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Smart integration of electric vehicles

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Abstract

SYM.conn is a device for smart grid integration of electric vehicles. It enables the integration of electric vehicles with a single- or two-phase charging system in private households via a simple and cost-effective procedure. SYM.conn comprises a measuring device, a control unit and a connecting device. It is preferably integrated in a wall box for charging electric vehicles in private households, but it can also be used in public charging stations. Before starting the charging process, the control unit determines via a measuring device the connection to the most favorable phase. The phase with the highest phase voltage is selected. Thus, asymmetries in public grid, caused by generation units on this phase or by loads on other phases, e.g. further electric vehicles, can be actively reduced with the start of the charging process. This principle does not only ensure the integration of a high number of electric vehicles, but also the possibility of increasing single- or two-phase charging power, without deteriorating the voltage quality in the distribution grid. Furthermore, the SYM.conn device can be integrated during the production of the charging station, retrofitted or even implemented without a commercial wall box in the house connection box. Thus, SYM.conn enables high penetration of electric vehicles and offers potential for higher charging power.

Grid integration, Electric vehicles, smart charging, one phase charging, grid symmetry, high power charging

1 Motivation

A growing penetration of electric vehicles is accompanied by various challenges for the distribution grids. A particular challenge is the effect of one- or two-phase charging for electric vehicles in a multi-phase distribution system. This might result into voltage unbalances. Since the grid operators are obliged to ensure a prescribed voltage quality at all times, the maximum voltage unbalances at a grid connection point are laid down in technical connection requirements or even in norms and guidelines like IEC 60364-7-722 or VDE AR N-4102. In EN 50160 the maximum voltage unbalance is limited to 2%. Hence, a user of an electric vehicle with a one-phase charging system can charge at home with a maximum power of only 4.6 kW in Germany [BDEW2011]. With this restriction, the grid operator tries to ensure the total system unbalance at all the time.

Despite these limitations, German automotive manufacturer in particular are currently focusing on one- or two-phase charging concepts. Examples are the BMW i3, the VW e-Golf or the Porsche Panamera. On one hand, the reason is a lower weight, which is of central importance for mobile use in electric vehicles. On the other hand, vehicles with the highest standardization could also be used in countries such as the USA, where the low-voltage-grid only has one phase.

Despite the advantages, there are still two key obstacles to the further promotion of one- or two-phase charging. First, the charging power is already severely restricted by technical connection requirements and second, a reduction of the permissible voltage unbalance is expected in the case of a higher penetration of electric vehicles.

Therefore, the product SYM.conn was developed. It enables active balancing of the voltage in the distribution grid and thus can achieve a comprehensive penetration of electric vehicles as well as an increase of the possible charging power. Unlike the current procedures, the technology also works for the connection of individual electric vehicles in the private household and not only focuses on the individual grid connection point.

2 Function

The product SYM.conn is a smart connecting device, which is preferably integrated in a wall box for charging electric vehicles in private households according to the present voltage unbalance. SYM.conn comprises a measuring, connecting, and control unit. Figure 1 shows the principle of SYM.conn.

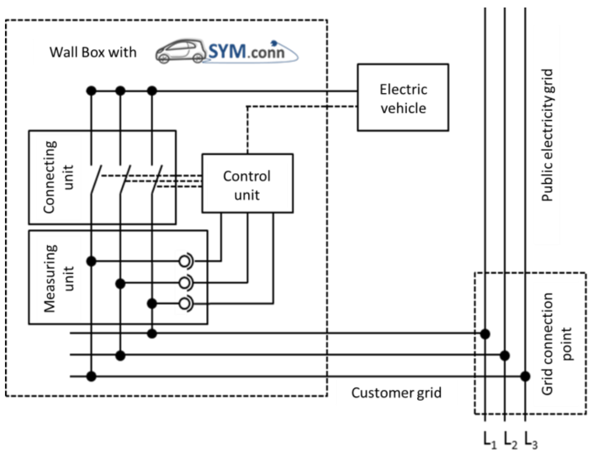

Figure 1: Principle of SYM.conn

Before starting the charging process, the control unit determines via the measuring device the connection to the most favorable phase. The measurement of the phase voltage is the decision criteria. It can easily be done locally on customer side and the result provides additionally global information on voltage symmetry in the public grid. Thus, by measuring the phase voltages, it can be assessed whether the public grid already has an asymmetry due to other one- or two-phase loads or generators. The system is only used to reduce local phase unbalance, so there is no communication to other components in the grid necessary as all can be done self-sufficient. However, if it is desired, it could get expanded by a remote controlled for manual interventions or switch off.

This is the key difference and advantage compared to known methods, which choose the most favorable phase in the sense of voltage unbalances via a current measurement. These procedures are based on reducing the voltage unbalance in the customer grid and measure the current as an indicator of the loads on the individual phases. However, this principle only works in a conglomerate of several charge stations, e.g. a public charging station, and is therefore not applicable to the relevant sector of private households. SYM.conn makes use of the functionality of a classic wall box. It will connect only to the power grid after the approval by the electric vehicle via a corresponding CP signal.

The control unit of SYM.conn takes the evaluation of the control signal in this case and determines the ideal phase before the connection. The voltage of the grid connection point, which is also influenced by voltage unbalances in public grid, can be measured at the connection line of the wall box, since it is unloaded at this time. During the charging process the electric vehicle remains on the phase, chosen at the beginning.

