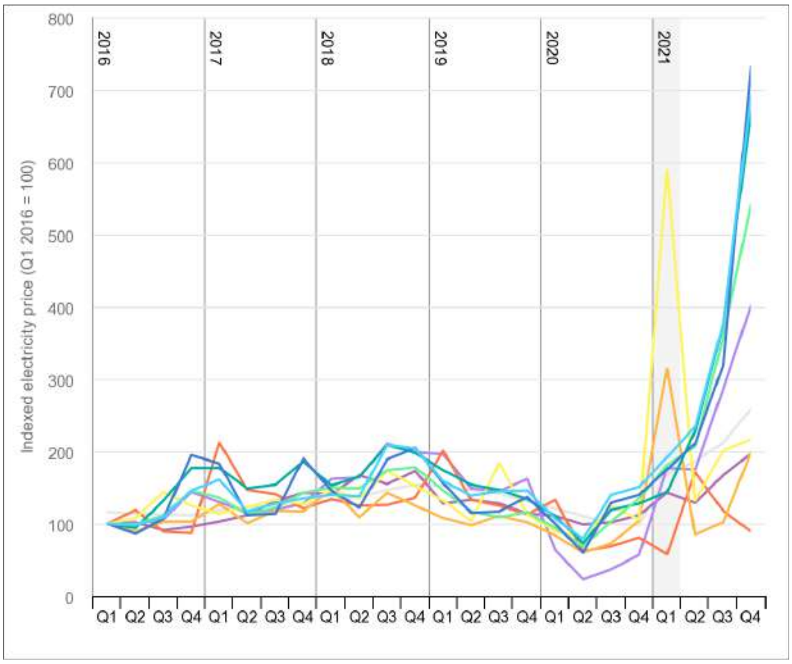


Fig. 1.4 Quarterly average wholesale prices in selected regions, 2016-2021 [1]

1.3 Power sector of Bangladesh

The economy of Bangladesh ranks 31st in terms of purchasing power parity and is the 42nd largest in nominal terms. It is a frontier market and one of the next eleven developing middle income economies. Bangladesh's GDP is the second fastest growing major economy in 2016, according to the International Monetary Fund (IMF), with a rate of 7.1%. In addition, the real GDP forecast for 2020 is 7.4.The steady supply of energy is required by an ever-growing economy. Bangladesh's primary energy source is natural gas. Power usage is continually increasing as technology advances. A reliable and sufficient supply of power is a key requirement for long-term economic growth [27]. Bangladesh is a developing country that has the potential to grow in terms of energy demand. Bangladesh is now experiencing an energy crisis. Around 70% of people in Bangladesh do not have access to electricity, and the majority of them live in villages. Around 40% of them are poor. Climate change, on the other hand, poses new challenges to development [28].Due to population increase, economic development, and technological innovation, today's energy requirements are on the rise. In addition, given the current state of energy search and use, found energy will be depleted within a few decades. Our lives have been claimed to be dependent on energy. In comparison to the rest of the globe, Bangladesh's primary energy resource condition is dire. Bangladesh's proven reserves of oil, natural gas, coal, and hydropower are limited, necessitating a bigger scale of infrastructure development.There are several natural resources in Bangladesh, including coal, gas, and petrol. Natural gas (24%) is Bangladesh's main source of energy, although it is expected to be depleted by 2020. The people of Bangladesh will then encounter various difficulties. In this situation, renewable energy benefits the Bangladeshi people. People have a high unmet energy demand, which is increasing by 10% every year [29]. Electricity is critical to economic progress and poverty reduction by facilitating the development of sustainable infrastructure. Electricity supply reliability is a critical concern for the world today. The long-term supply of power that is inexpensive, available, and environmentally benign is critical for future economic growth. Electricity is intertwined with security, climate change, and public health [30].Because of population increase, economic development, and technological innovation, today's energy requirements are on the rise.Bangladesh faces formidable energy difficulties, including rising fuel imports and limited domestic energy supplies for electricity generation. Bangladesh's current electricity consumption is around 6000MW, while its generation capacity is just 4000-4600MW. The capacity of the plant is 5936MW. Because of the power scarcity, severe load shading occurs throughout the year. Bangladesh is heavily reliant on fossil fuels for energy, but the current supply will be gone by 2015.Coal is still the primary source of electricity generation in this country. Bangladesh has a sufficient supply of high-quality coal. However, coal mining has not been adequately started. Natural gas resource exploration and development are almost non-existent. In addition, the future of coal exploration remains questionable. As a result, renewable energy resources, which are abundant in nature, can be used to meet the power shortage. In addition, given the current state of energy search and use, found energy will be depleted within a few decades.For a developing country like Bangladesh, power is one of the most critical things. The need for power in our country, like that of the rest of the globe, is growing by the day. Power outages have now become a serious issue in this country. Due to a lack of energy, the construction of significant physical infrastructure, the construction of new power plants, and the pace of industrialization in the country has slowed in recent years [31]. Our lives have been claimed to be dependent on energy. In comparison to the rest of the globe, Bangladesh's primary energy resource condition is dire. Bangladesh's proven reserves of oil, natural gas, coal, and hydropower are limited, necessitating a bigger scale of infrastructure development. According to the Ministry of Power, Energy, and Mineral Resources, Bangladesh's government provided power to 70% of the population in 2015 (Bangladesh: Increasing Access to Energy), and per capita energy generation is currently 372 kWh.Bangladesh generates around 62.31 percent of its electricity from national grid gas supply and petrol. According to the Bangla, gas accounts for 80% of Bangladesh's electricity output. As a result, the greatest generation of power is controlled by local sources of energy, with only 4.28 percent imported, which is a major problem for Bangladesh's future electrification [32]. In light of this, the Bangladesh government devised a comprehensive power generating strategy in order to ensure the power sector's long-term growth and the country's overall economic development. There is currently 22,031 MW of installed generation capacity in the public, commercial, joint venture, and import sectors. The governmental sector has 10,146 MW (46%), the private sector has 9,481 MW (43%), joint ventures have 1,244 MW (6%), and imports have 1,160 MW (5 percent).Electricity consumption is rising, while available generation is rising in lockstep with demand. A number of generation units in the public sector have reached the end of their useful lives and are now working at a reduced capacity [33]. Furthermore, the majority of existing power plants are gas-fired. Some power plants are unable to attain their normal generation capacity due to a gas supply shortfall. On April 27th, 2021, the maximum generation for this fiscal year is 13,792 MW. Currently, electricity is available to 99.5 percent of the population, with a per capita generation of 560 kWh (including captive and renewable energy). Bangladesh has now achieved improbable feats in the power sector. The government's goal was met with success, and it was even surpassed at a greater level (BPDB).

Demand shortages happened 30% of the time as recently as 2014. The Sirajganj Unit 4 project is planned to boost power generation by 3,000 gigawatts per hour. Furthermore, because the new plant is predicted to be one of Bangladesh's most efficient, it will aid in the modernization of the country's power sector and optimize the use of natural gas, which emits less than half the amount of carbon as coal when burned [34]. IFC has committed $165 million to a business formed by Sembcorp Utilities, a wholly owned subsidiary of Singapore-based Sembcorp Industries, to increase energy availability throughout Bangladesh. The funding comes from a $73 million loan from IFC's own account, as well as $92 million from Clifford Capital and the Japan International Cooperation Agency (JICA).Sembcorp will be able to greatly increase its power producing capacity thanks to the help. It will build Sirajganj Unit 4, a 414-megawatt power plant, with the support of a local sponsor, to cut the cost of energy generation and help Bangladesh fulfill its growing need for power. By 2019, around 5.8 million home consumers will have access to power.The IFC's support for Sirajganj Unit 4 aligns with our overall objective of bringing power to domestic consumers while increasing the quality and availability of power supply—a critical concern for the country's investment climate. The proposed investment is also in line with the IFC's South Asia regional strategy, which focuses on infrastructure, logistics and connectivity, and financial inclusion. The project's final cost is expected to be roughly $412 million.A total of$339 million in debt is being contributed by the United Kingdom's development finance organization CDC Group, Singapore-based infrastructure business Clifford Capital, and JICA, in addition to the IFC's financing. Sembcorp has a risk guarantee from the Multilateral Investment Guarantee Agency (MIGA), which is part of the World Bank Group.

1.4 Demand Side Management

Every year, the need for electricity, both domestic and industrial,is rising.New electricity generating stations must be built to accommodate this demand.According to a study, power demand in Kazakhstan might expand at a pace of 3% to 5% per year [35]. This has an effect on the grid during peak hours. Following it, the concept of demand side management came into light. Demand Side Management (DSM) is a method that involves changing consumer behavior in order to influence how much energy they consume. DSM's goal is to persuade consumers to use less energy during peak hours or to switch to off-peak times like the evenings and weekends. DSM has a lot of potential to reduce the peak electricity demand and produce electricity more cheaply and with lower carbon emissions [36] but it's not widely used yet, especially in developing nations,due to a lack of precise information of the household elements.It is critical to meet energy demand across the entire interlinked electric utility at all times, therefore electrical network and power generation capacity must be available to meet these demand at the peak hour which is cost inefficient. [23] During the same time span of 2017, demand for residential buildings increased by around 54% [37].To allow possible technology and demand changes in a future energy system,an integrated approach involving Green Energy Sources -based generation, DSM is required.However,A house management system (HEMS) with integrated Demand Response (DR) algorithms may coordinate and schedule multiple smart appliances in the most efficient and effective way [19]. [Izaz-Implementation]As generation of electricity and network capacity are only used around 50%, DSM has a lot of room to improve the system's efficiency [38]. There are a plethora of DSM methodologies such as Direct-load control Domestic,Load limiters Load,Time-of-use pricing,Frequency regulation System etc.Amongst all the techniques,There are other benefits of DSM that might be highlighted.

1.By implementing DSM, the electricity shortage can be resolved.

2.Helping to reduce CO_2 emissions and, as a result, helping to mitigate climate change.

DSM also creates a lot of new opportunities:

1. Keeping supply and demand equal
2. Contributing to the expansion of the distribution network
3. The system's effectiveness can be increased [38]

1.5 Research Gap

Because of the current situation of global warming, understanding how we produce power and how we utilize it has become more crucial than ever. Efficiency in energy usage and management are just as critical as changing power generating to green energy. In this paper, the applicability and effects of load shedding and energy conservation for residential customers were examined. We've created a new method for pulling consumer information from Excel and Simulink in order to offer a load profile that is more accurate. To get as close to the user's actual energy usage as possible, an excel spreadsheet was developed. To replicate the user's 24 hour load profile, a MATLAB simulink model of the user was built from the spreadsheet. We discovered that a 9 percent increase in energy savings and a 15% increase in load shifting from peak to off-peak electrical hours can be achieved. This research will aid in the collection of a vast amount of consumer data in order to construct a load profile of consumers for the purposes of analyzing and applying

DSM. This research also shows that these DSM approaches can be extremely effective in ensuring efficient power use and conservation in poor nations where DSM deployment is still in its early stages. The loads are divided into interruptible and non-interruptible loads when creating LPT [39].Installed generation capacity must be able to meet maximum (peak) demand in order to satisfy demand that varies daily and seasonally, and given that demand is mostly uncontrollable and disruptions are costly, installed generation capacity must be able to meet maximum (peak) demand. Furthermore, adequate capacity must be available to deal with the variability in generating availability as well as unanticipated demand surges. Historically, a capacity margin of roughly 20% was thought to be acceptable for ensuring adequate generation security.This low average plant utilization provides tremendous opportunity for DSM, as shifting demand from peak to off-peak periods reduces the requirement for generation capacity and increases the utilization of generating plant, hence enhancing the effectiveness of generation investment [38].

1.6 Objectives of this work

1. To study the impacts of Load shifting
2. To shift load from peak hour to off peak hour
3. To reduce production and demand cost
4. To decrease peak demand and cost savings

1.7 Outline

The thesis is ordered in the following order
chapter 1 provides background and introductory study to the thesis
chapter 2 gives literature review and DSM introduction
chapter 3 is the methodology and simulation
chapter 4 shows the result of this study
chapter 5 gives conclusion to this study

CHAPTER 2
LITERATURE REVIEW

2.1 Demand side management

Demand side management (DSM) is defined by Gellings as "activity influencing the demand" for energy rather than treating demand as a fixed quantity. DSM is defined as "the planning, implementation, and monitoring of those utility actions meant to affect customer consumption of power in ways that cause desired changes in the utility's load shape" in the context of electricity [40]. One part of this is energy efficiency, which entails offering the same or higher level of energy services while reducing the amount of energy utilized in the long run (e.g. kilowatt-hours).DSM, on the other hand, can help change load shapes by lowering peak demands, boosting the usage of a certain type of energy overall or at specific times of the day, or rendering energy demand more flexible by swiftly curbing or raising energy end-uses [41]. As a result, energy efficiency is one part of overall energy demand management. We use the term sustainable energy demand, or DSM, throughout the study to highlight these broader initiatives, and we mention energy efficiency when absolute decreases in energy demand are the major policy goal. Energy efficiency, conservation, and demand responsive actions, such as load control or load shifting, are only a few of the energy demand-reduction activities covered by the phrase Demand Side Management (DSM).As the industry's interest in demand management grew, and DSM's acceptance as a unifying umbrella to house programs or activities that could manage demand grew, it became clear that there were seven generic actions, taken together or separately, that could have the most impact on actually implementing DSM [42]. DSM programs are intended to accomplish two main goals: lower total energy consumption by promoting high-efficiency equipment and building design, and reduce load through modifying end-user energy usage habits, particularly during peak demand periods. Because electricity and natural gas are usually distributed by distinct utilities with their own regulatory systems, utility DSM initiatives have traditionally resided in fuel silos. Many jurisdictions do not have efficiency projects targeting non-regulated fuels like heating oil, wood, or petroleum-based transportation since savings do not offer the same utility system benefits as natural gas and electricity [43]. These barriers have been torn down by European policy that is more clearly focused on low-carbon transi-

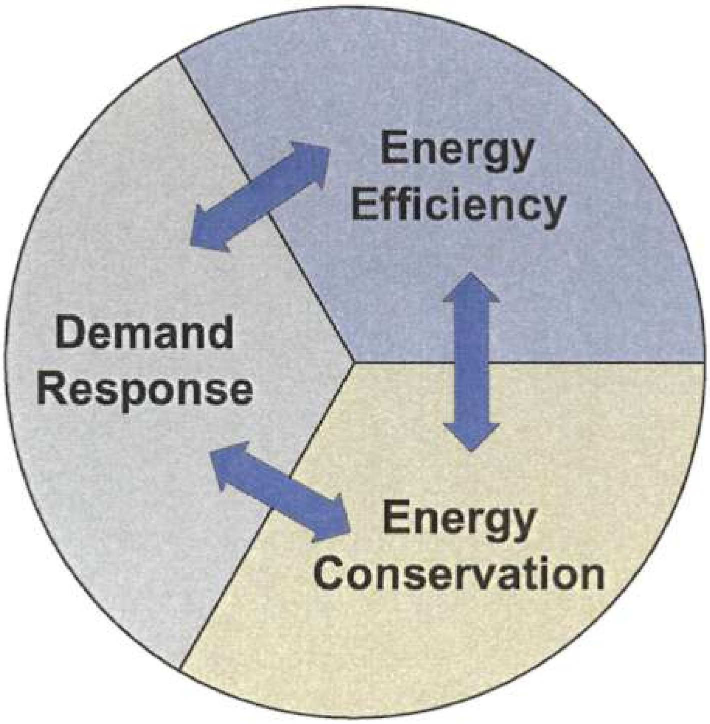


Fig. 2.1 Demand Side Management Concept Integration [2]

tions. From an early concentration on electricity in the 1990s to a multi-fuel target in the early 2000s, the UK energy savings obligation evolved into a Carbon Emission Reduction Target in 2008–2012 [44].Due to differences in efficiency and other factors, the cost of producing electricity varies from power plant to power plant. As a result, the cost of generating one kilowatt-hour (kWh) of electricity varies constantly depending on the power plants in use. As a result, utility firms offer their consumers varied electricity tariffs depending on fluctuating production costs [45]. An electrical system only experiences its genuine peak demand for a few hours per day, a few days per year. According to Kuwait's monthly peak power demand for 2013, peak power consumption in the month of July is about two times greater than in the month of February. This demand should be met by generation companies, who should be required to keep their generation capacity accessible. The power plants that are preserved for this reason are usually the oldest or the least efficient of the group. This will raise the overall electricity price during peak periods , and ESCOs will be required to purchase electricity at a higher price, affecting the electricity cost. ESCOs place a great premium on reducing consumption during this vital peak period, so specific arrangements with consumers are created. This will also assist to alleviate the strain on the electrical grid [46].

