Music City Power Quality
IEEE Control Tennessee Section
2015

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SQUARE D

by Schneider Electric

Make the most of your energy[SM]

Schneider Electric

Presenter

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- 25 years in the Electrical Industry
  - Gas turbine Systems Electrical Engineer (US Navy)
  - Industrial Electrician – 5 years
  - Product Application Engineer – 15 years
- Sr Drive Specialist with Schneider Electric – 9 years
  - Midwest Regional Team Leader – Michigan, Tennessee, Kentucky, Indiana, Ohio, Chicago, Wisconsin,
- Certified Energy Manager – Association or Energy Engineers

Schneider Electric U.S.

Schneider Electric

The Global Specialist in Energy Management

18000

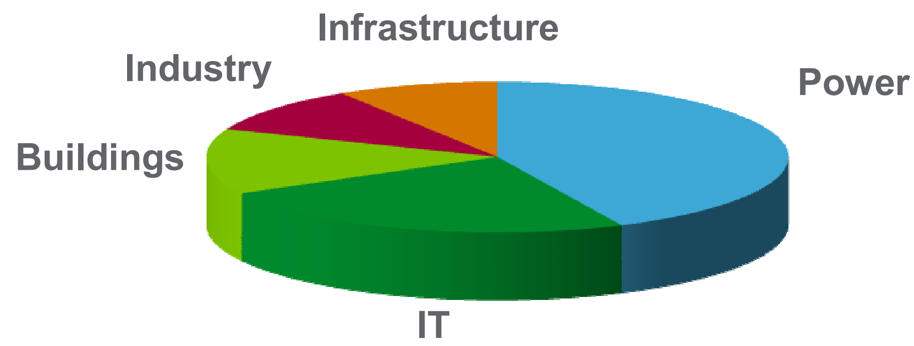
people across the country

240

facilities across the country

- 40 Manufacturing facilities
- 6 Distribution centers
- 6 R&D centers
- Business, sales & services

Sales



Market Leading Brands

APC by Schneider Electric

SQUARE D by Schneider Electric

PELCO by Schneider Electric

TELVENT

Today's Discussion

- **Variable Frequency Drives – Basic Technology**
- **Application Considerations**
- **VFD Control scheme discussion**
- **Q & A**

Variable Frequency Drives common names are:

- Variable Frequency Drives - VFD
- Adjustable Frequency Drives – AFD

- Variable Speed Controllers - VSC
- Adjustable Speed Controllers – ASC
- Variable Speed Drives - VSD
- Adjustable Speed Drives – ASD
- AC Drives
- Inverter Drives

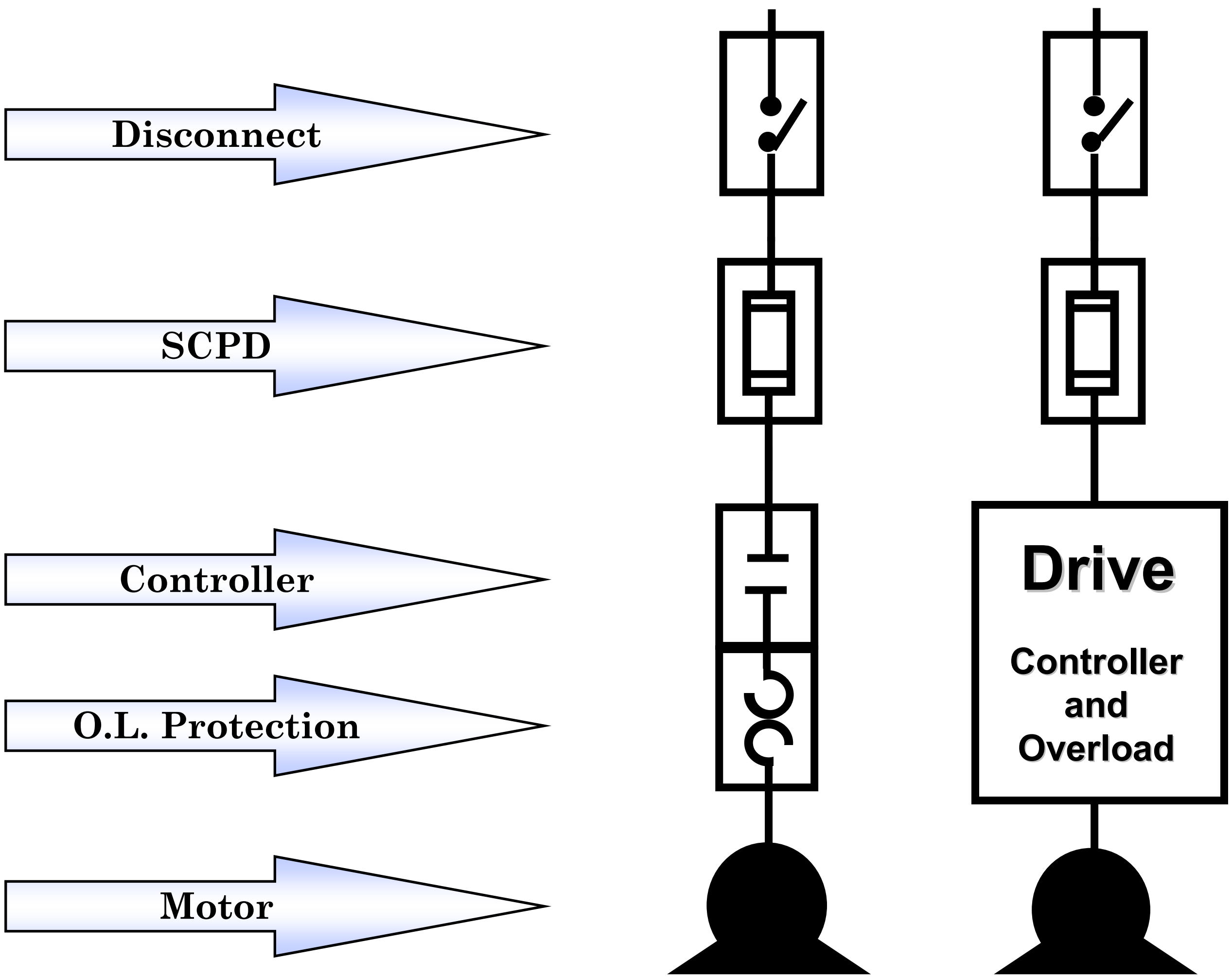
Soft Start vs VFD

Means of Controlling Flow & Pressure

- Typical Output Controls include:
  - Throttle valves
  - Inlet guide vanes
  - Outlet dampers
  - Mechanical speed changers
    - Eddy Current Clutch
    - Belt Drive
    - Two-speed Motor

- Motor runs at full speed
  - No energy savings

Why replace a motor starter with a VFD?



