European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	**AQUA**
Title	Analysis of power QUAlity through smart EV charging processes
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TA Call No.	**Call 1**

HOST RESEARCH INFRASTRUCTURE			
Name	**AIT SmartEST**		
Country	**Austria**		
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1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

The electrification of the mobility sector is seen as an opportunity to act as a compensatory element for volatile generation. This electrification comes with multiple challenges such as the lack of information on when, where, how long and how fast charging processes of electric vehicles will take place. This poses major challenges, especially for *Distribution System Operators (DSO)*. Furthermore, the unknown grid perturbations of electric cars in single or parallel operation must also be sufficiently well understood. Like the volatile feed-in structure, peak loads must be avoided but sufficient capacities for the charging processes must still be provided. To this regard, a good power planning is required to minimize the cost of upgrading the power grid to hold on the increased demand caused by charging processes. On the other hand, a mechanism for supporting the stability of the grid in terms of overloading the grid elements or other power quality issues can help DSOs in many cases. This mechanism should be decentralized to meet the scalability requirements.

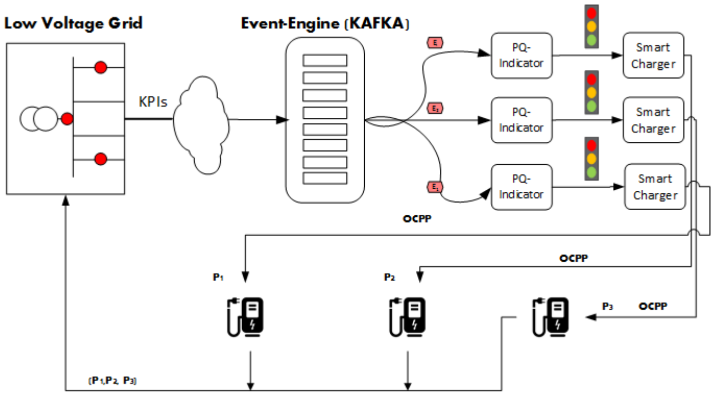

Figure 1: Proposed Architecture

In this project, we propose to analyse the stability of the grid by studying its power quality through the setting up of an ecosystem consisting of DSO, *Charging Station Operator (CSO)* and *Electric Vehicles (EVs)*. For this analysis, the utmost priority is the provision of such an ecosystem through the combination of both real physical and simulated environments. The main objective of this project is developing a decentralized load management controller that takes the power quality of the grid into account. This controller provides decentralized and automated load management at the level of the EV Charging Station (CS). Measurement devices that are installed in the low voltage grid collect data which are used by the controller in order to make decisions about the current situation in the grid in terms of power quality and to determine the best reaction from the CS. This controller can be seen as an extension of any existing Charging Station Management System (CSMS) or as a standalone component, since it can speak the same language between CSMS and the CS (i.e. using the OCPP protocol). We call this controller called Smart Charger. To achieve this goal, we propose an architecture that contains three components as depicted Figure 1:

1. A real-time handling of big data streams collected by measurement devices (*Apache Kafka*).
2. A component that indicates the status of the grid based on the collected data (*PQ Indicator*).
3. A controller that changes the used charging capacity regarding to some recommendation from PQ-indicator (*Smart Charger*).

The proposed smart charging algorithm should:

a. be decentralized,
b. be fair,
c. avoid starving and
d. avoid power quality problems that arise of drastic changes by smoothly adopting the charging power capacity of the charging process.

