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Renewable Energy based Multimode Electric Vehicle Charging Station: A Review

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Abstract: ***The goal of this work is to understand working of renewable energy based multimode EV charging station that should be suited for fast charging of Electric Vehicle and that must be putting the least amount of overload on the Utility-grid. The charging station is operated in such way that it is either powered by solar PV-array system or utility-grid, to improve grid stability during peak load hours. A DC bus connects the PV-array interfaced with DC-to-DC converter and the Utility-grid interfaced with DC to AC bidirectional converter. The efficiency of the utilized control approach is decided by a smooth transition between solar connected mode and grid connected mode. Although charging station infrastructure can be employed in many ways like it can be made only grid connected or only solar power connected but the coordinated operation of solar power system and grid can be efficient and economic option for implementation of EV charging stations on large scale. This renewable energy based multimode EV charging station can prove to be very much useful for reducing dependency on fossil fuel-based vehicles and promoting use of electric vehicles on large scale with very reasonable per unit cost of charging them.***
Keywords: Photovoltaic array (PV), Renewable energy, Grid connected EV Charging station, Electric Vehicle, Hybrid EV charging station

I. INTRODUCTION AND LITERATURE SURVEY

Now a day electric has become very popular means of transport. Electrical Vehicles are preferred due to many reasons and increasing fuel prices may be identified and key reason for success of electric vehicles in very short span of time. Secondly push towards green energy and control measures to reduce air pollution also led to adoption of more ecofriendly means of transport[1]. The use of electric vehicles has increased significantly in recent years but still wide scale adoption of electric vehicles in developing countries is facing many practical challenges. Main challenges are development of charging infrastructure, high cost of electric vehicles, small distance ranges of electric vehicles, high charging time and very few maintenance and repair facilities[2].

For the adaption of electric vehicles on large scale most urgent need of the hour is to design and develop fast charging stations at faster pace. Most of the existing EV charging stations are grid based so we cannot say that our electric vehicles are 100% environment friendly because the energy utilized for charging electric vehicles is still coming from fossil fuel-based power plants. All we need to do is to make our EV charging station work on energy obtained by renewable source of energy which is much clean and environment friendly. Also, existing system are increasing burden on existing grind and affecting power quality in long term[3].

Out of many available sources of energy solar energy is found to be most suitable for powering EV charging station. But again, there are few challenges with Solar powered EV charging station i.e., its dependency on whether and sunlight. At night the power generated by solar panels is very less. Many auxiliary equipment are required with solar power PV array system which increases the overall installation cost of the Charging station[4].

Hence to deal with all the above stated technological challenges in this paper we have discussed about multimode operation of EV charging station that will be connected to grid as well as solar panels and coordination is maintained in its operation such that there is very less burden on main grid. Also, when solar output is very low, we can switch back to grid connected mode[5].

A. Benefits of Adopting EV

Electric Vehicles are proved to be more beneficial than existing internal combustion engine-based vehicles. Not only in terms of cost efficiency but in terms of reducing carbon footprints of transportation system on environment. Now a days prices of gasoline and diesel have increased like anything due to various reasons thus it becomes very much important to adopt cost effective means of transportation[6]. Electric vehicles on single charge can travel about 100-120 miles or even more which cost consumer approx. 20-50 rupees which is very much less as compare to cost to cover same distance on gasoline-based vehicle[2].

Another benefit of electric vehicle adoption is achieving net carbon zero goals of country. As it is clearly evident that electric vehicles are environment friendly transportation option so it can prove to be very good solution in many cities where pollution has reached alarmingly high level such as New Delhi, Beijing, Rio, New York etc. Also, it can be adopted where further deterioration of air quality is to be avoided. If these electric vehicles are charged using renewable energy sources, then nothing can be as good as Electric Vehicles. Government also provides wavier or subsidies for buying electric vehicles[4].

Table 1
Five-year comparison of Electric vehicle & ICE vehicle (all value in ₹)

Vehicle Type	ICE Vehicle	Electric Vehicle
Capex	60000	120000
Salvage Value	21500	0
Maintenance & Insurance	47500	21600
Fuel	168000	20000
TCO	254000	161600

The above table shows comparison of cost involved with conventional IC engine vehicles and electric vehicles. It can be clearly seen that although initial cost for electric vehicles is high but they are more cost effective in terms of operation and maintenance.

