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Techno-Economic Feasibility Study of Solar Based Vehicle Charging Station at Tribhuvan International Airport

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Abstract
This article proposes to install the solar panels at the parking areas without affecting to park the vehicle but to provide shade and safe to the vehicles. The energy from the panels can be used to charge the electric vehicles especially electric taxis at Tribhuvan International Airport. The proposed Solar Based Vehicle Charging Station primarily consists of total number of 1900 Solar Panels of 280 Watt/30 V. The system voltage of the Solar System is 600 V, hence there will be 20 nos of Solar panel in Series and 95 nos of Panel in Parallel. The total capacity of battery bank is 6000 AH with each bank of 3000 AH. Each bank consists of 300 nos of Rolls Lead acid cell with each cell 3000 AH/2V. The system consists of 30 junction boxes and 6 combiner boxes with microprocessor based intelligent one main control unit inclusive of Visual Display Unit. The charging mechanism of the controller is primarily MPPT technology. The Charging Station can handle 90 Vehicles at a time with the major priority to Solar Source at the time of sunshine. If adequate solar energy is not available, then the power is supplied through the Battery which is automatically transferred and switched by the ATS. The Solar based Vehicle charging station is found to be feasible as it shows the excellent IRR of 15.03% at discount rate of 12% with satisfactory Payback period of 7.74 years. The levelized Cost of Electricity is found to be Rs.19.97/KWh.

Keywords
solar vehicle–solar panels–charging station

1. Introduction

As we know that at present condition the major fuel resource is the fossil fuel and it is also known that the reserve of fossil fuel is finite, so renewable energy is the solution for this problem of fossil fuel. There are many types of renewable energy, among them; solar energy is one of them. Nepal has high potential of solar energy [1]. But Nepal does not have any petroleum resource so it has imported all the necessary fossil fuels.

Though Nepal is not producing petroleum products but is highly depended on it. Import is the only method to meet the demand for petroleum products. The demand and supply both are increasing day by day. Since 1975 the supply had increased by almost 70 folds. The time period between 1987-1997 is regarded as the first time when there was more demand of Liquefied Petroleum Gas (LPG)[2].It is because LPG was introduced as an alternate of kerosene, electricity etc. in urban and semi urban area. Due to pressure of high population Nepal Oil Corporation (NOC) is being unable to supply properly. Though it has storage capacity of 70309 kiloliters (KL) it is suffering from problem of shortage. NOC maintains very low stock of petroleum products, heightening risks of shortage once supply is disrupted. The current stock cannot last for more than three days of demand in the capital.Also, there is a need for reduction in carbon emissions. Power electric vehicles using rooftop solar panels and charging stations are popular in recent days [3]. In Europe, gas vehicles will be banned in 2050. Many major car companies have come out with electric vehicles recently. Many new, smaller companies have also developed electric vehicles. The range of electric vehicles is less than that of gasoline powered vehicles[4]. Improvements in efficiency must be made to increase the range.

The 1960s and 1970s saw a need for alternative fueled

vehicles to reduce the problems of exhaust emissions from internal combustion engines and to reduce the dependency on imported foreign crude oil. During the years from 1960 to the present, many attempts to produce practical electric vehicles occurred and continue to occur[5]. The purpose of this study is to describe the technology used to produce an electric vehicle and explain why the electric engine is better than the internal combustion engine. It includes reasons why the electric vehicle is a necessity to better the world today. The report describes the most important parts in an electric vehicle. It compares the electric to the hybrid and internal combustion engine vehicle. It also includes the future of the electric vehicle.

The overall impact of the electric vehicle ultimately benefits the people. Compared to gasoline powered vehicles, electric vehicles are considered to be 97% cleaner, producing no tailpipe emissions that can place particulate matter into the air[6]. Particulate matter, carcinogens released into the atmosphere by gas-powered vehicles, "can increase asthma conditions, as well as irritate respiratory systems." [7] At the same time, the electric passenger cars that are being developed are not yet competitive with conventional vehicle technology[8]. Costs are still high and battery technology is still being developed, and there exist many uncertainties with respect to crucial issues such as:

Battery technology (energy capacity in relation to vehicle range, charging speed, durability, availability and environmental impacts of materials). Interaction with electricity generation.