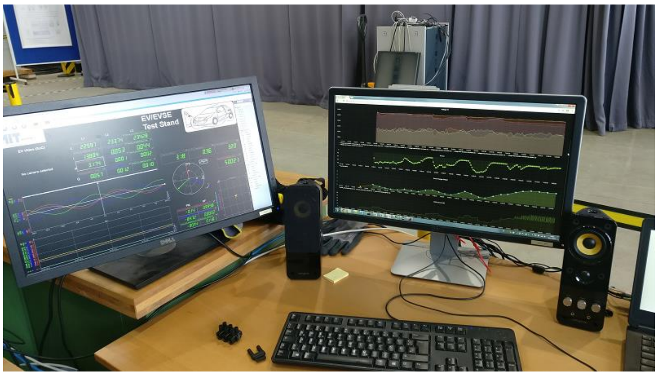

Figure 2: Experiment Monitoring

Testing the proposed architecture is done In the FlexEVLab which provides all required hardware and software components as well as the AIT Lablink middleware for PHIL (Power Hardware in the Loop) coupling for steady state co-emulation. In this lab we have a CS that can be controlled using a simple Modbus controller. The possible control options are start/stop charging operation and changing the charging current. These parameters can be set at the charging station using the AIT Lablink Phoenix EVSE client. The setup of experiments is shown in Figure 2. On the left screen the real charging station is monitored, and the right screen show the reaction of the smart charger and the grid simulated by a power simulation software.

2. MAIN ACHIEVEMENTS (results, conclusions, lessons learned)

The main achievements of this project is testing and validating a decentralized load controller responds in real time to the changes of power quality in the grid. It considers the overloading of transformer or any other element in the grid and the variation of the voltage magnitude in the low voltage grid, while trying to keep the voltage magnitude within the boundaries predefined by the DSO. To this end, the charging process is dynamically controlled with respect to the changes in the power quality of the grid. The developing of this controller needs a deep understanding of the car behavior during the charging process and its reactions on control commands. In the same way, we investigate Which effects we can expect from EV Charging on the Grid in terms of power quality. The achieved design success to a certain limit to guarantee the fairness between several charging processes.

