That’s why the dykes don’t break

(with power electronics)

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ATB Technology in Motion

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1931 Congrescentrum Den Bosch

POWER ELECTRONICS 2017

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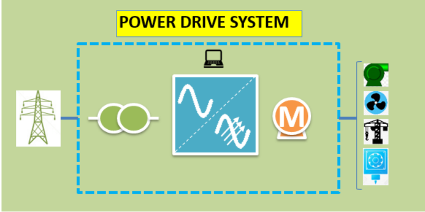






Technology in Motion

The Netherlands Waterland

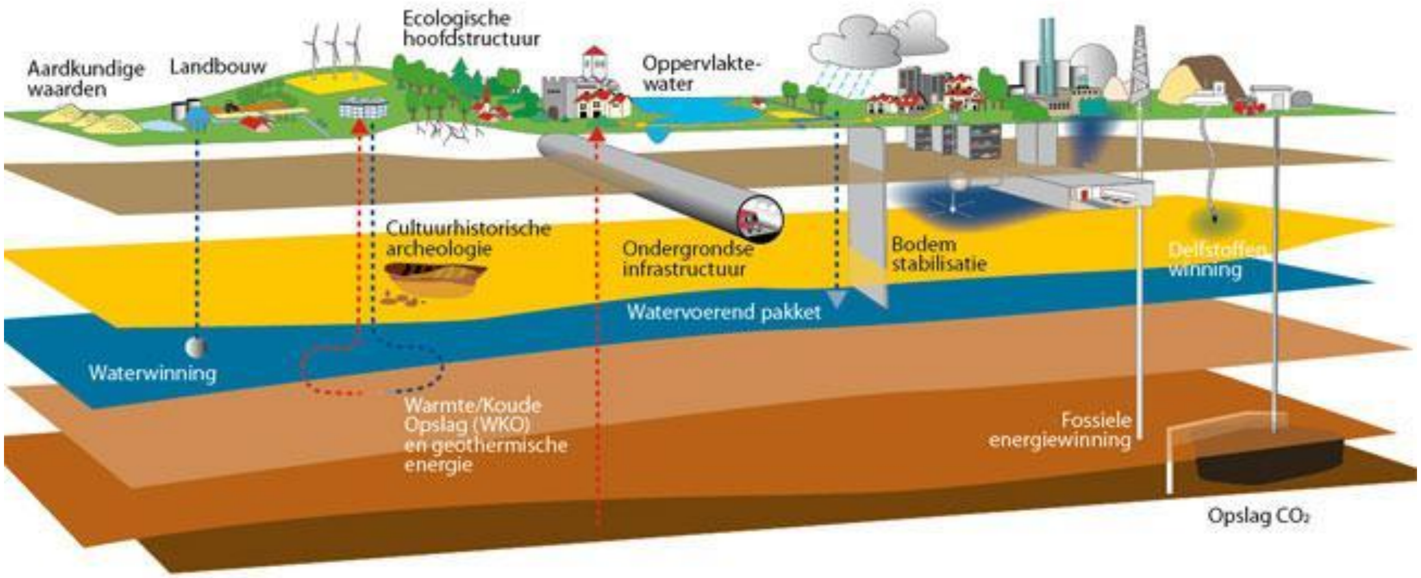
Technology in Motion

Expertise and Experience

- King Willem Alexander
  Former Chairman Water and Sanitation
- Expertise
- Creation of Land
- Availability of Water

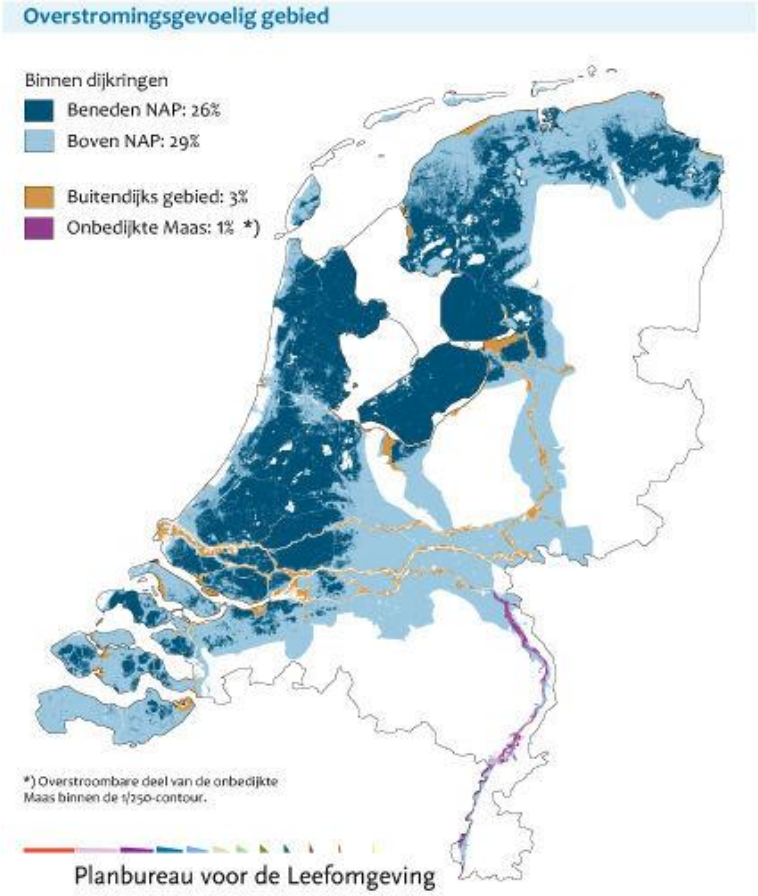
The Total picture

- **Waste water**
- **Clean water**
- **Surface water**

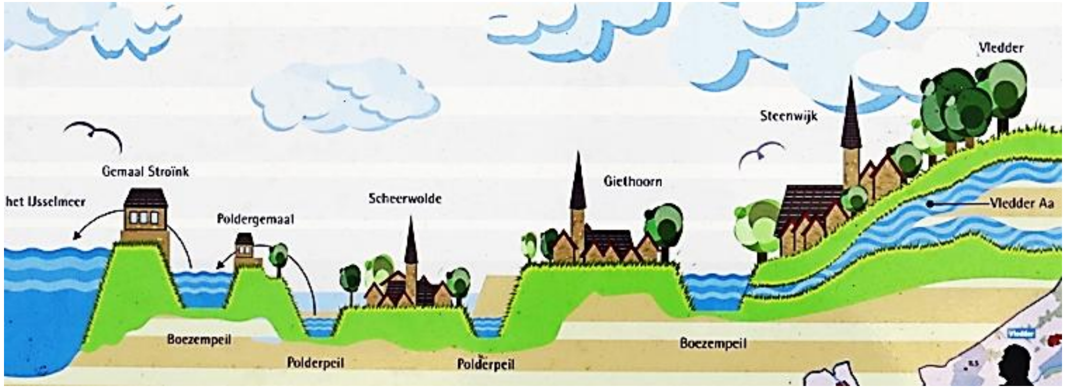


Water levelling

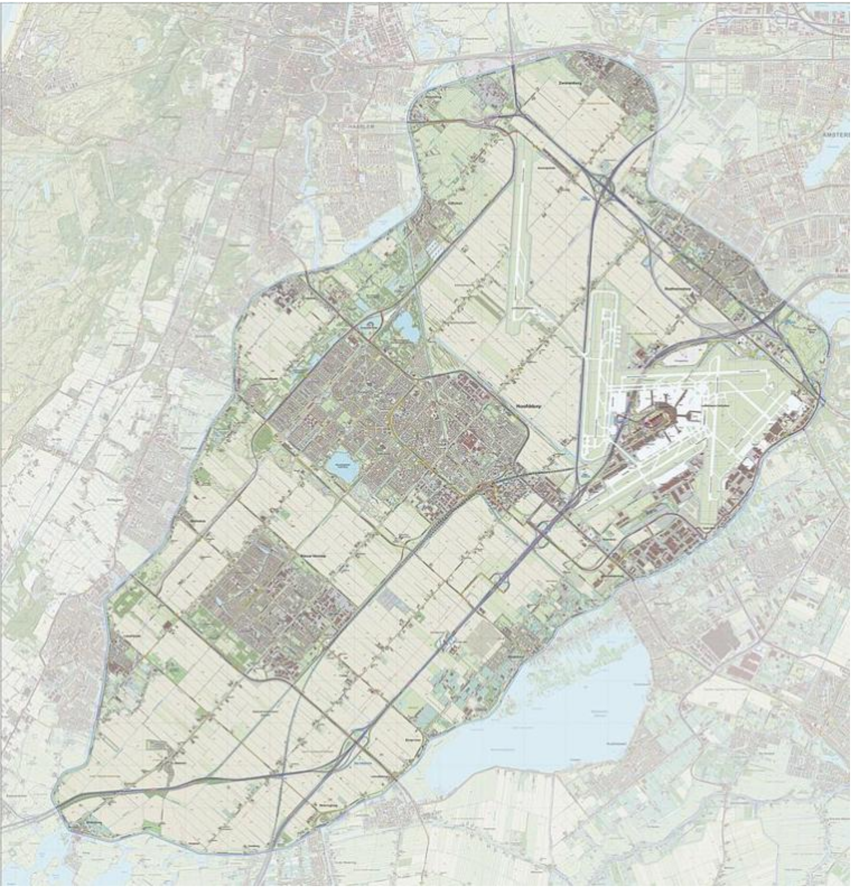
Water levelling is necessary



- Windmills
- Steam engine
- Diesel engine
- Electric motors
- VSD controlled motors
- VSD Electric "Direct Drive"



