Common failure modes of Data Center back up power systems

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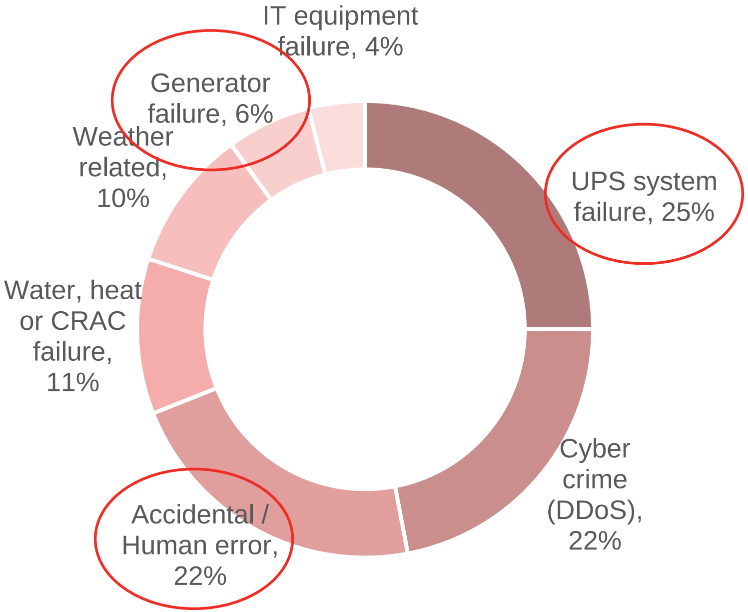
Introduction

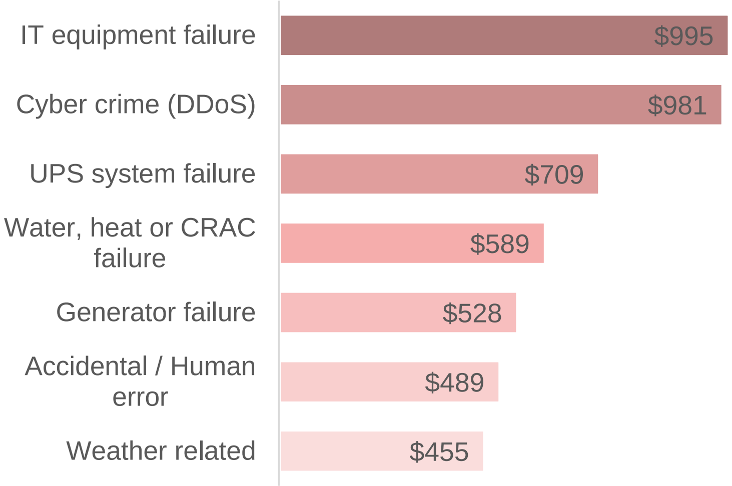
- Data Centers are designed for high reliability but still very often something goes wrong.
- The facilities are complex systems depending on both human and technology activity.
- The most common reason a data center goes down is due to a power failure.
- Virtually all failures can be linked back to errors in the design, testing, maintenance or operation of the facility.

Data Center outage is costly than ever!

Root causes for unplanned outages



Average cost per outage (k)



A unplanned data center outage costs **$740K** on average, **$8,851** per minute

Ponemon Institute© Research Report: Cost of Data Center Outages, January 2016

Recent high profile incidents…
Caused by failures in power distribution equipment and generator systems

Aug 2016, Airline business, North America

Cause

- Power surge, power / transfer switching failure, IT systems corrupted

Impact

- All operational systems in NA
- 1800 flights cancelled
- Exp.10% quarterly earnings down

2016 datacenter failures highlight growing complexity, high-profile consequences, 451 Research, October 2016

Sep 2016, Colocation Data Center, UK

Cause

- Fault in the high-voltage circuit breaker for one of the DRUPS devices, causing a 222ms high-voltage fault

Impact

- Impacted customers including managed hosting providers

2016 datacenter failures highlight growing complexity, high-profile consequences, 451 Research, October 2016

