Energy Management Workshop

Variable Frequency Drives for Water Systems

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Presenters

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Example VFD Application – Concord WTP

- **Booster Pump System for Plant Water**
- **Problems with system:**
  - Lack of response control
  - Pumps oversized
  - High energy usage per gallon of water pumped

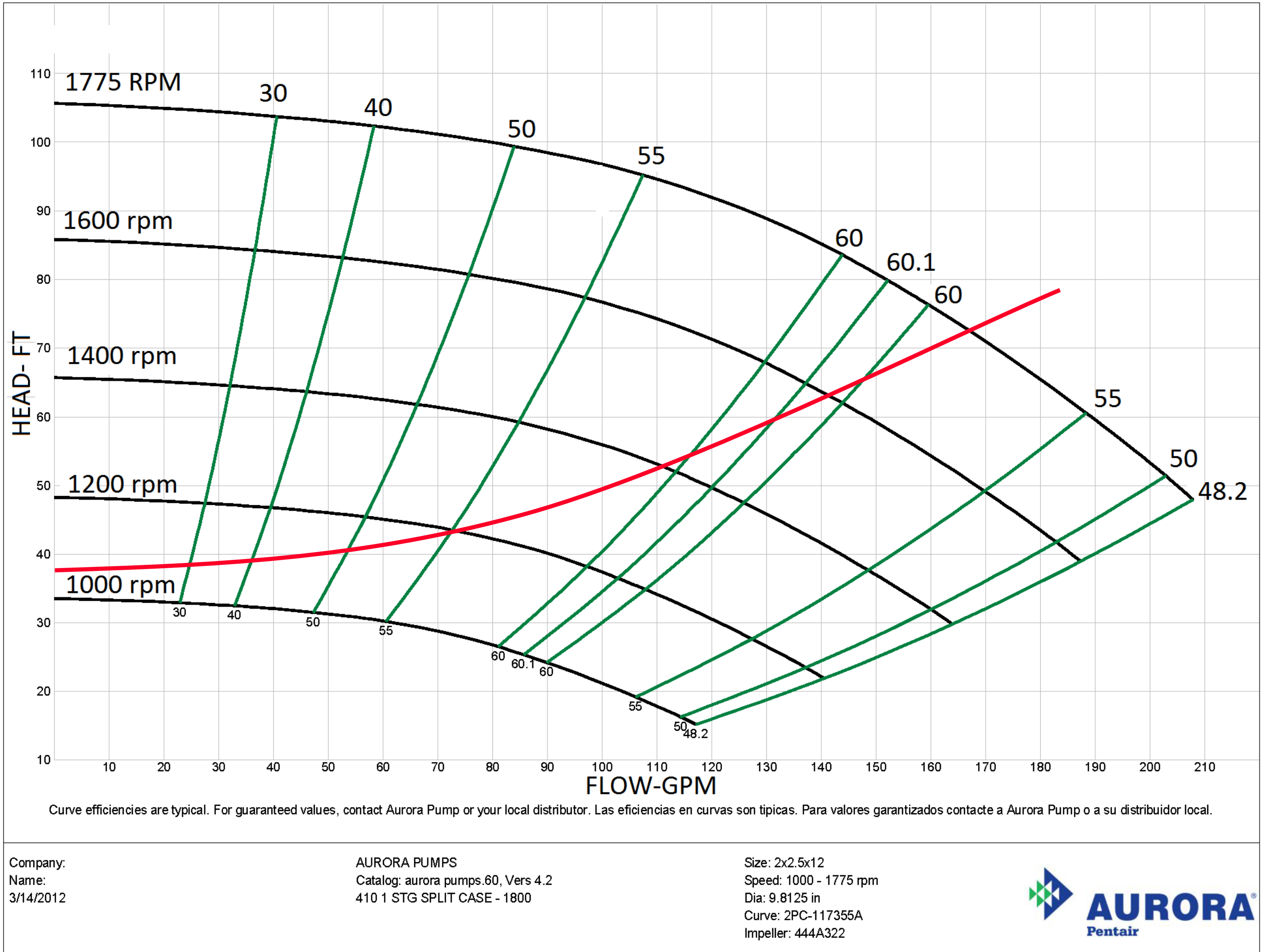
Example VFD Application – Concord WTP

Maintain constant discharge pressure under varying demand conditions

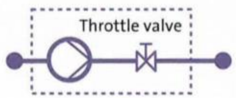
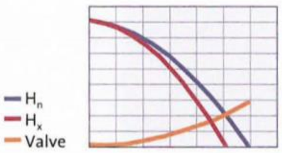
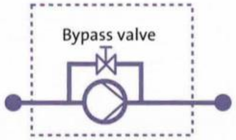
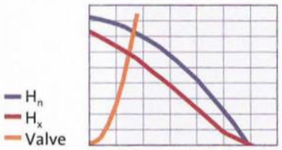
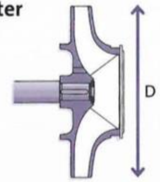
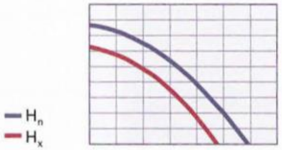
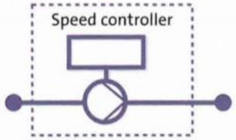
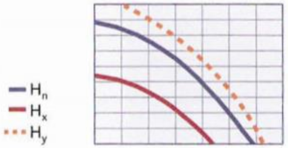
Pump Speed 101

- **Motor / pump designed to run on pump curve, head added will decrease as flow rate increases**
- **At the mercy of the system to determine where you fall on the pump curve**
- **If required flow ≠ pump operating point:**
  1. Cycle pumps on/off
  2. Adjust speed

Pump Curves at Various Speeds



Flow Adjustment Methods

