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Reducing Train Weight and Simplifying Train Design by Using Active Redundancy of Static Inverters for the Onboard Supply of Rolling Stock

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Abstract

Reliability of onboard power supply systems on rolling stock is a very important issue for the railway operator. While a failure of the HVAC supply results in a loss of comfort for the passengers, a failure of the supply for air compressors or for the traction cooling systems results in towing the train. This is, looking at the required availability of a train, not acceptable. An active redundancy concept for the onboard power supply maximizes the availability of the system.
This paper describes such a system under the aspect of
- Weight reduction
- Continuous operation when changing from normal to redundant operation
- Flexibility in train design

Keywords : *Static inverter, Rolling stock, Availability of power supply, Active redundancy*

1. Power Supplies on Rolling Stock

The power supply on rolling stock can be classified in two main parts as given in Figure 1.1. This paper focuses on the onboard loads.

The selection of onboard loads as given in Figure 1 again can be separated into two groups. Comfort loads such as HVAC and part of the lightning, and safety relevant loads like air compressors for the brakes and the cooling system for the traction system.

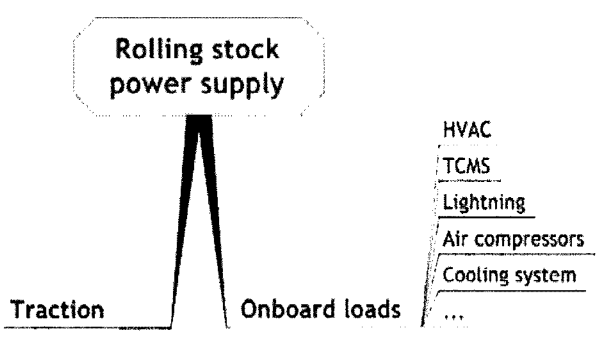

Fig. 1. Power Supply on Rolling Stock

For comfort loads redundancy is not necessary and for reasons of costs very unlikely to be installed. Some of the safety relevant loads like the TCMS system are fed by the train battery circuit (which is known to be reliable) in parallel to a DC supply. In case of an faulty DC supply the battery takes over the load.

For the systems like air compressor and cooling system a feeding from the battery is not reasonable due to the rather high power demand. Here redundancy concepts help to increase the availability.

2. Redundancy Concept

Redundancy basically means to install more equipment than required. Units are at least to be doubled in order to realize a high availability of a system. This usually results in a complex set-up. Redundancy also means that in case of a failure of one system the redundant system has to take over the load.

Up to now, redundant onboard power supplies have generally been implemented using two auxiliary converters which feed a common DC rail and separate onboard AC nets. The main disadvantage of this solution is the complexity of the onboard power distribution net in the vehicle and the corresponding switchgear. Everything has to be implemented twice. Resulting in additional weight and

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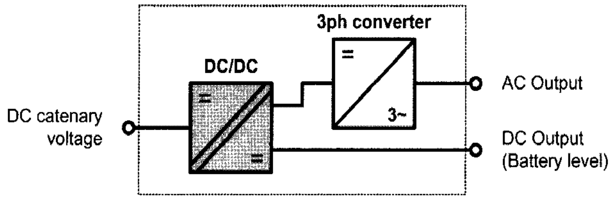

Fig. 2. Power Supply System

need for extra room for the installation. This solution is also inflexible - an addition of an extra car to the train is usually difficult, because it has to provide the same train specific installation as well.

The SMA approach here is to avoid double implementation of the on-board AC power distribution system. The AC converters are feeding a common AC net in parallel. This parallel operation is also known as active redundancy. While this kind of solution is considered as state-of-the-art for DC grids, it has, to date, only been used infrequently for AC grids on rolling stock.

The idea is to install two (ore more) identical onboard power supply systems shown in Figure 2. In this case there is a DC catenary supply. The input converter provides the required galvanic insulation and by means of medium frequency switching the converter can be realized very compact and light weighted.

Furthermore the input converter delivers a DC voltage output on battery voltage level.

