

# Challenges and Solutions of Protecting Variable Speed Drive Motors

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# Introduction

- Advantages of variable frequency drives (VFDs)
- Effects of VFDs
- Unique protection requirements of VFD-operated motors
- Arc-flash protection for motor control centers (MCCs)
- Motor control systems

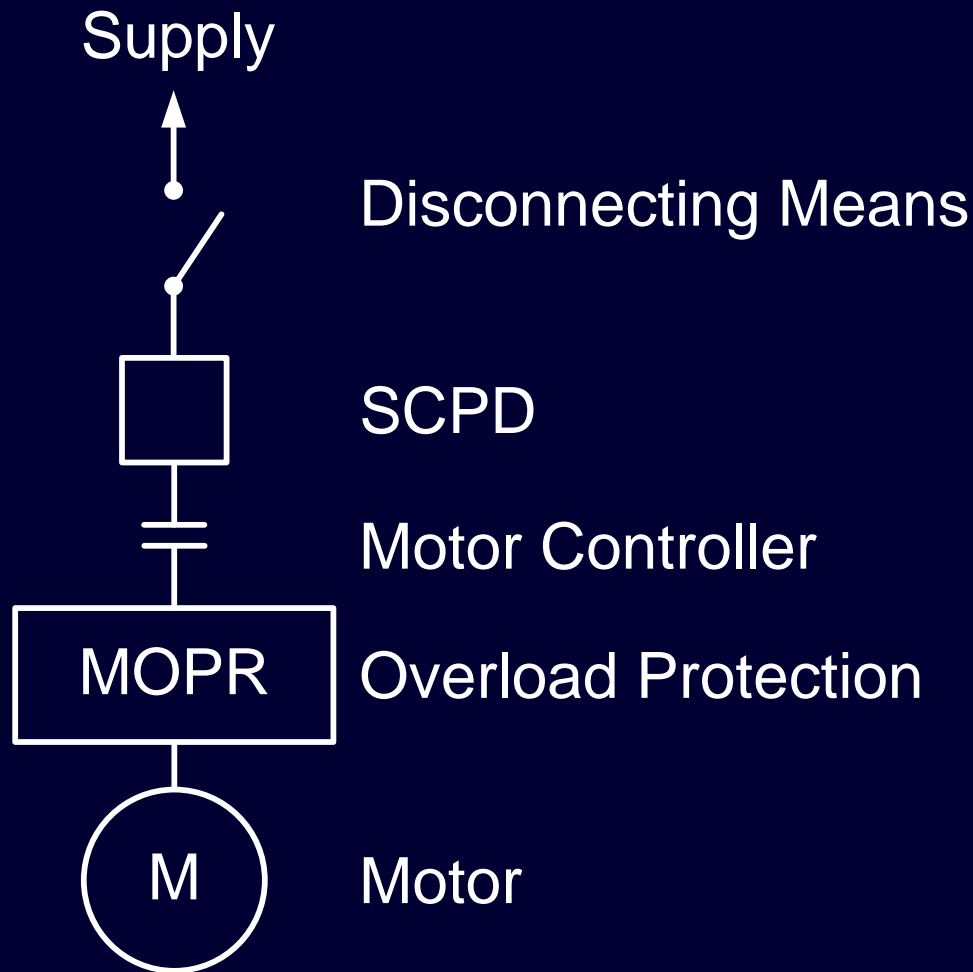
# Advantages of VFDs

- Reduced starting current
- Adjustable speed control
- Improved energy efficiency

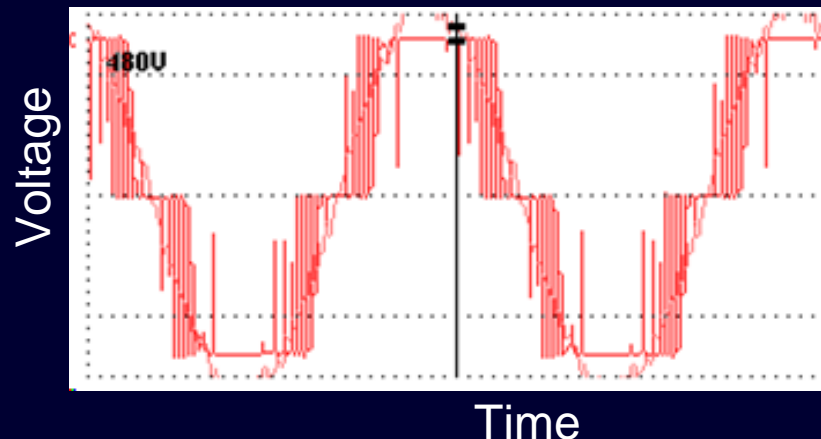
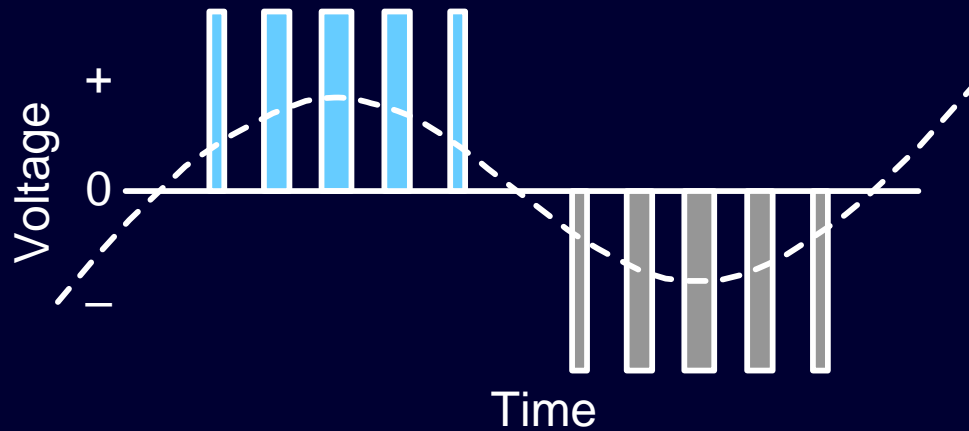
# Effects of VFDs