Method	Continuous adjustment possible?	The resulting performance curve will have	Overall efficiency of the pump system	Relative power consumption by 20% reduction in flow
Throttle control 	Yes	Reduced Q 	Considerably reduced	94%
Bypass control 	Yes	Reduced H and changed curve 	Considerably reduced	110%
Modifying impeller diameter 	No	Reduced Q and H 	Slightly reduced	67%
Speed control 	Yes	Reduced Q and H 	Slightly reduced	65%

What does a VFD Do?

- **The Cause:**
  - VFD decreases AC frequency
    - Example: 60 Hz → 30 Hz
- **The Effect:**
  - Motor Speed[1]
    - Example: 1200 rpm → 600 rpm
  - Flow Rate[1]
    - Example: 200 gpm → 100 gpm
  - Head[2]
    - Example: 100 ft → 25 ft
  - Horsepower[3]

$$\frac{Frequency_1}{Frequency_2} = \frac{Speed_1}{Speed_2}$$

$$\frac{Speed_1}{Speed_2} = \frac{Flow_1}{Flow_2}$$

$$\left(\frac{Speed_1}{Speed_2}\right)^2 = \frac{Head_1}{Head_2}$$

$$\left(\frac{Speed_1}{Speed_2}\right)^3 = \frac{Horsepower_1}{Horsepower_2}$$

Example of VFD Application

- Selecting best speed for well pump operation to reduce energy costs
- Field Measurements to measure flow rate, operating power, suction/discharge pressures

Pump Speed	Flow Rate (gpm)	Measured Pump Efficiency	kWh/ MG Pumped
50 Hz	1,645	0.72	1,104
54 Hz	1,977	0.76	1,163
60 Hz	2,415	0.73	1,325

