4.5 Induction motor

Induction motor is very easy to build, in comparison with DC-motor. Only the development of power electronics allows the general use of induction motors in electric traction, by the creation of three-phase voltage systems at variable frequency from a continuous voltage: contact line or intermediate circuit. At figure 4.164, a principle-drawing is presented: this example uses voltage-link, as usual since 1990. Each arm contains two static switches which pulse the u_d voltage to build a sinus-voltage (and harmonics). To avoid to high harmonics, the pulsing frequency must be 20 times the higher frequency of three-phase system. In the first generations of AC-AC converters, current-link converters were used and inverter with sequential phase control. For DC-AC converters, it was necessary to install a chopper between contact line and DC-current-link. The development of one arm – framed in dash-dotted green line at figure 4.164 – will be explained further at figure 4.167.

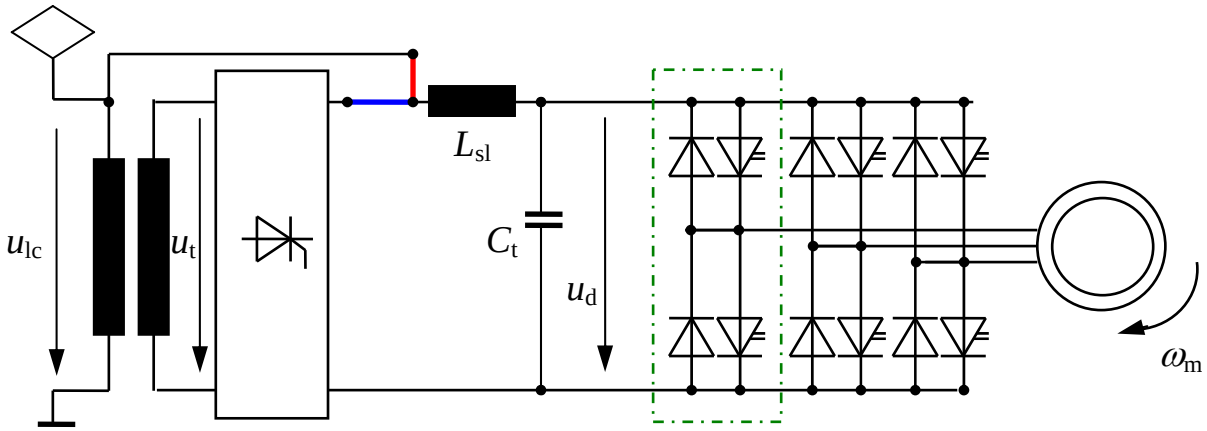


Fig. 4.164A Induction motor and three-phase converter for DC- or AC-contact line. Principle drawing.

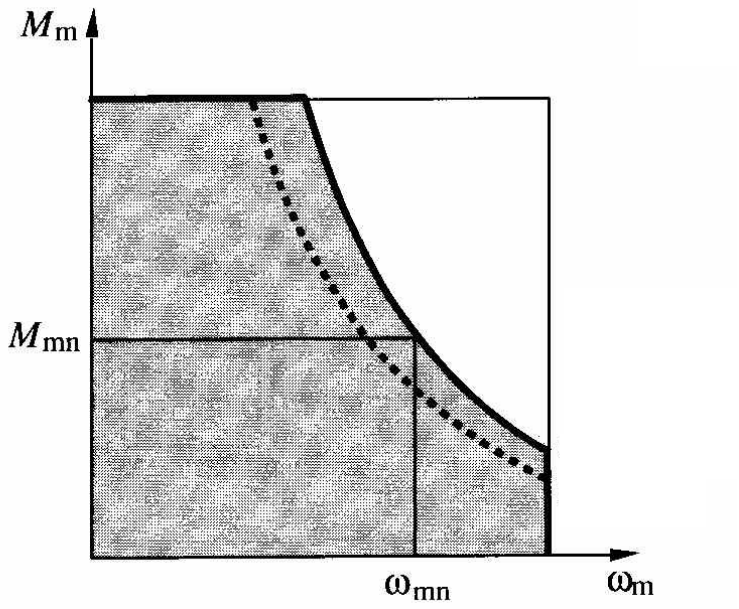


Fig. 4.164B Induction motor and three-phase converter: characteristics versus speed.

Induction motor is not only easier to build as DC-motor – no commutator – but its power is higher at the same mass. In addition, it does not need switches to change from traction to braking:

- If the motor-converter frequency is higher as induction machine speed, the machine works in motor and the converter in inverter.
- If the motor-converter frequency is lower as induction machine speed, the machine works in generator and the converter in rectifier.

