Welcome

Gerry Cellucci
Partick Farkas
Mark Washer
Housekeeping

- Phones, Pagers off or on Vibrate. If you must answer the phone wait until you are outside.
- Facilities are on the right as you exit this room.
- Binder material review.
- Lunch and breaks served in this room.
- Do not turn on Demos until asked.
YORKLAND

- Distributor / Systems Solutions Provider with over 35 years of controls experience
- Represent major control manufacturers
- Uniquely positioned to offer integrated control systems from various control manufacturers
- Support contractors as they offer control solutions
Distribution Channels

1. “ABCS” Systems (BAS) Distributor
   1. Johnson Controls
   2. Honeywell

2. Parts Sales

3. Energy Management Sales

4. Design

5. Engineering and Commissioning
Yorkland Controls
Value Added Services

- High level of technical support
- Engineering
- Sales & Marketing Support
- Panel Building
- Training
- Commissioning

“parts & smarts”
AGENDA
Variable Speed Drives (VFD)

• Why VFD use is increasing
• Energy Saving Examples
• Applications
• Terminology
• Setup Examples
• Labs and Quizzes
• Questions
Variable Speed (Frequency) Drive
What is it?

Converts Motor from Fixed to Variable Speed
Fixed Speed System - Typical

Power Input

Duty Required

Motor/Pump

Control Valve
Variable Speed System - Typical

- Power Input
- Duty Required
- VFD
- Motor/Pump
- Control Valve
  - Removed or locked open
How does it Work?

- Changes the speed of an AC HVAC fan or pump motor by adjusting or varying the frequency and voltage. For comparison, a DC motor speed is adjusted by only varying voltage.
- Typical frequency adjustment range in HVAC applications is from 10 - 60Hz AC. A VFD is wired in series between main power and motor.
- A Bypass is added to “Bypass” the VFD and run on main line power so HVAC operation is not interrupted if the VFD needs servicing.
How Does it Vary Frequency?

- A VFD, AC inverter, or electronic speed controller for AC motors converts the AC supply to DC using a rectifier (diode), then converts it back to a variable frequency by using a inverter bridge.
VFD Evolution to Reliability

- 1896 – Manual Adjusted DC Motor Speed Control
- 1924 – Variable Speed Control for AC Motors
- 1960 – Commercially Viable Variable Speed Drive

1993
- Expensive
- Large
- Inaccurate

2007
- Cost Effective
- Compact
- Reliable
Variable Speed Drives

- Reliable
- Lower Costs,
  - Hardware Cost has dropped by 2/3
- “Smaller” & “Smarter”, Feature - Rich Drives
Smaller

20 HP with By-Pass

YORKLAND CONTROLS
20-Hp VSD Comparison

- ABB ACS-400
  - 109-lbs

- Danfoss Graham
  - VLT-6000
  - 164-lbs

- Yaskawa E7
  - 109-lbs

- Cutler-Hammer SVX9000
  - 35-lbs
“Smarter” Tools for VFDs

- **PID Control, Multiple Sensor and Relays**
- **SVXDrive™**
  - Set Parameters
    - ONLINE/OFFLINE mode
  - Print-Outs of Parameter Settings
  - Copying of Parameter Settings
  - Trend Display
  - Operate the VS Series Drive
  - Monitoring
- **SVXLoad™**
  - Upload/Download
    - Custom Application Software
    - System Software Updates
    - Option Board Software
Network Ready

- Bacnet
- LON
- MODBUS
- N2/Metasys
- Profibus

Control

YORKLAND CONTROLS
Why Use?

1. To Save Energy !!!
2. Reduce Mechanical “wear and tear”
3. Increased Performance
Benefits of Variable Frequency Drives

- Gives continuous, precise control of acceleration, deceleration, and motor speed under varying conditions (better than phase modulation)
- Reduced energy cost
- Does not rely on cycling motors (reduces wear)
- Noise Reduction
Motor Facts

- Electric motors account for more than two-thirds of all energy used in industry
- 63% of the energy consumed is linked to air & liquid flow
- A typical 50HP industrial motor, with an efficiency of 90%, costs over $50,000 to operate continuously over a year.
More than half the energy consumed by AC motors powers air conditioning equipment.

Electrical energy costs are often the largest expenditure for building owners.
Energy Savings with Variable Speed Drives

• Energy Savings result from the following facts:
  – Equipment (Fans/Pumps) are designed for worst case conditions (oversized for 20% of the time)
  – Affinity Laws
  – Variable Flow Applications
Affinity Laws

% Flow, Torque, HP

<table>
<thead>
<tr>
<th>Speed</th>
<th>Volume or Flow</th>
<th>HP</th>
</tr>
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<tbody>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>90 %</td>
<td>90 %</td>
<td>73 %</td>
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<td>80 %</td>
<td>80 %</td>
<td>51 %</td>
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<td>70 %</td>
<td>70 %</td>
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<td>60 %</td>
<td>22 %</td>
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<td>50 %</td>
<td>50 %</td>
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<td>40 %</td>
<td>40 %</td>
<td>6 %</td>
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<tr>
<td>30 %</td>
<td>30 %</td>
<td>3 %</td>
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</table>
Air Handlers and VFDs

For a 50 Hp, this means that only 6.26 Hp is required for 50% flow.
Fan Duty Cycle (Variable)

% Total Operating Time

% Volume
MOTOR FACTS - Size Matters

- Under Sized Piping or Ductwork puts additional load on motors
- Motors are designed to operate at full rated output (24/7).
- In most cases the motor will be operating below its rated output
- Efficiency drops at partial loads
Motor Power

- Name Plate Power
- Measured Power – measure power using a RMS power Meter
- Load is the actual work (power) by the motor in KW
Energy Calculations

- Energy Usage = DEMAND x Daily Operating Hours x 365 days
- DEMAND = Motor HP x .746 x Load/ Motor Efficiency (%)
- KW = HP x .746
Sample Calculation

- 5 HP Motor Operates 100% Load at 100% efficiency
- DEMAND = 5 HP x .746 x 100%/100%
- DEMAND = 3.715 Kw
- Energy Use = 3.715 kw x 24 hr x 365 day
- Energy Use = 32,543 kw
- Energy Cost = 32,543 x .10 per kw
- Energy Cost = $ 3,254.00
Sample Calculation - 2

• 5 HP motor operates at 100% Load at 95% Efficiency
• DEMAND = 5 hp x .746 x 100% / 95%
• DEMAND = 3.93 kw
• Energy Use = 3.93 x 24hr x 365
• Energy Use = 34,427
• Energy Cost = 34,427 x .10
• Energy Cost = $3443.00
Sample Calculation - 3

• 5 HP motor operates at 80% Load at 95% Efficiency
• DEMAND = 5 hp x .746 x 80% / 95%
• DEMAND = 3.14 kw
• Energy Use = 3.14 x 24hr x 365
• Energy Use = 27,516
• Energy Cost = 27,516 x .10
• Energy Cost = $2,752.00
## Calculation Summary

<table>
<thead>
<tr>
<th></th>
<th>Calc # 1</th>
<th>Calc # 2</th>
<th>Calc # 3</th>
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<tr>
<td>Load</td>
<td>100 %</td>
<td>100 %</td>
<td>80%</td>
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<tr>
<td>Eff</td>
<td>100 %</td>
<td>95 %</td>
<td>95 %</td>
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<tr>
<td>DEMAND</td>
<td>3.175 kw</td>
<td>3.93 kw</td>
<td>3.14 kw</td>
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<tr>
<td>Energy Use</td>
<td>32,543 kw</td>
<td>34,427 kw</td>
<td>27,516 kw</td>
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<tr>
<td>Energy Cost @ .10/kwh</td>
<td>$ 3,254.00</td>
<td>$ 3,443.00</td>
<td>$ 2,752.00</td>
</tr>
</tbody>
</table>
Savings Calculation Example

• Worksheets Under Binder Tab 1
Exhaust Fans

• Situation: A manual 25 HP exhaust fan is found to run 24 hours - 7 days a week in a baking facility. The exhaust fan is NOT tied into a Make-Up Air Unit as it is general exhaust for the plant. The plant runs on 2 shifts – 7am to 12:00am for 5 days of the week.

• Calculate the savings if the exhaust fan was shut off by an automatic timer for the hours of 1:00am to 6:00am for 5 days of the week. Note that the plant is shut down for 2 weeks of the year in August and closed for Christmas and New Year.

