Electric Vehicle Charging

Charging Stations, V2G, V2H, V2V, Solar Charging, Impacts of EV on the power utility grid

getelectricvehicle.com

Introduction

Electric vehicles slowly capture the automotive market nowadays. Different types of electric vehicles include cars, trucks, buses, bikes, skateboards, tricycle, etc. The number of electric vehicles increased and surpassed 2 million in 2016. Battery electric vehicles have a higher growth rate in the market than plug-in hybrid electric vehicles.

Battery chargers are essential for an EV to charge the battery and make the vehicle travel. Charging of battery is common from residential chargers, public charging stations, and private charging stations. Long distance travel would happen only if battery charging facilities are available in intermediate locations.

A conventional vehicle fills fuel from gas stations which are common all over the world. Similarly, electric charging stations are being constructed to charge electric vehicles.

In this short eBook, we are discussing electric vehicle charging - not only charging stations but also the impact of charging and new trends in EV charging. The concepts of Vehicle to Grid (V2G), Vehicle to Home (V2H), Vehicle to Vehicle (V2V), and solar charging are explained in this book.

- getelectricvehicle.com

Table of Contents

Chapter 1

Electric Vehicle Charging Stations

Electric Vehicles use one or more electric motors for propulsion. Battery Electric Vehicle (BEV) and Plug-in Hybrid Electric Vehicle (PHEV) can be charged from external power sockets.

Petrol cars are common all over the world so petrol bunks. Whatever may be the vehicle they need the energy to move from one place to another. Vehicle manufacturers declared their goal of EV production and Electric vehicles (Battery, Hybrid, and Plug-in Hybrid) started to enter the automotive market. **Electric car charging stations** are also getting established since the arrival of Electric Cars to the vehicle market.

Charging stations are the infrastructures provide electricity to charge electric vehicles. EV manufacturers have already set up charging stations and developed standards for charging.

Types of Electric Car Charging Stations

Petrol cars travel a relatively longer distance than electric cars with tank full petrol. One of the disadvantages of the electric vehicle is their reduced range.

Charging stations are necessary at public places to recharge the batteries of Electric Cars. But charging stations are not limited to public places. There are a few other ways to charge an electric car. A broad classification of electric car charging stations is given below

Home-based charging station

The primary charging facility of an electric car is home-based charging. When you buy an electric car it's always necessary to have a battery charger at home. Overnight slow charging of electric vehicle is highly used and recommended method.

Residential charging of EVs doesn’t have a metered connection and dedicated wiring as that of public charging stations.

Public charging station

An electric vehicle has to be recharged if it runs out of charge while traveling a long distance. As gas stations fill fuel in conventional vehicles, charging stations at public places would recharge the battery of an electric vehicle.

Private charging Station

Charging stations – either free or paid - installed at movies, malls, Office, etc. are generally termed as private charging stations. Private charging facilities can be slow or fast. In addition to the services offered by hotels, shopping malls, they provide users a means to charge their vehicles as well.

Battery swapping

Battery swapping is a method in which a discharged battery is replaced with fully charged battery instantaneously from battery swapping stations so that to avoid delay due to slow charging time.

Fuel cell vehicles and EVs use battery swapping for getting the battery fully charged in less than 15 minutes. Tesla motor planned to install battery swapping in their fast-charging stations in 2013. Later they **called off** the battery swapping project to expand fast-charging stations.

Electric Vehicle Charging Standards

Standardization of electric vehicle charging is necessary as the number of vehicles increases day by day. All the charging stations could not set up by the vehicle manufacturers.

It's not always easy to find charging stations compatible with your vehicle. Standardization would solve the problem.

SAE international classified charging facilities as below

1. Level 1 charging
2. Level 2 charging
3. Level 3 charging

1. Level 1 charging

Standard house outlet is being used to charge an electric vehicle and it's comparatively slow. This is level 1 charging. Electric vehicles can be charged overnight using level 1 charger.