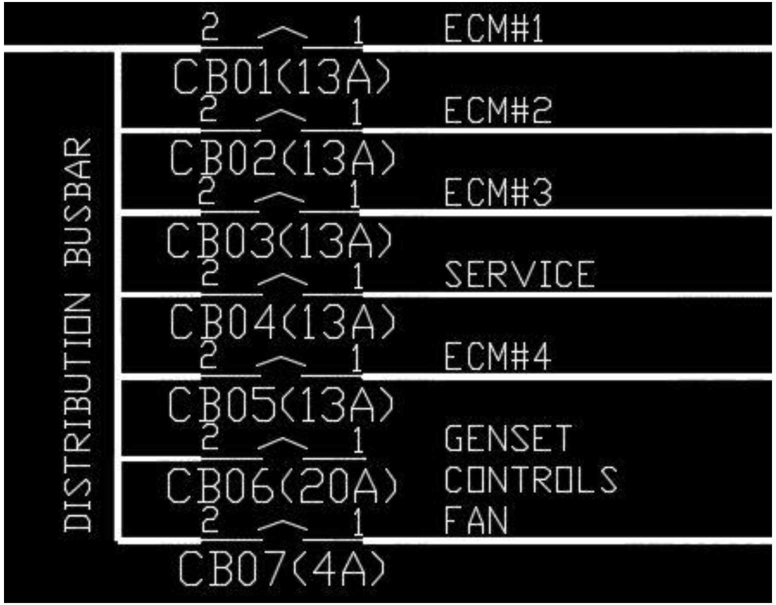
2017, Data Center, Asia

Cause

- Generator unable to start during weekly testing
- MCB supplying DC power to the ECM had tripped

Impact

- Need to implement aux. supply monitoring to all gensets worldwide

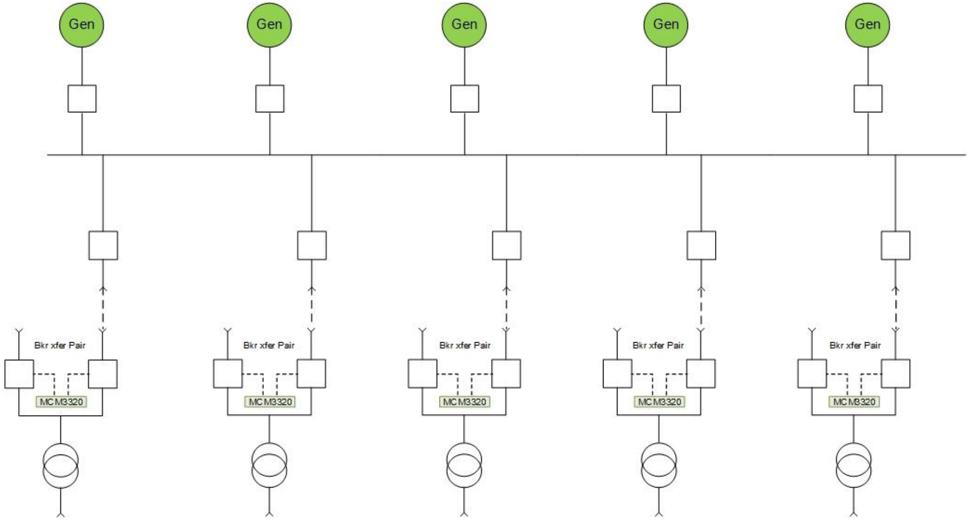


Common Failure Modes for Data Center Backup Power Systems

1. Electrical systems design
2. Mechanical design / installations
3. Generator subsystem design and maintenance
4. Generator and Load compatibility

