Total Optimisation for Energy Efficiency – Managing the Innovation

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Rising energy prices and the vital necessity to reduce CO2 emissions are encouraging Bombardier to develop energy efficient innovative rail vehicles. This is a challenge, since the customers are asking in parallel for shorter delivery times and the use of “proven technology”, emphasising the re-use of standardised, modularised and pre-tested assemblies. These standardised modules in turn can easily be optimised for sub-system performance, but hardly for train-wide energy efficiency.

To illustrate the difference between optimised sub-system and total (train-wide) performance we might think of a conventional power plant, where the electric power output is usually optimised with respect to fuel/coal consumption. But as soon as heating (of houses) is intended as well, a new balance between electric power output and thermal power output for heating is needed to ensure maximum total efficiency.
The goal is thus to aim simultaneously for both the optimisation of standardised sub-systems as well as for total energy optimisation. While the first goal targets short delivery times and possibly the use of proven technology, the second goals defines a new train-wide context, asking for variations to the “known and proven” design, i.e. innovation.
The Bombardier approach to overcome this dilemma between sub-system and total energy optimisation is the intensive simulation of all individual sub-systems within an integrated and centralised environment called Train Energy Performance – TEP tool.

Within the TEP tool, the parameters of each system, say the traction drive, are implemented by the respective expert, i.e. the traction expert. The tool will then provide details about voltage levels, currents, efficiencies and temperatures to him, allowing optimisation of the sub-system on sub-system level. When all sub-systems are optimised by their respective experts across all Bombardier sites for their nominal values, the complete train performance can be simulated on an arbitrary track and environmental (e.g. temperature and altitude) conditions, i.e. the detailed customer conditions. These “day-to-day” operational conditions of the rail vehicle usually differ substantially from the (more extreme) values from the specification, i.e. from the nominal values. The next step then focuses on the impact of variations to the sub-systems in order to optimise the performance train level for the customer specific conditions with respect to minimising the energy consumption (or initial cost).

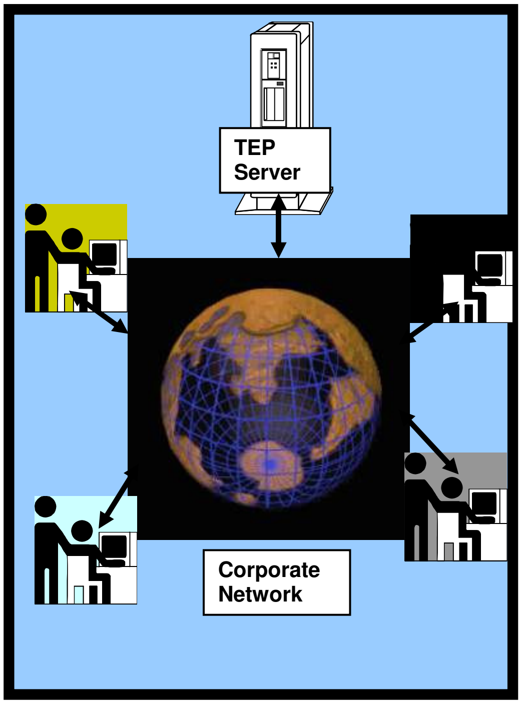

Figure 1: Bundling of distributed expert knowledge with centralised TEP tool

The optimisation on train level takes into account all sub-systems, such as the traction system (and its waste heat for heating purposes), Driver Assistance Systems, Brake recuperation and energy storage, auxiliary devices (e.g. HVAC) as well as the customer specific environmental conditions and drive cycles,.

To illustrate the difference between the two optima, we may look at the optimum size for an onboard energy storage system of a train with, say, a weight of 100t and a nominal top speed of 160 km/h. While E = ½ mv2 yields about 27 kWh (possibly reduced by the dynamic brake chain efficiency) to be stored while using the dynamic brake, an analyses of the real customer usage (i.e. the day-to-day drive cycles) might show that the train operates for only one or two long distance stretches with top speed 160 km/h, but has many more cycles during the day with top speeds not exceeding, say, 100 km/h. For this typical cycle at 100 km/h, the kinetic energy to be stored using the dynamic brake is only 10 kWh, or roughly 1/3 of what was needed for 160 km/h. The detailed TEP analyses will also show that the additional mass of the larger storage system deteriorates the train performance during the typical cycle, not to mention the costs for the installation of the unnecessary energy storage.

The Bombardier conclusion to total energy optimisation is thus not to rely on the assembly of individually optimised sub-systems, but instead to push forward the optimisation of the total (assembled) system in order to minimise the Life Cycle Cost for the customer.