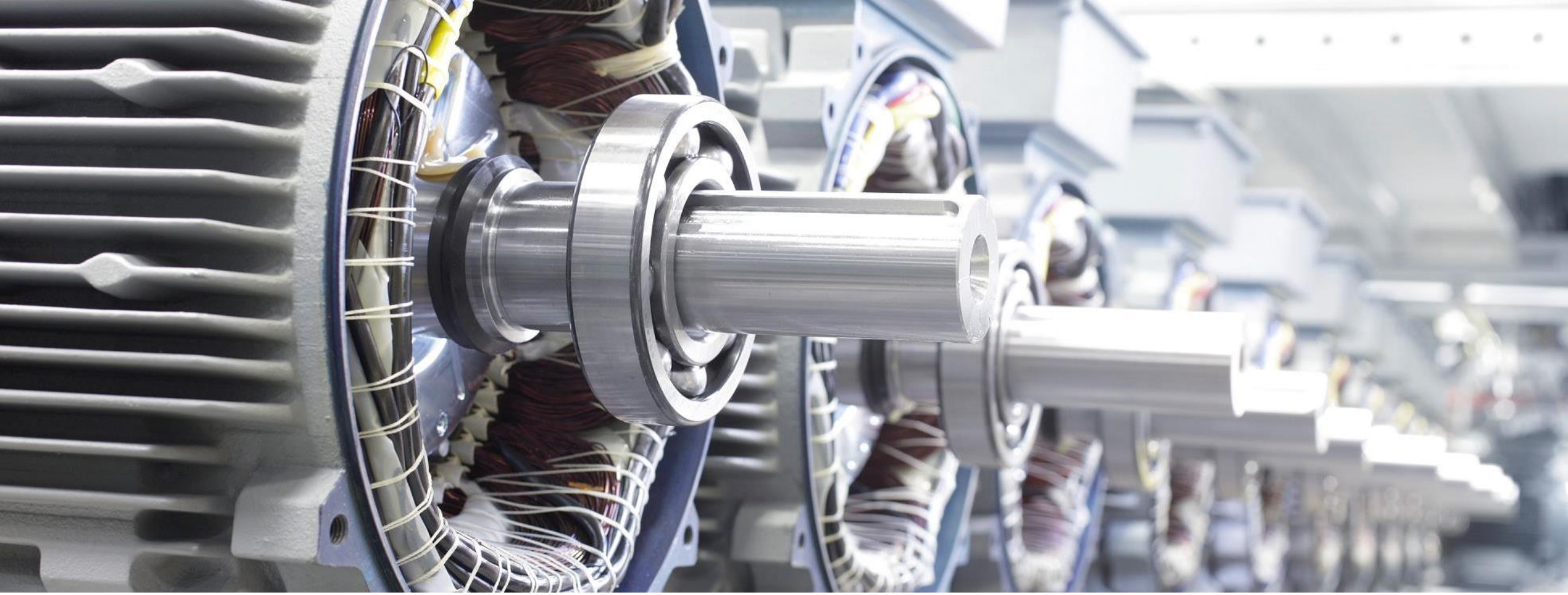


10TH DECEMBER 2021

IEC Low voltage motors

VFD Applications & Motor Technologies

Lokesh B M ,R&D Hub Manager ,LV Motors, India

Contents

- Motor performance characteristics
- Why VFD duty motor?
- Check list for VSD duty motors
- Type of loads
- Loadablity Curves for VFD duty motor
- VSD Efficiency & savings
- Problems to prevent when using VSD
- Pay special attention
- Learnings
- Energy Efficiency
- Case Studies

Motor performance characteristics

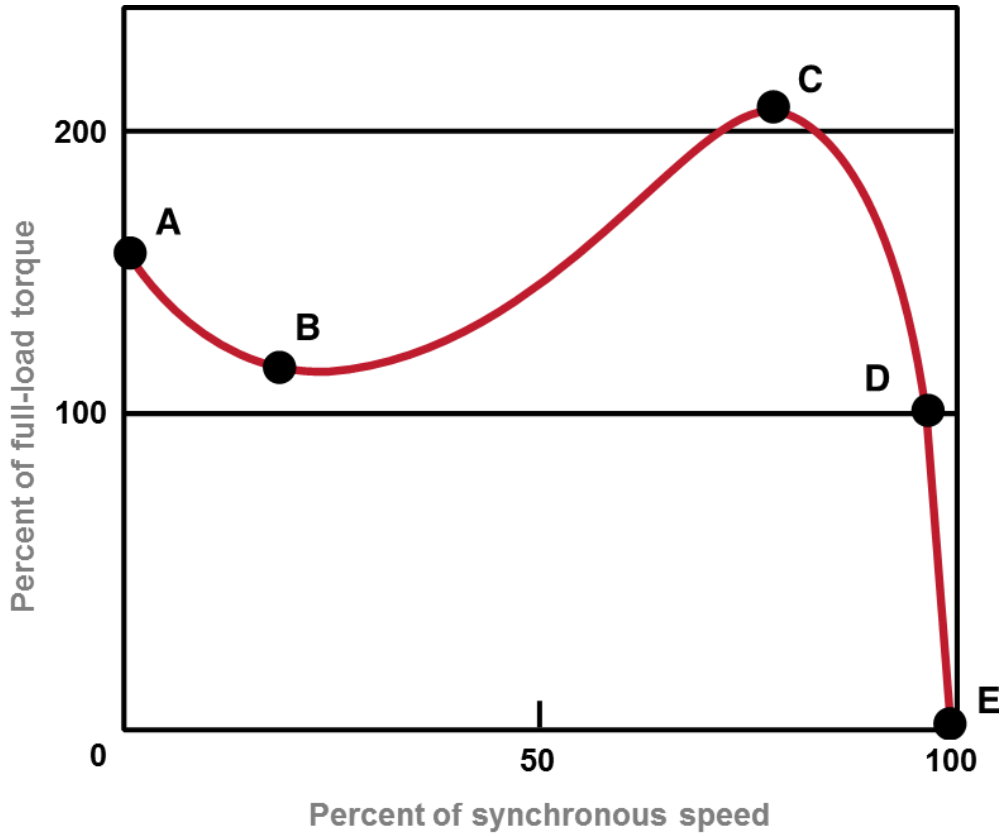
A – Locked rotor torque
(starting torque)

B – Pull-up torque

C – Breakdown torque

D – Full load torque

E – Synchronous speed



Selection criteria for Induction motors for VFD applications

Converter Drive – Why?

If we want to change the motor speed it can be done using Frequency Converters

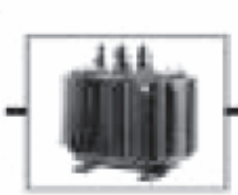
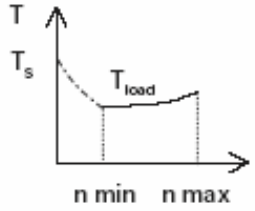
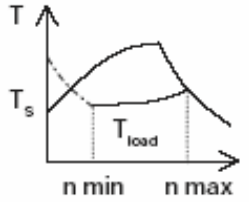
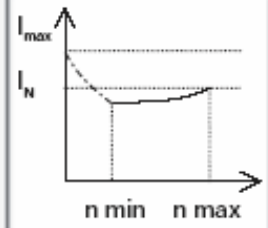
The main reasons are :

Changing the speed to meet process demand or energy savings.

however other advantages are:

- Reducing equipment in the system
- To get a “Soft Start” & lower starting current
- long service life for mechanical components
- Best quality of the finished products due to precise control
- Increases the efficiency of overall process & system

Basic Principle

Dimensioning phase	Network	Converter	Motor	Load
				
1) Chek the initial conditions of the network and load	f_N=50Hz, 60Hz U_N=380..690V			
2) Choose a motor according to: • Thermal loadability • Speed range • Maximum needed torque				
3) Choose a frequency converter according to: • Load type • Continous and maximum current • Network conditions				

