

Driving Qatar's Green Future

Integrating Smart EV Charging with Energy Storage and Solar PV System



Dr. Mohammad Amir,
Postdoctoral Research Associate, School of
Engineering, the University of Liverpool, United
Kingdom, Former Research Associate, Qatar University



Prof. Atif Iqbal,
IEEE Fellow and Professor of Electrical
Engineering, College of Engineering - Qatar
University

Abstract

Qatar is at the forefront of an energy transition shaped by its ambitious Qatar National Vision 2030. As the country invests in renewable energy and advanced grid technologies, electric vehicles (EVs) are emerging as key enablers of sustainable mobility. However, the integration of EVs into the national grid presents challenges, especially given Qatar's extreme climate and unique energy demand patterns. This article highlights research from Qatar University and international collaborators on integrating EVs with solar photovoltaic (PV) systems, energy storage, and intelligent charging strategies. The findings reveal a roadmap for balancing grid reliability, user convenience, and environmental sustainability, placing Qatar at the forefront of green transportation innovation in the Gulf region.

Introduction

Energy is central to sustainable development, powering transportation, industry, and communication systems. With the global shift from fossil fuels to renewable sources such as solar, wind, and hydrogen, nations are rethinking energy planning and infrastructure. In Qatar, abundant solar potential and progressive national goals make energy innovation a priority. The commissioning of the Al Kharsaah Solar Plant marked a significant milestone, supplying a large portion of peak demand and demonstrating Qatar's renewable energy ambitions.

For a nation balancing its role as a global energy exporter with domestic decarbonization needs, the integration of renewable energy, advanced storage, and intelligent grids is crucial. Against this backdrop, EVs offer an opportunity to decarbonize transport, but their integration into Qatar's power system requires smart, adaptive strategies.



Figure 1: Conceptual diagram of EV charging integrated with solar PV systems and energy storage units' control via an independent system operator.

Why Electric Vehicle Integration Matters for Qatar

Unlike internal combustion vehicles, EVs draw substantial electricity for charging, often during peak demand hours. In Qatar, this issue is exacerbated by the extreme summer conditions, where temperatures usually exceed 40°C. EV batteries require more cooling under such conditions, raising charging demand by up to 20%. If unmanaged, large-scale EV charging can overload transformers because of voltage drops, which could stress the national utility grid. Intelligent solutions are, therefore, essential to prevent these challenges from hindering Qatar's sustainable mobility goals.

Smart Models for Smarter Charging

Qatar University researchers have developed probabilistic models using Monte Carlo-based intelligent methods to simulate EV charging patterns across residential, commercial, and government sectors. Reflecting Qatar's distinct working hours, the models identified two stress points: early mornings and afternoons.

To mitigate risks, reward-based smart charging schemes were proposed. Instead of penalizing users, the model incentivizes them through:

- Lower tariffs for off-peak charging
- Free charging sessions
- Grocery vouchers or loyalty rewards
- Parking privileges for EVs charged using solar power

Such user-friendly approaches foster public acceptance while reducing grid strain, creating a win-win scenario for utilities and consumers.

Solar Synergy: EVs Meet PV

Qatar's vast solar potential makes PV systems an ideal complement to EV charging. By integrating a 1.5 MW solar PV system with EV charging, researchers observed significant improvements in



grid stability. Solar generation during daylight hours aligned well with peak charging demands, easing stress on the grid while maximizing renewable utilization.

This synergy illustrates how solar integration on campuses, highways, and urban centres can accelerate Qatar’s shift towards a clean transportation ecosystem.

Resilient Networks through Reconfiguration

Another innovation explored was distribution network reconfiguration, transitioning from radial to mesh structures. This adjustment improved voltage profiles by up to 18%, even under 20% EV penetration scenarios across residential, commercial, and industrial sectors. Such grid-level flexibility ensures that transportation electrification does not compromise reliability.

Qatar University: Towards a Sustainable Future

This research reflects Qatar University’s leadership in sustainable innovation. By blending advanced simulations, renewable integration, and consumer-centric strategies, the institution is setting benchmarks for green mobility in the Gulf region. Furthermore, the integration of machine learning in PV systems, covering inverter control, site

adaptation, and output power forecasting, enhances efficiency and reliability. These intelligent solutions contribute to resilient energy systems, reinforcing Qatar University’s mission of fostering sustainability and intelligent infrastructure on its campus and beyond.

Conclusion and Future Directions

Qatar stands at the threshold of a transformative era in energy and mobility. EV integration, when combined with solar PV, energy storage, and smart grids, can enable a resilient, low-carbon future aligned with Qatar National Vision 2030.

Future research and policy directions should focus on:

1. Expanding PV-powered EV charging hubs across cities.
 2. Deploying AI-driven demand forecasting and optimization algorithms.
 3. Enhancing incentive-based models to encourage consumer participation.
 4. Strengthening grid resilience through network reconfiguration and advanced storage technologies.
- By advancing these innovations, Qatar can establish itself as a global leader in sustainable transportation and intelligent energy management.

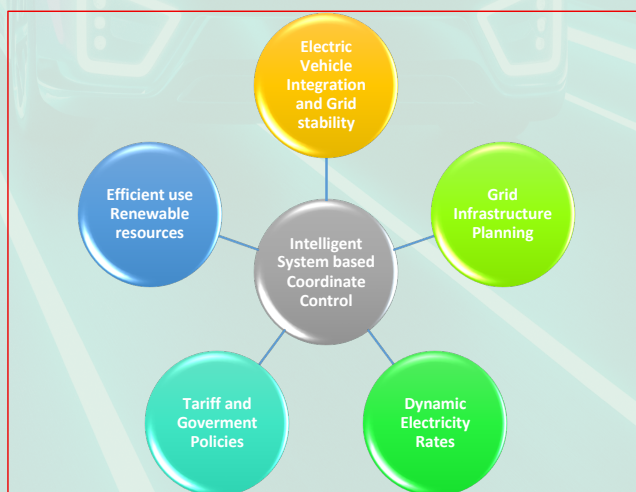


Figure 2: Recommendation for Overall Energy Management Strategies.

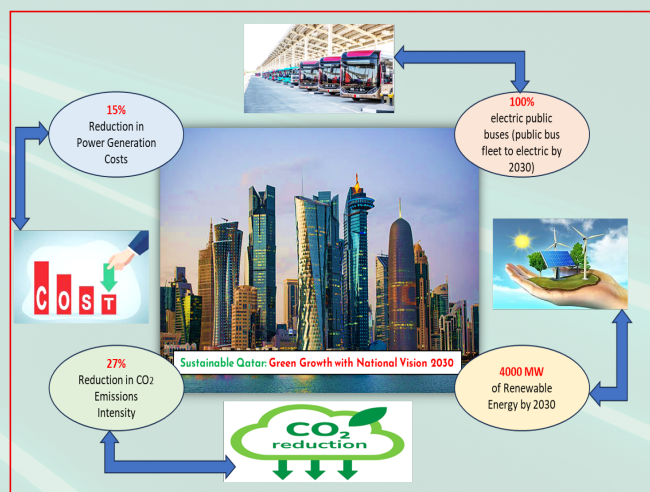


Figure 3: Qatar’s evolving energy system under the framework of National Vision 2030.