2.1.1 Types

DSM is a program run by electric utilities to encourage customers to adopt procedures and practices that are beneficial to both parties. Any effort aimed at changing load shapes by influencing consumers' electricity consumption behavior qualifies as one of these strategies [47].

2.1.2 Benefits of DSM

The possible benefits of DSM were evaluated based on the effects area (e.g., economic, environmental, market-wide, and technical implications). As a result, a literature review was undertaken on the effects of DSM on the reliability of electrical power networks.

1. Maintaining voltage stability power networks
2. Relieving transmission congestion
3. Increasing the flexibility of preventive maintenance scheduling
4. Deferring the required upgrading of electrical power system facilities
5. Balancing energy resources
6. Mitigating the drawbacks posed by the intermittency of renewable energy sources
7. Increasing the flexibility of electrical power system
8. Increasing the utilization of renewable energy sources
9. Reducing the startup and shutdown of thermal units that require excessive starting costs
10. Reducing the startup and shutdown of thermal units that require excessive starting costs
11. Avoiding capital costs
12. Increasing efficiency
13. Reducing running costs
14. Enhancing power quality, security and power factor

15. Improving the market performance of electricity power systems; and finally

16. Mitigating environmental damage These improvements can yield significant secondary benefits, such as reductions in losses and premature ageing and leads to the adoption of efficient residential appliances and industrial equipment

2.2 Load shifting

Demand is largely unpredictable, fluctuating according on the time of day and season (there have been insufficient incentives for demand to become responsive). Summer nights have the lowest demand, which is around 30%. The DSM technique focuses on

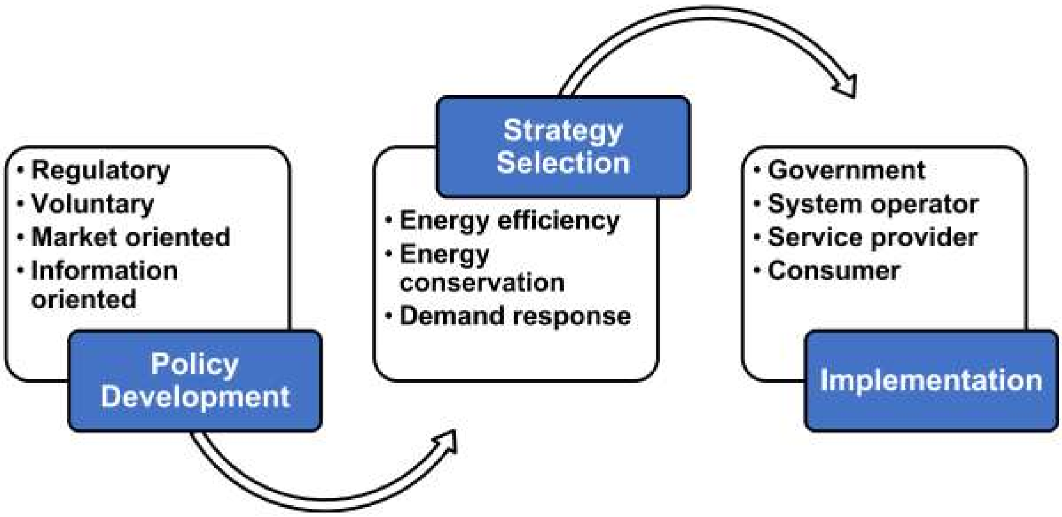


Fig. 2.2 Demand Side Management program development key steps.

balancing current generation values with demand by restricting appliance energy consumption and improving their function at the user level, such as shifting so-called wet appliances like dishwashers and washing machines from peak to off-peak periods. From statistical data, which demonstrates that household electricity consumption accounts for more than 30% of worldwide energy consumption, it can be inferred that energy usage optimization in a smart home is important. This is extensively utilized in both the design and operation of power systems. The capacity of an electricity system that serves thousands of households is only around 10% of the total capacity required if each household were self-sufficient (i.e. provide its own generation capacity).The importance of distribution energy networks in attaining this huge benefit of load diversity cannot be overstated [48]. However, increasing the number of households would not result in any significant increases in the capacity of the electrical supply system. This phenomenon is depicted in the graph, which demonstrates how the demand coincidence factor changes as the number of households increases.The coincidence factor is the ratio of a group of households' maximum coincident total demand to the sum of the group's individual consumers' maximum requests. In other words, the coincidence factor is the ratio of a system's capacity necessary to service a certain number of households to the total supply system capacity required if each household were self-sufficient.As balancing demand and supply at the household level is clearly inefficient, distribution networks offer enormous utility.Therfore Load Shifting plays the key role. The advantages of Load shifting are many:

1. Keeping supply and demand equal
2. Contributing to the expansion of the distribution network
3. The system's effectiveness can be increased [38]

2.2.1 Peak hour

Peak energy hours are defined as the times of day when a region's energy load is at its peak. Whereas a big section of the population is not at home during traditional work and school hours, most residences utilize less energy for the most of the day.In general, the hours between 5:00 p.m. and 11:00 p.m. on any given day are considered peak hours for all pertinent consumer categories. Although certain utilities' definitions differ, the electrical business divides use times into two categories: on-peak hours, which begin at 7:00 a.m. and end at 11:00 p.m. on weekdays, and off-peak hours, which are between 11:00 p.m. and 7:00 a.m. on weekdays and all day on Saturdays and Sundays. In Bangladesh, the residential peaks from the studied households occurred primarily at nighttime after the system peak hours (i.e., 5–11 p.m.).This is because the residents in the examined gas utility connections. With the agreement of one of the house owners, a smart meter was later placed for eight days.While this element can ensure the microgrid's power requirement, power support for the external grid cannot be supplied during peak hours. It can be seen that, with the exception of a few peak shifts, the estimated and measured demand peaks are rather near once the spikes in the observed demand profiles caused mostly by the microwave and high-capacity water pump are deleted [49]. For instance, the midday peak on April 2nd actually occurred at the peak. On the other hand, the evening peak shifted to the right. The midday and evening peaks on April 3rd coincided with the expected peaks. With the exception of April 5th, all of the measured midday peaks coincided with the expected peaks. Out of eight days' worth of demand profiles, three days' (2, 3, 7 April) measured nocturnal peaks were roughly in line with expected peaks [50]. The measured positions of the evening peaks migrated to the right of the anticipated placements. The morning measured peaks of 5, 6, 7, and 9 April, on the other hand, overlapped with the estimated ones. The peaks migrated to the right during the next four days. Importantly, disregarding the spikes, all of the observed peaks are within the projected demand (in watts) range. One factor for the shift in demand peak might be the energy-use habits of dwelling occupants [23].The demand profiles for the third and fourth of April fall within the category of weekends in Bangladesh, which are Friday and Saturday. However, no significant variations in assessed demand profiles for weekends in the investigated family were identified. According to the family's demographics, the rice cooker and the water pump are the main causes of the mid-day peak because the women are housewives who frequently engage in energy-demanding activities. For instance, it was found that many families continue to utilize cathode ray tube (CRT) televisions, which are no longer in use, which consumes more energy than LCD/LED/smart television. The same holds true with lighting. Because lights are such an important appliance, additional efficiency improvements or any innovative approach that may manage the degree of necessary lighting might be a possible source of future peak demand reduction in Bangladesh. Furthermore, good lighting system design that takes into account numerous characteristics such as room color or reflection effects might lessen demand. Although it may appear difficult to deploy a new control approach for ceiling fans, because they are utilized to promote occupant comfort, efficiency may be improved further. It displays the average demand variance over the preceding eight days in Bangladesh between 5 p.m. and 11 p.m. during the evening system peak demand.The median demand was discovered to be around 761W. The highest and lowest measured averages were around 824W and 724W, respectively. During this system peak, however, the projected average was around 749W. The differences between anticipated average demand and measured demand for eight distinct days range from 3.30 percent lower to 10% higher than the estimated average.The median variation was around 1.72 percent. On April 3rd, for example, the greatest 10% demand variance from the anticipated average demand was seen during the system peak in the evening. On the other hand, 3.3 percent less demand was recorded on

April 8th compared to the predicted average demand during system peak hours.The highest and minimum measured averages during off-peak hours such as mid-night to early morning [i.e., 12 a.m.–6 a.m.] were determined to be 531W and 438W, respectively. The median was around 503W. The smallest deviation from the projected average (361.55W) was found to be around 21% on April 2nd, and the largest variation was determined to be 47% on April 8th. The median difference was 39.18 percent.Because the highest demand fluctuation was around 10%, it was discovered that the anticipated demand profile may be utilized to implement demand side management related steps during peak hours. During peak hours, a recent research discovered a about 11% disparity between projected and measured demand [51].Regular power outages are a typical occurrence in most developing countries, since demand for energy exceeds output during system peak demand hours. A technique for constructing the demand profile of houses, particularly during system peak hours, might assist the national electrical authority in identifying the elements that contribute the most to the demand from dwellings during peak hours [52]. As a result of the predicted demand profile, appropriate demand side management measures may be able to lower demand during peak hours. Demand reduction is critical in assuring supply security and network stability, particularly during network peak hours. Previous research estimates that demand response may lower peak demand by 43 percent in the residential sector, but only 13 percent in the commercial and industrial sectors combined in the United States [21]. The HEMS (Home Energy Management System) is a technological platform that includes both software and hardware that allows users to monitor overall load profiles as well as automatically and/or manually shift and curb demand to reduce total consumption. The HEMS can shift or reduce load in response to DR signals (DLC (Direct Load Control) or price) and human comfort to optimize electricity usage during peak hours or when the network condition is compromised [18], [19]. When customers increase their consumption during peak hours, the load controller switches non-priority loads (such as the washing machine, dishwasher, etc.) to off-peak hours and only enables priority loads (AC, room heater, etc.) to function to preserve consumer comfort. Consumers can select the operational time of each non-priority load ahead of time. To manage the network, the utility can transmit load control signals to the HEMS. The controller also regulates load consumption below a particular limit (in this case, 2.5 kW maximum), ensuring that load consumption does not exceed the limit during peak hours. Previously, a peak load deficit (shortage) resulted in frequent load shedding (cut) during peak hours, but this has been reduced by a significant increase in generation together with infrastructural construction in recent days.The actual point of peak demand for an electric utility provider is a single half-hour or hourly time that indicates the highest point of customer usage of power . At this time of year, there is a combination of workplace and residential demand, as well as the fall of darkness at certain periods of the year.The cost of power remains constant with typical electricity plans. However, utilities are increasingly introducing time-of-use contracts, which charge more for power during peak hours but provide cheaper service during off-peak hours.Peak hours, also known as on-peak hours, are the times of day when demand for power is highest under a time-of-use electricity plan. During this time, we will pay the highest rate per kilowatt-hour (kWh) utilized.Peak hours differ based on the season and geography of the country. Peak hours are often defined as the period when the majority of individuals arrive home from work for the day. This is the time of day when people switch on their lights, turn on their televisions, and settle into their homes for the night, all of which demand more power than normal.Peak demand on an electrical grid is simply the maximum level of electrical power consumption that has occurred within a certain time period. Peak demand is often classified as yearly, daily, or seasonal, and has a power unit. Peak demand, peak load, or on-peak are phrases used in energy demand management to describe a period when electrical power is projected to be given at a much higher than normal supply level for an extended length of time. Peak demand changes can happen on a daily, monthly, seasonal, or annual basis.The actual point of peak demand for an electric utility provider is a single half-hour or hourly time that indicates the highest point of customer usage of power. At this time of year, there is a combination of workplace and residential demand, as well as the fall of darkness at certain periods of the year. Some utilities will bill customers depending on their peak usage. Charges may be calculated using the greatest demand for each month or even a single 15 to 30 minute period of peak consumption in the preceding year. Peak demand will be considered as part of the renewable energy transition. Peak load is negatively related to state economic development.Peaking power plants are power plants that are especially designed to provide electricity to electrical networks at times of peak demand. Natural gas-fueled power plants, in general, can be started up quickly and are thus frequently used during peak demand times. Combined cycle power plants can routinely meet peak demand while also running effectively for baseload power [53]. Peak demand is also met by hydroelectric power and pumped storage dams such as Carters Dam in the United States state of Georgia. Due to the capacity to store liquid fuels for use during peak demand, the risks of a wind farm failing to fulfill peak demand are higher than for a fossil-fueled power station. Peak output of solar electricity frequently coincides with peak consumption of air cooling during the day [54]. The total traded energy in a cycle is lowered as a result of the effect of the generation slope and, to a lesser extent, the demand slope, even though the number of energy purchase bids at the peak hour is equal to the number of buy bids at the off-peak hour.The power distribution utilities use demand side management to control peak demand by taking many steps to control energy usage. One of the most intriguing characteristics of this management style is that it is heavily reliant on consumer attitudes and usage. Because the primary purpose of this management is to encourage customers to reduce their energy consumption during peak hours or reschedule their usage during off-peak hours.

