Driving Green Mobility - RTPV Integrated EV Charging

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Introduction

Indian transport is massive and diverse in catering to the mobility needs of its 1.4 billion population. Road transport alone emits 0.24 G tonnes of CO_2 annually, 90% of the total transport sector emissions. Among the Indian Megacities, Bengaluru's transport sector contributes the most (about 40%) to the city's air pollution (Figure 1).

Figure 1: Sector-wise origin of PM2.5 in Indian megacities

The central and state governments are aggressively working towards decarbonising the road transport through various policy measures. This is crucial to meet India's target of reducing CO_2 emissions by 1 billion tonnes by 2030 to achieve net-zero carbon targets by 2070. Mode-shift to public transit and adoption of electric vehicles (EVs) are two major strategies considered successful in decarbonizing the transport sector. As per projections by NITI Aayog and WRI, Bengaluru could have around 8 lakh EVs by 2030. This scale of EV adoption would require about 3,000 GWh of energy, annually. Further, the source of this energy becomes crucial in achieving significant reduction in emissions. Currently, the energy mix to the grid is dominated by coal. Therefore, the renewable energy mix of grid electricity becomes essential in enabling green mobility in the truest sense. Use of clean energy for charging EVs paves way for transitioning towards green mobility.

Solar Energy – Based EV Charging: A Pilot Demonstration

The CSTEP's pilot project at the Bangalore Electricity Supply Company (BESCOM) Corporate Office premises demonstrated this concept of using a clean source of energy (solar) for charging EVs. This project was undertaken in collaboration with Delta Electronics Pvt. Ltd.

The system design for the pilot project consists of a power conversion unit (PCU), solar rooftop photovoltaic (SRTPV) panels, a lithium-ion battery bank, and an EV charger as the main components. An intelligent computing unit in the PCU commands the energy flow across these components to maximise the generated solar energy for self-consumption.
The project showcases

- an intelligent bi-directional converter (PCU) that interfaces with SRTPV and battery systems (with DC coupling) to manage the energy flow with EV chargers and the grid.
- the prioritisation of solar energy for local consumption before feeding it to the grid.
- the deployment of a novel charging algorithm where the EV charging load is made to follow the solar energy generation profile. Such a method reduces the need for a costly battery energy storage system (BESS).

System Configuration

The BESCOM corporate office houses a 50 kWp & 40 kWp RTPV system (Figure 1). The EV charging station, comprised of a combination of fast (Three DC 001 (15 kW DC + 3.3 kW AC) and slow chargers (One IS-17017 (25 kW CCS/CHAdeMO).

Figure 2: RTPV Installation at BESCOM premises

(A: Bharat DC 001 charger, B: lithium-ion battery bank, C: MPPT block, D: transformer, E: PCS, and F: distribution box)

Figure 3: Snapshot of the Integrated system at BESCOM premises

For the pilot, only 20 kWp from PV array and a fast charger was integrated for demonstration purposes.

The integrated system (Figure 2) consists of a power conversion system (PCS) to interface with the solar panels and the battery bank to channel the combined energy for EV charging. The PCS is governed by an energy management system (EMS) to ensure maximum utilisation of solar energy. The PCS, RenE EVSE PowerSuite (125 kW), is an integrated system to power EV charging units from multiple generation sources such as solar, grid, and an optional battery backup. The unit has the provision to connect direct inputs from the PV system and battery units while providing an output for the charging station. With its advanced control systems and intelligence, the PCS ensures maximum power availability at the charging point irrespective of the source dynamics and grid outages.

The set-up also uses a lithium-ion battery bank to power the EV charger. The two main uses of the battery bank are to maximise the utilisation of solar energy for charging and provide energy backup in the off-grid mode. The nominal battery capacity is 43.5 kWh, with a voltage and current specs of 725 V and 60 Ah respectively.

The EMS is an intelligent system that provides a grid dispatch interface and energy management for the battery banks in particular. The EMS communicates with the BMS, PowerSuite controller, and EV controller and follows various algorithms to compute the output that needs to be performed. The generated set point commands the PowerSuite and BMS as per the application.

