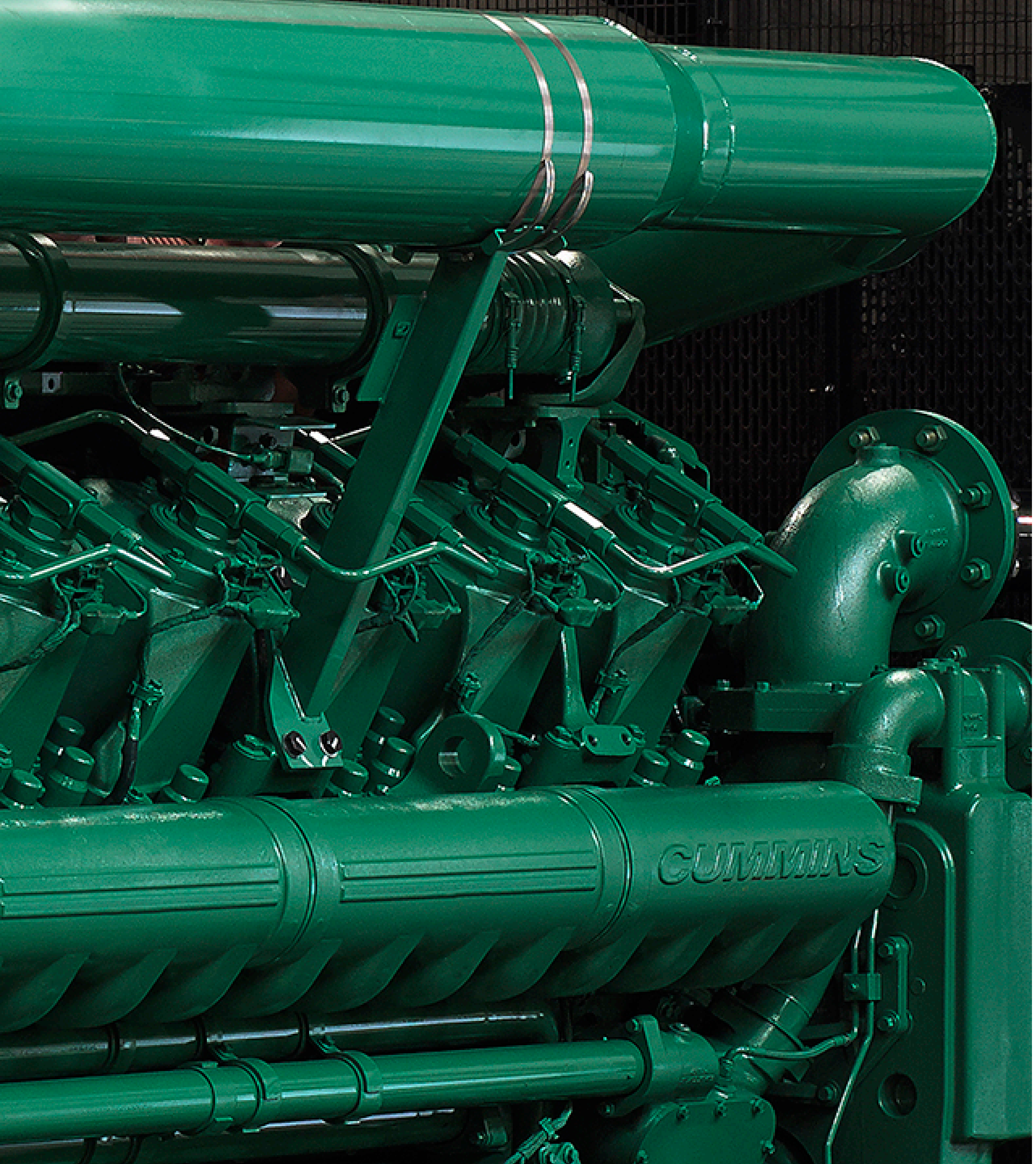

Paralleling Power System Design Considerations and System Level Control

PowerHour webinar series for consulting engineers

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

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Participants are encouraged to refer to the entire text of all referenced documents. In addition, when it doubt, reach out to the Authority Having Jurisdiction.

Course Objectives

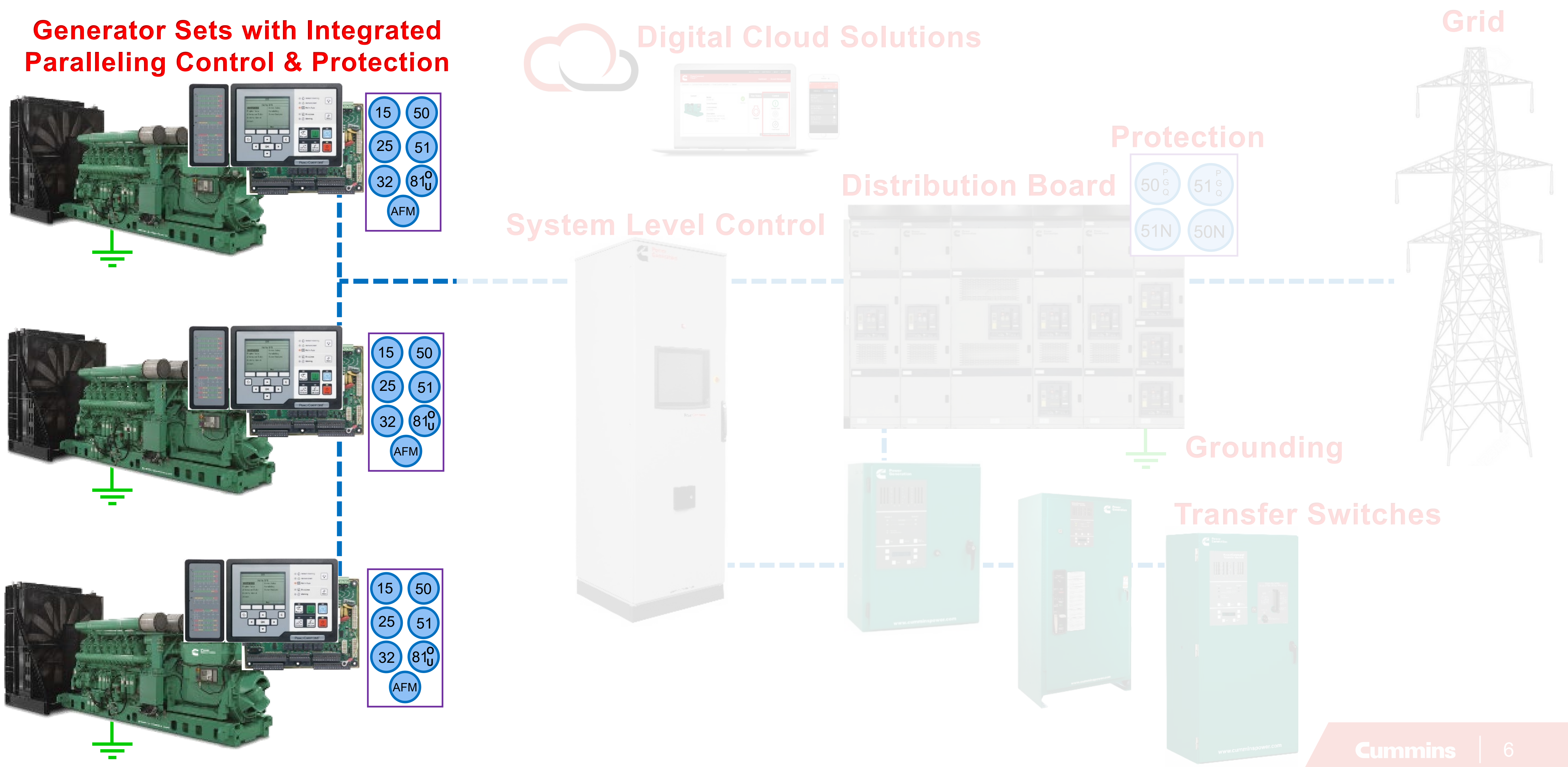
Paralleling Power System Design Considerations and System Level Control

This course provides an overview of power systems design and covers when and how a system level control fits in the power system. System level control reliability will be explored while the instructor reviews paralleling and control strategies employed to eliminate potential single points of failure. This course also covers the elements to consider for designing paralleling systems, automatic transfer switches, grounding, and protection.

After completing this course, participants will be able to:

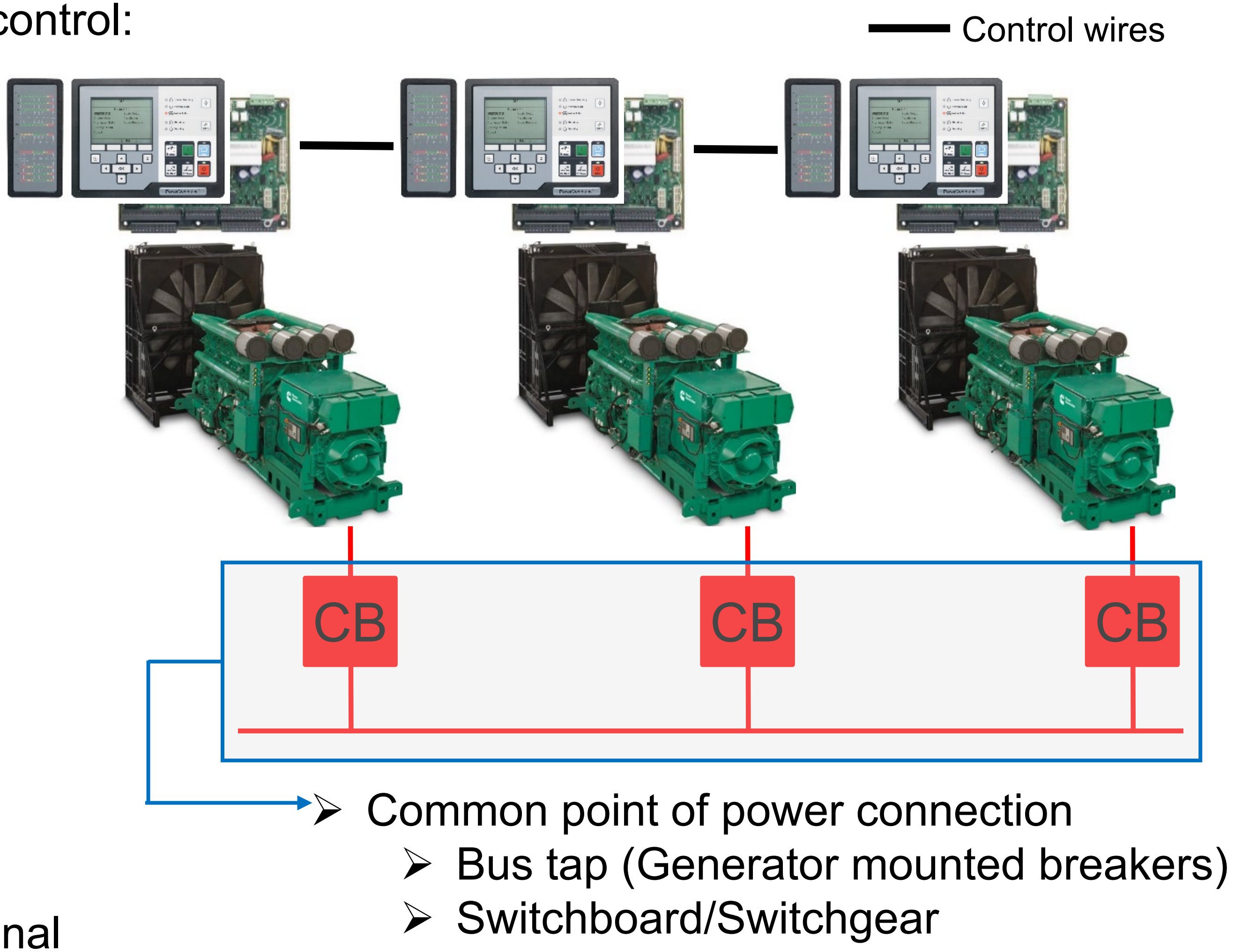
- Discuss the major differences between switchboards and switchgear (UL891 and UL 1558)
- Describe transfer switch design considerations in a power system scheme
- Describe the functionalities and applications of a system level control and how it fits in a power system
- Discuss protection and ground fault considerations

Power System Building Blocks



Integrated Autonomous Paralleling Control

- Paralleling functions are part of the generator set control:
  - First start arbitration
  - Synchronizing (Ø, V, Hz)
  - Load sharing (kW and kVAR)
  - Generator set protection
  - Metering and alarms
  - Built-in safe manual paralleling
  - Generation to load consumption matching
- Distributed logic architecture
- No paralleling master control
  - Single point of failure eliminated
- Consistent design
  - Easier to learn, operate, and troubleshoot
- Reduce wiring and footprint compared with traditional switchgear paralleling



