Motor and VFD for HVAC Application

2020-05-22, Trollhättan, SE, Deepak Singh

NEVS

National
Electric
Vehicle
Sweden

About Me

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PERSONAL INFORMATION

Nationality	**Nepalese.**
Gender	**Male.**

WORK EXPERIENCE

DEC. 2017 TO DATE	**Electrical Machine Specialist**, *National Electric Vehicle Sweden AB*, Trollhättan, Sweden.
MAY. 2017 OCT, 2017	**Postdoctoral Researcher**, *Tampere University of Technology Laboratory of Electrical Energy Engineering, Research Group of Electromechanics*, Tampere, Finland.
JAN. 2012 DEC. 2016	**Researcher**, *Aalto University School of Electrical Engineering, Department of Electrical Engineering and Automation*, Espoo, Finland.
JUN. 2010 DEC. 2011	**Research Assistant**, *Aalto University School of Electrical Engineering, Department of Electrical Engineering and Automation, ,* Espoo, Finland.

FORMAL EDUCATION

JAN. 2012 JAN. 2017	**Doctor of Science (Technology)** (Graduation: January 24, 2017), *Aalto University School of Electrical Engineering*, Espoo, Finland.
SEP. 2009 DEC. 2011	**Masters of Science (Technology)**, *Aalto University School of Electrical Engineering*, Espoo, Finland.
OCT. 2002 OCT. 2006	**Bachelor of Engineering (Electrical Engineering)**, *Tribhuvan University, Institute of Engineering, Pulchowk Campus*, Lalitpur, Nepal.

PUBLICATIONS

Authored and co-authored 12+ journal articles and 20 conference papers and digests..
More Information: https://scholar.google.fi/citations?user=GFASWPMAAAAJ&hl=en
http://orcid.org/0000-0003-1629-0156

NEVS

NEVS was founded 2012, by Kai Johan Jiang

The reasons why NEVS exists

- **Air pollution**
- **Climate change**
- **Congestion**

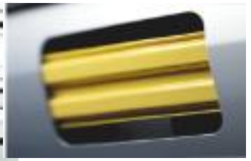
NEVS

A strong heritage – with 70 years of innovation

First Saab
”Ursaaben”

Dual Brake Circuit

Side impact protection



Turbocharging

Saab Trionic

SAHR

NEVS Production of SAAB MY14

Tianjin factory

Partnership batteries & development

恒大集团
世 界 500 强

Evergrande Group

Real Estate

Health

Tourism/ culture

New Energy Vehicle

Chinese Evergrande Group now owns more than 80% of NEVS AB

Kai Johan Jiang's company National Modern Energy Holding less than 20%

NEVS

With Evergrande, several essential events have impacted the course of action and priorities during 2019

January 2019

EVERGRANDE
Fortune Global 500

- Evergrande acquires 51% of NEVS AB
- (Now more than 80%)
- The R&D and manufacturing footprint grows with the Guangzhou/ Nansha site

- NEVS acquires a 65% share in a joint venture with Koenigsegg aiming to expand into new market segments
- NEVS also acquires 5% shares in Koenigsegg's parent company, with the option to acquire an additional 15%

March 2019

e-Traction
revolution in motion

- Evergrande acquires E-Traction

June 2019

- NEVS acquires Protean

July 2019

hofer
powertrain

- Evergrande acquires 67% of a joint venture with Hofer Powertrain that will focus on developing world's leading e-powertrain system in China

autox

- NEVS and AutoX signs agreement to collaborate on large scale RoboTaxi deployment in Europe

August 2019

BENTELER
makes it happen
FEV

- Evergrande purchases platform from Benteler and FEV

September 2019

MAGNA
iav
EDAG
AVL

- Evergrande forms an R&D collaboration with FEV, Magna, EDAG, IAV, AVL and Koenigsegg to develop Evergrande’s portfolio of Electric vehicles for the Chinese market

October 2019

- Evergrande signs cooperation agreement with 15 European design experts

)

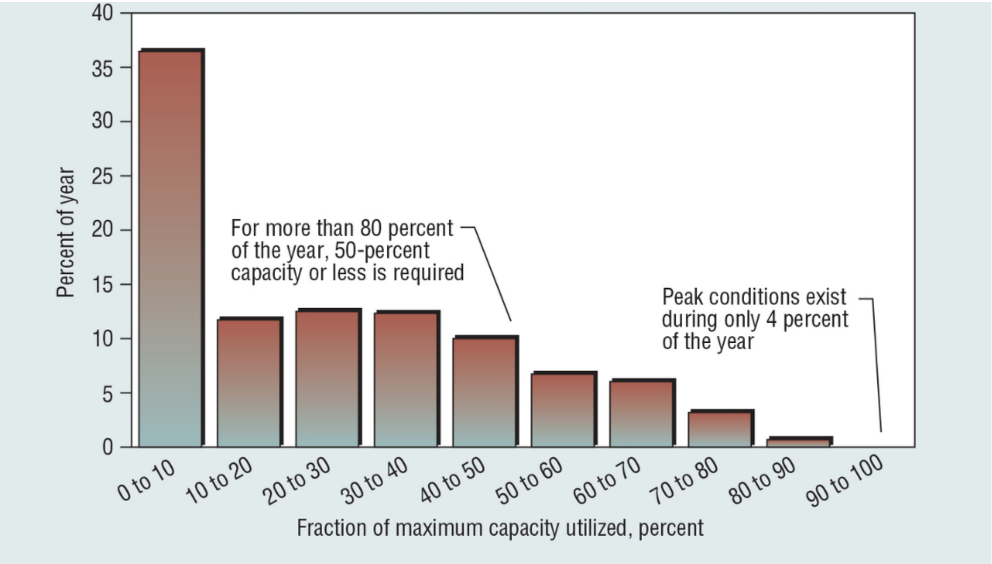
NEVS/Evergrande has also acquired Protean Electric, word leading in-wheel electric motor developer

