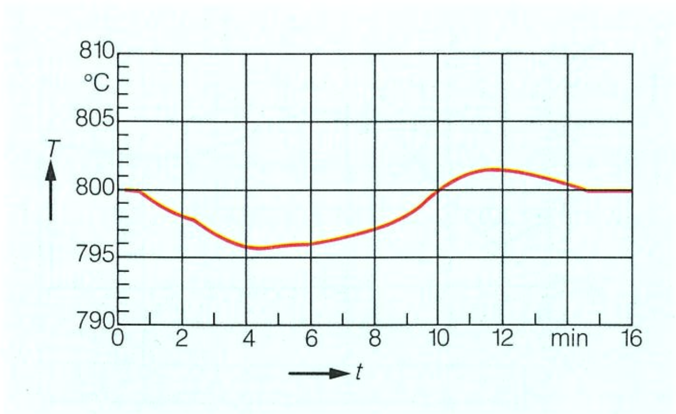
Gas turbine integration in ethylene plants improves overall efficiency by generating useful power and simultaneously providing preheated combustion air for the pyrolysis furnaces.



T Coil outlet temperature
t Time

Coil outlet temperature variation during transients caused by a gas turbine trip at OPC

15

Table 5: Energy improvement achieved with gas turbine integration at Osaka Petrochemical, Japan

	Without gas turbine	With gas turbine
Ethylene production (t/a)	300,000	300,000
Fuel fired (Gcal/h)		
Cracking heater	Base	– 20.76
Gas turbine	0	+ 63.18
Total	Base	+ 42.42
Steam production increased (t/h)		
From cracking heater	Base	+ 21.4
For fuel vaporizer of gas turbine	0	– 2.1
Total	Base	+ 19.3
Electric power generation (kW)		
Gas turbine	0	+23,827
Increased power associated with gas turbine	0	– 405
Total	0	+23,422
Energy improvement (Gcal/h)	Base	30.41

NO_x emissions are reduced

NO_x emissions from the cracking heaters operating on TEG are lower than before the integration system was installed, even though the TEG combustion air's NO_x content is higher. Typical NO_x concentrations in the heater effluent are 70 ppm with TEG and 95 ppm without TEG. The figures are based on dry gas and 0% oxygen content.

The saving in energy is considerable

The overall energy improvement achieved by integrating the cracking heaters with the gas turbine is shown in *Table 5*. With the integrated system, fuel fired in the cracking heaters decreases significantly while steam production increases. Overall, 30.41 million kcal/h of energy are saved. This translates into approximately 800 kcal/kg ethylene, which agrees favourably with the estimates given in *Tables 1* and *3*.

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Rail traffic over the Alps via the Brenner Pass is complicated by the different catenary power systems in Austria and Italy. The problem is solved by new dual-system locomotives which Austrian Federal Railways are placing in service on this route. Development of the locomotives was led by ABB Verkehrstechnik, based at Wiener Neudorf, near Vienna.

A new locomotive speeds up transalpine rail traffic

Traction equipment of the class 1822 dual-system locomotive

Austrian Federal Railways' class 1822 dual-system locomotive, referred to locally as the 'Brennerlok', or 'Brenner locomotive', is the product of an Austrian industrial group led by ABB. The new locomotive solves problems that are caused by the different catenary voltages on the north and south sides of the Brenner Pass; Germany and Austria use AC at 15 kV and 16⅔ Hz, Italy DC at 3 kV. The railway authorities of Germany, Austria and Italy were also involved in the design of the vehicle, giving the locomotive a number of innovative technical features that break with the railway traditions of the three nations.

Austria, situated in the heart of Europe, has a long history of transit trade and traffic, and several of Europe's main railway routes run through the country. Both Germany and Switzerland use the same catenary power system as Aus-
1 tria, but the other countries bordering Austria use a variety of systems. Uninterrupted rail transit through this part of Europe is essential for economic transportation and to achieve capacity goals. Only locomotives that can be operated with different catenary voltages allow this.

Main specifications of the locomotive

The class 1822 locomotive is designed for transit services
2 over the Brenner Pass, and in particular for piggyback rail traffic between Germany and Italy. Five units have been manufactured as part of a first, preproduction series.