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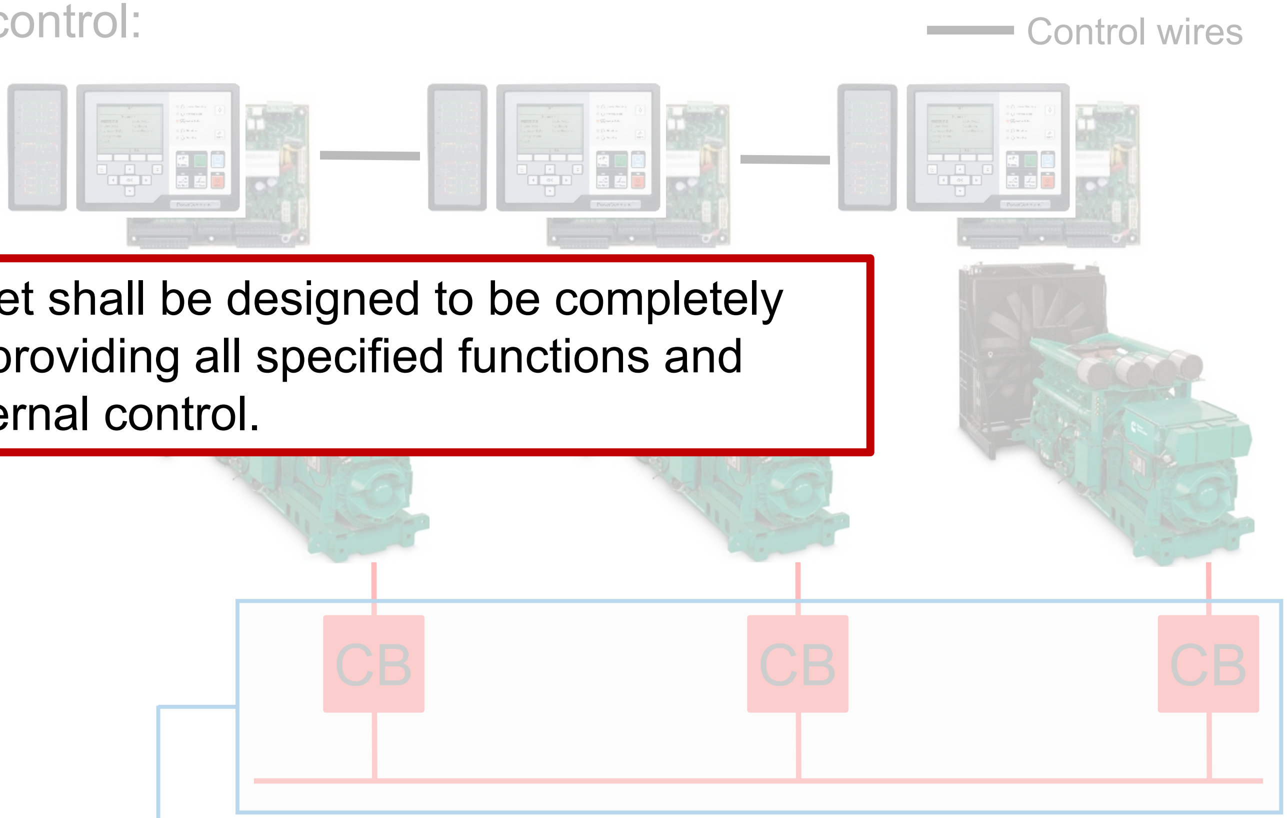
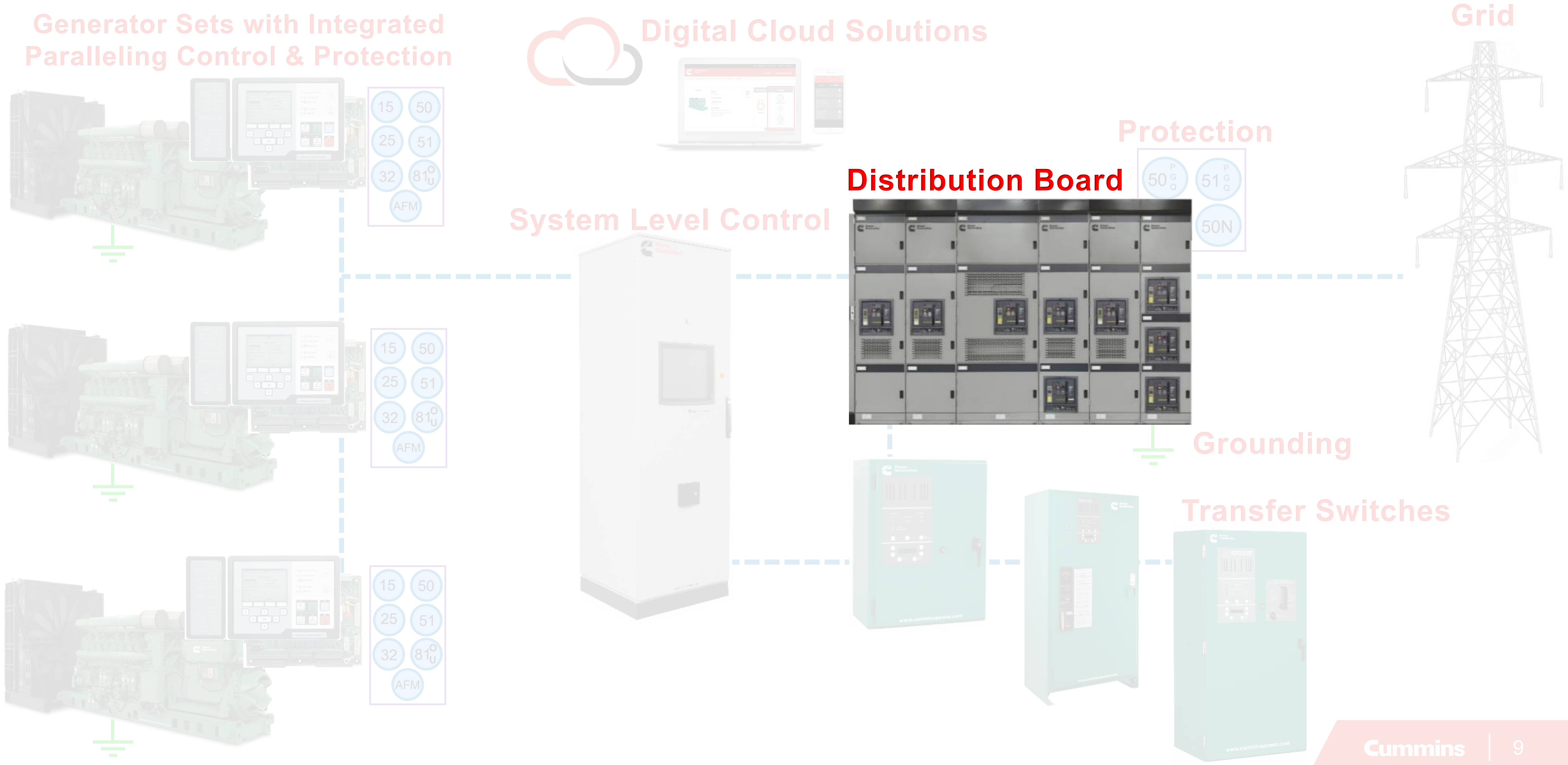
Spec Note Each generator set shall be designed to be completely autonomous and capable of providing all specified functions and performance without any external control.



- Common point of power connection
  - Bus tap (Generator mounted breakers)
  - Switchboard/Switchgear

Power System Building Blocks



Distribution Boards

- Distribution board is a means of controlling and distributing electrical power
- Distribution boards are metal structures comprised only of "power sections" and their related components
  - Switching devices: breakers, fuses
  - Conductors: bus bars, cables
  - Transformers: voltage, current
  - Protection: protective devices
- Voltages and standards:
  - Low Voltage
  - Medium Voltage
  - UL, ANSI, CSA, IEC

LV Switchboards vs. Switchgear

- **Switchboard**
- UL891
    - Dead-front Switchboard
    - Circuit breakers are typically UL489 MCCB/ICCB
        - Can contain UL-1066 breakers
    - Circuit breakers not required to be in individual compartments
    - Evaluated for short-circuit 0.05s (3 cycles) ONLY and NO short-time test
    - Instantaneous trip-response is required
    - Short-circuit 150KAIC, e.g.
    - Basic office, commercial building, and retail

- **Switchgear**
- UL1558 (IEEE C37.20.1 design & NEMA C37.51 test)
    - Metal-enclosed power circuit breaker switchgear
    - Circuit breakers are UL1066 (LVPCB)
        - No molded case circuit breakers
    - Circuit breakers required to be in separate metal compartments
    - Evaluated for short-circuit 0.067s (4 cycles) and short-time 0.5s (30 cycles)
    - Instantaneous can be turned off
    - Short-circuit 200KAIC, e.g.
    - Healthcare, hospitals

➢ UL1558 Switchgear can be 25%-30% more expensive than UL891 Switchboard

LV Switchboards vs. Switchgear

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Spec Note Evaluate the project requirements and specify a UL891 or 1558 distribution board accordingly.

➢ UL1558 Switchgear can be 25%-30% more expensive than UL891 Switchboard

MV Switchgear

- 1kV – 38kV
- No protection built-in the circuit breakers. External protection must be added
- Metal enclosed switches and metal-clad
  - Metal-clad
    - The main switching and interrupting device is of drawout type
    - All live parts are enclosed within grounded metal compartments
    - Primary bus conductors and connections are covered with insulating material
    - Automatic shutters
- Some of US Standards for switchgear over 1000 V
  - IEEE
    - C37.04 rating structure for circuit breakers
    - C37.09 Test Proc for circuit breaker
    - C37.20.2 Metal Clad switchgear
    - C37.20.3 Metal-Enclosed switchgear
    - C37.20.7 switches for use in Metal-Enclosed switchgear
    - C37.74 Pad-Mounted switchgear

Concept Check

Which of the following statements is true?

a) Switchgear contains UL 489 MCCB & ICCB and UL1006 power breakers

b) Switchboards evaluated for short-time 0.5 seconds (30 cycles)

c) Switchboards evaluated for short-circuit 0.067s (4 cycles)

d) Switchgear evaluated for short-time rating 0.5 seconds (30 cycles)

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Which of the following statements is true?

