DEMAND SIDE MANAGEMENT OF ELECTRICITY FOR CONTROLLING PEAK DEMAND IN BANGLADESH

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DECLARATION

We hereby declare that the research work presented in this thesis or any part of it has not been submitted elsewhere for any other kind of degree.

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ABSTRACT

Demand side management is very important for efficient use of resources. However, it is applicable in many parts of the power demand, preferably industrial processes, but also applications in the commercial and domestic sector. This study tries to find out the effects of industrial load shifting, use of energy storage batteries and electric vehicles for efficient management of power demand. Firstly-industrial load shifting has been considered along with its effectiveness. Comparison of industrial and domestic load provides an insight into the present scenario. Gradual shifting of industrial load up to 10% by 2020 -2025 can enhance day peak demand and control evening peak demand.

Secondly, the possibility of electric vehicles as a demand side managing tool has been analyzed and present scenario has been investigated. Mainly the possibility of auto rickshaws which run by electric charging has been considered in this research. Maintaining proper charging time for electric vehicles according to demand forecast and using them as energy storage under a unified rule of BRTA can be a good solution to peak demand. Also this methodology in this sector will increase economic feasibility and sustainability.

Lastly, the application of lithium ion battery has been considered for grid scale energy storage system. Energy storage can balance the stability in supply and meet the ever growing demand of power. For short duration requirements battery storage can bring about frequency control and stability and for longer duration requirements they can bring about energy management or reserves. This battery can store energy in the off peak hour and supply of–to mitigate at the evening peak demand .This study provides a basis for any further development of the process as well as practical implication.

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CHAPTER ONE

1.1 Introduction

Demand side management for controlling peak demands consists of several steps taken by the power distribution utilities in order to control energy consumption. It includes all activities related to planning, implementation and monitoring of the utility activities at the customer side. One of the interesting aspects of this management philosophy is that it largely depends upon the attitude and usage of the customers. Because the main goal of this management is to motivate the customers to minimize their usage during peak hours or reschedule their energy usage during off-peak hours. This strategy does not reduce the total energy consumption, instead the hassle required for fulfilling the peak demand is largely reduced.

Demand side management can be implemented in both residential and commercial programs although the former holds the key potential as the most electricity consumption occurs in household according to DoE, USA (2011). Also in industries the peak load can be shifted in order to maintain balance in the energy consumption thus predict the pattern of power generation at a uniform rate. Even in Bangladesh, the possibility of a systematic load management can improve the current condition of power supply according to the study of Das and Chakrobarty (2012). Their study also showed that with proper management, demand supply gap can be neutralized and different benefits can be gained in the present power sector.

Demand side management mainly helps to use the available energy resources more efficiently without adding any new infrastructure either in transmission or generation. It includes various programs like implementing smart grids, shifting industrial load, introduction of battery technologies in household, increased usage of electric vehicles, cross border power trade etc. All these steps can be implemented separately or a combination of all the possible methods. In addition to these, the increase installments of prepaid meters and application of renewable technologies can also play a vital role in controlling peak demands. However, a limited scale research has been conducted considering a few of the available options as well as analyze the present situations in order to provide a development plan which will be beneficial in conducting any further development on this aspect.

1.2 Background

Bangladesh is a developing country till date and in this country implementing demand side management strategy is very crucial for reducing peak demands and also to increase demand during off peak hours especially at winter season. Because, in order to meet up the peak demand the only available source of fuel is liquid fuel which is very costly and most of these liquid fuel based power plants sit idle during the off peak time. This increases the generation cost of electricity and to build additional distribution and transmission network keeping this huge gap of demand will not be beneficial for the economy. For this reason, the government of Bangladesh in collaboration with Japan International Cooperation Agency (JICA) and Sustainable and Renewable Energy Development Authority (SREDA) developed an energy efficiency and conservation master plan (EECMP) up to 2030 as part of the DSM program (Efficiency. E, 2015).

The private sector power producers stated that, during off peak hours negative electrical consumption has affected their power production. The minimum demand during off peak hours is much below the expected demand of the power producers forecast. Along with these, the sudden rise and fall of demand during peak and off peak hours has created problems in load management of power grid. According to Rahman A. (2019), power generation across the country has been reduced to around one-third of the overall capacity under a 'rationing' system in view of the sagging demand in winter.

The Bangladesh Power Development Board has to run some expensive fuel based power plants due to the huge gap between peak and off-peak. Moreover, government has plan to increase the generation capacity by a large margin which will be hampered if demand side management is not applied as soon as possible. Furthermore, different projects have been undertaken in order to strengthen the existing transmission network and the distribution facilities throughout the country. All these activities largely depend upon the balance between peak demand and off peak demand. So, a well-defined demand side management strategy needs to be undertaken in order to fulfill the goal of the power system master plan of Bangladesh.

1.3 Statement of Problem

From the existing peak demand pattern, it is quite evident that peak demand varies significantly from season to season and time to time. This affects the overall power sector starting from generation to distribution. This demand gap needs to be minimized in order to reduce generation cost and implement energy efficiency. For this reason, demand side management strategy needs to be implemented.

Though different methods are available for controlling peak demands, few of those are viable for this country.. Some preliminary steps have been proposed like use of tariff and incentives, energy audit, power factor charges, energy savings campaign etc. But there are scopes to improve and accelerate the process of demand side management. In this research, battery technology, electric cars and industrial load shifting will be considered for controlling peak demand.

1.4 Scope of the Study

Different methods are available for managing demand side which varies from country to country and location to location within a country. First of all, industrial load shifting is an important parameter which can be a good option for demand side management. If the industrial loads got shifted to off peak hours, it would provide an added advantage in load management. This option will be largely discussed in this research. Secondly, battery technology can be a good option for residential users which if implemented properly can be a useful tool. Thirdly, increased usage of electric vehicles is a new concept in a developing country like us but a potential candidate for demand side management strategy.

This study will consider the present demand condition of the country. Data will be collected from the Power Grid Company of Bangladesh, Bangladesh Power Development Board and Ministry of Power, Energy and Mineral Resources. Mainly secondary data will be used for the research purpose. Comparisons will also be made with the situation of neighboring countries like India, Sri Lanka, and Thailand. For some important information, local newspapers journals will be considered as the source. Mainly, this study will be in a limited scale due to the ongoing pandemic situation.

