Energy Savings with Variable Frequency Drives-AHRI/ANSI VFD standards IWEA-POC EPEC Seminar 2014

Your Presenters
Bill Bauer
&
Dave Waite
GOOD MORNING
HAVE A NICE DAY !!!
Schneider Electric (Square D)
Variable Frequency Drives

- Introductions
- Motor Basics
- VFD basics and how they operate
- Energy Savings with VFD’s
- Energy Savings VFD software tools
- HVAC fan pump application examples

- Discussion
- AHRI/ANSI New VFD standard-What is it and why is it important
- New Schneider Process/Pump Drive
AC Motor Basics

- The workhorse of industry:
- 3-PHASE AC INDUCTION MOTOR
AC Motor, Construction

→ Basic Components
AC Motor, **Principles of Operation**

1. Applied ac voltage/frequency causes ac stator current flow which produces rotating magnetic field.

2. Rotating magnetic field induces rotor bar voltages which cause rotor bar current flow creating magnetic fields around the rotor bars.

3. Interaction between rotating magnetic field and rotor bar fields produces force on rotor bars resulting in motor torque and rotor rotation.
AC Motor, Rotating Magnetic Field

Stator Field Rotation, 3 Phase, 2 Pole Construction

The magnetic field is also known as “flux”
Basics of Motors and VFDs

➔ VFDs controls:
  ■ Speed
  ■ Torque
  ■ Direction
  ■ And resulting Horsepower of a motor
Basics of Motors and VFDs

The AC Motor – Common Starter & Control Methods

The Across the Line Starter (ATL = DOL)

The Soft starter

The VFD

Each of these starting methods have many types and configurations
Basics of Motors and VFDs

The AC Motor Common Starting Method (ATL)

- Across-The-Line Starting
- The motor will initially pull 600%-700% starting current.
- Some new “super” high efficient motors can draw 800% to 1100% starting current.
- The current will decrease as the motor comes up to speed.
- The time required to come up to speed depends on the load on the motor.
- Cost $
Basics of Motors and VFDs

- Basic starting of motor – apply power using a motor starter/contactor (Across-the-line Starter)

- Inrush 7-10 times full load amps (FLA)
- Replace motor starter with VFD
Basics of Motors and VFDs

➡ Purpose of VFDs
- Control Speed & Torque

➡ What is a VFD?
- Microprocessor Controlled Power Converter
- Converts input power (ex: 480V, 3ph to DC)
  - Rectifier - Input Section
- Cleans up DC Bus Voltage
  - DC Link
- Switching Section outputs to motor
  - Inverter
Basics of Motors and VFDs
AC Drives

Input
Fixed Voltage
Fixed Frequency

(*) Rectifier = diode bridge

Output
Variable Voltage
Variable Frequency

Three-Phase Power

Rectifier
DC Link
Inverter

M
Basics of Motors and VFDs
AC Drives

AC Voltage and Frequency Control

Switching Frequency = 1000 - 20kHz

Effective Output
60 Hz
83% voltage
(60 Hz base)

Low duty cycle near zeroes
High duty cycle near peaks

Line to ‘Neutral’ Output Voltage of Inverter
What is a constant Torque Load

Constant Torque Loads – The most common in Industrial Application – limited opportunity for Energy Savings – But the other five reasons why customers buy drives apply!

Constant Torque (Power varies LINEARLY with speed)
Torque remains constant

Examples:
• Conveyors – skim, sludge
• Rotary Blowers
• Screw Type Air compressors
• Positive Displacement Pumps
• Progressive Cavity Pumps
• Vacuum Pumps
What is a Variable Torque Load

Reduced Energy Consumption – Save Energy
Variable Torque Loads – Centrifugal Pumps & Fans – lots of opportunity for Energy Savings

Variable Torque (Power varies with the CUBE of speed)
Flow is proportional to speed
Torque is proportional to the square of speed

Examples:
• Centrifugal Pumps
  • Well Pumps
  • Booster Pumps
  • Slurry Pumps
  • Sludge Pumps
• Centrifugal Fans

Diagram:
- % Flow, Torque & HP vs. Flow, voltage, amps, HP, KW
- Graph shows relationship between flow, torque, and power

Image by Square D by Schneider Electric
Energy Savings with VFD’s
Why use a VFD?