2.2.2 Effect of load shifting

Load shifting is the process of transferring load from on-peak to off-peak times by lowering peak demand without affecting overall energy consumption. As a result, it is one of the most successful load control strategies used in DSM.To offer a load-shifting algorithm for enhancing consumption patterns in accordance with customer preferences and electricity costs. A load shifting cost component is added to track consumer discomfort when load shifting. Load shifting cost represents consumer aversion to discomfort, when consumers differ in terms of preferences and expenses. The suggested technique would enable decentralized demand side management in the absence of load synchronization problems. To validate this approach, simulated tests using a multi-agent system were performed on three categories of customers: residential, commercial, and industrial.

The consumer's load shifting behavior is optimized using an optimization model that minimizes the consumer's overall cost of energy consumption and load-shifting discomfort over a fixed time horizon given day-ahead hourly pricing.Power system management is divided into two categories: supply-side management and demand-side management (DSM). Both solutions are effective in mitigating eventualities, increasing network loading capacity, and lowering peak loads.Furthermore,introduces three old types of ELM: peak clipping, valley filling, and load shifting, as well as three current forms of ELM:

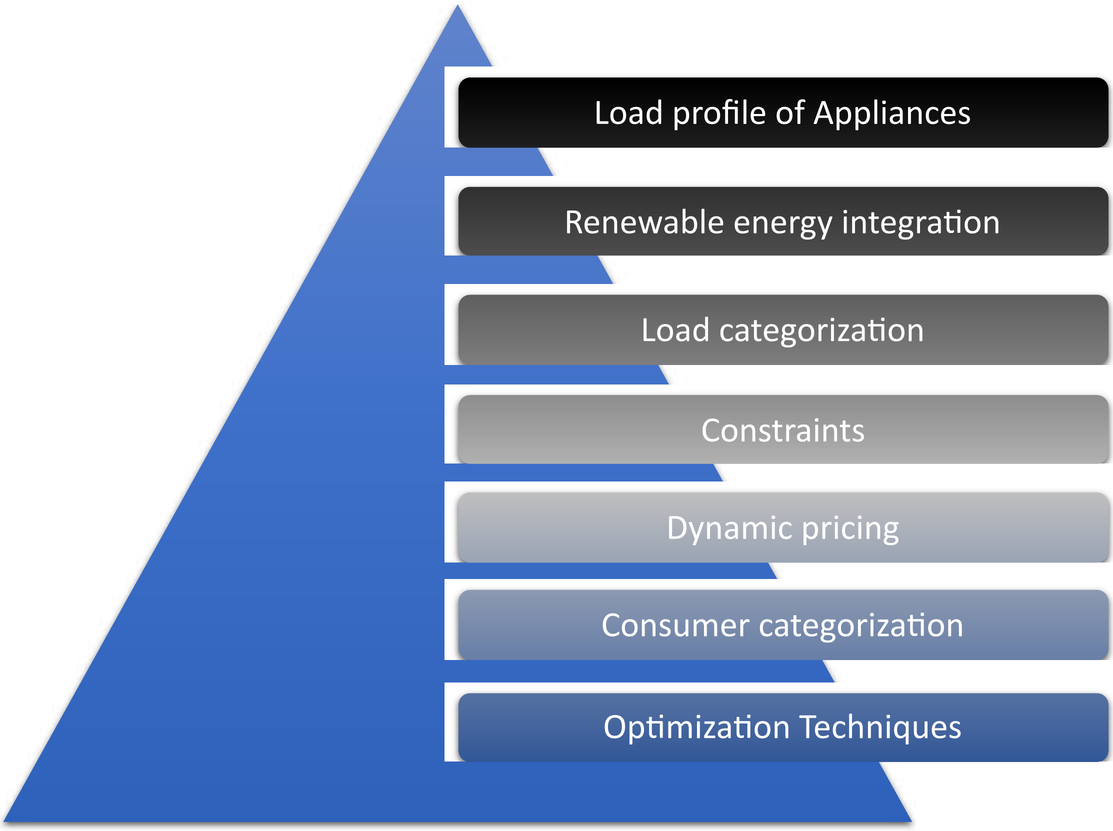


Fig. 2.3 DSM Challenges

strategic load increase, strategic conservation, and variable load shape. The definitions of ELM ideas and procedures described in [14] are now commonly referred to as a standard frame.Two methodologies have been developed to handle the issue of peak load reduction. The first way is to charge peak-load hours for load shifting, which means diverting some energy demand to off-peak hours, which may be indicated by particular indicators to alert clients, and the second option is to use load control devices. Both techniques necessitate communication mechanisms for utilities and clients [55]. Demand management is critical for resource efficiency. However, it is suitable in many areas of power demand, ideally industrial operations, but also applications in the commercial and home sectors. The purpose of this research is to determine the impact of industrial load shifting, energy storage batteries, and electric cars on the effective control of power demand [56]. First, industrial load shifting has been studied, as well as its efficacy. A comparison of industrial and home load offers insight into the current situation. Gradual shifts in industrial load of up to 10% by 2020-2025 can improve day peak demand while controlling nighttime peak demand.Though there are several strategies for managing peak demand, only a handful of them are suitable for this country. Some early initiatives have been suggested,

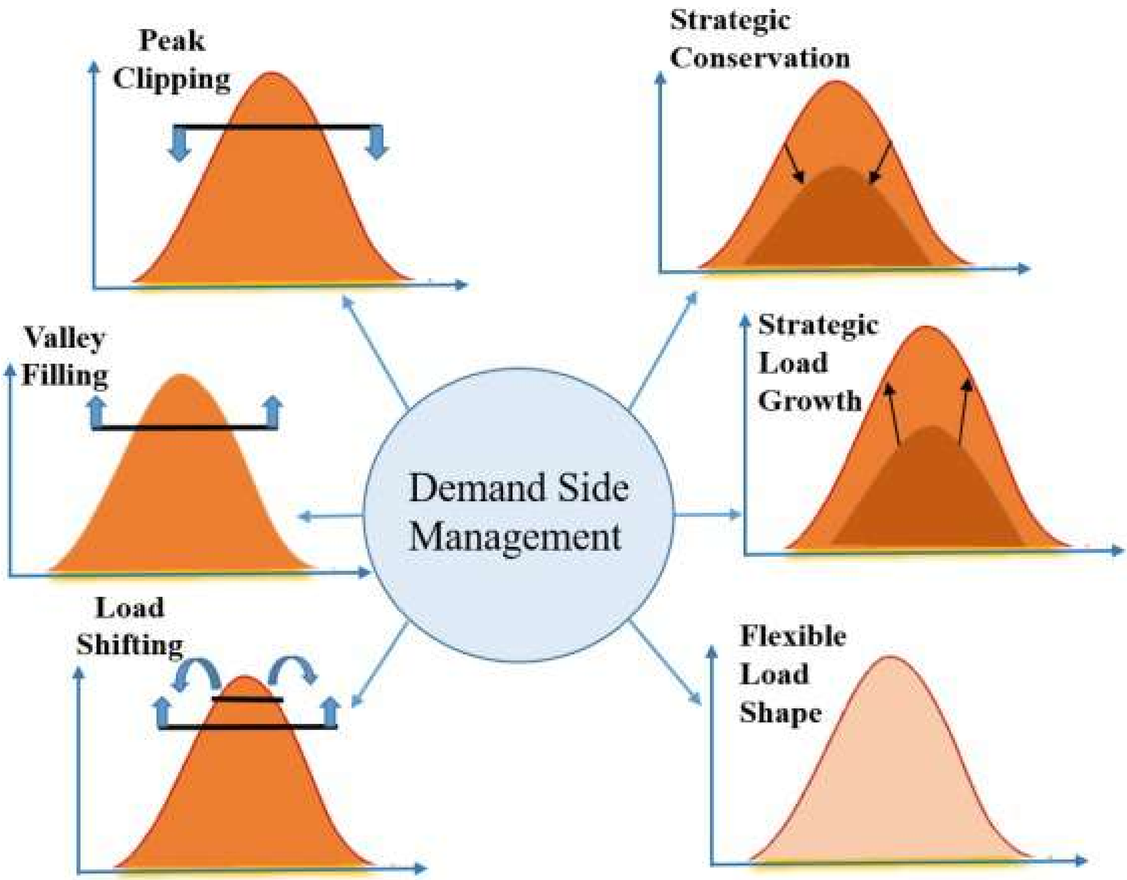


Fig. 2.4 DSM through Load shifting [3]

such as the use of tariffs and incentives, an energy audit, power factor charges, an energy savings program, and so on. However, there are opportunities to enhance and speed the demand side management process. Peak demand will be managed via battery technology, electric vehicles, and industrial load shifting.There are several ways for regulating demand, which vary from nation to country and place to location within a country. To begin with, industrial load shifting is a key characteristic that may be used to improve demand side management. If industrial loads could be transferred to off-peak hours, load management would be improved.In the case of commercial usage, the demand consumption percentage is also increasing day by day as new businesses are opening every day as a result of the country's steady economic expansion over the previous three to four years. Every year, the use of industrial equipment grows. It has exceeded 18000 MKWh in the previous two years. In the previous eight years, the industrial sector has risen by over 8000 MKWh. However, in terms of overall percentage, it has decreased little. With efficient load shifting, the industrial sector may contribute significantly to demand side management.Shifting industrial load from the evening peak hour load might be a feasible way to minimize peak demand. It has its own set of advantages and disadvantages. After careful consideration, a prognosis for the years 2020 to 2025 has been created, with a 10% shift in industrial load from the evening peak, and the following curve has been found-

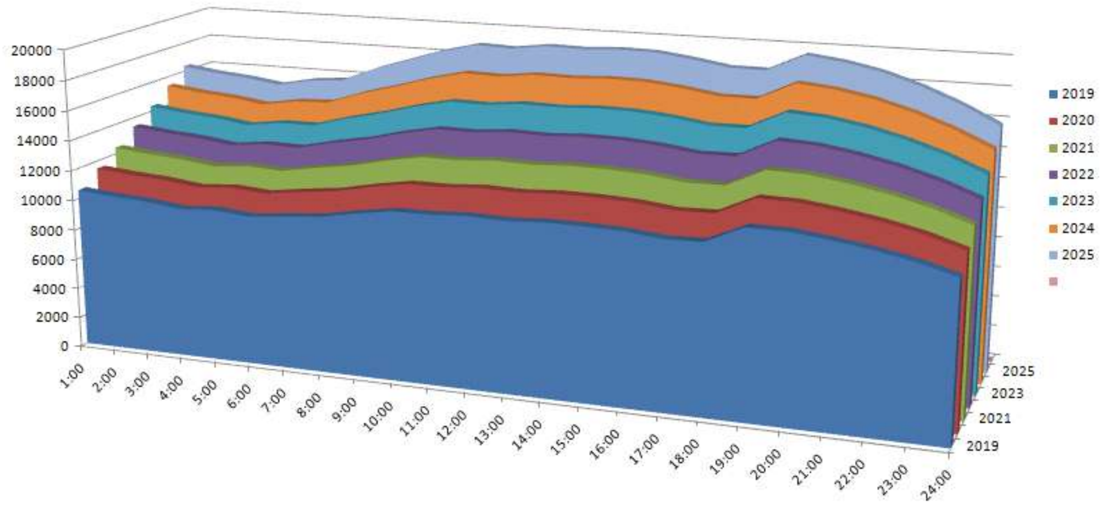


Fig. 2.5 Possible load curve after 10% industrial load shifting from evening peak [Source: [4]

It has been noted that two peak hours will be present at this rate in the year 2025. The first peak hour occurred at 1300 hrs, while the second peak hour occurred around 1900 hrs. Both of these peak hours happened in a scheduled manner, which is helpful for demand side management.To ensure that power is available at all times, a country's generation capacity must be greater than its peak demand at all times. If this peak demand lasts for a short time, a lot of resources are squandered. This study focuses on the equilibrium allocation of demand throughout the year in order to decrease peak demand and use resources efficiently. According to the study, by implementing energy-saving behaviors and modern technologies, there might be a considerable reduction in demand. This study attempts to assess the current state of peak demand and provide a solution through load shifting and permitting energy storage devices for household common usage.Demand Side Management has the ability to deliver several advantages to the electricity sector. This research examined several strategies for decreasing sudden changes in our national load curve that are very practical on the customer side. As previously demonstrated, a 10% shift in load, particularly industrial load, will have a significant influence on controlling the national load curve. This is advantageous for peak load management as well as cost effectiveness. Customers' storage devices can be implemented. Storage devices can be charged off-peak and discharged to the national grid during peak hours. These storage devices may be a useful alternative for storing energy during off-peak hours and using it during peak hours [4]. Because of the difference in energy prices during peak and off-peak hours, consumers who apply for load-shifting programs anticipate to save money on their electricity bills. However, when a large number of consumers shift an amount of energy from a peak hour to an off-peak hour, the price of the peak hour falls and the price of the off-peak hour rises.The price is lower during peak hours and higher during off-peak hours due to load-shifting. However, the increase during off-peak hours is slightly more than the decrease during peak hours. As a result, the arithmetic mean of the price rises with each load-shifting cycle.This unintended energy-saving side effect occurs when the energy reduction during peak hours is greater than the associated increase during off-peak hours.For all of the situations analyzed, load-shifting lowers the annual cost of energy negotiated in the market. As predicted by the linear qualitative model, the cost reduction is roughly proportionate to the amount of energy bids transferred from peak to off-peak.The inadvertent "partnership" of two types of customers is responsible for the unexpected energy-saving side-effect of load-shifting. On the one hand, there are a large number of (non-flexible) grid-dependent consumers who are willing to pay even the highest price. As a result, their buy offers are placed on the demand curve's initial flat region, with the highest price. Domestic users, for example, are willing to move some of their load from the peak to the valley in order to save money on their energy costs.On the other hand, a small number of flexible industrial customers acquire energy in the wholesale market only when the price is lower than their own cost of production or substitute. As a result, only medium-priced purchase bids are sent by flexible consumers.The load displacement effort is carried out by non-flexible customers, and the benefits of load shifting are realized by flexible consumers.In industries, peak loads can be adjusted to maintain energy consumption balance and predict power generation patterns at a consistent pace [57]. Industrial load shifting is a key element that can help with demand management. It would be beneficial to load management if industrial loads were transferred to off-peak hours.For regulating pea demand, industrial load shifting may be a viable alternative. The findings will assist distribution utilities in pressuring or motivating industrial users to boost their off-peak usage.Bangladesh is traditionally an agricultural country, but its industries now account for the majority of its GDP. These industries require a large portion of the electricity generated on a daily basis. Despite the fact that Bangladesh's industrial sector is rising every day, and with it its electrical demand, the percentage of electricity consumption in industries is decreasing every year (BPDB Annual Reports, 2019). The consumption profile of Bangladesh total electricity in recent years demonstrates this [5].