The principle of phase selection is conceivably simple. Since an electric vehicle is a load, the phase with the highest phase voltage is selected. Thus, asymmetries in the public grid, caused by generating units on this phase or by loads on other phases, e.g. further electric vehicles, can be actively reduced with the start of the charging process. This principle does not only ensure the integration of a high number of electric vehicles but also the possibility of increasing the single- or two-phase charging power, without deteriorating the voltage quality in the distribution grid.

3 Application and Potential

Integrating SYM.conn already during the production of charging stations, only a small additional amount is incurred by the three-phase design of the connecting device as well as by the measurement of the three phase voltages which are both available as standard components. The execution routines can be mapped on the existing system controller. In the same way, SYN.conn can be retrofitted very simply and still cost-effectively or even implemented without a commercial wall box in the house connection box. In this case, the communication between the vehicle and SYM.conn is carried out directly via the connection cable of the house installation using Powerline Communication. The benefit of SYM.conn helps the grid operator to keep the voltage limitations in the grid. The Customers benefit is given indirect by the possibility of higher charging powers for single- and two phase charging systems.

The functional principle of SYM.conn has already been successfully validated and documented in laboratory tests at the Test Center for Electric Mobility in Aachen. Emulated voltage unbalances in an experimental grid could be minimized by SYM.conn.

Simulative studies of distribution networks also show the challenges of grid integration of electric vehicles. Depending on the grid layout and the current grid utilization, two electric vehicles in neighboring houses can already lead to an exceedance of the maximum permissible voltage imbalance of 3%. Figure 2 shows a simulation in a real suburban low voltage grid in the late afternoon with nine electric vehicles charging at the same time.

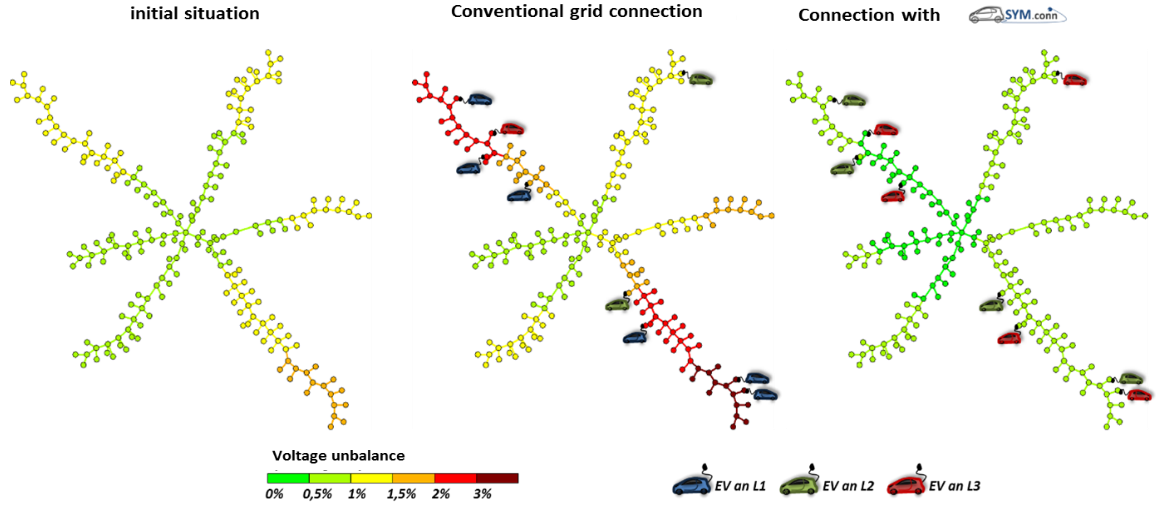

Figure 2: Operating principle in a suburban low voltage grid

The vehicles have been randomly placed as a reference for the conventional connection. In the SYM.conn simulation the vehicles are distributed in the same sequence to the three phases, according to the presented principle. Using the conventional method of random phase selection, unacceptable voltage unbalances occur. The simulations prove that the asymmetries that are already present in the initial situation are reduced by using SYM.conn.

4 Summary

SYM.conn offers the necessary technology for constantly increasing the penetration rates of electric vehicles with the following central characteristics:

- Active balancing the phase voltages
- Potential for higher charging power
- Robust and economical design
- Flexible usage

5 References

BDEW2011 Technische Anschlussbedingungen, TAB 2007, für den Anschluss an das Niederspannungsnetz

EN 50160 Voltage characteristics of electricity supplied by public distribution networks

VDE AR N-4102 Anschlussschränke im Freien am Niederspannungsnetz der allgemeinen Versorgung

IEC 60364-7-722 Low-voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles

Author

Sören Schrader studied Business Administration and Electrical Engineering from 2007 until 2012 at RWTH Aachen University, Germany. After his Master thesis which was about the multi-functional optimization of the utilisation of electric battery storage systems in distribution grids he started to work at P3 energy in the field of grid integration of new decentralized units. Within this time at P3 the electric vehicle stated to play a more and more important role for distribution grid operators. So he focused his work on the grid integration of electric vehicles.

Since 2016 he is team leader for e-Mobility projects at P3 energy.