II. PROBLEM IDENTIFICATION

The main challenge with adoption of electric vehicle is availability of charging stations in short distance. Range of electric vehicles in single charge is also matter of concern but it can be rectified by use of high-capacity modern lithium-ion batteries. Cost of electric vehicle is another big concern for its buyers but now a days as governments are also providing subsidies for buying electric vehicles their cost is now almost equivalent to conventional vehicles. At last, comes public awareness which is also a challenge with adoption of electric vehicles. Public is just reluctant to adopt new technology due to reliability factor and lack of awareness about electric vehicle technology[7].

For the adoption of EV's by public on large scale first and foremost need is to set up charging stations on sufficient distance just same as gas stations at very faster speed for quick adoption of Electric vehicles.

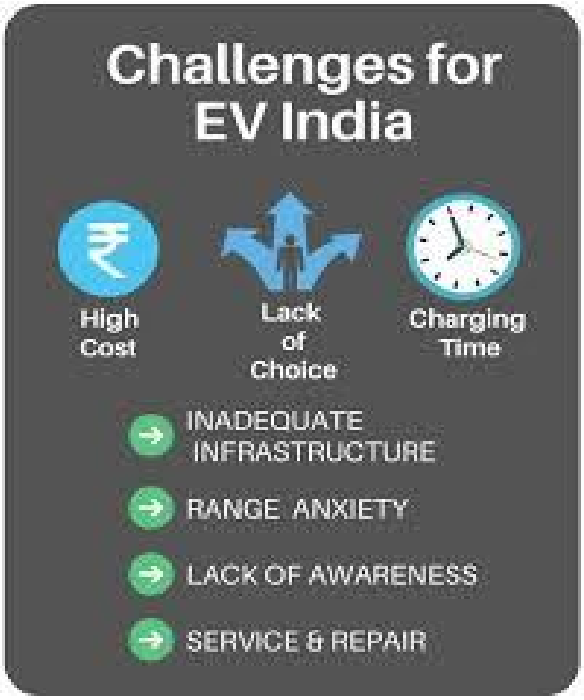

Fig. 1 Challenges for EV in India

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III. RESEARCH METHODOLOGY

As we can clearly see that main hindrance in adoption of electric vehicles is unavailability of charging station infrastructures, so in this paper we will discuss about the most economic and efficient EV charging station model. Charging stations for electric vehicles can be implemented with following three type of architectures and here we will discuss each type of architecture is discussed in detail with its limitations and advantages so that best possible method can be concluded for implementing EV charging station model.

A. Grid Connected EV Charging Station

Grid connected charging stations are usual charging stations which get electric power from fossil fuel-based power plants or hydro power plants. Hence this type of charging station is indirectly affecting the environment and are not eco-friendly. This grid-based charging stations can provide 24*7 electricity to charge electric vehicles.

1) *Design Of Grid Connected EV Charging Station:* This Grid connected charging station architecture uses only one AC-DC converter tied to main grid. It also has one DC bus that connects DC-DC converter to charging EV's in order to boost voltage. Three phase supply is supplied by utility grid which is then fed to step down transformer to reduce the voltage level from distribution level to EV charging level. Then it is AC power converted to DC power using AC-DC converter. And finally multiple electric vehicles can be connected to Dc bus for charging via DC-DC converter[8]. The schematic diagram of Grid connected EV charging station is shown in the figure 2.

