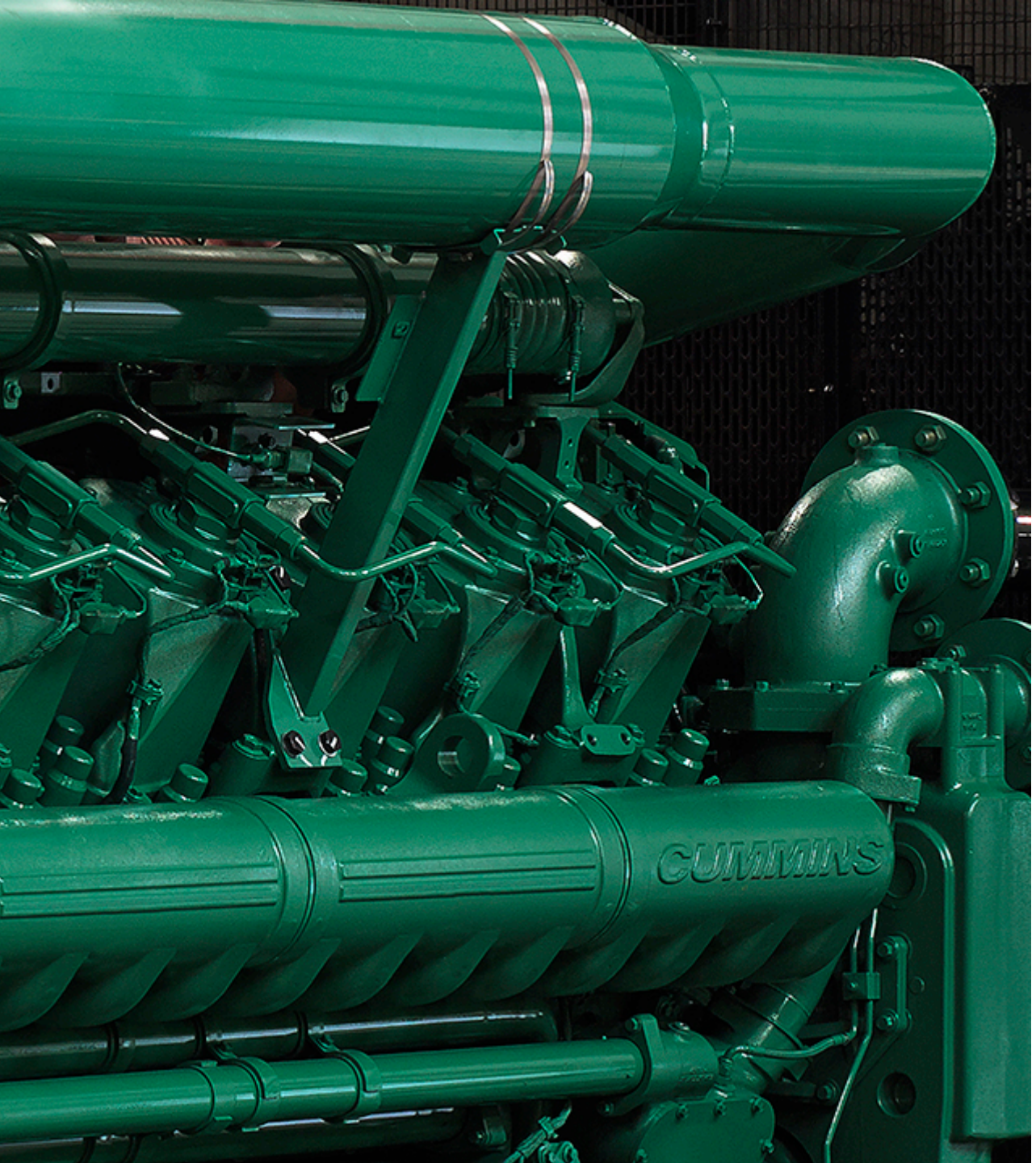

Functions and Features of Generator Set Control Based Paralleling

PowerHour webinar series for consulting engineers

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January 22nd, 2019 11:00 PDT / 13:00 CDT

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Course Objectives

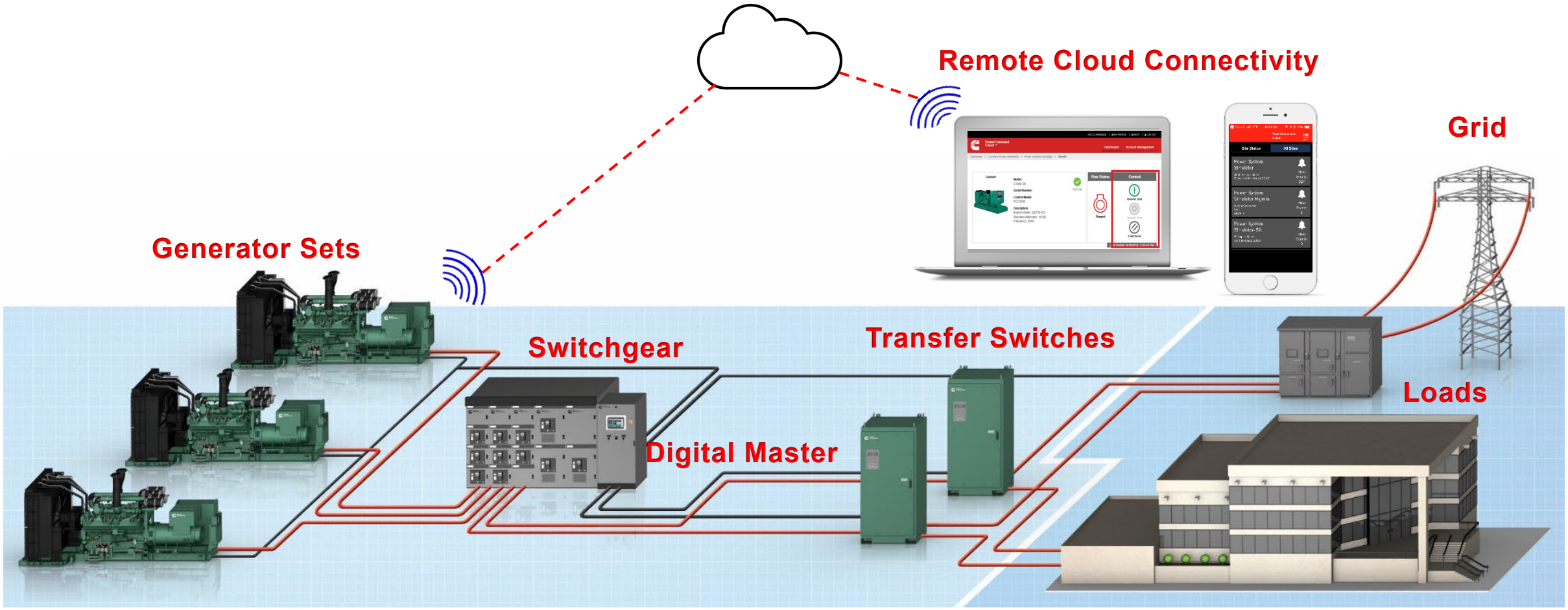
Functions and Features of Generator Set Control Based Paralleling

This course provides a comprehensive overview of a typical paralleling emergency power system and dives into the fundamental key features needed to parallel generator sets. Throughout this course, the instructor will review critical control functionality for paralleling systems and will compare distributed logic architecture with traditional switchgear paralleling. System reliability will be explored while the instructor reviews the ability of paralleling and control strategies employed to eliminate potential single points of failure.

After completing this course, participants will be able to:

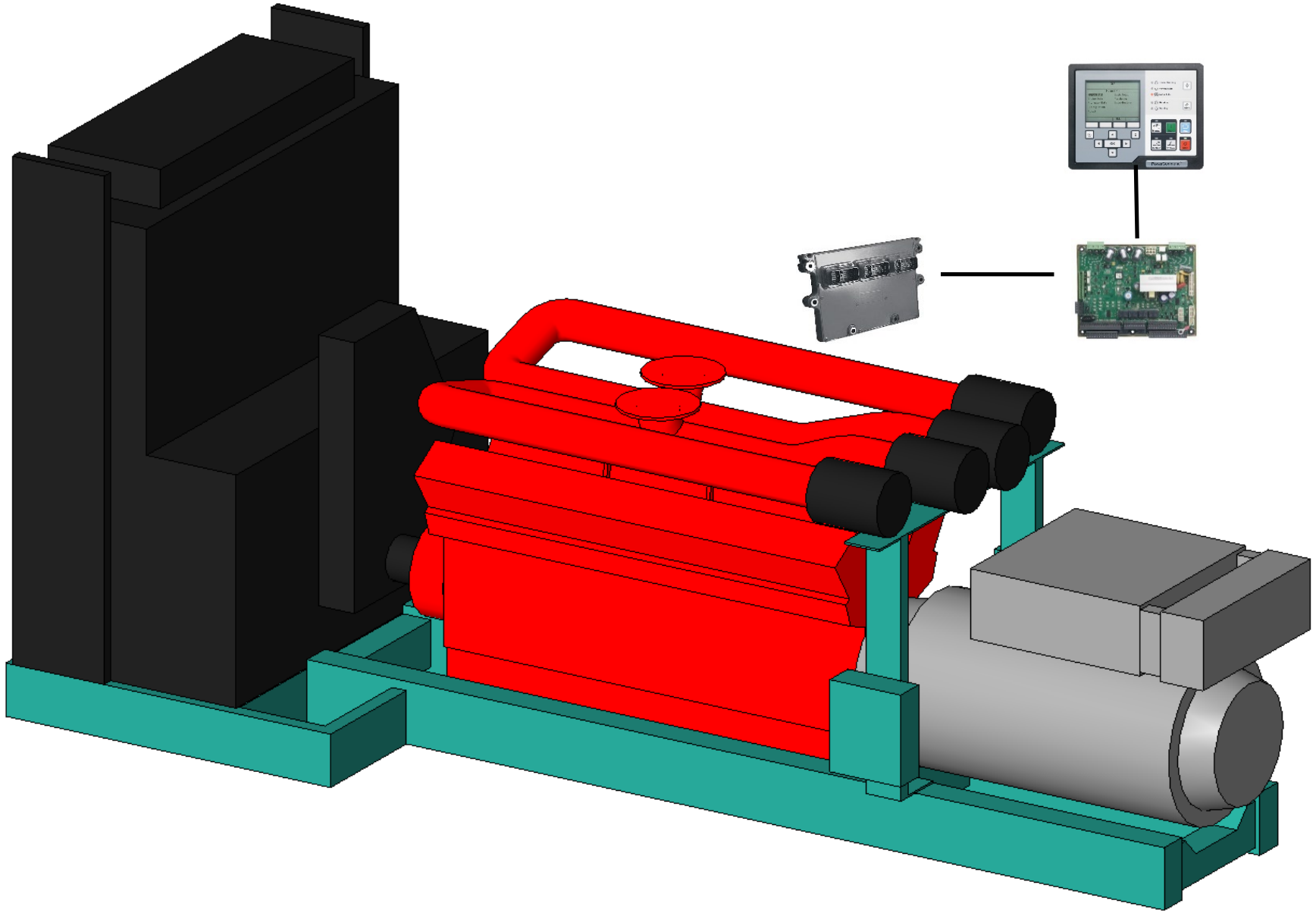
- Identify the advantages of paralleling as they relate to overall system reliability, performance and flexibility.
- Recognize basic generator set paralleling control components, functions and features.
- Describe common strategies employed by paralleling systems using distributed logic architecture.
- Discuss the benefits of distributed logic architecture as it relates to paralleling, system reliability and its ability to eliminate a single point of failure.

Power System Building Blocks



Generator Set

- Skid
- Engine
- Alternator
- Cooling
- Control



What is Paralleling?

