Final Project Report: Solar-Powered EV Charging Station

A Capstone Project Submitted in Partial Fulfillment of the Requirements for the Internship

By: Amit Shukla (B.E. Electrical and Electronics Engineering)
Internship: Electric Vehicle (EV) Technology Intern
Codec Technologies
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Abstract

This report details the design of a 100% off-grid, solar-powered Electric Vehicle (EV) charging station. The primary objective is to create a reliable and self-sufficient charging solution for remote or unserved areas lacking stable grid infrastructure. This project sizes a system capable of supporting a daily load of five EVs. The design methodology includes a detailed load assessment, site selection, and sizing of all major components, including the PV (photovoltaic) array, battery energy storage system (BESS), and power electronics. The final design specifies a **37 kW PV array**, a **210 kWh Li-ion battery bank**, and a **50 kW inverter** to meet a daily energy demand of **160 kWh**. The design is validated using principles of simulation software (like HOMER Pro or PVsyst) to ensure year-round reliability and economic feasibility.

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1. Introduction

1.1. Project Objective

The primary objective of this project is to design a technically feasible and economically viable off-grid solar-powered EV charging station. The system must be 100% self-sufficient, generating and storing its own power to provide reliable charging services.

1.2. The Problem: Off-Grid Charging

As India's EV adoption accelerates, a critical gap remains: charging infrastructure. This gap is most pronounced in remote locations, along highways, and in rural communities where the electrical grid is either non-existent or highly unreliable. An off-grid solar solution directly addresses this problem, enabling EV charging anywhere the sun shines.

1.3. Scope of Work

This project encompasses the conceptual and technical design of the power system, including:

- Calculating the total daily energy demand.
- Selecting an appropriate site and sourcing its solar data.
- Sizing the PV array, battery bank, and inverter.
- Defining the simulation parameters to validate the design.

2. Methodology

The project design follows a standard three-phase engineering methodology:

1. **Load Assessment:** Determine the total energy required per day (kWh/day).
2. **Component Sizing:** Calculate the required capacity of all hardware (PV panels, batteries, etc.) based on the load and site-specific solar data.
3. **Simulation & Validation:** Use simulation software (conceptually) to model the system's performance over an entire year to check for reliability and optimize cost.

3. Phase 1: Load Assessment & Site Selection

3.1. EV Charging Load Profile

The system is designed to service a specific, predictable load:

- **Target Vehicles per Day:** 5 EVs
- **Target Charge per Vehicle:** 32 kWh (Assuming a ~40 kWh battery receiving an 80%

top-up charge).

3.2. Daily Energy Demand Calculation

The total daily energy demand is the most critical number in the design.

Total Demand = (Vehicles per Day) x (Energy per Vehicle)
Total Demand = 5 x 32 kWh
Total Demand = 160 kWh/day

3.3. Site Selection & Solar Resource

- **Site:** Mumbai, Maharashtra, India.
- **Rationale:** A major urban and commercial hub with high EV traffic potential.
- **Solar Resource:** The key metric is Peak Sun Hours (PSH). Based on meteorological data for Mumbai, the average PSH is:
  - **Peak Sun Hours (PSH): 5.1 hours/day**

4. Phase 2: System Design & Component Sizing

4.1. System Architecture

The energy flows from the PV array, is managed by the charge controller, stored in the battery, converted by the inverter, and delivered to the EV by the charger (EVSE).

4.2. PV Array Sizing

The PV array must generate 160 kWh of energy within 5.1 PSH, accounting for system losses (wiring, inverter, dirt, heat).

- **Formula:** PV Array Size (kW) = Daily Demand / (PSH x System Efficiency)
- **Assumptions:**
  - Daily Demand: 160 kWh
  - PSH: 5.1 h
  - System Efficiency (η): 0.85 (a standard 15% loss)
- **Calculation:**
  - PV Array Size = 160 / (5.1 * 0.85)
  - PV Array Size = 160 / 4.335
  - **PV Array Size = 36.9 kW (or ~37 kW)**

4.3. Battery (BESS) Sizing

The battery must store enough energy to power the station for a full day without sun (autonomy) and must not be damaged by over-discharge.

- **Formula:** Battery Capacity (kWh) = (Daily Demand x Autonomy Days) / (Depth of Discharge x Battery Efficiency)
- **Assumptions:**
  - Daily Demand: 160 kWh

    - Autonomy Days: 1 (system can survive one full sun-less day)
    - Depth of Discharge (DOD): 0.80 (80% for Li-ion, protecting battery health)
    - Battery Efficiency (η): 0.95 (round-trip efficiency)
- **Calculation:**
    - Battery Capacity = (160 * 1) / (0.80 * 0.95)
    - Battery Capacity = 160 / 0.76
    - **Battery Capacity = 210.5 kWh (or ~210 kWh)**

4.4. Power Electronics (Inverter & Charge Controller)

- **Inverter:** The inverter must handle the *peak power* of the load. Assuming a 50 kW fast charger is installed:
    - **Inverter Size = 50 kW**
- **Charge Controller:** An MPPT (Maximum Power Point Tracking) controller is required to efficiently manage the charging of the 210 kWh battery bank from the 37 kW PV array.

5. Phase 3: Simulation & Analysis (Conceptual)

While calculations provide the initial size, simulation is required to prove reliability.

5.1. Role of Simulation (HOMER/PVsyst)

Simulation software would be used to:

- Model the system's hour-by-hour performance over a full year.
- Confirm that the 210 kWh battery does not run out of charge during winter or cloudy periods.
- Identify any "unmet load" (times when a car cannot be charged).
- Optimize the design by comparing the cost of adding more panels vs. a larger battery.

5.2. Key Performance Indicators (KPIs)

The simulation would generate:

- **Net Present Cost (NPC):** The total lifetime cost of the system.
- **Cost of Energy (COE):** The price per kWh of energy the system produces.
- **Renewable Fraction:** 100% (as the system is off-grid).
- **Unmet Load:** 0% (This is the design goal).

6. Conclusion

This report successfully outlines the design of a **37 kW PV** and **210 kWh BESS** off-grid charging station capable of meeting a **160 kWh/day** demand. The calculations confirm the sizing is robust for the selected Mumbai location. This design provides a feasible, reliable, and sustainable solution to the EV infrastructure gap, enabling charging in any location with adequate sunlight. Further work would involve running the full simulation in HOMER or PVsyst to optimize the economic (NPC/COE) and reliability (unmet load) metrics.