2. Level 2 charging

Level 2 chargers are similar to level 1 chargers but they are usually installed at public locations. They take shorter to charge an electric car than level 1 chargers. Level 2 chargers can use at home to charge EVs a little faster (4-6 hours).

3. Level 3 charging

Level 3 chargers are DC fast chargers that could recharge electric car battery in around one hour (Tesla Model S takes 75 minutes to full charge 85kWh battery). They can be deployed in electric charging stations and houses to charge the vehicle at a faster rate. 80% of the battery gets charged in 30 minutes and it takes a maximum of 1.5 hours to get fully charged.

IEC defines another set of standards for EV charging. Unavailability of the unique standard resulted in conflicts sometimes. You can read

Charger standards fight confuses electric vehicle buyers, puts car company investments at risk

Who invests to set up charging station?

Do car manufacturers invest in charging stations? Yeah. They do sometimes. Home-based charging facilities may be provided by car manufacturers themselves. But they haven't started investing in public charging stations (Tesla is an exception). Other organizations set up charging stations following different standards.

A list of a few electric car charging station manufacturers is given below.

- ✓ Bosch Automotive Service Solutions
- ✓ ABB
- ✓ Schneider Electric
- ✓ Fuji Electric
- ✓ Siemens

There are a few **charging network operators** managing charging network from various manufacturers. Tesla Inc is an example of charging network operator.

Conclusion

Electric Car charging stations and their characteristics are briefed in this chapter. It necessitates common standard and huge investments in charging stations to get widespread acceptance of Electric Vehicles.

We discuss Vehicle to Grid (V2G) and Vehicle to Home (V2H) Technologies in the next chapter.

Chapter 2

Vehicle to Grid (V2G) and (V2H) Technologies

Vehicle to Grid (V2G) and Vehicle to Home (V2H) are two technologies in which those electric vehicles having plug-in capability connect to the utility grid to charge the battery and supply energy to the power grid.

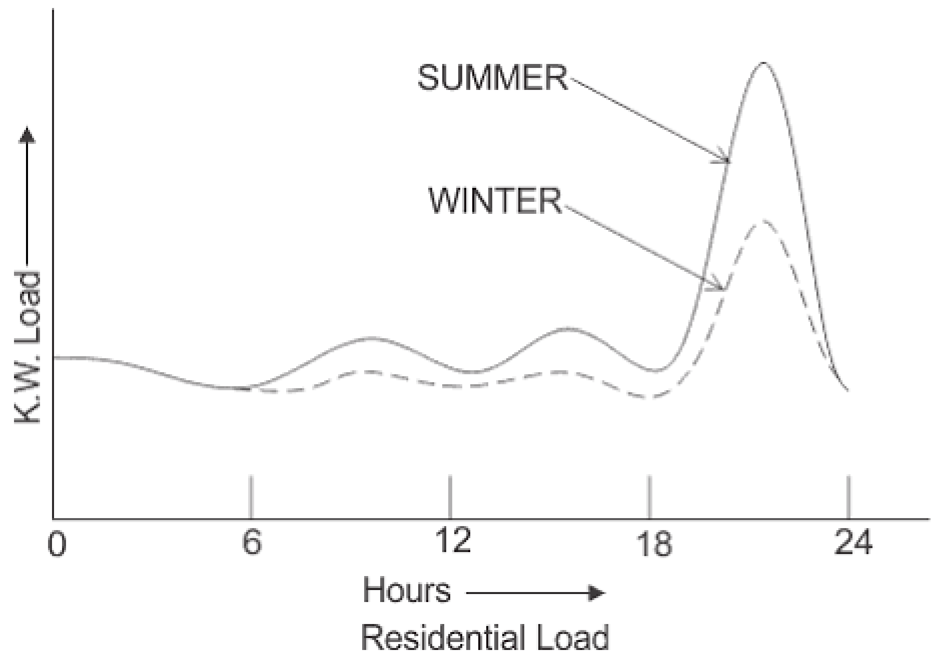
An electric vehicle with a bidirectional charger not only draws energy from the charging stations but also supplies energy to the power utility grid.