Motor efficiency = 93%
Load = 90%
Energy Cost Per kw = .11
Exhaust Fans

- Calculate Current Cost to Run
- Calculate Cost to Run with Timer
- Difference is Savings
Calculation & Payback

- Savings = $8,052.70
- Installation = $2,500.00
- Payback = 0.31 years

- 365 Day Timers = $600
- Real Time Clocks = $1,000
- Installation = $1,500 approx
VFD Savings Example

- 30 HP Pump in a constant flow (non-VFD) system runs 250 days a year and has a duty cycle of 80%.
- Converting to a VFD and an assumed 60% fan speed and fan running 22 hours /day

- Estimated savings = 270.6 Kw/day = $18.94 / day
- Savings = $ 4,735.00 (energy at .07 / Kw)
- 30 HP VFD List Price = $7500.00
  - (5 years ago 30HP VFD = $ 12,500 )
An Air Handler running on constant volume is considered to be retrofitted with a VFD. Yearly operating hours are estimated at 2500hrs.

Calculate Savings if the AHU runs:
- 100% speed for 25% of the time
- 80% speed for 50% of the time
- 60% speed for 25% of the time

Estimate Savings for VFD retrofit with $/KwHr at 0.08.
Manual Calculation

- Example
“Choice” – Eaton Electric

QuickCalc Step 1: Project & Financial Info.

Project
Name: Pumps
Prepared for: Enbridge
Prepared by: GDC
Date: 11/20/200
Ref: 123A anywhere

Financials
Cost of electricity ($/KWh): 0.11
Hardware cost ($): 6200.0
Installation cost ($): 4000
Demand cost ($): 0.0
Demand coincidence (%): 0.0

Drive System Type
- Fan
- Pump

Next > Cancel
### QuickCalc Step 2: Pump System Info.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Actual HP</td>
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<td>Motor efficiency %</td>
<td>89.0</td>
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<td>Design Flow:</td>
<td>400.0</td>
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<td>Static Head:</td>
<td>10.0</td>
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<td>Design Head:</td>
<td>200.0</td>
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<tr>
<td>Pump efficiency %</td>
<td>95.0</td>
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<tr>
<td>Design HP:</td>
<td>21.27</td>
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<tr>
<td>Drive efficiency %</td>
<td>97.0</td>
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<tr>
<td>Oversized by %</td>
<td>14.92</td>
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### QuickCalc Step 5: Results

<table>
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<tr>
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<th>Existing</th>
<th>Upgrade</th>
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<tbody>
<tr>
<td>Annual energy usage (KWh):</td>
<td>126,952.86</td>
<td>54,765.75</td>
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<tr>
<td>Annual energy cost ($):</td>
<td>$10,156.23</td>
<td>$4,381.26</td>
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<tr>
<td>Total upgrade cost ($)</td>
<td>$6,200.00</td>
<td></td>
</tr>
<tr>
<td>Energy saved (KWh):</td>
<td>72,187.11</td>
<td></td>
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<tr>
<td>Energy saved (%)</td>
<td>56.86%</td>
<td></td>
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<tr>
<td>Energy saved ($)</td>
<td>$5,774.97</td>
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<tr>
<td>Payback (Months):</td>
<td>12.88</td>
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<tr>
<td>Internal Rate of Return:</td>
<td>93.14%</td>
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<tr>
<td>Net Present Value:</td>
<td>$33,038.54</td>
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### Project Management Mode

**Project**
- Name: Eaton
- Prepared for: Enbridge
- Prepared by: GDC
- Date: 8/2/05

**Subsystems**

<table>
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<tr>
<th>Name</th>
<th>Include?</th>
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<td>Cooling Tower</td>
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<tr>
<td>Supply Fans</td>
<td>✓</td>
</tr>
<tr>
<td>Pumps</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Results**
- Annual energy usage (KWh): Existing: 141,184.71, Upgrade: 41,023.53
- Annual energy cost ($): Existing: $15,530.32, Upgrade: $4,512.59
- Total upgrade cost ($): $4,000.00
- Energy saved (KWh): Existing: 100,161.18
- Energy saved (%): Existing: 70.94%
- Energy saved ($): Existing: $11,017.73
- Payback (Months): 4.47
- Internal Rate of Return: Existing: 268.73%
- Net Present Value: Existing: $70,058.34

**Financials**
- Cost of electricity ($/KWh): Existing: $0.11
- Hardware cost ($): Existing: $4100.00
- Installation cost ($): Existing: $0.0
- Demand cost ($): Existing: $0.0
- Demand coincidence (%): Existing: $0.0

---

**Diagram**
- Project: Before vs. After
- Subsystem: Payback
- Drive Systems

---

**Yorkland Controls**
Patrick Farkas
Test Drive Software

• Choice
Applications

- Fan
- Hydronic
Constant Fan to Variable Flow
AHU Conversion – From Constant Volume

• Example
AHU Conversion from Inlet Vane
Flow Control Comparison

FLOW CONTROL TYPE COMPARISONS

<table>
<thead>
<tr>
<th>% FLOW (VOLUME)</th>
<th>CONSTANT VOLUME</th>
<th>DAMPERS</th>
<th>INLET VANES</th>
<th>VARIABLE SPEED</th>
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<tbody>
<tr>
<td>0%</td>
<td>1.00</td>
<td>0.97</td>
<td>0.82</td>
<td>1.00</td>
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<tr>
<td>20%</td>
<td>1.00</td>
<td>0.93</td>
<td>0.69</td>
<td>0.82</td>
</tr>
<tr>
<td>40%</td>
<td>1.00</td>
<td>0.88</td>
<td>0.59</td>
<td>0.65</td>
</tr>
<tr>
<td>60%</td>
<td>1.00</td>
<td>0.83</td>
<td>0.53</td>
<td>0.51</td>
</tr>
<tr>
<td>80%</td>
<td>1.00</td>
<td>0.77</td>
<td>0.47</td>
<td>0.38</td>
</tr>
<tr>
<td>100%</td>
<td>1.00</td>
<td>0.71</td>
<td>0.45</td>
<td>0.27</td>
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<tr>
<td>120%</td>
<td>1.00</td>
<td>0.63</td>
<td>0.42</td>
<td>0.18</td>
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<tr>
<td>140%</td>
<td>1.00</td>
<td>0.56</td>
<td>0.40</td>
<td>0.11</td>
</tr>
<tr>
<td>160%</td>
<td>1.00</td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
</tbody>
</table>
VFDs can be interlocked with time clocks or exhaust fan contacts to enable the programmed speed. For example, the VFD may be programmed to run at 60% flow during weekdays from 2 to 4 PM and from 1:00am to 5:00am. And 100% flow at all other times.

Indoor Air Quality (IAQ) sensors can be used to override and increase the speed of the VFD when the carbon dioxide (Co2) increases above the override IAQ setpoint (800 to 1200 ppm Co2).
Estimating Fan Curves

• Mixed Use
• Interior Supply Fans
• Exterior Supply fans
QuikFan 4.0

Project Name: QuikFan Example Project

Existing Fan Systems
- 125 HP
- 40HP inlet
- Fan_30HP
- 100_HPA
- 150 HP
- Return Fan #1
- Supply Fan #1

Add  Edit  Delete  Upgrade Analysis  Project Rollup
YORKLAND CONTROLS
DOE-QuikFan 4.0

Upgrade Options
- Add VSD, No Pressure Reset
- Add VSD, 1/3 Pressure Reset
- Add VSD, 2/3 Pressure Reset
- Add New Motor
- Resize Motor, Pulley and Drive

Financial Results
- Total Upgrade Cost [$]: $3,500.00
- Energy Costs Saved [$/yr]: $3,492.87
- Payback [Yrs]: 1.0
- IRR [%]: 74.51
- NPV [$]: $25,167.51

Annual Energy Results
- Existing
  - Hours [hrs]: 4,667
  - Load [Tonh]: 81,542
  - Energy [kWh]: 97,257
  - Energy Cost [$]: $11,670.87
  - Demand [kW]: 24.3

- Upgrade
  - Hours [hrs]: 4,667
  - Load [Tonh]: 81,542
  - Energy [kWh]: 68,150
  - Energy Cost [$]: $8,178.01
  - Demand [kW]: 21.1

Energy Saved [%]: 29.93
Energy Cost Saved [%]: 29.93
Demand Reduced [kW]: 3

% Load (CFM)
Cooling Tower VFD Savings Potential

- **Cooling Tower fans obey the Affinity Laws**
  - 20% reduction in speed = 50% reduction in HP

- **Towers are designed for High Load Conditions**
  - High Humidity, High temperature

- **On Low Load days, “Low Fan” may cycle**
  - Increased wear and maintenance
  - Lowers Cooling Tower Efficiency, therefore the Chiller efficiency
    - 1.2 % in chiller efficiency for every 1 degree in condenser water temperature
Typically the fan will run at 40-70% of full speed, thus saving 50% or more of the energy consumed by a fixed speed (constant volume) system.
Variable Air Volume

Outside Pressure Tip

LO Port

HI Port

Building Static Sensor

Building Pressure Tip

Temp

DDC Control

Static Pressure

VAV Boxes

Yorkland Controls
Static Pressure Reset

YORKLAND CONTROLS
Selected Curve

Name: VSD 1/3 Reset
Notes: VSD with 1/3 Pressure Reset Capability. With static pressure reset, precautions should be taken to ensure that all terminal boxes operate effectively.