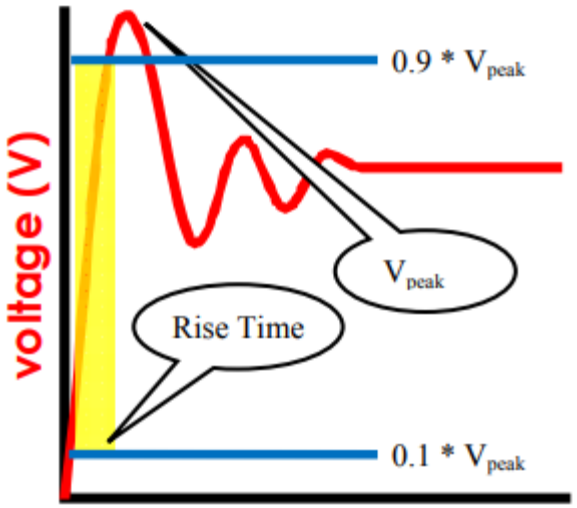
Motors suitable for VFD

Check List, Squirrel Cage Motor & VSD

Check list for selection of motors

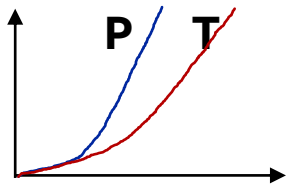
Always	Load Capacity
	Winding Insulation level (dv/dt)
	Bearing Insulation
At high speeds	Maximum Torque
	Bearing Construction and lubrication
	Fan noise and mechanical suitability
	Critical Speeds
At low speeds	Cooling
	Critical Speeds

ABB Offerings



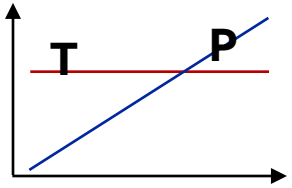
- Peak voltages
- dv/dt, Rise time
- Bearing circulating currents
- Overheating due to harmonics

Load types



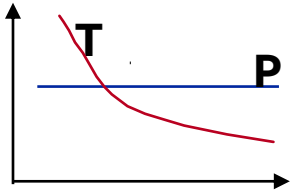
1. Quadratic torque

- Centrifugal pumps
- Fans



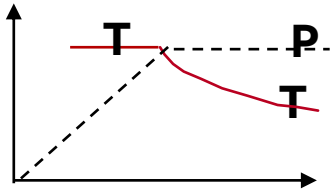
2. Constant torque

- Conveyors
- Feeders, screws
- Compressors



3. Constant power

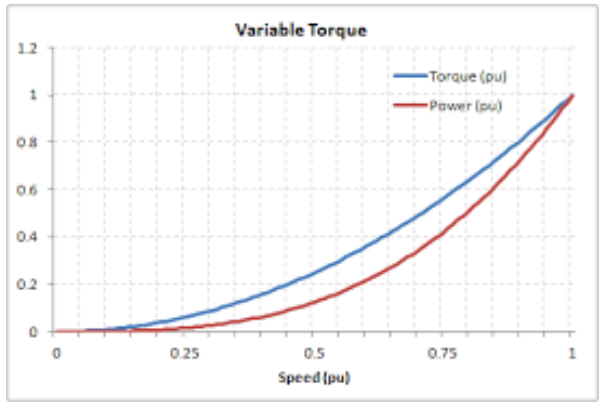
- Rollers

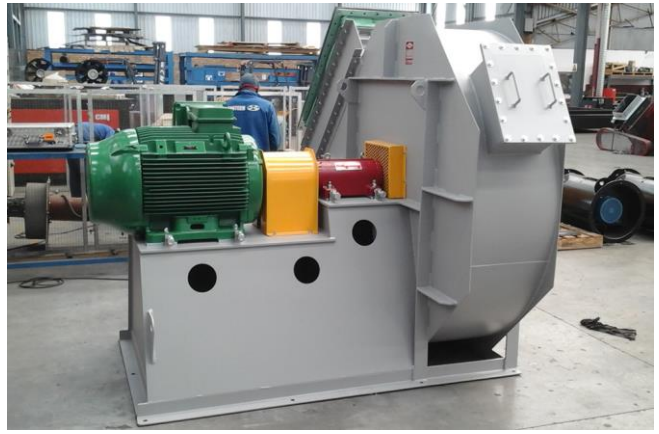


4. Constant power/ torque

- Paper machine rolls

Applications

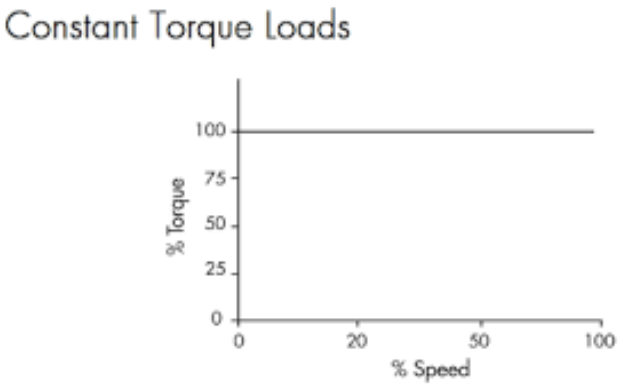




Squared/quadratic torque

Centrifugal pumps, fans and mixers

- Maximum speed is set to be nearer to base speed
- Self ventilation



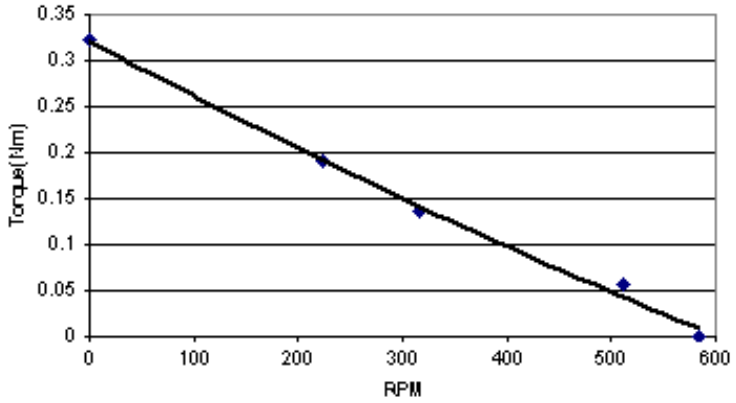
Constant torque

Conveyor, roller tables, elevators, crane drives

feeders, screws, compressors, extruders, cement kiln

- Minimum & maximum speed points are set as high as possible in motor loadability curve
- Self/separate ventilation
- Mechanical gear consideration
- Check overloadability