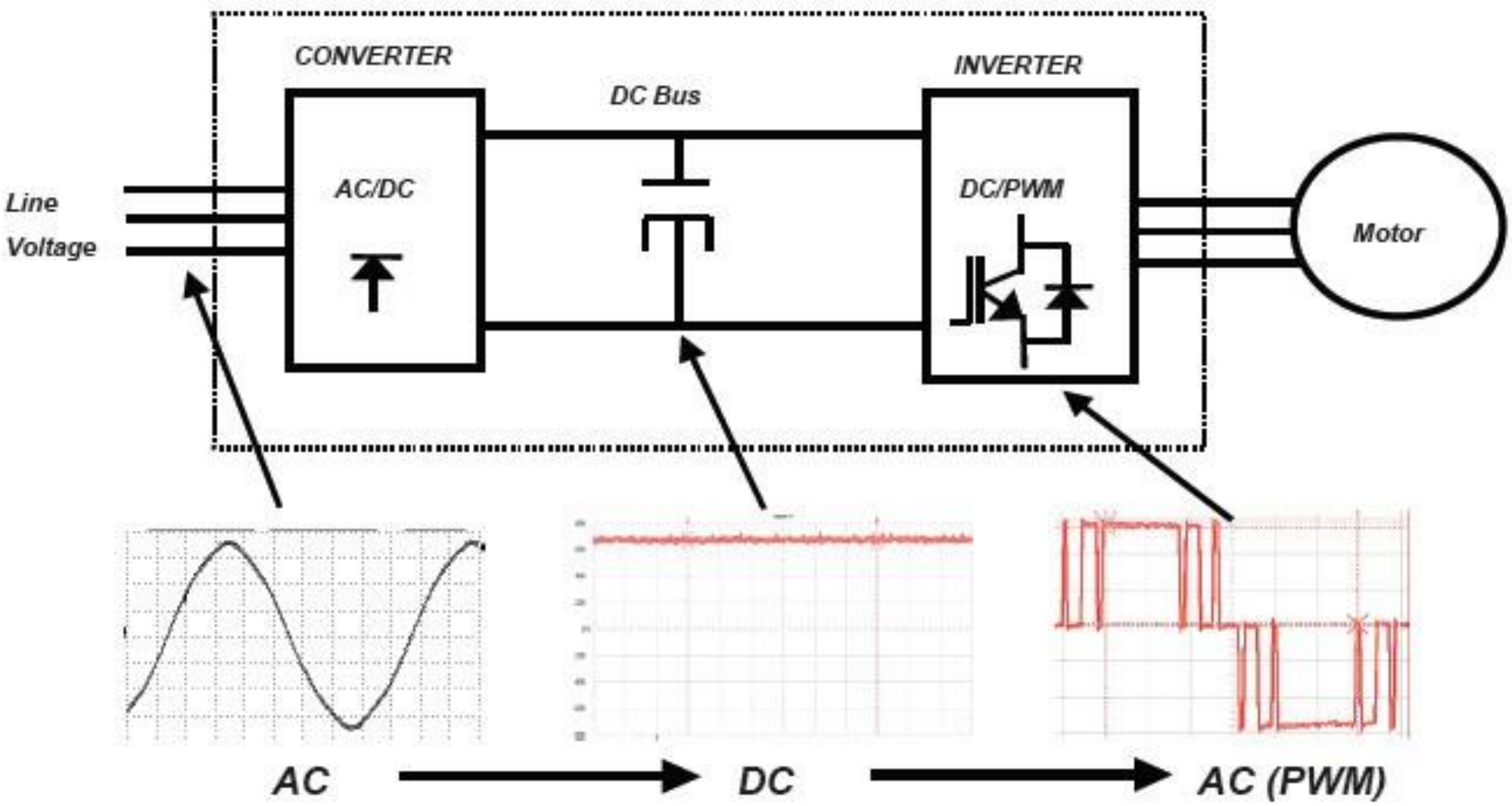
*Data collected by JKMuir for Tighe & Bond as part of Southington CT Capital Plan

Not So Fast…

- **Considerations before adding VFDs:**
  - Adds installation cost
  - Adds system complexity
  - Motor must be compatible (inverter duty rated)
  - VFDs generate heat and requires cooling and ventilation for proper operation
  - Process/System limitations
  - Lack of system controls

Variable Speed AC Drives

Drive Block Diagram



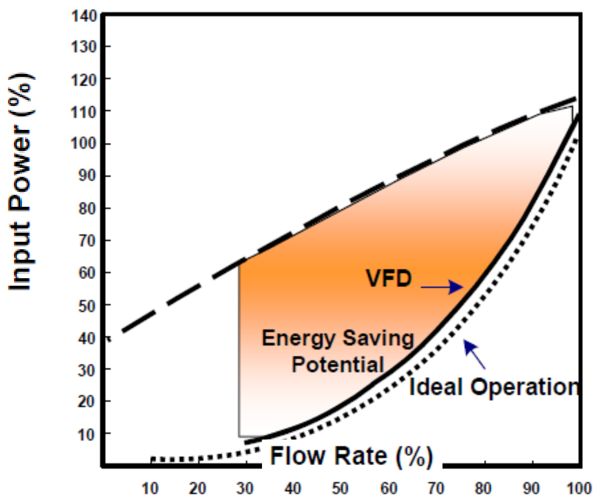
Introduction to VFD's

- **All 'good' drive products should have integral PID algorithm(s) available within the drive logic.**
- **That allows the operator to use the drive to regulate flow based on a setpoint (pressure, flow rate, temp etc). If the site does not have a SCADA or Control System that is doing the PID calculation**

