The Innovative traction system with the flywheel of the LIREX™

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Summary

A six-car diesel-electric prototype (figure 1) of the totally low-floor, modular vehicle family LIREX™ (Light Innovative Regional Express) has been developed as class 618/619 for the DB Regio fast regional traffic with a maximum speed of 160 kph. Important innovations are permanent-magnet traction alternators, flywheel brake energy storage and the arrangement of essential traction components on the vehicle roof. The modular traction concept permits options for catenary operation and hybrid solutions.

(Figure 1)

1 Introduction

Generally speaking, diesel powered rail vehicles can be equipped with purely hydraulic, hydro-mechanic, mechanic or electric traction drives. The three systems mentioned first are beneficial for the customer in terms of lower purchasing cost and reduced complexity of the system. For the design engineer, however, the arrangement of major components is not very flexible either.

The basic design requirements for LIREX™

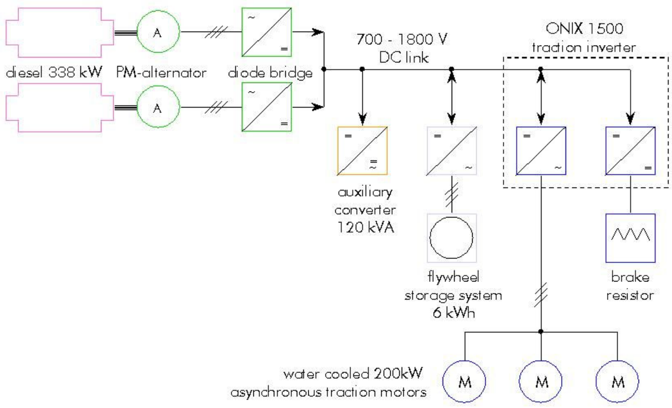
- totally low-floor and step-less passenger compartment
- super-wide carbodies using the steered single-axle bogies type KERF™

could not be implemented with any kind of purely mechanical transmission.

In contrast, the diesel-electric propulsion system offers a variety of specific benefits that are particularly noticeable in the LIREX™ due to its prototype character:

- possible optimization of diesel engine control independently of vehicle speed
- rheostatic braking with significant reduction of wear and noise
- option to integrate energy storage systems
- easy supply of high-power auxiliaries (e.g. air conditioning)
- high flexibility regarding mechanical arrangement
- far-reaching similarity between diesel and electric trains

The LIREX™ consists of two mechanically separable three-car units. Both halves are electrically identical and autarkic to ensure the highest redundancy possible. Apart from traction motors and fuel tanks, all traction components are put into functional units that are located on the roof to guarantee easy access and maintainability. For noise and mass reduction reasons, all major components are water-cooled.
The overall power scheme of one half-train is depicted in figure 2.



(Figure 2)

Two so-called powerpacks, each consisting of a diesel engine and alternator, supply in parallel one traction inverter that powers the traction motors. The limited engine power determines the tractive effort that drives three out of four wheelsets.

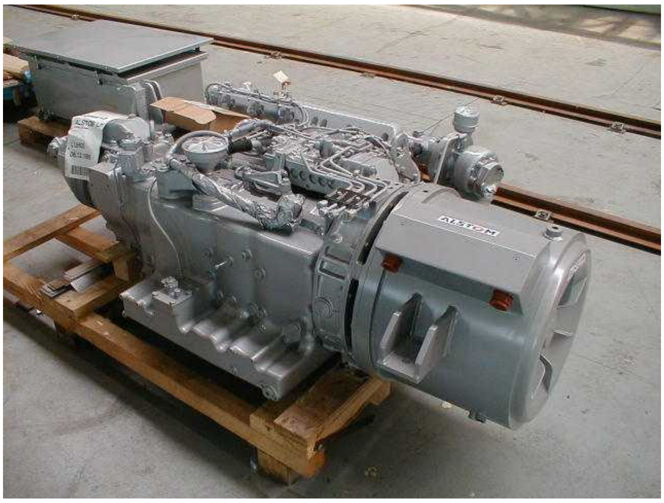
A 120 kW galvanically isolating step-down converter reduces the varying DC link voltage to a stable value of 650 V DC. From this level, the converters of the two air-conditioning units are fed as well as one converter for the vehicle's electrical system of 3-phase 400/230 V 50 Hz and two battery chargers.

The generated energy during electric braking is primarily supplied to the flywheel storage system; the remaining surplus is dissipated in the (fully rated) brake resistor.

The power flow is directed by the energy management controller taking into account various goals and optimization strategies.

