ENERGY-OPTIMIZED PROPULSION SYSTEM MITRAC 3000 FOR LOCOMOTIVES

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ABSTRACT

Liberalization of the European railway market stimulated the demand for new, cost efficient locomotives and power heads that contribute to profitable and sustainable operation of vehicle fleets across different railway systems and country borders. The new generation highly modular MITRAC 3300 propulsion system is developed to meet these needs and moreover to fulfill the needs of a global customer base. Based on a product platform the propulsion system can be configured very standardized for TRAXX locomotives and it can also be tailored for other vehicles. The later is also of interest for the modernization market.

Latest developments in power electronic and control allows the MITRAC TC 3300 traction converter family to serve up to four different supply systems with a single unit. Operators can not only select the suited solution for those corridors they need to serve, but also benefit from low energy consumption and operating cost of this new generation traction converters.

As first company in this industry Bombardier issues the environmental product declaration for its products. The total chain of materials and energy from cradle to grave is taken into account to set a base for today's products and future improvements. Since energy cost amount to 20 to 25% of total operating cost (value for European freight corridors), power efficiency of the propulsion chain plays a major role for low energy consumption and low operating cost. The following topics are discussed: a) environmental performance, b) optimized system design c) change to IGBT technology d) energy optimized driving style e) on-board energy storage.

1. MITRAC HIGH POWER TRACTION CONVERTERS BASIC DESIGN PRINCIPLES

The latest member of the MITRAC high power traction platform is the TC 3300 IGBT traction converter family. It is based on a unique modular concept allowing a maximum commonality and flexibility: one basic design can be adapted for a wide range of different applications to individual needs of the customer. To make up a complete propulsion chain the traction converter is combined with matching components: transformer, traction motor and gear. The MITRAC converter family covers all types of locomotive and power head applications from AC and DC to Multi System solutions for cross-border operation. It covers Diesel-Electric as well as Dual Power (pure electric or diesel- electric operation) locomotives to extend coverage into non-electrified areas.

2. ENVIRONMENTAL PERFORMANCE

Global warming, energy cost increase, demographic change and urbanization is a tremendous challenge for our planet and people and call for environment friendly and sustainable transportation solutions. The great advantage of Bombardiers electric trains is the absence of zero CO2 and particle emission, assumed that electricity is produced by zero-emission power plants.

Being leading in environmental sustainability Bombardier executes life-cycle assessments (LCA) to continuously improve product offerings. The LCA covers the environmental aspects for the extraction, production and transportation of raw materials used for manufacturing and its foreseen mission until end of life and decomposition. Figure 1 describes the utilization of materials and primary energy resources from a life cycle perspective from cradle to grave for the Bombardier MITRAC TC3300 high power traction converter.

The total primary energy resources in the use phase is 10 GWh (based on the EU-15 average energy mix), where as the energy consumption of the TC3300 MS in use is about 3.1 GWh. In contrast: The energy required until end of manufacturing is as low as 0.125 GWh. This points out, that efforts improving the efficiency of the energy utilization have by far the highest impact on energy cost. Negative values at the end of product life are due to effects of material recycling and avoidance of virgin materials as well as avoidance of energy consumption from conventional sources. Based on commercially available processes 99% of the production and maintenance materials can be recycled [1].

3. MINIMIZING ENERGY CONSUMPTION

Bombardier applies and further develops a portfolio of innovative technologies to cover a wide spectrum of performance requirements, to offer specific benefit for train operators, to create substantial overall energy savings and to ensure economic sustainability. A focal point is energy cost that piles up to 20 25 % of the total operating cost.

3.1 Optimal System TopoLogy

The propulsion chain consisting of transformer, traction converter, motor, gearbox and auxiliary supply has the most significant impact on the overall power efficiency of a vehicle. Figure 2 shows the power loss versus tractive effort and speed. The best overall efficiency is achieved, when all system components are optimized, matched and operated in the area of highest efficiency (power management functions).

Over decades Bombardier has in depth experience with a wide variety of propulsion chain topologies (Figure 3). All MITRAC traction converters operate with a power factor of unity in AC systems and recuperate energy in all catenary systems (AC and DC) up to the same power level used for traction. In extreme cases, when traveling over the Alps from Zürich to Chiasso 35% of the traction energy can be recovered when braking the train. In normal cases about 10% of energy can be recovered.