2. Materials and Methods

2.1 Site Selection and Data Collection

The site of Tribhuvan International Airport has been selected. The three parking areas were measured and the area in front of the international terminal was selected for the study.

Figure 1 shows the parking area in front of the international terminal which I have selected for the study. It has an area of 5995.46 m^2. 1900 number of panels is planning to be placed in this area. This area is rectangular in shape having 152.44 m in length and 39.33 m in width. Most of the vehicles do park here as it lies just opposite to the departure and arrival of international terminal.

Figure 1: Parking area in front of the international terminal

Figure 2: Parking area in between international and domestic terminal

Figure 3: Parking area infront of the domestic terminal

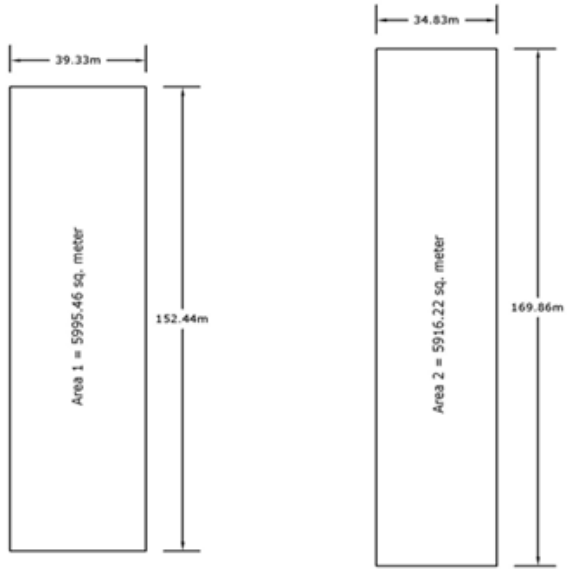

Figure 4: Dimension of parking area at international and between two terminals

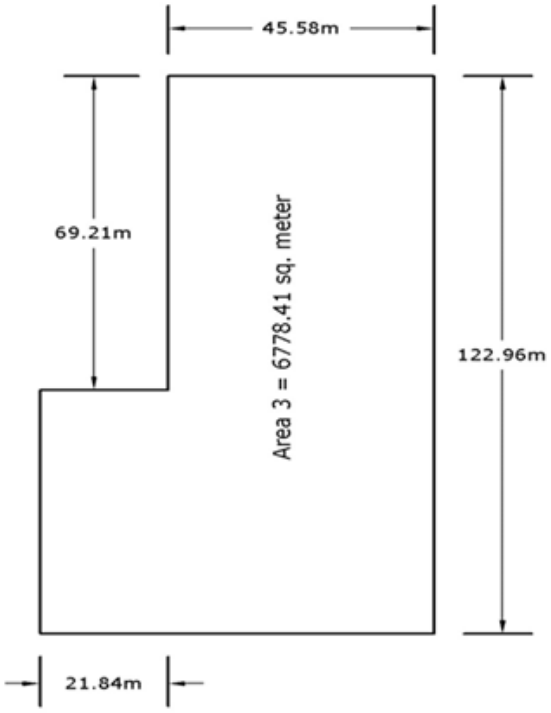

Figure 5: Dimension of parking area in front of domestic terminal

The area in front of the international terminal has the length of 152.44 m and breadth 39.33 m having area of 5995.46 m^2. Similarly the parking area in between the domestic and international terminal have the area of 5916.22 m^2, the length is 169.86 m and breadth is 34.83 m.

The parking area in front of domestic terminal has an area of 6778.41 m^2. It have an "L" shape structure having dimension as shown above.

2.2 Current Taxi Service at TIA

There are altogether 200 numbers of taxis with prepaid service. Among them 165 number of taxis are serviced at International terminal and 35 numbers of taxis are serviced at domestic terminal.Longest destination the taxi is reaching is 36 km within Kathmandu valley. So the maximum distance that should be travel by a taxi at one time is 72 km.The maximum distance a taxi covers per day is 120 km and a taxi get maximum chances 2 to 3 times per day to travel. The load that it can bear is 5 person plus 150 kg luggage. But the general load is 3 to 4 person plus 50 kg of load.