- Synchronous operation of two or more generator sets connected together on a bus in order to provide power to loads

$$f(Hz) = \frac{nP}{120}$$
$$n: rpm, P: Poles$$

Generator Sets

Point of Power Connection:
Switchgear, Collector Bus,…

Transfer Switches

Emergency

Legally Required

Optional

NEC2017-700.10 (B) (5)

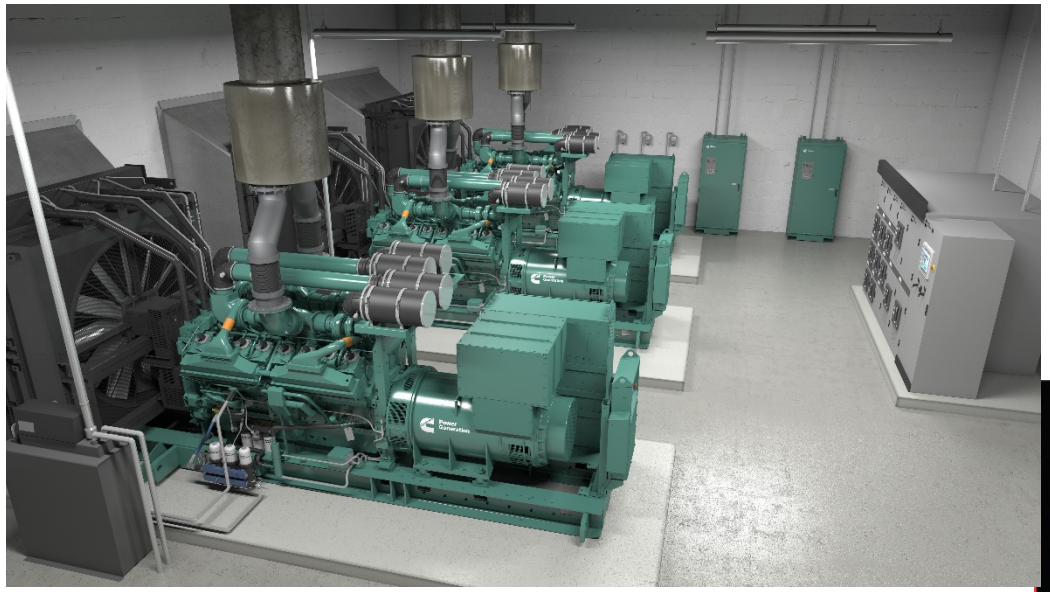
Why Parallel?

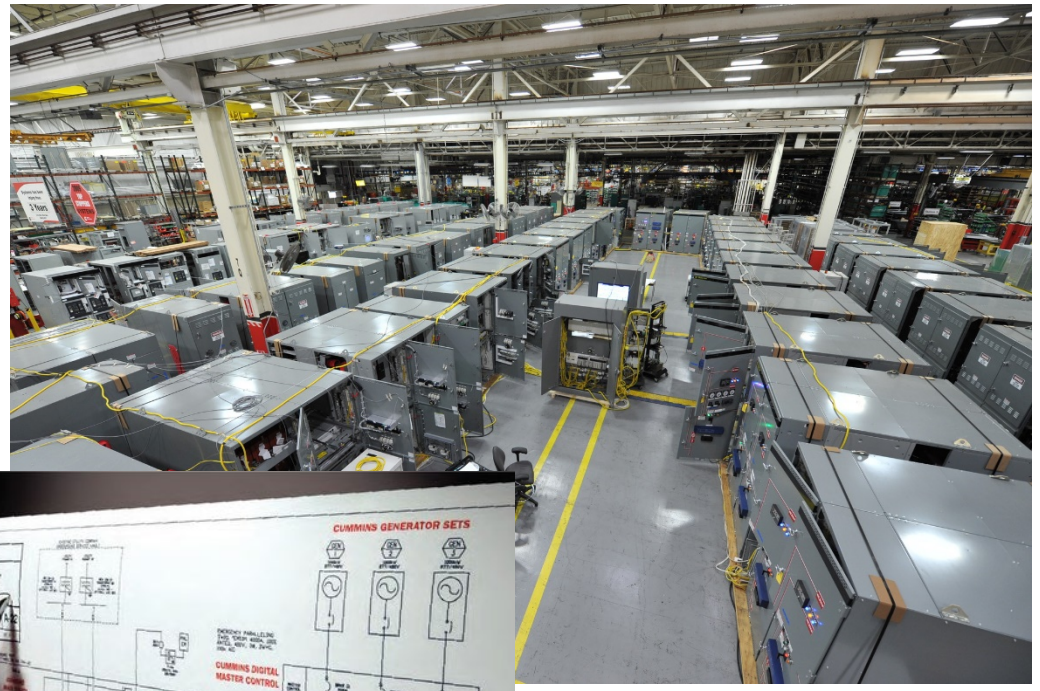
- Reliability
  - Not dependent on a single generator. If one generator fails, there are other generators to power the load
- Performance
  - A large generator bus capacity will act more like a utility. There will be less frequency and voltage variations during load steps
- Redundancy
  - Creating an N+1 or N+2 configuration is easier in paralleling designs
- Scalability/Expandability
  - Easy to add generators to a paralleling architecture as power demand increases
- Serviceability
  - A single generator can be serviced while the remaining generators are available to provide power

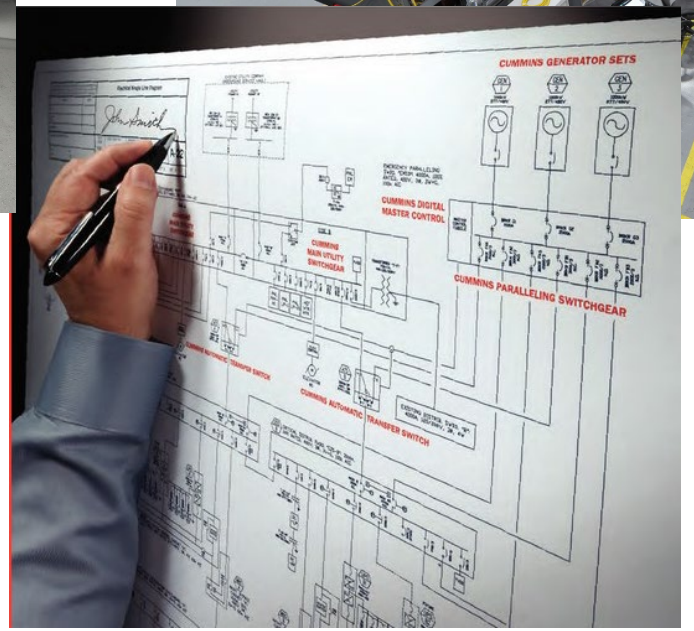
What To Specify For a Paralleled Power System

- Seamless operation if a generator set fails
  - During a start
  - While paralleled
- No single point of failure
  - Control architecture redundancy
  - Not dependent on a paralleling master control
- Capacity to load consumption optimization
  - Prolong generator sets life expectancy
  - Save fuel
- Ability of generator sets to self-protect
  - Overload, reverse power,…
  - Intelligent control with built-in protection
- Energy reducing maintenance switching
  - If there is a need to work on an energized generator set
- Comprehensive remote monitoring
  - Manage assets, monitor alarms, mitigate issues, etc. in real-time

Paralleling Control

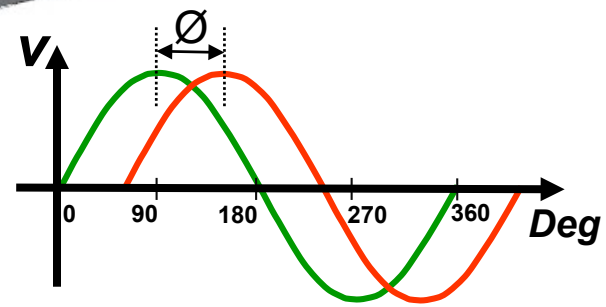


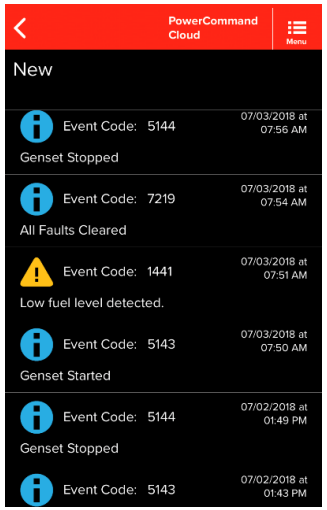


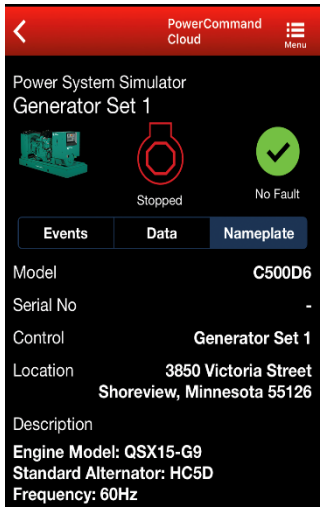


Elements of Paralleling Controls

- Speed control – Governor (ECM)
- Voltage control – Automatic Voltage Regulator (AVR)
- Generator set arbitration
  - De-energized bus: which generator set closes its breaker first
- Synchronization (frequency, phase and voltage)
  - Energized bus
- Load sharing
  - (kW: governor and kVAR: voltage regulator)
- Protection: engine and generator
  - Reverse Power, Under/Over Voltage & Frequency, Sync Check,…
- Metering, faults, alarms
  - kW, kVA, V, PF, Hz, Battery Voltage, Engine Temp,…

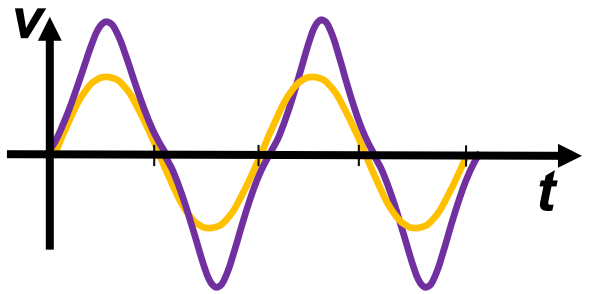


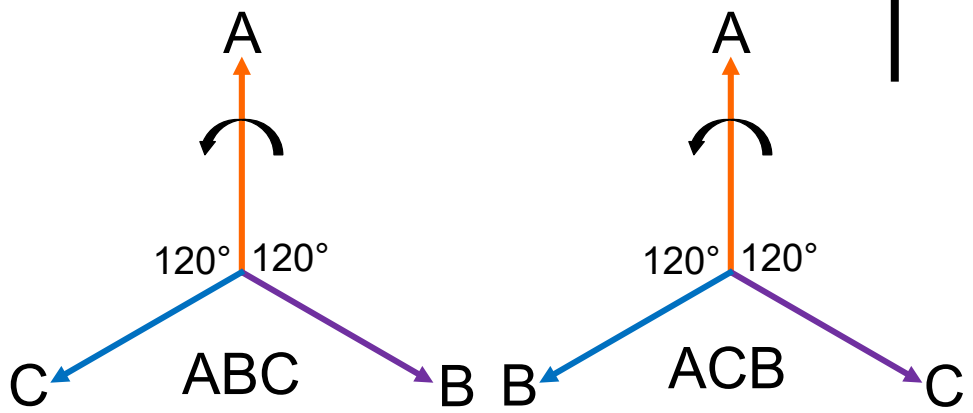


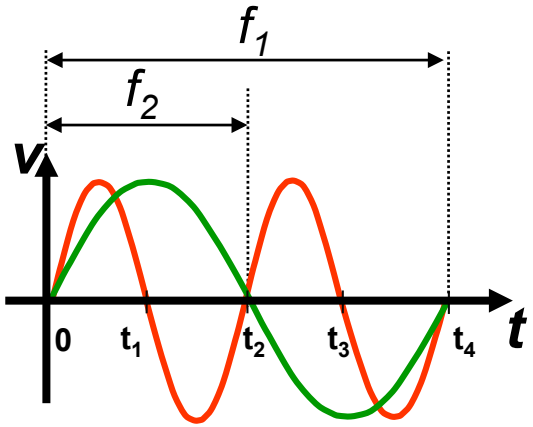


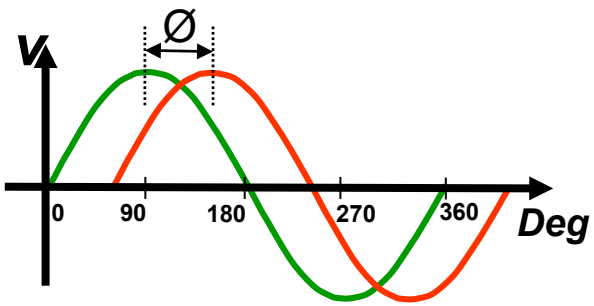
Paralleling Generator Sets

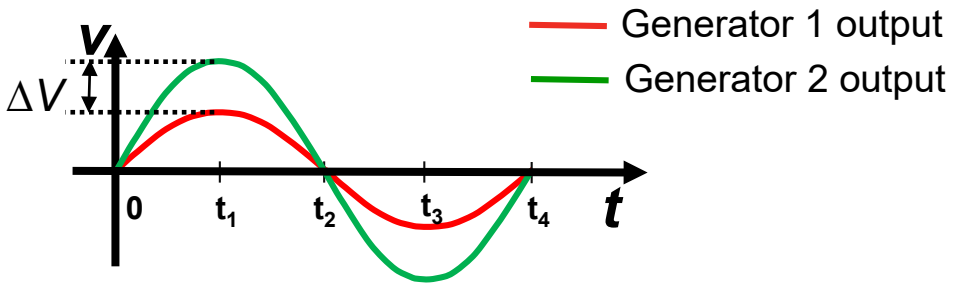
- A generator set output power can be connected to a another generator source only when the following conditions are met:
  - Waveform (2/3rd pitch or 5/6th pitch)
  - Phase sequence
  - Speed difference (frequency)
  - Phase angle difference
  - Voltage amplitude difference