What is Vehicle to Grid and Vehicle to Home?

Electric vehicles are classified as Battery EV, Hybrid, and Plug-in Hybrid EVs. Battery EVs and PHEVs have plug-in capability. Their battery can be charged from a power socket. EVs connect to charging stations and power socket when the battery runs out of charge.

If the charger is a bidirectional converter that could flow power from battery to power grid and vice versa then the direction of power flow can be controlled. The concept of the vehicle to grid (electric vehicle grid integration) is that an EV is connected to the power grid in such a way that energy can flow from and to the battery based on the power demands in the grid.

Most of the private charging stations equipped with bidirectional charging facility can act as mini power generating stations if a few EVs are plugged in. Electrical load vs time graph (known as load curve) shows peaks at day time and evenings. Those peaks in loads can be reduced using energy from Electric Vehicles.



Typical daily load curve of a house [Image reference]

Power system experiences a relatively large demand at peak load time (6 pm to 11 pm). If there are a number of EVs connected to the grid then energy can be taken from the battery of electric cars to meet the demand of the grid. The amount of power that drawn from car battery depends on the factors such as

- ✓ State of Charge of battery (SOC)
- ✓ How long the car would be connected to charging port
- ✓ Battery capacity

Vehicle to Grid helps to meet energy requirements of the power system at peak demand by drawing power from the battery of Electric Vehicle.

An electric vehicle usually never consumes its complete energy form battery in a day. Average distance traveled by car in a day is 80 km and energy consumption would be 10 kWh/100km.

An electric car of 60kWh battery capacity is capable of supplying a household of 3 kWh per day consumption for 20 days (ideally). What does this mean?

Most of the energy is being stored and kept unused in the battery of the electric vehicle.

If I own an electric car and I'm ready to have grid integration, then the car can be act as a generator as well as load. The vehicle will be connected to the home charging port which is a bidirectional charge at night.

If the vehicle is going to plug in overnight and the amount of energy required is already set, the battery will be charged at off-peak hours and power flows from the battery to grid during peak load time.

A battery of EV would have a capacity more than that of uninterruptible power supply battery in the home.

How does grid integration of Electric Vehicle help utility

Grid integration helps power utility in many ways. Below are a few advantages they get from a bidirectional power flow from Electric Vehicle.

- ✓ Peak load shaving
- ✓ Load leveling
- ✓ Power system stability

- ✓ Reduced losses during peak hours
- ✓ Capacity reduction of generation at peak hours

Utility encourages V2G and V2H due to these advantages.

How does grid integration of EVs help vehicle owner?

An electric vehicle is a micro-generator and load if it is grid connected with a bidirectional charger. As the number of Electric Vehicle increases, power demand from utility grid also increases.

Bidirectional charging stations help to draw power from battery to the grid. Power grid incentivizes the owners to encourage V2G so that the grid would be stabilized. And the owner of the car would have a **reduced burden of charging expenses**.

Peak load shaving is an advantage of V2H technology. Load at peak hours and hence the **energy charges can be reduced** by transferring power from battery of Electric Vehicle to home.

Challenges of V2G and V2H

Why don't we use vehicle to grid and vehicle to home technologies widely? There are a few challenges in implementing electric vehicle grid integration

- ✓ Life of EV batteries
- ✓ Unavailability of bidirectional charging stations
- ✓ Reduced number of EVs
- ✓ Right Government policies

Life of Electric Vehicle battery is a major concern in the EV market. The number of charge-discharge cycles affects how long a battery lasts. Power flow to and fro battery might reduce the life of the battery. People go for V2G and V2H only if the potential of earning is more than the expense.

Bidirectional converters are not that popular as unidirectional EV chargers. As long as chargers are not standardized for bidirectional function, the process of V2G would lag.

Effective vehicle to grid happens only if the number of EVs is more. Government policy should also have to be in favor of grid integration.

