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Solar Charging Station for Easy Bikes in Bangladesh: Validation and Post-Model Evaluation

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Abstract

The significance of renewable sources of energy is enormous in reducing the demand, use, and also price of fossil fuels following recent advances in related technologies allowing for the development of solar-powered cars. The number of users of electric vehicles (EVs) is increasing rapidly day by day all over the world. Due to the growing number of users of EVs, our existing electrical network is facing a lack of electric power because of the overload. As the number of electric and hybrid vehicles increases, efficient and integrated charging stations must be developed to solve the overload issues in existing networks. To address this, the paper proposes using onsite renewable energy sources such as solar energy and existing networks to improve the efficiency and effectiveness of charging stations. Combining photovoltaic with battery storage in a grid-connected system ensures the reliable functioning of the hybrid charging station. The paper focuses on the post-model evaluation, charging station distribution and location, business model, limitations, and software simulation and corresponding calculation. The results show that hybrid-powered charging stations can be economical, dependable, and efficient enough to fulfill the various demands of electric vehicle loads.

Keywords: Charging Stations, Electric Vehicles, Easy Bikes, Integration Photovoltaic Energy, Battery Storage.

Highlights

- Integration of solar energy for eco-friendly charging solutions.
- Cost-saving benefits for electric vehicle users in Bangladesh.
- Comparison between gasoline and electric vehicles for sustainability.

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1 Introduction

At present, developed countries around the world are working rigorously on renewable energy. Among the renewable energy sources, the resource that is the most broadly utilized resource from nature is solar power. Solar power is collected from natural resources that as sunlight by using photovoltaic (PV) panels. Based on its characteristics, the PV panel will produce the most energy when maintained at a constant temperature. Methane, carbon dioxide, nitrous oxide, and other man-made compounds include significant greenhouse gases. Since carbon dioxide is now responsible for the majority of the warming produced by human activity, it is widely accepted that carbon dioxide is the most significant anthropogenic greenhouse gas. In this case, by using solar energy as a form of renewable energy in place of fossil fuels, greenhouse gas emissions are reduced and climate change is prevented. To give the next generation the gift of a sustainable and green future, we need to not only innovate but also deploy renewable energy technology together with the shift in the consumer mindset [1]. Governments of many countries are constantly taking mega projects on renewable energy sources [2]. Recent breakthroughs have accelerated the development of cars driven by solar energy. However, to power electric vehicles, renewable energy sources are required. There are many different ways to produce electric power. In addition to the growing popularity of electric vehicles, almost everyone will install a solar power system in their houses in the next years. [3].

In Bangladesh, similar trends are also in action. Bangladesh's environment is suitable for the setup of Photovoltaic panels and widespread battery charging station deployment that is eco-friendly. However, this requires in-depth study in terms of feasibility, efficient design choice, policy adaptation, and private and public investments regarding Solar Battery Charging Stations for Electric Vehicles [4]. One thing we have noticed is that in many countries like the USA, Japan, China, and Sweden, there have been successful projects already running with traction for generating battery charging stations for electric vehicles using PV panels [5].

The need for public transportation has significantly increased due to the increasing urbanization and population rise. Internal combustion engines powered by fossil fuels are increasingly used for transportation, which has an adverse effect on the environment. In Bangladesh, public transportation offers improved opportunities for electric three-wheelers (E3W) or easy bikes. Because of its services that are both pollution- free and passenger-friendly, Easy bikes are becoming more and more popular. The stability of the vehicles, regulations, the availability of energy, battery disposal, etc. are just a few of the difficulties [6]. With the increasing worldwide use of electric cars and renewable energy, collaboration between the energy and transportation sectors provides a unique and fascinating case study [7][8][9]. The present article analyzes the current literature on the construction of renewable energy charging stations from two different perspectives: study objectives and techniques.

