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ALL-IN-ONE CONVERTER FOR A DIESEL ELECTRIC MULTIPLE UNIT

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Abstract
The paper presents the concept of advanced and highly integrated IGBT propulsion and an auxiliary power supply converter for diesel electric multiple unit. The incoming power from the diesel-generator group is transformed into traction power by the propulsion converter. The auxiliary power supply converter supplies energy to the on board network and the vehicle battery directly from the same DC□link. Energy recuperated during braking is fed back into the DC-link, where it may be consumed by the auxiliary systems, or dissipated into heat by the braking chopper.

All propulsion and auxiliary supply equipment as well as cooling system are integrated into a roof-mounted converter box, while a high degree of functional integration as well as the maintenance cost optimized design are realized. The increased power density of the new generation converters enables compact and light-weighted vehicle designs.

1. Introduction

Based on a former joint venture with TŽV Gredelj the Končar group is designing a new generation diesel electric multiple unit (DEMU). For this purpose a thorough redesign of the converter has been made. Considerable experience gathered during the design, production, commissioning and exploitation of the previous generation converter has resulted in many improvements implemented in the new All-In-One converter KONTRAC GP550DE for Končar DEMU. GP550DE converter is realized with two separate inverter units both fed from the same DC-link and can be mounted on the roof. This implementation proved to be room and cost efficient given all the power units and other components are cooled with a single heat exchanger [1], [2]. The converter DC input is fed from a roof power pack (RPP) – three-phase generator with rectifier unit. The generator is powered by a diesel engine. Both the propulsion and auxiliary converter as well as the battery charger are controlled by the same digital control unit KONTRAC DCU222. The DCU222 and its subordinated FPGA and DSP cores ensure high performance measurement and control. The auxiliary converter powers the onboard three-phase and single-phase devices as well as the battery charger. All of the above mentioned features of the GP550DE converter enable the design and production of the Končar DEMU according to the newest safety demands and best passenger experience.

2. Converter description

In Fig. 1 is shown a simplified schematic of the propulsion and auxiliary converter power circuit.

As mentioned beforehand, converter input terminals are connected to outputs from three-phase generator and diode rectifier. The propulsion converter supplies power 3 x (0…1200) V, 0…200 Hz for propulsion motors. Auxiliary power supply converter produces:

- three-phase voltage 3 x 400 V, 50 Hz, 85 kVA, for powering induction motors
- single-phase voltage 230 V, 50 Hz,
- 24 V_{DC} for battery charging and battery loads, 10 kW.

In addition to monitoring the converter operation, the DCU222 takes part in the overall vehicle control by communicating with the Vehicle Control Unit (VCU) and Brake Control Unit (BCU). During traction, vehicle target acceleration delivered by the VCU is used for calculation of power and voltage demand by the DCU222. Voltage and power setpoints are sent to the RPP control unit. According to diesel motor state the DCU222 lower level processors calculate optimum torque and flux setpoints for the propulsion motors. Respectively, during braking a percentage of total brake force is delivered by propulsion motors while the remaining force setpoint is forwarded to the BCU by DCU222. Onboard communication is based on redundant CAN busses for control and measurement and Ethernet bus for monitoring and diagnostic. On the converter level, critical control signals are fed through optical fibers.