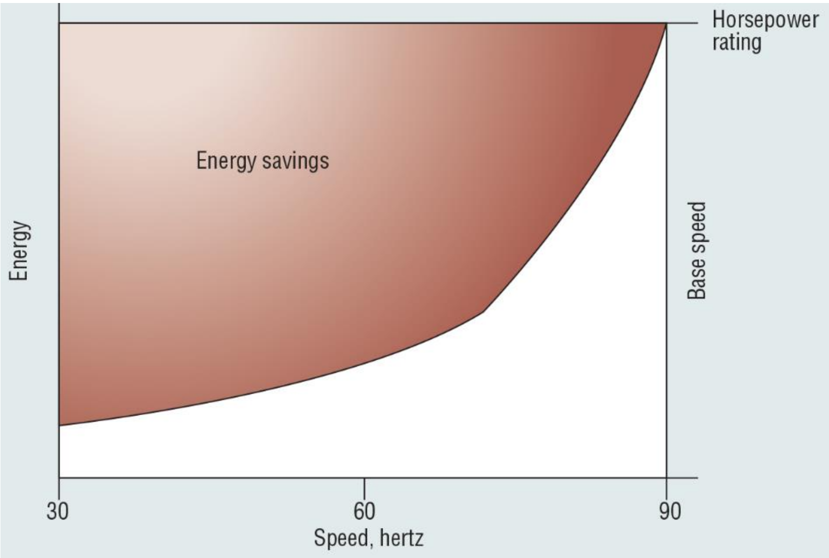
PROTEAN

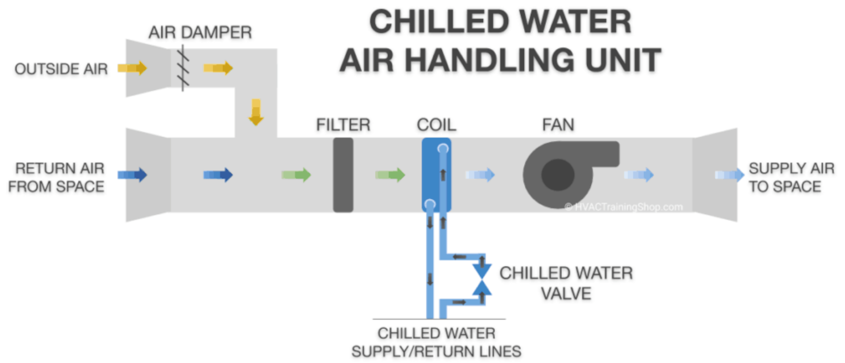
Electric Automotive Technology

WHY

- HVAC system with ON/OFF type compressor operates at max/zero speed (respectively)
- Compressors are modulated in two or multi stages for load matching, this leads to high energy consumption
- ON/OFF modulation of compressor draws high starting (inrush) current, causing mechanical, electrical and thermal strain on compressor components
- Similarly, fans (AHU and Exhaust unit) operating at max speed and the flow regulated by actuator controlled valves/vents/dampers etc… consumes high energy

