The Improvement of Grid Integration for Electromobility through Innovative Business Models

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***Abstract*—The competence center for innovative business models, under the leadership of Prof. Dr. Anna Nagl, researches and develops new, economically resilient business models for sustainable electromobility. Ecological possibilities to charge electric vehicles with solar power are investigated. The project is state subsidized by the Bundesministerium für Bildung und Forschung (BMBF, i.e. German Federal Ministry of Education and Research) from August 1, 2016, to July, 31, 2018, under the reference 02K12A150 and 02K12A151. Überlandzentrale Wörth/I.-Altheim Netz AG (ÜZW) supports the research project as regional distribution system operator. Bozem | consulting associates | munich provides business expertise concerning renewable energy and competitive strategy. In the context of the research project, business models were developed that generate added value for the stakeholders such as electric vehicle users, grid operators, energy suppliers and other companies. Furthermore, grid load arising from simultaneous charging of electric vehicles is reduced.**

Keywords-electric vehicles; charging infrastructure; grid integration of large-scale electromobility solutions; innovative business models; storage; market design; power system integration and operation; stakeholders of the renewable energy industry

I. Introduction

Grid integration of electric vehicles is particularly advisable for companies as, in the near future, multiple vehicles shall be charged almost simultaneously when the vehicle owners, i.e. the employees, commence their working day. To prevent harmful peak loads, the long standing time of the vehicles of approximately eight hours during the day can be used to adapt or reduce charging capacity. Since the German electricity price for key account business customers is divided into commodity price and capacity charge, it has to be observed not to exceed the corporate power peaks so that no additional capacity charge applies.

The specifically developed business models were examined for cost-effectiveness on the basis of actual consumption data of companies. It was found that economical added value can be generated for all stakeholders. Identifying this potential for companies on an individual level, an Excel tool was created. This tool determines and visualizes the potential as well as the required reduction of the charging capacity based on company specific data (number of electric vehicles, start and end of the load course). Thus, business models can individually be adapted for the respective companies to maximize the added value for all stakeholders.

To combine the volatile feed-in of the de-centrally produced, renewable energies – leading to peak loads in the distribution grid – with the economically resilient business models developed for sustainable electromobility, a pilot project is currently ongoing. This pilot project for the charging of electric vehicles is anticipated to show the consumption of self-produced photovoltaic electricity at different locations. The consumption shall take place at a charging station on the company site and simultaneously be accounted with the employee's feed-in of photovoltaic electricity. Hence, peak loads can be reduced when charging electric vehicles at the company site. At the same time, peak loads caused by excessive feed-in of photovoltaic electricity, arising in superimposed network levels, can be countered.

II. Relevance of the Research

The increasing number of electric vehicles requires an adequate charging infrastructure. Consumers preferably want to charge their vehicles at home or at work demanding companies to provide a growing number of charging stations. Not only do these consumer needs and preferences influence investment decisions, but running costs for electricity and network charges could rise immensely.

To be able to estimate potential cost effects on a company-specific basis, an Excel tool was developed which simulates effects based on individual load profiles and provides a cost forecast given the number of electric vehicles for the next few years is not foreseeable with certainty.

An increased current load results in higher network charges. An intelligent control of charging processes can avoid this. Furthermore, an intelligent control can prevent a costly network expansion. This solutions requires an IT system monitoring actual energy consumption and dynamically adjusting charging processes according to this consumption. Additional costs could hold companies from investing into the charging infrastructure. Making the installation and the operation of charging stations economically as attractive as possible, two business models were developed generating added value for the companies, the network operators, the electricity suppliers and the consumers. The charging stations, the IT system as well as further services such as the billing of the charging processes, for example, are part of the business models.