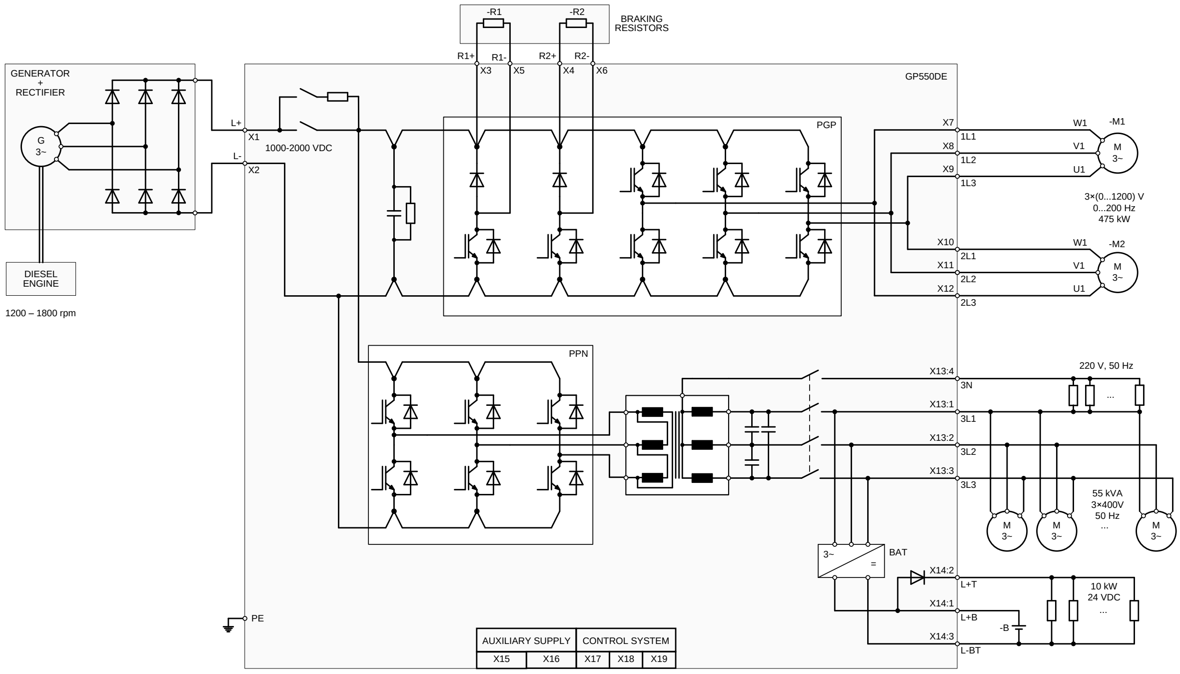

Fig. 1 Power circuit diagram of the GP550DE converter mounted on a train

2.1. Propulsion converter

Its main function is to transform the DC-link energy into adequate three-phase voltages for the propulsion motors. The PWM voltages must result with currents needed for inducing the requested torque and rotation speed based on the vehicle speed, DC-link voltage level and acceleration demand from VCU [3], [4]. During braking, the converter ensures requested braking torque and transfers the induced energy to the DC-link. Braking energy which is not consumed by the auxiliary converter is fed to the braking chopper in order to keep the DC-link voltage level in safe limits, Fig. 2.

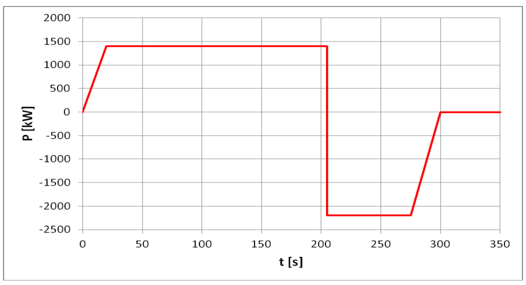

Fig. 2 Diagram of total vehicle propulsion/braking power

2.2. Auxiliary converter

The auxiliary three-phase converter transfers power from the DC-link to AC devices over a three-phase transformer [5]. In addition to its galvanic function it also serves as a filter due to its large leakage inductance. In order to improve the voltage waveform and reduce losses due to higher harmonics, sine filter is added on the transformer output. The filter base frequency has been chosen so that it suppresses higher harmonics in the inverter output waveform while preserving the 50Hz harmonic [6].

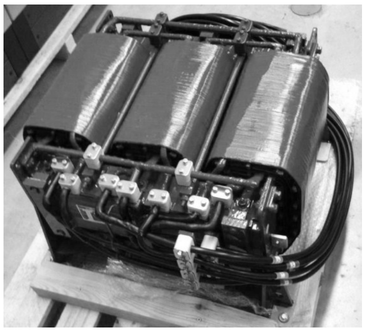

Fig. 3 Three-phase transformer with an additional magnetic core (increased leakage inductance)

To reduce the overall weight of the converter, sine filter inductors have been integrated into the transformer [7]. Filter capacitors are therefore connected directly to the transformer secondary terminals, as shown in Fig. 1. The sine filter ensures:

- nearly sinusoidal voltage waveforms,
- reducing voltage rate of change dV/dt,
- peak voltage amplitude limitation,
- reduction of peak current for long cable lines,
- reduction of additional losses and noise in transformers and induction motors powered by the auxiliary power supply converter.

2.3. Battery charger

The charger unit charges the vehicle battery and powers all 24 V_{DC} devices. This includes electronic control and measurement devices, relays, screens and all other DC circuits. Its rated current is 360 A at 24 V_{DC}. The device charging characteristic is I/U which enables the battery to be charged with constant voltage or constant current. Battery charging voltage can be regulated between 20 and 30 V.

The charger is designed as an independent AC/DC converter. Its input is fed from the auxiliary converter. Three-phase voltage input is rectified on a diode bridge and fed into the DC-link. A voltage regulated IGBT H-bridge forms 0 - 30 V_{DC} output using PWM modulation [8].

2.4. Converter design and cooling system

All necessary propulsion and auxiliary supply equipment as well as a cooling system are integrated into the same converter box which can be mounted on the roof. The converter box is divided into 2 sections with different degree of mechanical protection.

The first section houses the IGBT power units, measurement and control units. The second section includes air intake, transformer, heat exchanger and ventilator. In order to simplify maintenance and repairs, main equipment inside of the converter is realized in modular version. Fig. 4 and 5 show the propulsion and auxiliary converter IGBT power units [9].

The autonomous forced liquid cooling system uses a mixture of ethyl glycol and water to cool the power units. The liquid itself is cooled by an internal air-to-liquid heat exchanger. The fan positioned in second converter section takes in fresh air which also cools the auxiliary transformer before it is blown through the heat exchanger grid and further outside of the converter.