Nowadays the highlighted two-level topologies (Figure 3) are implemented with the MITRAC TC3300 for high reliability and high efficiency using IGBT module technology. Low losses are achieved with a regulated DC link that allows designing and operating the system at its optimal point of efficiency. In addition high performance control algorithms, i.e. adhesion control, reduce the losses further.

3.2 IGBT Converter Technology

With the transition from GTO technology to IGBT (Insulated Gate Bipolar Transistor) technology a couple of benefits are achieved. Snubber circuits can be avoided completely. This led to significant reduction of power losses as well as to reduction of weight, volume and cost. The power density (kW/m3) of the MITRAC TC3300 is twice as high as the MITRAC GTO traction converter. Energy savings per locomotive are in the range of 60'000 kWh per year.

3.3 Energy Optimized Auxiliary Control

With two independent auxiliary supplies the speed for the motor fan can be adjusted to the required level thus reducing energy consumption and noise level.

3.4 Energy Optimized Driving Style

Like with other vehicles (i.e. cars) the driving style has large influence on energy consumption. Field studies with locomotives and EMU show that depended on the driver's style the difference can be up to 20% in hilly topology. With a smart driving style the driver considers the topology of the landscape, track signals, load and speed of the train, the inherent momentum of the train and so on. From this information he derives the best choice for the tractive effort and uses the maximum possible extend of regenerative braking and avoids mechanical braking when possible. With the EBI Drive 50 drivers assistance this optimization can be done automatically and better (Figure 4). Optimal tractive effort is calculated in real time and proposed to the driver on the display of the driver's desk together with his energy consumption. Optimization is even done with considering time table changes, track changes and speed restrictions. Thereby the driver can achieve lowest energy consumption.

3.5 Outlook On-Board Energy Storage

On-board storage will have beneficial impact on energy consumption, emission levels and railway infra-structure. The topology of the traction converter gives a unique option to add energy storages to the propulsion system. Accumulators, super caps or gyro storage can be attached in an elegant way electrically to the DC circuit. The approach is to store recuperated braking energy on-board when it is not useful to transfer to the catenary system, or when simply no catenary system exists.

Having the energy in an on-board storage, the energy can be re-used whenever needed. This gives various benefits to electrical and diesel electrical vehicles. For diesel electric it can save significantly energy consumption and diesel emission as well when performing stops in railway stations. It can also boost available power and increase vehicle acceleration. For electric vehicles it can reduce transformers in sub stations along tracks and required peak power. Even catenary free operation of electric vehicles is feasible at least for low power vehicles.

[1] Bombardier, Environmental Product Declaration - MITRAC TC3300 MS V04, Sep 2008

Material resources (tons)	Manufaturing	Use	End-of-life	Total Life-Cycle
Non-renewable	326.9	5'392.8	-253.8	5'465.9
Renewable	190.8	13'037.1	-115.2	13'112.6
Total	517.7	18'429.8	-369.0	18'578.5

Primary energy resources (MWh)	Manufaturing	Use	End-of-life	Total Life-Cycle
Non-renewable	112.5	9'271.4	-89.4	9'294.5
Renewable	13.8	779.9	-12.2	781.4
Total	126.4	10'051.3	-101.6	10'075.9

Figure 1: Resource utilization for the Bombardier MITRAC TC3300 MS V04 on the Bombardier TRAXX F140 Multi System (30 years operation time, average running distance 150'000 km per year)