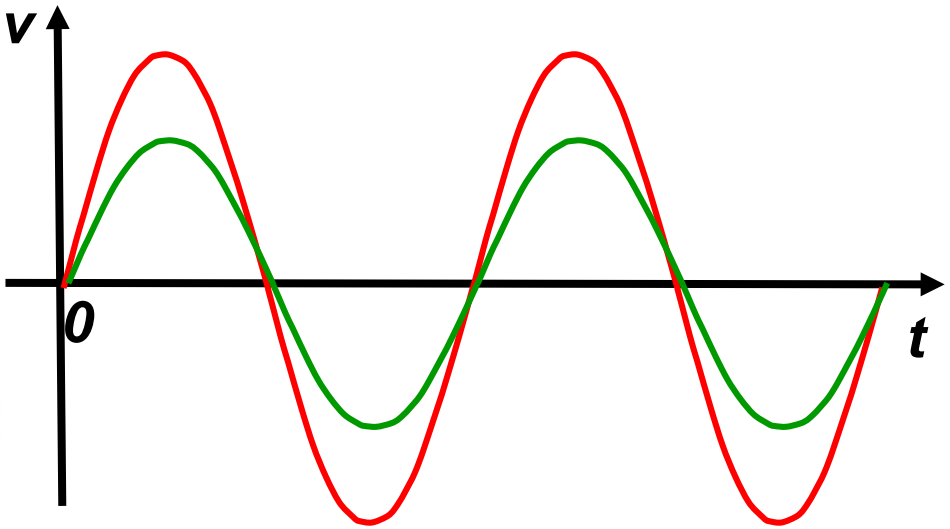




Synchronizing

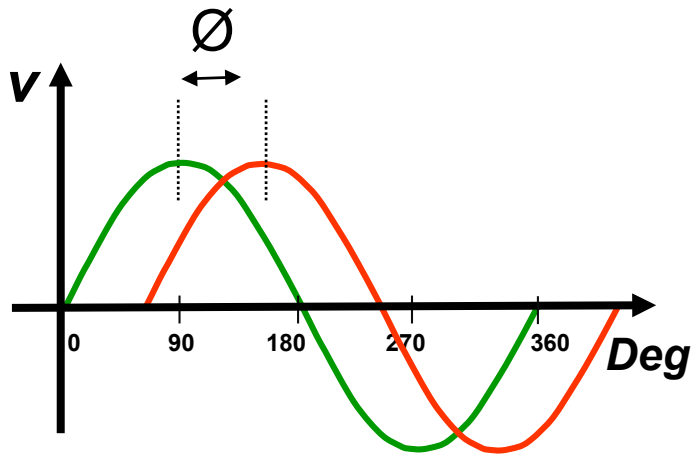
- Phase and Frequency: engine governor fuel
- Voltage: alternator field excitation

Voltage



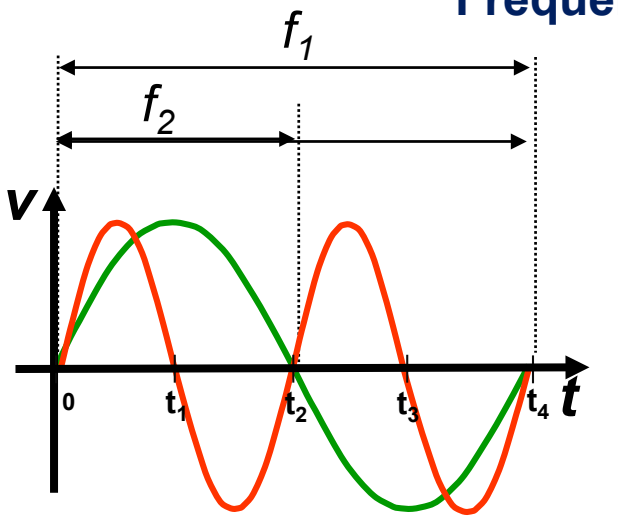
AVR

Phase



ECM

Frequency



Generator 1 output

Generator 2 output

Concept Check

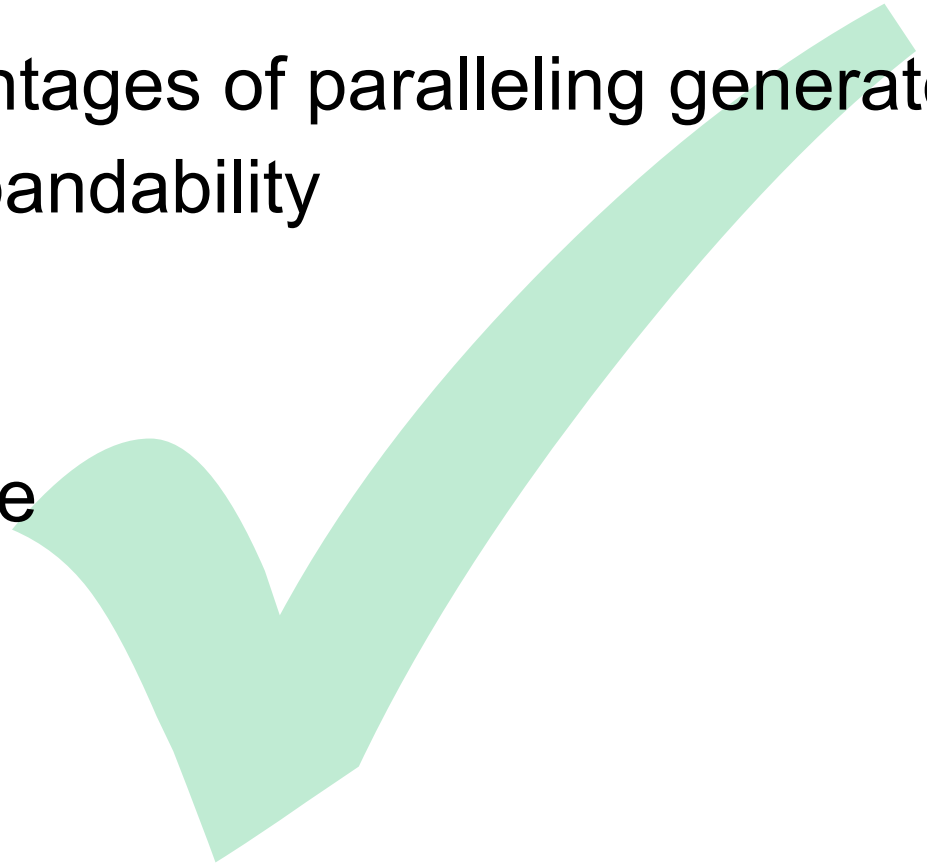
What are the advantages of paralleling generator sets?

a) Scalability/Expandability

b) Reliability

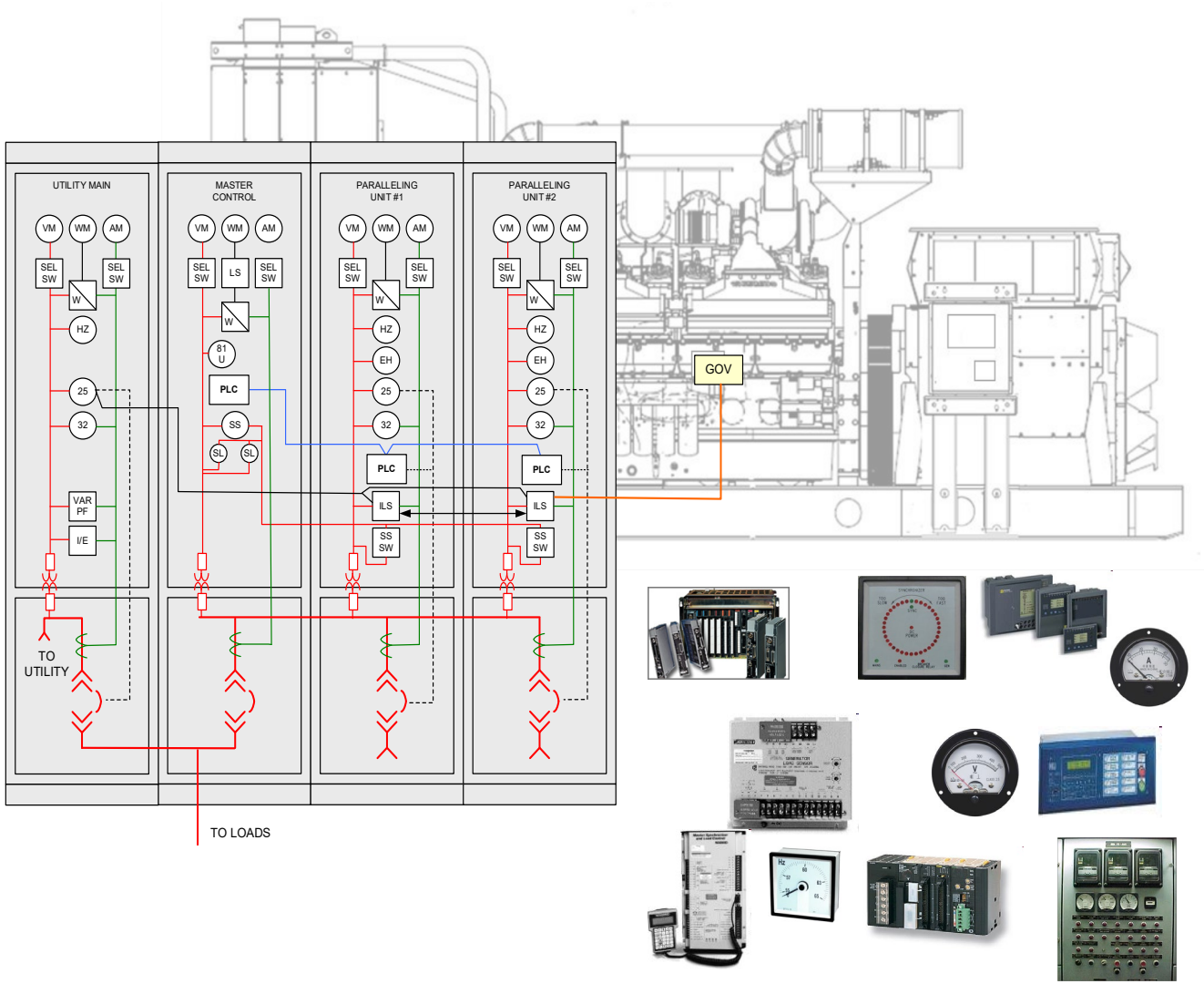
c) Redundancy

d) All of the Above

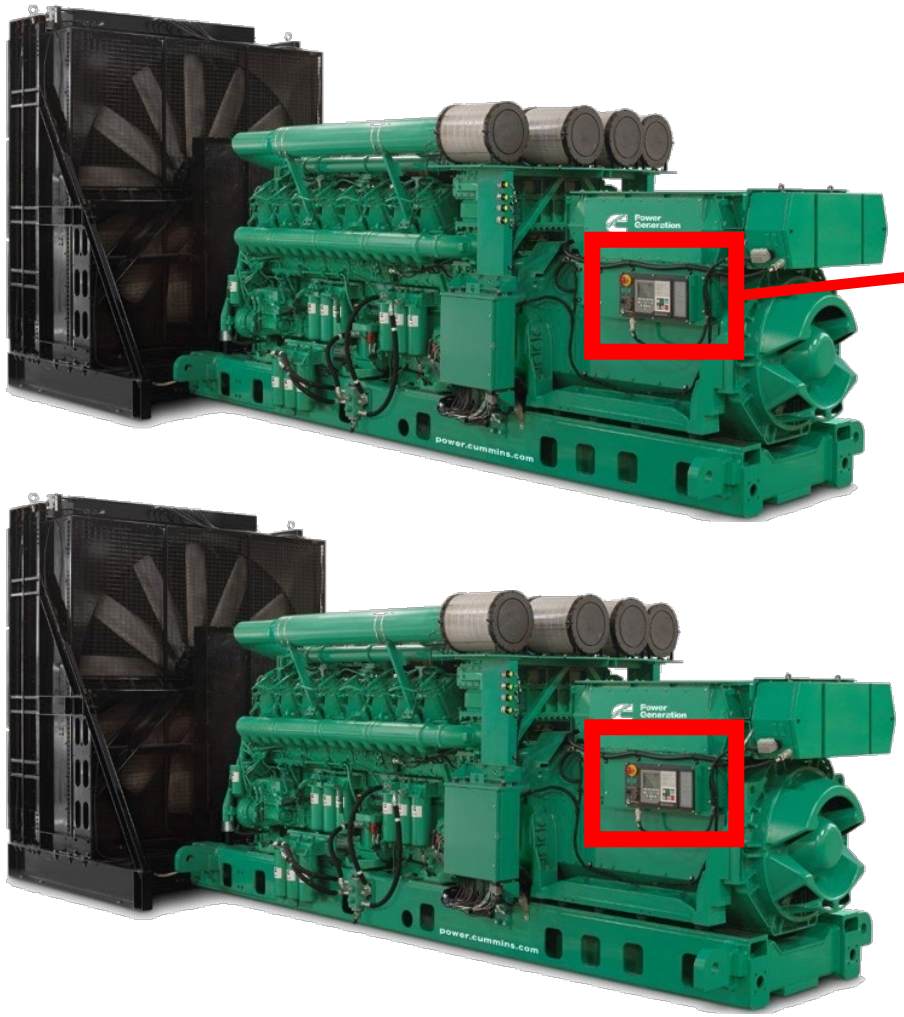


Traditional Paralleling Control Design

- Paralleling control in the switchgear
- Master paralleling control
  - Single point of failure
- Component based design
- PLC-based core
- Variability in the design
- Lots of wiring
- Nightmare to troubleshoot