2.3 Module selection

Yingli panel has been selected because of its higher efficiency as compared to other models[9]. As the world's largest solar panel manufacturer, Yingli Solar has produced more than 40 million solar panels for homes, businesses, and power plants. Yingli Solar panels are trusted around the world for their performance, quality, and reliability. 280 Wp, 30V, Si-Poly Yingli Solar is used. 20 modules are connected in series and 95 modules in parallel making total number of modules to be 1900. The dimensions of the used panel are as shown in the figure 6

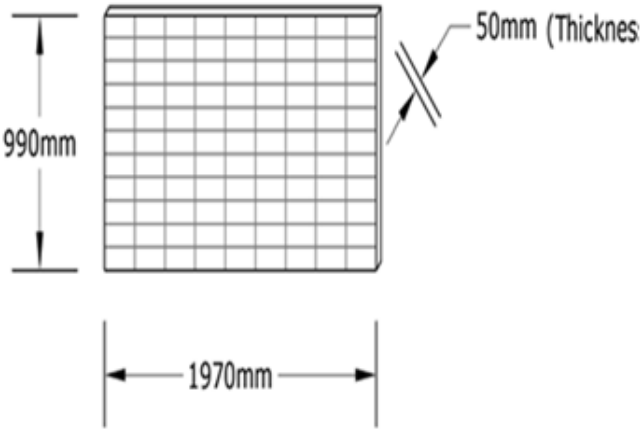

Figure 6: Single Module

The selected solar module, Yingli solar has length of 1970 mm and width of 990 mm having 50 mm of thickness.

2.4 Battery Selection

Here 2V, 3000Ah, Rolls Battery has been used. 300 numbers of batteries are connected in series and 2 numbers in parallel to make total number of batteries to be 600.

2.5 Civil Design

There are altogether 1900 solar panels mounted at a height of 5m to 9.45m high. There are 19 panels in a row with 10 columns in an array. There are 10 arrays. So there are 100 numbers of panels in column making altogether 1900 panels. The panels are mounted at an angle of 30° to the horizontal. Every array has a length of 39.33m and width of 9.9m and when projected to the horizontal plane its width is 8.57m. 7.07m of gap is placed after each array so that the shade of one array will not affect the other array. The top view and side view of the complete designed array system are as shown in figure 7.

