Present and Future Load Optimization of Electric Three Wheelers in Bangladesh

Riyad Salehdin[1], Showrov Rahman[1], Istiak Ahmed[1], and Taskin Jamal[1]

[1]Affiliation not available

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Riyad Salehdin
Dept. of Electrical & Electronic Engineering
Islamic University of Technology
Gazipur, Bangladesh
riyadsalehdin@iut-dhaka.edu

Showrov Rahman
Dept. of Electrical, Computer & Biomedical Engineering
University of Rhode Island
Rhode Island, USA
showrov_rahman@uri.edu

Istiak Ahmed
Dept. of Electrical & Electronic Engineering
Independent University Bangladesh
Dhaka, Bangladesh
istiak@iub.edu.bd

Taskin Jamal
Dept. of Electrical & Electronic Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
t.jamal.eee@aust.edu

Abstract— **Electric Vehicles (EVs) have already been playing a key role in reducing carbon emissions; and in the future, their importance is expected to grow even more. The number of EVs in developing countries is also increasing with time. Bangladesh, a developing country located in South Asia has witnessed a remarkable bloom in the number of Electric 3-wheelers vehicles. However, like other developing countries, Bangladesh faces great difficulties in balancing the net energy supply and demand. To address this issue of maintaining grid stability and fostering the ever-growing trend of EV adoption, this study introduces an optimization approach that regulates the total load of electric vehicles. Utilizing a heuristic method, this paper focuses on peak shaving and valley filling techniques for the specific EV charging patterns of Bangladesh. This approach incorporates three objective functions designed to amplify the difference between power generation and EV load during peak hours while reducing it during valley hours, all while considering the inclusion of weightage factors. Simulation data demonstrate that the implemented algorithm offers superior performance compared to the non-optimized system. Furthermore, we also estimated the electricity generation and EV load for the year 2030, and the result shows that the algorithm also function well with the forecasted data of electricity generation and demand.**

Keywords— electric three-wheelers, EV charging, electric vehicle, heuristic optimization, peak shaving, valley filling.

I. Introduction

Bangladesh is a small but rapidly growing country situated in the South Asian region. In recent years, Bangladesh has seen rapid economic growth and at the same time a significant increase in population [1]. Therefore, it is facing a continuous challenge balancing the net energy supply with the net energy demand. To make things worse, the country is also one of the major victims of climate change and global warming[2]. Although the share of carbon emissions of Bangladesh is negligible compared to global demand, the country also faces the growing burden to keep up with the other countries to achieve the sustainable development goals. Increasing the number of EVs and higher penetration of renewable energy can be the solution for all these challenges.

The transportation sector is one of the biggest economic sectors in Bangladesh, and according to a study the estimated number of vehicles (four-wheelers) in Bangladesh would be higher than 0.7 million by 2040[3]. Now, when it comes to the number of EVs in Bangladesh, the market is greatly dominated by Electric three-wheelers (3-Wheelers) vehicles often called “Easy Bike” or “Tomtom” or “Auto” in the local language. The electric three-wheelers are easy to use, cheaper in cost, easy maintenance, suitable for ride-sharing, and therefore they are particularly suitable for the present socio-economic condition of Bangladesh. One study conducted in 2019 shows that the number of estimated easy-bikes and the motorized electric rickshaws are 1 million and 240000 respectively [4]. The government is also taking various measures to facilitate the growth of EV adoption and EV market even further. The Automobile Industry Development Policy 2021 established by the government aims to sustainably power at least 15% of the registered vehicles by 2030[5]. To achieve this goal, the policy has introduced several initiatives such as tax holidays and fiscal incentives for local assembly of EVs. According to the estimation of Syed Abdullah-Al-Nahid et al taking the insertion of a 40% carbon-tax into account, the EV numbers in Bangladesh could potentially reach 3 million by 2040[3].

Like other developing countries, Bangladesh is highly vulnerable to global energy shortages. Maintaining an optimal balance of generation cost and reliable supply of electricity is a big challenge [6]. Load shedding is often observed in many areas in Bangladesh. The inclusion of a higher number of EVs can make the situation even worse. Approximately 1 million easy bikes are currently residing in this country and the consumed power can be several kilo watts per easy bike [7]. Therefore, optimized charging of EVs is essential to ensure optimal EV charging load consider peak and off-peak load size and load hours. A research study on EV charging station optimization for Bangladesh employing a fuzzy logic technique has been presented in[8]. The implemented optimization algorithm adjusts the charging rate for different condition.