III. Theoretical Foundations of Electricity Supply

A. Electricity Grids

To transport electrical energy from the site of energy production to the end customers, electricity grids are required. They can be divided into the following network types [1]:

- Transport networks have the highest voltage from 220 kV to 765 kV. These networks are used for the transport of large quantities of electrical energy over long distances, e.g. in the integrated European network.
- High-voltage networks have nominal voltages of 110 kV and are placed downstream of the transport networks. Their task is to supply medium-voltage networks and large-scale consumers.
- Medium-voltage networks with voltages from 10 kV to 20 kV receive electrical energy from upstream high-voltage networks and distribute power also to industrial consumers and local network stations.
- Low-voltage networks are operated with 235 V, 400 V and 690 V and are supplied from upstream network levels.

Network levels are linked among each other through voltage transformer stations [2].

B. Stakeholders

1) Electricity Producers: Electricity producers are plant operators which can be divided into the following two groups.

- Central electricity producers with larger power plants: Usually, these plants are located at central points of the electricity grid and are either nuclear power plants or power plants transforming fossil fuels into electrical energy.
- Decentralized electricity producers with smaller power plants: Commonly, these plants are in private hands or in the hands of regional electricity producers and electricity is mostly generated from renewable energies through photovoltaic systems or hydroelectric facilities, for instance. The great number of decentralized plants poses a challenge for the grids since the feed-in volume of the individual power plants cannot be controlled. In the future, these plants are likely to be bundled to virtual power plants and, thus, be able to offer balancing power [3].

2) Grid Operators: Grid operators are responsible for the transmission and distribution of electrical energy. They are legally bound to provide nondiscriminatory grid access to all grid users. The German Federal Network Agency controls and regulates the grid operators [4]. Costs arising from system services are included in the grid utilization charges determined by the German Federal Network Agency. Grid operators can be divided into two groups: transmission system operators and distribution system operators [5].

3) Suppliers / Dealers: Power plant operators and dealers act as suppliers that buy and sell electricity, for example, on the stock exchange. These suppliers are balancing group managers toward the transmission system operators and have to report schedules for extraction and feed-in points to the balancing group coordinator of their control area every 15 minutes. In case the demanded and supplied energy amounts differ, the network operator has to compensate for the deviations by control energy. Costs incurred are allocated to the dealer according to the causative principle [1].

4) End Customers: End customers obtain electrical energy from the electricity grid and are to be differentiated into two groups: Metered customers and basic supply customers [1]. Metered customers are considered special contract customers as in the times of the monopoly market. Moreover, large-scale customers belong to this group. Usually, they are large industry organizations which operate their own electricity production. According to the energy industry law (EnWG), basic supply customers or end users are those who have an annual usage lower than 10,000 kWh/a. Their supply is carried out by basic suppliers which are in charge of their network area [6].

C. *Electricity Trading and Retail Price*

Electricity trading is conducted either over the counter, i.e. off-market, or at the electricity exchange. The most relevant trading place for electricity in Europe is the European Energy Exchange located in Leipzig, Germany. There are two market segments: the term market and the spot market. In the term market, long-term deals are closed to hedge price risks for electricity. In the spot market, short-term deals are concluded either intraday, i.e. for the same day, or day ahead, i.e. for the following day [1].

D. *Energy management*

Contracts between customers and suppliers can be separated into agreements on tariffs and individual agreements. With an annual consumption of 100,000 kWh, a customer is rated as a large-scale customer allowing them to close an individual/special agreement which usually includes lower prices.

IV. BUSINESS MODELS

A. *Theoretical Foundations*

The description of the business models is based on the definitions of the business model builder (Fig. 1) designed for the development of innovative business models [7].