- **Energy Savings**
  - Centrifugal fan and pump loads operated with VFD reduces energy consumption.
  - Since variable torque load profile has HP proportional to the cube of speed and T proportional to the square of speed, if speed of fan can be run lower, HP is greatly reduced.

Benefit of VFD:
- Save $$$
- Payback on better control
Energy Savings
Variable Torque Load

Frequency vs. Flow/Torque/Power

Flow varies linearly with speed

Torque requirement varies as the square of speed

Power requirement varies as the cube of speed

Flow, % Torque, % Power

% Flow, % Torque, % Power

Frequency (Hz)

0 1 0 2 0 3 0 4 0 5 0 6
Energy Savings

Pump Control
Control Methods
Comparison

- Recirculation
- Throttle
- On/Off
- VFD

System Curve

Pump Flow

Power Consumption

0%
50%
100%
0%
50%
100%
Energy Savings

Theoretical Affinity Law
Centrifugal Pump and Fan

<table>
<thead>
<tr>
<th>Speed</th>
<th>Flow</th>
<th>Voltage</th>
<th>Pressure</th>
<th>Amps</th>
<th>HP Required</th>
<th>KW</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>100%</td>
<td>480</td>
<td>100%</td>
<td>120</td>
<td>100</td>
<td>74.6</td>
</tr>
<tr>
<td>90%</td>
<td>90%</td>
<td>432</td>
<td>81%</td>
<td>97.2</td>
<td>72.9</td>
<td>54.3</td>
</tr>
<tr>
<td>80%</td>
<td>80%</td>
<td>384</td>
<td>64%</td>
<td>76.8</td>
<td>51.2</td>
<td>38.2</td>
</tr>
<tr>
<td>70%</td>
<td>70%</td>
<td>336</td>
<td>49%</td>
<td>58.9</td>
<td>34.3</td>
<td>25.6</td>
</tr>
<tr>
<td>60%</td>
<td>60%</td>
<td>288</td>
<td>36%</td>
<td>43.2</td>
<td>21.6</td>
<td>16.1</td>
</tr>
<tr>
<td>50%</td>
<td>50%</td>
<td>240</td>
<td>25%</td>
<td>30</td>
<td>12.5</td>
<td>9.3</td>
</tr>
<tr>
<td>40%</td>
<td>40%</td>
<td>192</td>
<td>16%</td>
<td>19.2</td>
<td>6.4</td>
<td>4.8</td>
</tr>
<tr>
<td>30%</td>
<td>30%</td>
<td>144</td>
<td>9%</td>
<td>10.8</td>
<td>2.7</td>
<td>0.2</td>
</tr>
</tbody>
</table>

- Running at 70% of speed, use 1/3 kW
- Running at 50% of speed, uses 1/8 kW
- Below 30% usually results in turbulence and energy savings is negligible
VFD Energy Software Analysis Tools
Energy Savings Calculator
For Altivar™ variable speed drives (VSD)

This savings calculator quantifies the energy savings when variable speed drives are applied in place of traditional mechanical systems using damper controls to control commercial and industrial fans.

**Conventional Mechanical System**
- The motor continuously runs at full speed regardless of need
- The amount of flow is controlled by a damper

**Variable Speed Drive System**
- The motor speed matches required power demand
- Eliminates the energy and cost losses caused by dampers

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**Power consumed**

[Graph showing power consumption vs. flow (RPM) with a comparison between traditional solution with damper and solution with Altivar variable speed drive.]

