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Re 460.025-0 on piggyback train. *Photo SBB*

The SBB Class 460 Part 2

Electronics and Control

by A.E.Hauser-Gubser

Concluded from page 18, June 1994 Swiss Express

6: The Electrical Equipment

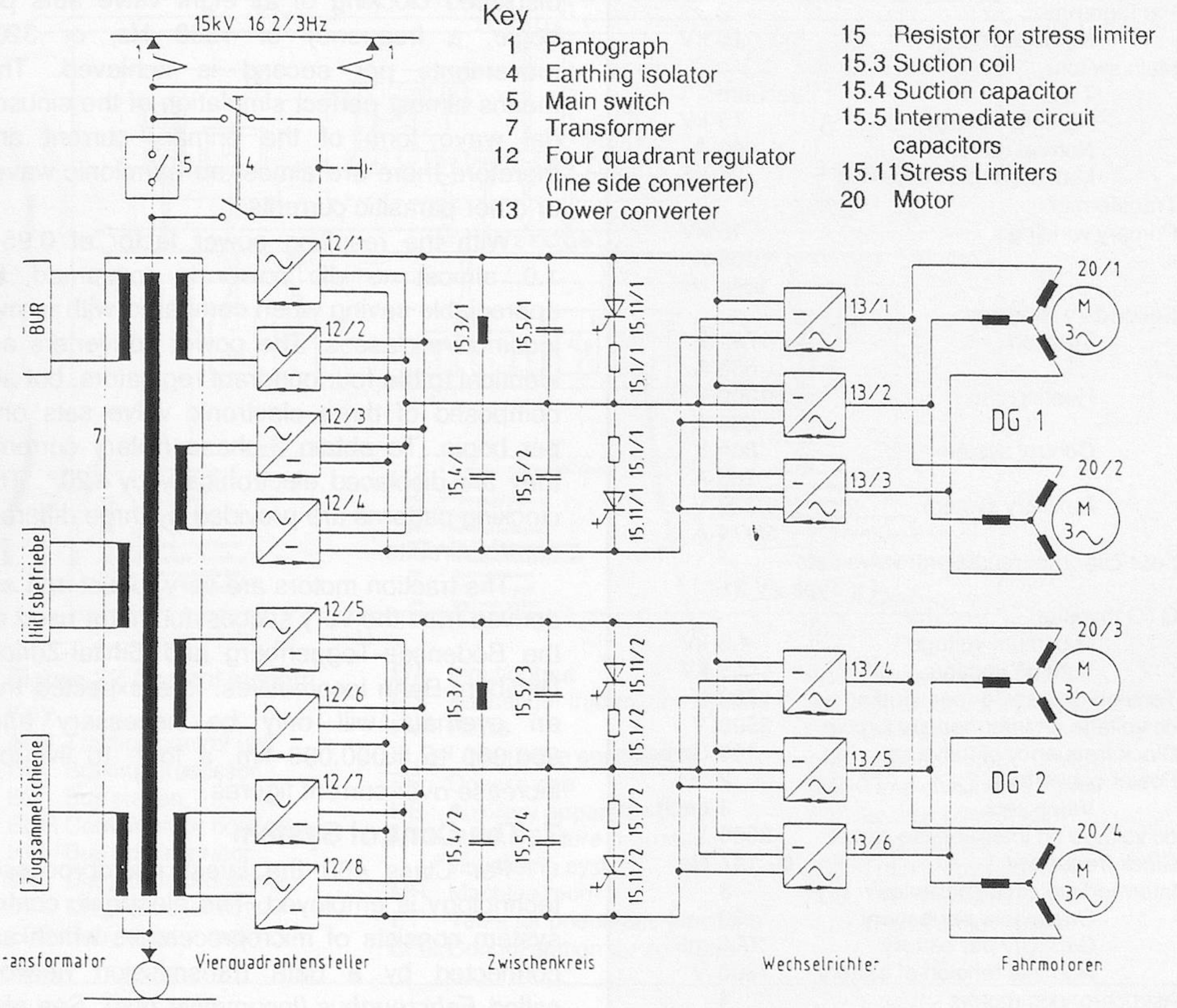
It is important to know that the advent of the converter locomotive was made possible by the invention of the thyristor, especially the GTO (gate turn off) thyristor. By their capacity to turn direct current on and off rhythmically and precisely at high clocking rates, direct current is converted into alternating current. If the switching of the circuits is done in such a way that they are displaced by $^1/_3$ of a full phase, or 120°, then rotary or 3-phase current is produced. The frequency, the amplitude and the tension of this current is continuously variable. With 3-phase asynchronous motors it is possible to approach the limit of adhesion much better than with the classic series wound motor.