This article presents an optimization approach for regulating the load of electric vehicles (EVs) by a heuristic method that is intended to carry out peak shaving and valley filling techniques while taking special parameters related to Bangladesh's EV charging patterns into account. The technique makes use of three objective functions to increase the generation and EV load difference during peak hours and decrease it during valley (off-peak) hours with weightage factors in consideration. The performance of the algorithm has been evaluated against the typical non-optimized load pattern for both the current conditions (2023) and also with the estimated of power generation and demand in 2030.

The organization of this article: Section 2 explains the EV load optimization process and algorithm, Section 3 demonstrates the simulation results, and lastly Section 4 conclude the article.

II. EV Load Optimization

A. EV Load and Charging Pattern Specifications

For optimizing the total EV charging load, the specification of the vehicles is required. The power rating of an EV can vary depending on the EV size, specification of motor and the energy storage system. In recent years, different energy storage devices such as fuel-cell and supercapacitors are also being tested in EV technology along with batteries [9].

In this study, electric three-wheeler vehicle is considered. The electric three-wheeler vehicles in Bangladesh are also popularly called Easy Bikes (EB). Figure 1 shows a typical electric 3-wheeler (E3W) used in Bangladesh and Table I provides the specifications of a singles E3W considered for this study [10].

Fig. 1. Electric Three-Wheeler in Bangladesh [10]

TABLE I. Specification of a single electric three-wheeler vechile

Parameters	Value
Average Power (Motor Capacity)	1200 W
Battery Capacity(E_m)	130 Ah
Battery Configuration	5 Batteries (12V | 30 Ah)

TABLE II. Input-Output Parameters for the Algorithm

Input	Output
Electric Load(P_i) : 1.2 kW	EV load at time t $L(t) = P_i * N * d(t)$
Total EV numbers (N): $1 * 10^6$ (2023) $1.5 * 10^6$ (2030)	
Charging Distribution($d(t)$)	

In this study, a specific type of easy bike is being considered which indicates load for a single EB is fixed as per the below equation [7], [11].

$$P_i = (1 - S_i) * \frac{E_m}{C_i} \quad (1)$$

Here, i refers to the index of easy-bikes; P_i refers to electric load; E_m , C_i and S_i indicates the maximum energy storage capacity of the easy-bike in study, charging time, and the state of charge respectively. To find out the optimized total load due to EV charging as per the heuristic algorithm at a specific hour, the parameters listed in Table II are considered [7].

Some studies have been conducted to examine the share of EV connected to the grid in a day [4] [11]. We also considered a similar charging pattern as presented in [4] [11] and the charging distribution pattern is shown in Fig 2. This charging distribution follows a similar approach of hourly-based charging schedule for Bangladesh. Considering the traffic intensity and the tendency to charge during rush hours[7], [11] the hourly number of EVs charging can be configured as shown in Fig. 3.

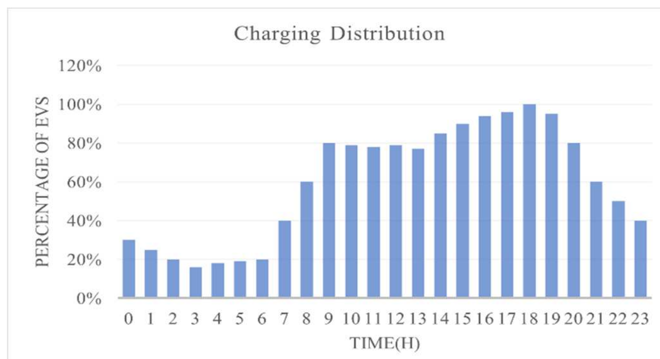

Fig. 2. Percentage of distribution of EV charging in a typical day

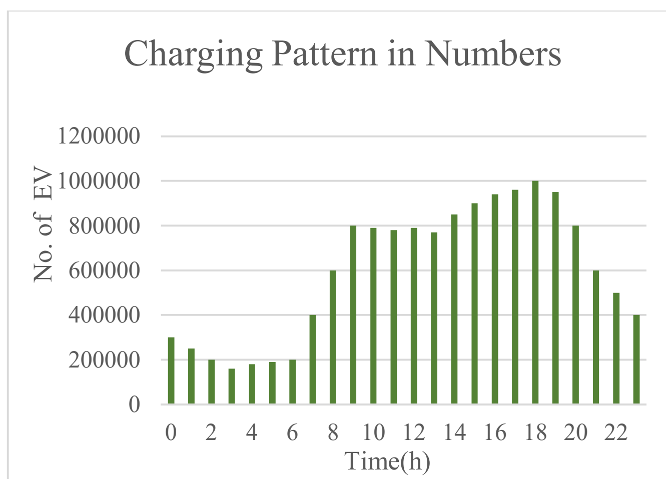

Fig. 3. Number of electric vehicles connected for charging in different time of a day

