AC Drive Technology

An Overview for the Converting Industry

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AC Drive Technology

Drive Systems

- AC Motors
- AC Drives

AC Drive Technology

Drive Systems

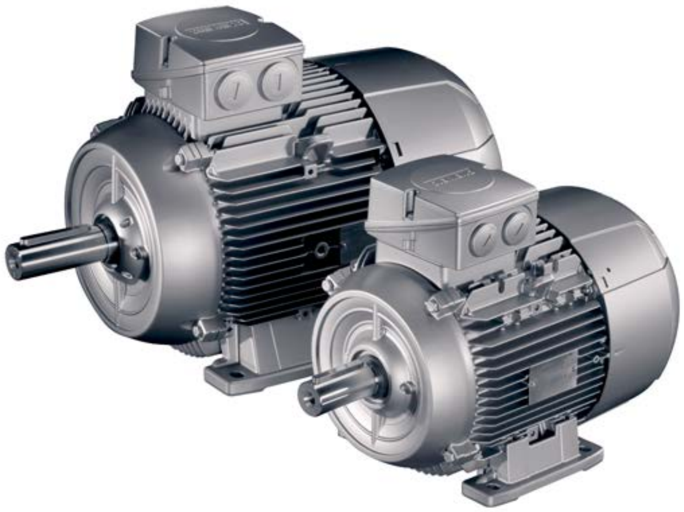
AC Motors

AC Drives

AC Motor Technology - Motor Construction

Two types of motors are commonly used with AC drive systems, asynchronous (induction) and synchronous.

Induction / Asynchronous	Synchronous



AC Motor Technology - Motor Construction

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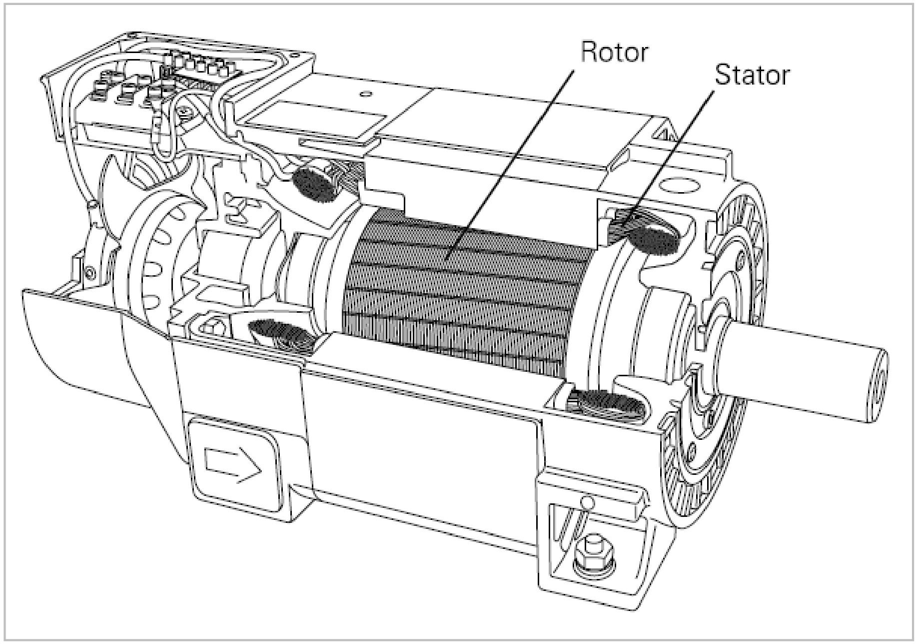
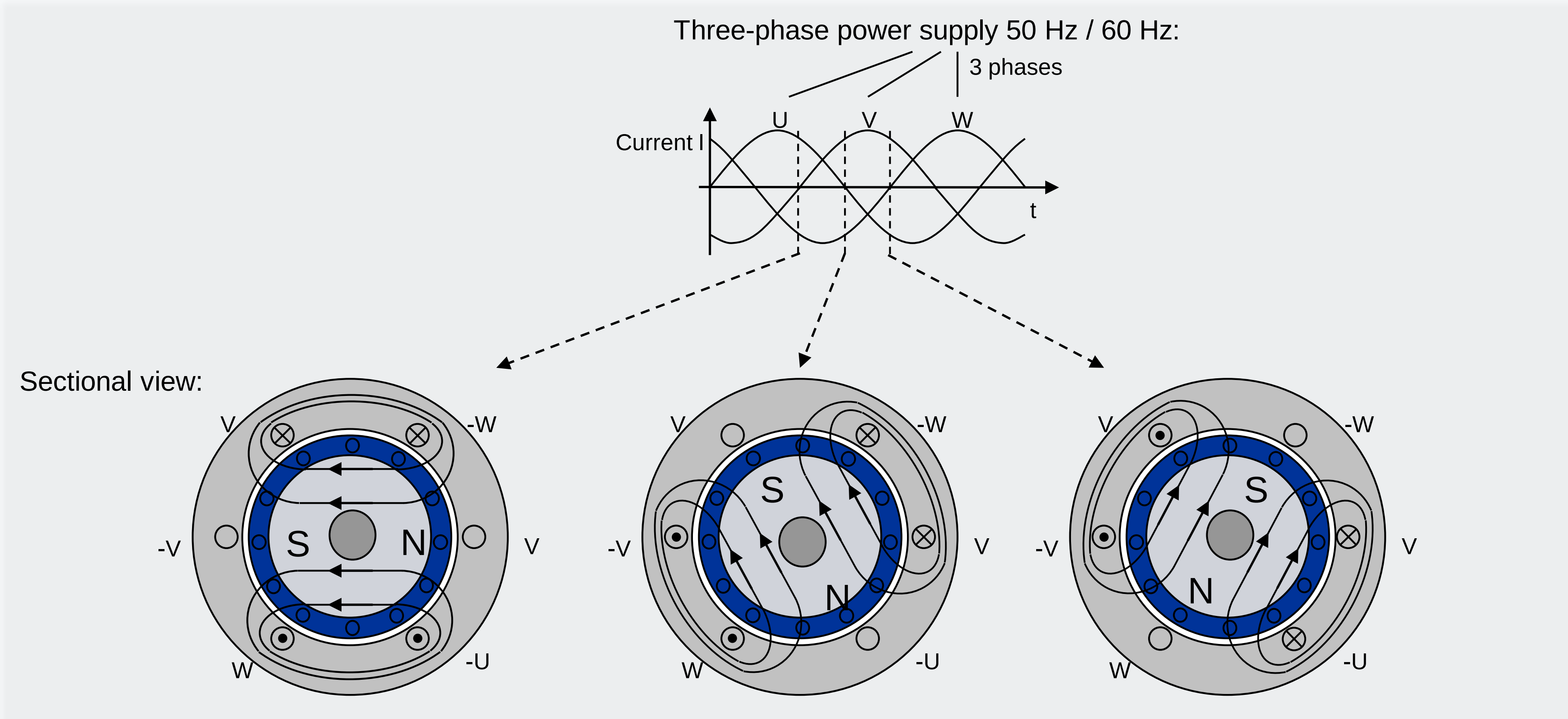


The basic elements of both motor types are the stator and the rotor.

The function of the stator is the same in both motors, it creates the magnetic field that rotates the rotor when an AC voltage is supplied.

The main differences in motors are in the rotor construction.

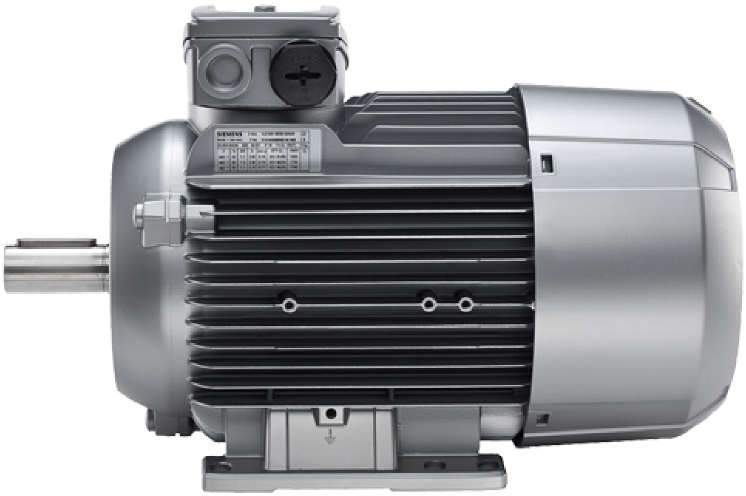
AC Motor Technology - The Rotating Magnetic Field

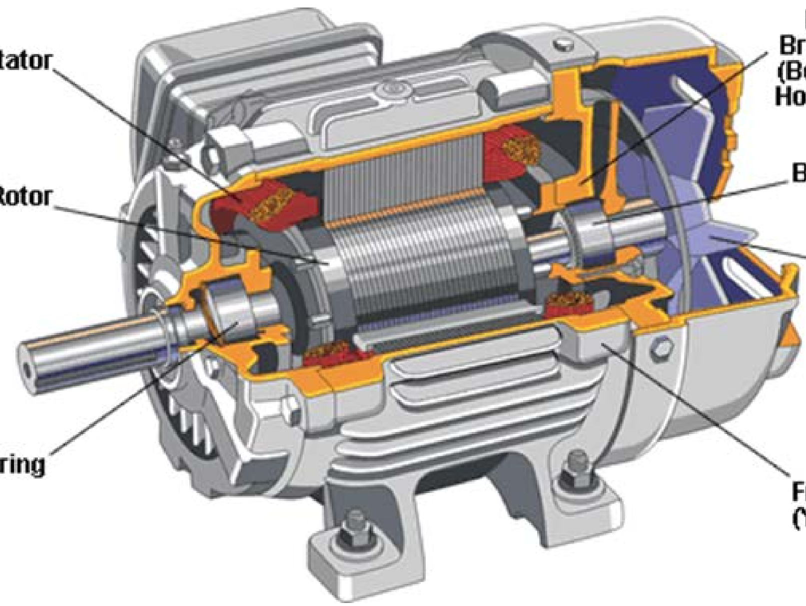


⇨The three-phase current generates a rotating magnetic field in the stator
⇨Current is induced in the rotor
⇨The current flows in a circle in the bars of the rotor
⇨A dynamic effect is produced as the current-carrying bars are in the magnetic field of the stator
⇨The rotor is pulled round, but rotates at a slower speed (=asynchronous)

AC Motor Technology – Asynchronous

The Asynchronous motor's rotor has a laminated frame, copper bar construction.

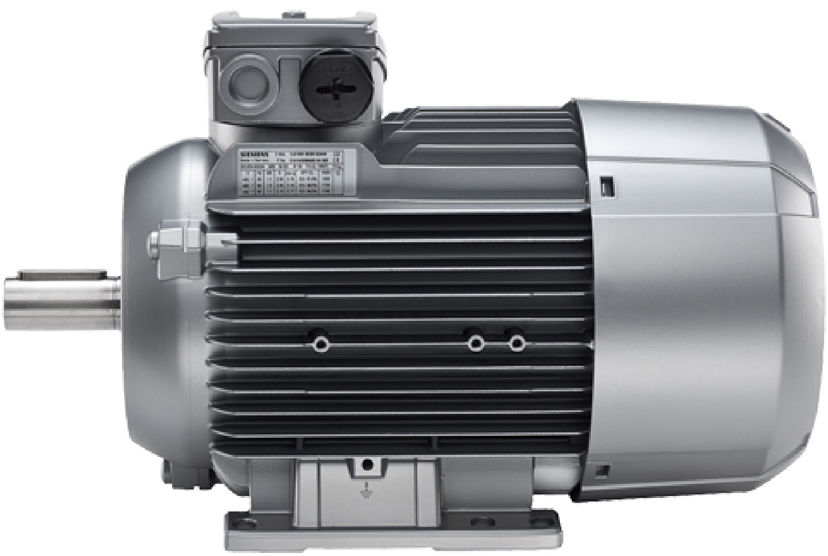




The rotors field is induced and under operation the rotor rotates at a slower (slip) speed than the stator’s field where it develops the optimum torque.