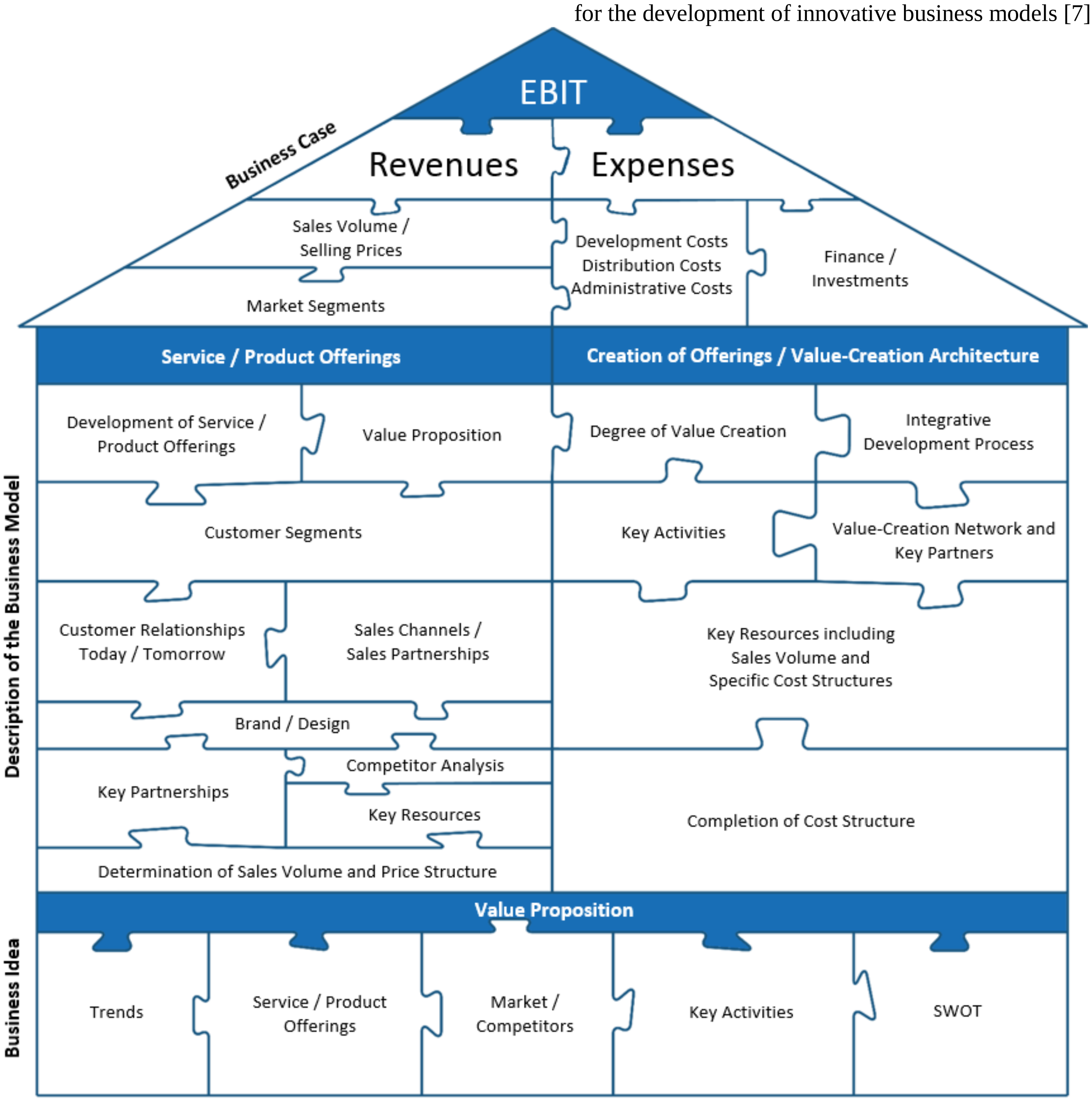

Figure 1. Structure of a business model following the business model builder [7]

B. Description of the Business Models

The following section outlines two business models including their product and service offering based on the value proposition, key partners, key resources and further details [8].

- Key partners: Both business models require diverse partnerships. Depending on customer needs and requirements, different charging stations from partners have to be used. The compatibility with the backend system or the server, respectively, has to be ensured. The server and the software needed can also be obtained from partners. The installation of charging stations and network connection requires qualified installation partners in the particular area. Partnerships with financial service providers are necessary for the financing of the charging stations.