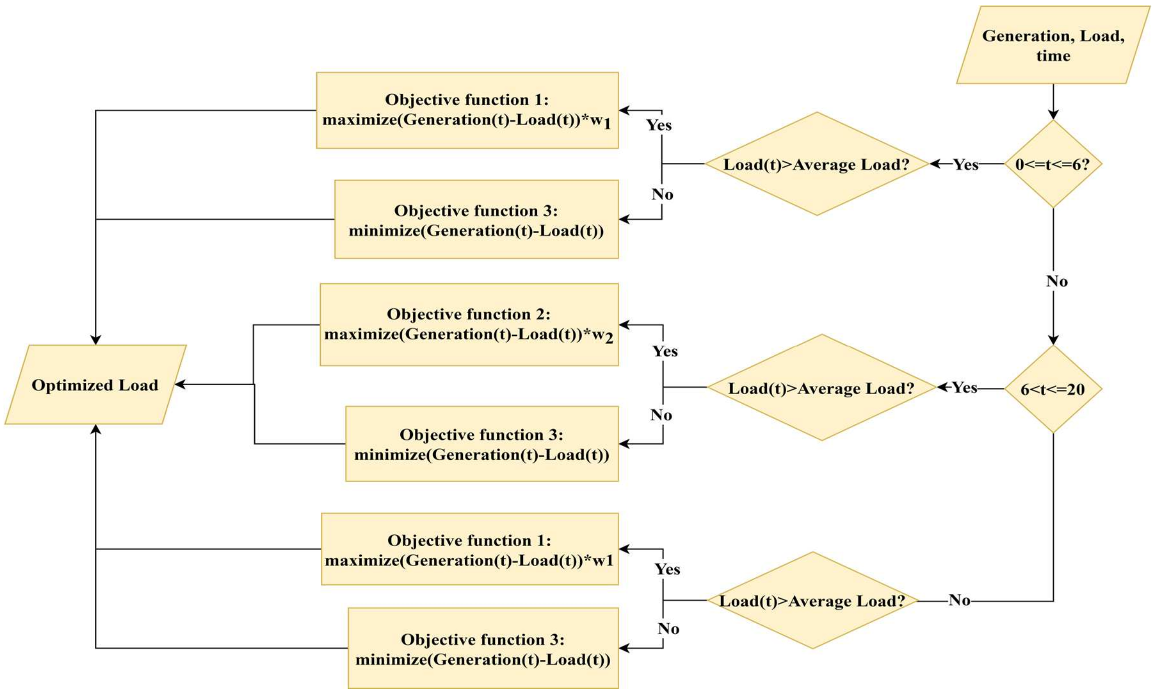

Fig. 4. Flowchart showing the implemented Heuristic Algorithm considered in this study.

B. Objective Function

Three objective functions have been employed for load optimization, considering variations in charging patterns during the day, night, and electric three-wheeler charging behavior. It is observed that E3Ws tend to begin their peak charging hours around 8 PM and drivers typically depart with their vehicles around 6 AM. In response to this scenario, weightage factors are incorporated into the load optimization process to ensure that drivers are not compelled to refrain from charging during peak hours to achieve peak shaving. When identifying peak loads falling within the 8 PM to 6 AM time frame, a weight factor is applied for 10 out of 24 hours. If peak loads occur outside this time window, a weight factor is applied for 14 out of 24 hours. Weight factors are not applied during valley hours. Below are the three objective functions:

$$O_{p_1} = maximize\ [G(t) - L(t)] * w_1 \quad (3)$$

$$O_{p_2} = maximize\ [G(t) - L(t)] * w_2 \quad (4)$$

$$O_v = minimize\ [G(t) - L(t)] \quad (5)$$

Here, O_{p_1}: objective function for peak shaving between 8 PM to 6 AM, O_{p_2}: Objective function for peak shaving between 6 AM to 8 PM, O_v :Objective function for valley filling for the entire 24 hours, $G(t)$:Power Generated by grid at time t, $L(t)$: EV load at time t, ω_1 :weightage factor (10/24) for 8 PM to 6 AM for peak hours, ω_2:weightage factor (14/24) for 6 AM to 8 PM for peak hours.

