4.1 DC-Motor

The collector motor, or DC-motor, as guaranteed the expansion of electric traction from the origin to a recent past: the end of 20th century. Supplied from a DC-current contact line, its work point is adjusted by a rheostat R_{rh} – which acts on voltage – and a shunt R_{sh} – which acts on the excitation – with a variable ohmic value. The excitation is mostly in series with the armature.

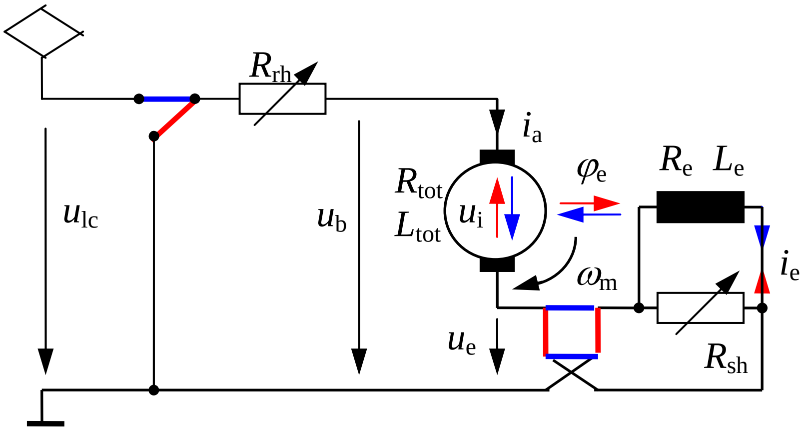

Fig. 4.4 Motor series in traction.
Fig. 4.9 DC-Motor: rheostatic braking with series excitation.

The internal equations are written below, neglecting leakage inductances in the motor. The motor constant is C_m, N_p is the number of whorls per pole and p the number of pole pairs. The total flow is Ψ_e and the gap flow φ_e.

$$\Psi_e = 2pN_p\phi_e \tag{4.3}$$

$$u_i = C_m\phi_e\omega_m \tag{4.4}$$

$$M_m = C_m\phi_e i_a \tag{4.5}$$

The dynamic equation shows the dependence of motor– with inertia (proper and herited) J – on the external torque M_{ex}. The rotation speed is ω_m.

$$\frac{d\omega_m}{dt} = \frac{1}{J}(M_m - M_{ex}) \tag{4.7}$$

In traction, the electric mesh equations can be written.

$$\frac{di_a}{dt} = \frac{1}{L_{tot}}(u_{lc} - R_{rh}i_a - R_{tot}i_a - u_i - R_{sh}(i_a - i_e)) \tag{4.8}$$

$$\frac{d\Psi_e}{dt} = R_{sh}i_a - (R_{sh} + R_e)i_e \tag{4.9}$$

In braking mode, only (4.8) has to be fitted: u_{lc} is zero and sign from u_i has to be changed. The three contactors allow select the coupling in traction (blue) or braking (red) in one sense of drive. In the other sense of drive the positions of both excitation contactors are exchanged: braking (blue) and traction (red), but the rule of contactor on the power supply side remains the same (AOMC: BDeh 4/4).

The characteristics for different ohmic values can be designed. Because the number of values is not very high, the working point variations go stepwise.

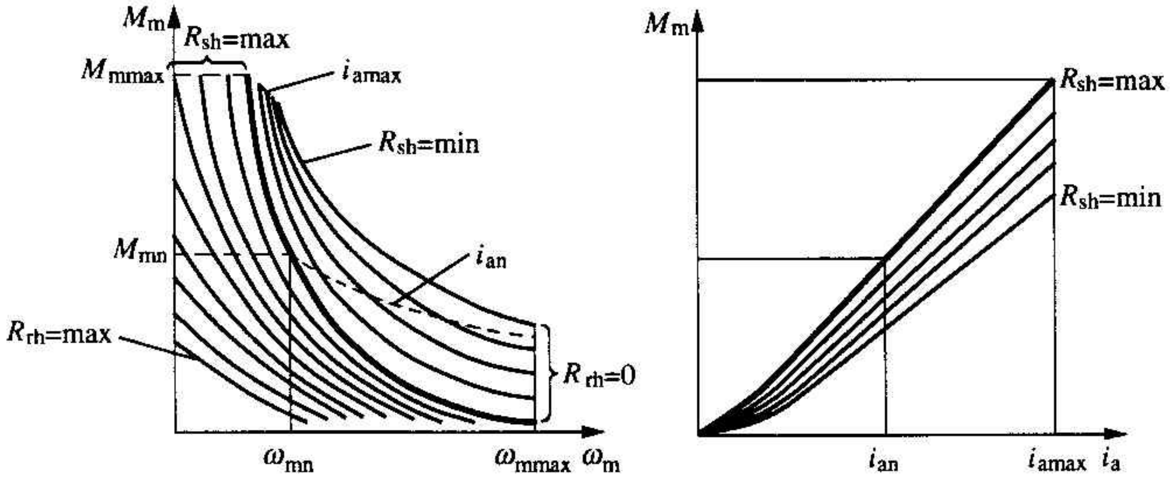

Fig. 4.6 Motor series in traction: torque characteristics versus current and speed.