Haarlemmermeer Polder The First One



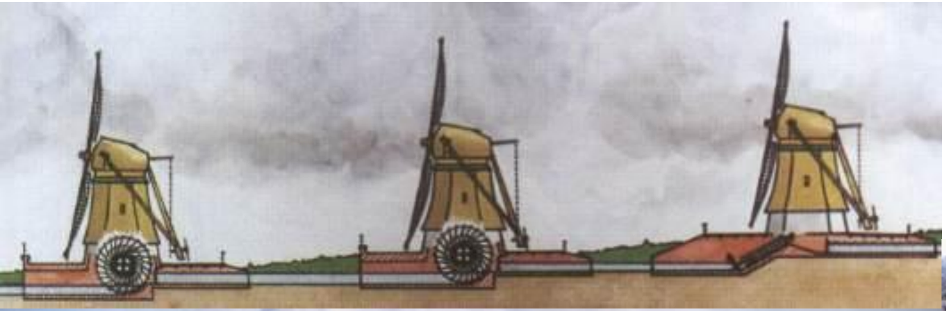
- The lake was originally 17.000 hectare
- In 1855 after 3 years of pumping
  800 million m^3 water was pumped out!
- Todays water capacity: 2 million m^3
  An average pump station has capacity of
  120 m^3 / SECOND
- The first pump station was named “De Leeghwater” after one the spiritual fathers of the project:

  Mr. Jan Adriaanszoon Leeghwater

Technology in Motion

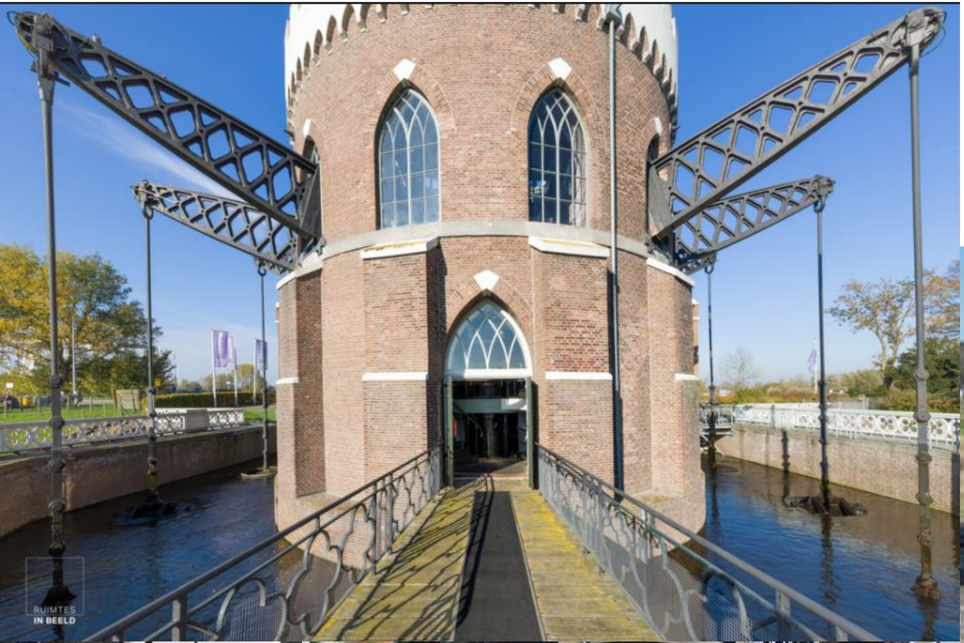
Windmills (from 1600)

- We need WIND!
- Kinderdijke started in 1738
- 19 mills
- UNESCO world heritage

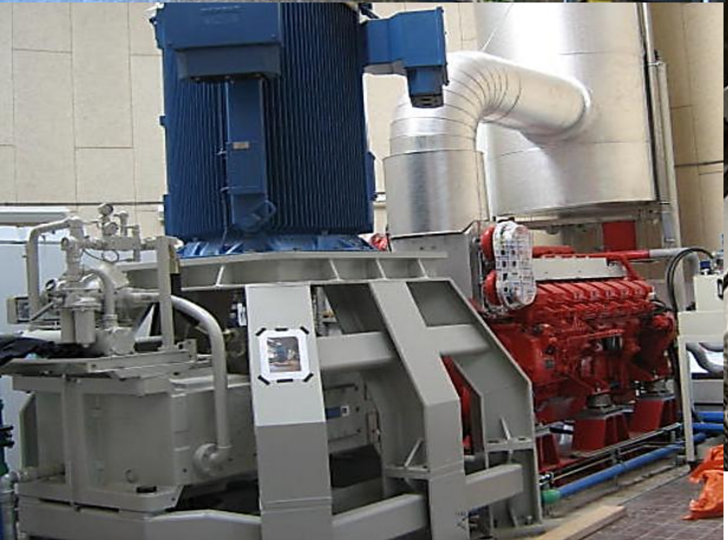


Steam (until 1900)

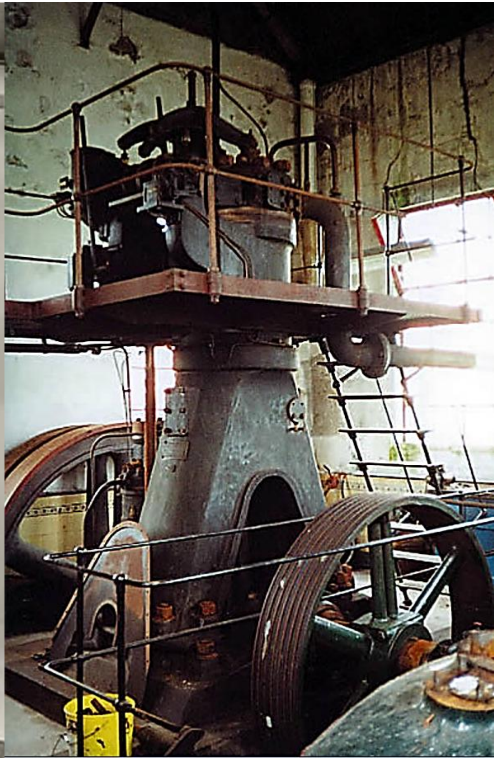
- Pumpstation “ De Cruquis”
- Started 1849
- Steam cylinder 3,6 m diameter
- 8000ltr / 5m per piston
- 5 strokes per minute



Diesel engines



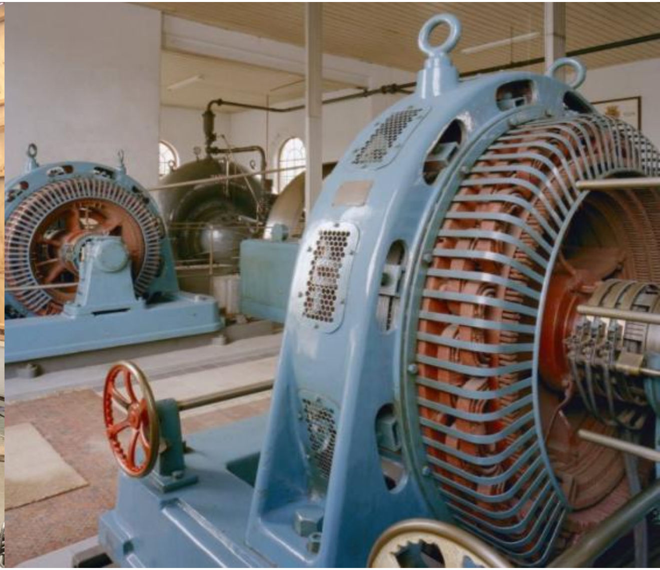
- From 1900- 1990
- Still used as emergency back up