The weightage factors are decided in such a way accommodating the ratio of total hours from 8 PM to 6 AM to total hours for the day for ω_1 and the ratio of total hours from 6 AM to 8 PM to total hours for the day for ω_2.

Objective function 1, which is active during night-time hours (from 8 PM to 6 AM), serves as a crucial element in the optimization process. It maximizes the difference between the generation and EV load during these hours, thus promoting peak shaving. Peak shaving is achieved when the algorithm reduces the load on the grid during high-demand hours, helping to prevent grid overloading.

Objective function 2 takes charge during daytime peak hours (from 6 AM to 8 PM). Like objective function 1, it also maximizes the difference between generation and EV load. By adjusting the load during daytime peak hours, it further contributes to the peak-load-shaving strategy, ensuring that the grid can manage the higher demand for electricity efficiently.

Objective function 3 addresses valley hours where its primary objective is to minimize the difference between generation and EV load during these hours. However, it is crucial to note that the weightage factors are not considered for valley hours, as the focus is on enhancing load during these periods.

The load optimization process, driven by the three objective functions and weighted factors, successfully achieves the twin objectives of peak-demand shaving and valley-filling, ensuring that the generation and load profiles remain harmonized.

C. Heuristic Algorithm

The implemented heuristic algorithm is illustrated in Fig 4 using a flowchart diagram. The result of the load optimization process demonstrates the practical implications of the heuristic algorithm. This process focuses on optimizing EV load on an hourly basis by striking a balance between generation and load, thus ensuring grid stability and sustainability. The three objective functions play a pivotal role in achieving this balance.

The algorithm considers three objective functions mathematically described in Eq. (4), (5), and (3). The main goal is making sure that the load never surpasses the generation. This algorithm optimizes the load so that peak shaving is guaranteed for loads greater than average and valley filling occurs when the unoptimized load is lower than the average load, all in an effort to meet the growing demand for EVs and EV charging. Three inputs are required by the algorithm for hourly optimized load calculation: generation, load, and time. It confirms whether the time zone is from 0:00 AM to 6:00 AM. This allows for the implementation of (3), which identifies peak hours by determining if the load is higher than average load and ensures peak shaving in a way that allows it to have enough room to deliver enough optimized load curve to meet the increased charging demands during this time period. Eq. (5) is taken into consideration if it determines that the load is less than the average load. If the algorithm determines that the load is in the peak hours from between 6:00 AM and 20:00 PM, it optimizes the load to achieve peak shaving or else to facilitate valley filling and to better distribute the load among the charging stations, the load is increased during valley hours. The optimized load is either made higher than the unoptimized load to guarantee valley filling when the algorithm detects valley hours for the time period between 20:00 PM and 24:00 PM, or it is made lower while taking the weightage factor into consideration when peak hours are detected.

III. Simulation Result

Based on the generation capacity of the grid on an hourly basis, the load optimized considering peak shaving and valley filling. MATLAB software was used for performing the simulation, and the result have been presented in this section. The Power Grid Company of Bangladesh Limited (PGCB) published the daily power generation data in their website in an hourly basis [12]. We took the data from November 2022 to October 2023. For every month we considered the power generation data for the 1st day, 15th day and the last day of the month and then we considered the average power generation of these three days. Since the generation data may very day to day, averaging the data will prevent any rapid fluctuation in the data being used.

A. Current Load Optimization

For 2023, total of 1 million electric three vehicle number is considered where each vehicle can consume an average power of 1.2 kW. For the generic unoptimized load, the charging pattern of Fig 3 is considered. The power generation data, non-optimized load and the optimized load acquired from the heuristic algorithm model are illustrated in Fig 5. Fig 5. is generated using the heuristic algorithm applying Eq. (3), (4), and

Eq. (5). In Fig 5, the x-axis shows the hourly time where 0 indicates the time 12 AM, and 23 refers to 11 PM at night.