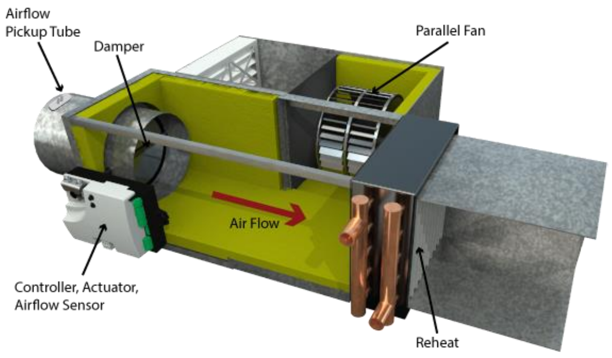


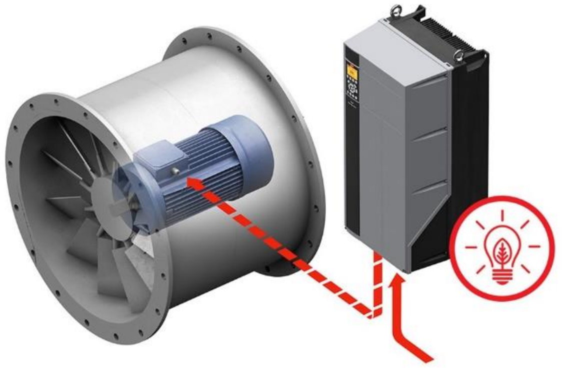


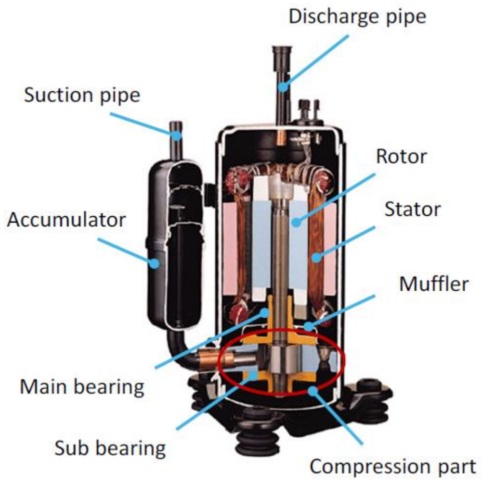


Motor usage in HVAC

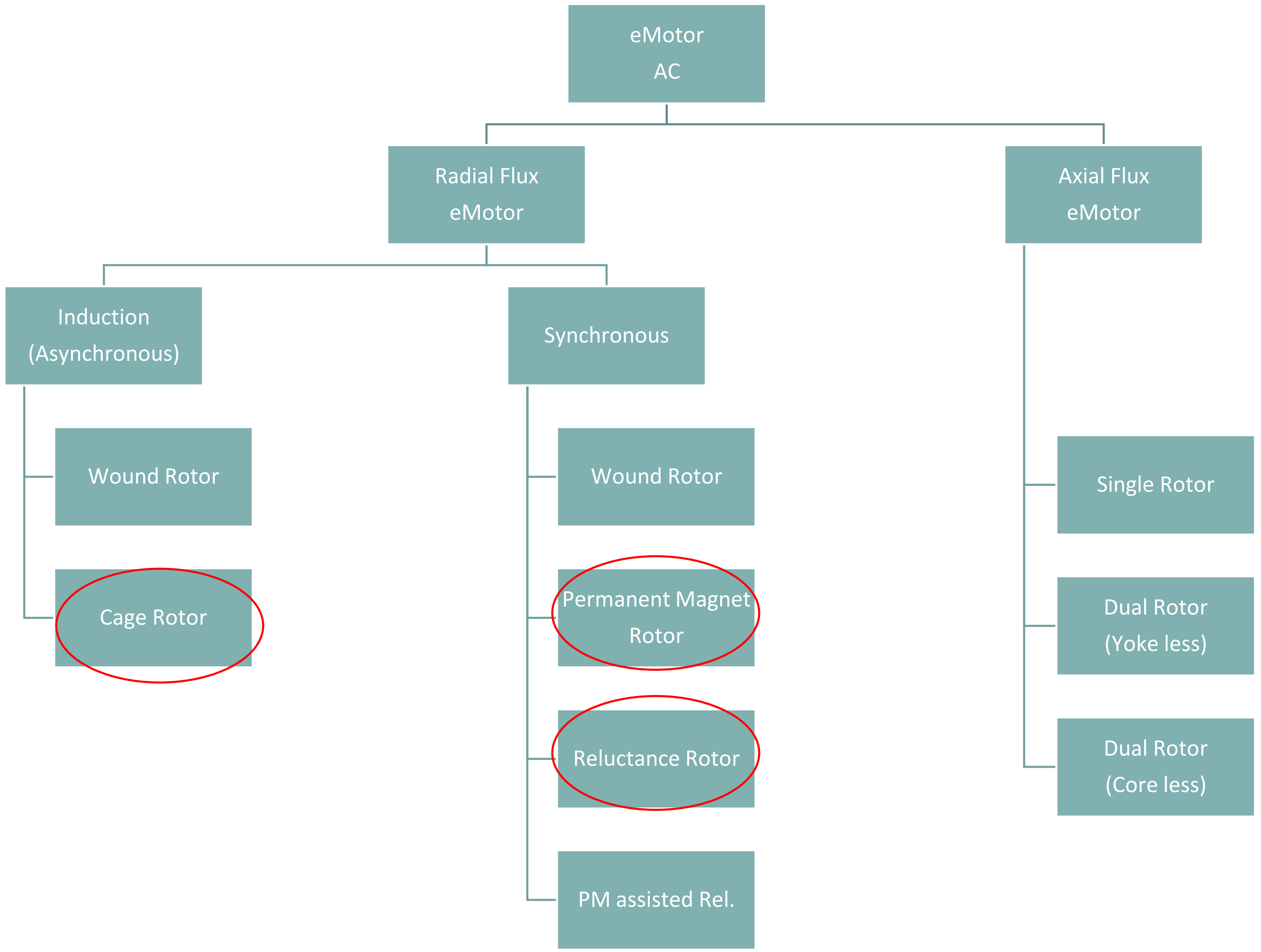
- Compressor for Refrigerant/water
- Fans (supply and return duct, cooling tower) and blower
- Pumps to circulate refrigerant/coolant



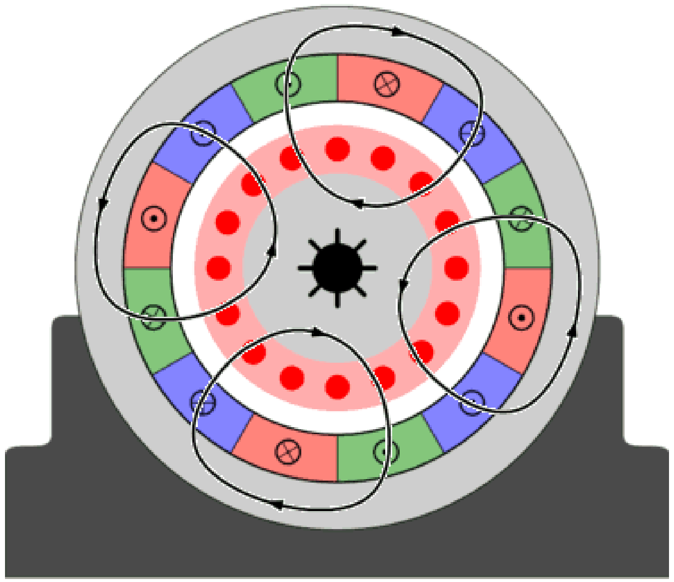




AC Motor
(Classification)