Bin Values

<table>
<thead>
<tr>
<th>% CFM</th>
<th>% Power</th>
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<tr>
<td>0-5</td>
<td>7.0</td>
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<tr>
<td>5-10</td>
<td>9.0</td>
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<tr>
<td>10-15</td>
<td>10.0</td>
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<tr>
<td>15-20</td>
<td>11.0</td>
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<td>20-25</td>
<td>13.0</td>
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<td>90-95</td>
<td>85.0</td>
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<td>95-100</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Carbon Monoxide
Optimization
Mark Washer – Johnson Controls

- Product Sales Manager, Canada
Case Study: Condo MUA

- 100% OA
- Dx Cooling
- Glycol Heating Coil
- 25HP Supply Fan
- Operates 24 hours / Day
• Modulating Hot Gas Bypass Valve was used on Dx coil. Allowing use of VFD on fan.
• Fan run between 40-80% depending on time day.
• Better control of Supply Air Temp.
• Because of HW from central boilers triggered an Enbridge rebate
Condo MUA / Savings

- Installed Cost $10,000
- Savings $8000 / year
- Payback just over 1 year
- Less if Enbridge Rebate Factored in.
Case Study: VAV AHU

- Mixed Air
- Cooling Coil
- 25 HP Supply Fan
- 15 HP Return Fan
- Variable Inlet Vanes
Case Study VAV AHU
VAV AHU / Savings

- Reduced operating cost by 40%
- Installation cost $15,000
- Payback around 18 months
Use of Variable Frequency Drives for Fan and Pump Control

Description

In the past 10 years, variable speed control for fans, pumps, chillers and HVAC systems has become an affordable way to save energy, thanks to advances in microelectronics and control technology. Initially, utility companies introduced incentives to make it practical to switch from fixed speed and flow-throttling controls to variable frequency drives (VFDs) (Figure 1). Since then, more building designs have been specifying VFDs, and many building HVAC retrofits can become more cost-effective by replacing flow controls with VFDs at installed costs as low as $250 per kilowatt. Naturally, the process must be carefully studied to ensure that the application will be successful.

Technical Specifications

Drive Specification – VFDs operate by converting the incoming AC power to a DC signal and then re-transmitting the power signal to the motor at varying frequencies and voltages. VFDs can operate rotating equipment at speeds ranging from nearly 0 RPM to as high as 150 percent of the rated speed for the motor. The use of a frequency drive requires installing high-efficiency Class F insulated motors that can withstand the variations in voltage and current flux.

Applications – Some good applications include 1) replacing outlet dampers or variable inlet vanes (VIVs) in supply fan systems; controlling variable air volume (VAV) boxes; 2) controlling air supply to multiple zones by adding a VFD and isolation dampers in zones with different occupancy and operating schedules; and 3) controlling pump speed by maintaining a pressure setpoint. Other advantages of variable frequency drives include less wear on the motor due to reduced speed and torque, gentler starting through gradual acceleration, and fewer moving parts (i.e., no damper or inlet vanes to wear out). Figure 2 shows a typical fan application requiring two VFDs with pressure control feedback.

Energy Information

The real energy savings from variable frequency drives come from the basic law of fan and pump operation. Theoretically, fan power input will drop according to the cube of the flow rate (load). This is illustrated in the equation below:

\[ W_2 = W_1 \times \left( \frac{Q_2}{Q_1} \right)^3 \]

Figure 1 – Typical Variable Frequency Drive Control Panel

Figure 2 – Schematic of VFD Installation
Hydronic Applications
Pump Curves

Head or Pressure

System Curve

Flow (GPM)

Pump Curve

Less Pressure, More Flow

Operating Point

Friction Head Coil, Valve & Pipe Loss

Constant Pressure

B

A

YORKLAND CONTROLS
Pump Duty Cycle
Duty Point

Diagram showing the relationship between flow (USGPM) and head (Feet), indicating the duty point with 120 gpm and 150° head.
Pump Duty Cycle.
Pump Sized for End of the Curve (EOC)

EOC = 255 gpm @ 80' head
EOC BHP = 3.8
Pumps Curves & Throttling Valve

Typical Operating Point

Designed Operating Point

Unthrottled System Curve

Pump Curve

Head or Pressure

Throttled System

Flow (GPM)

700 GPM  1200 GPM
**Pumps with VFD**

Same Flow – Less Pressure

P1, P2, P3 = Outlet Valve Flow Positions
V1, V2, V3 = VFD Operating Points
SH = Static Head
CP = Constant Pressure
3 way valve operates at “CP”
VFD on Pumps

• Three important facts to consider about variable-torque type pumps. The affinity laws:
  – *Flow* produced is proportional to the motor speed.
  – *Pressure* produced is proportional to the motor speed squared.
  – *Horsepower* required is proportional to the motor speed cubed.
Example - 100 hp Pump

• Compare 100-hp pump energy use on systems with
  – Bypass valve
  – Throttling Valve
  – Variable Frequency Drives

<table>
<thead>
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<th>Load %</th>
<th>% of Day</th>
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<td>10</td>
</tr>
<tr>
<td>60</td>
<td>15</td>
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<tr>
<td>70</td>
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</tr>
<tr>
<td>90</td>
<td>15</td>
</tr>
<tr>
<td>100</td>
<td>15</td>
</tr>
</tbody>
</table>

• Looking at a 100-hp pump. *If the flow needed* is only one-half of rated, then the motor could be operated at half speed and the pressure would become \((0.5)^2 = 25\%\) of rated. The horsepower needed to operate the pump would be \((0.5)^3 = 12.5\) hp.
Annual Dollars Comparison

Total Annual Dollars at $0.10 / Kwhr

- Bypass vlv $71,032
- Throttle vlv $61,727
- VFD $39,565
Variable Flow from Constant Flow

Pump Curve
- Constant Pressure
- Operating Point
  - Maximum-Bypass
  - Zero-Bypass

System Curve

Flow (GPM)

Figure: 3

YORKLAND CONTROLS
3 way valve converted to 2 way operation
VFDs and Pumps

Figure 1:

- Boiler or Chiller
- Supply T
- VFD
- Coil
- DP = Differential Pressure
- Return T
- Constant Pumps

Diagram showing VFD control systems with flow rate and energy saving potential graph.
**Differential Pressure**

- **Position 1**: VFD Application Sensor at Position 1
- **Position 2**: VFD Application Sensor at Position 2

**Flow (GPM)**
- Design Operating Point
- "worst-case" setpoint

- **Pump Curve at Part Load Conditions**
- **Head (or Pressure)**
- 700 GPM, 1200 GPM

**YORKLAND CONTROLS**
Pressure Sensor

Mamac PR-283

Ball Valve
Field Installed

High  Low

Supply  Return
By Pass Conversion

YORKLAND CONTROLS

Figure: 2

By Pass Conversion

Boiler

Coil

Coil

Coil

P

Pressure Sensor

Differential Bypass Valve

"Locked" Closed

Boiler

Coil

Coil

Coil

P

Pressure Sensor

Differential Bypass Valve

"Locked" Closed

Figure: 2
Booster Pumps

Supply added pressure to a building’s water supply – washrooms, bathrooms, etc.

Pressure Valve regulates pressure as flow decreases and avoid over pressurization.

Savings from “oversized” pumps matched with demand
Duplex Pumps

Figure 1: Standby or "Lag" Pump

Figure 2: Pump Sequencer
Heat Pumps

Figure: 2

YORKLAND CONTROLS
Demand Savings with VFDs

Demand Charge Savings

Without Demand Limiting

With Demand Limiting

Peak Rate Period

6:00 am  NOON  6:00 pm

Time of Day
Refrigeration – Condenser Fan Control
Why Are Condenser Fan Controls Necessary?

