



Paralleling Generator Systems for Emergency Standby Applications

Basic Guideline and Design Concepts

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Company Background/About Me

- BPS
 - Family owned and operated since 1947
 - *9 locations throughout Ohio and Indiana*
 - Longest running Kohler distributor in the country
 - Total power system package support
 - *Systems design and application*
 - *Sales, rental and equipment delivery*
 - *Service, planned maintenance, parts and repair*
- Josh Matthias
 - Applications Engineer, Power Systems
 - BSME – Purdue School of Engineering & Technology



Topics and learning objectives:

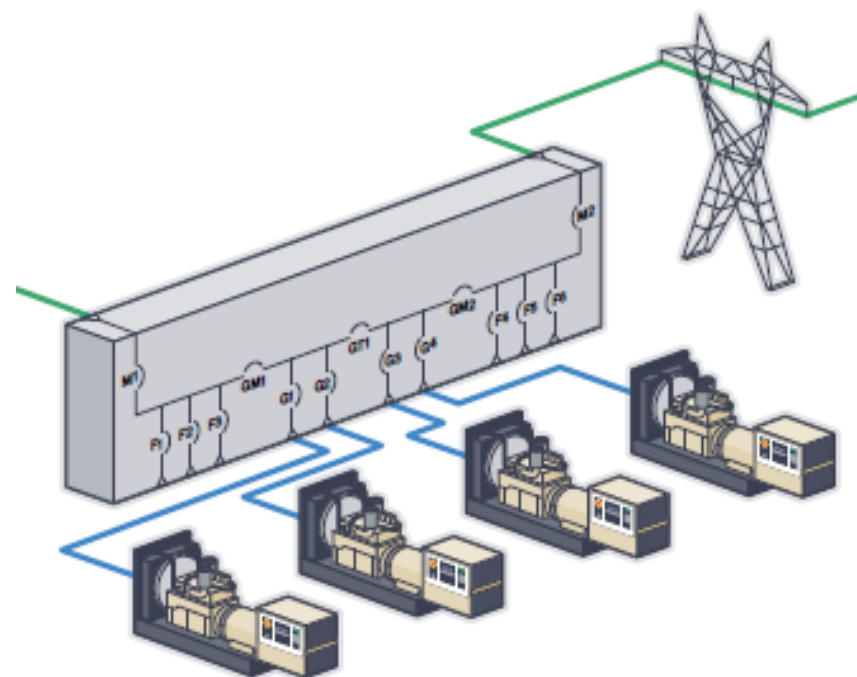
- Introduction and concepts for generator paralleling
- Paralleling generators for redundancy and capacity
- On-board vs. Traditional Paralleling
- Best practices and considerations



Paralleling Concepts

Paralleling

- Synchronous operation of two or more generator sets connected together on a common bus
- Typically done to meet large load demands, provide reliability or both
- Also possible to parallel to utility
 - Peak shaving
 - Base loading





Benefits and Considerations

Redundancy

- Increases reliability and availability
 - N+1 generator scheme – 99.96% reliability
- Removes a single point of failure

Operational Flexibility

- Multiple gensets provide easier maintenance scheduling. One unit can be available to supply power to critical loads, while the others are offline for servicing.
- Utilization of all available resources. Some facilities have multiple gensets without them being paralleled. Should one genset fail, it would not be possible to utilize the other gensets on campus.
- Gensets can share load or run on intervals. This can improve fuel efficiency, prolong equipment life and reduce maintenance costs.