AC Motor Technology – Asynchronous Types

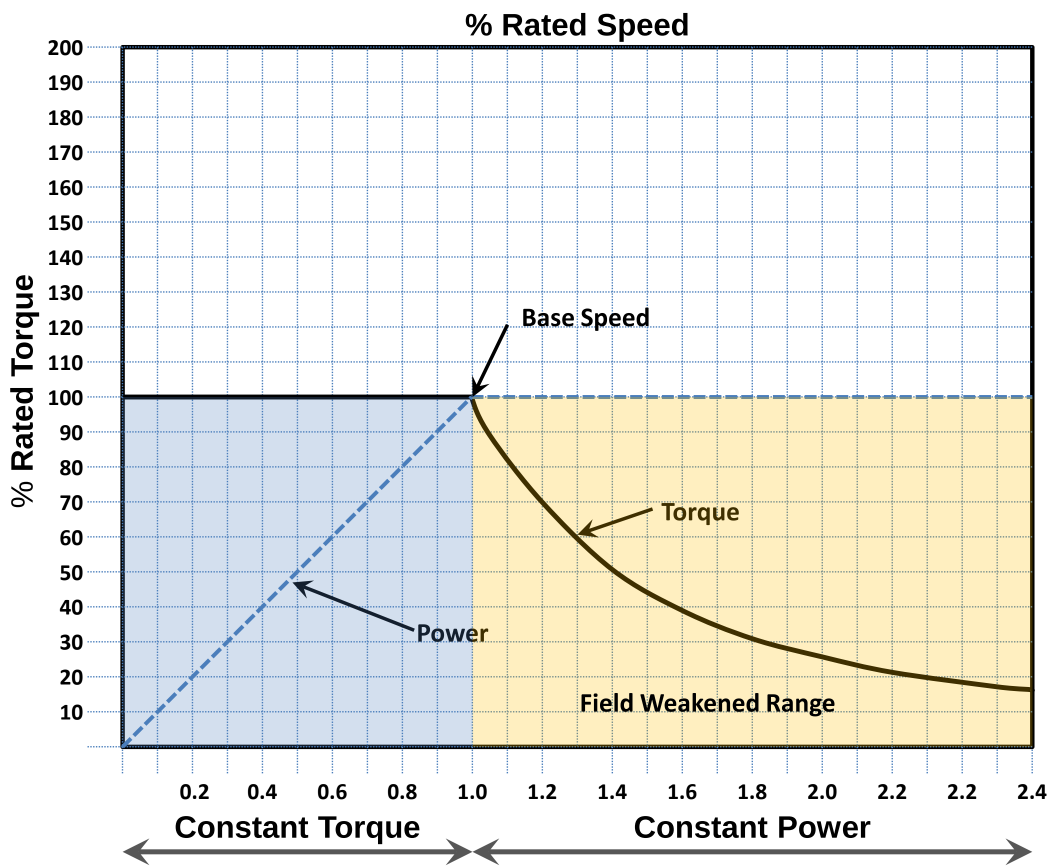
Standard Asynchronous
(NEMA / IEC)

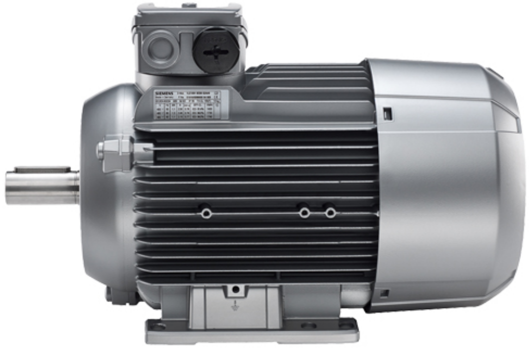


High Performance
Asynchronous

AC Motor Technology – Asynchronous Speed Torque

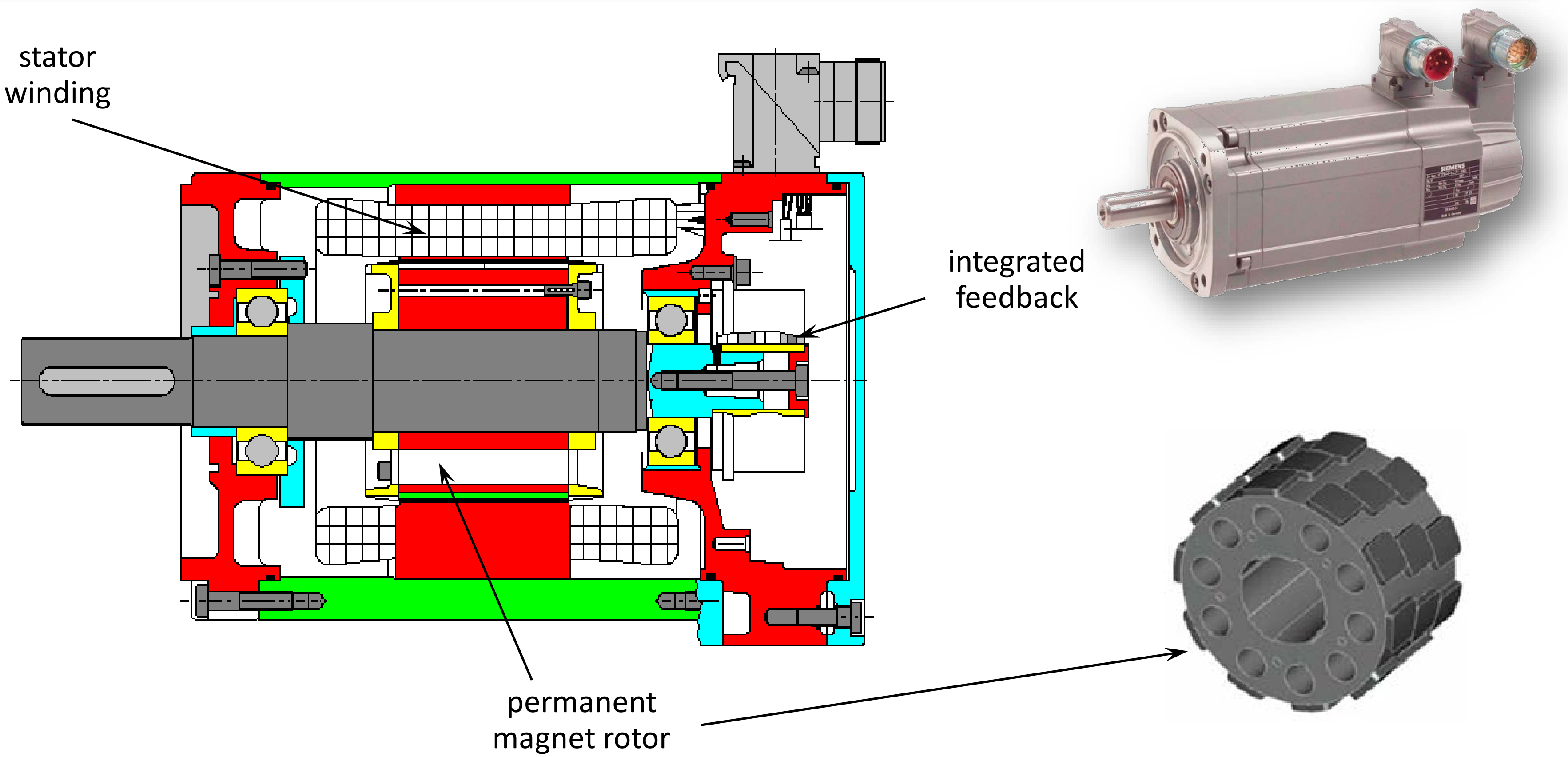
The asynchronous motor has a speed torque characteristic that provides constant torque up to the base speed and then a decreasing torque (at constant power) above the base speed.





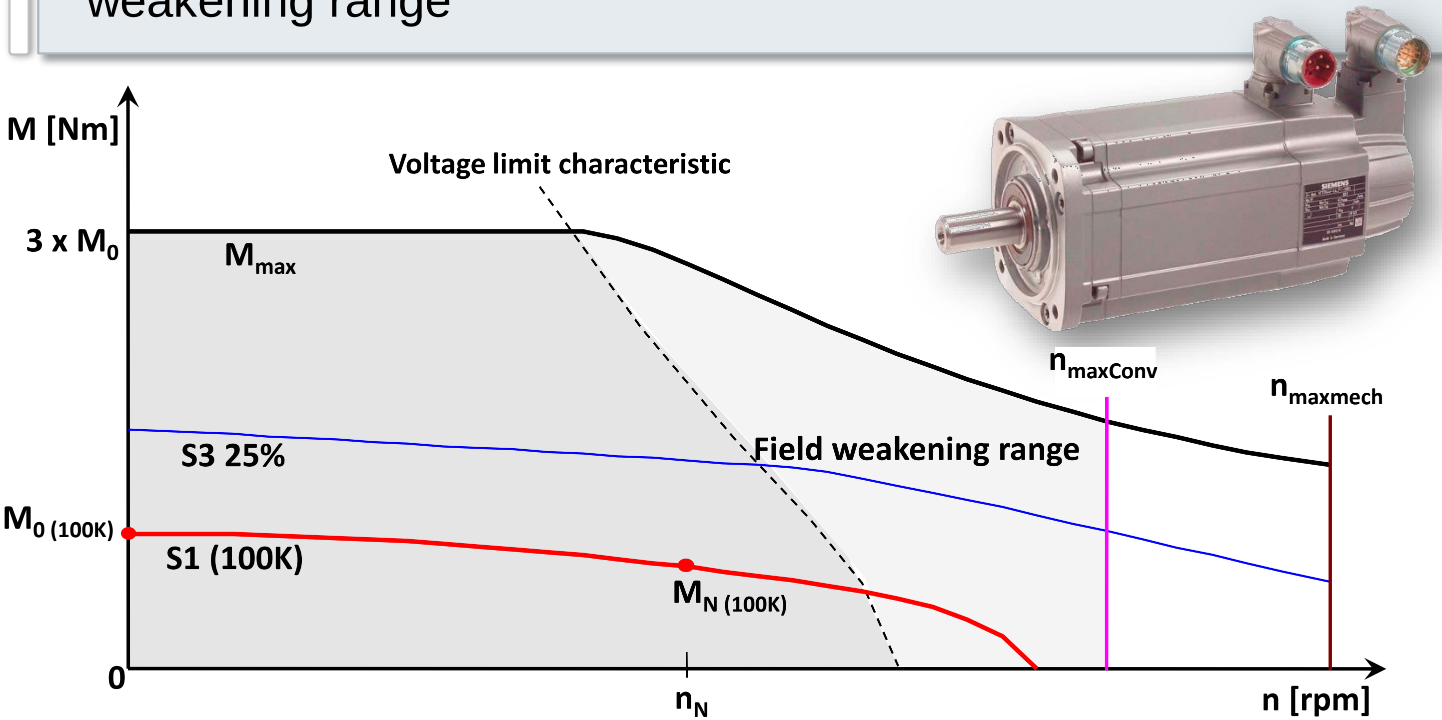
AC Motors

The synchronous motor's rotor is composed of permanent magnets and under operation rotates at the exact same rate as the stators field.