1.5 Significance of the Study

This study on demand side management will be beneficial for the power sector utilities especially for the distribution companies. The distribution companies are mainly responsible to supply power at the customer's end which enables them to apply different rules and regulations required by the power division of the country to implement immediately. The study will show how industrial load shifting can be a good option for controlling pea demands. The analysis will help the distribution utilities to force or motivate the industrial users to increase their usage during off peak hours.

The analysis on battery usage is another important aspect of this research work. Battery technology can be the most vital option in controlling peak demands mainly for the residential users. Battery technology is growing day by day and it has a lot of potential to become an off grid source for power generation. Different types of batteries are available like solar battery, lithium ion battery, dry cell battery etc. A comparison will be made among the existing technologies in order to identify the suitable one. This study will assist the power distribution utilities to implement battery technology among the customers in order to reduce demand during peak hours.

Another important aspect of this research work is the introduction of electric vehicles as a demand side managing step. Electric vehicle is a new but promising technology for a developing country like Bangladesh which is to be considered a developed nation in coming decades. This study will show the potential of electric vehicles as a valid option for controlling peak demands. Mainly the current scenario of electric vehicles will be analyzed and compared with neighboring countries. Since electric vehicles have not been totally allowed by the road transport authority till date, the analysis will be made based on secondary data of other countries and the findings will be made in order to implement this idea in our country.

1.6 Research Questions

In this research, we will try to find out the answers of following questions:

- What are the factors responsible for present instability in load curve?
- Why current measures are not enough to manage demand side?
- How customers can be inspired to consume electricity during off peak hours instead of peak hours?
- How load forecasting system can be improved to control peak demand?
- How industrial load can be shifted to reduce the steepness of load curve?
- How much demand can be increased at night by charging electric vehicles?
- Can high density alkaline batteries make any impact during peak load condition?

1.7 Objectives

The objectives of this research work are as follows:

- To analyze the present demand variation during peak and off peak hours
- To investigate the effects of industrial load shifting in order to control peak demand
- To identify the potential of electric vehicles for demand side management
- To analyze the effects of battery technology during off peak hours

1.8 Literature Review

A lot of researches have been done in the field of demand side management in case of developing countries. Different types of solutions and predications have been suggested by the researchers throughout the world. From the analysis of energy saving behavior of Bangladesh it has been found that, energy demand can be reduced by 21.9% by applying proper energy saving behavior. It was also found that, efficient improvement in the usage of home appliances could reduce the residential sector demand by 28.8%. Most importantly, this study was specified for Bangladesh in order to implement demand side management strategy. (Khan I., 2019)

The concept of smart grid was investigated by Paul et al (2014) for the purpose of demand side load curtailment. In their study it has been found that, proper application of smart grid technology could improve the present condition of dissatisfaction among the customers. The researchers proposed a model where the customers were categorized into three different types namely high, medium and low consumption users. Also, the appliances were categorized based on load. The concept of smart meter has also been introduced in this paper which is already existing in different utilities. In a nutshell, this paper proposed a model to implement demand side load curtailment for the smart grid technology.

A scalable approach for Demand Side Management of plug-in hybrid vehicles was performed by Vandael et al (2012). In their work, a scalable computation of a charging plan based on hybrid vehicles has been described. Three steps formed the skeleton of their work which are aggregation, optimization, and control. This was an agent-based approach where one agent's objective was to charge the vehicle before departure time considering local power limitations while the other agent emphasized minimizing energy costs.

A cost model was developed by determining a collective charging plan that minimizes the costs of the supplies. This approach was evaluated two centralized benchmark solutions which were predefined. The total charging cost was numerically calculated after simulating 100times with various driving cycles. Uncontrolled charging at off-peak hours was assumed as the benchmark solution. But during weekends, vehicle owners can get benefitted from lower electricity prices. However, their approximation cannot predict fully the real-time charging pattern of the vehicles.

An Adaptive Learning-based Approach for Nearly-Optimal Dynamic Charging of Electric Vehicle Fleets was investigated by Korkas et al, 2017. The aim of this paper is to tackle the problem of intelligent charging/discharging of EVs via a nearly-optimal control approach. An Approximate Dynamic Programming (ADP) method is used. The main motivation for using a Dynamic Programming (DP)-based method is that it leads to feedback based optimal results.

However, they distinguish themselves from other literature in EV charging/discharging in the following threefold sense: first, while a classical DP algorithm aims at solving the optimal control problem exactly and using a look-up table for the value function, the proposed ADP algorithm aims at solving the optimal control problem iteratively by parameterizing the value function; second, differently from classical ADP approaches based on discrete state space and action space, they aim at developing a method with continuous state space and action space (which better represent the continuous charge and power variables involved in the charging problem); third, since a single feedback action is not enough due to different pricing schemes and availability of renewable energy, they embed multiple feedback actions in the optimization problem.

The proposed approach will therefore be referred to as Multi-Modal ADP (MM-ADP). A charging station case study shows that the proposed MMADP approach results in a set of controllers whose action is activated or deactivated depending on the availability of solar energy and pricing model, thus managing a wide range of operating regimes like rule-driven approaches. At the same time, the activation and deactivation of the feedback action come out of the optimization, thus recovering the 'objective-driven' feature of open-loop strategies.

The potential benefits of using electric vehicles were investigated by Pang et al (2012) for managing the demand side. Their work emphasized on using electric vehicles as distributed energy resources in the smart distribution grid. In order to define the role of electric vehicles, a numerical investigation of test cases has been demonstrated. Two popular electric vehicles have been selected in order to investigate the potential which was "Chevy Volt" and "Nissan Leaf "respectively. Different specifications of the vehicles like weight, battery type, capacity, charging time, etc. have been compared and summarized. Two separate cases have been studied in this research which was a grid to vehicle known as "G2V" and vehicle to building was known as "V2B". To establish communication between electric vehicles and the power grid, different communication modules have been studied. Both temporal and special characteristics of battery load have been studied as the charging place of the vehicles vary from time to time. In this study, six different driving cycles have been considered under two driver categories.