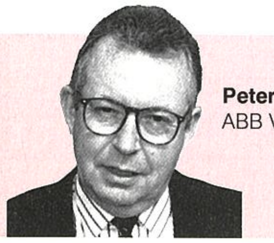
Table 1 lists the locomotive's main specifications. The tractive efforts and the traction power of 4400 kW are the result of data specified by Austrian Federal Railways (OeBB). They will allow trains weighing 1100 t to be hauled up the northern side of the Brenner Pass, which has ruling gradients of up to 2.6 percent, at 70 km/h in dual traction. This
3 corresponds to the draw-bar power limit. On the downhill sections the train has to be able to run at speeds of up to 120 km/h with the same load. The 4400 kW at the motor shaft takes account of the locomotive's own weight and the required acceleration reserve. This power is provided by both the AC and the DC catenary system.
4 The overview in Fig. 4 shows the main traction power circuits.

Table 1: Technical specifications of the OeBB's class 1822 dual-system locomotive

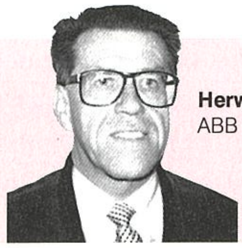
Gauge	1435 mm
Axle arrangement	Bo'Bo'
Total weight	83 t
Top speed	140 km/h
Wheel diameter, new	1100 mm
Gear ratio	1:4.136
Traction power	4400 kW
Regenerative brake power	4400 kW
Rheostatic brake power	1000 kW
Max. starting tractive effort	280 kN
Continuous tractive efforts	250 kN
Catenary voltage	
OeBB, DB	15 kV + 25%, –20% 16⅔ Hz
FS	2.0 to 4.2 kV DC
DC link voltage	
AC mode	3500 V
DC mode	2000–4200 V
Power supply for train	600 kVA
Control battery voltage	24 V
Onboard system for auxiliaries	3 × 380 V, 0–50 Hz 210 V, 300 Hz

The HV equipment is designed for two different traction power systems

The high primary current in the 3-kV Italian power system allows two pantographs to be raised on this section of the route. To make sure they are at least the minimum distance



Peter Jahn
ABB Verkehrstechnik Gesellschaft m.b.H.



Herwig Leichtfried
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The class 1822 dual-system locomotive includes many innovative features, such as a device for identifying the traction power system and a system transfer switch which ensures protection against erroneous action by the driver during raising of the pantograph(s).

apart, the pantographs are located at each end of the locomotive. They include a device for lubricating the current-collector bows which is controlled according to the height the pantograph is raised. Only one pantograph is needed when the train is running on the 15-kV AC system.

A dual-system locomotive has to be able to detect and identify its power source. The class 1822 does this by means of a combination of instrument transformers, installed with a system transfer switch on the vehicle's roof. This facility automatically identifies the voltage system on the catenary and monitors the pantograph(s) preselected by the engine driver. It guards against erroneous action by the driver during raising of the pantographs, and provides good protection should the system limits be unintentionally overrun, taking account of both the locomotive's speed and the length of the neutral section in the contact line.

The main DC circuit-breaker is ABB's proven high-speed UR26 – a single-pole, non-directional breaker featuring electromagnetic blowout. The circuit-breaker is closed electrically and has an indirect overcurrent trip which is activated by the converter control system.

The main AC circuit-breaker is the DBTF20i200 air-blast breaker, which is also used in many other types of locomotive.

The transformer is located under the locomotive body. To save weight, it was installed together with the power circuit reactors in a common, lightweight tank. The total weight of the unit is only 12 t. The transformer has a primary power rating of 4640 kVA for a nominal voltage of 15 kV; its four traction windings are rated 1009 kVA each at 1886 V and 535 A. The winding for the heating has a 600 kVA rating for 1000 V. The dimensions of the transformer, which had to be designed for a very low psophometric interference current, resulted in a short-circuit voltage equivalent to approximately 20 percent of the nominal voltage.

The input reactor, which has two mechanically coupled windings, damps the switching surges in the Italien power system. In accordance with the regulations of Italian State Railways (FS), it ensures that the total impedance is 2.5 ohms at 50 Hz. The second reactor, also with two windings, is connected to capacitors to form the two series resonant circuits for 33⅓ Hz.

The transformer unit is fully oil-cooled. The heat is dissipated by two cryo-circuits, one for each bogie. This arrangement allows part-load operation of the transformer if one bogie fails, enabling the other bogie to continue running. Since the temperature of the oil circuit is monitored, the fans only have to be run when necessary.