AC Motors

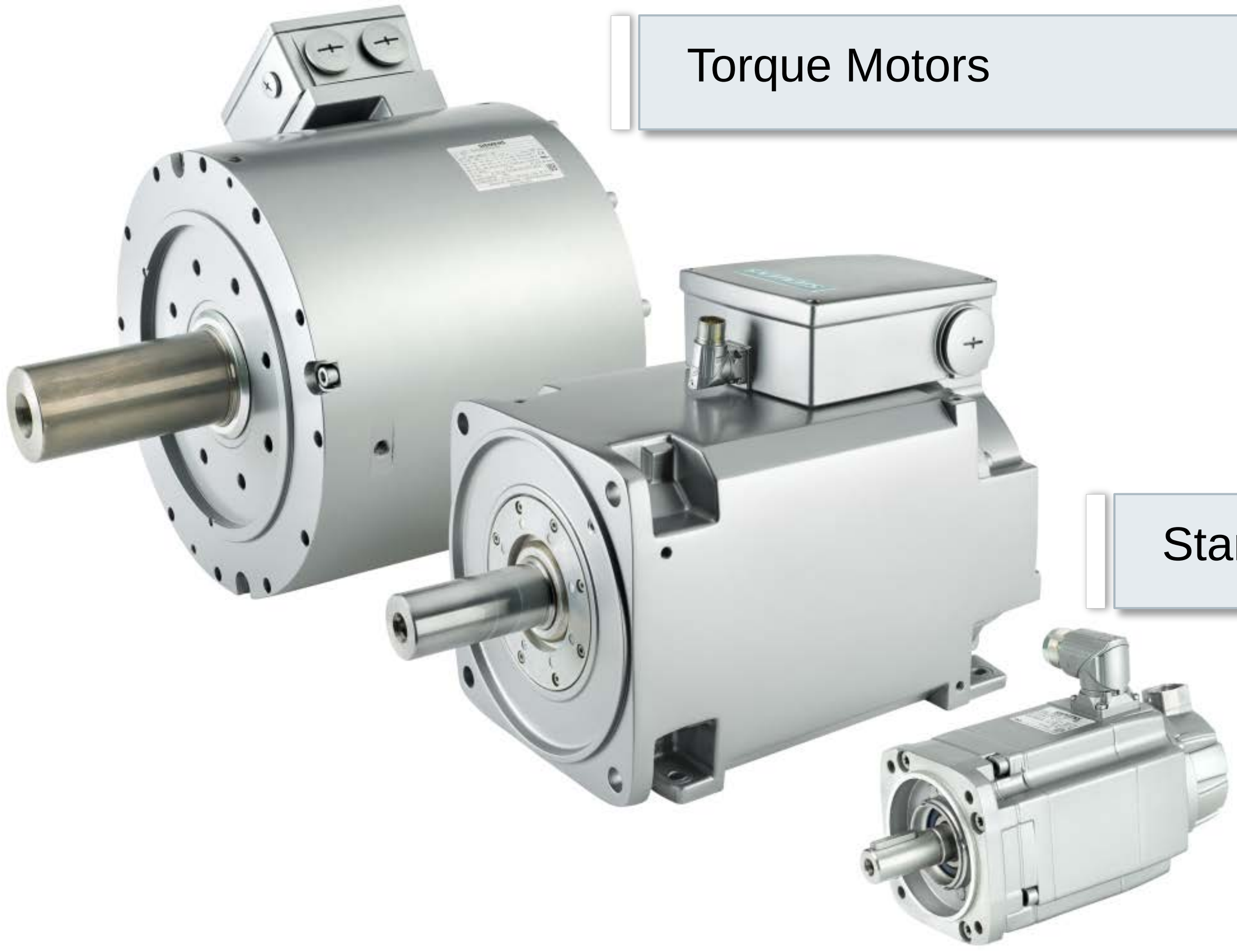
The synchronous motor has a speed torque characteristic in which the torque drops off linear through the base speed range, then at a faster rate in the field weakening range



n_N	Rated motor speed
M	Torque
M_0	Stall Torque
M_n	Rated Torque
M_{max}	Torque at I_{max}
S1	Continuous rating
S3	25% Duty Cycle

The ability of the synchronous motor to run in field wakening will depend on the capability of the drive.

AC Motor Technology – Synchronous Types



Torque Motors

Standard Synchronous

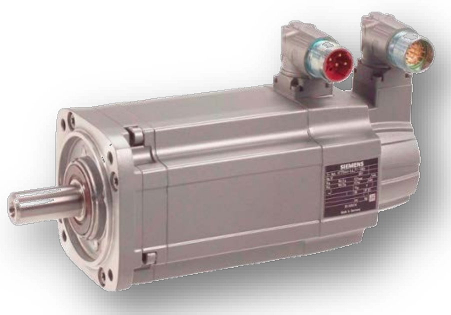
AC Motor Technology – Synchronous vs. Asynchronous

Asynchronous

Higher rotor inertia – Better disturbance rejection
Field weakening range true constant power
Lower cost / kW – Larger motors
Less Efficient

Synchronous

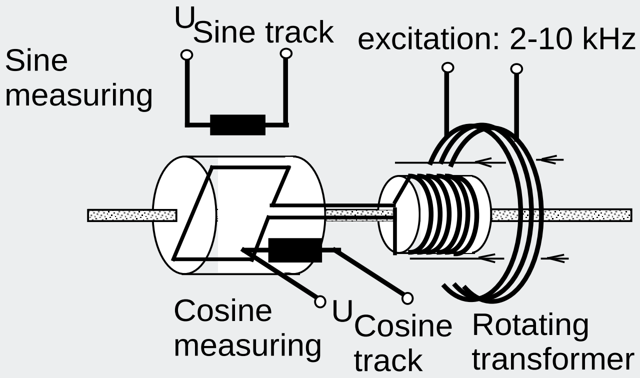
Lower rotor Inertia – Higher dynamics
More Efficient – Permanent magnetic rotor field
Smaller size / kW

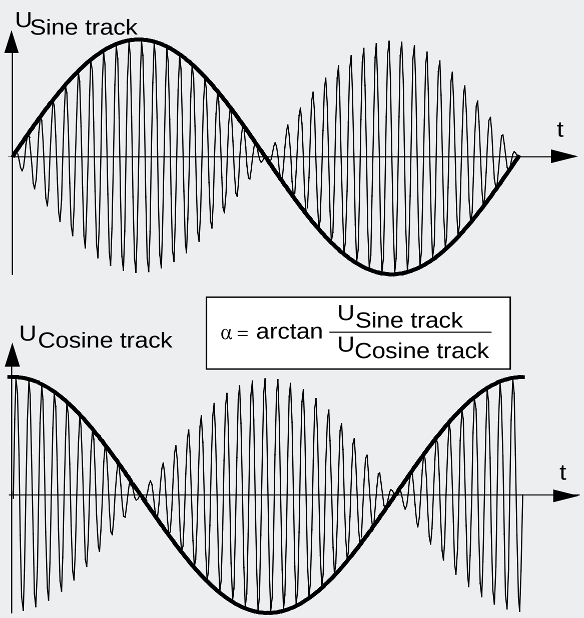


Feedback – Motor Encoder Types

Resolver	Incremental encoder	Absolute encoder single-turn	Absolute encoder multi-turn
			
• Outputs an angular position between 0° and 360° in the specified resolution • Supplies an absolute position value only within one revolution • **Low accuracy**	• Measures relative moments • No absolute position • Reference can be determined using the Zero pulse	• Outputs an angular position between 0° and 360° in the specified resolution • Supplies an absolute position value only within one revolution	• Outputs an absolute angular position between 0° and 360° in the specified resolution • Internal gearbox • 4096 resolutions can be detected • No reference point run necessary

Feedback Technology – Resolver





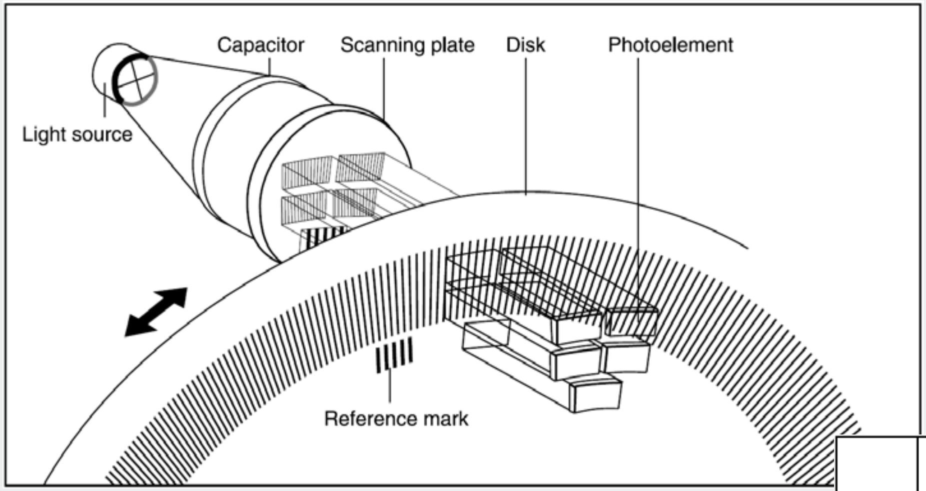
- Rotating transformer
- Evaluates envelope curve of output voltage
- Determines Rotor position by

$$\varphi = \arctan \frac{V_{Sine\ track}}{V_{Cosine\ track}}$$

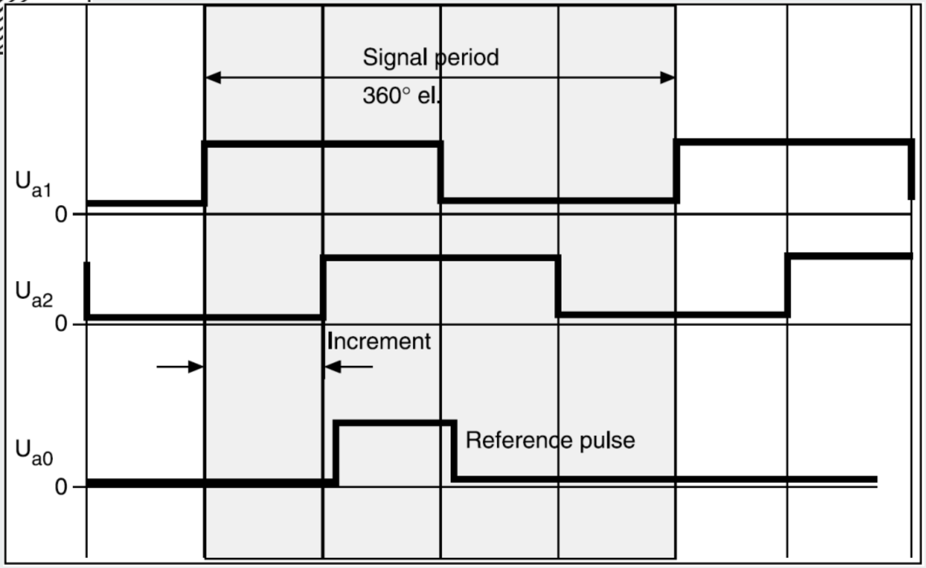
$$12' = \frac{12}{60'/1^\circ} = 0.2^\circ$$

