FLUKE®
Reliability

Impact of Power Quality Events on Motor Driven Systems

Best Practices Webinar Series

Meet the Speaker

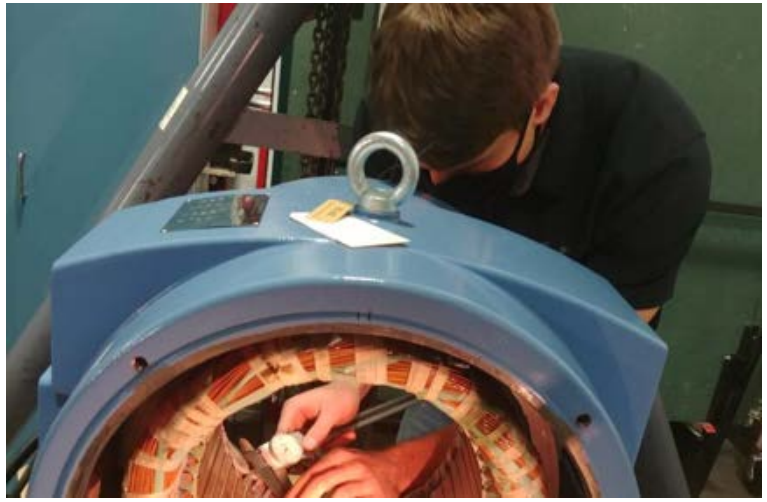
Michael Lyda, P.E.

Electrical Engineer

- Understand electric utility basics
- Identify the most common types of power quality events
- Examine various power quality solutions

About Advanced Energy

- Advanced Energy is a nonprofit energy consulting firm. We work with electric utilities, government and a wide variety of private organizations in the residential, commercial and industrial, renewables, motors and drives, and electric transportation markets. Our customized services include research, testing, training, consulting and program design.



Advanced Energy Vision & Mission

OUR VISION

Advanced Energy's vision is to ensure that energy is clean, affordable, reliable, efficient and safe for all people.

OUR MISSION

Advanced Energy's mission is to provide economic, environmental and societal benefits through innovative and practical approaches to energy issues.

FLUKE® Reliability

Advanced Energy Motors and Drives

- Motor Driven systems account for approximately 50 percent of all electricity generated in the world. Advanced Energy started work in Motors in the late 1980’s and continues work in motors today. In our internationally accredited test lab, we offer independent and unbiased services to governments, original equipment manufacturers, motor and drive manufacturers, utilities, distributors, motor repair facilities and others.

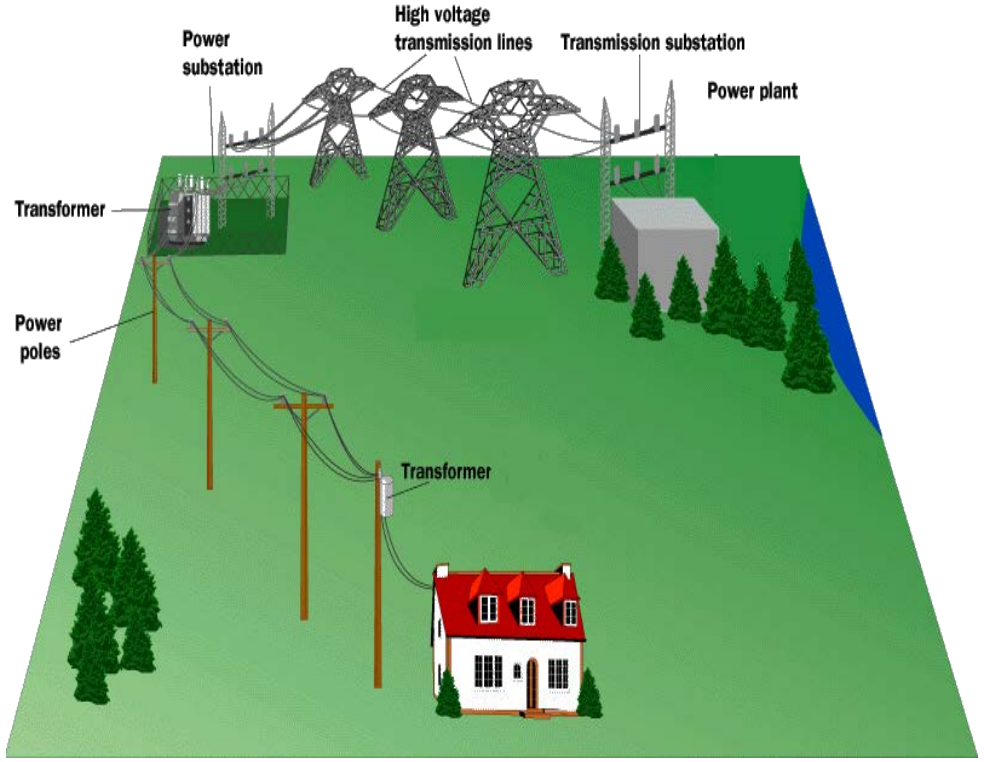
Impact of Power Quality Events on Motor-Driven Systems

- Electric Utility Basics
  - Transmission
  - Distribution
  - Capacitors
- Common Power Quality Events
  - Voltage unbalance
  - Voltage variation
  - Single-phasing
  - Momentary Interruptions
- Power Quality Solutions
  - Machine level
  - Control level
  - Case study