Starting at the transformer secondary windings, the power circuits of the converter system are arranged in a two-channel configuration, ie, each bogie has its own, separate channel. The same applies to the main control system and the auxiliaries, underscoring the principle of redundancy that is employed throughout the circuits.

A new three-point circuit for the converter

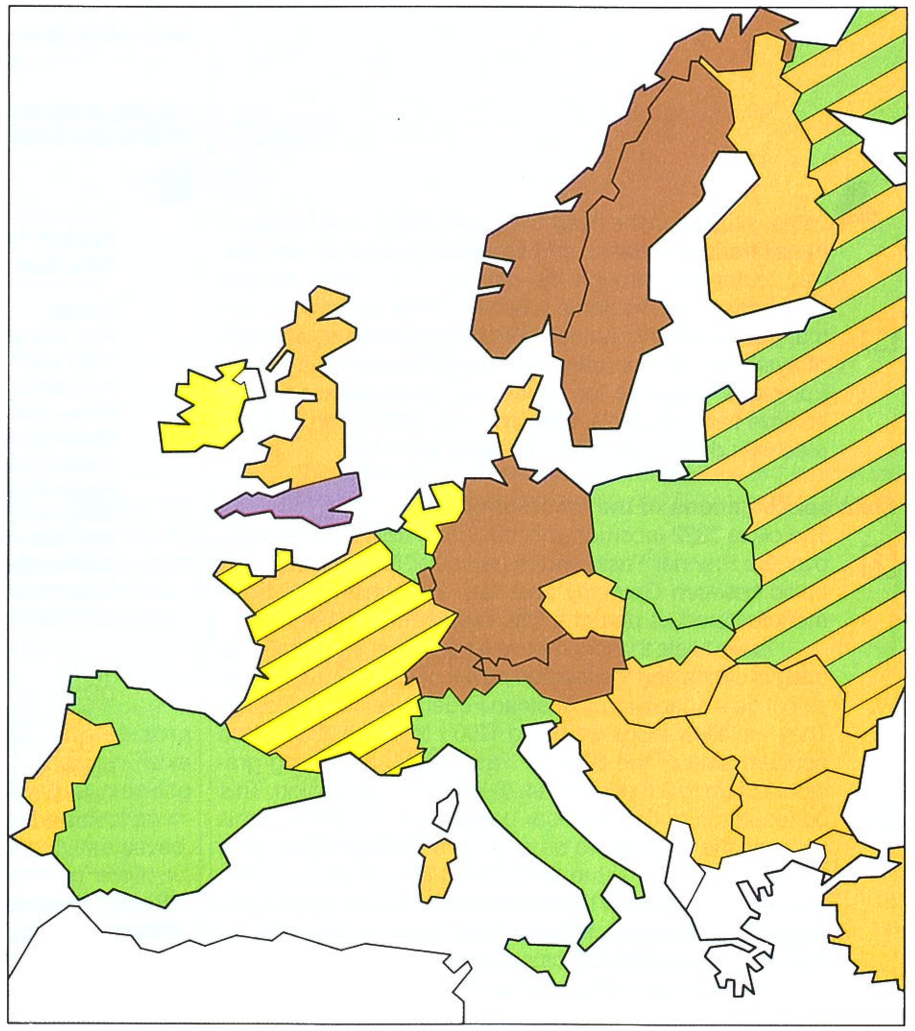
The converter system consists of the input converters, DC link and drive inverters. The class 1822 locomotive is the first dual-system vehicle to employ ABB's newly developed three-point converter circuit, which allows access to the direct voltage neutral in the DC link. Because of this special configuration the GTO thyristors are connected in series, and the motor windings can be switched into the circuit in two steps. The advantage of this is that reactors are not needed in the incoming circuit. Neither does the voltage rise as steeply, which reduces the stresses that the insulation has to withstand.