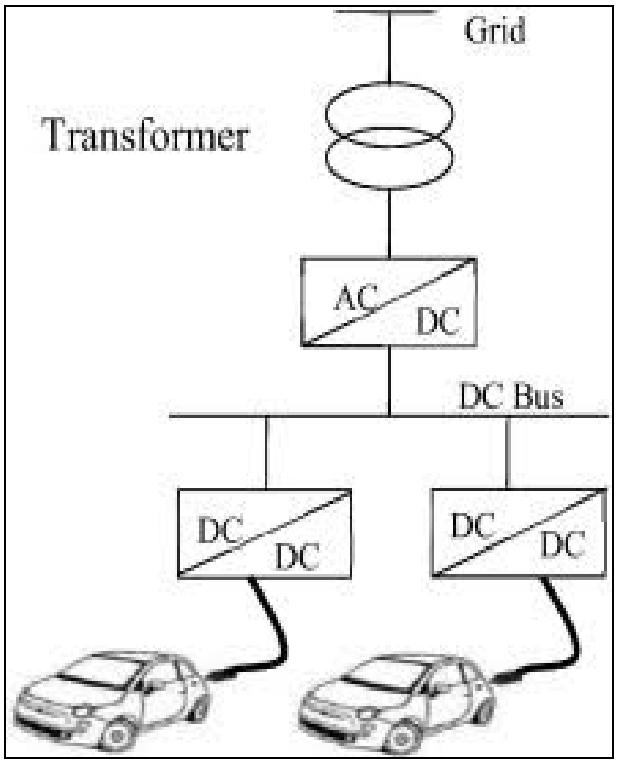

Fig. 2 Grid connected EV charging station

2) *Limitations Of Grid Connected EV Charging Station:* This architecture when employed for charging electric vehicles causes extra burden on utility grid due to increase in electricity demand. At the time of peak hours this condition become even more severe. Followed by detailed research about impacts of grid integration of electric vehicles it is evident that charging and discharging of electric vehicles i.e., vehicle to grid (V2G) and grid to vehicle (G2V) technologies affect the power quality, grid stability and energy economies of utility grid. Power quality problems may include phase imbalance, voltage surges and dips, higher order harmonics in line currents, stray fluxes, dc offset etc. these problems mainly arise due to nonlinear nature of high-speed DC chargers used for charging electric vehicles. These power quality issues affect the performance and endurance of distribution system network[9].

B. Solar Based EV Charging Station

Solar based EV charging station is the best example of renewable energy source-based EV charging station which generates electrical energy from the solar radiation received through sunrays. This solar based EV charging station generate electrical energy in a fully environment friendly manner and does not cause any type of pollution. Hence making electric vehicles green and clean in true sense.

In order to get maximum output from solar panels MPPT (Maximum Power Point Tracking) charge controller is employed. This solar based EV charging station uses constant voltage method or CV method for MPPT control of PV output where solar panels output voltage is compared with reference voltage and maximum power point voltage is decided[10].

Flow chart for CV method is shown in figure 3.

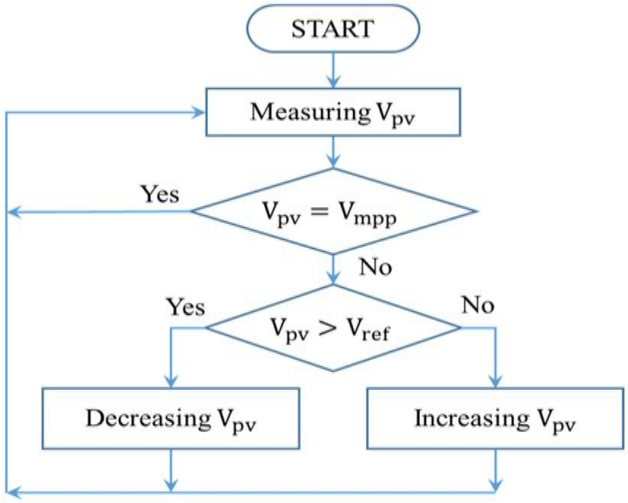

Fig. 3 Flow chart for CV method algorithm

1) *Design Of Solar Based EV Charging Station:* Solar power-based EV charging stations employs buck converters and boost converters for increasing or decreasing the DC voltage level. Boost converter which is basically a DC-to-DC converter is used to increase the voltage obtained from output of solar panels whereas Buck converter is also DC to DC converter is used to decrease voltage level of DC bus. The electrical energy obtained from solar panels is stored in battery bank with the help of Bidirectional DC-DC converter. Charge and discharge controller is used to control charging and discharging of battery bank and avoids over charging of battery bank. Standard DC fast chargers are used to charge electrical vehicles using this type of charging station[11]. Architecture for Solar based EV charging station is shown in figure 4.