Applications



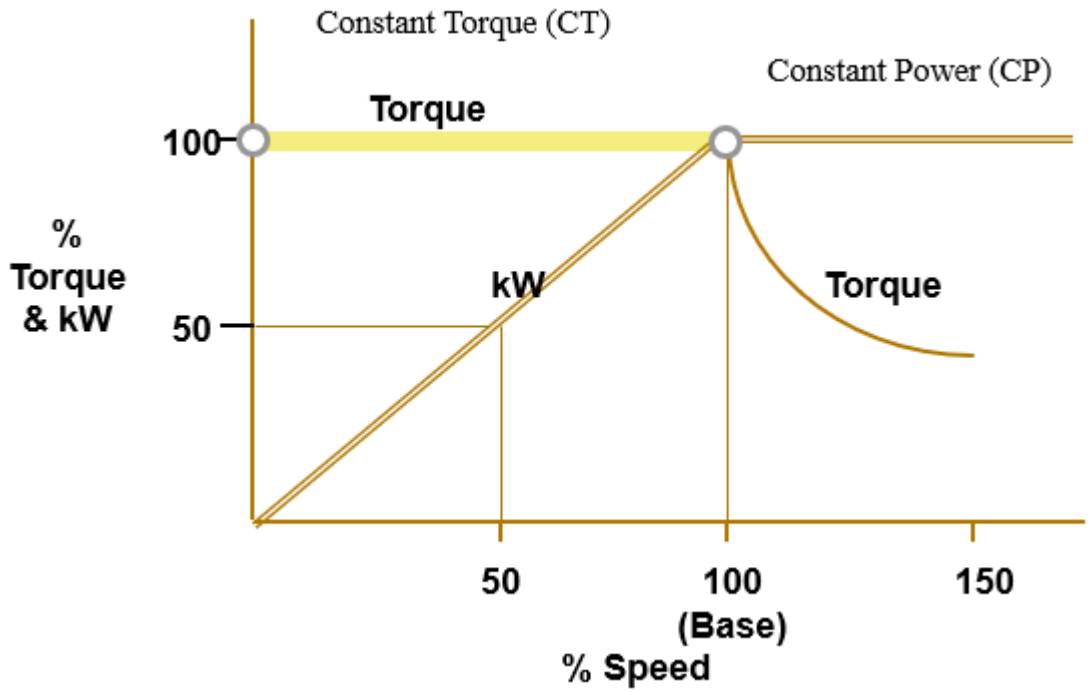
Constant Power

Winders, coilers, rollers

- Speed range is set to field weakening area
- Self ventilation
- Check overloadability

Applications

Constant Torque, constant power Applications

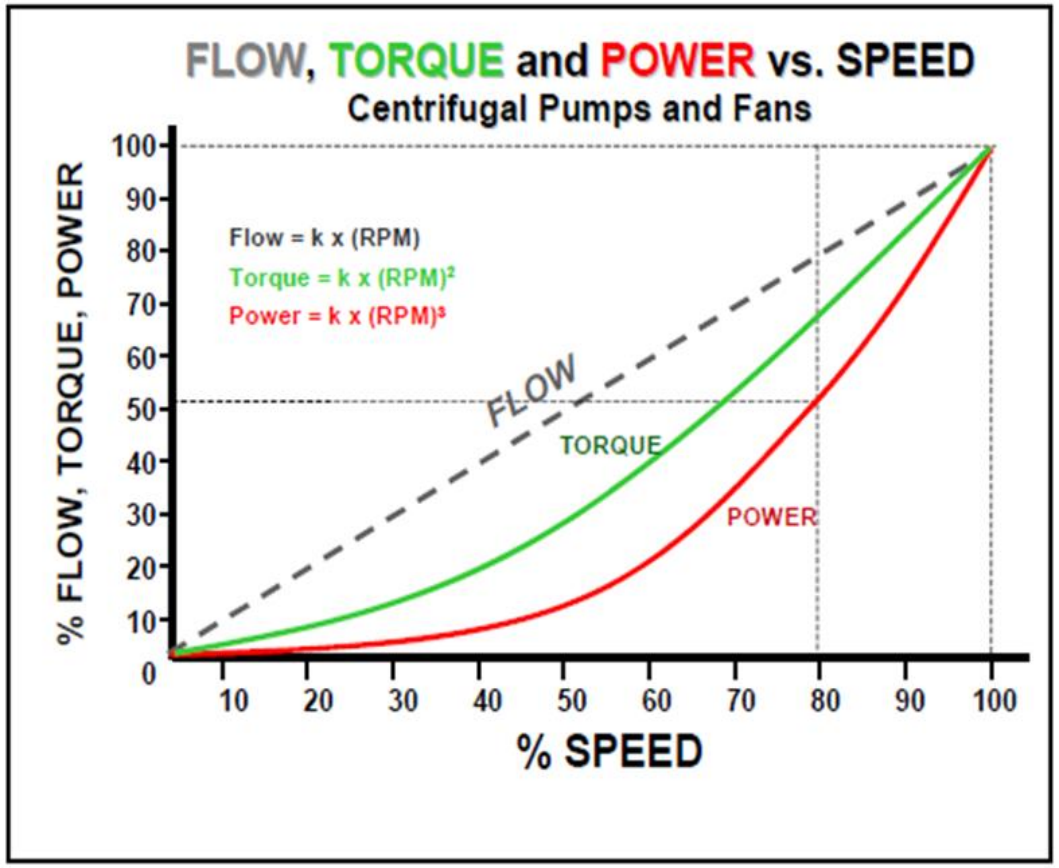


Example: Applications include Rolling mill, Bridle motor

VSD Energy savings

- Traditional pump system is usually controlled by mechanical throttling & dimensioned according to maximum flow requirement

- In Quadratic loads, power demand increases cube times the speed and torque demand increases square times the speed
  - The average needed flow will be much lower.
  - A converter drive follows the pumping system requirements and cause no additional pressure loss at pump or valve



Savings from 30% to 70% energy compared with throttling

Energy Efficiency

- The affinity laws for pumps & fans describe the relationship between their performance variables. The pump/fan **flow** (what customer needs) is proportional to the speed, but the **power** is proportional to the cube (x^3) of the shaft speed!
- This means that a pump running at 80% of its nominal speed will produce 80% of its nominal flow, requiring only 50% of the nominal power => 50% less ENERGY needed!
- In reality most pumps and motors are oversized and/or designed for extreme conditions. But if you switch on the motor/pump it will run at full speed, so how does the customer control the needed normal flow?

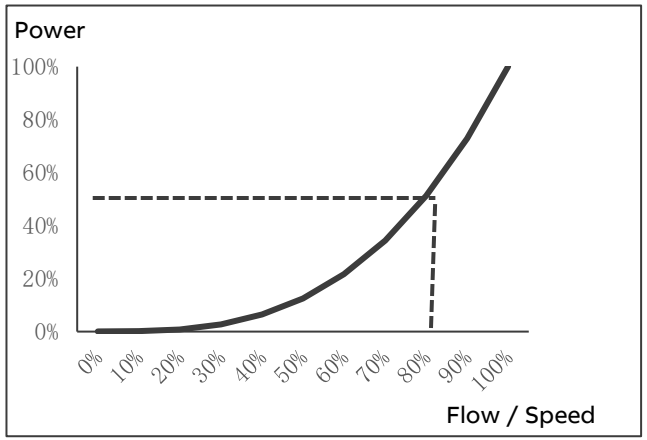
Most used solutions:

Throttling (closing valve)

Bypassing

On/Off –control(1, 2, x pumps)

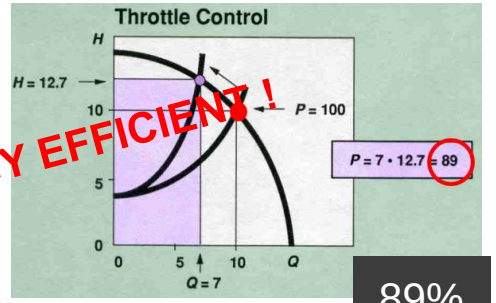
Affinity laws	
Flow	$\frac{Q1}{Q2} = \frac{n1}{n2}$
Pressure	$\frac{H1}{H2} = \left(\frac{n1}{n2}\right)^2$
Power	$\frac{P1}{P2} = \left(\frac{n1}{n2}\right)^3$



Energy Efficiency - Motors & Drives

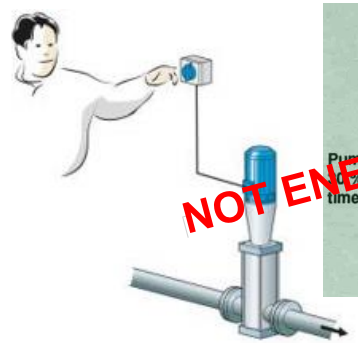
How do these “control solutions” compare if the needed flow is for example 70% of the installed nominal capacity? How much Power or Energy is consumed to produce that flow?