Integrated Autonomous Paralleling Design



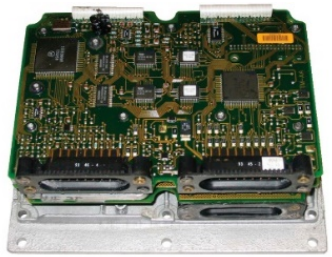
Integrated Generator Set Control

Human Machine Interface

Paralleling Control – Closer Look

Data Link

Data Link



Human Machine Interface

- User Interface
- Configurations/Settings
- Alarms
- Start/Stop
- Manual Paralleling

Generator Set Controller

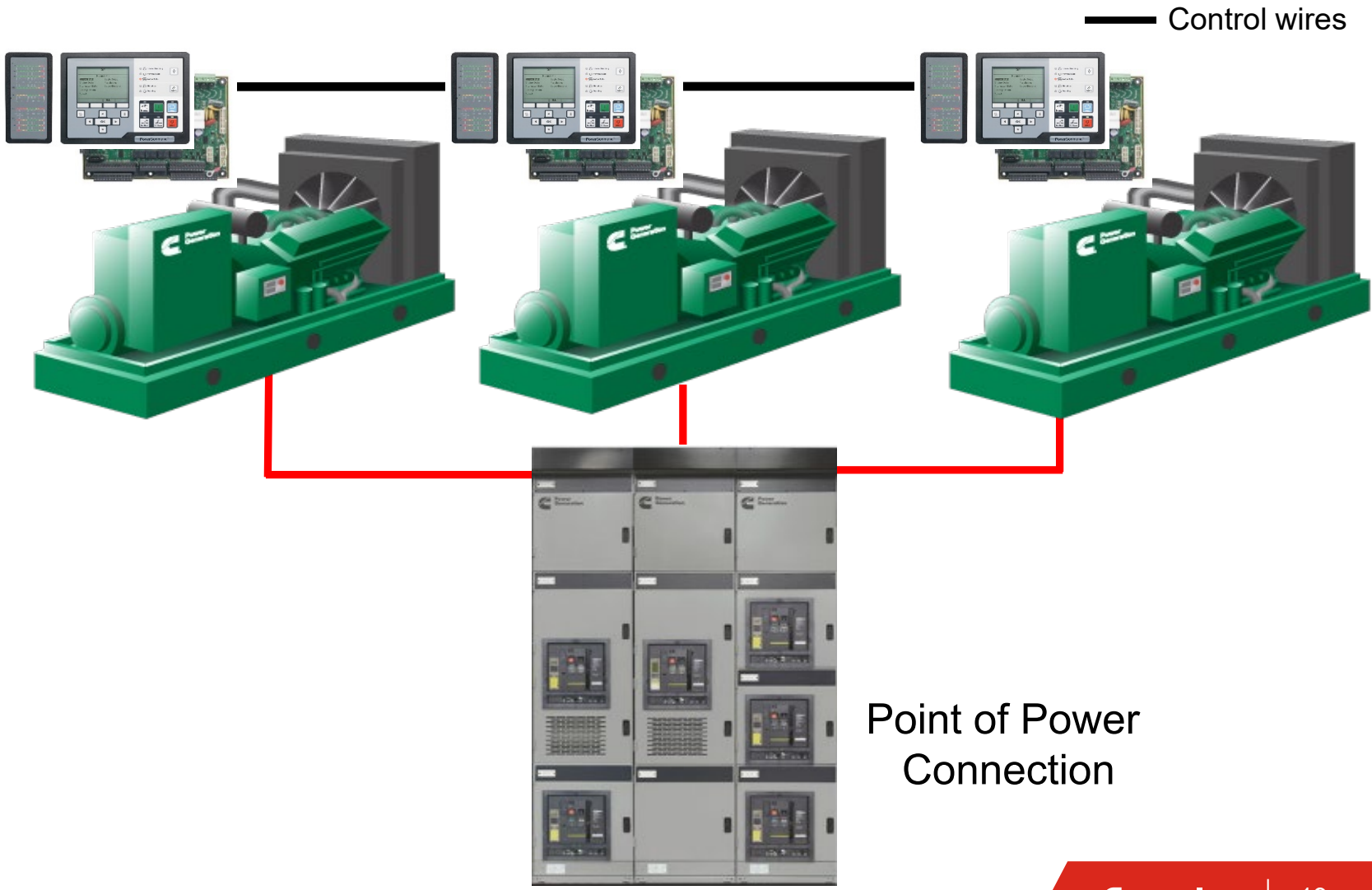
- First Start Arbitration
- Synchronizing (Ø, V, Hz)
- Voltage Regulation
- Load Sharing (kW, kVAR)
- Generator Set Metering
- Generator Set Protection

Engine Control Module

- Governing
- Engine Protection
- Engine metering

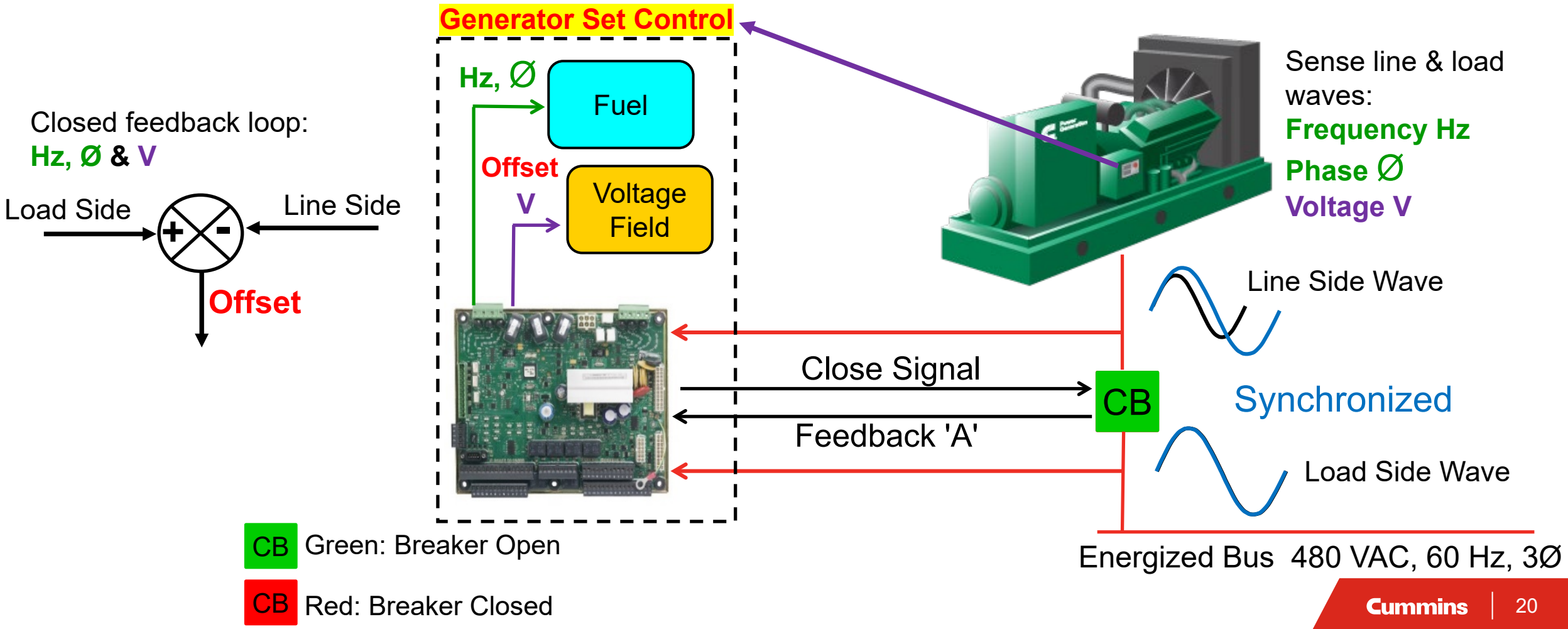
Integrated Autonomous Paralleling Design

- No paralleling master
  - No single point of failure
- Consistent design
- Reduce wiring
- Reduce footprint
- Easy to learn and operate
- Low or medium voltage



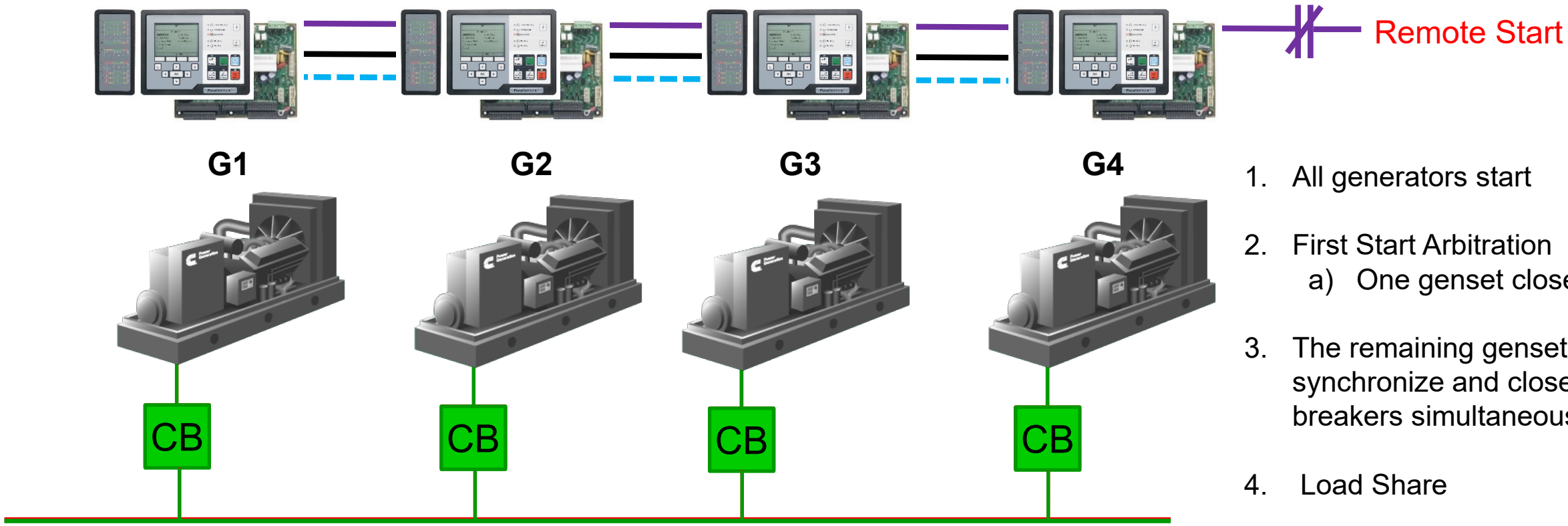
Paralleling Control (Energized Bus)