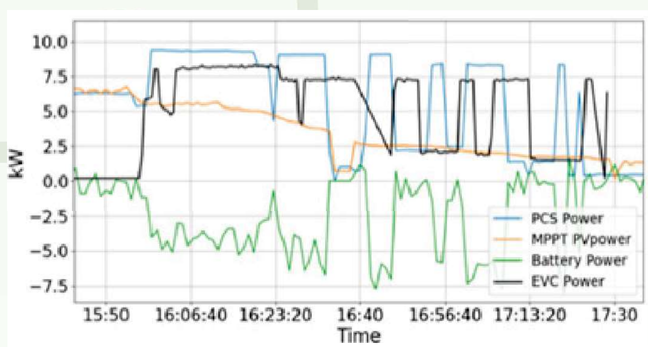


Figure 4: Energy and Charging Profiles during a typical day

The energy management strategies deployed in the system is as follows: PV energy forms the first priority, followed by battery and then grid energy. The EV charger demands constant power (during charging events). To compensate for the decreasing PV energy, the battery starts discharging accordingly so that the total power can follow the EV demand. The energy and charging profiles, for short time window, during a operations on a typical day is as shown in Figure 3.

Techno-Economics of Grid-Tied RTPV Plus Storage-Based EV Charging

A simplified schematic (Figure 4) is used for arriving at the relevant metrics and equations for cost estimations. The main components are the PV block, the battery energy storage block (which also includes the PCS), EV supply equipment (chargers), and a distribution box (denoted as DB in the figure), which represents the point of interaction with the grid connection. System A consists of only the EV charging equipment (EVCE), and System B represents the solar plus storage systems. System C represents the integrated Solar RTPV, Battery and Grid systems. An RTPV system size of 40 kWp was considered for this analysis.

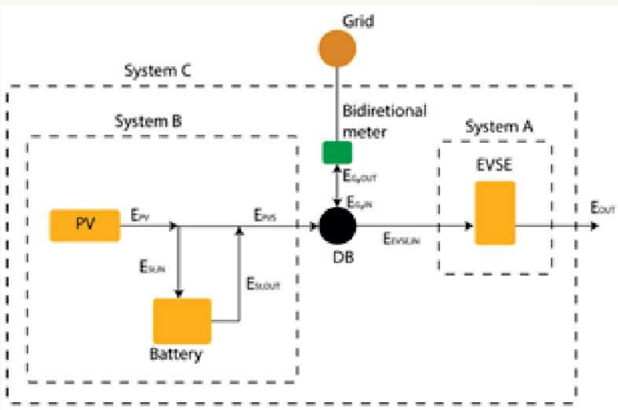


Figure 5: Schematic of the system for techno-economic modelling

The objective was to calculate the Levelised Cost of Charging (LCOC) considering both Levelised Cost of Energy (LCOE), from RTPV systems and Levelised Cost of Storage (LCOS), depending upon the type of system considered. The estimations also considered the current subsidies provided to various sub-systems (Solar RTPV, Charing equipment's, grid energy costs for EV charging etc.). For techno-economic modelling, all the four chargers available at the BECOM premises were considered.

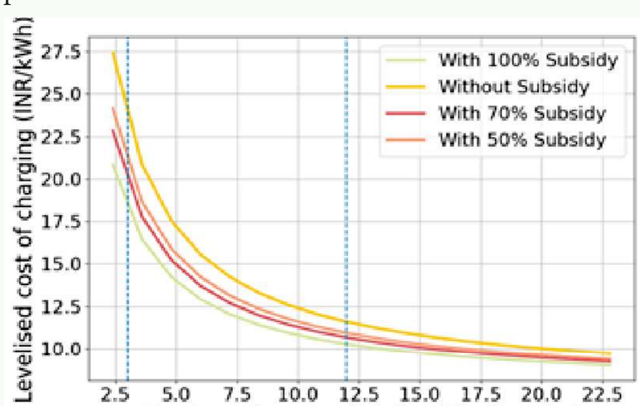


Figure 6: The effect of subsidies on the LCOC at the model EVCS (cost of grid electricity = INR 5/kWh for all cases)

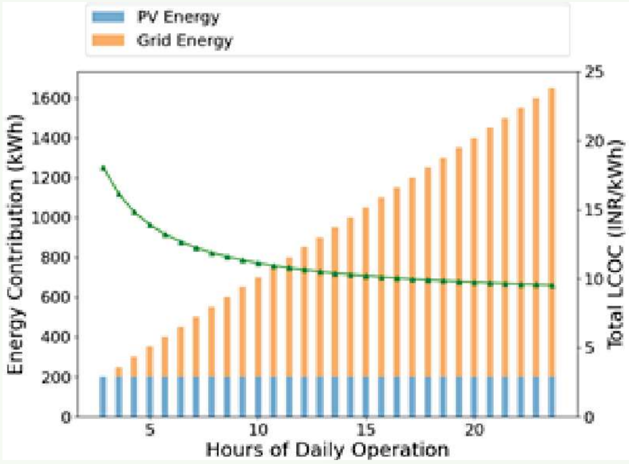
It was observed that, the duration of use of chargers per day has an impact on the levelized costs. Figure 5 shows the impact of subsidies on the LCOC for System A. It can be seen that the contribution of incentives towards cost reduction is relatively more pronounced at lower utilisation, which is currently the case across the country owing to the low adoption of EVs.