Like shown in Figure 3 the redundant converter systems

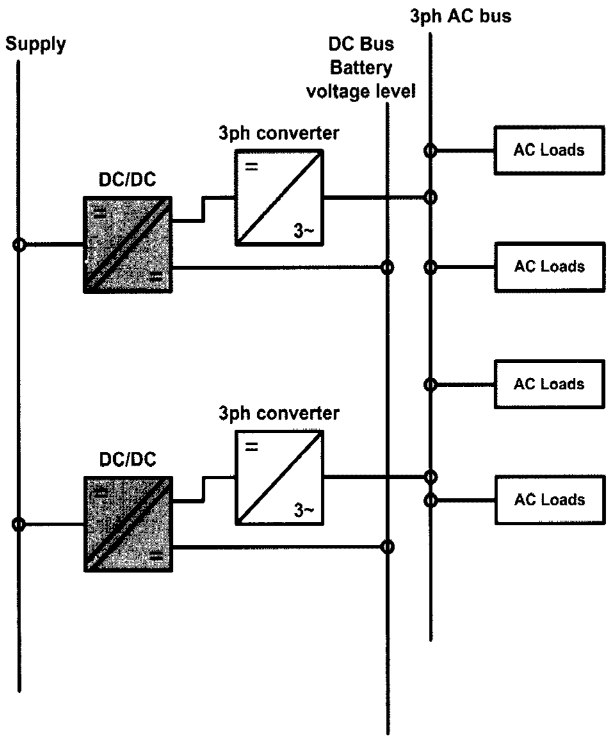

Fig. 3. Active Redundant Power Supply

are in a parallel connection on input as well as on output side. The electrical wiring needs not to be doubled. So a complex switchgear on the train is not necessary. In terms of weight and installation effort, this solution is optimal. In case the train shall be extended by one ore more cars, they can simply be added. Theoretically a car with its own power supply like shown in Figure 2 can be added as well and be integrated in the active redundancy concept.

While DC coupling is quite easy to realize, AC coupling is far more sophisticated. Both, active and reactive power have to be balanced to avoid some reactive power flow between the converters. SMA realizes the parallel operation without synchronisation wires.

As the onboard power supplies (AUX converters) are working in parallel on the 3ph AC bus it is possible to switch off one AUX in case of an internal failure. In case of an overload for the remaining system a load shedding procedure has to be taken into account, of course.

A further advantage of active redundancy is that it already exists in normal operation. In contrast to the standard solution, no coupling contactors must be closed to create redundancy. Therefore, if the systems are suitably designed, and the load management in the vehicle is appropriate, faulty components can be disconnected without having to shut down and restart the converters.

The system can be adapted for AC input voltages as well.

3. System Design and Operation Management

With active redundancy several scenarios for the train onboard power supply are possible:

- Design according to the n+1 principle, i.e. in case of a faulty AUX the remaining systems can feed all the dedicated loads. There is no constraint in supplying the loads, immediate corrective maintenance is not required.
- Intelligent load shedding in case of a faulty AUX. To supply full load both AUX are required. If one fails, there is an overload condition for the remaining one. This is reported to the TCMS, some loads have to be switched off.
- Energy saving by setting one (or more) AUX in "sleep mode" during low load conditions (e.g. no air conditioning during winter season). Sleep mode means that the control electronics monitors the system state. In case of any failures in the supplying converter or increasing load, it starts again.
- Operate each AUX with its own AC grid. The AC grids are coupled in case of a failure. This solution is

reasonable only for two AUX converters, for larger numbers the AC switchgear is rather complex, and the weight and low effort installation advantages might be lost.

Irrespective of the realisation of an active redundant system there is a need for some intelligence in the control system to provide for the correct change over from normal to redundant operation mode. This can be realized either by the TCMS, by direct communication between the AUX converters (e.g. CAN, digital signal lines, ...) or by monitoring the electrical quantities of the AC bus. The latter solution is rather complex to realize because the evaluation of the criteria for changing the operating mode.

Depending on how the change over to active redundant mode is realized and how many AUX converters are working in parallel the converter has to provide some overload capability. The faster the fault detection works, the smaller the overload capability can be.

Here again the system can be optimized for weight. The faster the information on the current load state of the power supply is available, the faster the system can react in case of a failure. If there is no or only limited need for overload capability the system can be realized more compact and light weighted.