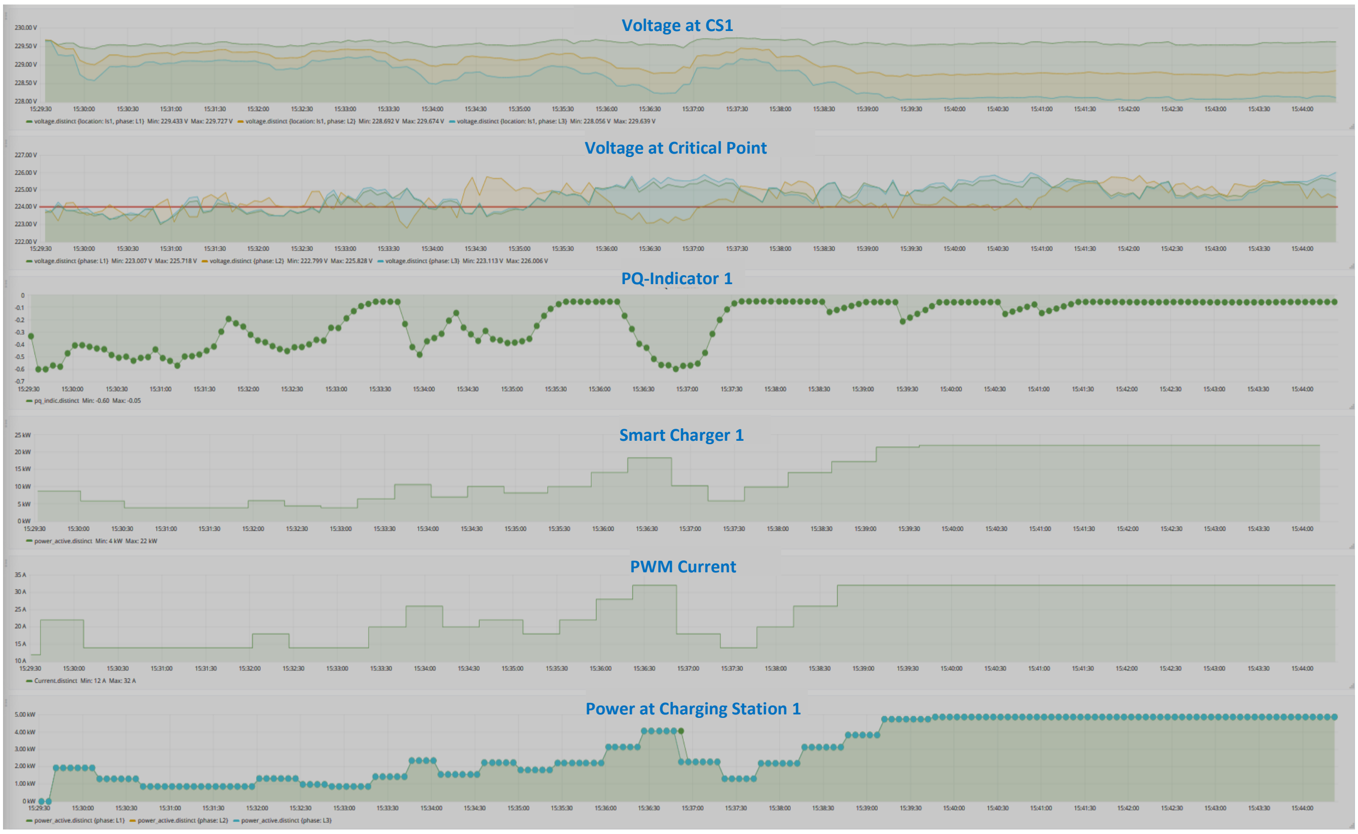

Figure 3: Reaction of the proposed smart charger on an emulated real grid from Bavaria

We run tests of our smart charging algorithm on an emulated real low voltage grid from Bavaria. This grid contains dozens of households and industry, as well as 4 charging stations located at a place near to the transformer, where we activated our smart charging algorithm. The first part of Figure 3 show the voltage fluctuation at the transformer/charging station (upper lines) and at the most critical point in the grid (lower lines). The second part depicts the output of the PQ Indicator to which the smart charger reacts. The last three graphs show the output of the smart charger, the charging current that is set to the charging station and the measured charging power from the car. The results show the ability of our smart charger to response to the different long-term voltage sags and swells by indicating them correctly and react in the correct way to reduce them and keep the voltage in the required bounds. In our example we used the boundary of ± 3 % of nominal voltage. The Figure depicts how the smart charger changes the used charging capacity accordingly to the voltage changes at the CS (3 phases) and the most critical point in the grid which can give a global view of the voltage on the line.

Conclusion:

Adopt the charging rates according to the voltage variations can lead to an intelligent charging process that keeps the voltage within certain bounds. The result is a continuing charging process with less harming effect of the grid. This controlled charging process allows the DSOs to use electric vehicles as an additional ancillary service to stabilize their grid.

Lessons Learned:

- After a certain value of *State of Charge (SoC)* of the battery, especially during the constant voltage phase, the car will not be increasing the charging current over a certain limit. This threshold of SoC differs from car to car, but usually it is bigger than 80%. A smart charging algorithm needs to take this into account.
- Moreover, there is also a lower limit for charging a car. Once crossing this limit result in disconnection of the car and restarting the charging process requires human interventions. For instance, the Nissan iMiev stops charging, when the charging stations proposes a charging current lower than 7 Ampere. Again, this value differs by the car type and charging mode.
- A completely decentralized controller that only takes the local grid values into account is sufficient for controlling the power quality of a low voltage grid. The decentralized controller needs to take the most critical point of the grid into account to have a more global view.
- A 30 second based triggering time of the smart charger sometimes is too fast, because of the reaction time of the measurement infrastructure on changes in the grid and the car on changes of the charging current. During the initial phase of the charging process 30 second interval is reasonable to reach the desired maximum possible charging power as soon as possible. In case there are critical voltage changes a fast trigger, time is required as well. During a phase where the grid is not critical a higher trigger time of the smart charger, e.g. every 5 minutes, is enough to react on long term voltage changes. Hence, we propose a granularity of 5 minutes used with a smart approach to decide about the critical events.
- A centralized component coordinating among the different smart chargers and other power quality compensation equipment can improve the performance and fairness of regulations.

3. PLANNED DISSEMINATION OF RESULTS (journals, conferences, others)

- A scientific publication with the draft title “Smart Charging Algorithm for Power Quality Control in the Electrical Distribution System”
  - Ammar Alyousef, Dominik Danner, Friederich Kupzog, Herman de Meer
  - Target: E-energy 2018, submission until 22nd of January 2018
- Enhancement of the content of the lectures at the Chair of Prof. de Meer, for example in “Computer Networking and Energy Systems”, where the basic principles of energy supply and distribution are explained, but also the topic safe network operation is discussed.