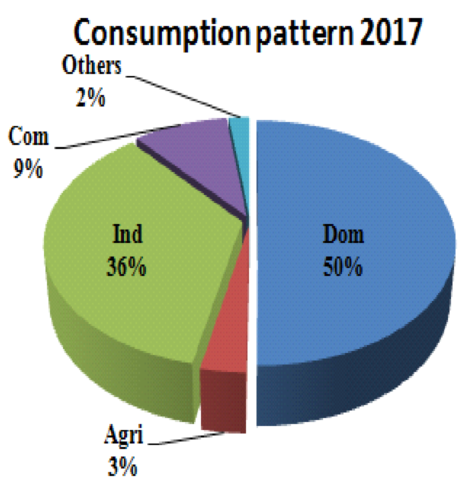
The models were simulated and it was found that the use of electric vehicles can accelerate the flexibility required for demand-side management operation. The researchers also concluded that on-peak load demand can be shifted by using controlled charging of vehicles. The feasibility study of the proposed model has also been demonstrated so that it can support the electricity demand of a typical building as well as earn revenue. Battery technology has also been considered as one of the main instrument for demand side management. Different studies have been made over the effectiveness of different types of batteries in different applications. Nowadays, most transmission and distribution substations are equipped with batteries. These batteries are used as an emergency power supply for critical loads and therefore play a crucial role in substation availability. At present vented lead-acid batteries are deeply entrenched in the market but are big, heavy, and require regular maintenance. These disadvantages inhibit substation development in areas that have limited space and also need more emergency. Lithium-ion batteries (McDowall, J., 2008) now offer an attractive combination of materials, compact, light, maintenance-free, long life, and high power and energy density.

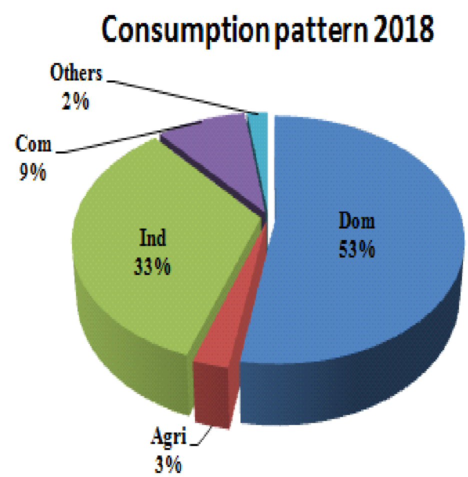
Battery systems connected to large solid-state converters have been used to stabilize power distribution networks. Some grid batteries are co-located with renewable energy plants, either to smooth the power supplied by the intermittent wind or solar output or to shift the power output into other hours of the day when the renewable plant cannot produce power directly. These hybrid systems (generation + storage) can either alleviate the pressure on the grid when connecting renewable sources or be used to reach self-sufficiency and work "off-the-grid" (McDowall et al, 2007). Li-ion is used where high-energy density and lightweight is of prime importance. Operating life: from 2 to 5 years of life for consumer goods (computers, mobile phones) to 5, 10 and up to 20 years of life for industrial capital equipment such as vehicles or power generation assets.

CHAPTER TWO

2.1 AN OVERVIEW OF PRESENT SITUATION

Industrialization is an essential pre requisite for rapid and sustainable economic development and social progress. Traditionally Bangladesh is an agriculture based country but most contributing factor to the GDP is its industries nowadays. These industries consume a bulk amount of power that is generated daily. Though industry sector in Bangladesh is growing every day and its electricity demand with it, percentage of electricity consumption in industries is reducing every year (BPDB Annual Reports, 2019). This can be seen from the consumption profile of Bangladesh total power in recent years.





[Source: BPDB]

Fig.2.1: Consumer Pattern of FY (2017)

Fig.2.2: Consumer Pattern of FY (2018)

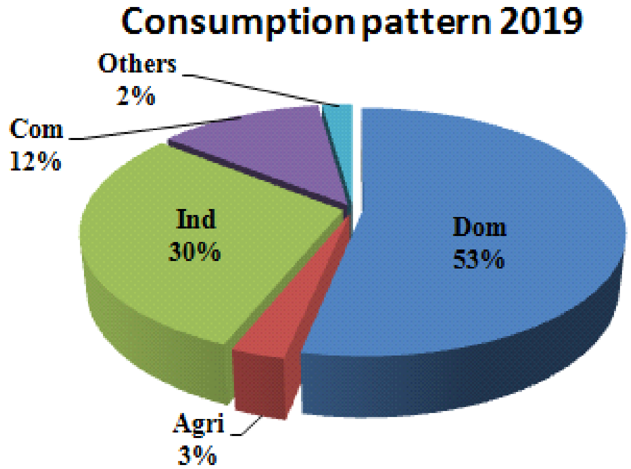


Fig. 2.3: Consumer Pattern of FY (2019) [Source: BPDB]

From the above charts, the consumer pattern of the recent years have been compared. The variation in industrial usage is the result of using more energy efficient machineries. Different energy efficient policies have also been implemented by the industries in order to reduce their expenditure. Some industries have also started producing their own power supplying system by installing captive power plants due to the interruption of grid power.

On the other hand, quite opposite scenario has been observed in case of domestic use. It has been increasing day by day although in slower rate. One of the main reason behind this increased usage is that, in previous years the application of new electrical connection was discouraged but it is encouraged nowadays. Another reason is that, the introduction of different technological devices like mobile, laptop, router etc. has increased the consumption of domestic users. Again, with the living standard becoming high day by day, people are using more electronic apparatus like washing machine, microwave oven, refrigerator etc. So due to these reasons, the domestic consumption is increasing rapidly.

In case of commercial usage, the demand consumption percentage is also increasing day by day as new business is growing everyday due to the continuous economic growth of the country for the last 3 to 4 years.