- Distorted current and voltage waveforms
- Torque derating due to harmonics and reduced cooling
- Reduced cooling effects on overload protection
- Instrument transformer saturation at low frequencies

# Conventional Motor Protection Compliant With NEC Article 430



# Typical Voltage and Current Waveforms for PWM Drive and VFD

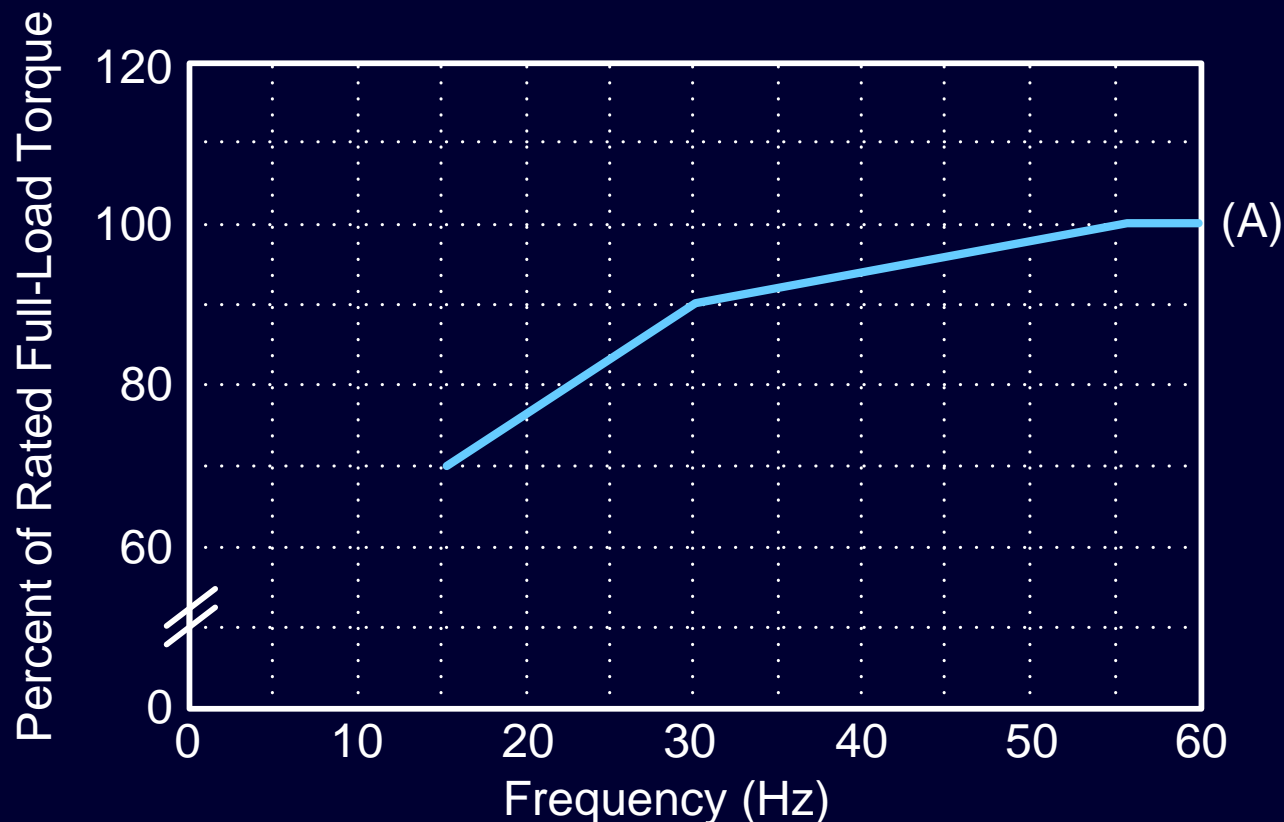


# Effect of Harmonics on Overload Protection

- Typical thermal model uses fundamental components of current
  - ◆ Positive sequence
  - ◆ Negative sequence
  - ◆ Harmonics filtered out
- Thermal model for VFDs uses average of true rms magnitude to account for harmonics

