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Bangladesh Power System Peak Demand Shaving through Demand Side Management of the Battery Operated Easy Bike Load

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***Abstract*— Electric vehicle (EV) charging is an important contributor to the peak load of a power system. A survey carried out by the author shows addition of significant load to the grid during peak hour due to the plugging in of battery-operated three-wheel 'easy-bike' for their charging. Demand-side management involves changing energy use habits of consumers, and this can be adopted to shift pattern of connecting EVs to the grid so that no vehicle is connected and charged during peak hours. The other way to solve the issue is to use technology to compel the EVs to be charged during off-peak hours. In this paper a suitable technique of Demand Side Management has been proposed to mitigate the problem.**

Keywords—Bangladesh National Grid, Daily Load Curve, Demand Side Management, Easy Bikes, Electric Vehicles, Timer Control

I. INTRODUCTION

Electric vehicles (EV) such as motorized three-wheelers vehicles and rickshaws, commonly known as Easy Bikes (EB), have started to dominate the transportation sector of Bangladesh in recent past. These vehicles were first introduced in 2004 and were fully marketed by 2008. Most of these vehicles are either locally assembled or bought from china. In many major cities, they are serving as the major intra-city transport system. These vehicles are rapidly increasing in number, starting from a few and now there are about 1 million [1]–[3]

Electric vehicles are equipped with five batteries of different sizes depending on the type of the vehicle, which needs to be connected to the grid for charging. Lead-acid batteries are used as the energy storage device and over 1.9 million batteries are used all over the country every year [4]. Easy Bikes are usually connected overnight and require a large amount of electrical power to charge, thereby is likely to have a negative impact on the grid due to its high demand. Average power consumption of a battery-operated auto-rickshaw is about 8 - 11 kWh per day [5]–[7]. These vehicles are interfaced to the grid as active loads in an uncontrolled way. No specific measures are taken to ensure the vehicles to be appropriately connected to the electric grid.

Due to the rapid economic growth the electricity demand has increased significantly in recent time. This has put pressure on the distribution network which has been the major contributor in load shedding [8], [9]. The Government has taken massive plan to expand the distribution network. The demand for electricity in the system varies throughout the day and night with maximum demand occurring from 5 pm to 11 pm as `peak load`. The Easy-bike charging generally starts during peak hour, thus it affects the peak demand significantly. The amount of peak load can be shaved up through demand side management for better capacity utilization of the power grid [10], [11].

A survey on Easy Bikes has been carried out by the authors in different cities of Bangladesh to investigate various technical and economic facts. The impact on Bangladesh national grid due to energy requirements of an increased number of unexpected and unaware load of Easy Bike and its Demand Side Management has been studied. This paper presents the analysis of the survey, the results of the study of the effects of EV on national grid and the technique to manage these load with the timer control system.

II. FIELD SURVEY ON EASY BIKES

A field survey on Easy Bikes has been carried out by the authors physically in different cities of Bangladesh to get proper view of its impact on the daily load curve of national grid. More than 200 Easy Bike was surveyed. Most of the vehicles surveyed belong to the first owner, i.e. they are procured as new vehicles. About one-fourth of the samples were second-hand vehicles.

The life of a flooded Lead Acid battery depends on the depth of discharge (DoD) of the battery. As the easy bike batteries generally has a very high DoD value the cycle life is considerably lower. The survey shows that majority battery banks have a life less than 9 months as shown in fig.1.

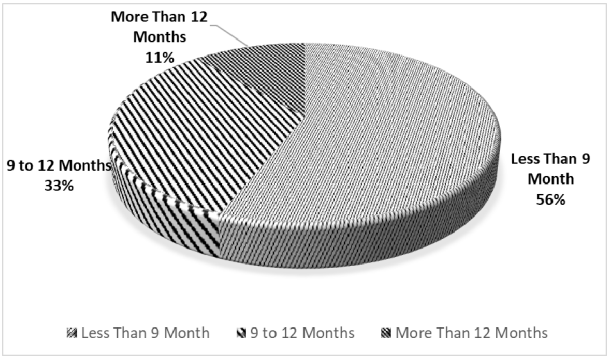

Fig. 1. Life of Easy Bike Battery.