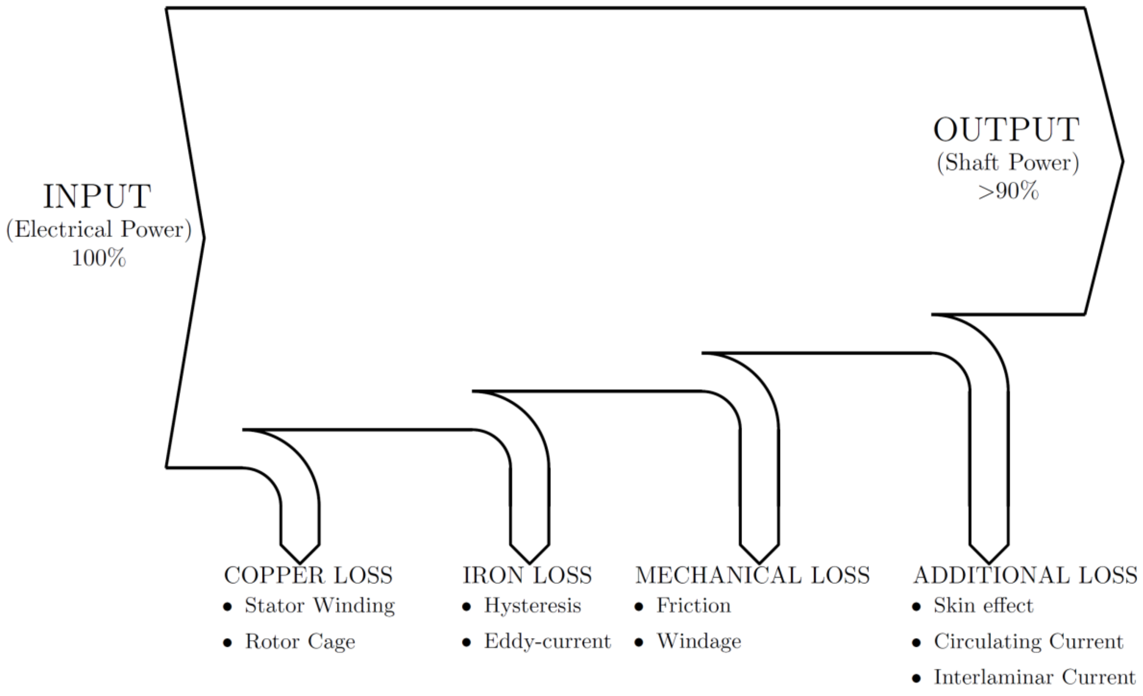


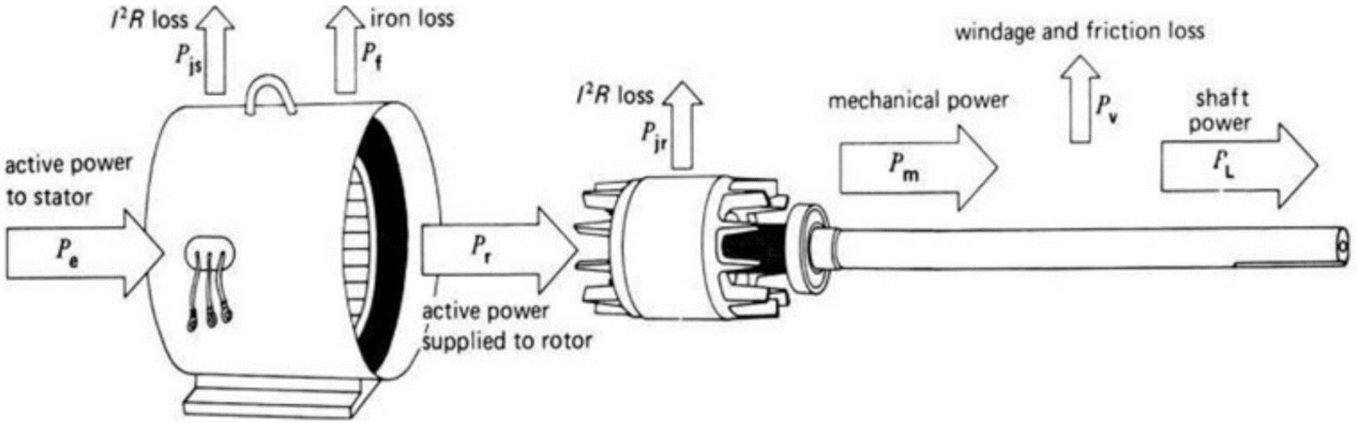
Motor
(Working Principle)



