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# Review on Feasibility of Solar Carport Charging Stations

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***Abstract*—** It is expected that up-to 2030 the present e-vehicle demand raise from 2% to 22% worldwide[1]. India being a developing country has moderately launched electrical vehicles and not yet started adequate charging infrastructures. In India major electricity is produced using coal. Introduction of EVs and requirement of charging infrastructure will increase more amount of greenhouse emission. In India total of 798 MUs/year electricity consumption is likely to happened from EVs charging in 2030[2]. Indian power distribution companies are in starving to fulfill today's energy demand. Non conventional energy charging stations can be easiest solution to reduce the energy demand load. The present paper proposes a model of carport charging stations for electric vehicles to cope with the increasing power demand by electric vehicles for the near future. This study applies the proposed model to Nanded City to verify its technical and economic feasibility. Nanded city is situated in rural area having potential of more than 300 clear solar days per year with 5.76 Kwh/$m^2$/day average energy irradiance [3].

***Keywords-*** *EVs; battery charging stations; solar carports; solar;*

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## I. INTRODUCTION

Need of electrical vehicle :

India is one of the top automotive markets in the world. Increasing demand and price of petroleum product innovate alternate to conventional IC engine, which also reduces bad pollution effects on environment. Here comes the alternative technology in automobiles such as electric vehicles (EV) in India. Although the initial investment is more than conventional IC engine, but time has come when cost of environment is now more of concern than the cost of vehicle. The world market finds that EV sale has increased more than double in last two years[4]. Together the deployment of charging station also growing very fast in all those countries.

Comparison of fuel and electricity :

A common Indian family consumes almost Rs.500/- per month on fuel bill. The table below shows cost comparison of three different fuels with reference to today's fuel prices. Considering 20km/lt average and 4.16 Km/KWh consumption rate the total km work per month can be calculated. It shows that the use of electrical energy is much economical than the other two. The EVs will work almost triple than the traditional petrol as fuel. But main threat is increase in electricity demand may lead to price hike.

## II. EVS TECHNOLOGY

### *A. Electric vehicle technology*

There are three main types of electric vehicles (EVs), classed by the degree that electricity is used as their energy source[5].

Table – 1 COMPARISON OF PETROLEUM AND ELECTRIC ENERGY USAGE

| Fuel | Petrol | Diesel | Electricity |
|---|---|---|---|
| Unit Cost | Rs. 75 | Rs. 60 | Rs.5.75 / unit |
| Consumption @500 per month | 6.7 | 8.3 | 87 |
| Km per month | 134km | 167km | 362km |

Battery electric vehicle (BEV):

A battery electric vehicle (BEV) runs entirely using an electric motor and battery, without the support of a traditional internal combustion engine and must be plugged into an external source of electricity to recharge its battery. BEVs support regeneration of battery while in operation. Regeneration is the technology which converts the kinetic energy during braking of vehicle into electrical energy, wherein the propulsion motor acts as a generator. The electrical energy generated is then stored in the battery in the form of chemical energy. Models: Mahindra e20, Mahindra e-Verito and Tata Tigor EV etc.

Plug-in hybrids electric vehicles (PHEVs):

Plug-in hybrids (PHEVs) use an electric motor and battery that can be plugged into the power grid to charge the battery, but also has the support of an internal combustion engine that may be used to recharge the vehicle's battery and/or to replace the electric motor when the battery is low.

Models: Volvo XC90 T8, Volkswagen Passat GTE, Mitsubishi Outlander

Hybrid electric vehicles (HEVs):

Hybrid Electric Vehicles (HEVs) have two complementary drive systems: a gasoline engine with a fuel tank and an electric motor with a battery. Both the engine and the electric motor can turn the transmission at the same time, and the transmission then turns the wheels. HEVs cannot be recharged from the electricity grid – all their energy comes from gasoline and from regenerative braking

Models: BMW i8, Toyota Camry Hybrid, Mahindra Scorpio S10 Intelli-Hybrid, Mercedes C-Class C300h

Fuel cell electric vehicles (FCEV):

Fuel cell electric vehicles (FCEVs) are powered by hydrogen. They are more efficient than conventional internal combustion engine vehicles and produce no tailpipe emissions—they only emit water vapor and warm air. FCEVs use a propulsion

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system like that of electric vehicles, where energy stored as hydrogen is converted to electricity by the fuel cell. FCEVs are fueled with pure hydrogen gas stored in a tank on the vehicle.