On a single-phase line, for regenerative braking, the single-phase bridge at contact line side has to be able to work in inverter. For rheostatic braking, the schema has to be completed by a resistance and a static switch to convert on board the braking power in thermic power.

At time of classical thyristors, they needed a special swich-off circuit with thyristor, self and capacitors. With GTO, which can be switched off by a negative voltage on their gate, the arms were simplified. With the increasing of blocking voltage and conduction current in GTO development, simplification could go on. The IGBT follow the same progress, but later. They were used only recently for high power. Their control needs lower power as GTO and their conduction and commutation losses are lower. In opposition of GTO, their parallel mounting is very easy.

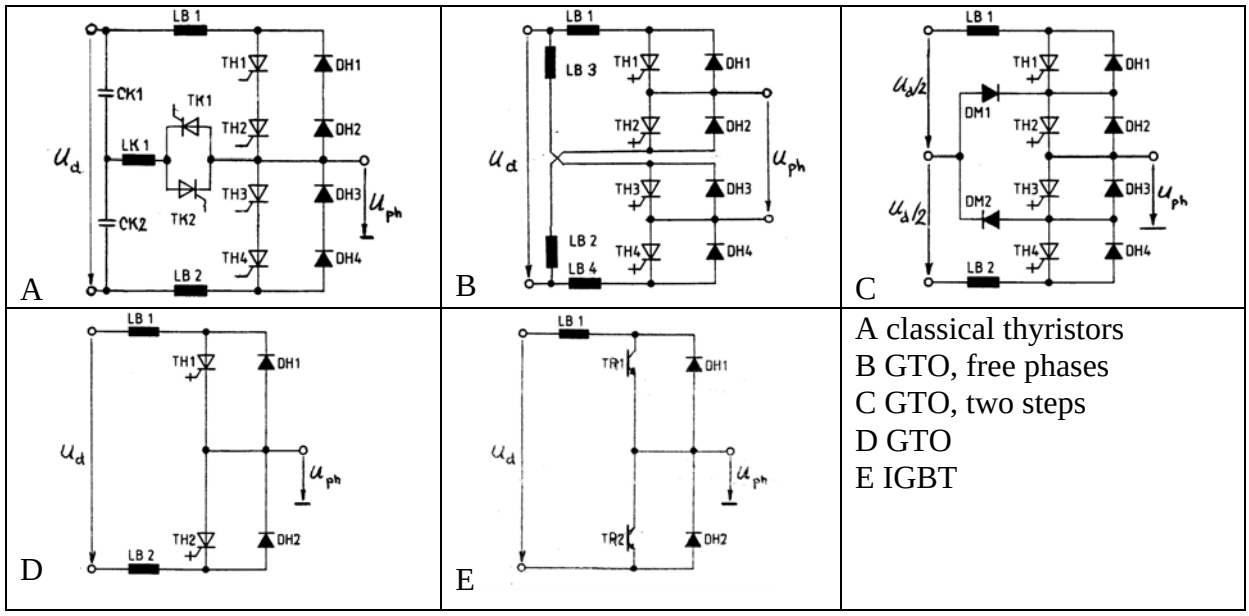


Fig. 4.167 Architectures of inverters arms.

The arm control has also changed in function of the switch-time of semi-conductors. The single-pole control is today used by all industries.