Even more interesting is the "self control" of the system. If the wheels of one axle begin to skid, then they turn somewhat faster. The asynchronous motor then produces a smaller torque and the wheel revolutions are reduced.

There are two basic types of 3-phase motors, the synchronous and the asynchronous patterns. The former is used in large numbers on the SNCF in the "Sybic" (*synchrone bi-courant*) locomotives. Power output is only possible if speed of the stator revolutions is synchronous with the frequency of the feeding alternate current. The torque is produced by the rotating field in a combined action with an exciting winding fed by direct current. The synchronous motor is regulated by static converters and semi-conductors. Brushes and collector rings are required to feed the exciting current. It is correct to say that the synchronous motor locomotive was a transitional step towards the converter locomotive with asynchronous motors.

In the asynchronous motor the 3-phase current produces a rotating magnetic field in the poles placed in a circle on the stator. This field induces currents in the squirrel cage, these currents creating the magnetic forces which turn

Figure 21 Diagram of main electric circuit



Key
1 Pantograph
4 Earthing isolator
5 Main switch
7 Transformer
12 Four quadrant regulator (line side converter)
13 Power converter
15 Resistor for stress limiter
15.3 Suction coil
15.4 Suction capacitor
15.5 Intermediate circuit capacitors
15.11 Stress Limiters
20 Motor

the rotor. The torque depends on the difference between the frequency of the rotor and the frequency of the rotary field. No brushes or collector rings are needed.

Two basic constructional concepts for the converter locomotive have been developed by ASEA Brown Boveri, ie the three point switching circuit with four transformer windings and an intermediate circuit tension of 3.5 Kv, one converter per bogie and four 4-pole asynchronous motors for Class 460. For the BLS class 465, a two point circuit, six transformer windings, an intermediate circuit tension of 2.8 Kv and two converters per bogie (one per axle) and four 6-pole motors are intended.

In Figure 21 the key wiring diagram of Class 460 is shown. The 15 kV, $16^2/_3$ Hz ac current flows from the pantograph through the main switch to the transformer which is provided with four secondary windings (two for each converter and bogie). Three further secondary windings supply the heating circuit, the auxiliary electric devices and the converters for internal circuits.

In the line-side converters (also four quadrantregulators), the alternating current is converted into a wave-shaped direct current of $33^1/_3$ Hz and fed into the intermediate circuit. Since the energy flow per time interval in the four quadrant regulators is not the always the same as in the power converters, the intermediate circuit acts as an accumulator using high capacity metallised paper capacitors. The $33^1/_3$ Hz pulsations are suppressed in the

Table 2 Main Data of Electric Components, Class 460

Pantographs:		2
	Nominal voltage	15 kV
Main switch:		
	Type	vacuum
	Nominal voltage	15 kV
	Normal current	800 A
	Max current on breaking	25 kA
Transformer		
Primary winding:		15 kV
		365 A
		$16^2/_3$ Hz
Secondary windings:		
	Traction	4 x 1783 V
		630 A
	Heating line	1000 V
		800 A
	Control system	804 V
		285 A
	Auxiliary system	110/220 V
		69/74 A
Four quadrant regulators: valve sets		4 x Type ZV 31
GTO thyristor		
	Maximum voltage	4.5 kV
	Turn off voltage	3.5 kV
Tension on transformer winding		1783 V
dc voltage on intermediate circuit		3500 V
Clock frequency of valve set		100 Hz each
Power converters		2
	Valve sets	3 each
dc voltage on intermediate circuit		3500 V
Clock frequency		0 - 147 Hz
Intermediate circuit batteries		3
	Capacitors per battery	30
	Capacity per battery	27.6 mF
	Nominal tension of battery	1800 V
Asynchronous motors		4
	Number of poles	4 each
	Revolutions	0 - 4180 rpm
	Power output at shaft	1560 kW each

suction circuit by a high performance throttle coil and capacitor to obtain a pure direct current for the power converters. Stress limiters prevent excess voltages to protect the gate turn off thyristors. In the power converters, dc is converted into a 3-phase ac current (rotary current) of continuously variable frequency and amplitude. The asynchronous motors are powered by this 3-phase current. During regenerative braking, the motors generate electrical energy which is fed back to the catenary.