- Variable speed drives use 50% less energy vs. traditional systems; at 80% flow

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Energy Efficiency

for fan applications

OK
Energy Savings Calculator
For Altivar™ variable speed drives (VSD)

Average Annual Air Flow Required

- Fan control operation with mechanical damper = Waste of energy
- Fan control operation with an Altivar™ VSD = Energy saving

Energy Consumption

- Mechanical System: 80%
- Variable Speed Drive System: 20%

Energy Consumption/Year @ 15 HP
- Mechanical System: 88,691 kWh
- Variable Speed Drive System: 16,611 kWh

Energy Cost/Year
- Mechanical System: $5,649.66
- Variable Speed Drive System: $1,058.17

Potential Savings
- 72,079 kWh
- $4,591.49

State: Illinois
Service Type: Industrial
kW/Hour: 6.37 $
Application Examples
Data Center Unitary Chiller VFD Energy Upgrade Project

Schneider Electric Solution:

- **VFD Technology ($130K)** – Major International Data center location in Chicago-Retrofit and installation of 70 Libert Unitary Chillers Plenum Fan/motors with 70 ATV212 Variable torque drives. 70 M168 HVAC controllers controlling head pressures of all Compressors and regulating Fan speed via Modbus to ATV212 Drive. Contact Dave Waite @ RRA Inc.

**Estimated Energy Savings and Return On investment**

<table>
<thead>
<tr>
<th>Estimated Energy Savings</th>
<th>Estimated Carbon Dioxide Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td><strong>Energy Usage</strong></td>
</tr>
<tr>
<td>Present System:</td>
<td>7,219,946 kWh</td>
</tr>
<tr>
<td>VFD System:</td>
<td>1,591,599 kWh</td>
</tr>
<tr>
<td><strong>Energy Saved:</strong></td>
<td>5,628,357 kWh</td>
</tr>
<tr>
<td><strong>Estimated Savings:</strong></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td>Energy Saved/Year:</td>
<td>$393,985</td>
</tr>
<tr>
<td>Yearly Savings:</td>
<td>$393,985</td>
</tr>
</tbody>
</table>
Recirculation Pump Project Overview

Schneider Electric Solution:

- **VFD Technology ($300K)** – Recycle House using (6) 250hp VFDs to vary water pressure generating cost savings vs. across the line starters. Eng. Contact is Leyland Gilford and Neil Young.

- **Pump Control Panel ($90K)** – M340 PLC and Magelis HMI assembled and programmed by Orion Eng. Corp.

**Estimated Energy Savings and Return On Investment**

<table>
<thead>
<tr>
<th>System</th>
<th>Energy Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present System:</td>
<td>1,719,035 kWh</td>
</tr>
<tr>
<td>Drive System:</td>
<td>757,616 kWh</td>
</tr>
<tr>
<td><strong>Energy Saved:</strong></td>
<td>961,419 kWh</td>
</tr>
<tr>
<td><strong>Estimated Savings:</strong></td>
<td>$67,321</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System</th>
<th>Carbon Footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present System:</td>
<td>605.96 Ton(s)</td>
</tr>
<tr>
<td>Drive System:</td>
<td>267.06 Ton(s)</td>
</tr>
<tr>
<td><strong>Carbon Dioxide Savings:</strong></td>
<td>338.90 Ton(s)</td>
</tr>
</tbody>
</table>

**Estimated Payback Time:** 0.282 Years
Business Case/ROI

Each pump is 250Hp, 480V 3ph.
Present system runs 3 pumps at full speed 24/7/365.
Energy used per pump, per year – 1719,035 KW.
1719,035Kw x 3 = 5157,105Kw annually.
Pumps being run at 75% flow use 757,616Kw annually.
6 x 757,616 = 4545,696Kw annually.
5157,105 minus 4545,696 = 611,409Kw saved annually.
Fan Applications

• Supply Fans
  for heating and cooling

• Ventilation Fans
  for intake and exhaust

• Cooling Towers Fans
  for tower efficiency
II. Applications

Pump Applications

• Chilled and Hot water supply for heating and cooling

• Fresh water pumping in-building booster pumps

• Cooling tower pumps for tower efficiency
AHRI/ANSI NEW VFD standard - What is it?
New Standard for VFD Testing

→ AHRI Standard “VFD Performance Ratings” will level the playing field for Drive’s