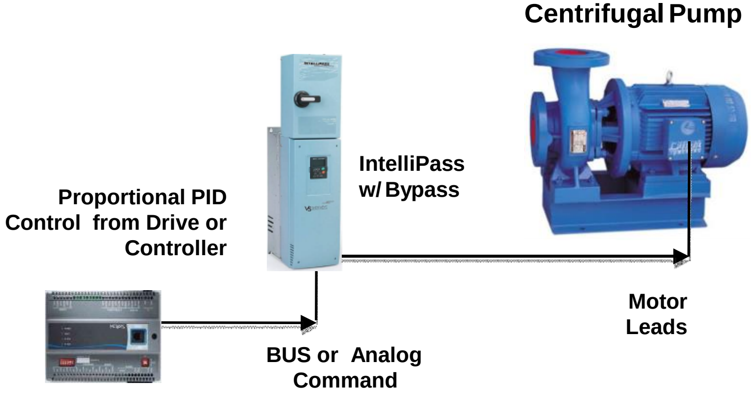
Centrifugal Pumps

Typical Pump Applications

- Chilled and Hot water Pumps
- Condenser Water Pumps
- Booster Pumps



Feature	Benefit
Variable Speed Drive	– Variable Flow to Demand – Operating at reduced pressures – Longer pump seal life & reduced impeller wear & less system vibration
High Efficiency	– Significant savings at reduced flows – Constant volume pumps can be converted to variable volume
Soft Start	– Reduces in rush current by 5X – Saves on wear of system – Pump can be ramped up to speed vs. going to full GPM

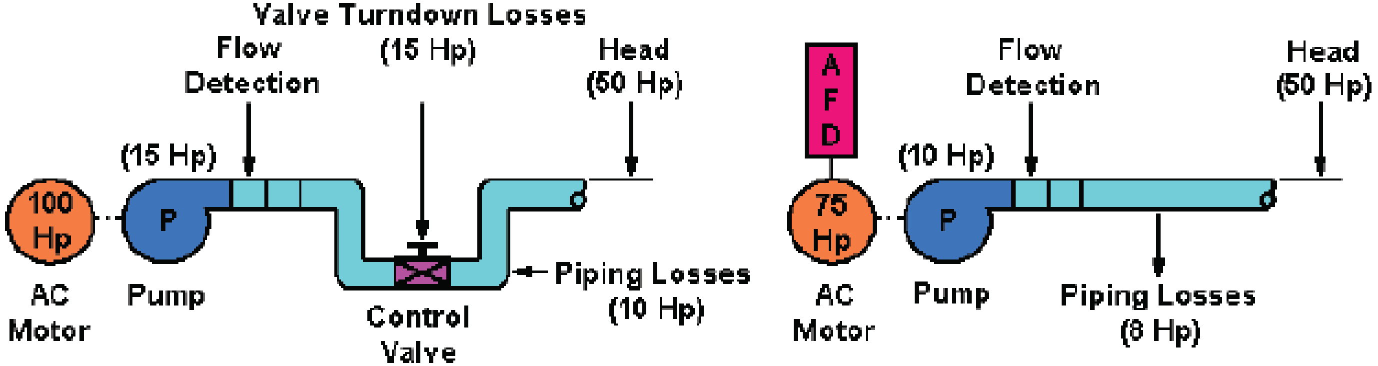


Centrifugal Pump

Centrifugal Pump

- Energy Usage Valve vs. AFD

Valve Control | **Speed Control**



Valve Control			Speed Control		
Losses:	15 Hp	Valve Turndown	Losses:	0 Hp	Valve Turndown
	10 Hp	Piping		8 Hp	Piping
	15 Hp	Pump		10 Hp	Pump
	50 Hp	Head (Load)		50 Hp	Head (Load)
Requires:	90 Hp		Requires:	68 Hp	

Energy Savings Report Example

Project: 100hp Application Example - NH VFD Workshop

Utility:

Cost per kWh: $ 0.12

Estimated Energy Savings

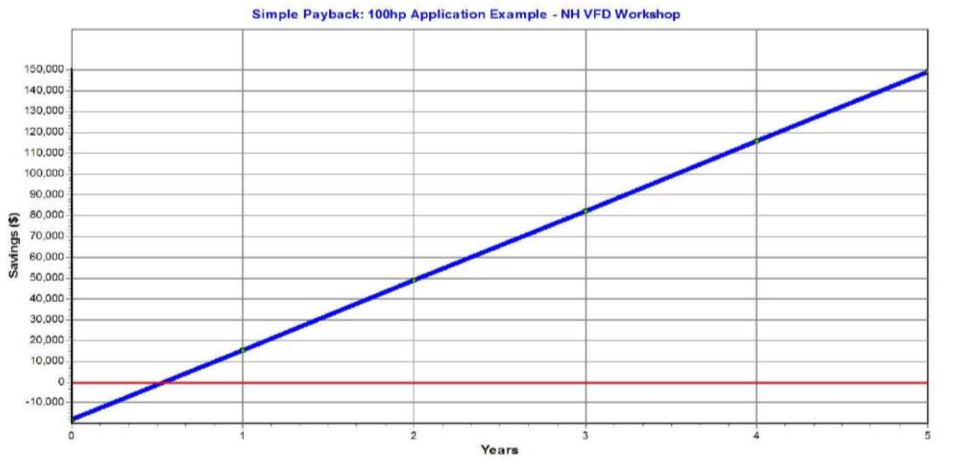
System	Energy Usage
Present System:	399,751 kWh
AFD System:	121,125 kWh
Energy Saved:	**278,625 kWh**

Estimated Savings:	Total
Energy Saved/Year:	$ 33,440
Yearly Savings:	**$ 33,440**

Estimated Carbon Dioxide Emissions

System	Carbon Footprint
Present System:	140.91 Ton(s)
AFD System:	42.70 Ton(s)
Carbon Dioxide Savings:	**98.22 Ton(s)**

Estimated Payback Time: 0.538 Years



Carbon Dioxide (CO_2) savings estimation based on electricity produced from Coal at 0.705 of CO2/Lbs

Weight Units: English

Energy Savings Report Example

100hp Influent Pump

System Data — **Pump System**

System Identification: 100hp Influent Pump
Type: Pump System
Flow Control: Throttling Valve

Utility

Cost per kWh:	$ 0.12
Utility Incentive:	$ 0 per HP; One-time

Motor Data

Power:	100 HP
Efficiency:	95 %

AFD Data

Drive Cost:	$ 13,000
Install Cost:	$ 5,000

Operation

Hours per Day of Operation:	20 Hours
Days per Week of Operation:	7 Days
Weeks per Year of Operation:	50 Weeks
Total Hours:	7000 Hours/Year

Duty Cycle Information

Flow (%)	Time (%)	Time (Hours)
100 %	1 %	70
90 %	2 %	140
80 %	9 %	630
70 %	17 %	1190
60 %	24 %	1680
50 %	17 %	1190
40 %	13 %	910
30 %	11 %	770
20 %	6 %	420
10 %	0 %	0

Estimated Carbon Dioxide Emissions

System	Carbon Footprint Single	Carbon Footprint Total
Present System:	140.91 Ton(s)	140.91 Ton(s)
Drive System:	42.70 Ton(s)	42.70 Ton(s)
Savings:	**98.22 Ton(s)**	**98.22 Ton(s)**

Payback Analysis	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Equipment Cost:	$ 13,000					$ 13,000
Installation Cost:	$ 5,000					$ 5,000
Utility Rebate:	$ 0					$ 0
Energy Saved:	$ 33,440	$ 33,440	$ 33,440	$ 33,440	$ 33,440	$ 167,199
Total:	**$ 15,440**	**$ 48,879**	**$ 82,319**	**$ 115,759**	**$ 149,199**	**$ 149,199**

Estimated Energy Savings

Operating Info:	Single	Total
Operating Hours:	7,000 Hrs	7,000 Hrs
Present System:	399,751 kWh	399,751 kWh
AFD System:	121,125 kWh	121,125 kWh
Energy Saved:	**278,625 kWh**	**278,625 kWh**