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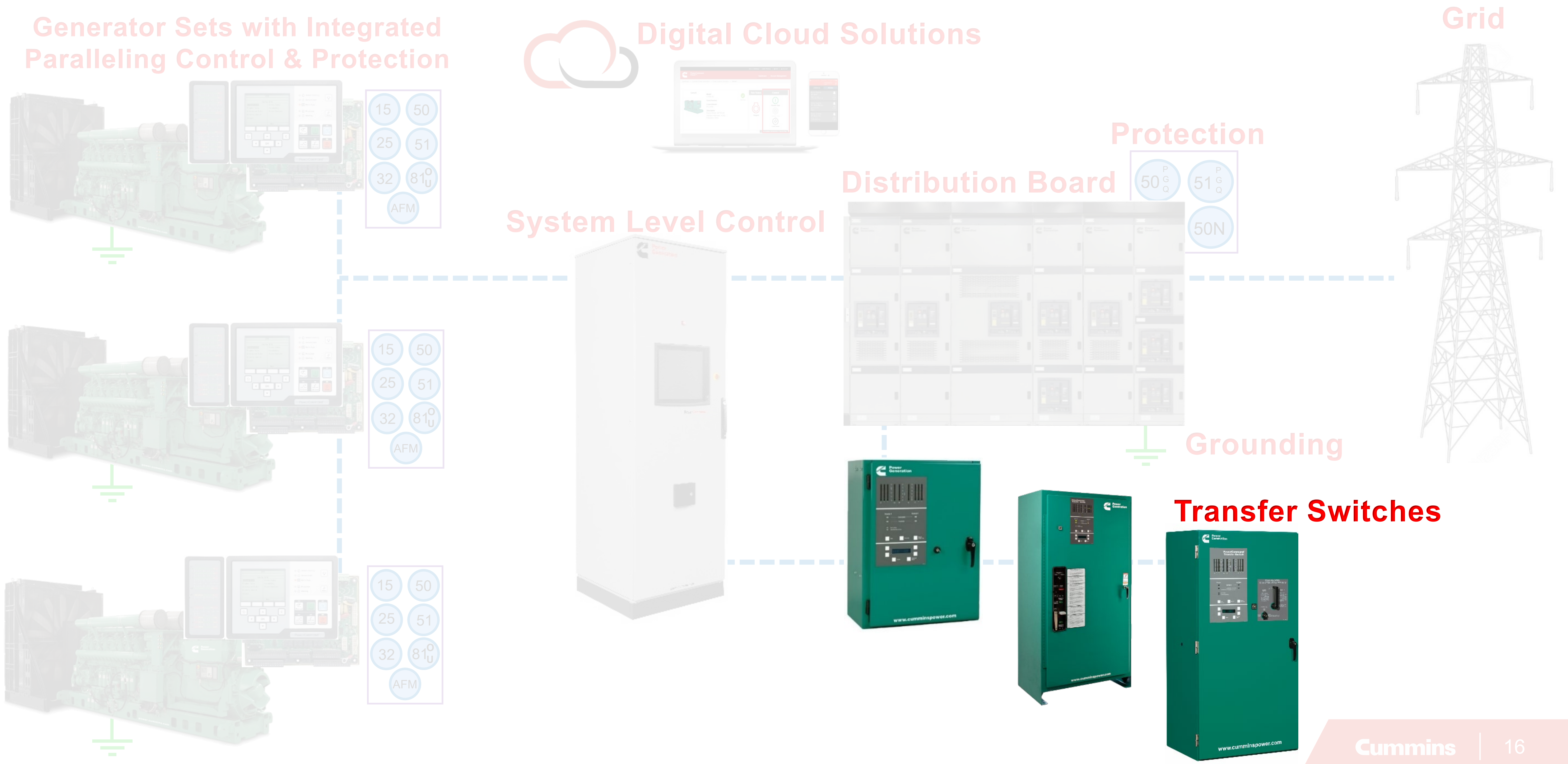
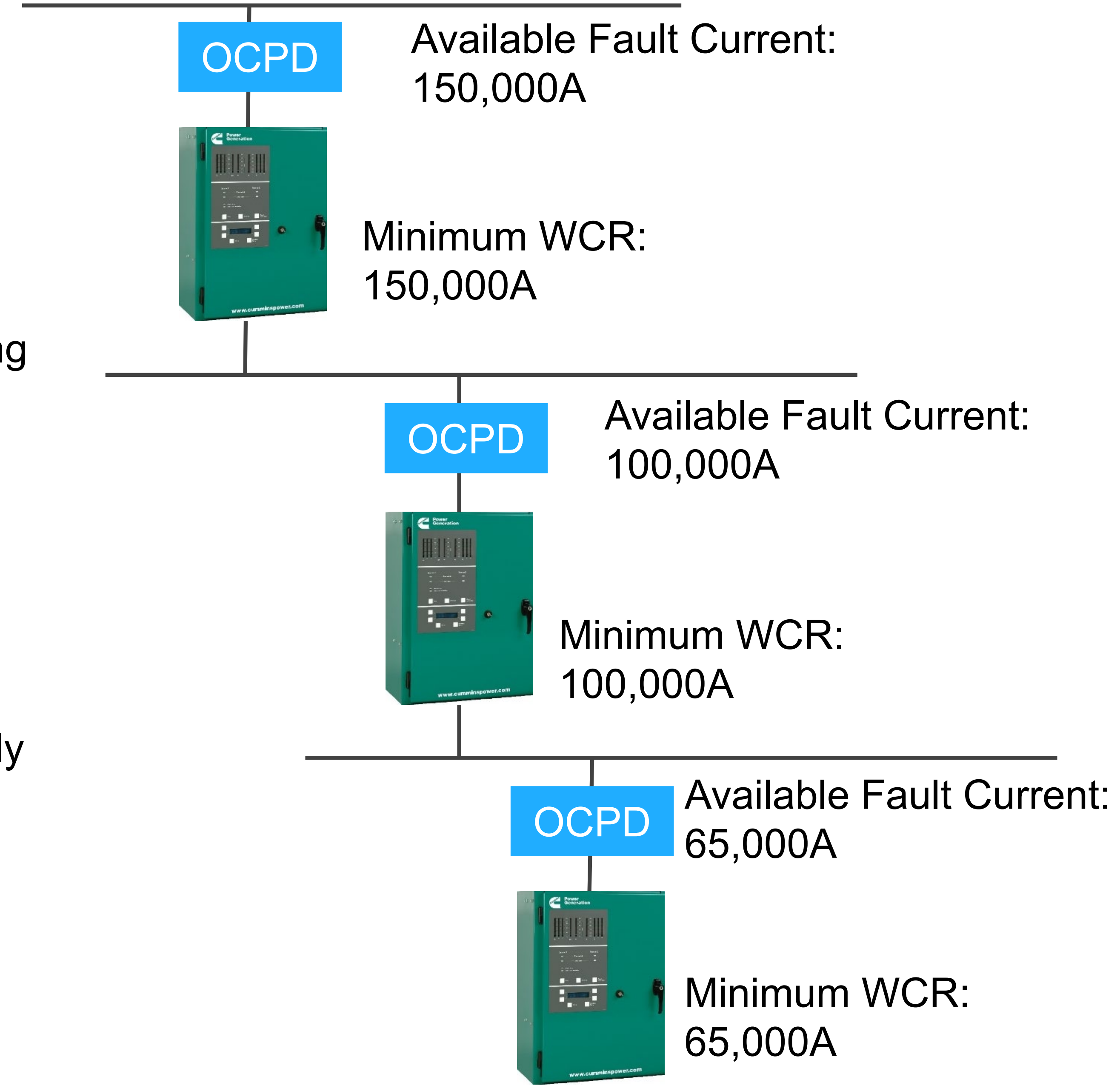
d) Switchgear evaluated for short-time rating 0.5 seconds (30 cycles)

Power System Building Blocks



ATS Consideration

- Per UL1008, ATSs must have a short-circuit rating called Withstand and Closing Rating (WCR)
  - WCR can either be based on:
    - Time
    - Specific device
- ATSs must be capable of withstanding the available fault current at their line side terminals and protected by an OCPD selected appropriately
- ATSs may have a short-time rating



OCPD: Overcurrent Protection Device

ATS Coordination

Figure 1

UL891 Switchboard

Breaker has instantaneous trip response

AFC: 65,000A

Short-Circuit Rating:
65,000A @600 VAC
for 0.05 seconds (3 Cycles)

Figure 2

UL1558 Switchgear

Breaker has short-time trip response. Instantaneous is turned OFF
AFC: 42,000A

Short-Circuit Rating:
42,000A @600 VAC
for 0.5 seconds (30 Cycles)

- In Figure 1, the ATS is fed by a UL891 switchboard
  - The circuit breaker must include an instantaneous trip response
  - Circuit breaker must trip in 0.05s (3 cycles) or faster

- In Figure 2, the ATS is fed by a UL1558 switchgear
  - UL-1066 breaker have a short-time trip response, ATS may need to have a short-time rating
  - The circuit breaker must include an instantaneous trip response unless the available short circuit current is less than or equal to short-time rating of the transfer switch
  - When protected with a circuit breaker with a short-time trip response, the short-time response of the circuit breaker must be coordinated with short-time current rating of the ATS

AFC: Available Fault Current

Concept Check

Transfer Switches fed by UL891 board must have a short-time rating of, e.g.,18 cycles or 30 cycles:

a) True

b) False

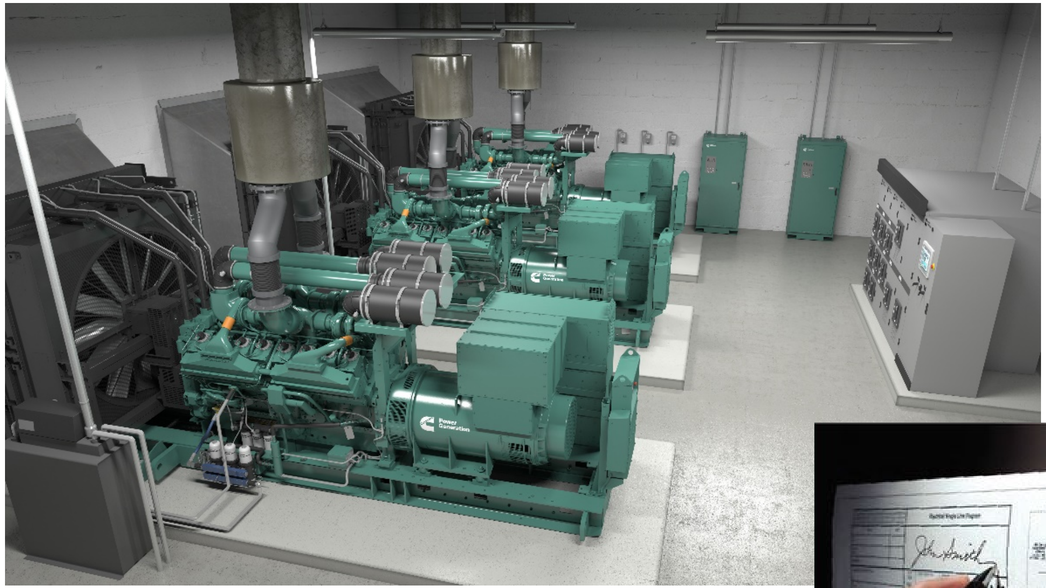
Concept Check

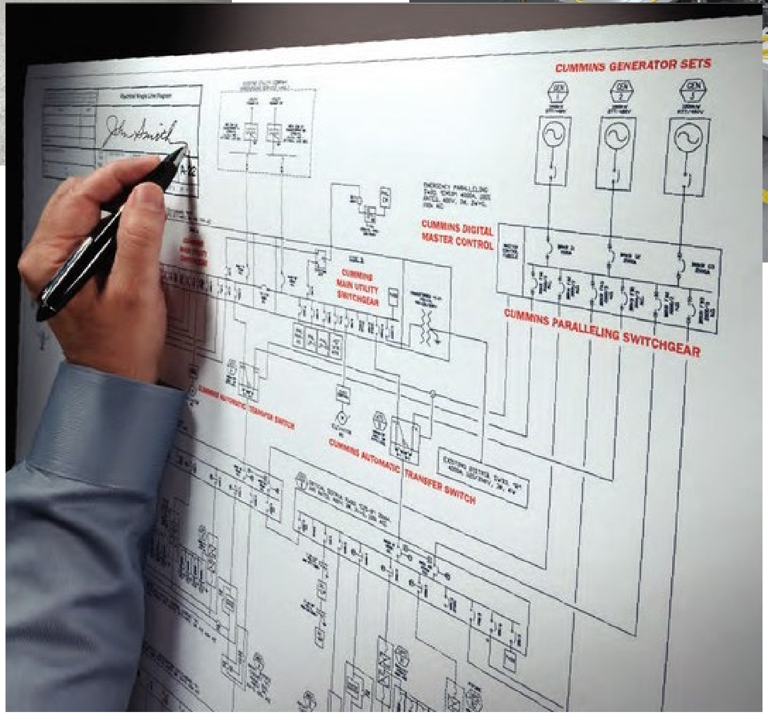
Transfer Switches fed by UL891 board must have a short-time rating of, e.g.,18 cycles or 30 cycles:

a) True

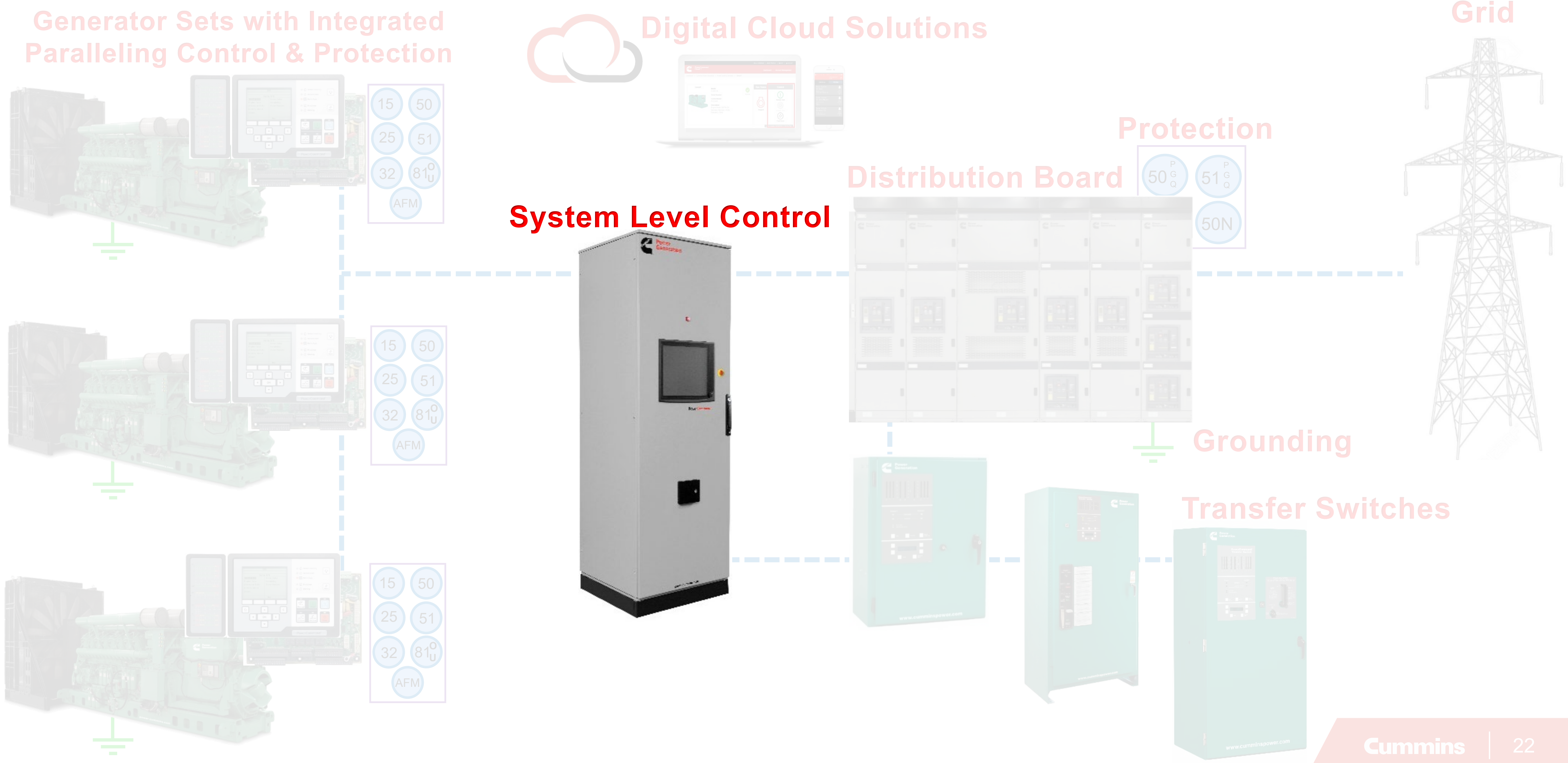
b) False

Power System Design



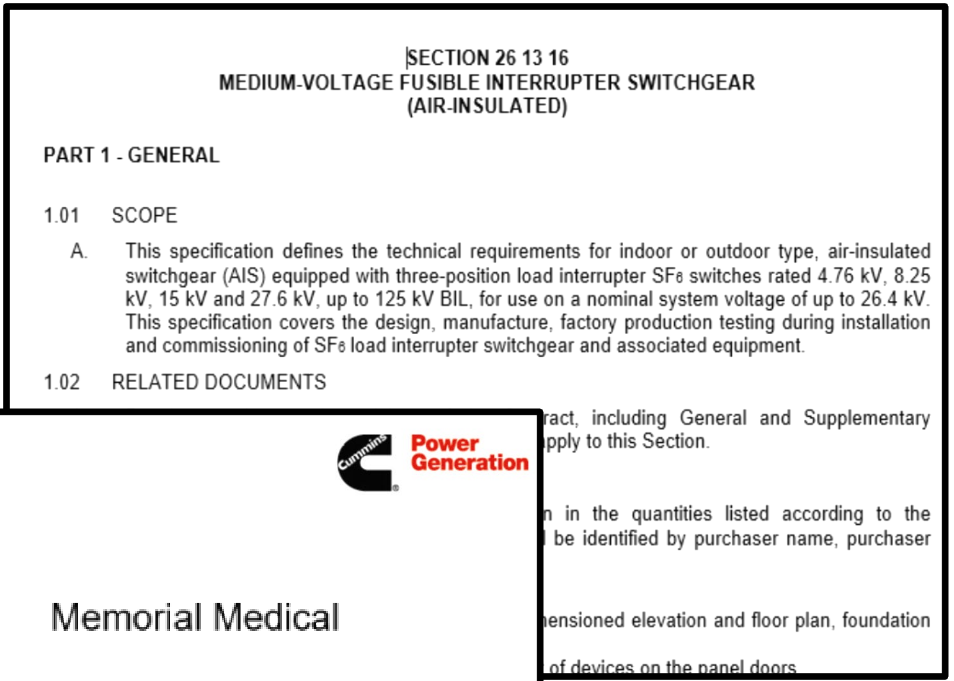


Power System Building Blocks



System Design Consideration

- Project Scope
    - Sequence of Operation
    - Plans and Specifications
- System voltage, wires, and frequency
    - 480V, 600V, 13.8kV,
    - 3Phase/4Wire, 3Phase/3Wire
    - 50/60Hz



SECTION 26 13 16
MEDIUM-VOLTAGE FUSIBLE INTERRUPTER SWITCHGEAR
(AIR-INSULATED)

PART 1 - GENERAL

1.01 SCOPE

A. This specification defines the technical requirements for indoor or outdoor type, air-insulated switchgear (AIS) equipped with three-position load interrupter SF_6 switches rated 4.76 kV, 8.25 kV, 15 kV and 27.6 kV, up to 125 kV BIL, for use on a nominal system voltage of up to 26.4 kV. This specification covers the design, manufacture, factory production testing during installation and commissioning of SF_6 load interrupter switchgear and associated equipment.

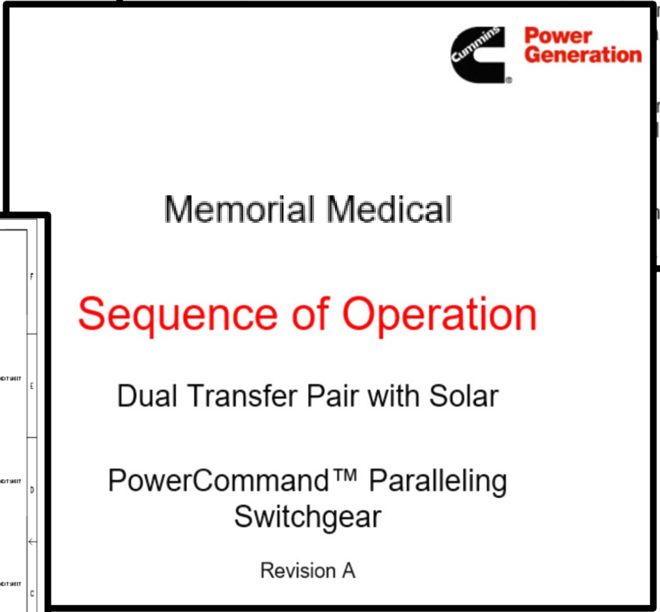
1.02 RELATED DOCUMENTS

…ract, including General and Supplementary …pply to this Section.

…n in the quantities listed according to the …l be identified by purchaser name, purchaser

…ensioned elevation and floor plan, foundation

…of devices on the panel doors



Power Generation

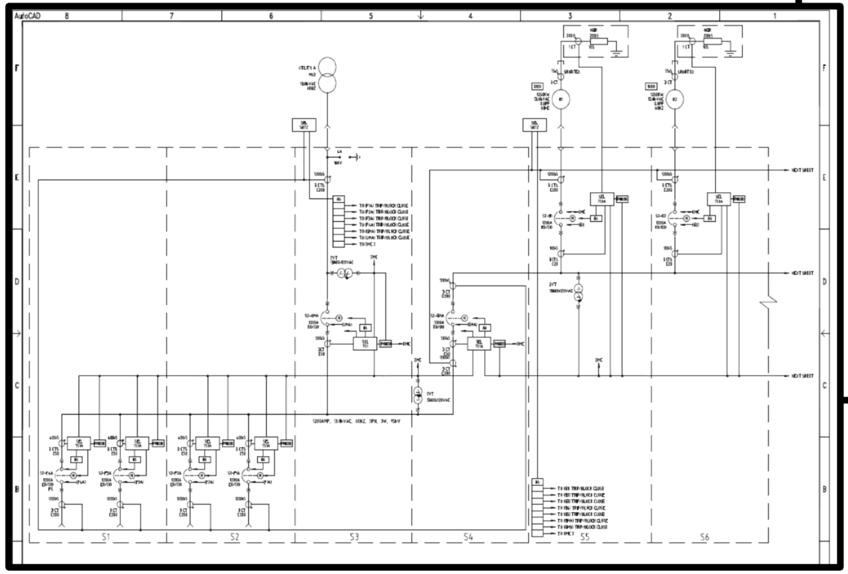
Memorial Medical

Sequence of Operation

Dual Transfer Pair with Solar

PowerCommand™ Paralleling Switchgear

Revision A

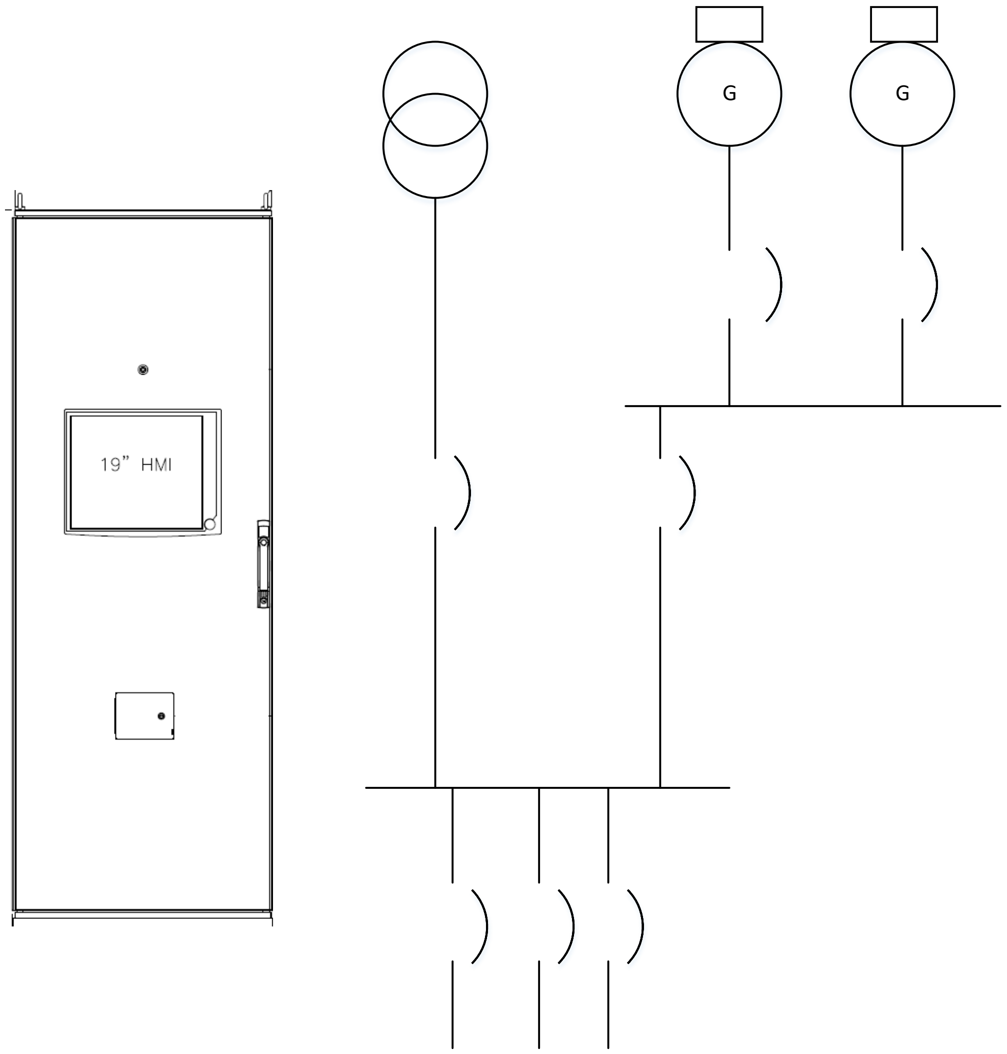


Distribution Board Considerations

- Distribution board codes and standards
  - CSA 22.2, UL891, UL1558 – Low Voltage
  - IEEE (C37.20.2) and NEMA – Medium Voltage
- Bus rating and bracing
  - 2000A, 3000A, 4000A, 5000A (LV)
  - 1200A, 2000A, 3000A (MV)
  - 65KAIC, 100KAIC, 200KAIC
- Bus type and insulation
  - Copper, aluminum
  - Silver-plated, tin-plated
  - Insulated
- Conduit entry
  - Top, bottom, sides
- Rear and front door types
  - Hinged, bolts, door handles, locks
- Enclosure types
  - NEMA1, NEMA3R (Walk-In, Non Walk-In)
- Control voltage for the circuit breakers
  - 24VDC, 48VDC, 125VDC, 120VAC
  - CPTs (Control Power Transformers)
  - Station batteries with charger and alarms
- Surge arrestors and capacitors and their classes
- Arc flash reduction switches
- Real estate available
- Protection – grounding and coordination
- Utility connection and type of connection and operation
- Accessories and spare parts

Utility Connection Considerations

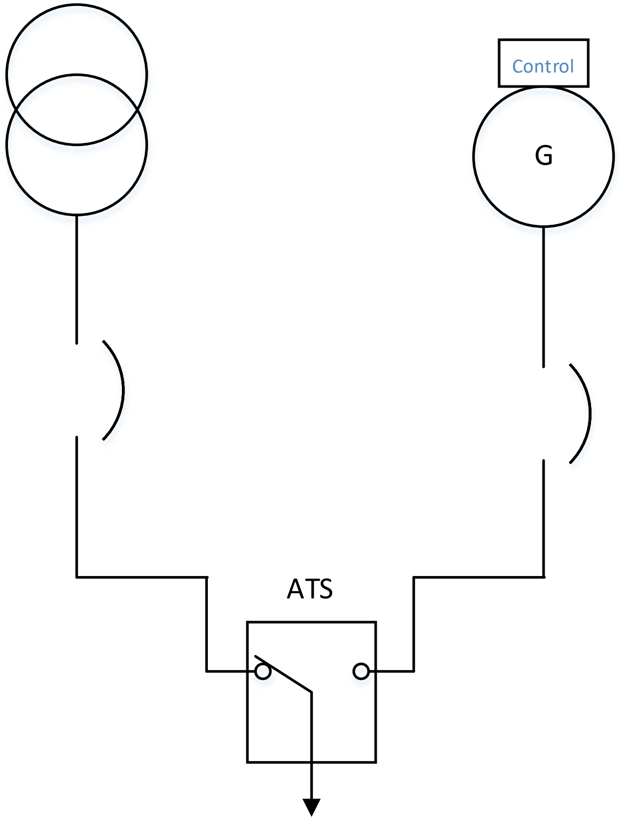
- Understand the intertie agreement with the utility
- Utility connections:
  - Hard-closed
    - 100ms or less
    - Some utilities allow longer time
  - Soft-ramp: long enough to ramp the load
    - Time is determined by the utility and AHJ
  - Extended paralleling: indefinite amount of time
    - Peak shave/base load
    - Demand response
- Protection
  - Sync check, reverse power, under/over voltage & frequency, and lockout
  - External max parallel timer (depends on the application)