4. AUX for Metro Kaohsiung

One example of SMA's redundant power supply systems is the AUX converter for Metro Kaohsiung. The new rolling stock manufactured by Siemens is equipped with an onboard power supply by SMA. The vehicles are conventional 3-car metro trains with a redundant auxiliary power supply. The auxiliary power supply mainly consists of two identical main static converters with a total power of 160 kVA each. The static converters feed a common

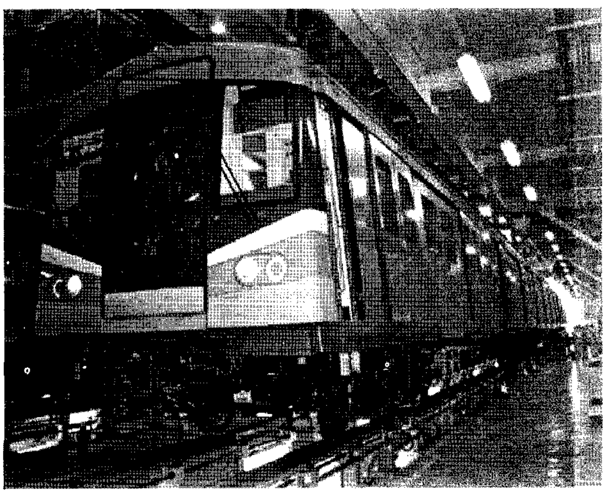

Fig. 4. New Metro Kaohsiung Rolling Stock

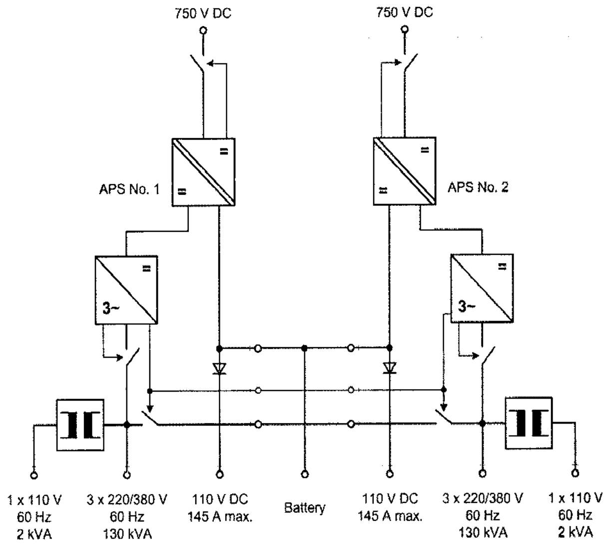

Fig. 5. Onboard Power Supply

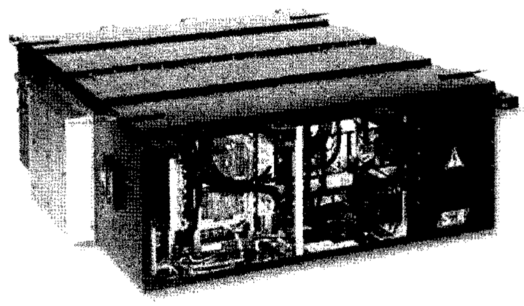

Fig. 6. AUX converter for Metro Kaohsiung

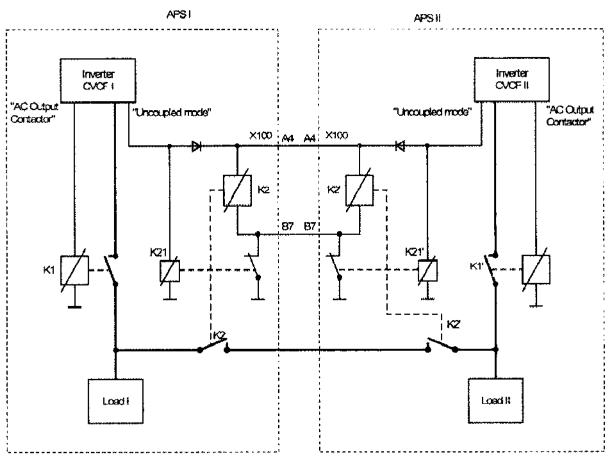

Fig. 7. Signal Wiring Between the AUX Converters

DC grid and separate AC grids.

