4.2 Direct Motor

The commutator motor was the masterpiece of electric traction from the beginning until the end of the 20th century. It can be supplied from a single phase contact-line, the working point is adjusted by a transformer, which gives its voltage across. The excitation is mostly in series with the armature. This is a DC-motor *direct*ly supplied by a sinus voltage, giving its name *direct-motor*. This sinus voltage requires special fitting, which were developed by Behn-Eschenburg near 1905.

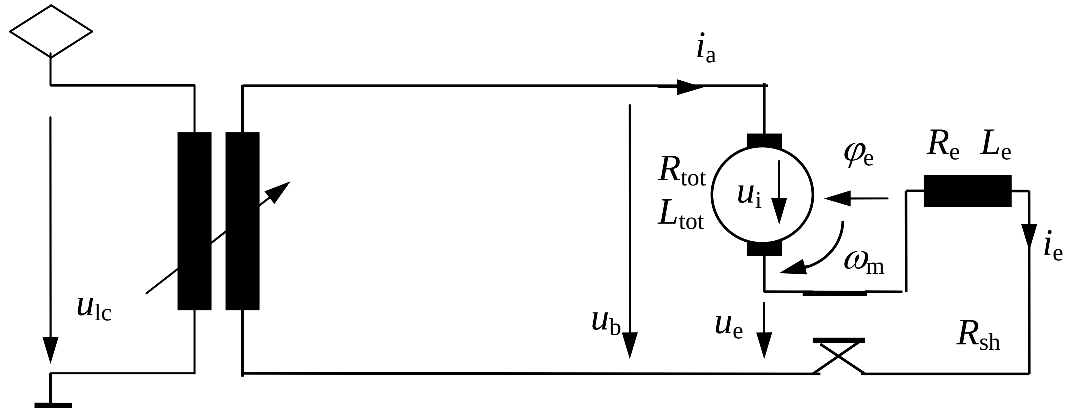

Fig. 4.42 Series motor in traction.

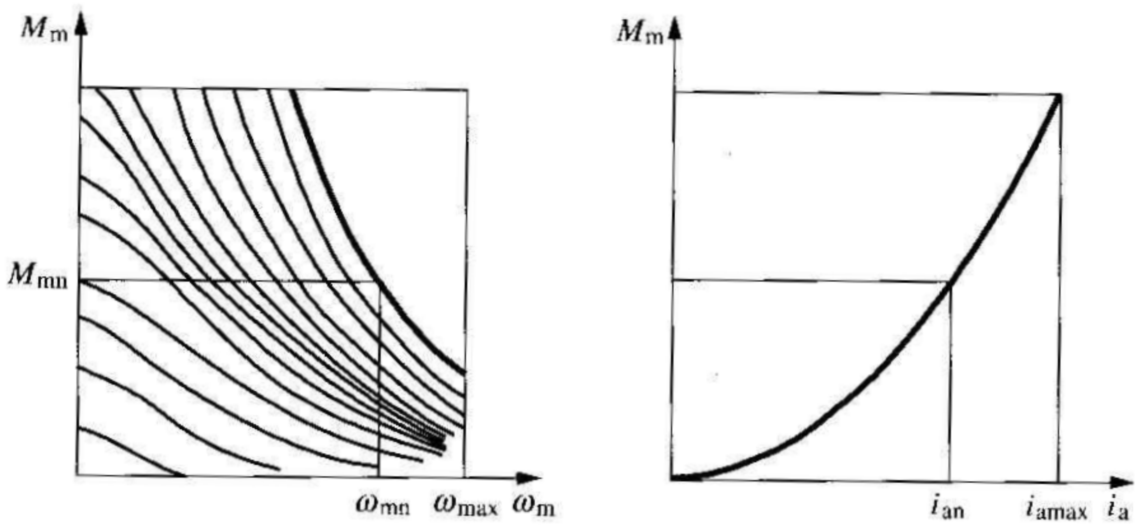

Fig. 4.44 Direct motor in traction: torque characteristics versus current and speed.