The industrial consumption pattern can also be understood from the following table:

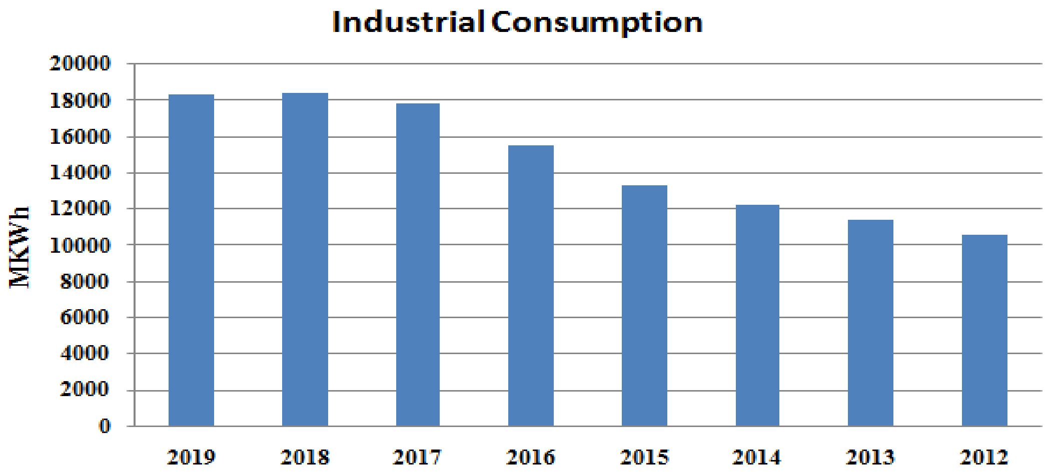


Fig. 2.4: Industrial consumption comparison Source: Study Team

Financial Year	**Domestic Consumption (MKWh)**	**Industrial Consumption (MKWh)**	**% of industrial consumption**
2012	14678	10579	35.30
2013	16351	11445	34.96
2014	18453	12270	33.86
2015	20471	13305	33.58
2016	23051	15527	34.28
2017	25225	17820	35.45
2018	29013	18415	33.42
2019	33072	18329	29.54

Table 2.1 comparison of Industrial consumption and domestic consumption) Source: Study Team

So it has been observed from the above chart and table that, industrial usage has been increasing in every year. For the last two years it has crossed 18000 MKWh. In last 8 years almost 8000 MKWh has been increased in industrial sector. But in terms of total percentage, it has reduced a little .It can be said that, industrial sector can contribute a lot in demand side management with proper load shifting.

The above comparison shows that, both industrial and domestic usage has increased in last 5 years although the increasing rate was different.

Rise in peak demand can also be observed from the following curve where latest data has been used (PGCB Daily Reports, 2019).

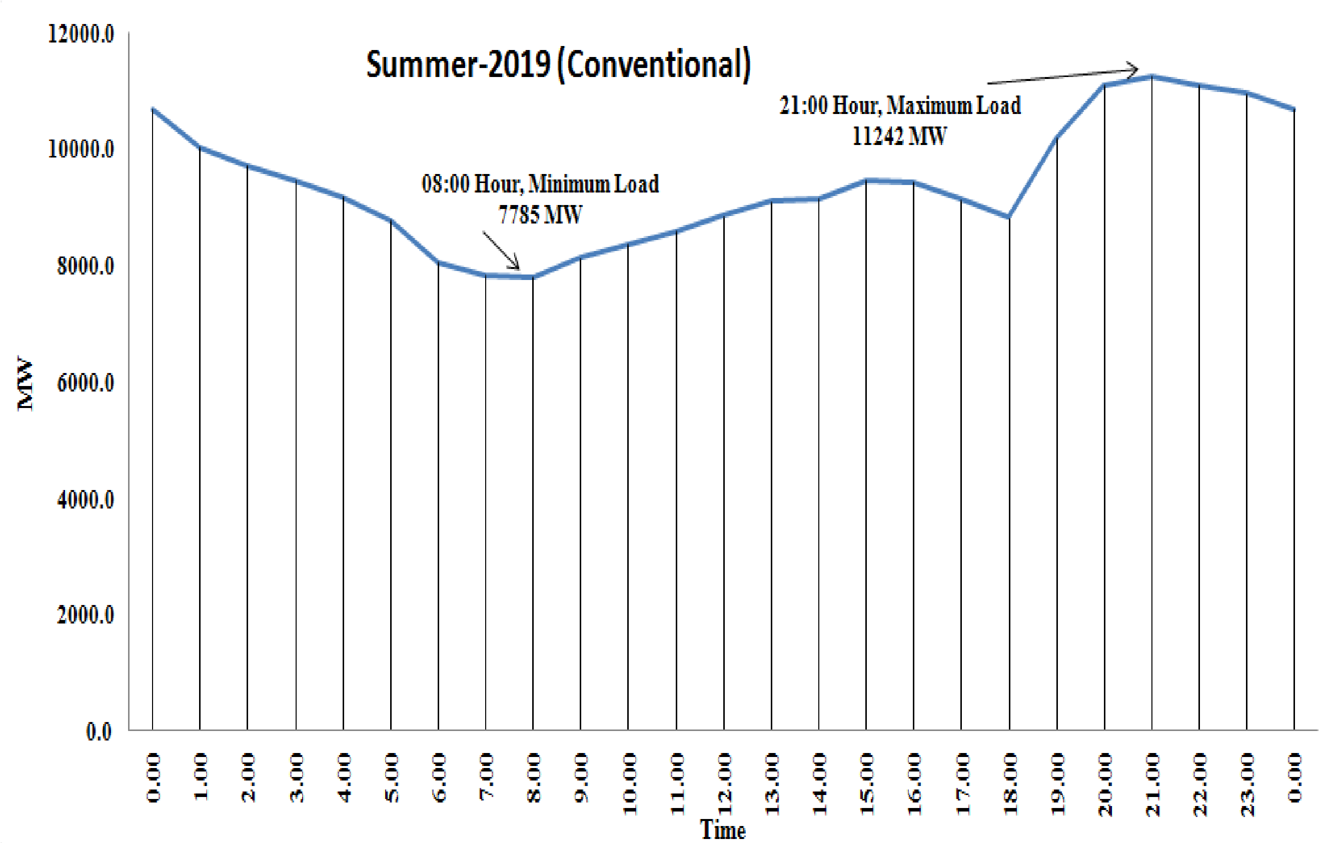


Figure 2.5 Load curve random days (summer'2019) Source: Study Team

Analyzing the load curve, the sharp rise can be seen. There are two peaks one in daytime and one in the evening. There is also some dissimilarity between the curves of winter (October, November, December, and January) and summer (April, May, June, July) in respect of peak timing though overall shape remains same. In summer the peak demand happens to be around 7.00 pm and in winter it's around 5.00 pm. This is time when domestic lightening load is superimposed upon the existing base load and industrial and commercial load. There is a big depression of demand in the first morning. With the offices and industries opening in the morning, demand also rises to a day peak. In the evening the peak comprises of all base demand, domestic appliances use and industrial uses.