Throttling (closing valve)

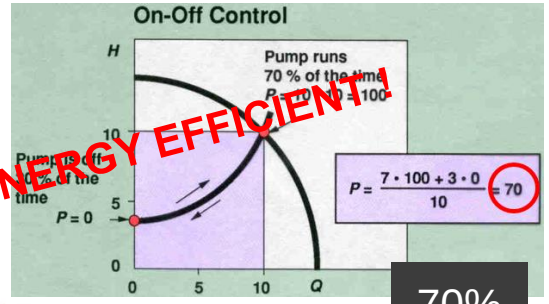


NOT ENERGY EFFICIENT !

89%



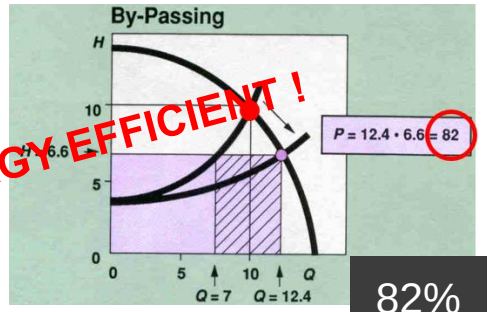
On/Off –control(1, 2, x pumps)



NOT ENERGY EFFICIENT !

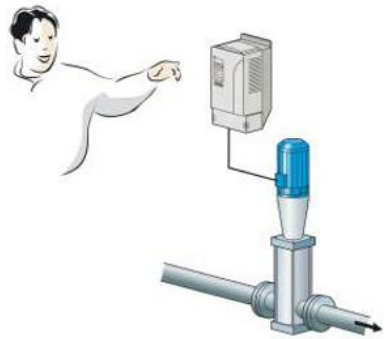
70%

Bypassing

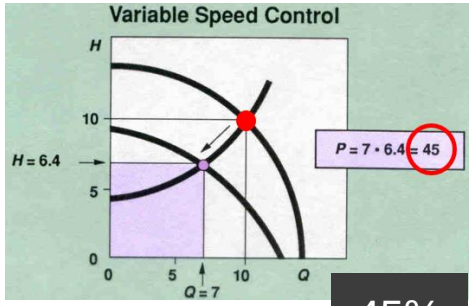


NOT ENERGY EFFICIENT !

82%



Speedcontrol using VSD



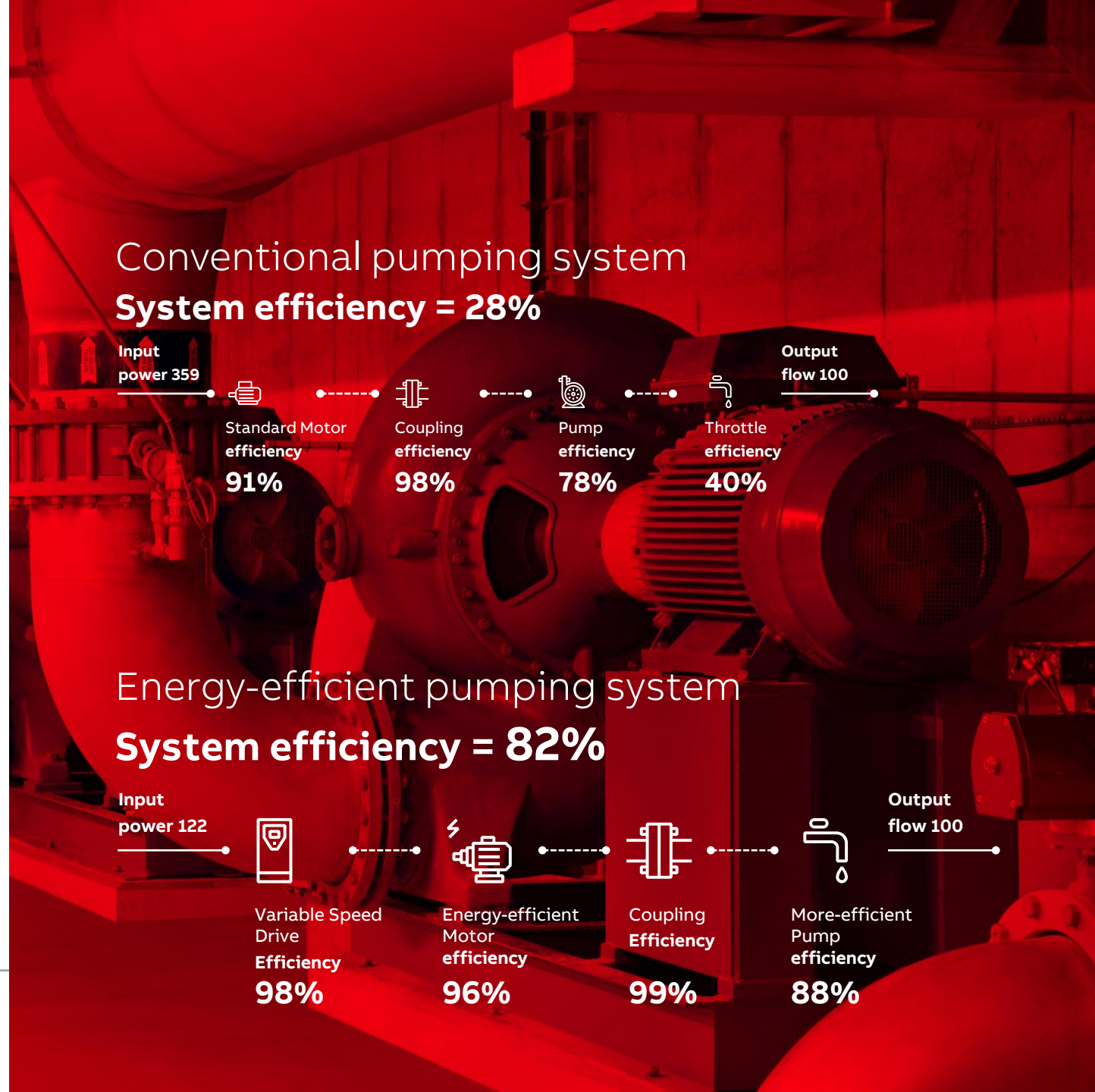
45%

NOTE: High Efficiency Motors can also save the customer Energy and reduce his carbon footprint.

The underappreciated role of drives

- Upgrading a motor offers significant efficiency gains. But still **greater energy savings** are achievable when it is used in combination with a variable-speed drive (VSD)

- A VSD **adjusts the speed and torque** of a motor to match the system's load requirements



Problems to prevent, when using VSD

Winding insulation

To ensure that motors operate reliably, the effects of non-sinusoidal output voltages from the converter must be taken into consideration when selecting the correct insulation system for the motor and output filters for the converter. The insulation and filters must be selected according to below table.

VPI and dual coat copper : To protect windings from corona discharge during conversion from ac to dc in the drive and voltage stresses.