2 Powerpack

The powerpack mainly consists of a 338 kW MAN diesel engine and the ALSTOM alternator which are directly coupled (see figure 3) and suspended in a specific frame. This construction also supports the fresh air and exhaust system as well as the cooling circuits and a heating unit. The latter is only used for warming up and when the waste heat of the engine is not sufficient.



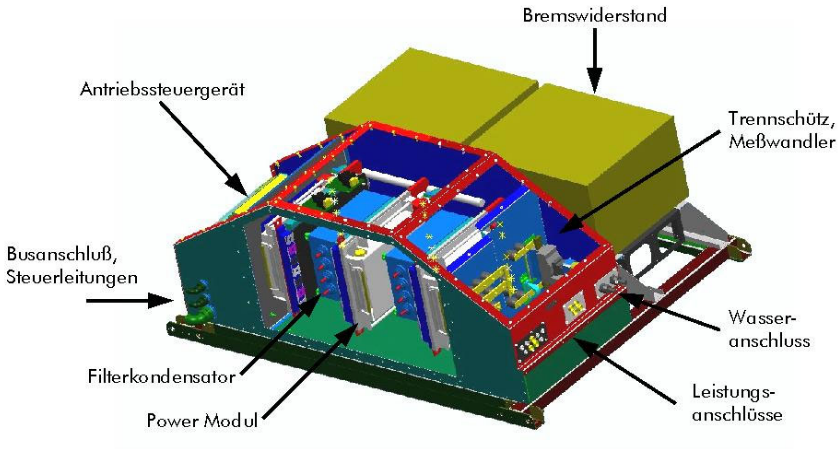
(Figure 3)

Additionally, six rectifier diodes are mounted directly onto the water jacket of the stator, so that there is no need for separate power electronics.

The DC output voltage of the alternator is roughly proportional to the speed of the engine that is controlled according to the current power demand of the train. The voltage excursion between 700 and 1800 V DC can be handled by the subsequent converters without additional adjustment.

3 Traction drive

The ALSTOM ONIX™ 1500 traction drive is characterized by the traction inverter module that also incorporates the brake resistor (3D drawing in figure 4). Following the strategy to totally separate power cables from control wiring for EMC reasons, the inverter case itself is divided into three chambers: On the one side you can find the control unit, on the other side voltage and current transducers and the isolating switch. Filter capacitors and power modules are located in the center. Each module supplies one motor phase and forms part of the braking chopper. In order to realize a high power density for the roof-mounted equipment the inverter modules are water-cooled.



(Figure 4)

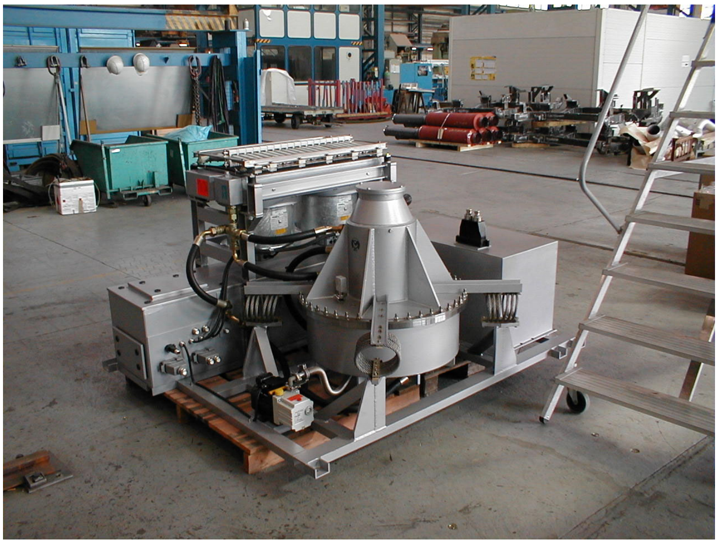
To maintain the low floor height also above the bogies, the traction motor cannot be conventionally placed between the wheels. The only space envelope available is fairly restricted in both length and diameter. Therefore the maximum speed of the water-cooled asynchronous motor is more than 6000 rpm. The torque is transmitted via a curved-tooth coupling and a double reduction gearbox. Its housing has already been designed for various gear ratios to enable an increase of the maximum speed of the train, assuming sufficient traction power.

4 Flywheel storage system

A completely new application for diesel powered rail vehicles is a system which can store braking energy for any later demand.

The mechanical part is built up from the carbon-fibre flywheel itself and its driving motor, which are enclosed in a specially suspended and evacuated housing. The maximum speed is 25,000 rpm that provides 6 kWh of rotational energy. About 75 % of this amount can be used in normal duty cycles. The short-term power rating is 350 kW while charging the flywheel. The no load losses of the flywheel at full speed are low (6 kW.)