TABLE – 2 ASSESSMENT OF INDIAN EVS MARKET [1]

| Vehicle model | Battery type/capacity | Type of motor | Regeneration | Top speed (kmph) | Range (km) | Charging time | |
|---|---|---|---|---|---|---|---|
| | | | | | | Slow charging | Fast charging |
| Mahindra e20 P2 | Lithium-ion-48V/15 kWh | 3-phase AC induction | Yes | 81 | 140 km | 7 hrs 20 min | 1hr 35 min |
| Mahindra e-Verito D6 | Lithium-ion-72V/18.55 kWh | 3-phase AC induction | Yes | 86 | 140 km | 11 hours 30 min | 1 hour 30 mins |
| Tata Tigor EV | Lithium-ion-72V /15.55 kW | 3-Phase AC Induction | Yes | 100 | 130 km | 6 hours | 90 minutes |

Like conventional internal combustion engine vehicles, they can fuel in less than five minutes and have a driving range over 500 kilometers
Models: Honda Clarity FCEV, Hyundai Tucson FCEV, Toyota Mirai FCEV

Focusing on electric vehicle technologies, following table covers the prominent BEV models present in the Indian market. Table elaborates the charging time requirement in hours for various vehicles available in India. The fast charging stations also divided in two types slow charging and fast charging.

### *B. Indian/Maharashtra current senario of charging stations*

Technical study of Electrical vehicles and charging infrastructures has been carried out in March 2019 be BEE[1]. Mainly three different cities have been selected for study Delhi, Lucknow and Nagpur. The impact of electricity mobility on distribution infrastructure was assessed using statistical models. After understanding the total number of charges per day across different charging locations and assuming 14 hours per day service total number of chargers can be calculated. It is estimated that in 2030, 2.6 lakhs charging points requirements may exist in Nagpur, with 93% being home chargers, followed by 5% bulk swappable battery charging points, and remaining 2% at office/private and public charging stations. This includes all EVs and all charging points, including home chargers, which may yield EV to EVSE ratio of 3.53 by 2030. The detail study prevails that in near future a huge demand of charging station is a major challenge.

### *C. Analysis and identification of charging stations*

The charging options available in India has following categories

- Public charging stations: stations available for public use and are not dedicated to any consumer category.
- Private charging stations: charging stations available for specific authorized users.
- Fleet charging stations: stations dedicated to fleet charging (Ola/Uber).
- Battery swapping stations: a battery swapping (or switching) station is a place where a vehicle's discharged battery or battery pack can be immediately swapped for a fully charged one, eliminating the waiting period for charging the vehicle's battery.

As per BEE[1] report available existing charging stations are in cities like Delhi, Lucknow and Nagpur. A sample table below highlights the existing number of charging stations operated by various service operators in Nagpur. Through on-ground city level surveys it was observed that Delhi has 158,

TABLE – 3 CHARGING OPTIONS AVAILABLE IN NAGPUR CITY [1]

| Type (Usage) | Operator | Type (fast/slow) | Number of charging points |
|---|---|---|---|
| Nagpur<br>Total chargers - 41 | | | |
| Public | HPCL | Bharat AC001 slow chargers | 1 |
| | | Bharat DC001 fast chargers | 1 |
| | BPCL | Bharat AC001 slow chargers | 1 |
| | | Bharat DC001 fast chargers | 1 |
| | Suresh Bhat Auditorium | Type 2 AC fast chargers | 5 |
| | | CHAdeMO DC fast chargers | 5 |
| | | CCS AC/DC fast chargers | 5 |
| Private/fleet | Collaboration of OLA, IOCL and Mahindra & Mahindra | Bharat AC001 slow chargers | 11 |
| | | Bharat DC001 fast chargers | 11 |
| Swapping | - | - | 0 |
| Total | | | 41 |

Nagpur has 41 and Lucknow had no chargers at the time of observation.

The report identified that Nagpur city is expected to grow at a faster rate with supporting ecosystem including smart city, Metro, MIHAN and EVs heads-up. By two projections, city population is expected to double-up in next 15 and 25 years, respectively. We assumed this to happen in 20 years, with population CAGR of 3.5%, giving some 41.5 lakhs population in 2030. Total vehicles on-road are expected to rise to 28 lakhs, with estimated 680 vehicles per 1000 population. Two-wheelers are expected to continue forming highest modal share of 87%, followed by passenger cars and rising share of fleet vehicles including 4-wheelers and 3-wheelers.

Similar kind of situation will be observed in all different cities in India. The replacement of existing IC engines with EVs have been shown in following table, the percentage of replacement at national and small cities have compared below. It can be predicted that energy demand in all cities will get doubled due to adoption of EVs.