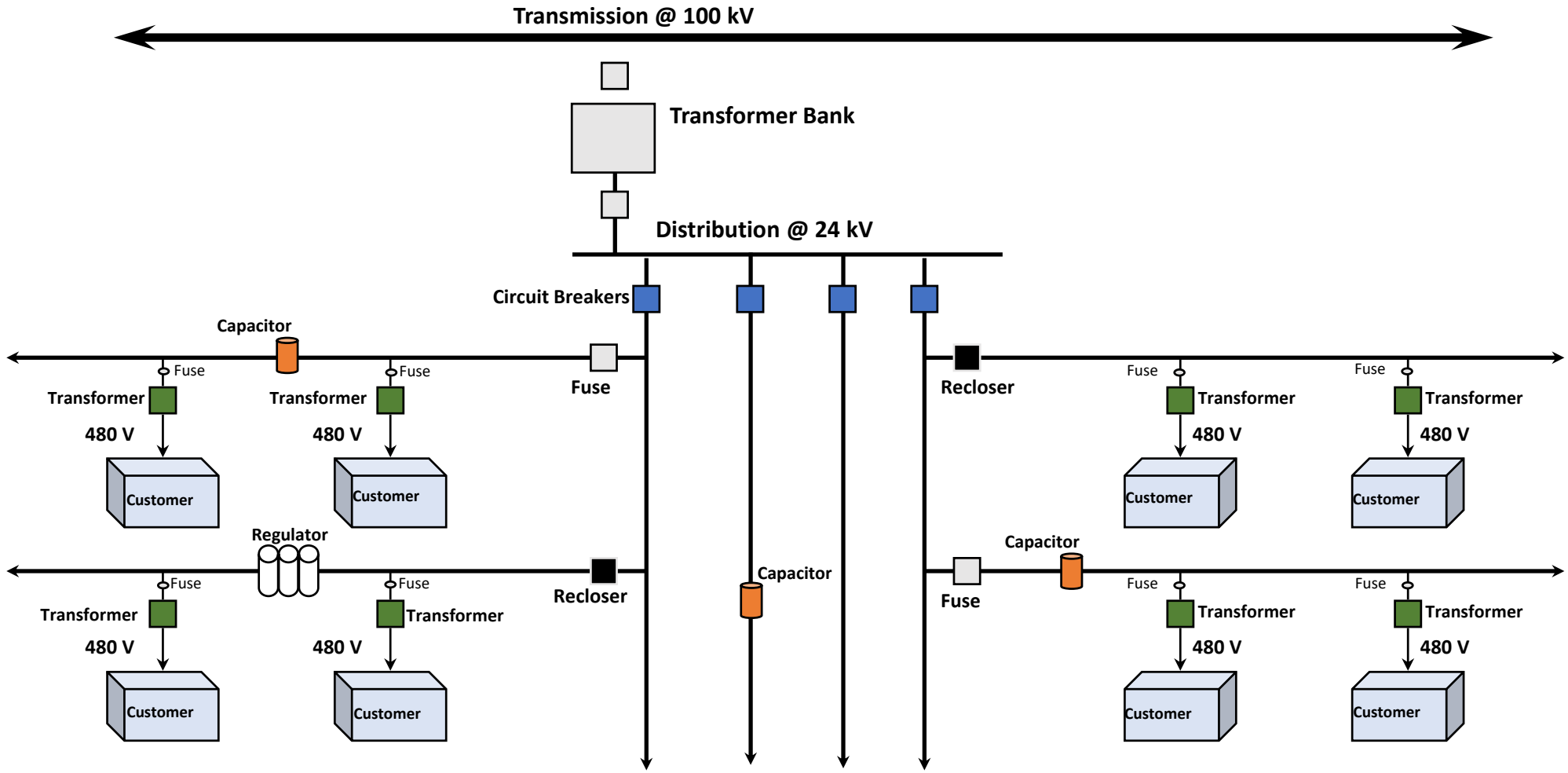
Electric Utility Basics

Electric Utility Basics

- Transmission
  - High voltage electrical lines ranging from 44 kV to 525kV phase-phase
- Distribution
  - Typical Voltages 4kV, 12kV, and 24kV phase–phase
- Circuit/Feeder
  - Circuit emanating from a substation
- Right Of Way (ROW)
  - Corridor for the electrical lines to which electric utility has the right to maintain and use. (easement)