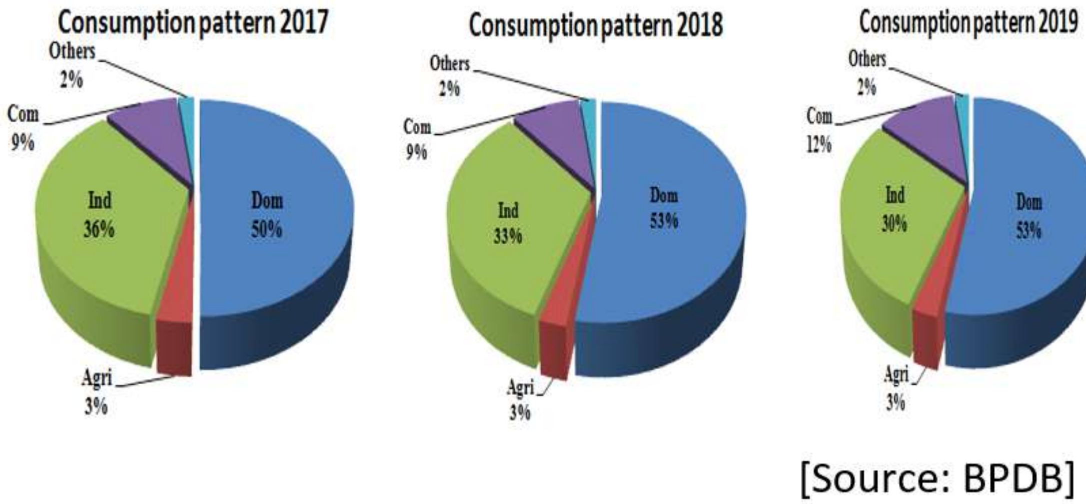


Fig. 2.6 Consumer Pattern of FY (2017,2018,2019) [Source: [5]

The consumer pattern of recent years has been compared using the charts above. To demonstrate the effects over the existing system, load shifting and behavior-based energy conservation are used. Energy conservation is clearly viewed as behavior change and load shifting combined, which results in the most efficient use of electricity.The effects of dynamic pricing (or other pricing policies) are unlikely to have a significant impact on electricity consumption or load balancing between peak and off-peak times if subsistence consumption accounts for a sizeable portion of total consumption. Dynamic pricing's long-term impacts may instead be realized, with peak prices functioning as incentives to invest in energy efficiency to reduce expensive subsistence demand, i.e. energy saving rather than load shifting [58]. Subsistence levels, of course, vary from day to day and from home to household (and possibly also across months). For instance, it is anticipated that the subsistence level will be higher during peak hours when household members are at home than it will be during off-peak hours (off-peak hours). Similarly, subsistence levels are likely to vary throughout the year, with winter (dark and cold) being greater than summer (bright and warm), implying that the summer has more possibility for load shifting.This shift in relative consumption between seasons is more significant in the summer than in the winter, at least up to a certain price threshold. That is, during the summer, the possibility for load shifting appears to be greater. Furthermore, as relative prices rise, the effect on relative consumption declines, implying that consumers may only re-allocate so much consumption from peak to off-peak hours.

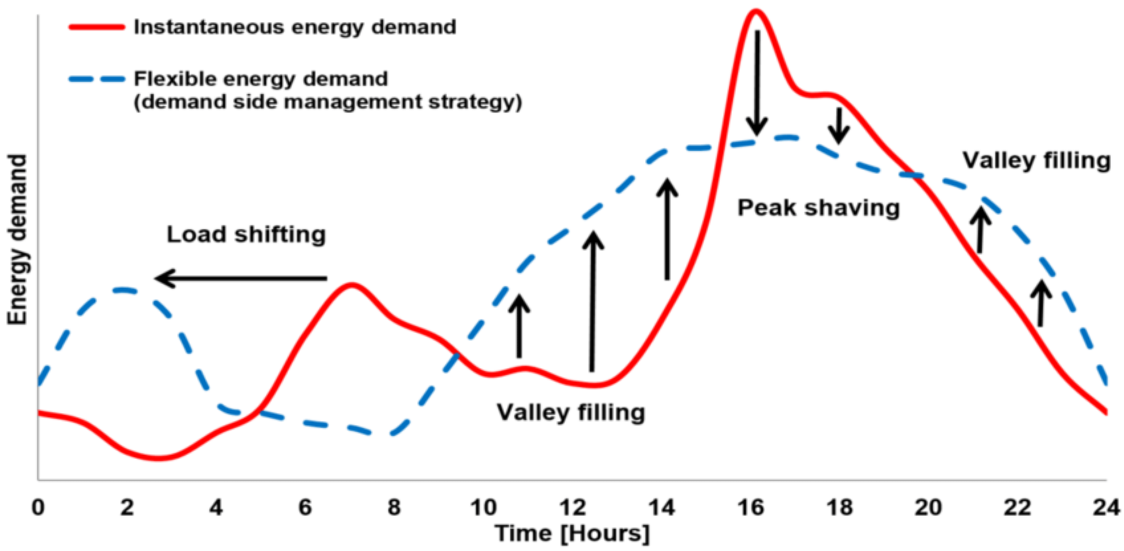


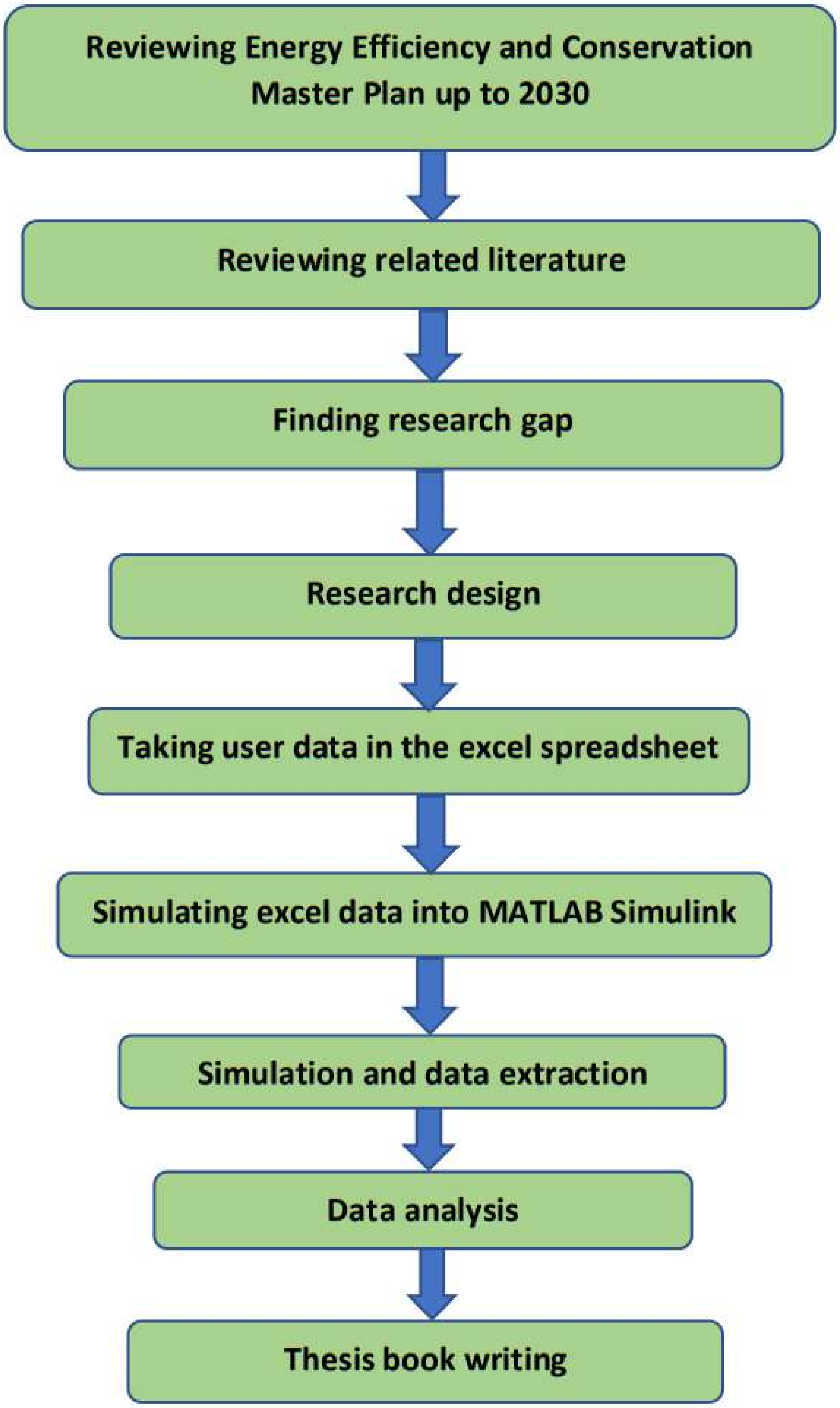
Fig. 2.7 Example of Energy flexibility [Source: [6]

CHAPTER 3

METHODOLOGY

3.1 Working procedure

The workflow for this thesis goes as follows



3.2 Data collection

For this work, we have followed the load taking approach from [59] to take 10 individual real electricity users data from different location of the country so that we can show the variation in the electricity usage behavior. For the purpose of illustrating the suggested notion, we used the 24-hour load profile of ten home users. One such home user's information is provided in **Table 3.1**.

Table 3.1 Information about a home's users

User information	
Name of owner	Ryhan
Type of building	Concrete
Total Number of rooms	8
Location	Chakaria
Zone of distribution	BPDB
Total number of meters	1
Type of Meter	Post paid
Total amount consumed (month)	**438 unit/kWh (August, 21)**
Average consumption of units (daily)	**14.129 unit/kWh (August, 21)**
Monthly bill	2360.37 (2841) tk
Some general questions asked	
q1- knowledge at peak hours	no
q2- general knowledge application	yes
q3- knowledge of energy efficiency	no
q4- information on energy demand use duration for appliances	no
q5- energy saving mentality	partial
q6- interest in pv installation	no
q7- interest in buying energy efficient appliances	partial
q8- week day and weekend usage	almost same
q9- production of energy's impact on environment	no knoledge
q10- usage of alternative appliances	no
q11- interest in modifying energy usage behavior	yes

The user's patterns of electricity use have been tracked for a number of days. Then, based on the observation, an excel spreadsheet was made to simulate the user's typical patterns of energy use. For each individual load, 5 changeover times have been taken into account. Although some loads need switching more than five times, the majority of loads may be handled with just five switches. Only 7 of the 38 loads in this particular residence have five switching times, which indicates that no more than 5 of them will be switched more than five times every day. If we ignore brief switching durations, such as switching between a few seconds or minutes, this represents between 15 and 20 percent of all loads. Based on a load's switching times, the spreadsheet automatically calculates a load's overall runtime and power usage. The calculation of total power using the load's power rating and runtime is shown in equations (3.1) to (3.4).

$$Runtime_i = off\ time_i - on\ time_i \tag{3.1}$$

$$Total\ Runtime = \sum_{i=1}^{i=5} Runtime_i \tag{3.2}$$

$$Power\ usage_n = \frac{Power\ rating \times Total\ Runtime}{1000} \tag{3.3}$$

$$Total\ Power\ usage = \sum_{n=1}^{n=38} Power\ usage_n \tag{3.4}$$

According to the excel spreadsheet, the residence uses **8.9** kWh of power everyday, which is higher than the **8.7** kWh shown on the electric bill. There is a very slight difference between the spreadsheet and the actual data, but it is insignificant because several factors affect how much electricity is used. Despite the fact that the season is not changing, this slight difference causes us to have varied electric costs in different months. The house's whole list of loads is provided in **Table 3.2**.

Table 3.2 Load List

Loads	**Quantity**
LED bulb	4
Energy bulb	5
Ceiling Fan	4
Refrigerator	1
TV	1
Tube Light	0
Oven	0
Water Pump	1
Dry Iron	1
Machine	
Laptop	0
smartphone	2
Blender machine	1
Total	**20**

3.3 Simulation

We have simulated the power usage scenario of each user from the excel spreadsheet. The simulation parameters for the simulation is given in **Table 3.3**. The simulation model is shown in **Fig. 3.3**.

Table 3.3 Simulation parameters

Parameters	**Data**
source voltage	220 V DC equivalent (constant)
Total number of house	10
Total number of loads	NA
Total number of flexible loads	NA
Simulation run time	2.4 s
Sampling time	1×10^{-5} s

