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ICT INFRASTRUCTURE FOR INTEGRATION OF ELECTRO VEHICLES IN DISTRIBUTION POWER SYSTEMS

Michael Kratz, Steffen Schlegel, Dirk Westermann

ABSTRACT

The discussion about substitute fossil driven vehicles by electros has opened questions from a system operation point of view. The focuses are distribution networks due to the expected impact electro vehicles have. They will be connected to the grid at low and mid voltages level. The charging of electro vehicles is concentrated in the evening due to user behavior [1, 2]. This results in an additional power peak, which stresses the distribution grid. The main problem will be load capacity of cables, transmission lines and transformers. Depending on used charge controllers the voltage stability and harmonics will be possible issues for investigation. Enhancing the grid is critical due to public acceptance and building costs. Application of Information and Communication Technologies (ICT) for demand side management purposes can ease the situation in the primary process and a platform for high level applications to get load the following the stochastic infeed of regenerative generation, especially wind or solar power, with respect to the power system limits [3].

One special project aims on creating deliverables for publication of experiences with controlled charging is the "Mini E" under supervision of Vattenfall Europe [4]. The Ilmenau University of Technology is responsible for the Information and Communication infrastructure and the charging algorithms with special focus on optimization between charging time for electric vehicles, wind generation and power system limits. Forty cars will be installed decentralized in Berlin, equipped with a battery capacity of 35 kWh and special boxes for loading. These boxes are equipped with GPRS based communication and information system for sending information to a central operation control system. The low voltage side of the distribution network infeed is observed and equipped with GPRS based communication and information system for estimating power system stress level. The central operation system decides whether each car has ability to load or not.

This paper describes the project "E-Mini" and the architecture for controlled charging of electro vehicles with respect to power system stress, wind power and loading level of the vehicles. First results are presented and a forecast of needs a network control system will have to integrate electro vehicles in the grid and avoid extension of power systems primary equipment.

Index Terms – Electro Vehicle, Coordinated Control, SCADA Systems, GPRS Communication, Power Distribution, Demand Side Management

1. INTRODUCTION

The discussion about substitute fossil driven vehicles by electros has opened questions from a system operation point of view. The focuses are distribution networks due to the expected impact electro vehicles have. They will be connected to the grid at low and mid voltages level. The charging of electro vehicles is concentrated in the evening due to user behavior [1, 2]. This results in an additional power peak, which stresses the distribution grid. The main problem will be load capacity of cables, transmission lines and transformers. Depending on used charge controllers the voltage stability and harmonics will be possible issues for investigation. Enhancing the grid is critical due to public acceptance and building costs. Application of Information and Communication Technologies (ICT) for demand side management (DSM) purposes can ease the situation in the primary process and create a platform for high level applications to get the grid load following the stochastic infeed of regenerative generation, especially wind or solar power, with respect to the power system limits [3].

Electro vehicle themselves are not the only load which can be shifted to get a high correlation between regenerative infeed and demand. The concepts of demand side are simple but difficult to realize. Due to liberalization it is not easy to take impact to the load of private households. Historically approaches like ripple control is a one way once, switching loads one the demand side in a unicast manner. Today's requirements to realize DSM are driven by liberalization laws. The only way to get the customers influenced is to establish a market place which supports price signals to the households. It is assumed that the customer will switch on power intensive devices if the price is lower and switches them of if the price gets higher than a specific threshold. If the customer not himself manually switches his devices but a home automation system the DSM system becomes intelligent and reaches a high impact, which could be used for adapt loads to regenerative infeed and/or power system operation requirements like frequency or load flow control. Some work in this context is done in [3].