- Accuracy: 0.2° (2 pole)
- Resolution 4096 ppr
- Absolute rotor position within one revolution
- Robust, inexpensive, poor accuracy

Feedback Technology – Rotary Pulse Encoder



Typical measuring signals:
1024 or 2048 pulses / revolution
➔ Typical resolution 4x using A,B track
4096 or 8192 pulses / revolution
➔ Accuracy: Approx. ±1‘ (angular minute)



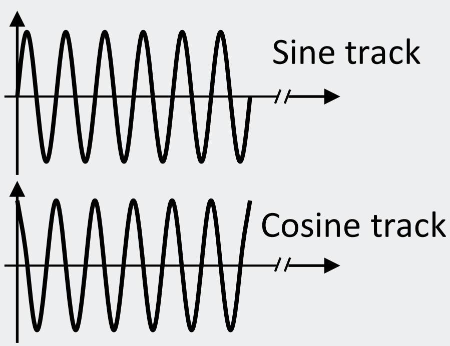
Supply voltage: +10...30V
Output signals: Squarewave pulse
Digital Reference pulse

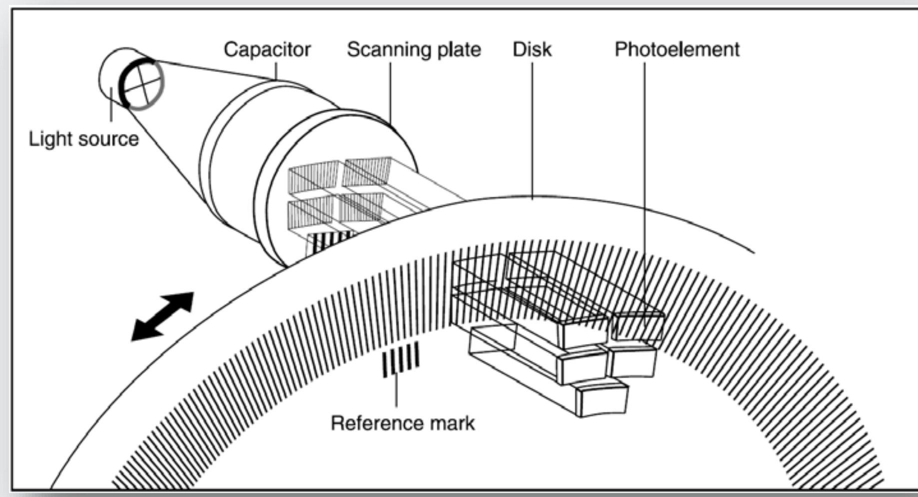
Limit frequency: 160 kHz

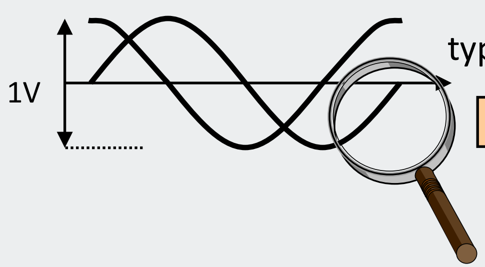
Rugged signals, long cable lengths
from 150 m - 300 m (with inversion)

Feedback Technology – Sin / Cos Pulse Encoder

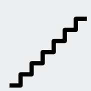
2048 periods
per revolution





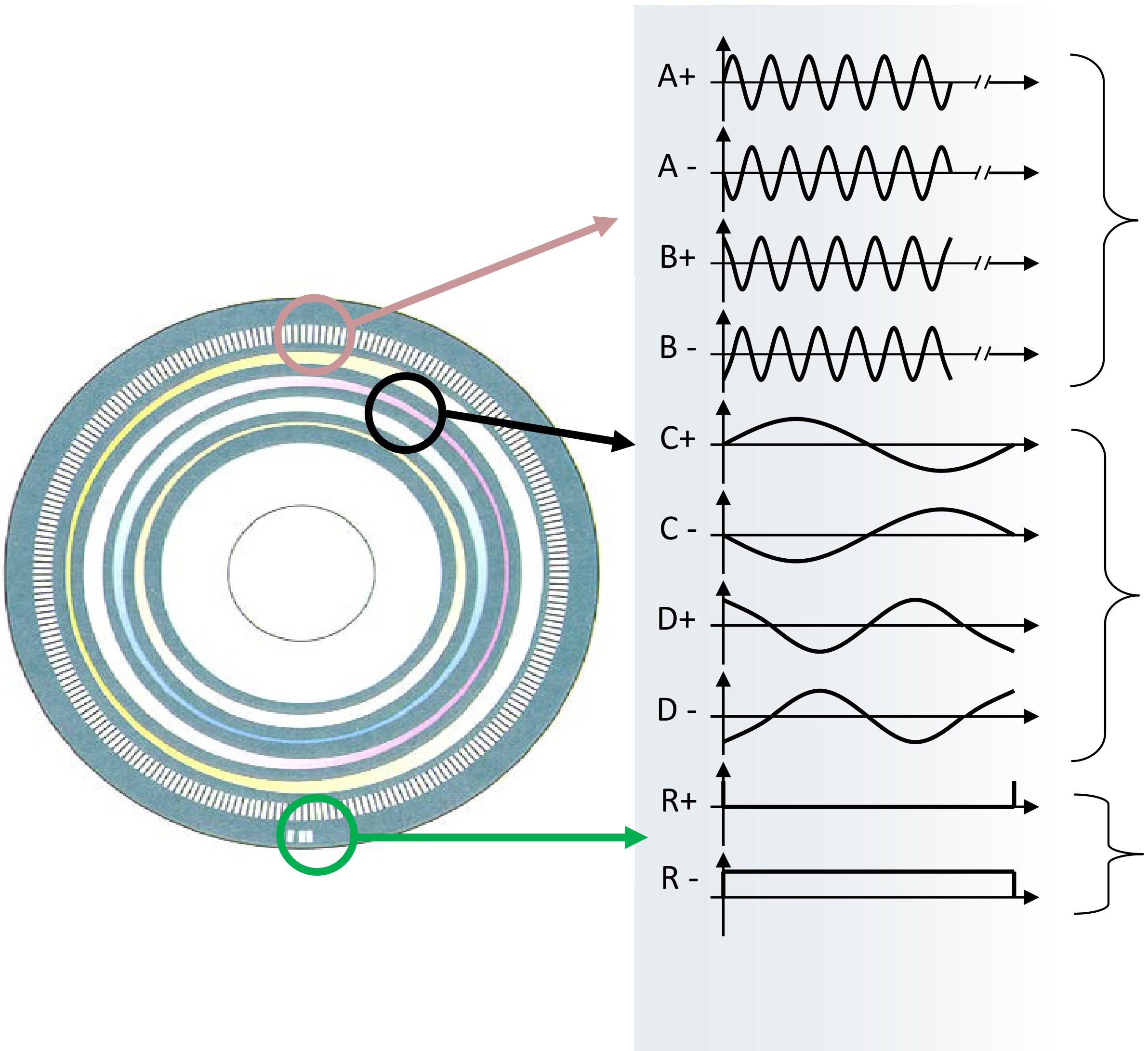


Fine resolution of the
analog signal with V_{pp} = 1V
using A/D conversion
typical: **2048** pulses per sine period



Typical resolution:
2048 x 2048 = 4.19 million PPR
Accuracy: approx. 40”
(angular seconds)

Feedback Technology – Sin / Cos Pulse Encoder

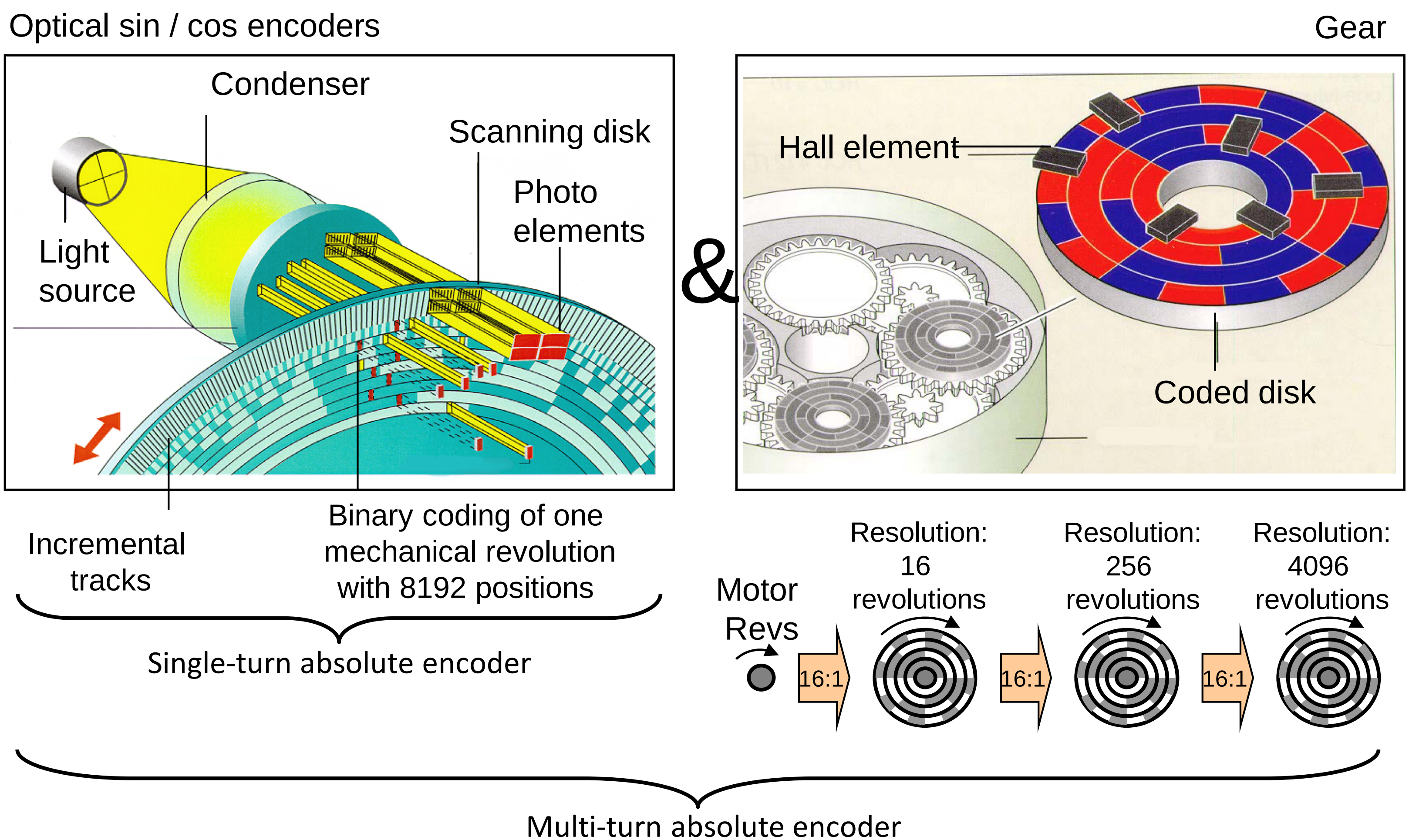


2048 Incremental signals per rev. for closed-loop speed control

1 Absolute signal per rev. for electronic commutation

1 Reference mark per rev. for homing

Sin / Cos multi-turn absolute encoder



Encoder Selection – Lowest Regulated Speeds

The higher the resolution of the motor feedback sensor, the lower the speed that the drive system can effectively regulate.

