LOCAL E-MOBILITY PREDICTION AND DEVIATED GRID DEVELOPMENT BASED ON DATA ANALYSIS

Florian SCHABER
Germany
f.schaber@westnetz.de

Helmut LÜHRSEN
Germany
helmut.luehrsen@westnetz.de

Dieter JUCHEM
Germany
dieter.juchem@westnetz.de

ABSTRACT

The growing e-mobility sector increasingly affects distribution grids. At the same time main parts of distribution grids have a lifetime of more than 40 years which should be used in the best possible way. That is why even today's grid development has to consider future needs, in particular the expected demand from future e-mobility charging points. This approach leads to a well-founded and localized e-mobility prediction that helps Westnetz to develop its grids in a future-focused and sustainable way.

INTRODUCTION

E-mobility is coming – sure! But when? And where? Where are the first movers and where are the hot-spots? An accelerating growth is predicted for e-mobility. In fact, we recognize additional charging stations and electric vehicles every day. This has a massive impact on several duties:

Example 1: urban management:
For a working e-mobility-system a large number of charging points is needed – a much higher amount compared to nowadays fuel stations, because charging of electric vehicles lasts significantly longer than to refuel conventional vehicles with combustion engines. An associated effect is, that electric vehicles mostly have to be charged wherever they are parked or spend time and even fast charging points have to be built at locations where users can spend some time conveniently. The upcoming challenge of urban management is to develop the necessary public charging infrastructure on a public demand basis.

Example 2: charging service operation:
Beside urban management also charging system operators (CSOs) are looking for the best sites to build and operate charging points for electric vehicles. Only a good degree of utilization can provide a positive business case. The necessity to identify the customer's needs is essential for CSOs as well.

Focus: Development and operation of distribution grids:
For DSOs and also TSOs it is essential to implement the development and operation of their grids in a future-focused and sustainable way. One of the main drivers for this is a lifetime of more than 40 years of main parts of the grids, for which distribution grids are planned for and which in general should be used as best as possible.

Necessary grid adjustments or reinforcements may cause early substitutions of these parts even before the end of their depreciable life or may lead to additional costs, e.g. for a necessary reopening of cable trenches.
To avoid these and similar effects a good forecast of the local future supply task and its development is necessary. One main aspect in this case is the development of the e-mobility sector and the answer to the question of when and where charging points will be established.
With the gained information Westnetz is able to specify general grid development standards, to develop local grids future-focused and sustainable and possibly to identify helpful adaptions of the relevant legal circumstances.

For these and other additional duties suggestions are needed in a very detailed resolution. In consequence, we, together with data scientists from FfE and innogy, developed an approach that determines an e-mobility prediction in a temporal and local resolution by data analysis. In a further step it is especially important to derivate the immediate grid effects. By combining the e-mobility prediction parameters with our grid information systems we created the necessary environment to answer this question and to ensure a robust and sustainable handling of our aforementioned tasks.

DATA BASE AND DATA PREPARATION

For a best possible prediction of the future development of e-mobility we first had to gain useful and available information that affects this development. At the end we identified and procured data like population density, residence size, household income, age of inhabitants and other socio-demographic data like education and profession. In addition to that we also used data like installed photovoltaic plants on private buildings and their size and statistic information about in- and out-commuters of the relevant townships. Image 1 shows the commuter-flow and the commuted distances in Germany.