[5] By using GTO thyristors with an off-state voltage of 4.5 kV and a turn-off current of 3 kA in combination with the new circuit, it has been possible to achieve a nominal DC link voltage of 3.5 kV, with a maximum value of 4.2 kV. As a result the 3-kV voltage on the Italian catenary can be fed direct, via just the reactor in the incoming circuit, to the DC link. There is no need for an input chopper to reduce the mains voltage. The converter system was designed by ABB and built by Siemens. Both the input converters and the

1

Traction power systems used by Europe's railways

Brown	15 kV, 16⅔ Hz
Orange	25 kV, 50 Hz
Yellow	1.5 kV (DC)
Green	3 kV (DC)
Violet	600–1200 V (DC)
White	Steam or diesel locomotives



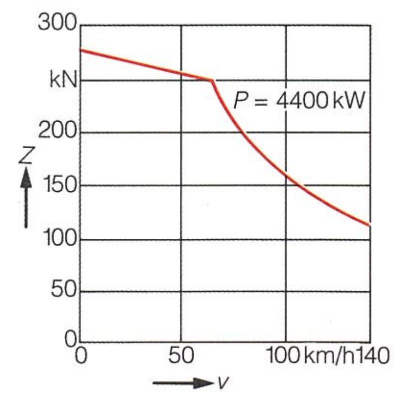
2

OeBB's class 1822 dual-system locomotive, designed to run on the Brenner Pass route

3

Tractive effort versus speed diagram for the class 1822 locomotive

Z Tractive effort
v Speed
P Power



The class 1822 is the first dual-system locomotive to include a DC link with the new three-point circuit developed by ABB.

drive inverters are modular constructions. All the semiconductor devices are vapour-cooled.

The input converter is a four-quadrant controller which feeds the nominal 3500 VDC to the intermediate DC link. This controller allows energy to be taken from the catenary with a displacement factor and a power factor which are virtually unity.

The DC link has a series resonant circuit tuned to 33⅓ Hz, as filter, and a back-up capacitor. By storing energy, the latter ensures that the inverter supplies a constant AC power to the traction motors despite the catenary delivering pulsating, single-phase power. The speed of the traction motors is controlled by varying the voltage and frequency.

On the sections of route served by the AC catenary, energy is recovered during braking and can be fed back into the catenary via the four-quadrant controller. The maximum recoverable energy is 4400 kW.

Protection for the converter is based on the principle of 'preventive turn-off'. The state of the GTO thyristors is detected by the thyristor control units and signalled back to the drive controllers. These prevent critical turn-on malfunctions. A fault or defect causes a turn-off signal to be sent to all the GTO thyristors. If, as a result, the DC link voltage increases during braking, a resistor is connected into the circuit to dissipate the additional energy before the acceptable limit for the off-state voltage is exceeded.

The protection has five hierarchical levels, each with different consequences for the system. The lowest level is permanently active during normal service, and operation is not disrupted when it responds. The protection at the highest level is only tripped when there is serious danger, in which case it disconnects the converters one bogie at a time.

The converters feature advanced control

A newly developed system of direct self-regulation is used to control the converters in the class 1822 locomotives. The magnetic flux and torque values are calculated from the voltage, current and motor speed, and then compared with the setpoint torque. The torque controller transmits only two commands, signalling agreement with 'yes' or deviation with 'no'. Control takes place within a narrow tolerance band and with the maximum possible pulse frequency. The new method was made possible by use of advanced microprocessor systems from the latest range of MICAS equipment.

The cage induction traction motor used in the class 1822 locomotive weighs only about 60 percent of the DC motor in a 'thyristor' locomotive having approximately the same power rating.