Conclusion

We discussed Vehicle to Grid (V2G) and Vehicle to Home (V2H) technologies are discussed in the chapter. Advantages and disadvantages are also covered in the chapter. We discuss the Impact of Electric Vehicles on Power Utility Grid in the next chapter.

Chapter 3

Impacts of Electric Vehicles on Power Utility Grid

Electric vehicles are increasing day by day in the EV market. The expected boom in the number of EVs would considerably affect the power utility grid. How would be the impact of EV on the power grid?

Electric vehicle battery charges with the help of different types of chargers. A charger converts electric energy to DC and charges the battery in an electric vehicle.

An electric vehicle with a unidirectional charging capability would act as a load in the power system. Unidirectional chargers connected to the power utility grid draw power to charge the battery of electric cars and other EVs.

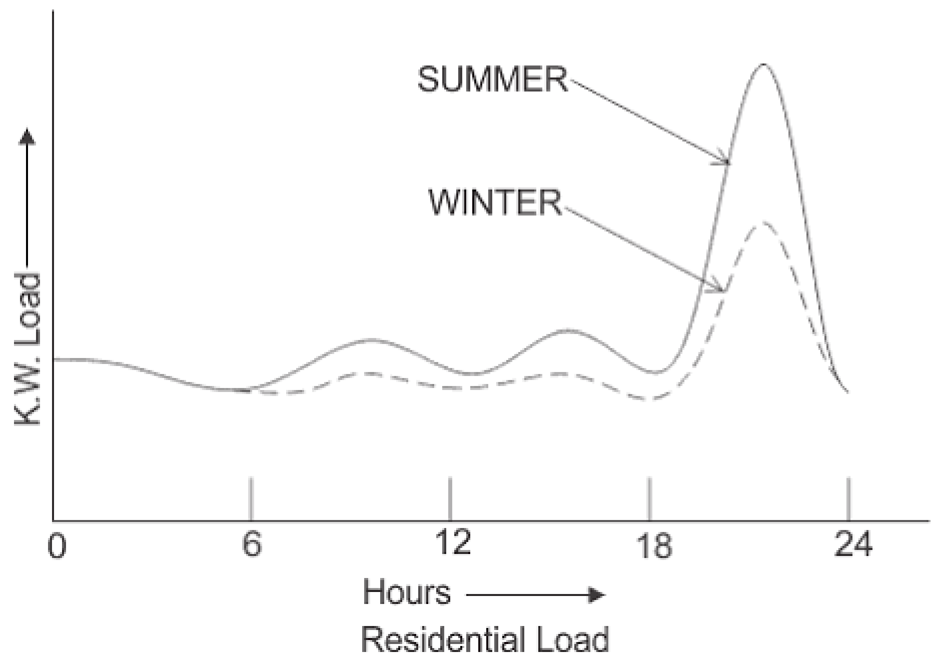
Electric Vehicles are comparatively large loads that connected to the power grid when they are being charged. Let's see how large an electric car battery load is. If an electric car with a 60 kWh battery charges 80% in 6 hours, it consumes 8 kWh/hour. A typical household consumes less than 5 kWh in a day!

Imagine how much would be the load if a large number of electric cars are connected to the grid for charging.

Impact of EV on the power grid during peak hours

Electric vehicles come home during the evening and connect to a power socket for charging. As we explained in the above session an electric vehicle consumes relatively large energy while charging. So a group of electric cars in and around a transformer add more load to it.

What is the peak load time?



Typical daily load curve of a house [Image reference]

See typical load curve of a household. Power demand from 19:00 to 23:00 is much higher than the rest of the time. An electric vehicle which connects to the power utility grid results shoot up the peak demand further.

Increase of the load in peak time decreases the **load factor** of the grid. Load factor is the ratio of average load to maximum load in the power system at a specific time.

A high load factor indicates relatively constant power usage and low load factor shows a system with occasional high loads. A power utility must have the capacity to serve the peak load and the capacity stays unutilized rest of the time.