Why use VFD's?

- Provide substantial energy savings - #1

- Built in Soft Start – reduces mechanical shock
- Reduces downtime & improves system reliability
- Reduces maintenance & operational cost
- Improves system efficiency
- Precise process speed & torque control
- Provides application flexibility

Energy Savings $$$

Studies show 60% of the energy used in the USA is used by motors.

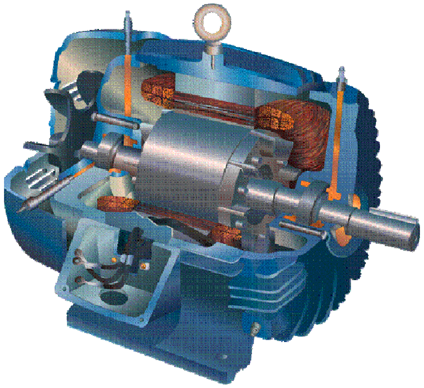
Many of these motors are on fans & pumps (70% +)

Affinity Laws govern savings

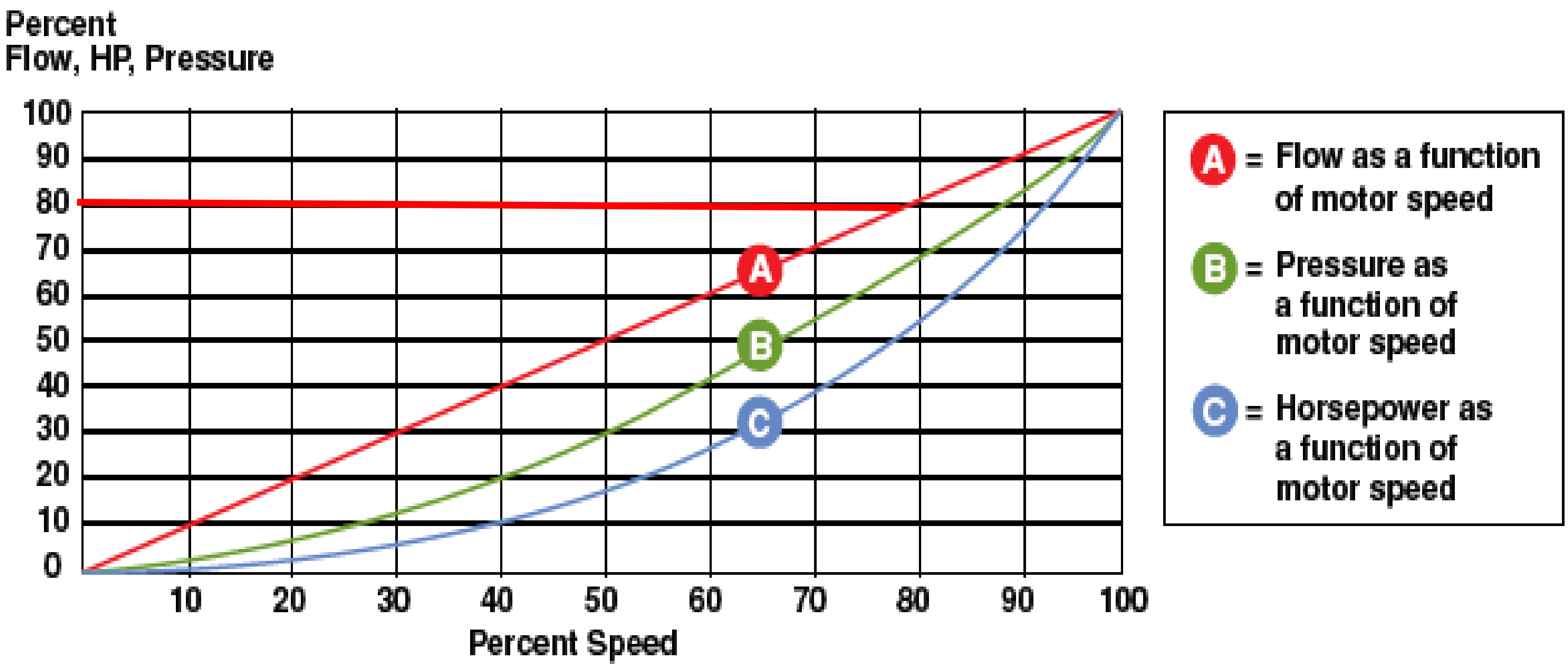
Variable torque loads = fans, blowers & centrifugal pumps

Larger motors eat your lunch money!

Feed Me!



VFD Basics – Energy Savings



Motor Speed

A motor running at <u>80%</u> of full speed requires <u>half</u> of the electricity of a motor running at full speed.

Energy Savings Analysis

Where's the money going?

Typical drive energy payback period

- 1 – 3 year on just energy saved (demo software)

Payback based upon

- Energy cost, hours & speed of operation
- On-line software tool

VFD Basics – Energy Savings

- Situation – Aeration basin
  - A 500hp centrifugal blower
  - Supply air 10 hours/day for 250 days
  - Cost at full speed would be:
    500 hp x 0.746 kW/hp x 2500hours x $0.08 /kWhr = $74,600.00
- Assuming the blower does not have to run at full speed all the time
  - 25% of time at 100% speed = 625 hours
  - 50% of time at 80% speed = 1250 hours
  - 25% of time at 60% speed = 625 hours
- Cost running with a Schneider Electric AC Drive:
  - 500 x $(1.0)^3$ x 0.746 x 625 x $0.08 = $18,650.00
  - 500 x $(0.8)^3$ x 0.746 x1250 x $0.08 = $19,097.60
  - 500 x $(0.6)^3$ x 0.746 x 625 x $0.08 = $ 4,028.40

- Annual savings ($74,600.00 - $41,776.00) is $32,824.00

VFD – What does it give you?

- Controls speed of an AC motor.
- Controls inrush current of an AC motor.
- Generates full torque of the motor at very low speeds.
- Protects the motor and wiring from overload currents.
- Provides built in power factor correction.

- Allows simple connection to a communication network.
- Allows automatic set point control throughout the entire speed range.
- Provides a simple means to continuously monitor & diagnose.