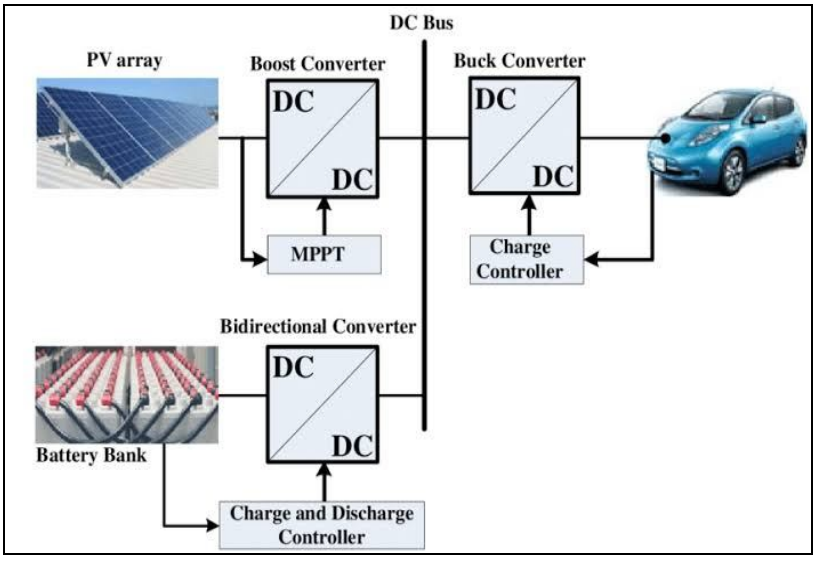

Fig. 4 Solar based EV charging station

2) *Limitations Of Solar Based EV Charging Station:* The main problem with this type of charging station is that its operation is fully weather dependent. If it is bright sunny day then solar panel will develop more power but if it is cloudy or rainy day then output of solar panel will also get reduced. This decreases the reliability of charging station. For large scale implementation of charging stations, we need continuous power without any interruption. Many factors involved with implementation of solar based EV charging station are requirement of large area for installation of solar panel, high cost of solar panel and maintenance solar panel system, along with all these factors this type of charging station involves large number of auxiliary components which increases the overall cost of charging station[12].

C. Hybrid EV Charging Station

A Hybrid EV charging station is modern EV charging station based on integration of solar based charging station and utility grid. Hybrid EV charging station can also be considered as multimode EV charging station that works in two different modes of operation. First mode is when charging station receives electrical power directly from utility grid and second mode is when charging station receives power from solar panels. In this way operation of EV charging station is managed in such way that maximum utilization of solar energy is made possible and burden on main grid is reduced significantly. In order to achieve best results coordinated operation of both the power sources is very much necessary. The efficiency of the utilized control approach is decided by a smooth transition between solar connected mode and grid connected mode[13].

