25th ITS World Congress, Copenhagen, Denmark, 17-21 September 2018

Paper ID **EU-TP1278**

EV charging QoS and power system robustness through ICT applications; NeMo's approach

T. Theodoropoulos , G. Drainakis, C. Anagnostopoulou, A. Amditis
1. **Institute of communication & Computer Systems (ICCS),**
Email: t.theodoropoulos@iccs.gr, giorgos.drainakis@iccs.gr, christina.anagnostopoulou@iccs.gr, a.amditis@iccs.gr

Abstract
Transport electrification is a major part of global decarbonization and CO2 emission reduction. EVs are an enabler of potential reduction of emissions on the basis of a clean energy power mix. Distributed energy generation has the potential to provide a basis for clean energy consumption and energy efficiency due to decreased energy transport and associated losses. However, potential increase of EV fleet size could create the need to re evaluate practices ensuring grid quality and reliability. ICT applications could contribute towards the green energy shift in transport, in a reliable manner. Such services will be designed and developed by NeMo, a 4 year European H2020 project.

Keywords:
Smart grid, charging management, networks

Introduction

Transport electrification is a major part of global decarbonization and CO2 emission reduction [1]. EVs are an enabler of potential reduction of emissions on the basis of a clean energy power mix. Distributed energy generation has the potential to provide a basis for clean energy consumption and energy efficiency due to decreased energy transport and associated losses. However, potential increase of EV fleet size could create the need to re evaluate practices ensuring grid quality and reliability [2]. Innovative ICT applications could contribute towards the green energy shift in transport, in a reliable manner [3].
Such services will be designed and developed by NeMo [4], a 4 year European H2020 project. NeMo proposes the following set of applications in order to address the aforementioned matters.

- Navigation to CP (Charge points) based on user and grid power requirements

- Load management (Demand side management)
- Global customer charging behavior
- Load forecasting due to EV charging.
- Local energy management.

Grid aware charge point navigation aims at guiding vehicles to charge points according EV driver criteria and grid constraints which could be associated to grid metrics such as voltage stability and transformer congestion. Load management (Demand Side Management or Smart charging) enables energy efficiency by introducing local energy supply in the charging power mix and reduction of peak power effects, through collaborative charging optimization [5] . Of course such applications required precise demand and supply analytics in order to deduce control strategies. Area wide customer charging behavior can be captured and monitored through the deployment of ADVANCED Metering Infrastructure (AMI), whereas analytic predictive mechanisms such as Deep Learning LSTM networks can digest monitored demand to forecast region wide EV charging needs [6].

In order to harmonize data and create such applications, a high level of collaboration between business actors is required. For example, grid aware EV driver navigation to charge points, requires exchange of data between Charging Point Operators, Distribution System Operator, Energy retailers and EVs, in order to provide optimized routes that take power system requirements into consideration. The same principle applies also to smart charging [7]. NeMo proposes business actor integration through a collaborative service hyper network, thus breaking communication barriers and fostering collaboration and enabling grid services (Figure 1).

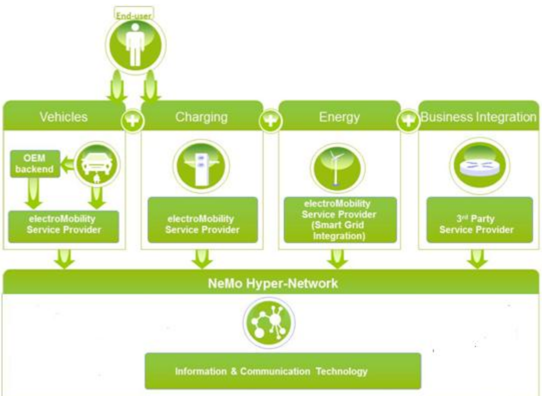

Figure 1 Electromobility actors connected through NeMo's hypernetwork.

ICT application orchestration for grid and EV charging

Grid service orchestration is essential in building applications that take the whole EV charging ecosystem into consideration towards EV charging quality of service, emission reductions, energy efficiency and grid power quality assurance. The overall charging lifecycle can be decomposed in two main processes. EV navigation to the charge point and the charging process itself. Control of both processes can lead to optimized charging cycles along both grid and user criteria. EV driver acceptance is crucial in opting-in to such processes and could be achieved by financial incentives provided to drivers by their Electromobility provider.