VFD Driven Loads

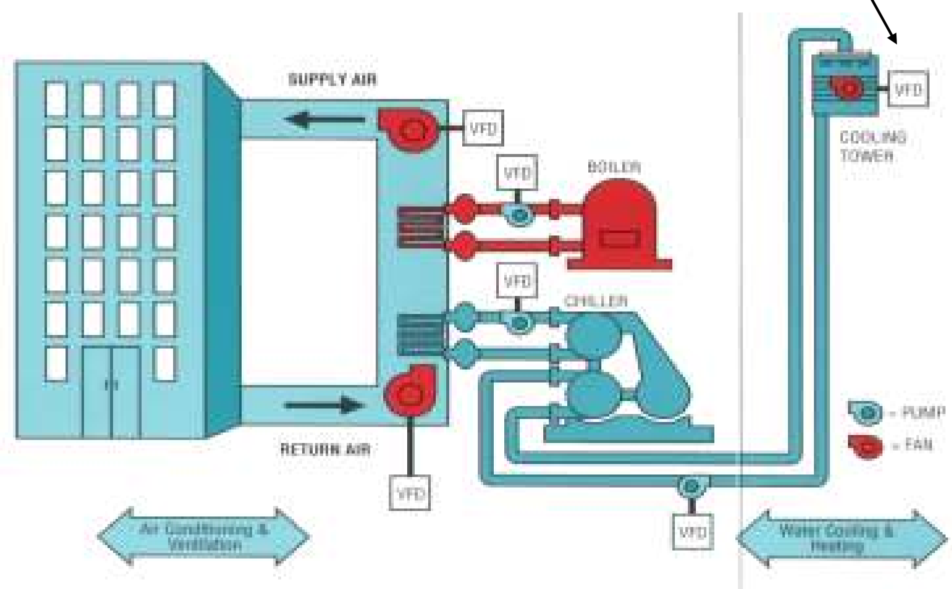
- Constant Torque – 150% over current for 1 minute
  - Positive displacement pumps
  - Extruders
  - Centrifuges
  - Mixers
  - Agitators
  - Conveyors
  - Cranes
  - Paper machines
- Variable Torque – 110% over current for 1 minute
  - Centrifugal pumps
  - Fans
  - Blowers

Applications

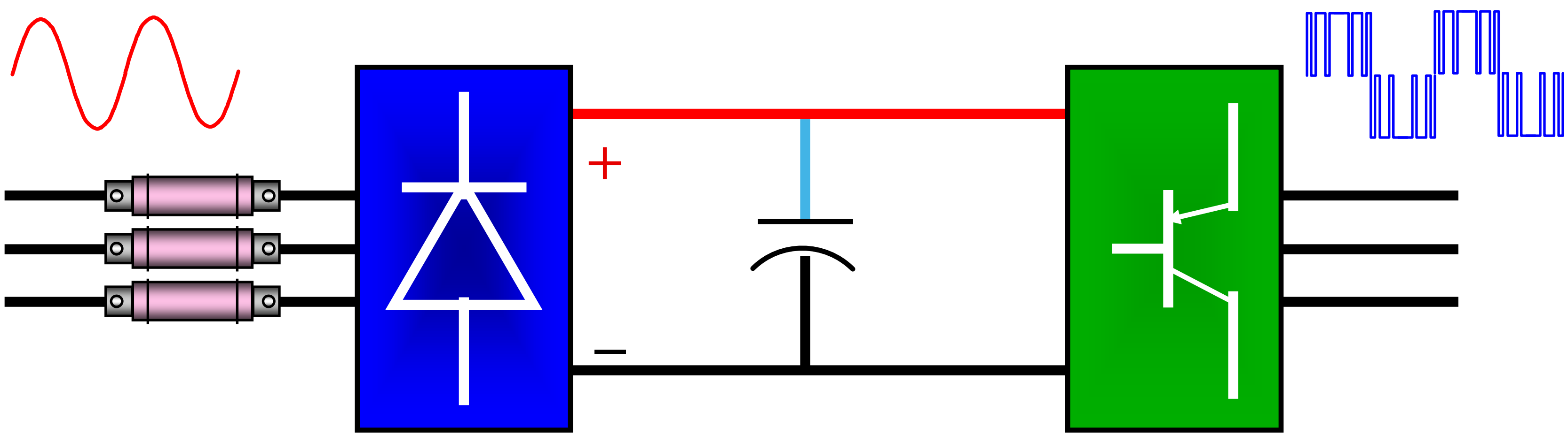
- **Booster Pumps**
  - **Energy savings, soft start**
- **Exhaust Fans**
  - **Energy savings**
- **Blower Compressors**
  - **Flow control, energy savings**

Typical Building Applications

Cooling Tower Fans



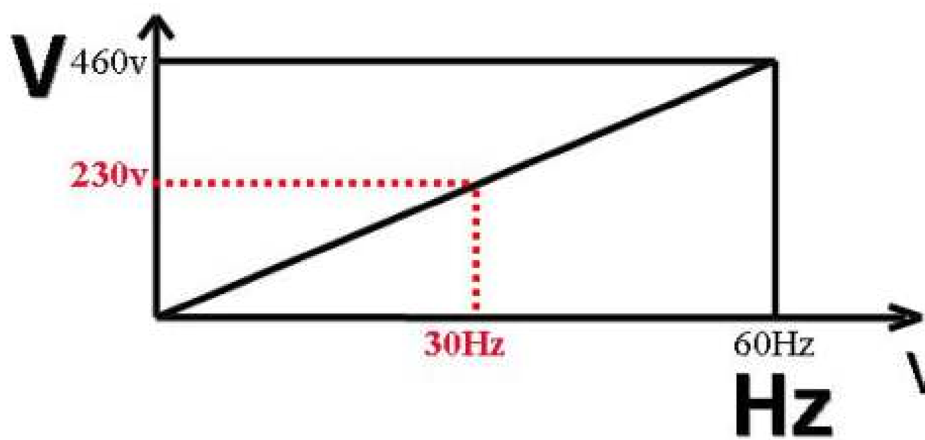
VFD Basics

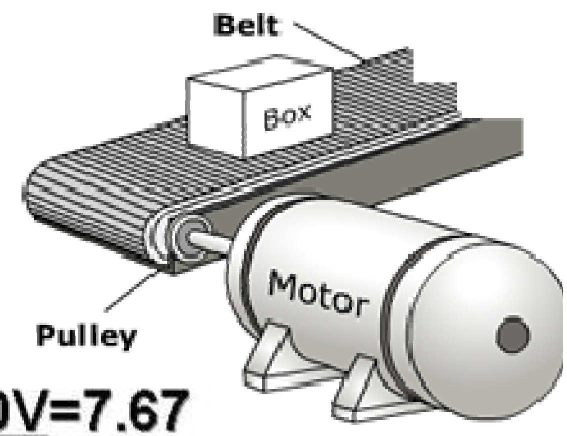


AC Line Input | **Diode Bridge Converter** | **DC Bus Link** | **Transistor Inverter** | **AC Output**