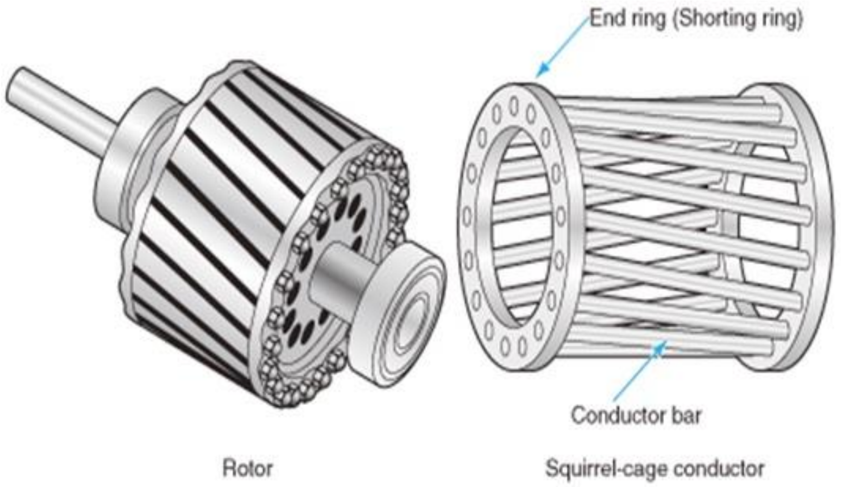
- All electric motors operate by opposing magnetic forces at the air gap causing the rotation motion
- Stator (Stationary) contains rotating magnetic field by virtue of AC current thru distributed coils
- Key difference is in **“How the Rotor gets its magnetic field”**
- **How Rotor gets its magnetic field**
  - Induction Motor – Induction effect (transformer principle) in short circuited coil or Cu/Al bars
  - PM motor – PM (special material), no current
  - Syn. Motor – Coil on rotor with DC
  - Syn. Reluctance – Flux from stator
  - Switched reluctance – Flux from stator and shape effect

Power Flow Diagram (General Motor)



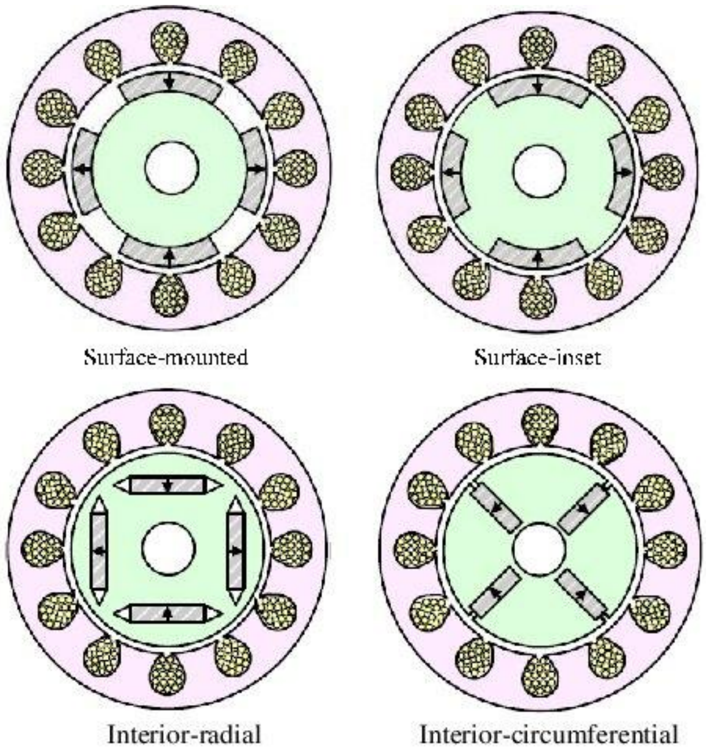


Induction Motor (Cage)



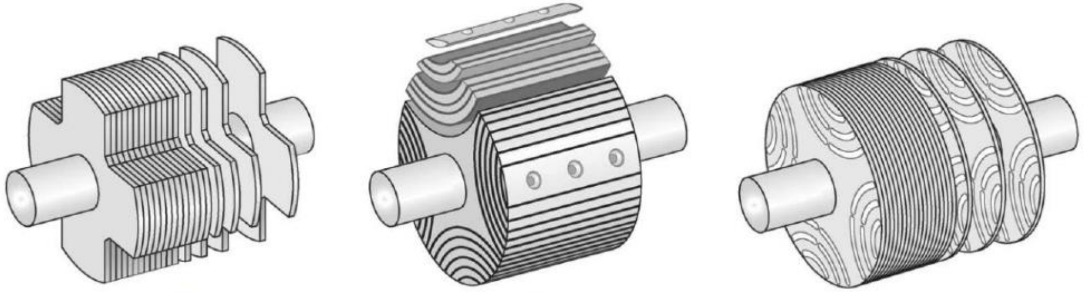
- Mature technology, as IM are the most used industrial motor
- Controls, well developed
- Lower efficiency due to losses in rotor copper bars
- Reliable and very robust (better then PM motors)
- Cost: Cheap (no rear earth material)
- Possible to implement sensor-less control (reduces the sensor costs)
- ONLY motor capable of Line-Start

PM Syn. Motor (PMSM)