1) *Design Of Solar Based EV Charging Station*

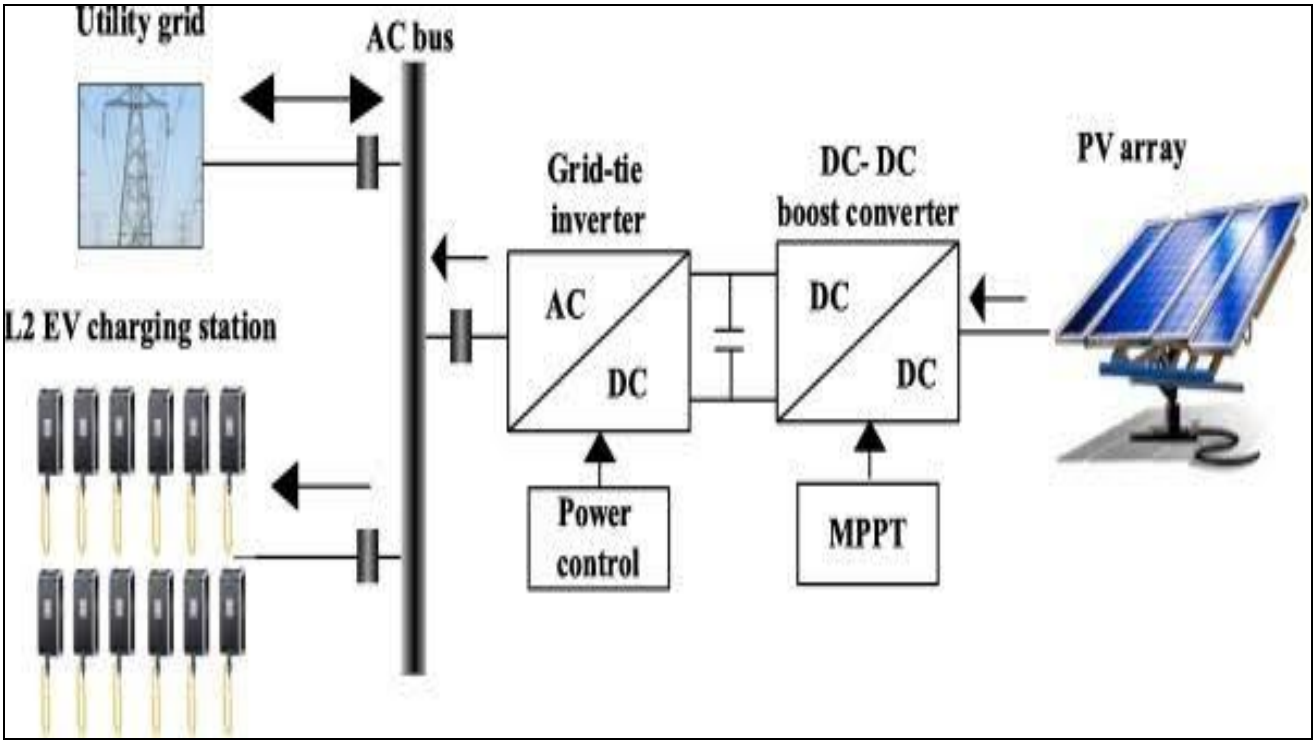

Fig. 5 Hybrid EV charging station

Architecture for Hybrid EV charging station is shown in fig. 5 It consist of PV array system, DC-DC boost converter, Grid tied DC-AC inverter, power controller, battery bank, MPPT charge controller, AC bus and most important of all it has automatic switching control circuit which is based on output voltage comparison algorithm and is responsible for smooth switching of charging station between grid connected mode and solar connected mode. Boost converter amplifies the DC output of solar panel. MPPT charge controller ensures the maximum output form solar panels. And is whole solar panel system along with MPPT charge controller and boost converter is interfaced to the AC bus via automatic switching circuit. Also grid and EV chargers are interfaced to this AC bus only. Along with batter bank a charge-discharge controller is additionally provided to control the charging and discharging mechanism of battery bank and ensures that battery never over charges and never discharges below fixed point for the long life of battery bank[14].

2) *Operating Strategy of Hybrid EV Charging Station:* In this Hybrid EV charging station when sufficient sunlight is available and sky is clear then chargiing station is operated in soalr power connected mode as output of solar panels is sufficent to charge the batttery bank. Here also MPPT controller is employed to get maiximum power output from solar panels. A automatic switching device based on voltage comaprision algorithim does the automatic switching of load to utility grid when sufficent solar power is not available and output of solar panel is very low. In peak hours of day solar panel supply energy to charging station and in off peak hours charging station can be powered by grid[15].

The operating strategy of multimode EV charging station is shown with the help of flow chart in figure 6.

