PV-Powered Charging Stations

Requirements, barriers, solutions and social acceptance

IEA PVPS Task 17, Report IEA-PVPS T17-04:2025, January 2025

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Executive Summary

As the shift to electric mobility gains momentum, the deployment of efficient and sustainable Electric Vehicle (EV) charging solutions becomes crucial. In this context, the first report published by IEA Task 17 Subtask 2 highlights the main requirements and feasibility conditions for increasing the benefits of photovoltaic (PV) energy through PV-powered charging stations (PVCS).

This second report delves into the technical, economic, environmental, and social dimensions of EV charging infrastructure, with a particular emphasis on microgrid-based stations that integrate photovoltaic sources, as well as the smart energy management of these stations through intelligent charging systems. Furthermore, it explores the socio-technical challenges surrounding user acceptance and the social acceptability of EV charging infrastructure, reflecting on how these factors impact the successful implementation of electromobility solutions.

Key recommendations

- Public grid impact
  - Considering the possibility of 10% of EVs simultaneously using rapid charging (50 kW), the network must allocate at least 19% of its total installed power to support the charging needs of 5 million EVs. Smart charging is essential, and it must extend beyond the usual reduction of power at charging terminals.
  - The widespread use of PV sources during daytime charging can reduce dependence on the electricity grid. Through local energy production, PVCS enables the charging of EVs, the return of excess energy to the grid, and the use of vehicle-to-grid (V2G) applications.
- Optimized Energy Use
  - Smart charging adjusts the charging power and timing based on PV energy availability, grid conditions, and user preferences, ensuring efficient use of PV energy and avoiding grid overload.
  - Human-System Interfaces (HSI) for PVCS are essential for enabling the characterization of services and facilitating the retrieval of various information. This includes the frequency of

charging sessions, EV load patterns, management of EV charging sessions, PV energy consumption, sustainability reports of charging sessions via email, valley and peak power consumption from the utility grid, and time-of-use tariff proposals for EV drivers. HSI is crucial for communicating with users to satisfy their requests and inform them about the energy distribution during charging, whether from the grid, PV, or stationary storage.

  - Real-time control, based on an energy management optimization algorithm, maximizes PV energy benefits and minimizes total energy costs while meeting user demand through HSi.
  - Based on users' forecasted departure times, real-time control can fully recharge the EV's battery while maximizing the use of PV energy during the recharge. Depending on the departure time, most EVs are charged with more than 80% PV energy.
  - Using real parking occupancy data collected over a full year, smart charging at a PV-powered parking lot near a suburban train station on the outskirts of Lisbon, Portugal, revealed a significant reduction (over 35%) in electricity imports from the grid.
- Global Cost and Carbon Impact Assessment
  - Based on the LCA, a specific calculation methodology is necessary to assess the overall cost and carbon impact of PVCS.
  - For a 30-year life cycle for PVCS:
    - Global cost includes approximately 40% investment costs and 49% maintenance costs.
    - Compared to traditional charging stations powered by grid electricity, the PVCS carbon impact is between 1,5 and 10 times smaller, depending on the energy mix implemented in the electricity grid.
  - Case Study: PVCS located in the north of France, covering 5 parking spots, equipped with a 22kWh stationary battery storage capacity, and recycled using pyrometallurgy. The installation consists of 28 kWp peak power across 70 panels installed on a surface of 124 m^2.
    - The global cost requires an initial investment of almost 65 k€, and may present a total cost of 150 k€ after 30 years.
    - The carbon impact assessment results show 40,7 gCO2eq/kWh, while a public grid-powered charging station shows an average of 275 gCO2eq/kWh for the European Union and 368 gCO2eq/kWh for the USA.
- Social acceptance
  - Based on a survey conducted in France on the social acceptance of PVCS and new services (particularly V2G), the study reveals that PVCS is socially acceptable to a large majority. However, some aspects, such as location, business model, and design, require careful consideration. Notably, over 83% of the 864 respondents agree with the V2G service. The main obstacles to the use of PVCS are often related to the efficiency of the PV panels, the recycling process, and pollution during the production phase.

A. *EV charging control and power management with demand response*

The contribution of EVs in reducing greenhouse gas emissions depends on the energetic mix of the public grid. On the other hand, the public grid may become vulnerable when EVs number drastically increase, as predicted in many worldwide scenarios. Considering several scenarios, i.e., passenger EVs number, charging power values, EV consumption, and average daily urban/peri-urban trip of 20 - 60 km, and based on French power grid data, a study investigates the power grid issues regarding the EVs charging. Its results show that the total required energy for EVs charging can be assumed by the grid while the total required power may represent an issue.

B. Human-System Interface for PVCS

Human-System Interface (HSi) is essential for PVCS as it enhances user interaction and system management. A well-designed HSi provides users with real-time data on charging status, energy production, and consumption, allowing them to make informed decisions about their charging habits. It also facilitates monitoring and control of the charging process, enabling users to adjust settings based on their needs or preferences.
Additionally, HSi can play a crucial role in troubleshooting and maintenance, providing alerts for system malfunctions or performance issues.
By improving the overall user experience, HSi encourages greater adoption of PV charging technology and supports the transition to renewable energy sources.

C. Smart Charging and real-time management for EVs

Smart charging and real-time management for EVs represent a transformative approach to energy utilization in the transportation sector, particularly when integrated with PV systems.
By leveraging advanced technologies and communication networks, smart charging systems optimize the charging process based on grid conditions, energy prices, and user preferences.
This dynamic management enables vehicles to charge during off-peak hours when energy demand is low, reducing costs for users and minimizing strain on the grid. When combined with PV integration, these systems can harness solar energy to power EV charging, further enhancing sustainability.
Real-time data analytics allows for efficient energy distribution, ensuring that charging stations adapt to fluctuating demand and utilize renewable energy sources effectively.
A real-time energy management system utilizing MILP optimization, implemented in France, demonstrated the feasibility of controlling EV charging while reducing energy costs.
Another study conducted in France demonstrated that it is feasible to synchronize the power consumption of 24 charging points with solar energy production, while increasing the self-production ratio and satisfying user needs.
A study in Portugal highlighted the potential of solar parking lots to enhance electric mobility while addressing challenges in aligning peak solar production with demand. With careful management and consideration of electricity pricing, these systems can achieve favourable economic returns within a reasonable payback period.

D. Technical and economic feasibility analysis of PVCS

The PVCS has been analyzed from a technical, economic, and environmental point of view. A three-step methodology, leading to a quantitative evaluation of the PV benefits obtained for PVCS, was designed. A tool has been proposed to adjust the investment cost of the PVCS using four parameters: the type of PV panels, number of PV panels, number of terminals, and the capacity of the stationary storage. The tool can be used to optimally size the PVCS and then, to obtain by simulation the operating modes aiming at increasing the use of PV energy for EV charging.

E. Societal impact and social acceptability of PVCS

The social acceptability of the PVCS should be studied alongside the technical study aiming at improving the project as well as increasing public knowledge. The purpose is to assess the acceptability of PVCS and their new associated services like smart charging and bidirectional energy transfer through a field study.

The study was carried out on a city scale and involved a large number of stakeholders. Hence, it tends to analyze the concept's limitations from a public point of view and highlights the evolution of people's mindsets through the years.