As a conservative rule of thumb, consider the following minimum regulated speed for these encoder types.

Encoder Type	Usable Resolution	Minimum Regulated Speed	
Resolver (16 Bit)	1024ppr	20.00	RPM
1024 Pulse HTL (Square Wave)	4096ppr	10.00	RPM
2048 Pulse HTL (Square Wave)	8192ppr	5.00	RPM
2048 Pulse SIN/COS Encoder (22 Bit)	4.19M ppr	0.250	RPM
8192 Pulse SIN/COS Encoder (24 Bit)	16.4M ppr	0.125	RPM

AC Drive Technology

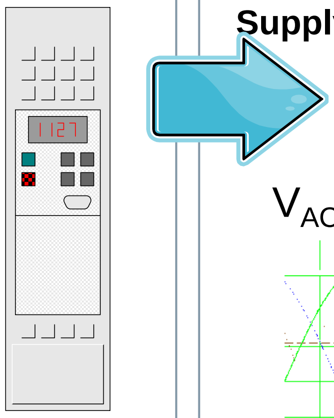
Drive Systems

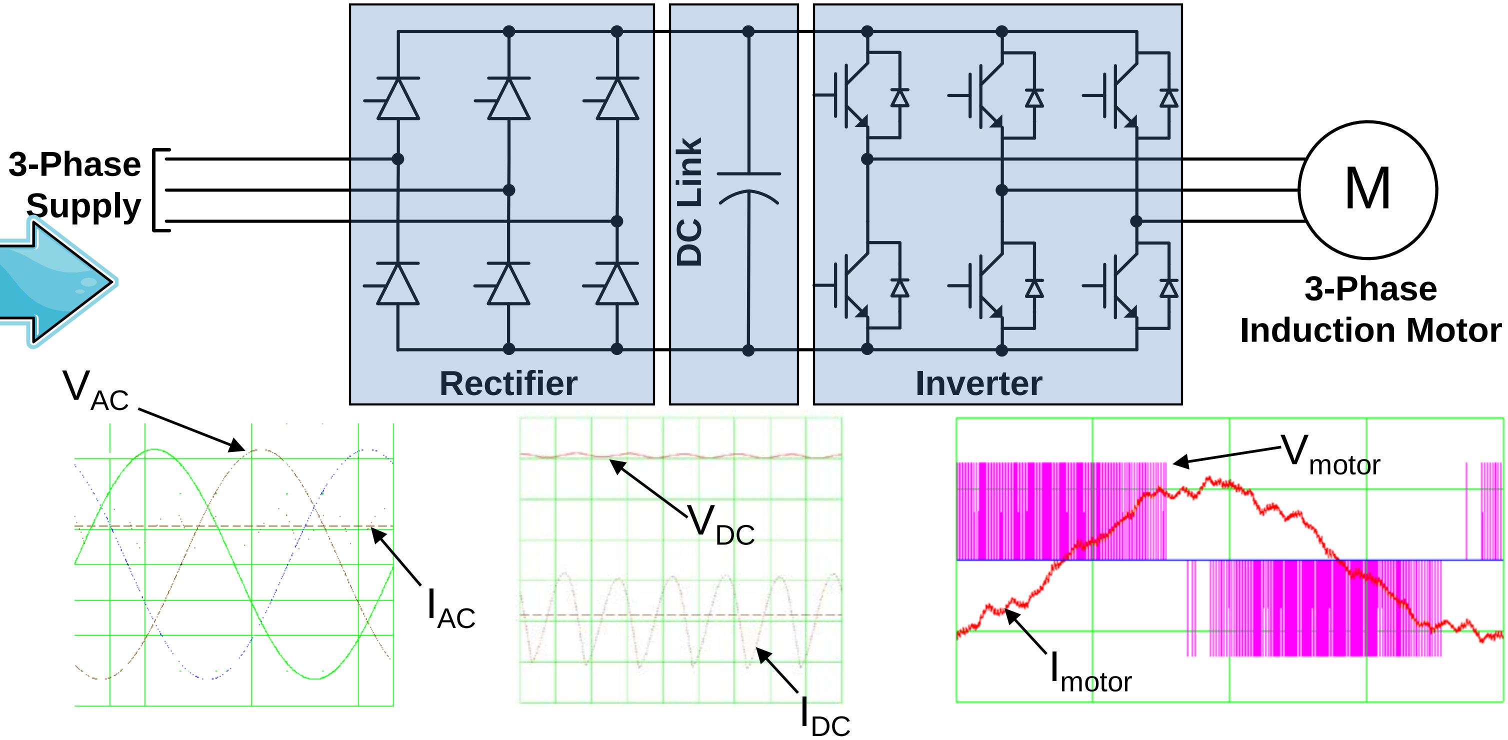
AC Motors

AC Drives

Stand Alone (AC / AC) Drive Overview

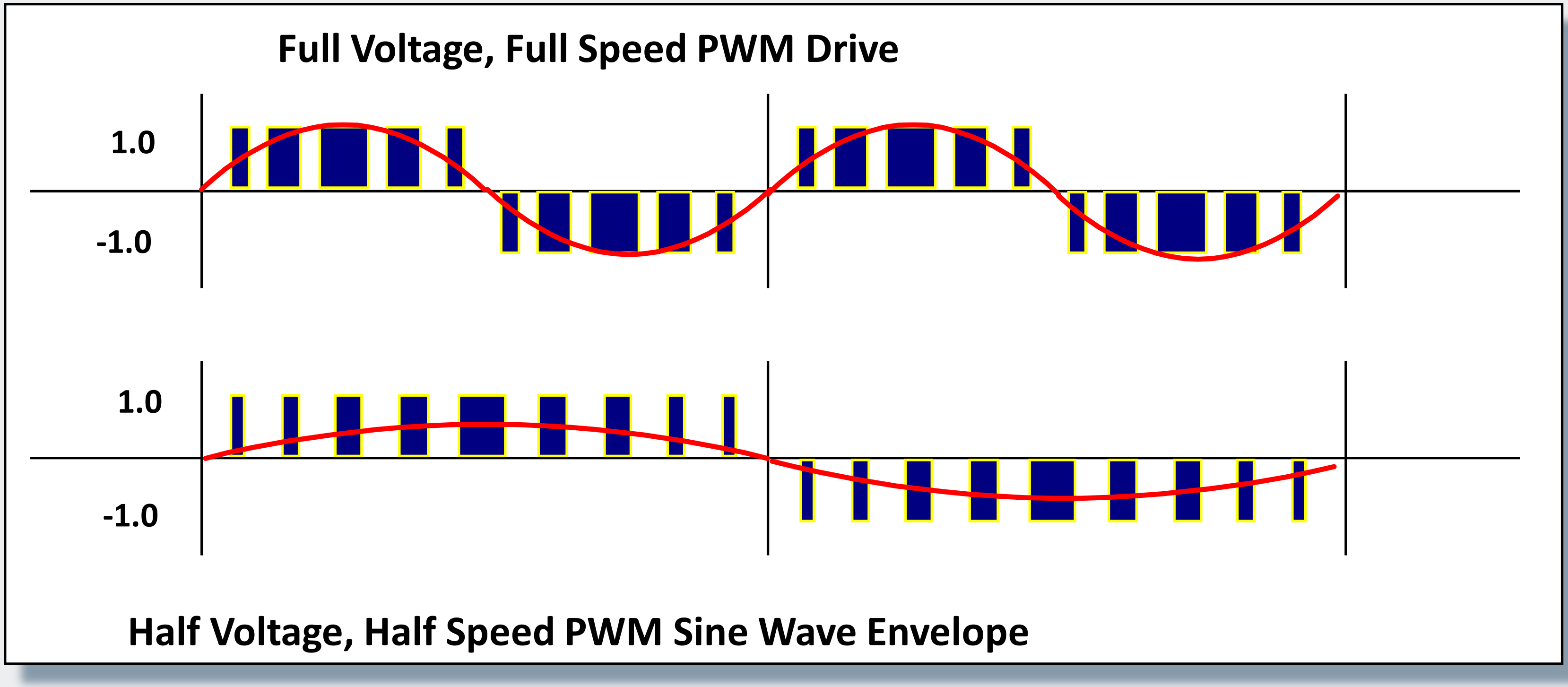
The Pulse Width Modulated **AC / AC** drive is made up of three sections.



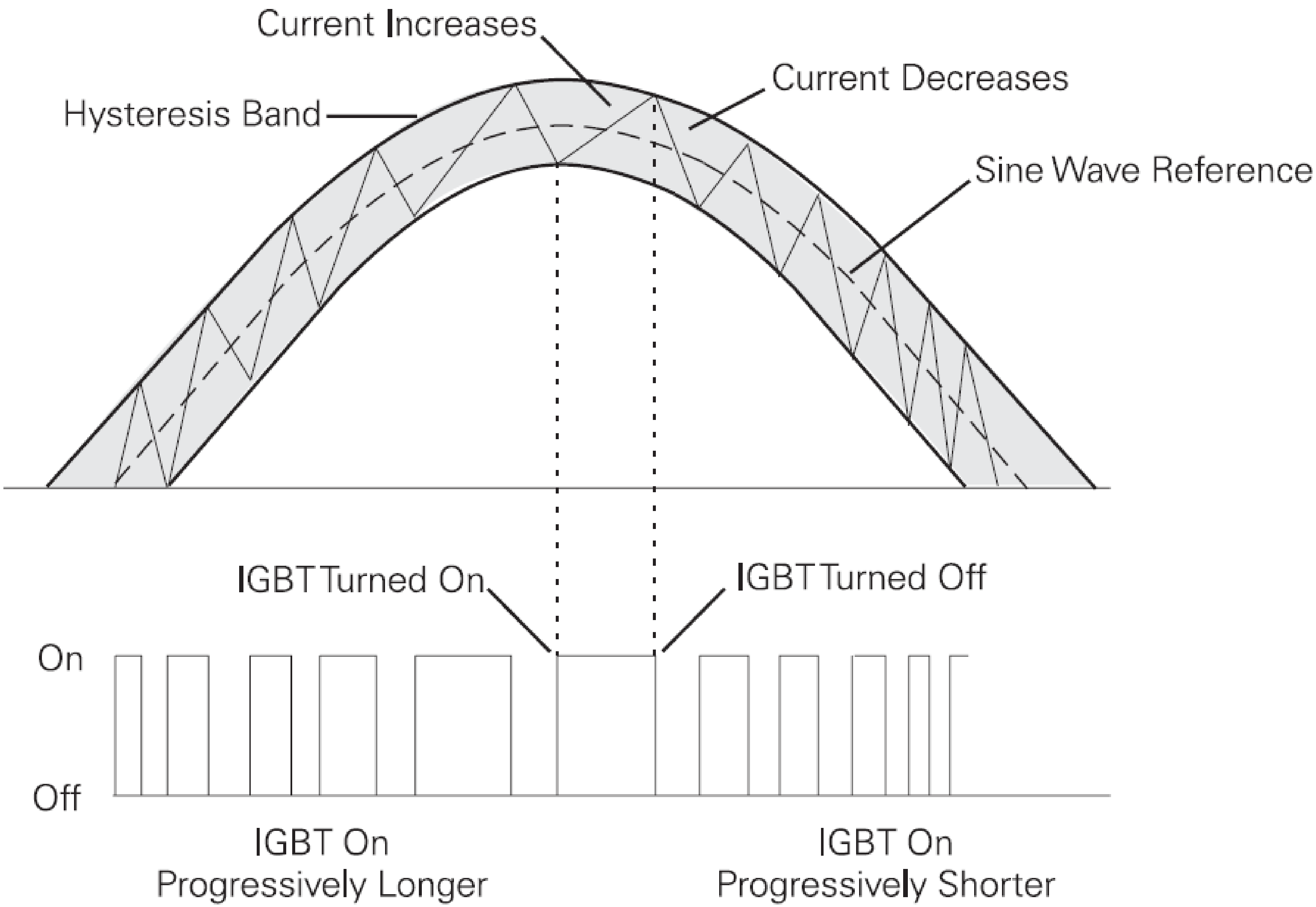


The inverter section which pulses the DC voltage into a three phase PWM output variable in voltage and frequency.