## III. SOLAR POTENTIAL STUDY OF NANDED CITY

Nanded is one of the historical places in Marathwada region of Maharashtra State. It is situated on the north bank of Godavari river. Nanded is situated at latitude of 19.15º and Longitude of 77.30º. The population of Nanded city is 442348 as on 2013 and predicted 1413478 up-to 2023 as per report [3].

Table – 4 VEHICLE GROWTH RATE REPORT [1]

| Vehicle | Fast adoption percentage rate as per NITI Ayog Report up-to 2030 | Prediction of adoption in Cities as per BEE report up-to 2030 |
|---|---|---|
| 2-Wheeler | 40 % | 30 % |
| 3-Wheeler | 100 % | 50 % |
| 4- Wheeler –PV | 40 % | 35 % |
| 4- Wheeler – CV | 100 % | 35 % |
| Bus –Pub. | 100 % | 60 % |
| Bus –Pvt. | 50 % | 60 % |

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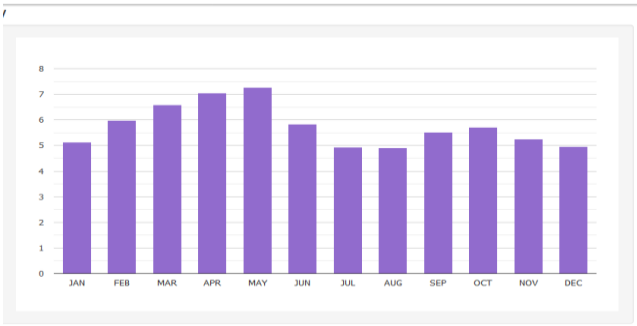


Graph -1 Showing Kwh/m2/day solar irradiance at Nanded

Today's consumption rate of petrol and diesel is 30000 KL and 12000 KL per year and predicated [1] more than 40000KL and 15000 KL as per exiting growth of vehicles. This growth rate in future IC engines will definitely diverted towards EVs. The NWMC has already started solar and green city project to overcome with future demand. As per 2013 report on road vehicles in Nanded district is more than 3,26,151[3] and it is growing almost 20% every year [3]. From this it can be predicted that in coming future every year addition 60000 EVs cab be under demand.

Solar energy potential in Nanded city can be predicted and shown in the graph. Nanded city is having potential of more than 300 clear solar days per year with 5.76 Kwh/$m^2$/day average energy irradiance [3].

The graph shows that Nanded has good potential to store reneable solar energy for different uses. The future demand of EVs can be undertaken by different projects using solar energy. The radiation and details of solar potential can be studied in details by using Solar Radiation Resource Assessment (SRRA) Stations commissioned in Nanded by MEDA but it is out of scope of this paper.

## IV. SOLAR CARPORT STATION

It is expected from the predictions and future demand of EVs in different cities in India, there is need of private and public charging stations in every places wherever available/ The vehicles are placed almost 6-8 hours daily in parking places in day time. The parking palaces generally observed in different offices and commercial buildings. Effective use of these parking as charging station and its feasibility has been studied here. A Solar – EV charging carport model is shown in figure. It consist of Solar panels installed on an outdoor parking station are conned to the grid through a bi-denominated meter, along with EVs.

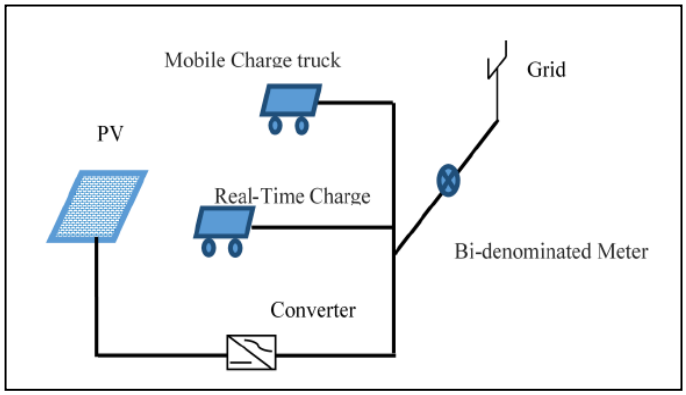


Figure 1. Carport model

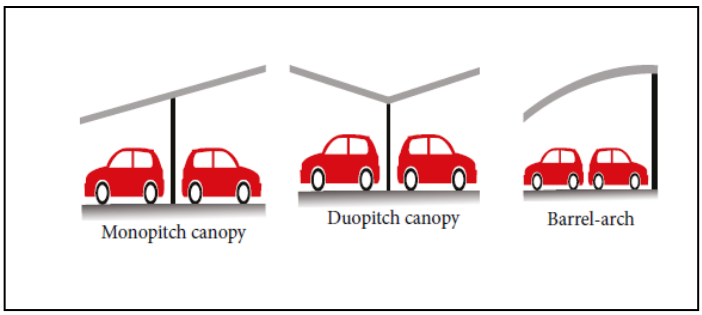


Figure 2 Canopy types [4]