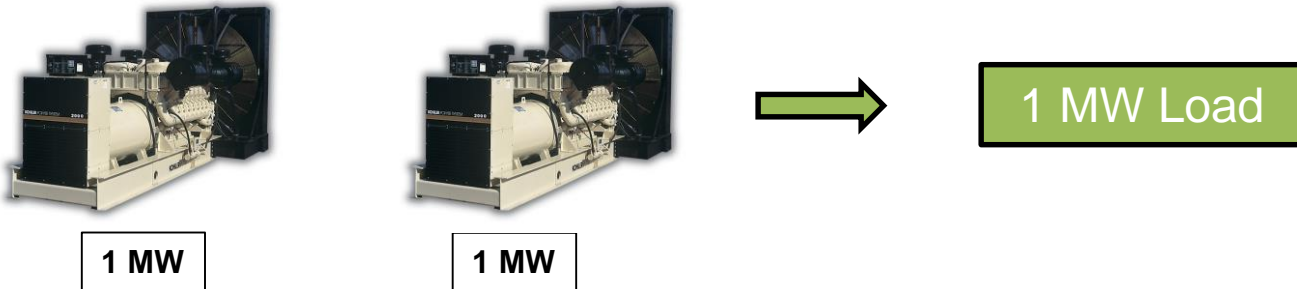
Expandability

- Paralleling generator systems inherently provides protection against facility growth and/or an increase in electrical demand. With a paralleled generator system in place, additional generator capacity or redundancy can be added as needed.

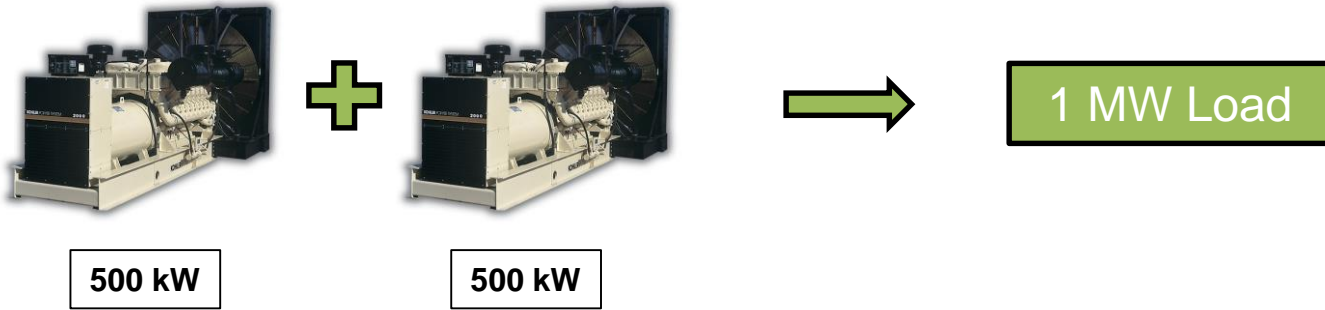


Redundancy vs. Capacity

Redundancy (N+1): Each generator can support entire load



Capacity: Multiple units paralleled together to meet load demand



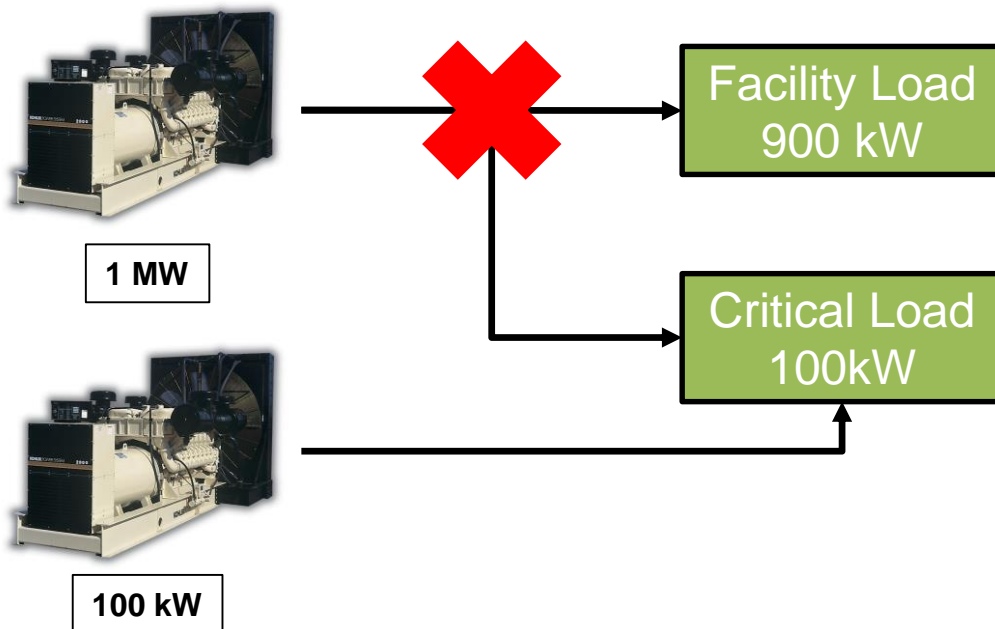
Note: Redundancy (N+1) can be also achieved by adding another 500kW unit.