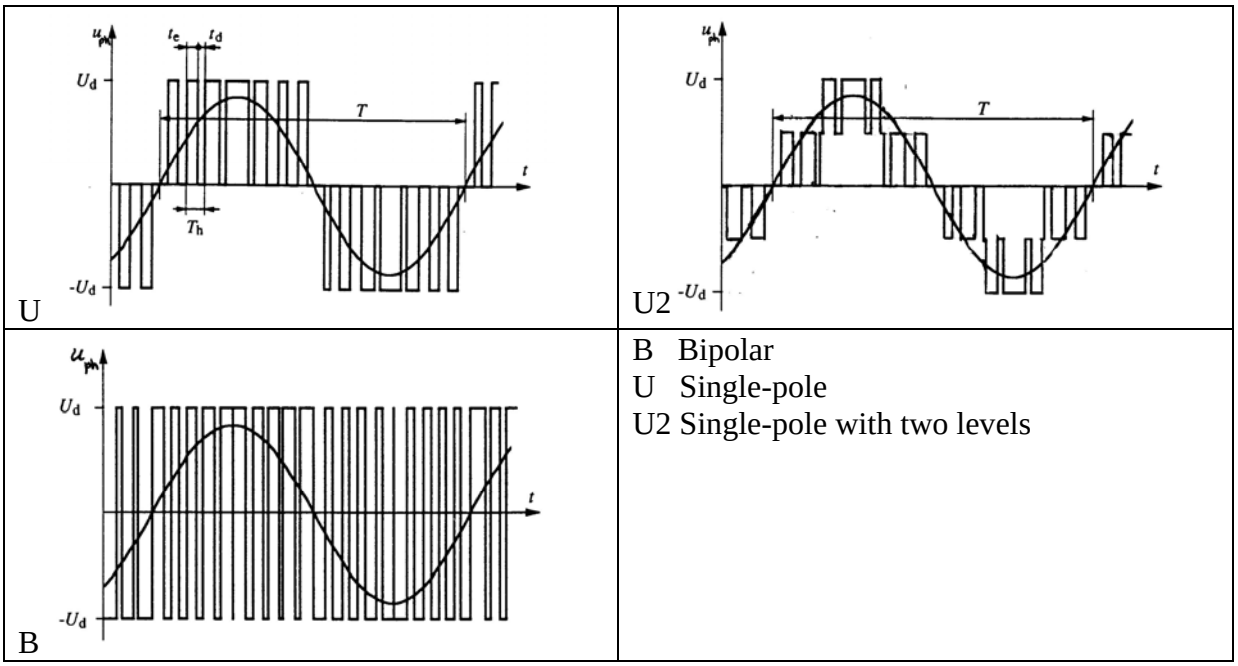


Fig. 4.168 Inverter arm-control.

Arm	A	B	C	D	E
Diodes	8	4	6	2	2
Semi–conductors	18 Thy	4 GTO	4 GTO	2 GTO	2 IGBT
Selfs	4	4	2	1	1
Capacitors	2	0	0	0	0
Control	B	B	U2	U	U
Power [MW]	0,3 – 0,5	0,5	0,4 – 1	0,3 – 0,9	0,5 – 0,9
Year of beginning	1979	1987	1990	1992	(1997) 2004
Examples	DB : 120 NSB: El17 DSB: EA3000	BT: Re 456 CFF: Re 450	CFF: Re 460 ÖBB : 1822 FS: ETR500	BLS: Re 465 SNCF : BB 36000 DB : 185	(ABB: 12X) DB : 185.2 SNCF : BB 447000

Fig. 4.168 & 4.167 Examples : inverters arms.

The first installations used controller with sequential phase control, where classical thyristors were used without forced quenching device. It needs DC-current-link.

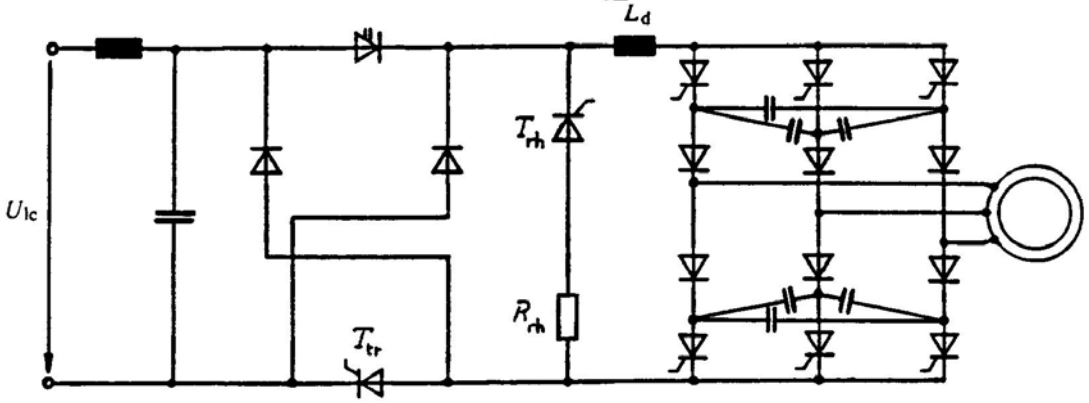


Fig. 4.165 Bidirectionnal I-converter for DC contact line (SNCF : Z20500).

Actually (2005), the more frequent form is the U-converter, with DC-voltage-link. Under DC line, the three-phase converter can be directly connected to line, with a LC-filter. The arms of single-phase bridge are identical as ones of the three-phase bridge (Fig. 4.167D).