Electric motors (from 1920 – today)

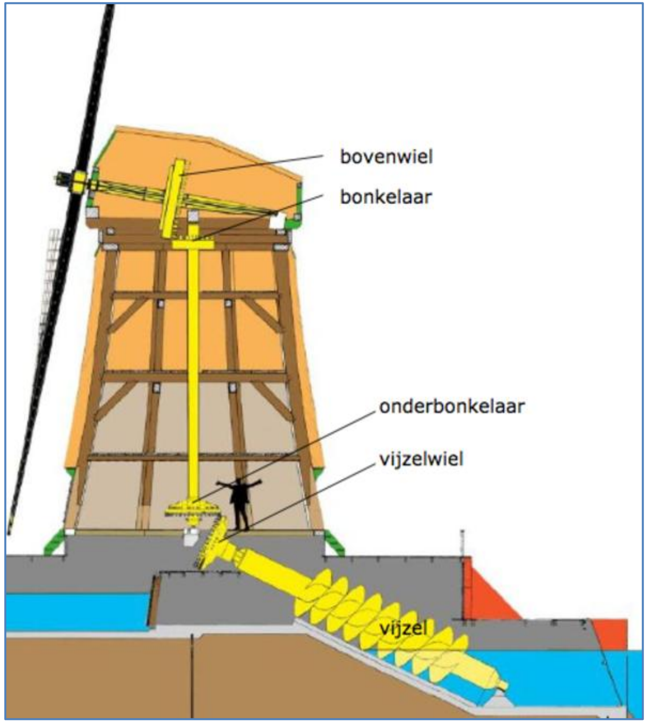
- First direct on line with gear box
- Today with VSD
- Latest development with
  "Direct Drive" VSD controlled
- Pumps can do up to 32 m^3 / second