Electric vehicles connected to the grid for charging during peak hours worsen the situation. Power utility grid suffers to meet the demand.

How does peak demand affect the power utility grid?

At peak demand current in the power line increases. **Losses** in the transformer and transmission line increases. **Voltage drop** in the transmission line increases. Total network voltage drops in peak hour. **Power factor** decreases.

Finally, it results in high active power demand in generating stations. Power utility grids could not meet high power demand that arises only during peak hours. Electric vehicle charging at peak hours considerably increases the load in the power utility grid. It’s a large burden on utilities to keep their power generating capacity idle for low demand and start during high demand.

As a result of uncontrolled EV charging distribution transformers get overloaded. Overload in the transformer causes **thermal losses** and reduction of life of components.

Finally, power quality would be affected by electric vehicle charging.

Congestion in power lines due to Electric Car Charging

An area where the number of electric vehicles is more would increase localized power demand. Power transmission lines experience large stress to transmit power to that area.

We have seen the effects of electric car home charging on a power utility grid in the previous section. Other types of charging facilities also trouble the power grid.

How would be the impact of public charging stations on the power utility grid?

Electric vehicles at public charging stations would also be an inconsistent load on the grid. Electric vehicles are high loads connected to the grid during charging. If 5 vehicles connected together to the charging station, obviously demand from the grid shoots up.

What if they are not connected? No wonder, the load would be less. Generation of electricity could not be consistently scheduled in this intermittent loading. Impact of EV on the power grid would be more negative if the vehicle is charging at peak hours.

Do electric cars only adversely affect the power utility grid?

No, electric vehicles can do *something* to strengthen the grid if the charging is well managed.

Load balancing using an electric vehicle

Impact of EVs on the power grid can be positive as well! Electric cars are large loads connected to the grid. As we have seen in the load curve, electric loads are not uniformly distributed always. Hence power utility comes across unbalanced power load and most of the time power generation capacity stays unused.

If an electric vehicle charges at off-peak hours (which is not an addition to peak load) load on the grid will be uniform to an extent.

An electric utility grid can control the power demand from customer imposing time of use tariff. High cost at peak hours and low cost at off-peak hours tend the customer to charge his electric vehicle at off-peak hours rather than peak hours.

What if an electric car can supply power to the utility grid?

If an electric vehicle supplies energy to the grid at peak load time instead of drawing energy from the grid, load factor reduces. Thus Losses, voltage drop, high stress on generating station, and other drawbacks of peak load can be effectively minimized.

Advantages of peak load shaving and load leveling make utility grids to promote scheduled charging of electric vehicles (off-peak hours).

A bidirectional converter to flow energy to and fro vehicle battery is necessary to make peak load shaving possible.

The concept is nothing but Vehicle to Grid (V2G)

But who connects a vehicle to the power socket unless to charge one's electric car?

Incentives are necessary to succeed in implementing V2G technology. An electric car owner who plugs his vehicle to home charging system to get it fully charged by the next morning. The vehicle doesn't spend more 12 hours to get the battery fully charged. So it's possible to draw energy from the battery during peak hour and charge the battery at off-peak hours.

V2G is possible and might help the utility as well as a car owner!

Conclusion

Let's summarize what we have discussed in this chapter. Electric vehicles have an impact on the power utility grid at the time of charging. Uncontrolled charging of electric cars considerably reduces the quality of the power utility grid. A well managed bidirectional charging of electric vehicle can reduce the negative impact of EV on a power grid. It is needful in a grid as the numbers of electric cars increase.

Electric vehicles can also be used to stabilize the power utility grid. An electric car charging that scheduled in such a way to support the grid during peak hours as a micro-generator and as load in off-peak hours really helpful for the utility grid.

Next chapter we would discuss Vehicle to Vehicle (V2V) charging technology.