Electricity generated from the PV power plants in daytime can be stored directly in the electric cars. If the electricity ggenerated exceeds the storage capacity of EVs batteries, the surplus energy can be sold to the grid. In night time, the EVs can begin charging when the grid electricity price is relatively low. There are generally three types of canopies are used in different carports. The figure shows its types and the area of each canopy can be varying as per dimensions of vehicle.

A detailed comparison has been done between the above mentioned carport canopies, and the results showed that for a maximum generation of solar energy, the monopitch carport structure is the best to choose when taking the tilt angle of 10° into consideration. Duopitch yielded 93% of energy with respect to monopitch with the same installation capacity, and the barrel-arch canopy yielded 90% with respect to the monopitch canopy. The best suitable carport canopy type is mono-pitch canopy. This model of canopy can be setup as per solar irradiation angle required. Nanded is situated at latitude of 19.15º and Longitude of 77.30º and best suitable angle of PV inclination is $20^0$. The average clear sunlight days are more than three hundred in a year. There is lots of scope available for sun energy utilization at local level.

## V. TECHNICAL FEASIBILITY REPORT

By 2020 plenty of cars will be launch in Indian market. Amount of electric power consumed and average charging cost can be evaluated. The following table shows various Indian EVs and average charging cost of each.

TABLE -5 CHARGING POWER AND COST OF EVS

| EVs | Charging unit | Carport capacity KW | Car Prize lakhs | Unit prize | Maximum Power | Total running cost for Rs /100Km |
|---|---|---|---|---|---|---|
| Mahindra e2o | 10 | 3 | 8 | 5.75 | 25.5bhp @3750rpm | 50.75 |
| Tata Tigor EV | 18 | 5 | 11 | 5.75 | 40.23bhp@4500 rpm | 103.5 |
| Hyundai Kona | 60 | 15 | 24 | 5.75 | 134bhp | 346.7 |

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TABLE-6 SOLAR CARPORT INSTILLATION AND PAYBACK

| EVs | Charging unit | Charging g carport KW | Unit construction cost Rs 0.6Lakhs/KW | Daily charging cost @5.75 Rs/KWh for 100KM | Pay back period in years on carport investment |
|---|---|---|---|---|---|
| Mahindra e2o | 10 | 3 | 1.8 | 50.75 | 9.85 |
| Tata Tigor EV | 18 | 5 | 3.0 | 103.5 | 8.05 |
| Hyundai Kona | 60 | 15 | 9.0 | 346.7 | 7.21 |

The amount power station capacity in KW is compared in the table given above for three Indian EVs. It is found that the range of power capacity required is varying and depends upon how units are consumed during single charge. Solar charging carport capacity will be varying depends upon EV used. Comparing solar carport cost and payback period it is found that the amount of charging will be waved off in almost 8yrs of charging service by carport. The table shows comparison charging station installation and payback period required for three sample cars taken for reference.

## VI. CARPORT SOLAR ROOFTOP CALCULATIONS

Carport rooftop solar power plant calculations as per Ministry of renewable energy source (MNRE) has stated here. The sample calculation of Mahindra 2e0 having required capacity of 3KW has presented here.

1. Size of power plant : 3KW
2. Plant prize as per MNRE : 1.8 Lakhs
3. Total electricity generation annual : 4500KWh
4. Total generation in life time 25yrs : 112500KWh
5. Carbon emission mitigated : 92 tones
6. Environmental savings : 148 teak plants

## CONCLUSIONS

Solar car parking lots provide shade to cars and solar photovoltaic (PV) energy. It is beneficial for consumers as it can offset their monthly energy demand from the grid and dependency on the grid. In addition following conclusions are important.

1. Renewable energy sources are utilized effectively
2. Carbon dioxide emission will reduce
3. The amount invested can be pay back within next 7-8 years irrespective of EVs
4. Less dependency on charging stations
5. Rented income can be possible when not in use for own vehicle

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