Power System Examples

Example 1

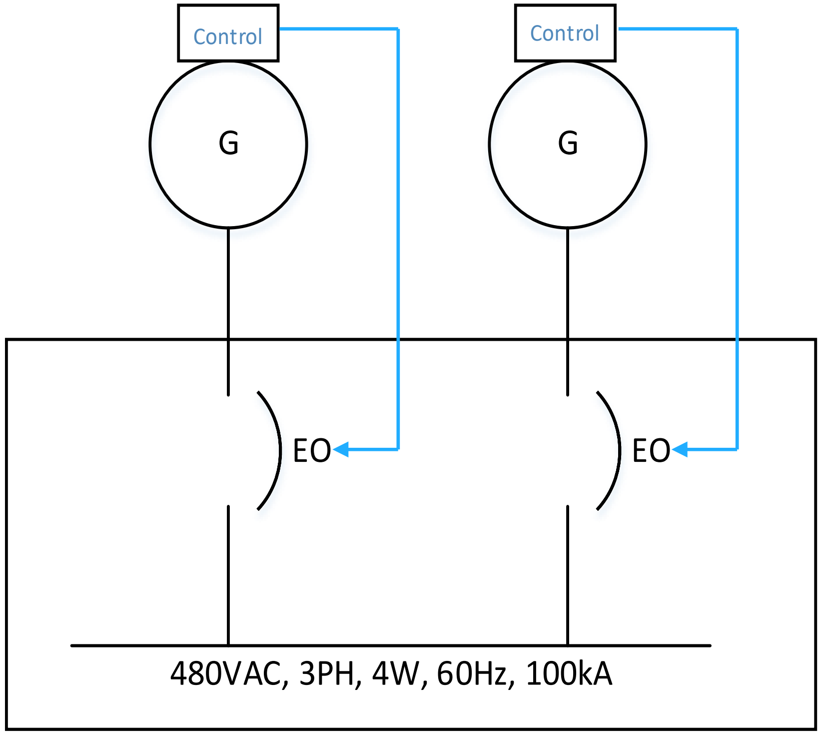
- An office requires a 120kW backup power when the normal source fails - open transition:
  - A generator set and a transfer switch



Paralleling Generators

Example 2

- An application requires paralleling two 500kW generator sets (campus building):
  - Two generator sets with paralleling control
  - Point of common connection
    - Switchboard, e.g., with two electrically operated (EO) circuit breakers

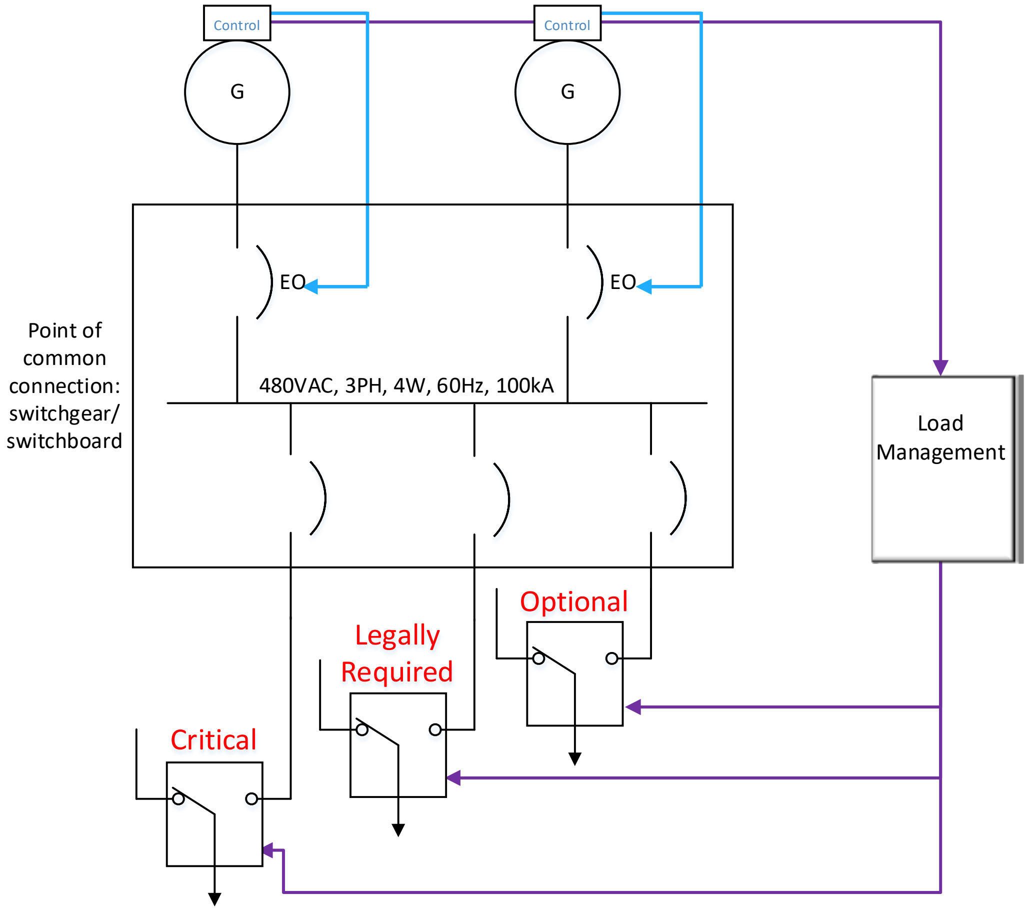


Point of common connection: switchgear/switchboard

Adding Load Control Capability

Example 2 Cont.

- If we add three transfer switches to the project in Example 2 and also add a feature for priority load add/shed on the transfer switches
- NEC 2017- 700.4 (B)

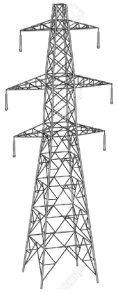


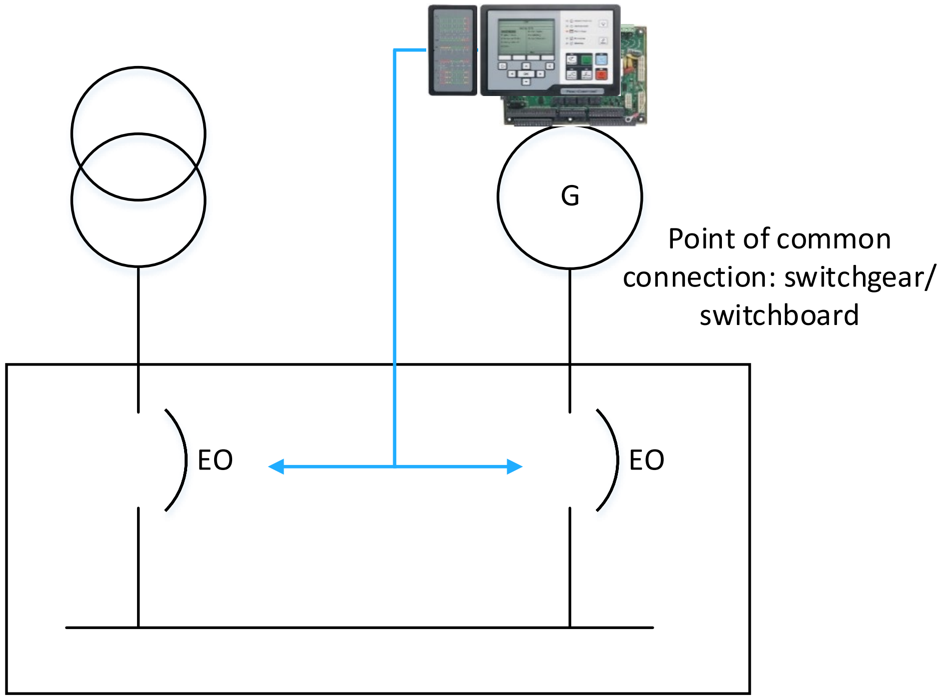
Utility Paralleling Example

Example 3

- One utility and one generator set (LV or MV)
- Open/Closed transition
  - Extended paralleling: peak shave/base load
- Point of common connection
  - Switchboard, e.g. with two electrically operated circuit breakers
- Controller: to perform the sequence of operation
  - e.g. generator set controller
- Utility breaker protection: 25, 27, 32R, 59, 81O/U and 86
  - e.g. SEL 751



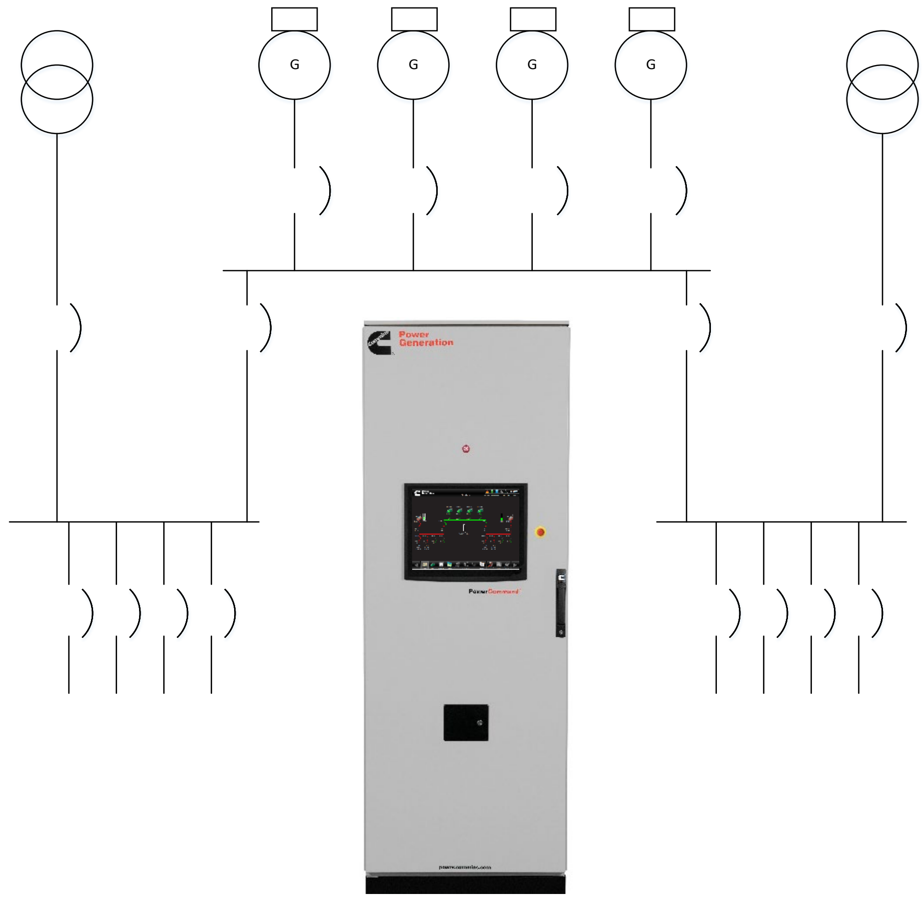


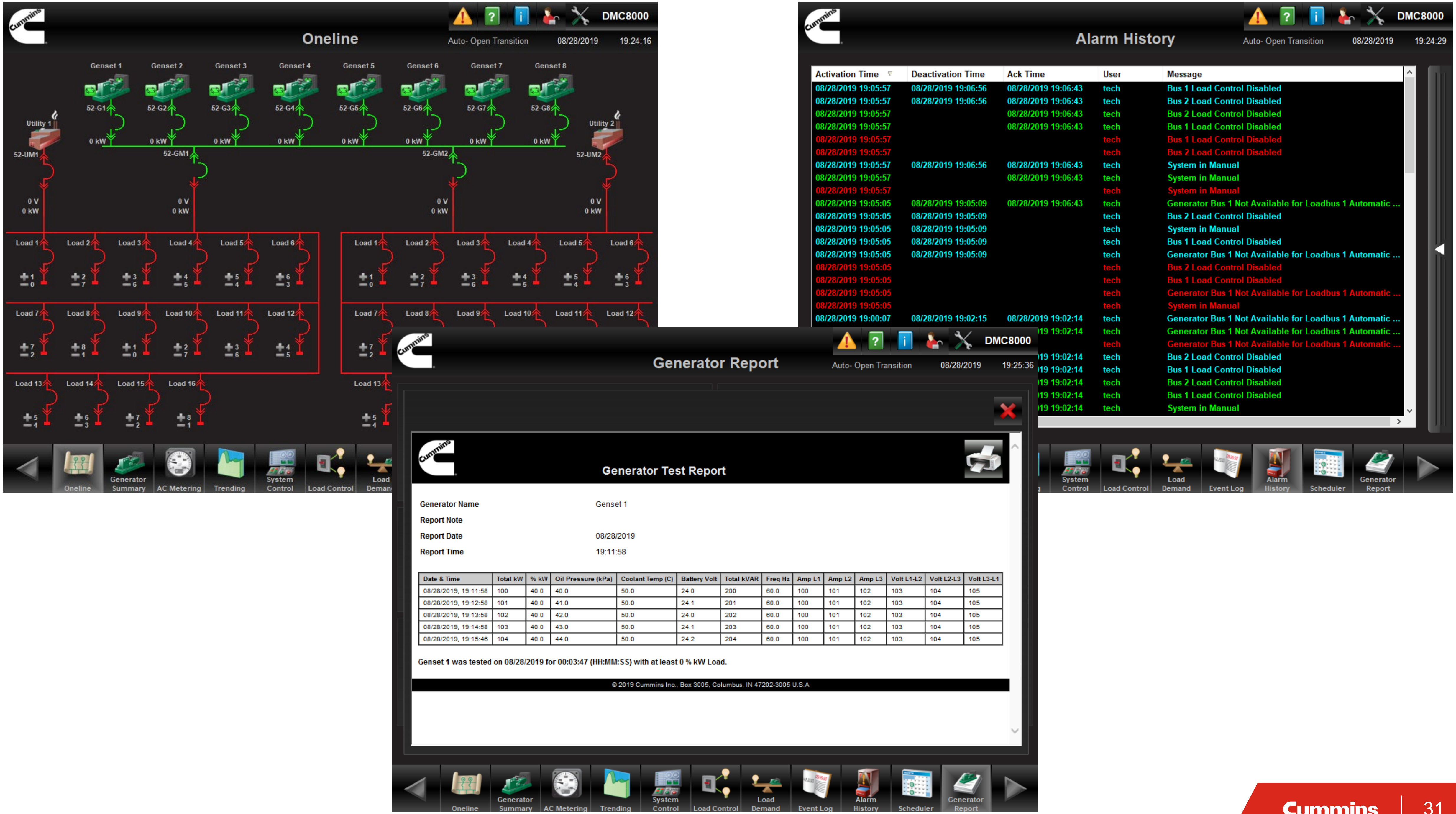


System Level Control

Example 4

- Extensive sequence of operation with layers of failure logic
- Parallel multiple generators with a utility or multiple utilities
- Multi system level breaker control
  - Utility main breakers
  - Generator main breakers
  - Tie breakers
  - Downstream feeders and transfer switches
- A touchscreen operator interface HMI with SLD
- Reports (e.g. JCAHO), alarms, trending
- Redundant processors and redundant I/O
- A system level control is a solution!
- Applications: Healthcare, Data Centers, Water/Waste Water. Limitless!





Generator Test Report

Generator Name Genset 1

Report Note

Report Date 08/28/2019

Report Time 19:11:58

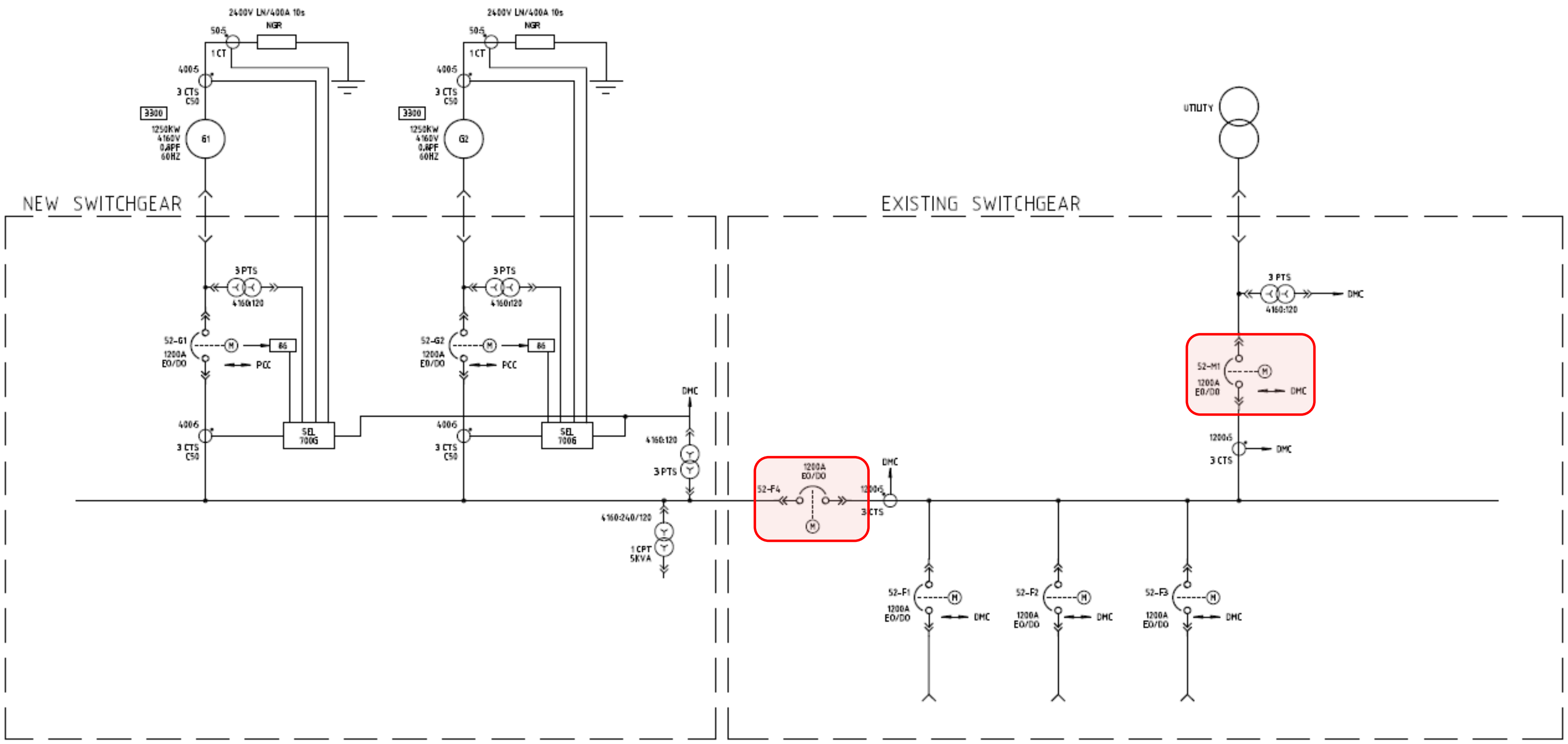
Date & Time	Total kW	% kW	Oil Pressure (kPa)	Coolant Temp (C)	Battery Volt	Total kVAR	Freq Hz	Amp L1	Amp L2	Amp L3	Volt L1-L2	Volt L2-L3	Volt L3-L1
08/28/2019, 19:11:58	100	40.0	40.0	50.0	24.0	200	60.0	100	101	102	103	104	105
08/28/2019, 19:12:58	101	40.0	41.0	50.0	24.1	201	60.0	100	101	102	103	104	105
08/28/2019, 19:13:58	102	40.0	42.0	50.0	24.0	202	60.0	100	101	102	103	104	105
08/28/2019, 19:14:58	103	40.0	43.0	50.0	24.1	203	60.0	100	101	102	103	104	105
08/28/2019, 19:15:46	104	40.0	44.0	50.0	24.2	204	60.0	100	101	102	103	104	105

Genset 1 was tested on 08/28/2019 for 00:03:47 (HH:MM:SS) with at least 0 % kW Load.

System Level Control Reliability

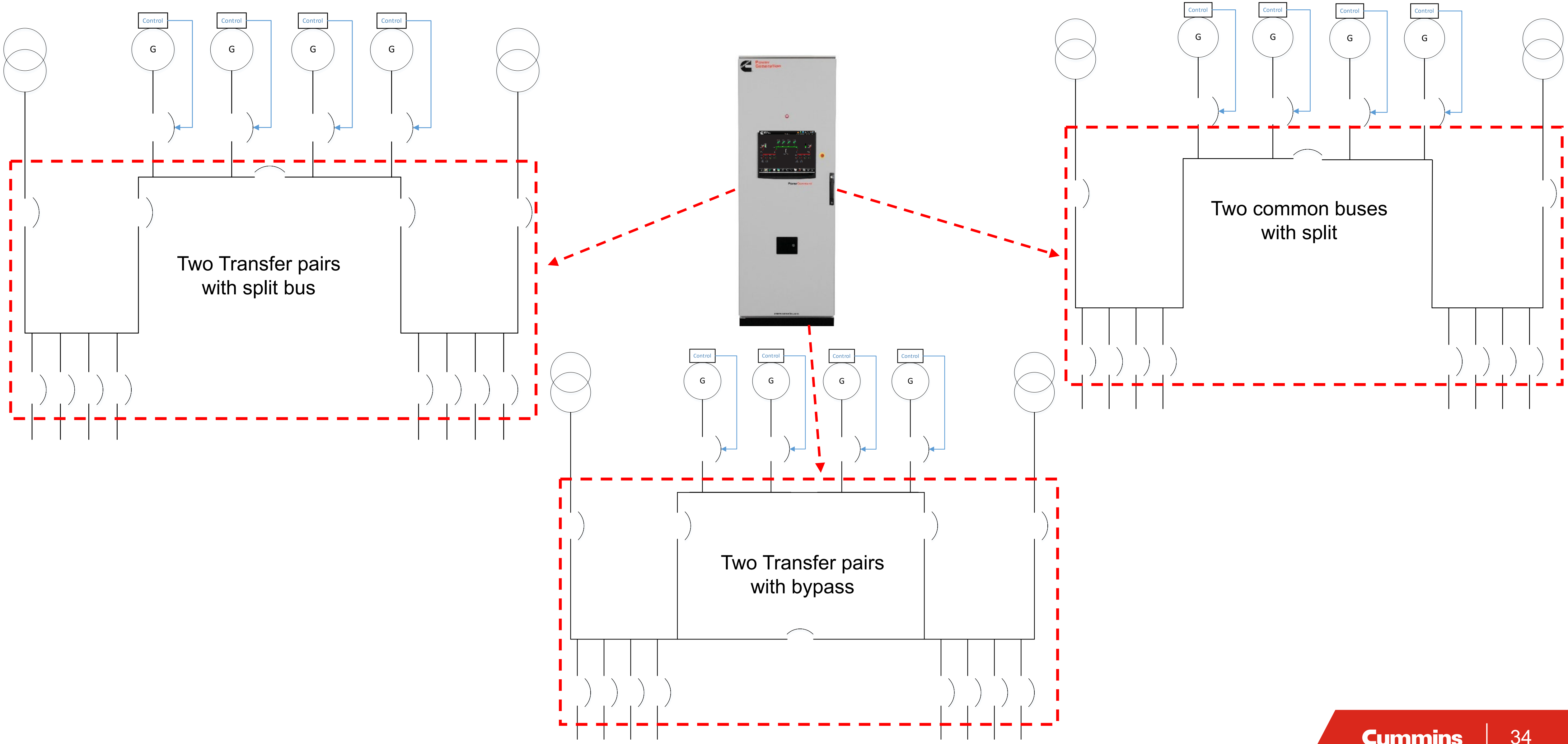
- Failure of the system level control shall not jeopardize the overall power system reliability
- Some of the components that can fail:
  - HMI (screen)
  - PLC
  - Networking devices: I/O cards, communication
- Failures must be analyzed and mitigated so the system fails gracefully
  - Continuous system diagnostics of controller, network, and I/O cards
  - With HMI failure, the system should be able to transfer power
    - System can be operated manually if needed
    - Generators can be started manually
    - Generators can be paralleled manually through their local control/HMI
  - Unexpected events, i.e. racking out a UM breaker while the system in Auto