Electric Utility Basics



Electric Utility Basics

Substation Transformer

Substation Circuit Breaker

Electric Utility Basics

Line Recloser

Line Regulator

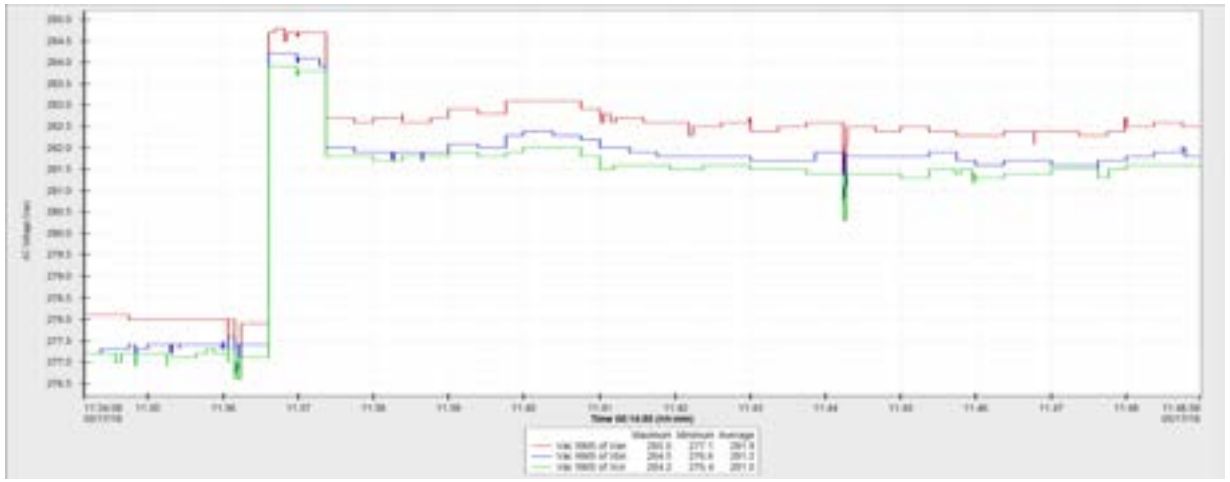
Line Capacitor

Capacitors

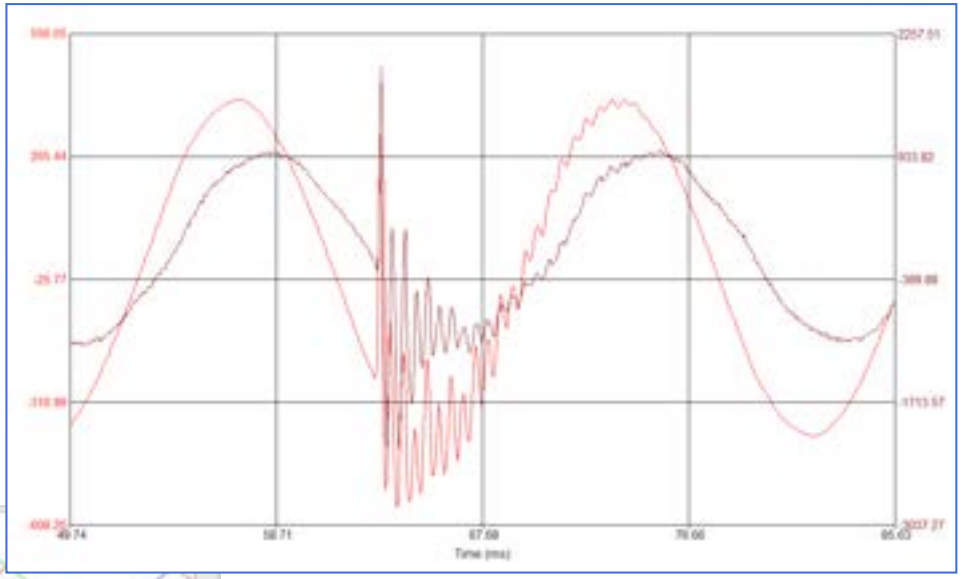
- Use case
  - Power factor correction and voltage support
  - Meet the reactive power requirements of inductive loads such as motors
- Deployment options
  - Transmission Level
  - Substation Level
  - Distribution Level
- Energization can create an oscillatory transient

