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Electric grid integration of a large scale overhead contact line ERS for truck applications

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Summary

ERS pose additional loads to the existing power supply grids. In larger applications they will require individual high voltage connections along with medium voltage supplies along the electrified highways. This conference paper examines power requirements for different traffic and infrastructures scenarios, with variable headways and road topographies. In an outlook it discusses chances for a dedicated power supply by renewables only to maximize environmental benefits. The study conducted and presented is part of the Siemens research project ELANO funded by the German Federal Ministry for the Environment.

1 Research Questions

This study has been carried within the framework of the Siemens research project ELANO to investigate the following points:

- How would the optimal and most cost-effective network infrastructure for an electrified highway look like?
- What are the expected costs?
- What are the estimated necessary decentralized energy resources (DER) to cover the power and energy demand?

Considering the differences in the needed power while driving on a mountain or on a flat road, two highways with different topology profiles and with the same length of 100 km were examined. “Road A” is a flat highway which represents the profile between Hamburg and Lübeck. “Road B” is a highway through the mountains and represents a profile around Kassel. Two different electrification infrastructure models were evaluated, one with almost 95 % and one with 50 % electrification. In the first one (S-95), the e-Trucks would take the necessary power for traction and would charge their batteries only marginally. In the second one (S-50), only the half of the highway is electrified which means the distance is divided into sections with equal lengths of 10 km with and without the overhead contact line. In the electrified segments the e-Trucks would take power to both charge the batteries and drive. In the section without overhead contact line they would use the batteries.

The considered headway of the truck traffic is approximately 5 seconds (s5). Assuming that all these trucks will be electrically powered in the future this worst-case scenario will be defined. For the progress of the electrification of this traffic segment one additional scenario with a lower penetration of the trucks traffic was considered with e-Truck headways of 10 seconds (s10).

Furthermore, a traffic jam scenario was simulated for both route profiles. In traffic jams, e-Trucks need more power to accelerate. This causes a brief punctual increase of the power demand.

As a part of the investigations those variants and scenarios were considered. For the design of the traction power supply various traffic simulations were done. Their results were load profiles of each traction substation and were used as the input of the presented study.

2 Methodology

Based on the described load profiles in the previous section a methodology has been developed to determine the rating of the different network components. In the different scenarios of each structure of the considered topology profiles, the maximal load in each secondary (traction) substation has been determined. The dimensioning was done stepwise, starting with the secondary substation transformers then the medium voltage (MV) lines (cables) then primary substation transformers and finally the high voltage (HV) lines. Figure 1 shows an overview of the considered network structure in case S-95 for 20 km.

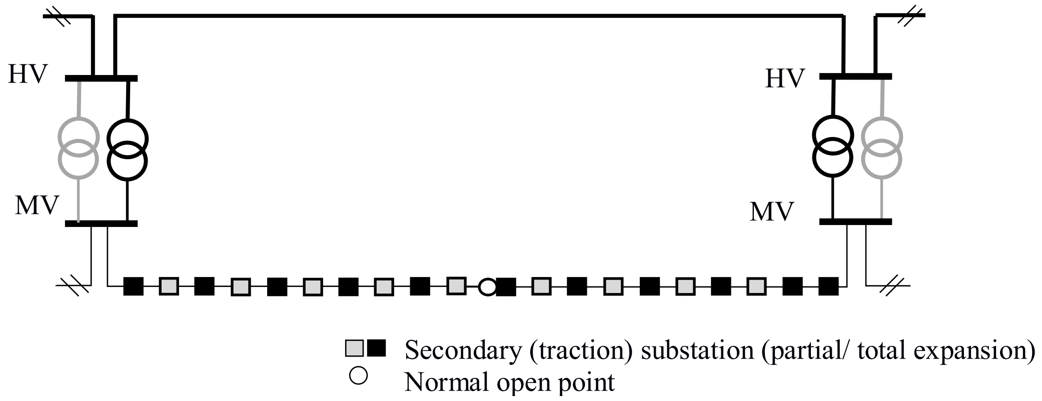

Figure 1: Overview of the network infrastructure in case S-95 for a 20 km segment

Depending on the dimensioning of the network components, the simultaneous and/or the non-simultaneous maximal loads in a section were taken into consideration. For the rating of the secondary substation transformers, the maximum load in a substation must be extracted from the load profile simulations. In this case, a distinction between continuous load (normal traffic) and peak-load (traffic jam) must be made.