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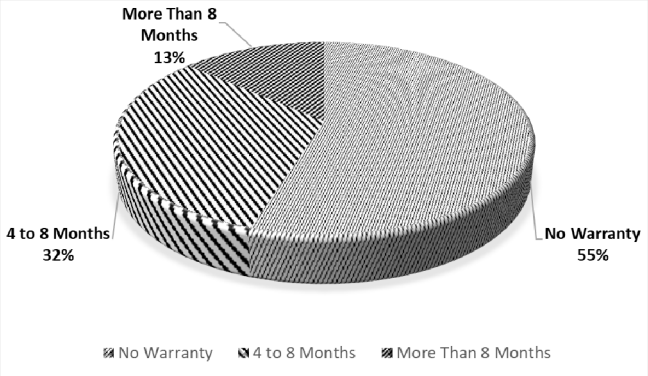

Fig. 2. Warranty of Easy Bike Battery.

Most of the local battery manufacturer do not offer any warranty for their battery if used for easy bikes. This may be due to the inefficient charger and high DoD of the system. According to the dealers outside Dhaka, some Chinese manufacturer offers warranty. The survey results show that majority of the vehicles have battery warranty in the range of 4 to 8 months as shown in fig. 2. About 55% of the sample does not have warranty for their battery bank. Though the dealers offer a warranty, the users also expressed that it is very difficult to get replacement during warranty period. The dealers try to repair the used battery instead of replacing it. Because of the large number of vehicles, there is a huge demand for battery in the market. The batteries are of 180AH in capacity according to the nameplate data and each Easy Bike has five of them. The cost of five batteries is around BDT 40,000.00 to 60,000.00. There is a value of the old or damaged battery and generally the value of such battery bank ranges from BDT 15,000.00 to 20,000.00 and they can be sold directly to the battery seller. In this section, a detailed analysis of the field survey is given.

A. Battery charging and Charger Analysis

Most of the vehicles are charged in the garage. This may be because of the convenience of the whole system. The garage does not only provide the charging connection but also ensure the security of the vehicles. Most of the home in the rural area does not have sufficient space to store the vehicles securely. Additionally the guard/caretaker of the garages also can attend the vehicle in case of some emergency. The excessive gassing of the battery during overcharging also makes it inconvenient for charging at home. The charging cost of the vehicles varies from garage to garage. Most of the user need to pay BDT 100.00 to 125.00. But the charging rate can be higher than BDT 150.00 as shown in fig. 3.

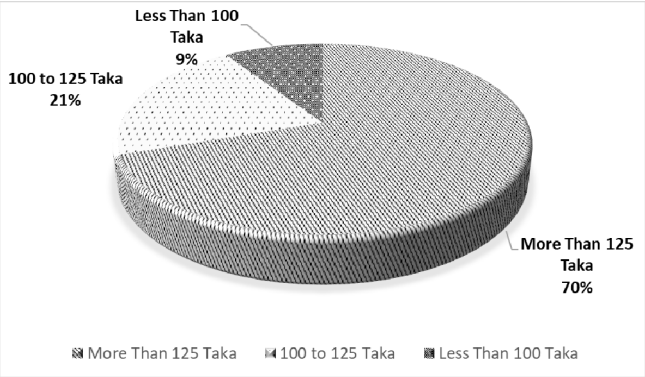

Fig. 3. Charging Cost of Easy Bikes.

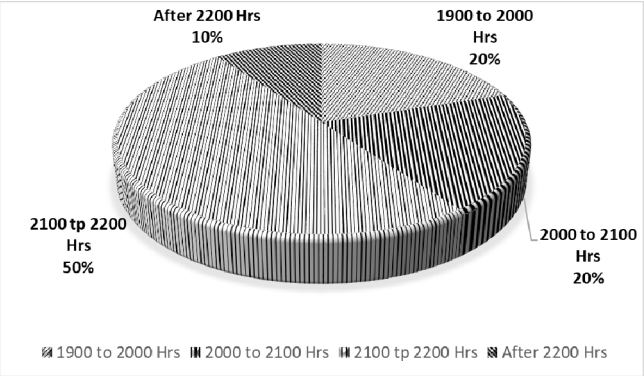

Fig. 4. Easy Bike plug-in time.