**Demand on refrigeration system changes with:**

- **Ambient temperature**
  - Time of day
  - Seasons

- **Refrigeration load**
  - More frequent opening of doors
  - Warm items placed in refrigerated area
3-Phase Condenser Fan Control Strategies

- Fan Cycling (On/Off)
- Phase Modulation
- Variable Frequency Drives
Fan Cycling

- **Benefits of Fan Cycling**
  - Simple
  - Uncomplicated interface
  - Reliable
  - Easy to set and adjust

- **Drawbacks of Fan Cycling**
  - Less stable system pressure than with other methods
  - Pronounced wear on equipment, especially on motors and electrical contacts
  - More electricity used than with other methods
Phase Modulation – “Works Like a light dimmer”
Drawbacks of Phase Modulation

- Requires special motors
- Hard on motors at low speeds
- Heat build-up in motor windings
Variable Frequency Drives

- Sends voltage to 3-phase motor in pulses
- Approximates a sine wave
- Controls frequency and voltage
- Motor speed is proportional to frequency
Variable Frequency Drives

- Normal AC Supply to Motor
- VFD DC Supply to Motor in Pulses (Mimics AC)

60 Hz

80 Hz

YORKLAND CONTROLS
Results of Using a VFD

- **System effects**
  - Less fluctuation in head pressure
  - Less fluctuation in evaporator temperature
  - More uniform air flow over condenser coil
- **Visible effects**
  - Increased system efficiency
  - Lower electricity costs
  - Reduced maintenance
Energy Savings

- Variable frequency drives have greatest energy savings of all condenser fan control methods
- Greater Energy Savings = Lower Energy Costs
- Over time, a VFD can pay for itself by money saved on energy costs!
# Payback Period

<table>
<thead>
<tr>
<th>Average Fan Duty Cycle</th>
<th>Annual Savings with 6 hp fan total, $0.07/KWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>$1048.57</td>
</tr>
<tr>
<td>60%</td>
<td>$1073.74</td>
</tr>
<tr>
<td>70%</td>
<td>$998.24</td>
</tr>
<tr>
<td>80%</td>
<td>$805.30</td>
</tr>
</tbody>
</table>

Comparison to On/Off switch function

YORKLAND CONTROLS
Applications

- Refrigeration Racks
- Air Conditioners
- Walk-in Coolers
- Cooling Towers
- Evaporative Condensers
- Reciprocating Chillers
- Process Water Chillers
- Condensing Units
- Packaged Roof Tops
- Packaged (Water) Chillers
- Computer Room AC
- Environmental (Test) Chambers
Additional Benefits

- Inherently “Soft Start”
- Integral PID Control
- Self Diagnostic
  - Belt Breakage
  - Shaft Breakage
- Built-in control curves for “linear” control
Match VFD with Motor

- Review motor horsepower and load to be operated.
  - Review existing motor insulation class
  - Service factor of Motor 1.15 of higher
- Enclosure type required for environment
- First cost, life-cycle cost and operating cost.
- Available and preferred voltage.
- Phase and frequency.
## Motor Name Plate Example

<table>
<thead>
<tr>
<th>MODEL #</th>
<th>awe213THFaal</th>
<th>FRAME</th>
<th>212L</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>POLES</th>
<th>4</th>
<th>TYPE</th>
<th>TRF</th>
<th>INS</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLTS</td>
<td>230/460</td>
<td>FL RPM</td>
<td>1770</td>
<td>FL AMPS</td>
<td>21.4/10.7</td>
</tr>
<tr>
<td>SF</td>
<td>1.1</td>
<td>DUTY</td>
<td>Cont.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hz</th>
<th>HP</th>
<th>RPM</th>
<th>TORQUE</th>
<th>VOLTS</th>
<th>AMPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3.5</td>
<td>90</td>
<td>22.3</td>
<td>---</td>
<td>10.5</td>
</tr>
<tr>
<td>60</td>
<td>7.5</td>
<td>1770</td>
<td>22.3</td>
<td>460</td>
<td>10.5</td>
</tr>
<tr>
<td>120</td>
<td>7.6</td>
<td>3530</td>
<td>11.2</td>
<td>460</td>
<td>10.6</td>
</tr>
</tbody>
</table>

PHASE INVERTER DUTY AC INDUCTION MOTOR
YORKLAND CONTROLS

Quiz
Control Arrangements for a VFD

- Local (Hand Control)
- Remote (Auto) Control
- Multi-motor Operation
- Master/Slave (Lead/Follower)
- PID Control
- Cascade Control
- BAS Enable and Control
- BAS Serial
Typical Functions

- Start-Stop / Manual / Auto
- Ramping
  - Acceleration
  - Deceleration
- Setting up Motor Profile
- Operating Limits
- Optional Input and Output Configurations
Function - Start-Stop
Local Control Operation through keypad
Function – Speed Control

- Change Speed
  - Manual or Auto
- Maintain Speed
Remote or Auto Control

DI – Digital On/Off Input
  • 2 Position On/Off for Start – Stop – Enabling

AI – Modulating
  • 0-10/4-20ma signals from external controls

AO – Modulating
  • Signal(s) sent by the VFD to another device

DO – Digital On/Off Output
  • On/Off relay output sent by the VFD to lights etc. (alarms)

YORKLAND CONTROLS
• Multiple inputs and outputs are available for other functions:
  – Speed adjustment with potentiometers (AI)
  – Essential Service (DI)
  – Preset Speed(s) (DI)
  – Alarms – Visual, Buzzer (DO)
  – Enable other devices when VFD is enables
Terminals

---

Indicates Connections for Inverted Signals
Multiple Motors

One VFD may control multiple motors.

Total Amp draw from all the motors cannot be greater than the rated VFD amps.

Each motor to have protection.
One VFD is designated as the “Lead” or Master and set up to send signals (on/off and reference) to the “follower” or Slave VFD. Slave may be set up to be a % of the Master VFD.

Typical application:
- Supply and Return Fan volume matching
Function - Limits

- **Max and Min Frequency**
  - Because of the possibility of overheating, fans should **not be run less than** 6Hz.
  - For lubrication purposes a pump should have a **minimum speed of at least** 18Hz.

- **Torque Limits**
  - If the fans gets stuck, there are torque limits that the VFD monitors stopping the motor if they are exceeded.

- **Current Limits for Motor Protection**
Function -Ramping

To reduce mechanical wear, it is important to control the acceleration, ramp up and deceleration, ramp down

- Acceleration, it is important that there is no sudden jump to the reference speed,
  - stress on the gear boxes.
- Prevent the drive trip on an over-current alarm or torque limit. Many VFDs have an automatic reset setting of 1 time to infinite times.
- Ramping is very important for pumps, to avoid water hammer.
• All ramp times are based on motor speed
• If the ramp time is set for 60 seconds as in the picture above, but the reference is set to 30Hz (1/2 of 60Hz), it takes 30/60 x 60 seconds (½ the time) or 30 seconds to ramp up
Motor Profile Parameters

- Voltage Input
- Frequency
- Break-away or Starting torque (the first 0.5 seconds after start – parameter usually set to 110% of amps)
• DDC Controller sends a Start/Stop command and may also send a reference.

In the example the Controller only sends an Enable (on/off) Signal.
Cascade or Vernier

- Pressure demand
- Cascade - Vernier
- Contact out 1
- Contact out 2
Linear Flow Control Feature

Flow Curve with Standard 1 to 1 Control

Flow Curve with VFD Curve Feature

Figure: 1

55 Hz

Standard 1 to 1 Control

VFD Curve Feature

Figure: 2
Both speed and torque are compared to a user-defined tolerance band. If the parameters do not match, the drive trips in the event of belt or pump failure.
Input – Output Configuration

- Configurable Inputs and Outputs for:
  - Status
  - Alarming
  - Control
  - Preset Speeds
Power Input Terminology

- Protect the VFD
  - Swell/Sag
  - Switching the Input
  - Transient and Spikes
  - Phase Imbalance
  - Fuses, Connectors and Voltages

- Protect the Supply Line
  - RFI – “Noise”
  - Harmonics
Basic Drive Components

VFD Block Diagram

- Main Power
- Rectifier/Converter
- Capacitor
- Switches (IGBT’s)
  - “Insulated Gate Bi-Polar Transistors"
- Motor
Protect The Drive

Numerous Stray Voltages and power changes from incoming power can effect the VFD.