Failure Design Rule Example

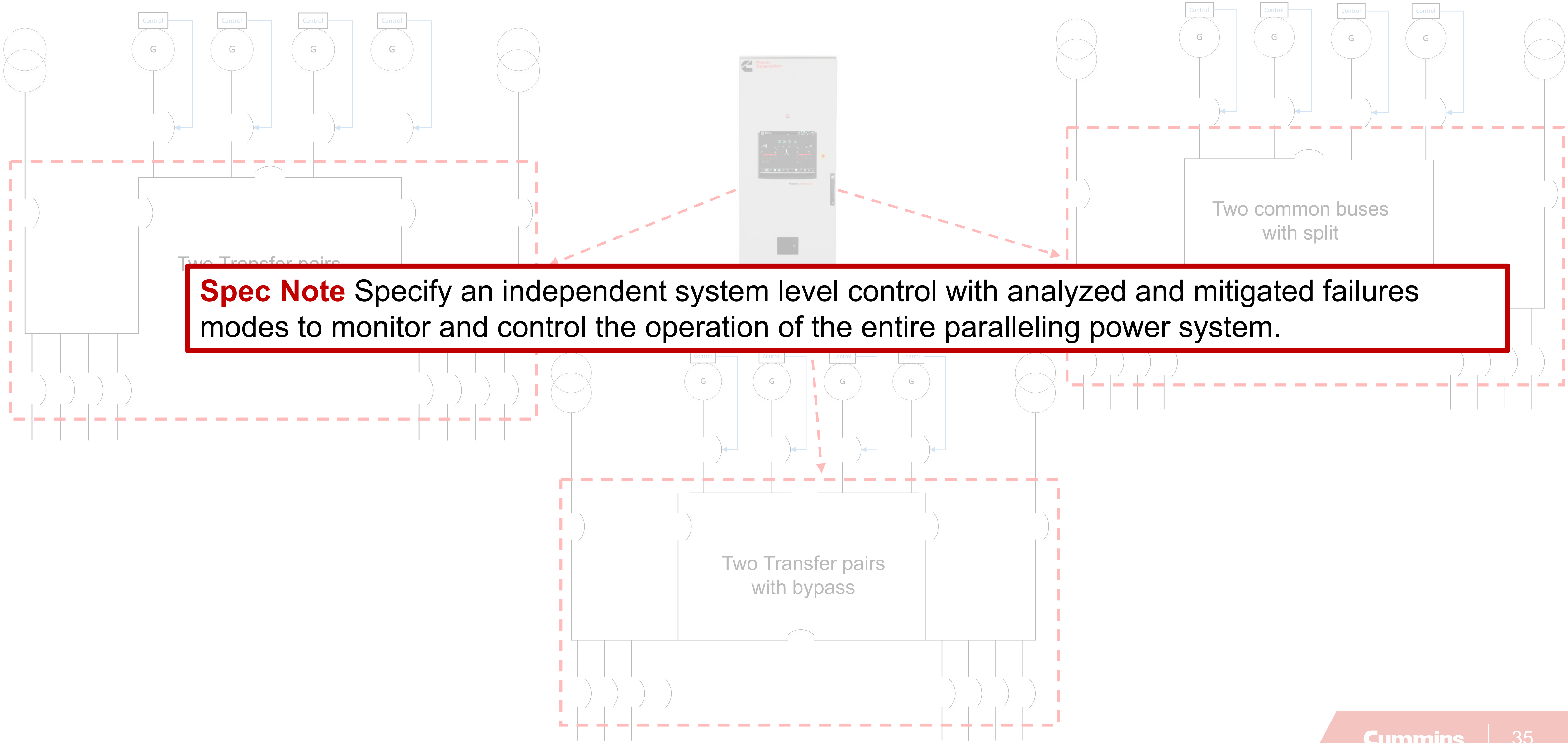


- Breaker States:
  - Open
  - Closed
  - Unknown
- If the status is unknown, then how does the system behave?
- Failures must be analyzed and mitigated

System Level Control Boundaries

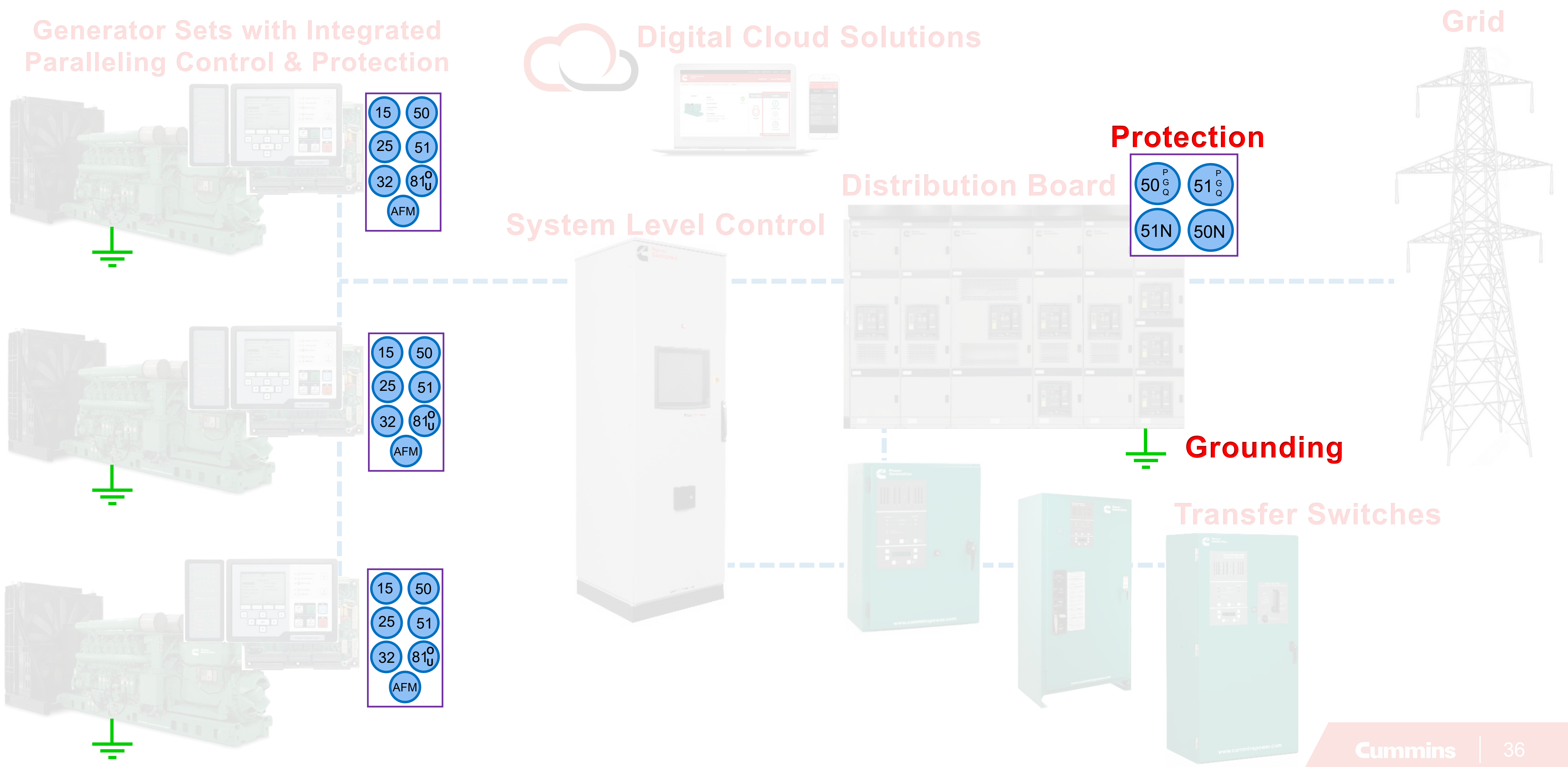


System Level Control Boundaries



Spec Note Specify an independent system level control with analyzed and mitigated failures modes to monitor and control the operation of the entire paralleling power system.

Power System Building Blocks

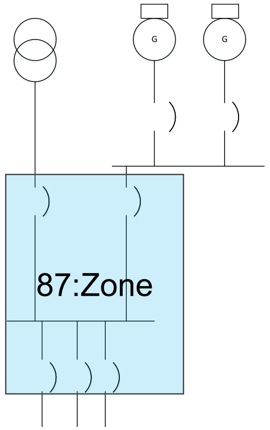


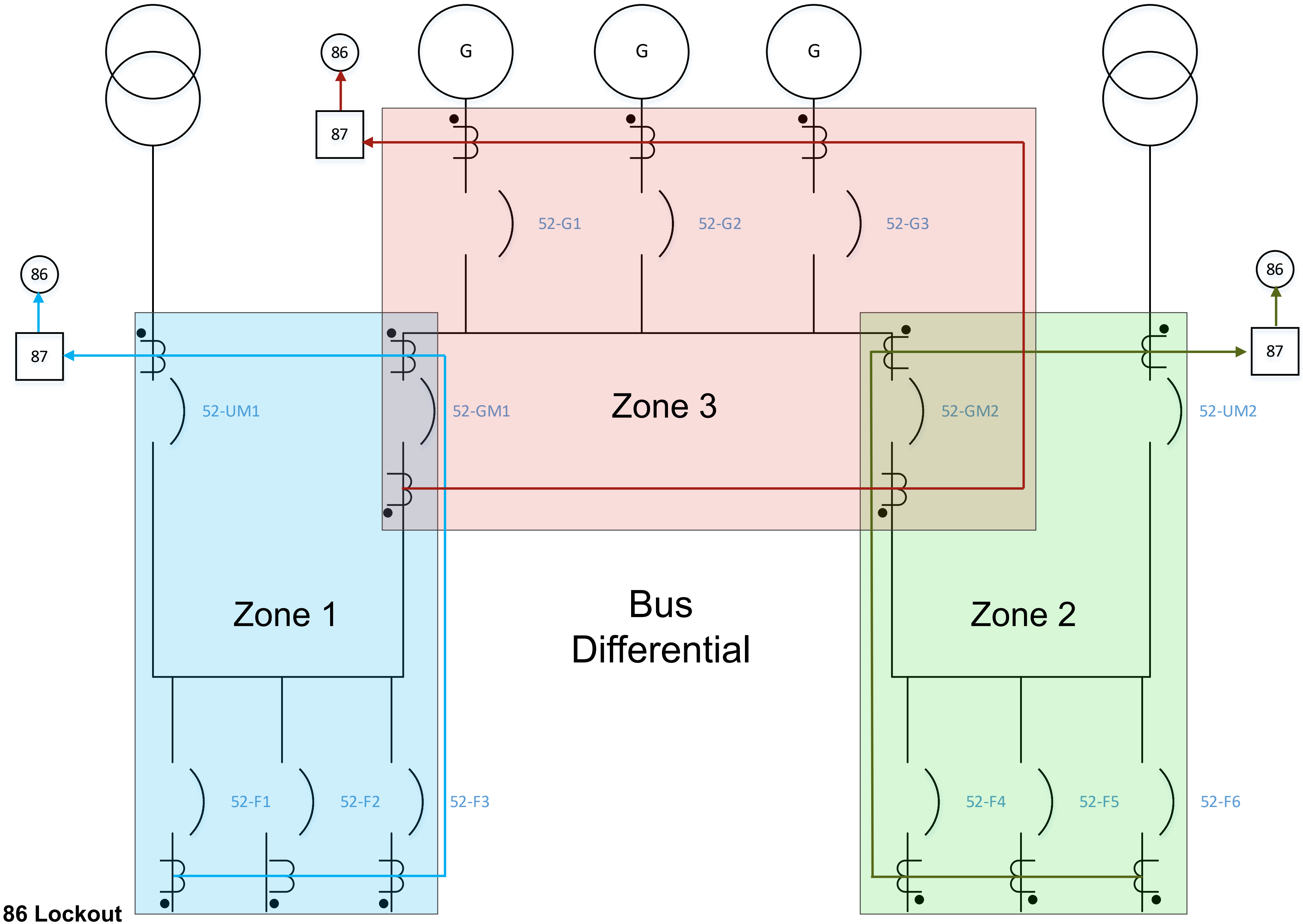
Protection

- Typical protection (not inclusive):

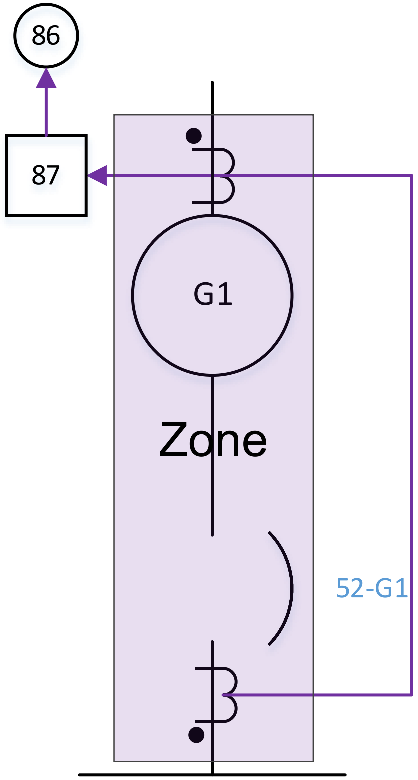
Breaker	Low Voltage	Medium Voltage
	Integrated with the breaker	**Discreet external relay**
Feeder	LSI, LSIG	50/51, 50/51N, 51G, 86
Gen Paralleling	LSI, LSIA	50/51, 50/51N, 51G, 86
Utility	LSI, LSIG External Relay: 25, 27, 32R, 59, 81O/U & 86	25, 27, 32R, 50/51, 59, 81O/U, 86
Tie	LSI, LSIG, External Relay: 25	50/51, 25, 86

- Other protection considerations:
  - 81R
  - 87
  - AFD





Bus Differential



Generator Set Differential

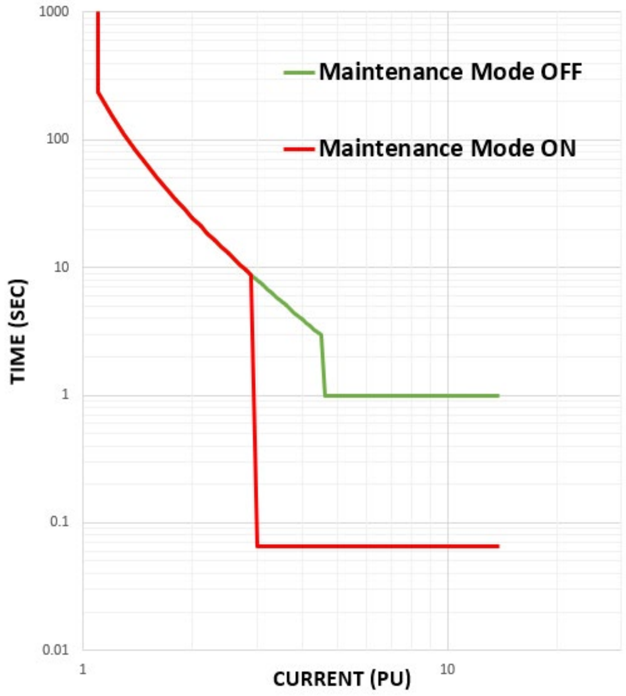
Is it necessary?

- 86 Lockout
- 87 Differential

Protection: Generator Set

15 – Synchronizer (Ø, V, Hz)
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

Arc Flash Maintenance Mode



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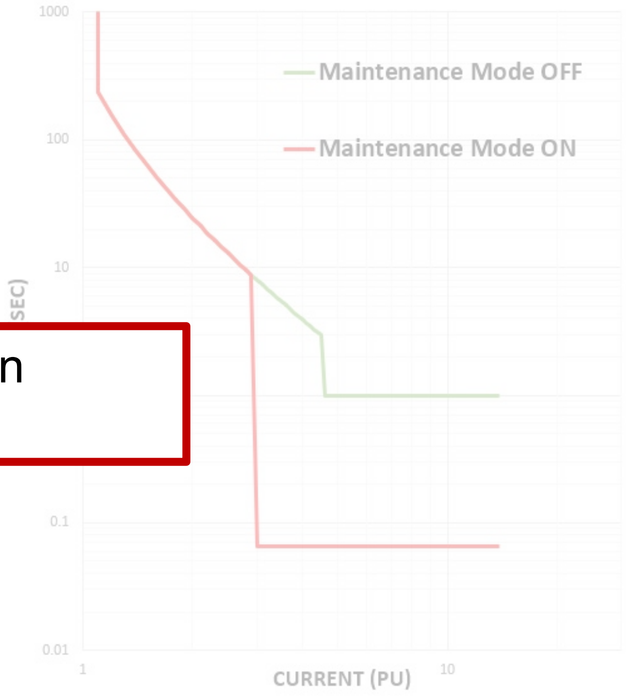
Spec Note Each generator set shall be provided with integral protection functions to prevent damage on overload or overcurrent condition.

59 – Overvoltage

81U/O – Under/Over Frequency

Arc Flash Maintenance Mode



Grounding: Why Is It Required?

- It provides common reference for the different power sources
- It prevents voltages from rising to dangerous levels
  - Safety to working personnel and equipment
- It is required by code
- It provides the path for ground fault current to return back to the source thus allowing current detection relays to operate and isolate the fault source

NEC 230.95 (CEC 14-102)

Ground Fault Protection (GFP) of equipment is required at the **service** disconnect (utility breaker) for systems with:

- **Solidly grounded wye electrical service**
- **More than 150 volts to ground (277/480 or 347/600VAC)**
- **Overcurrent device rating of 1000A or more (CEC 120/208VAC & 2000A)**

NEC 700.6 (D)

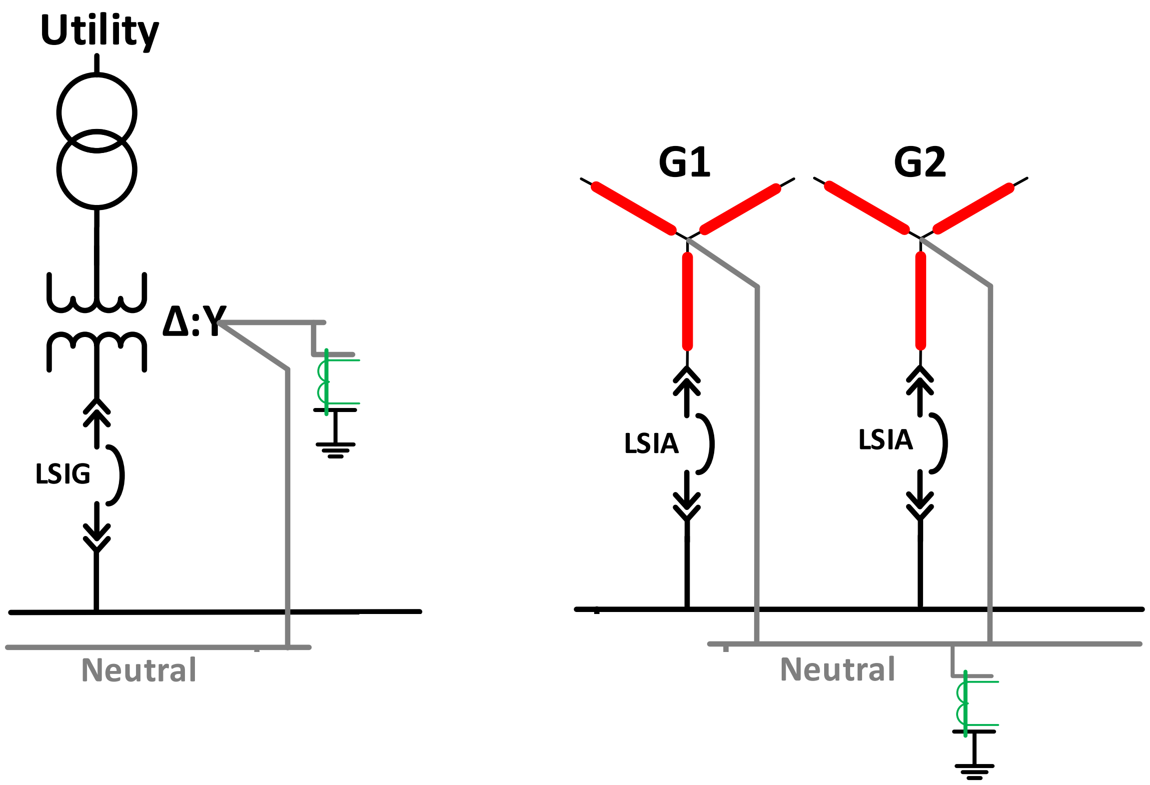
Ground Fault Indication (GFI) is required at the **emergency source**

Questions To Consider For Grounding Schemes

- Is the system 3Ph/3Wire or 3Ph/4Wire?
- Are the ATSs in the system 3-Pole or 4-Pole?
- Is the system open transition or closed transition?
- Does the system have multiple grounds?
  - For example: utilities are grounded at source and generator sets are grounded in switchgear
- Are there tie breakers between the source breakers?
- Is there space available to install 4-Pole breakers instead of 3-Pole breakers in open transition system?
- Does the utility breaker have LSIG trip unit and do generator breakers have LSIA trip units?
- All of the above will help in narrowing down the number of solutions to properly ground the system

Grounding Example

- 3Ph/4Wire
- Open transition
- Utility grounded at the source
- Generator grounded in the gear
- Breakers are 3-Pole
- LSIG on the utility
- LSIA on the generators
- 4-Pole ATSs must be used



Course Summary

Paralleling Power System Design Considerations and System Level Control

- Discuss the major differences between switchboards and switchgear (UL891 and UL 1558)
- Describe transfer switch design considerations in a power system scheme
- Describe the functionalities and applications of a system level control and how it fits in a power system
- Discuss protection and ground fault considerations

Specify:

- Write specifications based on functions and performance
- Integrated paralleling and protection control for the generator set paralleling aspect
- Distribution board (LV):
  - UL891 when 3-cycles meets the system requirements
  - UL1558 when 30-cycles might be needed. Make sure it is truly required for the application and the electrical system matches the requirement
- Specifying an ATS with a Withstand and Closing Rating (WCR) is sufficient when the ATS is fed by a UL891 distribution board
- System level control with analyzed and mitigated failures modes for controlling and monitoring the entire paralleling/distribution system
- When specifying a ground fault scheme, work closely with the supplier to ensure the best and most cost effective solution is utilized

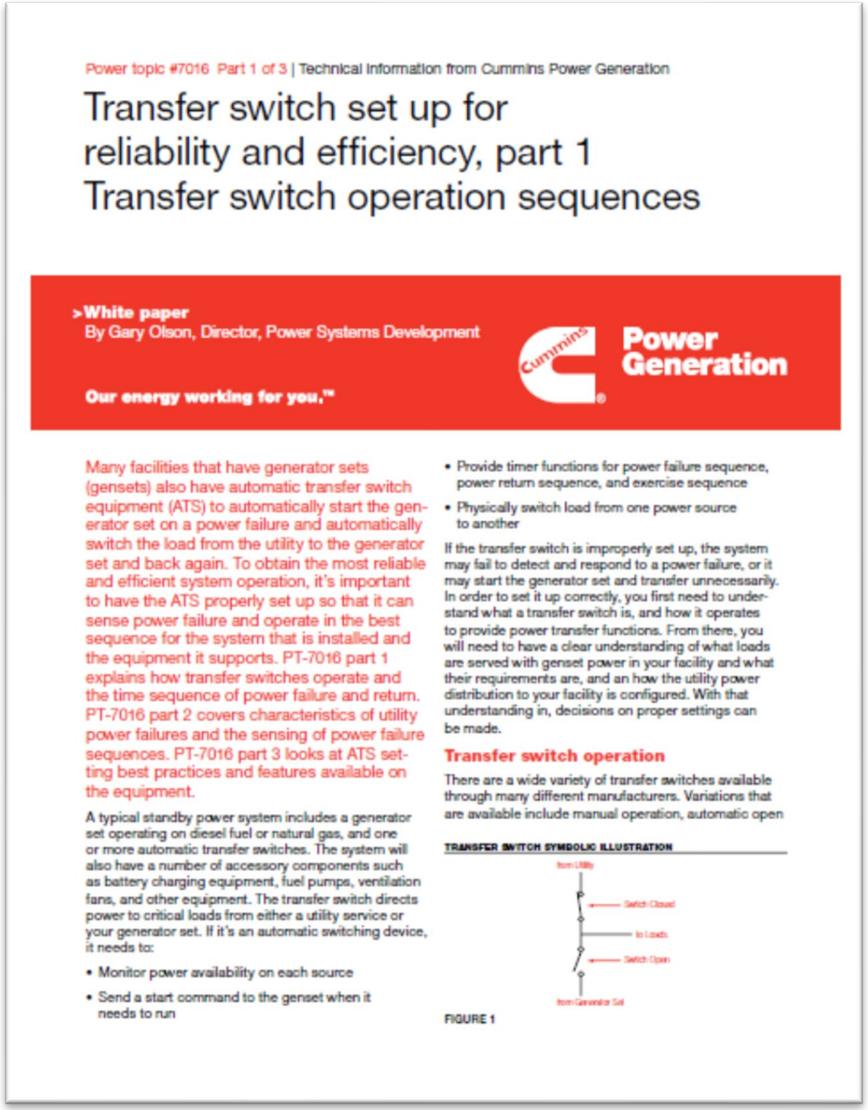
Additional Resources

Cummins White Papers

- Transfer switch set up for reliability and efficiency, parts 1, 2 & 3
- Generator Protection And Disconnect Requirements
- UL 1008 Withstand and Close on Ratings
- Considerations When Paralleling Generating Sets
- Design considerations for generator set mounted paralleling breakers
- Reliability Considerations in Simple Paralleling Applications

Cummins On-Demand Webinars

- Functions and Features of Generator Set Control Based Paralleling
- Transfer Switch Operation and Application


Power topic #7016 Part 1 of 3 | Technical information from Cummins Power Generation

Transfer switch set up for reliability and efficiency, part 1
Transfer switch operation sequences

>White paper
By Gary Olson, Director, Power Systems Development

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Power Generation

Many facilities that have generator sets (gensets) also have automatic transfer switch equipment (ATS) to automatically start the generator set on a power failure and automatically switch the load from the utility to the generator set and back again. To obtain the most reliable and efficient system operation, it's important to have the ATS properly set up so that it can sense power failure and operate in the best sequence for the system that is installed and the equipment it supports. PT-7016 part 1 explains how transfer switches operate and the time sequence of power failure and return. PT-7016 part 2 covers characteristics of utility power failures and the sensing of power failure sequences. PT-7016 part 3 looks at ATS setting best practices and features available on the equipment.

A typical standby power system includes a generator set operating on diesel fuel or natural gas, and one or more automatic transfer switches. The system will also have a number of accessory components such as battery charging equipment, fuel pumps, ventilation fans, and other equipment. The transfer switch directs power to critical loads from either a utility service or your generator set. If it's an automatic switching device, it needs to:

- Monitor power availability on each source
- Send a start command to the genset when it needs to run
- Provide timer functions for power failure sequence, power return sequence, and exercise sequence
- Physically switch load from one power source to another

If the transfer switch is improperly set up, the system may fail to detect and respond to a power failure, or it may start the generator set and transfer unnecessarily. In order to set it up correctly, you first need to understand what a transfer switch is, and how it operates to provide power transfer functions. From there, you will need to have a clear understanding of what loads are served with genset power in your facility and what their requirements are, and an how the utility power distribution to your facility is configured. With that understanding in, decisions on proper settings can be made.

Transfer switch operation

There are a wide variety of transfer switches available through many different manufacturers. Variations that are available include manual operation, automatic open

TRANSFER SWITCH SYMBOLIC ILLUSTRATION

FIGURE 1

Q&A

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

We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

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Closing

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- A PDH Certificate

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Upcoming PowerHour Webinars:

- September 24th – Generator Set Overcurrent Protection
- October – Generator Set ISO 8528 Ratings

Please contact Mohammed Gulam if you have any questions related to the PowerHour webinar (mohammed.gulam@cummins.com)

Q+A


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