- Match Frequency, Phase and Voltage



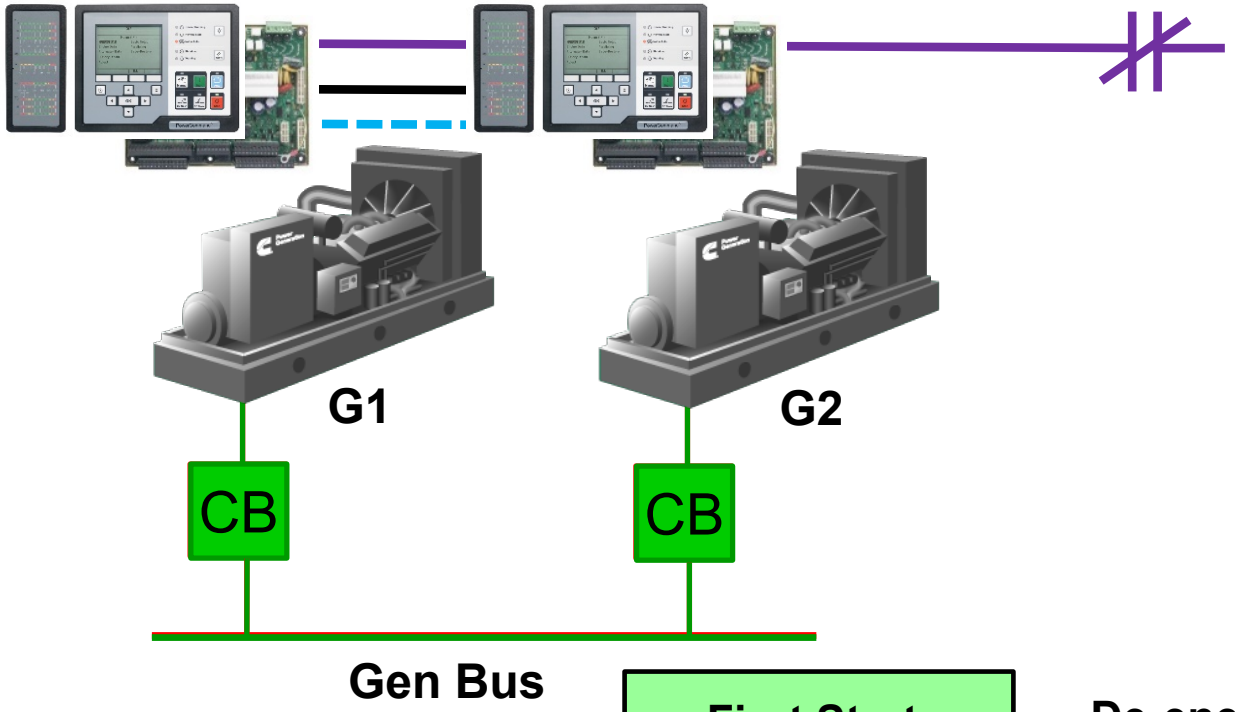
Paralleling Control (De-Energized Bus)

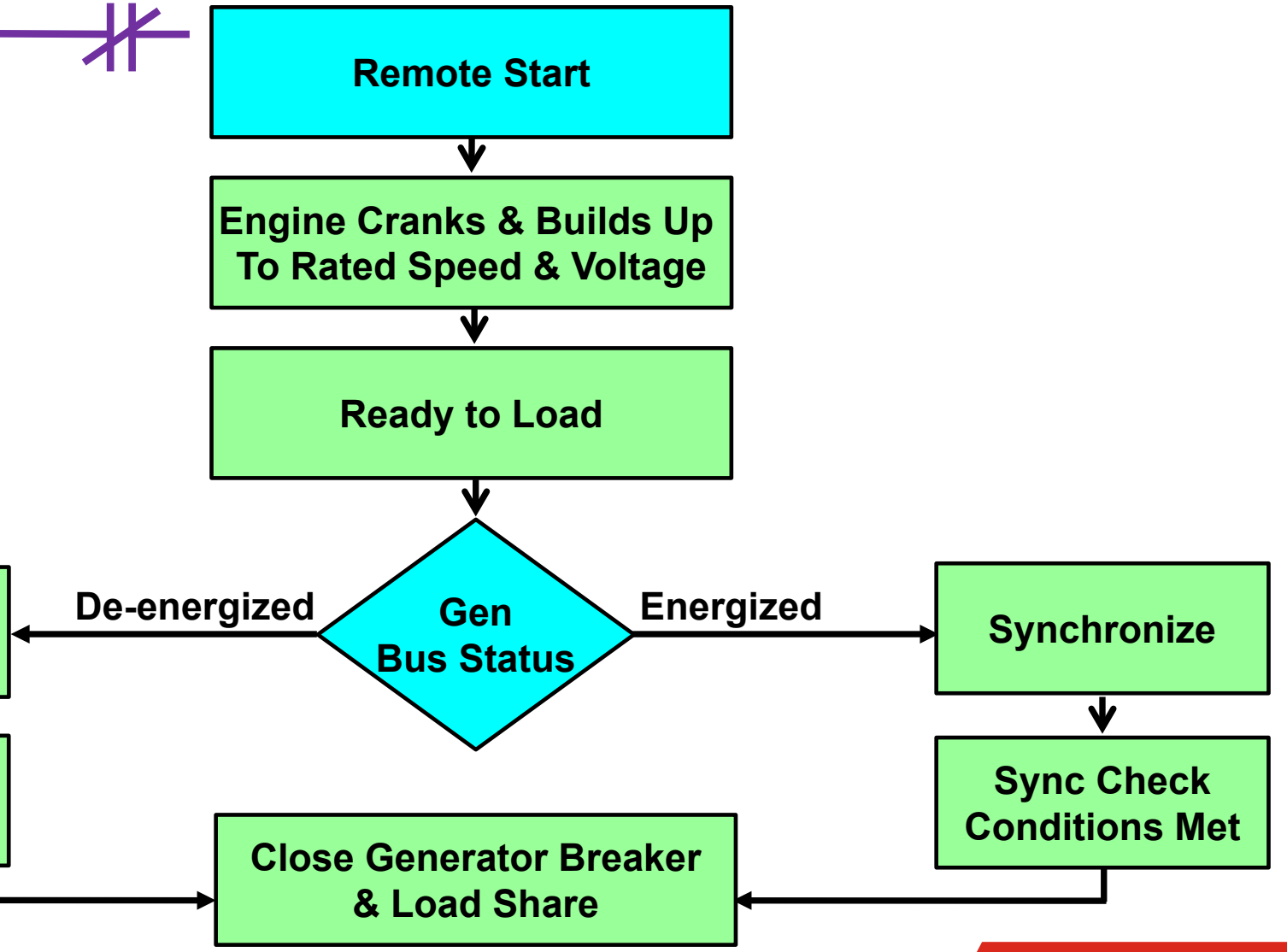
Start
First Start Arbitration
Load Share Lines



1. All generators start
2. First Start Arbitration
   a) One genset closes
3. The remaining genset sets synchronize and close breakers simultaneously
4. Load Share

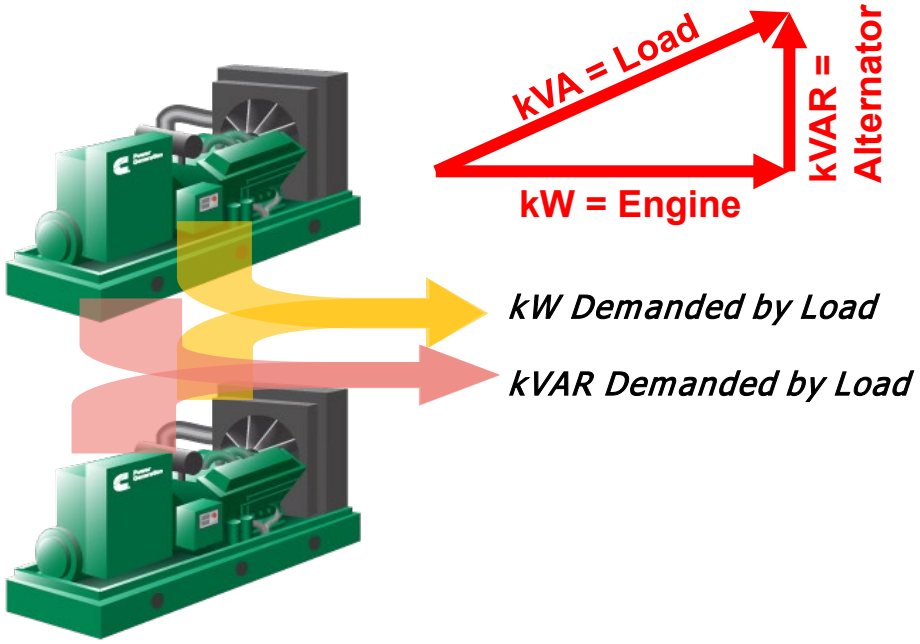
Paralleling Sequence of Operation

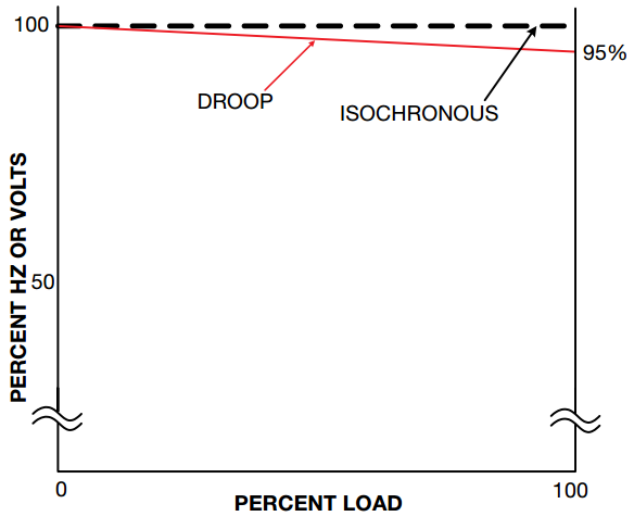


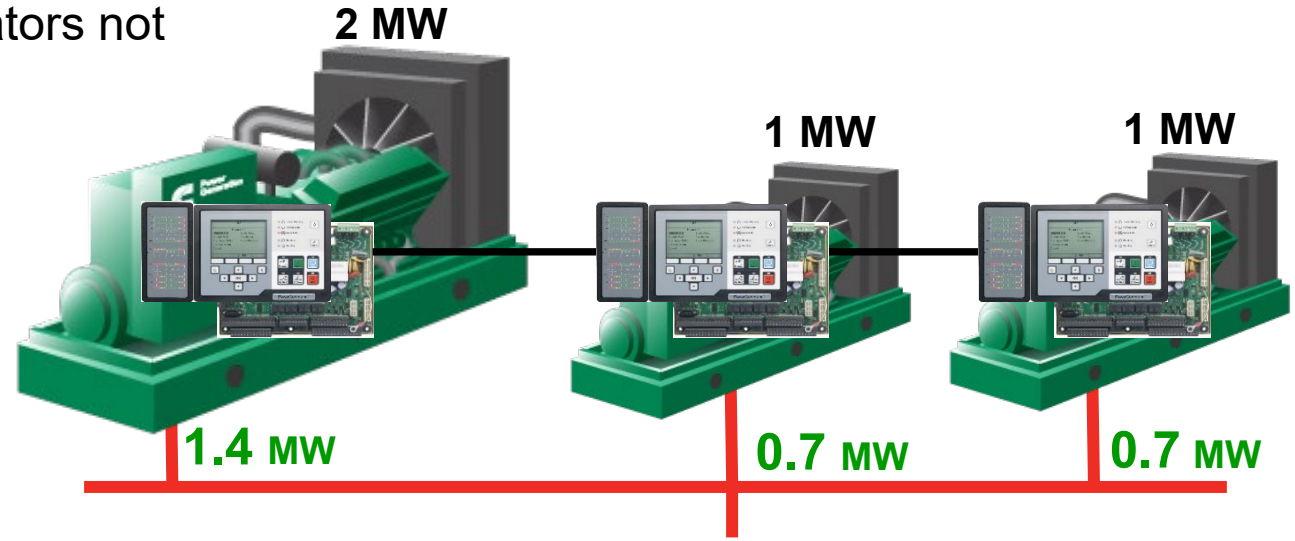


Load Sharing

- The proportional division of the kW and kVAR total load between multiple generator sets in a paralleled system
  - Load sharing is essential to avoid overloading and stability problems on the generator sets
- Load share can be Isochronous or Droop
  - Isochronous: frequency & voltage are fixed regardless of the load. Requires communication wiring
  - Droop: frequency & voltage vary as the load varies. Communication wiring between generators not needed