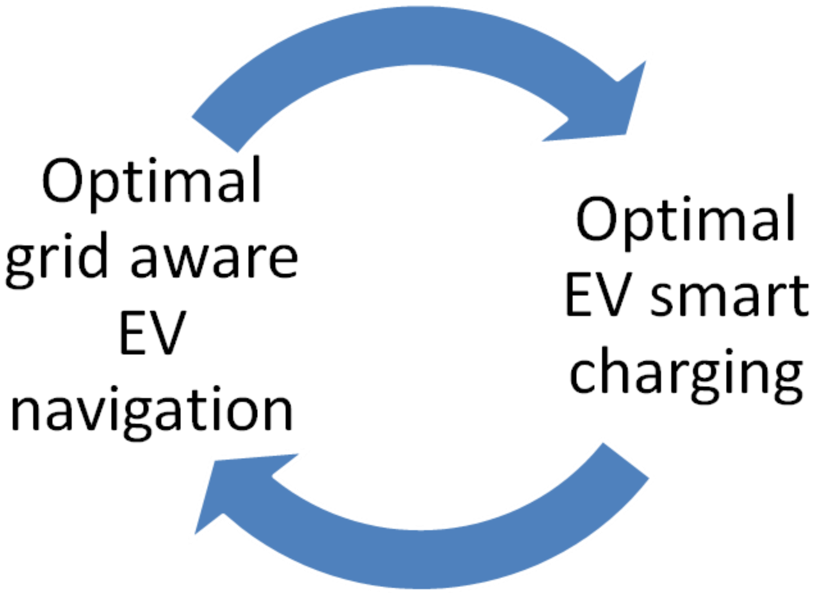

Figure 2 EV charging lifecycle

The analysis of each one of the applications follows in the subsequent chapters.

Optimal grid aware EV navigation

Grid quality of service can be defined on the basis of load flow analysis performed by the distribution system operator (DSO). DSOs determine distribution line voltage profiles and transformer loading based on demand and supply forecasts. On the basis of load flows the DSO can deduce power capacity constraints in order to ensure stable voltage and thermal profiles within acceptable limits. Such a capacity limit time series can be transferred to the CPO who would ensure operational robustness under the defined limits. Moreover, additional capacity constraints can be set by the energy retailer associated to a given CPO, so as to ensure financial criteria and optimal energy usage. Specification of the optimality, would be defined on a contractual basis between a given CPO and a given energy retailer. CPO's can thus deduce, its capacity and future availability for future charging operations. Journey planners can use such information in order to schedule EV trips. Additionally navigation devices can enrich charge point (CP) related data with indicators of remaining grid capacity or grid congestion indicators informing EV drivers about charging opportunities in proximity of the EV.

Figure 3 Grid aware EV navigation lifecycle

Smart charging

EV charging is a flexible process; EV drivers are usually interested in the amount of energy the EV should be charged with until departure time. Such flexibility can be considered as an additional asset, that could be further exploited by the grid. For example, charging can be shifted to off peak time periods or periods with increased renewable generation. Charge operation shifting seems to be an enabler of increased grid reliability and energy efficiency. There is also a striking analogy between the processes of grid aware EV navigation and smart charging. The former makes an attempt of shifting EV fleets towards CPs according to grid optimisation, where as the latter shifts charging operations of a given fleet of vehicles according to grid optimisation. **Error! Reference source not found.** depicts the process.

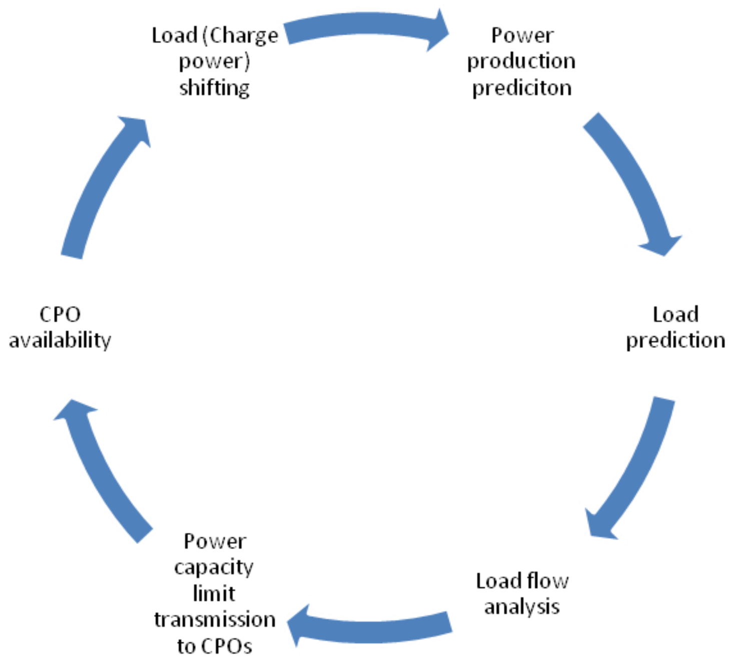

Figure 4 Smart charging lifecycle

Communication requirements

As presented previously, in order to develop applications such as grid aware EV navigation, multiple sub processes must be executed. Data required to implement the aforementioned sub processes is scattered across actors of the electromobility system. On the basis of data availability the following roles could be foreseen for the following actors, within the context of smart charging and grid aware EV navigation.