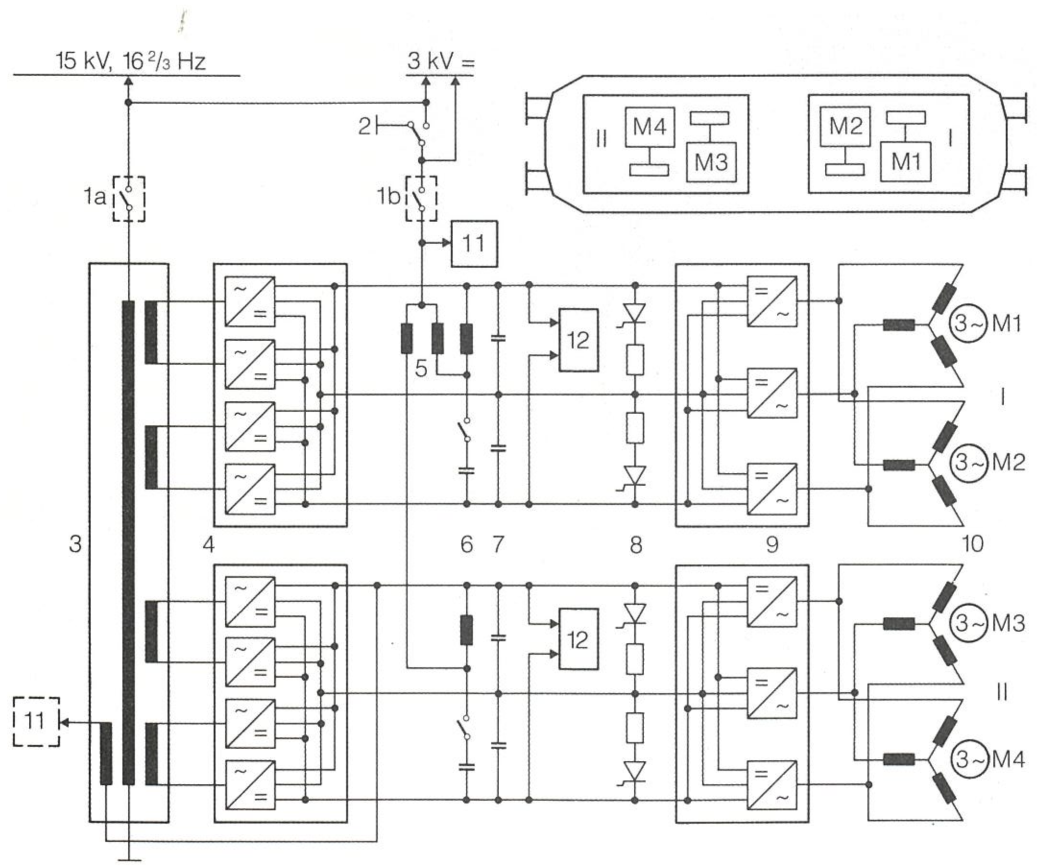
Cage-induction traction motors are used in the new locomotive

The successor to the single-phase commutator motor and the pulsating current motor in the 'thyristor' locomotive, the three-phase cage induction motor in the class 1822 unit is the 'ideal' traction motor. Rugged, lightweight and requiring only minimal maintenance, its use is made possible by modern inverter technology. Open-type cage induction motors with six poles are used in the 'Brenner' locomotives. [6] The winding insulation in the forced-ventilated machines conforms to insulation class 200 – a new class allowing a temperature rise in the windings of 200 K. *Table 2* gives the main motor specifications; all the nominal data are continuous ratings.

Table 2: Technical data of the traction motors

Nominal power	1105 kW
Phase-to-phase voltage	2190 V
Nominal current	364 A
Maximum current	434 A
Nominal speed, frequency	1300 rev/min, 66 Hz
Maximum speed, frequency	2900 rev/min, 148 Hz

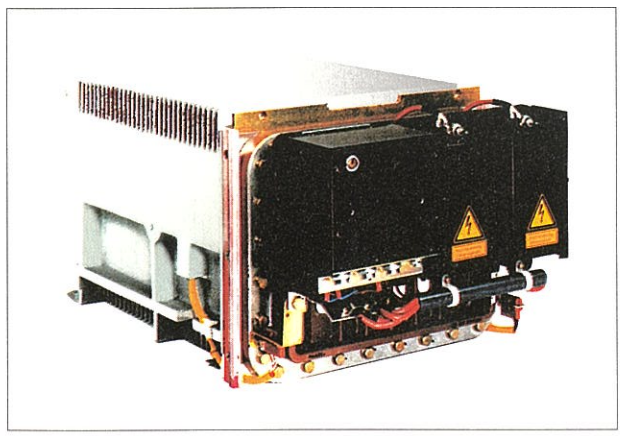
[7] The motor used in the class 1822 locomotive weighs 2100 kg. Fig. 7 compares the respective weights and volumes of the induction and pulsating current motor for a comparable power rating.



4 **Main power circuits of the class 1822 dual-system locomotive of OeBB**

I	Bogie 1
II	Bogie 2
1a	Main circuit-breaker (AC)
1b	Main circuit-breaker (DC)
2	System transfer switch
3	Transformer
4	Four-quadrant controller (input converter)
5	Dual-input reactor
6	Series resonant circuits
7	Back-up capacitors
8	Braking resistors
9	Driver inverter
10	Traction motors (M1 to M4)
11	Heating
12	Onboard system converter

5 **Converter module of the class 1822 locomotive. The converter system was designed by ABB and built by Siemens.**
Photo: Siemens



6 **Traction motor of the 'Brenner' locomotive – a six-pole cage induction motor rated at 1105 kW for a phase-to-phase voltage of 2190 V**

The MICAS S2 distributed control system employs modules situated at the load centers and communicating with each other over a high-speed vehicle bus. This saves numerous cable connections, and there is no need for a busmaster.

