The electropneumatic brake

The electropneumatic brake, to be distinguished from the electropneumatic assist (also called electropneumatic brake, or EP brake: see corresponding page), corresponds to an architecture for which:

- Brake control is ensured in a purely electric way
- Actuation energy (providing brake force) is pneumatic

Thus there is only one pneumatic pipe, i.e. the Main Reservoir Pipe (MRP) which makes it possible to supply all train equipment with compressed air (brakes, pneumatic secondary suspension, doors, etc.).

The electropneumatic brake has been developed in the years 1960 to dramatically improve the performances of urbans rolling stock, in particular metros for which the first automatic train control systems has been developed at this time. It has been also of evidence that, due to its very short response times, only an electric control could be coupled with a fully automatic train control (like the VAL or Météor line in Paris).

The present page describes the main aspects of this type of architecture. For more details on some aspects or components linked to the pneumatic portion of the system, the reader can also access to the pages dedicated to the pneumatic brake.

Service braking control

Braking control at train level

Service braking control is most of time associated to traction control: both are using the same master controller, which has a traction range when pushed forwards and a braking range when pulled backwards (it is the contrary in the UK or in Australia !).

The master controller includes electric potentiometers which deliver a voltage that is proportional to the position of the handle in each range, as well as contacts indicating if it’s the traction or braking range.

The voltage delivered by the potentiometers and the status of contacts are supplied to an electronic device (encoder), which has in charge to encode the force demand (traction or braking) in form of a signal which is:

- Either of the analogic type (PWM most of time): distinction between traction and braking is performed by means of the sign of the PWM signal (+ for traction, - for braking), or by different ranges for traction and braking (e.g. 52% to 95% = traction, 52% to 48% = coasting, 48% to 10% = braking), or coding in parallel binary train lines (supplied from battery voltage, and being either powered or switched off) and indicating whether the required brake force shall be a traction or braking one.
- Or of the digital type: a digital bus is substituted to PWM and traction/braking train lines mentioned above, all traction, braking and demand information being then transferred in a purely digital way by means of the main processor unit.

Braking control at bogie level

For each motorized vehicle or motor bogie, a traction/braking electronic control unit receives traction and braking orders (analogic signals or/and digital information). These orders are decoded by this electronic unit, and transformed into a traction or brake force to be applied.

Internal algorithms then decide, in case of braking, to require first the dynamic brake, then the mechanical brake as a complement. This mechanical brake complement can be determined locally for the bogie itself (local blending), or being determined from a demand calculated by a central management unit (main processor unit of the digital bus, global blending). If a mechanical brake complement is required on the concerned motorized vehicle or motor bogie, the demand is transferred to an electronic unit dedicated to mechanical brake control.

For each trailer vehicle or bogie, an electronic brake control unit also receives traction and braking orders (analogic signals or/and digital information). These signals are decoded by this electronic unit and transformed into a brake force to be applied (in this case: no action in traction phase). In case of local blending, internal algorithms decide to apply or not a brake force according to predefined blending strategies; in case of global blending, the brake demand to apply is received for the central management unit and applied as it is.

Brake force correction according to the vehicle load can be performed:

- Either by measuring the load by means of potentiometric sensors, installed between the car body and a bogie, and measuring the deflection of the car body; these sensors are interfaced with one of the electronic units of the vehicle or with the digital bus, which makes it possible to calculate the global load and, in the case of a local blending strategy, to transfer it back to the other electronic units.
- Or by measuring the pressure in the air bags of the pneumatic secondary suspension.
- Or by means of a deceleration control: brake demands issued by the traction/braking master controller are transformed into a deceleration, which shall be obtained for any load of the vehicle; Control units (central management unit or local electronic control units) then increase the brake forces until the required deceleration is reached, the latter being permanently calculated by derivation of the speed value vs time.

Brake demand is the eventually corrected by the wheel slide protection function (adaptation to available wheel-rail adhesion).

Each local electronic control unit will then controls an electropneumatic transducer, in order to transform the brake demand into a pneumatic pressure. There are two types of transducers:

- The modérable magnet valve: the output pressure is a function of the supply current.
- The analogic converter: the output pressure is controlled by means of two on-off type magnet valves (one for filling, one for venting) controlling the pressure in a very small reservoir, a pressure sensor making it possible for the electronic unit to control both magnet valves for fine tuning of the pressure in the reservoir.

The control pressure issued by the transducer is delivered to a relay valve, which in turn supplies the brake cylinders of the vehicle or bogie.

Emergency braking control

<u>Braking control at train level</u>

Emergency braking control is totally distinct from the service braking control, in order to guarantee higher safety and availability levels. Control is performed by means of an emergency loop which runs all along the train, and is looped at the level of the last bogie and runs back towards train front end. In case of multiple unit operation, the loop is automatically reconfigured to be looped at the level of the last bogie of the rear trainset.

The emergency loop is permanently powered, being supplied directly from the batteries. Initiation of emergency braking is done by opening of one of the contacts installed in series on the loop, so that the latter is at potential zero, meaning that emergency braking has been required.

Each of the contacts in the loop is actuated by a specific device: emergency position of the traction/braking master controller or safety equipment (dead man's device, speed control, etc.).

Braking control at bogie level

For each vehicle or bogie, an emergency magnet valve is either directly connected to the emergency loop, or supplied by means of an electric emergency relay directly connected to the emergency loop. When the latter is powered, each emergency magnet valve is kept energized, and delivers no output pressure. When the emergency braking loop is switched off, each emergency magnet valve is de-energized, and supplies a predefined pneumatic pressure corresponding to the emergency braking force.

The output pressure of the emergency magnet valve is supplied to the relay valve, either directly to a specific control chamber (distinct from the one dedicated to service braking) or by interruption of the service braking channel. The relay valve then supplies the brake cylinders of the vehicle or bogie.