The cost is not only for charging the vehicles but also for ensuring security. The easy bike has a range of more than 100 km in single charging. There are two types of charger available in the market, one with copper transformer and another with aluminium transformer. The copper one costs more. The chargers sometimes get damaged due to overheating caused by overcharging. The survey data also shows that a substantial amount of the vehicles need to procure the chargers separately from the market. Depending on the quality of the system, the cost of a battery charger varies from BDT 2500 to 5000.

The current three-wheeler charger technology is very simple consisting of few power-electronic components. The charger should be most reliable and long-lasting for them. In the field of power electronics simplicity begets reliability. This charger is very simple and reliable, though it suffers from few problems like overcharging, wastage of energy, environmental hazard etc. One of the major difficulties of this charger is that it takes 8 to 10 hours to charge the battery fully which affects the plug-in and plug-out time.

B. Existing Connecting Pattern (Plug in and Plug out Time) of Easy Bike

The vehicles are charged overnight, starting to get connected to the grid by 7 pm and all vehicles connected by 11 pm. From 7 pm to 6 am the next morning a high load is observed in recent years due to easy bike charging. Most of the vehicles are plugged out from the grid between 6 am to 7 am. Whereas almost all the vehicles are disconnected by 8 am. Fig. 4 and fig. 5 shows the plug-in and plug-out time of easy bikes respectively. Table I shows the percentage of vehicles plugged in to and plugged out from the grid for charging purpose.

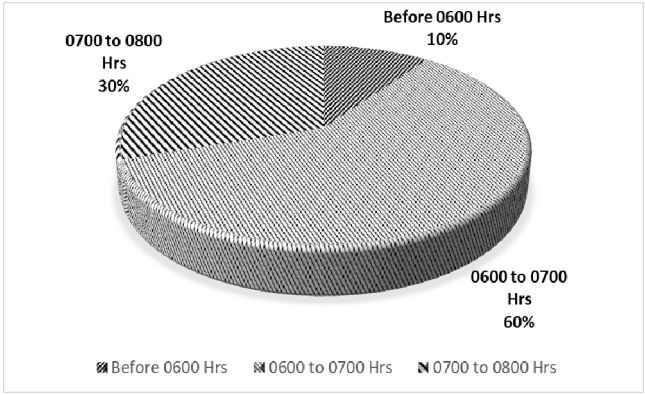

Fig. 5. Easy Bike plug-out time.

TABLE I. PERCENTAGES OF VEHICLES PLUGGED IN AND PLUGGED OUT FROM THE GRID

Status	Time	Percentage of Vehicles
Plug-in EVs	7 pm to 8 pm	20
	8 pm to 9 pm	20
	9 pm to 10 pm	50
All connected	10 pm to 6 am	100
Plug-out EVs	6 am to 7 am	60
	7 am to 8 am	30
Not connected	8 am to 7 pm	100

III. LOAD CURVE AND DEMAND SIDE MANAGEMENT ANALYSIS

A. Electric Grid Scenario of Bangladesh

Electricity plays a vital role in the economic growth through sustainable structure as well as poverty eradication and security of any country. Future economic growth crucially depends on the long-term availability of electricity, which is affordable, available and environmentally friendly. In line with this, Bangladesh is moving ahead extensively to create sustainable growth of power sector for overall development of the country economy. Present installed generation capacity in public, private & import sector is 15,953 MW [12], [13]. Up to date, maximum generation achieved is 10,958 MW on May 28, 2018 [12]. At present, 90% of the total population has access to electricity and per capita generation has increased to 464 kWh (including captive).

The change in the vital parameters of the electrical grid - installed capacity, maximum demand, maximum peak generation and maximum load shedding from 2005 to 2018 have been pictured in fig. 6. It is observed that over the last ten years installed capacity and generation has been increased. At the same time demand has been increased significantly. As such, load shedding has never been reduced.

B. Load Curve Analysis

A load curve shows the variation of load on the electrical power station with respect to time. The generation (in MW) at every hour can be extracted from the load curve.