Regarding the methodology for the study, the two primary tools are implemented into the computer Proteus 8 simulation software through mathematical design. Considering the previously mentioned methods, applying a nonlinear programming enhancement approach, Nakata et al. [10] maximize system setup and working for a Japanese heat and power supply company. Muis et al. [11] optimize a power generation plan for a country to fulfill its CO2 emission objectives using a hybrid mathematical linear integer programming demonstration model. A multiple-use developmental programming technique is used by Bhusal et al. [12] to support the remote energy system concept. A multiple-objective optimization method is proposed by Kim et al. [13] to ascertain the ideal distribution of renewable energy production. These frameworks can be suitable for relevant investigations since they are determined. However, It requires time to create a new tool for each evaluation. Therefore Significant mathematical programming and debugging effort can be avoided if useful and easily accessible tools are provided. Connolly et al.'s research [14] examined computer methods for analyzing how renewable energy is integrated into multiple energy networks. The INVERT energy tool is assessed by Tsioliaridou et al. [15] to effectively encourage renewable energy source innovations in the energy industry. Mahmud et al. [16] used a computer dynamic economic analysis model to assess three supply choices for an independent energy system. In Bangladesh, the number of auto-rickshaws, easy bikes, and electric vehicles powered by batteries has increased, respectively. Easy bikes are both comfortable and eco-friendly. However, despite the increase in the number of electric vehicles, Bangladesh lacks even a single charging point [17]. To charge all of these electric rickshaws-autos, consumers have to pay a large number of electricity bills. However, as the quantity of electric cars is growing in Bangladesh, at the same time the number of fossil-fuel vehicles is decreasing. We already know that gasoline-powered vehicles release a significant amount of carbon dioxide. On the one hand, this is extremely detrimental to the environment; on the other hand, our fossil resources are rapidly depleting [18]. We can employ clean energy and prevent environmental contamination from the earth's warm atmosphere. By the year 2021, the Bangladeshi government (Govt.) plans to have installed in place 2000 MW of energy from renewable sources. We will use fewer fossil fuel power plants overall if we install solar-powered charging stations for electric automobiles [17]. Since solar energy is environmentally friendly and appropriate for Bangladesh, the primary mechanism for PV-EV in this system is sun heat. So far, we have been able to prevent environmental pollution and ensure that there is an inherent demand for electricity by charging electric vehicles with solar power.

2 Model Description

In this instance, it will provide the grid with additional current throughout the summer and continue to charge from the grid even when there is less sunlight:

1. Create an innovative proposed arrangement that includes solar energy generation and electric vehicles to simultaneously reduce contaminating emissions from the energy generation and transport sectors, which we explained in the previous part of this paper.

2. To explore the economic viability of MATLAB simulation and the main variables influencing it based on a case study in Bangladesh.

3. Present recommendations for the successful implementation of imaginary architectural models found in urban areas, operations, and finance.

The photovoltaic panels installed in the outside parking spaces are linked using bide nomination meters to connect to the grid together with the electric vehicles. The Energy of the photovoltaic system will be instantly preserved in electric automobiles or other vehicles throughout the day. If more energy is generated than what the batteries in electric vehicles can store, the extra energy may be sold on the National Grid. When grid prices are low enough at night, electric vehicles can begin charging.
Here, we illustrate how two different Power charging station models operate. The first is the concept of real-time charging which contends that as long as solar electricity is available, electric automobiles or other vehicles can be recharged at any time. The second option is to use autos or other vehicles that have mobile charging stations.
The two filling kinds are treated differently in the simulation model due to the two filling types' highly distinct systemic features. The biggest load is what's known as real-time load, or the power requirements that must be satisfied at a specific moment. One may consider the mobile charging vehicle to be a deferrable load, an electrical request that may be satisfied at any moment within a predetermined time window, although the actual timing is variable. Fig. 2. represents the theoretical model of the charging system.
The remaining portion of this research is arranged in the following order: Section 3 represents the post-model evaluation. MATLAB simulation and calculation are highlighted in Section 4. Finally, this manuscript concluded with the conclusion and valuable future recommendations based on our analysis, which is presented in Section 5.

3 Post-Model Evaluation

3.1 Charging Station Distribution and Location

Urban region land is highly desirable in the majority of cities. Finding an enclosed, undeveloped space in a city to install photovoltaic solar panels is therefore impractical. An alternative to consider is mounting solar panels on rooftops, but it seems difficult to bridge the ownership and interest gap between homeowners and solar power plant owners. As a result, there is a very small area of urban land suitable for the installation of solar PV arrays. Additionally, the installation of solar panels is suitable for use as a solar charging station in large cities like Chittagong due to their placement and distribution.

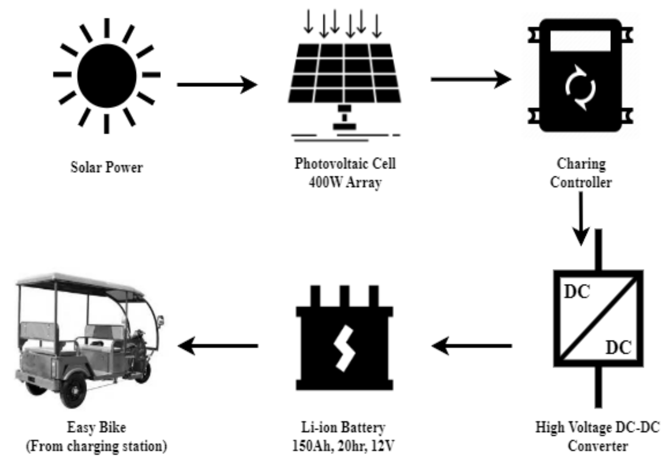

Fig 1. An easy bicycle solar power charging station model in theory.