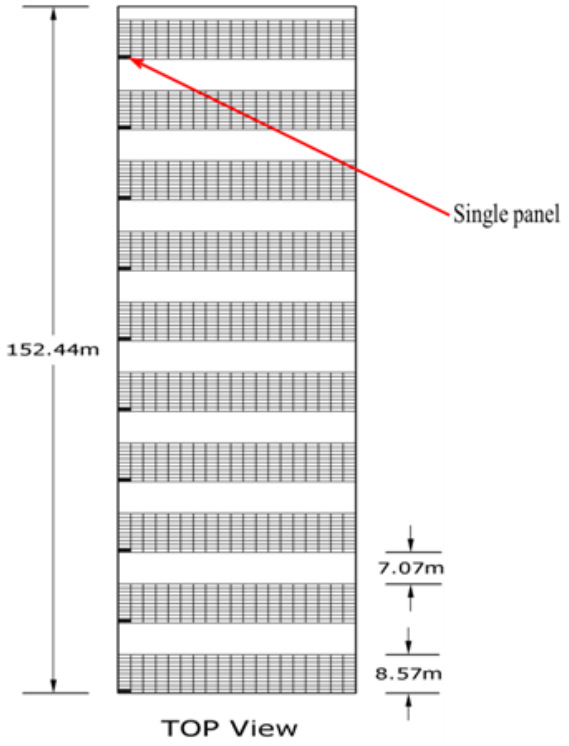

Figure 7: Top view of solar array after installation

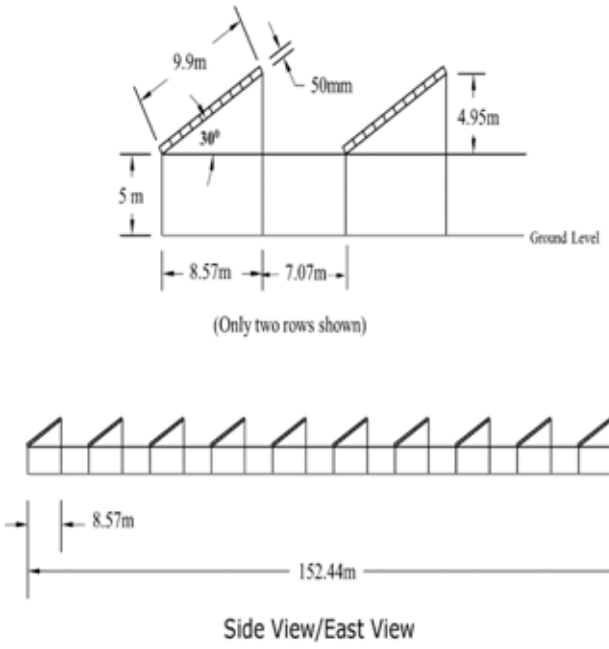

Figure 8: Side view of the array

2.6 Cleaning Technology

For the cleaning purpose, a ladder is placed at the end of each array. Water will be used for the cleaning from both sides.