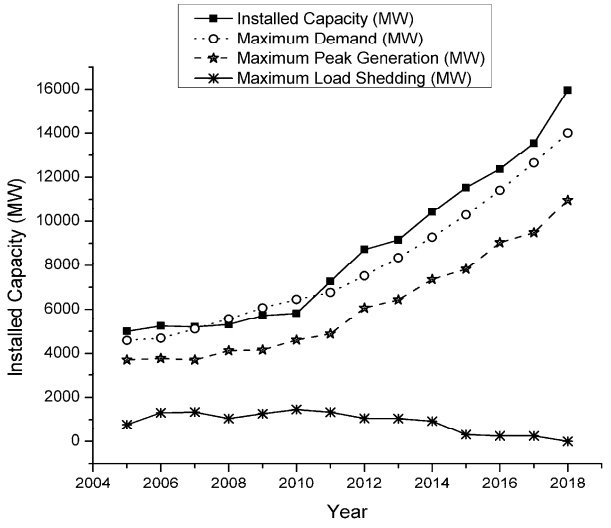

Fig. 6. Power and energy generation scenario of the Bangladesh electrical grid from 2005 to 2018.

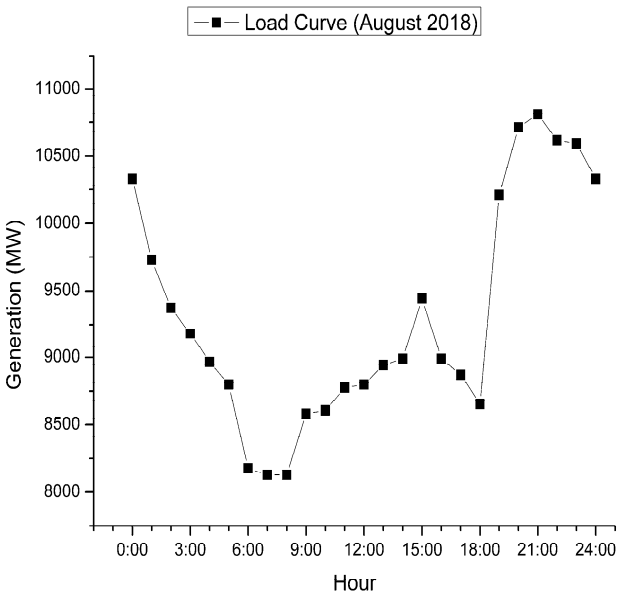

Fig. 7. Daily load curve of a day in August 2018.

Important parameters such as average load, maximum demand, size and the number of generating unit and operating schedule can be determined from the curve. Fluctuations in load curves are observed during holidays or certain circumstances like change in weather or natural disasters. Fig. 7 shows a daily load curve of a day in 2018. The daily load curve of a day in 2018 has been plotted for study and analysis where the peak generation load is 10,862 MW. It is observed that the difference between peak and off-peak load is almost 3500 MW, which is a large variation. The load curves are available in Bangladesh Power Development Board (BPDB) website [14].

There are many reasons for the increase of peak load but an increase of easy-bikes and motorized rickshaws connected to the grid for charging is one of the main reasons for raising peak load. These loads in the system during peak hour can be avoided or minimized by the consumers if the demand Side Management is exercised by the authority. In order to shift these kinds of loads from peak hour to off-peak hour appropriate authority can motivate, formulate and apply regulation and introduce mechanism.

C. Load Factor and Load Management

The demand for electricity in the system varies throughout the day and night. The maximum demand occurs from 5 pm to 11 pm which is termed as 'peak hour' and another part of the time is termed as off-peak hour. The extent of this variation is measured in terms of Load Factor, which is the ratio of average and maximum demand. For economic reasons, it is desirable to have a higher Load Factor, as this would permit better utilization of plant capacity. Moreover, the cost of energy supply during peak hour is higher, because some relatively more utility appliance is required to put in operation during the peak hour. For these reasons, load management is essential throughout the year for better capacity utilization of power plants and minimum generation cost.

There are some loads in the system which can be avoided or minimized by consumers during peak hour. In order to shift these kinds of loads from peak hour to off-peak hour by introducing some mechanism is termed as load management.

