Newfoundland Labrador

2018 Clean and Safe Drinking Water Workshop
Hotel Gander

Variable Speed Drives

Controlling Centrifugal Pumps
Energy Savings

ABB Drives
Sales, Support & Service

Authorized value provider
ABB

Presenter:
Dave Galbraith

SANSOM EQUIPMENT LIMITED

What is a Variable Speed (Frequency) Drive?

AKA… VFD, VSD, ASD, Drive, Inverter, Converter, etc.

A **VFD** converts the 50-60Hz fixed-frequency and fixed-voltage AC power supply into a DC supply, using an integrated rectifier.

Integrated power electronics then inverts the DC supply into a simulated PWM sinusoidal output with continuously variable frequency and voltage, which is used to drive the motor.

Converters = change AC to DC
Inverters = change DC to AC

Speed Formula

$$RPM = \frac{120 \times F}{P}$$

F = Frequency in Hz

P = Poles in the Motor

Examples of Synchronous Speed:

120 x Hz / Poles = RPM

120 x 60 / 2 = 3600

120 x 60 / 4 = 1800

120 x 60 / 6 = 1200

120 x 60 / 8 = 900

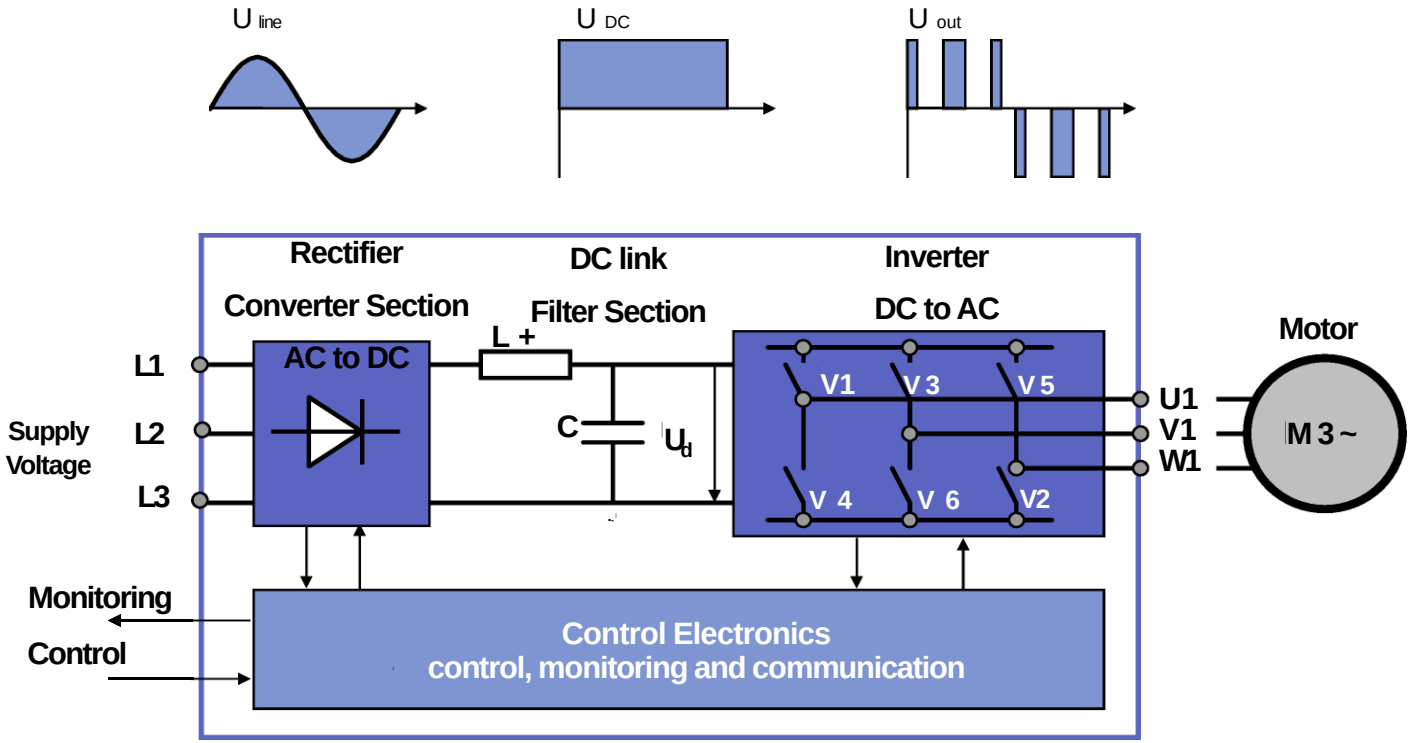
Examples:

30Hz = 50% speed

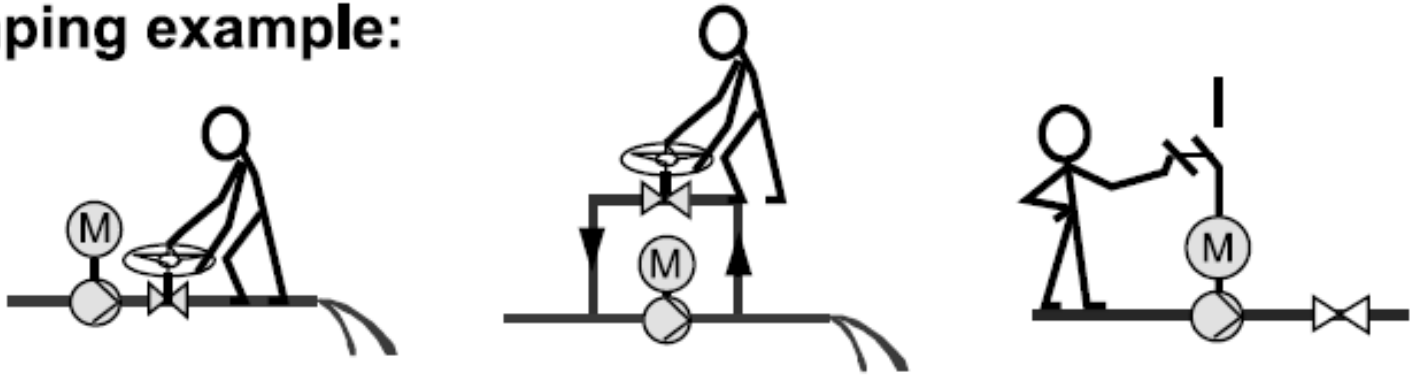
45Hz = 75% speed

90Hz = 150% speed

Basic Construction of VFD

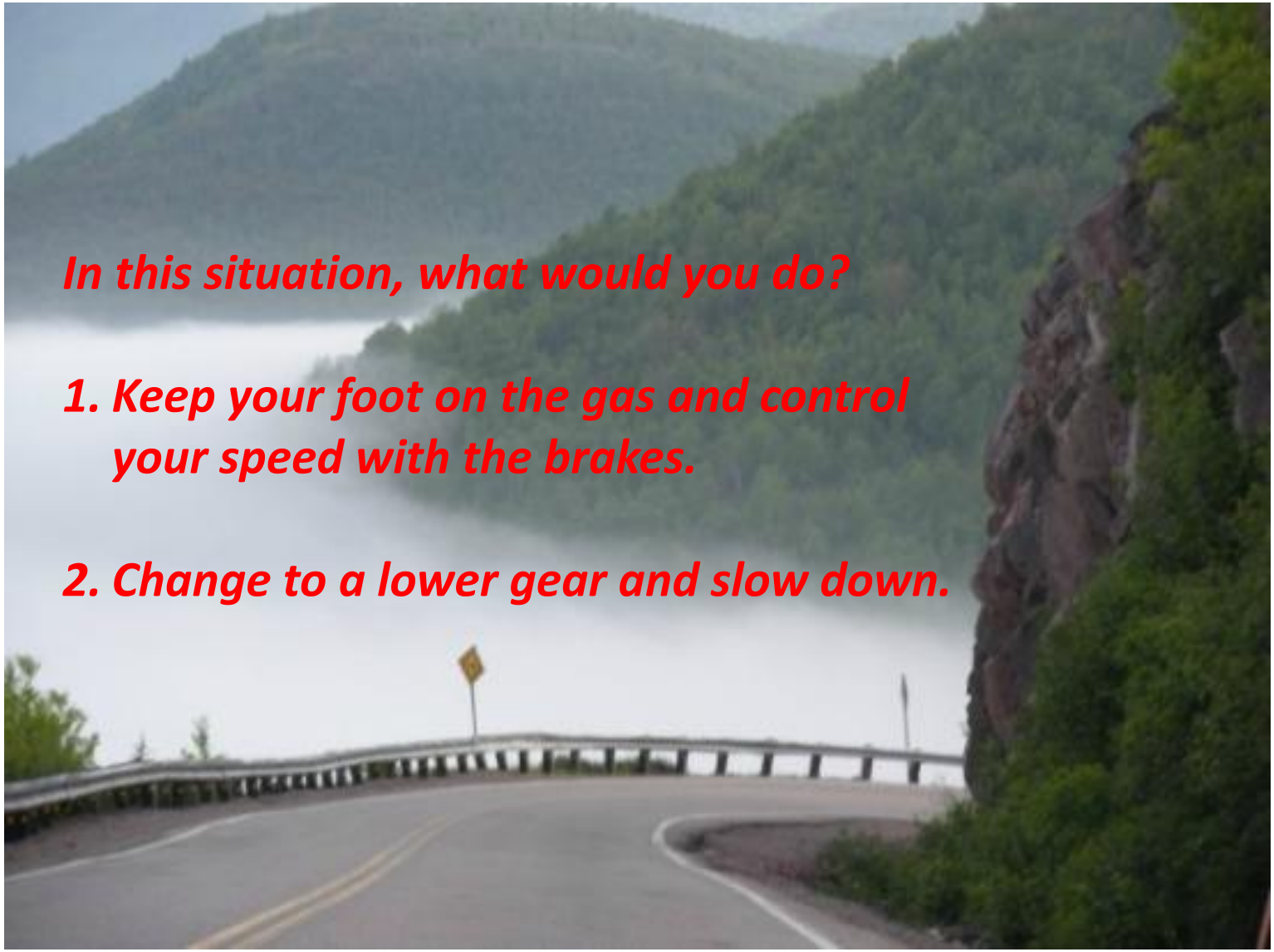


Pumping example:

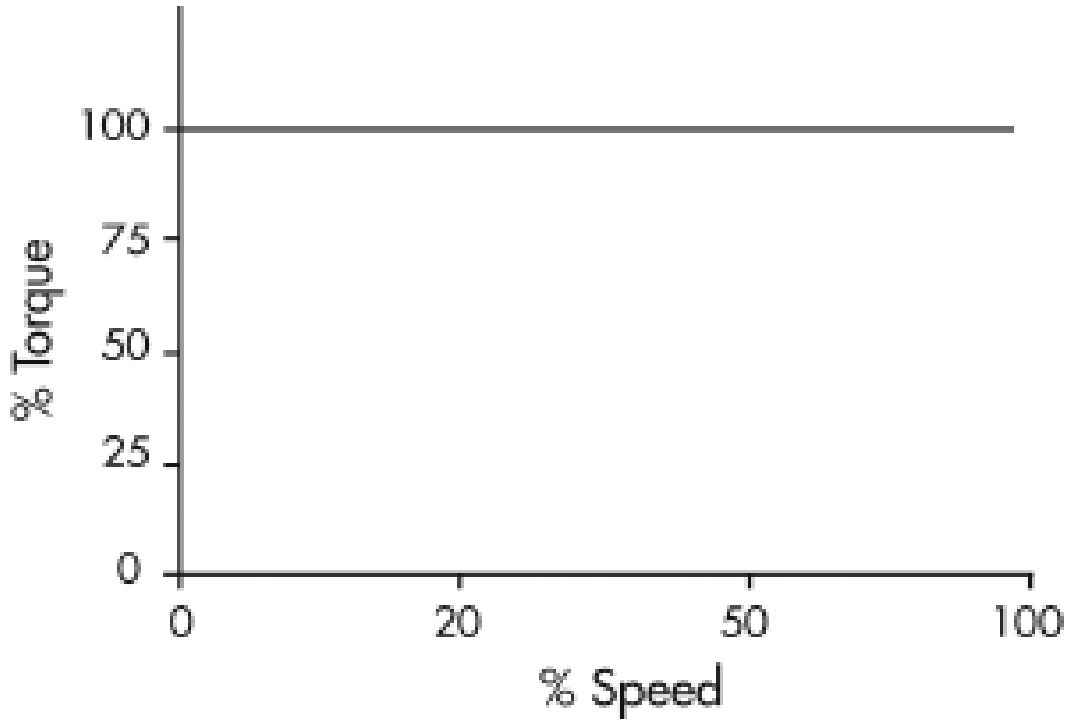


Throttling Bypass control On-Off control

- **Simple construction**
- **Optimal capacity is difficult to achieve**
- **An increase in capacity means reconstruction of the system**
- **Control by throttling, recirculation or start and stop**
- **Risk of damage at start-up**
- **Operating costs are high**

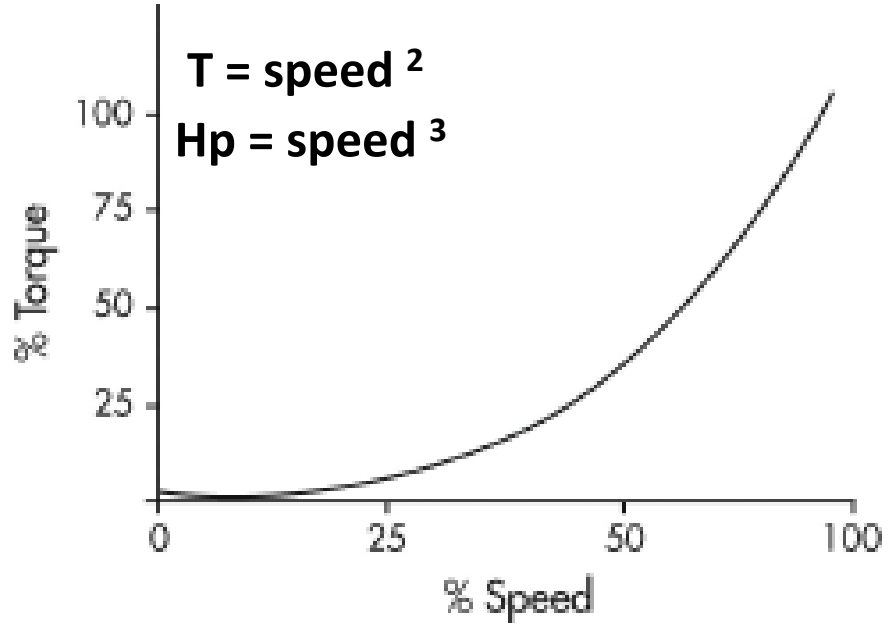

In this situation, what would you do?
1. Keep your foot on the gas and control your speed with the brakes.
2. Change to a lower gear and slow down.

