Exploring the prospects of 25kV static converter feeder stations
T1061

For more information contact: enquirydesk@rssb.co.uk

June 2016
Performance and characteristics of different architectures and technologies of static converters for 25 kV, 50 Hz feeder stations

Aims

On behalf of the Vehicle/Train Energy System Interface Committee (V/TE SIC) and the Future Electrification Group (FEG), the aims of this research have been to:

• Analyse the types of static converters for 25 kV, 50 Hz systems as described in the available technical literature and review the commercial products offered by suppliers.
• Develop a software model in Matlab/ Simulink for the three converter types that are offered or most likely to be offered by suppliers, and guidance on the use of the models.
• Test and assess the models for typical railway operations, highlighting their relative advantages and drawbacks in terms of performance, applicability and reliability, and recommend how to select a static converter for a specific application.

Work Package 01 (WP01) has completed the first two points above, WP02 is addressing the third.

Findings

Three types of static converters are feasible for 25 kV, 50 Hz railway electrification systems:

The results of the simulations have shown that all of the converter topologies have similar performance and can operate in dual end mesh feeding without causing circulating currents in parallel to the high voltage grid. However, the semiconductor devices of the converters have very limited overload capacity which requires that they are designed for the peak power of the feeder system.

Only types 1,2 (in the table opposite) have so far been developed as commercial products and both have been deployed by DeutschBahn in Germany and in support of railway operations in Norway, Sweden, Austria, and Australia.

Impacts and benefits

This study will help the railway industry to understand the benefits of using static converters for 25 kV, 50 Hz feeder stations to replace single-phase transformers, the key benefits of which are:

• Static converters will transform the railway electrification systems from purely passive loads on the utility grid to active interfaces between the railway and the grid.
• Static converters have reduced impact on the utility grid compared with transformers. Therefore, feeder stations with converters can be connected to medium voltage grids instead of high voltage grids, with considerable savings in the cost of connection. This aspect has another important impact on the planning of new railways, because the location of the feeder stations would no longer be dependent on the crossing points of the transmission lines on the railway network.
<table>
<thead>
<tr>
<th>Type</th>
<th>Availability</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Back-to-back converters with central DC-link</td>
<td>Available as commercial product</td>
<td>Simple to control and based on rugged semiconductor devices</td>
</tr>
<tr>
<td>2</td>
<td>Converters with multiple DC-links</td>
<td>Available as commercial product</td>
<td>Slightly more complex to control, but more scalable and with a higher level of redundancy. Quality of the voltage output is better than that of the back to back converter.</td>
</tr>
<tr>
<td>3</td>
<td>Indirect modular multilevel converter</td>
<td>Not currently available as a product, but might be in the near future</td>
<td>Elimination of high voltage capacitors, second harmonic filters, three-phase input filter, single-phase output filter and single-phase output transformer. This converter can use semiconductor devices with low voltage blocking capabilities and is highly scalable</td>
</tr>
</tbody>
</table>

- Feeder stations with static converters enable dual-end feeding or mesh feeding of the overhead lines and, hence, the elimination of neutral sections that are a significant constraint in the design of the electrification system, especially for railways with multiple junctions at short distances.

- The better voltage regulation of the overhead line and the possibility of dual-end feeding or mesh feeding enable a larger spacing between the feeder stations, thereby reducing the total number of feeder stations, the construction of which is always critical in the planning of new railway lines.

### Background

Traditional AC traction power supply systems in the UK use feeder stations with single-phase transformers. The feeder stations supply the different sections of the electrified overhead line, electrically isolated by neutral sections. This feeding system causes a static imbalance of the grid current and the consumption of reactive power, with high costs.
of connection and limited distance between feeder stations. These issues are becoming increasingly important for the higher demands of new rolling stock and high-speed trains.

Static converters overcome all the limitations of single-phase transformers and have been widely used with excellent results across Europe for the feeding stations of 15 kV, 16.66 Hz railways. The case is less evident for the UK 50 Hz railways, because transformers are significantly cheaper than static converters and a more in-depth investigation of the capital and running costs at system level is required. The substantial development of the technology and early applications for 50 Hz railways in Australia suggest that this is now worth reconsidering.

The V/TE SIC and the FEG asked for this research to understand in detail the performance and characteristics of static converters for 25 kV, 50 Hz railways and to support the next steps on the comparative evaluation with single-phase transformers.

Method

The project has been based on the modelling of static converters for 25 kV, 50 Hz railways using Matlab/Simulink, a software suitable for the analysis of power conversion systems and their control. The reference designs of static converters for the analysis have been taken from the technical literature published in this field and through discussion with suppliers.

The models have been used to understand the characteristics of static converters under different scenarios of the utility grid, the electrical loads on the railway and the parameters of the converter. The performance and characteristics of the static converters have been assessed to determine the most important aspects for the procurement of this technology.

The models have also been prepared for staff to enable them to evaluate the performance and characteristics of the static converters.

Next steps

A further package of work (WP-02) is planned, the main objective of which is to quantify the performance and cost of different ac system configurations using static converters compared with the equivalent conventional feeder station transformers.

The performance and costs of feeder station traction transformers used for heavy and light rail will be compared, along with the conversion of dc to ac for the static converter option. A representative example (the East Coast Main Line), will be used in the whole life cost comparison.

Where to find out more

The WP01 summary reports are available on www.SPARKrail.org and copies of the software models can be provided to RSSB members on request through enquirydesk@rssb.co.uk.