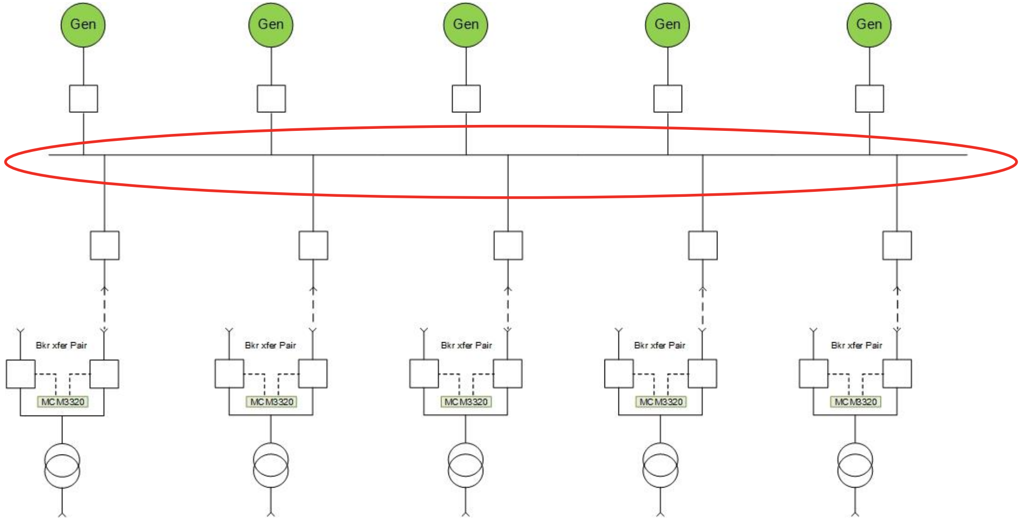
#1: Electrical systems design

Generator paralleling



#1: Electrical systems design

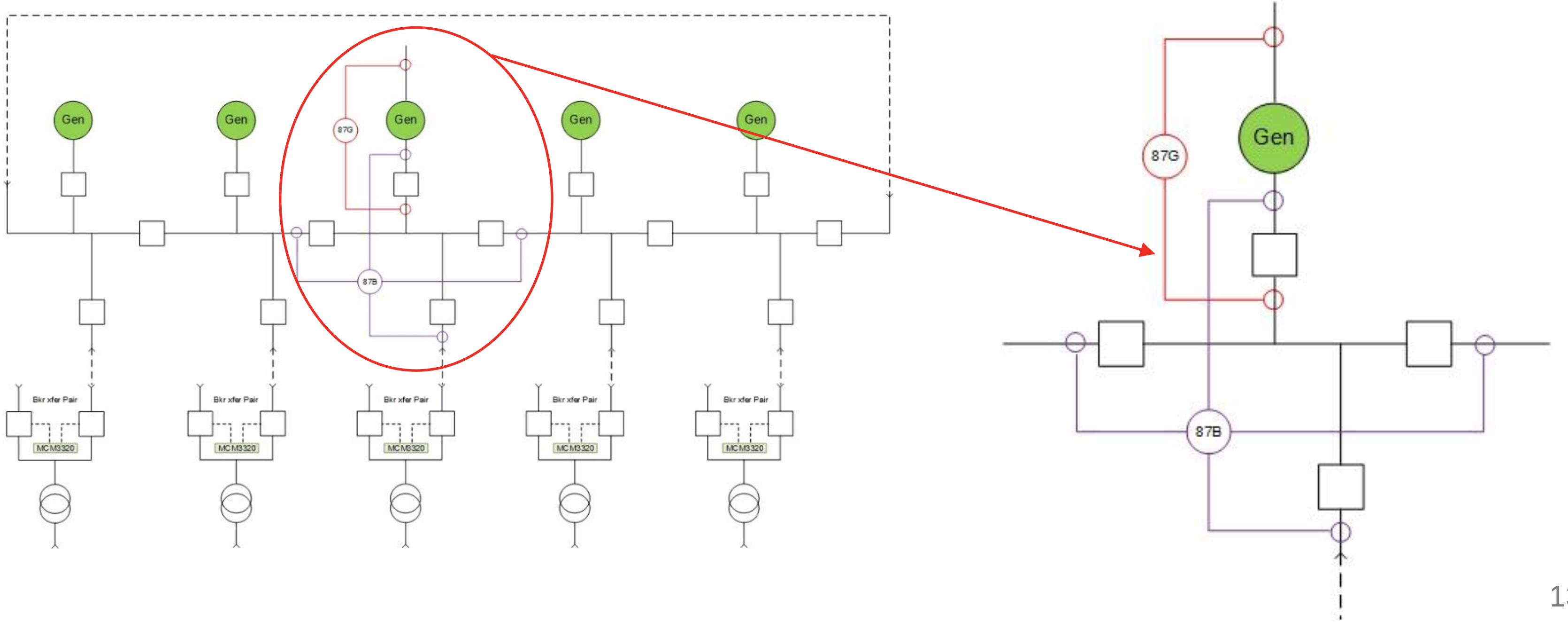
Generator paralleling bus fault – single point of failure



#1: Electrical systems design - Paralleling
Recommendations: Segmented Bus Design

Segment the paralleling bus with tie breakers

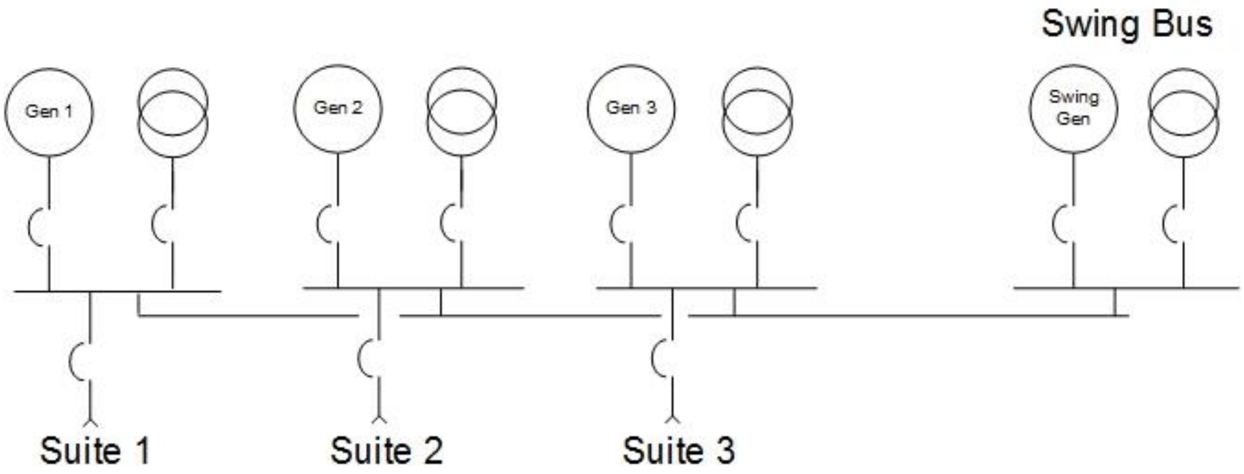
- Design the bus protection to take out only one generator for a bus fault.