Two converters in series, a DC chopper and a high frequency three-phase inverter, connect the flywheel to the main DC link. An additional brake resistor allows the complete shutdown of the system internally; i.e. without any interconnection to the train. The complete system including the water cooling circuit for motor and power electronics is mounted on its own steel frame. Therefore the unit is modular and easily exchangeable (figure 5).



(Figure 5)

The stored energy shall be used for various purposes as follows:

- noise reduction during departure
- provision of additional traction power "booster"
- significant reduction of fuel consumption
- emission-free operation on short distances
- silent supply of auxiliaries during longer station stops (i.e. without diesels)

A frequently asked question is the impact of the flywheel operation on the wheelset forces. Neither entering in curves nor variations of line gradient are followed by wheel force differences inferior to 400 N so that these gyroeffects are negligible.

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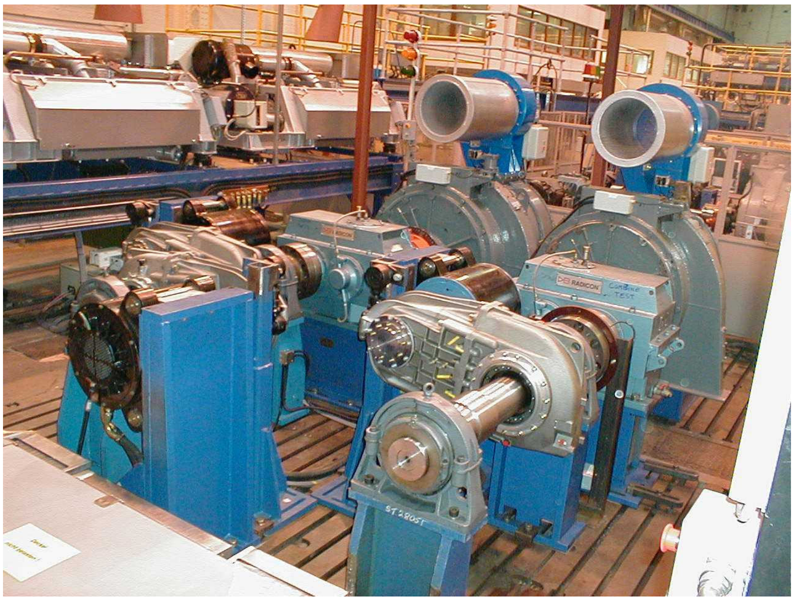
5 Combined test

Before commissioning of the vehicle, an extensive Combined Test is carried out with the complete propulsion system of one half-train (as described above). This saves both time and money and provides repeatable test results under very defined conditions.

Main objectives of this testing period are
- integration of the different sub-systems
- simulation of duties on real route profiles
- validation of thermal performances
- system reaction to various fault conditions

Figure 6 shows the setup of the traction drive with motors, gearboxes and load machines in the foreground, whereas you can see the two powerpacks in the background.

(Figure 6)



Hence, very effective testing is being carried out so that the functionality of the innovative traction system (in particular link stability, flywheel integration and energy management) is satisfying before starting line trials.

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6 Conclusion

The diesel-electric traction system for LIREX™ was designed to meet very specific requirements in terms of weight, flexibility and efficiency. It enables the prototype train to be a benchmark in rail technologies.

Key innovations within the existing system are the permanent-magnet alternators and the flywheel system. For the first time on a diesel-powered vehicle, braking energy is not lost but can be stored for later use.

The train (without mounted flywheel system on the roof) was successfully commissioned in summer 2001 up to speeds of 60 kph. Until summer 2002 intensive test runs of DB AG will be done to check the running, braking and traction performances of the prototype (including flywheel system). The next import milestone will be the approval by Eisenbahn-Bundesamt (German Rail Authority).

After one year in regular passenger service in the German state Sachsen-Anhalt, the train shall be rebuilt into a hybrid. In exchange for one powerpack, a transformer and four-quadrant converter will qualify the train for high-power operation under 15 kV, alternatively to the three remaining diesel powerpacks.

Furthermore, based on many innovations of the LIREX™ prototype the modular CORADIA™ LIREX™ family is developed to correspond to the market needs for 100 % low-floor, high comfort vehicles for fast regional and inter-city relations (maximum speed between 160 and 200 kph) with electrical, diesel-electrical or hybrid operation.

More advanced power sources such as micro gas turbines or fuel cells can also be tested on the LIREX™prototype once they are available for rail applications.