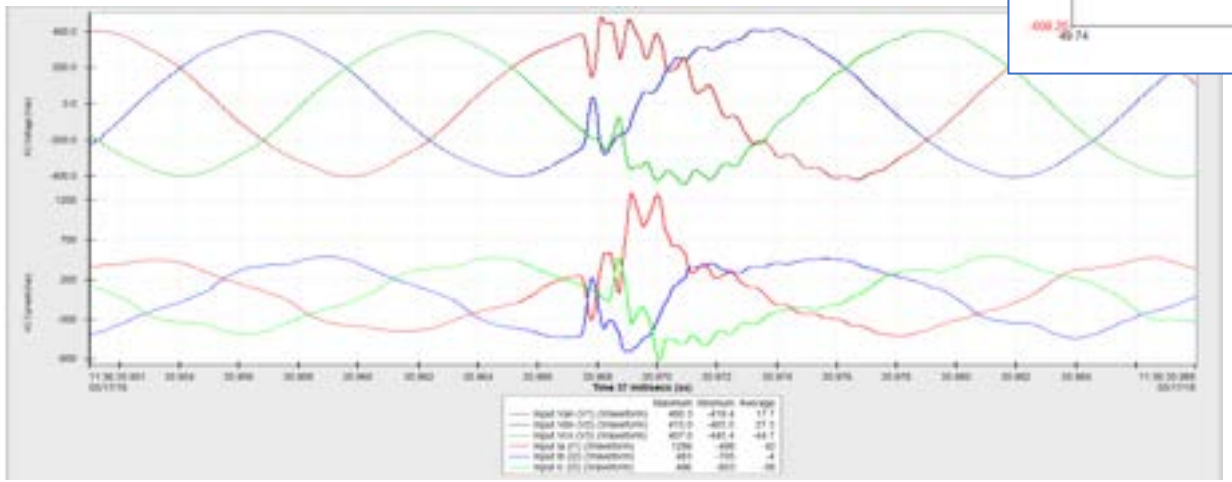
Capacitor Switching Transients

Voltage Support



Major Transient

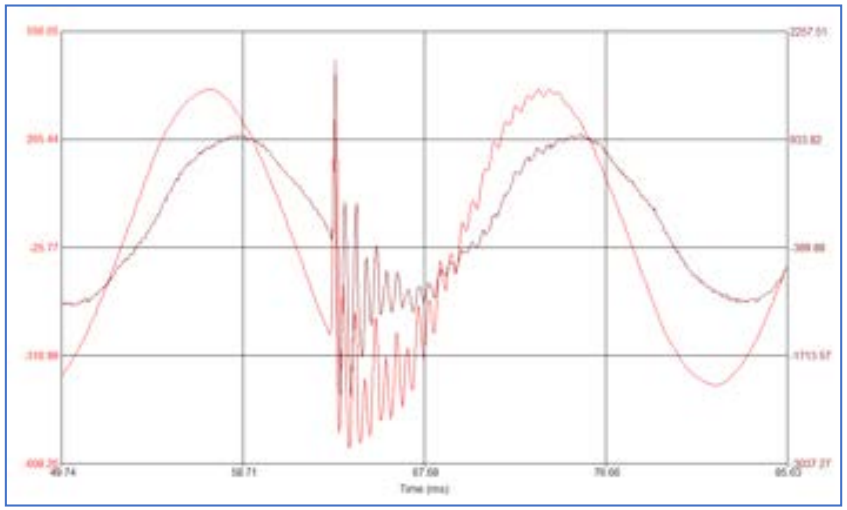


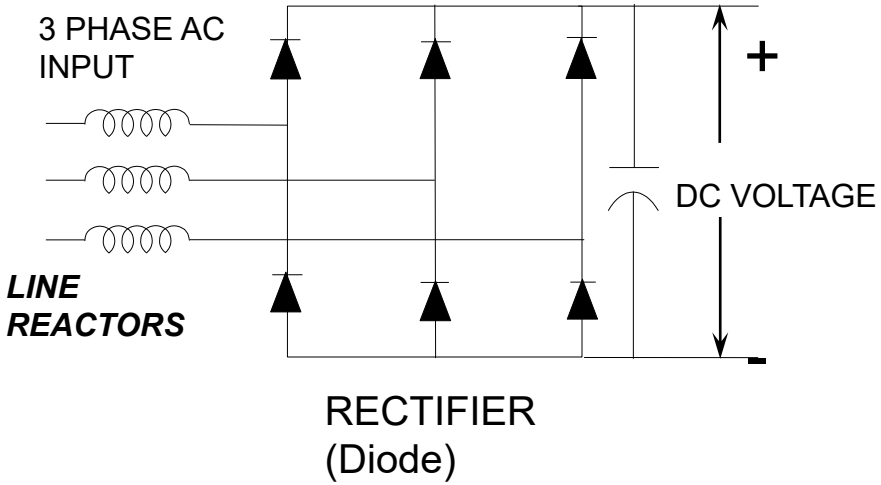


Minor Transient

Capacitor Switching Transients

- Most common issue
  - Drive DC bus overvoltage trip
  - Small drives are more sensitive
  - Larger drives can be impacted by larger transients
- Solution is to use Line Reactors
  - Used to dampen the over voltage transients from capacitor switching





RECTIFIER
(Diode)

Source: Line and Load Reactors Basics – Precision Automation | Specialists in Industrial Automation

Common Power Quality Events

Voltage Unbalance

- What is it? What causes it?
- Equation: ((Maximum deviation from Average) / Average) * 100
- Example: 475V, 460V, 453V {Phase –phase voltages for a 3-phase system}
- Average = (475 + 460 + 453) / 3 = 462.7V
- Solve for Unbalance = ((475 – 462.7) / 462.7) * 100
- Voltage Unbalance = 2.7%

Voltage Unbalance

- NEMA MG1 states - AC motors shall operate successfully under running conditions at rated load when the voltage unbalance at motor terminals does not exceed 1%!

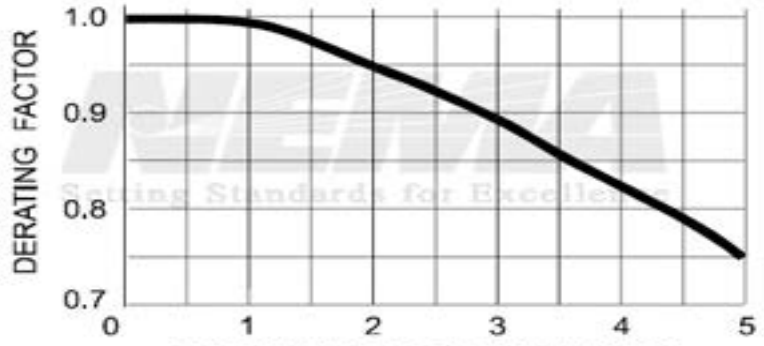


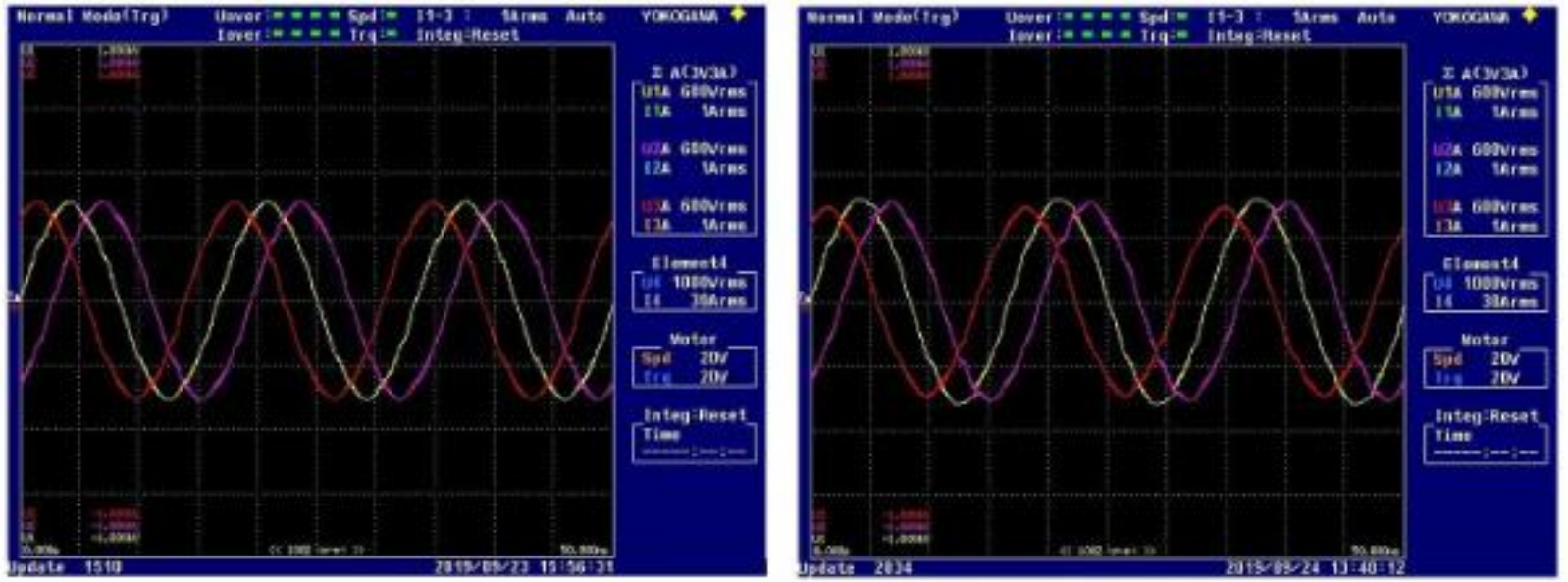
FIGURE 7 [MG1 FIGURE 14-1]