As simple the idea is as complex the control system becomes. The private households are dispersed and this time there is no technology existing to realize a significant impact of demand side management. The German government initiated the “IuK Energy Initiative” with ambition to get experience in intelligent networks which have a higher adaption of regenerative generation and demand. With modern communication and information technologies the grid should become smart. First of all smart meters are installed which allow metering demand with different rates of costs. Additionally technologies will be developed and tested which give customers information about their energy demand and real time prices. Those technologies are not the great solution for power system operation tasks, because they all are in both way’s unidirectional with the customer himself as the closing element in the control loop. It is difficult to imagine that they have a long term ambition to switch loads on or off if the price signal is presented. The next step is to automate this task depending on each customer’s requirement with a home automation system. If this is done the vision could be that the home automation system is connected to an power system control interface which collects data about waiting and running load with deeper information which load is available in the next time to be switched on or off. This information is fundamental if efficient power system impacts with a deterministic character should become reality with no negative effect for the costumer. This scenario is outlined by many research projects and the vision of smart or intelligent grids. To get the system intelligent including the demand communication and information technology is indispensible. With today’s technologies a widespread spectrum of communication is available. They differ in latency, bandwidth and operational availability. For dispersed applications it is clear that radio communication is convenient, because no additionally hardware is necessary but with a lack of reliability and bandwidth. Alternatives, especially for household applications, are the use of Digital Subscribers Line or Power Line Carrier to the next transforming station. The question is which architecture could be useful to get millions of households integrated into power system operation and organize a higher match of regenerative infeed and demand.

One special project aims on creating deliverables for publication of experiences with controlled charging is the “Mini-E” under supervision of Vattenfall Europe [4]. The Ilmenau University of Technology is responsible for the Information and Communication infrastructure and the charging algorithms with special focus on optimization between charging time for electric vehicles, wind generation and power system limits. Forty cars will be installed decentralized in Berlin, equipped with a battery capacity of 35 kWh and remote controlled boxes for loading. These boxes are equipped with GPRS based communication and information system for sending information to a central operation control system. The low voltage side of the distribution network infeed is observed and equipped with GPRS based communication and information system for estimating power system stress level. The central operation system decides whether each car has ability to load or not.

2. CHARGING OF ELECTRO VEHICLES ON PUBLIC INFRASTRUCTURES

To take impact to costumers demand some aspects have to be considered. Today it is normally if somebody likes to use electrical devices he is free to use it every time around the clock with no restrictions. Especially in the occidental culture driving a car is also characterized by liberty of use. So far charging the Electric cars will take, up to 5 hours if there are empty. That means if a customer likes to drive an electro vehicle he has to schedule the using of the car and charging. It is unimaginable that a car could be empty if it’s needed only by a gap of available regenerative power. This would create an acceptance problem, so that electro cars are loaded with conventional power (fossil or nuclear) or the customers buy conventional cars. Both scenarios are contrary to the intention of creating an environmental friendly individual mobility.

On the other hand – the primary process itself has technological constraints. Some additionally loads in the beginning process have not the impact to the limits the grid has on the lower and midvoltage distribution grid, but if the amount gets higher these limits become important. If the load is not shifted the grid has to be reinforced by adding primary equipment, which could become cost intensive. A load shifting system could release the power system. The cars are loaded if the amount of classic load is low, e.g. during the night.

The aim of loading electro vehicles if the demand is low and consider costumer requirements, regenerative power is available and consideration of technologically limits are contradictory. Other works show, that if a load optimization system exists these goals could combined if and only if a bidirectional communication system exists which supply's additionally information, e.g. charging state, battery state, the time the customer needs the car to be fully loaded. This system differs from classical demand side management ideas because it integrates application specific requirements. One communication infrastructure implemented for the described electric vehicle project is presented next.

3. ICT INFRATRUCTURE FOR CONTROLLED CHARGING OF ELECTRIC VEHICLES

The University of Technology is responsible for the Information and Communication infrastructure and the charging algorithms with special focus on optimization between charging time for electric vehicles, wind generation and power system limits. Figure 1 illustrates the communication architecture.

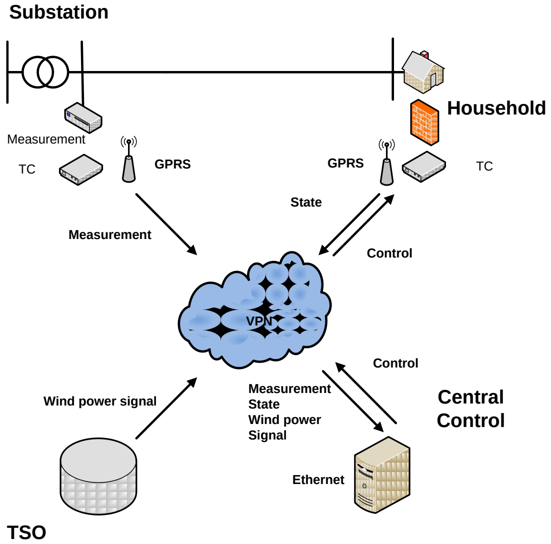

Figure 1: Dedicated Communication Infrastructure for Controlled Charging of Electro Vehicles