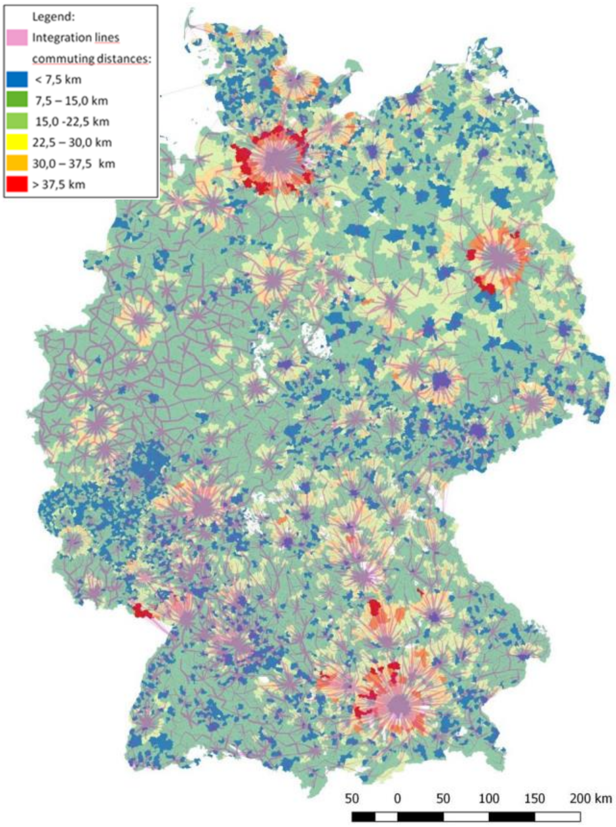

Image 1: commuting-flow in Germany [1]

The utilized data for our approach was merged out of different sources:
Partly it has already been on hand of Westnetz, like the photovoltaic plants connected to our grid. Other parts could be gained out of external available sources like free census-data [2] or could be purchased from data providing entities.

For the following analysis of different scenarios we had 28 basis attributes available, that can be grouped in structural and characteristic attributes:
Structural attributes (like the number of public parking lots) specify the quantity of prospective charging points, characteristic attributes (like the medium household income) specify the affinity to electric vehicles.
These basis attributes are mostly available in a raster of 100 meters x 100 meters. This raster corresponds to the German Census Atlas. Attributes with any other resolution were interpolated to this raster, so that the developed algorithms were able to process them.

The derivation of the algorithms to process the e-mobility prediction was an intensive process of data assessment. For example we examined the development of electric vehicle pricings and compared our approach with our knowledge about already existing electric vehicles.
Additional to that we initially distinguished between private mobility, commercial mobility and long distance traffic, which was mainly based on known traffic statistics, and examined them independently. In a following step we merged them to the final result.

DERIVATION OF THE E-MOBILITY PREDICTION

As an outcome of our approach we got the amount of electric vehicles in every 100 meter x 100 meter pixel of the aforementioned raster of Germany distinguished for several years.
To derive a certain number of electric vehicles, we first had to define the total number of electric vehicles in Germany in certain years of the future. This task could be solved by combining information about the existing stock of all vehicles and about all electric vehicles in Germany [3] with the aims of the German government [4] and by analyzation of different studies regarding this topic.
With a run-up of e-mobility aligned to the target scenario by the German government we set 100.000 electric vehicles by the end of 2017 (fix stock of the past), 1 Mio. in 2020, 6 Mio. in 2030 (declared target of the German government) and 40 Mio. electric vehicles somewhere in the far future as a most stringent scenario. This is mentioned in table 1.

year	number of electric vehicles
2017	100.000
2020	1.000.000
2030	6.000.000
far future (most stringent)	40.000.000

Table 1: number of electric vehicles in Germany

Although our further findings are based on these assumptions other scenarios or the later adaption of them depending on new awareness can be integrated easily. The forecast of the number of electric vehicles of the years in between can also be done on the basis of different studies. We asume an exponential growth in the next few years followed by a proper linearization.

SCENARIOS

On the basis of the aforementioned run-up of e-mobility we examined the two extreme scenarios “individual mobility” und “car-sharing”. The scenario “individual mobility” assumes, that 100 % of individual mobility by vehicles is covered by private cars (including company cars) – like it is mostly today. The second scenario “car-sharing” assumes that 100 % of individual mobility by vehicles is covered by car-sharing vehicles. The reality will fit in between those extreme scenarios and can be evaluated by mixing up these two scenarios. This as well gives us the flexibility to examine different scenarios and to adapt our assumptions if the circumstances change. Depending on our prediction we mixed these scenarios up to our basic approach.

The run-up of e-mobility in both scenarios was simulated in three different phases (“early adopter”, “not only early adopter” and “electric vehicles become the new standard”) with differently weighed structural and characteristic attributes.

AGGREGATION OF DATA

After achieving the examination results it was important to prepare the outcome for our internal duties, so that interested departments can easily handle the produced information:

For the strategy department and managers we brought out general awareness like the effect on our grids, so that managerial decisions like investment or technological strategies can be done on a suitable basis.