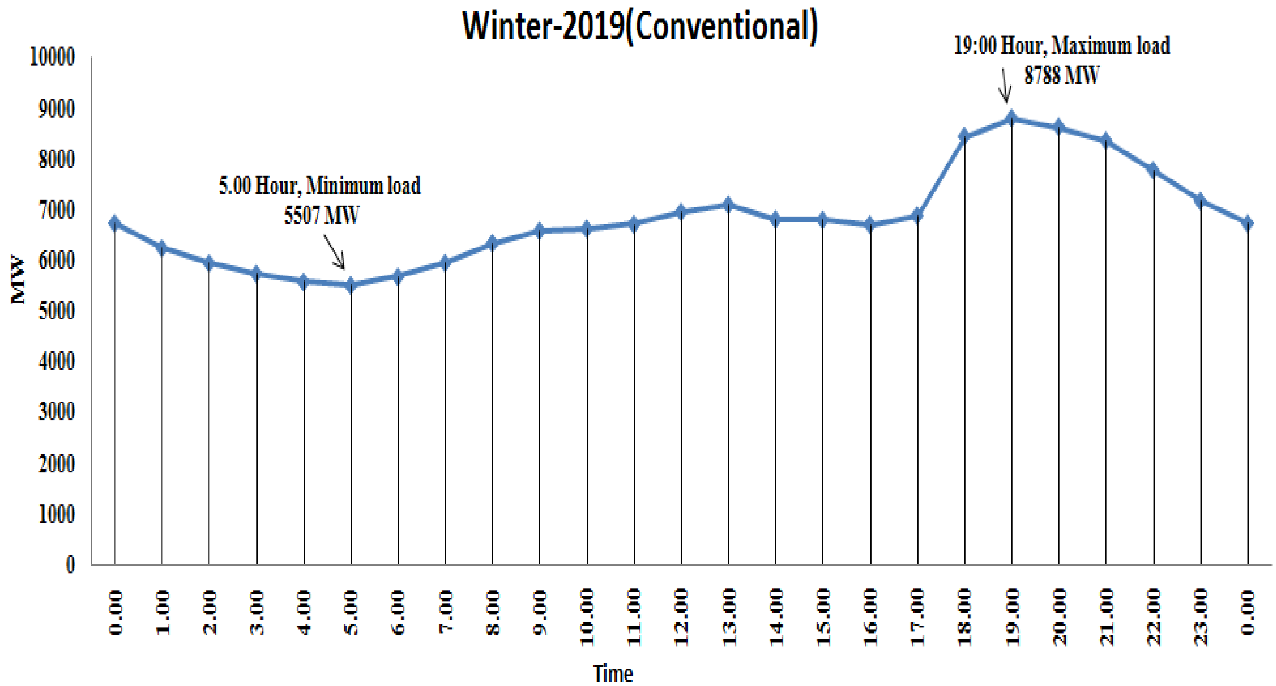


Figure 2.6 Load curve random days (winter'2019) Source: Study Team

From the two curves, it has also been observed that, demand pattern is quite similar in case of summer and winter where in both cases same peak problem has been experienced. This is one important area which needs to be improved for the sake of demand side management. A lot of parameters are involved in this peak demand times which needs to be focused and altered according to the necessity. Mostly, any change in the consumer side needs to be implemented by the respective utilities. The rise of two peaks in a day can easily be seen from the curve.

	Summer'2019	Winter'2019
Increment of Day peak load to evening Peak load / evening peak load (%)	16	13.7
Increment of minimum load to day Peak load / evening peak load (%)	14	22.4

Table 2.2: Incremental Rise of loads Source: BPDB

From the above table it has been observed again that, incremental day load percentage of winter has been decreased but in summer it has increased. The difference of increment of minimum load is much larger in winter than summer which is another important area which needs to be improved for the sake of managing demand side.

For ensuring electricity at all time, generation companies have to be capable of more than generating the peak demand at all time. But the peak demand only happens to be a short event. This hampers efficient use of resources and the govt. has to be bear the expenses to ensure a healthy grid and quality electricity to all. Again, off peak demand is much lower than summer off peak demand. If we can shift even a few percentage of total peak industrial load to an off peak time like very early in the morning by convincing the owners to run the industries that time, the peak demand can be reduced to a significant amount.

CHAPTER THREE

3.1 Findings

Different solutions are available for demand side management. Some of those have been considered in this research work like industrial load shifting, increased usage of electric vehicles, applications of battery technology etc.

3.2 Possible Outcome of Industrial Load Shifting

To reduce the peak demand, shifting of industrial load may be a possible solution from the evening peak hour load. Though it has its own merits and demerits with it. After analyzing previous data, a prediction has been made for the years 2020 to 2025 gradually with 10% shifting of industrial load from evening peak and following curve has been found-

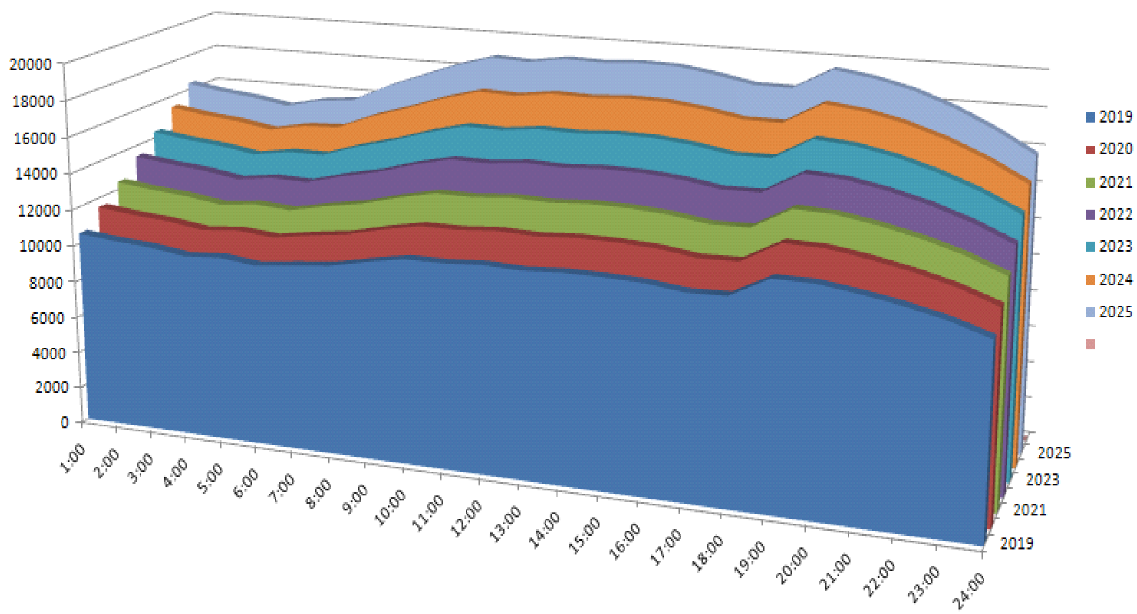


Figure 3.1: Possible load curve after 10 % industrial load shifting from evening peak

