Format for uploading details of completed projects

1. **Project details**

a. *Title*: Impact of harmonics on Power Distribution Network due to Electric Vehicle Charging

b. *Institute*: Power System Division, CPRI

2. **Aim / Objectives:**

- Collection and analysis of power quality data from charging station(s) corresponding to various charging scenarios.
- Development and validation of EV Charger models for Level 1, 2 and 3 EVSEs using computer software, based on the current and voltage harmonics data collected.
- Integration of EV charger models with the distribution network in simulation environment
- Analysis of effect of harmonics generated by the EV Chargers on the distribution network with special emphasis on simultaneous charging of multiple EVs
- Preparation and submission of detailed report on the study with summary of Power quality compliance as per IEEE 519-2014 standard.

3. **Executive Summary (*One page*):**

The project analyzes the impact of DC/AC EV chargers on power quality in distribution grids. Data on current and voltage harmonics was collected from chargers of various ratings, including Level 2/Level 3 DC chargers (15 kW, 25 kW, 30 kW, 50 kW), 240 kW DC super-fast charger and 3.3 kW AC slow charger. MATLAB Simulink models were developed to simulate these chargers and study their effects on distribution systems in relation to harmonics, Total Harmonic Distortion (THD) and Total Demand Distortion (TDD), particularly during simultaneous EV charging. DC Level 2 chargers with ratings of 15 kW and 25 kW, commonly used in commercial and public spaces, were found to generate significant THD_i throughout the charging cycle, with values exceeding permissible limits and doubling the threshold when charging between 80% and 100% SOC, leading to severe power quality issues. Current unbalance was also observed in 15 kW chargers. Level 3 chargers, such as the 30 kW and 50 kW models, exhibited higher THD_i for battery SOCs beyond 80%, with the 30 kW charger additionally demonstrating poor power factor after 80% SOC. For the 240 kW DC super-fast charger used for e-buses, voltage THD remained within limits, but current THD increased during the CC-to-CV phase transition and near thermal thresholds. The phase current also varied with operating temperatures, increasing the charging time and underlining the importance of effective thermal management. Field data from the BESCOM charging station showed voltage drops of over 10% below the nominal value of 250 V during peak hours (9 am to 12 pm) when three to five EVs were charged simultaneously. Lastly, simulation studies of 3.3 kW AC onboard chargers at residential levels have been carried out. The study highlights the importance of addressing power quality issues, especially THD, TDD and voltage dips and suggests exploring coordinated EV charging strategies and further power quality studies to support widespread EV adoption in India.

4. Scope for further work

Future research can focus on the following areas to ensure the smoother integration of EV chargers into power grids:

- Optimized charger placement for minimal grid impact
- Smart transformers and SSTs to enhance power quality in EV-dense areas
- Coordinated charging strategies to mitigate peak loads and harmonics
- AI/ML-based real-time monitoring and adaptive filtering for harmonic mitigation
- Harmonic interactions analysis between chargers and nonlinear loads
- Passive filter optimization based on network impedance profiles
- Impact of charger-induced harmonics in renewable energy-integrated microgrids
- Utility incentives for deploying grid-friendly EV chargers
- Impact of V2G Integration on Power Quality

5. Benefits visualized

The study provides valuable insights into the impact of EV charging infrastructure on distribution network power quality. By analysing chargers of various ratings under real operating conditions and through simulation, the project helps identify key issues such as high harmonic distortion, voltage dips, current unbalance and power factor deterioration during EV charging. The results enable utilities and planners to better understand the behaviour of EV chargers at different states of charge and loading conditions. This knowledge supports the development of coordinated charging strategies, improved charger design and appropriate grid planning measures to mitigate power quality problems, thereby facilitating reliable and large-scale integration of electric vehicles into the power distribution system.