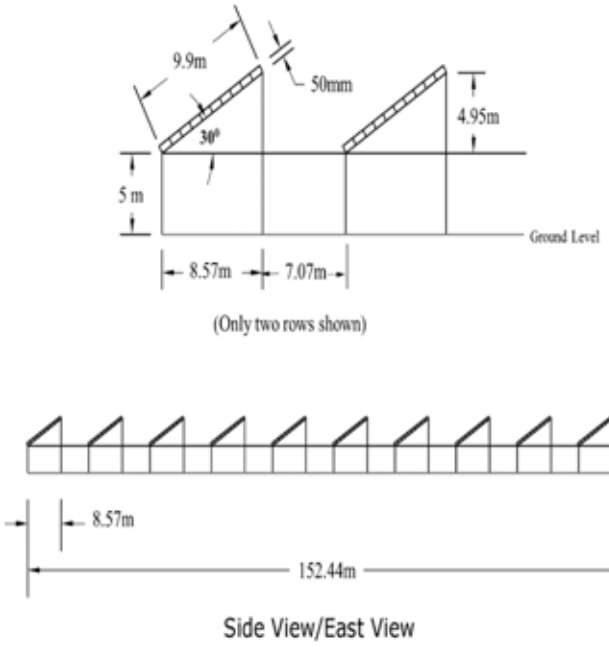

Figure 9: Cleaning technology of the panels

3. Vehicle Selection

3.1 Vehicle model

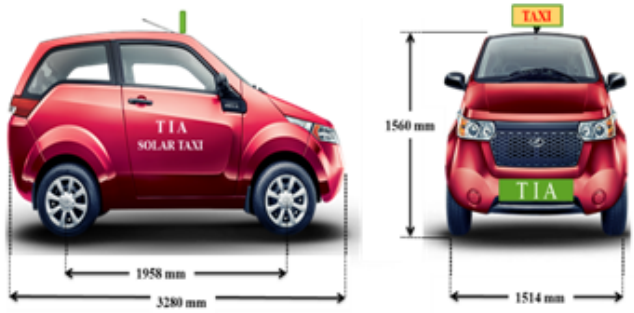

Figure 10: Proposed Vehicle Model

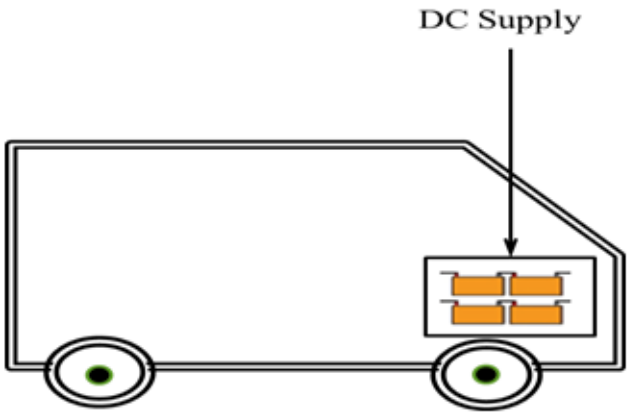

Figure 11: Charging of vehicle

4. Calculation

One vehicle is of 19KW
One vehicle travels 120 km at the speed of 81km/hr.
Now if the vehicle travels at full speed the charge will be finished in 120/81=1.48 hrs.
So, the energy required to charge the one vehicle is 19kW*1.48hr=28.14kWhr
Here array normal energy is 532 kW*5(sunshine hours) =2660kwhr
So the numbers of vehicle that can be charged at once is given by 2660/28.14=94.5 numbers
Take 90 numbers of vehicles to charge at once. So energy required is 90*28.14=2532.6kwhr
So power need is 2532.6/5=506.52kw
Also,
Weight of single panel=26kg
For a row:
Weight of total panel=190*26=4940 kg
Weight of angle support=1218.75 Kg
Weight of 50mm pipe=1729.14Kg
Weight of 125mm pipe=3645.47Kg
Total weight=11533.66Kg
Again,
There are 36 heavy pipe of 135mm(NB)
Assuming UDL, Point load at one support pipe=Total weight/36=11533.66/36 = 320.37 Kg.
135mm pipe should bear 320.37 kg

5. Charging Design

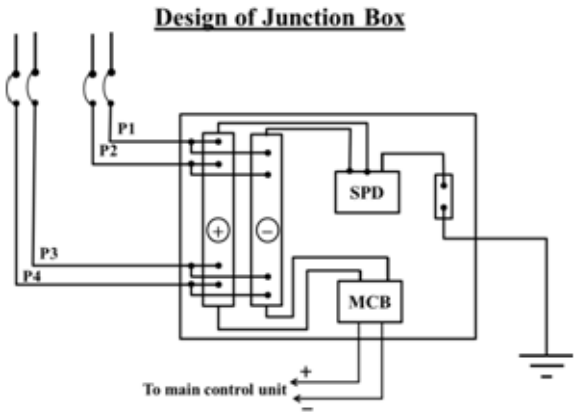

Figure 12: Design of Junction Box

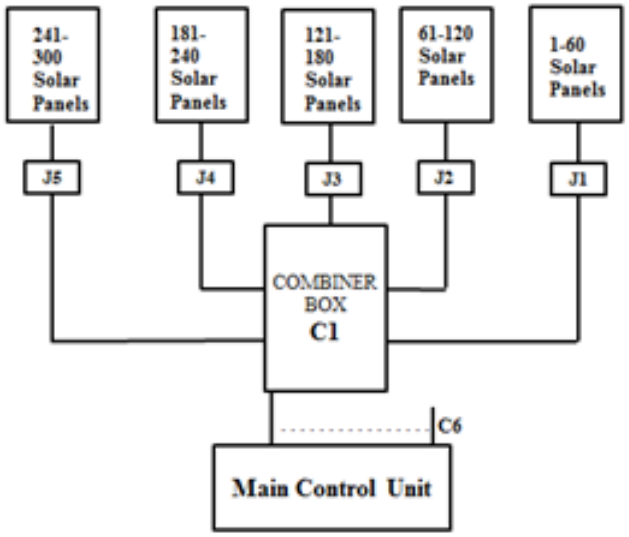

Figure 13: Design of Junction Box

Total nos of 30 junction boxes have been used. Every junction box is connected with 3-4 parallels. Every parallels consists of 60-80 panels. 20 panels are connected in series and 95 panels are connected in parallel[10].

Altogether there are 6 Combiner boxes. Each combiner box is connected with 5 junction boxes. i.e. 300-320 solar panels.

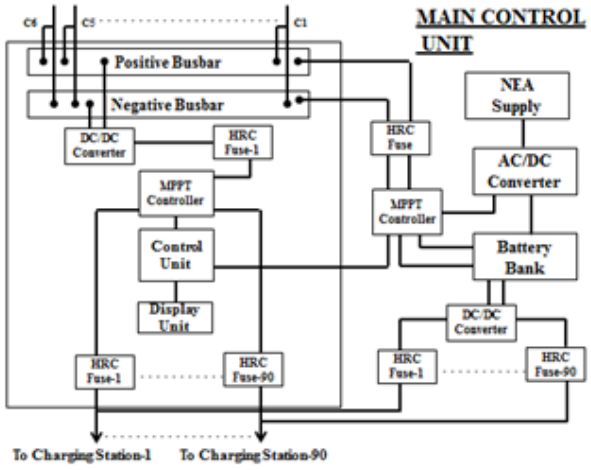

Figure 14: Design of Main Control Unit

Main Control Unit Consists of Processor, Control Unit, HRC Fuses,Display Unit etc. MCU is connected with Battery bank and Charging stations. MPPT Charge controller is used for control unit.