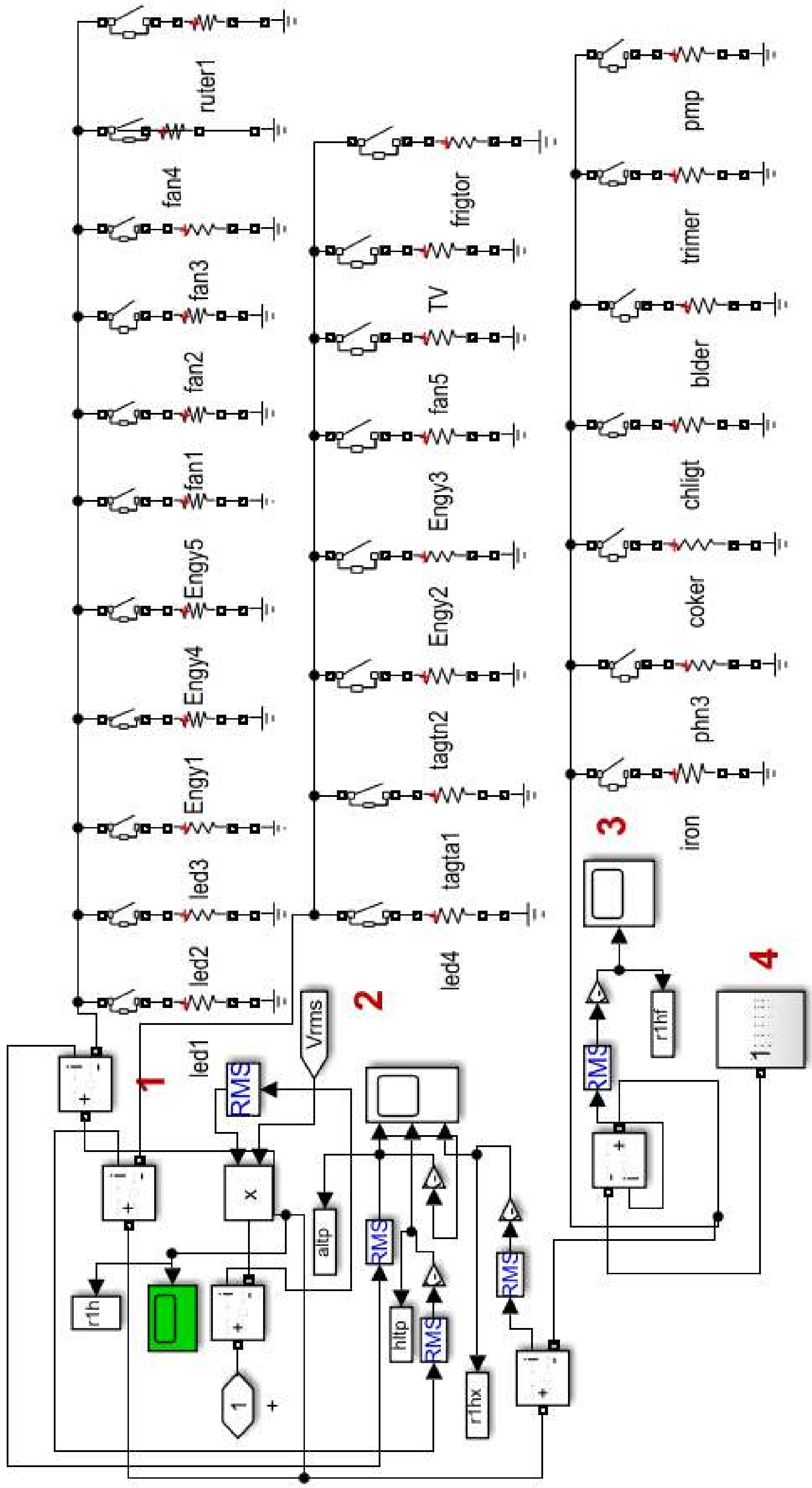


Fig. 3.1 Simulation block of house-1

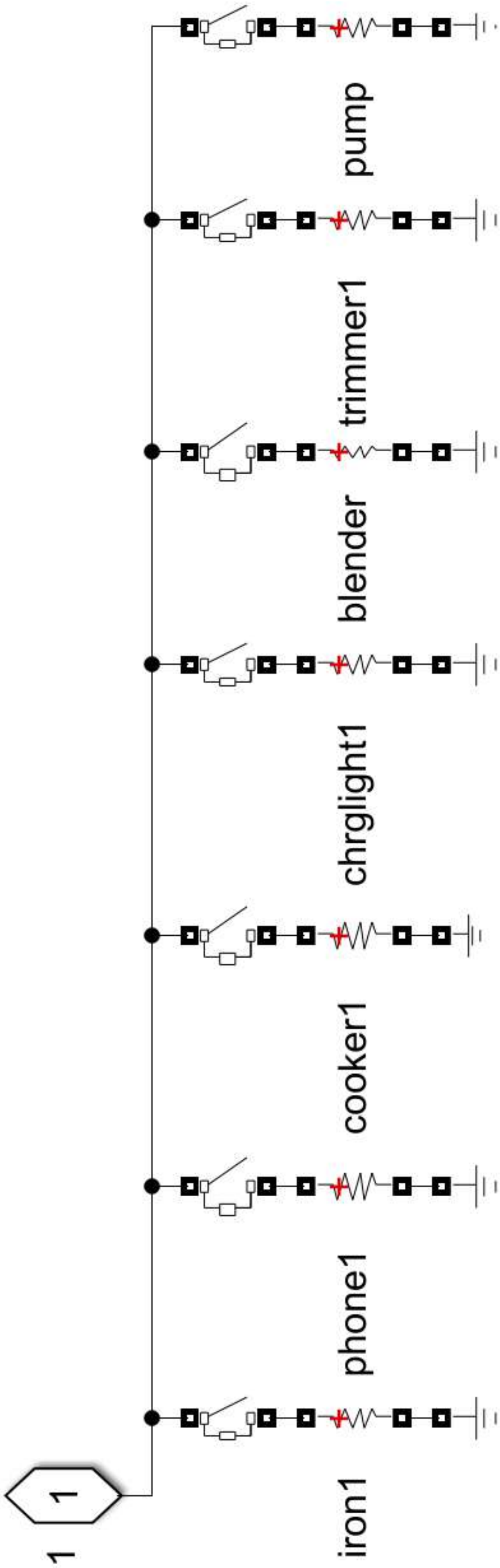


Fig. 3.2 Simulation block of house-1 after load shifted

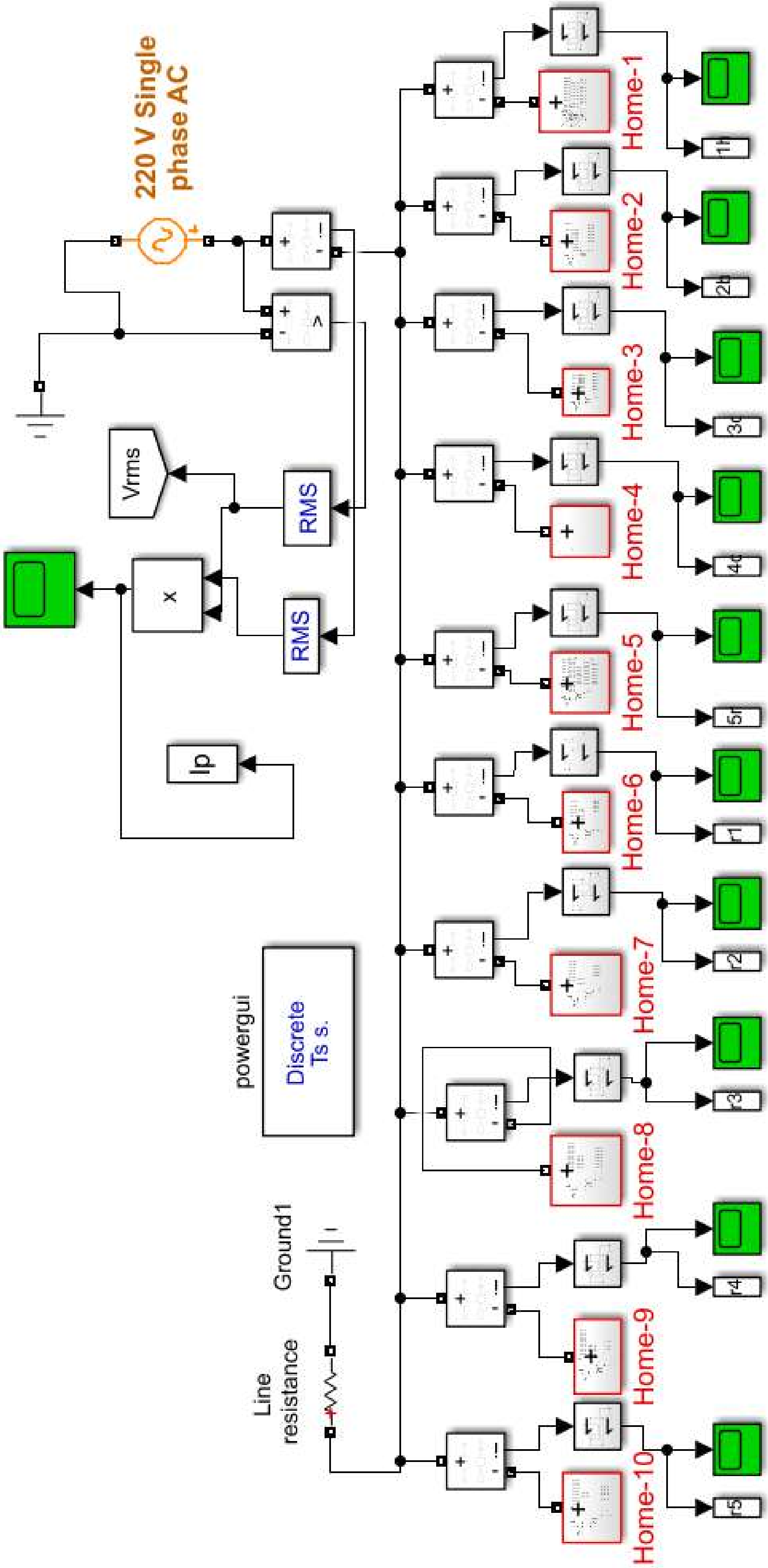


Fig. 3.3 Simulation block of All houses together

CHAPTER 4

RESULT AND DISCUSSION

In this chapter, we will discuss about the results of our work. We have found the results of all the homes. At first we will discuss about the individual home and their load condition. Then we will see the results of all loads together.

4.1 Individual home simulation result

4.1.1 Home - 1

The simulation result for home 1 in normal condition is shown in **Fig. 4.1**. This figure demonstrates the electrical peak hour and off peak hour loads of this home clearly.

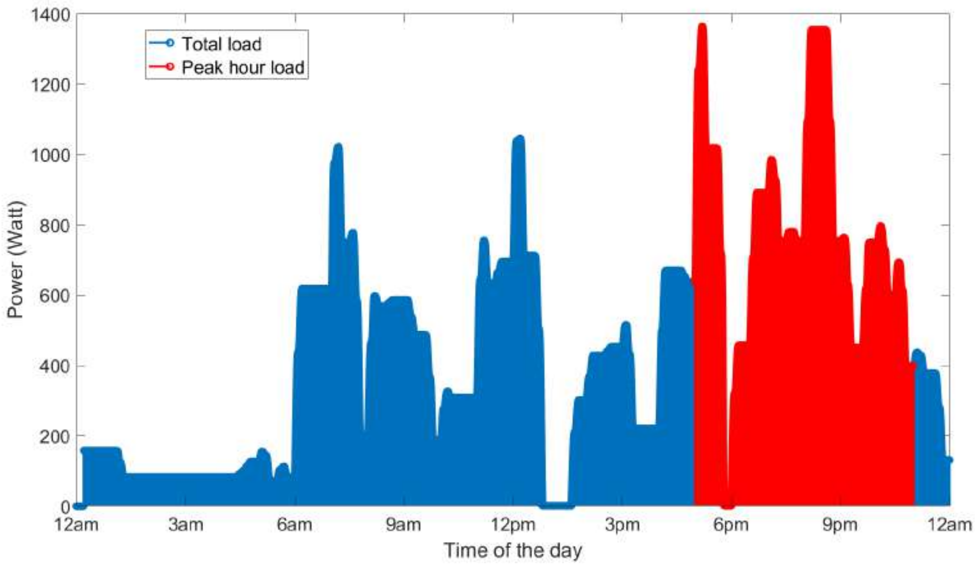


Fig. 4.1 Comparison of normal and peak hour load in house 1

Table 4.1 shows the total load list of home 1. There are a total of 28 loads in this home, among which 8 are flexible loads. So these flexible loads if run in the peak hour can be transferred to off peak hour. Flexible loads generally can be shifted because their use time are comparatively flexible than those of other or non-flexible loads. For example, an user can run a water pump at morning and evening to fulfill his water demand. But, electrical peak hours occurs between 5 pm to 11 am in Bangladesh, the evening run time of the water pump falls within peak hour. If the owner have the knowledge and understand of electricity generation, distribution then he won't run this water pump at the evening. Because he knows that generation of 1 kWh electricity is far more costly at the peak hour rather than it is in the off peak hour.

Table 4.1 Load list of home 1

Load name	**Quantity**	**Flexible - Yes/No**
LED bulb	4	No
Tangstan bulb	2	No
Energy bulb	5	No
Ceiling Fan	5	No
Refrigerator	1	No
TV	1	No
Water Pump	1	Yes
Dry Iron Machine	1	Yes
Electric cooker	1	No
smartphone	3	Yes
Chargin Light	1	Yes
Blender machine	1	Yes
Router	1	No
Shavers & Trimmers	1	Yes
Total	**28**	

Normal and flexible loads of the home and their respective power consumption in a 24 hour time span is shown in **Fig. 4.2**.

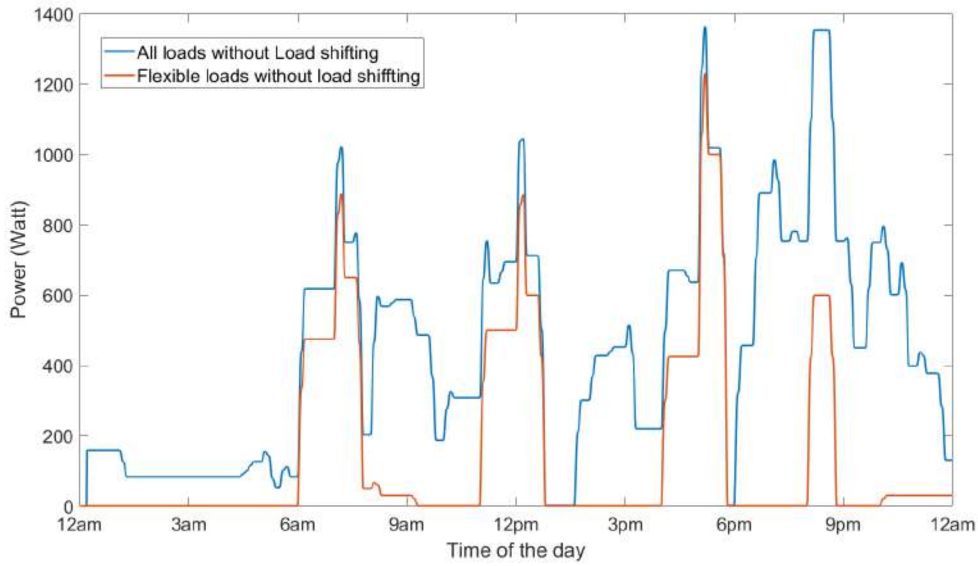


Fig. 4.2 Comparison of normal load and flexible load power consumption of the home

Now we can apply load shifting for this home. In **Fig. 4.3**, the power consumption pattern of the flexible loads is shown before and after applying load shifting. Finally, **Fig. 4.4** demonstrates the complete scenario of load profile before and after applying

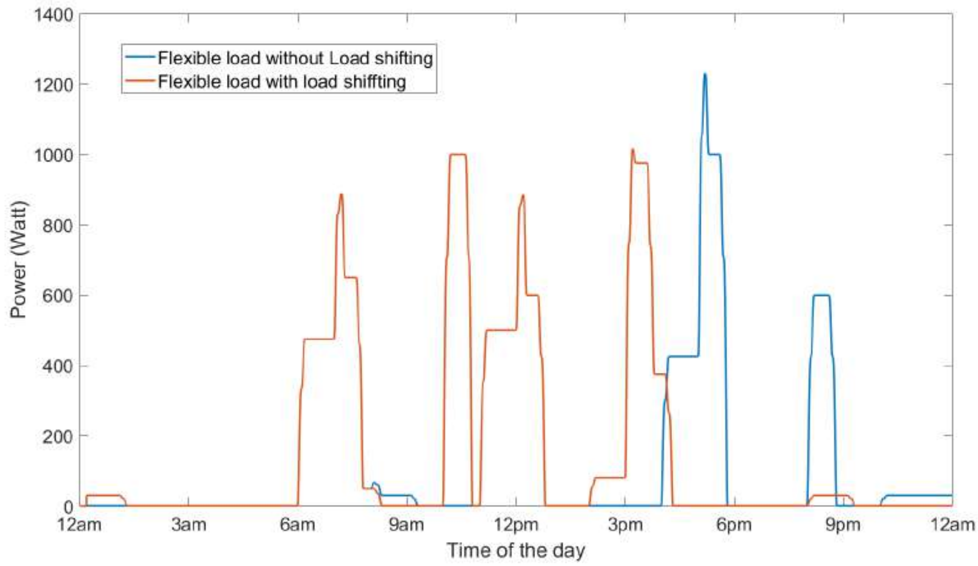


Fig. 4.3 Flexible loads with and without load shifting

load shifting. From the figure it is clear that the pressure of load has been released at least at some extent after applying load shifting.