# Effect on Torque for VFD Operation

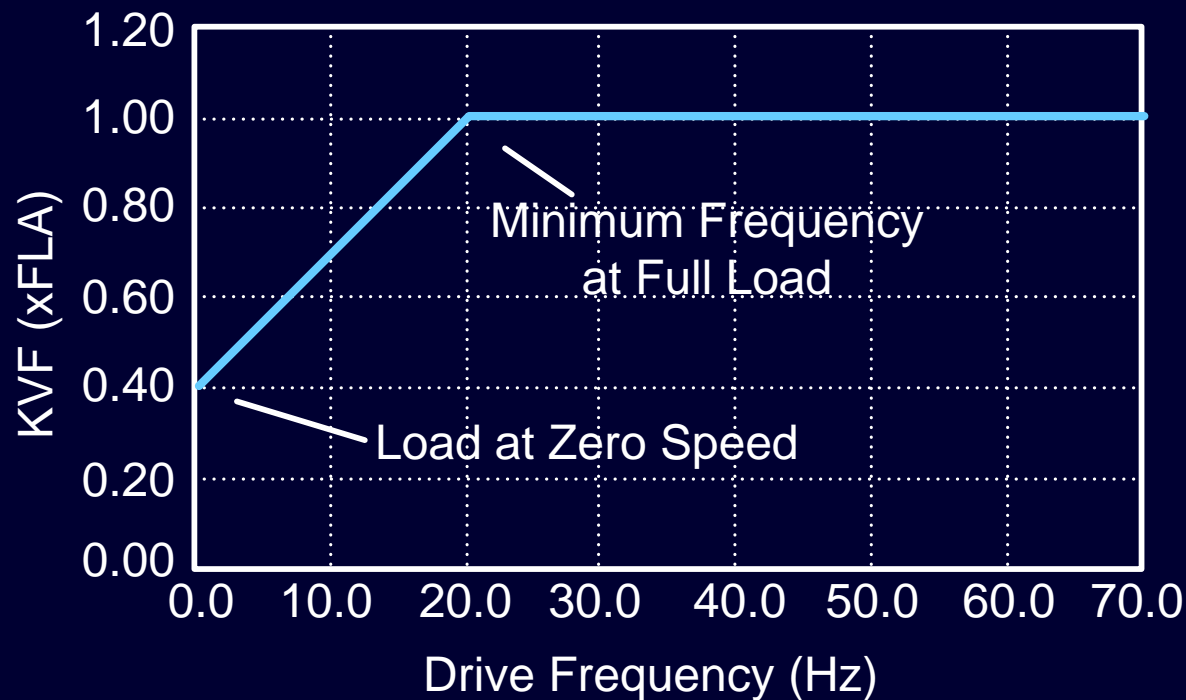
- Torque derating due to harmonics
- Torque derating due to reduced cooling





# Effect of Cooling on Overload Protection for VFD Operation

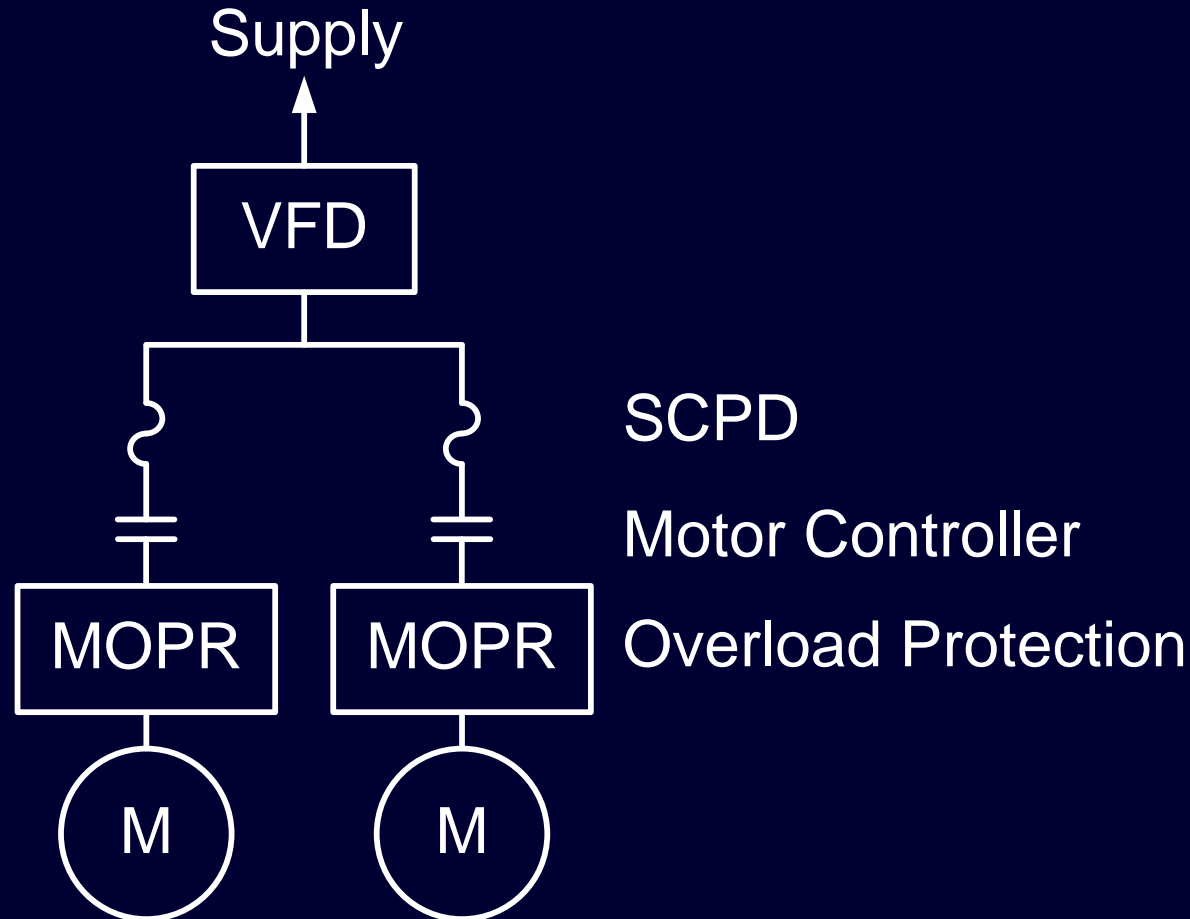
- Low-speed operation means reduced cooling
- KVF multiplier accounts for reduced cooling