#1: Electrical systems design example
Recommendation: Swing Bus Design

Single Generator / Swing Bus Design

- Each load block has a dedicated generator
- Swing generator provides redundant backup power
- Requires well thought out procedures for testing and maintenance

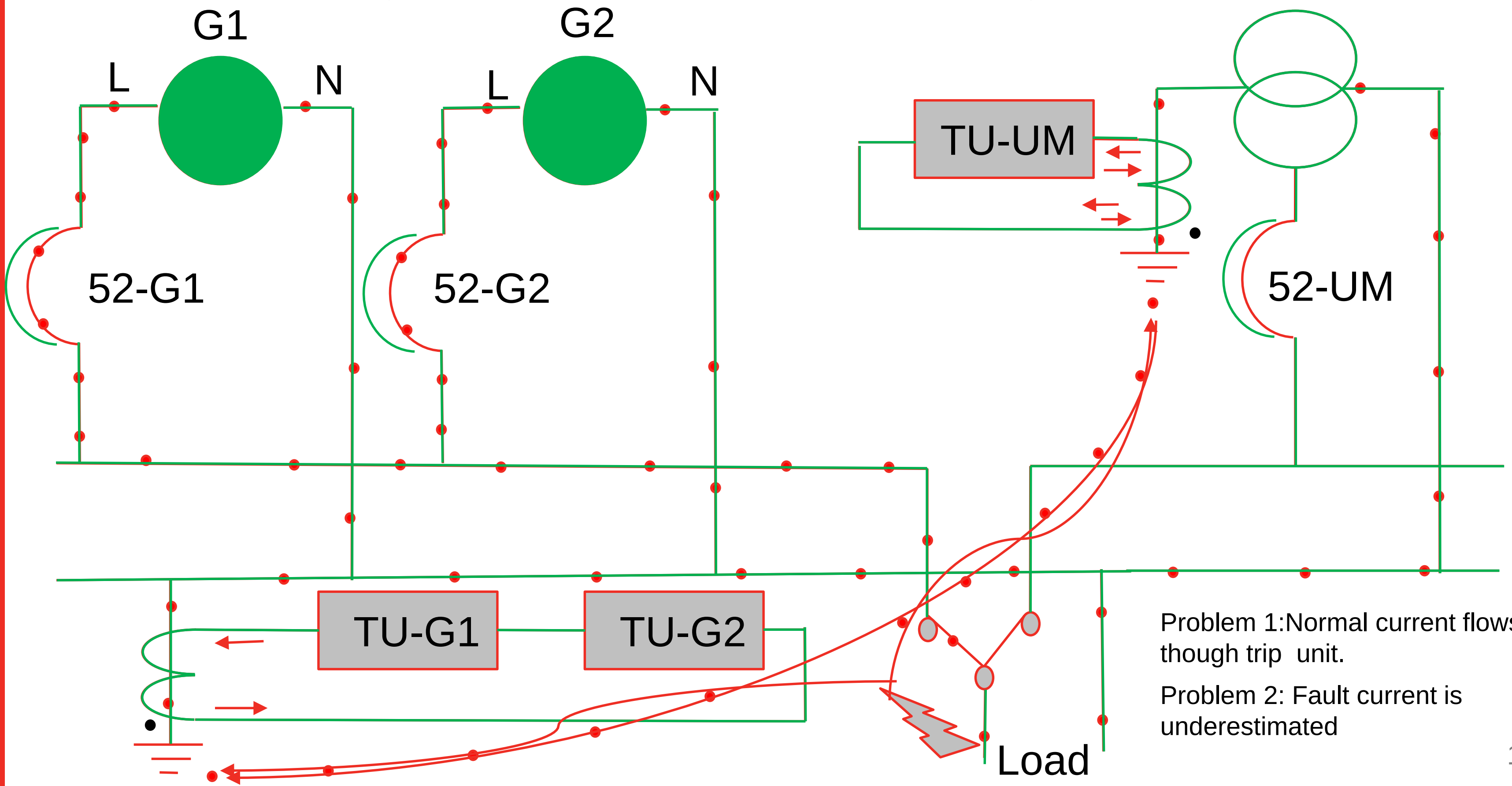


#1: Electrical systems design

Grounding and Ground Fault Protection on a 4-wire System

- One of the most common misses by consultants
- Why this is difficult:
  - Meeting the code
  - Carrying the neutral (4^{th} wire) throughout the building
  - Providing accurate ground fault protection
  - Eliminating nuisance trips
- Many times the issue is not recognized until late in the design/construction process.