Power is supplied to the auxiliaries on a per-bogie basis

The auxiliaries are supplied with power on a per-bogie basis by static converters connected to the DC link. There are two outputs for each converter – a variable-frequency output for the parallel-connected fans which cool the traction motors, main converters and oil-coolers, and a constant-frequency output for all the other loads, including the battery charger. Special socket outlets are provided for supplying the auxiliaries with external power during testing.

The distributed control electronics works with high transmission speeds

The locomotives are controlled and monitored by MICAS S2, a digital, distributed traction control system with modules located at the load centers and connected over the MICAS vehicle bus. This allows a considerable reduction in the amount of cabling needed. Fig. 8 shows an overview of the control system. [8]

The stations located at points along the bus form the smallest functional units of the traction control system. The hardware is connected to the local process peripheral over the shortest possible length of conventional cable. Both analog and digital signals can be exchanged.

A vehicle controller performs all the locomotive control functions that are not bogie-specific. These include the settings for the tractive and braking efforts, speed control, the settings for the auxiliaries, and certain sequence control functions. Maximum operating safety and reliability are ensured by the vehicle controller's redundant configuration.

The bogie-specific controls consist of the drive and converter controllers, one of each being provided for every bogie. If a converter's electronics no longer functions correctly for any reason, the affected converter unit is disconnected. The locomotive can continue to run when only half the tractive effort is still available.

Communication between the control units is via the MICAS vehicle bus. Here, a distinction has to be made between the local bus for communication within the confines of a subassembly, and the data highway, which has optical waveguides for interconnecting the distributed stations. The vehicle bus is a high-speed serial bus with a gross data transmission rate of 1.5 Mbit/s, and is optimized for cyclic transmission. The data transmitted by it can be divided into process, service and diagnostics data, each with its own priority. The latter data are transmitted to the diagnostics computer, which has a memory for storing historical events.

Data traffic on the vehicle bus is coordinated by a central bus controller. This instructs each signal source to transmit its data in accordance with a scan cycle time. Signal sinks, linked by programming to the signal sources, receive the data from the bus, process them in a user-program, and transmit signals to the process. Each station along the bus therefore transmits its data direct to the signal sinks; there is no 'busmaster' over which all the data must run. It is this future-oriented configuration which facilitates the high data transmission rates for the vehicle control system.

The diagnostics computer monitors the values supplied by the peripherals and compares them with the setpoints. If a deviation or fault occurs, the most relevant data are stored. The same data are displayed in the driver's cab. They can also be processed via a serial service interface, with the resulting information assigned either to the engine driver, the engineering department, or the main workshops, depending on who is responsible for acting upon the information.

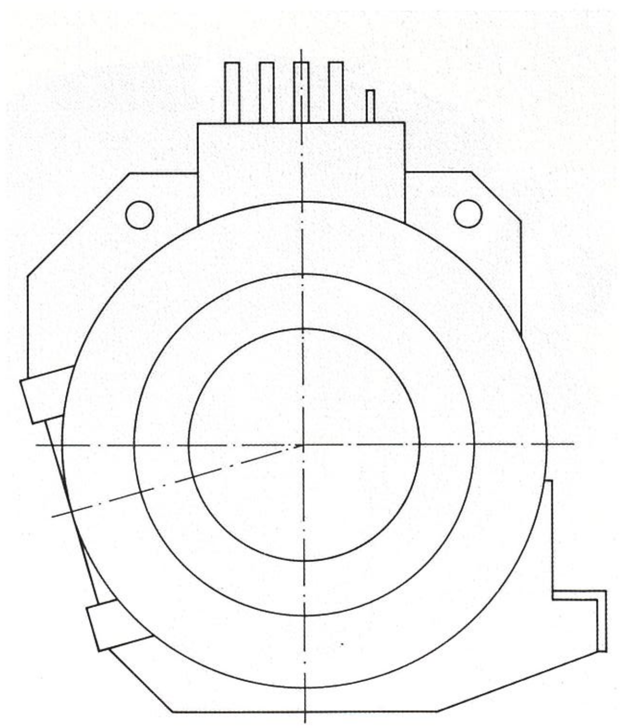
The locomotive control system is designed for multiple traction, with data exchanged between the vehicles over the train bus. Coupling is based on the principle of time-division multiplex control. The UIC line is used for the transmissions.