Voltz/Hz Ratio

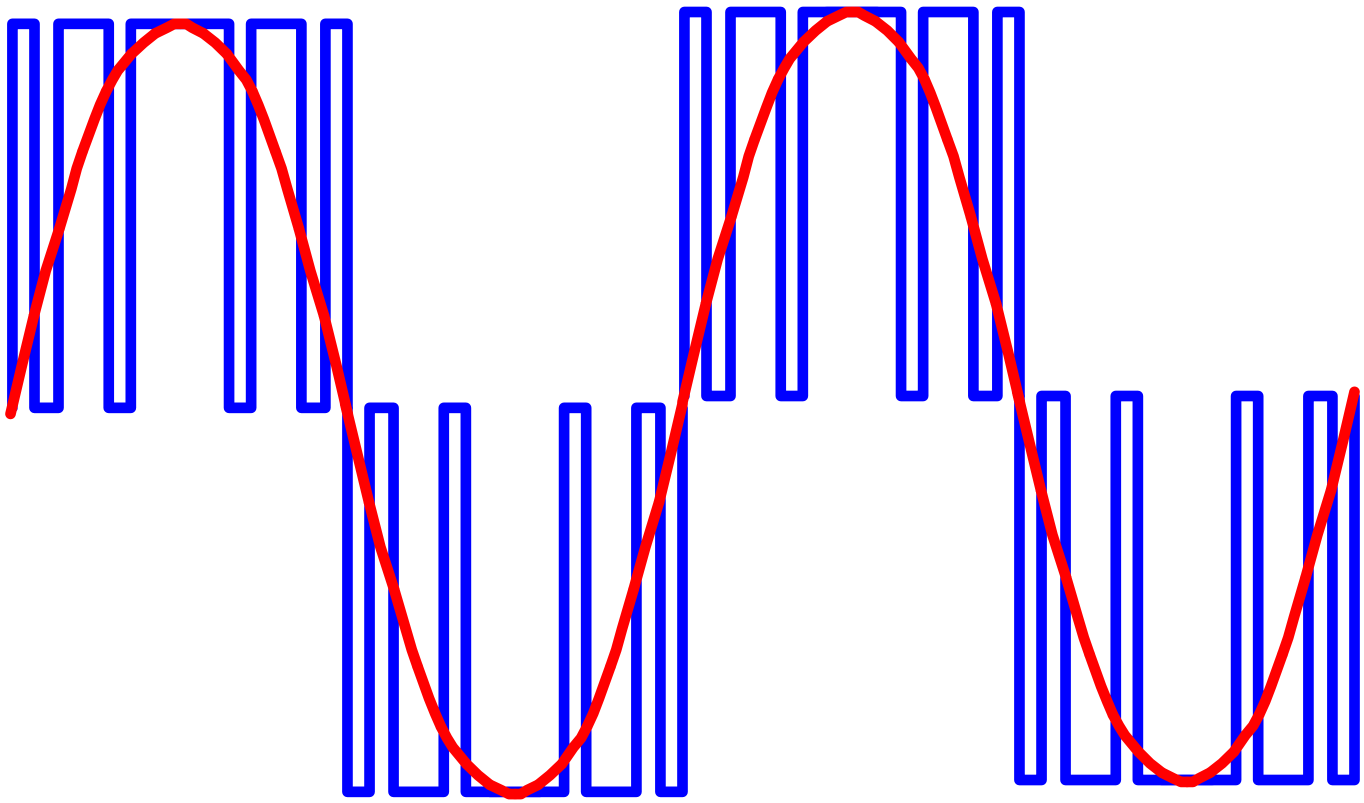
- When current is applied to an induction motor it generates magnetic flux in its rotating field and torque is produced.
- This magnetic flux must remain constant in order to produce full-load torque, which is most important when running a motor at less than full speed.
- Since AC drives are used to provide slower running speeds, there must be a means of maintaining a constant magnetic flux in the motor. This method of magnetic flux control is called the volts-per-hertz ratio.
- With this method, the frequency and voltage must increase/decrease in the same proportion to maintain good torque production at the motor.