The most congested areas of the city can practically accommodate solar charging stations; ground resource congestion happens when there is not enough space for parking and charging electric automobiles. In these circumstances, the idea of mobile charging can be applied. Only vehicles with high-capacity battery banks are permitted to be parked in this kind for recharging. Electric automobiles or vehicles that are fully charged can travel throughout and return if they need to recharge.

Table 1. Cost analysis of 10 easy bike charging stations (solar and grid)

Name of Equipment	Qty.	Unit	Per PCS Rate	Total Approx. Rate (BDT)	Remarks
PV Panel 400W	41	PCS	3,048	1,24,968	400W × 41PCS=16.4KW
Li-ion Batteries	40	PCS	20,000	8,00,000	1 Vehicle for 4 Batteries
Charging Controller	10	PCS	2,500	25000	For 5 Zone PV Array
DC-DC Converter	10	PCS	850	8,500	Each Electric Vehicles
Inverter (600W, 48V)	1	PCS	25,000	25,000	For Grid Connection
NYY 3 × 10RM Cable	1	Coil	25,000	25,000	Connection
Solar DC cable 10 RM	1	Coil	20,000	20,000	Battery terminal connection
Transformer 250 kVA	1	PCS	380,000	380,000	Step down transformer
Software cost	1	-	40,000	40,000	Auto transaction detection
Collecting Lug	100	PCS	5	500	Batteries Connection
PV Stand	5	PCS	1,600	8,000	Basement
Land Cost	675	RFT	0	0	Public Parking (45 × 15 sqrt.)
			30,000	30,000	
Govt. Permit charge			40,000	40,000	
Civil work Installation Charge			50,000	50,000	Average Initial Cost
Grand Total Value				15,76,968 BDT	
Sub-total Cost for Solar Installation				10,52,000 BDT	
Sub-total for Grid Connection Cost				5,25,000 BDT	

3.2 Creating a Business Model and Findings of Limitations

When it comes to the commercialization of electric vehicles in the majority of Bangladeshi regions, the lack of charging stations is a significant concern. The commercial strategy being created and put into action, in this case, does not adequately balance the interests of all parties.

Few social entrepreneurs, however, are prepared to spend money on renewable charging stations. Another possibility is that certain government- and semi-government-funded charging station initiatives are dormant due to ineffective management and location, squandering important social assets. The higher initial cost is an additional essential aspect limiting the adoption of electric vehicles. The" Electric Vehicle Timeshare Rental (EVTR)" business plan can overcome two obstacles to the marketing of electric vehicles. A standard car rental and an" Electric Vehicle Timeshare Rental (EVTR)" differ in the following ways: To begin with, "Electric Vehicle Timeshare Rental (EVTR)" is only appropriate for quick trips within cities because it is priced per hour. To save money, small or micro EVs are regularly automobiles that are hired out as targets. Second, Costs for electricity are included in the rental charge, allowing consumers to save money on gas. Third, an essential factor affecting the achievement of this business model is the requirement to dissolve several rental businesses across the nation. The number of refill points should be sufficient for customers to pick up and cost-effectively return EVs; these outlets do not need to be larger. The solar-powered plant in the wind and rain corridor has numerous points of convergence in this scenario. Future solar charging stations may be gradually installed on pathways, and rooftops of private and public buildings, schools, and universities as a result of the rising popularity of electric vehicles. Any place with sunlight and a roof can serve as a small Photo Voltaic – Electric Vehicle charging station and an Electric Vehicle Timeshare Rental (EVTR) system node.

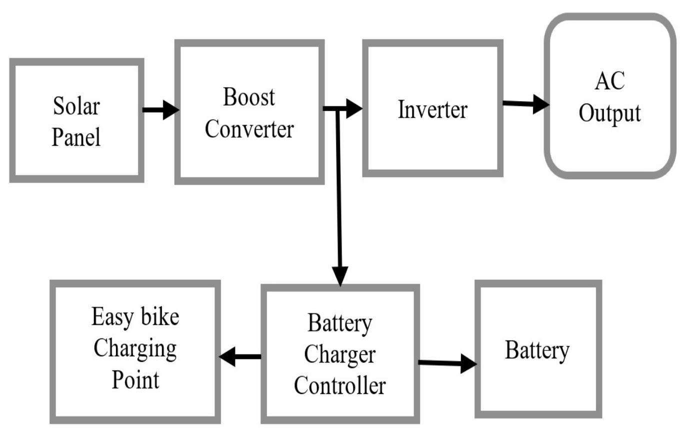

Fig 2. Schematic diagram model of a solar power charging station for easy bikes.