Since the 1822 is designed to be run on track in three countries, the locomotive has to incorporate the train control, signalling and communication systems used in these

7

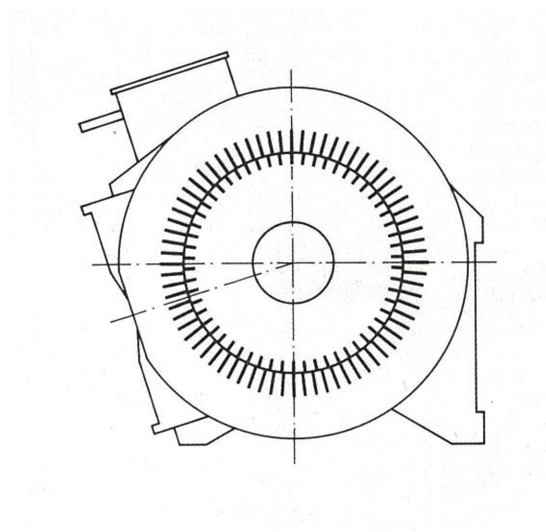
Comparison of an induction motor and commutator motor for a similar power rating

a Class 1044 'thyristor' locomotive's type WM 1301 DC motor: power rating 1250 kW, speed 1130 rev/min, torque 10.6 kNm, outside diameter 1185 mm, length 1000 mm, mass 3750 kg



a

b Class 1822 'Brenner' locomotive's induction motor of type 6FRA 7059: power rating 1105 kW, speed 1300 rev/min, torque 8.1 kNm, outside diameter 800 mm, length 800 mm, mass 2100 kg



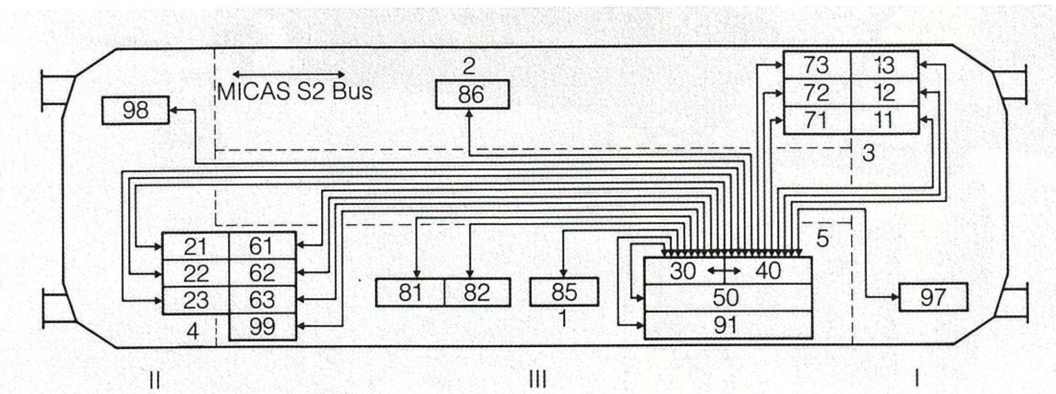
b

8

MICAS S2 control electronics – diagram showing the signal paths

I Driver's cab I
II Driver's cab II
III Motor compartment

1, 2	Main power cubicles
3, 4	Motor compartment cubicles
5	Electronics cubicle
11, 12, 13	Data bus stations, cab I
21, 22, 23	Data bus stations, cab II
30, 40	Vehicle controllers
50	External electronics
61, 62, 63	Data bus stations, auxiliaries
71, 72, 73	Data bus stations, control current unit
81, 82	Onboard system converters
85	Converter electronic I } converter and drive controller
86	Converter electronic II } converter and drive controller
91	Speed measurement
97, 98	Displays
99	Braking computer



The driver's cab was developed jointly by the Austrian, German and Italian railways, and has technical features that break with the railway traditions of the three nations.

countries. As it happens, the systems used by German Federal Railways of (DB) and OeBB are the same, so only two different versions had to be provided, one for DB/OeBB and one for FS. The driver has a selector switch in his cab for activating the relevant system.