- Key resources: Implementing the business models, customer-centric employees with a high technical knowhow are needed. Especially in the starting phase, the business models show a high capital requirement.

- Sales channels / sales partnerships: Sales are mainly generated via the Internet to offer products and trans-regional services. Furthermore, a broadly positioned after sales service is supposed to increase customer retention. Since electricity suppliers and network providers indirectly profit from the business models, advertising partnerships are possible.

- Customer relationship today/tomorrow: A high customer satisfaction regarding the charging stations can lead customers to be interested in further products and services. Thus, customer retention can be strengthened. Metered customers show a high electricity utilization which makes them interesting candidates for supplemental consultancy services in the area of energy management.

- Customer segmentation: Customers can mainly be differentiated through employment figures and energy consumption parameters. This is based on the assumption that companies with a large number of employees usually reveal a higher energy consumption.

Concerning their attractiveness for the business models, customer segments can be classified as shown in Table 1:

TABLE I. CUSTOMER SEGMENTATION

	Small companies	**Medium-sized companies**	**Large companies**
Number of employees	< 50	< 250	> 250
Number of companies	+++	+	-
Electricity consumption	+	++	+++
Potential intelligent charging processes	-	++	+++
Price acceptance	+	++	+
Cross selling	+	+++	++

+ small / ++ medium / +++ large extent/number

C. Development of the Business Model 1: Purchase of Stations and Receipt of Service (Fig. 2)

The key player of this business model is a service provider that allows companies to economically integrate electric vehicles into the corporate electricity network. After analyzing the load profile and possibly available charging stations free of charge, the service provider makes an individual offer to the company. Apart from the planning and installation of charging stations, this offer includes an intelligent load control in form of a load management system to prevent a rise in service costs.

The billing of the charging processes is also part of the service offer and conducted by the service provider. Prices can vary depending on the charging speed and charging capacity. In this business model, the company pays for the purchase of the charging stations. Running expenses for operation, maintenance and management can be covered by the charging processes paid by the employees.

D. Development of the Business Model 2: Financing of Stations and Receipt of Service (Fig. 3)

The second business model differs from the first business model mainly in the aspect that the customer does not completely pay for the charging stations and the costs of their installation in the beginning. Instead, the customer receives a financing contract from the service provider.

After contract closure, the financing partner transfers the amount of money deducting interest to the service provider. The possible risk of non-payment is on the side of the financing partner. The customer transfers the financing rate in a previously defined interval. With the complete redemption of the charging stations, the stations become the customer’s property. A low-interest debt financing arrangement can create advantages for the customer, i.e. the company, since higher liquidity allows the company to invest in the corporate core business in the meantime.