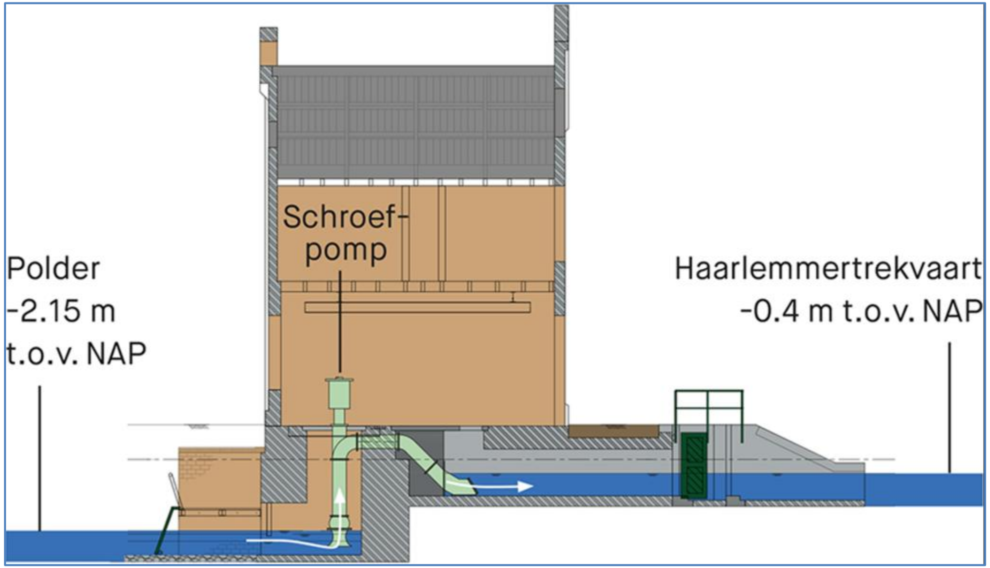


The outside of a pump station

The inside of a pump station

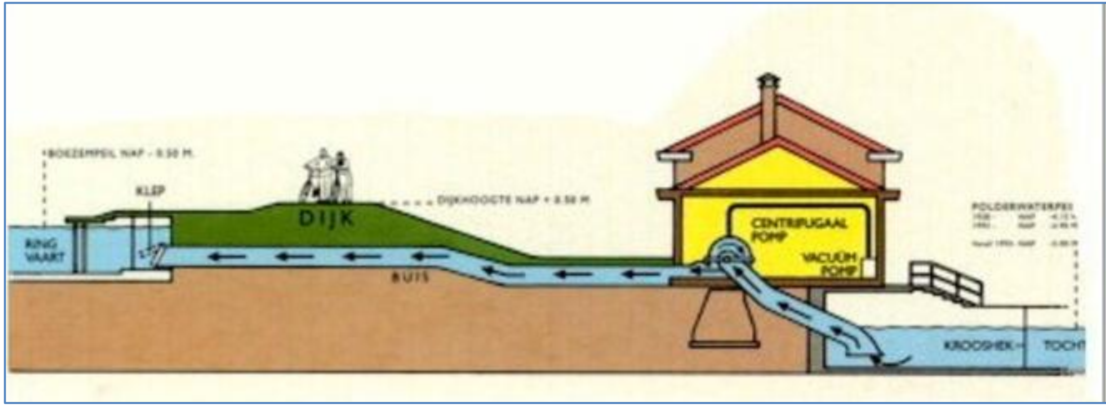


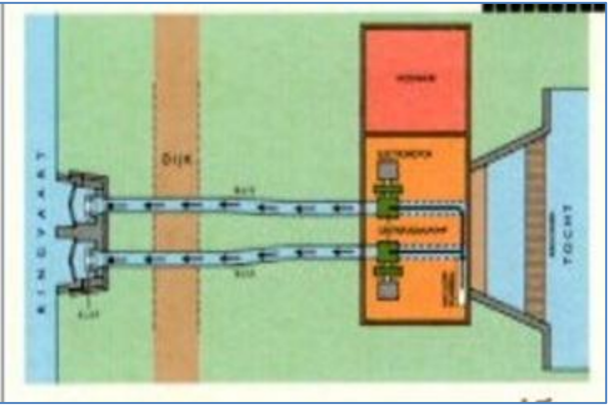
Archimedes pump



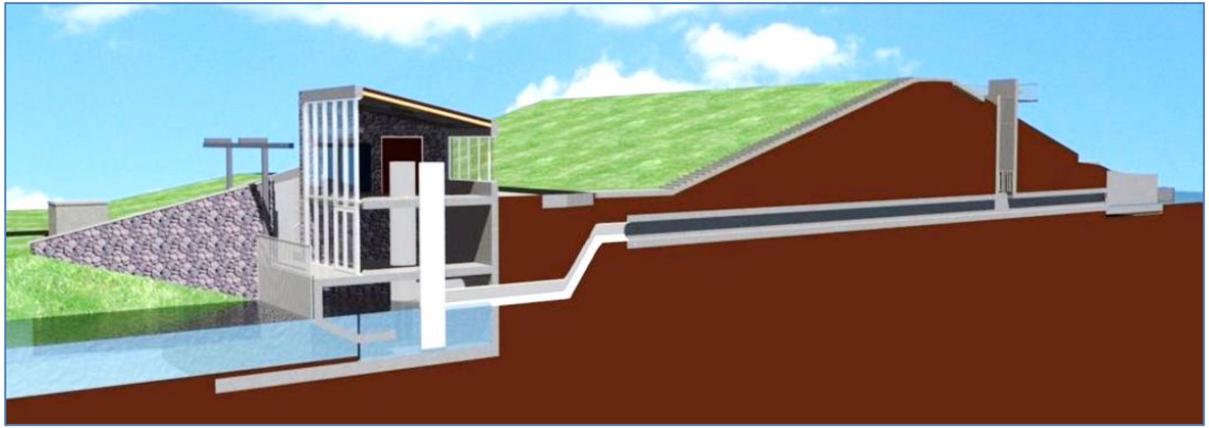
Screw pump

Topology of a pump station

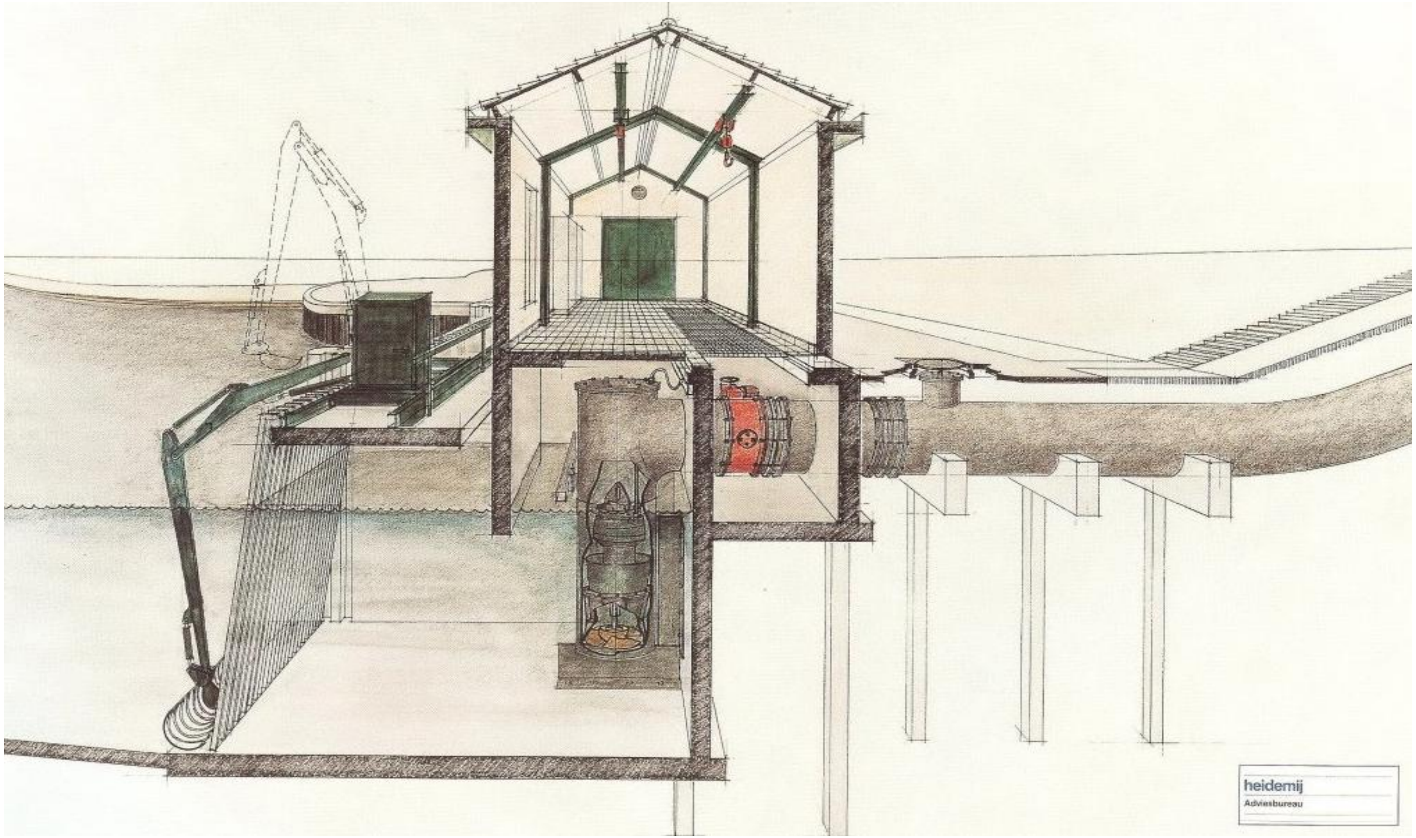




Centrifugal pump



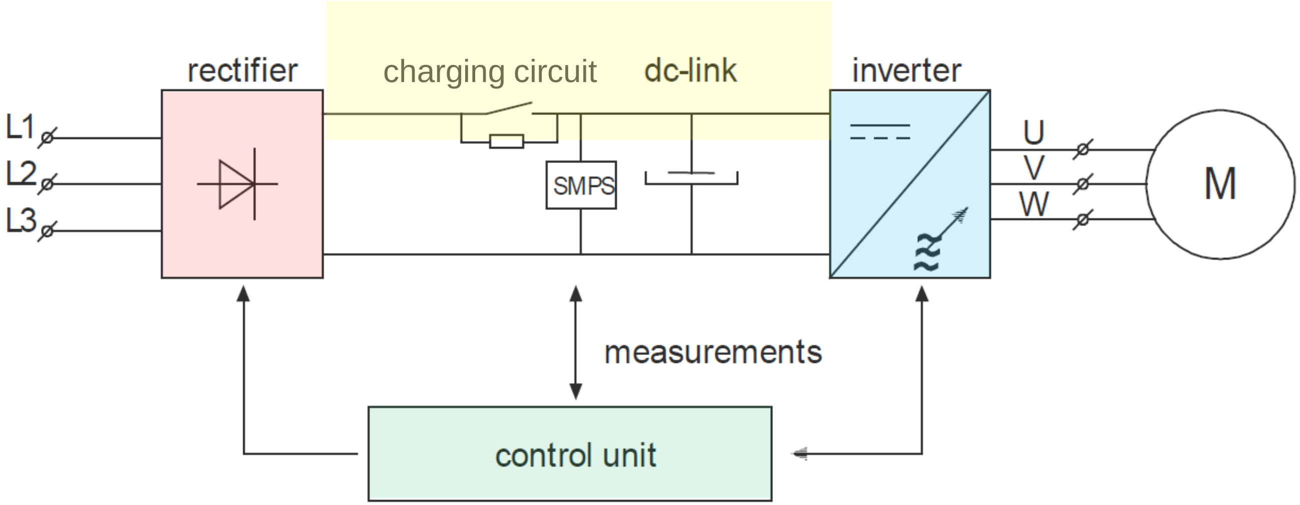
Topology of a pump station



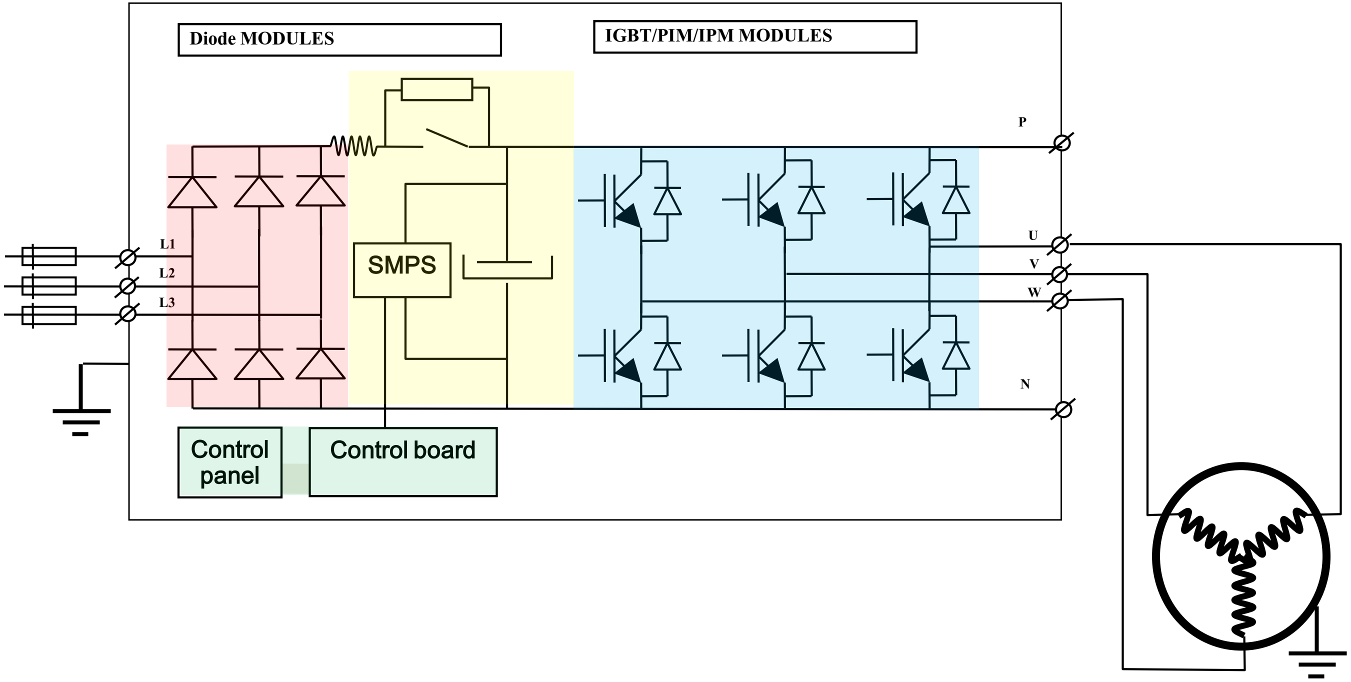
Underwater pump

The Variable Speed Drive VSD

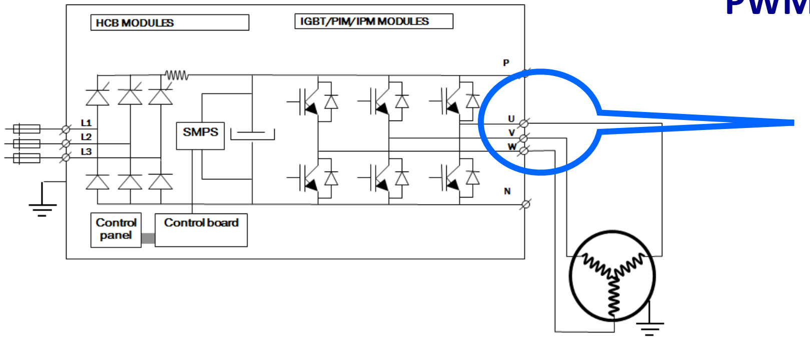
Block Diagram



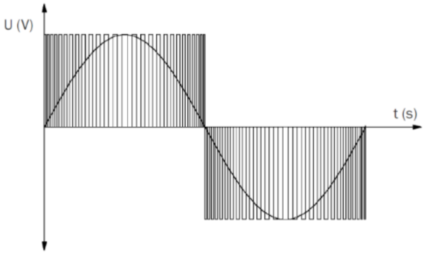
Schematic Diagram



Modulator (PWM based V/f controller)



PWM = Pulse Width Modulation



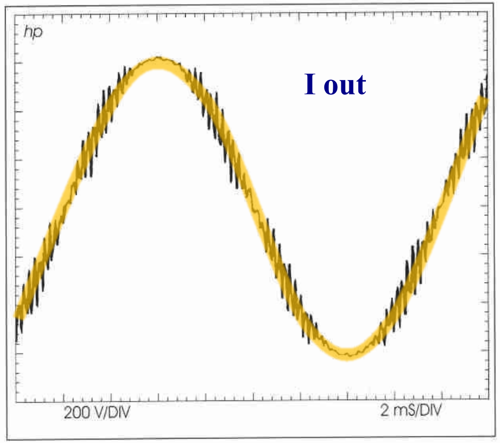


Abbildung 2 : Ausgangsspannung eines Sinusfilters einer Phase