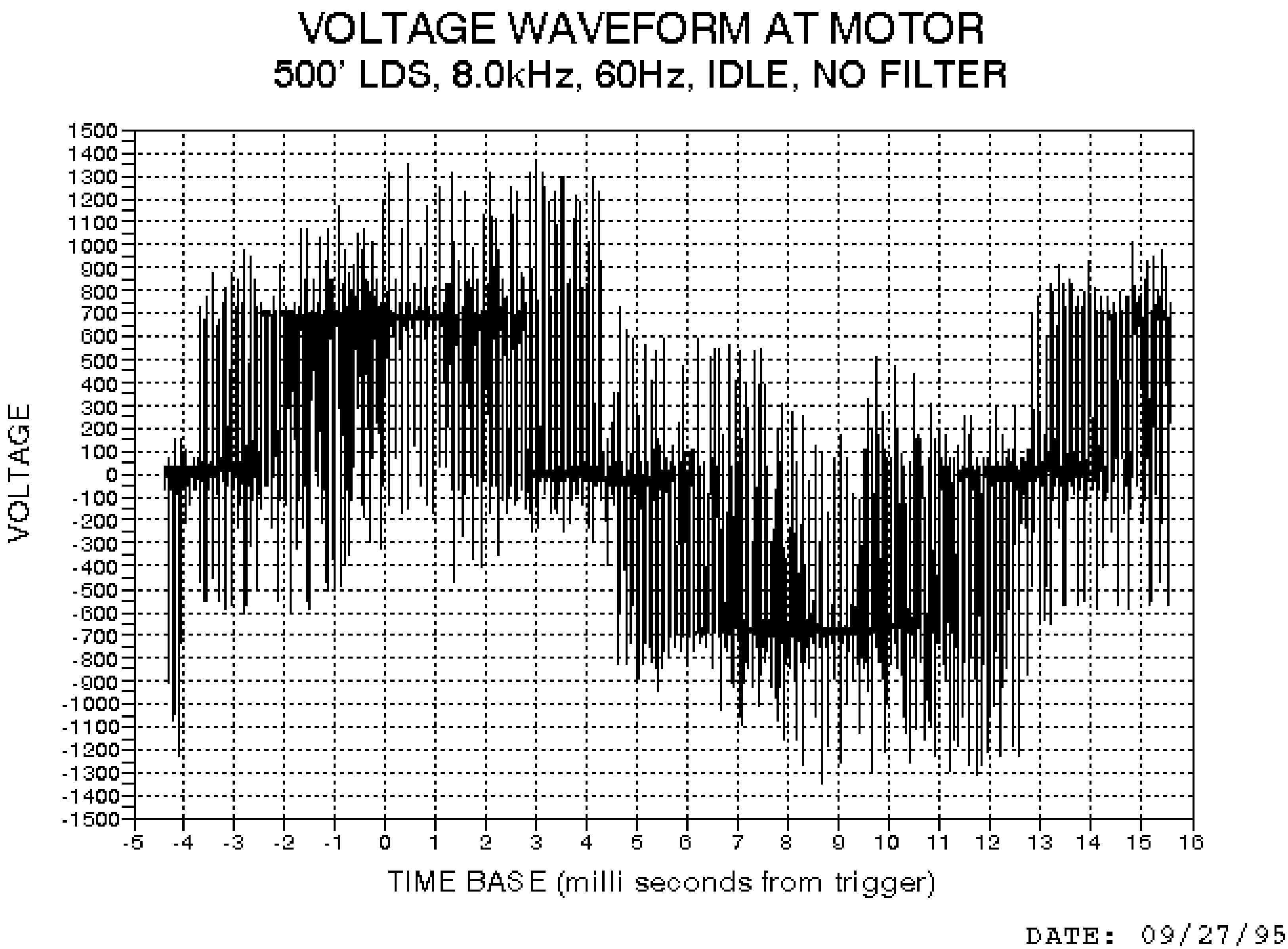




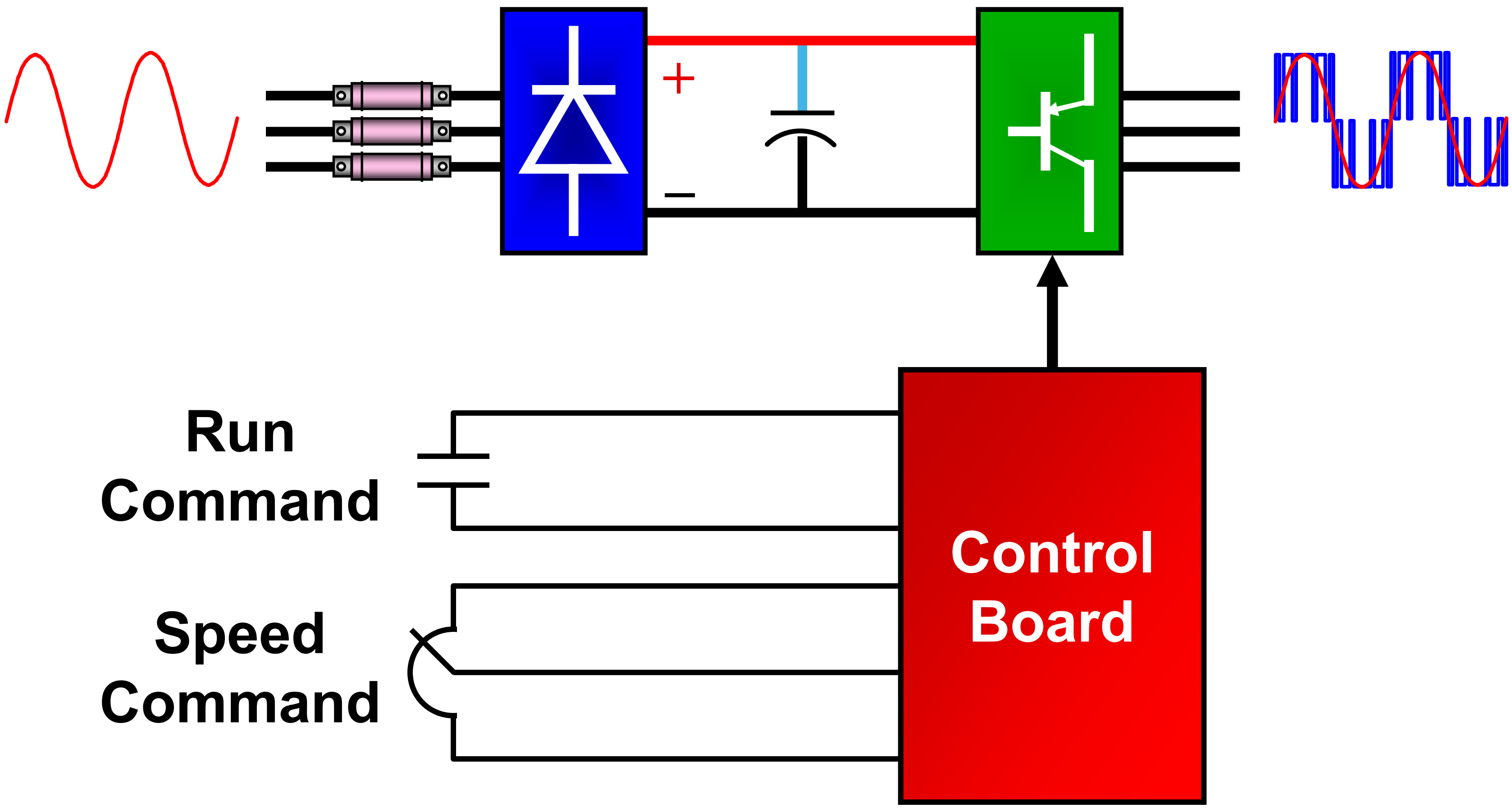
$$\text{Volts/Hertz} = \frac{460V}{60\ Hz} = 7.67$$