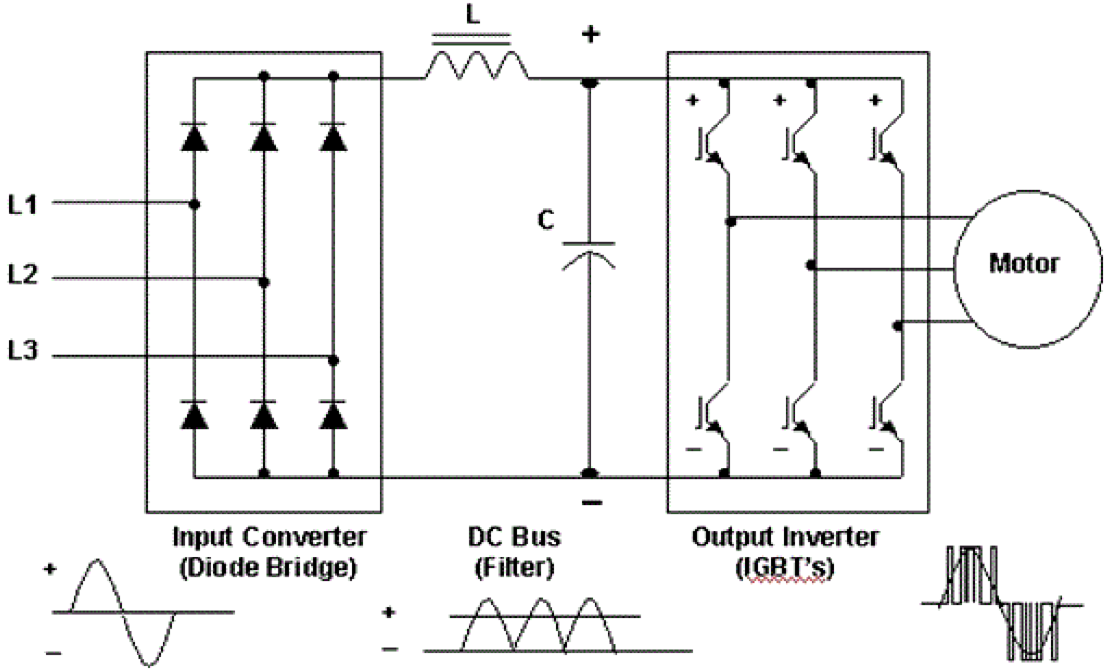
- High torque density (compact motor for same application)
- Good technology maturity
- Controls, well developed
- High efficiency, no conductor in rotor, however considerable eddy current loss in PM at high speeds/switching frequency
- Less reliable (compared to IM and SyRM), risk of PM demagnetization due to overheating, over current and aging
- Relatively expensive due to use of rare earth material
- Possible to implement sensor-less control
- CANNOT line start, controller (inverter) required

Syn. Rel. Motor (SRM)


(a) (b) (c)

- Latest in the trend of Ultra Premium Efficiency (IE5)
- Controls, fairly developed
- Highest efficiency, no copper or magnet losses in rotor
- Reliable and very robust (better then IM motors)
- Cost: Cheap (no rear earth material or copper)
- Difficult to implement sensor-less control (research on going)
- CANNOT Line-Start, require controller to operate

VFD
(working principal)



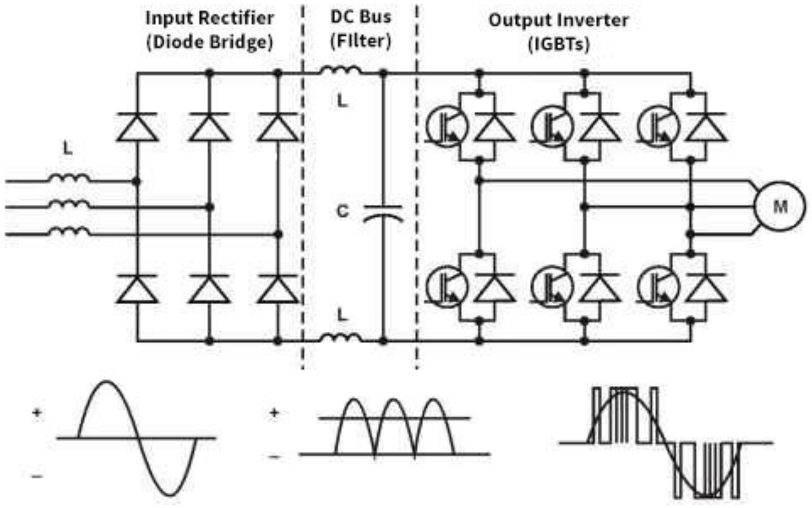
A VFD, delivers power from the source — AC mains — to a motor in three basic steps:

Step 1: A rectifier converts the AC power to DC
Step 2: A DC bus receives, smooths, and stores the power
Step 3: An inverter converts the DC power back into AC with the necessary frequency and voltage via pulse width modulation (PWM)

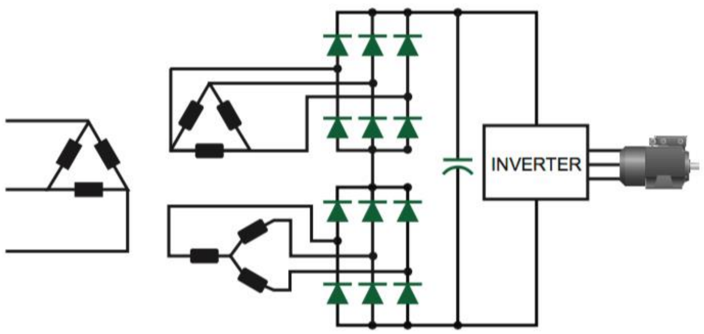
VFD
(Classification)

Multi Pulse Front End VFDs

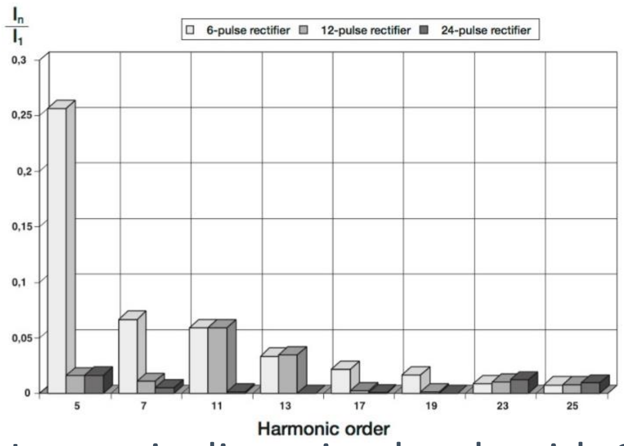
- 6 pulse VFD are the simplest and the cheapest, but has the worst THD
- THD can be reduced by implementing higher pulse rectifier (typically multiple of 6)
- 12 and 18 pulse VFD use 2 and 3, 6-pulse rectifier respectively
- Furthermore, they use multi-phase transformer with 30 and 20 deg phase shift in the supply respectively
- Added rectifier and other components for higher 12,18 and 24 pulse VFD push the cost up