Voltage Unbalance	Horsepower Derating	Heat Rise
2%	5%	8%
3%	10%	18%
4%	18%	32%
5%	25%	50%

$$\%\ \text{Temperature rise in motor windings} = 2 \times (\%\ \text{Voltage Imbalance})^2$$

Voltage Variation

- Under Voltage/Over Voltage
- Reduces motor torque - 10% voltage drop reduces designed torque by about 20%
  - Reduces Efficiency
  - Higher current draw
  - Overheats winding insulation and motor fails prematurely



Voltage Waveform: Balanced vs. 5% Unbalanced

Single-Phasing

- Complete phase loss
  - damaged starter contacts
  - open pole in circuit breaker
  - open cable, damaged connecting lug
  - open connection in motor
  - open winding in motor
- Leads to excessive voltage unbalance
- High current across energized phases
- Motor heats up very quickly

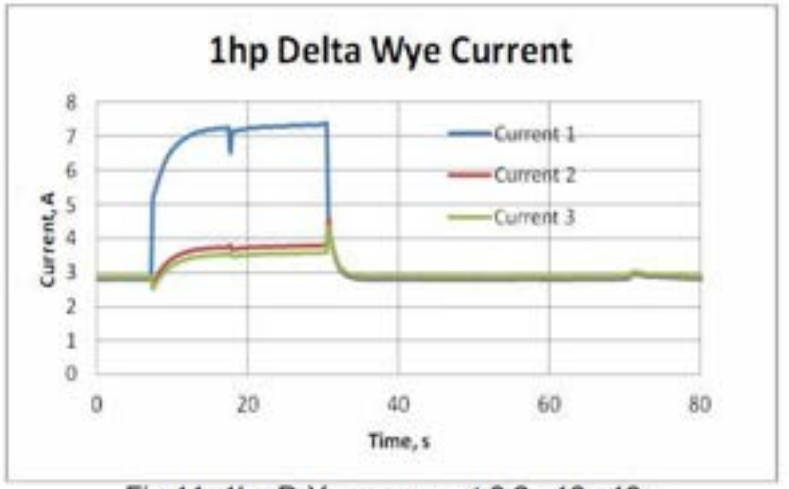


Fig 11: 1hp D-Y rms current 0.2s-10s-13s

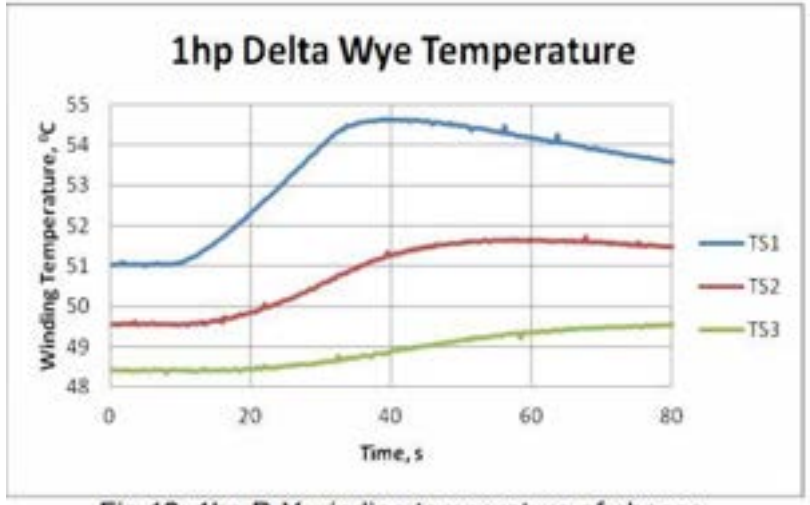
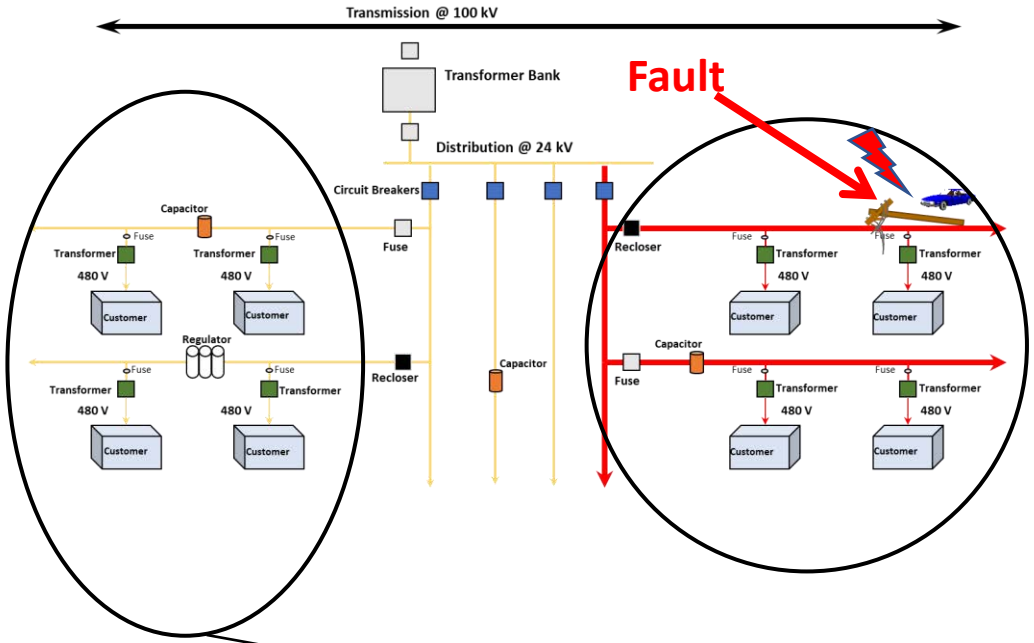