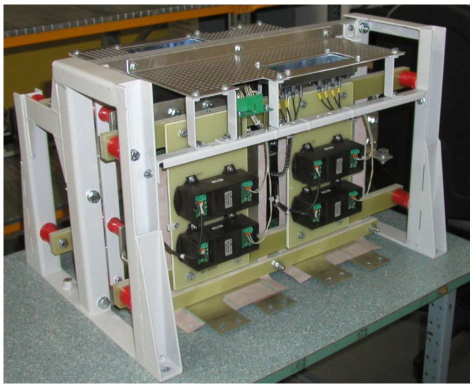

Fig. 4 Propulsion converter IGBT power unit

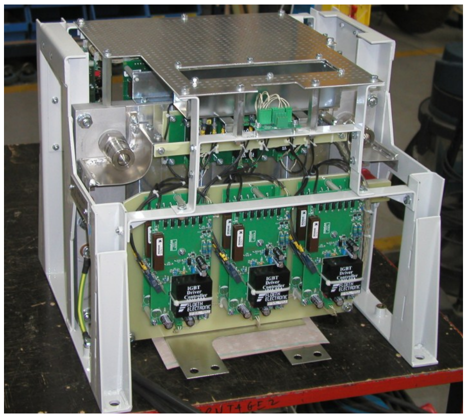

Fig. 5 Auxiliary converter IGBT power unit

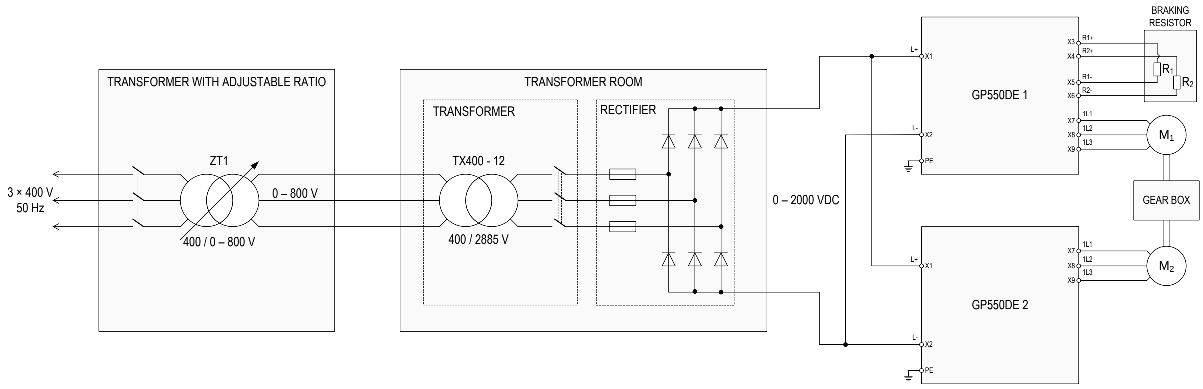

Fig. 6 Principle diagram of propulsion converter testing method

3. Converter testing

In order to prove functionality and performance of the GP550DE converter, it had to undergo thorough prototype and series testing. During testing the biggest challenge was to test converter propulsion operation under rated load. Thus a back to back method for testing 2 converters was used in Fig. 6. Each of the converters powers one propulsion motor which acts as a motor or load device. The converter which is tested operates in a propulsion or braking mode (torque regulation) and the load converter and motor operate in speed regulation.

Converter inputs have been fed from the same DC lab source. This way the tested converter consumes the braking energy returned to the DC-link by the load converter. There is no need for a lab source with rated power equal to double converter power (more than 1 MW).

As far as the auxiliary converter and battery charger are concerned, during series testing it is enough to use a resistive load. A waveform of the three-phase converter output (under rated load) is presented in Fig. 7.

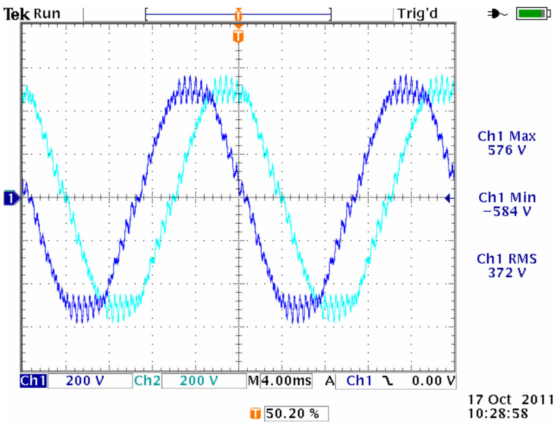

Fig. 7 auxiliary converter output waveform U_{12} (CH1-black), U_{32} (CH2-gray), scale: 200 V/div, 4 ms/div

4. Conclusion

This converter offers a well-integrated solution for powering trains since it powers propulsion, auxiliary and battery loads. It has been designed to meet customer demand for a well-integrated and robust converter unit. In order to achieve high efficiency and dynamics, modern IGBT technology has been implemented. Because of experience gathered during exploitation of the previous generation converter high quality and reliability has been achieved. It must be emphasized that with minor corrections this converter is suitable to operate with various power sources, as long as they are 1000-2000 V_{DC}.

4. References

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