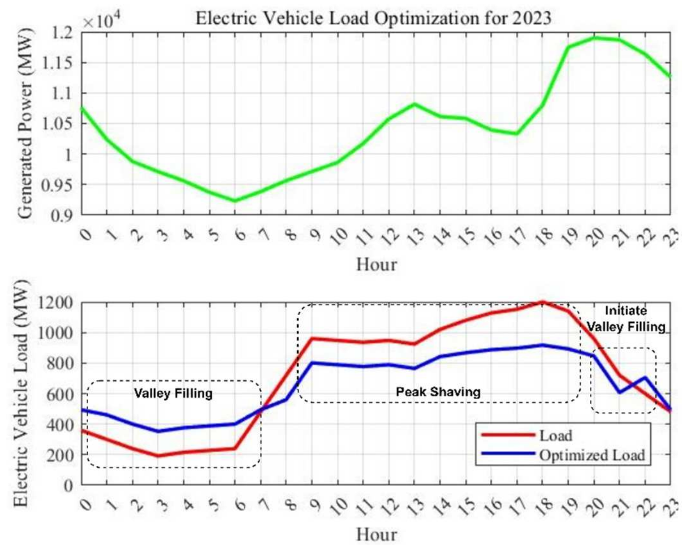

Fig. 5. Hourly power generation, non-optimized and optimized hourly EV load for the year 2023

Since drivers tend to charge more frequently between the hours of 20:00 PM and 6:00 AM, the weighting factor in Eq. (3) ensures that the load is optimized just enough to meet the high demand for charging hours from EV drivers while also preventing it from surpassing the generation during that time. When the load is lower than average between 0:00 AM and 6:00 AM, which are known as the valley hours, because of the charging distribution. In this instance, the load is optimized by Eq. (5) during these hours. Consequently, valley filling is guaranteed, allowing for the charging of more EVs. The load unexpectedly increases after 6:00 AM in accordance with the charging distribution, exceeding the average load. To ensure peak shaving, the optimized load is now made smaller than the unoptimized load during peak hours due to Eq. (4). This confirms that the load will never exceed the graph's minimum generation point. After 20:00 PM, the algorithm detects and optimizes the load in a way that ensures valley filling when the unoptimized load falls below the average load. As seen from Fig 5., compared to the non-optimized load, the implemented algorithm offers better performance.

B. Future Load Optimization

Fig 6 shows the forecasted power generation data, non-optimized load, and the optimized load for the year 2030. To acquire the forecasted power generation data, we first analysed the forecasted power demand for future. The forecasted total electricity demand for Bangladesh can be found in several studies which may use different estimation method [13], [14]. For this study we considered the total energy demand data recorded by S. M. Hossain et al [13]. According to [13], the total electricity demand increased from 15,800 in 2022 to around 34,000 in 2030. We calculated the Compound Annual Growth Rate (CAGR) using these data for time of 8 years and found that the rate of growth (CAGR) is approximately 10%. Now, assuming the power generation would highly corelate with the forecasted demand, we applied the similar 10% CAGR growth rate on the power generation data in available in 2023 to find an

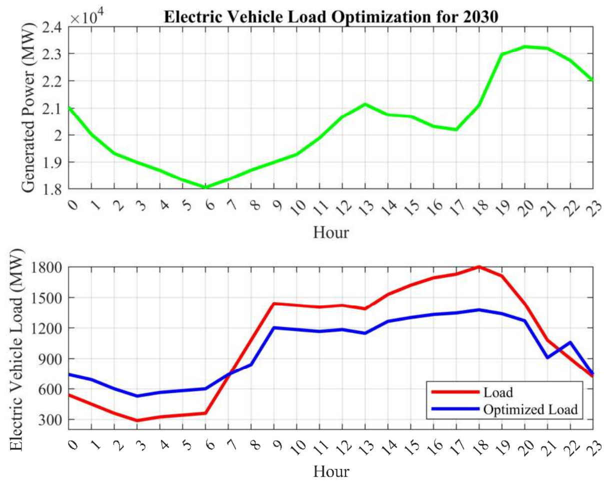

Fig. 6. Hourly power generation, non-optimized and optimized hourly EV load for the year 2030

approximate estimation of the hourly power generation for the year 2030. For the EV load, the total number of 1.5 million Electric three-wheeler (E3W) has been considered. The simulation result is shown in Fig 6.

IV. Conclusion

A heuristic algorithm-based total EV load optimization process has been presented in this study. The algorithm considers the hourly power generation in Bangladesh, the number of total electric three-wheelers in Bangladesh, and their estimated hourly charging profile. It has been found that the algorithm provides a better result compared to the non-optimized system. We also estimated the approximate future electricity generation and EV load in Bangladesh for the year 2030; and we applied the algorithm considering the future electric power generation and load. The algorithm functioned quite well for future generation and electricity demands. However, EV technology changes very rapidly; and besides that electricity generation and load forecasting also depend on several factors and assumptions. Therefore, it is difficult to predict the accurate numbers and data. The future aim of this project is to implement a smart charging application for the EVs in Bangladesh enabling the optimized allocation of charging stations in different divisions of the country.

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