Schneider Learning Series – ASCO Offer

Source and Load Management in Critical Applications

4th March 2021

ASCO Power Technologies™

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Learning Objectives

1	Critical Applications in Varying Market Segments
2	Power Control System Networks
3	Network Connected Products
4	Generator Control Features ○ Synchronizing ○ Load (kW and VAR) sharing ○ Design considerations
5	Master Control Features ○ Source management ○ Load management ○ Manual controls
6	Emergency Standby System ○ System architecture
7	Soft load / Parallel with Utility ○ System architecture

Please use the "Questions" feature to ask technical questions.

Speaker's Biography

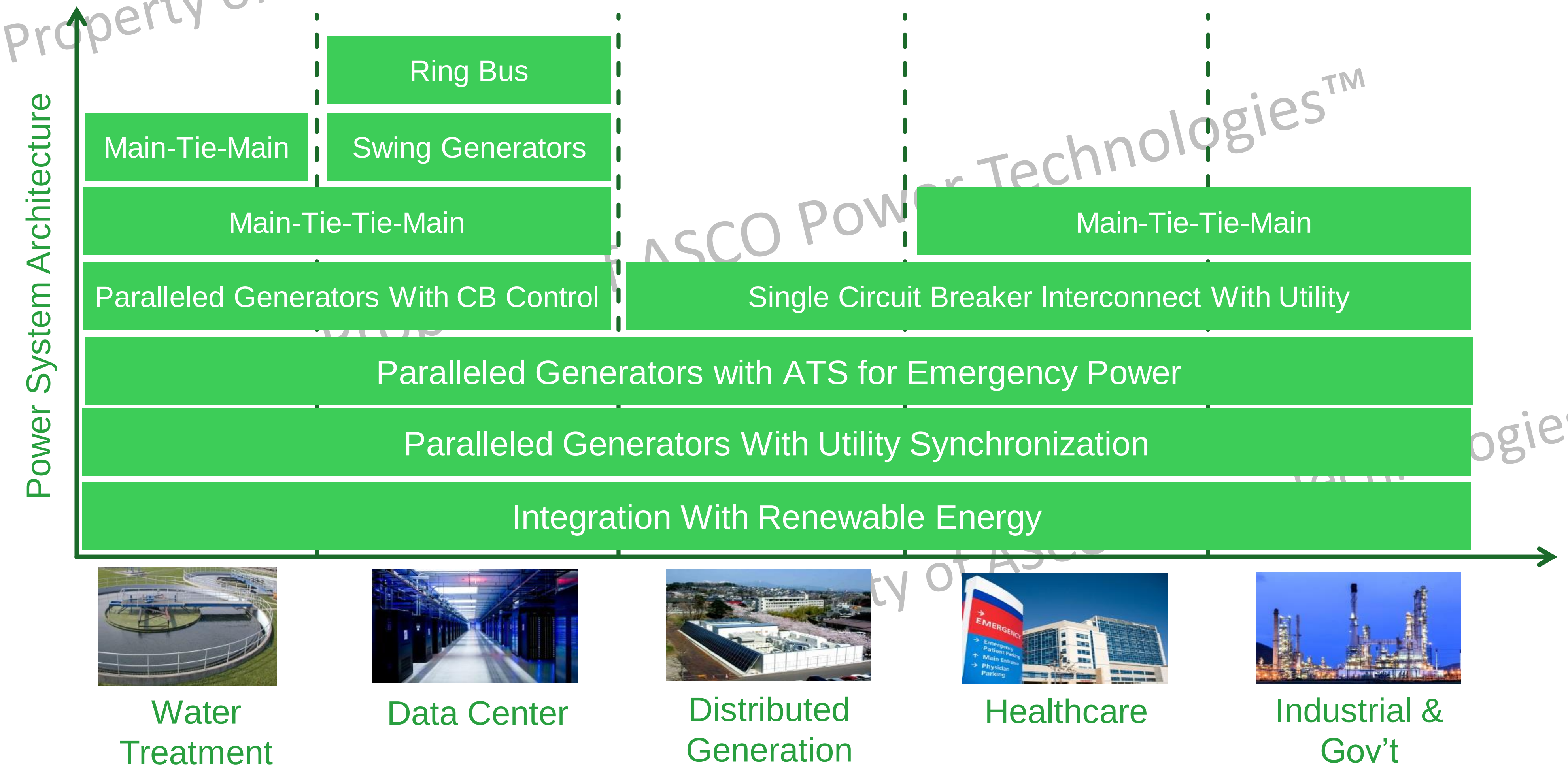
Peter Rossomando

Director of Applications Engineering

- 30+ years with ASCO, 36 years industry experience
- 3 years as Applications Engineer
- 15 years as Project Manager in Northeast and Southeast regions
- 12+ years experience in Applications Engineering Management for both ATS & PCS products
- BSEE in Electrical Engineering from New Jersey Institute Technology