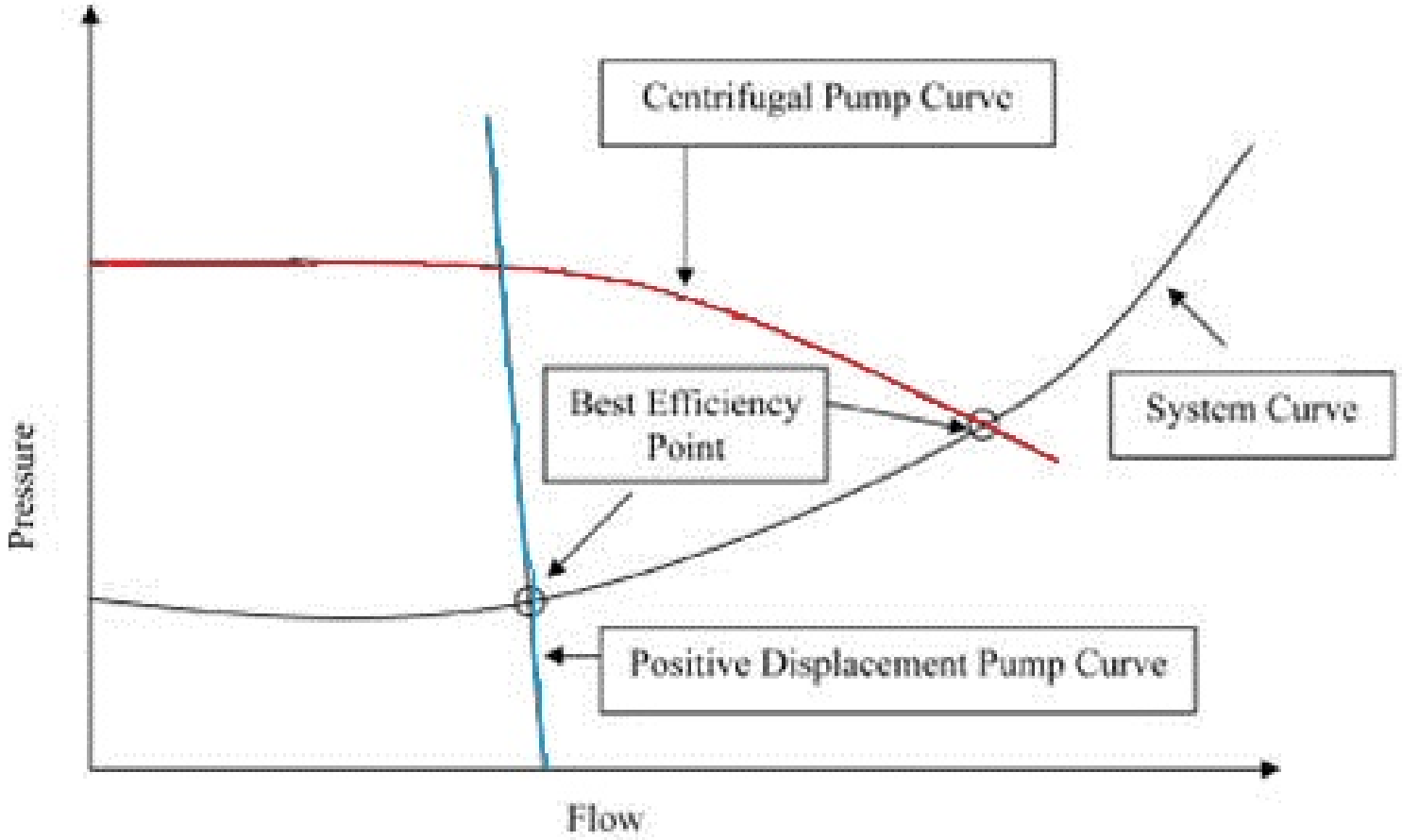
Constant Torque Loads



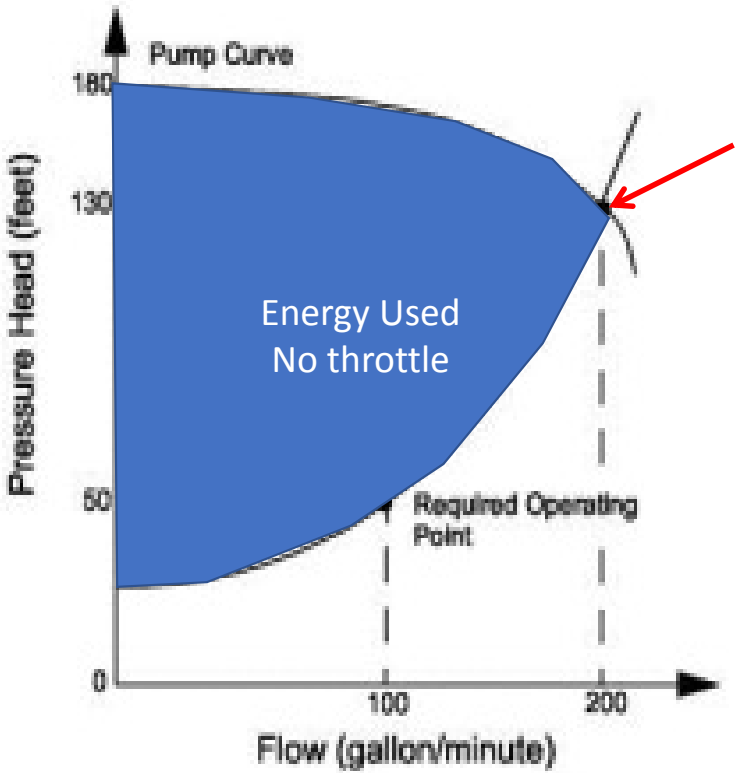
Centrifugal *Fans, Blowers &* *Pumps*

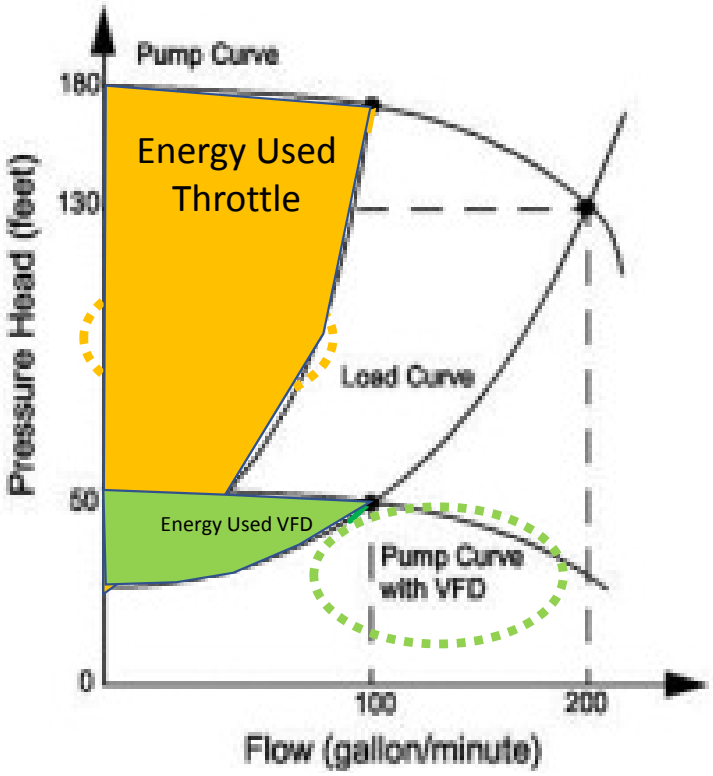
Variable Torque Loads




Centrifugal Pump Curve
Best Efficiency Point
System Curve
Positive Displacement Pump Curve
Pressure
Flow

Full Speed & Throttled versus Variable Speed





AC & DC VFDs are to be rated by

Supply Voltage & Current

(208V, 240V, 380V, 460V, 575V, 600V, 690V, etc)