Chapter 4

Vehicle to Vehicle (V2V) Charging

Vehicle to Grid (V2G) and Vehicle to Home (V2H) are two technologies popular in the field of electric vehicles. Vehicle to Vehicle (V2V) charging of electric cars opens the door for charging an electric car from another one.

Does it seem interesting?

An electric car with a bidirectional charger is capable of supplying power to the grid and accepting power from the grid. AC-DC converter could be used for grid connection at charging stations. We have discussed V2G and V2H concepts, how they affect the power utility grid in the previous chapter.

Here the V2V charging comes!

Vehicle to Vehicle charging

An electric vehicle with bidirectional charging facility might be used to charge another electric vehicle. Battery electric cars and plug-in hybrid electric cars plugged into a power socket to get charged. Why can't they charge from another electric vehicle?

An electric car can act as an emergency charging station.

If a car is solar powered then it can charge another EV accepting remuneration.

Vehicle to Vehicle charging. A photo from a Tweet by Laurin Hahn (Sonomotors)

As far as electric cars are concerned they can serve electric loads in emergency situations. For example, a 60kW battery can uninterruptedly power a household electric load of 1kW for 60 hours!

Vehicle to Home connection minimizes the high cost of electricity at peak hours.

Types of Vehicle to Vehicle Charging

An electric vehicle charges from another electric vehicle in two ways. **Isolated mode (Off-Grid mode)** and **power sharing at charging stations (Grid-connected mode)**. What are the differences?

1. Isolated mode of charging

An electric car can directly connect to another in isolated mode. Energy from one battery transfers to other vehicle battery according to the setting in the vehicle.

The pre-set quantity of energy flows from one battery to other vehicle's battery when they are connected for power sharing. For example, if a vehicle with 50kWh energy in battery decides to share 10kWh to another car and make it travels 40 km (if it travels 4km for 1kWh).

2. **Power sharing at charging stations**

An electric car can be connected to the charging stations and allow another vehicle to charge from the car itself instead of drawing energy from the power grid. Here vehicles are not directly connected to each other. And both of them are connected to the charging stations.

The optimal power-sharing algorithm in charging stations take energy from one vehicle to another without disturbing grid.

Who does Electric V2V charging?

Does anyone do V2V charging? It's inconvenient for the drivers of both vehicles to wait for the car get charged. Of course, it can be done in an emergency.

Electric vehicle to vehicle charging could be conveniently possible in below scenario

- ✓ A solar-powered electric vehicle that parked near any confluence where electric cars need a charge
- ✓ At parking areas where other cars need power
- ✓ At charging stations during peak hours of energy demand - a fully charged vehicle reduces power demand from the grid and make owner earn for shared power

- ✓ Private charging stations to share power with other electric vehicles

Conclusion

Vehicle to vehicle charging is a concept that is accepted and implemented by a few manufacturers. Bidirectional charging and a common standard of charging stations will make on grid vehicle to vehicle charging a success.

We can discuss the solar charging of electric vehicles in details in the next chapter.

Chapter 5

Solar charging for Electric Vehicles

Electric vehicles charge from home, public charging stations, and private charging stations. Charging of a vehicle from the electricity generated from solar panels is called solar charging for electric vehicles.

Electric car charging from home, private, and public charging stations stress the power utility grid since they are relatively high load. Solar charging for electric cars is advantageous to the environment as well as the power grid. Let's classify Electric cars solar charging into two and explore them one by one.

1. Solar charging station

A solar charging station (Reference: Sinovoltaics)

Electric vehicle charging stations get energy from power utility grid usually. A home charging of electric cars also makes use of energy from a power utility grid to charge the vehicle.

A solar charging station generates electricity from solar panels, stores them, and charges electric vehicles when they plugged in for charging.

The solar charging station is not only for electric car's solar charging but also act as a micro generating station. It’s a distributed generating station that generates the electricity at the place where it gets utilized.