4 Matlab Simulation and Calculation

4.1 MATLAB Simulation and Output Calculation

It is a simulation-based work because, At the moment, Bangladesh doesn't have solar energy charging stations. So, we have no way to visit or collect DATA physically. But the solar system is not new in our country; we already use it in the agricultural water pump, Nano Grid of home applications, road lamps, etc. Anyway, very few countries work on solar-powered charging stations for commercial purposes. So, we observed DATA analysis, what limitations there are, the working procedures, and how cost-effective for Bangladesh. Therefore, we performed physical DATA analysis and visited different Easy bikes, Autos, Rickshaws, and electric car drivers and noted their opinions.

Table 2. Battery sizing (lithium-ion battery)

Characteristic	**Description**	**Remarks**
Vehicle Requesting Charging	$1500 \times 10 = 15000$ W/h	
Nominal Battery Voltage	12V	
Days of Autonomy	$1clay$	
Battery Loss	0.85	
Depth of Discharge	0.8	
Nominal Voltage	12V	
Total Battery Amp-hourse	$\left(\frac{1500}{0.85} \times 0.8 \times 12\right) \times 1$	$P = VI, I = P/V$
Battery size for One-day Autonomy	$15,000Ah, 12V$	

Table 3. Load calculation for 10 easy bikes)

Connecting Load	**Power (KW)**
Required Fall Charged Per Auto Bike	1.5
For 10 AUto Bikes	$1.4 \times 10 = 15$
5 Times/Day(Need 2hrs Battery Full)	75
Extra Capacity (10%)	82.5
Extra Capacity (10%)	85

4.2 Calculating the Size of the PV Panel

4.2.1 Determining Power Consumption Demands (Load):

For the Total PV panel required,
Vehicles that want to charge
$= 48V, 32\ Ah; [12V \times 4\ PCS]$
$= 1536\ Wh/day$
Total applicance
$= (watt - hoursperday) \times \phi$
$= 1500 \times 1.3$
$= 1950\ Wh/day$
Here,
ϕ = 1.3 is the loss factor in the system [PV module(0.5% - 1.5%)]
As a calculation,
We are charging 10 vehicles/day
$= 1950 \times 10$
$= 19500\ Wh/day$

Table 4. System analysis: solar vs. Grid charging

Comparison Parameter	From Solar Charging Station	From Grid Charging
Cost per unit	3	5.5
Required charging time per Auto bike	2 hours	3 hours
Required power per Auto bike	1500 W	1500 W
Monthly charging cost per bike	270 BDT	1,283 BDT
Monthly charging cost for 10 bikes	2,700 BDT	12,825 BDT
Annual Consumption	32,400 BDT	1,53,900 BDT
Yearly Cost Minimization	1,21,500 BDT	-

4.2.2 Size of PV Panel:

Panel generation factor = 4.32 (For Bangladesh)
Suppose, we will take here 8 hours per day of panel generation factor.
The total power rating of the panel
$= \frac{\text{power consumption demands}}{\text{panel generation factor}}$
$= \frac{19500}{4.32}$
$= 4.514$

4.3 Cost Analysis

where Table 1 represents the cost analysis of 10 easy bike charging stations, and the following Table 2 highlights the battery sizing-related information we used in this study.

4.3.1 Solar Charge Controller Sizing:

Here, The size of the solar charge controller = The overall current of the Photovoltaic panel for short circuits The

Table 5. System analysis: comparison between Gasoline and Electric vehicles

Description	Gasoline Vehicles	Grid Charging Vehicles	Solar Charging Vehicles	Remarks
Cost per kilometer	7 BDT	3 BDT	0.08 BDT	SCVs are cost effective
Running hours per day	16 hours	12 hours	14 hours	SCV is good enough
Speed per kilometer	80 km/h	40 km/h	50 km/h	SCV speed is sufficient for situations in Bangladesh
Normal capacity	5 persons	8 persons	8 persons	SCVs have better capacity
Carbon emission per kilometer	1.7 kg/km	0.98 kg/km	0.06 kg/km	Eco-friendly SCV has lower carbon emission