# Effect of Low Frequencies on CTs for VFD Operation

- Magnetic CTs – saturation concerns at low-frequency operation
- Rogowski coils
  - ◆ No saturation
  - ◆ Wider range for frequencies and currents

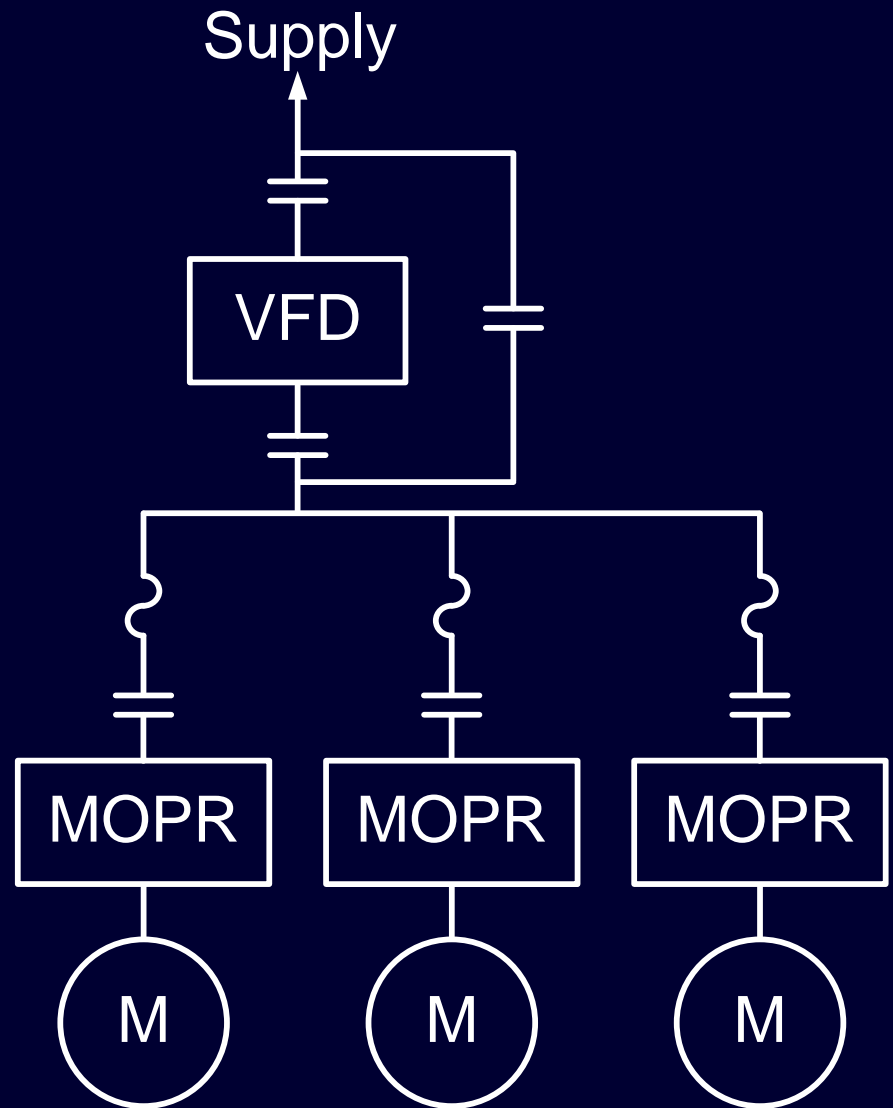
# Multiple Motors Using Single VFD



Each motor needs an SCPD and MOPR

# Major Applications for VFD Bypass

- Isolation for maintenance
- Sharing one VFD for soft start

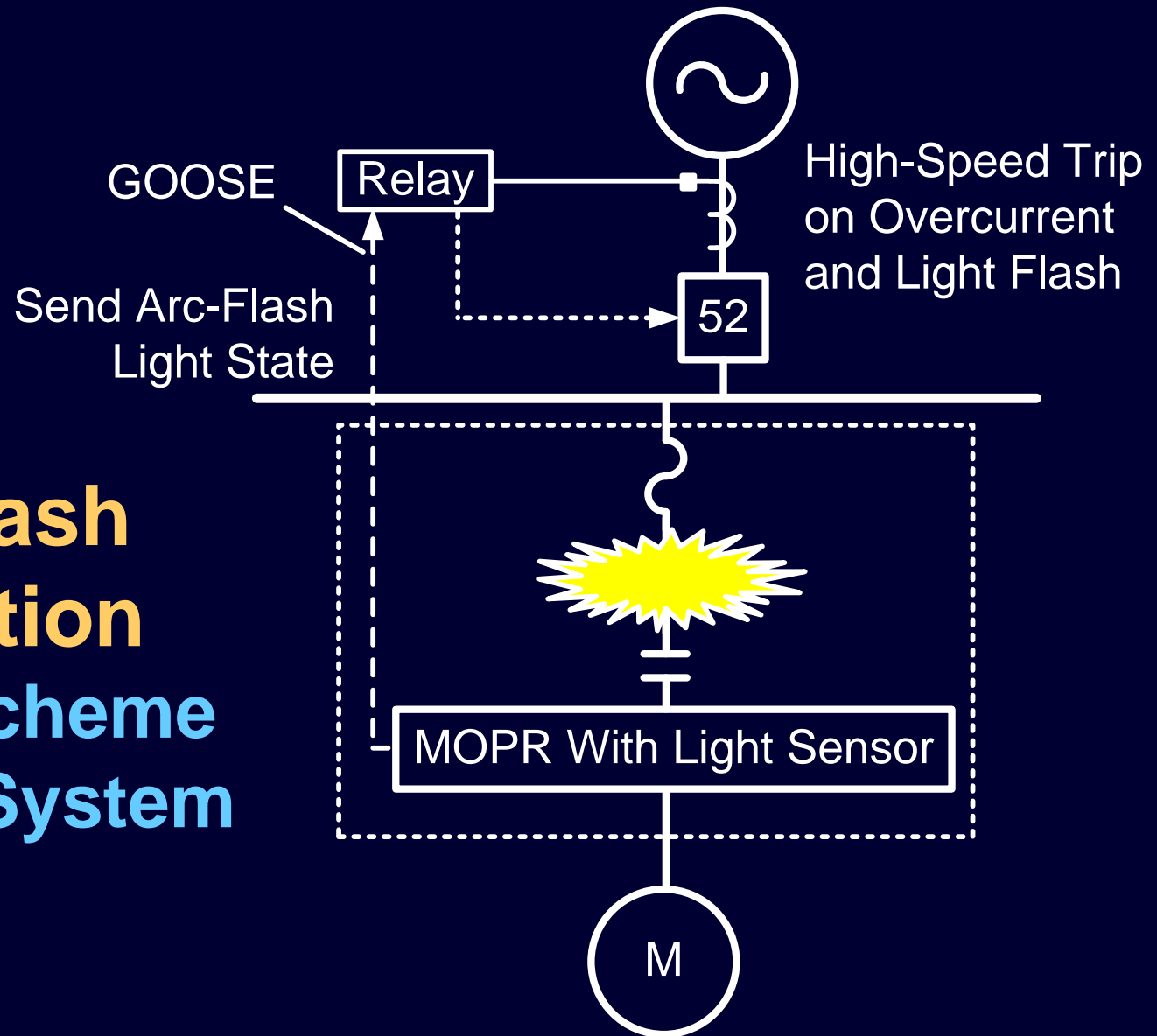


# VFD Bypass Considerations

- VFD and across-the-line operation
- Continuous full-speed operation
- Forward / reverse operation
- MOPR and SCPD for VFD and VFD bypass operations