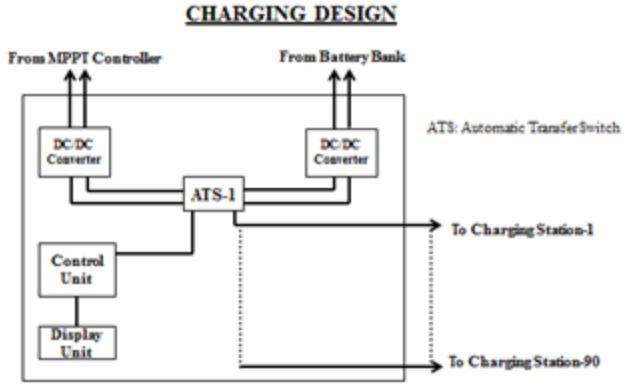

Figure 15: Automatic Transfer Switch(ATS)

Automatic Transfer Switch gives first priority for solar panels and then to battery bank[11].

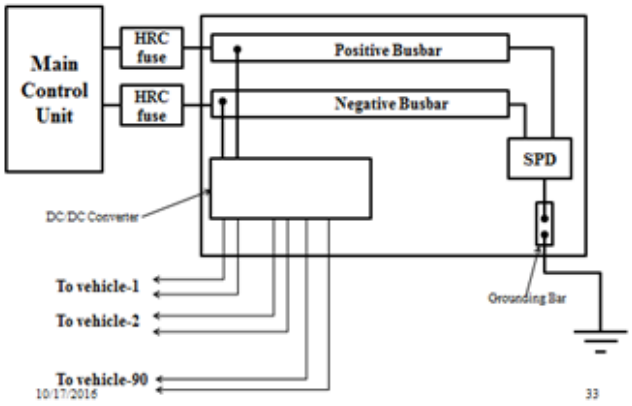

Figure 16: Vehicle Charging

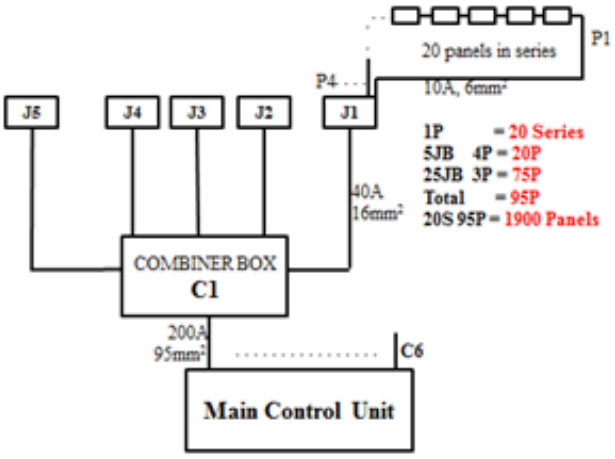

Figure 17: Cable Sizing

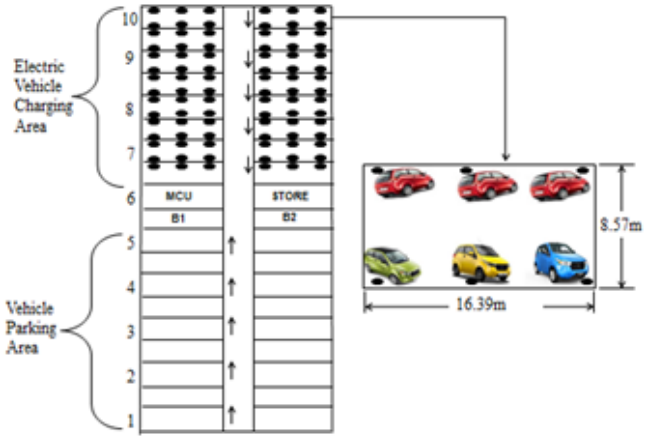

Figure 18: Charging and parking Area

Different cables are used for different connection. 6 mm^2

cable is used to connect the panels in series. Similarly, 16 mm^2 cable is used for the connection between junction box and combiner box. 95 mm^2 cable is used for the connection between combiner box and main control unit.