→ 3 Certified Tests Required for compliance
  ■ Drive Efficiency
  ■ Harmonic Distortion
  ■ Motor Output Waveform

First Certification for VFD Performance....
Inside Standard 1210 (IP)

Standardized Test Procedure
including test motor
Inside Standard 1210 (IP)

Required Testing

- Drive Efficiency (%) at 40, 50, 75 and 100% Speed
- Harmonics (%THD) at 40, 50, 75 and 100% Speed
- Dv/dt Peak Voltage (V) and Rise Time (μsec) at 100% Speed

### Table 1B. Power Classifications

<table>
<thead>
<tr>
<th>Size Classification</th>
<th>Power (hp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>208 V</td>
</tr>
<tr>
<td>Small</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>25.0</td>
</tr>
<tr>
<td>Large</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Nominal horsepower ranges are determined for applied motors that fall within NEC current ratings table.

### Table 1C. Percent Torque

<table>
<thead>
<tr>
<th>Percent Speed</th>
<th>16%</th>
<th>25%</th>
<th>56%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>VT</td>
<td></td>
<td>CT</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>VT</td>
<td></td>
<td>CT</td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td>VT</td>
<td></td>
<td>CT</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td></td>
<td>CT/VT</td>
<td></td>
</tr>
</tbody>
</table>
# AHRI sample Data Sheet – ATV212HD45N4

## PRODUCT PERFORMANCE RATINGS

**Drive System Efficiency (%) - express to the nearest 0.5%**

<table>
<thead>
<tr>
<th>% Torque</th>
<th>16%</th>
<th>25%</th>
<th>56%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>81.0%</td>
<td></td>
<td></td>
<td>83.0%</td>
</tr>
<tr>
<td>50%</td>
<td>85.5%</td>
<td></td>
<td></td>
<td>85.0%</td>
</tr>
<tr>
<td>75%</td>
<td>90.0%</td>
<td></td>
<td></td>
<td>88.5%</td>
</tr>
<tr>
<td>100%</td>
<td>91.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: Only complete applicable data cells depending on load designation.*

### Harmonic Current Distortion (%) - express to the nearest 1%

<table>
<thead>
<tr>
<th>% Speed</th>
<th>% Torque</th>
<th>I₂</th>
<th>I₇</th>
<th>I₁₁</th>
<th>I₁₃</th>
<th>THD</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>25%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VT</td>
</tr>
<tr>
<td>75%</td>
<td>56%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VT</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>26%</td>
<td>14%</td>
<td>8%</td>
<td>9%</td>
<td>34%</td>
</tr>
<tr>
<td>40%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CT</td>
</tr>
<tr>
<td>50%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CT</td>
</tr>
<tr>
<td>75%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CT</td>
</tr>
</tbody>
</table>

*Note: All values are an arithmetic average of the three power line phase currents.*
*Note: Power line impedance < 1%, based on drive full load*
*Note: Only complete applicable data cells depending on load designation.*

## Motor insulation Stress (V and μs) - express to the nearest 10 V and 0.01 μsec, respectively

<table>
<thead>
<tr>
<th>Motor Cable Length:</th>
<th>peak V</th>
<th>rise time</th>
</tr>
</thead>
<tbody>
<tr>
<td>6m</td>
<td>970 V</td>
<td>0.13 μs</td>
</tr>
<tr>
<td>15m</td>
<td>1120 V</td>
<td>0.14 μs</td>
</tr>
<tr>
<td>30m</td>
<td>1230 V</td>
<td>0.15 μs</td>
</tr>
</tbody>
</table>

*Note: All testing performed at 100% Speed and 100% Motor Torque after thermal stabilization*
*Note: Only complete applicable data cells depending on load designation.*
AHRI Test Data – ATV212

VT Plot

Rise Time Plot

Individual Harmonic Plot

THD Plot
Use new AHRI Standard 1210 Certification

Sample Spec Text

“ All VFD’s shall not generate greater than 36% THDI at drive terminal input. AHRI Standard 1210 shall dictate harmonic method of testing for this current distortion maximum limit. Certification to AHRI Standard 1210 stating compliance with specified limit shall be provided with VFD submittal package and be published for reference at AHRI.net product listing web site.”