Redundancy Requirements

Consider whether redundancy is needed for the entire facility or critical loads only. It's possible to have one large generator that can support the entire facility and utilize a smaller generator for only critical loads.



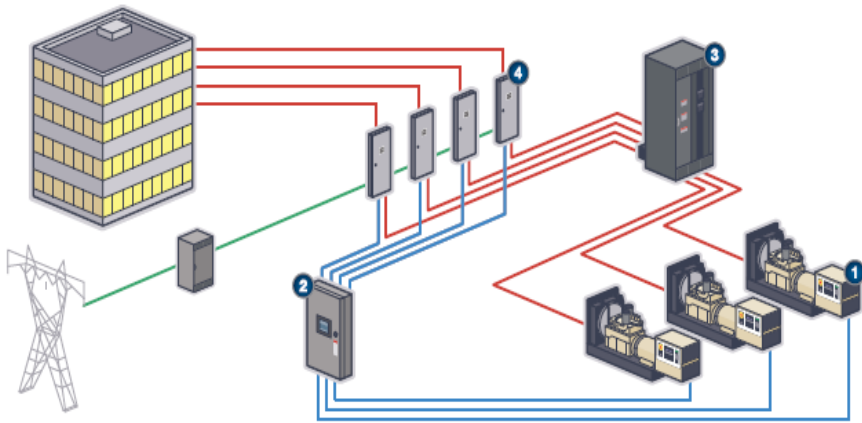
- Cost savings
- Spatial savings
- Redundancy for critical systems
- Still provides ease of serviceability



Paralleling Operation

Typical Sequence of Operation (Emergency)

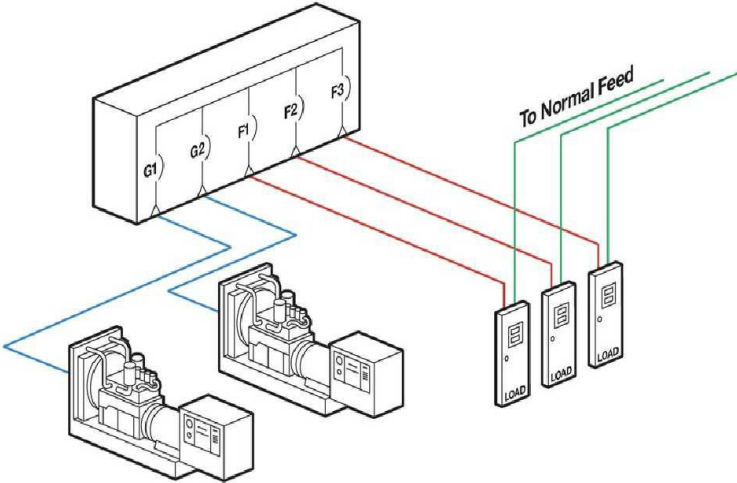
- Generator Start
- Load Management: Load Shed
- First-On Logic
- Synchronization
- Load Share (kW and kVAR)
- Load management: Add Load
- Generator Management
- Load Management: Failure/Overload Load Shed





Generator Start

In the event of a loss of utility service, one or more of the automatic transfer switches sends a start signal. All available generators start.





Load Management: Load Shed

If one generator cannot support the entire system load, lower priority loads are shed. This prevents the first-on generator from being overloaded.