For grid planning purposes we related the local information to our grids and implemented this in our technical information system, where it is immediately available at the relevant place.

Relating the data to the grid

To get the best possible forecast for every of our secondary substations (transforms medium voltage to low voltage) we related the local raster information to the existing connection points of the Westnetz grid. For that it was important to know the geographical coordinates of every connection point and of the centre point of every pixel of the aforementioned raster. By calculation of the distance between every connection point and the centre points of the raster-pixels, we were able to relate the connection points to the each relevant raster-pixel (image 2).

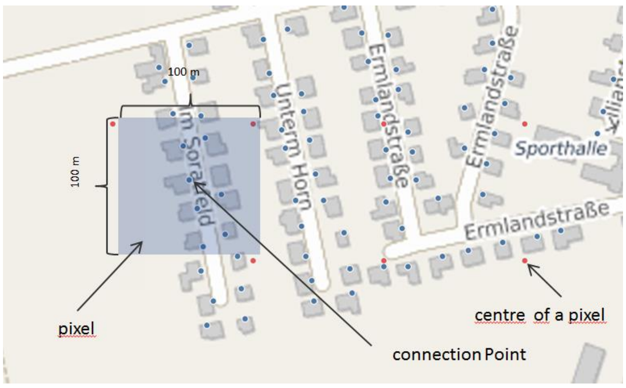

Image 2: Relation of connection points to the relevant raster-pixel; (basemap ©OpenStreetMap contributors)

Additionally the basic attributes and the results of the simulated scenarios were related to the each relevant connection point. For these connection points to the Westnetz grids, we also know by which secondary substation this connection point is supplied.

Aggregation on secondary substation level

The first step of the following data analysis was to examine the e-mobility development on the level of secondary substations and the connected low voltage grids. For this we aggregated the parameters for each secondary substation, which were related to the connection points before.

In the case of more than one connection point in a pixel which are supplied by different secondary substations we weighted the relation of the forecast parameters (image 3).

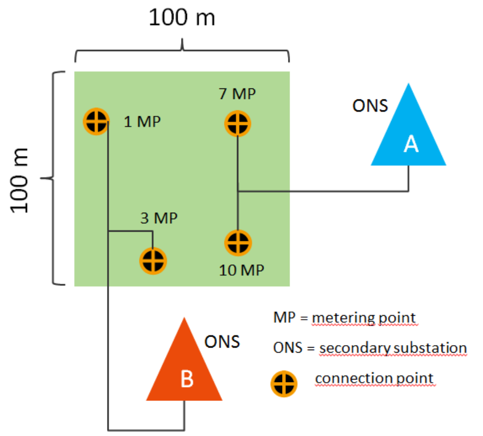

Image 3: Drawing of the correlation of raster pixels to secondary substations

As a result of this aggregation all 28 basis parameters and the outcome of the simulated scenarios for every secondary substation and the connected low voltage grids are known and available. This data is now being purchased for all relevant employees of Westnetz by our geographic information system (image 4).

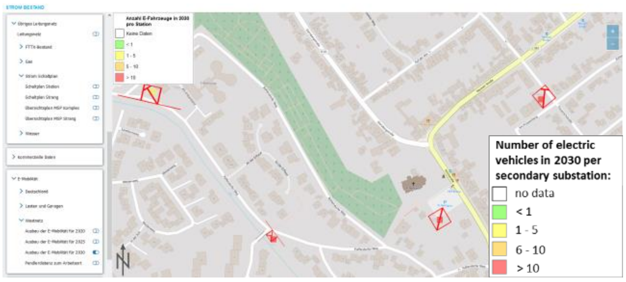

Image 4: Screenshot of Westnetz’s geographic information system with in-faded secondary substations and the predicted number of electric vehicles for each (colour); (basemap ©OpenStreetMap contributors)

In this geographic information system the user can easily display the forecast of the number of electric vehicles for every secondary substation (images 4 and 5) and choose between various certain points in time. Beside the predicted number of electric vehicles also various other information can be faded in, like the low- and medium voltage grids, solar power plants and other data which could be used for grid planning duties. An important advantage is, that all the relevant data is available in one system and the user has not to switch between different systems.