Circulating current in 4 wire system



Problem 1:Normal current flows though trip unit.

Problem 2: Fault current is underestimated

Grounding and Ground Fault Protection on a 4-wire System

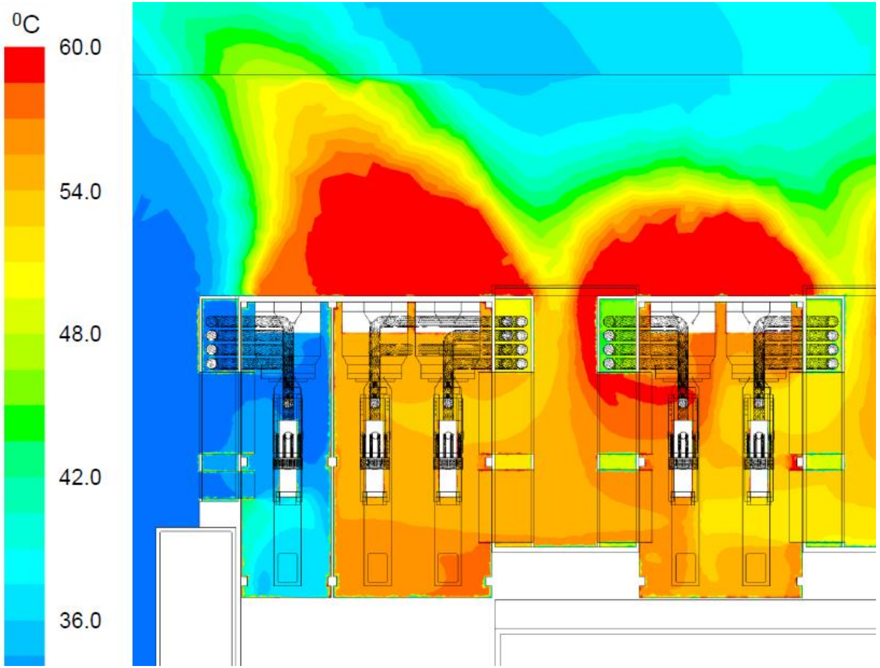
- Solutions:
  - Single point of ground on utility with generator differential.
  - 4-pole breakers and 4-pole transfer switches
  - Modified Differential Ground Fault (MDGF)
  - Design a 3-wire System. Install transformers when you need line to neutral (277 volt) power source.

#2: Mechanical design and installations

Air Flow - multiple generators (microclimate)

CFD Analysis:

- Look for Problem Temperatures
- Prevent Exhaust or Discharge recirculation in Building’s Air Intake