YORKLAND CONTROLS
Protect the Drive – Excessive Switching

Recommended maximum switching on input is 2 times per minute

Charge circuits may heat up with excessive starts, and charging and discharging of the capacitors needs to be limited.

YORKLAND CONTROLS
Swell is an incoming voltage above its expected level
Sag is an incoming voltage below its expected level
Frequency shifts between 45Hz to 65Hz, can also occur.
Voltage Spikes and Transients

Transformer

Fuses & Disconnect

Motor
Voltage Imbalance on one of the Phases causes excessive stress on filter capacitors, so the VFD shuts down and sends out an alarm.

(2% Phase imbalance or more) CH can tolerate 50% phase imbalance

The closer to maximum load of the VFD the more sensitive it becomes to an incoming voltage imbalance.
• Voltage and current distortions caused by the VFD can effect in-coming power.

• High Noise above 450kHz is called Radio Frequency Interference (RFI) and low noise below 3kHz is called Harmonics.
RFI – Radio Frequency Interference

Amplitude (Positive Amplitude)

Amplitude (Negative Amplitude)

Wavelength

Trough

Crest

AC

Distortion

Workstation
Harmonics – Tab5

Diagram: Summation of all harmonic frequencies

Fundamental
Interference

- Generally if total VFD load is less than 100 h.p. on any separately derived power segment (after a transformer) no special harmonic remediation methods are needed. RFI mitigation may be needed to protect sensitive electronic equipment (health care facilities for example).

- Both Harmonics and RFI can travel down cable and conduit runs, and following proper grounding practices is crucial for successful VFD installations.
How a Drive Works – the Parts

- Line Reactor and input filters
- Converter/Rectifier Section
- DC Bus
- Inverter Section
If 240 Vac is coming in, 324 Vdc is generated.
If 380 Vac is coming in, 513 Vdc is generated.
If 460 Vac is the line voltage, 621 Vdc is generated.
If 575 Vac is the line voltage, 776 Vdc is generated.
The Motor responds to the PWM as if it were sinusoidal wave
Carrier Frequency - PWM

- PWM frequency can vary from 1.0 KHz to 16 kHz, which means it is audible.
- It is also known as the Carrier Frequency.
- A low carrier frequency can have an annoying noise,
- A higher carrier frequency generates more heat in the drive and motor.
- If the carrier frequency noise is too loud particularly with supply fans, filters can be placed between the VFD and motor and the noise stops at this filter.
Protection of the Drive

• **Input Filters or Reactors**
  - Protect the VFD from transient incoming AC voltage

• **Phase Imbalance**
  - A voltage imbalance on one of the phases causes excessive stress on filter capacitors.
  - Beyond 2%, the VFD shuts down and alarms the operator letting him know that there is a problem with the incoming power.
  - Maintenance – Keep it Dry, Keep it Clean
Motor Protection

- Start with an “Inverter” rated motor
- In retrofit applications, motor should have an insulation class F or better
- Service Factor 1.10 or Higher
- Use “filters” when in doubt

Filter

dT/dV – “wave trap”
Why dT/dV Filters?

- Also known as Reflective Wave Trap
- One size fits all – fits all voltages and HP
- Better voltage peak suppression
- Cost Effective
- Can have longer lead length
- Because of metal content, filters have gone up in cost.
  (consider a new higher efficiency motor)
Protecting the Motor – dV/dT Filters

Before dV/dT Filter

After dV/dT Filter
The Product

- "House Brands"
  - Cutler - Hammer

- Accessories
  - Filters
  - Motor
VS Series Drives

- .5 Hp – 200 Hp @ 690V
- 1-400 Hz Freq range
- Sensorless Vector
- Constant or Var Torque
- Removable Keypad
- PID control
VS Series Parts Modules

Control Module & Keypad + Power Section = 2 Standard I/O Cards
Menu-driven Quick Commissioning

- Set point DC 0...10 V
- Start / stop
- Running / fault
- Fault acknowledge
- w/ P1: More than 95 parameters

Commissioning Time ~ 10 Minutes

3 wire AC

BAS

“Hard wiring”

OR

P1

YORKLAND CONTROLS
Removable Keypad/Display

- Backlit Display
- Explorer Type Menu
  - Navigation indicator
  - Operates the same for all H.P.
  - HVAC defaults for PID loops; W.C., Deg F, PSI, etc.
- Operate Display can show 3 at the same time
  - Speed (Hertz), Amps, VAC…
Removable Keypad/Display

- Language Choice for Operate Menu
- Lights for Run, Fault, Ready
- Ready Flashes during Bypass Operation
3 VFD Control Modes

- **Manual Keypad**
  - Start-Up Wizard
  - Start –Stop
  - Hand/Off/Auto
  - Electronic Bypass
  - Fault Reset
  - One Touch Menu

- **Terminal to BAS**
  - Closed loop I/O
  - Run/fault

- **Fieldbus** - N2, LON…
HVAC Startup Wizard for JCI

Enter Motor Parameters

Choose one of PID Apps

- Remote (External BAS)
- PID-Duct Static (WC)
- PID-Building Static (WC)
- PID-Temperature (T)
- PID-Pressure (PSI)
- Generic PID

Wizard loads – at first power up
- or hold stop/reset for 5 seconds & cycle power
HVAC Startup Wizard for JCI

Start of the Start-Up Wizard

Language selection

Generic PI, Duct, Building, Pressure, Temperature

By pressing enter setup will start
By pressing HRA the setup will be stopped

Motor Name Plate current in Amps
XX.X A – Default will vary depending on drive size

Motor Name Plate voltage in Volts
XXX V – Default is same as drive nominal voltage

Continued
HVAC Startup Wizard
for JCI

Motor Name Plate Frequency
default 60.00 Hz

Motor Name Plate Speed
1720 rpm

Drive Minimum Output Frequency
default 12.00 Hz

Drive Maximum Output Frequency
default 60.00 Hz

Acceleration time from Min. Frequency
to Max. Frequency
default 60.0 seconds

Deceleration time from Max. Frequency
to Min. Frequency
default 60.0 seconds
HVAC Startup Wizard for JCI

- **START SRCE AUTO**
  - DI-1 START
  - Start/Stop command source in AUTO mode
default DI-1 (only in Remote Input application)

- **REF SOURCE AUTO**
  - AI-1
  - Reference/setpoint source in AUTO mode
default AI-1 (only in Remote Input application)

- **PI-INPUT SOURCE**
  - (R) AI-1
  - PI Input/Feedback source, when PI is active

- **SENSOR MIN. SCALE**
  - XXXXX
  - PID feedback device min. value
  - This is min. scale value for "Actual 1 Input"
  - (not available in Remote Input and Generic PI applications)

- **SENSOR MAX. SCALE**
  - XXXXX
  - PID feedback device max. value
  - This is max. scale value for "Actual 1 Input"
  - (not available in Remote Input and Generic PI applications)

Continued
HVAC Startup Wizard for JCI

PI-CONTR. P-GAIN
0.10

PI control gain value
default will vary depending on application

Jump to
*

PI-CONTR I-TIME
100.00

PI control integration time
default 100.00 second

Repeat Setup?
Press

By pressing the left arrow, the setup will be repeated.
Press HOA or enter to continue

Hoa
or

This message will be displayed 2 seconds to indicate that setup is completed

Setup Done

YORKLAND CONTROLS
Competitive Analysis
VFD Application Guide

- Application Guide Sources: (I didn’t just make them up !)
  - Manufacturers
  - ASHREA
  - Case Studies
    - DOE - USA
    - OEE – Canada
- [www.yorkland.net](http://www.yorkland.net) – Download Energy Saving Software
Quizzes

• Tab 4
Labs

- A word about the Demos
- Review Quick Reference Guide (tab 4)
- Lab 1 and Lab 2 (use the Quick Reference and if needed the VS manual (tab 2)
- Example 1
- Example 2
Applying VFDs - Examples
Exercise #: 1
Application:

Customer has an existing supply fan that requires a new drive. It will be mounted in the same location in the equipment room as the original.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>240</td>
<td>7.2</td>
<td>1775</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection:

Application Selection:

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>N/O from PLC</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>4-20ma from PLC</td>
<td>Keypad</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. N/C that will cause the drive to fault when the building fire alarm system is activated.
2. A relay output to the PLC to indicate drive run.
3. A relay output to the PLC to indicate drive fault.
4. A 0-10VDC analog output representing motor rpm.
Exercise #: 1
Connection Drawing
## Exercise #1:

### Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes:

**YORKLAND CONTROLS**
Exercise #: 2  
Application: 
This application is a chill water pump. Customer requires a rapid acceleration to ensure quick opening of the pump’s check valve, and slow deceleration to prevent sudden closing of the check valve and the resulting water hammer. This drive will require bypass.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>600</td>
<td>21.2</td>
<td>1785</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection:  
Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Remote)</td>
<td>(Local)</td>
</tr>
<tr>
<td>Start/Stop Control</td>
<td>DDC – N/O contact</td>
<td>Door mounted 3 position &quot;S-A switch&quot;</td>
</tr>
<tr>
<td>Speed Control</td>
<td>DDC – 4-20mA</td>
<td>Door mounted 0-10VDC pot</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. N/O contact that indicates “drive run” when closed.
2. 0-10VDC analog output representing "Output Frequency".
3. Digital output that energizes when drive is “at speed”.
4. Acceleration rate required: 10 Seconds.
5. Deceleration rate required: 1 minute 30 seconds.
6. Minimum pump speed required is 600 RPM.
Exercise #: 2
Connection Drawing
Exercise #:
Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
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<td></td>
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</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Hand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Hand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
Exercise #: 1

Application:

Customer has an existing supply fan that requires a new drive. It will be mounted in the same location in the equipment room as the original.

Motor Information:

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<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>575</td>
<td>48</td>
<td>1775</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection:

Application Selection:

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>N/O from BAS</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>4-20ma from BAS</td>
<td>Keypad</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. N/C that will cause the drive to fault when the building fire alarm system is activated.
2. A relay output to the BAS to indicate drive run.
3. A relay output to the BAS to indicate drive fault.
4. A 0-10VDC analog output representing motor rpm.
Exercise #: 1
Application:

Customer has an existing supply fan that requires a new drive. It will be mounted in the same location in the equipment room as the original.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>575</td>
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<td>1775</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection: VS050510A-00000

Application Selection: Remote

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>N/O from BAS</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>4-20ma from BAS</td>
<td>Keypad</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. N/C that will cause the drive to fault when the building fire alarm system is activated.
2. A relay output to the BAS to indicate drive run.
3. A relay output to the BAS to indicate drive fault.
4. A 0-10VDC analog output representing motor rpm.
Exercise #: 1
Connection Drawing

- To BAS 4-20 ma
- To BAS Start command
- To Fire Alarm system
- To BAS 0-10VDC Motor Speed
- To BAS “Drive Run”
- To BAS “Drive Fault”
Exercise #:
Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Man</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Man</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 2</td>
<td></td>
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</tr>
</tbody>
</table>
## Exercise #:1

### Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
<td>1.2.11</td>
<td>Value=1, AI-2 Range (4-20ma), (Default setting)</td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td>1.2.4</td>
<td>Value=2, External fault opening contact</td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td>1.3.1</td>
<td>Value=3, AO-1 Function, use 500ohm Resistor or set Dip Switches</td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Auto</td>
<td>1.1.14</td>
<td>Value=2, DI-1 Start (default)</td>
</tr>
<tr>
<td>Start Source Man</td>
<td>1.1.12</td>
<td>Value=1, Keypad (Default)</td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td>1.1.15</td>
<td>Value=1, AI-2</td>
</tr>
<tr>
<td>Speed Src Man</td>
<td>1.1.13</td>
<td>Value=2, Speed Set point From Keypad</td>
</tr>
<tr>
<td>Relay 1</td>
<td>1.3.7</td>
<td>Value=2, RO-1 Function</td>
</tr>
<tr>
<td>Relay 2</td>
<td>1.3.8</td>
<td>Value=3, RO-2 Function</td>
</tr>
</tbody>
</table>

### Notes:

1. 2.11 Value=1, AI-2 Range (4-20ma), (Default setting)
2. 1.2.4 Value=2, External fault opening contact
3. 1.3.1 Value=3, AO-1 Function, use 500ohm Resistor or set Dip Switches
4. 1.1.14 Value=2, DI-1 Start (default)
5. 1.1.12 Value=1, Keypad (Default)
6. 1.1.15 Value=1, AI-2
7. 1.1.13 Value=2, Speed Set point From Keypad
8. 1.3.7 Value=2, RO-1 Function
9. 1.3.8 Value=3, RO-2 Function
Exercise #: 2

Application:
This application is a chill water pump. Customer requires a rapid acceleration to ensure quick opening of the pump’s check valve, and slow deceleration to prevent sudden closing of the check valve and the resulting water hammer. This drive will be mounted in an enclosure provided by the customer.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>230</td>
<td>63</td>
<td>1785</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection:

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>BAS – N/O contact</td>
<td>Door mounted two position switch</td>
</tr>
<tr>
<td>Speed Control</td>
<td>BAS – 0-10VDC</td>
<td>Door mounted 0-10VDC pot</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. N/O contact that indicates “drive run” when closed.
2. 0-10VDC analog output representing “Output Frequency”.
3. Digital output that energizes when drive is “at speed”.
4. Acceleration rate required: 10 Seconds.
5. Deceleration rate required: 1 minute 30 seconds.
6. Minimum pump speed required is 600 RPM.
Exercise #: 2

Application:
This application is a chill water pump. Customer requires a rapid acceleration to ensure quick opening of the pump’s check valve, and slow deceleration to prevent sudden closing of the check valve and the resulting water hammer. This drive will be mounted in an enclosure provided by the customer.

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</tr>
</tbody>
</table>

Drive Selection: VS025210A-00000

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>BAS – N/O contact</td>
<td>Door mounted two position switch</td>
</tr>
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<td>Speed Control</td>
<td>BAS – 0-10VDC</td>
<td>Door mounted 0-10VDC pot</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. N/O contact that indicates “drive run” when closed.
2. 0-10VDC analog output representing "Output Frequency".
3. Digital output that energizes when drive is “at speed”.
4. Acceleration rate required: 10 Seconds.
5. Deceleration rate required: 1 minute 30 seconds.
6. Minimum pump speed required is 600 RPM.
Exercise #: 2
Connection Drawing

Application Selected: Remote

Remote to BAS 0-10 VDC
Door Mounted Switch
BAS Start

BAS 0-10VDC = Output Freq
To BAS = Drive Run
To BAS = "At Speed"
Exercise #:

Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Man</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
## Exercise #:2

### Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
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<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td>1.3.1</td>
<td>Value=1, Output Frequency (Default)</td>
</tr>
<tr>
<td>Digital Output</td>
<td>1.3.6</td>
<td>Value=11, Drive ‘At Speed”</td>
</tr>
<tr>
<td>Start Source Auto</td>
<td>1.1.14</td>
<td>Value=2, DI-1 Start (default)</td>
</tr>
<tr>
<td>Start Source Man</td>
<td>1.1.12</td>
<td>Value=2, DI-1 Start</td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td>1.1.15</td>
<td>Value=1, AI-2, use 500 ohm resistor or set dip switches</td>
</tr>
<tr>
<td>Speed Src Man</td>
<td>1.1.13</td>
<td>Value=0, AI-1</td>
</tr>
<tr>
<td>Relay 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 2</td>
<td>1.3.8</td>
<td>Value=2, Set to Drive Running</td>
</tr>
</tbody>
</table>

### Notes:

- **Accel Time** 1.1.3 Set to 10 Seconds (Default 60s)
- **Decel Time** 1.1.4 Set to 90 Seconds (Default 60s)
- **Min Frequency** 1.1.1 Set to 20Hz Aprox 1/3 full speed
Exercise #: 3

Application:
This drive is a running #1 return fan and will be mounted in the #2 equipment room on the wall near the motor. It is critical that the return fan not begin running until the return fan damper is open. The customer wants the return fan damper to open when the fan is commanded to run by the BAS. In hand operation the damper will be opened by the operator.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
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<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>230</td>
<td>52</td>
<td>1785</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection: 

Application Selection: 

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>BAS – N/O contact closed in run.</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>BAS – 0-10VDC</td>
<td>Door mounted 0-10VDC pot</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. Digital output that energizes when drive is “at speed”.

2. Relay outputs for lighting a “drive run”, “drive stopped”, and “drive fault” indicator lights at the BAS control panel. (115VAC lights).

3. Customer requires a digital input to be programmed for “external fault” when the fault contact is closed.

4. Customer requires auto restart to occur when the external fault is cleared.
Exercise #: 3
Application:

This drive is a running #1 return fan and will be mounted in the #2 equipment room on the wall near the motor. It is critical that the return fan not begin running until the return fan damper is open. The customer wants the return fan damper to open when the fan is commanded to run by the BAS. In hand operation the damper will be opened by the operator.