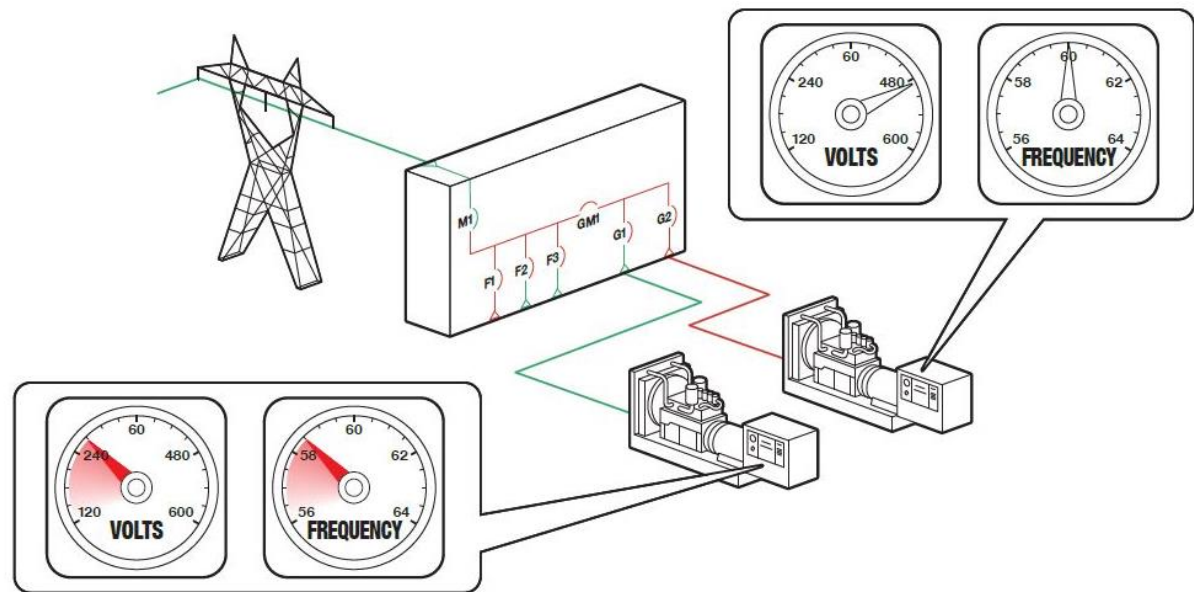
- ATS inhibit transfer
- Feeder breakers open
- Dry contact to signal downstream loads



First-On Logic

First-on logic, also known as random access paralleling, allows the first generator to reach rated speed and voltage to close to the dead bus.

- Prevents multiple generators from simultaneously closing to the bus
- Used to get power to critical loads as soon as possible
- Low priority loads may remain shed

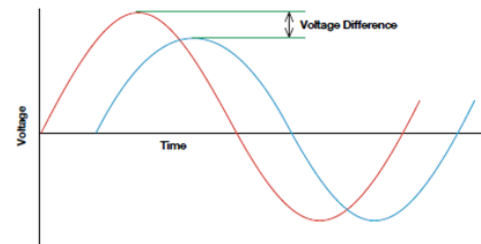




Synchronization

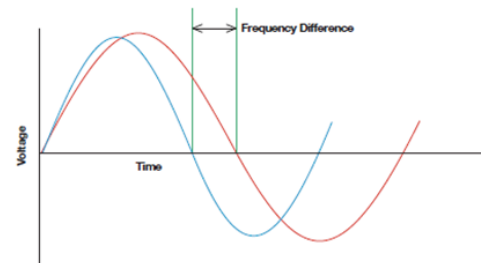
Voltage Match

- Synchronizer adjusts the incoming generator's voltage to match running bus



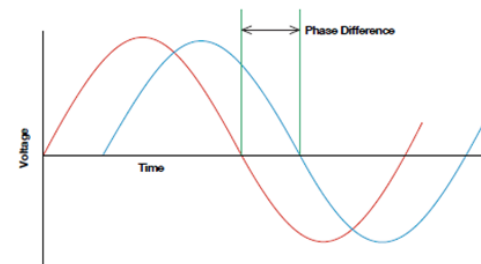
Frequency Match

- Synchronizer adjusts the incoming generator's speed to match frequency of running bus



Phase Match

- Synchronizer adjusts the incoming generator's speed to match phase of running bus





Load Share (kW and kVAR)

As additional generator power is available, the system's load sharing controls actively control the kW and kVAR output of each generator. Each unit proportionally share the load so that percent load on each generator is the same.