Diagram 2 : one phase of the sinusodial filter output voltage

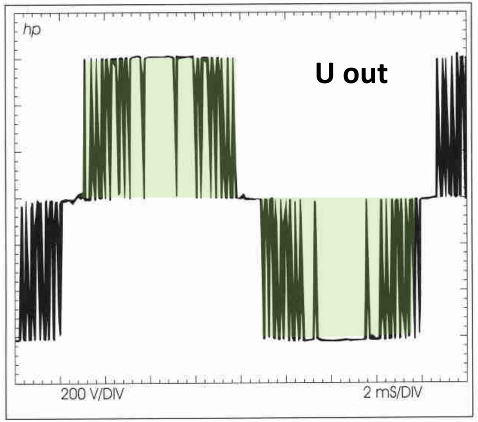
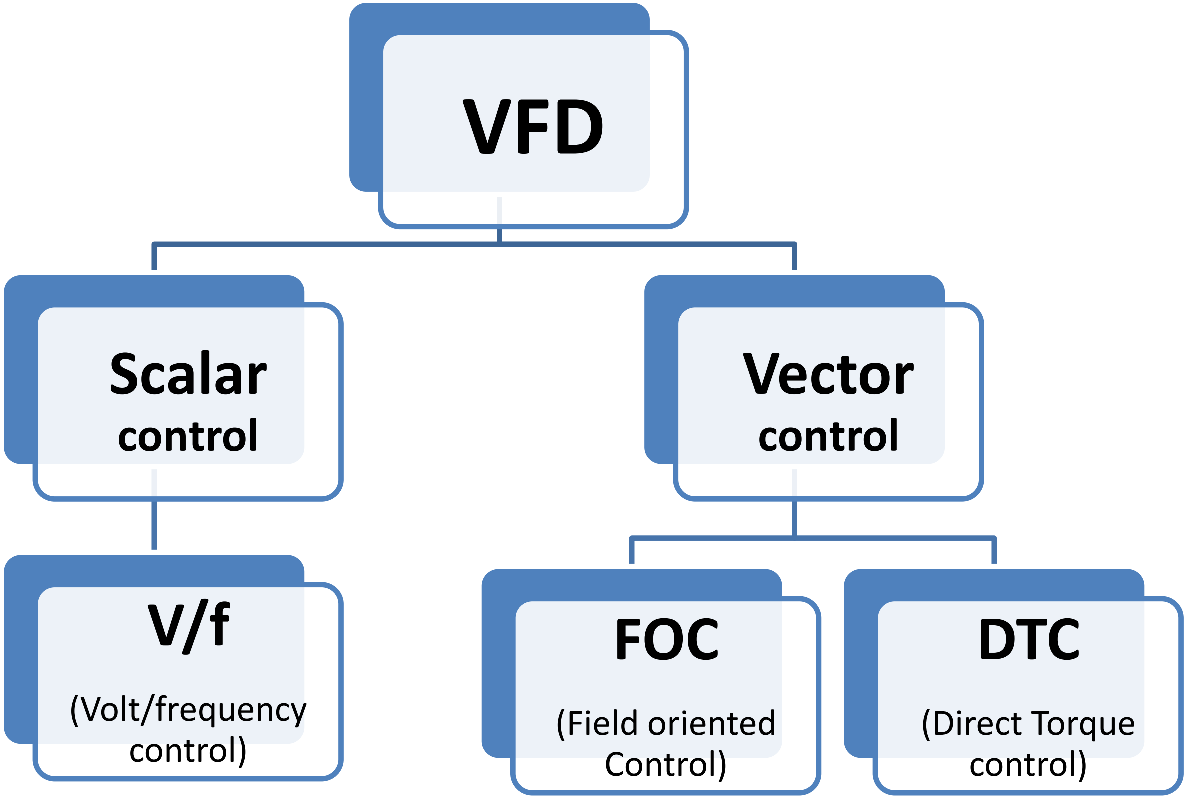


Abbildung 1 : Umrichter-Ausgangsspannung einer Phase
Diagram 1 : one phase of the frequency converter output

VSD control principles

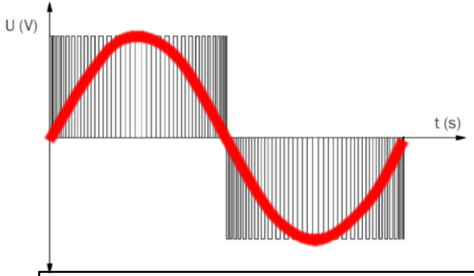


BEWARE: Different suppliers use different terminologies. Always check the specifications!

The Drive Control Principles

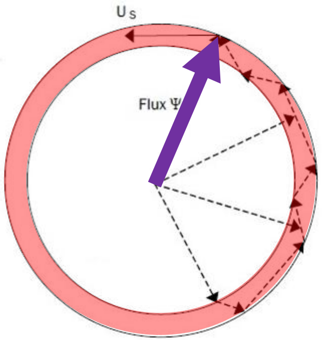
In general there are 2 different **Drive Control** principles:

- **V/f controlled modulators**
  - **PWM "Pulse Width Modulation"**
    (aka: V/Hz, Scalar, Space vector PWM)
  - ~ 80% of all applications,
    <u>low/ normal dynamic performance</u>:
    - Fans, pumps, blowers, compressor, thrusters, conveyers, etc.