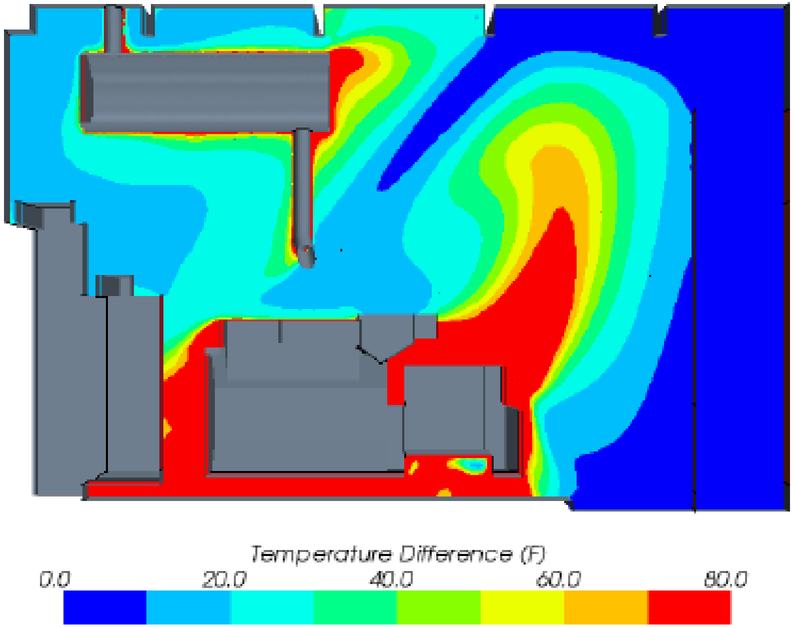


#2: Mechanical design and installations

Air Flow – genset enclosure

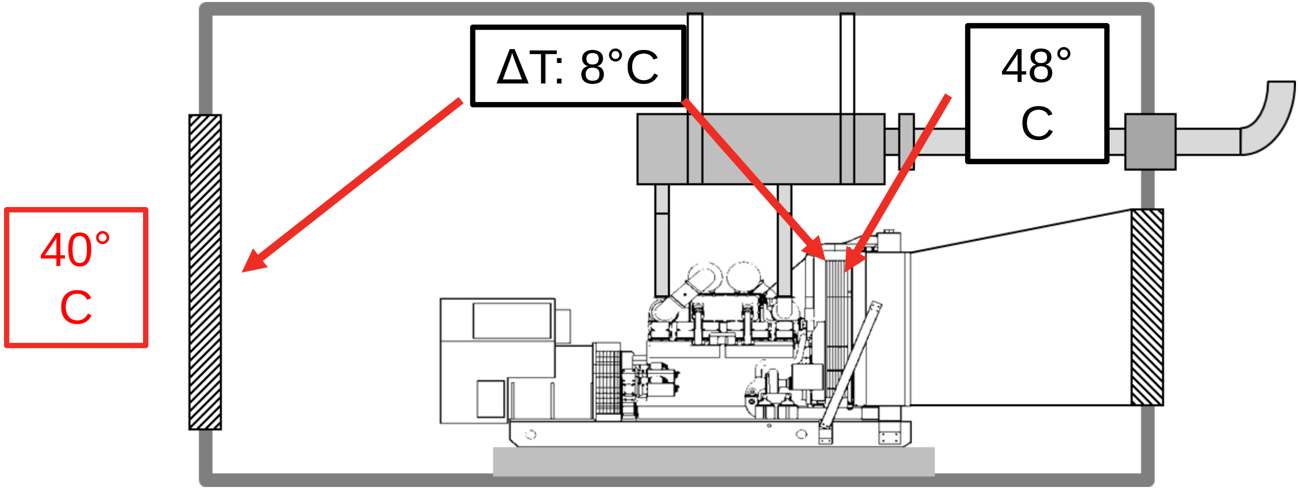
CFD Analysis:

- Verify the design and look for Problem Areas
- Verify the design and validate the installation - perform Installation Quality Assurance



#2: Mechanical design and installations

Air Flow - Cooling System Ratings

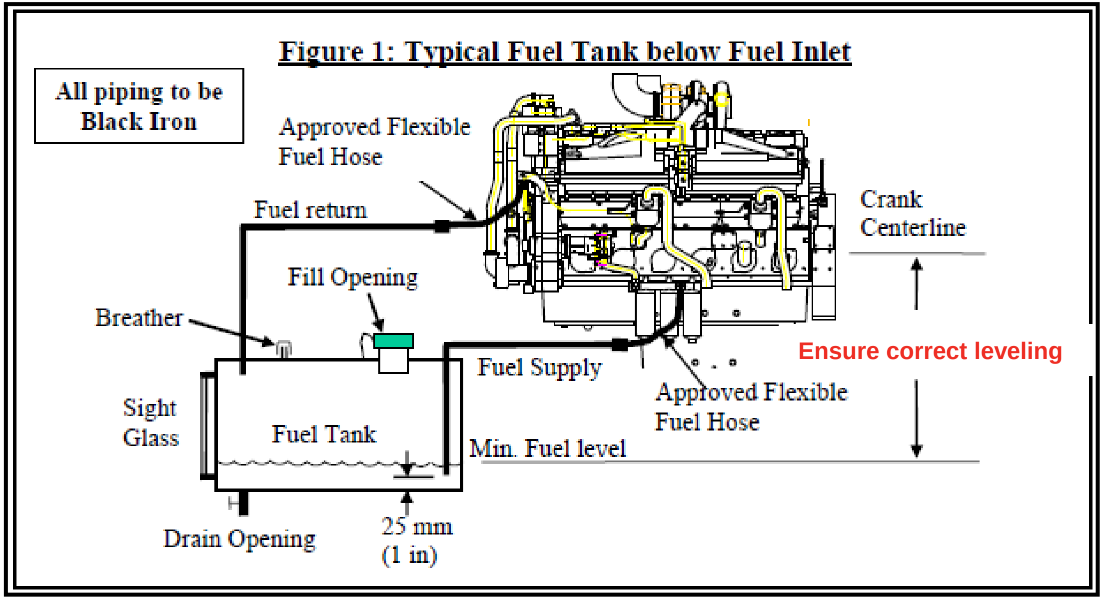


- Air-on-Core: 40°C ≈ 32°C Ambient
- Ambient: 40°C ≈ 48°C Air-on-Core

#2: Mechanical design and installations

Fuel delivery – fuel restriction, head pressure, etc.