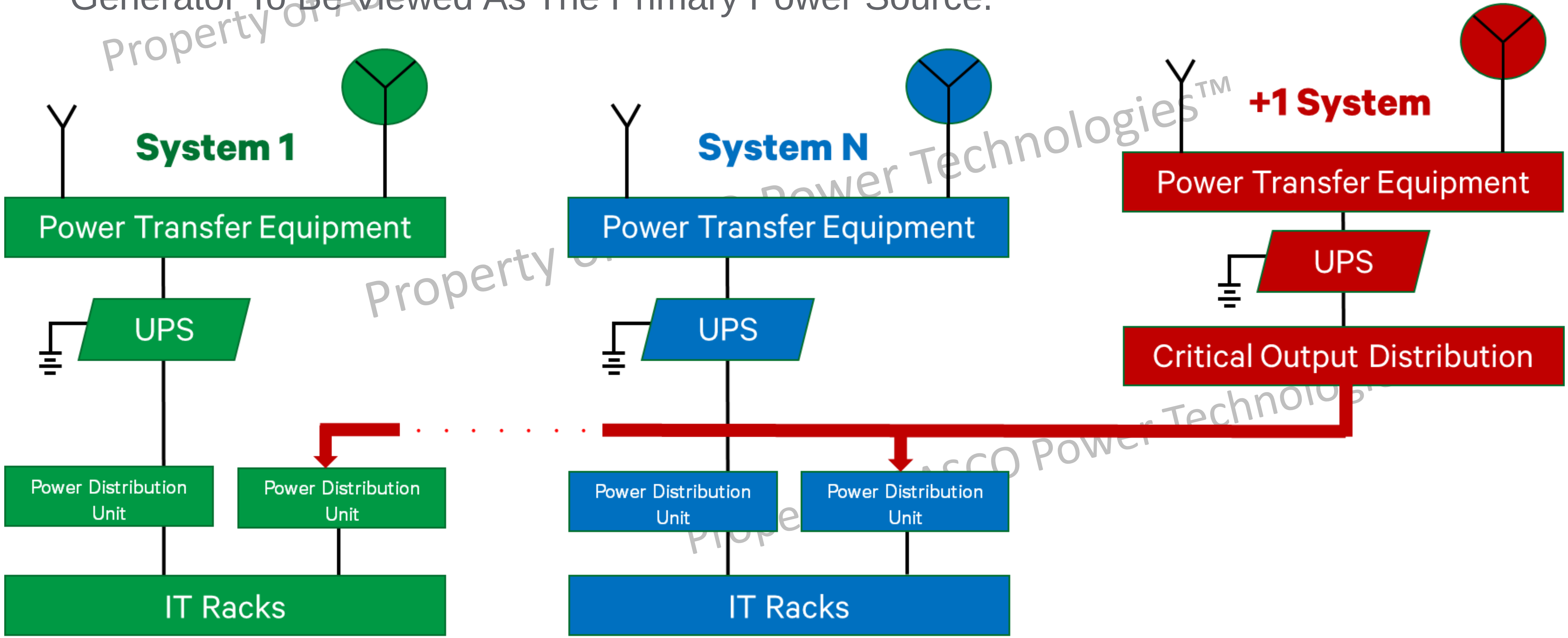
Critical Applications in Varying Market Segments

Similar Control Techniques Are Used Across All Market Segments And Power System Architectures



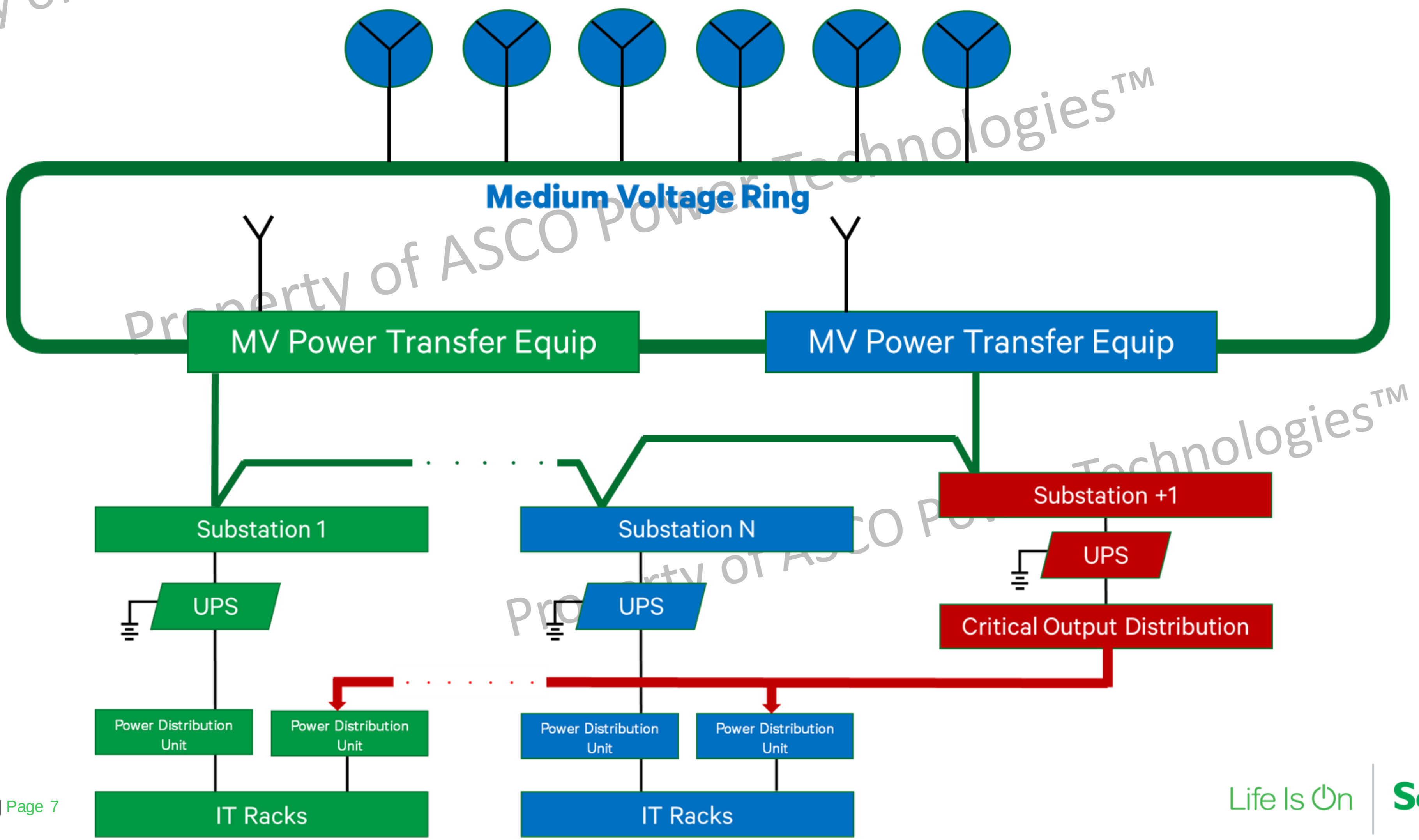
Typical Uptime Modular Low Voltage Data Center

Provide A Redundant System To Support Concurrent Maintainability. This Tier Requires The Generator To Be Viewed As The Primary Power Source.