Each line-side converter is composed of four electronic valve sets in three-point switching mode. The control commands for the GTO thyristors are formed by pulse-width modulation with 12 times clocking. Each valve set therefore clocks at 12 x $16^2/_3$ Hz = 200 Hz, or 400 switching movements. By synchronous and displaced clocking of all eight valve sets per bogie, a frequency of 1600 Hz, or 3200 movements per second is achieved. This means almost perfect simulation of the sinusoidal wave form of the primary current and therefore there are almost no harmionic waves or other parasitic currents.

With the resulting power factor of 0.95 - 1.0, almost no idle power is consumed, an appreciable saving when compared with former locomotive classes. The power converters are identical to the four quadrant regulators, but are composed of three electronic valve sets only per bogie. To obtain 3-phase (rotary current), they are displaced electronically by 120°. The clocking patterns are provided by three different control circuits.

The traction motors are very robust and are derived from the very successful motor used on the Bodensee-Toggenberg and Sihltal-Zürich-Üetliberg-Bahn locomotives. It is expected that an overhaul will only be necessary after 800,000 to 1,000,000 km, a four- to five-fold increase over current figures.

7: The Control System

For Class 460 the latest microprocessor technology is employed. The electronic control system consists of microprocessors which are connected by a data transmission network called *Fahrzeugbus* (locomotive bus). See also Figure 22. To transmit the data flow, the MICAS S2 locomotive bus works with beam waveguides as a medium, which has the advantage of complete insensitivity to electromagnetic noise fields. The gross data rate is 1.5 Mbits/s, the useful range is 1.1 Mbits/s, depending on the length of the messages. The address capacity of the 256 processors is sufficient for any future expansion.

The messages are transmitted simultaneously. There are two beam waveguides, on one the bus stations receive the messages addressed to them, on the other messages are despatches as the result of light pulses produced by photo-diodes. Two bus administrators regulate the message traffic on the bus, polling each bus station in a sequence of 100-500 ms, depending on the importance of the duties. The bus stations are the interfaces between the bus