# Arc-Flash Protection

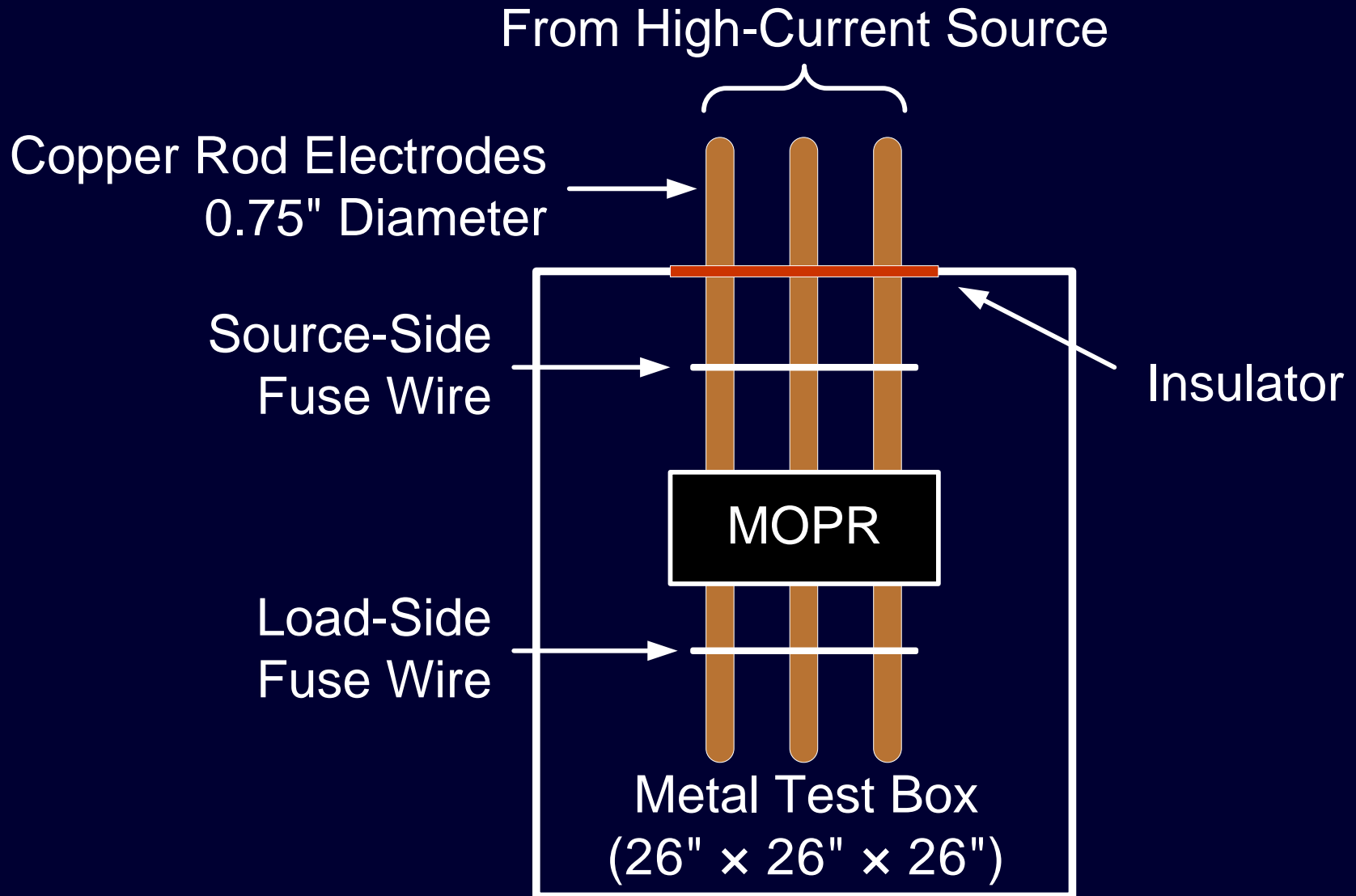
## Typical Scheme for MCC System



# Arc-Flash Trip Times

	<b>Trip Time (ms) From Application of Current</b>
<b>Minimum</b>	4
<b>Maximum</b>	13