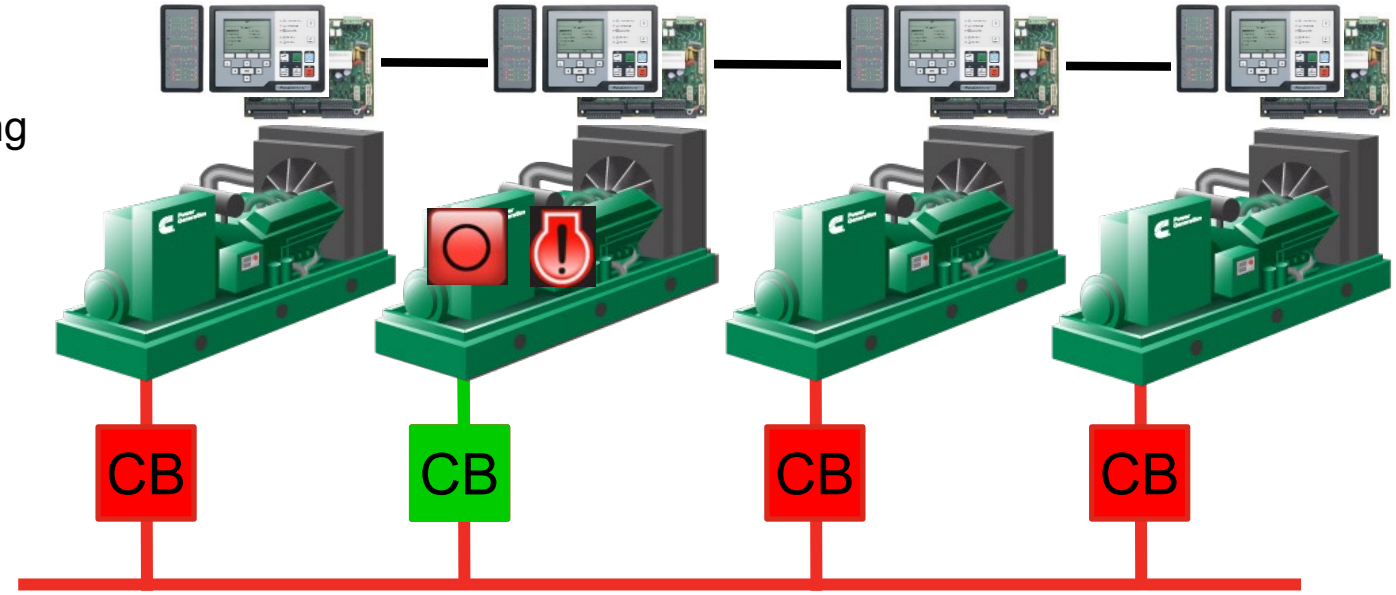


All generator set are 70% Loaded

e.g. 2.8MW Load

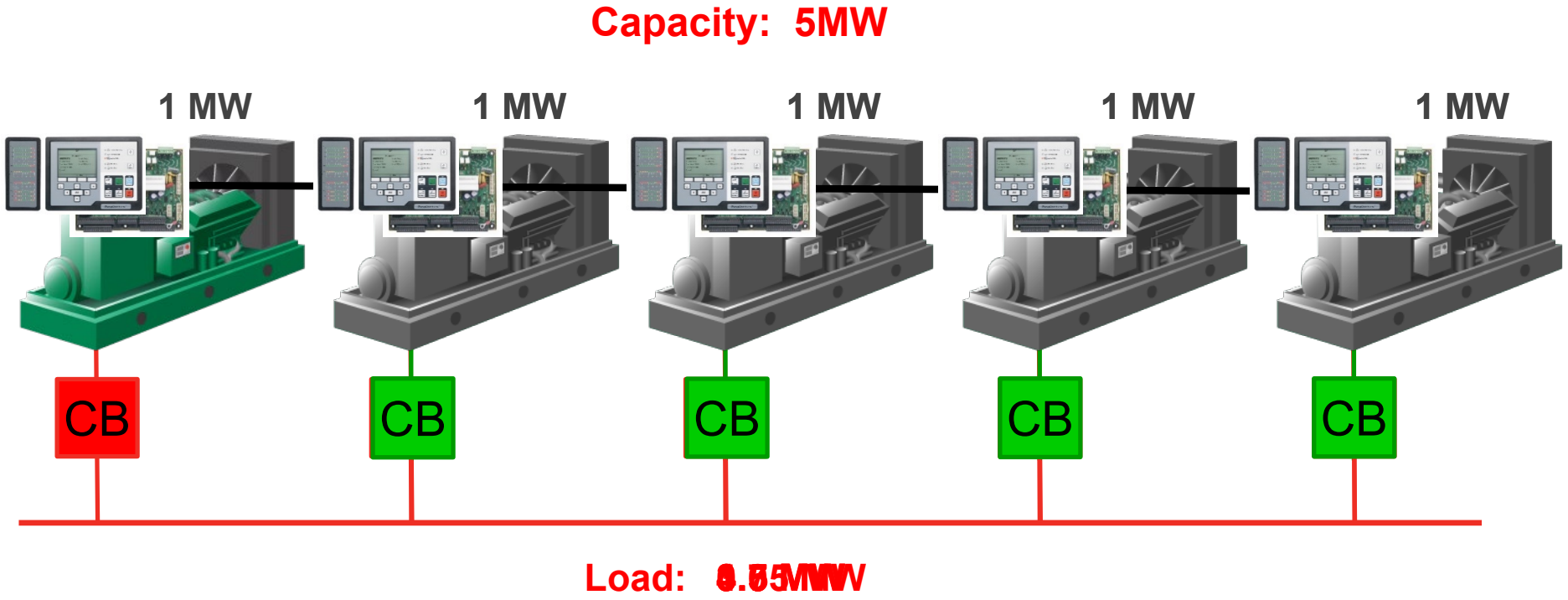
Seamless Paralleling Operation

- Paralleling is a function of the generator set control
- Distributed logic architecture (control redundancy):
  - The paralleling logic (synchronizing, load sharing, governing, protection,...) is repeated on each generator set
  - If a generator set fails
    - Open paralleling breaker
    - Shutdown generator set
    - The paralleling system continues running
- No paralleling master control
  - Single point of failure eliminated



Capacity to Load Consumption Optimization

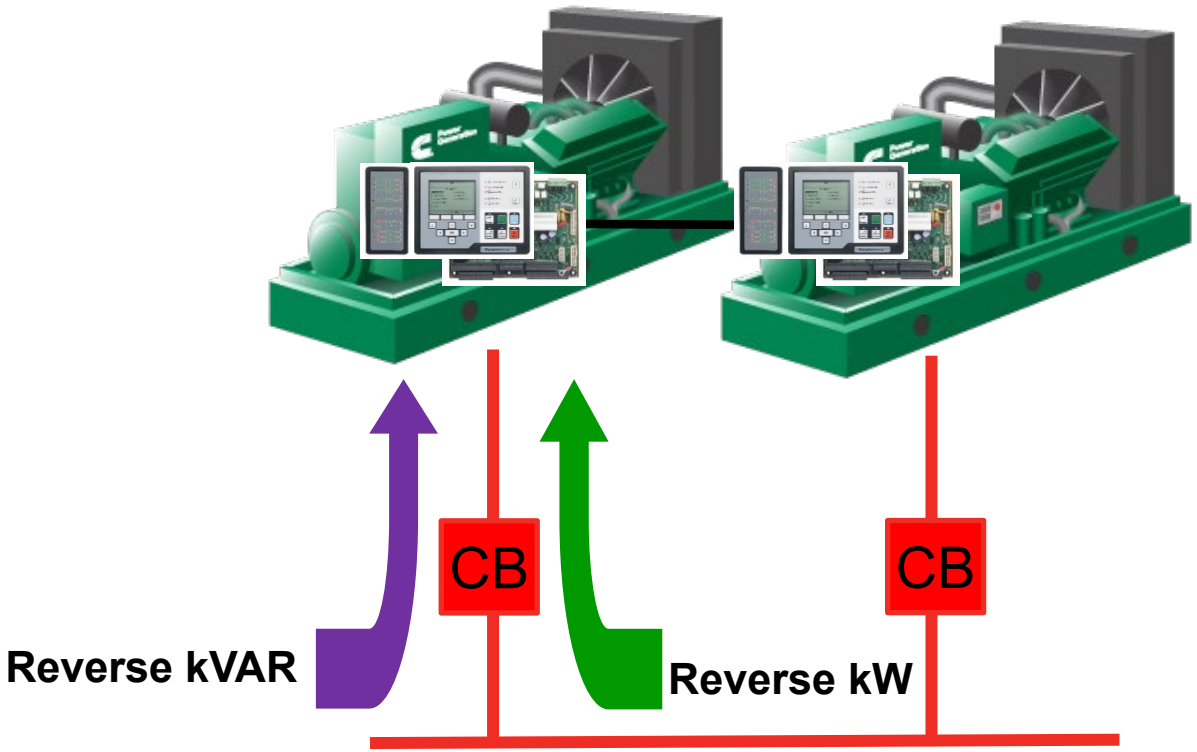
- Prolong generator sets life expectancy
- Save fuel



Generator Protection Elements

- 15 – Synchronizer
- 25 – Synch Check
- 27 – Undervoltage
- 32 – Directional Power
- 40 – Loss of Excitation/Reverse kVAR
- 46 – Phase Balance Current
- 47 – Phase Sequence Voltage
- 50 – Instantaneous overcurrent
- 51 – Time Overcurrent
- 59 – Overvoltage
- 81U/O – Under/Over Frequency

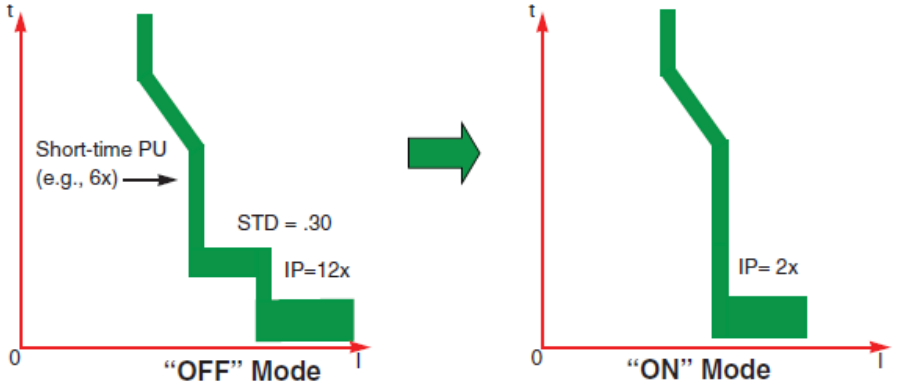
The numbers represent
ANSI device numbers



Energy Reducing Maintenance Switching

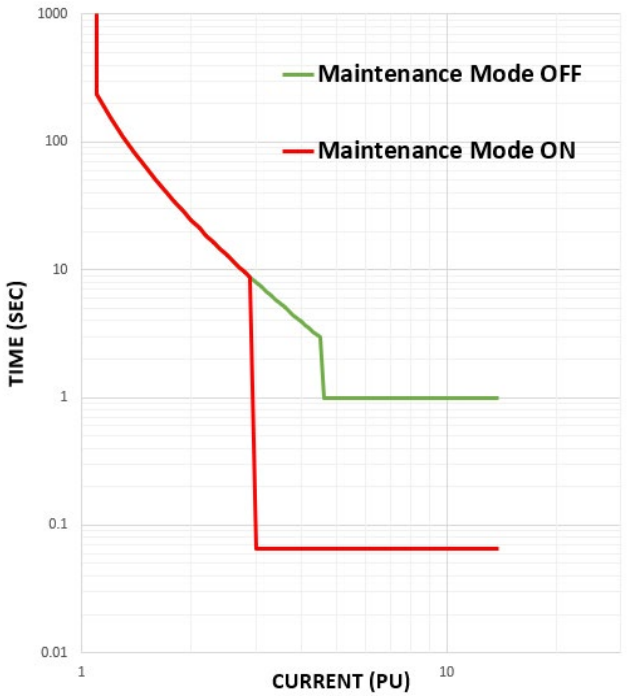
- Energy Reduction Maintenance Setting (ERMS)