- DSO: Sets real power setpoints to CPOs according to grid criteria (Voltage, stability etc)
- Energy retailer: Sets real power setpoints to CPOs according to bilateral contracting
- CPO: Ensures operation under DSO limits and energy retailer agreement, while ensuring an EV charging Quality Of Service (QoS). Forecasts load due to EV charging operations.
- Electromobility Provider (EMP): Acts on behalf of the EV driver during grid aware EV navigation and smart charging.
- EV: Charges according to load shifting strategies.

As electormobility is constantly evolving, networks that enable seamless integration of such actors is essential as it paves the way to application development. The NeMo Hyper-Network is a distributed environment with open architecture based on standardised interfaces, in which all electro mobility actors, physical (i.e. CP, electricity grid, EVs) or digital (i.e. CPOs, DSOs, EMPs, EV owners, etc.) can connect and interact seamlessly, in order to exchange data and to provide more elaborate e-mobility ICT services in a fully integrated and interoperable way for both B2B and B2C.

The connection will be based on dynamic translation of data and services interfaces according to the needs of the specific local scenario and the involved stakeholders. The NeMo project will also design a Common Information Model (meta-model) that will contain and describe all the data required by electro mobility actors in a structured and normalised way, incorporating existing information representation and exchange standards.The core business actor integration functionality will be developed on the basis of Blockchain technology that will host business objects modeled according to the Common Information Model (CIM). Blockchaing technology comprises the distributed ledger which enables recoding of transactions and visibility of permitted electromobility based services. Smart contracting encapsulates business rules and terms which are embedded in the transaction database and are executed with transactions. The aforementioned operations are governed by a privacy environment which ensures that transactions are secure, authenticated and verifiable through the distributed consensus layer which ensures that all actors agree on network verified transactions.

Conclusion

ICT applications such as grid aware EV navigation and smart charging could pave the way towards energy efficiency without requiring grid over dimensioning. However, such ICT services are not interoperable or standardised– with the exception of the V2G interface standard between the EV and the Recharging Spot. Each Distribution System Operator (DSO) uses proprietary software and data formats to retrieve and make available information that is necessary for such services. Also, service providers do not have access to data from a larger region so as to forecast demand and efficiently optimise charging. Analysing large amounts of data through advanced data analytics algorithms, may support grid impact evaluation and lead to more efficient forecasting and global load optimisation, thus avoiding the need for unnecessary investments in grid infrastructure. Connecting electromobility services demand (EVs) and supply (grid) will also lead to new business models (e.g. a CPO-Grid energy market allowing the use of spot prices), creating an environment which requires an advanced networking basis. NeMo proposes a network of services, based on blockchain technology to dynamically interlink grid based services in a manner that will ease wide scale deployment of grid applications.

References

[1] M. Gereon, "European Roadmap: Electrification of Road Transport".

[2] D. Wu, D. Aliprantis and L. Ying, "Load scheduling and dispatch for aggregators of plug-in electric vehicles," *IEEE Trans. Smart Grid*, vol. 3, no. 1, pp. 368-376, 2012.

[3] E. Karfopoulos and N. Hatziargyriou, "A multi-agent system for controlled charging of a large population of electric vehicles," *IEEE Trans. Power Systems*, vol. 28, no. 2, pp. 1196-1204, 2013.

[4] "NeMo hyper-network fr electroMobility," 2017. [Online]. Available: http://nemo-emobility.eu/.

[5] Z. Fan, "A distributed demand response algorithm and its application to phev charging in smart grids," *IEEE Trans. Smart Grid*, vol. 3, no. 3, pp. 1289-1290, 2012.

[6] Q. Le, "A Tutorial on Deep Learning: Part 2: Autoencoders, Convolutional Neural Networks and Recurrent Neural Networks," 2015.

[7] "Flexible Charging Optimization for Electric Vehicles Considering Distribution System Constraints," *IEEE Transactions on Smart Grid*, vol. 3, no. 1, 2012.