Winding insulation and filters required	
Un ≤ 500V	Standard insulation
Un ≤ 600V	Standard insulation + dU/dt filters OR Special insulation
Un ≤ 690V	Special insulation AND dU/dt-filters at converter output
600V < Un ≤ 690V cable length > 150m	Special insulation

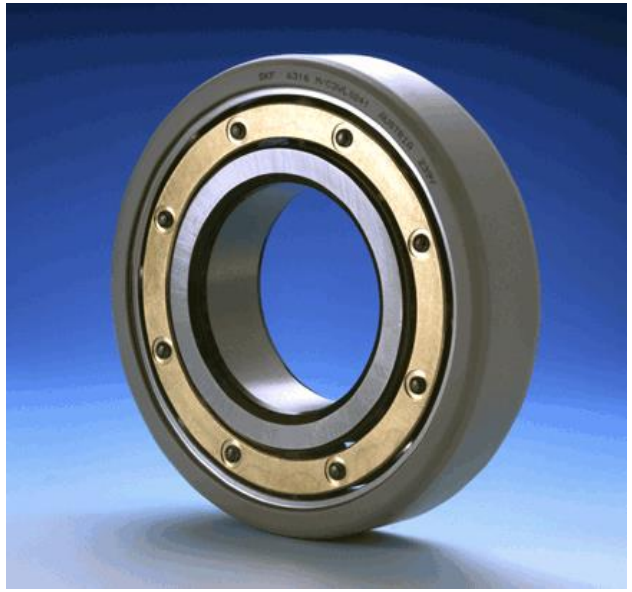
Problems to prevent, when using VSD

Bearing currents

Bearing voltages and currents must be avoided in all motors to ensure reliable operation of the entire application.

Table gives the selection rules depending on motor output power and frame size when used together with ABB converters; the same rules can also be applied as guidance when using ABB process performance motors with other converters.

Nominal Power (Pn and/or frame size)	Recommended measures
Pn < 100kW	No action needed
Pn ≥ 100kW OR IEC 315 ≤ frame size ≤ IEC 355	Insulated non-drive end bearing
Pn ≥ 350kW OR IEC 400 ≤ frame size ≤ IEC 500	Insulated non-drive end bearing AND common mode filter at the converter

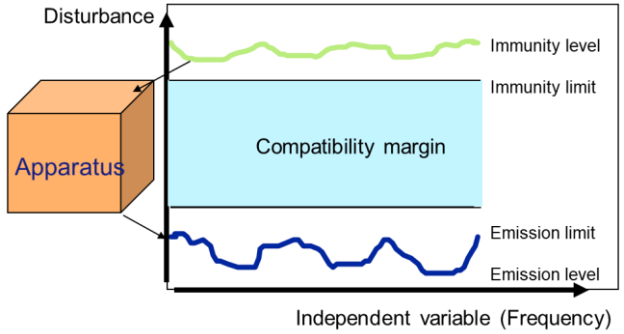


Problems to prevent, when using VSD

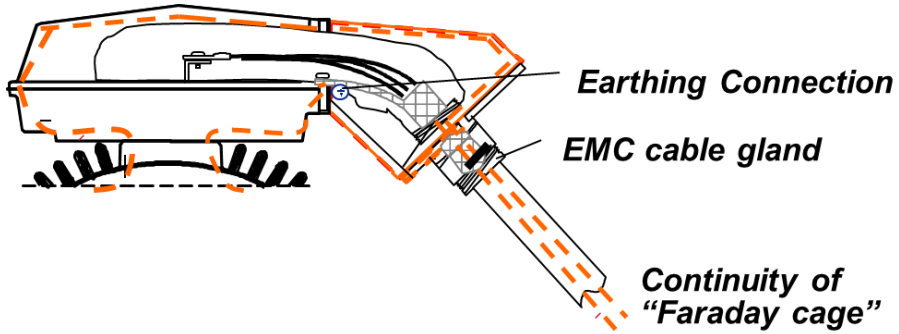
Electromagnetic compatibility (EMC)

The high-frequency components in a variable-speed drive might cause electromagnetic interference with other equipment in the installation.

To avoid this, certain measures should be taken. To meet EMC requirements, special EMC cables glands with a 360° connection to the concentric protective earth conductor should be used.



EMC is the ability of an electrical/electronic equipment to operate without problems within an electromagnetic environment. Equipment must not disturb or interfere with any other product or system within its locality.



Technical solutions in EMC Connection of motor cable shielding to a motor terminal box
Two possibilities (variant code 704)
EMC cable gland
EMC cable box

Problems to prevent, when using VSD

Common mode filters : Common mode filters are installed at the output of the frequency converter.

- Filters are made of toroidal cores installed around motor cables
- These filters reduce common mode currents and so decrease the risk of bearing currents.
- Common mode filters do not significantly affect the phase of main voltages on motor terminals.

dU/dt filter : Series reactor.

- Decreases the changing rate of the phase and main voltages and thus reduces voltage stresses in the windings.
- Decrease so called common mode currents and risk of bearing currents
- Designed so that du/dt-rate of main voltages at motor terminals is approx. 1kV/µs.

Note: According to IEC, for Ex nA -applications dU/dt-rate 500 V /µs or less is required. Refer IEC 60079-15,

Pay special attention!

1. Select motor according the correct load type
2. Use correct minimum speed for constant torque drive
3. Remember that force ventilation selection is sometimes more optimized than self ventilation.
4. Limit temperature rise to Class-B ,Use Class-F rise based on customer requirements.
5. Define overload speed range correctly
6. Inverter dimension should be based on duty cycle & motor current with drive.
7. Remember that voltage dips affect to motor breakdown torque
8. Type of cable and cable length.

Learnings

VFD’s improve productivity & offer excellent energy saving opportunities. however, the motor reliability must be ensured through proper selection.

Below are the five questions to be addressed while offering a VFD duty motor:

1) What is the application?

2) How is the load demand Curve?

3) What is the speed range & overload cycle?

4) Type of VFD?

5) Whether motor starts with DOL as well?

Energy Efficiency

What we care for

How we can help use energy more efficiently

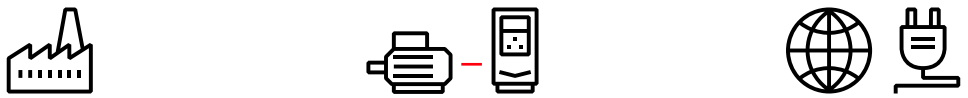
Electricity needs keep rising globally

A lot of this electricity is used to power industrial electric motors

>40%
of all electricity used power industry

2/3
of this is used by electric motors

~30%
Global electricity consumption



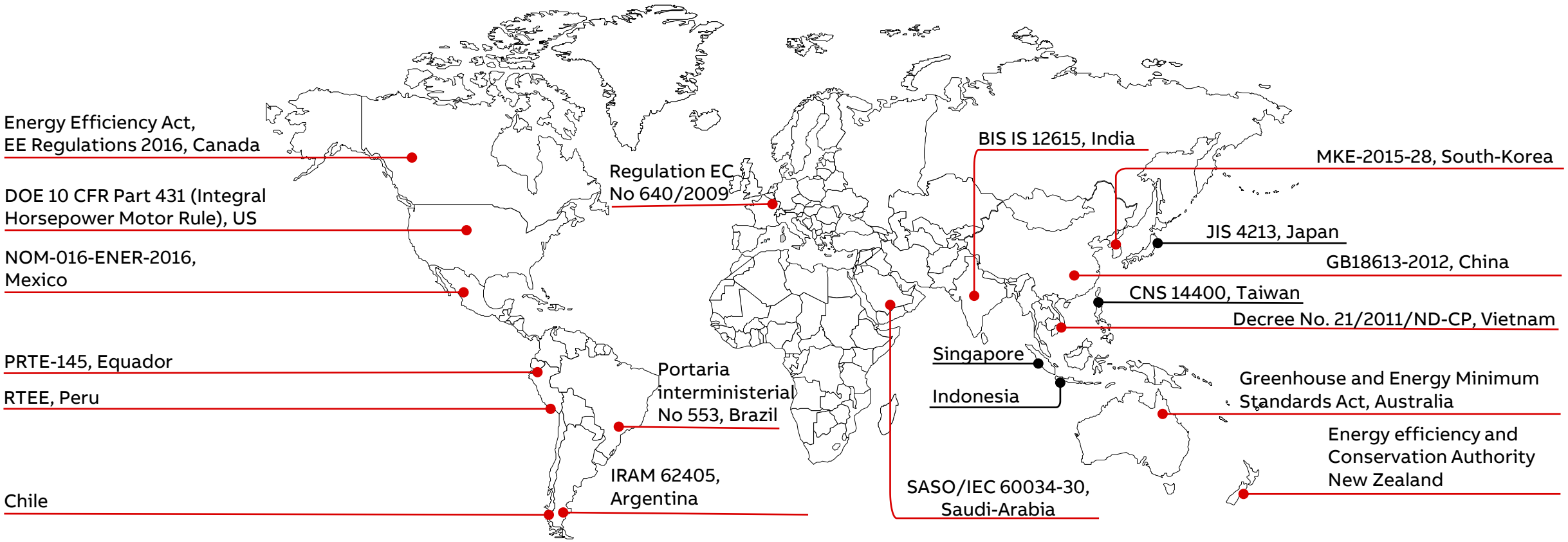
Guaranteed energy efficiency

Energy efficiency measures can reduce consumption by up to **60 %**

- ABB LV motors fulfill all mandatory national regulations
- ABB offers LV motor and variable speed drive packages