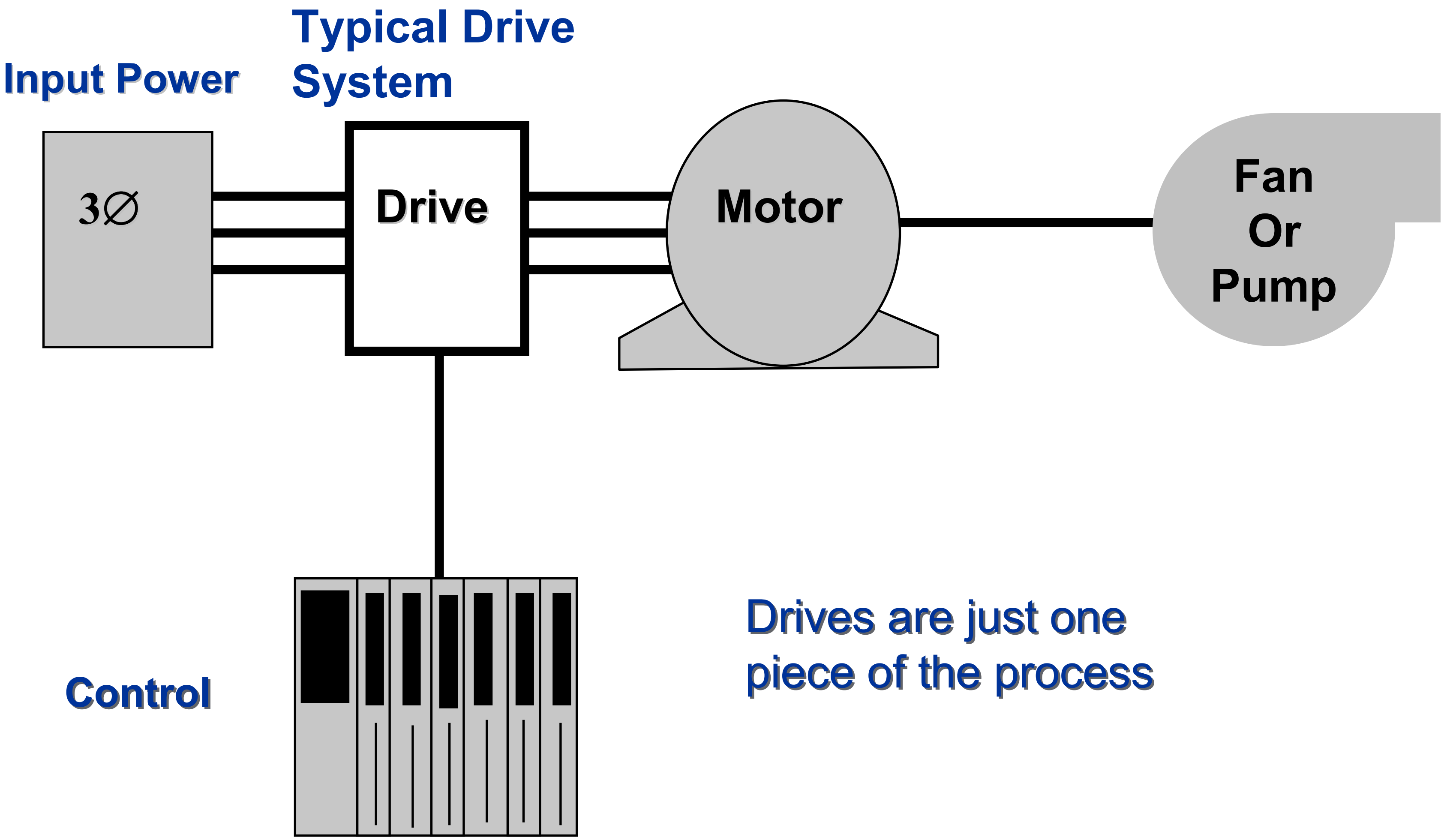
Pulse Width Modulation




VOLTAGE WAVEFORM AT MOTOR
500' LDS, 8.0kHz, 60Hz, IDLE, NO FILTER
VOLTAGE
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
TIME BASE (milli seconds from trigger)
DATE: 09/27/95

Control Signals





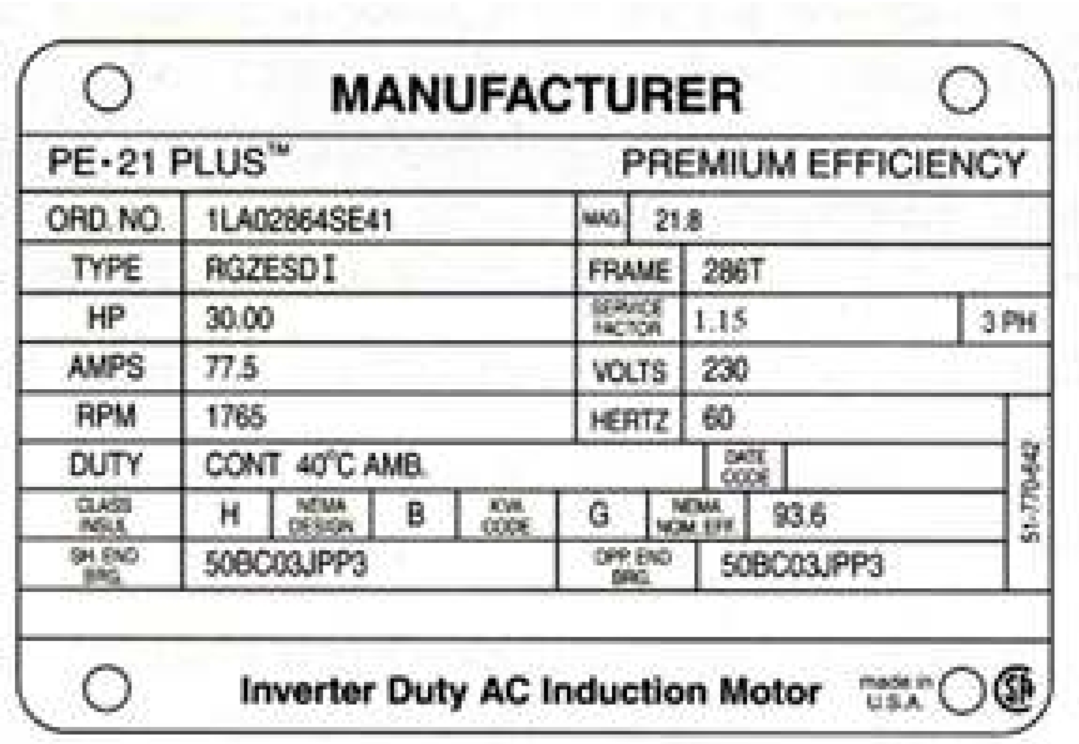
Drives are just one piece of the process

Application Considerations

Power- What kind of Power?

- An important point, to control the speed of a motor it must be a 3 Phase Motor!!!
- Typical VFDs on the low voltage side can control 208V, 230V, 380V, 460V, 575V motors!

Selecting AC Drives



- Size by Motor FLA.
- Voltage, HP and Load Type/Application
- It's also useful to know the motor base speed, service factor, enclosure type, insulation Class of the motor and Nema design.

What type of Enclosure?