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<tbody>
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<td>230</td>
<td>52</td>
<td>1785</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection: VS020210A-00000
Application Selection: Remote

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>BAS – N/O contact closed in run.</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>BAS – 0-10VDC</td>
<td>Door mounted 0-10VDC pot</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. Digital output that energizes when drive is “at speed”.
2. Relay outputs for lighting a “drive run”, “drive stopped”, and “drive fault” indicator lights at the BAS control panel. (115VAC lights).
3. Customer requires a digital input to be programmed for “external fault” when the fault contact is closed.
4. Customer requires auto restart to occur when the external fault is cleared.
Exercise #: 3
Connection Drawing

From BAS 0-10VDC
To BAS = "At Speed"
To BAS = Open Damper command

115VAC from BAS
Drive Stopped
Drive Run

Drive Fault
<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
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<td></td>
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<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Man</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Man</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

Relay 1
Relay 2
## Exercise #:3

### Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
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<td>Analog Input 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td>1.2.4</td>
<td>Value=14, External Interlock Open</td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td>1.3.6</td>
<td>Value=11, Drive ‘At Speed”</td>
</tr>
<tr>
<td>Start Source Auto</td>
<td>1.1.14</td>
<td>Value=2, DI-1 Start (default)</td>
</tr>
<tr>
<td>Start Source Man</td>
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<td>Value=1, Keypad (default)</td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td>1.1.15</td>
<td>Value=1, Al-2, use 500 ohm resistor or set dip switches</td>
</tr>
<tr>
<td>Speed Src Man</td>
<td>1.1.13</td>
<td>Value=0, Al-1</td>
</tr>
<tr>
<td>Relay 1</td>
<td>1.3.7</td>
<td>Value=24, Relay to Energize External element</td>
</tr>
<tr>
<td>Relay 2</td>
<td>1.3.8</td>
<td>Value=2, Set to Drive Running</td>
</tr>
</tbody>
</table>

### Notes:

- **Relay 3** 1.3.11 Value=3, Drive Vault
- **DI-2** 1.2.4 Value=2. Can also be set as external Fault open, Drive will be off until damper is open.
- **Auto Restart** 1.7.6 Value=1, Auto restart enabled
Exercise #: 4

Application:
This drive is running a supply fan in an HVAC system. Because this project is on a shoestring budget, the drive will be required to maintain a positive pressure in the building automatically (No building automation). The building static pressure is being sensed via a pressure transducer that is providing a 4-20ma (-.5 to .5 wc) actual building static pressure feedback to the drive. The drives keypad is used to set the building pressure.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>S.F.</th>
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</thead>
<tbody>
<tr>
<td>20</td>
<td>575</td>
<td>18</td>
<td>1175</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection:

Application Selection:

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>Three wire control using a n/c stop button and a n/o start switch</td>
<td>Drive Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>Keypad</td>
<td>Keypad</td>
</tr>
</tbody>
</table>

I/O Requirements:

1. Customer wishes to monitor Pressure set point, actual pressure, and motor speed on the keypad.
2. Configure to run at 80% speed when Fire mode is activated.
3. Fire mode is activated with a N/O key switch.
4. A N/C contact is needed to light a 230 VAC “Drive Fault” lamp.
5. A digital output is activated when the drive is placed in “Fire Mode.”
Exercise #: 4

Application:
This drive is running a supply fan in an HVAC system. Because this project is on a shoestring budget, the drive will be required to maintain a positive pressure in the building automatically (No building automation). The building static pressure is being sensed via a pressure transducer that is providing a 4-20ma (0-20 psig) actual building static pressure feedback to the drive. The drive's keypad is used to set the building pressure.

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>575</td>
<td>18</td>
<td>1175</td>
<td>1.10</td>
<td>.85</td>
</tr>
</tbody>
</table>

Drive Selection: **VS020510A-00000**

Application Selection: **Building Static**

Control Specifications:

<table>
<thead>
<tr>
<th>Start/Stop Control</th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three wire control using a n/c stop button and a n/o start switch</td>
<td>Drive Keypad</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed Control</th>
<th>Keypad</th>
<th>Keypad</th>
</tr>
</thead>
</table>

I/O Requirements:

1. Customer wishes to monitor Pressure set point, actual pressure, and motor speed on the keypad.
2. Configure to run at 80% speed when Fire mode is activated.
3. Fire mode is activated with a N/O key switch.
4. A N/C contact is needed to light a 230 VAC “Drive Fault” lamp.
5. A digital output is activated when the drive is placed in “Fire Mode.”
Exercise #:
Connection Drawing

Pressure Transducer
0-20 PSIG

Fire Mode Key Switch

BAS Fire mode status

BAS Drive Fault Status
Exercise #:

Programming List:

<table>
<thead>
<tr>
<th>Input/output</th>
<th>Parameter #</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Input 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Input 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Source Man</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Src Man</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relay 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
Exercise #: 5

Application:
A new drive is needed for a circulating pump for a hot water heating system. The goal is to maintain 105 degree F water during the winter heating season automatically with the drive. With this system, as the water temperature rises, the circulating pump speed must decrease. The customer will select the desired water temperature using their building automation (N2). Water temperature is detected from a temperature transducer providing a 0-10VDC signal (0-150 degree range).

Motor Information:

<table>
<thead>
<tr>
<th>HP</th>
<th>Volts</th>
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<th>RPM</th>
<th>S.F.</th>
<th>Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>575</td>
<td>25</td>
<td>1775</td>
<td>1.0</td>
<td>.96</td>
</tr>
</tbody>
</table>

Drive Selection:

Application Selection:

Control Specifications:

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>Building Automation (N2)</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>Building Automation (N2)</td>
<td>Keypad</td>
</tr>
</tbody>
</table>

I/O Requirements:
1. N/C relay contact that is closed when the drive is faulted.
2. N/O relay contact that is closed when the drive is running.
3. Customer wishes to monitor the hot water temperature, circulating pump speed, and motor output power on the keypad.
Exercise #: 5

Application:
A new drive is needed for a circulating pump for a hot water heating system. The goal is to maintain 105 degree F water during the winter heating season automatically with the drive. With this system, as the water temperature rises, the circulating pump speed must decrease. The customer will select the desired water temperature using their building automation (N2). Water temperature is detected from a temperature transducer providing a 0-10VDC signal (0-150 degree range).

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<td>1775</td>
<td>1.0</td>
<td>.96</td>
</tr>
</tbody>
</table>

Drive Selection: VS025510A-N0000

Application Selection: Temperature

Control Specifications:

<table>
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<tr>
<th></th>
<th>Auto</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Stop Control</td>
<td>Building Automation (N2)</td>
<td>Keypad</td>
</tr>
<tr>
<td>Speed Control</td>
<td>Building Automation (N2)</td>
<td>Keypad</td>
</tr>
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</table>

I/O Requirements:

1. N/C relay contact that is closed when the drive is faulted.
2. N/O relay contact that is closed when the drive is running.
3. Customer wishes to monitor the hot water temperature, circulating pump speed, and motor output power on the keypad.
Exercise #:
Connection Drawing

Actual Temperature Feedback
0-150 Degree Transducer = 0-10VDC

Drive Fault
Drive Running
## Exercise #:

### Programming List:

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<tr>
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<tr>
<td>Relay 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
Service and Maintenance
Incoming power, outgoing motor, and control wiring are each in their own conduit.

The source of power for the VFD and its connected load is of sufficient size to operate the equipment.

All wiring has been accomplished according to local codes and to Eaton Electrical specifications for the size of the VFD and its connected load.

The VFD is clean and free of installation debris, equipment, or tools.

If installed, remove line and motor connections at the VFD in preparation for pre-power checks.
Static Checks of the Converter/Rectifier Section

Using a digital multimeter with a diode and resistance scale:

a. Select the diode scale of the multimeter.

b. Use the (B+) and (B–) bus as the reference point for both converter and inverter checks.

c. Start with the positive meter lead on the B+ terminal and check each VFD line connection with the negative lead.
Static Checks of the Converter Section

Start with the positive meter lead on the B+ terminal and check each VFD line connection with the negative lead.