Save energy and optimize operations in a sustainable way

Fulfilling all international and national efficiency regulations



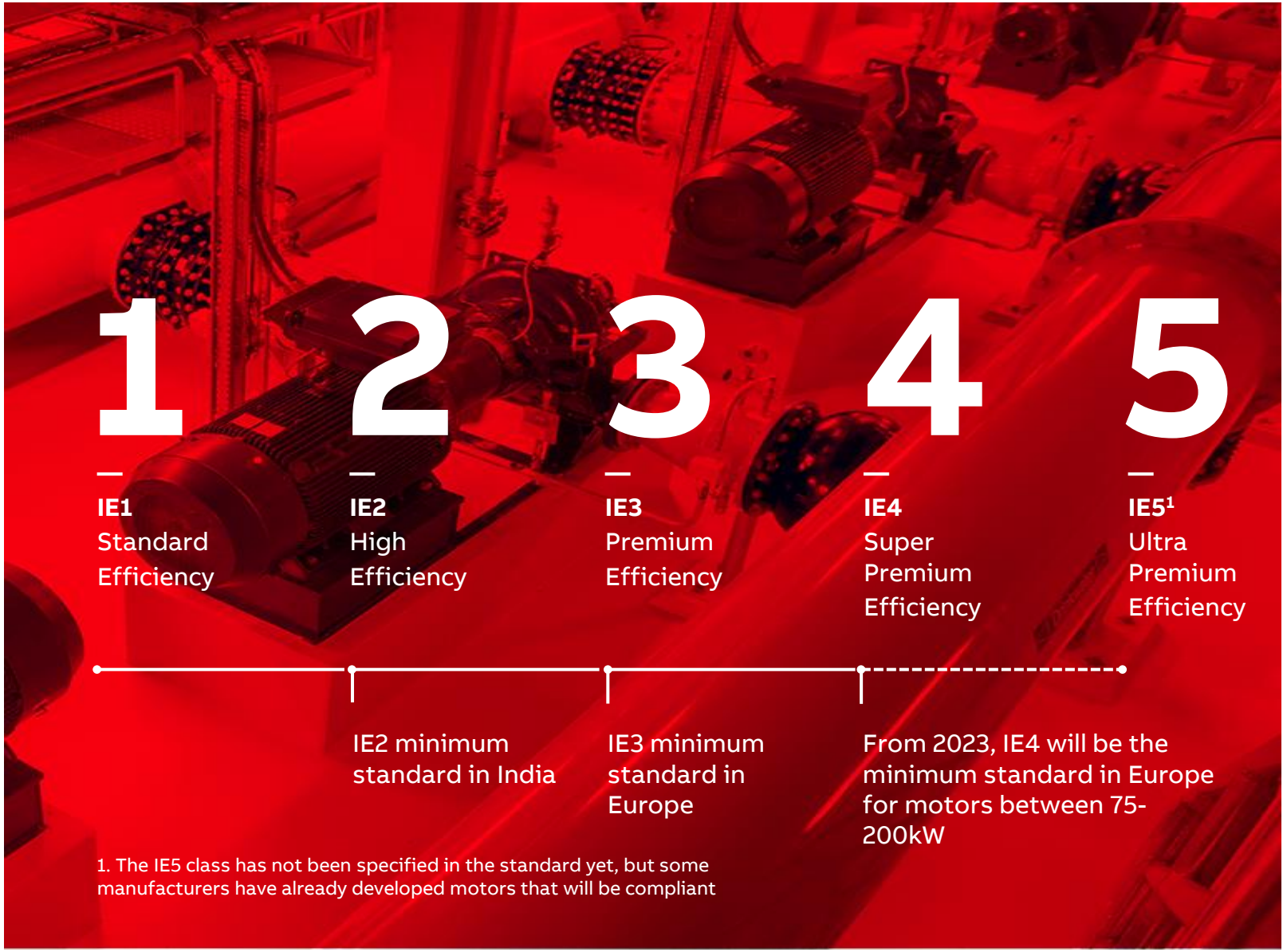
https://new.abb.com/motors-generators/energy-efficiency

Energy Efficiency Standards

Motors are at the forefront of global efforts : to improve efficiency and reduce emissions.

Motor efficiency is rated according to a scale published by the International Electrotechnical Commission(IEC).

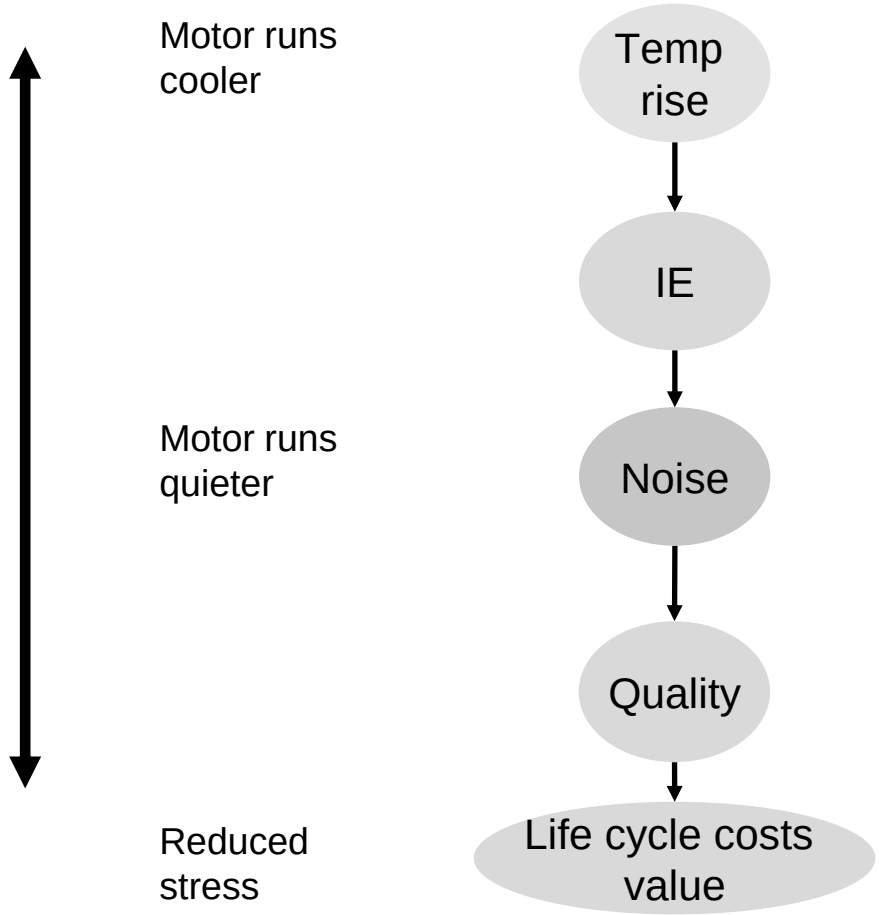
Even as the world seeks to increase energy efficiency in general, new applications have emerged that place a premium on efficient motor designs.