- Ensures that one generator doesn't work harder than the other
- Especially important on generators with varying capacity



Load Management: Load Add

Lower priority loads added by:

- **Generator Bus Capacity**
 - Based on the kW capacity of the bus and a preset kW demand of the load
- **Number of Generators Online**
 - Based on how many generators are connected to the bus
 - Most effective in systems with same size generators



Generator Management

Optimizes the number of online generators based on load's kW demand, starting and stopping as required

- User sets all parameters associated with generator management and can enable or disable this mode of operation
- Right side of screen graphically displays settings and current state of the system

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Transfer Active: View Only
Timer Active: 11/19/2014
Mode Active: 2:45:24 PM

Order	Adjust Gens	Gen	Runtime	Status
1	▼	1	0.0 Hrs	Circuit Breaker Closed
2	▲	2	0.0 Hrs	Circuit Breaker Closed

Stop Gen Load Level: Start Gen Load Level

5:00 G2: 1500 kW
G2: 1100 kW 0:10

Online Capacity: 4000
Actual Total Load: 9028

Control

Parameter	Control
Operation	Auto Off
Order Selection Method	Runtime Manual

Setpoints

Parameter	% Load	Delay
Start Gens	55	10 Sec
Stop Gens	75	5 Min
Overload Start	105	3 Sec
Stable Timer		10 Min 10:00



Load Management: Failure/Overload Load Shed

Load shed event triggered by:

- **Generator Failure**
 - Loads are shed based on the number of failed gensets
- **kW Overload**
 - When the generators reach their overload setpoints, low-priority loads are sequentially shed until load falls below setpoint
- **Underfrequency**
 - Often an indication the generators are fully loaded, when bus frequency reaches its underfrequency setpoint, preset loads are shed

Note: It is important to specify what loads can be shed and how they should be shed.



Traditional Paralleling



Paralleling Switchgear

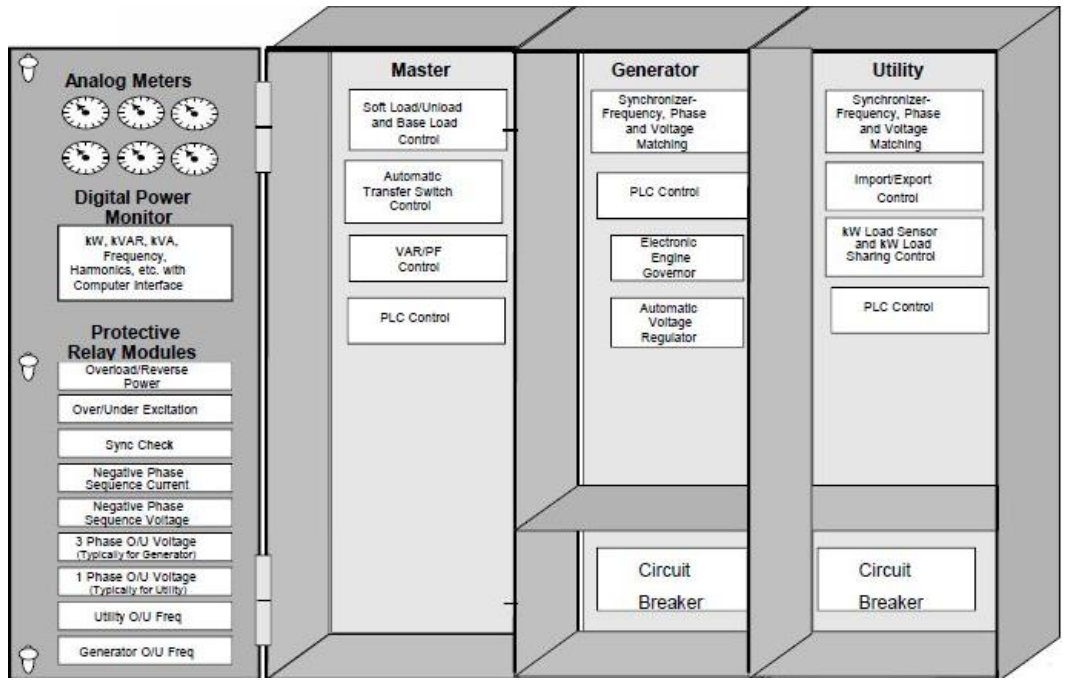
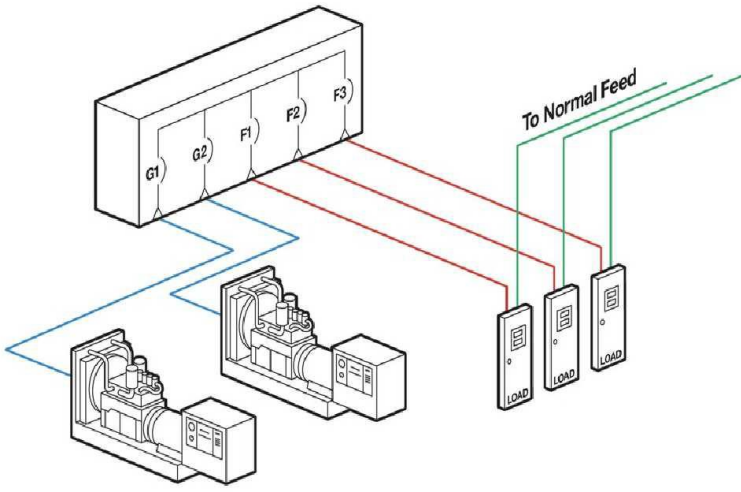