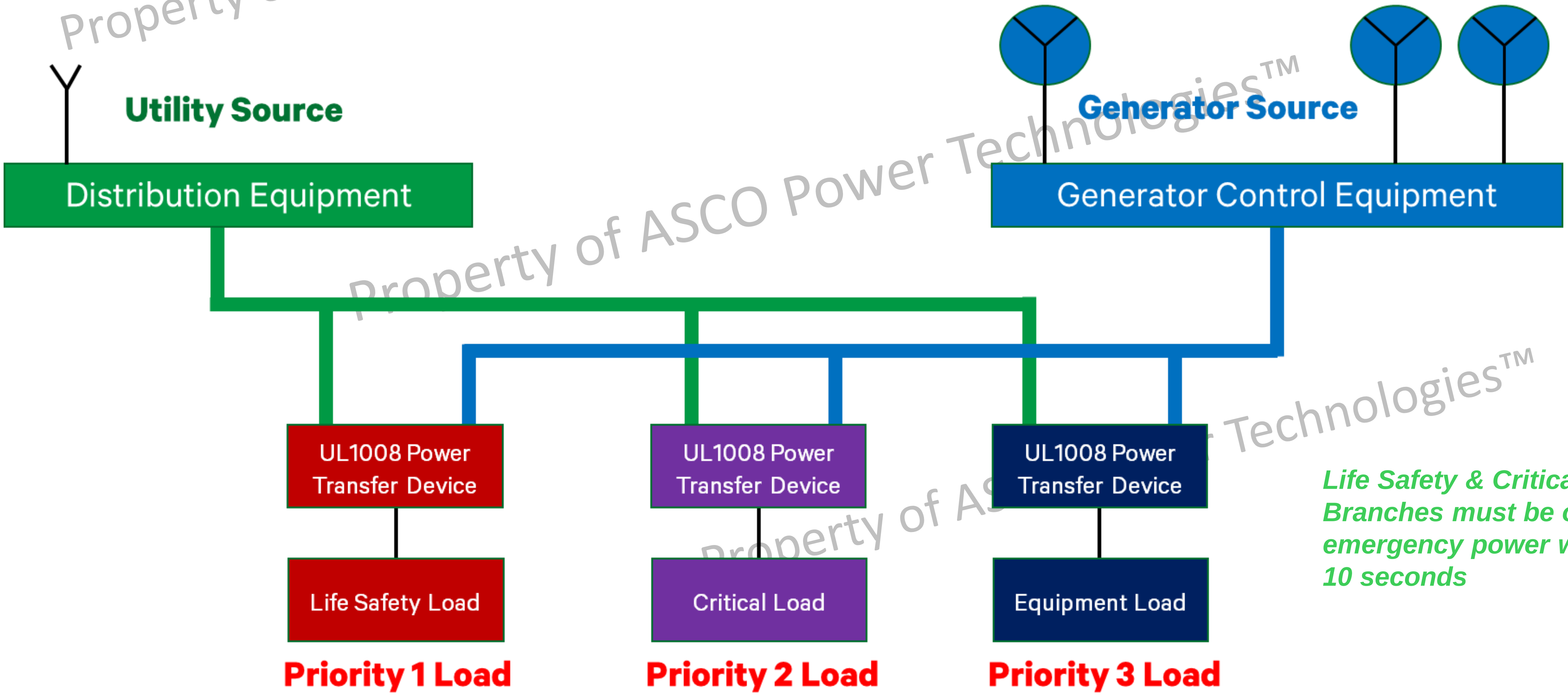
Medium Voltage Concurrently Maintainable Data Center

An Alternate Approach To The Typical Modular Data Center Is To Provide An MV Ring Bus Configuration, Which Accommodates Large Power Block Deployments.