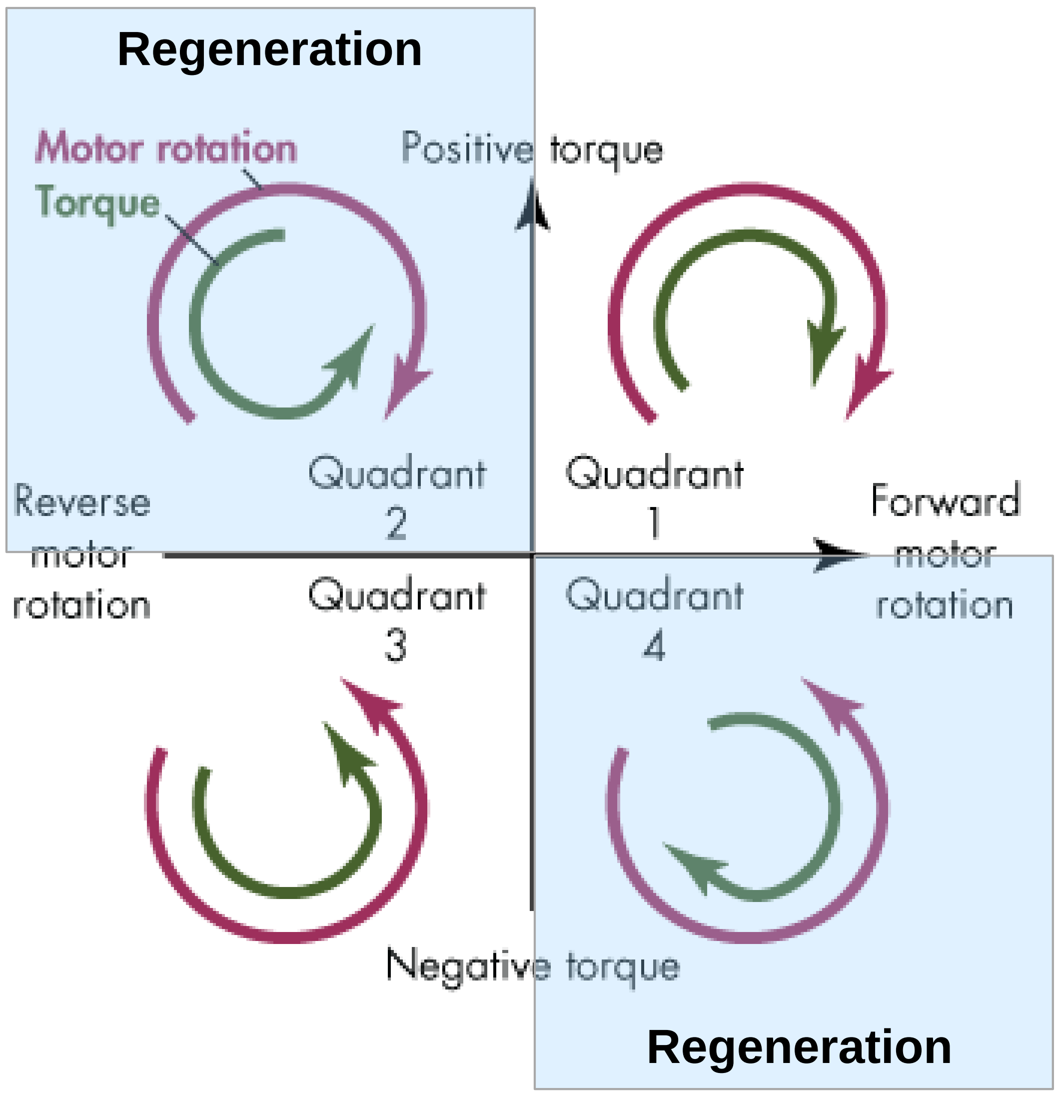
Pulse Width Modulation (PWM)



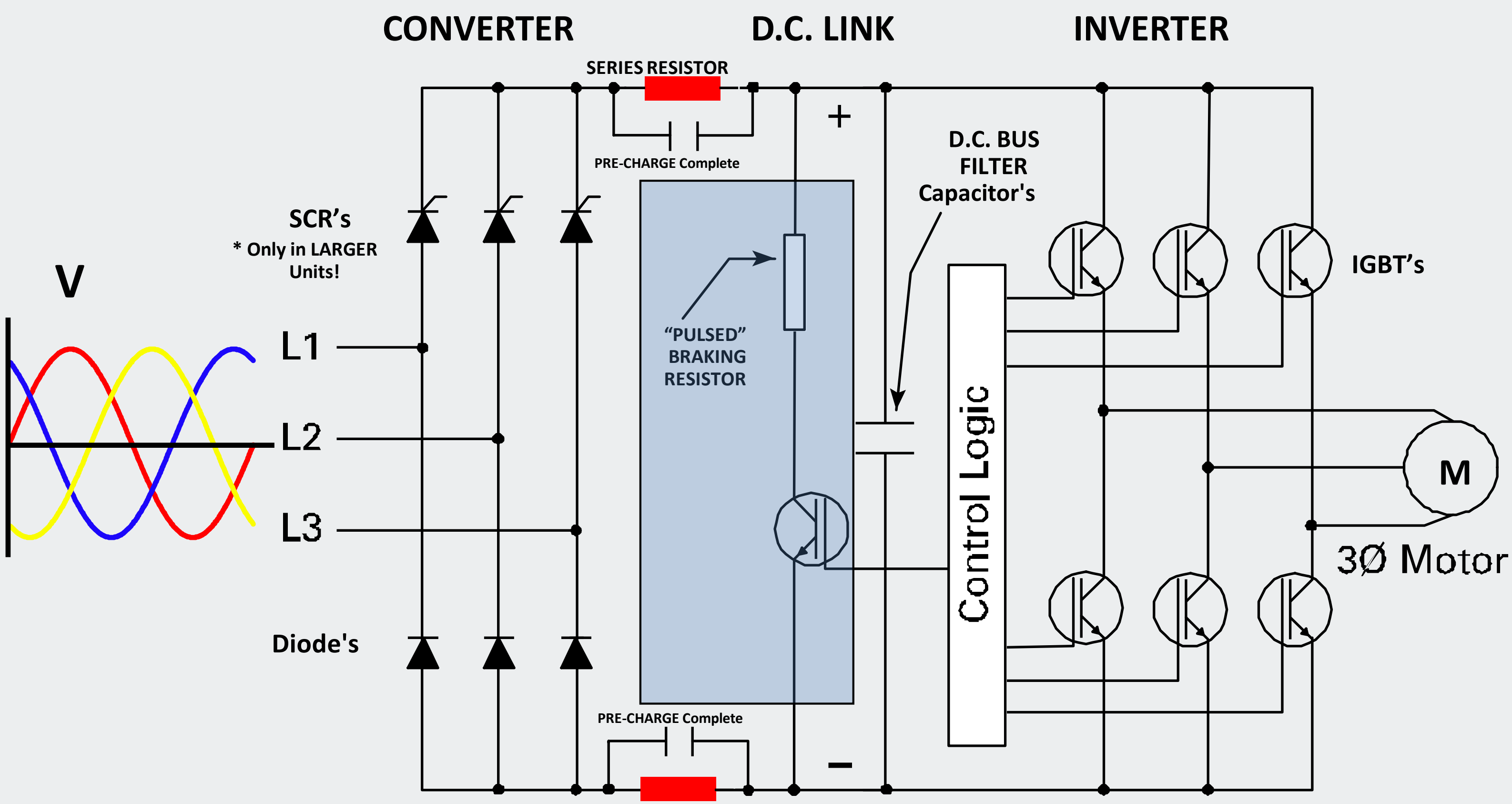
Pulse Width Modulation (PWM)