At section 4.1, the *commutation winding* was not mentioned; it allows to compensate the commutation voltage u_k which appears between two adjacent collector blades (see Traité d'Electricité, vol. X, § 8.6.4), this winding accelerate the return to zero of the current in the abandoned winding by the brushes on the collector. This winding did not exist on the first motor at the early beginning of electric traction.

$$u_k = L_\sigma \frac{di_a}{dt} \tag{4.19}$$

On single phase motors appears a transformation voltage u_{tm}.

$$u_{tm} = 4{,}44\,\phi_e\ f_{lc}\ N \tag{4.18}$$

To compensate these both voltages, an ohmic shunt R_c is put in parallel to the commutation winding. The *compensation winding* L_{comp} compensate partially la chute de tension the inductive voltage drop in the motor.

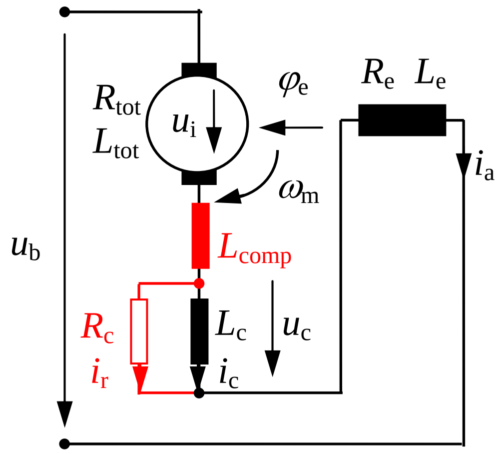

Fig. 4.37 Windings in single-phase motor.

A vector diagram of motor show the voltage u_c on the commutation winding and both ainsi voltages u_k et u_{tm} : the effect of ohmic du shunt is clear.

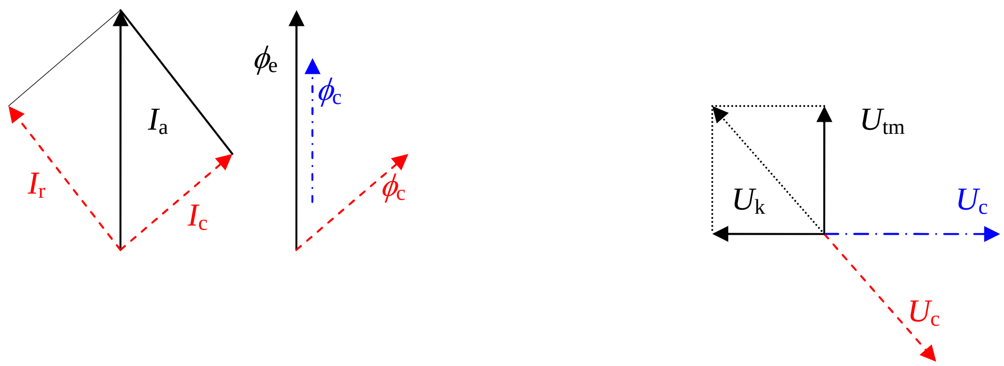

Fig. 4.38 & 4.39 Commutation in single-phase motor without and with ohmic shunt.

Without ohmic shunt, only one component – u_k – of collector voltage is compensated. The derivative of current in rotor winding depends on the speed, the compensation is only good at the speed where shunt calculation were done; in other speeds, it remains a residual voltage u_f.

Fig. 4.40 Commutation in single-phase motor at low or nominal speed.

In braking modes, not all wiring diagrams are studied in this summary, but only two examples: one in rheostatic and one in regenerative. Excitation energy can be supplied by an embedded converter (BLS : Ae 4/4).