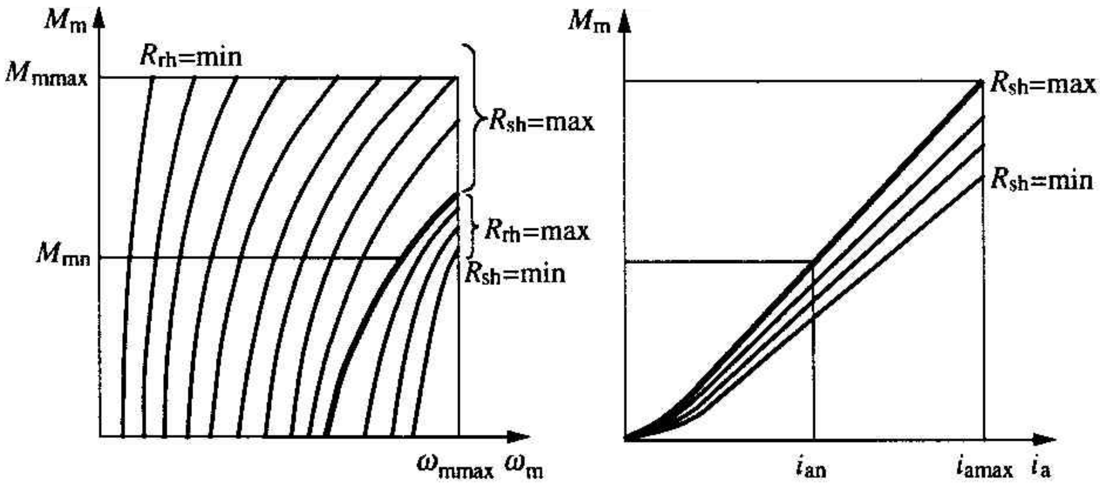

Fig. 4.11 Motor series in braking: torque characteristics versus current and speed.

On rheostatic braking, it can also be chosen separate excitation u_e, given from battery (SNCF: CC 6500), or from a generator moved by a motor, which is supplied from contact line (CFF: RAe TEE II).

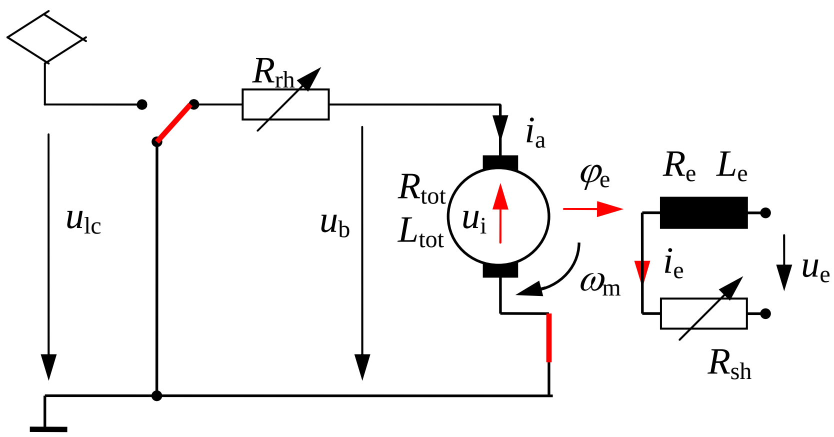

Fig. 4.13 DC-motor: rheostatic braking with separate excitation.