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Traditional Paralleling Layout





Traditional Paralleling Concepts

BENEFITS

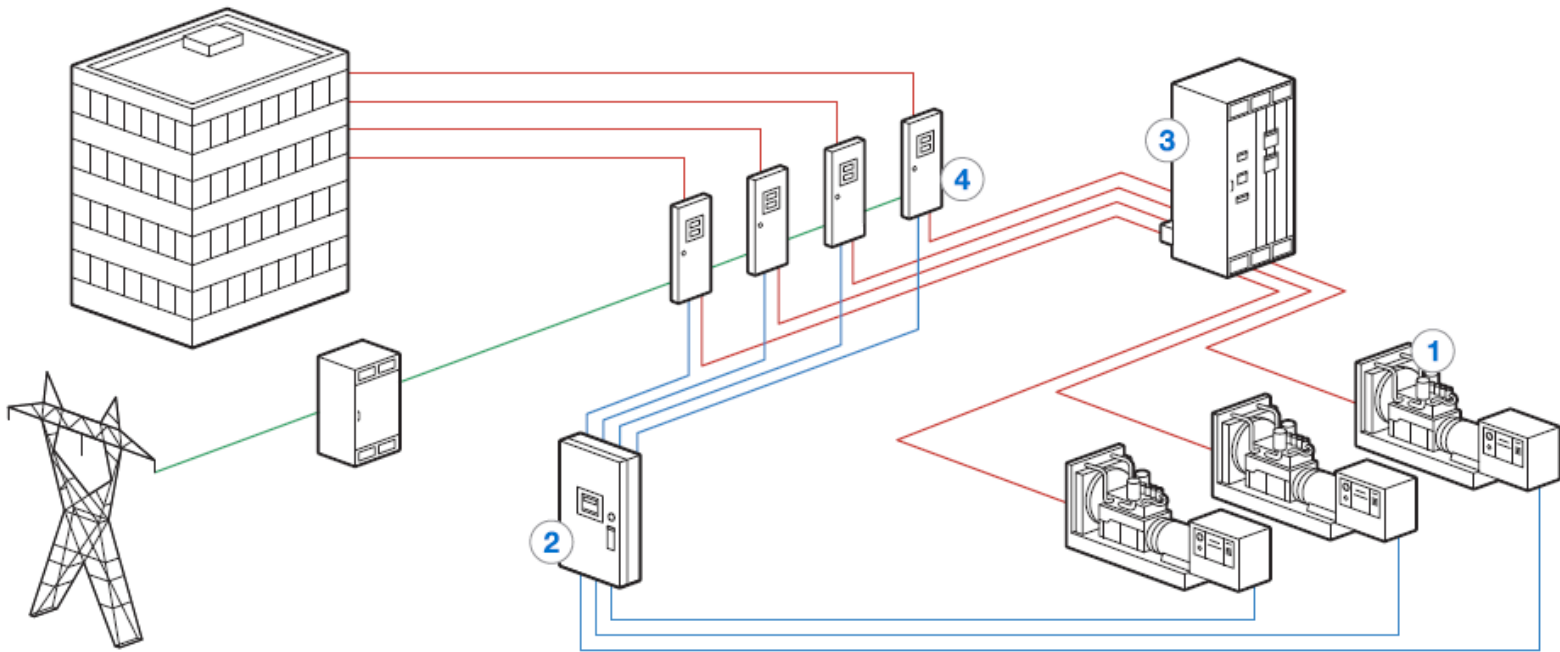
- Customizable configurations and solutions
- Complex sequence of operations
- Everything located in one place, genset controls, breakers, utilities, protections
- Able to parallel more than one utility source