Table 6. Cost comparison: Plant consumption vs. Profit

Description	Solar Charging	Grid Charging
Total Cost (Initial installation value)	10,52,000 BDT	5,25,000 BDT
Operation & Maintenance Cost (Annual)	15,000 BDT	50,000 BDT
Battery Replacement Cost (After 10 Yrs., Annual)	1,00,000 BDT	-
Inverter Replacement Cost (After 12 Yrs., Annual)	25,000 BDT	80,000 BDT
Transformer maintaining (Annual)	0 BDT	25,000 BDT
Generated power (Annual)	162 MW	40 MW
Utility Consumption (Annual)	3,28,050 BDT	2,62,500 BDT
Revenue of system (Annual)	5,00,000 BDT	3,50,000 BDT
Payback period (months)	76 months	24 months
Profit (Annual)	1,71,950 BDT	87,500 BDT

short circuit current of the 4.514 kW panel is,

$$9.3112A = 111.72A$$

So, the solar charge controller rating should be 120A or greater. Table 2 presents the equipment name and their charge controller sizing ratings.
Charging time of the battery,

$$T = \frac{Ah}{A}$$

Where, T = Time, Ah = Ampere Hour rating of the battery, and A = Current in Amperes.

4.4 Plant Capacity and Load Calculation

Plant capacity and load-related calculations are presented in this segment. Table 3 represents the example load calculation for 10 easy bikes along with plant capacity.

4.5 State of Charge and Depth of Discharge

State of charge (SOC): The amount of charge an electric battery has about its capacity is known as its state of charge. It is the ratio of charged stored $\mu(t)$in the battery to nominal capacity $\mu(n)$.

$$\text{state of charge} = \frac{\mu(t)}{\mu(n)}$$

Depth of Discharge (DOD): The percentage of power that can be extracted from the battery is determined by the depth of discharge. As example, an 1800Ah battery having 80% of Depth of Discharge, the solution:

Battery Ah $\times$ DOD in%
$= 800 \times 0.8$
$= 440$Ah can be drawn from the battery

4.6 Fundamental Parameter (Electricity Requirements)

Bangladesh does not currently manufacture PV solar cells. That is why we are researching the Chinese solar business, and in the future, we will simply import it and install it in our nation. Everything we use in this project will come from China. However, Bangladesh is a big marketplace for solar industries. So hopefully, the solar array, devices, chipset, controller, and all modules will be produced in Bangladesh.
This photovoltaic power plant is expected to be able to requirements the energy needs of 100 fully charged elec-

tric cars in real-time, as well as mobile charging trolleys. A portable charging truck and a fully charged electric automobile or vehicle require 45 and 500 kWh of power respectively. Therefore, for a single photovoltaic system, the total demand power consumption is 4,300 kWh per day or 1,569,500 kilowatts per year.

4.7 System Analysis

System analysis benefits of - Solar vs. Grid comparison are highlighted in Table 4.
Remarks:
An auto bike driver earns an average of BDT 20,000 per month. The price to pay for his bike charging is 1,283 BDT per month, if we have a charge from solar then he has to pay 270 BDT only. So, he may save 1,013 BDT.

4.8 Comparison of Gasoline vs. Electric Vehicles

A comparison between gasoline vs. electric vehicles is necessary to determine the benefit of electric vehicles over traditional ones. Therefore, Table 5 represents the comparison between gasoline-driven and electric vehicles.

4.9 Consumption

In this segment, we compared plant consumption vs. profit. The details comparison is shown in Table 6.
Notes: Though the initial Solar charging Station installation cost is high, it is more effective than grid connection flowing as sustainable developments.

5 Conclusion and Future Works

In Bangladesh, a solar power plant for electric vehicles is a wonderful prospective location for environmentally friendly and economic applications. Without renewable energy, there is no other way to save the environment as the climate change annually. The efficiency of solar energy charging stations being developed by America, China, Sweden, and Japan now stands at around 60%. If we start this proposal as an experiment in the Chittagong region, it will be a sight to behold for the world and create an innovative idea. Bangladesh intends to advance its commercial economy by introducing a solar hybrid power plant together with an electric car charging station. The consumption of fossil fuels will decline with consideration for future generations. The context of Bangladesh has been thoroughly examined all over the whole concept, as of right present, Bangladesh does not have any solar charging power stations. Without a doubt, if such a project is implemented in both public and private companies, it will be effective. However, the feeder transmission network and grid connection with the controller device are missing in the proposal. In the future, we will be demonstrating the system for controlling using PLC (Programmable Logic Controllers monitoring.

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