Performance Analysis of Solar Charging Station for Electric Vehicle: A Case Study Based on 21.1 kWp Solar Charging Station in Bangladesh

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Abstract— Sustainable transportation can be achieved by the application of a solar charging station for electrical vehicle charging. In Bangladesh, several solar charging stations have been financed and installed by the government authority to a certain extent. However, the economic performance of the existing solar charging station is not satisfactory. Moreover, the illegal use of electricity charging is also proving a hindrance to solar energy adoption in transportation on a rapid scale. This research identifies the charging structure, shading effects, and proper installation are the critical reasons for decreasing viability. To complete the case study, this paper investigates the solar potential, charging tariff, and associated costs to find more technological and economic potential. Based on the present situation and yearlong data analysis, this paper recommends some suggestions which may lead to more financial stability and increase adoption.

Index— Solar Photovoltaic (PV), Electrical Vehicle (EV), Hybrid Electrical Vehicle (HEV), Effective solar hour, Shading Stations (SPCS).

1 INTRODUCTION

Electric vehicles are the light bearers for sustainable transportation. But sustainability can be achieved if the required electricity can be harnessed from a renewable source such as solar energy. Most of the grid electricity comes from fossil fuels[1]. That is why reduction of carbon emission will have a more indirect effect, and for this reason, the solar charging station is well accepted in policy level. The Renewable Energy Policy envisions that 10% of total energy production will have to be achieved by 2020. Bangladesh is very successful in running the Solar Home System (SHS) in rural electrification in off-grid areas. Solar energy should be utilized in urban areas too. In urban areas, high traffic seeks numbers of vehicle running. When these can be converted mostly to electric cars, there's a vast scope of utilizing solar energy and controlling environmental degradation in urban areas. An efficient solar charging station is a must for the successful execution of such a motive.

The government is trying to solve this problem but still failed with convenient resources. There are approximately 900,000 comfortable bikes in Bangladesh, so they need to charge their batteries for which about 9000000kWh electricity is required daily from the grid. Due to the energy crisis, load shedding occurs, and they not able to charge correctly on time. So, to reduce the grid dependency government took a project to build a small charging station all over Bangladesh. It is implemented by the Sustainable and Renewable Energy Development Authority (SREDA) and supervised by Cumilla Palli Bidyut Samity-2. This writing deals with a case study prepared on the above-mentioned solar charging station. The site location is visited several times to analyze its condition and data collection. As a result, a necessary insight is guided for efficiency and better performance. Such case studies will be beneficial for the optimal design of solar charging stations for electric vehicles at the field level.

The power sector in Bangladesh is booming day by day. As demand is racing upwards, so is the production. According to BPDB total installed capacity for power generation in Bangladesh by the year, 2018 is 20,000MW, and the maximum peak generation was 10,958MW. Overall, 91% of the total population in Bangladesh had access to electricity [2]. Bangladesh will need an estimated 34,000 MW of power by 2030 to sustain its economic growth of over 7 percent [3]. Another important issue is the estimated future crisis of fossil fuel. In Bangladesh, commercial energy resources are used to meet the demand for the following end-use sectors: fertilizer (35%), industry (19%), transport (19%) and domestic (17%) sectors [4] consume more energy than other energy sectors. All of these sectors use electricity, and 90% of this electricity is generated from natural gas, while fertilizer production requires the supply of natural gas. Considering the projected future demand and concern about the security of supply, the overuse of natural gas resources, therefore, needs to be avoided as energy demand is increas-