Efficiency and motor insulation stress levels may be published in similar manner within consultants specifications……
NEW Process/Pump drive-2014
The Process Offer

Introduction

- application functions dedicated to segment solutions
  - Safety embedded as standard (STO SIL3)
    - Advance graphic terminal
  - Modbus and Ethernet Modbus TCP as standard
    - Option cards
      - Extension of inputs-outputs
      - communications protocol
  - Conform to standards and international directives
    Green Premium, EMC, safety, and environment
The Process Offer
product & solutions

**Product offer**
- 1 - 500 HP
- UL Type 1
- UL Type 12
- Low Harmonic Drive
  - 40 - 500 HP

**System offer**
- 150 – 1500 HP
- Modular design based on modules
- Configurable with standard options
Altivar Process Frame Size overview

Type 1

ATV630 Wall mounting products  IP21/UL Type1 (200V class up to 250HP, 690V class from 3HP)

ATV630 Floor standing Type 1

Motor Control Equipment  (USA offer)  UL Type 1

ATV640 LH-products IP21/UL Type1

ATV660  Drive Systems Type1  (690V only)

ATV680  Low Harmonic Drive Systems Type 1

ATV680  (690V only)

1  7.5  15  30  60  125  150  250  500  700  1000  1500 HP
Human Machine Interface
Advance Keypad

● **Functions:**
  - LCD Graphic Display
  - Graphic dashboard for quick monitoring
  - Connection to PC (files exchange)
  - Battery to for real time clock
  - Multi-file storage function
  - Multi drives connection

● **Innovations:**
  - Bi-color backlight
  - Native Type 12 with capacitive
  - Type 12 door kit via 22.5Φ hole
  - Display dynamic QR code

**Values:**

- Innovative dialog to monitor and control, Energy Efficiency and performance
- Flexibility to follow your complete applications!
The Process Offer

With Dynamic QR codes

Advanced technical documentation: “QR 2 doc”
Contextual help to guide you fixing your problem

Online troubleshooting
Step by step description of procedure to follow

Customer Care Center: “QR2 case”
Automatic creation of technical support request

Repair instruction and Service ordering “QR2 warranty”
Identify defective area

Simplicity in maintenance – minimize down time
Technical Specifications
Control Terminals

- 6 Digital Inputs
- 2 Safe Torque Off (Power removal) Input
- 3 Analog Inputs
  - 3 Relays
- 2 Analog Outputs
  - 1 switch for configuration (Sink/Source)
- 3 RJ 45 connector for communication
- color coded per I/O group
**10 year lifetime**
- Normal Duty Pn (Overload 110%)
- High Duty Pn-1 (Overload 150%)
- Induction & Permanent Magnet Motor

**Operating temperature:**
- -15°C to +50°C w/o derating
- Up to +60°C with derating on power

**Altitude:**
- up to 4800m within defined conditions

**Harsh environment:**
- Chemical env 3C3
- - H2S, Ozone, SO2
- - Salt mist
- Mechanical 3S3
- - Pollution degree 3
- - Coated boards

**IEC61000-3-12 compliance:**
- Enlarged THDi 48% from 100% to 80% of motor nominal load

**Human Machine Interface:**
- Several languages more than 20
- Customizable (units, ...)
- Energy/Pump monitoring
- Trend and drift energy
- Dedicated application functions
- Removable HMI with RTC, fast replacement functions, innovative door mounting kit (hole Dia22), red backlight in case of error detection

**Conducted Emission IEC/EN 61800-3**
- Up to 45kW 400v C2 50m C3 150m
- Above 45kW C3 150m

**2 slot for “SHI options”:**
- Fieldbus
- Digital & Analog I/O
- Relays (3)

**Embedded Fieldbus:**
- Ethernet Modbus TCP
- Modbus

**Options Fieldbus:**
- Ethernet IP/Modbus TCP (dual port)
- DeviceNet
- CANopen
- Profinet & ProfiNet
Make the most of your energy