Engine Generator Paralleling Concepts

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What Topics Will Be Covered

Upon completion of this presentation, participants will be able to describe the basic concepts and implementation approaches to parallel generator operation including both “Traditional” and today’s “Integrated” techniques. They will also be able to identify the advantages of integrated parallel systems over single generator applications. Specifically they will be able to:

- Describe the concept of creating larger power systems using paralleled generators.
- Describe generator to grid and generator to generator configurations.
- Describe the differences between the “traditional” and “integrated” approach to generator paralleling.
- Describe the electrical requirements needed for proper operation of parallel operation.
- List and describe the functional and economic limitations of “Traditional” generator paralleling.
- List and describe the key benefits of the “Integrated” approach to generator paralleling.
- List and describe the key benefits of an “Integrated” parallel system over a “Single” generator.
What is paralleling?

- Generator to Utility (Grid Inter-Connected)
- Generator to Generator
Generator to Utility Grid Connection

- Electrically connected to the utility grid
- Energy management
  - Emissions (natural gas engines)
  - Spark Spread (cost feasibility)
  - Utility barriers (standby charges, ratchets, grid interconnect)
  - EPA Regulated – Tier 4 Required Engines if utilizing diesel
“Make-before-break” transfers

- CTTS (less than 100 msec)
- Soft-load Closed transition (few seconds)
- Synchronize the generator to the utility momentarily

- Exercise with load
- No outage on retransfer
- Circuit Breaker or Contactor Styles available
• What is a paralleling system?
  Two or more generators are electrically coupled together using special equipment to form a larger capacity power source.
Paralleling Generators for Redundancy

- **N + 1**

  The customers' load requirements would be 500kW even though the system can create 1000kW. This leaves the system the ability to maintain the critical load in the event that one of the generators is taken off-line.
Paralleling Generators

Why use a paralleling system?

Reliability
- Accepted market reliability for single engine is 98-99%
- Redundant systems offer multiple nines reliable for the critical loads
  - N+1 reliability (99.96 to 99.99%)
  - N+2 reliability (99.9992 to 99.9999%)

Scalable
- Ability to expand as your client’s needs grow
- Don’t over build – preserve capital

Serviceable
- Protect the critical loads while servicing the generator(s)
Why not use a paralleling system?

Traditional implementations have limitations

- Cost (capital, installation, commissioning)
- Complexity
- Space
What is Required to Parallel Generators

- Synchronizing
- Switching Device
- Load Sharing
- Protection
Prior to Synchronizing

- Electronic governor -- load sharing
- Electronic voltage regulator w/ paralleling capability
- Identical internal alternator winding pitch (i.e. 2/3, 4/5, etc).
- Same number of phases
- Same phase to phase voltage
- Same phase rotation
**Synchronization**

Key Elements for paralleling generators
Light goes dim – Push it in!
Synchronizing Controls

- Waveform Alignment
  - Engine Speed needs to be controlled
  - Alternator Voltage needs to be adjusted
Synchronization – Wave Form Alignment

Electrically **locking** two “machines” together

- Voltages matched
- Frequencies matched + Slip frequency offset
- Phase angles matched

![Graphs showing phase voltages and angles](image)
Voltage level and alignment has been satisfied
Device Switching

Traditional Switching – Utilizing Circuit Breakers
Integrated Switching

Integrated Switching – Utilizing Contactor Mounted on Generator
Generators are now electrically interlocked

There is not enough force provided by the prime mover to break the generators apart
Load Sharing – Power Balance

\[ \text{kVA} - \text{kVAR} - \theta - \text{kW} \]
Load Sharing Protection

“Reverse Power” & “Under-excited”

Normal Operation

(+ kVAR)

(+ kW)

(- kW)

(+ kW)

(- kW)

(+ kVAR)

(- kVAR)

“Reverse Power”
Load Sharing (Matching)

Real Power (kW)
Isochronous load sharing or speed droop

Reactive Power (kVAR)
Reactive cross current or voltage droop

Load Sharing

Generator

Engine

kW

kVAR

kVA

kVA INDUCTIVE (LAG)

kVA CAPACITIVE (LEAD)

NET kVAR (LAG)

Phase Angle
Isochronous Governors

Isochronous governors
What happens if two are connected together??