An 'international' compromise was found for the driver's cab

After several rounds of discussions between the representatives of the Austrian, German and Italian railways, each of which has different operating traditions, a design was found for the driver's cab which represents a good compromise. A major problem that had to be resolved was that the FS traditionally placed the driver's seat on the left, with the brake positioned so that the driver operates it with his left hand; the opposite was true for the OeBB and DB, where the driver sits on the right and operates the pneumatic brake using his right hand. Fig. 9 shows the user-friendly driver's console finally chosen. 9

Regular service is due to start by the end of 1992

After completing tests in Austria and Italy, the preproduction series of class 1822 locomotives will go into operation on the Brenner route by the end of 1992. It is expected that later a large series – a total of 80 of these dual-system locomotives are planned – will substantially increase capacity on the Munich–Verona route, and so relieve the tense transit situation on this line. The locomotive can be easily modified to allow it to also be used with systems operating at 25 kV and 50 Hz. This conversion would make it suitable for use throughout Europe.

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9
The user-friendly driver's console was developed jointly by the railway authorities of Austria, Germany and Italy.

The variable-speed, converter-fed cage induction motor operates with low losses over the full speed range. It is used mainly in compressor drive applications. If the drive can be made gearless, its cost can be reduced and it will also be smaller. High availability is ensured for this kind of drive by modern power electronics.

Power electronics moves variable-speed drives with a cage induction motor to higher power levels

Inverter-fed induction motors for the megawatt range

With the help of modern converter technology, drives with induction motors designed for the megawatt range and speeds of 3000 rev/min and higher can be built today as variable-speed units. They are mainly used as compressor drives in the chemical and petrochemical industries. ABB confirms the good design and operating behaviour of ordered motors in its own factory prior to delivery.

1 Designers of drives fed from a voltage-source inverter have to pay attention to a number of points:

- Bending (lateral) critical speeds are not allowed to occur at any point in the speed range for which the unit is designed. Despite high speeds, the vibration severity recommended for electrical machines should not be exceeded.
- The centrifugal forces caused by the high speeds must not lead to excessive mechanical loading in any part of the machine.
- The high fundamental frequency of the current and the converter voltage harmonics cause additional losses, pulsating torques and 'magnetic' noise. Temperature rise, shaft train loads and environmental impact all have to be kept within acceptable limits.
- The aerodynamic, or 'windage', noise increases with speed, but should not exceed the usual levels for electrical machines when possible. Neither should the mechanical losses, which also increase as the speed rises, significantly reduce motor efficiency.

Proper design is a guarantee for reliability

Bending critical speeds

For the power and speed ranges indicated, it can happen that a natural bending frequency of a rotor designed for a mains-operated machine will lie within the area of the operating speed or too close to it. Operation close to a bending critical speed is a cause of disturbance and has to be avoided; some standards (eg, API 541 of the American Petroleum Industry) even prohibit it.

In the first place, it is the rotor that has to be dimensioned so that its flexural strength will guarantee that no bending critical speed can occur in the operating range. Two different cases have to be considered:

- Case A: The operating speed range is so large – in the extreme case from a fraction of the maximum speed to the maximum – that the first bending critical speed has to lie above the operating speed range. The motor has to be designed for *speeds below critical*.
- Case B: The operating speed range lies between the first and the second bending critical speed (the speed range in which the first critical speed occurs is simply passed through during the run-up). The motor has to be designed to run at *speeds above critical*.

In case A, the first bending critical speed has to lie far enough above the highest operating speed. In case B, the first bending critical speed and the lower speed, as well as the second bending critical speed and the upper operating speed, must be sufficiently far apart.

Several international standards specify a difference of up to 25 percent between the operating range and the bending critical speeds for mains-operated motors. Differences of this order are not always possible with inverter-fed motors with high power and speed ratings; neither are they necessary when the rotor has been properly manufactured and balanced.

2 Fig. 2 compares cases A and B in terms of rotor shape and behaviour at bending critical speeds.

The shaft of the rotor for speeds above critical (Fig. 2b) is narrower, being similar to that of a mains-operated machine. The shaft for speeds below critical (Fig. 2a) is thick compared with the rotor's outside diameter, and the distance between the journals is comparatively small.

It is seen from the speed versus total bearing flexibility curve in Fig. 2 what an important role the compliance of the