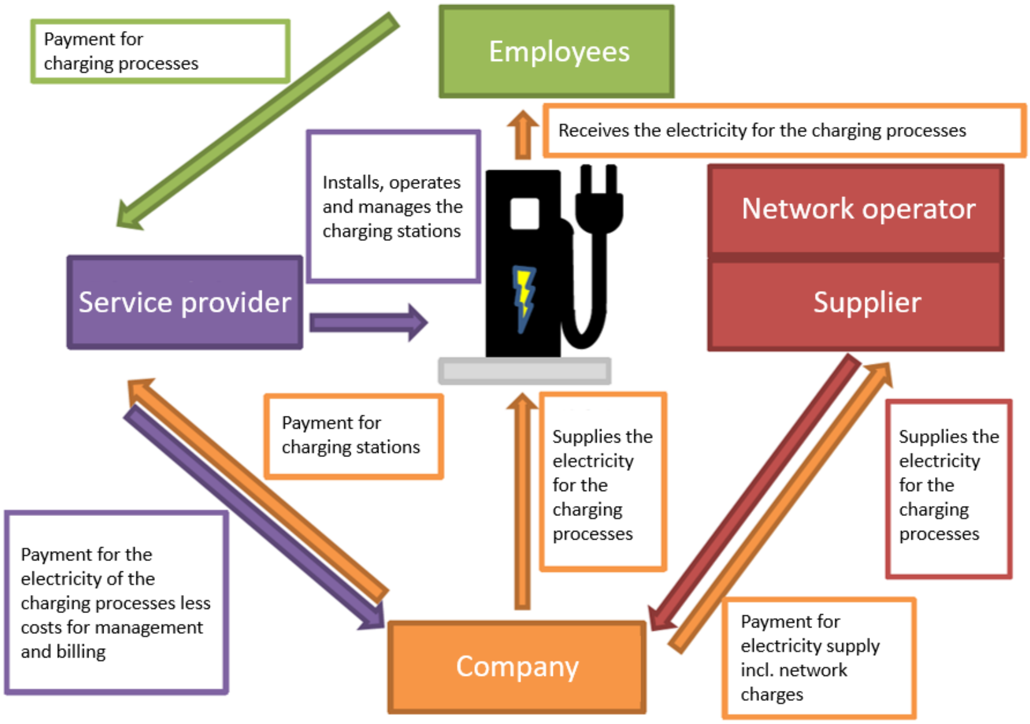

Figure 2. Business model 1: purchase of stations and receipt of service [8]