This checks these diodes or SCRs in the converter section.
Static Checks of the Converter Section

Power OFF

Value should increase until “OL” is reached

YORKLAND CONTROLS
Static Checks of the Converter Section

Power OFF

Value should increase until “OL” is reached

YORKLAND CONTROLS
Static Checks of the Converter Section

Power OFF

Value should increase until “OL” is reached

.YOL

- +
Static Checks of the Converter Section

Switch the positive lead to the (B-) bus connection and test VFD line connections again with the negative lead.

This checks these diodes or SCRs in the converter section.
Static Checks of the Converter Section

Power OFF

0.25vdc to 0.40vdc
+/-10% range

.350vdc

YORKLAND CONTROLS
Static Checks of the Converter Section

Power OFF

0.25vdc to 0.40vdc
+/-10% range

.350vdc

YORKLAND CONTROLS
Static Checks of the Converter Section

Power OFF

0.25vdc to 0.40vdc

+/-10% range

.350vdc
Static Checks of the Converter Section

Switch to negative meter lead to the (B+) bus connection and test VFD line connections with the positive lead.

This checks these diodes or SCRs in the converter section
Static Checks of the Converter Section

Power OFF

0.25vdc to 0.40vdc
+-10% range

.350vdc

YORKLAND CONTROLS
Static Checks of the Converter Section

Power OFF

0.25vdc to 0.40vdc
+-10% range

.350vdc
Static Checks of the Converter Section

Power OFF

0.25vdc to 0.40vdc
+/-10% range

.350vdc
Static Checks of the Converter Section

Switch to negative meter lead to the (B-) bus connection and test VFD line connections again with the positive lead.

This checks these diodes or SCRs in the converter section.
Static Checks of the Converter Section

Power OFF

Value should increase until “OL” is reached
Static Checks of the Converter Section

Power OFF

Value should increase until “OL” is reached

Power Terminals

Motor Terminals

DC Terminals

Brake Terminals

Ground Terminals

OL

YORKLAND CONTROLS
Static Checks of the Converter Section

Power OFF
Value should increase until “OL” is reached

[Diagram showing power terminals, motor terminals, brake terminals, dc terminals, and ground terminals]
Static Checks of the Inverter Section
Static Checks of the Inverter Section

Return the positive meter lead to the (B+) bus connection and test VFD motor connections with the negative lead.

This checks these IGBTs and Diodes in the Inverter section.
Static Checks of the Inverter Section

Power OFF
Value should increase until “OL” is reached

Power Terminals
Motor Terminals
DC Terminals
Brake Terminals
Ground Terminals

.YORKLAND CONTROLS
Static Checks of the Inverter Section

Power OFF

Value should increase until “OL” is reached

OL

YORKLAND CONTROLS
Static Checks of the Inverter Section

Power OFF

Value should increase until “OL” is reached

OL

Power Terminals
Motor Terminals
DC Terminals
Brake Terminals
Ground Terminals
Move the positive meter lead to the (B-) bus connection and again test VFD motor connections with the negative lead.

This checks these IGBTs and Diodes in the Inverter section.
Static Checks of the Inverter Section

Power OFF
0.25vdc to 0.40vdc
+/-10% range

.350vdc
Static Checks of the Inverter Section

Power OFF

0.25vdc to 0.40vdc
+/-10% range

.350vdc

YORKLAND CONTROLS
Static Checks of the Inverter Section

Power OFF
0.25vdc to 0.40vdc
+/-10% range

.350vdc
Static Checks of the Inverter Section

Move the negative meter lead to the (B+) bus connection and test VFD motor connections with the positive lead.

This checks these IGBTs and Diodes in the Inverter section
Static Checks of the Inverter Section

Power OFF

0.25vdc to 0.40vdc

+/-10% range

.350vdc

YORKLAND CONTROLS
Static Checks of the Inverter Section

Power OFF

0.25vdc to 0.40vdc
+/-10% range

.350vdc

Power Terminals
Motor Terminals
DC Terminals
Brake Terminals
Ground Terminals
Static Checks of the Inverter Section

Power OFF

0.25vdc to 0.40vdc
+/-10% range

.350vdc

YORKLAND CONTROLS
Static Checks of the Converter Section

Return the negative meter lead to the (B-) bus connection and test VFD motor connections with the positive lead.

This checks these IGBTs and Diodes in the Inverter section.
Static Checks of the Inverter Section

Power OFF
Value should increase until “OL” is reached
Static Checks of the Inverter Section

Power OFF

Value should increase until “OL” is reached
Static Checks of the Inverter Section

Power OFF

Value should increase until “OL” is reached
Static Checks of the DC Bus
Static Checks of the DC Bus Section

Power OFF
Value should increase until “OL” is reached

YORKLAND CONTROLS
Static Checks of the DC Bus Section

Power OFF

Value should be in the Meg Ohm range.

Meg $$\Omega$$

- $$\Omega$$

+ $$\Omega$$
Static Checks of the DC Bus Section

Power OFF
Value should be in the Meg Ohm range.
Perform Initial power on safety checks.

a. Confirm that all power is still tagged and locked out to the VFD.

b. Reconnect the line and motor cables to the proper VFD terminals.

c. Ensure all appropriate control wiring has been reconnected.

d. Once all electrical connections are restored conduct a walk around of the VFD and it’s connected load.

e. Remove tags and locks for the disconnect supplying power to the VFD disconnect.

YORKLAND CONTROLS
Perform initial power on safety checks.

f. When safe to do so, keeping the VFD disconnect locked and tagged, energize the disconnect that supplies power to the VFD disconnect.

g. Using the DVM measure the AC line voltage at the supply side of the VFD disconnect.

h. Record phase to phase voltage and phase to ground voltage.
   • Phase to phase are balanced within < 5%.
   • Phase to ground are balanced within < 5%.
Perform initial power on checks.

- When it is safe to do so remove all tags and locks from the VFD disconnect.
- Re-install any covers that have been removed from the VFD or motor.
- When it is safe to do so close the VFD disconnect.
- Conduct the Power on checks.
Perform power on checks.

Measure phase to phase voltage at L1, L2 and L3.
Readings should be <= 5% of each other.

Measure phase to ground at L1, L2, and L3.
Readings should be <= 5% of each other.
Measure phase to phase and phase to ground at L1, L2, and L3

Power ON
460Vac
-15% / +10%

466Vac

- Vac
+ Vac
Measuring the Supply Voltage

Power ON

460Vac

-15% / +10%

466Vac

YORKLAND CONTROLS
Measuring the Supply Voltage

Power ON

460 Vac

-15% / +10%

466 Vac
Perform DC bus voltage check.

a. Measure DC bus voltage at terminals B+ and B-.

b. Compare reading to the calculated DC bus voltage using the following formula:
   \[ \text{Bus Voltage} = \text{line voltage} \times 1.414 \]  
   (CutlerHammer)

c. The voltage value measured in the previous step should correspond to the DC Bus Voltage Value displayed in the Monitor section

They should be within +/- 10Vdc.
Measuring the DC Bus Voltage

Power ON

680Vdc

-15% / +10%

687Vdc

Vdc

+ 

-
Measuring the Terminal Voltages

Power ON

Terminal Blocks 1 and 3 are the supply for the speed pot.

Terminal 1 is 10Vdc and 3 is GND

YORKLAND CONTROLS
Measuring the Terminal Voltages

Terminal Blocks 6 and 7 are the supply for the Digital Inputs.

Terminal 6 is 24Vdc and 7 is GND
Check motor direction of rotation

Bump the motor to check it’s direction of rotation in the following order:

If a bypass is connected check it first.

After checking bypass check VFD rotation.
Solving Rotation Errors

Problem:
Drive Rotation is Wrong.
Bypass Rotation is Wrong.

Solution:
Swap any 2 leads at the “T” leads or motor terminal block.
Problem:
Drive Rotation is Right.
Bypass Rotation is Wrong.
Solution:
Swap any 2 leads on the supply wires to the enclosure.
Solving Rotation Errors

Problem:
Drive Rotation is Wrong.
Bypass Rotation is Right.

Solution:
Swap any 2 leads of the incoming supply.

&

Swap any 2 leads at the “T” leads or motor terminal block.
Measure Motor Voltage

Measure the voltage Phase to Phase on the output terminals and record this reading in the commissioning documentation.

Compare this Value with the drive display for Motor Voltage and record.
Measure the Current on each Phase to the motor and record this reading in the commissioning documentation.

Compare this Value with the drive display for Motor Current and record.
Measure the voltage Phase to Phase on the input terminals and record this reading in the commissioning documentation.
Measure the Current on each Phase to the drive and record this reading in the commissioning documentation.