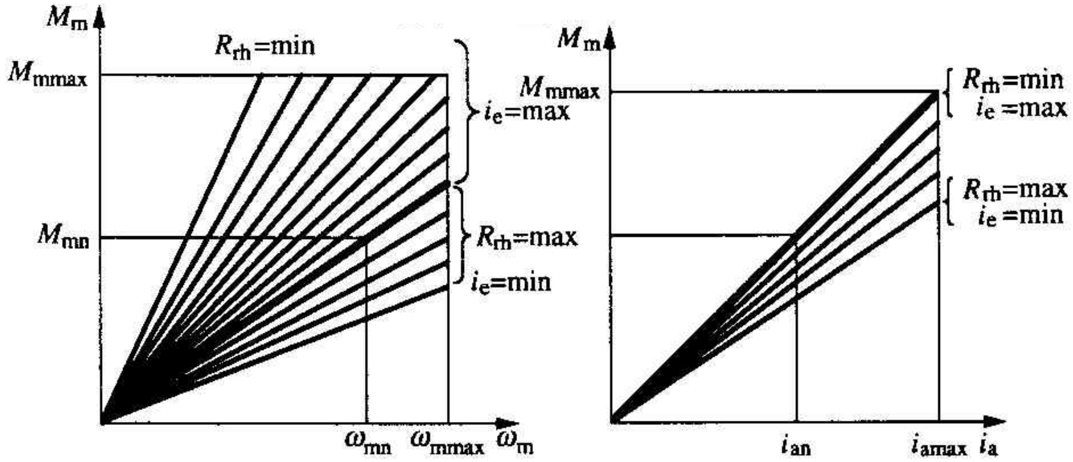

Fig. 4.15 DC-motor: rheostatic braking with separate excitation: torque characteristics.

Instead of take away (cinetic or potential) braking energy in a resistor, it can be injected on contact line: this is regenerative braking.

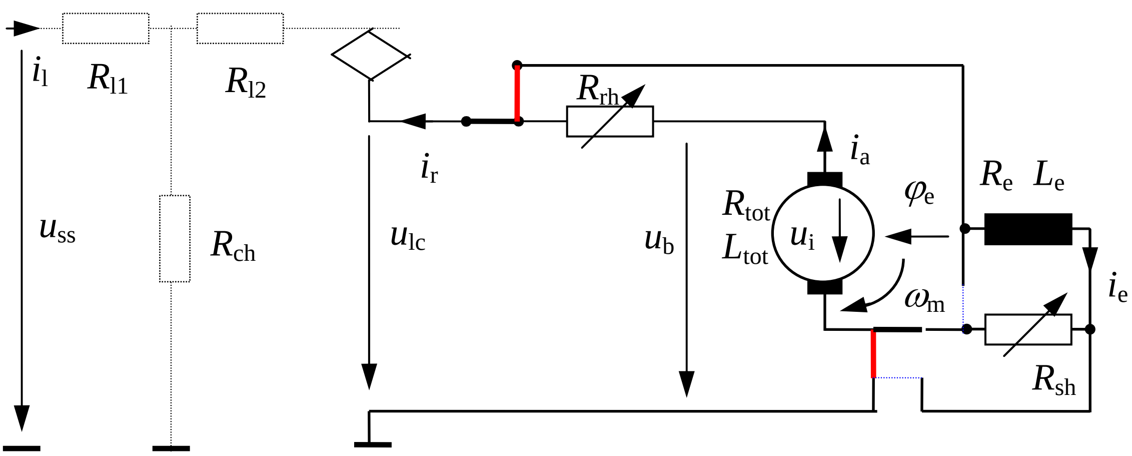

Fig. 4.17 DC-motor with separate excitation: principle of regenerative braking.

In traction the red contactors are open and the blue dotted are closed.

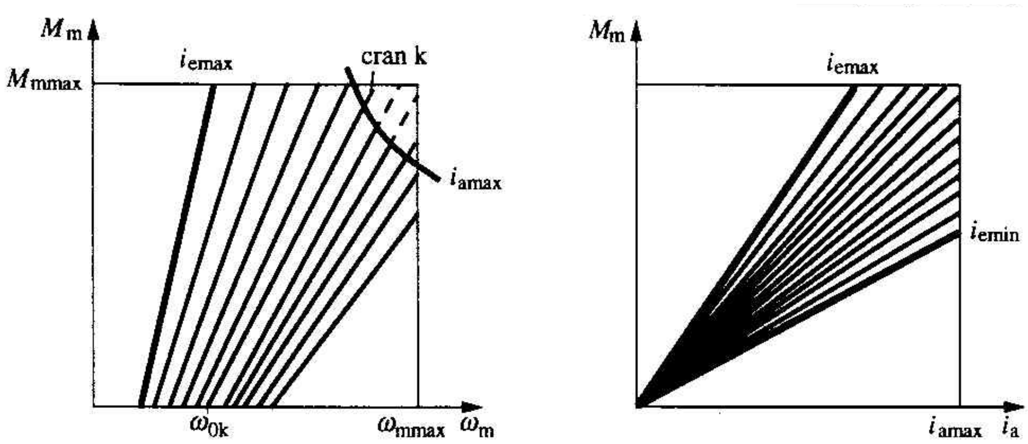

Fig. 4.19 DC-motor: regenerative braking with separate excitation: torque characteristics.