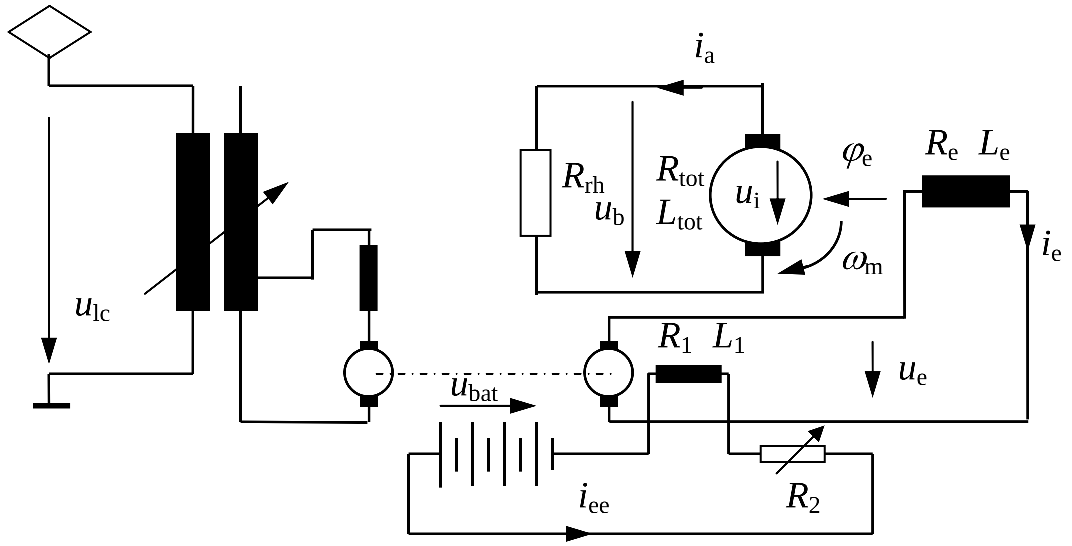

Fig. 4.46 & 4.48 Rheostatic braking at DC-excitation: diagram with generator group.

The excitation current i_{ee} in exciting machine is low, the resistance R_2 is built for continuous variation and not with steps.

One of traction motors can be used as generator to supply the others (DB:150). The diagram is similar but the « exciting machine» is driven by the axle.

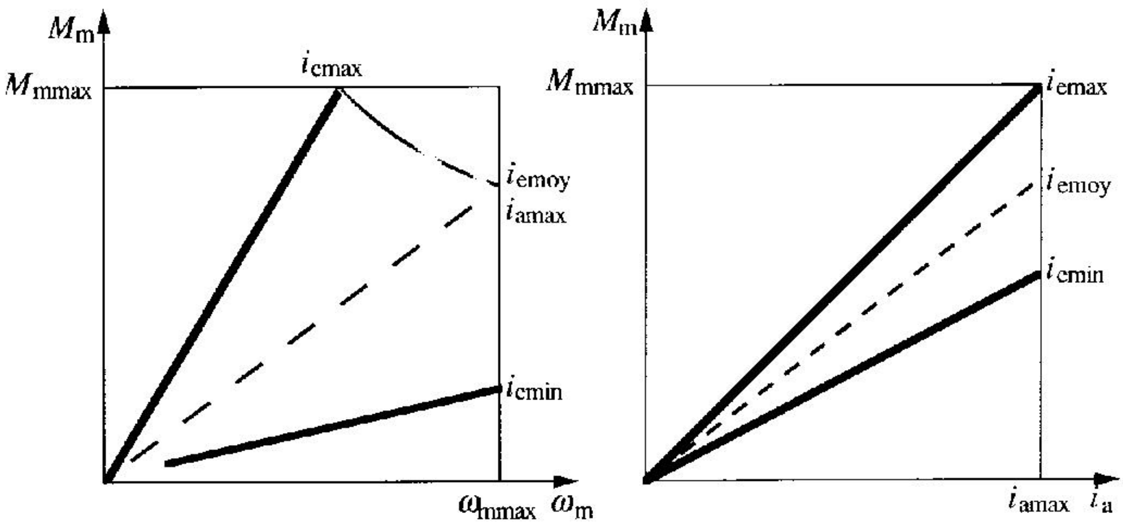

Fig. 4.50 Rheostatic braking at DC-excitation: characteristics.

Instead of take away the braking energy in a resistor it can be injected on supply network. The ultimate version Behn-Eschenburg-principle is the excitation by one of traction motors (CFF : Re 4/4 II).