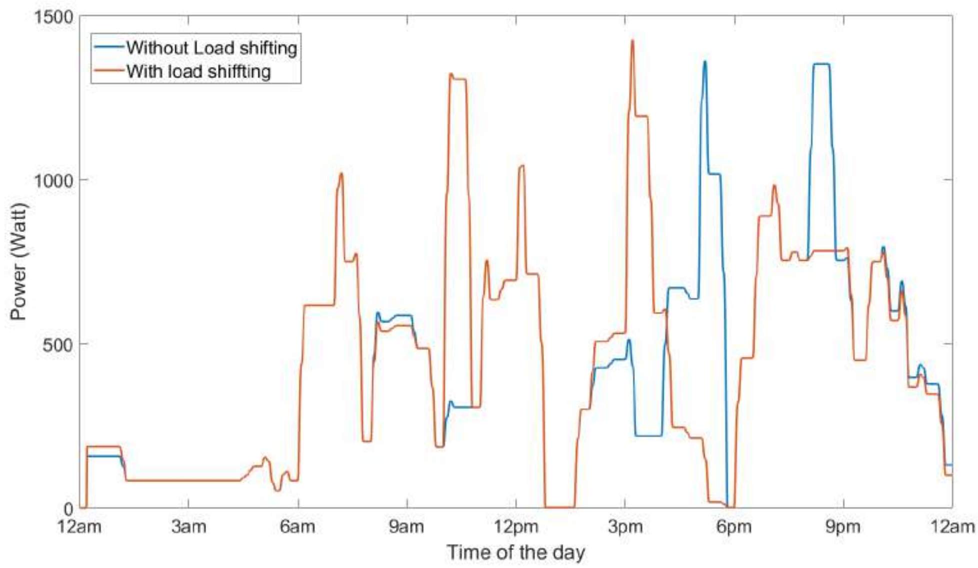


Fig. 4.4 Pre- and post-load shifting comparison of the load profile

4.1.2 Home - 2

This home is a medium sized residential home with 22 loads and around 7.5 kWh daily demand. The comparison of normal and laod shifted load profile is shown in **Fig. 4.5**.

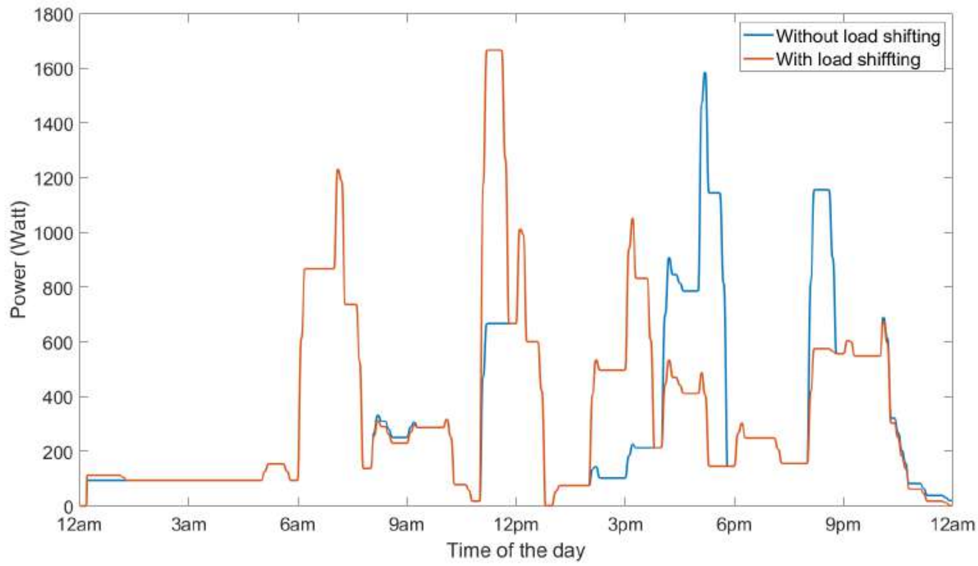


Fig. 4.5 Comparison of load profile before and after load shifting

Fig. 4.6 shows the flexible power consumption within 24 hours.

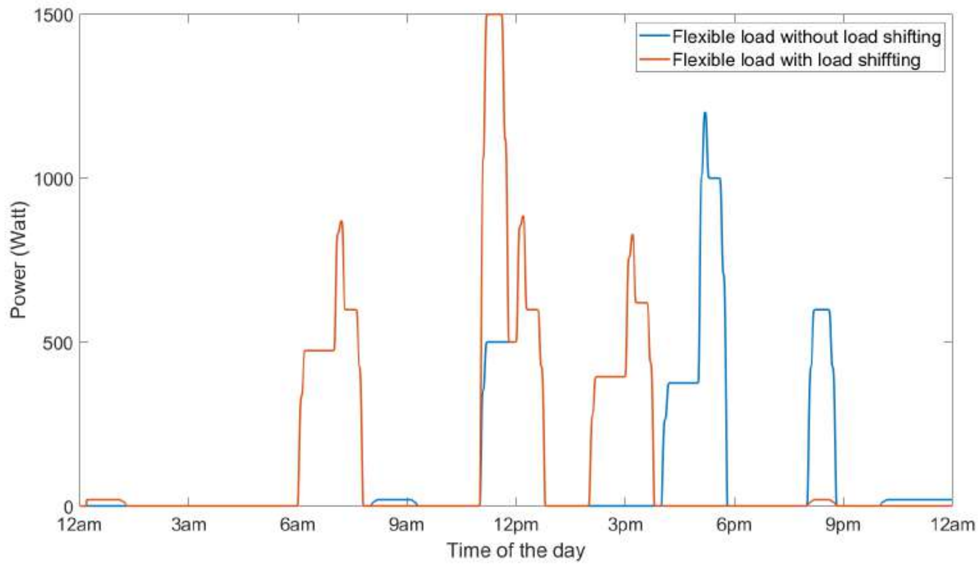


Fig. 4.6 Flexible loads with and without load shifting

4.1.3 Home - 3

A medium-sized residential residence, this one has 21 loads and a daily requirement of about 9 kWh. The comparison of normal and laod shifted load profile is shown in **Fig. 4.7**.

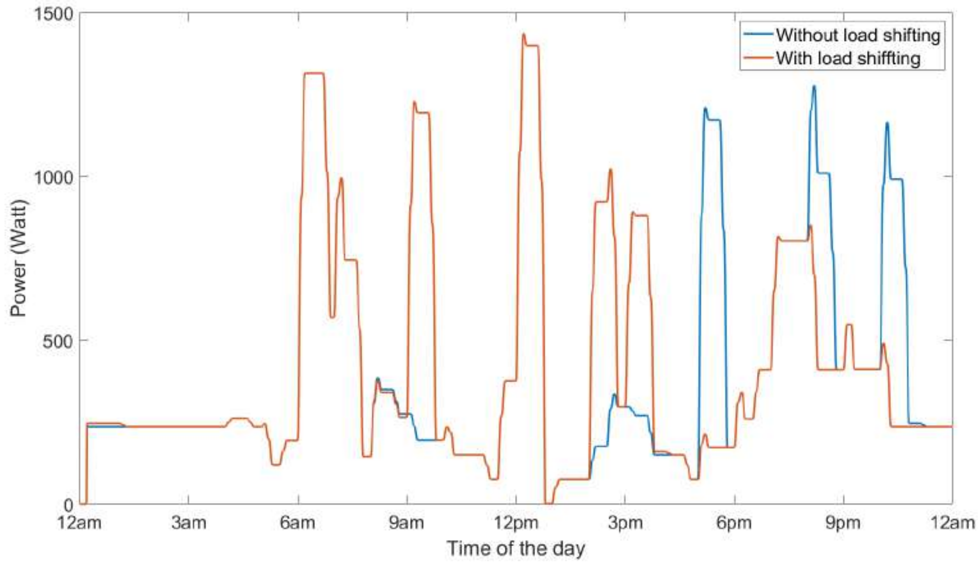


Fig. 4.7 Pre- and post-load shifting comparison of the load profile

Fig. 4.8 shows the flexible power consumption within 24 hours.

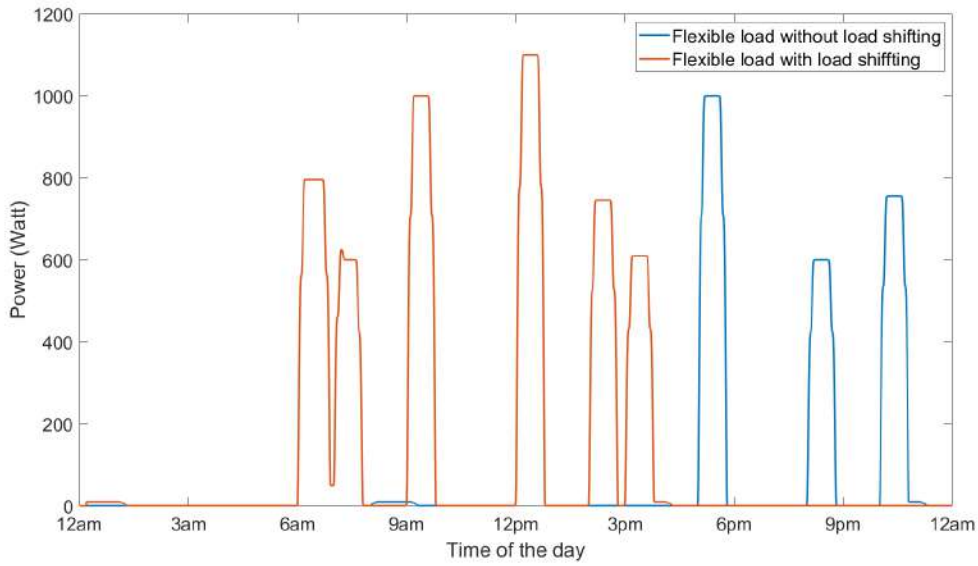


Fig. 4.8 Flexible loads with and without load shifting

4.1.4 Home - 4

This residence is of medium size with 45 loads and a daily consumption of about 9.5 kWh. The comparison of normal and laod shifted load profile is shown in **Fig. 4.9**.

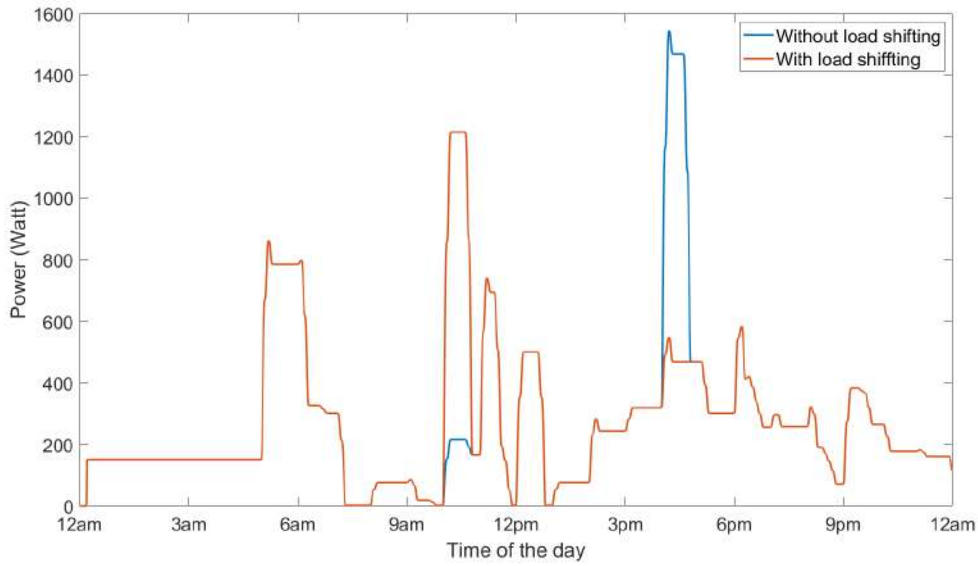


Fig. 4.9 Pre- and post-load shifting comparison of the load profile

Fig. 4.10 shows the flexible power consumption within 24 hours.

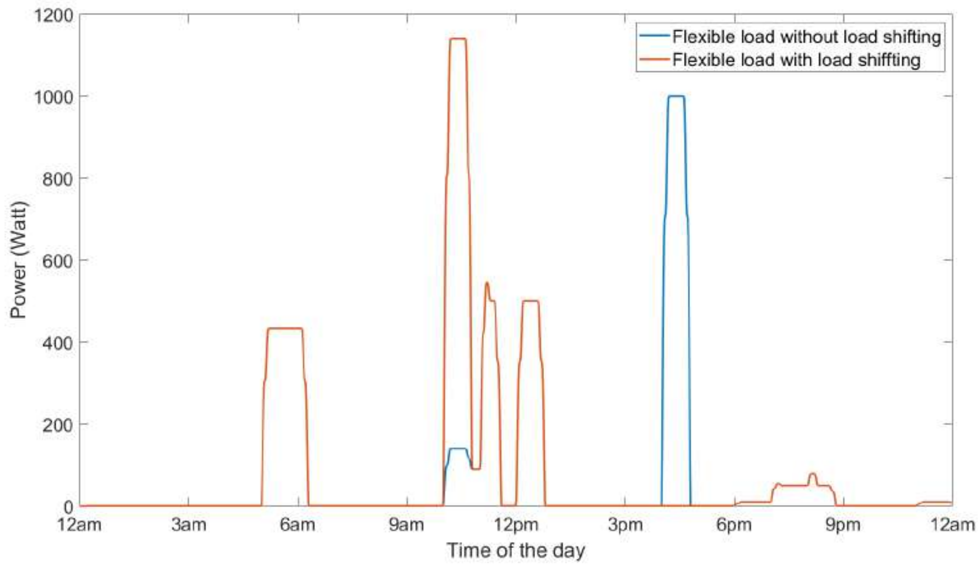


Fig. 4.10 Flexible loads with and without load shifting

4.1.5 Home - 5

This home is a medium sized residential home with 37 loads and around 6 kWh daily demand. The comparison of normal and laod shifted load profile is shown in **Fig. 4.11**.

