Figure 8 and Figure 9 shows the calculated power in ten chosen substations, the amount of the power in 1, 2, 5, 6, and 7 is very small as their position relatively far from the derived path, as shown in Figure 8. The other five substations, which are showed in Figure 9, share the highest demand, depending on the bus position with respect to them. For example, when the bus is at point 4, a very small amount of power is supplied by substation 7, more value provided by 8 and 9.

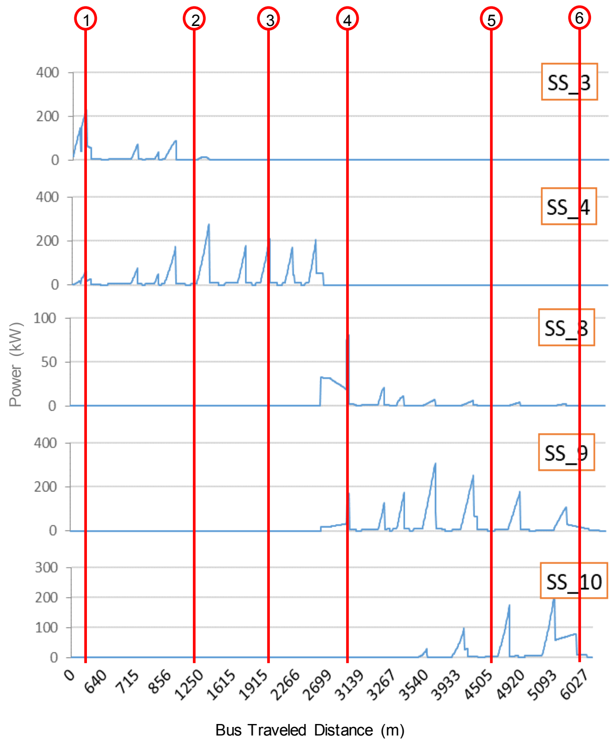

Figure 9: Substation power profile referenced to the trolleybus crossed distance

The BOB model was tested in the simulation program. The onboard battery trolleybus operated outside the DC overhead lines cutting a distance of 1.7 km for around 10 minutes. The battery SoC dropped to almost 60% since the outdoor temperature was adjusted for typical winter conditions. By this, a sufficiently low SoC was reached in order to obtain the charging modes impact. The time for charging the battery to its maximum capacity was about 35 minutes. The charging started immediately as the BOB reconnected with the overhead lines. The consumed power has been increased slightly by the new bus.

From the first look, the grid seems to be capable of handling the operation of one BOB without impacting the existing grid infrastructure. The aforementioned risk might rise dramatically with an increasing number of BOB in the grid.

IV. Conclusion And Future Work

Within this paper a methodical approach of modelling a public transport system was introduced by adding new components to the trolleybus network. A first impact on grid stability has been achieved, but further simulations are needed to validate. Adding battery trolleybuses destructively influences the grid stability due to the fact that additional energy from the overhead is consumed instead of receiving the same energy from the diesel combustion engine.

For the future, a further developed simulation environment with bidirectionally operating substations and enhanced models for the BOBs and the EV charging stations is planned to be implemented. The integration and reliability of the EV charging stations depends basically on the given information. The simulation model in progress will enable to make reliable statements whether EV charging stations are reasonable at specific positions in the Smart-Trolleybus-System or not. The sense of purpose will be regarded with consideration of the EV charging stations capability to relieve the DC overhead grid. In order to implement bidirectionally operating substations a steadily enhanced model for the DC power flow needs to be developed, since this case example is not that common. The further development of the BOBs basically depends on real measured values helping to validate the aforementioned simulation model.

Acknowledgment

The presented work in this publication is based on research activities, supported by the Federal Ministry of Transport and Digital Infrastructure, the described topics are included in the project "BOB Solingen". Only the authors are responsible for the content of this paper.

References

[1] D. Baumeister, M. Salih, M. Wazifehdust et al., "Modelling and Simulation of a Public Transport System with Battery-trolleybuses for an Efficient E-mobility Integration," 1st E-Mobility Power System Integration Symposium, 2017.

[2] E. Schoop, "Stationäre Batterie-Anlagen: Auslegung, Installation und Wartung," vol. 2., 2018, pp.82–74.

[3] T. Khatib and W. Elmenreich, "Modeling of Photovoltaic Systems Using MATLAB: Simplified Green Codes," 2016, pp. 13-15.

[4] A. Keyhani, "Design of Smart Power Grid Renewable Energy Systems," 1st Edition, John Wiley & Sons, pp. 394-439, 2011.

[5] E. Zhou and A. Nasle, "Simulation of DC power distribution systems,", IEEE, Papers Presented at the 1994 Annual Meeting, Industrial and Commercial Power Systems Technical Conference, 1994, pp. 191-195, 1994.

Gefördert durch:

Bundesministerium für Verkehr und digitale Infrastruktur

Koordiniert durch:

NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie