Frequency converter with induction motor

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Frequency converter with induction motor

Basics Frequency converter
- Servo – Frequency Converter
- Rectifier – Mains Choke
- Pre-charging
- Inverter
- Motor Filter
- Mains Filter
- Braking Resistor

Basics Inductance Motor
- Construction
- Stator Rotating Field
- Function

Basics motor control
- V/f
- Field orientated control
- Sensor less field orientated control

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Difference between frequency converter an servo controller?

The construction is identical
Both are V-converters

Output of variable frequency and voltage

Differences only in application / possibilities of the Firmware

Servo
High peak power
SM and ASM
Always with encoder
Mostly position mode

Frequency converter
High continuous power
ASM (inductance motor)
With or without encoder
Mostly velocity controlled

In the Rexroth language „open Loop“ means „without encoder“

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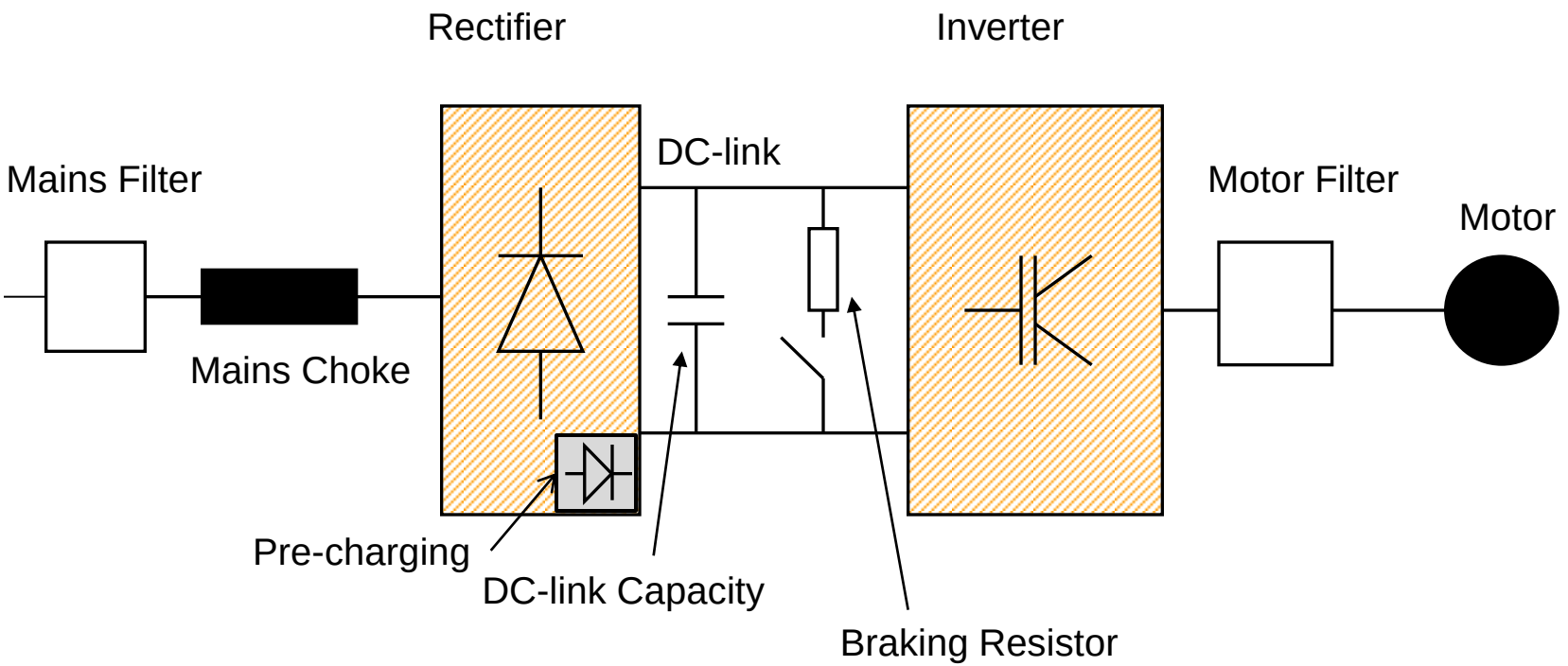
Construction of a Frequency Converter



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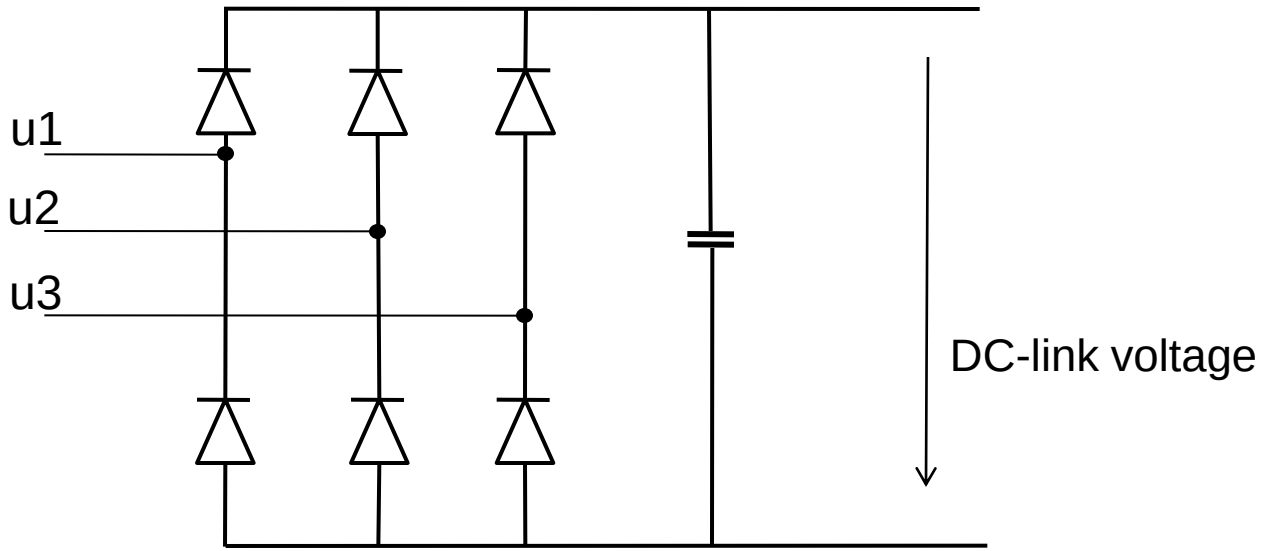
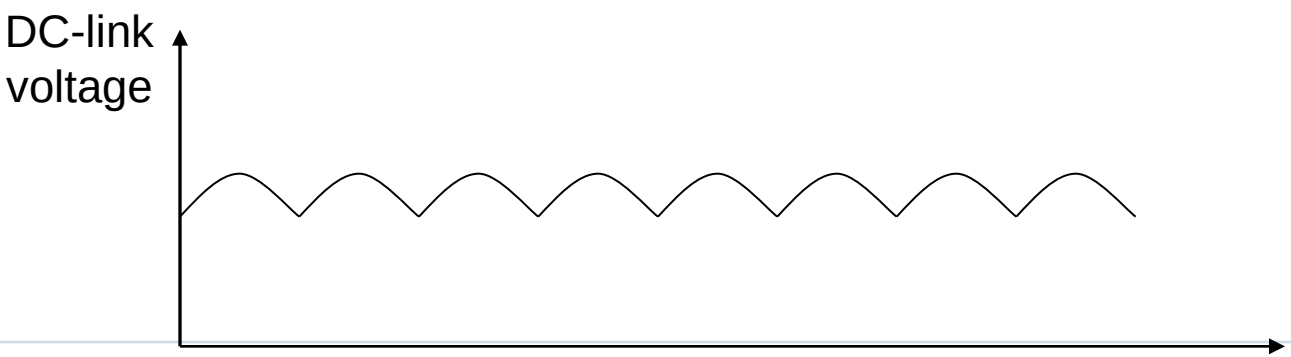
Rectifier





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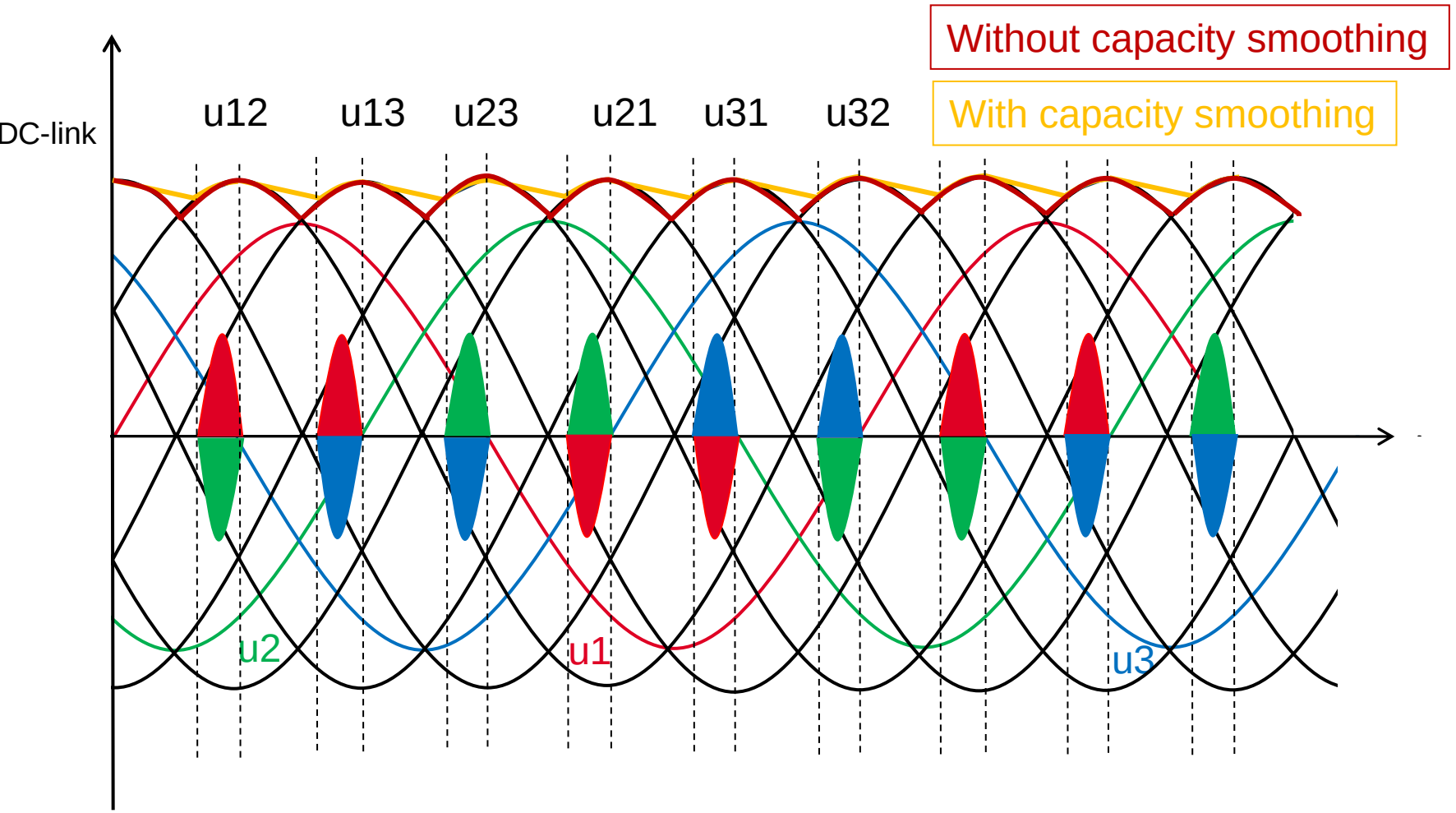
Basics frequency converters



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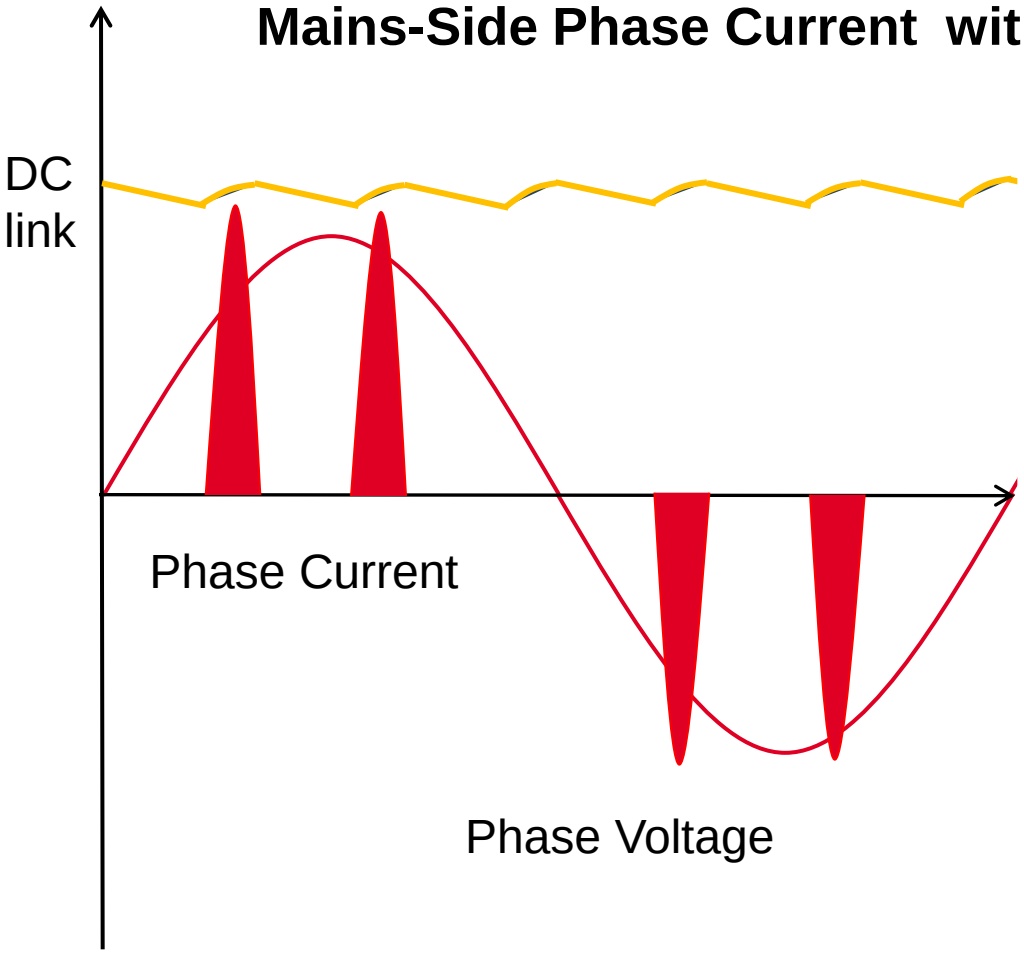
Mains-Side Phase Current without mains choke



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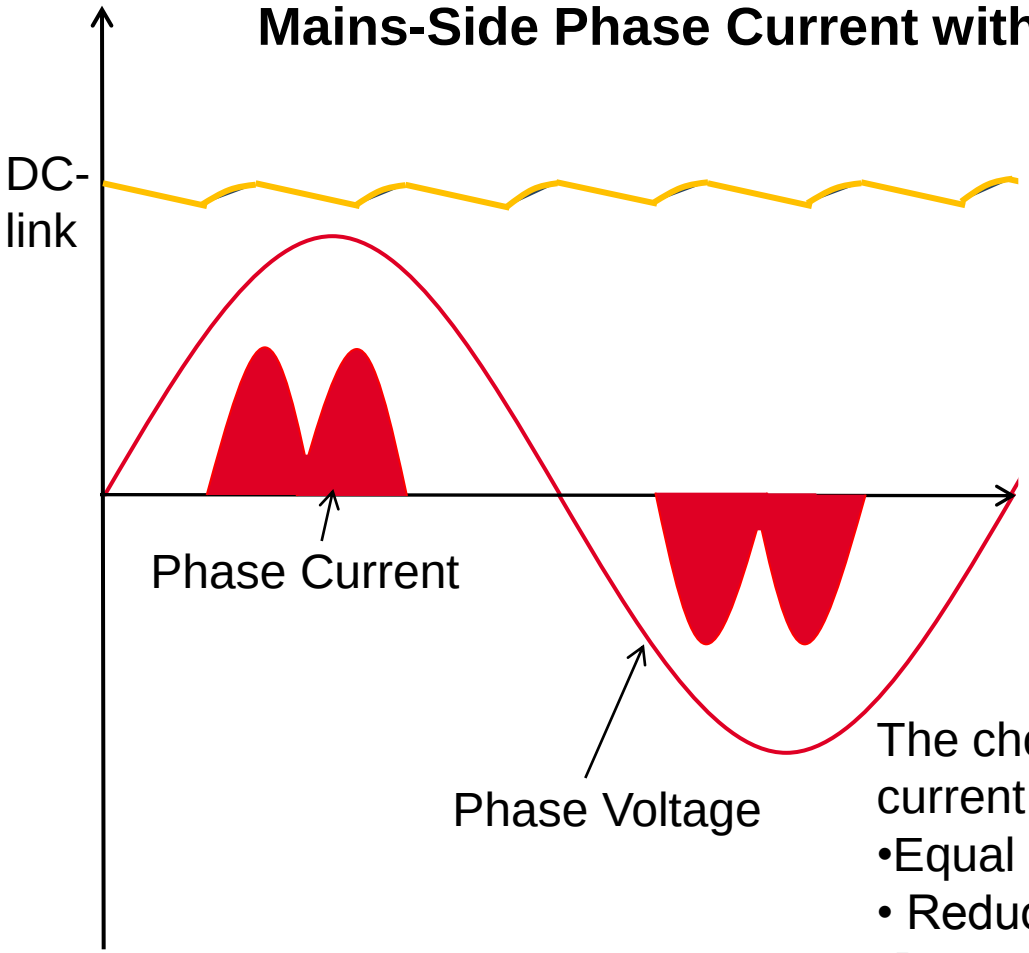
Mains-Side Phase Current with Mains Choke



The choke extends the time of current flow

- Equal current-time area
- Reduction of the amplitude
- Decrease of harmonics

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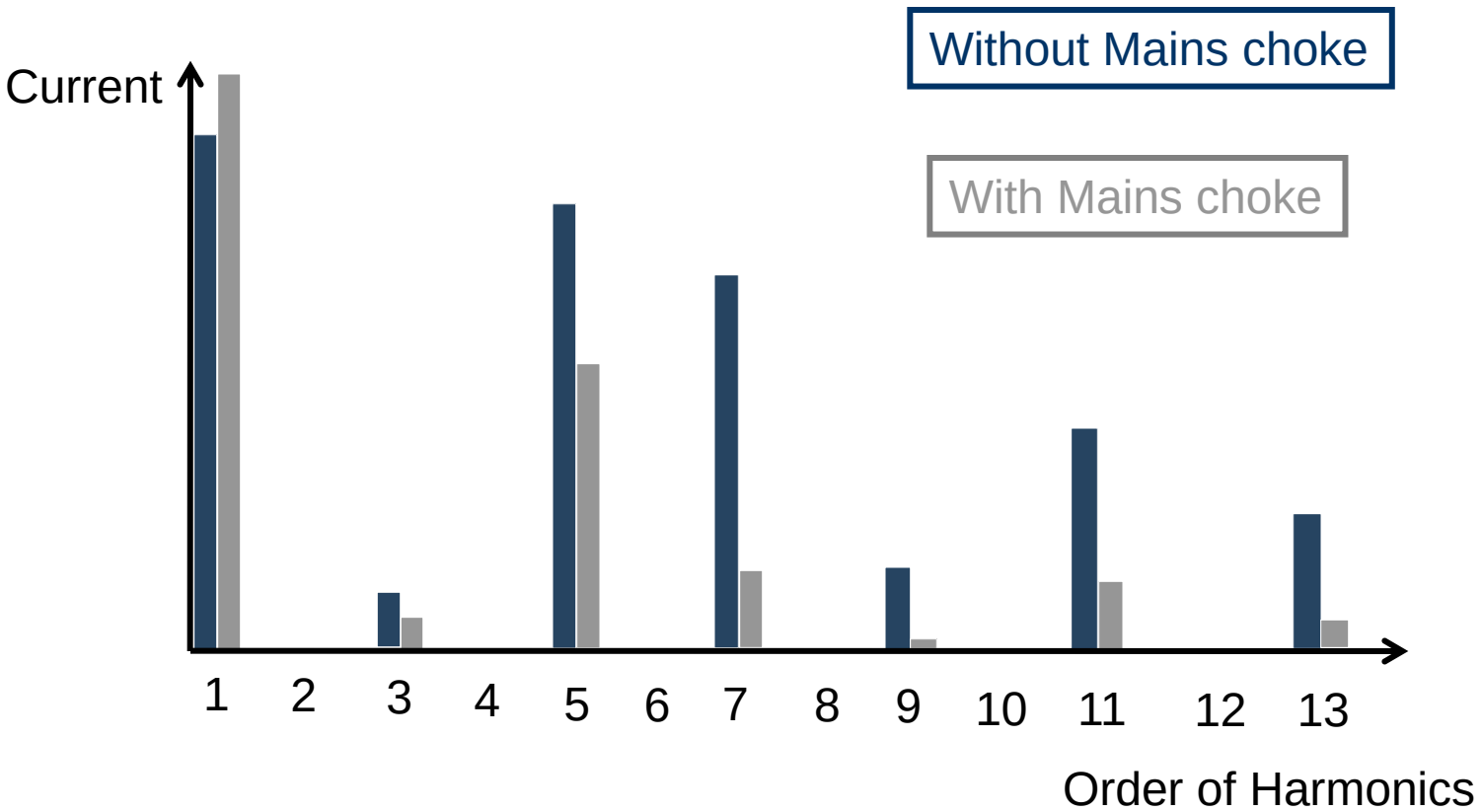
Frequency Spectrum



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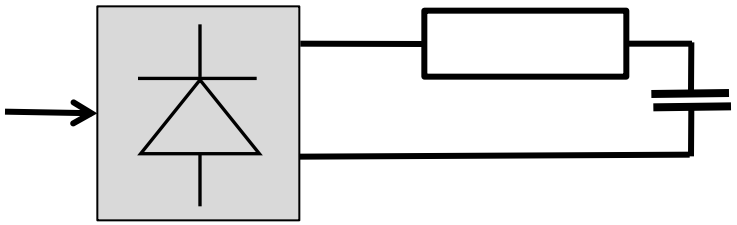
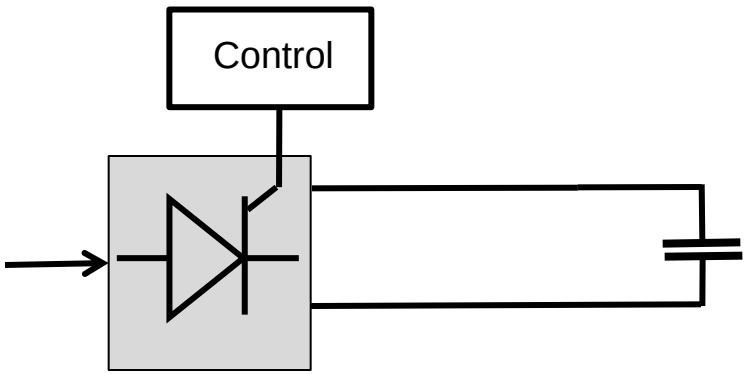
Pre-charging / Softstart



Charging current is limitated by a resistor e.g. Braking Resistor



Controlled voltage by a thyristor (phase shift control)

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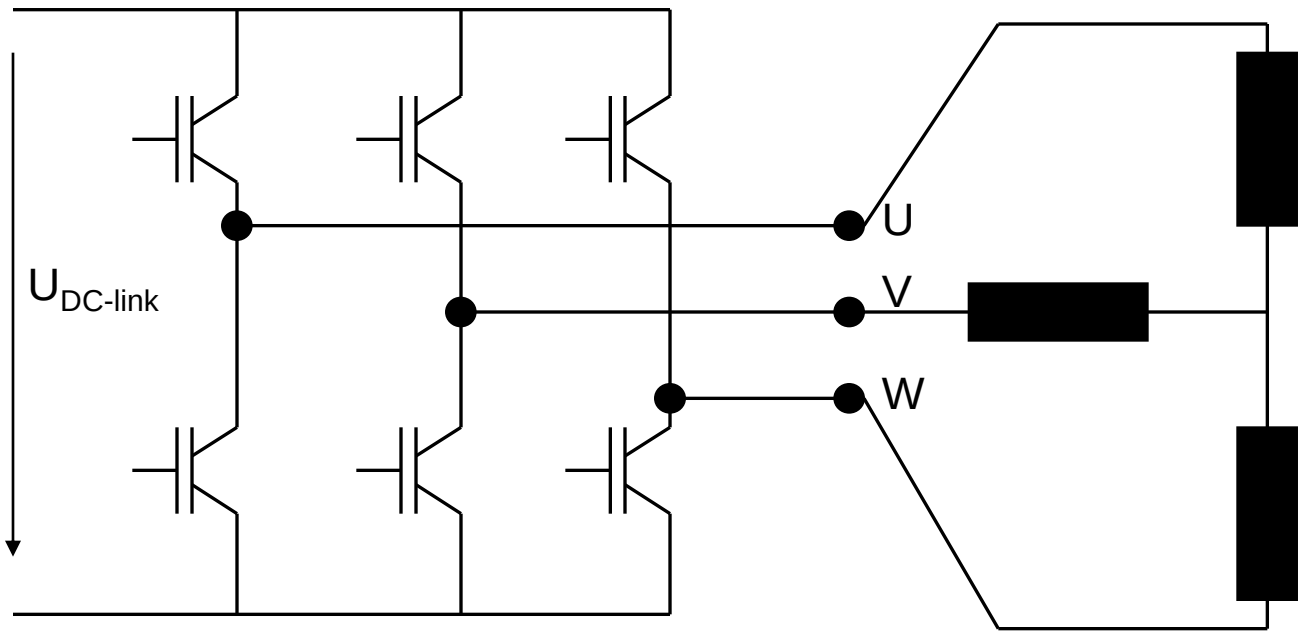
Inverter



IGBT‘s are used as semiconductor switches

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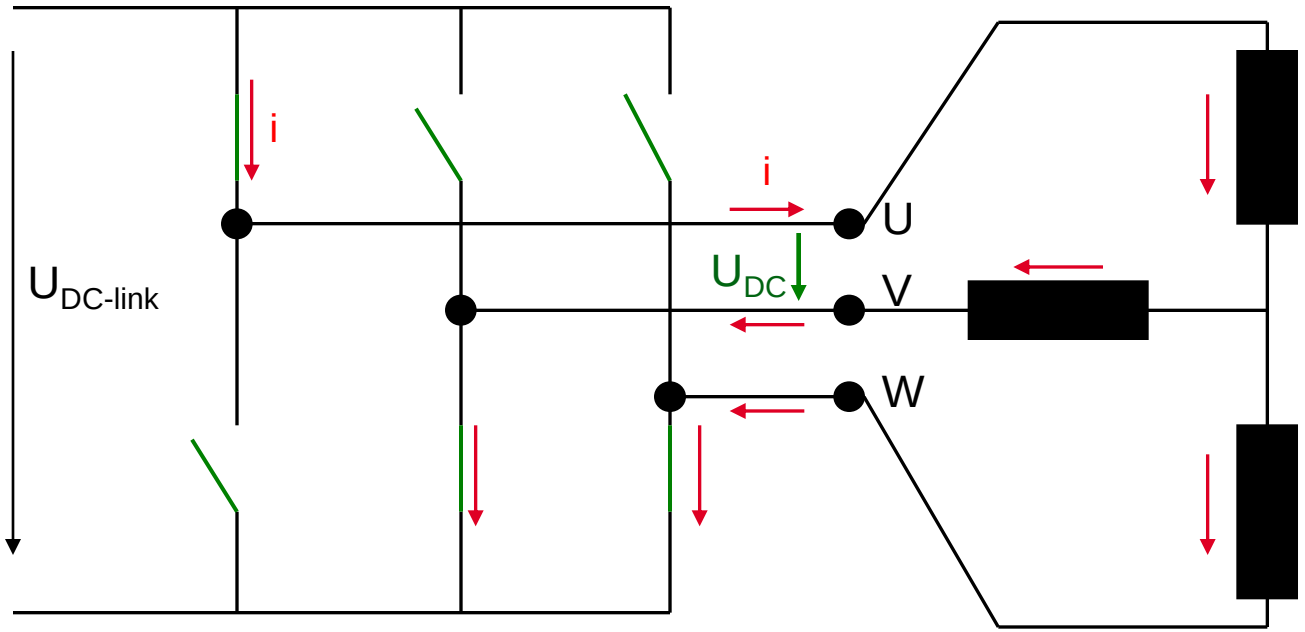
Basics frequency converters



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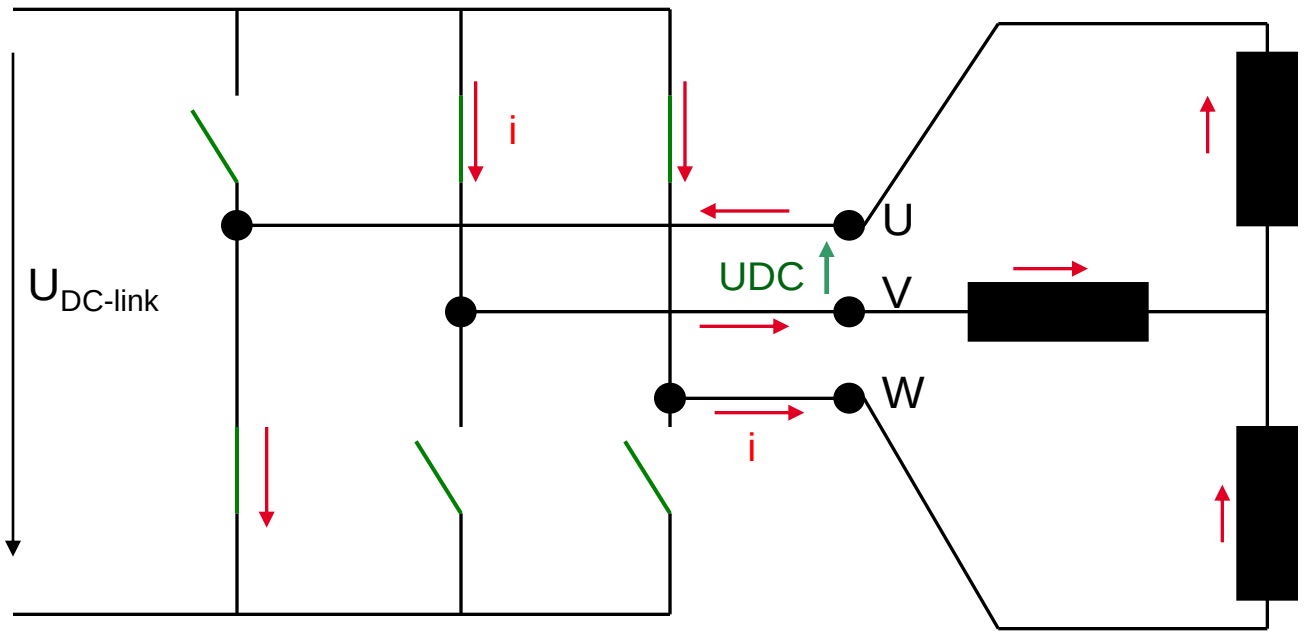
Basics frequency converters



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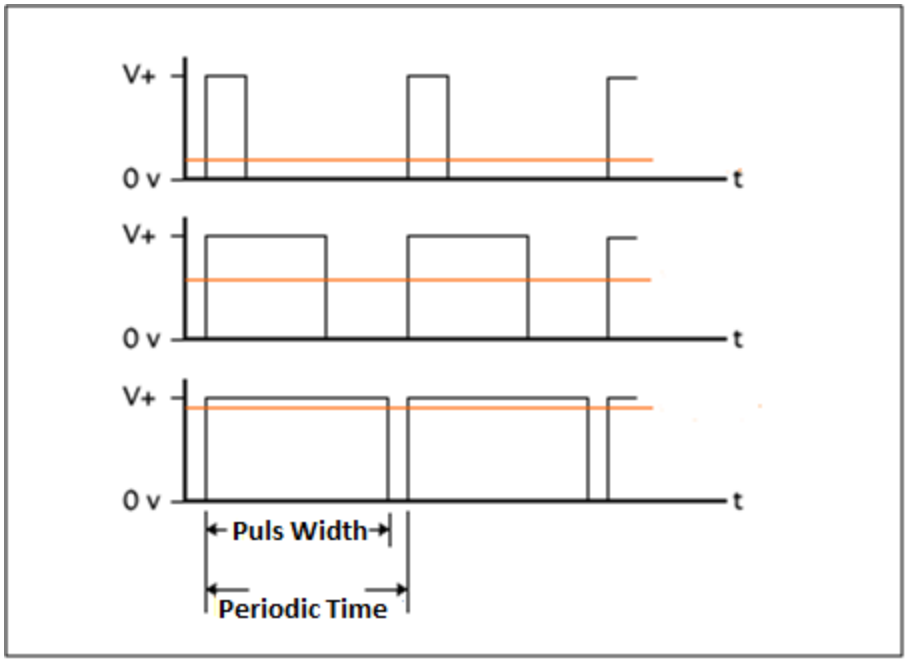
Puls Width Modulation

The converter output voltage is adjusted by the puls/break ratio



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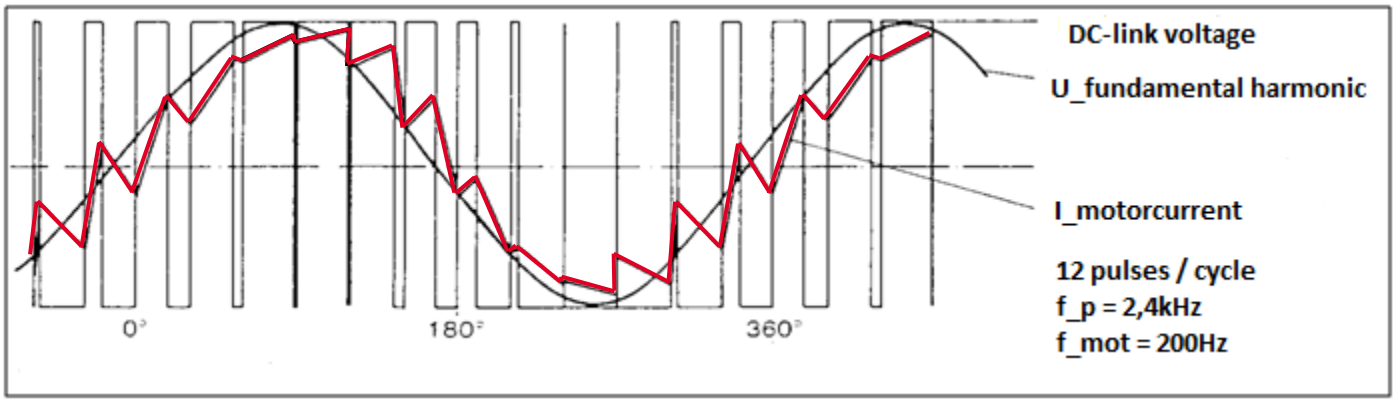
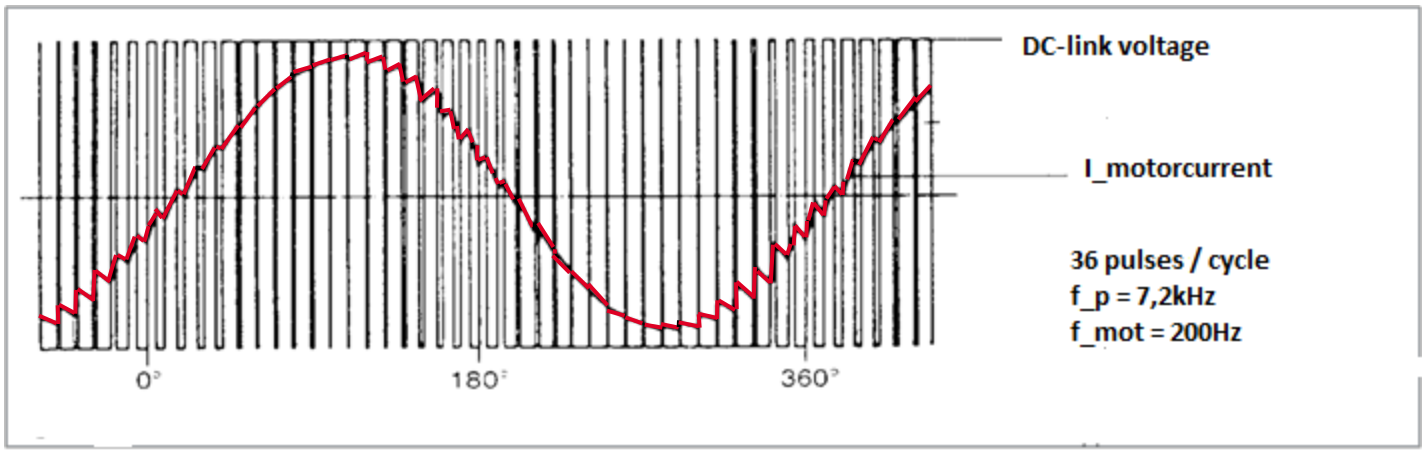
Effect of the Puls Frequency





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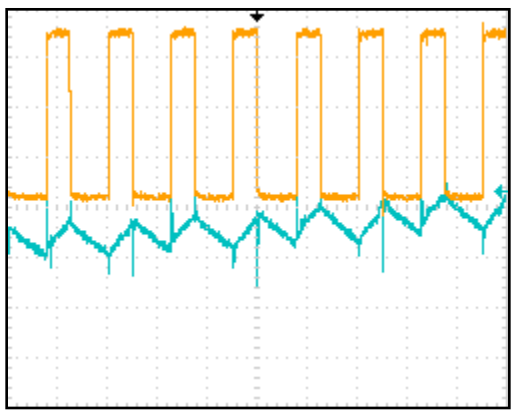
Effect of the Puls Frequency

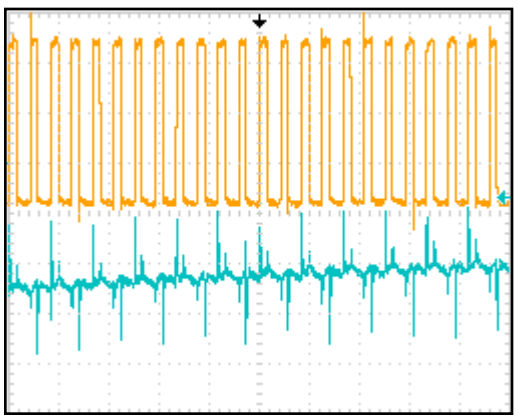
4kHz



Voltage

Current

12kHz



- Meassured with standard norm motor and HCS02
- 20 Hz motor frequency
- no load running

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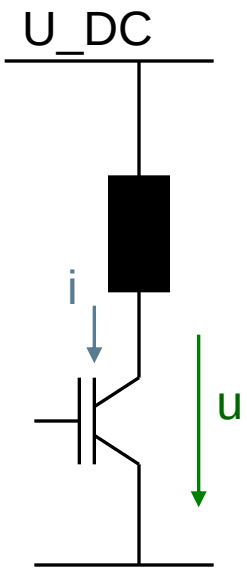
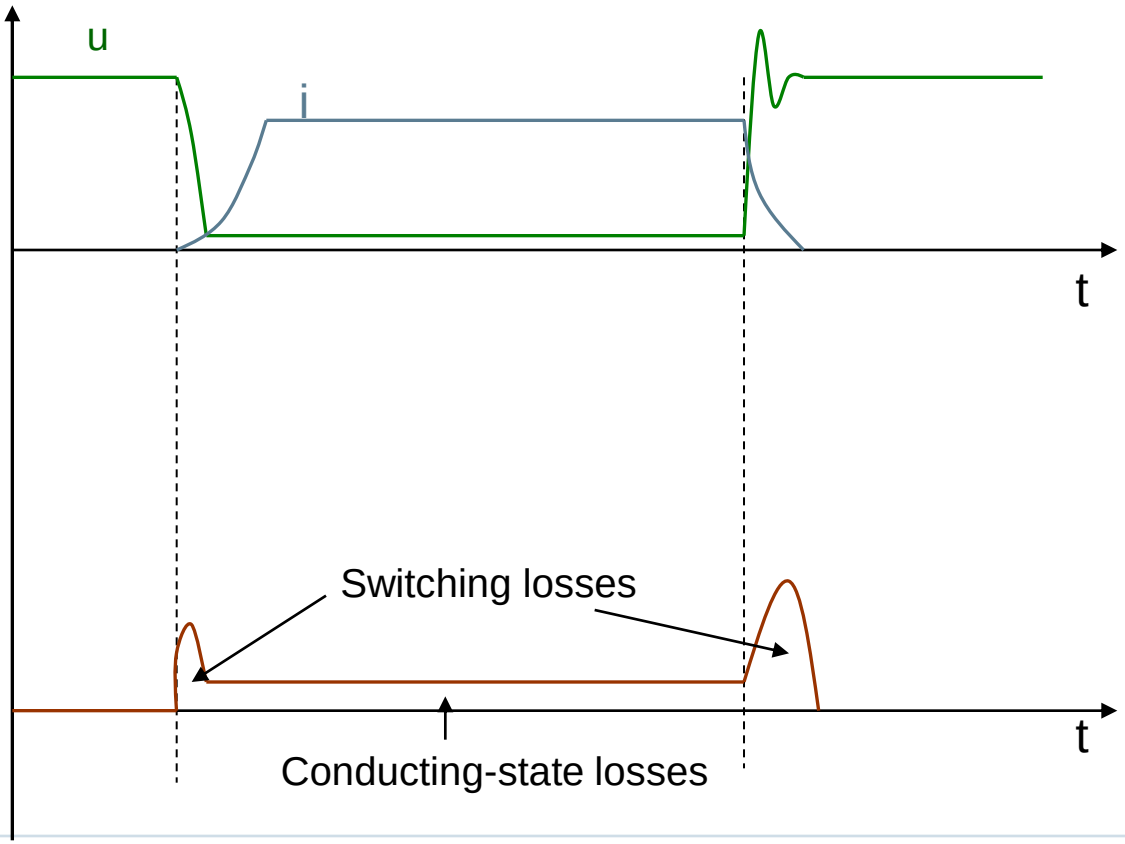
Switching loss





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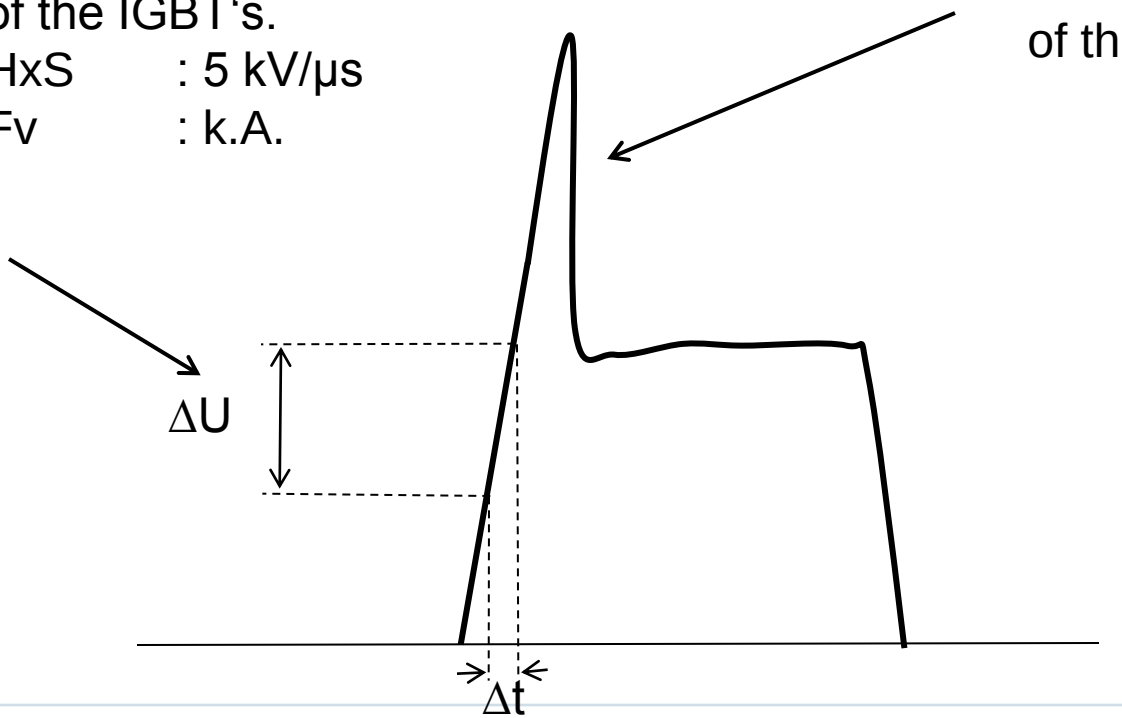
Risks for the motor windings

Rate of rise of voltage
Made by the fast switching time of the IGBT‘s.
HxS : 5 kV/µs
Fv : k.A.

Overvoltage
Determined by inteferences of the voltage pulses



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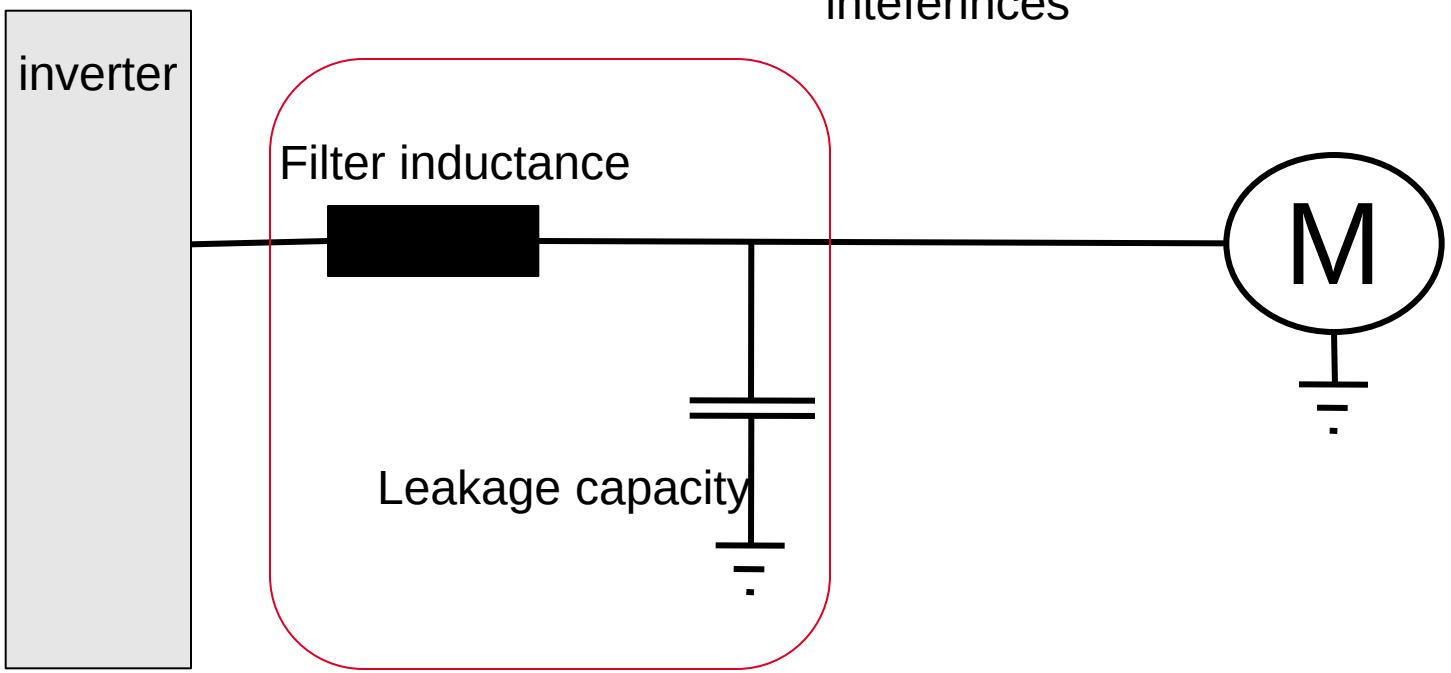
Motorfilter / Linedumping

Adjusting of the wave impedance of the cable for a better load matching to avoid inteferinces



Lowpass – filtering high frequency parts

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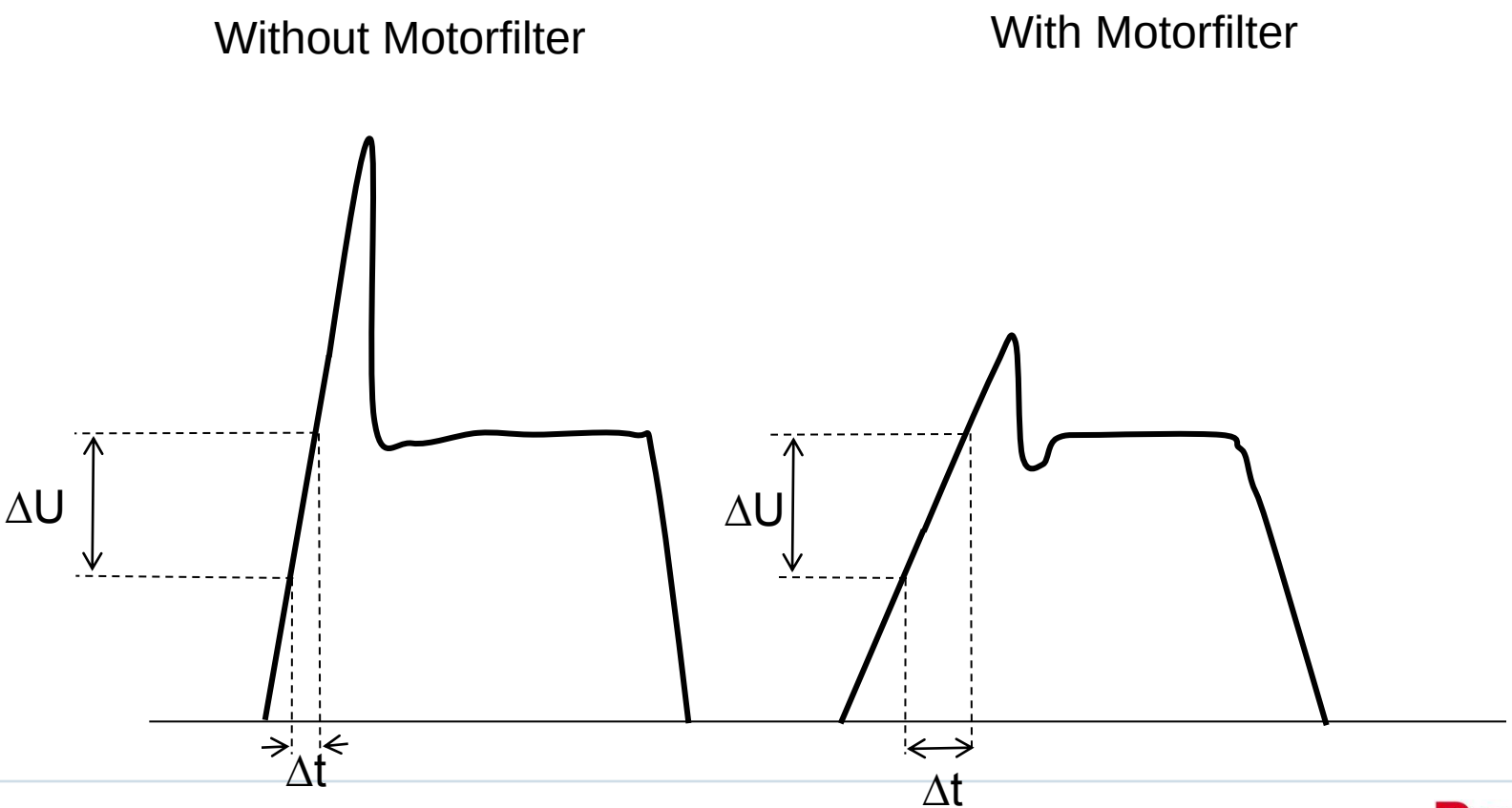
Voltage Pulse



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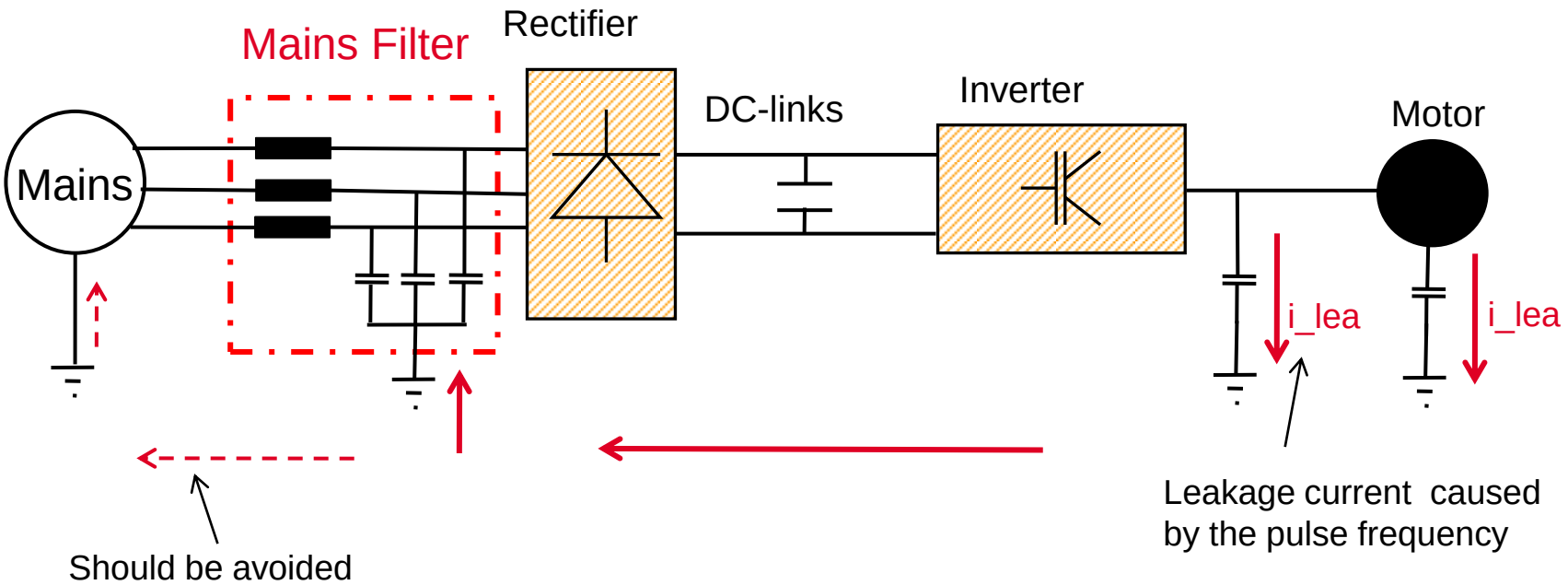
Mains Filter / EMC Filter



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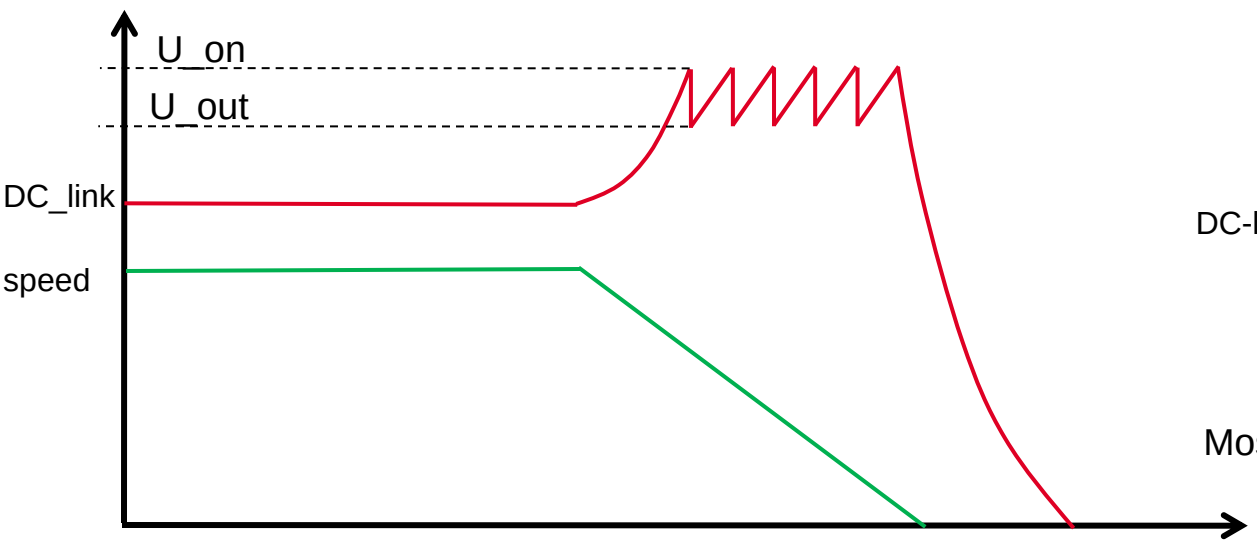
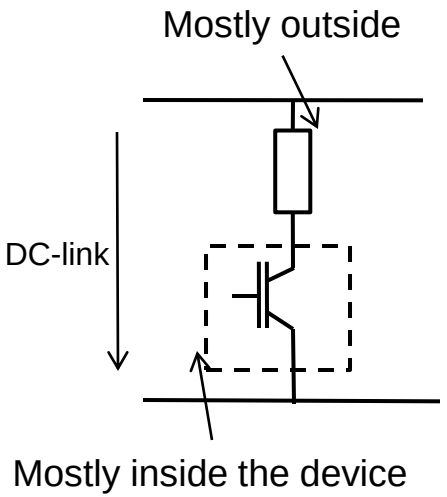
Brakingresistor

A braking resistor converts regenerative kinetic energy into thermal energy.
The DC-link voltage is short circuited over the braking resistor by the braking transistor(Chopper).
Switching on threshold between 780 and 820V.
The difference between U_on and U_out is 30….40V.





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Basics Motor control
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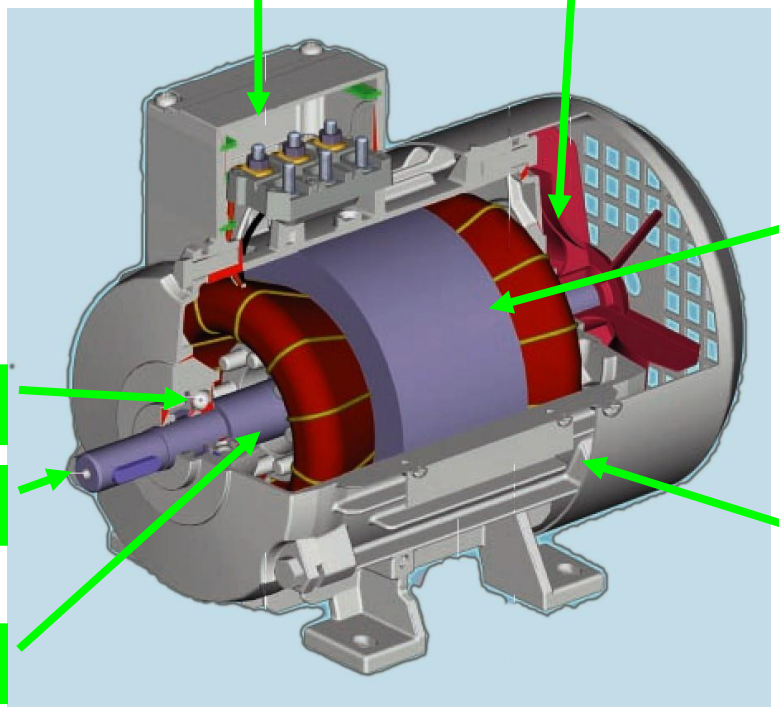
Inductance motor - Construction



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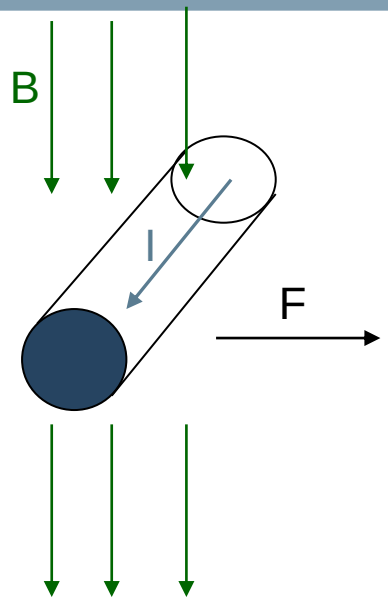
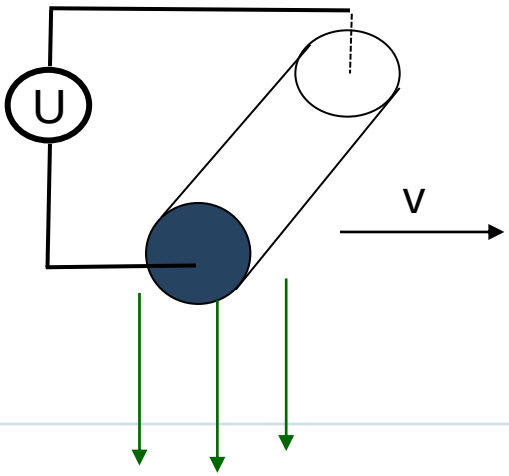
Basics induction motor



Principle of a motor.
On a current carrying wire which is inside a magnetic field, a force is be appealed

$$F = B * l * I$$



Principle of a generator
A voltage is been induced when the wire is been moved.

$$U = B * l * v$$

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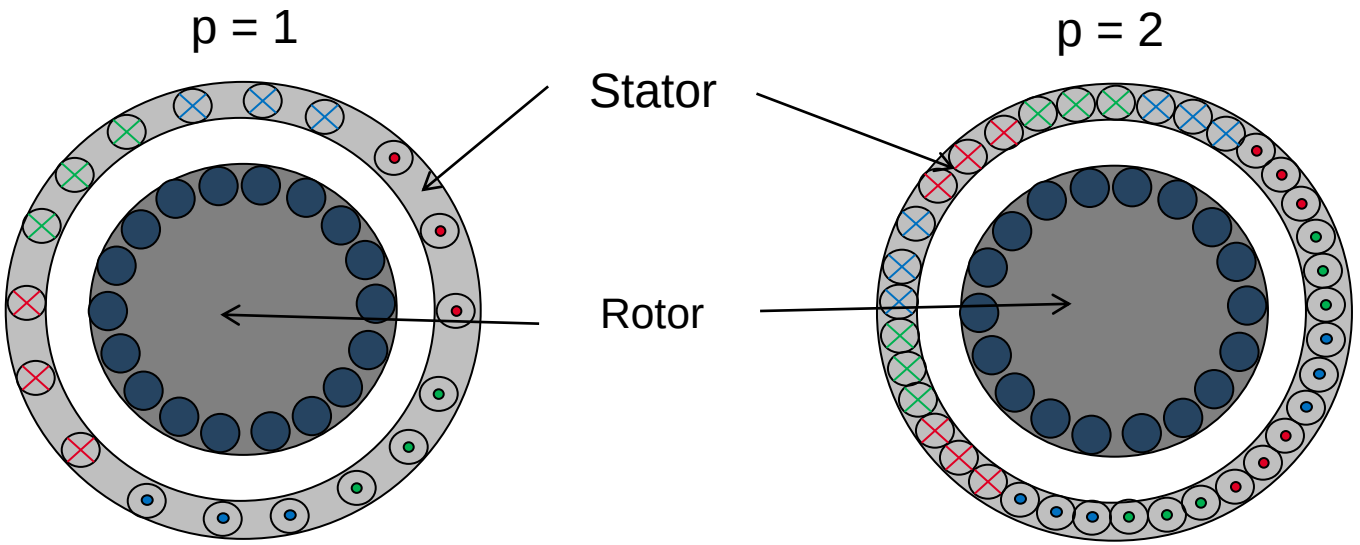
Basics induction motor

Number of pole oairs



One U, V and W winding.