Estimated Savings:	Single	Total
Energy Saved/Year:	$ 33,440	$ 33,440
Demand Savings/Year:	$ 0	$ 0
Yearly Savings:	**$ 33,440**	**$ 33,440**
Estimated Payback Time:	0.538 Years	

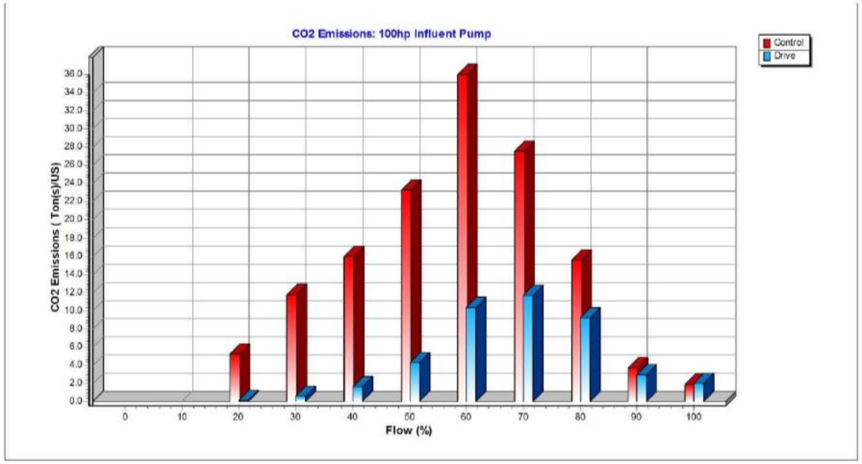
Carbon Dioxide (CO_2) savings estimation based on electricity produced from Coal at 0.705 of CO_2/Lbs
Weight Units: English

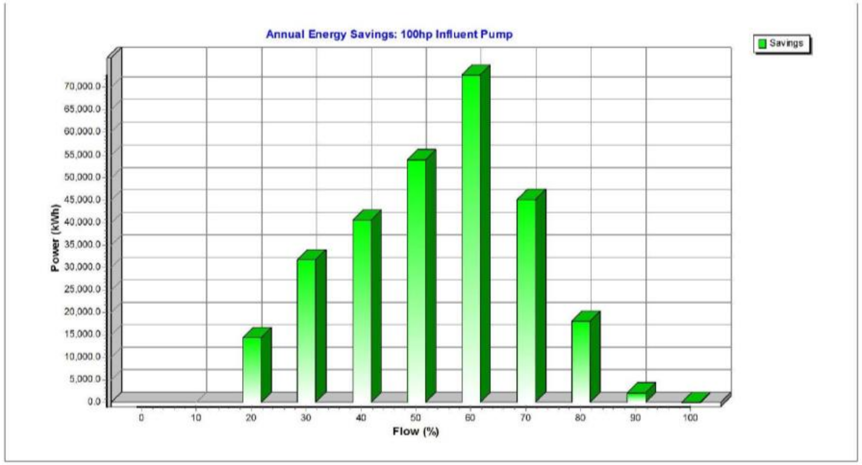
Tighe&Bond

Energy Savings Report Example

100hp Influent Pump

Chart(s)





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Key Takeaways

- **Adjustable Frequency Drive Benefits**
  - Reduce energy consumption
  - Longer mechanical life
  - Reduce maintenance
  - Eliminate power surges during starts and stops
  - Improve power factor

Harmonic Reduction Methods Available

- Standard 3-5% Impedance Line Reactors on all HVX Drives (Frame Dependent)
- Optional 5% Line Reactors on Enclosed Drives, N12 Intellipass
- Options for Integral Passive Harmonic Filters for standard 6 Pulse Drives (TCI or MTE Broadband Filters)
- CFX Model – Integrates Passive Filter into 6 Pulse VFD Enclosure
- 12 Pulse VFD Construction (integral or external phase / shift transformer)
- 18 Pulse Clean Power VFD Construction
- External Active Filter Products (for use in Motor Control Center Construction)
- 24 Pulse Medium Voltage Design (2400v & 4160v up to 10,000HP)

Energy Savings with Variable Speed Drives

- **Target Equipment:**
  - Pumps and Motors
  - Boiler Equipment
  - Building Automation Systems
  - Chillers
  - Cooling Towers
  - Compressors
  - Heat Treating Equipment
  - Humidification (Dehumidification)