Horsepower & kW are only used as a guide

The type of Load and the application will determine the proper size of the VFD

VFD Enclosures are typically NEMA 1 (IP21)
NEMA 12, 3R, 4X etc are options

VFDs are most often used with Centrifugal Pumps
…which are typically Variable Torque Loads

VFDs are also being used with Blowers for Aeration
in Lagoons and other Wastewater tanks
….which are mainly Constant Torque Loads

VFDs on Progressive Cavity & Positive Displacement
Pumps; Mixers or Screws, Conveyors, Hoists, Drills,
are Constant Torque Loads

Variable Torque

In these applications:

- Torque varies directly with speed squared
- Power varies directly with speed cubed

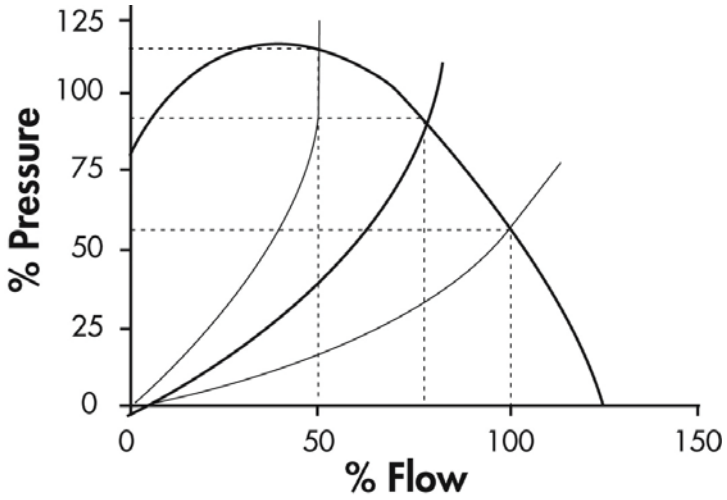
This means that at *half speed*, the horsepower required is approximately *one eighth of rated maximum*.

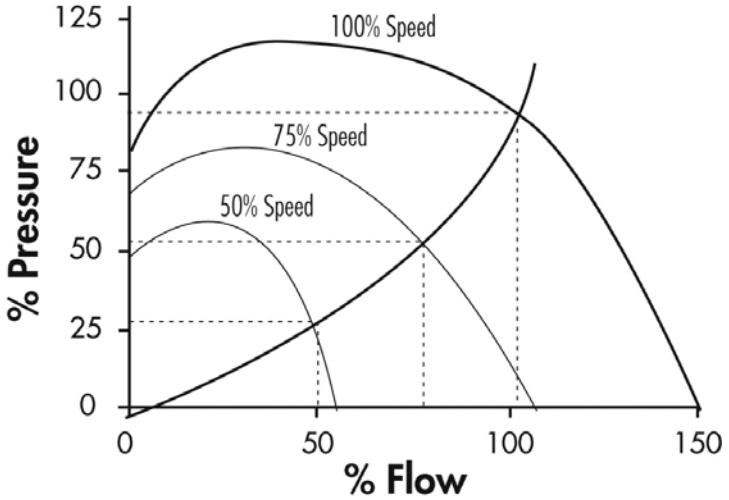
Throttling a system by using a valve or damper is an inefficient method of control because the throttling device dissipates energy which has been imparted to the fluid. A variable frequency drive simply reduces the total energy into the system when it is not needed.

- In addition to the major energy saving potential, a drive also offers the benefits of increased process