50Hz rated frequency

Synchronous velocity of 3000 U/min

Two U, V and W windings

50Hz rated frequency

Synchronous velocity of 1500 U/min

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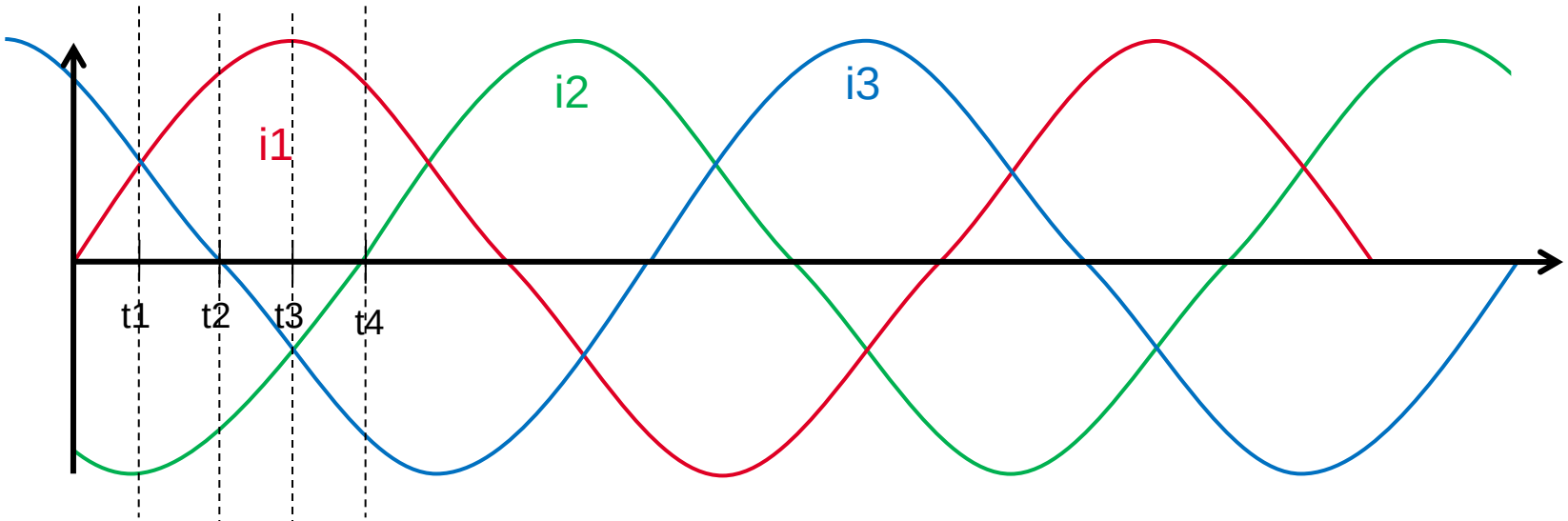
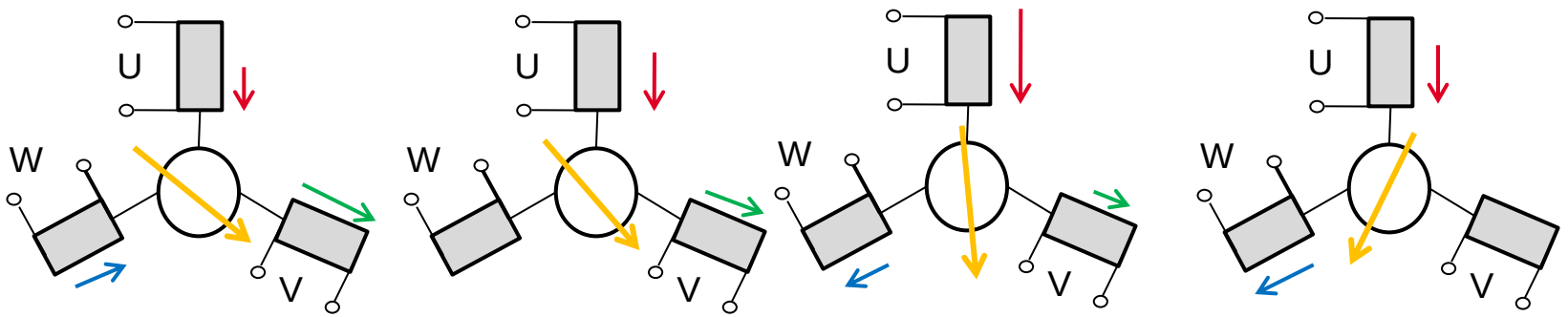
Basics induction motor





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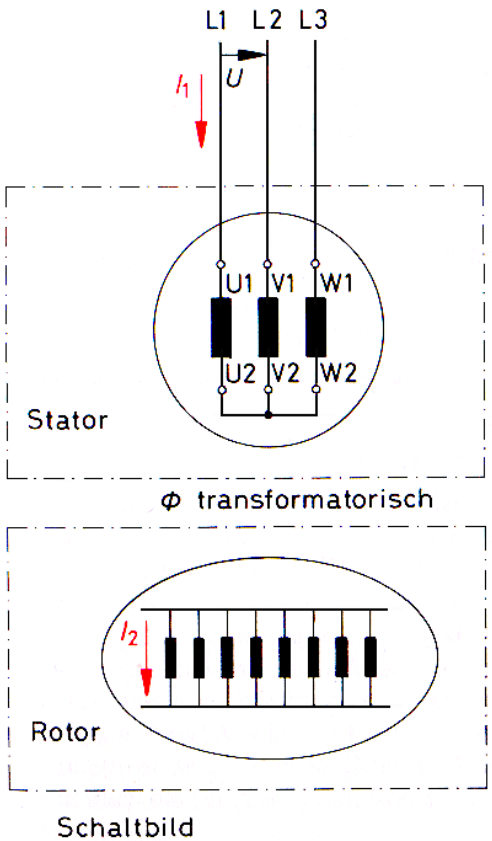
Basics induction motor



- The asynchonous motor can be considered like a transformer
- The stator current I1 generates a alternating magnetic field Φ in the air gap
- Because the phase shifting of 120° a rotating field is generated.
- The flux induces a voltage in the rotor.
- A current I2 flows through the short circuit rotor.
- These short cut current effects a force F.

Important: The speed of the rotor must be unequal (asynchonous) to the speed of the stator field.

➡ Asynchronous motor

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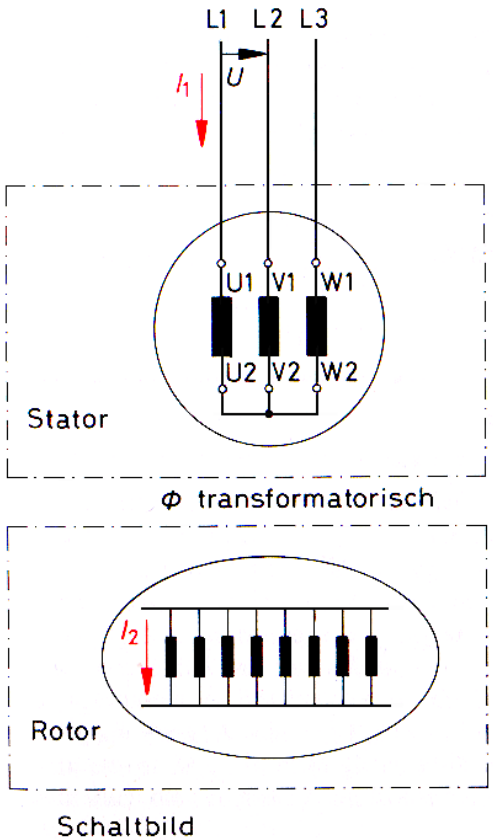
Basics induction motor



- The torque M_i at the motor- shaft is proportional to the current in the short circuit rotor and proportional to the magnetic flux Φ of the rotor field.

$$M_i \sim I_2 * \Phi_d$$

- The speed n_d depends on the frequency in the stator windings

$$n_d = \frac{f_1}{p}$$

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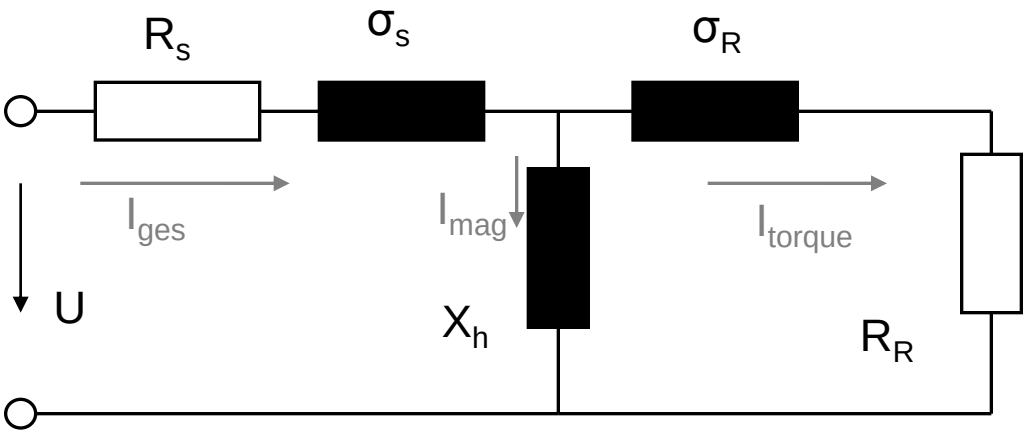
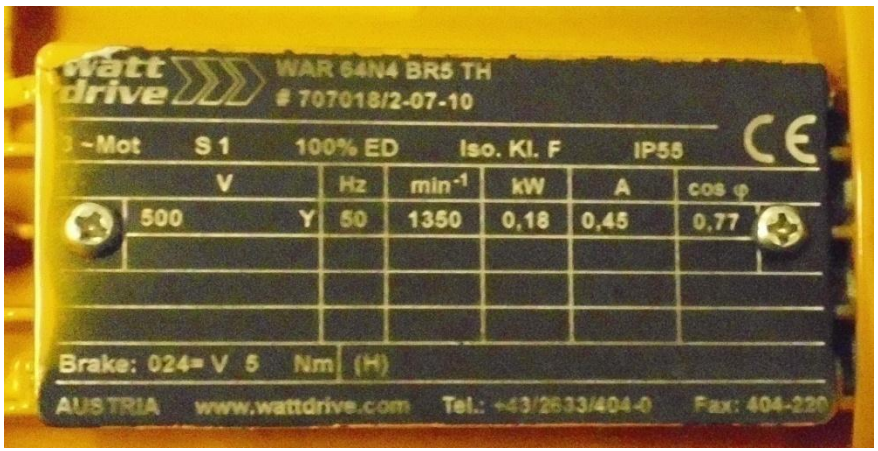
Basics induction motor



R_s= Stator resistor
σ_s= Stator leakage inductance
R_R= Rotor resistor
σ_R=Rotor leakage inductance
X_h=Main inductance



Rating plate:
6 values are always declared
- Voltage
- Speed
- Frequency
- Power
- Current
- Cos(phi)

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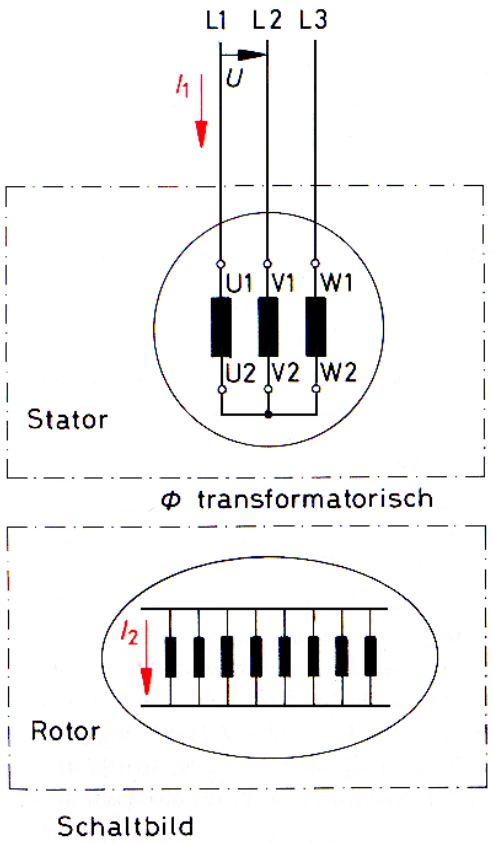

A constant flux in the air gap has to be generated.

$$\Phi = L \cdot I_{magn}$$

When the ohmic part is neglect the magnetising current can be described by this formula.

$$I_{magn} = \frac{U}{j\omega L} = \frac{U}{2 \cdot \pi \cdot f \cdot L}$$

To get a constant flux the following condition must be met.