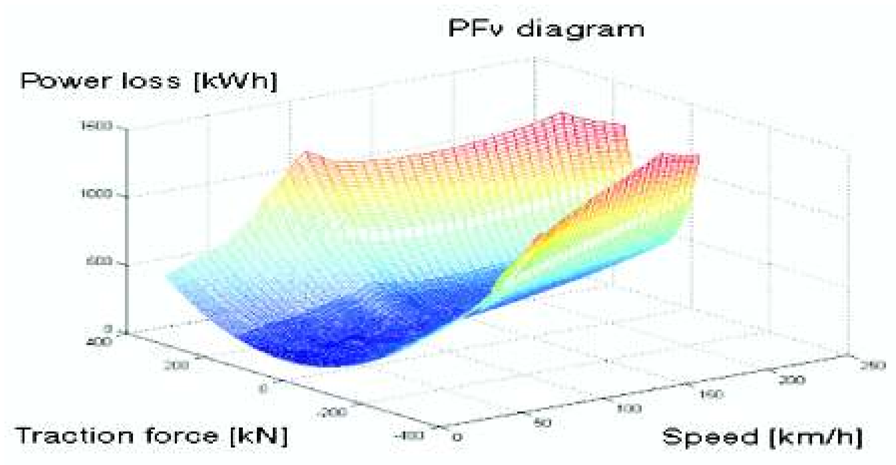

Figure 2: Optimized propulsion system components and characteristic losses (transformer, converter, motor, gear, control regime)

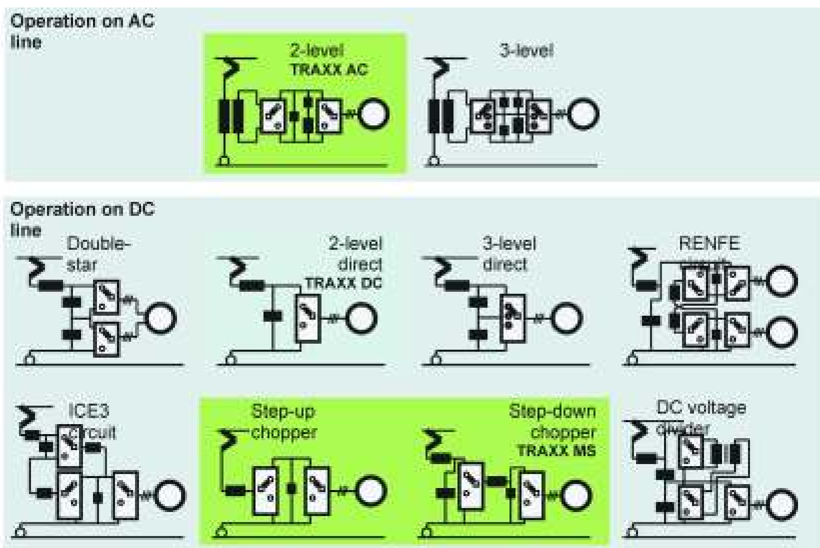

Figure 3: System topologies (all with regeneration of electric power)

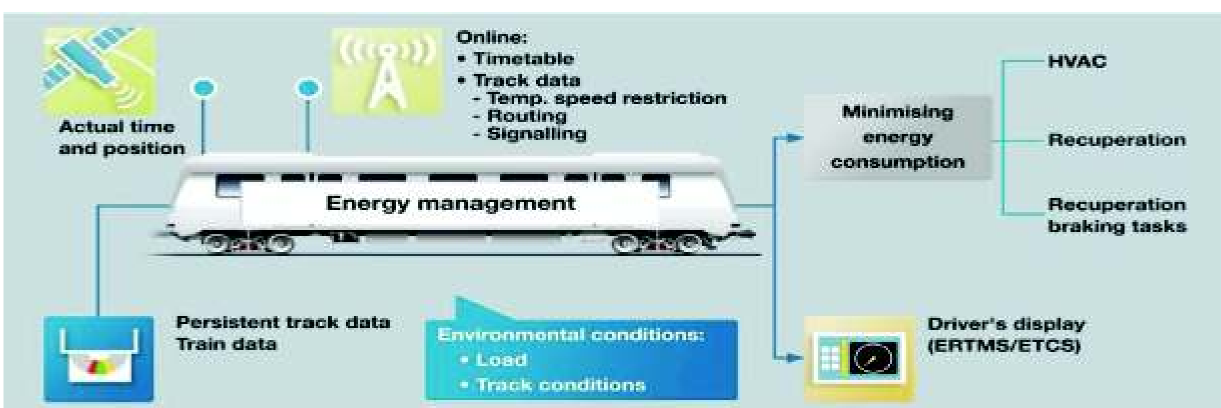

Figure 4: Energy saving driving style - driver assistance system

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