Speed of Fan/Pump	Mechanical Power Required
100%	100%
90%	73%
75%	42%
50%	13%

Power Required by Fan/pump as a Function of Speed





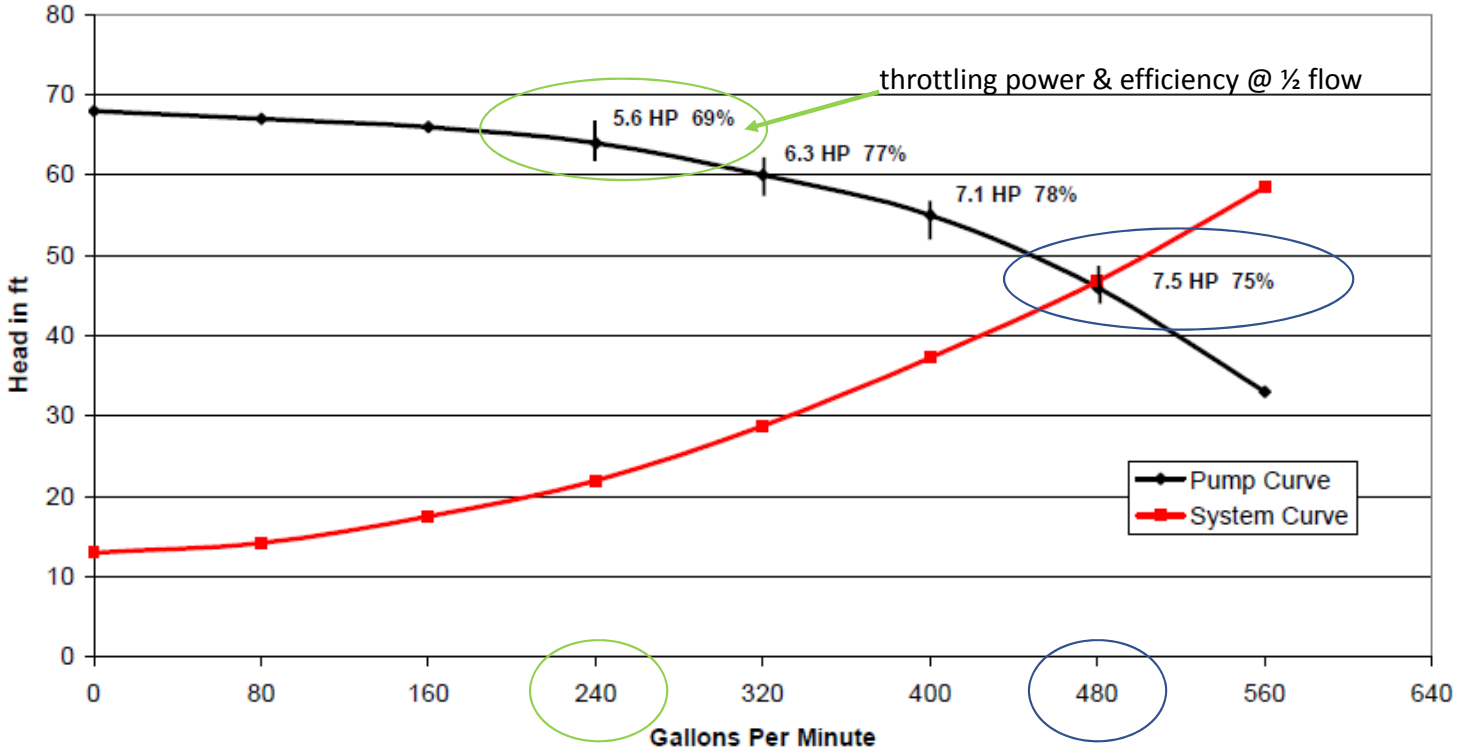
Common Stresses on Pump Systems

Hydraulic Stress (AKA Water Hammer) is caused by abrupt change in flow; usually from quick starting or stop of the pump without a "Soft Start or Soft Stop". The shock wave can travel at the speed of sound and could create up to 600PSI depending on the size of pipe and length.

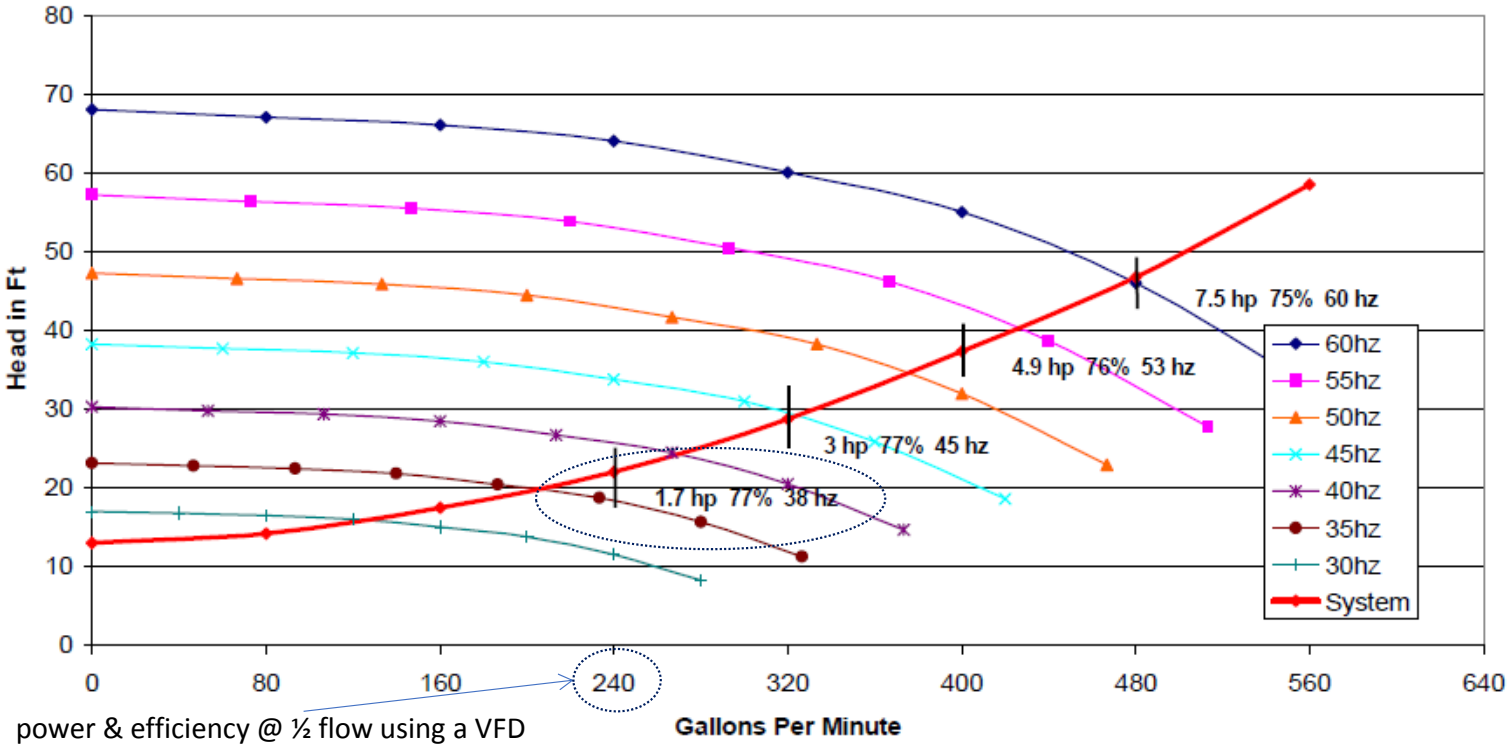
Electrical Stress can affect the Motor and the power supply. A typical motor can use at least five times the inrush current when started across-the-line at 60Hz. Frequent starts can cause damage to the motor, pump and possibly overload the electrical system. This causes overheating in the motor windings, the wires and the breakers. Using a VFD on a Centrifugal Pump eliminates the inrush current completely by controlling the Ramp up and Ramp down (with Soft Starting & Soft Stopping).