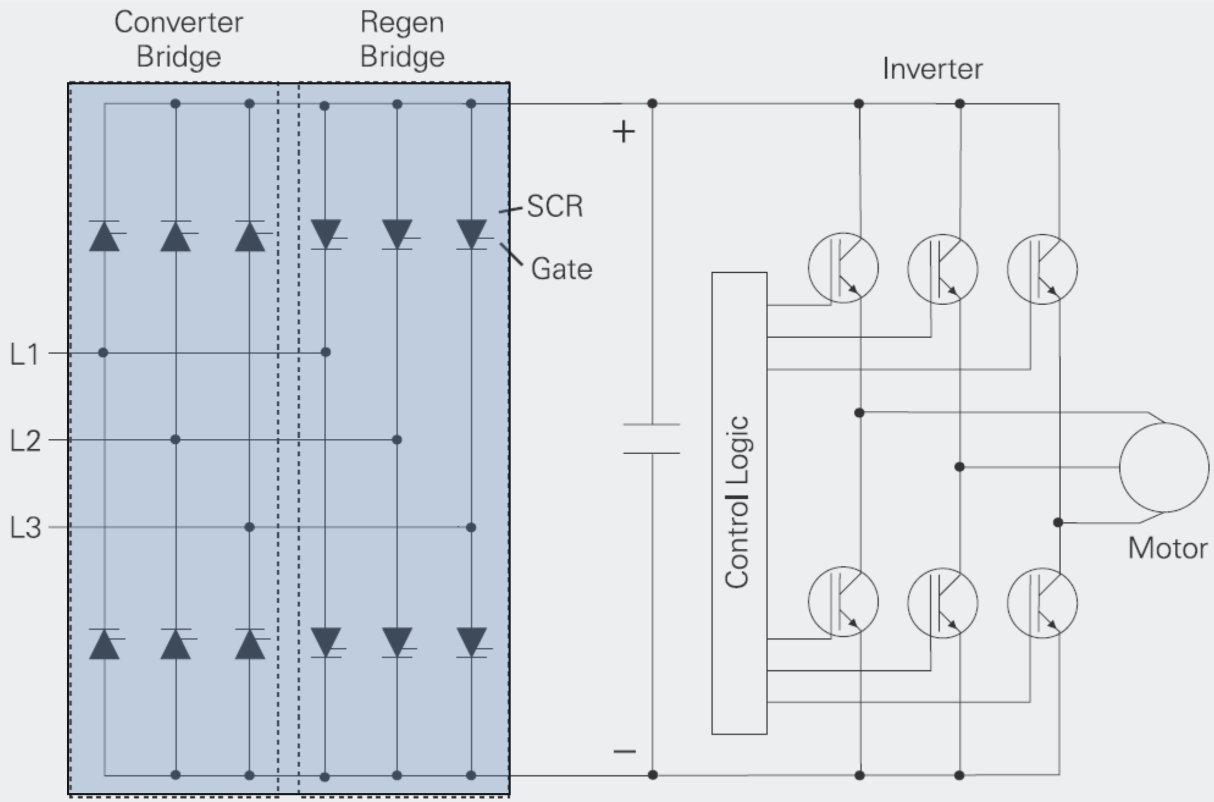
Regeneration – Bus Voltage



Regenerative Energy – Braking Resistors

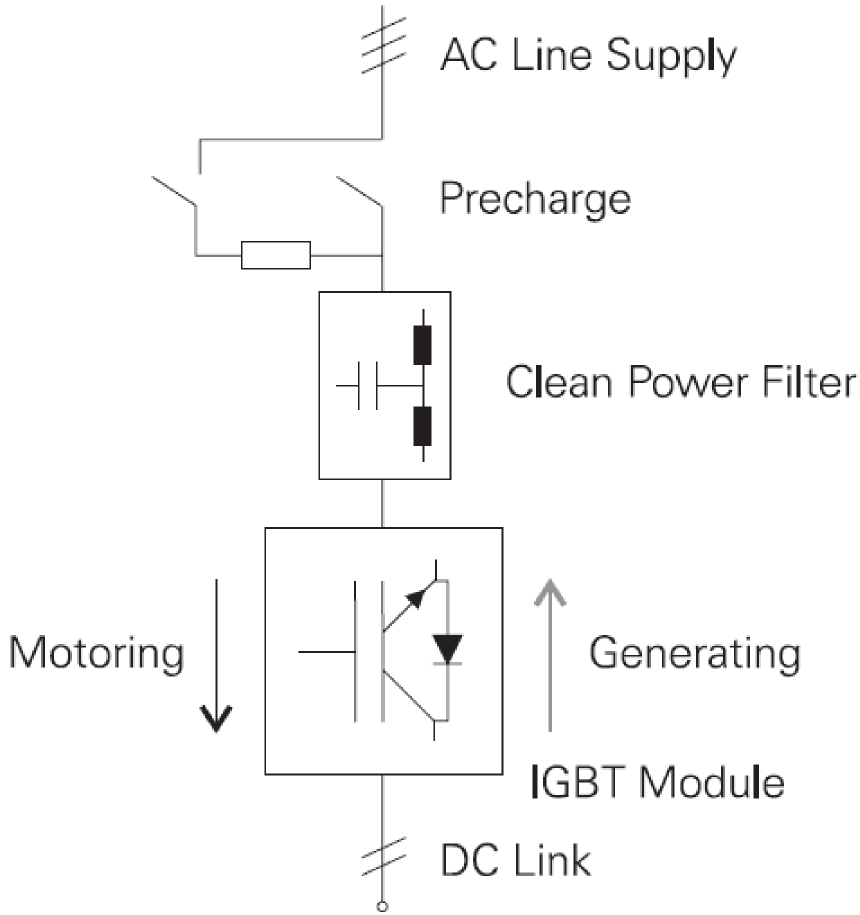


Regenerative Energy – Regenerative Converter Section



When the DC link voltage reaches a predetermined level the motoring SCRs are switched off and the regen (generating) SCRs are switched on. This allows the excess energy to be returned to the AC line in the form of AC current.

Active Front End Technology (AFE)



An Active Front End (AFE) is another option to control regenerative voltage.

The diodes in the converter bridge are replaced with IGBT modules and a Clean Power Filter.

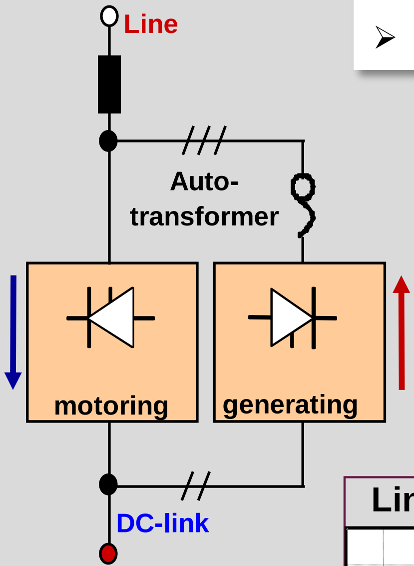
The DC Link (Bus) is regulated.

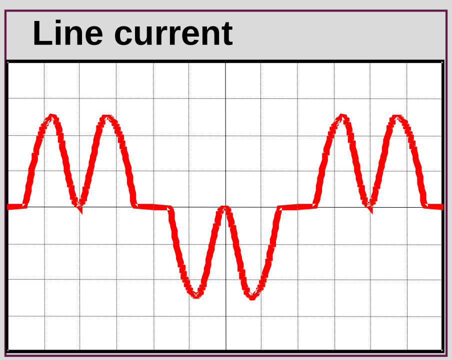
The AFE provides low stressing of the line supply. Harmonics are extremely low and the power returned is in the form of sinusoidal current.

Regen (SCR) vs. Active Front End (AFE)

Diode / SCR Bridge

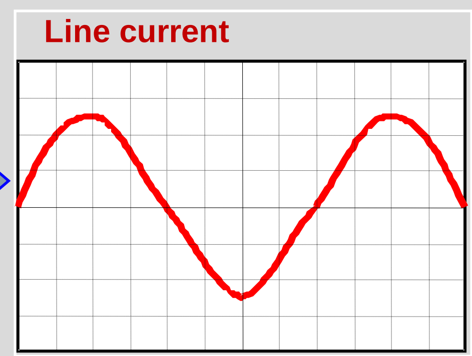
- Stresses Supplies
- Restricts Performance

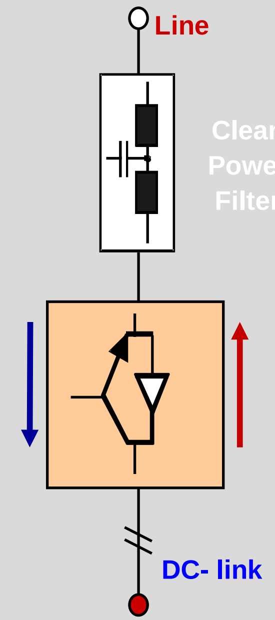




Active Front End (AFE)

- Free of harmonics
- Improves Performance

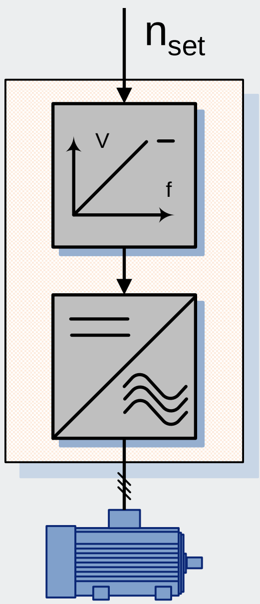




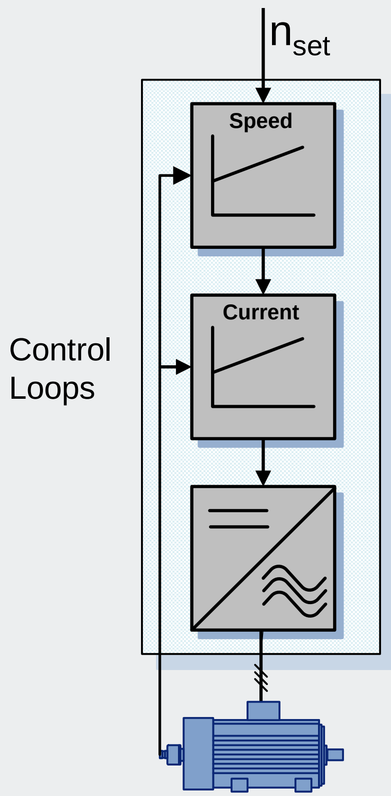
Regulated

Drive Technology – Control Modes

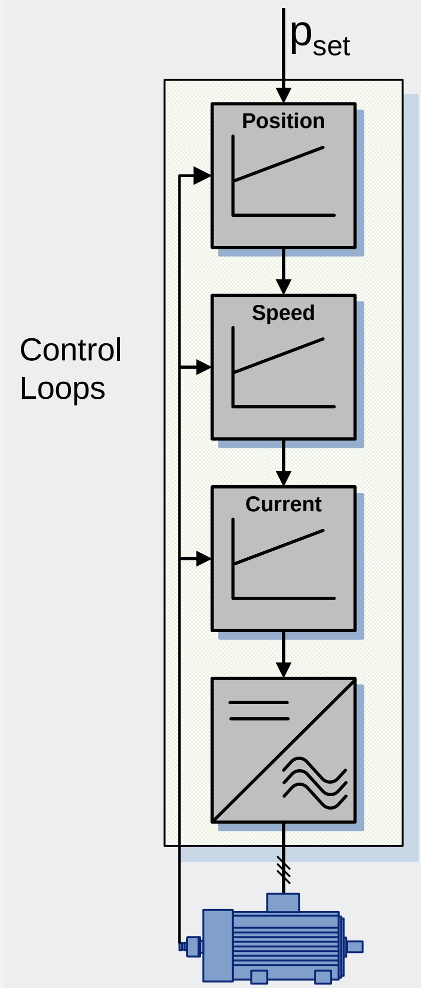
V/f Control



Vector

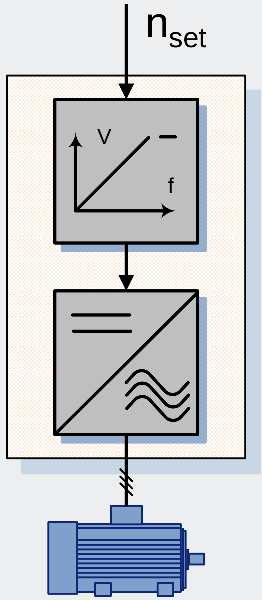


Servo



Drive Technology – V/f Control Mode

V/f Control



Basic Speed Control
No Encoder Feedback

Advantages

- Simplicity
- Low cost

Disadvantages

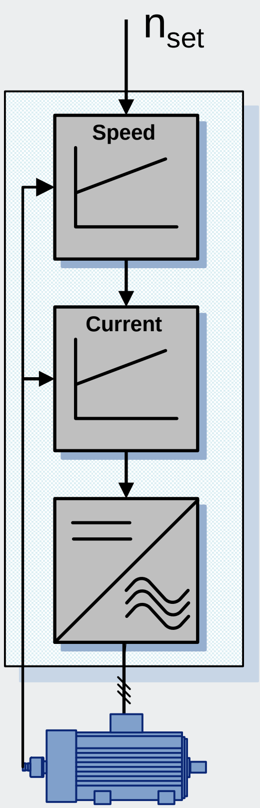
- Low Performance
- Low starting torque
- Narrow Speed Range

Applications

Pumps & Fans

Drive Technology – Vector Control Mode

Vector



Uses Encoder feedback (most encoder options)
Open loop Vector possible

Advantages

- Good Dynamic Response
- High Speed Range
- High current control accuracy
- Full Torque @ Zero Speed
- Common DC Bus Systems
- Active Front End (AFE) options