ing day by day due to various reasons. As strong solar radiation (varies from 4 to 4.5 kW/m^2/day, which is a very favorable range for solar energy extraction) is available in Bangladesh throughout the whole year, photovoltaic technology is a feasible option to provide an alternative source of energy to meet the immediate requirement. In many places, electric vehicles and charging stations are getting popularized. In July 2018, a report shows there were more than 55,000 Electric Vehicles (EVs) in Sweden. There are already about 3 million EVs and expected to increase to between 125 million and 220 million by 2030 worldwide. Volvo Cars have announced they will no longer launch vehicles driven solely by internal combustion engines rather will transform the portfolio into hybrids and plug-in EVs. Buses and different other heavier vehicles are increasingly becoming electrified, too [5]. China has become the global leader with 343,500 units deployed in 2016 in the market. China has more than 99% of the all-electric bus stock in the world. They aim to deploy 5 million new Electric Vehicles (NEVs) by 2020. By the end of 2014, the Central Government had already spent approximately 33.4 billion Yuan on NEV subsidies [6]. On the streets of Kathmandu, there are about 714 electric three-wheelers (SAFA tempos) that offer public transport services [7]. Sonam Gyaljen Tamang et el. Have worked on problems and solutions of classical electrical vehicles in Kathmandu [5]. They discussed batteries, geographical structure of routes, passenger-carrying capability, etc. As a solution, they suggested hybrid vehicles or plugin hybrids and high capacity batteries. Charging infrastructure research is also emerging rapidly as EVs seems to be a promising future transportation alternative. Study shows that solar charging station has a potential business in Bangladesh. In rural areas, there are many successful projects for solar energy harnessing such as Solar Home System (SHS). Under the umbrella of Infrastructure Development Company Limited (IDCOL), a solar home system has popularized in rural areas. After the inception of Grameen Shakti in 1996, the program has got impetus. Now Bangladesh has over 1.4 million SHS with a total capacity of 65 MW [8]. But micro or mini-grid PV system has not explored yet in Bangladesh. For the first time in Bangladesh, LGED has completed solar market electrification in a rural market at Gangutia under Shoilkupa Upazila in Jhenaidah district. The successful installation of solar market electrification has created great enthusiasm among the local villagers, and it will act as a milestone for green energy movement in the country. Recently a 10KWp mini-grid system has been installed in Barkal under the Rangamati district by PDB. Also, there is a 5kW mini-grid system in Ukhia under cox's bazar district. Bangladesh Bank has set up a 20.3kWp PV system in its headquarter in Dhaka. Soon solar power vehicles will be the next concern to develop. And the network of Solar Photovoltaic Charging Stations (SPCS) is obvious for solar power vehicles to be in operation in bulk state. There are many examples of the SPCS being installed and financed by a power company. Such examples include the Tesla Supercharger network that is financed by Tesla [9]. In the Netherlands many investors are working on a corporation to install a network of SPCS [10] Even, institutes like Stanford University is installing SPCS on campus and using a power purchase agreement [11]. In California, Washington DC, and Texas, there are hundreds of eV go charging stations installed by NRG Energy Inc. [12]. Coulomb Technologies is operating successfully in Texas, Florida, New York, Michigan, and other US regions, and also in 13 other countries [13]. These companies in their specific regions are fueling the market of electric vehicles. And the growth in electric vehicles not only reducing the burden on peak load but also reducing pollution to a great extent. Jessica Robinson et el have discussed how various business models can be adopted for SPCS and have a profound impact on conserving fossil fuel [14]. This is high time Bangladesh should take steps to flourish the market of electric vehicles too. To popularize this sector, Govt. can reduce taxes, introduce incentives. But proper design and successful operation in a cost-effective and profitable manner is a must. □

I. CASE STUDY

Around 9000MWh energy is used daily from the supply grid to meet comfortable bike charging demand in Bangladesh, resulting in more energy crisis and load shedding. So, the REB has taken a pilot project in hand to set many small systems like 21.0 kWp Solar Power System suitable for supplying 230 Volt, 50 Hz to Easy Bike/Auto Rickshaw Chargers for to reduce the electricity demand. SREDA funds this project. For the case study, the **T&R Solar charging station** is selected here. The location of the charging station is near (11.9 km) to Dhaka Chittagong Highway (**Latitude: 23.372233, Longitude: 91.1446266**). The detailed analysis resulted in finding out some key issues depicting degraded performance. As well as lack of economic viability is also addressed. From the case study, we can summarize the following observations.

The solar charging station is placed in a village location. The electricity generation is hampered due to shading. The production is minimal. The electricity generation is 70 percent of the allocated plant 14.7kW on average. Electricity charging for vehicles is time-based. The Electricity generation for charging stations is 80 kWh per day. The handling of customers for the charging station is abysmal. The rate (BDT) for vehicle charging is not economically viable. The inverter and charge controller is costly (1896000 BDT). Days of autonomy is only one day. Different types of conversion are not very efficient.

II. RESULTS AND RECOMMENDATIONS

For our study, we consider different conditions to perform the financial analysis. We have done the report in three case scenarios. First, we believe the analysis for the following terms shown in Table I.

Table I: Base case scenarios

Fuel Escalation rate	10%
Inflation	5.50%
Life cycle	20yrs

The financial analysis consists of NPV, IRR, BCR, and Payback period for different electricity, and the simultaneous charging rate are shown in table 6.2.