# Arc-Flash Test Box

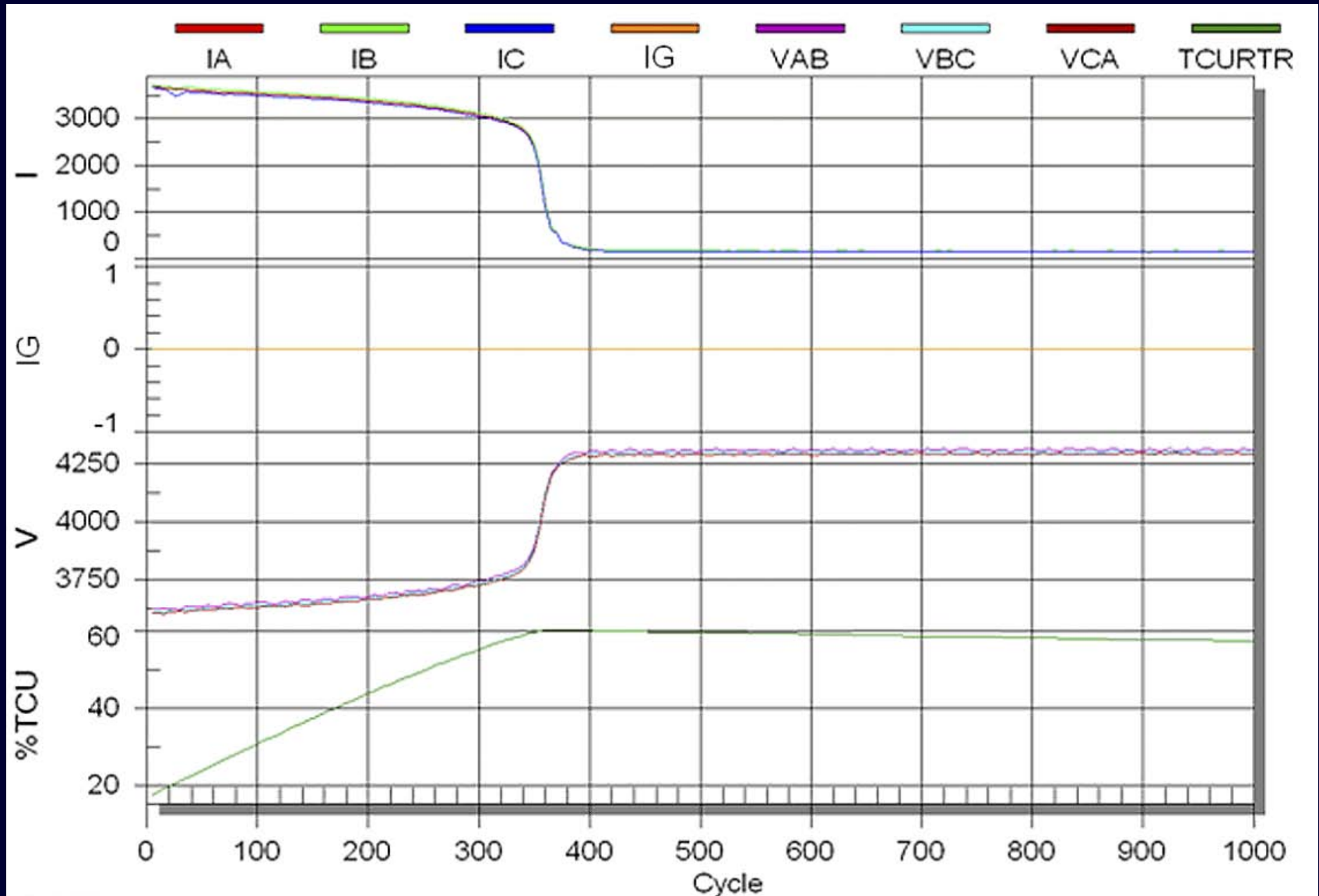




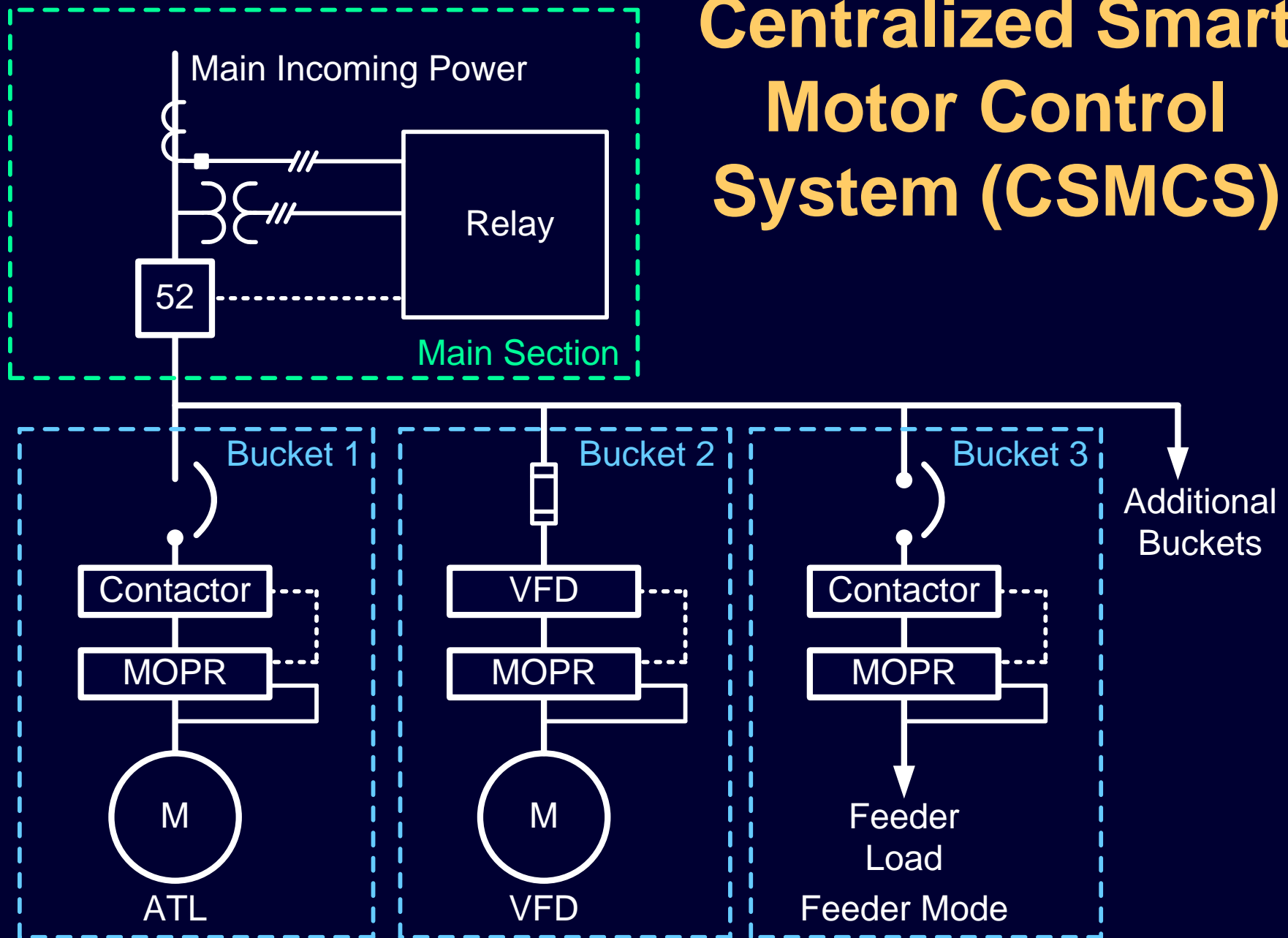
# Commonly Provided Event Reports

- Oscillography
- SOE capture
- THD measurement
- Load profile
- Motor operating statistics
- Motor start