Speed Reference (90 - 110%)

Must be 0

Throttle Position

Power (kW)

Speed

PID

(0 - 100%)
Understanding Droop

- Speed Reference (100 - 105%)
- Must be 0
- Throttle Position
- Power (kW)
- Speed
- Droop (.05)
Traditional load sharing
Isochronous load sharing
Reactive Cross Current Compensation
Struggles with calibration, stability, electrical noise
Droop Load Sharing

Speed droop graphical representation
Will two speed droop governors share load?
What is the negative consequence?
Traditional Control vs. Integrated Approach

**Traditional Approach**
- Simple
- Reliable
- Single Source

**Integrated Approach**
- Simple
- Reliable
- Single Source

**Diagram**
- Generator Controller
- Gov. Controller
- Voltage Reg.
- CPU
- kW Share Module
- kVAR Share Module
- Analog Control Lines
- Digital Control Lines
- Sensing Lines
- Power Lines
- RS485
- System Controller
- To Emergency Distribution
Protection

- **Synchronizing process**
  - 25 sync check relay

- **Real power system (governor & engine)**
  - 32 reverse power
  - 81 o/u frequency protection

- **Reactive power system (regulation & excitation)**
  - 27 / 59 voltage protection
  - 24 over excitation & volts/Hz

- **Cabling & alternator**
  - 50 / 51 Overcurrent
Integrated Sequence of Operation

Status:
Normal.

Diagram:
- Critical Transfer Switch
- Emergency Distribution Panel
- Equipment Transfer Switch
- System Controller
- Generator 1
- Generator 2
- Power Line
Integrated Sequence of Operation

Status:
Utility failure.
**Status:**
Generators start.

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**Integrated Sequence of Operation**

- **Critical Transfer Switch**
- **Equipment Distribution Panel**
- **System Controller**
- **Generator 1**
- **Generator 2**
Integrated Sequence of Operation

**Status:**
First generator at rated output. Energizes the emergency distribution panel.

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**Diagram:**
- **Critical Transfer Switch**
- **Emergency Distribution Panel**
- **Equipment Transfer Switch**
- **System Controller**
- **Generator 1**
- **Generator 2**
**Integrated Sequence of Operation**

**Status:**
Picking up the critical load in 10 seconds.
Integrated Sequence of Operation

**Status:**
Equipment load transfers to the generators.

- Critical Transfer Switch
- Equipment Transfer Switch
- Emergency Distribution Panel
- System Controller
- Generator 1
- Generator 2
**Integrated Sequence of Operation**

**Status:**
If a generator is out of service, it separates from the system. Non-critical load is shed.
**Integrated Sequence of Operation**

**Status:**
Generator is restarted.

Diagram showing the sequence of operation involving a critical transfer switch, equipment, emergency distribution panel, system controller, and generators.
Integrated Sequence of Operation

**Status:**
Generator parallels to the system.
Status:
Equipment load is re-energized.
Status:
Utility is re-energized.
**Status:**
Load is transferred back to utility.

`Integrated Sequence of Operation`
Integrated Sequence of Operation

Status:
Generators cool down.
**Status:**
Generators disconnect from system.
Generators shut down.
Paralleling Advantages

Paralleling Vs. Signal Generator

Reliability
Scalable
Cost
Footprint
Serviceability
Accepted market reliability for single unit
98 to 99% (multiple third party references)

Integrated paralleling adds redundancy
Typical load factors
Minimal load shedding / management
Results in redundancy without increasing generator capacity
N+1 reliability (99.96 to 99.99%)
N+2 reliability (99.9992 to 99.99999%)
Scalability

Start with a single generator
Planned growth
Unanticipated growth
Lower initial investment
Budget / capital constraints
Protection against uncertainty

Single generator implementations offers no cost effective expansion capabilities
   – This solution typically uses sizing safety factors to protect against uncertainty and load growth.
Integrated Paralleling /Single Generator’s Cost

- **Capital cost**
  - Optimizing market engine pricing (high volume engines)

- **Installation cost**
  - Same amps, same distance
  - Potential for smaller cabling (NEC 800 amp breaker roundup rule)
  - Potential crane reduction (40 ton vs. 80 ton)
  - Pad thickness reduction (6” vs. 10-12”)

- **Maintenance cost**
  - More manageable fluids
  - Comparable consumables
  - “Ask for PM quotations for both options”
Capital Cost - Traditional
Capital Cost - Integrated
Footprint

Foot Print Size vs. Location Flexibility

Foot print examples

- 1000 kW (26.1’ x 8.4’)
- 2 x 500 kW (19.2’ x 13.5’)
- 1500 kW (33.3’ x 8.4’)
- 2 x 750 kW (16.9’ x 16.5’)

Location flexibility
- Various layouts
- Units can be separated
- Parking garages
- Rooftops
Serviceability

Single generator implementations
Limited to no protection while servicing

Can your critical loads go without protection?
Oil & coolant changes
Belts, hoses, batteries
Load bank connection
Minor repairs
Major repairs

At what point do you bring in a rental?
Change-over time

Paralleled implementations provide protection during servicing
Conclusion

• Traditional
• Integrated
• Scalability
• Serviceability
• Reliability