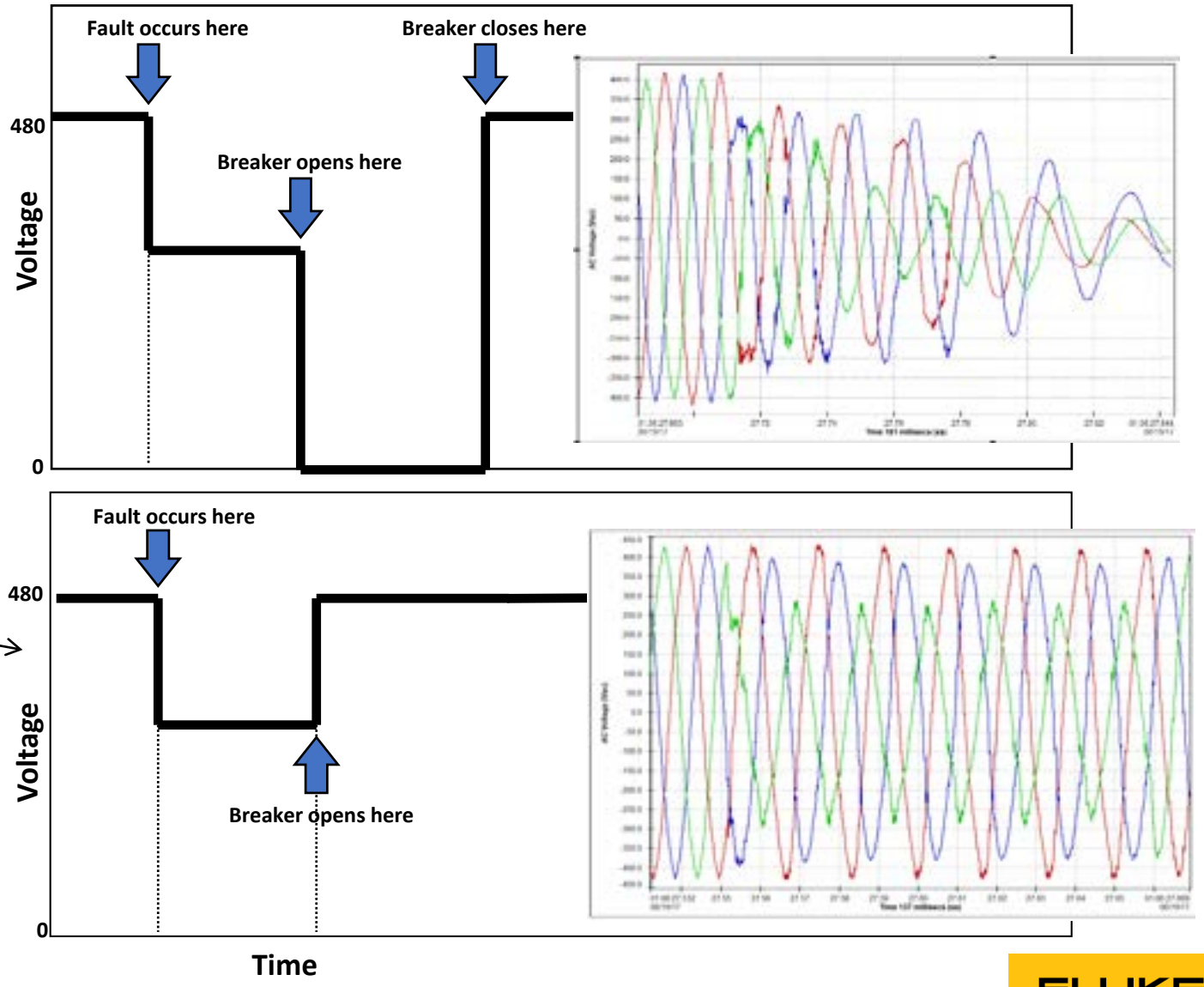
Fig 12: 1hp D-Y winding temperature of phases

Momentary Interruptions

- Momentary Voltage Sag:
  - Drop in voltage by at least 10% and not more than 90%
  - Usually lasting less than 0.2 seconds
- Momentary Voltage Swell:
  - Rise in voltage from 110% to 180% of nominal
  - Usually lasting less than 0.2 seconds
- Momentary Interruption:
  - Drop in voltage by more than 90% of nominal
  - Usually lasting less than 5 seconds
- Outage:
  - Complete loss of voltage for more than one minute