Based on the continuous load a first approximation of the transformer rating can be made and in order to avoid an over-dimensioning, the overload-capacity of the transformer, the time course of the overload and the preload will be taken into consideration. In further steps the MV cables, primary (bulk) substation transformers and HV cables were dimensioned.

Based on the fixed ratings and the actual market prices, a global estimation of the infrastructure costs has been done. According to the prices, it can be assumed, which is the most cost-effective network structure.

Regarding the last research question, a typical daily load profile has been extracted based on the results of [1]. Combined with the maximal simultaneous load of the investigated series, a global approximation of the yearly profile can be derived. The installed components must be able to cover the peak-load of the traffic as well as the annual energy demand.

3 Results

The analysis of the load profiles shows that for both investigated structures, the highest loads in the secondary substations as shown in Table 1 were recorded in the mountain Road B in both S-95 and S-50 and in normal traffic as well as in traffic jam. For S-50 a 5 MVA rated transformer can be suitable as a secondary substation transformer. It can be overloaded up to 10 MVA for10 minutes in case of a preload of 90 %. In this case the overload time is lower than 9 minutes. 3.5 MVA transformers are suitable for S-95 structure. In this case the overload takes only 6 minutes which is still in the range of the permitted overload duration.

	S-50 normal traffic	S-50 traffic jam	S-95 normal traffic	S-95 traffic jam
Road A	3.91 MVA	8.64 MVA	2.87 MVA	2.95 MVA
Road B	4.49 MVA	10.14 MVA	3.37 MVA	4.04 MVA

Table 1: Maximum load in secondary substations for different profiles and scenarios

Considering the maximum load in a 20 km section, the optimal number of secondary substations, the distance between them, the medium voltage level and the necessary cable systems can be determined. This load has been equally divided on the secondary substations taking into consideration the maximum supported power by the transformers. If a failure occurs close to one of the primary (bulk) supply stations, the MV cabling needs to supply all secondary (traction) substations. In this case two cable systems of the type N2XS20 3x1x500 are needed. By contingency investigations (critical outage of the MV cable) the primary substations transformers should be able to cover at least total feeder load in the 20 km section by changing the normal open point position (compare figure 1). That means 150 % of the initial peak load in structure S-95. Due to different MV network layout in structure S-50 200 % of the initial peak load are needed.

Considering the maximum load in each section, the permitted continuous overload of a Transformer and the timing of the truck traffic (s5 or s10) following results were obtained:

Scenario	**S-95 s10**	**S-95 s5**	**S-50 s10 and s5**
Transformer	1x40 MVA	2x40 MVA	1x 50 MVA (or 1x40 MVA ONAF)
Maximum supported load	48 MVA	86 MVA	57,5 MVA

Table a: Rating of the primary substation transformers

For the investigated 100 km highway section, a supply power demand of about 280 MVA for both configurations is needed. To cover this demand and fulfilling the (n-1) criterium, one 110 kV cable system of type (A)2XS(FL)2Y 630 and three connection points to the transmission system (one each 50 km) are needed.

According to the estimated component structure of the supply network, cost estimations were derived. The total costs for grid infrastructure referred to 100 km highway sections range around 95 M€ with moderate deviations between the variants considered. This estimation matches with comparable figures derived for grid integration of other ERS technologies ranging at 0.75 M€/km for lower traffic assumptions [2].

References

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