Consider the case of 3 hours per day of daily utilisation; the LCOC without subsidy is close to INR 24.5/kWh. With 100% subsidy, it comes down by 32% to ~INR 18.5/kWh.

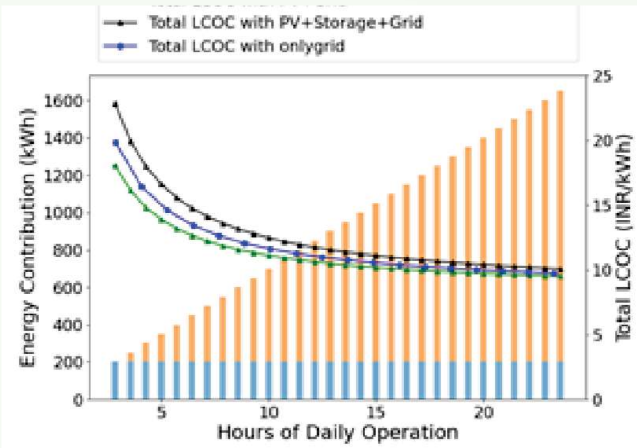
In a scenario where the utilisation is 12 hours per day, the corresponding reduction is 11%. Overall, there is a substantial reduction in the LCOC with the addition of subsidies.

Figure 6 shows how the LCOC of the model EVCS varies when connected to an RTPV or RTPV plus energy storage system as a function of hours of operation per day. The EVCS relying only on the grid energy is taken to be the baseline case. The levelised cost upon using RTPV energy (green line plot in the figure) in the total energy mix is slightly lowered compared to the baseline case of the EVCS relying completely on the grid. It can be seen that the difference in LCOC estimated for the two cases—PV plus grid and grid only—are not much (less than 0.01%). This can be attributed to the fact that the LCOE of PV estimated here is only slightly lower (by INR 0.5/kWh) than the electricity cost from the grid, which is reflected as the cost difference between the two cases.

Furthermore, the difference in the LCOC decreased with a higher mix of the grid energy as expected. Note that (as emphasised earlier) the arguments and analysis being presented here assume operation under the net-metering policy, which ensures complete utilisation of the generated solar energy even when there is a mismatch between generation and consumption/charging events. The LCOC for the EVCS depending on RTPV plus storage plus grid is seen to be higher than that of the grid only scenario (blue curve) at all times of operation, as expected, owing to the additional cost of energy storage. This difference is higher at lower utilisation. The difference is ~INR 4/kWh at 2.8 hours of daily utilisation, while it is ~INR 0.5/kWh at 20 hours of daily utilisation. This reduced difference at higher utilisation between the LCOCTot of the two cases is because of the increasing contribution of the cheaper grid energy since there is no change in the utilisation/operation of the solar plus storage power plant.



(a) Grid tied RTPV without Storage



(b) Grid tied RTPV with Storage

Figure 7: Comparison of the levelised cost of charging (LCOC)

Conclusions and Recommendations:

Above sections analysed the commercial aspects of using grid-connected solar rooftop PV with and without a battery energy storage system (BESS) to power an EV charging station (EVCS). A helpful parameter used in the study to estimate the economic benefits of using solar energy and BESS for EV charging is the levelised cost of charging (LCOC; also referred to as the cost of charging), which considers all the costs incurred over the lifetime of the assets.

- The cost of charging service from a charging station depends on the utilisation of the chargers, as expected. Lower utilisation increases the cost of charging service offered by the station.
- Subsidy on chargers (as currently offered by the DHI) can considerably reduce the charging cost, especially at lower charger utilisation. However, future investments related to replacing the chargers at their end of life will increase this cost in the long term.
- The net-metering policy plays an important role in lowering the LCOE, which otherwise would increase owing to the mismatch between energy generation and consumption. With net metering, the excess energy generated that is fed to the grid during the day can be thought of as being drawn back, free of cost, if no net energy is exchanged with the grid during the billing cycle. Hence, under this policy, the grid acts as a "virtual battery" that helps to time-shift excess energy during the day back to the night for consumption. Without this facility, the levelised cost would increase whenever the cheaper PV energy is fed to the grid because of the mismatch with the consumption. Hence, it is recommended that an EVCS with a solar RTPV system should also use this policy for cost savings.