From the viewpoint of load management, (i) Two-part tariff is introduced for 3-phase consumers (LT & HT) where peak hour price is much higher than the off-peak hour that motivates consumers to avoid or use less in the peak hour; (ii) Market & Shopping malls are kept close after 8.00 PM; (iii) Holiday staggering is implemented to keep industries, markets & shopping malls close on area basis holiday marked day; (iv) Consumers are encouraged to use energy-efficient bulb, electric appliances, pumps etc; (v) Consumers are encouraged to keep their air-conditioners temperature at 25 degrees and so on. These measures also minimize load-shedding across the country.

D. Demand Side Management

Demand-side management (DSM) modifies energy use to maximize energy efficiency. DSM tries to get the maximum benefit out of existing energy generation. DSM involves changing energy use habits of consumers and encouraging them for using energy-efficient appliances, equipment etc. at their premises. To keep load shedding at a minimum level, BPDB has taken a number of steps for demand-side management, which are as follows:

- To shift irrigation load from peak hour to off-peak hour, BPDB has started a campaign through electronic and print media. In the last few years, it is estimated that about 500 MW irrigation load was shifted from peak hour to off-peak hour.
- BPDB has taken motivational programs to enhance awareness of the consumers during peak hours. Consumers are being urged through electronic and print media to be rational and economical in electricity use during peak hour by switching off unnecessary loads like extra lighting, ironing, pumps, air conditioners, welding machines etc. As part of the demand-side management program, BPDB has taken steps to use CFL in BPDB's offices and also trying to motivate consumers to use Energy efficient lamps.
- Industries operating in two shifts are being requested not to operate during peak hours. Holiday staggering for industries has been implemented, which contributes about 200 MW load shifting.
- Load Management Committee has been formed in every distribution zone/circle/division to monitor the proper load distribution during irrigation. As part of DSM, BPDB is monitoring shop/market closure time at 8 p.m. It is estimated that this measure contributes about 400 MW [12], [13]. Load shifting from peak hour thereby reduces load shedding. Table II shows total load shift from peak to off-peak hour by the process of DSM.

TABLE II. LOAD SHIFTED USING DSM METHOD

Item	Irrigation (MW)	Industry (MW)	Shops (MW)	Total Load Shifted (MW)
Load Shifted	500	200	400	1100

BPDP is unaware of a load of approximately 700 MW which is connected to the grid during peak hour due to the charging of EVs mostly by Easy Bike. If this load is shifted from peak to off-peak period than peak load period will be considerably relaxed.

IV. SUGGESTED SOLUTION

Due to the addition of unplanned low priority load, the peak load has become unmanageable. Demand-side management is one of the important tools to manage energy during peak and off-peak hour. If 70% Easy Bike is connected at a time to the grid out of one million it will add more than 700 MW of load to the system. It remains unaware of the authority and needs proper management. As a part of motivation or regulations BPDB can take a step to shift pattern of connecting EV to the grid so that no vehicle is connected and charged during peak hour. The other way to solve the issue is to compel the vehicles to be charged with control using technology. Both the solutions are discussed in this section.

A. Suggested Pattern of Connectivity of EV to the Grid

Most of the vehicles are plying in urban areas and most of the drivers complete their trips by 7 pm. Thus vehicles are connected to the grid for charging as soon as they return to the garage. The government may formulate regulation to restrict connecting this EV to the national grid during peak hour. Table III suggests percentage of vehicle to be connected to the grid to eradicate the problem. In this process it is assumed that 90% vehicles will be connected by 10:30 pm. Since charging period is almost 8 to 10 hours and due to the habit of the driver it is expected that 60% vehicles will be plugged out from charging by 7 am. 30% vehicle may be plugged out by 8 am. There are some Auto drivers who come for charging or topping up even in day time, thus provision to be kept to connect during off-peak hour till 5 pm. Authority may motivate drivers and encourage them to plug in their vehicle for charging at off-peak hours and facilitate in terms of reduced charging cost.