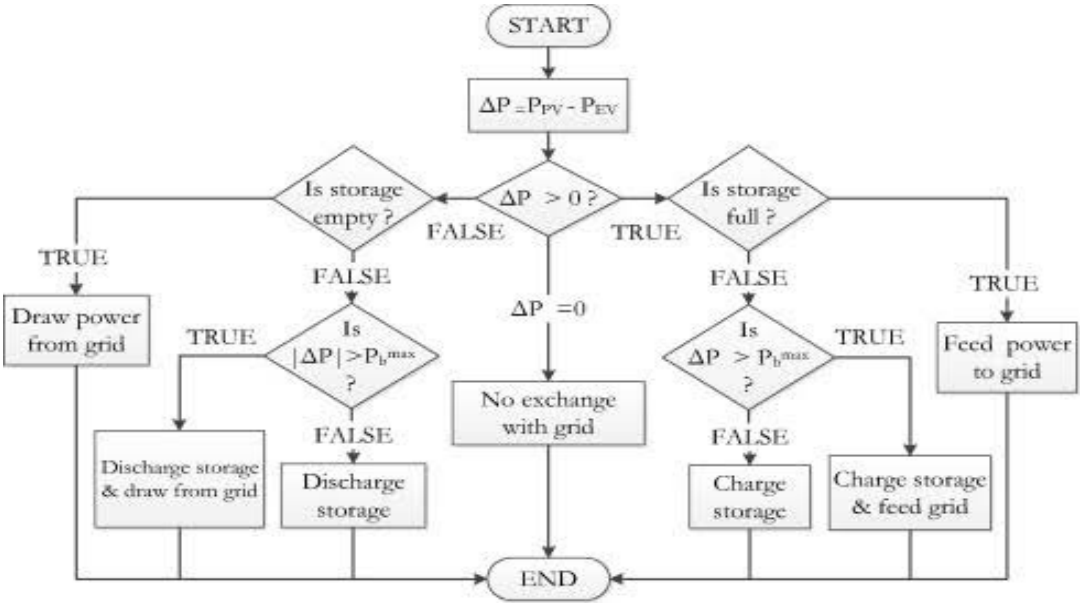

Fig. 6 Operating strategy of multimode EV charging station

IV. ADVANTAGES WITH INTEGRATION OF RENEWABLE ENERGY BASED SYSTEM WITH GRID

When EV charging station is operated in multimode condition with the integration of renewable energy-based energy sources the efficiency and reliability of EV charging station can improved. Stress on main grid can be reduced hence their improvement in grid's power quality and stability[16]. In this way this multimode operation of EV charging station serves the purpose of providing green and clean energy to electric vehicles which itself operates in environment friendly manner and making one step forward towards goal of achieving net carbon zero.

Some main advantages of integrating renewable energy-based system with utility grid are listed below-

1) Energy demand of main utility grid is reduced as power to charge electric vehicles is generated locally with solar panels.
2) Charging of electric vehicles from DC sources is more efficient than the charging electric vehicles with AC grid.
3) Renewable energy-based charging system can prove to be more useful in hilly areas or distant regions where AC grid connection is unable to reach.
4) Charging stations infrastructure can be implemented on large scale at rapid pace with integration of renewable energy sources.
5) Per unit cost of charging electric vehicles can be reduced significantly with the integration of renewable energy-based system with grid.
6) As main grid is not overloaded thus grid stability is increased significantly and power quality of grid is also improved.
7) Integrated Renewable energy-based charging infrastructure is eco-friendly way of supplying power to electric vehicles.
8) With the integration of renewable energy sources with grid-based charging infrastructure efficiency and reliability of charging station can be increased significantly.
9) This type of setup is well suited for government offices and public parking spaces where vehicle are parked for very long duration in day time.
10) Government providing subsidies for implementing renewable energy options can be beneficial in reducing initial installation cost of charging station.

V. CHALLENGES WITH INTEGRATION OF RENEWABLE ENERGY BASED SYSTEM WITH GRID

Although there are many advantages of integrating renewable energy sources with main grid but there are also some serious challenges in integration which must be taken into account. Proper methods must be adopted to overcome these challenges for implanting hybrid charging stations on large scale[17].

Some of the main challenges involved with integration of renewable energy sources with main grid are listed below-

1) First challenge involved in integration of renewable energy system and utility grid for charging infrastructure is increased cost of installation due to requirements of additional auxiliary equipment and solar panels.

2) To integrate renewable energy sources with main grid power electronics converters are generally used which introduces harmonics in the line currents which affects the power quality and causes additional I^2R losses.

3) Renewable energy sources such as solar and wind power generation systems are mostly weather dependent and their operations are severely affected due to adverse weather conditions.

4) Due to integration of renewable energy sources with main grid sometimes problems are faced in synchronism of combined systems.

5) Additional battery banks required to store the energy produced by renewable energy sources considerably increases the expenses and also requires large area for storage.

If dealt properly with some use of some advance technologies many of the challenges involved with integration of renewable energy sources and utility gird can be managed. Like Harmonic filters can be used to filter out dc harmonics due to non-linear power electronics converters, using high efficiency solar panels with MPPT charge controllers to get the maximum output from solar panels. Appling for waivers and subsidies provided by governments to reduce installation cost[18].

VI. CONCLUSIONS

This paper presents a review of the existing advancements in Electric Vehicle charging station infrastructure and also the various hybrid EV charging station options along with the ongoing prospective requirements for addressing the technological issues associated with the large-scale implementation of EV charging stations are analysed.