It is clear that in all points where the ohmic value of rheostat is not zero, one part of the energy from contact line is lost in heat in the resistor.

In order to increase the working point where the rheostat is zero (efficency 100 % in the motor control devices), contactors are installed to allow different motor arrangement in series or in parallel. It is possible to install contactors to allow transitions series-parallel without loss of tractive effort.

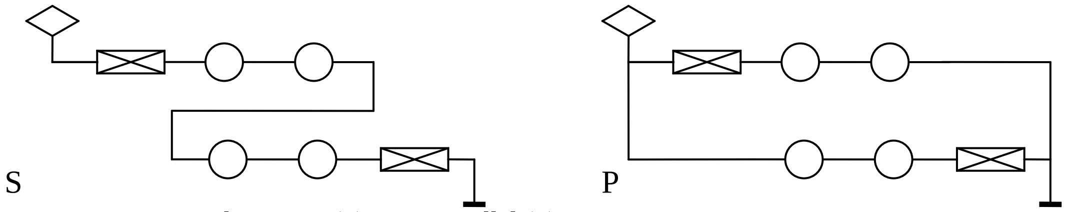

Fig 4.21B motors arranged in series (S) ou en parallel (P).

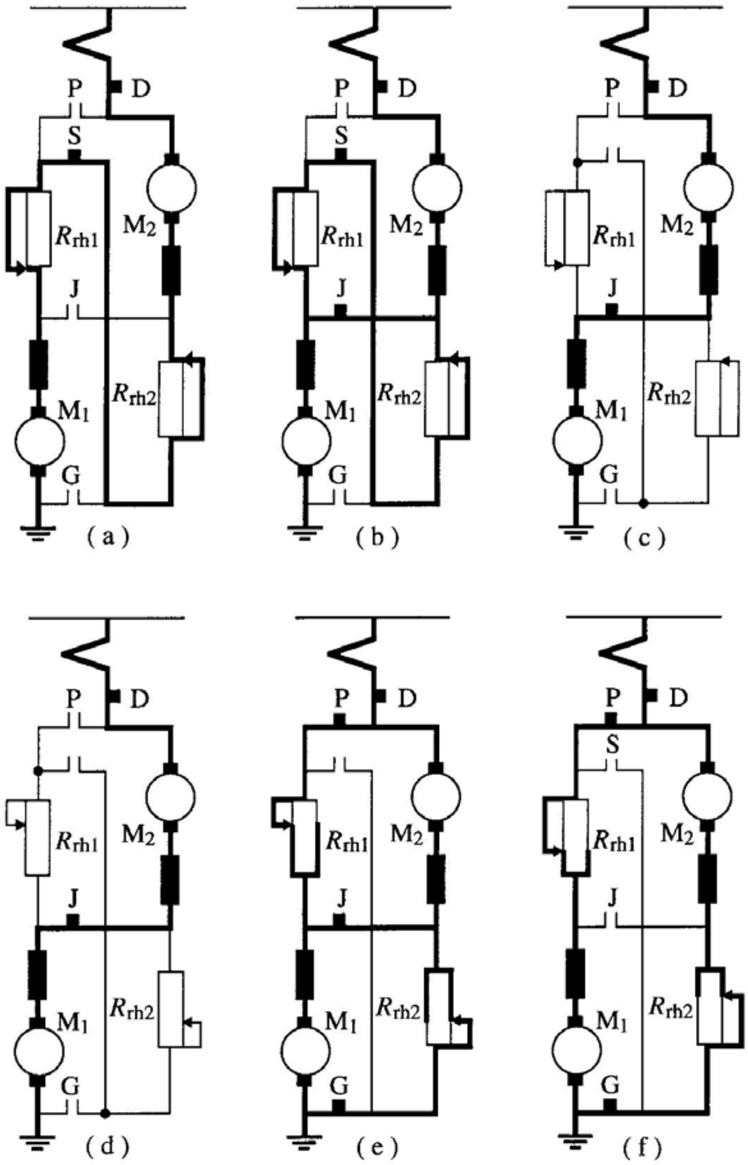

Fig. 4.22 Sequence from steps in a series-parallel transition with bridge-method (BOB : ABeh 4/4 II).