- Day Tanks, Belly Tanks, Fuel Header System



Issues to avoid:

- High restrictions in fuel lines (consider static head);
- Air in fuel (check valves, foot valves, etc.)
- Fuel cleanliness and free of water (avoid condensation in the tanks)

Other Reliability Enhancements

- Increased fuel capacity
- Automatic fuel filtering system

#3: Subsystems and maintenance

Batteries / Charger

- Dead or insufficiently charged
- Damaged under extreme environmental condition
- Battery Charger - failure to re-charge the battery
- Not tested regularly or replaced per maintenance procedure

Fuel systems

- Contaminated fuel clogging fuel filters
- Air in the fuel systems causing frequency/voltage fluctuation and inability to parallel
- Fuel contamination may also affect injectors
- Operation errors (fueling procedure, valve position, etc.)

#3: Design of Subsystems and maintenance Recommendation:

Project design and installation

- Spec for redundant (“change on the fly”) fuel filters
- Use filters with indication/alarm for high restriction (clogging)
- Validate installed systems, e.g. Cummins Installation Quality Assurance (IQA)

Test and maintenance

- Follow manufacturer recommendation
- Establish a fuel sampling and maintenance program
- Use telematics / remote monitoring to monitor the condition of the filters during operation

#3: Subsystems and maintenance

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Fuel systems

- Contaminated fuel clogging fuel filters
- Air in the fuel systems causing frequency/voltage fluctuation and inability to parallel
- Fuel contamination may also affect injectors

#3: Design of Subsystems and maintenance Recommendation:

Project design and installation

- Spec for redundant batteries and chargers
- Work with experienced supplier for battery charger sizing
- Validate installed systems, e.g. Cummins Installation Quality Assurance (IQA)

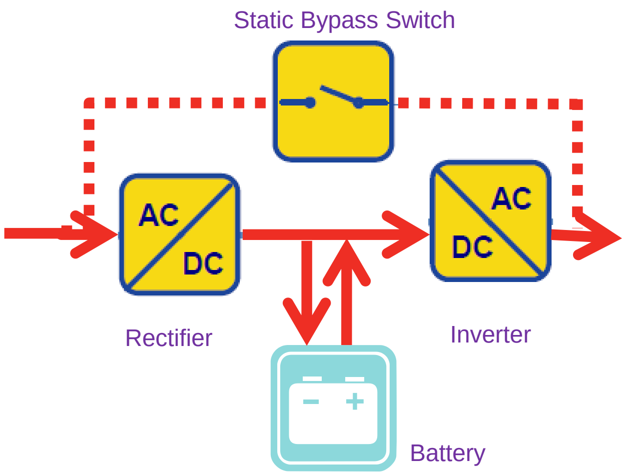
Test and maintenance

- Follow manufacturer recommendation
- Use telematics / remote monitoring to monitor the health of the batteries and chargers

#4: UPS / generator systems compatibility

Cause of failure examples

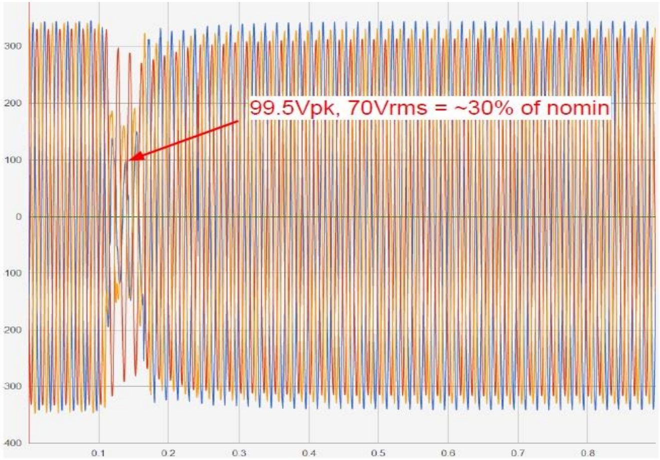
- Oscillation between batteries and generator input
- Coordinating UPS Protection/Alarms with Generator Response
- Voltage rise due to capacitive filters
- Frequency fluctuations
- Synchronizing to bypass
- Step/ramp Loading



#4: UPS / generator systems compatibility

Oscillation between UPS/Rectifiers and generator input

- Can show up after data center is in service and there is a load change.
- Example below caused by change in load ramp time ramp time (battery to generator).