Local ERMS Switch



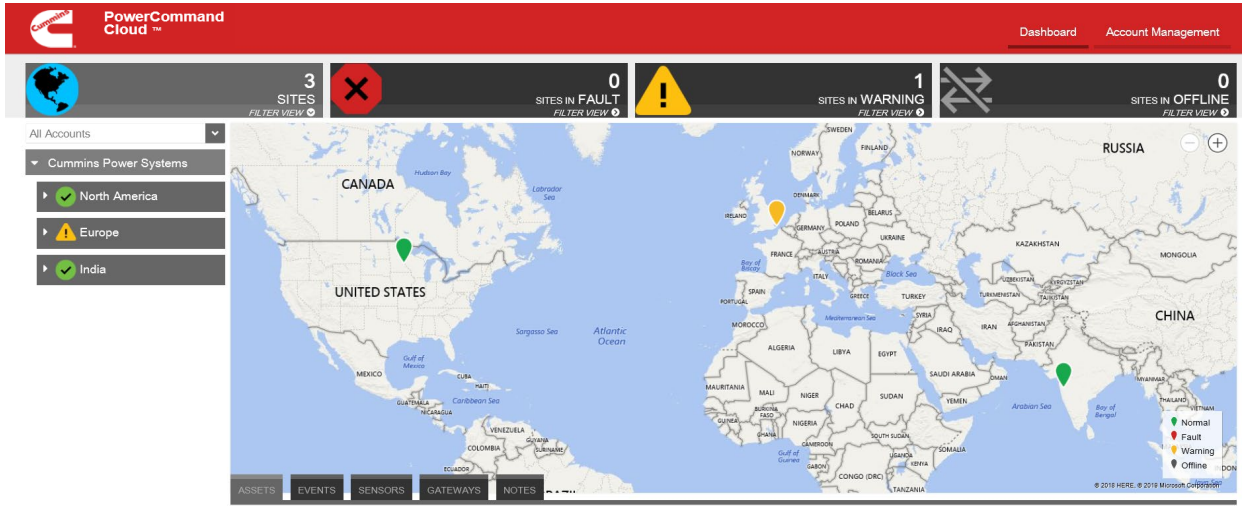
ERMS Switch "OFF" and "ON" Mode

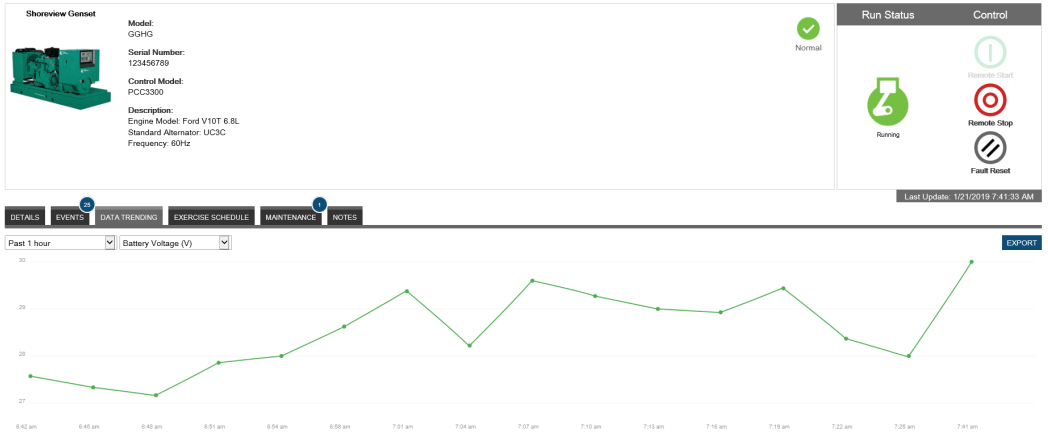
- Some generator set manufacturers have built into their controls:
  - Overcurrent protection
  - Maintenance mode
    - Bypasses all time delays

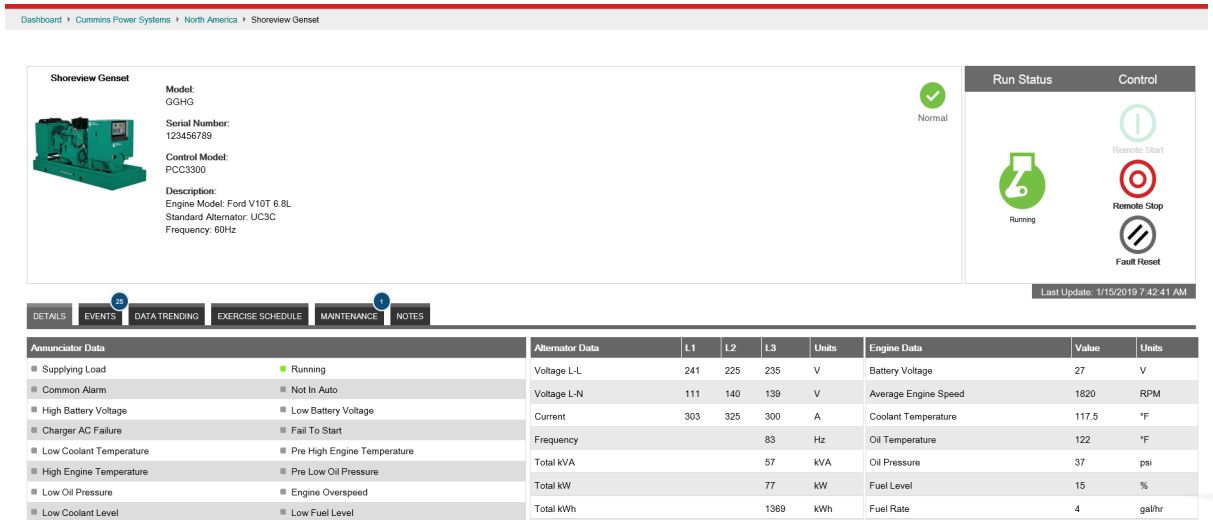


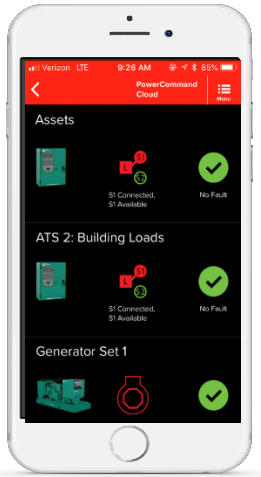
Comprehensive Remote Monitoring

- Single point visibility to assets and site performance anytime anywhere
- Immediate notification of any critical or non-critical issues through automated emails and push notifications
- Access to historical performance data to any asset through reports and trending









Concept Check

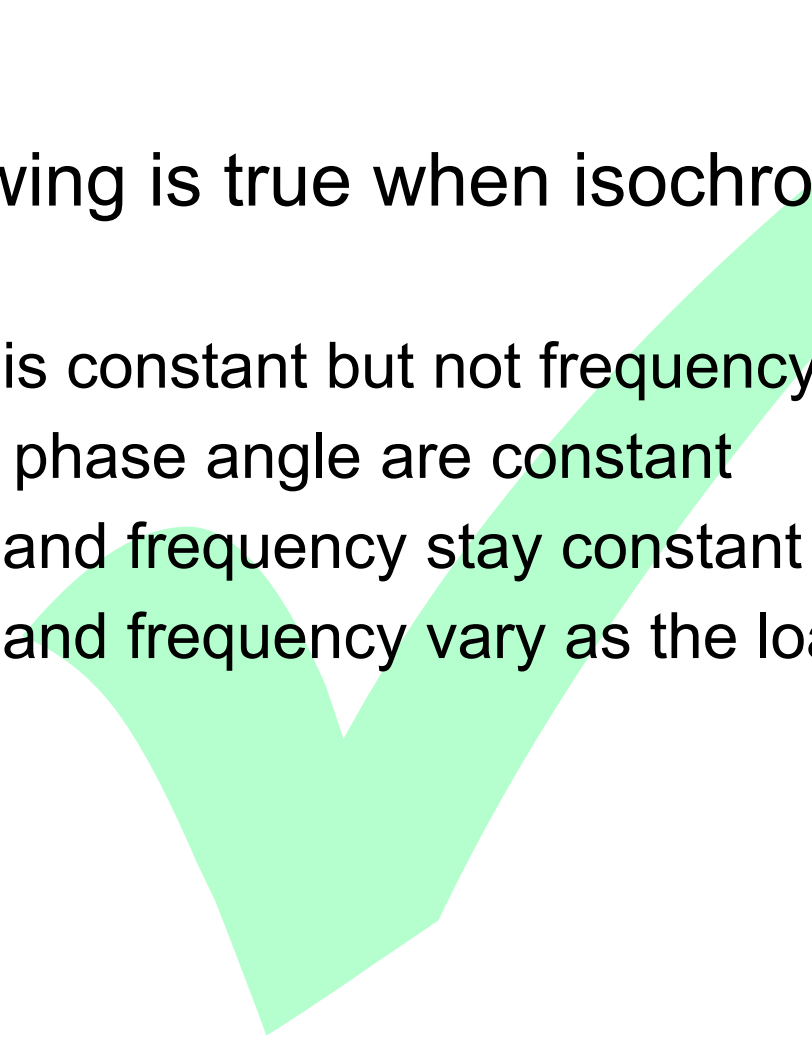
Which of the following is true when isochronous load sharing is utilized:

a) Output voltage is constant but not frequency

b) Frequency and phase angle are constant

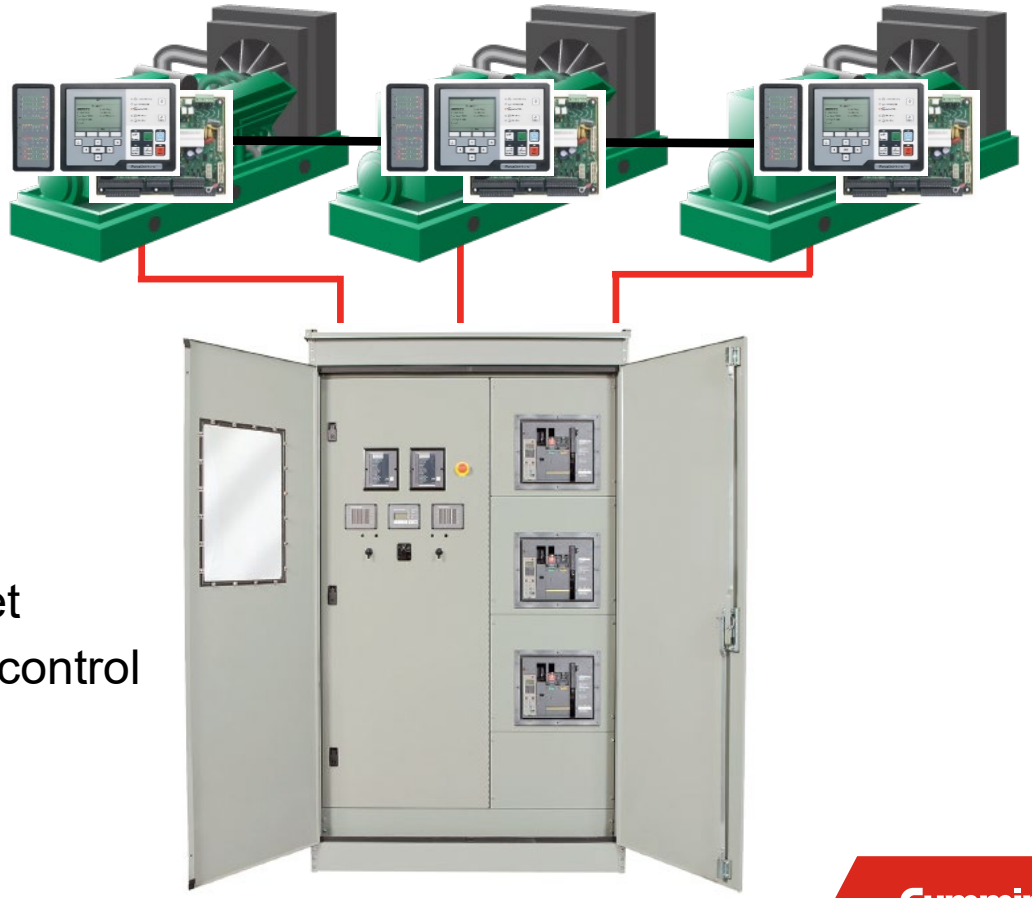
c) Output voltage and frequency stay constant as the load varies

d) Output voltage and frequency vary as the load varies

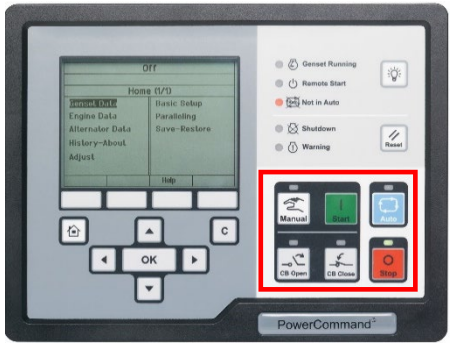


Paralleling Hardware

- What is needed to parallel generators:
  - Two or more generator sets
  - Electrically operated breakers: one per generator (in switchgear or generator set mounted)
    - Open coil
    - Close coil
    - Breaker position status
    - Breaker charging motor
    - Power supply to operate coils
      - (CPT's, batteries)
  - Point of common connection
    - Switchgear
    - Collector bus
  - Paralleling functions for each generator set
    - For example: Integrated in generator control