Among 10 rows, 4 rows and 4 gaps between the rows are used for charging area. One row and one gap between rows are used for battery bank, main control unit and for store room. Remaining 5 rows and 5 gaps between rows are used for vehicle parking. In an area of 8.57m $\times$ 16.39m, six numbers of vehicle can be charged.

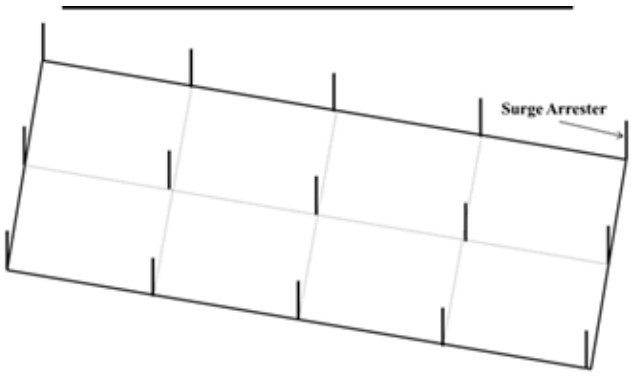

Figure 19: Lighting Protection

For the lighting Protection there are altogether 15 Surge Arresters. Surge arrester is used to protect equipment from over-voltage transients caused by lightning.

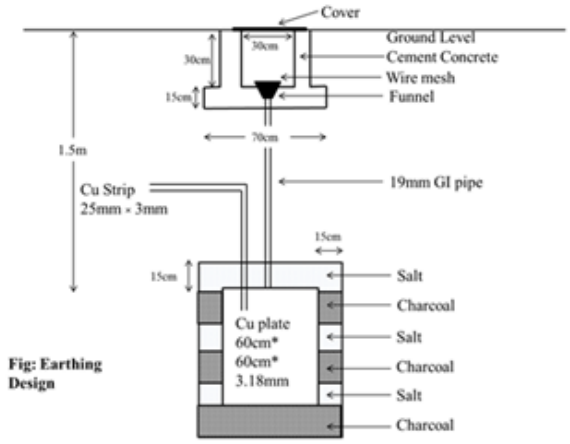

Figure 20: Earthing

6. Economic Analysis

The total weight of iron pipes for the solar panel support structure and its cost if found to be NRs. 6,478,030.16 in total. The Total Cost Estimate for Solar Panel and accessories is found to be Rs.98,548,409.52 inclusive of Civil Structure Cost and the whole labor costs.

Table 1: Assumption on Petrol Vehicle

Petrol Vehicle			
S.N.	Description		Units
1	Petrol Consumption rate	12	Km/l
2	Per Day Km covered	120	KM
3	Petrol Consumption	10	
4	Cost of Petrol/liter	98	Rs/Liter
5	Total Cost of Petrol/day	980	Rs
6	Annual Petrol Consumption cost	357,700.00	Rs/year
7	Servicing and Maintenance Cost	20,000.00	Rs/year
8	No of Vehicles	200.00	Nos
9	Cost for O&M and petrol cost for 200 vehicles under consideration per year	75,540,000.00	Rs

Table 2: Assumption on Electric Vehicle

Electrical Vehicle				
S.N.	Description		Units	
1	Energy required to charge one vehicle in 1 hrs	33.77	kwhr	20 % is considered to be system losses so 33.78 = 28.14*1.2
2	Per day km covered	120.00	Km	
3	cost of charging per day	674.20	Rs	
4	Annual charging cost	246,083.44	Rs/Year	
5	Servicing and maintenance cost including change in battery after five years	12,000.00	Rs/year	
6	No of vehicle	200.00	Nos	
7	Total O&m cost of ELV plus charging cost under consideration per year	51,616,688.25	Rs	

Table 3: Investment Assumptions

TOTAL INVESTMENT	101,012,120	
EQUITY	20%	20,202,424
DEBT	80%	80,809,696
Equity cost of capital	20%	
Debt interest rate	10%	
ANNUAL ESCALATION RATE	8%	
WACC		12.00%
Electricity generated daily	2660.00	kWh
Annual electricity generated	970,900	kWh