Typical Healthcare Facility Architecture

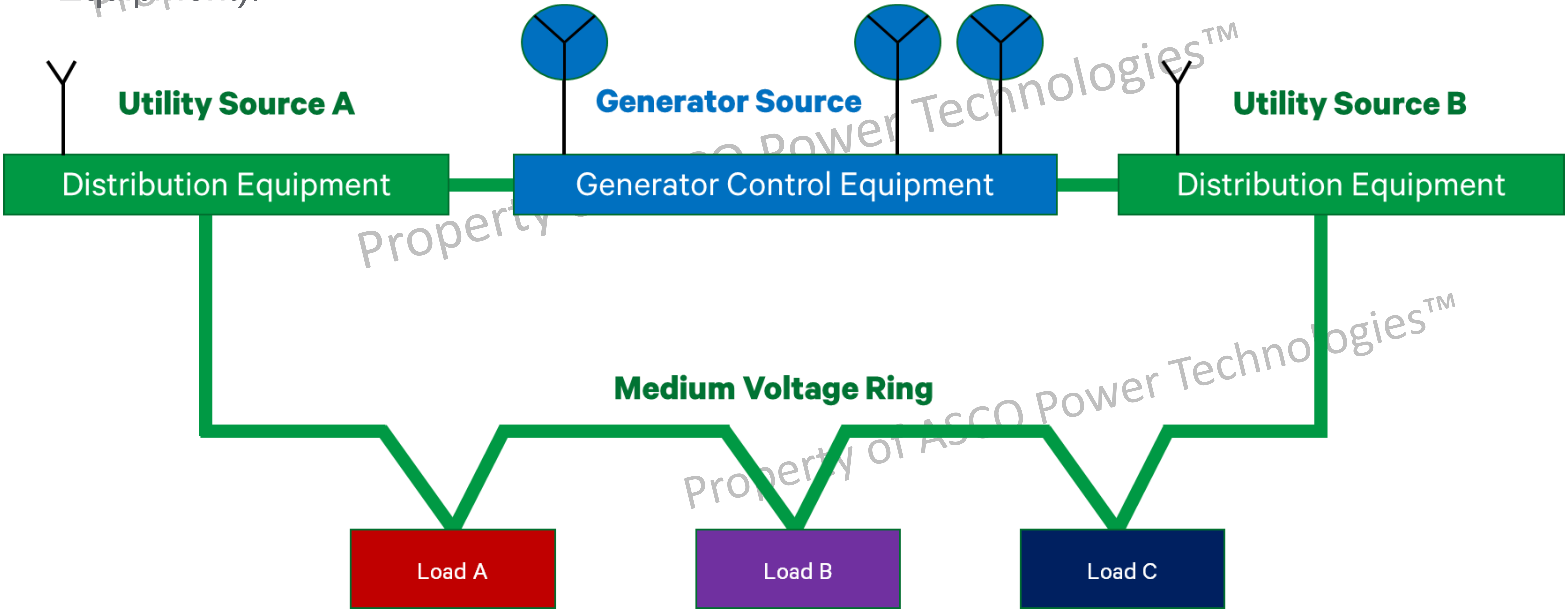
Healthcare Power Architecture Is Driven By Electrical Code (NFPA, NEC), Requiring Segregation Of (3) Distinct Branches: Life Safety, Critical And Equipment.



Life Safety & Critical Branches must be on emergency power with in 10 seconds

Typical Industrial Facility

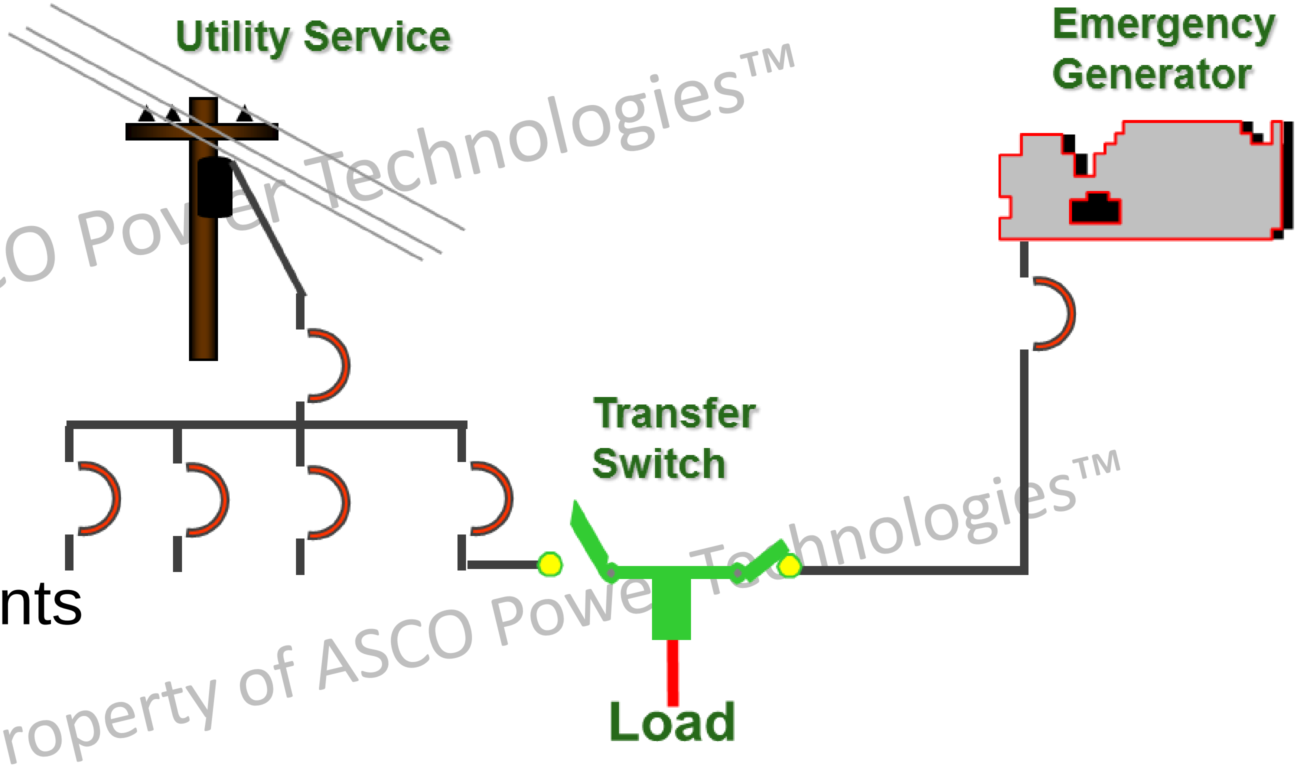
Industrial Facilities Typically Provide A Power Architecture That Natively Accommodates The Provided Equipment (I.E. Water Treatment Plants Architect MV Power Networks For MV Equipment).