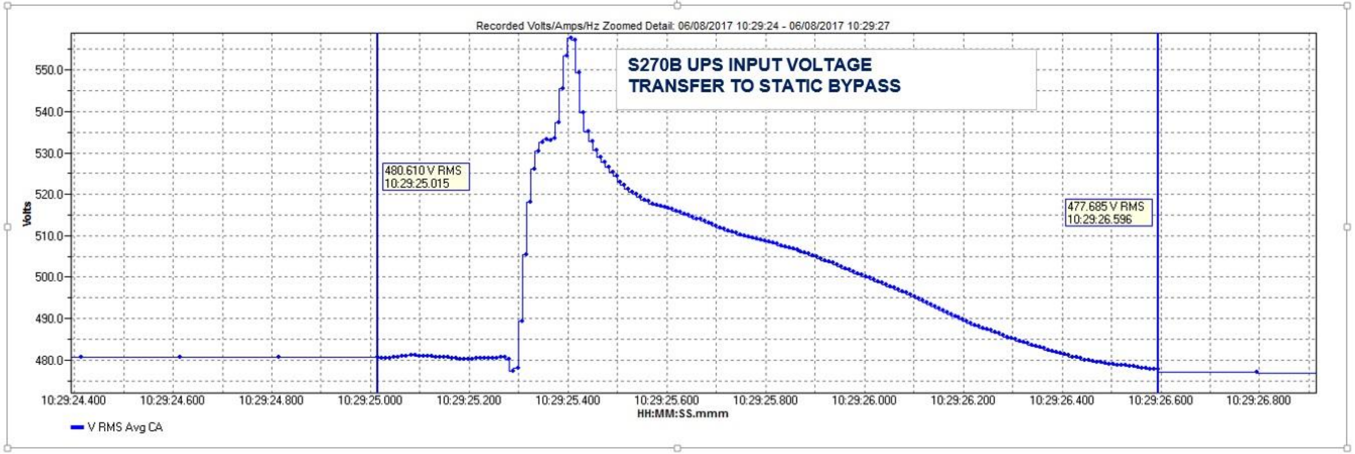


#4: UPS / generator systems compatibility

Coordinating UPS Protection / Alarms with Generator Response

- Sudden switch to bypass operation exposed generator to capacitive load
- Voltage response of the generator caused UPS overvoltage alarms

PF 0.99 Lagging to 0.996 Leading: 558V <= 450 msec



#4: UPS / generator systems compatibility

Recommendation:

- Go through a thorough commissioning procedure
- Let the UPS vendors and genset vendors work together to meet performance based spec
- Make sure your alternator is sized properly for the type of load and operating conditions for the entire life cycle of the facility.

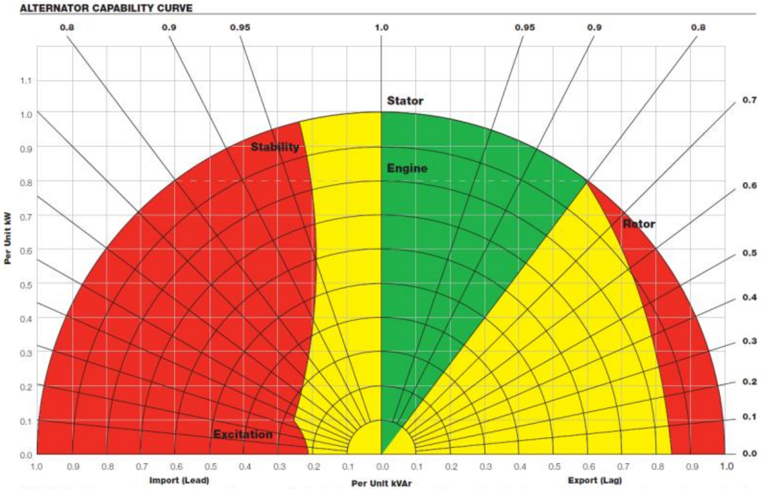
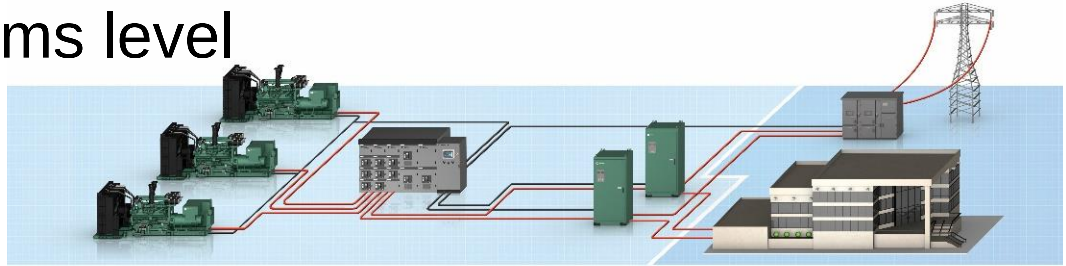


FIGURE 2 – Green area is normal operating range of a typical synchronous machine, yellow is abnormal but not damaging, and operating in

Final thoughts

- Genset backup system is your critical line of defense
- Work with experienced suppliers and leverage their expertise to prevent failure modes
- Develop well thought out testing and maintenance procedures (MOP or methods of procedure)
- Seek long term reliability through integrated systems - Component compatibility improves performance and reliability at systems level



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