Table 6.2: The results for the base case scenarios in Table 6.1

Base Electricity Price	Easy bike charging price	NPV	IRR	BCR	Pay back
8	72	negative	negative	-1.2	16
10	90	negative	negative	-0.71	12.1
12	108	negative	negative	-0.21	9.7
14	126	negative	negative	0.29	8.1
16	144	negative	negative	0.79	7
18	162	positive	10.5	1.28	6.1
20	180	positive	23	1.78	5.4
22	198	positive	31.5	2.28	4.9
24	216	positive	39.2	2.78	4.5
26	234	positive	46.6	3.27	4.1

Here the assumption is made at full load condition at all the eight units are operation. The charging rate is 125 Tk per bike and 9 kWh for complete charging. The project is not viable at the current pricing where base electricity price 14 BDT,

Easy bike charging price 126 BDT, NPV (-), IRR (-), BCR (0.29), and payback 8.1 years. Moreover, all the units are not operational. In current scenarios, maximum of 4 units can work at a time.

Table 6.3: Base case assumption for Case 2

Fuel escalation rate	10%
Inflation	5.50%
Discount rate	5%
Life cycle	20yrs
Grant	0
Inverter (BDT)	1,000,000

In a solar charging project in Chuadanga, Bangladesh, the world bank and IDCOL financed the project at 50 percent grants and 30 percent soft loan. If these mechanisms are implemented, then we have found some promising results.
The base case and results are shown in Table 6.5 and 6.6.

Table 6.4 – Result shown for case 2.

Base Electricity Price	Easy bike charging price	NPV	IRR	BCR	Payback
8	72	negative	negative	-0.48	25.9
12	108	negative	negative	0.36	15.7
14	125	negative	1.5	0.68	13.7
16	144	positive	6.8	1.2	11.3
18	162	positive	9.9	1.63	9.9
20	180	positive	12.5	2.05	8.8
22	198	positive	14.8	2.47	7.9
24	216	positive	16.9	2.89	7.2

In our study, we have analyzed that the inverter price is higher. If we reduce the inverter price by 50% to 100000 BDT, then the following results and base cases are shown in Table 6.3 and 6.4.

Table 6.5 Base Case Scenarios for Case Study 3

Base case	
fuel escalation rate	10%
Inflation	5.50%
discount rate	5%
life cycle	20yrs
Finance	
Grants	50%
Debt ratio	30%
interest	5%
debt term	Ten year
inverter	1,000,000

Table 6.6 Result for base case in Case Study -3

Base Electricity Price	Easy Bike Charging Price	NPV	IRR	BCR	payback
8	72	negative	negative	negative	11.4
10	90	negative	negative	0.19	9.4
12	108	negative	negative	0.8	6.7
14	125	positive	14.9	1.4	5.5
16	144	positive	21	1.8	4.6
18	162	positive	35	1.9	4

From the above conditions, we can see that the project is viable at the current charging rate at 125 BDT/kWh.

From the base case, as the charging station is in condition, this

project is not economically viable. The solar charging station is not feasible because the rate for charging a vehicle is abysmal. Economic viability can be achieved if the electricity price is increased. The following recommendation can be deduced from the findings: The charging station needs to be free of shading and encourage auto drivers to charge from the station rather than from their homes. The plant should use an efficient tracking system, and the PV module must be cleaned regularly to enhance its power generation. An electricity charging scheme needs to be developed. The charging capacity needs to be increased according to the load demand. Here, the ability to load is minimal. The management system should build a charging schedule for charging. The government should provide subsidies and facilities on equipment so that the cost becomes less so that a more efficient system can be built. The system day of autonomy needs to be increased to the standard stand. Should look for a smaller number of conversion design.

III. Conclusions

A case study has been done in an existing solar charging station for the electric vehicles from the many that were financed and installed by the government of Bangladesh. Many design problems as site selection, shading effect, time-based charging policy, very expensive inverter, less day of autonomy, and so many are detected. Financial analysis has been carried out with three base case to make the project valid and find out the easy bike charging price(125 BDT), IRR (14.9), NPV (positive), BCR (1.4), payback period (5.5 years) in which this project will be economically viable. Recommendations have been listed to fix the existing problems. From this study, we will be able to make some decisions for the future while choosing a site for a solar charging station.

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