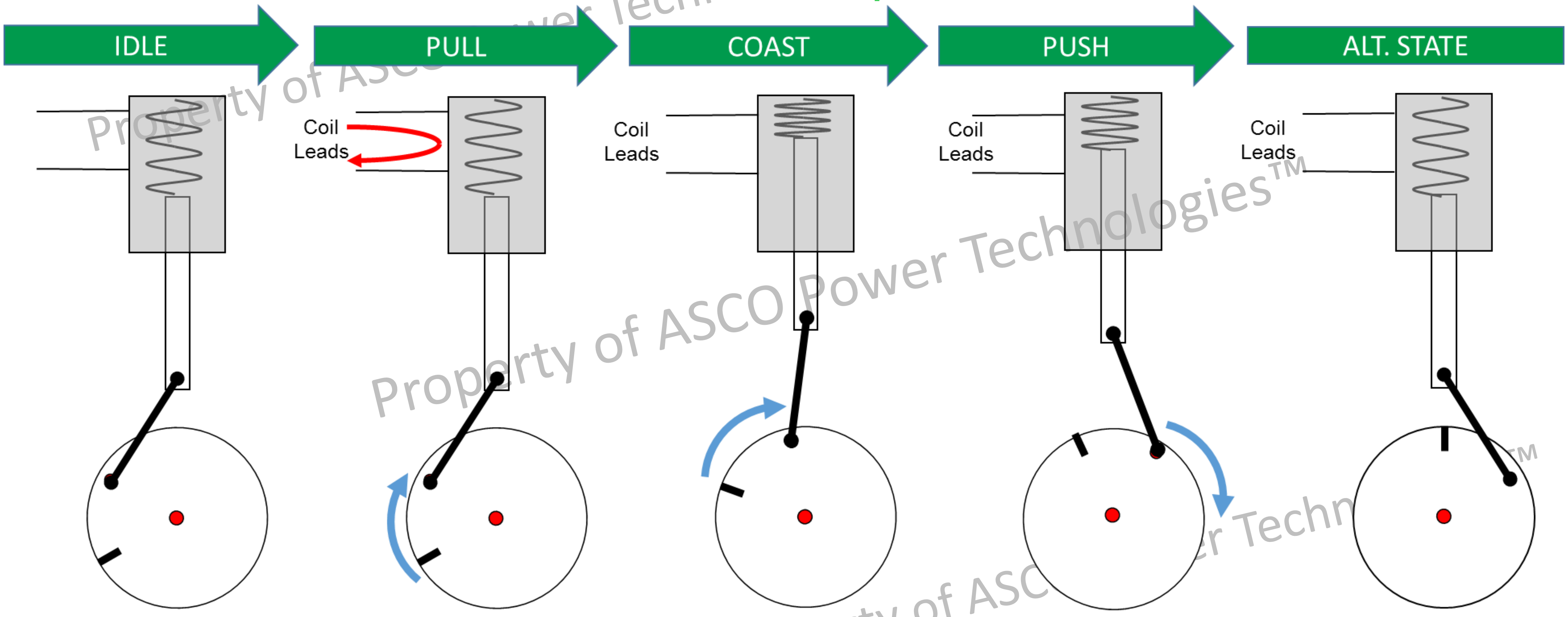
Purpose Of An Automatic Transfer Switch

Seven Major Functions of An Automatic Transfer Switch

- Carry Current Continuously
- Detect Power Failures
- Initiate Alternate Source
- Transfer Load
- Sense Restoration of Normal
- Retransfer Load To Normal
- Withstand And Close On Fault Currents



Automatic Transfer Switch Solenoid Operator



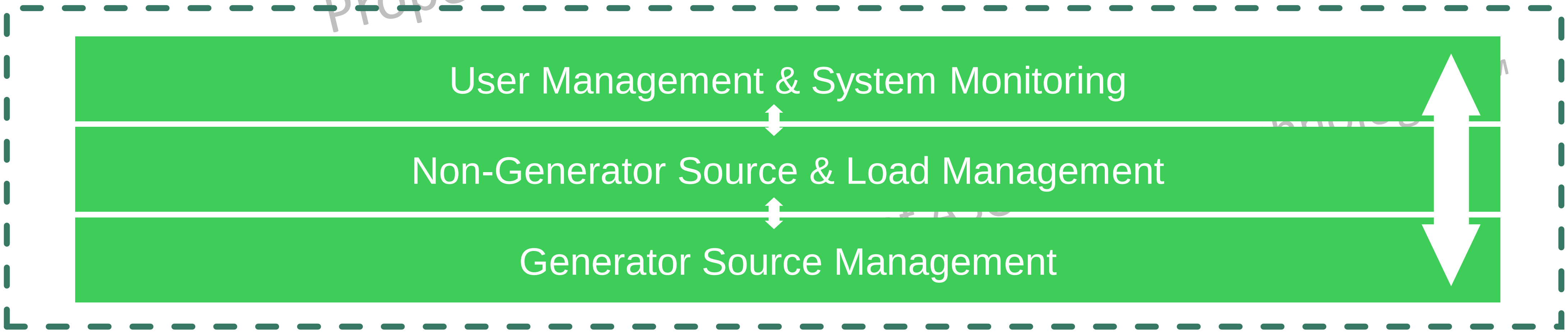
IDLE	PULL	COAST	PUSH	ALT. STATE
Transfer Switch In Idle	Current Applied To Solenoid	Current To Solenoid Interrupted	Spring Pushes Down On Linkage	Transfer Switch In Idle
ATS On Primary (Utility) Source	***Operator Energized via voltage from alternate source***	***Inertia allows motion to continue***	***Spring pushes ATS to its alternate position***	***ATS On Alternate (Generator) Source***

Side View representation of shaft that drives an ATS – Single operator that drives the ATS from one source to another source