Switching off the emergency loop generally requires opening of the main circuit breaker, which inhibits dynamic brake but also guarantees a safe traction inhibition.

In case of local blending strategy, emergency braking information received from the emergency loop means, for each electronic unit, that it shall require a brake force corresponding to emergency braking.

In case of global blending strategy, emergency braking information is also supplied to the central management unit, which in turn forces brake demands to levels corresponding to emergency braking. Emergency braking information also supplied locally to brake control units is then only used as a redundancy to endure a minimum force in case the brake demand received from the central management unit is wrong.

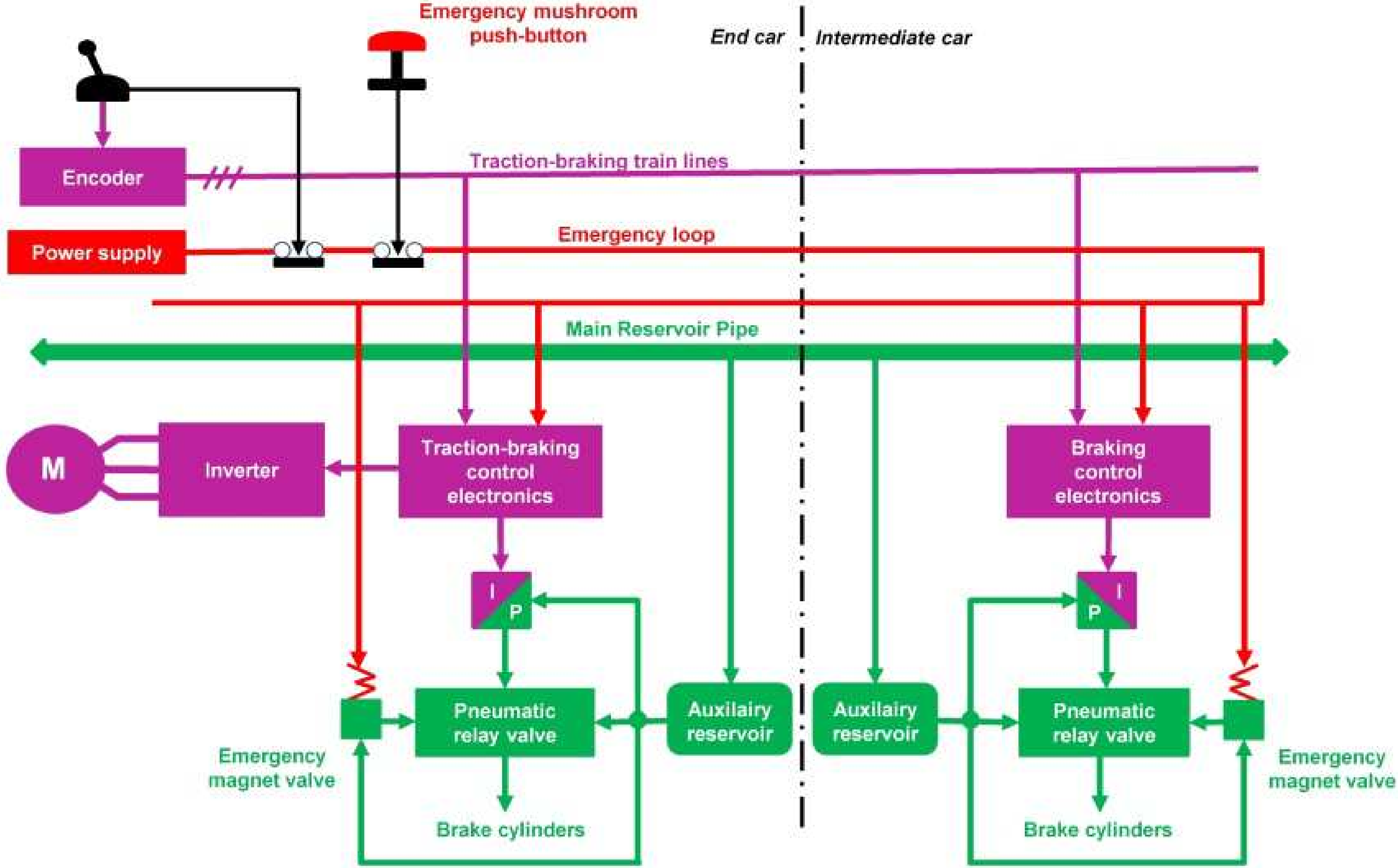
Each control unit then controls forces the output pressure of the electropneumatic transducer to a pressure level corresponding to the emergency braking force: this way of working guarantees that, in case of failure on the emergency magnet valve, the emergency braking force will be required.

Load correction in this case is ensured either by means of the relay valve (if of the load variable type) or by means of a pressure limiting valve connected to the pneumatic secondary suspension or to the load sensor, and enabling the emergency magnet valve to supply an output pressure that is proportional to the load, within the limit of a predefined maximum load.

The wheel slide protection device also ensures a brake force correction if need be, by means of the dump valve(s) installed downstream the relay valve.

Generic synoptic diagram of an electropneumatic brake

As most of the applications for this type of brake system are the metros, we propose under the generic synoptic diagram for this type of vehicle.


Emergency mushroom push-button
End car
Intermediate car
Encoder
Traction-braking train lines
Power supply
Emergency loop
Main Reservoir Pipe
M
Inverter
Traction-braking control electronics
Braking control electronics
I
P
I
P
Pneumatic relay valve
Auxilairy reservoir
Auxilairy reservoir
Pneumatic relay valve
Emergency magnet valve
Emergency magnet valve
Brake cylinders
Brake cylinders