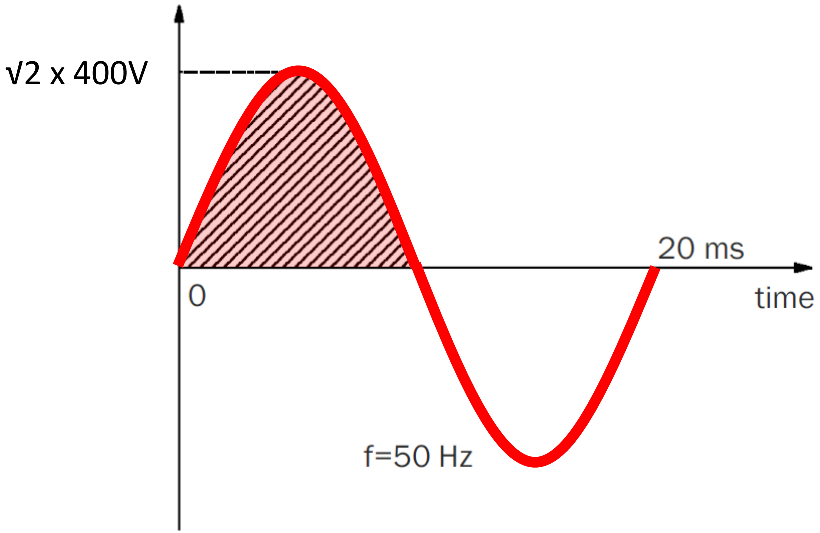
Create the perfect Sine wave

- **Vector controlled modulators**
  - There are 2 very similar:
    - **Field Oriented control (FOC)**
      (aka: Vector flux, Field flux, VVC, etc.)
    - **Direct Torque control (DTC)**
  - ~ 20% of all applications,
    <u>high dynamic performance</u>:
    - Cranes, crushers, extruders, mills, mixers, tooling machines
  - Open loop or Closed loop



Create the perfect Flux > Torque

The Flux in the Motor



- The Flux (magnetic field) is determined by the Voltage-Time area of the applied voltage

$$\Phi \approx E/\omega s$$

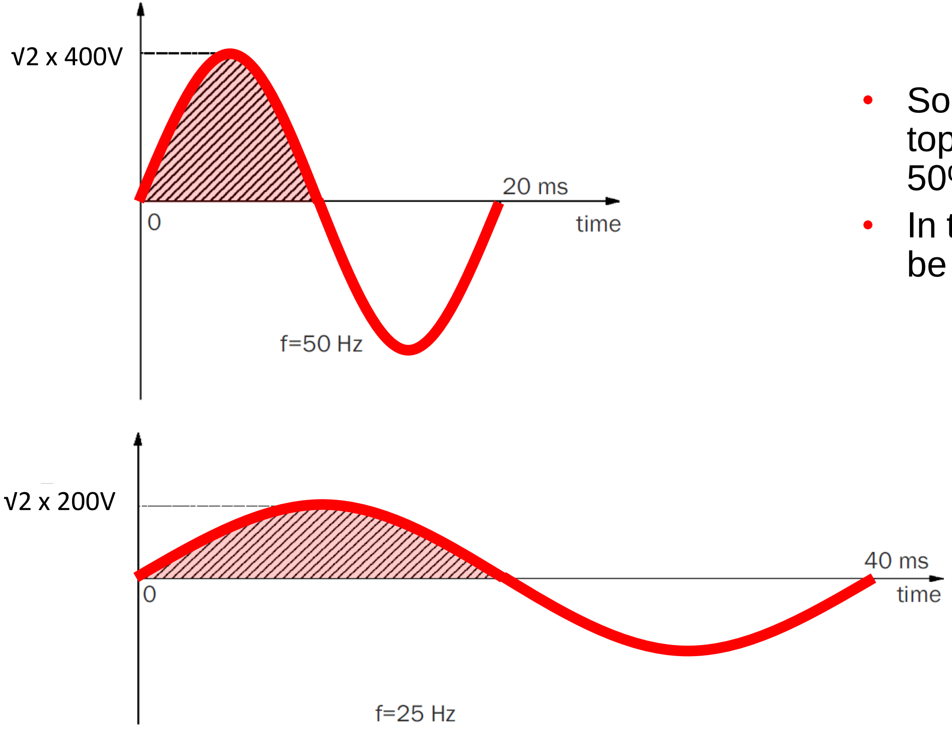
Φ = flux

E = voltage

ωs = angle speed

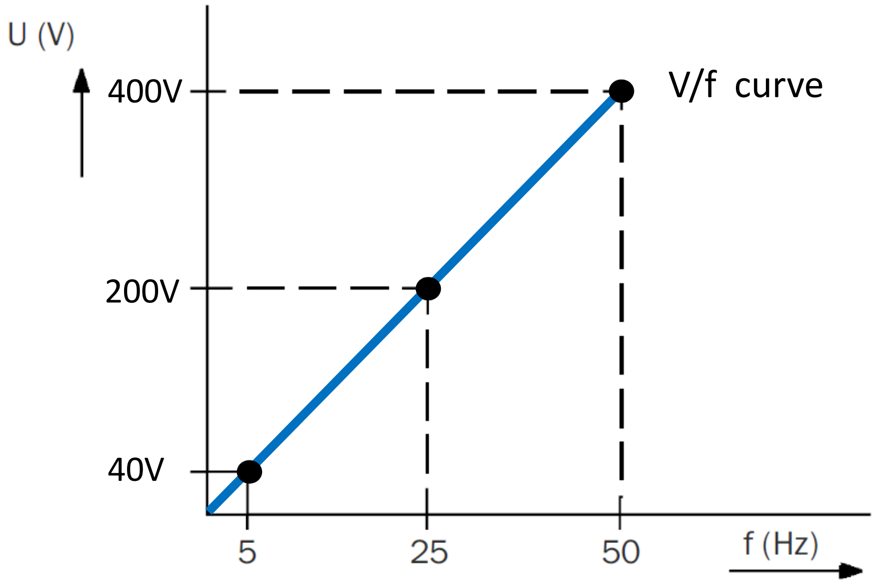
- With a VSD the frequency will change , so we need to keep the FLUX constant at each frequency

The Flux in the Motor



- So at 50% frequency the top voltage will be also 50%
- In that case the FLUX will be constant

V/Hz ratio

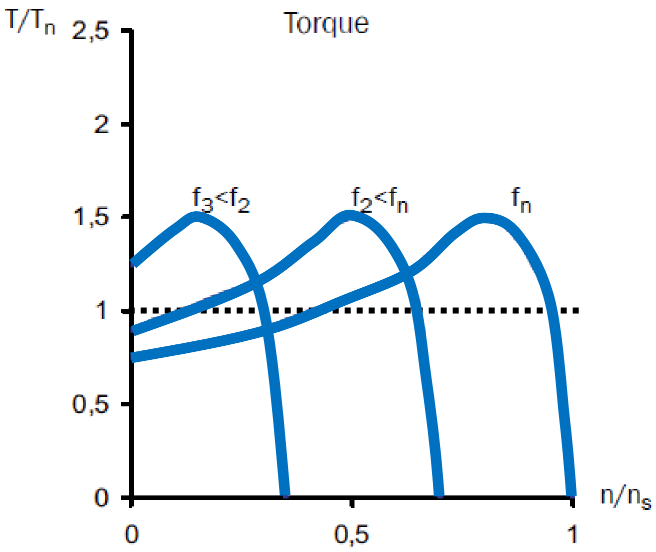


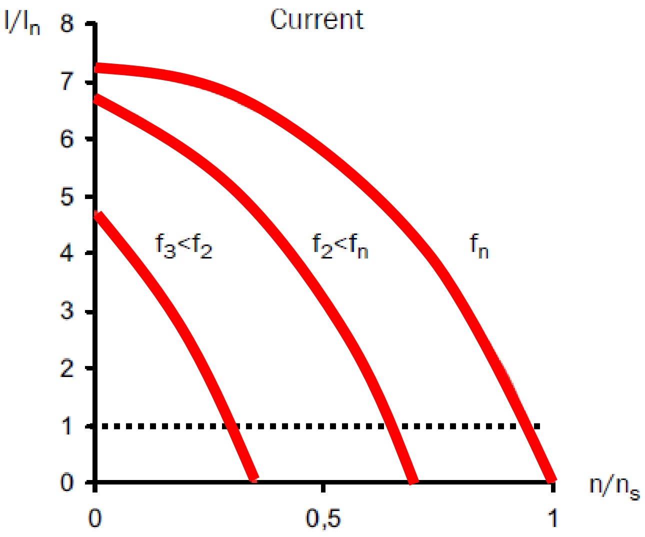
V/Hz value remains constant during frequency control:

V/f ratio = 400V/50Hz = 200V/25Hz = 8.0 V/Hz

The flux remains constant also at lower frequencies!

