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Volvo follows the current by taking a model based approach

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The future of the vehicle industry

Transportation of people and goods is a fundamental prerequisite for growth and prosperity in the world, and more so for every year. Traveling is central to our understanding of other cultures, countries, and the planet we inhabit. Ordering things online from the other side of the world has become common practice for everything from clothes and furniture to chewy candy cars and fancy whisky. Meanwhile, the transportation sector is facing one of its greatest challenges yet: taking an active role in reducing greenhouse emissions released to the atmosphere. In northern Europe, the country of Sweden has the ambition of having a vehicle fleet which does not depend on fossil fuels at all by the year 2030.

It is here in the cold north that Volvo has been thriving for decades, developing vehicles renowned for their safety and comfort. Over the course of the past few years, some of their buses powered by electricity have made their way to the market as well. Their electric hybrid double-deckers driving down the streets of London are estimated to produce between 30-40 percent lower carbon dioxide emissions compared to a conventional vehicle. Somewhat closer to home, their fully electric buses have been in use on line 55 in Gothenburg since 2015.



A Volvo electric hybrid bus on the streets of Gothenburg.

Ripples in the electrical system

Developing electric vehicles, however, is not always as smooth a ride as driving one. While an electric vehicle may only require an energy storage system such as a battery powering an electric motor connected to the wheels in order to move forward, the ride would be rather unpleasant. Components which provide additional functions to the vehicle can therefore be found in Volvo's buses as well. An air compressor used to pressurize tanks of air which can then be used to operate the doors and kneel the bus is one example of such a component. Different components controlling lights, steering servo, dashboard, ventilation and other functionalities are also required. Connecting them all to the battery's DC link are power electronic converters (or inverters), or PEC's for short.

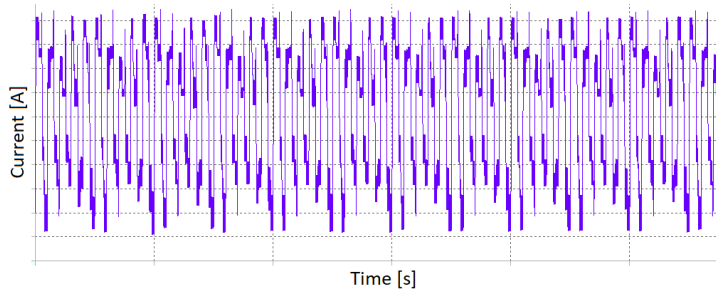
Power electronics can be used to change the current from DC to DC, AC to AC,

DC to AC, and vice versa in order to provide the respective loads with what they need to function. In an electric bus, a PEC chops the DC current provided by the battery into rectangular pulses of a certain frequency. The width of the pulses can vary over time depending on the load they power. Unfortunately, the chopped up current pulses tend to spread on the DC side of the inverter to some extent as well. Here, the pulses are referred to as current ripple, and they are a constant thorn in the side of power engineers. When several components in the electric bus are active at the same time, the different PEC's will generate current ripple of different frequencies and amplitudes depending on the application they power. The result is a cacophony of alternating currents at different frequencies spreading throughout the DC link. Exactly how the current ripple spreads varies not only with which components are used, but also where in the bus they are placed and the lengths of the cables connecting the different components to each other.

Current ripple can potentially cause a lot of harm to a DC system, reducing component lifetime or even frying a component. Different current ripple frequencies typically affect, and are in turn affected by the DC system in different ways. Luckily, there are some ways to combat current ripple. By using filters, usually in the form of inductors and capacitors which are fitted on the DC-side of the PEC's, the ripple can be attenuated to some extent. Unfortunately, these measures are rarely enough to completely prevent current ripple from wreaking havoc. So what can be done?

A model based approach

For the past year, the bus department at Volvo has taken a model based approach. If the spreading of the current ripple in the DC system of an electric bus can be simulated before the bus is even built, there is both money and time to be saved. By building a model library consisting of different components which can be put together in many different configurations, both existing and future buses can be modeled and their respective current ripple simulated in a matter of hours. Just like a lego fort can be put together in many different ways by arranging the pieces differently, so can the traction voltage system of an electric vehicle. Answers to questions such as optimal component placement, filter sizes and component lifetime calculations can be estimated with the click of a button. It can also be used to determine whether any switching frequencies of the PEC's are likely to cause trouble somewhere in the DC grid. Harmful frequencies and sensitive components can then be avoided or adjusted before the harm is ever done.



A simulation of what current ripple spreading in the DC-link of the traction voltage system in an electric vehicle can look like.

There are, however, still many possible improvements standing in the way of such a model based design being really accurate. The models have to represent the electrical behavior of all the different components very closely over a broad band of frequencies for the current

ripple to look the same in the simulations and reality. In other words, the scaling factor between voltage and current known as impedance has to be found and modeled thoroughly for remaining components in use today as well as new components in the future. By using certain measurement instruments and methods developed during the past year, this can now be done one component at a time, providing a solid foundation for future work.

Looking ahead

For Volvo, the ambition to continue making world-class vehicles is never ending. A next step in reducing the time to market and development costs for electric vehicles is therefore to keep looking at the tiniest details of the traction voltage system. By further expanding the model library based on these carefully measured details, the electrical behavior of the entire DC system of a bus can eventually be modeled and simulated before the eleven o'clock coffee.