TABLE III. PROPOSED PERCENTAGES OF VEHICLES PLUGGED IN AND PLUGGED OUT FROM GRID

Status	Time	Percentage of Vehicles
Plug-in EVs	10 pm to 10:30 pm	90
	10:30 pm to 11 pm	10
All connected	11 pm to 6 am	100
Plug-out EVs	6 am to 7 am	60
	7 am to 8 am	30
	8 am to 5 pm	10
Not connected	5 pm to 10 pm	100

B. Controlling the Charging System using Timer Circuit

The timer circuit can be incorporated into the Easy Bike charging system to limit the charging start time. Easy Bike drivers after completion of their duty can plug in the vehicle in their respective garage as usual but timer circuit will decide the start time of charging. Considering the off-peak hour and charging period of the charger, start time of timer circuit can be maintained from 10 pm. In this system there will be a provision to allow the charging station to plug in the vehicles during daytime till 5 pm. A restriction will be imposed for charging between 5 pm to 10 pm.

The timer-circuit can be incorporated in three ways, (i) Central system with one timer-circuit at the charging station,

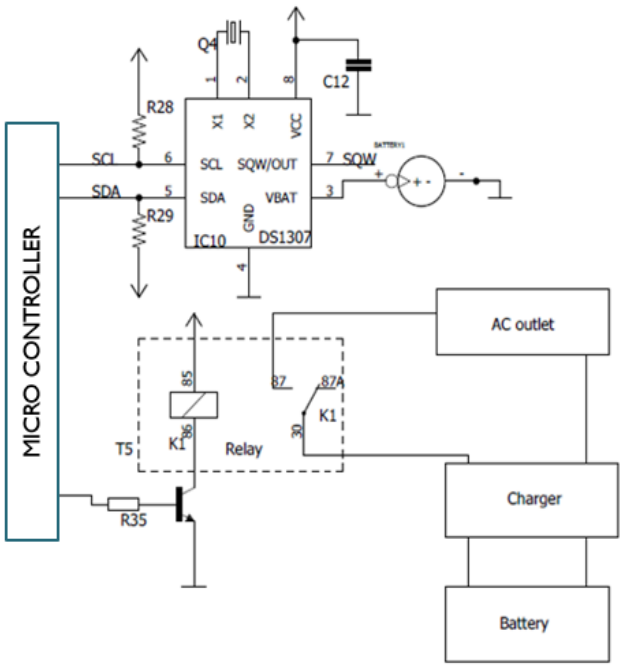

Fig. 8. Controlling the Charging System using Timer Circuit.

(ii) Central system with one timer-circuit at the charging station and individual relay coil at the charger (iii) Staggered system with individual timer to the charger. There are advantages and disadvantages of all the three systems. If the system is centrally controlled all the vehicle will be charged simultaneously creating huge imbalance in load. To minimize this, individual relay coil may be introduced to the chargers. In this case control is dependent on charging station as well as individual charger. If the timer circuit is set to individual charger with random generation number then the load can be staggered and controlling will be easier. It will be programmed to add all the vehicles to the charger within 15 to 30 minutes from start time to facilitate generating random number and connect the vehicle in staggered time. In this case authority will have to ensure that drivers purchase charger with timer circuit. Fig. 8 and fig. 9 shows the timer circuit and the algorithm of the timer circuit for staggered connection respectively.

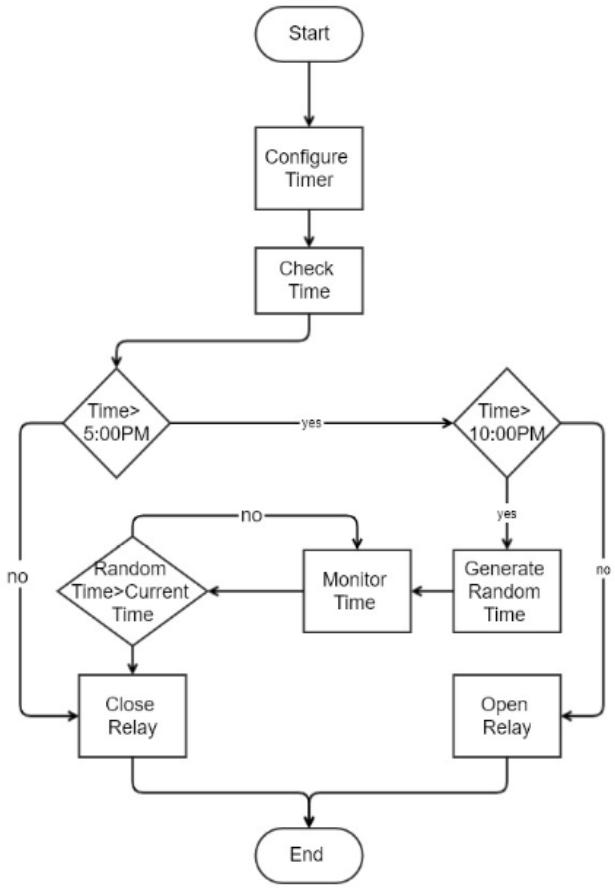

Fig. 9. Charging System Control Algorithm.

V. Results and Discussions

The electrical grid of Bangladesh needs to adapt to address the effect of electric vehicles. According to the analysis of the pattern of connection, if all the EVs are connected to the grid after 10 pm a significant reduction in peak load can be ensured. It is expected that 70% of the total Easy Bike is connected to the grid and with average consumption of 1 KW by one Easy Bike highest 700 MW load can be shifted from peak hour to off-peak hour in this process. By controlling the charging system with the timer control circuit the load shifting amount can be estimated using the data in table I and table III. Table IV shows percentage and total load shifted from peak to off-peak hour.

TABLE IV. Percentages of Load Shifted from Peak to Off-Peak Hour

Time	Load, %	Total Load (MW)
Load shifted from 7 to 8 pm	20	140
Load shifted from 8 to 9 pm	40	280
Load shifted from 9 to 10 pm	90	630
Load shifted from 10 to 11 pm	50	350
Load added from 6 to 7 am	20	140
Load added from 7 to 8 am	40	210
Load added from 8 to 9 am	40	210

The analysis shows that the peak load has been shifted significantly from peak hour to off-peak hour. Fig. 10 shows

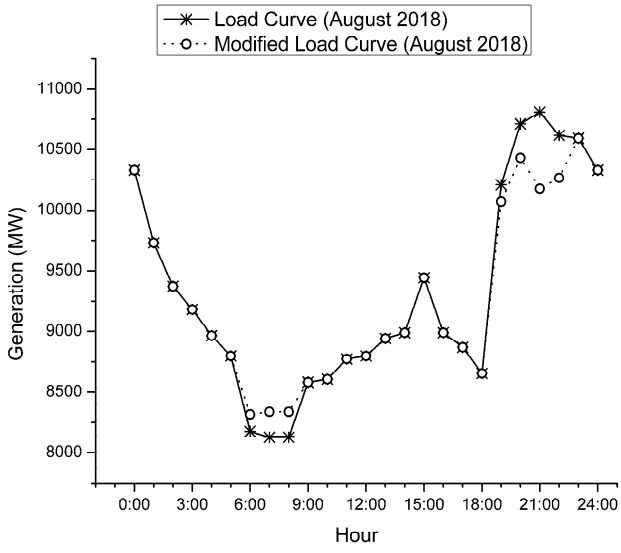

Fig. 10. Load shifted from peak to off-peak hour using Timer Circuit.

the graphical representation of load shifting due to timer control management. It can be observed from table IV as well as from the graph that maximum 630 MW of load has been reduced in the time range of 9 pm to 10 pm due to the shifting of the charging load using timer control system. It is also observed from the graph that the peak load has been reduced significantly using timer control system. The load, which has been added to the off-peak hours due to the shifting of charging load using timer control system, mostly from 6 am to 9 am does not pose any negative effect to the power grid.

Since charging will start at 10 pm, as such, drivers can plug out the vehicle in the morning in a convenient time, thus overcharge will not create overheat and gassing of the battery can be avoided. Again, due to the control charging system, safety and security can be better maintained.

VI. Conclusions

In this paper, an inclusive study has been carried out on the effect of EVs on the Bangladesh national power grid. A huge load is consistently observed at night from 7 pm to 6 am the next day due to the integration of a dominant load like EV charging, which is approximately 700 MW during peak hours. A physical survey has been carried out for an in-depth analysis of the effects of Easy Bikes. Various important technical facts and problems were discussed, especially on Easy Bike battery charger and charging system. Demand-side management was addressed to find out the peak demand shaving of the load. To reduce the impact of the battery operated vehicle on power grid a timer control mechanism has been developed. A substantial amount of load was considered can be shifted from peak to off-peak hour if the mechanism is executed.

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