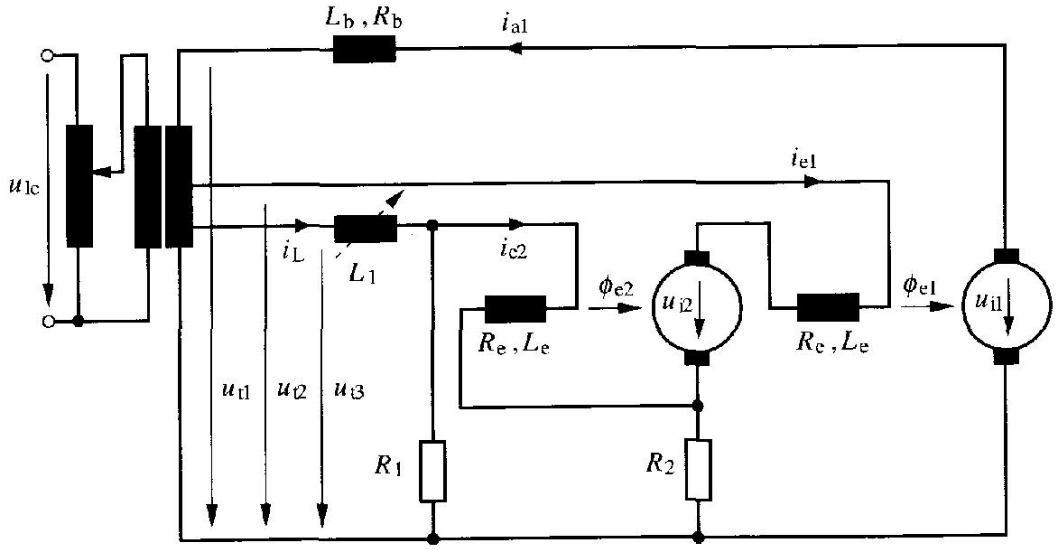

Fig. 4.59 Regenerative braking with separate excitation: diagram with excitation motor.

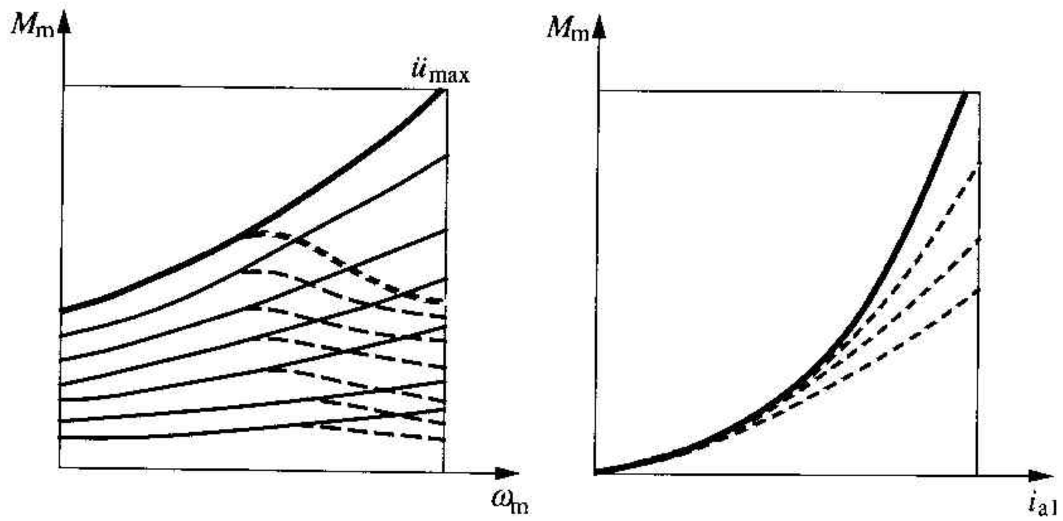

Fig. 4.61 Regenerative braking with separate excitation: characteristics.

The power ratio of this diagram is very low.

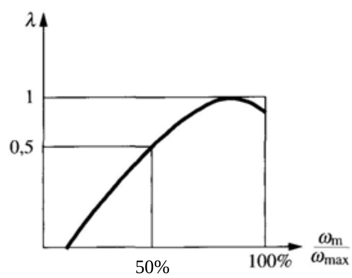

Fig. 4.62 Power ratio for braking with excitation motor.

The last conceived series of locomotives with direct motors were delivered from 1972 (CFF: Re 6/6) et 1974 (DB : 155). Last built units went in service in the middle of eighties (CFF : Re 4/4 II et DB : 155).