VFD with 6 pulse rectifier



VFD with 12 pulse rectifier

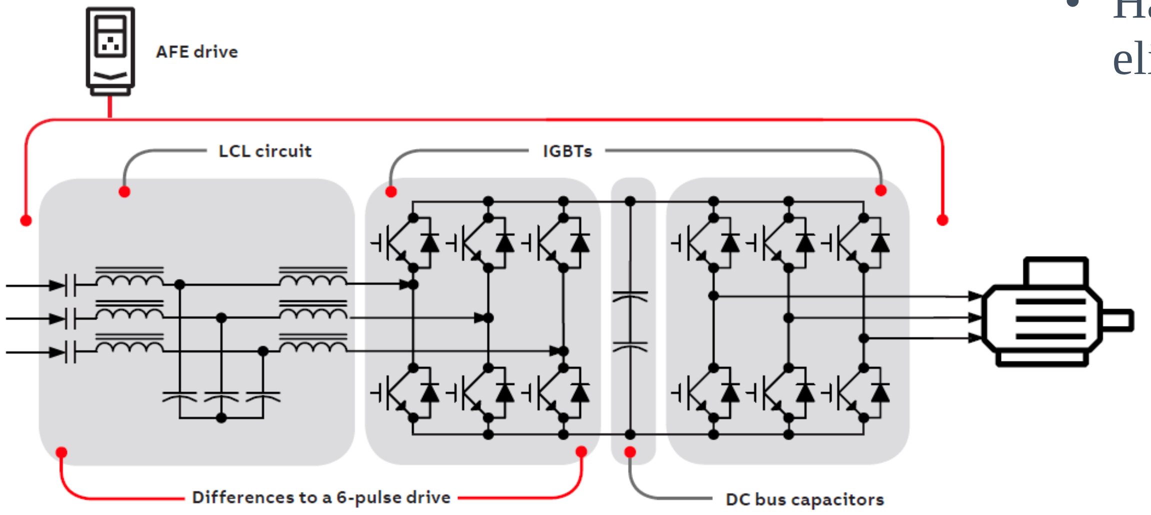


Harmonic distortion levels with 6-, 12-, and 24-pulse rectifiers

Active Front End VFDs

VFD
(Classification)

- Input current waveform is monitored and shapes it to be sinusoidal, thereby SIGNIFICANTLY reducing the THD
- THD monitored for lower order harmonics only, thus require LCL filter to reduce higher order harmonics
- $PF = \frac{cos\theta}{\sqrt{1+THD^2}}$: cosθ is kept to near unity and THD significantly reduced, thus improving PF
- Handle regenerative power and put it back to the AC mains, thus eliminating the need of resistor bank to dump regenerative energy

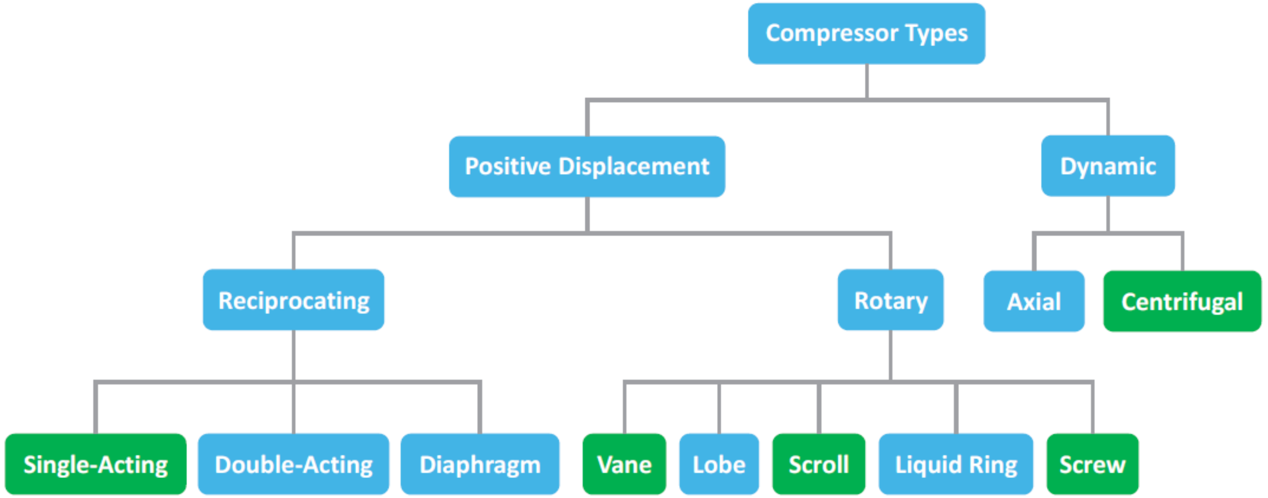


VFDs
(Other issues)