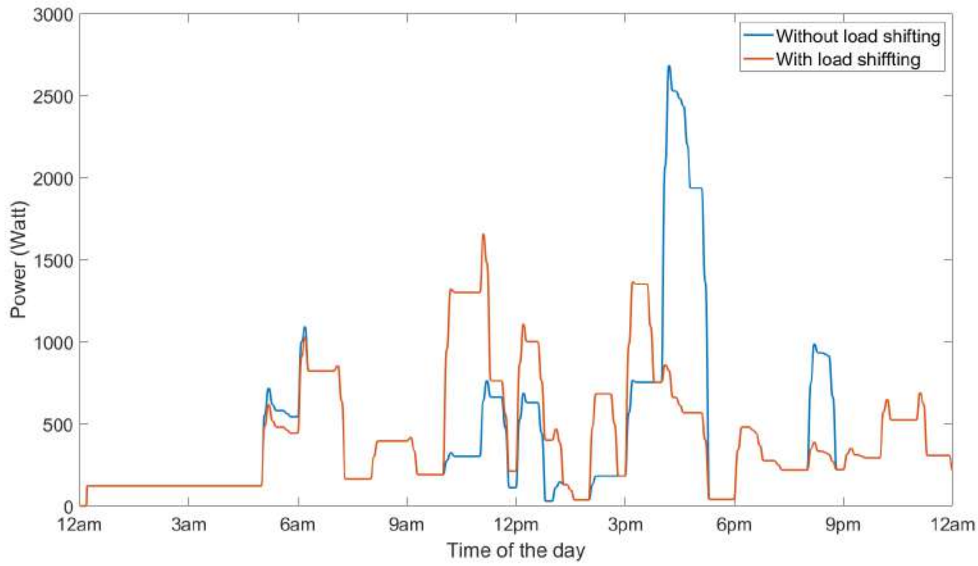


Fig. 4.11 Pre- and post-load shifting comparison of the load profile

Fig. 4.12 shows the flexible power consumption within 24 hours.

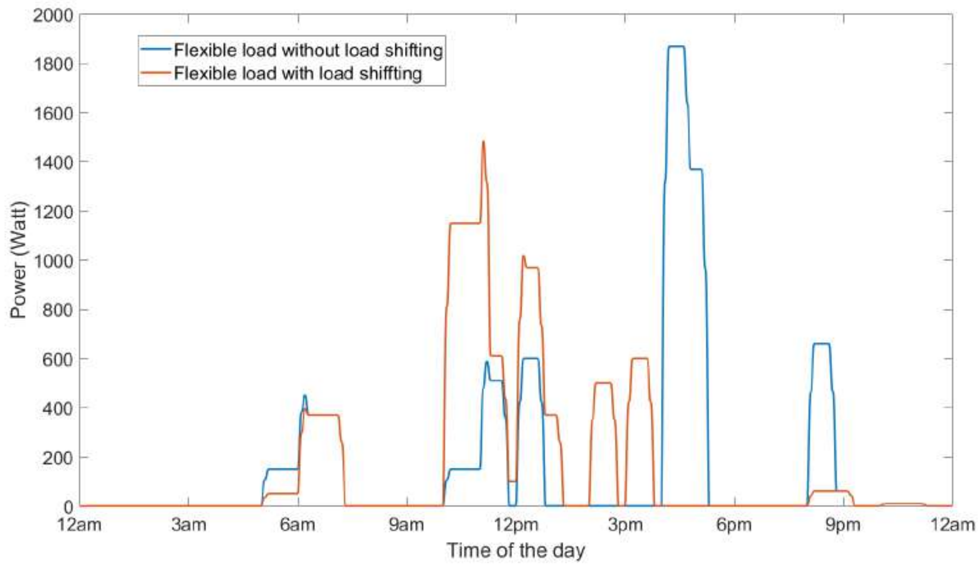


Fig. 4.12 Flexible loads with and without load shifting

4.1.6 Home - 6

A medium-sized residential dwelling, this one has 25 loads and a daily requirement of about 10.5 kWh. The comparison of normal and laod shifted load profile is shown in **Fig. 4.13**.

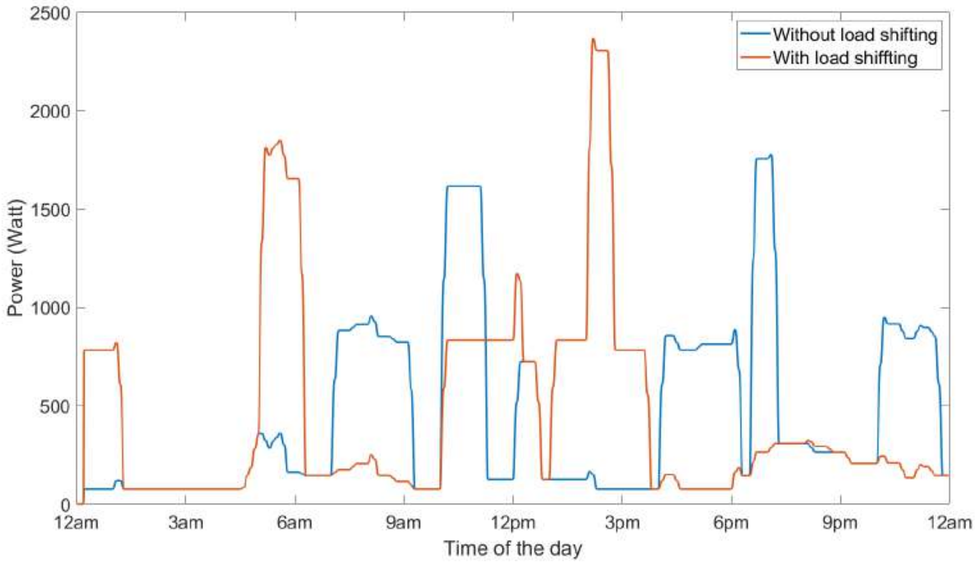


Fig. 4.13 Pre- and post-load shifting comparison of the load profile

4.1.7 Home - 7

This residence is of medium size with 13 loads and a daily consumption of about 4.6 kWh. The comparison of normal and laod shifted load profile is shown in **Fig. 4.14**.

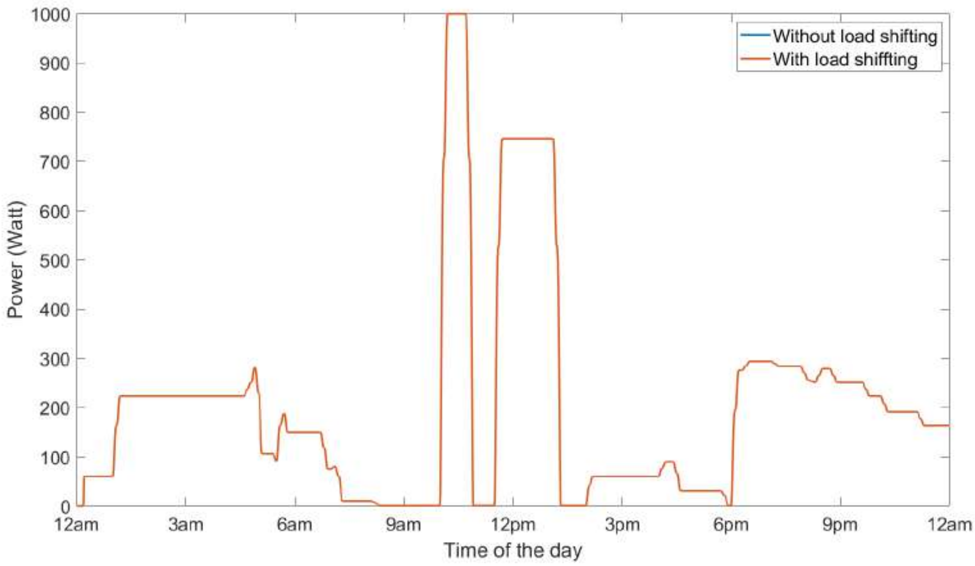


Fig. 4.14 Pre- and post-load shifting comparison of the load profile

4.1.8 Home - 8

This home is a medium sized residential home with 33 loads and around 11 kWh daily demand. The comparison of normal and laod shifted load profile is shown in **Fig. 4.15**.

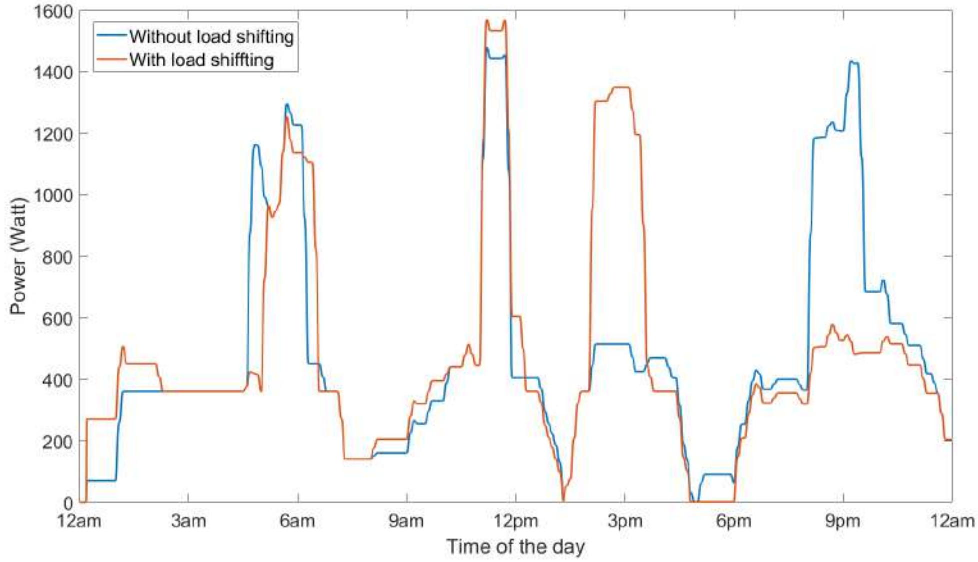


Fig. 4.15 Pre- and post-load shifting comparison of the load profile

Fig. 4.16 shows the flexible power consumption within 24 hours.

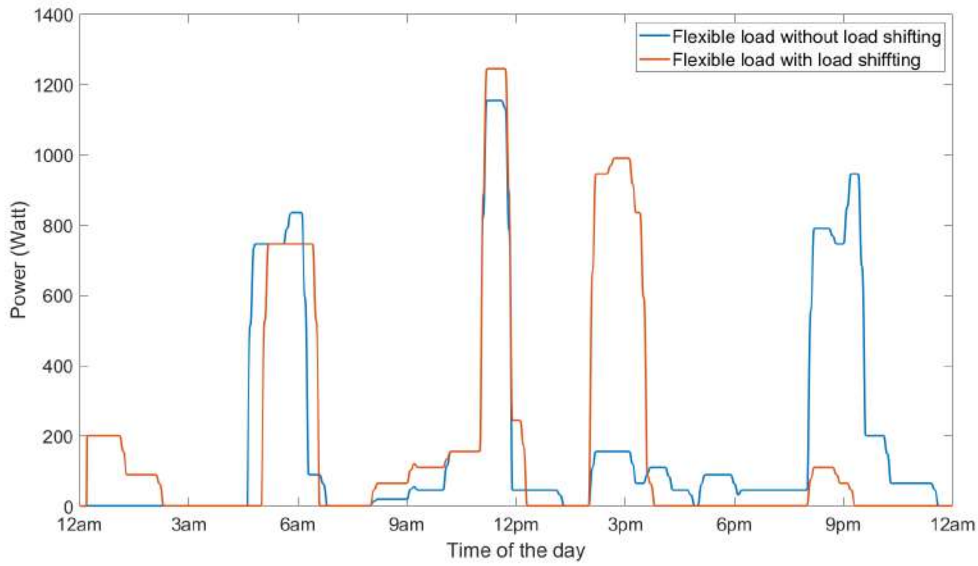


Fig. 4.16 Flexible loads with and without load shifting

4.1.9 Home - 9

A medium-sized residential residence, this one has 23 loads and a daily requirement of about 8.5 kWh. The comparison of normal and laod shifted load profile is shown in **Fig. 4.17**.

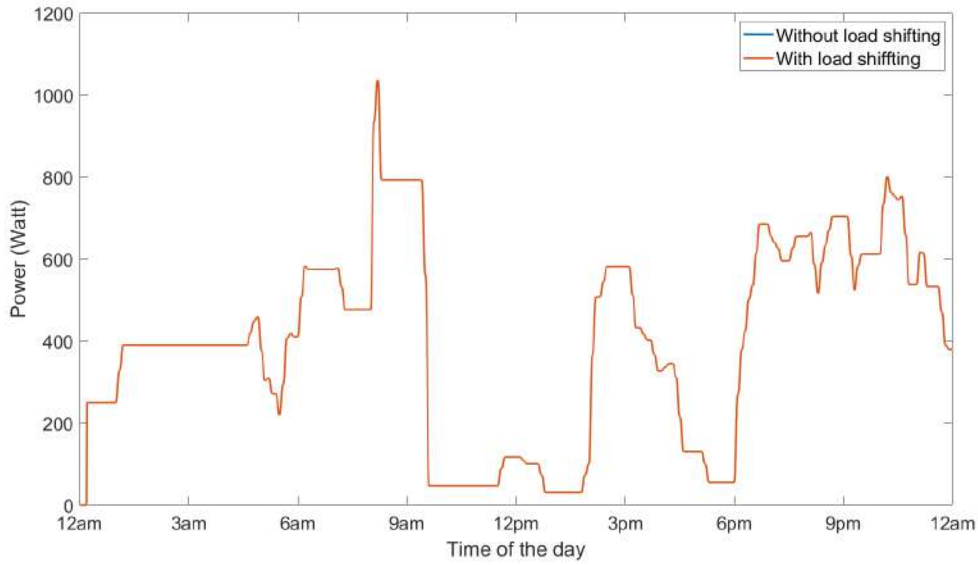


Fig. 4.17 Pre- and post-load shifting comparison of the load profile

4.1.10 Home - 10

This home is a medium sized residential home with 22 loads and around 7.5 kWh daily demand. The comparison of normal and laod shifted load profile is shown in **Fig. 4.18**.