[Source: Study Team]

At the year 2025, it has been observed that, two peak hour are present at this rate. First peak hour has been observed around 1300 hours and the second peak hour has been observed around 1900 hrs. Both of this peak hour has been occurred in a preplanned way and it is effective for demand side management. This can easily be seen from the curve that it is much flatter than previous actual demand curves. In previous condition, it was found that a lot of rise and fall of demand dominated the demand pattern of the country. Mainly at two corners of the graph sudden rise has been observed. But if the load is shifted like the above curves, much more stability will be achieved compared to the present unstable condition.

Flatness of the curve simply signifies more efficient use of our resources and more system stability. If different energy efficient devices are introduced then it will have much more impact towards achieving the proposed demand pattern. Smoothness of the curve can be achieved by adding other factors like establishing battery storage system, charging electric vehicle, charging extra money for peak load usage i.e. revising the tariff, providing incentives for using electricity at off peak hours etc. But in order to achieve this pattern a well-organized plan is needed by the distribution utilities as they work totally at consumers end and this process is totally involved with the customers. Since this process is largely involved with the economy of the country, tariff rate is also very important.

3.3 Role of Electrical Vehicles (EV) on demand side Management

An EV is a forth coming technology that has many environmental and economic benefits in the transportation and energy sectors. So, there is rapid growth of Electric Vehicles (EVs) in the market. EVs play a significant role in reducing air pollution and emission of greenhouse gases. Despite of the demerits of using EVs like limited driving range, high cost of battery, short life cycle of battery, high charging time, scarcity of electricity required for charging EVs are still gaining popularity. This popularity of electric vehicles can be utilized to implement demand side management. A huge amount of load can be shifted from peak hour to off peak hour to ensure stability in demand. These electric vehicles consume a reasonable amount of electricity. An analysis of electricity consumption of different EV's have been done here. In this case the data of Gemelli. Fabio (2018) has been considered for the electric vehicles of Italy.

Cars	Electricity consumption per 100km
Hyundai Kona	13.1 KWh
Renault Zoe R110	13.7 KWh
Smart EQ Fortwo	15.1 KWh
Nissan Leaf	18.9 KWh
Tesla Model S	19.5 KWh
Jaguar I-Pace	23.9 KWh

Table 3.1: Electricity consumption of electric vehicles per 100 km

So it has been observed from the above table that, different vehicles have different electric consumption. But a minimum of 13 KWh of electricity is consumed by the electric vehicles. Since the cars in our country comes from abroad, a similar amount can be predicted to be consumed by the electric vehicles A shift in demand is possible with such type of consumptions but still a lot of different factors are involved in it. Most importantly, a comparison is needed with other electric appliances in order to justify the significance of electric vehicles as a demand side managing option.

Charging stations are regarded as the point of fueling EVs. Good charging infrastructure is one of the key factors for deployment of EVs. Three different levels of charging stations are categorized globally. A comparative analysis of different charging level has been done and data have been collected from the work of Harris (2009).

Type	Input Voltage	Input Current	Charging Time
Level 1 AC	120 V	15 A	10-13 Hrs
Level 2 AC	240 V	40 A	1-3 Hrs
Level 1 DC	210 V	80 A	0.5-1.44 Hrs

Table 3.2: Comparative analysis of different charging level) [Source: Study Team]

In most cases, electric vehicles need to be supplied by up to several kW of power, which is actually below than most of electric furnaces when in operation. Although there are some plug-in models with 10 or 20 kW home systems.

Another important aspect in the field of electric vehicles a demand side management is that, a comparison needs to be made with other appliances in order to justify its use during peak hours. A comparison of drawing power has been made in the following graph. Here data has been collected from the work of Schmidt (2017).

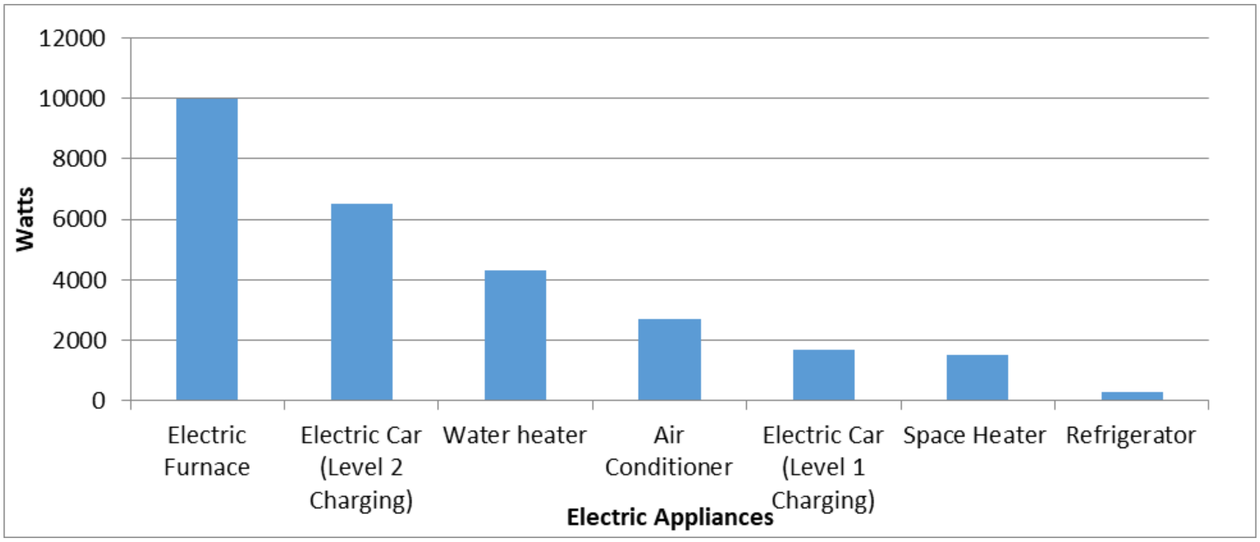


Figure 3.2: Power draw of different types of appliances

Bangladesh is moving towards introducing electric vehicles very quickly. Although, different type's electric vehicles are currently available in this country, no valid data is available about the exact number of electric vehicles. But we can consider auto rickshaws as electric vehicles since these vehicles consume a lot of electricity and these are spread throughout the country. An analysis of increasing number of auto rickshaws has been given below with the help of BRTA website. (BRTA, 2019)