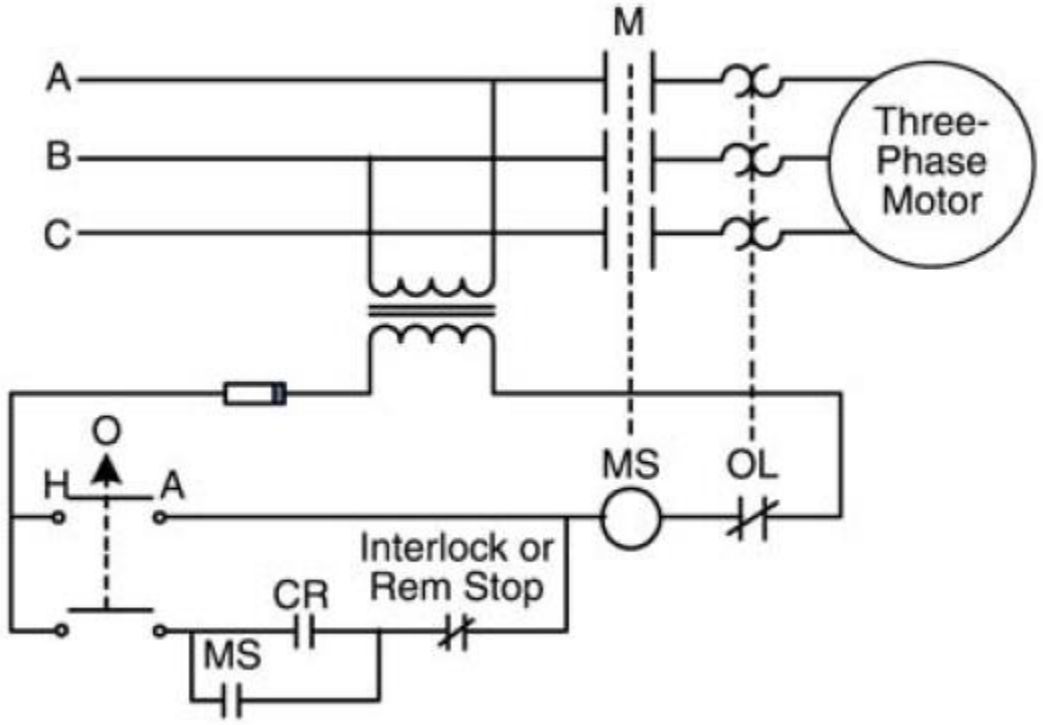
Voltage Sags





Voltage Sags – Effect on Motor Controls

- Motor Starters/Contactors
  - Cause nuisance tripping
  - Even for very minor sags
  - Chattering and additional wear
- Same effects apply to relays
- Can cause contactor and relay failure

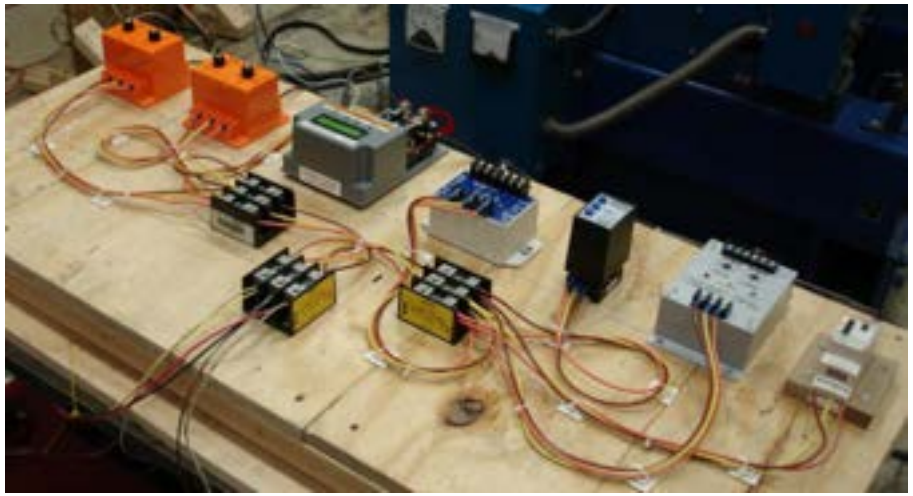


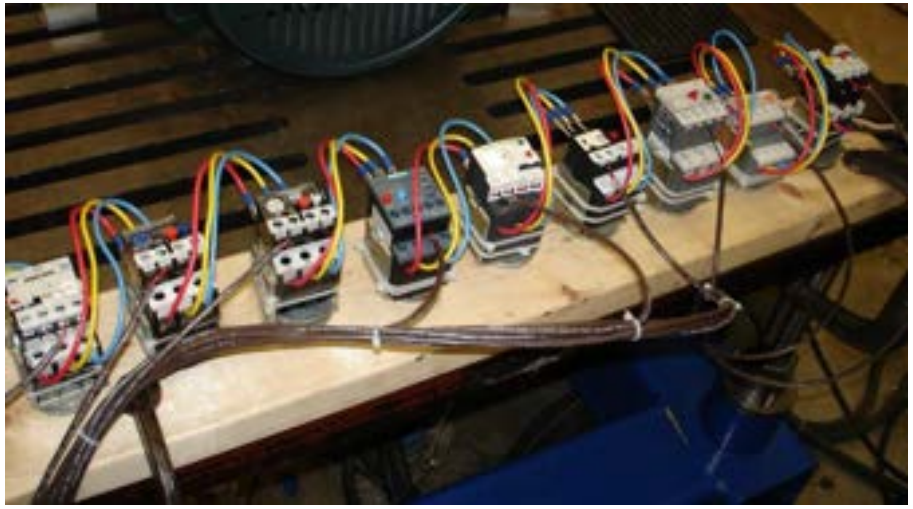
Source: EPRI - Hardening Manufacturing Processes Against Voltage Sags