VFD Selection Criteria

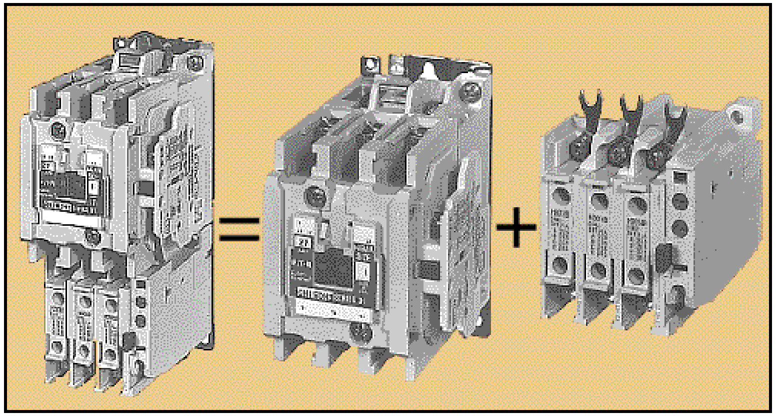
- Motor full load amps
- Motor voltage, RPOM and HP
- Application (pump, fan, conveyor, grinder, etc.)
- Variable or Constant Torque (Low or High Overload)
- Supply voltage and phase
- Motor voltage
- Type of enclosure (NEMA 1,12,3R, 4X, MCC)
- Mounting environment (indoors, outdoors, caustic, wash-down, etc.)
- VFD Topology Requirements (6 pulse, 18 pulse, 6 pulse with harmonic filter)

VFD Selection Criteria (cont.)

- Input Line Reactor or DC Choke Required
- Cable Distance VFD to Motor
- Control Source (local, remote, PLC, SCADA/BAS)
- Communications Network Required for Control (Modbus, Ethernet, etc.)
- Speed Reference Input (analog, transducer, 4-20ma, 0-10Vd)
- Dynamic Braking Required?
- Power Options Required (disconnect, bypass, etc.)
- Cover Control Options (lights, pushbuttons, selector switches, meters…) or is Keypad Operation OK

Motor Starting Methods

- Across the line, Full Voltage (NEMA, IEC, Definite Purpose)
- Reduced Voltage (electromechanical, solid-state)
- Adjustable Frequency Drives

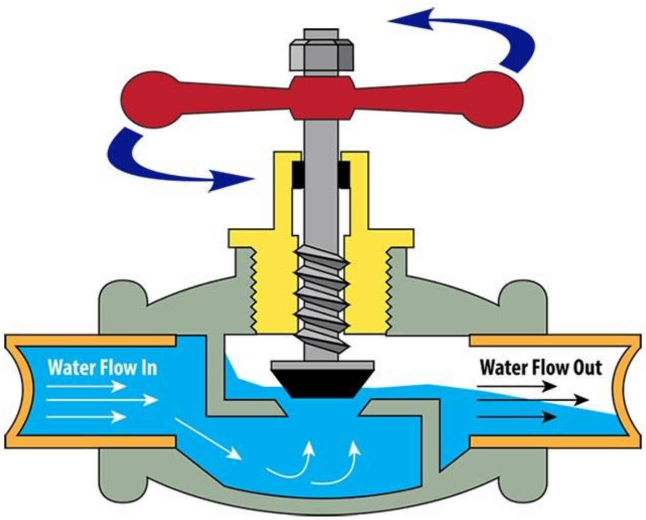


Starter = Contact + Overload Protection

VFD in NEMA 3R Enclosure

Introduction to VFD's

- **Flow control techniques for pumps and fans include throttling or restrictive devices such as**
  - Valves
  - Outlet dampers
  - Inlet vanes
  - Diffusers
  - Mechanical speed changers
  - Recirculation systems



THROTTLING

Introduction to VFD's

- **Restrictive Devices Waste Energy and Increase Costs**
  - Friction and heat
  - Premature mechanical wear
  - Require high maintenance
  - As inefficient as driving a car with the gas pedal to the floor and controlling speed by pressing the brake petal

Introduction to VFD's

- **Variable Frequency Drives eliminate the losses and cost of throttling devices.**
  - Low cost retrofit to existing motors
  - Ideal soft starting and stopping
  - High system efficiency
  - Noise reduction
  - Reduce mechanical wear and maintenance
  - Reduce KW demand