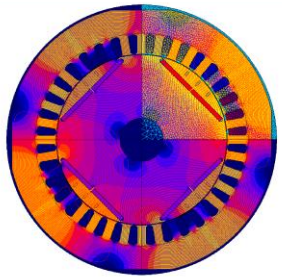
A positive effect on lifecycle cost

Four steps to added value

- High permeability steel –Reduce magnetic losses
- Increased amout of copper – Reduced copper losses
- Improved manufacturing techniques – Reduced heat and stress
- Reduced Iron, Rotor, Stator and copper losses
- Reduced windage and friction losses
- Improved airflow
- Improved fan/cowl and bearing designs
- Improved balancing
- Improved bearings housing design
- Use of quality bearing / grease

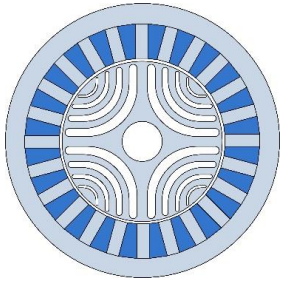


Advanced Motor Technologies to Reach IE5



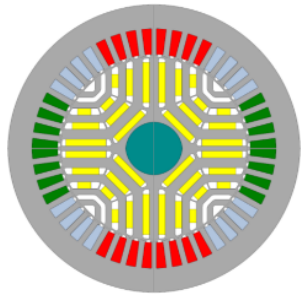
PM motor

- High energy efficiency
- Highest power density
- Accurate speed control even without sensors
- Low bearing temperatures and longer bearing lifetime
- High cost
- Only for VSD operation
- Rare-earth magnets
  - Uncertain cost variation
  - Demagnetization risk
  - More difficult service due to forces from magnets



SynRM

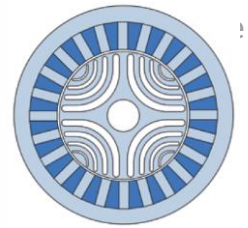
- High energy efficiency
- High power density
- Accurate speed control even without sensors
- Low bearing temperatures and longer bearing lifetime
- Easy to use and maintain.
- Designed exclusively for variable speed operation
- Package efficiency verified by ABB



Ferrite Assisted SynRM Motor

- High Energy Efficiency: IE5+
- Requires Variable Speed Drive
- Excellent Power Density
- Accurate speed control even without sensors
- Low bearing/winding temperatures
- Efficiency at low speeds
- Tailored design performance
- Uses Ferrite magnet (instead of rare earth magnet)

Two new innovative motor and drive packages



Standard motor + special rotor

+

Standard drive + new software

→

A new revolutionary drive package!

The High Output SynRM package

- Powerful, yet highly compact motor with up to two frame sizes smaller than conventional induction motor without compromising efficiency
- Lighter and smaller motors enable cost effective machine designs

The IE5 Ultra Premium Efficiency SynRM package

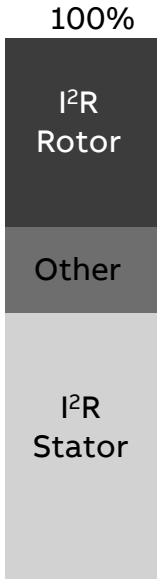
- Energy losses reduced by up to 40% compared to IE3 efficiency class
- Interchangeable with IE3 induction motor without costly mechanical modifications

Both packages are based on perfectly controlled synchronous motor technology without permanent magnets materials. Optimized for VSD operation, they combine motor, drive and advanced software into complete solutions.

Key to success

Elimination of rotor losses

IE3 Induction motor



Losses

60%

Other

I²R
Stator

IE5 SynRM motor

80–90%

Other

I²R
Stator

High output SynRM motor

New revolutionary motor and drive package

- Magnet free design combining advantages of permanent magnet technology with simplicity and service-friendliness of an induction motor.
- Packages available for quadratic torque applications such as pumps and fans.
- Competitive product offering compared to traditional or other new technologies.
- Higher reliability through lower bearing temperature.
- Designed exclusively for variable speed operation.
- Advanced open loop control software.
- Package efficiency verified by ABB.
- Global ABB support.

Setting the stage to compare the different motor technologies

Today it is challenging to compare full efficiency performance of different motors

– Motor losses in partial load conditions are not available easily in VSD duty today

Regulation EU 2019/1781 (Ecodesign directive)

Manufacturers need to provide the losses at these points for the motor (1.7. 2022) and drive (1.7.2021)

This enables comparison of different motors in partial load conditions with VSD (variable speed drive) duty.

IEC TS 60034-30-2 defines IE (International Efficiency) classes of variable speed AC (alternating current) motors

The new standard allows comparison of different motors in the IE class level, regardless of which standard is used for IE classification

This is the first time the IE5 class has been officially defined.

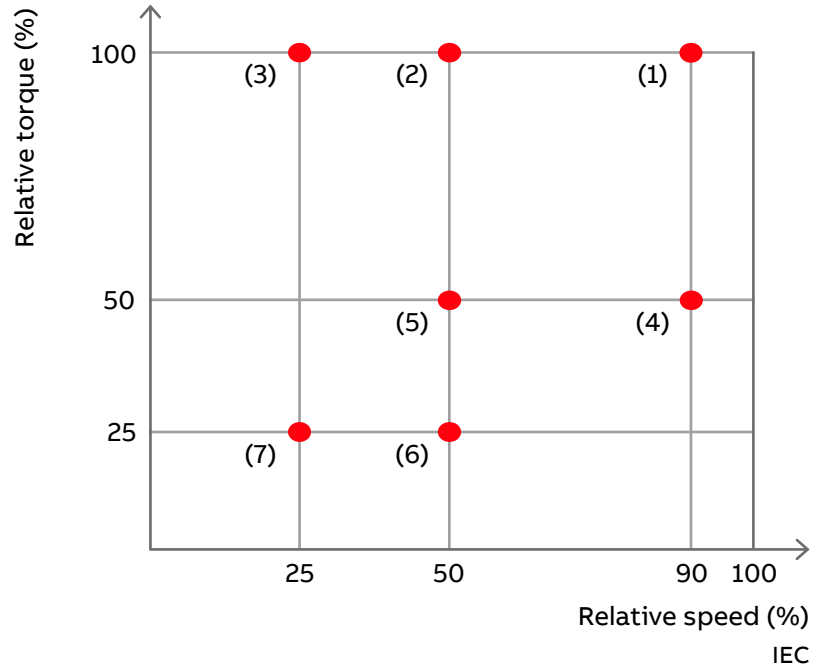


Fig-9: IEC 60034-2-3

Points (3), (2) and (1) are mostly relevant for constant torque applications (conveyor belts, lifts, hoist drives) at full load and test points (5) and (4) are relevant at half load.