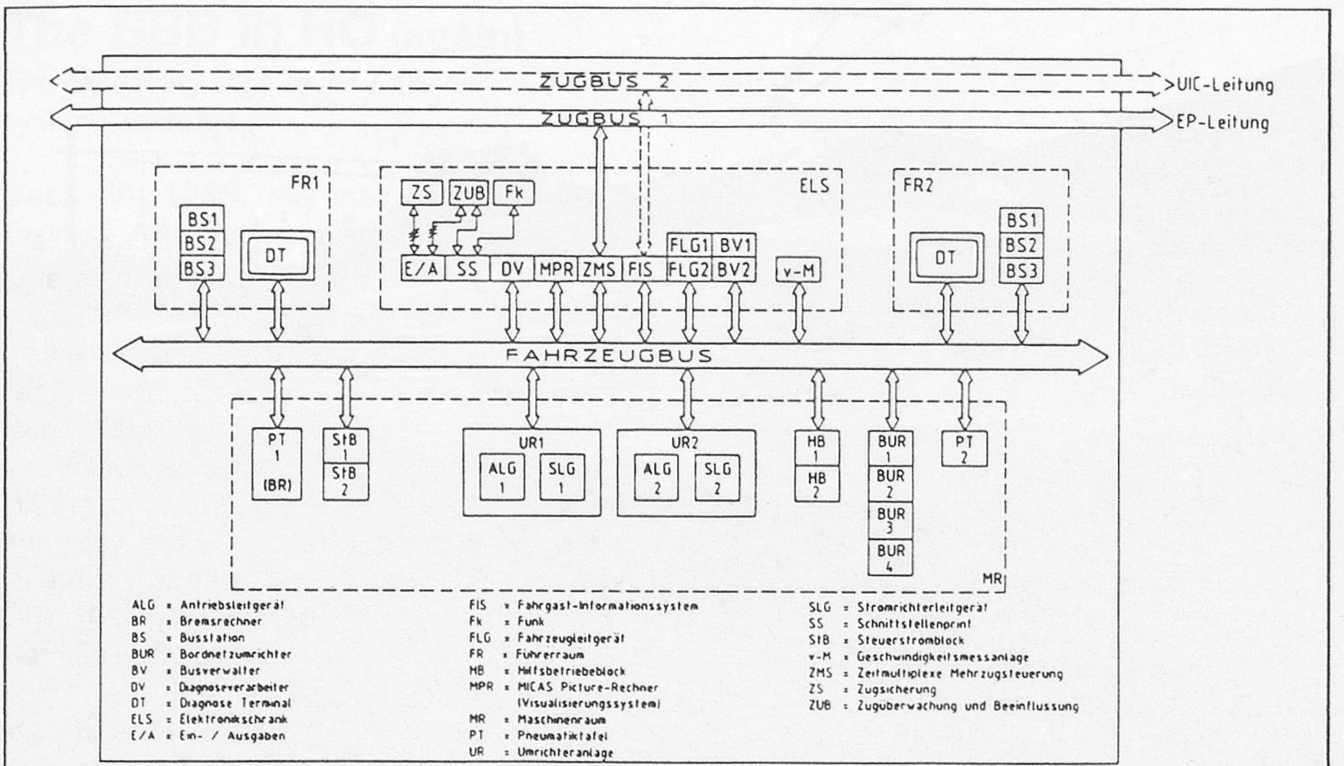


Figure 22 Control system

Key

ALG Traction control unit
BR Braking processor
BS Bus station
BUR Converter for bord system
BV Bus administrator
DV Diagnostic processor
DT Diagnostic terminal
ELS Cabinet type rack
E/A Input/output
FIS Passenger information system
Fk Radio
FLG Locomotive control unit
FR Driver's cab
HB Auxiliary apparatus block
MPR MICAS picture processor visualising system
MR Machine room
PT Table for pneumatic functions
SLG Control station for converters
SS Interface print
StB Block for control circuits
UR Converter
v-M Speedometer
ZMS Time division multiplex access control for 4 locomotives
ZS Train protection
ZUB Train monitoring and interference system

and the pre-mounted electrical appliances.

To obtain a correct hierarchial data flow, two traction data processors carry out the important functions, such as preparing the engine for service, disconnecting all functions, control of the traction and brake forces with set values for the braking processor, division of the brake force on the electric regenerative brake and the mechanical brakes, supervision of critical values and the function of protector relays, control of the air pressure in the brake lines and, finally, control of the safety devices.

One system is always in active mode. Should it fail a second back-up system takes over immediately.

Each converter block is provided with two bus stations, one to control the converter and the other for the drive unit. These devices turn the functions of the converters and drive units on and off. The nominal values are transmitted by the main traction control system over the bus stations in the form of traction or brake force set values. For instance, if a driver orders the locomotive to pull, then both converter groups are first fed with the same set values for tractive force. Should the first bogie reach the limit of adhesion, the anti-skid protection in the converter control unit is alerted. This bus station then regulates the traction force according to the optimum adhesion values. The main traction control unit the increases the traction force at the second bogie in order to achieve the pre-set value.

A similar system called *Zugbus* (train bus) is available for multiple control of up to four locomotives. In this case the leading driver's cab is defined as the master unit.

A diagnostic processor transmits each fault to the terminal in the driver's cab, suggesting at the same time the steps needed to correct the

Re 460s double heading a container train. *Photo SBB*

error. All such malfunctions are recorded, this record is used in the workshops to determine the maintenance required.

Conclusion

Locomotive 2000 is undoubtedly one of the most advanced concepts. Unfortunately the introduction of this class was accompanied by a series of minor troubles which made headlines due to the fact that in some cases, the sequential timetable of passenger trains was disrupted. In view of the complexity of the design and, more importantly, that no prototypes were built and subjected to prolonged testing, it is correct to attribute these to teething problems. They have now been eliminated.

It is tempting to compare the Class 460 with other modern locomotives. One such is the *Eurosprinter* by Siemens/Krauss-Maffei, which has a similar technical concept. Tests are being carried out on the Gotthard and Lötschberg routes at the time of writing this article and the final results have not yet been published. Whatever they may be, it is quite certain that the converter locomotive with asynchronous motors is gaining ground, not only in Europe, but throughout the world.

The SOB Bar Wagen

The history of the SOB *Teak Bar Wagen* which is run in special trains is of considerable interest. It began life in the workshops of Ringhoffer in Smichow, Prague, and was built to the same standards as contemporary *Wagon Lits*, and became No.10 of the Schweizerischen Speisewagengesellschaft (SSG).

In 1947 it was taken over by the SBB as $Dr4_u$ 10210 and was subsequently converted to Cinema Coach Y536, renumbered in 1950 to Xd4 91140. At the end of the 1960s it became X 30 85 97-00 002.

In 1987 it was purchased by the now defunct Oswald Steam Centre at Samstagern. Here it was completely renovated from 1988 onwards, with new interior and exterior cladding. On 17 May 1991 it was passed for traffic by the state and was registered by the SOB as P504.

The coach was bought by the SOB on 31 December 1993 and on 1 January 1994 was renumbered SR 50 47 88-03 380. On 8 May it entered service as an *Aperowagen* and on 2 June it bwecame a *Rolling Restaraunt* with its "Hotel Kitchen" in an accompanying vehicle.