Torque / Speed

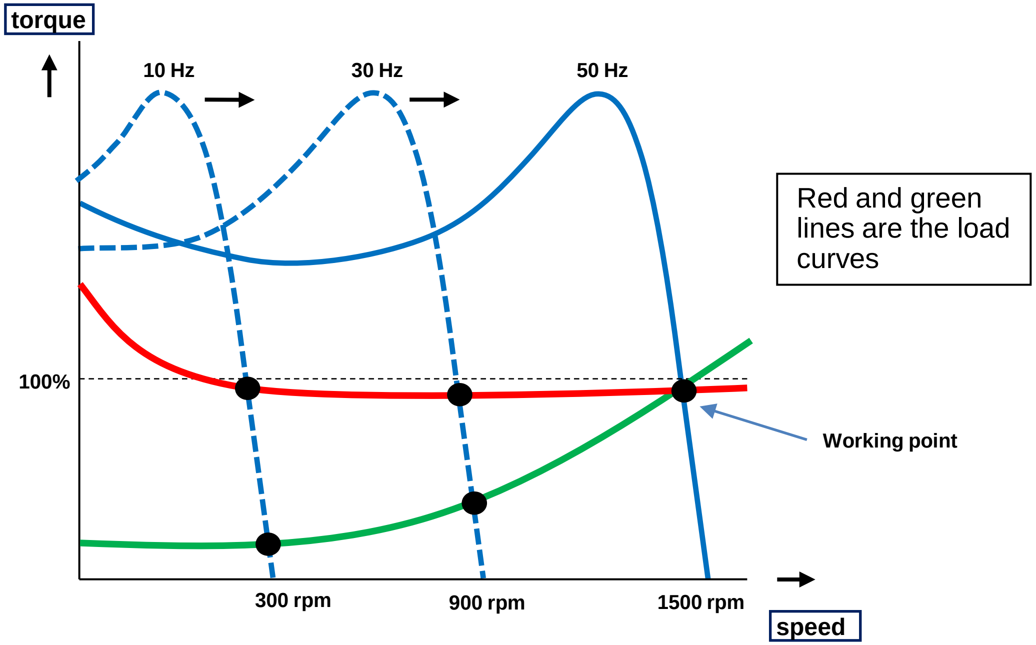




The torque / speed curve moves across the shaft speed

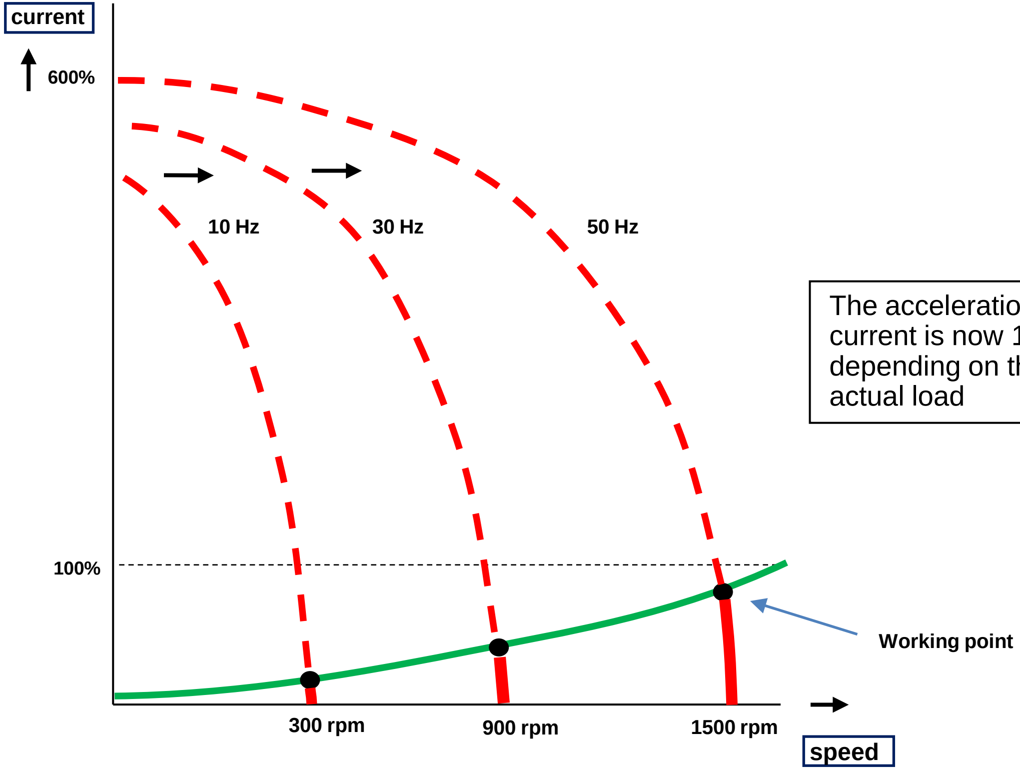
Starting with a drive: working point

- Motor starts always in the **working point** of the curve.
- The torque speed curve moves from left to right over the speed curve
- **Acceleration with nominal current!**



Starting with a drive: Starting Current

• Acceleration with nominal current, following the load curve!



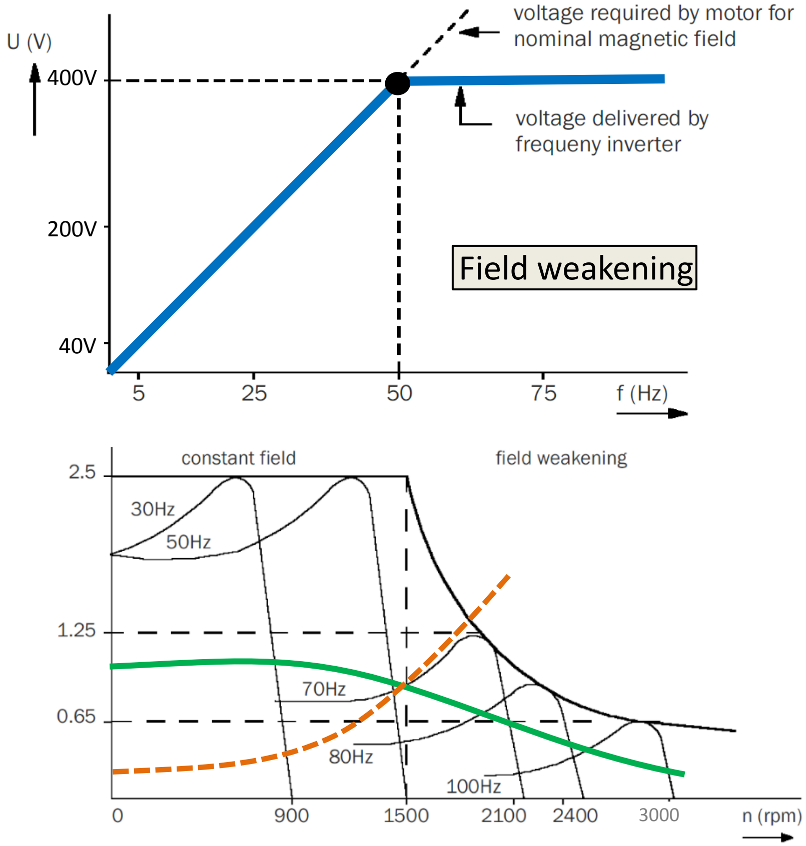
The acceleration current is now 100% depending on the actual load

Operation > Nominal speed: Field weakening

- When the drive goes above nominal speed the V/Hz ratio goes down.
  The magnetic field will <u>decrease</u>

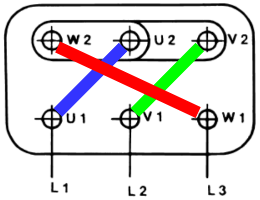
- Depending on torque/ speed curve of the application it is possible to drive the motor

- Example contstant power application (machine tool, winder)

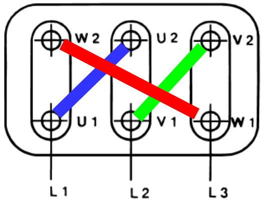


Star / Delta

STAR



DELTA



STAR CONNECTION:

Vline = Vphase x √3

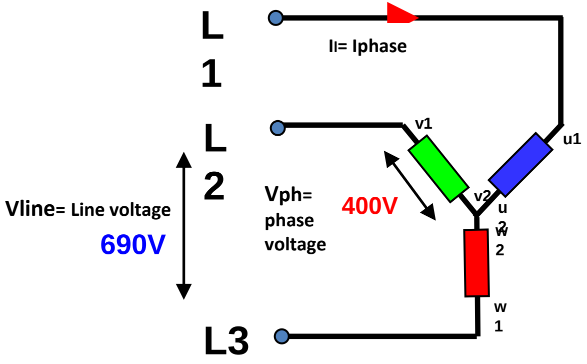
Iline = Iphase

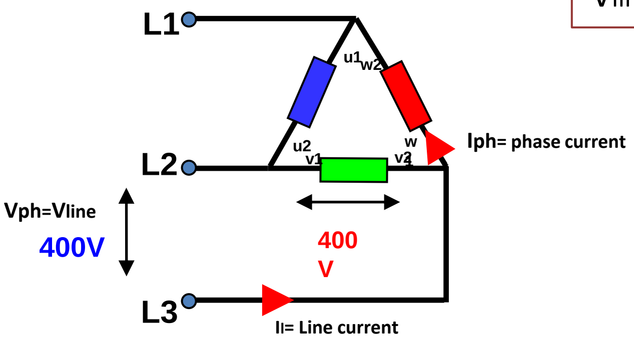
On type plate: 400 / 690V Δ / Y

DELTA CONNECTION:

Iline = Iphase x √3

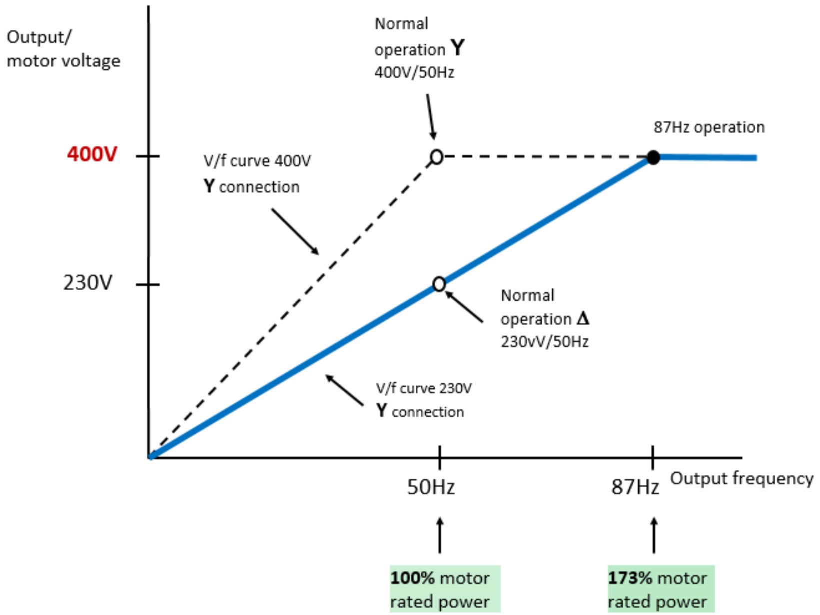
Vline = Vphase





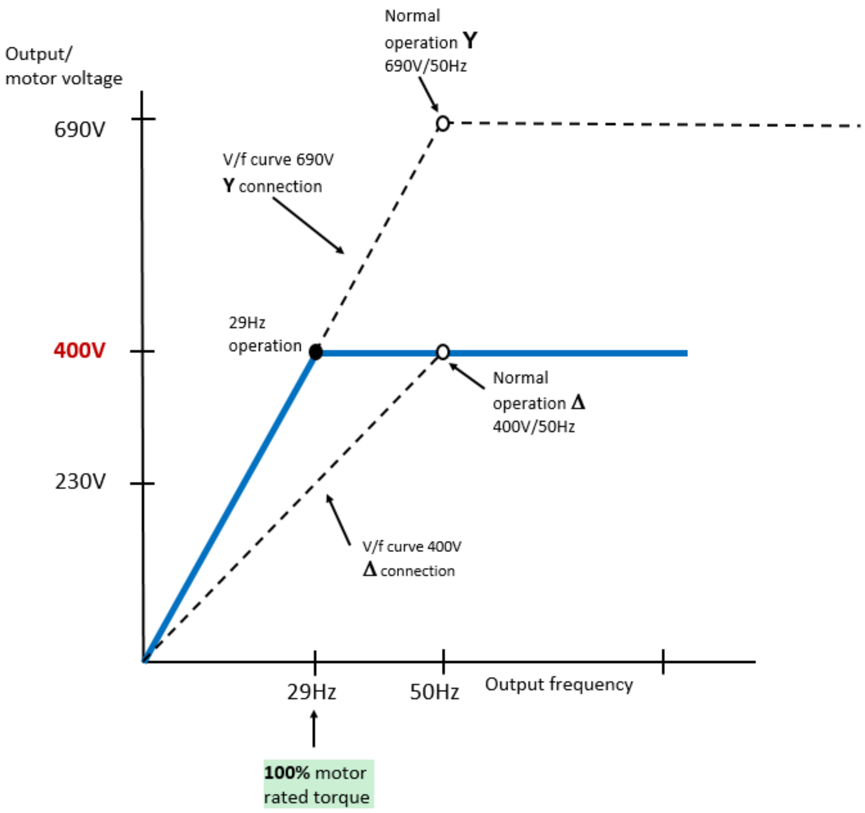
Tip: The lowest voltage is always the phase voltage

87Hz operation with 230/400V motor



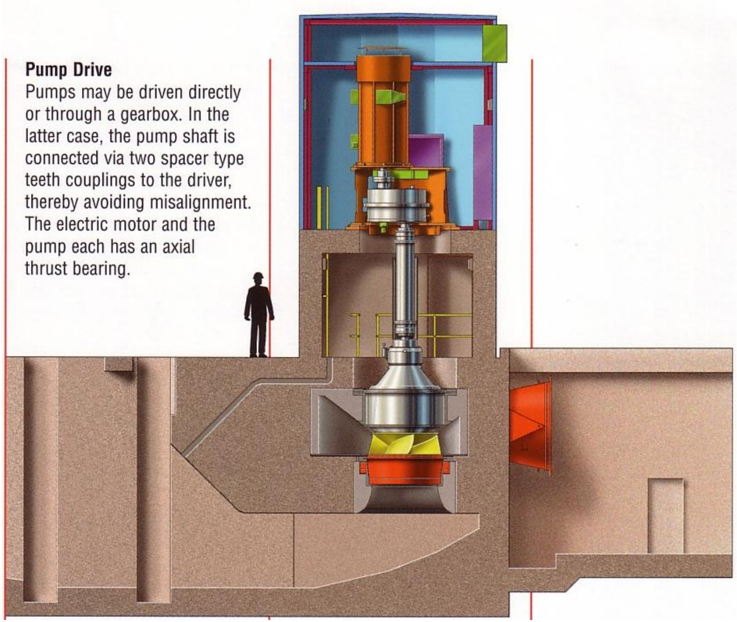
- Operate the motor at the lower voltage e.g 230V
- Supply voltage is 400V
  The V/hz will be constant until 87Hz
- The TORQUE will be constant
  The power will increase with 173% (√3)
- The current will raise with 173%!
- Note that the Isolation voltage of the motor needs to withstand a 400V supply!

29Hz operation with 400/690V motor



- Operate the motor at the higher voltage e.g 690V
- Supply voltage is 400V
- The V/Hz will be constant untill 29Hz
- The TORQUE will be constant
- Application slow speed pump (see applications)

“Direct Drive” pump system

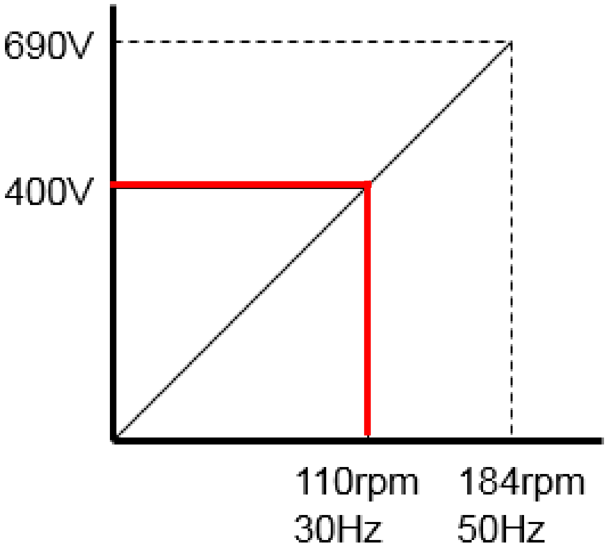


- Pumping stations for level drainage usually have special pumps with a large bore that operate at a relatively low speed. If this is the case, it is important to know the Torque in the working point and the related rotational speed.

- In level drainage, so-called 'direct drives' are used increasingly more often to reduce maintenance and to simplify automation. In this respect, it is useful to know whether the stakeholders are interested in this choice.

Technology in Motion

“Direct Drive” pump system



Motor:

- 250 kW
- Star connected 690V
- 32 pole Nom speed: 184 rpm
- Max pump speed: 110rpm

VSD:

- 250Kw
- Input voltage: 400V
- Max output frequency : 30Hz

THANK YOU!