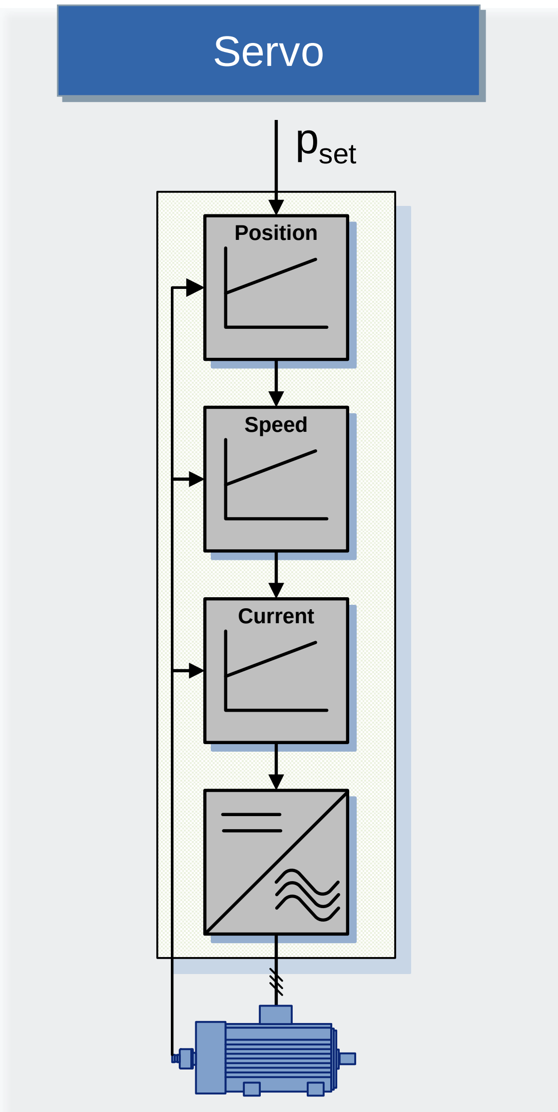
Disadvantages

Does not have the dynamic range of Servo mode
- Camming

Applications

Most continuous drive applications including some positioning and gearing

Drive Technology – Servo Control Mode



Requires Encoder feedback (uses all encoder options)

Advantages

- Highest Dynamic Response
- Widest Speed Range
- Highest Efficiency, (motor & controller)
- Induction or Synchronous
- Common DC Bus Systems
- Future trends, Innovations
- Active Front End (AFE)

Disadvantages

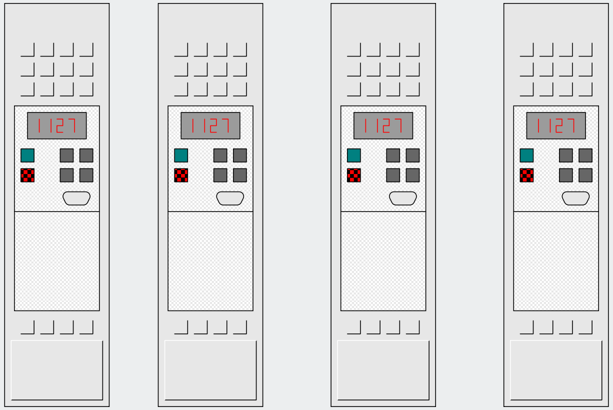
Complexity

Applications

Continuous drive applications, positioning, gearing and camming

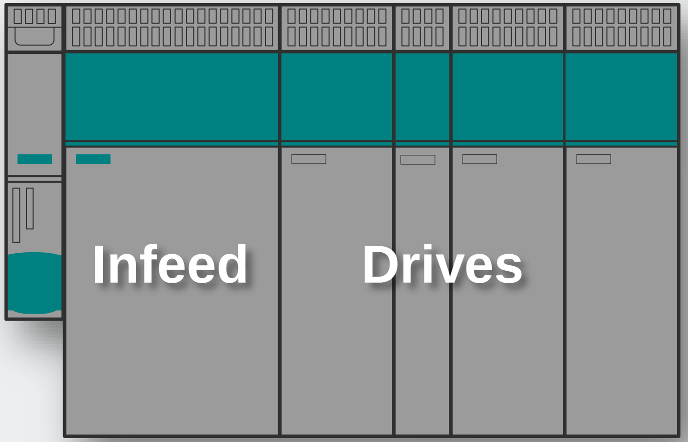
Single AC/AC vs. Common DC Bus

AC/AC



- vs. -

Common DC Bus



Reduced Component Count

- Fewer Contactors, Electronic Brakes, Fuses, etc.

Reduced Space

- Smaller enclosure size compared to converters

Reduced Power Consumption

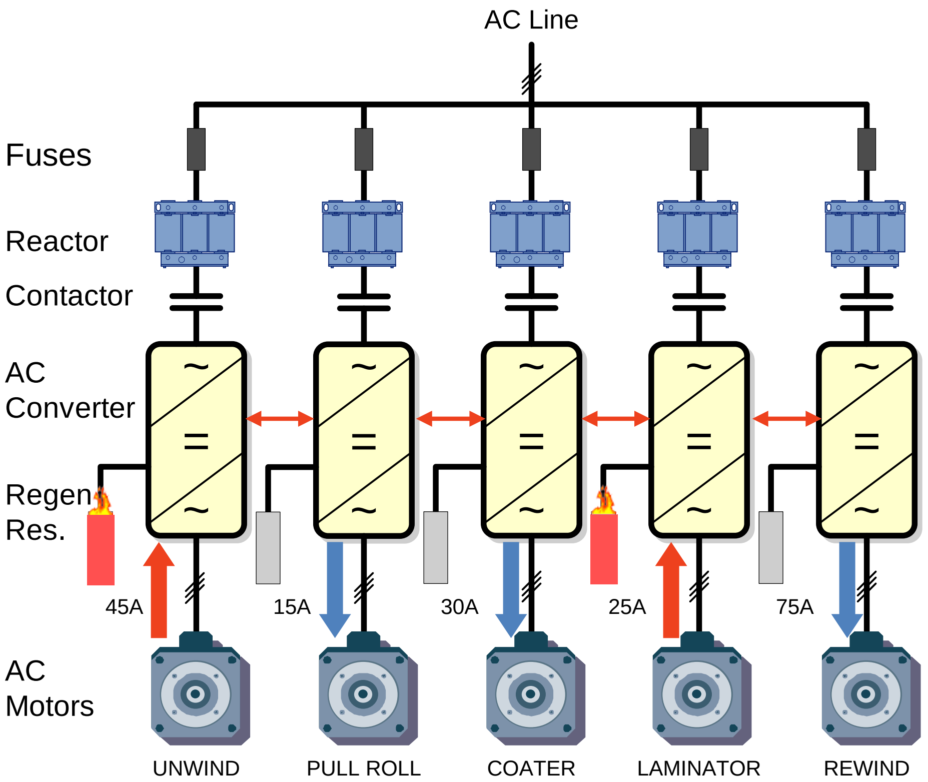
- Generated Power Back to the DC Bus
- Allow Use of the Infeed options including Active Front End

Single AC/AC vs. Common DC Bus

Example configuration of AC / AC drives in a multi-axes coordinated drive system.

Each drive must have individual line components (fuses, reactors, contactors).

Each drive section individually regulates it's own regenerative power.

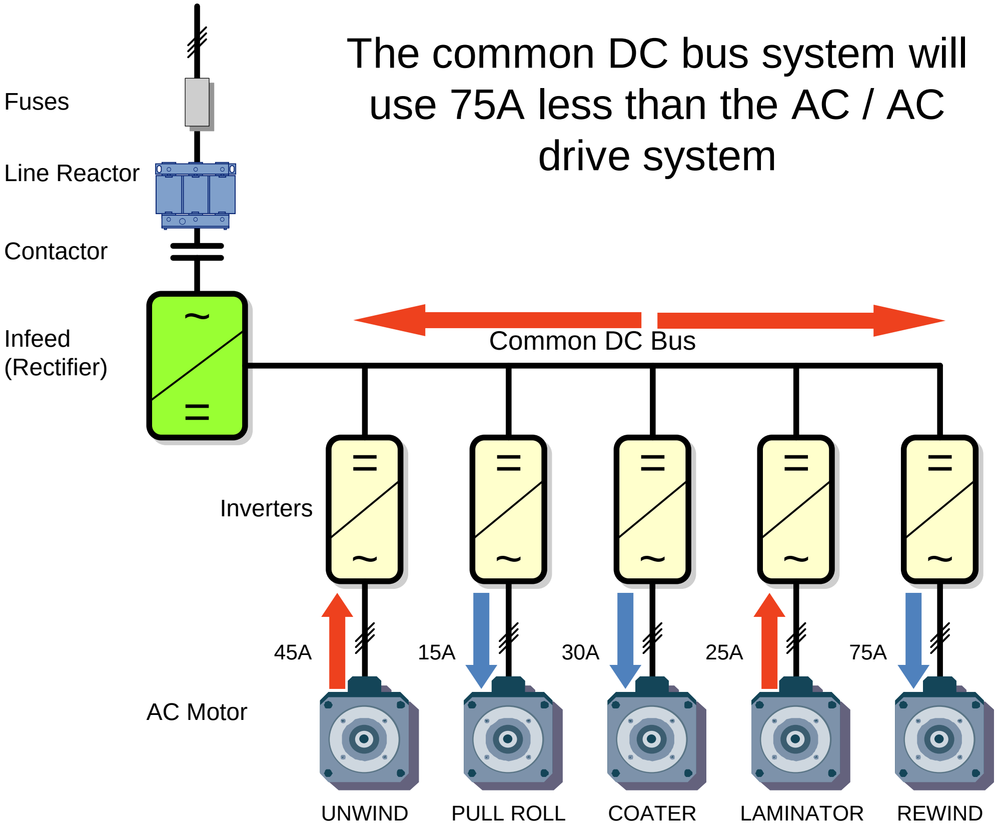


A Pseudo-Common DC bus can be created by wiring the external bus connections together. The current carrying capability of the bus connections do not always match the drive power rating. Precautions also must be taken to prevent the smaller drives from charging the larger drives.

Single AC/AC vs. Common DC Bus

The same drive line-up with a common DC bus architecture

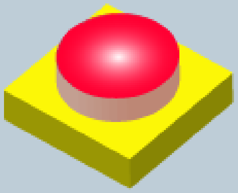
The common DC bus design, uses a single infeed section that converts the AC power supply into a DC bus common to all motor modules



The common DC bus system will use 75A less than the AC / AC drive system

The line components (i.e. contactor, reactor, fuses,) and Infeed can be sized based for the maximum current draw, system not the summation of the individual axes. Results: A much more efficient design.

Integrated Drive Safety



Functions to Stop a Drive	Abbr.	Description
Safe Torque Off	STO	Torque is safely switched off
Safe Stop 1	SS1	Active braking, the STO
Safe Stop 2	SS2	Active braking, the SOS

Motion monitoring Functions	Abbr.	Description
Safe Direction	SDI	Safe direction of rotation
Safe Limited Speed	SLS	Speed is safely limited
Safe Stop 2	SSM	Signal if speed falls below a limit
Safe Brake Control	SBC	Braking is safely controlled

Position Monitoring Functions	Abbr.	Description
Safe Limited Position	SLP	Traversing range is safely limited
Safe Cam	SCA	Safe software output cams
Safe operating Stop	SOS	Drive position is safely monitored

Conclusions

- Choices
- Motors
- DC Common Bus Architecture
- Integrated Drive Safety

Thank You - Questions

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