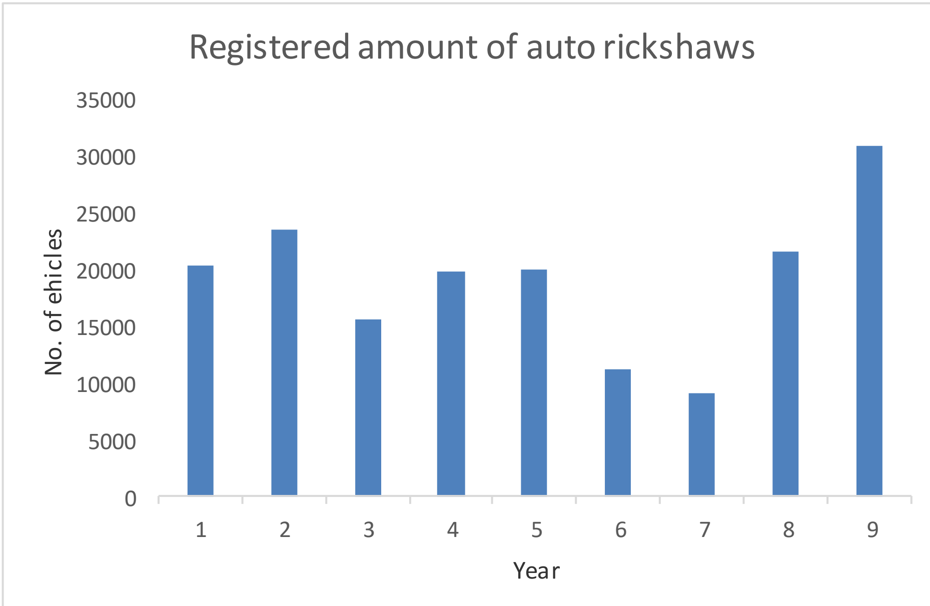


Fig.3.3: Number of auto rickshaws in Bangladesh across the years [Source: BRTA]

So it has been observed that, a huge amount of auto rickshaws have been registered in our country over the years and all of them runs of electric charging. If these auto rickshaws are brought under a unified regulation under BRTA regarding the charging hours, it will contribute a lot towards implementing demand side management.

3.4 Aspects of Li-ion Batteries (LIB) in Demand Side Management

The demand for electrical power varies daily, seasonally, and even emergently. Moreover, a large peak-to-valley difference between day and night can be observed. Therefore, storing the generated power and providing vacant power during peak load by peak shaving and load leveling are necessary. In addition, the renewable energy sources are susceptible to geological, seasonal, and temporal conditions. The intermittent nature leads to unpredictable fluctuations of output power, which cannot meet the demand for application to the electrical grid directly.

In recent years, the substantial growth of variable renewable sources promotes the development of electrical energy storage systems and requires them to be more flexible. Battery energy storage systems can effectively store the generated electricity of renewable sources, contributing to grid system stability and reliability, which in turn promote the use of renewable energy sources.

Wind power generation represents one of the main renewable energy sources. However, given that it is strongly influenced by the season and geographical location, wind power generation considerably suffers from intermittence. Moreover, mismatch between peak power generation and demand is often observed. Storing the excess energy produced by wind farms to supply electrical energy when the power demand reaches its peak is an effective solution. Solar photovoltaic power farms can also benefit from the integrated LIBs for storing the electrical energy and smoothing the output power. One of the main challenges to solar photovoltaic power generation is intermittence during the night and during periods when sunlight is blocked. The combination with batteries forms a perfect operating system that can cope with high-gradient power spikes and steady-state power requirements.

Generally, grid energy storage systems demand sufficient power and energy for their stable operation. To effectively drive the complex and wide-range devices in the grid, the number of power supplies should be large, in the order of hundreds and even thousands. Therefore, given the complex functionality and large-scale deployments of various devices in the grid, efficient power network management encounters serious challenges to ensure independent and cooperative work. The key hurdle is to design a power management system that can ensure long-term stability, reliable operation, work and storage safety, and cost-effectiveness. Moreover, when a large variety of batteries are packed in a stack, the power management service must balance the electrical characteristics (e.g., voltage and current) of each battery in the stack. The power management system is an essential contributor to the capability of the battery to satisfy the requirements of grid-level energy storage applications, which have a considerable effect on the operation of the overall battery stack and its safety and cost.

Although LIBs exhibit high energy density, one cell is insufficient to satisfy the requirements of the power grid. Therefore, the batteries need to be assembled in parallel to increase the current capability or in series to increase the voltage, which poses serious challenges to the stability, voltage operation, safety, and cycle life. For example, with just a few cells in series, the charge current and voltage are divided nearly equally among the cells. However, to achieve a high voltage, many cells need to be connected in series, which will result in unevenly divided voltage among these cells, leading to unbalanced cells with some cells fully charged and others overcharged. LIBs do not deal well with overcharging, resulting in potential safety issues and limited cycle life of the system. Therefore, establishing a system monitor to prevent any cell from being overcharged and balance the batteries to maximize the performance of the entire system is essential.

LIBs have the potential to become a key component in achieving energy sustainability at the grid scale because of their high energy density, high Energy Efficiency, and long cycle life. In this perspective, the characteristics of LIBs for applications to grid-level energy storage systems are discussed. Moreover, the performances of LIBs in terms of the following grid services are highlighted: (1) frequency regulation; (2) peak shifting; (3) integration with renewable energy sources; and (4) power management.

Despite the potential of LIBs for application, several challenges with respect to their grid-scale applications that should be addressed to ensure substantial room for improvement and tremendous opportunities for application in different directions are as follows:

Decreasing cost further: Especially in a country like Bangladesh, Cost plays a significant role in the application of LIBs to grid-level energy storage systems. However, the use of LIBs in stationary applications is costly because of the potential resource limitations of lithium. Therefore, substantial cost reductions are required to enable ongoing accelerated market growth, particularly for its use in the power grid.