Power Control System Networks – Multisource, Multiload Architectures

The Power Control System Is Comprised Of (3) Distinct Networks

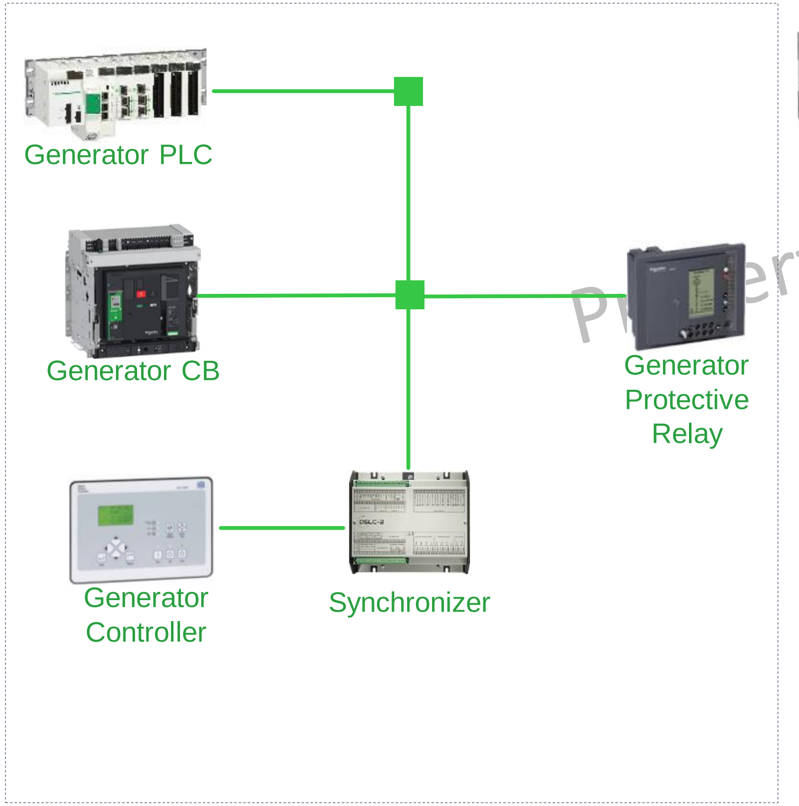
- The Generator Source Management Network (Generator Control System) Provides Direct Control Of Each Generator And Controls Its Connection To The Bus
- The Non-generator Source & Load Management Network (Master Control System) Provides System Load Management And Non-generator Source Connection To The Bus
- The User Management & System Monitoring Network (SCADA System) Allows For User Input Of System Settings And Monitors All Connected Devices



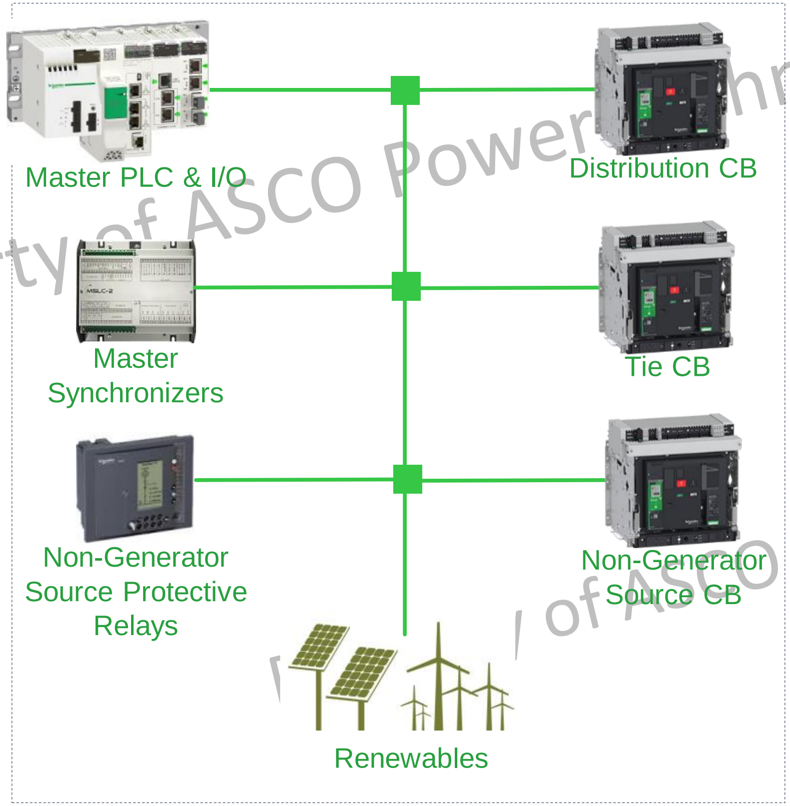
Separate networks allows for easier maintenance and troubleshooting

Network Connected Products

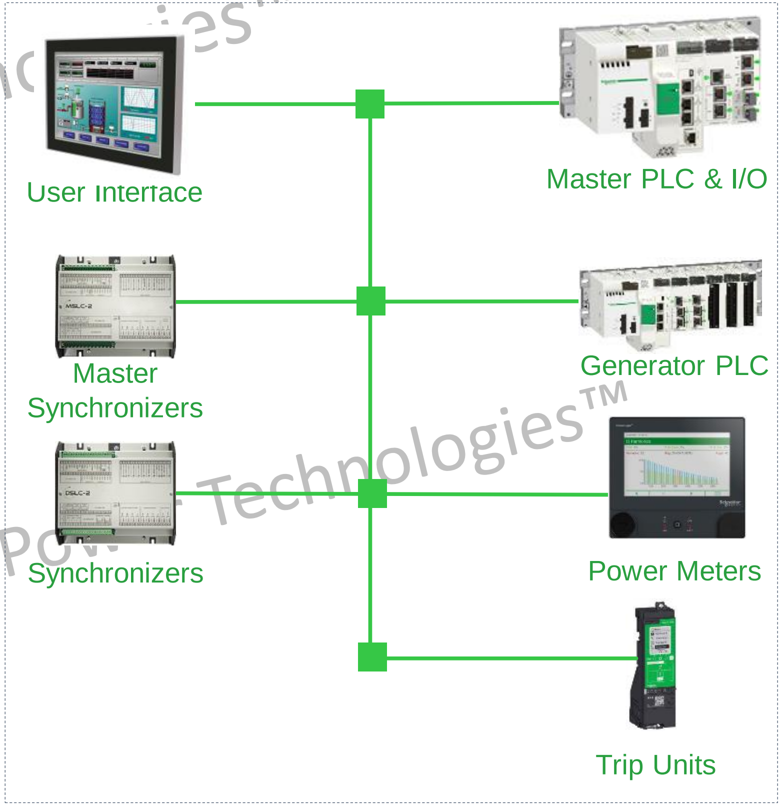
Generator Source Management
“The Generator Control System”