- Brand Names
  - Open Panel

    - Sold when others mount in an enclosure
    - OEMs , system integrators, panel builders
    - Sold for wall mounted applications
  - Enclosed

    - Sold to customers needing a “ready to use” solution
    - Sold to customers who value a package designed and assembled by a major company

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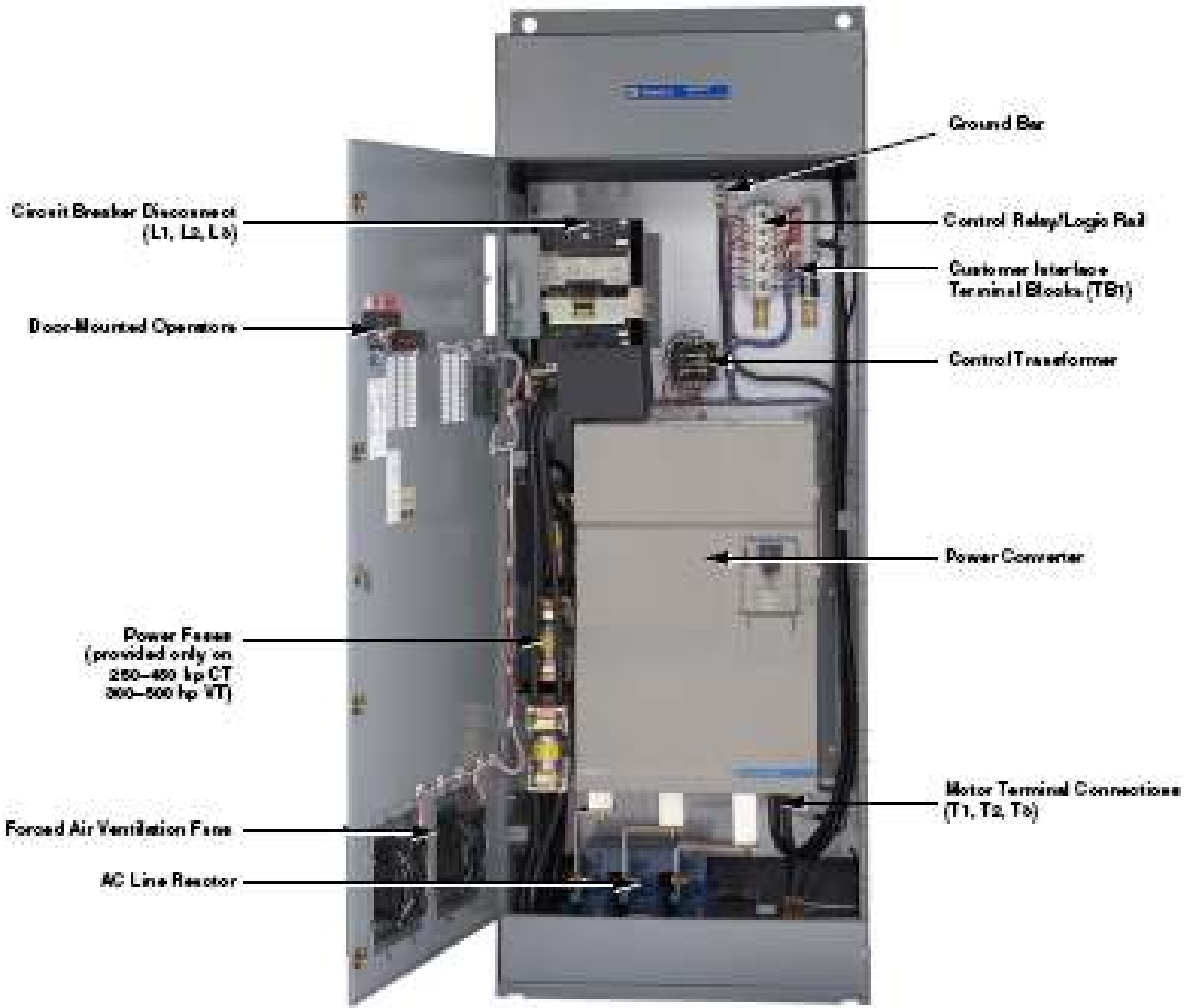
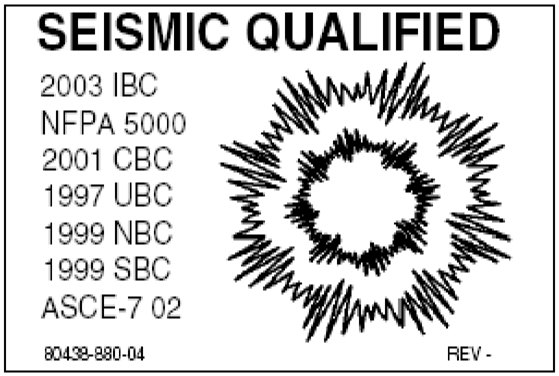
Altivar 61

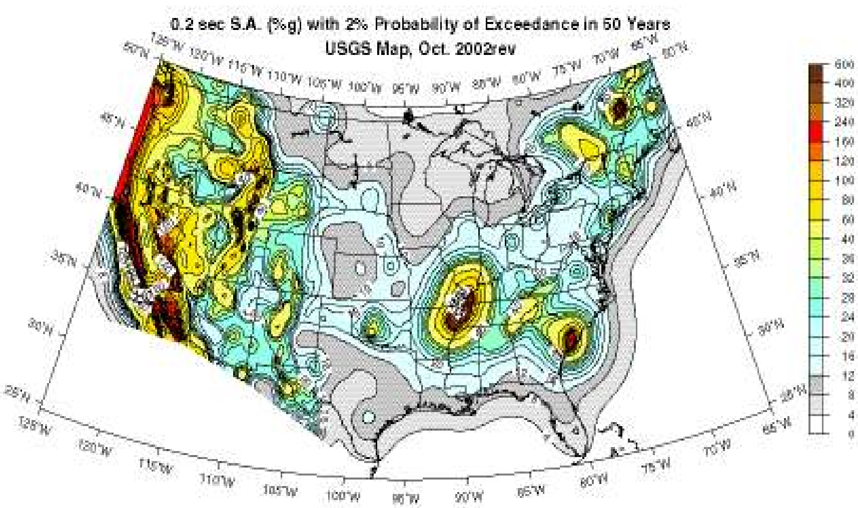
- Type 1 solution for wall mounting
  - Optional conduit kit
    - 460 Vac range
      - 1 to 450 HP
    - 208/230 Vac range
      - 1 to 75 HP
  - Ability to order one part number
    - Add “**T1**” to the end of part number
    - Drive and conduit kit ship together
      - in one box
      - or strapped together

M-Flex VFD (1 to 500hp)