Table 4: WACC and LCOE

WACC	12%	
Initial cost	(101,012,120)	
PV of FCF	(43,780,672)	
Total cost	(144,792,792)	
PV of electricity generated	7,252,083	
LCOE	19.97	NR/kWh

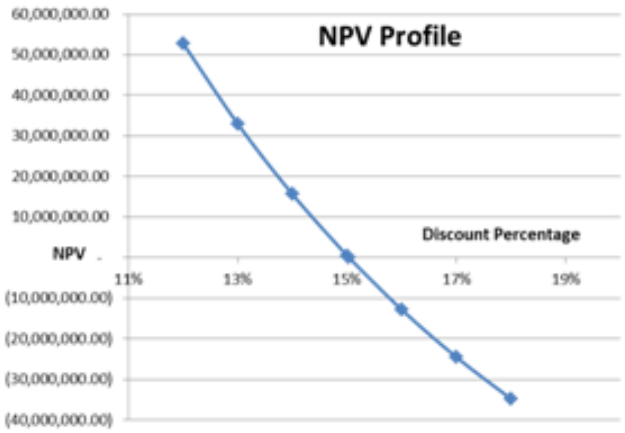

Figure 21: NPV Profile

Table 5: NPV

NPV of O&M cost plus cost of petrol for petrol vehicle for 20 years	976,002,579.38
NPV of O & M cost plus cost of charging battery of ELV for 20 years	666,905,227.31
NPV of O & M of solar system for 20 years	28,938,160.96

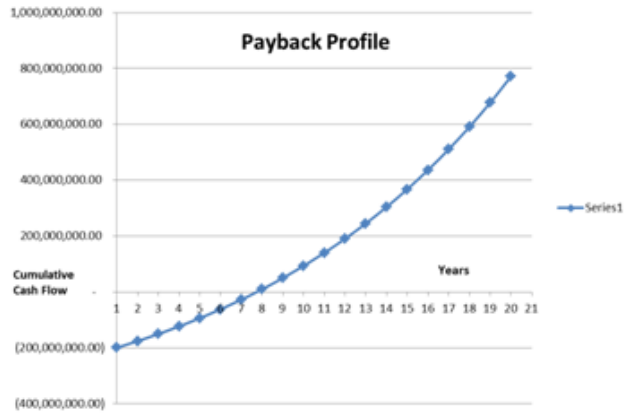

Figure 22: Payback Profile

Table 6

NPV of O&M cost plus cost of petrol for petrol vehicle for 20 years	976,002,579.38
Investment for solar system at 0 year	101,012,119.76
Investment in vehicle to shift from petrol to ELV at 0 year	120,000,000.00
NPV of O&M of solar system for 20 years at 0 year	28,938,160.96
NPV of O & M cost plus cost of charging energy of ELV for 20 years at 0 year	666,905,227.31
NPV of saving in O&M by use of ELV instead of petrol vehicle for 20 years	59,147,071.35
NPV of the charging system project	59,147,071.35
Payback period	**7.74**
IRR	**15.03%**

7. Conclusion

From the results, it has been found that the NPV of the project is Rs. 59,147,071.35 at discount rate of 12%(equivalent to WACC). The payback period of the project is found to be 7.74 years and its IRR is found to be 15.03%. Since, the IRR is greater than market rate of return, therefore, the project seems to be feasible. Assumption of 10% in debt which is 80% of the total investment is made while 20% in equity which is 20% of the total investment is made as shown in table above. While summing up the both assumptions, we obtain the WACC of 12%. The Levelized Cost of Electricity is found to be Rs.19.97/KWh. Summarizing above mentioned result, the Solar based excellent IRR with satisfactory Payback period. From this we can conclude that the solar vehicle in case of country like Nepal is very useful where high potential of solar can be found.

Vehicle charging station is found to be feasible as it shows the excellent IRR with satisfactory payback period of 7.74 years.

8. Recommendations

The study considered only one parking area among three parking areas at Tribhuvan International Airport. There are also other open areas for the solar panel installation. Further study can be done for the improvement in vehicle model and charging system. With Further study and research maximum benefit can be obtained.

Acknowledgements

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