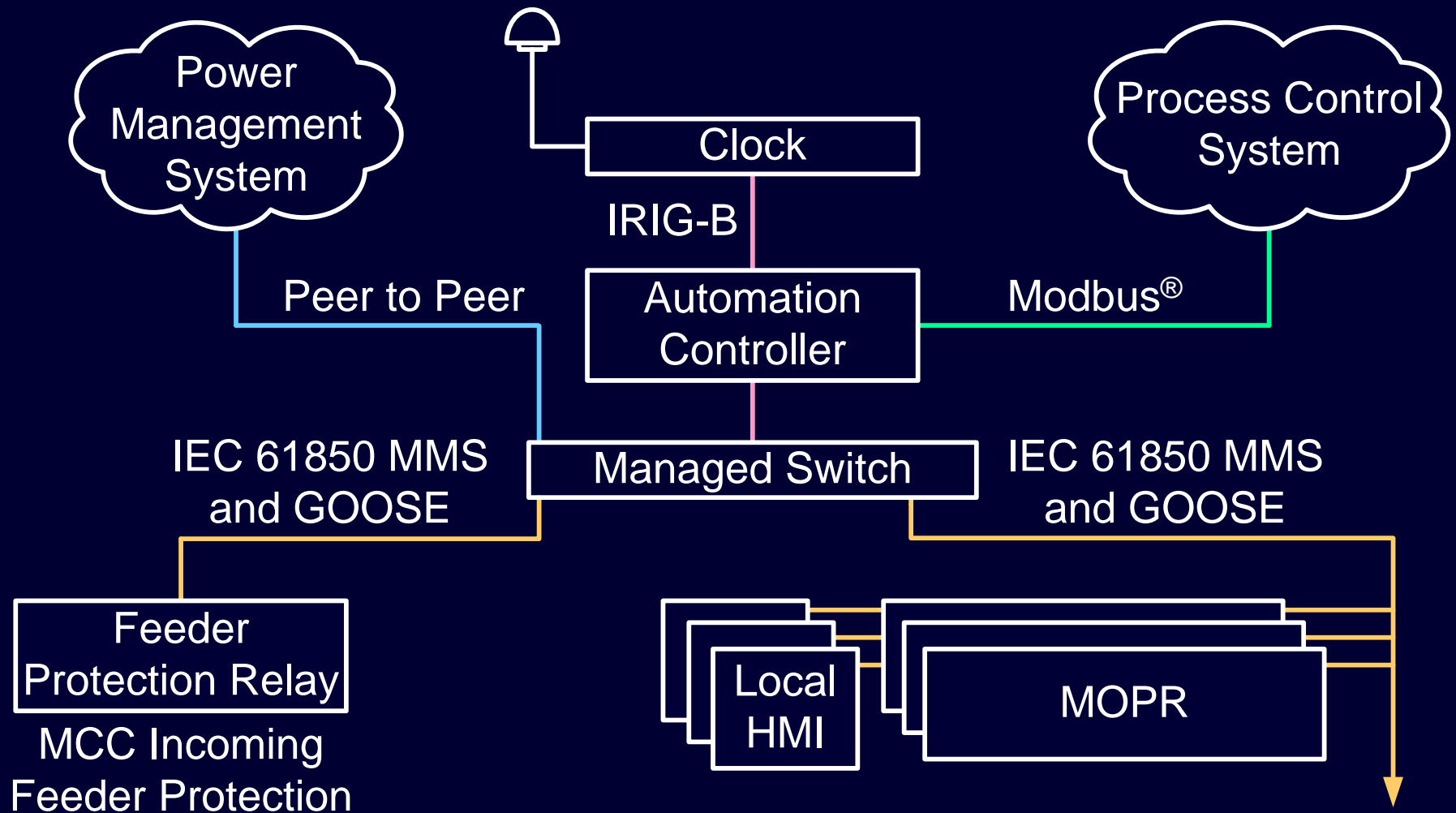
# Motor Start Report



# Centralized Smart Motor Control System (CSMCS)



# CSMCS Communications Diagram



# CSMCS Attributes

- Built-in arc-flash detection (AFD) in MOPR
- Ethernet network
- Feeder protection
- Control and monitoring
- Bidirectional communication

# CSMCS Attributes

- HMI
- Remote power management system monitoring
- Remote trip mechanism
- Centralized event diagnostics

# Conclusion

- RMS-based thermal model for overload protection
- Compensation for reduced cooling at low-speed operation
- Built-in AFD for reduced arc-flash incident energy
- Protection, control, and monitoring management with CSMCS

# Questions?