Out of all the available renewable sources of energy, charging station based on solar photovoltaic (PV) system is an easily accessible and feasible solution. In the day time, when the solar PV energy is available, the CS uses the PV array power to feed the loads and to charge both the storage battery and EVs. The multimode EV Charging Station can have long term benefits. The coordinated operation of PV array and grid can be efficient and economic option for implementation of EV Charging Stations on large scale.

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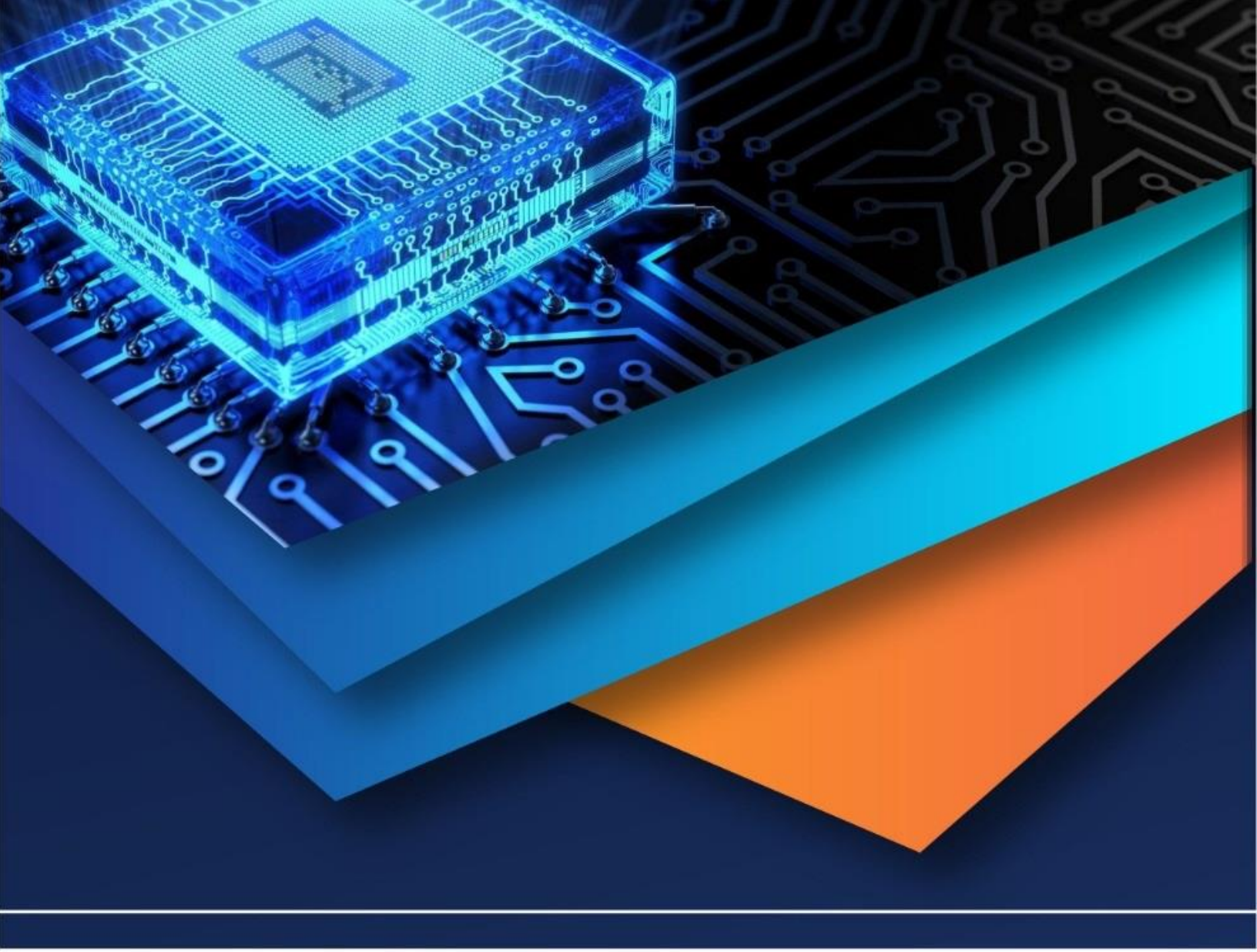

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