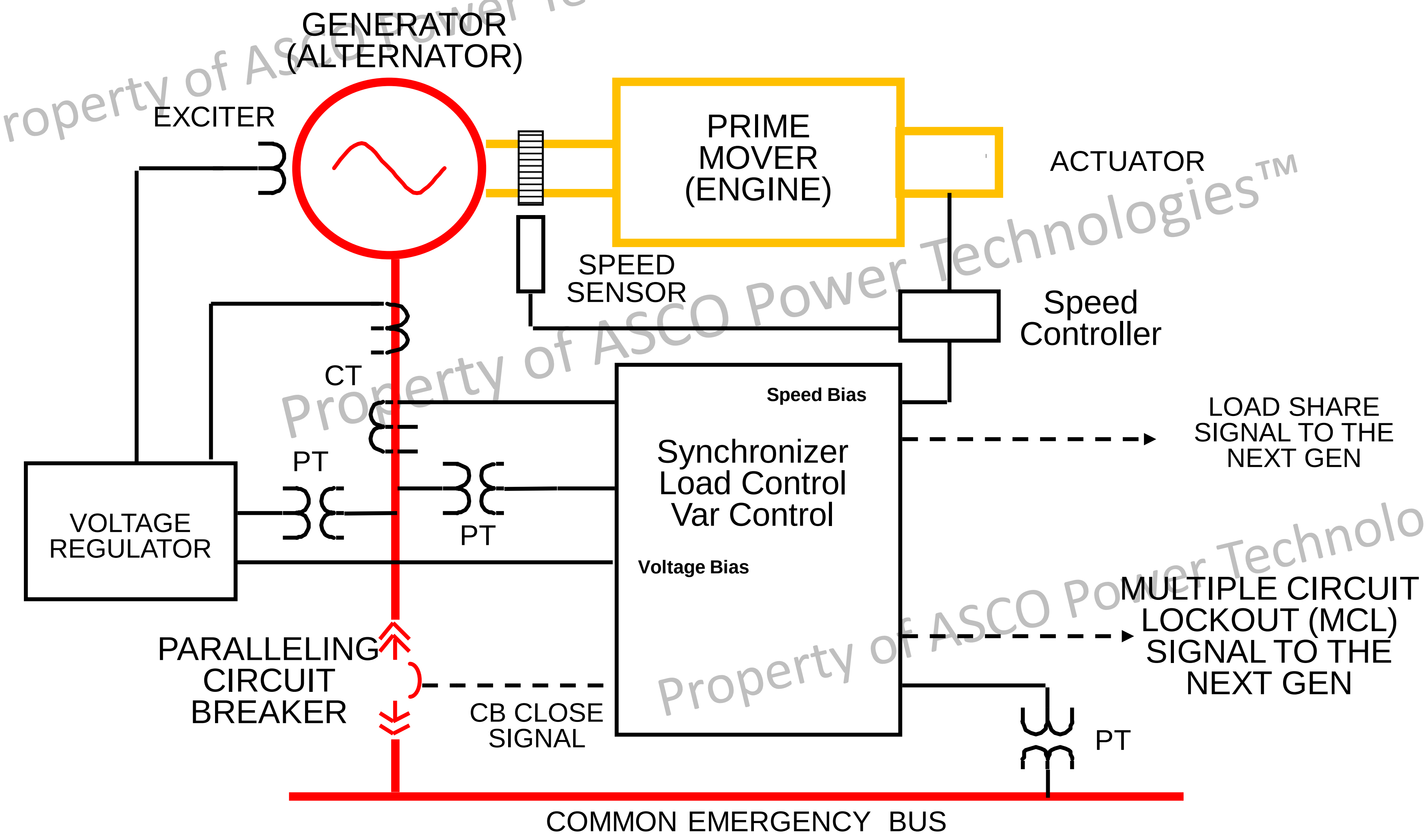
Non-Generator Source & Load Management
“The Master System”



User Management & System Monitoring
“The SCADA System”