Figure 5 shows a simplified circuit diagram of the Metro Kaoshiung onboard power supply. One AUX converter is shown in Figure 6.

Two of the converters shown in Figure 6 are used to realize the structure like given in Figure 5. All the contactors required for coupling the AC grids and isolating the faulty AUX are inside this container. There is no additional switchgear required.

In normal operation the two converters work completely independent from each other.

Figure 7 shows the signal wiring between the two AUX converters. Here the change over from normal operation to redundant mode is realized. By this direct communication the change in operation mode can be realized very fast.

Both of the Metro Kaohsiung AUX power supplies are connected to each other in a hard-wired XOR connection. This means that if an AUX drops out, then the other AUX supplies the entire (reduced) load of the power supply system. In normal Operation the AC Line is not coupled.

The faulty AUX opens the output contactor (K1 or K1′). The interconnection between the both inverter outputs is active when in both converters the coupling contactors (K2 and K2′) are closed. This switching is controlled by the two "Uncoupled Mode" digital outputs of the two AUX units (with the auxiliary relays K21 and K21′). Coupling occurs as soon as one of the two outputs has the "false" state (K21 and/or K21′ are not set) . This means that whichever AUX has dropped out will activate the coupling.

5. AUX for Coradia Lirex X60

Another project where SMA realized an active redundant power supply is the Coradia Lirex X60 from Alstom. This train is running in Stockholm. Here the onboard power supply is realized according Figure 3.

For the CORADIA LIREX, SMA even went one step further in the redundancy concept. A total of four redundantly powered distribution nets were created (Figure 10), which are fed by two converters. Two galvanic isolating input converters feed a regulated +/−400 V DC rail for the entire train, to which both the two battery chargers and the two output inverters, as well as the inverters integrated in

Fig. 8. Coradia Lirex X60 (Photo Copyright Alstom 2005)

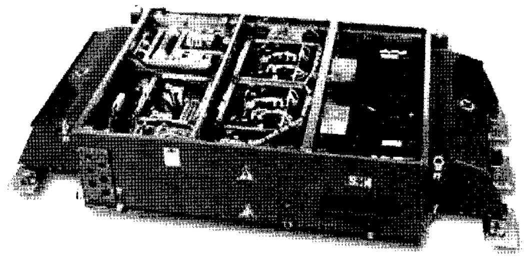

Fig. 9. Converter for Roof Mounting

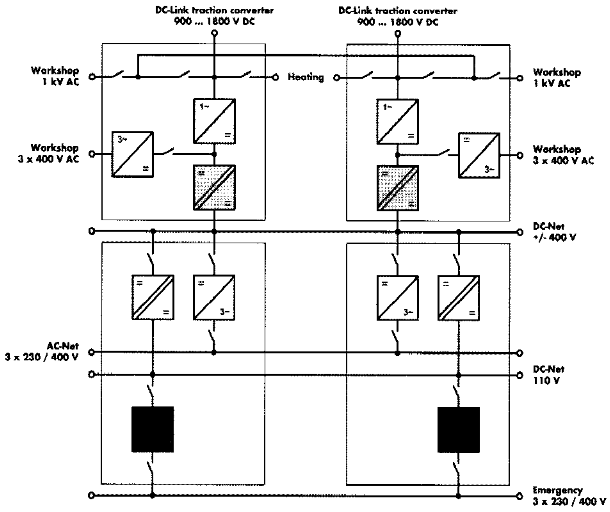

Fig. 10. X60 Onboard Power Supply Scheme

the air conditioning systems for the compressors are connected. The two output inverters power a 3×230/400 V AC power distribution net to which all AC loads are connected. The battery chargers feed a 110 V DC rail for the entire train, to which the emergency inverters are connected, and charge the batteries. Even the two emergency inverters are implemented with active redundancy. They feed another 3×230/400 V AC distribution net.

6. Conclusion

In this paper active redundant converter systems are presented. By realizing a special converter control it is possible to operate two converters in parallel on a common AC bus without a need for synchronization wires. As a result, there is no need for additional wiring or switchgear assembly for the redundant operation mode, if required a car can easily be added to the train-set. Due to the direct communication between the converters a fast reaction in case of a failure is possible, the loads can be fed without interruption.

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Bibliographies

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