One question ✋ - If power utility grid generates electricity from solar energy and a conventional charging station that connected to grid utilizes the energy to charge an electric car. *Is that considered as solar charging for electric vehicles?*

The answer is “No”. We consider charging stations that generate electricity themselves from solar energy to charge electric vehicles as solar charging stations.

2. Solar powered electric vehicle

A solar vehicle is a vehicle that converts solar energy to electric energy and charges its battery. Photo-voltaic energy conversion using solar cells are made use for the same. A vehicle that partially uses solar energy for propulsion can also be called a solar-powered electric vehicle. They are called Solar Assisted Electric Vehicles (SAEVs) in particular. Solar-powered vehicles have separate power plugs also, to charge from a conventional charging station.

Solar panels have to be integrated into the vehicle to generate electricity. How much electricity can be generated from the solar panels on the vehicle? Would that be sufficient to run the vehicle?

Let's have a look at the list of a few amazing vehicles that pop up when we think about solar charging for electric vehicles.

Solar Impulse 2 (Reference Wikipedia)

Solar Impulse 1: Impulse 1 is a solar-powered aircraft designed to fly only using solar energy. It has been developed in Switzerland and had its first flight in December 2009.

Solar Impulse 2: Solar impulse 2 circumnavigated earth using only solar energy generated by the panel installed on it. Solar Impulse 2 started its mission from Abu Dhabi airport on 9th March 2015. The airplane has 17248 photovoltaic solar cells cover the top of wings, fuselage, and tailplane for a total area of 269.5 sq meter (2901 sq ft) generates 66kW of electricity peak. (Wikipedia)

Sion Solar Car by Sono Motors

Solar electric cars: Sono motors - a startup in Germany developed solar-powered electric car (Sion) and they are making them charge another car also. Vehicle to vehicle (V2V) charging facility in Sonar car is a great advantage that they offer. Sion would travel 30 kilometers per day with the energy generated by solar (cells under proper conditions) integrated on the car body.

First solar powered train, buses, etc. are also manufactured experimentally and yet to manufacture commercially.

Advantages of solar charging stations

- ✓ ***Solar charging stations result in no environmental pollution***. Thermal power plants generate electricity and charging stations use it for charging in general. Environmental pollution as a result of this process is completely avoided in solar charging stations. "Carbon positive life," says a thermal power plant emits 0.94 kg of carbon dioxide to generate 1kWhr of electricity.
- ✓ ***Solar charging stations reduces the burden on the power utility grid***. Solar charging stations minimize impacts of electric vehicles on the power utility grid**.**
- ✓ ***A solar charging station acts as a power generating station that could supply energy to a power utility grid***. They generate electricity, stores in a battery, and can be supplied to the grid during peak hours for **load shaving**. A well-managed system could be helpful for **load leveling** in the utility grid.

Disadvantages of solar charging for electric vehicles

- ✓ A most important drawback of solar charging is the **low power density** of solar panels. The energy generated from the solar panel of an electric car is limited to the area of the panel that exposed to sunlight. The efficiency of solar panels is less than 20% and a 1 sq meter solar panel can generate less than 200 W of electricity if solar irradiance is around 1000W/sq. meter.
- ✓ Life of photo-voltaic cells is around 25 years. **Power conversion capacity reduces as they age** and it results in the poor performance of the vehicle.
- ✓ **Cost of photo-voltaic cells** to generate unit electricity is more compared to electricity generation from other sources
- ✓ **Climate-dependent energy availability** is another constraint of solar-powered electric vehicles

Conclusion

Solar charging for electric vehicles is classified into two - solar charging stations and solar-powered electric vehicles. A vehicle gets charged from solar energy results in little environmental pollution. Solar charging stations are advantageous to the power utility grid in terms of load minimization, peak load shaving, etc.

Summary

Electric Vehicle charging, Vehicle to Grid (V2G), Vehicle to Home (V2H), impacts of EVs on the power utility grid, solar charging of EVs, etc. are discussed in the book. You can read more about electric vehicles here: http://getelectricvehicle.com

Hope you enjoyed the book.

Thank you.. ☺