DRAWBACKS

- Large equipment footprint
 - Control sections needed for each generator
- Higher cost
- Engineer to order product – longer lead times



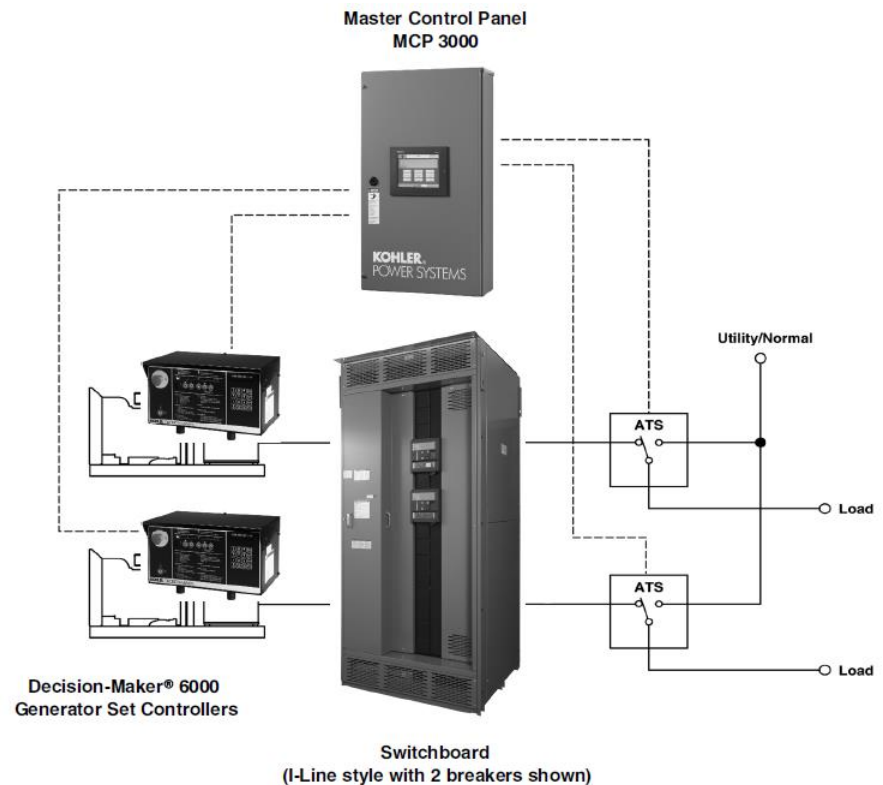
On-board Paralleling Concepts





On-board Paralleling Concepts

- **Paralleling takes place in the generator controllers**
 - *First-on logic*
 - *Automatic synchronizer*
 - *kW load and kVAR load sharing*
 - *Protective relays*
 - *Generator set control and protection*
- **Paralleling and distribution breakers can be mounted on the gensets or in switchboard/switchgear**
 - *Electrically operated breakers used when mounted on genset*
 - *Fixed mounted breakers and electrically or manual operated breakers can be used in switchboards*
- **Master control panel handles generator and load management, monitoring and metering**





On-board Paralleling Concepts

BENEFITS

- Smaller equipment footprint
 - No control sections for genset
- Lower cost
- Many paralleling applications simple enough on-board paralleling system can utilized
- Simple design with fewer points of failure
- Assembly to order product – shorter lead times

DRAWBACKS

- Limited on customization
- Not suitable for more complex system designs
- May be difficult to integrate components



Paralleling Best Practices

Smallest genset should be large enough to power all life safety and critical loads

- *Ensures that smallest genset to first close on the bus can take on these loads within 10 seconds*

Diesel preferred fuel source

- *Better transient performance*
- *Wider range of generator sizes*
- *All units available to take load within 10 seconds at whereas larger natural gas units require more time to get up to speed*
- *On site fuel supply, which may be required by code*

Match new paralleled system generators with the same manufacturer

- *Provides continuity and compatibility*
- *Enhances maintenance and simplifies operations*



Questions?



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Thank you!



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