As well the substation as the households are telemonitored. Both send current measurements to monitor charging electro vehicles as well as cable load to avoid overload situations. The Transmission System Operator (TSO) supports wind power signal which is needed in the central control system for charging algorithm purposes. Additional information are send from households to the central control system, e.g. if a car is connected and the charging state for controlling purposes. The communication itself is encrypted via VPN. The communication protocol IEC60870-5-104 is used to transmit telemonitoring and telecontrolling signals. The central control system is a development of the Power System Department of the Ilmenau University of Technology. Figure 2 illustrates the system architecture.

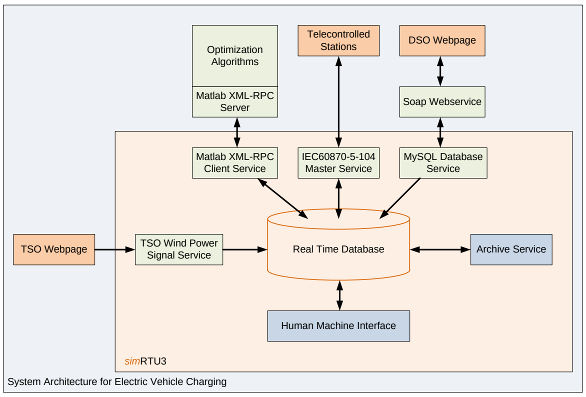

Figure 2: System Architecture for Electric Vehicle Charging

The system consists of a communication module (Master 104 Service) to communicate with the telecontrolled stations and several services, which are needed to collect necessary data. From the TSO webpage the system receives the actual wind power forecast. The customers are allowed to set up special profiles for their charging preferences. The can set up an every day time they want a full loaded car, also differing times they expect they need a charged battery. These data are used in the optimization algorithms running on Matlab/Simulink.

4. FIRST RESULTS

Some experiences are made during implementation of the software and communication architecture. To save all data VPN encryption is chosen. All telecontrolled stations consist of a modem and micro telecontrolling system. Both need an own network address and represent a special private network. In the VPN gateway these networks have to be manually defined, also in the modems. This approach is a simple one if there are only some stations to be configured but it becomes very time intensive if the amount of stations increases. If a widespread management system should be established this approach is not industrial conformant.

The use of GRPS communication has some disadvantages. Depending on the quality of the GPRS/EDGE signal the amount of package delay or loss unsatisfactory. If the whole system should become user friendly this bottleneck has to be resolved. Another problem is expected if every DSM system for every household consists of a special radio communication. It is not defined how many stations can be used simultaneously with today's communication networks without breaking down the services.

5. CONCLUSION AND OUTLOOK

A special project aims on creating deliverables for publication of experiences with controlled charging is the “Mini-E” under supervision of Vattenfall Europe is presented. The Imenau University of Technology is responsible for the Information and Communication infrastructure and the charging algorithms with special focus on optimization between charging time for electric vehicles, wind generation and power system limits. Forty cars will be installed decentralized in Berlin, equipped with a battery capacity of 35 kWh and special boxes for loading. These boxes are equipped with GPRS based communication and information system for sending information to a central operation control system. The low voltage side of the distribution network infeed is observed and equipped with GPRS based communication and information system for estimating power system stress level. The central operation system decides whether each car has ability to load or not.

Some questions occurred. If a dispersed infrastructure for DSM applications should be established the main problem is the communication between households and the controlling station. Not everywhere the communication service quality is satisfactory enough for stable communication. One question occurs. It is possible to use existing ISDN or DSL communication channels of the households? And which judicial consequences occur? If not only forty cars but more than thousands have to be managed it is suggestive to control all of them centralized or is it superior to establish a hierarchical architecture and which set up should it have?

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