Bangladesh has a huge potential for battery market. A study report (Shehab, 2019) shows the present and future conditions of battery market in Bangladesh considering automotive industries. The graphical representation is stated below-

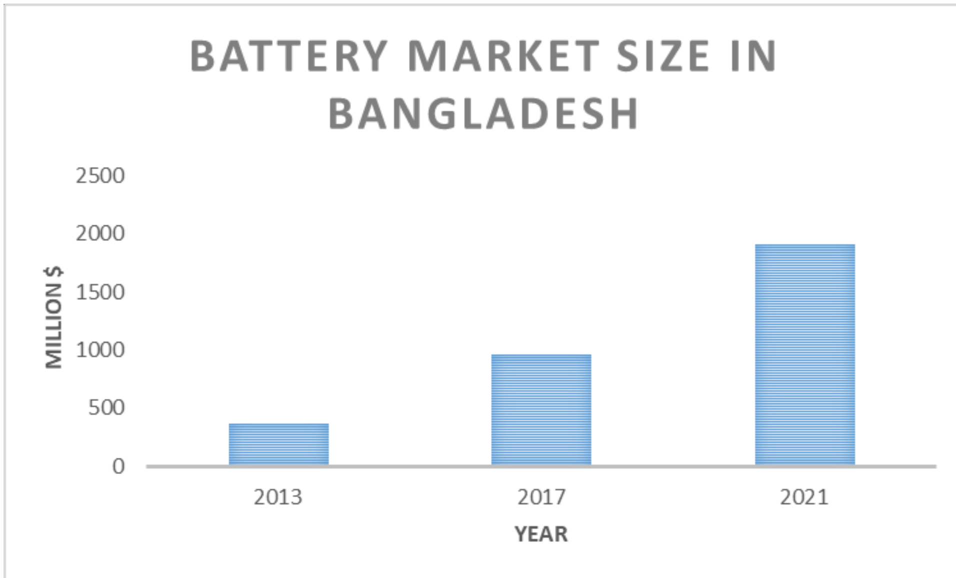


Figure 3.4: Battery market Size in Bangladesh

From the figure, it has been observed that, the amount of battery is increasing at a much faster rate. In last year, it has been almost thrice more than the market size of 2013 and by 2021 it is expected to cross near 2000 million $. With this rate, batteries especially lithium ion batteries (LIB) expected to become a vital element in demand size managing opportunity. Establishing an effective and far-reaching LIB recovery and recycling scheme is important. The industry needs to successfully reduce the environmental impact of raw material extraction and battery disposal and to mitigate material bottlenecks and their price impacts to ensure ongoing accelerated market growth.

Research on grid-level energy storage system must focus on the improvement of battery performance, including operating voltage, Energy Efficiency, cycle life, energy and power densities, safety, environmental friendliness, and cost. Thus far, LIBs have exceeded other previously competitive battery types (e.g., lead–acid and nickel metal hydride batteries) but still need extensive and in-depth investigations to improve the energy density, reduce the cost, and develop safe battery systems.

CHAPTER FOUR

4.1 DISCUSSION:

To ensure electricity at all times, generation capacity of a country has to be higher than the peak demand at any time. If this peak demand stays for a short period, then a lot of resources get wasted. This research is focused on the equilibrium allocation of demand throughout the year so that we can reduce the peak demand and utilize the resources wisely. Study shows there can be a significant reduction in demand by applying energy saving behavior and advanced technology. This research tries to evaluate the present condition of peak demand and find solution by load shifting and enabling energy storage devices to domestic common uses.

Shifting of industrial load from the peak demand time can be suitable alternative solution as this research shows. This will save costly use of the diesel plants as demand curve is smoothened by shifting load. Forecasting demand correctly with this amendment will enable us to save extra energy produced at lower cost. Advanced storage system will help. Electric vehicle charging at the right time will ensure a significant amount of storage facility. It was also found that improvement in this sector will ensure energy stability and rightful use. Another alternative can be the use of Li-ion batteries for constant storage system. By establishing net metering system these small storage systems on a large scale will ensure constant demand all time.

This study was based on mainly secondary data due to limitation of time and resources. Main obstacles to implement these will be the consciousness and motivation required to enable people to work at a different time than usual. Building infrastructure for charging and storage will be crucial as lack of land in our country is extreme and financial help from the govt. will be required. Further study on the economic analysis and consciousness among the public can be performed and primary data will make this study more realistic in present condition. However, load shift and advanced storage system will definitely help to improve the present demand condition in Bangladesh.

CHAPTER FIVE

5.1 CONCLUSION:

Demand Side Management has the potential to provide many benefits to power sector. Different concepts for reducing abrupt change of our national load curve has been analyzed in this study which are much practical at customer side. It has been shown above that 10% load shifting preferably industrial load will have major impact for managing national load curve. This is beneficial for managing peak load as well as cost effectiveness. Storage devices can be implemented in customers' end. Storage devices can be charged during off-peak hour and discharge to the national grid during peak hour. These storage devices can be a good option to storage energy in off peak hour and use for the peak hour. However, the storage system is expensive in now days but in future it plays a great role in power market. In Bangladesh Electric Vehicles can be introduced in large scale to charge our grid system on off peak hour. EVs' charging help to uplift off peak load which will stabilize our daily load curve. Though its implementation needs huge investments and infrastructure development, but in the long run it will help the stability and efficiency of our power system.

5.2 RECOMMENDATIONS:

- Industrial load should be gradually shifted and increased to enhance the day peak demand;
- Enhancing day peak should increase stability of our power system and increase in industrial load will contribute largely to our GDP establishing a way forward to a developed nation;
- Li-ion battery storage system should be introduced for high energy density and efficiency to store surplus energy at low demand;
- Proper infrastructure should be made for electric vehicle charging and the time must be scheduled to charge them at low demand;
- Lithium ion battery should be introduced to the customers to store energy from grid at off peak and supply back at peak hours through net metering;
- Incentives should be announced for charging electric vehicles at off peak hours;
- Training should be given to vehicles owners to increase the power consumption of the electric vehicles , efficient use and benefit of electric vehicles;
- Distribution utilities should encourage customers about efficient usage of energy.

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