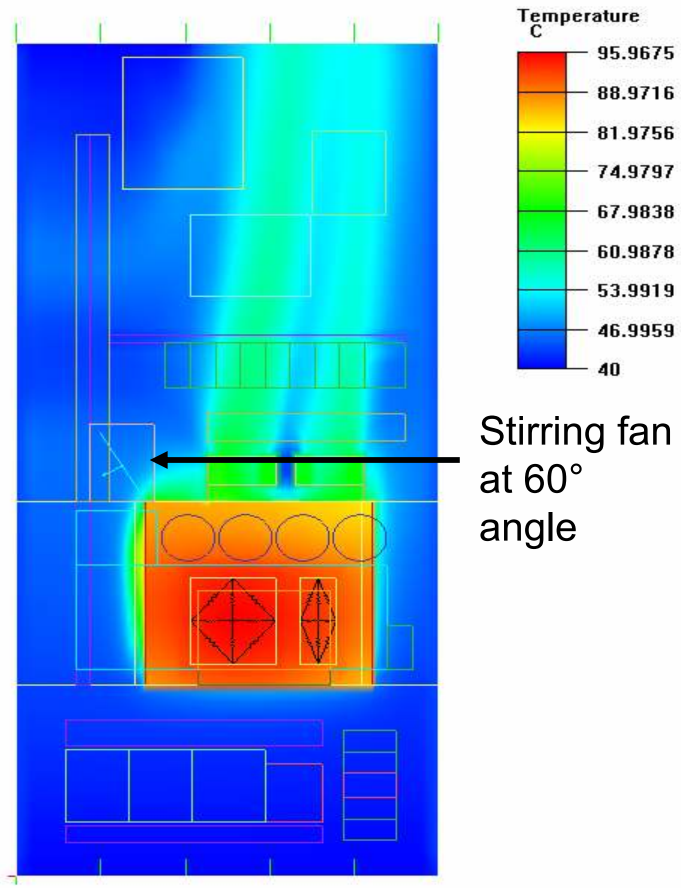
Seismic Qualification





- 1st Drive manufacturer to meet new standards
  - New Seismic Design Categories replace Seismic Zones
- Tested to ICC ES AC156
  - Uniform acceptance test protocol
  - Shaker table tested at Wylie Labs
  - Importance factor of 1.5
    - Operational after event
  - Ss (spectral response acceleration at one second period) > 2.67g

Reliability & Thermal Management



- Thermal modeling
  - 50°C de-rating, high altitude, clogged filters simulations
  - Air flow and direction optimization
- Design Verification
  - Extreme tolerance verification
    - 40°C, 2% AC line voltage unbalance
    - 460 VAC±10% under full load
    - Elevated input currents (low impedance system)
  - Thermal couple measurements for verification

Long Lead Length – Stator Issues

- Special considerations
  - Impedance mismatch between drive/cable and motor
  - Carrier frequency / switching frequency
  - Cable lead length
  - dV/dT – Rise time of IGBT's
  - Voltage spikes
  - Reflected waveform can cause voltage doubling at the motor

Stator Failure

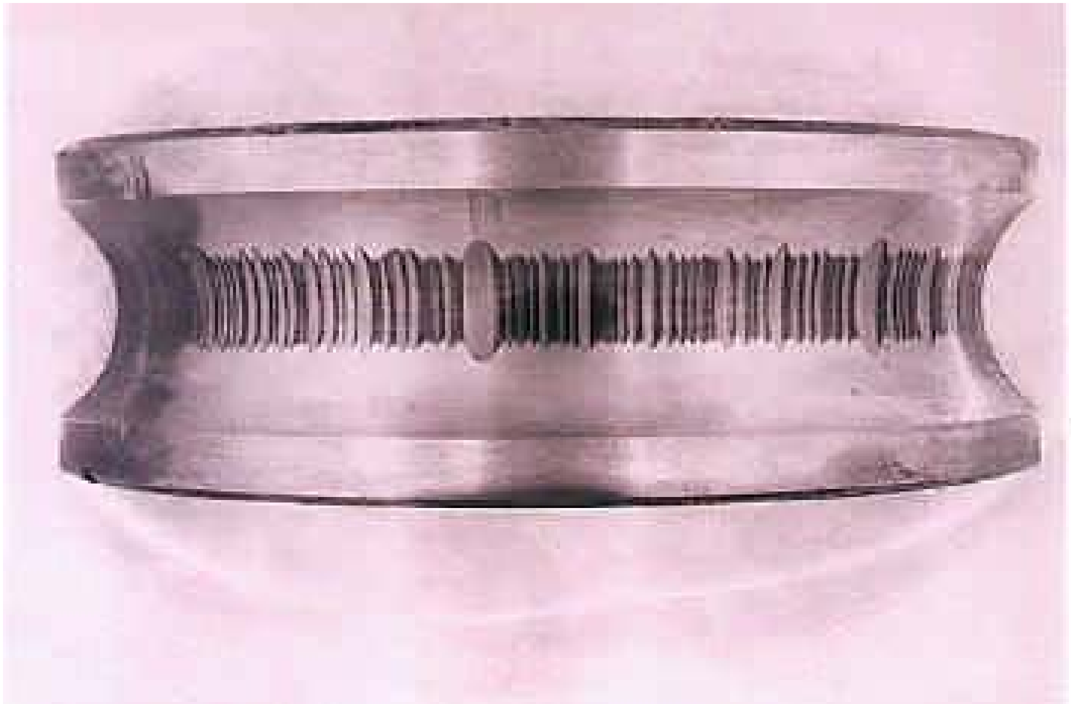
- The Result – Phase to Phase, Coil to Coil and Turn to Turn Failures

➢Insulation Failure

✓Highest voltage stress occurs between the turns in the first one or two coils in a phase group

VFD Design Considerations – Bearings

- Special considerations:
  - Rectifiers switching 3 Output / Unbalanced
  - Fluctuation of Motor V respect to Ground
  - Common Mode Voltage a primary cause of Bearing Current
  - Voltage build-up of 5-30VDC on the shaft is possible
  - Typical flash point is bearings



VFD Design Considerations – Motors

- Bearing Solutions
  - Decrease carrier frequency from drive
  - Insulate bearings / Ground shaft with a brush
  - Common mode filter
  - Specify and purchase NEMA MG1, Part 31 Motors

- Stator Solutions
  - Lower the carrier frequency of the drive
  - Load reactor / Output filters
  - Specify and purchase NEMA MG-1, Part 31 motors
    - Standard NEMA B motors with class F HPE insulation
      - 1.15 Service factor or Better
    - Output Filters where recommended

Consider specifying NEMA MG1, Part 31 motors

Power Factor Correction Capacitors

- Issues
  - Install on line side of VFD
  - Analyze to avoid harmonic frequency resonance conditions
  - Random switching of PF correction capacitors may cause voltage transients on the AC line that could cause nuisance overvoltage control tripping.
- Solution
  - Install a line reactor to reduce the magnitude of the line transients, thus preventing tripping
  - Have PF correction capacitors tuned to avoid harmonic frequency resonance conditions

Questions

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