Mechanical Stress in a typical small 1750RPM motor (unloaded) will accelerate from zero to synchronous speed in less than one second without any ill effects. By adding a Centrifugal Pump Load, the motor will accelerate up to full speed in less than two seconds depending on the application, pump design, impeller diameter, mass, type of fluid flowing, etc. The inertia can be quite significant and additional stresses and radial forces are put on the shaft, bearings, keyway, etc. If the shaft coupling is misaligned, then additional stresses can also affect the motor/pump. With the use of a VFD, the abrupt mechanical stresses can be reduced.

Constant Speed Pump Curve



Variable Speed Pump Curves



power & efficiency @ ½ flow using a VFD

PumpSave Payback Calculation Software Example

System Data

Liquid density	62	lb/ft³	Static head	20 ft

Pump Data

Nominal volume flow	480	gpm	Efficiency	77%
Nominal head	43	ft	Max head	55 ft

Existing Flow Control

Throttling control

Motor and Supply Data

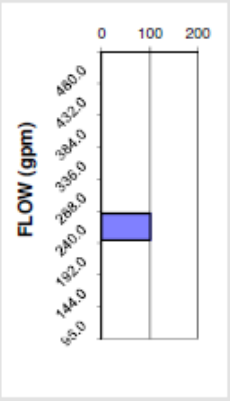
Supply voltage	690 V	525/550/575/600/660/690 V
Motor power	7.5 Hp	Required motor power: 7.5 Hp including 10% safety margin
Motor efficiency	96.0 %	

Operating Profile

Annual running time: 8,760 h

0 %	=	0 h	at nom. flow
0 %	=	0 h	at 90% flow
0 %	=	0 h	at 80% flow
0 %	=	0 h	at 70% flow
0 %	=	0 h	at 60% flow
100 %	=	8760 h	at half flow
0 %	=	0 h	at 40% flow
0 %	=	0 h	at 30% flow
0 %	=	0 h	at 20% flow

100



Measurement Units

Calculated by:	
Calculated for:	
Pump ID:	

Improved Flow Control by ABB Drive series:

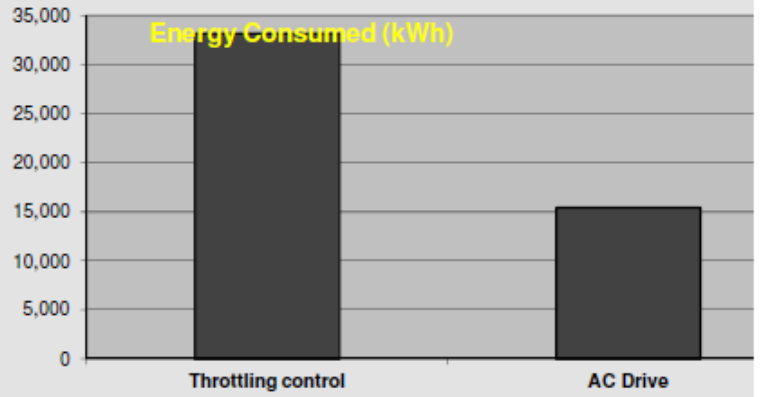
ACS550

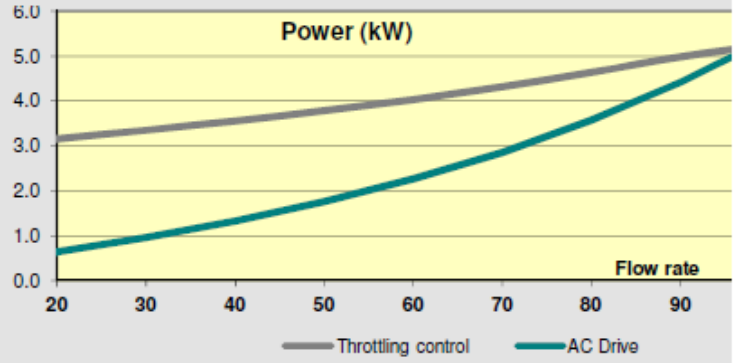
ACS550-U1-011A-6

Results

Saving percentage	53.6 %	
Annual energy consumption:		
with existing control method	33	MWh
with improved control method	15	MWh
Annual energy saving	18	MWh
Annual CO2 reduction	9	t
CO2 emission/unit	0.5	lb/kWh

Energy Consumption





Economic Data

Currency unit	$	
Energy price	0.14	$/kWh
Investment cost	2,000	$
Interest rate	4%	
Service life	10	years

Economic Results

Annual saving	2,489	$
Payback period	0.8	years
Net present value	18,192	$

Common problems when starting and stopping motors with different starting methods

Type of problem — Type of starting method

	Direct-on-line	Star-delta start	Drives	Softstarter
Slipping belts and heavy wear on bearings	Yes	Medium	No	No
High inrush current	Yes	No	No	No
Heavy wear and tear on gear boxes	Yes	Yes (loaded start)	No	No
Damaged goods / products during stop	Yes	Yes	No	No
Water hammering in pipe system when stopping	Yes	Yes	Best solution	Reduced
Transmission peaks	Yes	Yes	No	No

VFD

Draw Backs & Solutions

- Harmonics generated from Input Diode Bridge
  - Solution is to provide Line Choke/Reactor to reduce
    - Recommend Line Choke/Reactor to be included with VFD as part of the manufacture's design

- Voltage Spikes and non-sinusoidal wave forms
  - Solution is to use motor with MG1-Part 31 Ratings
  - Solution is to use DV/DT Filter – reduces the effects
    - MG1-Part 31 is a spec that describes that the motor can be used with a VFD because the insulation rating on the windings.