$$\Phi \approx I_{magn} \approx \frac{U}{f} = const.$$

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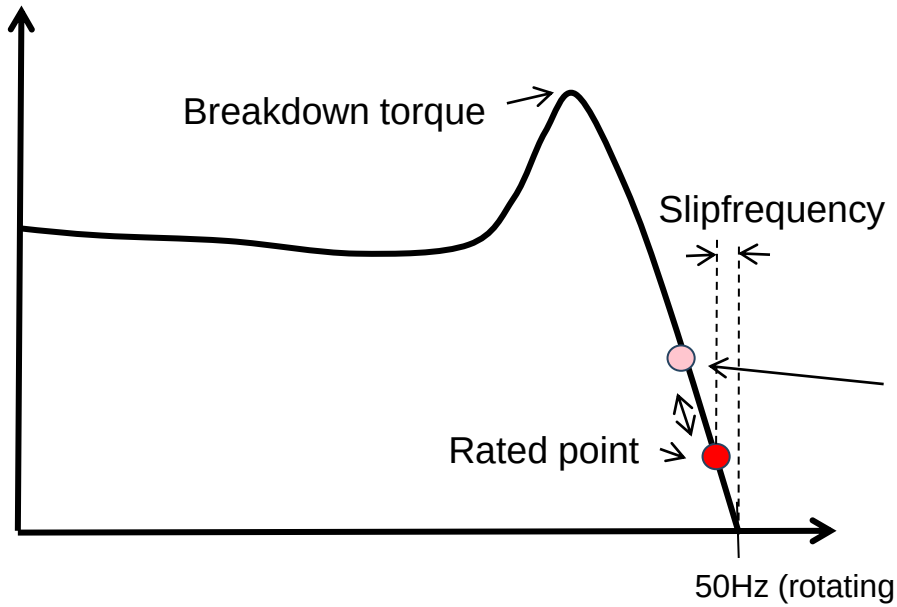
Motor characteristic of an ASM with 50 Hz rated frequency



Slip= Difference between the real frequency of the rotor and the rotating field frequency

Depending on the load the operation point is moving on the charecteristic

Big slip ⇨ Big torque

Small slip ⇨ Small torque

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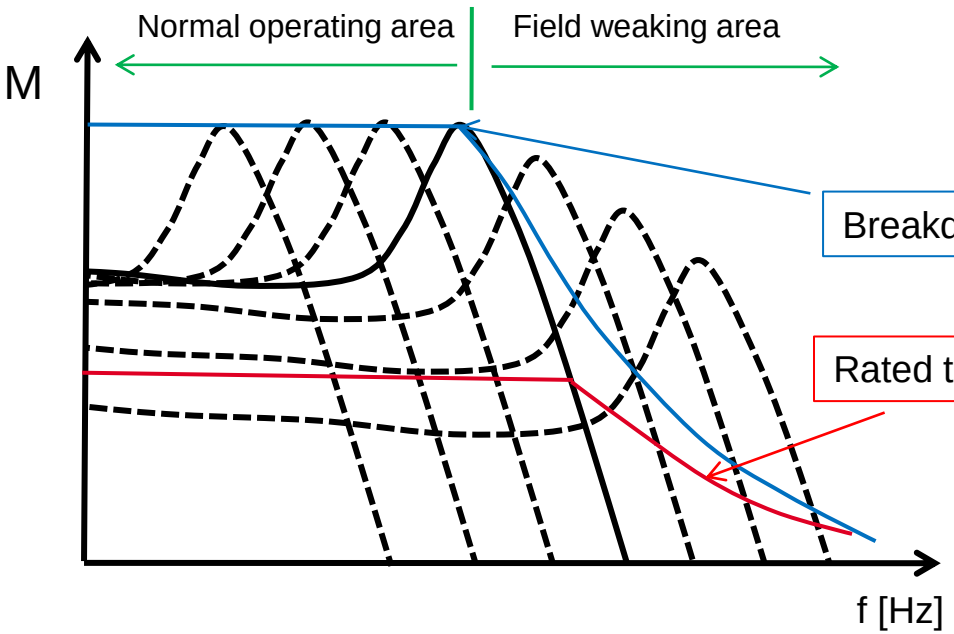
Inductance motor with frequency converter

The characteristic is moved by the variable converter frequency



The torque is reduced in the field weaking area

$$M_{N(n)} = M_N * \frac{n_N}{n}$$

$$M_{breakdown(n)} = M_{breakdown} * \left(\frac{n_N}{n}\right)^2$$

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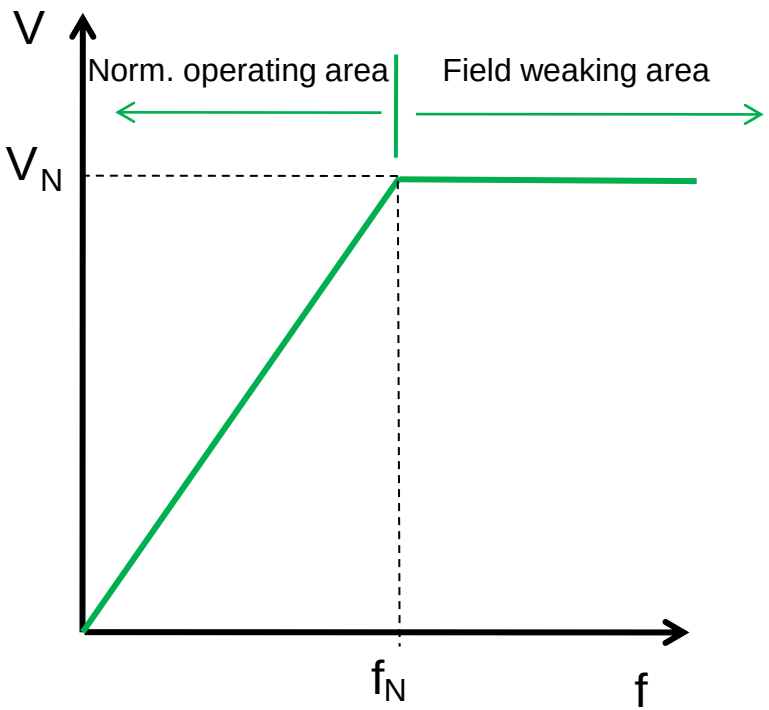
V/f-control



It‘s an open loop voltage control

For every frequency (demand speed) the converter gives a specific voltage out.

The relation between voltage and frequency is constant to get a constant flux in the mashine.

Optimisations modify the form of the curve.

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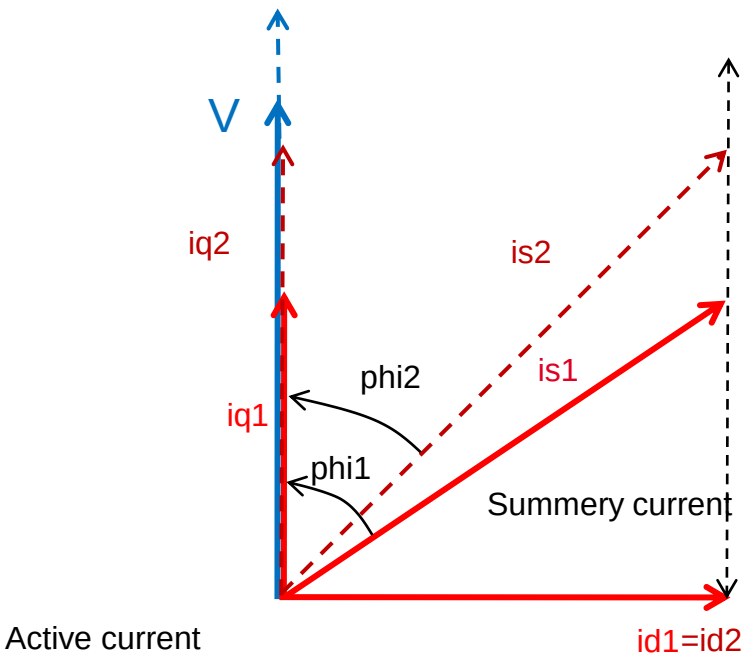
Field orientated control- FOC



The motor current is devided in two parts.
Iq = Torque generating current
Id = Magnetising current

Both currents can be independently of each other impressed into the maschine

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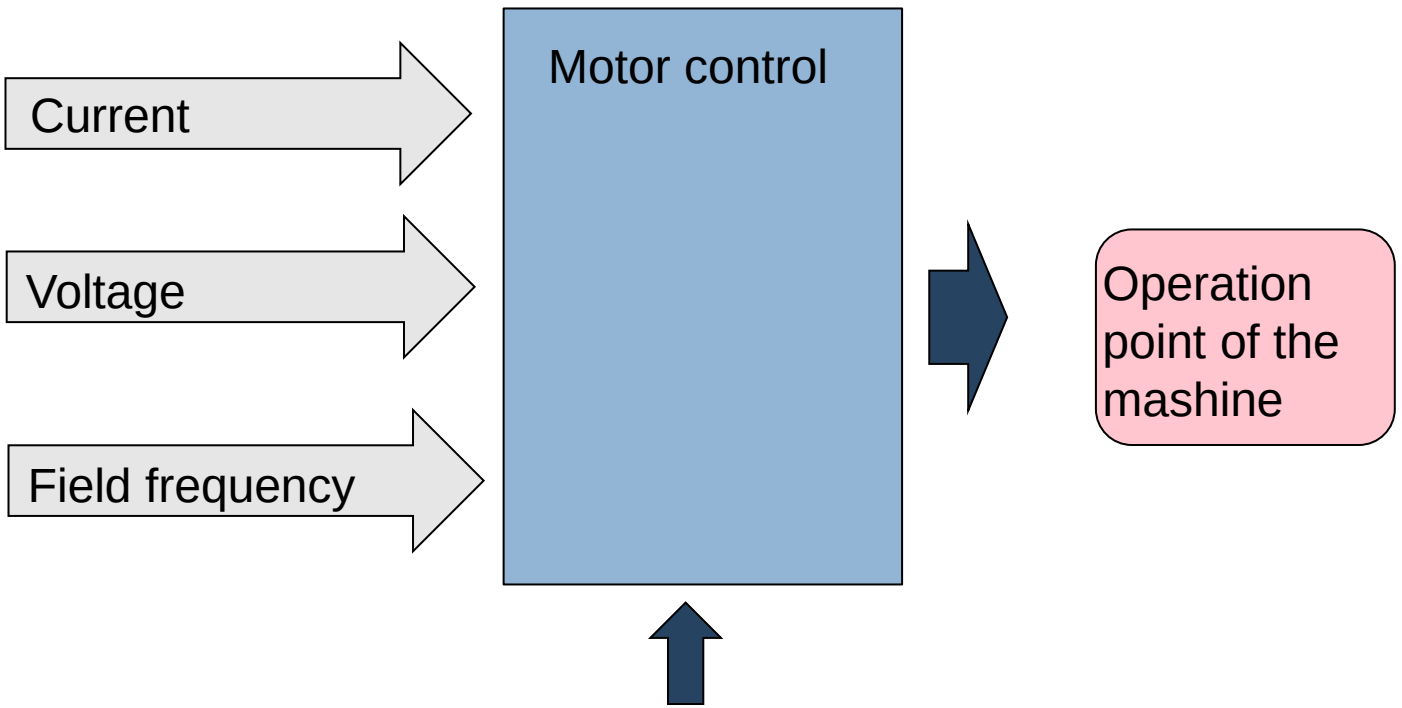
Sensor less field orientated control - FXC , SVC

Calculating of actual speed and slip



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Comparison of the three control modes

	V/f	FOC	Sensorless FOC
Complete torque at standstill	no	yes	no
Speed accuracy	- -	+++	+
Knowledge of motorparameters	low	much	a lot of
Torquelimitter	no	yes	yes
More motors at one converter	yes	no	no
Positioning	no	yes	no

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