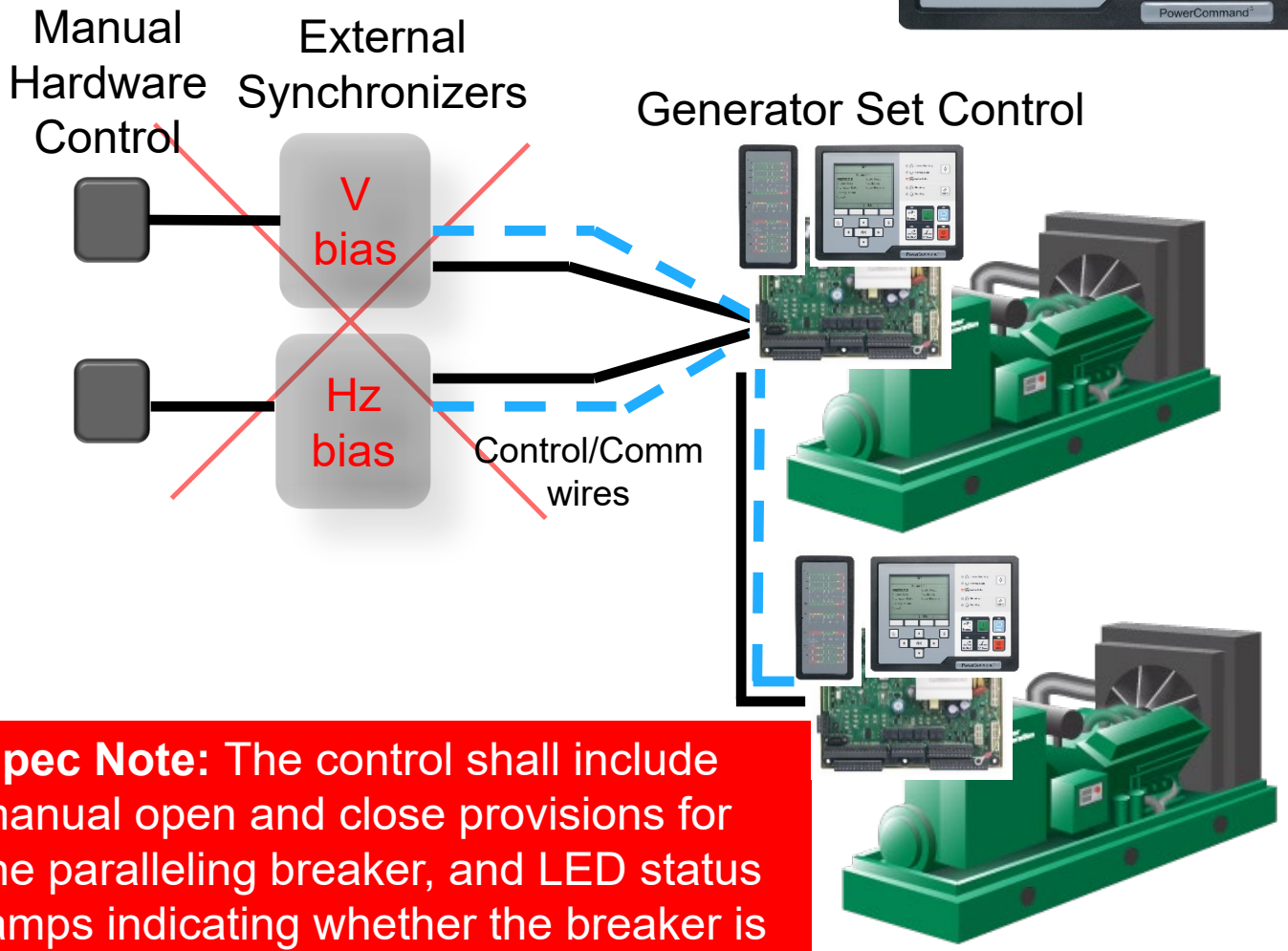
Generator Sets Manual Paralleling



- How to manually parallel generator sets with integrated control?
  - Start/Stop generator sets
  - Synchronize generator sets and close paralleling circuit breaker

- Some Generator set manufacturers are able to incorporate manual operation into their integrated control
  - CB Close: initiates synchronizing and breaker closes when synchronized (phase, voltage and frequency)

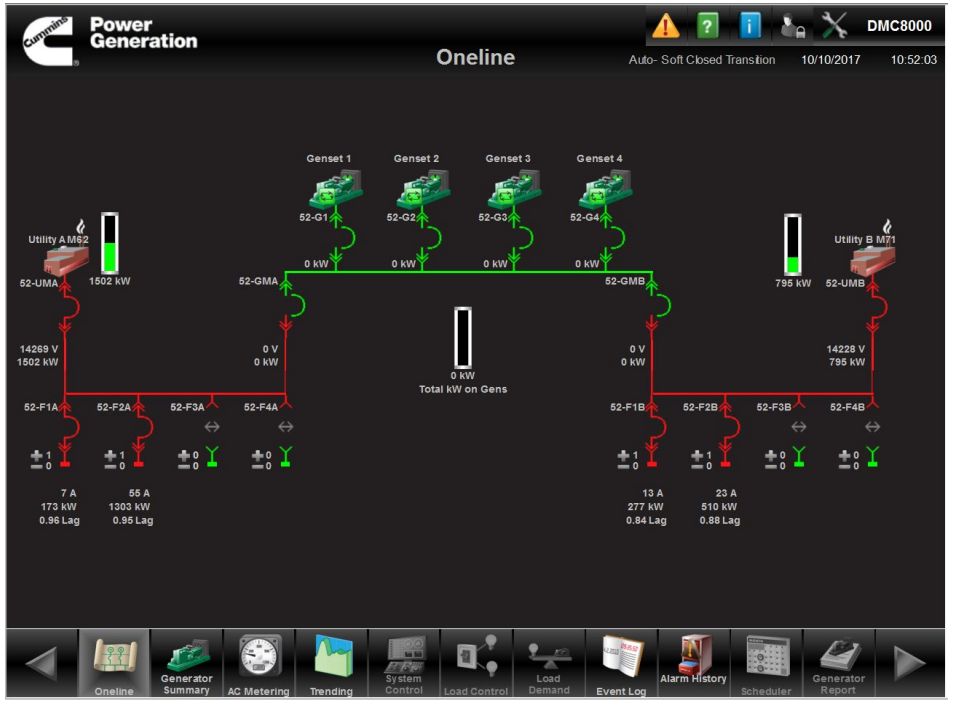
- What to avoid?
  - Additional components to perform manual operation
    - Still communicating to the generator set control
    - More components that can fail
    - False sense of reliability



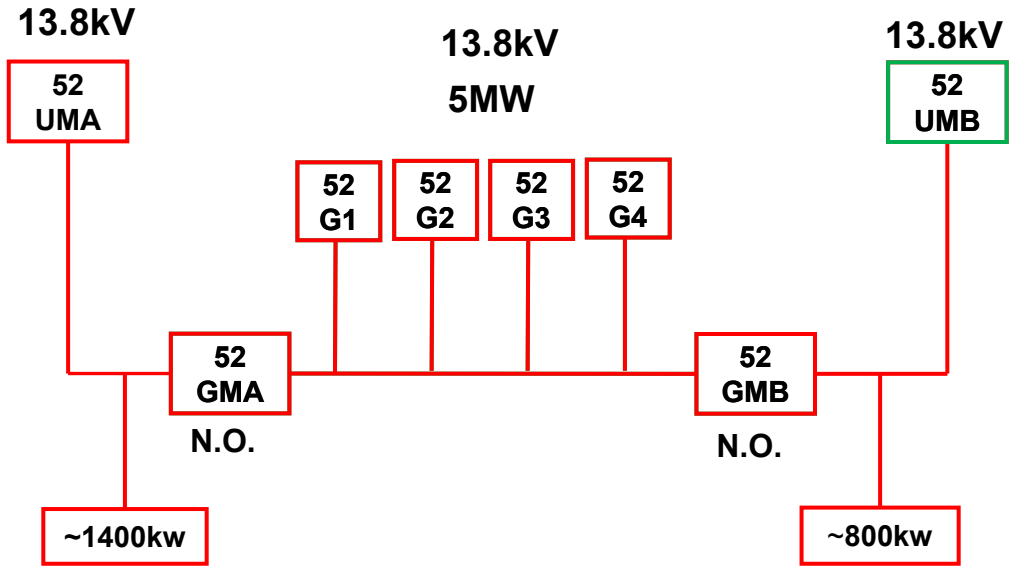
Spec Note: The control shall include manual open and close provisions for the paralleling breaker, and LED status lamps indicating whether the breaker is open or closed.

Extended Paralleling Example

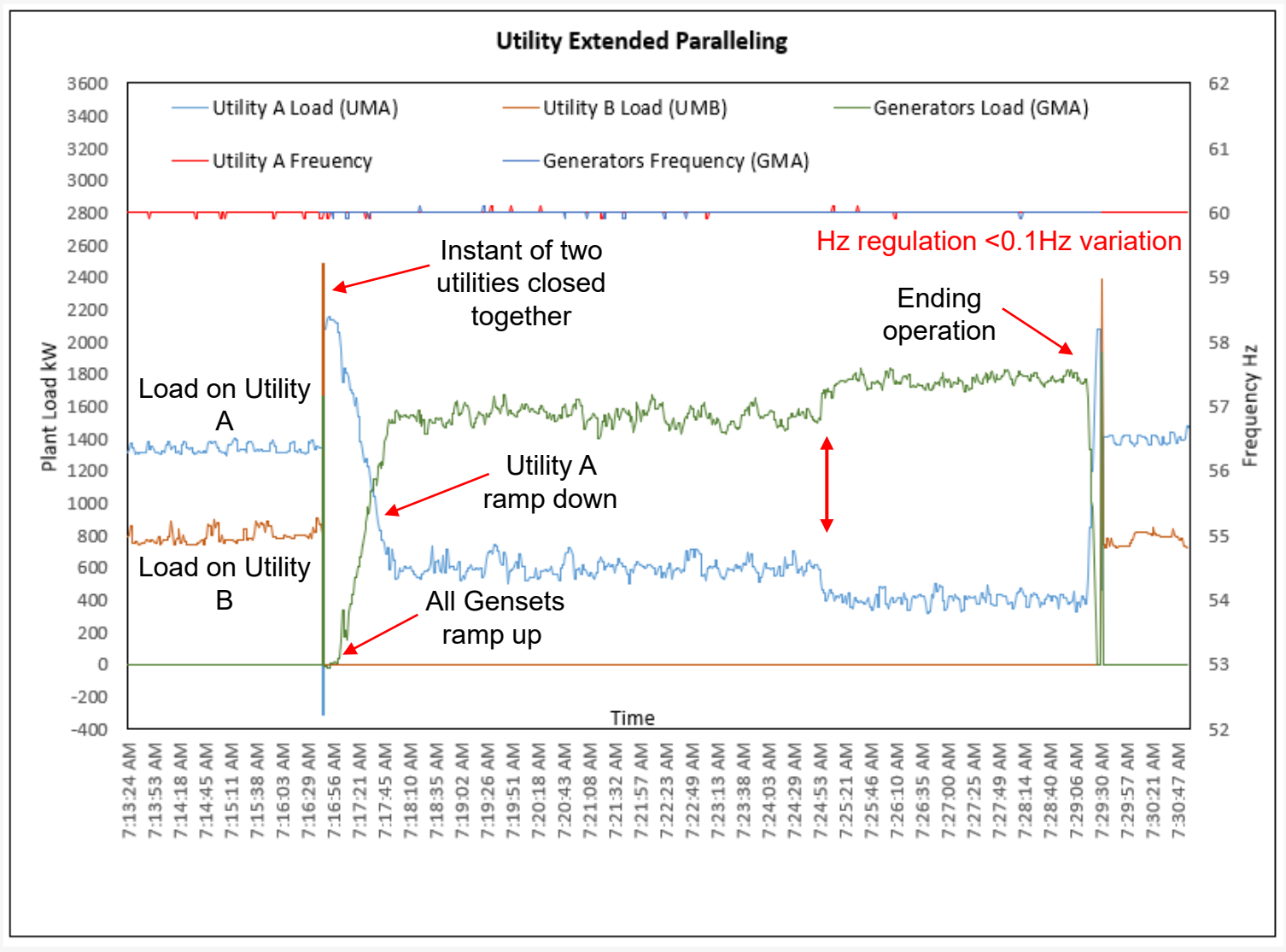
- Obtain approval from the utility
  - Hard-closed transition (100msec)
  - Soft-Closed transition (>100msec, load ramp)
  - Extended closed transition
- Minimum import set point
- Power export back to the utility?
  - Reverse power protection
- Extended closed-transition control algorithm expectations:
  - Keep the lights on!
  - Follow the utility
  - Output power regulation
  - Fast response as load changes



Extended Paralleling Example



- Extended parallel with UMA:
  - Close GMA and GMB
  - Open UMB
  - Start all generator sets and ramp load
- Utility import set points:
  - Start at 600 kW
  - @ Approx. 7:24:37 import set point changed to 400kW
- Frequency of four generator sets and utility during operation locked at 60Hz



Course Summary

Functions and Features of Generator Set Control Based Paralleling

- Identify the advantages of paralleling as they relate to overall system reliability, performance and flexibility.
- Recognize basic generator set paralleling control components, functions and features.
- Describe common strategies employed by paralleling systems using distributed logic architecture.
- Discuss the benefits of distributed logic architecture as it relates to paralleling, system reliability and its ability to eliminate a single point of failure.

Specify:

- Write specifications based on functions and performance
- Integrated paralleling and protection control
- Seamless paralleling operation if a generator set fails
- Paralleling control architecture redundancy
- Capacity to load consumption optimization to reduce fuel and wear/tear on generator sets
- Request a paralleling demonstration/witness testing for future projects

Avoid specifying:

- Specific hardware and components
- External hardware to perform generator set manual paralleling

Q&A

Type your questions, comments, feedback in the **WebEx Q&A box**. We will get to as many questions as we can

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Q+A


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