- Common Mode Voltages – in motor cable
  - Solution is to use Common Mode Filters
    - In addition; VFD rated cable also helps mitigate the effects

Adverse effects on sensitive Instrumentation

- Ultrasonic Level, Magnetic Flow Meters, Generator Controllers, Solid State Circuit Breakers tripping, etc.
  - Partial list of Solutions
    - Provide proper grounding for all equipment (high and low voltage)
    - Locate VFD cables away from sensitive equipment and cables
    - Use shielded cables for Instrumentation
    - Adhere to Mfg.'s installation Instructions i.e. special Grounding

- Ultimate solution – use and Ultra-Low Harmonic VFD
  - Provides less than 4% Current Total Harmonic Distortion
  - Produces better Current Sine Wave for Motor

VFD

Major Benefits

- Reduction in speed reduces wear of pump parts
  - bearings, seals, other moving parts – life is extended
    - Bearing wear reduces by the seventh power of speed
      - Slowing the pump speed reduces the requirement of maintenance

- MTBF (mean time between failure) = 20 years
  - Provided regular maintenance is performed
    - Cleaning out dust, cooling fan replacement, etc.

- Excellent Displacement Power Factor ~ 97%
  - No requirement for PF Correction Capacitors
    - No inrush currents – as with Direct Online Starting

- Open Loop VFD/Motor speed control
  - No requirement for Motor Shaft Encoder Feedback Sensor
    - Process control can be optimized via 4 - 20 mA Transducer/Signals
      - Flow, Level, Temperature & Pressure are measurements used for inputs

- Integral Diagnostics and Fault Protections
  - Micro-processors – monitors and protects VFD and Motor
    - Protections - Short Circuit, Ground Fault, Overload, Motor Stall, Underload, Over Voltage, Under Voltage, Phase Loss, Over Temperature, etc.

- Serial Communications & PLC Functions Available
  - EtherNet, Modbus, DeviceNet, Profibus, etc.
    - Multiple I/O – Analogue and Digital – fully programmable

- Variable Speed – Over & Under Base Speed
  - If Motor is lightly loaded, the VFD can output above 60Hz (within reason)
    - Over Speeding Pump - Provides additional flows (if motor is under-loaded & can handle higher speed) to help occasional peak conditions without requiring a different pump.
      - Pressures and Motor Current draw to be monitored for protection.

  – VFD can output below 60Hz (system curve dependant)
    - Reducing Speed of Pump - Provides additional process, pressure and flow controls.
    - Considerable energy savings with operating Rotodynamic (AKA) Centrifugal Pumps at reduced speeds… Affinity Laws.

Various Versions…

Wall Mounted
Modules
Cabinet-Built

Analog I/O

Digital Inputs

Relay Outputs

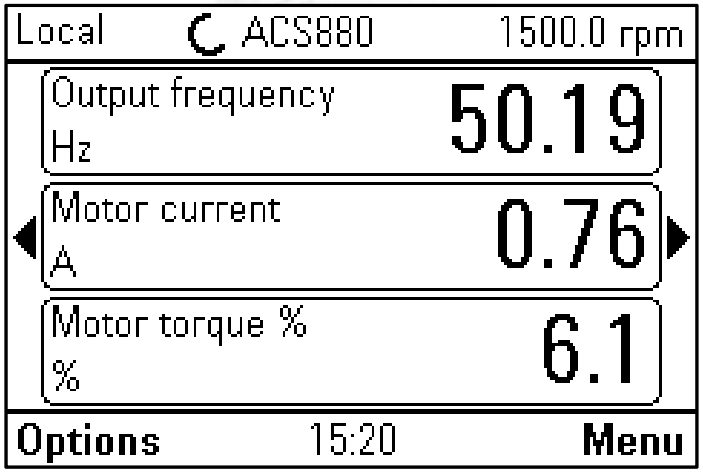
Expansion Slots – I/O & Fieldbus

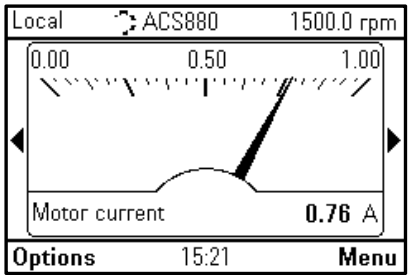
Built-in Modbus using EIA-485

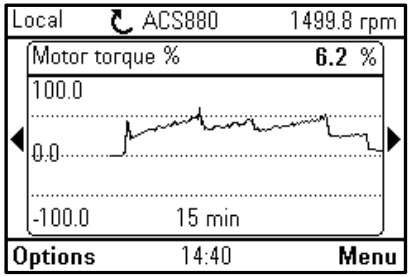
Mains Input & Motor Terminals

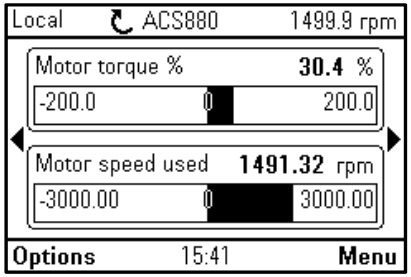
Removable Conduit Box


Local ACS880 1400.0 Rpm
Motor speed 1400.0
Rpm
Motor current 28.8
A
Flow rate 10.9
m³/s
Options 07:38 Menu
Stop
Loc/Rem
Start


Local ACS880 1500.0 rpm
Output frequency
Hz
50.19
Motor current
A
0.76
Motor torque %
%
6.1
Options 15:20 Menu


Local ACS880 1500.0 rpm
0.00 0.50 1.00
Motor current 0.76 A
Options 15:21 Menu


Local ACS880 1499.8 rpm
Motor torque % 6.2 %
100.0
0.0
-100.0 15 min
Options 14:40 Menu


Local ACS880 1499.9 rpm
Motor torque % 30.4 %
-200.0 200.0
Motor speed used 1491.32 rpm
-3000.00 3000.00
Options 15:41 Menu

Thank you

Questions?