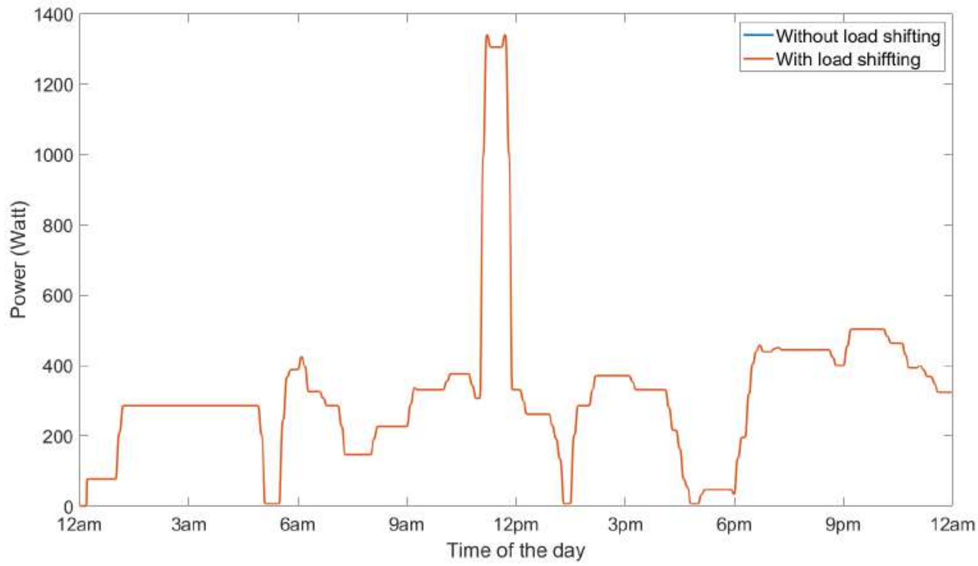


Fig. 4.18 Pre- and post-load shifting comparison of the load profile

4.2 All house together

Now, we have connected every house together to simulate the total scenario as a neighborhood. From the individual load profiles we have seen that among 10 houses, 3 houses don't have any impact to this methodology because those houses don't have any flexible loads that can be shifted or no necessary loads that needed to be shifted. Hence,

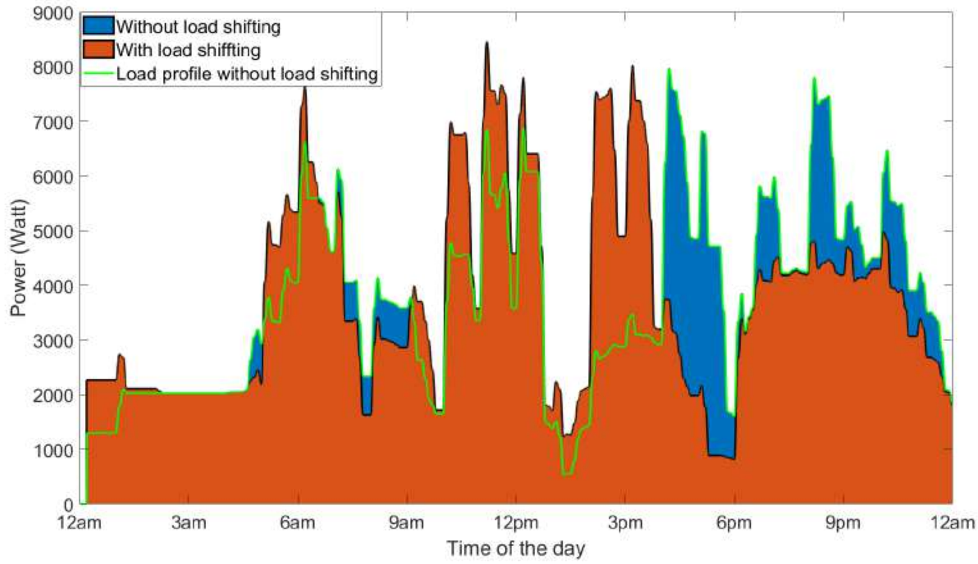


Fig. 4.19 Pre- and post-load shifting comparison of the load profile

their load profiles remain the same. Total power consumption scenario of these houses is shown in **Fig. 4.19**. The blue area plot is the actual load profile without load shifting

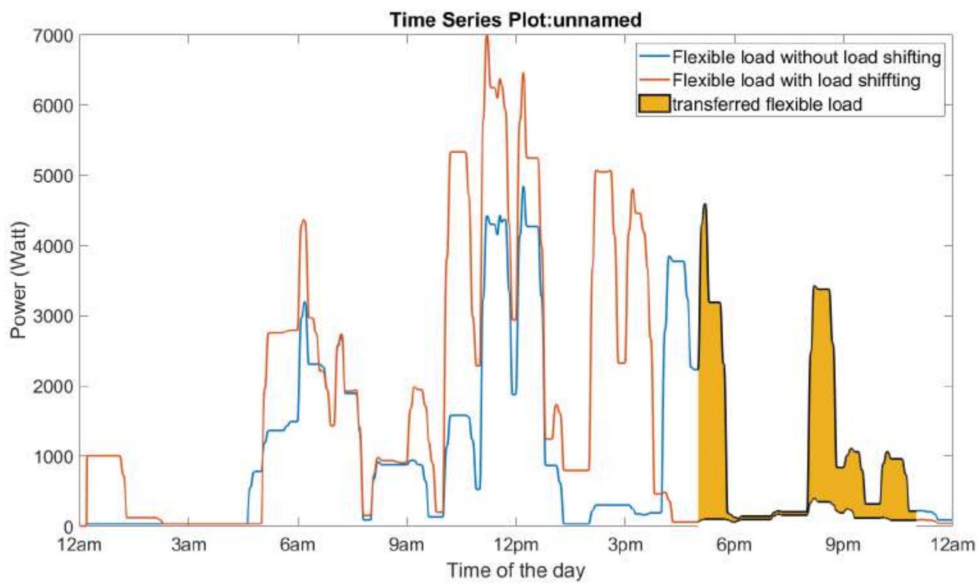


Fig. 4.20 Comparison of flexible loads before and after load shifting

which is highlighted with green line. The orange line is the load profile with load shifting. **Fig. 4.20** shows the flexible loads of every house together. The yellow highlighted area is the amount of energy that has been transferred from peak hour to off peak hour.

4.3 Result Analysis

To sum up everything, in this work we have tried to show the impacts of load shifting, a DSM strategy in our existing power system. For this purpose we have taken actual load data of 10 houses from various parts of the country. Then we have simulated those house data in MATLAB Simulink to perform load shifting and show the result. From the study we have found the following things -

Table 4.2 Final findings

Parameter	**Value**
Total energy consumption in 24 hours by all house	88.86 kWh
Total size of all flexible loads	25.95 kWh
Total load transferred from peak to off-peak hours	5.95 kWh
Shifted load percentage over total load	6.69 %
Shifted load percentage over flexible loads	22.92 %

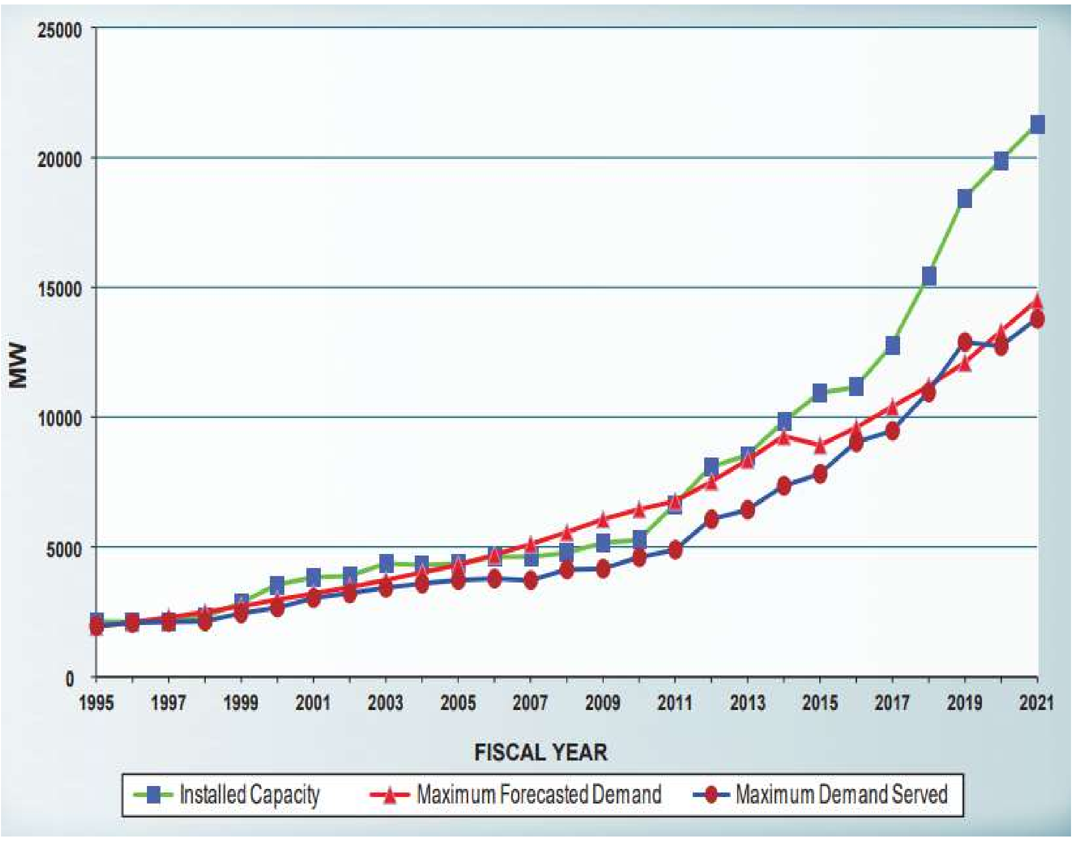


Fig. 4.21 Installed Capacity and Maximum Demand Served curve - BPDB

According to BPDB's annual report for 2020–2021, the residential sector accounts for an astounding 56.43 % of all electricity usage in Bangladesh [12]. Residential energy consumption is the primary driver to shape the demand served and production load curve as shown in **Fig. 4.21** and **Fig. 4.22**. The average electricity production is around 13000

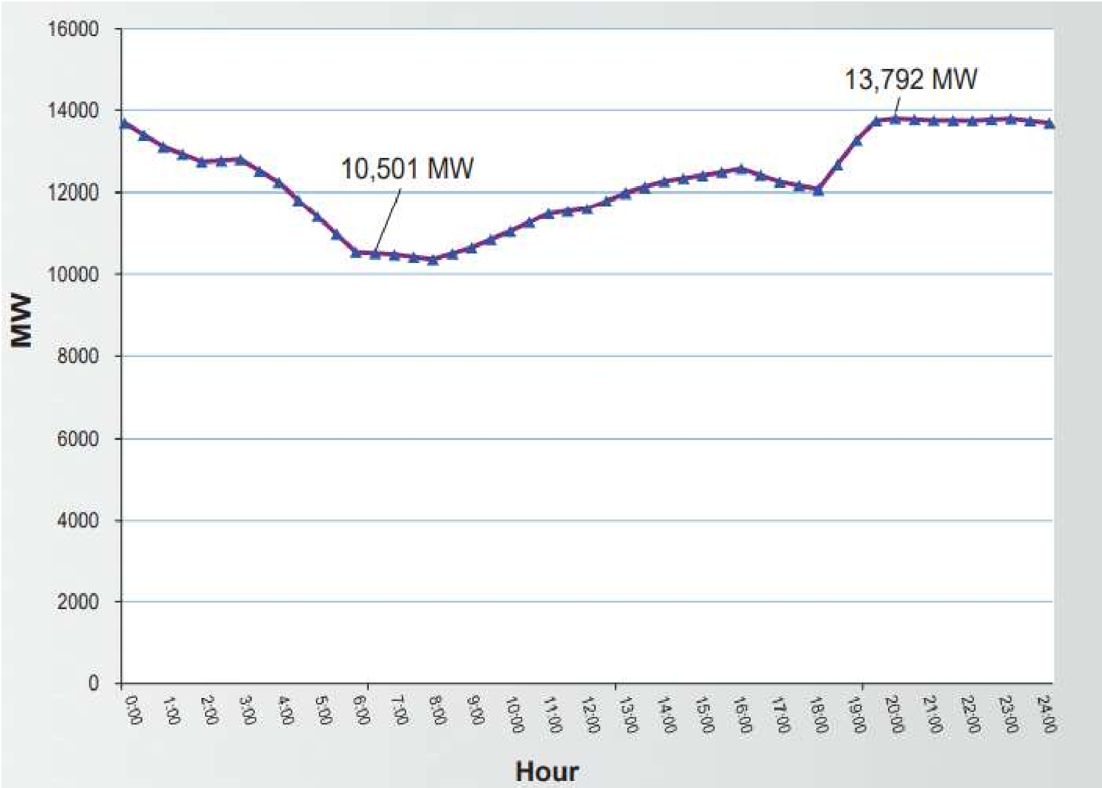


Fig. 4.22 24 hour production load curve - BPDB

MW in a particular summer day. Residential sector consumes almost 7280 MW. From our study we found that about 6.7% of the total load can be shifted from peak hour, which makes 487 MW of peak hour electricity. If load shifting can be achieved nationwide then 487 MW of peak electricity usage can be distributed to off peak hour.

CHAPTER 5
CONCLUSION

5.1 Conclusions

This work analyze the impacts of load shifting in a neighboring locality in Bangladesh. This will help to understand and further analysis of load shifting in the power system of Bangladesh. To perform this study, we got the inspiration from some similar studies. The author in [59], studies the impact of load shifting and energy conservation in a residential house in Bangladesh. We have followed the steps of this study. But, that study has it's limitation because that study considers only one house. Based on the load profile of that one house the author concluded that 15.03 % load can be shifted which we found 6.7% less than half of that claim.

We have followed the data collection strategy of that paper. We have taken 10 real time house data in excel spreadsheet. Then we have built Simulink model from those excel data. We have applied load shifting and analyzed the result individually and collectively. Among the 10 houses, 3 house didn't have any flexible loads hence no load shifting could be applied. This means that all house might not have flexible loads which is true in real case. In many village users they don't have significant flexible loads, so they might not need to adopt their energy usage pattern to participate in this load shifting process.

Our results shows that almost 23% of the flexible loads need to be shifted from peak hour to off peak hour. In terms of total loads 6.7% of the loads can be shifted towards off peak hour. This load shifting strategy has a potential of shifting almost 500 MW of daily power production from peak hour to off peak hour. This will cost of electricity, since generating peak hour electricity is costlier than off peak hour. This will also be beneficial for environment, since peaking power plants are generally fossil fuel based and they pollutes environment, releases GHG. In Bangladesh, generally peaking power plants are private sector owned hence govt. need to give a significant amount of subsidy to these plants, reducing peak demand by 500 MW will give greater economical benefit to the govt and to the consumer as a whole.

5.2 Future works

We believe this work has lots of potential and practical implementation opportunity. However, we have plan to perform this study even bigger scale to get a more accurate scenario. This study can be taken as an example of how to perform a bigger study to collect this type of power consumption and user side data at the absence of smart meter to go to implementation phase.

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