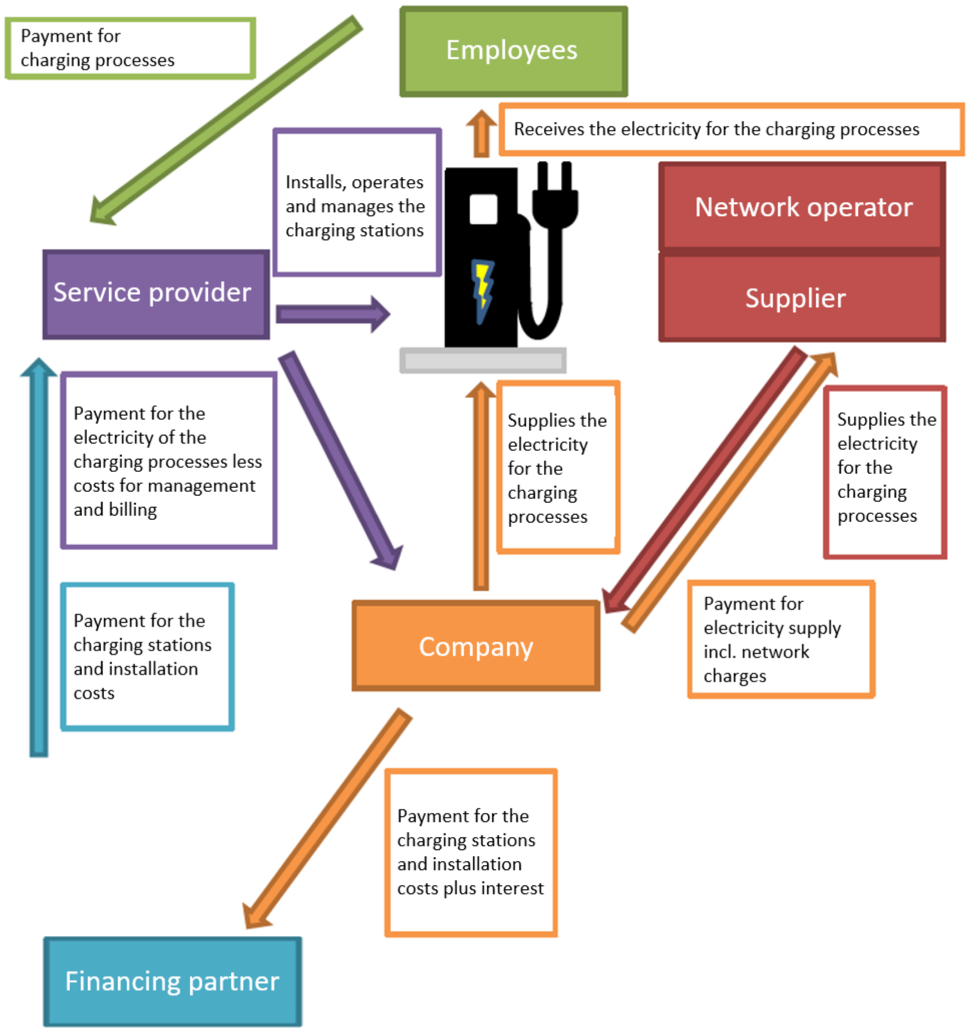

Figure 3. Business model 2: financing of stations and receipt of service [8]

V. Business Case

The business case consists of the revenues and costs. Details on both parts are provided in the following paragraphs and Table 2. The revenue side involves one-off proceeds and ongoing proceeds. The former is generated through the sales and installations of charging stations including the server. The latter is achieved through the charging processes of the employees and complementary consultancy services. As the service provider receives insights into the corporate load profile already at the beginning and has the opportunity to analyze this data, the provider can estimate at an early stage if the company is suited for further product and service offerings or consultancy services. The cost side includes investment costs which occur at the beginning of the project, e.g. for product development, business equipment or marketing, and running costs, e.g. for human resources.

TABLE II. Revenues and Costs of the Business Case

Business Case	
Revenues	***Costs***
Sales · Server · Charging stations	Investments
Management · Installation and operation of charging stations · Controlled charging processes · Energy consultancy	Marketing (e.g. Internet presence)
	Vehicles
	Human resources
	Imputed rent
	Interest

Charging processes in public areas are currently billed in different ways [9]. The user usually pays for the time their vehicle is parked at a charging station, independent of the duration of the charging process. The fees without basic charge from the large providers ChargeNow, EnBW and RWE range from 3.95 €/h to 5.00 €/h assuming a charging capacity of 3.7 kW. Hence, the users pay between 1.07 € and 1.35 € per kilowatt hour.

In respect of the user acceptance, the costs of the charging processes at the employer should not exceed those of the charging processes at home. A comparison to industrial electricity prices [10] reveals that charging processes at corporate sites ought to be considerably less expensive than those at public charging stations. This holds true even if the costs for load control are included.

VI. Summary and Implications

The share of renewable energies in the German power mix is increasing and the Federal Government is planning to increase this share to at least 80 % by 2050 [11]. However, feed-in power depends on external factors such as wind and sun. Consequently, it can be planned only to a limited extent. To guarantee the network stability nonetheless, power plant output – mostly from nuclear power or fossil fuels – must be provided.

Simultaneously, the increasing number of electric vehicles poses a challenge to the electricity grids because peak charging loads can cause local network overload. The market development or the number of electric vehicles, respectively, cannot be precisely forecasted at this stage. Companies will offer more charging stations to their employees to efficiently use the long standing times of electric vehicles at the company site. An extension of the charging infrastructure can result in increased network charges, especially for companies.

To assess the effects of additional charging stations, in particular for metered companies, a profound analysis of the load profile ought to be conducted before a network integration. A dynamic load management which adapts the charging processes to actual load rates is suited for this purpose. The controlled charging processes build the foundation of the business models which allow a network integration of electric vehicles in large companies without increasing network charges.

The business models can be evaluated according to their revenues and costs. Nevertheless, uncertainty exists in respect of the individual character of the load profiles and market development risks. The economic value of the business models highly depends on the company profiles and the number of electric vehicles. However, it can be expected that dynamically adjusted charging processes will gain more relevance within the next few years.

The technical challenge of some vehicles falling into an error mode when charging capacity is decreased is a threat to the business models. At this point, manufacturers are called upon to implement respective norms and, if applicable, to update existing vehicles.

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