Image 5: Screenshot of Westnetz's geographic information system of Westnetz with infaded low- and medium voltage cables (basemap ©OpenStreetMap contributors)

UTILIZATION OF THE RESULTS

As mentioned before our approach predicts the number of electric vehicles on different aggregation levels. To derivate the impact on the local grid structures additional information is needed: What is the charging power of the electric vehicles? How many vehicles connected to a certain grid element will load simultaneously? Where do they load how much energy? Are the charging processes controllable by the DSO to limit the maximum load? These and other questions have been forecasted at Westnetz with the knowledge we built up by our different activities like carrying out different studies and our various standardization activities.

Beside the aforementioned usage for local grid planning purposes, the aggregated information (on secondary substation level) can also be used for additional purposes. For example larger areas or regions can be examined regarding its e-mobility development or can be compared with other areas or regions. In image 6 an overview of a larger region is shown.

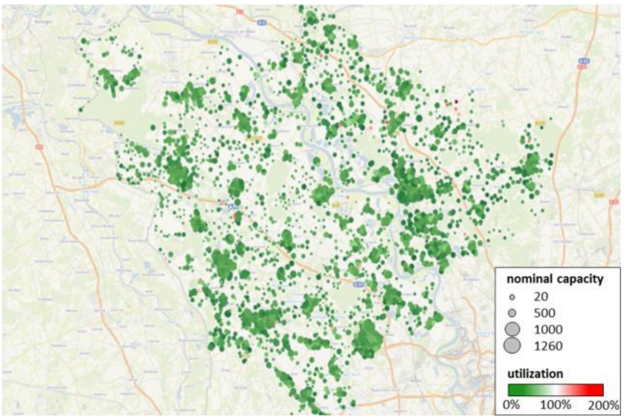

Image 6: utilization of secondary substations with e-mobility loads in 2020; (basemap ©OpenStreetMap contributors)

We also know for each secondary substation to which primary substation (transforms high voltage to medium voltage) it is connected to. In a second step we aggregated the e-mobility forecast to these primary substations. The results show the effects on the high-voltage level. By comparing them among each other e-mobility hot-spots in high voltage can also be identified.
Image 7 shows the number of predicted electric vehicles for each primary substation. The length of the bars shows the number of connected secondary substations, the colour of the bars shows the number of predicted electric vehicles for each primary substation.

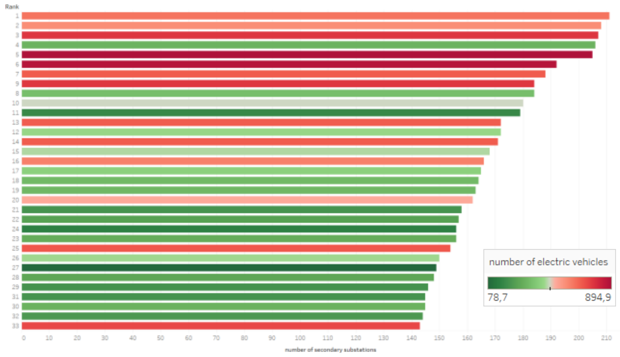

Image 7: Comparison of primary substations regarding connected secondary substations (lengths of the column) and number of predicted electric vehicles (colour)

CONCLUSION

As intended in the beginning of our approach, we developed a solution to consider the future e-mobility-loads in the grid planning activities at Westnetz. This ensures a realistic and robust prediction of e-mobility and is part of all relevant strategic and dimensioning activities. With this we did an important and necessary step into the e-mobility future from a DSO's point of view.
Last but not least our external partners like municipalities are interested in our e-mobility predictions. The final usage in this case has to be discussed individually in every single case, but in general we can say that it helps us to give an additional benefit to our external partners and strengthens our relationship to them.

REFERENCES

[1] FfE e.V., 2018, Munich

[2] Zensus-Atlas (https://atlas.zensus2011.de/)

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[4] Bundesministerium für Bildung und Forschung, 2011, „Regierungsprogramm Elektromobilität", 10. (https://www.bmbf.de/files/programm_elektromobilitaet(1).pdf)