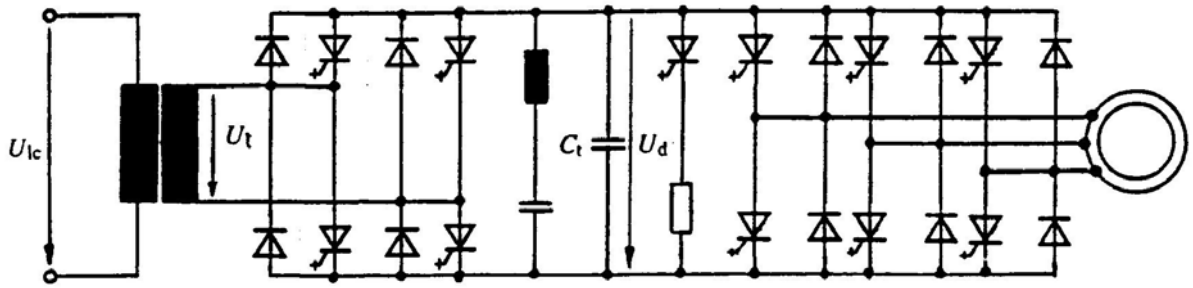
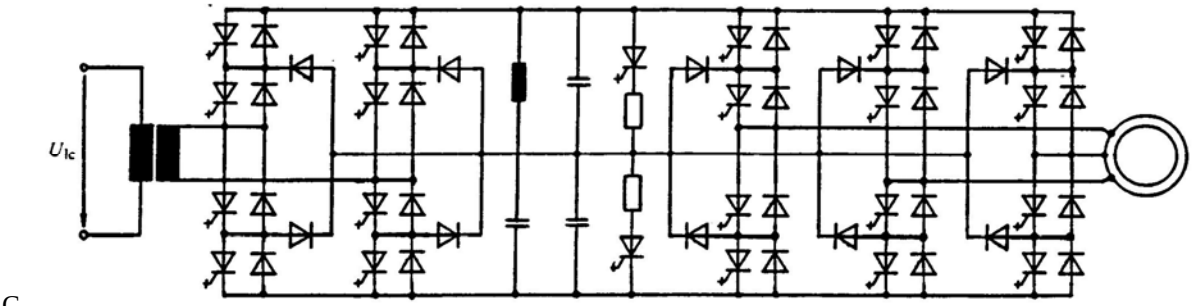
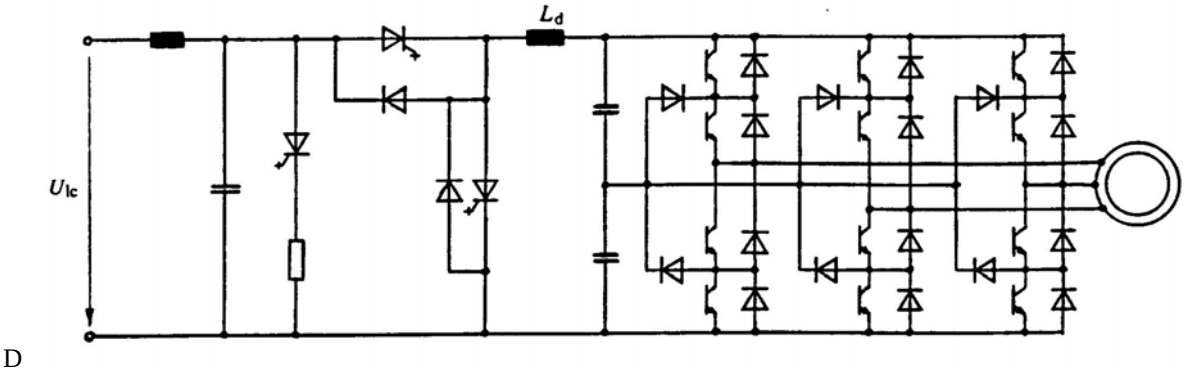


Fig. 4.166A Bidirectionnal U-converter for AC contact line (BLS : Re 465).

During development phase an intermediate circuit with middle point was also used. At this time, the blocking voltage of available GTOs or IGBTs was not sufficient to have a simple arm with the requested power.



C



D

Fig. 4.166 C Bidirectionnal U-converter with GTO for AC contact line GTO (CFF : Re 460).
D Bidirectionnal U-converter with IGBT for DC contact line (JNR : 207).

The evolution in semi-conductors goes in direction to operate schema 4.166A with IGBT. So converter has same performances as ones with GTO with higher efficiency and lower weight.

The converters at network side were at the beginning the same as ones used for DC-motors. They are actually pulsing converters (20 times network frequency) similar as motor converters. The line- and motor-converters in the same locomotive have often exchangeable arms: same spare parts are to be stored. In multi-current vehicles, the line-converter can be configured as step-down chopper to operate under 3 kV= (CFF: Re 484: multi-current version of DB 185.2) in other, a 3,8 kV voltage-link was chosen, which can be directly supplied from 3 kV= (SNCF: BB 447000).