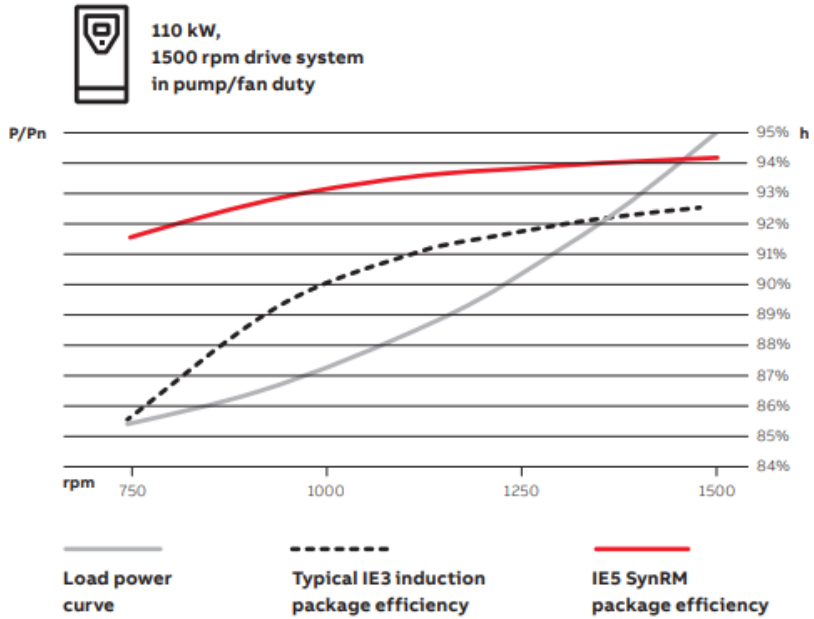
Points (7), (6), (5), (4) and (1) are mostly relevant for quadratic torque applications like fans, pumps and compressors

IE5 SynRM versus IE3 induction motors in VSD duty

Behavior based on ABB measurements

ABB laboratory measurements confirm SynRM efficiency advantage also at partial load conditions

There is about a 2% of benefit at full load, while at partial load the benefit can be as much as 6-7%



Example: For a 110 kW 1500 rpm drive system in pump/fan duty, with an IE3 induction motor the package efficiency is 92.5%, while for an IE5 SynRM motor the package efficiency is 94.2%.

The relative saving of SynRM IE5 motor is higher at partial load conditions

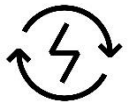
IE5 SynRM motor + drive package vs IE3 package

Practical example

- 110 kW motor
- 1 year
- Energy consumption of 8760h
- Average 75% power

IE5

Standard package efficiency
94,2%



Energy consumed
788 MWh

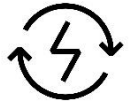
CO2 produced
330 t

▲ **~ 2%** ▼ **~ 2%** ▼ **~ 2%**

▲ Incremental investment with an estimated ROI
~1 year

IE3

Standard package efficiency
92,5%



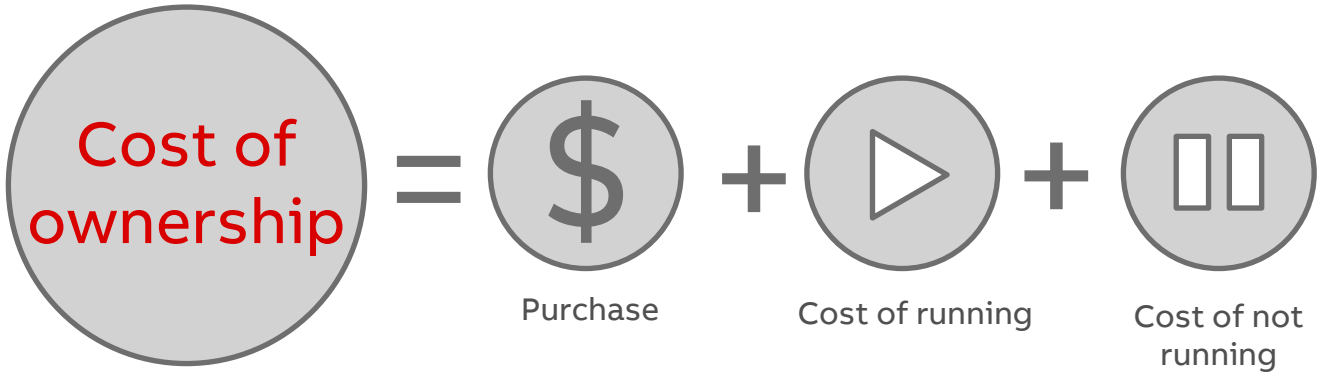
Energy consumed
802 MWh

CO2 produced
338 t

*The CO_2 reduction of a 110kW IE5 motor in a year is equivalent to taking 5 petrol-fueled cars off the roads.

Cost of ownership - more than energy efficiency

Think long term



– How much does it cost to own a product over its expected lifetime? A cheaper motor is not always the best buy:

  • A motor, irrespective of its rating, will consume its purchase price in energy costs during its first month of continuous operation.

  • Downtime at a major plant might cost $1 million per day

– Reliable, high efficiency motors deliver the lowest life cycle costs. Advanced diagnosis tools preserve and enhance equipment reliability and minimize unplanned system downtime.

Case Study

Shri Mahabir Ferro Alloys,

Manufacturer of metal products

- **Customer**: Shri Mahabir Ferro Alloys (P) Ltd. Rourkela
- **ABB offering** : IE4 Motors (184 nos.) for applications like fans, compressors, pumps, conveyors, blowers, gear-boxes in Pellet Plant, Direct Reduced Iron Plant and Captive Power Plant
- **Benefit:** Annual energy savings of ~250 MWh achieved using 68 motors. Further potential to save ~550 MWh annually when balance 116 motors replace the existing old motors

  Overall savings equivalent to average annual energy consumption of an Indian village

Alufluoride Ltd.,

a leading Chemical company

- **Customer**: Alufloride Ltd., Visakhapatnam, **OEM** : D. Parikh Engineering Works

- **ABB offering** : 200kW AC regenerative Drive for Chemical and Pharma Centrifuge.
  Regenerative drive feeds back the braking energy to the grid saving additional energy

- **Benefit**: Energy savings and better power quality improves reliability and availability.
  Annual savings of 66MWh, equivalent to INR 4 Lakhs savings per machine with ROI ~3 years

Evides Waterbedrijf,
pumping station to supply fresh water

- **Customer**: Evides Waterbedrijf built a new pumping station to supply fresh water to their customers. Because their success is based on a philosophy of sustainability, they decided to pioneer the first use of ABB's low-energy SynRM synchronous reluctance motor and variable frequency drive (VFD) technology in the Netherlands

- **Benefit:** Evides water company was the first in the Netherlands who put the SynRM technology into their system and it worked very well for us. The new motors are much cooler, meaning heat and energy losses are lower. In addition, the noise levels are much reduced as well. We calculated that the energy savings must be about 20%." says Joost van Belzen, Project Engineer and Toine Rijsdijk, Process Automation Engineer, at Evides

- The delivery included ACS880 industrial drives and SynRM motor package.

Orchid Laminates, Bangalore,
a leading manufacturer
of coated paper boards
and laminate sheets

- **Customer**: Orchid Laminates Pvt. Ltd.
  Sys. Integrator: Rcube Electric

- **ABB offering:** Promoting energy efficiency concepts by collaborating with end-user. Integrated solution with 55kW Synchronous reluctance motor (SynRM) and drive for improved energy efficiency beyond IE4

- **Benefit:** Energy saving of approx. **13%** compared to conventional running with additional improvements in process and reliability

JW Marriott, Pune,
a landmark hotel in the city of Pune

- **Customer**: JW Marriot hotel, Pune
- **ABB offering**: 2 nos. 15.5 kW 350 rpm Cooling Tower Direct Drive (CTDD) for air handling unit application
- **Benefit:** ABB's Cooling Tower Direct Drive (CTDD) and motor improved energy efficiency by 35%, reduced maintenance costs while delivering quieter operation as compared to the conventional Motor-Gearbox systems

  Energy saved in a day with this solution can charge an EV car to run for ~ 1500 Kms

Motors for Pharma Industry

– **Customer**: EU- ACG FILMS& FOILS

- **ABB offering**: 1 # 5.5 kw 4p IE5- ECT Motors
  Application: Centrifugal Pump

- **Benefit:** Energy conservation with IE5-ECT motors
  12.59 KWH saved over IE3 motor


ABB