Power Quality Solutions

Machine Solutions

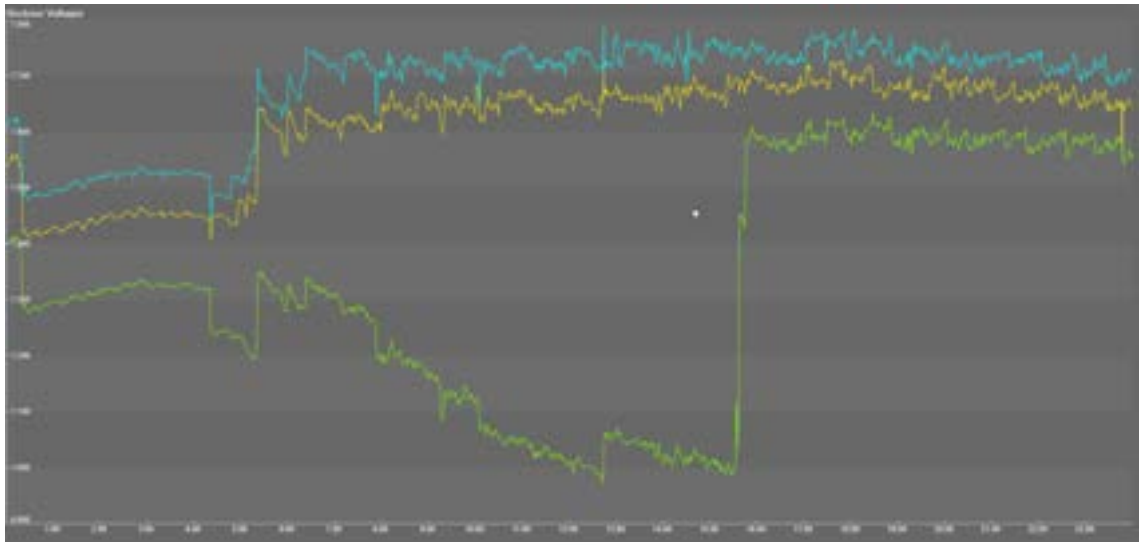
- 3-phase power conditioner
- Phase Monitors
  - Over/undervoltage
  - Voltage unbalance
  - Phase loss
  - Phase reversal
- Thermal overload relay
  - Overcurrent only, with time delay

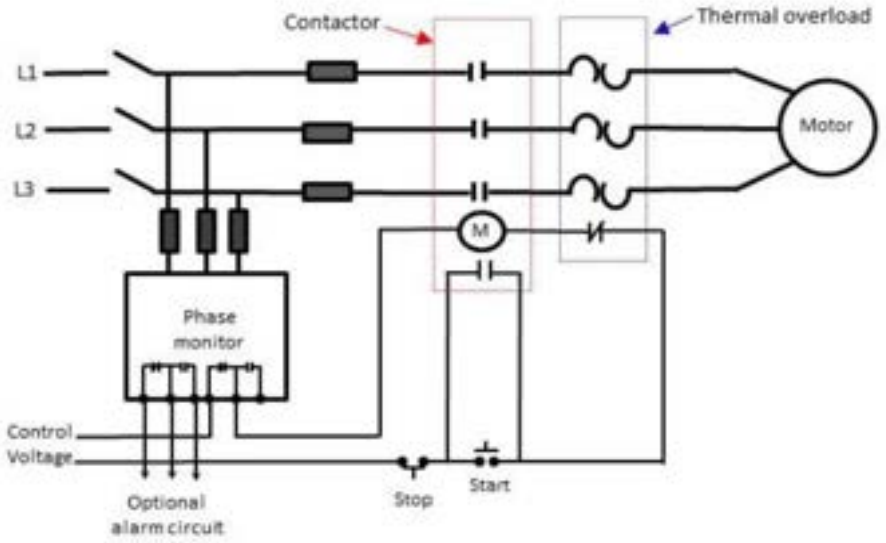




Phase Monitors

- Long duration power quality events
  - Severe Under / Over Voltage
  - Voltage Unbalance >5%
  - Single Phasing
- Best to shut equipment down until problem is resolved
- Voltage phase monitors can shutdown equipment quickly and automatically
  - Proper configuration necessary to prevent nuisance tripping





Source: IEEE - Response of motor thermal overload relays and phase monitors to power quality events

Ride-through assist equipment

- Constant voltage transformer (CVT)
  - Ferroresonant transformer
  - Design for 2.5x nominal Volt-Amperes
  - Can provide 100% nominal output voltage with input as low as 45%
- Uninterruptible power supply (UPS)
  - Battery backup
  - Costly for large sizes
- Switch mode power supply
- Variable frequency drive programming

VFD Programming configuration

- Automatic restart / reset
- Automatic restart time delay
- Flying restart
- Motor voltage compensation
- Acceleration and deceleration times for ramp to stop
- Torque limit setting
- Phase loss and time delay
- DC Bus undervoltage fault settings

Case Study

- PROBLEM
  - Pharmaceutical plant
  - Clean rooms must be kept at positive pressure
  - HVAC supply fans shutting off intermittently
  - Experiencing voltage sags and swells

- SOLUTION
  - Work with VFD manufacturers
  - Program VFDs for ride-through
  - Install small uninterruptible power supply (UPS) at each VFD control power
  - Install large UPS (long-term solution)

Questions

QUESTIONS?

Thank you!

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