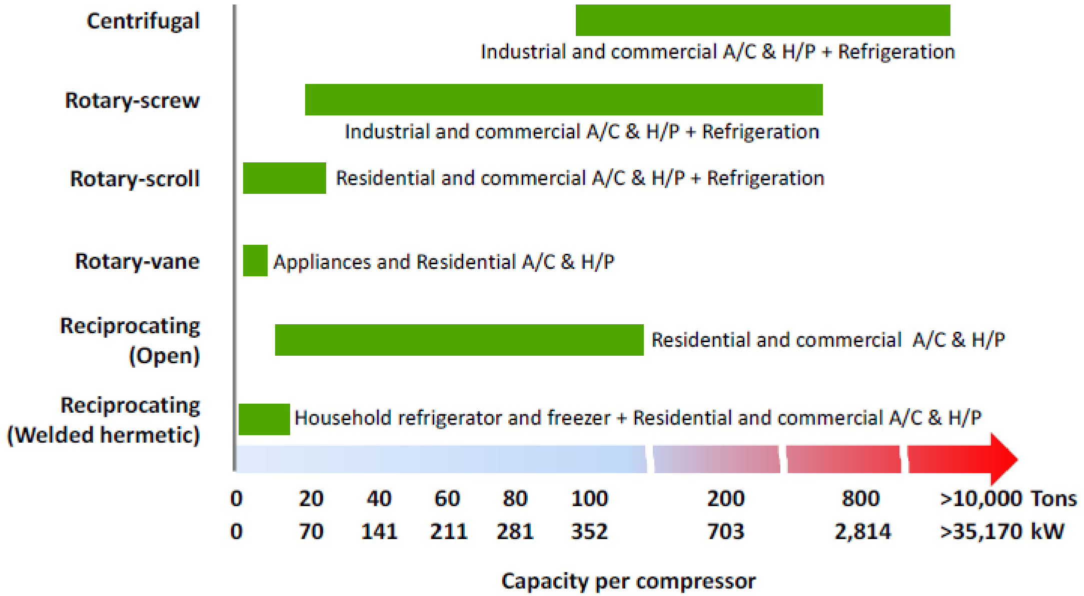
- Additional heating in motor core and magnets (in PM Motors)
- Motor bearing current
- Voltage stresses ($^{dV}/_{dt}$) on motor insulation

Compressor
(Classification)

Typical Technical Classification



Capacity, size and usage



Compressor
(application of VFDs)

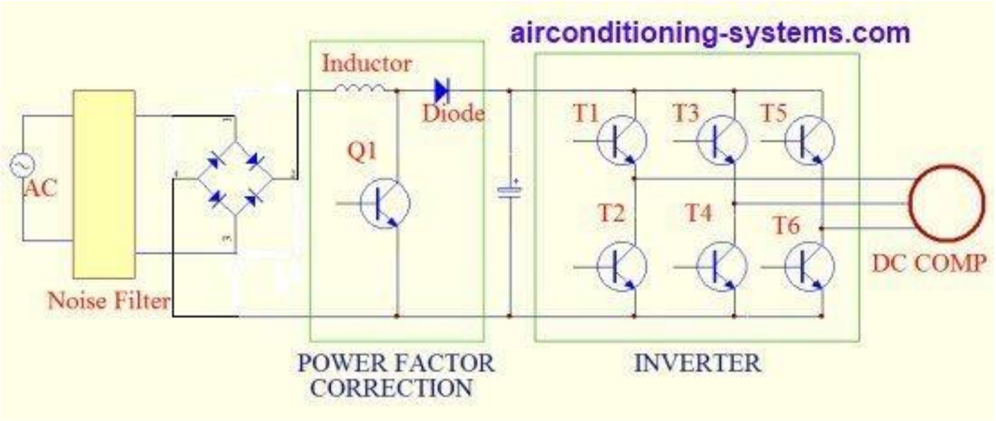
Application of VFDs on fixed capacity compressors

- Typically use IM to operate in narrow frequency band 45-65 HZ
- Operation frequency band expanded to 35-75 Hz when used in conjuction with VFD, after ensuring proper lubrication and bearings
- NOT a pure variable speed application

Application of VFDs with dedicated Variable Speed Compressor

- Each compressor is therefore paired, tuned, and optimized with a VFD
- Compressor protection and diagnostic features are built directly into the drive to ensure maximum reliability
- Dedicated oil pump to provide adequate lubrication across a broad speed range

Retrofitting of VFD (considerations)



VFD to operate 3 phase motor from 1 phase source

Commercial/residential building HVAC

- Compressor
  - Compatibility: lubrication and bearings
  - Safety: pressure build-up, over-heating and type of refrigerant
- Motor
  - 3 phase Induction Motors
  - Inverter duty rated: Winding insulation, bearing and cooling
  - Fan motors low torque application, careful in selecting VFD

Home AC unit

- Compressor: Compatibility and safety
- Motor
  - Most cases its capacitor start/run induction motor; this type of IM will require special VFD
  - BLDC (Brush-less DC; don’t get confused, it is still a PM motor with controller in the packaged product); variable speed application possible with incorporated controller

Conclusion

- VFDs have great energy saving potential especially in HVAC application
- VFD controlled compressor eliminate the need of multiple compressor setup required for modulation
- VFD controlled fans eliminate the need of many (not all) valves/vents/dampers...
- Active Front End – VFDs might be cost effective solution (both component and operational cost) compared to 12,18- pulse VFDs
- NOT ALL compressor are designed for variable speed application; careful when retrofitting old compressor with VFDs
- Retrofitting home AC unit – not feasible (give technical challenge and limited gains)

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