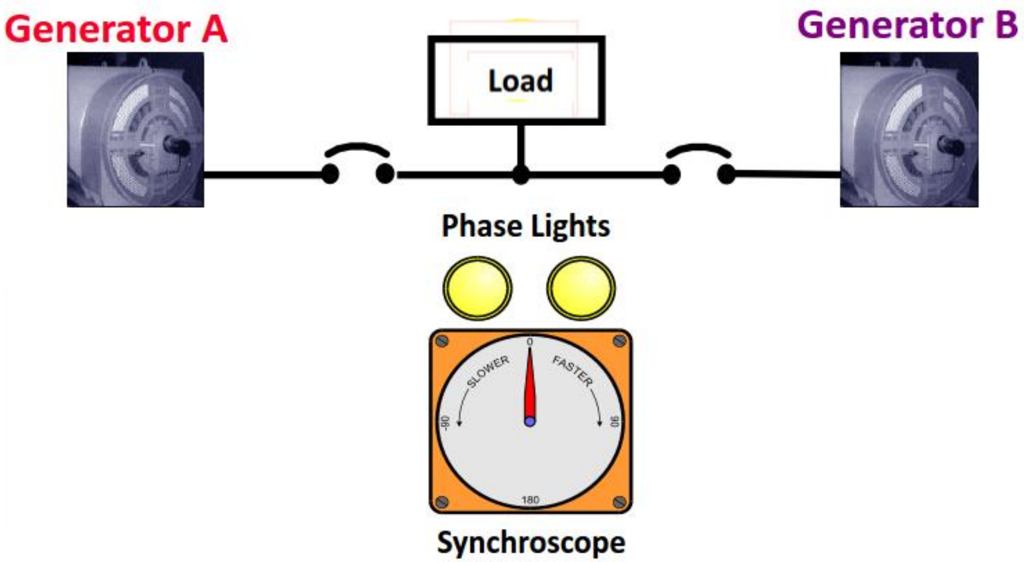


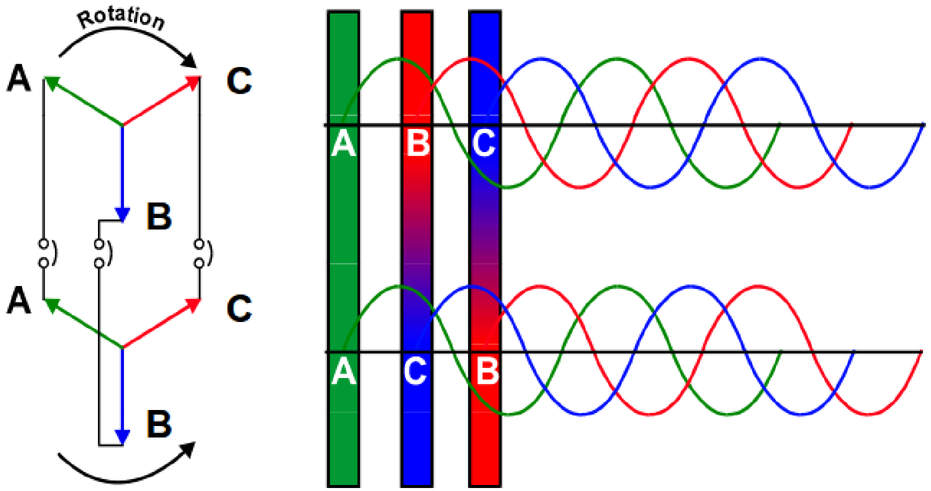
Generator Control Architecture



What is Synchronization?

- What is generator synchronization?
  - Generator synchronization matches generator speed/frequency with another source (Other generators and/or utility).
  - Voltage levels and phase relationships need to be considered.
- Why is synchronization needed?
  - Controls power surges. Avoids reverse power, overpower and mitigates transients when bringing additional power sources online.
  - Reduces electrical stress on generators and switchgear. Helps prevent high currents and breaker wear.
  - Reduces mechanical stress on generators and prime movers. Helps prevent bent drive shafts and broken couplings.
- What conditions must be met for two sources to be synchronized?
  1. The number of phases must be the same.
  2. The direction of rotation must be the same.
  3. The voltage amplitudes must be closely matched.
  4. The frequencies must be closely matched.
  5. The phase angles must be closely matched.



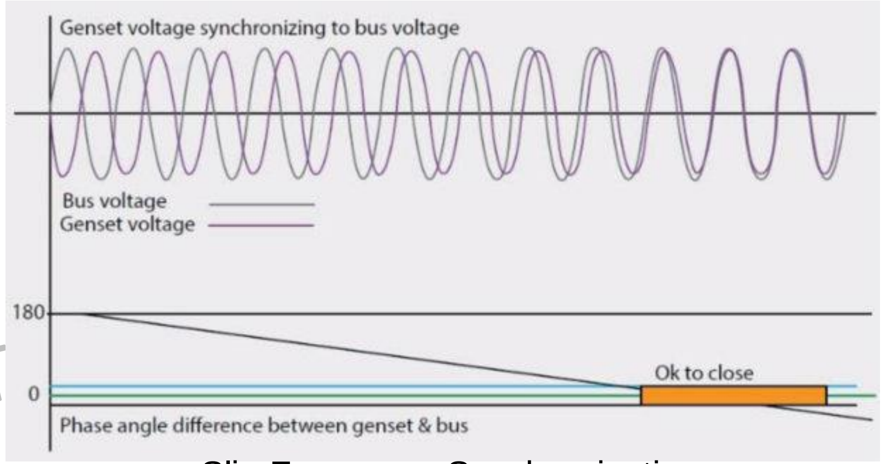


What Synchronization Methods Are Available?

How are multiple generators connected to a common bus?

Slip Frequency

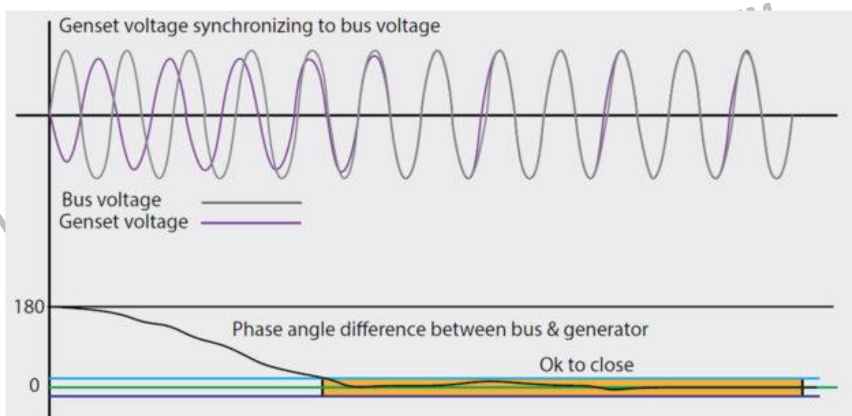
- The oncoming generator has a frequency slightly higher or lower than the bus
- Breaker closure is timed to occur at the moment the measured voltage sine waves align
- Useful when direction of power flow needs to be controlled at the moment of paralleling – *Ensures the source is pushing power*
- Typical of a closed transition transfer switch application – Passive synchronization



Slip Frequency Synchronization

Phase Match

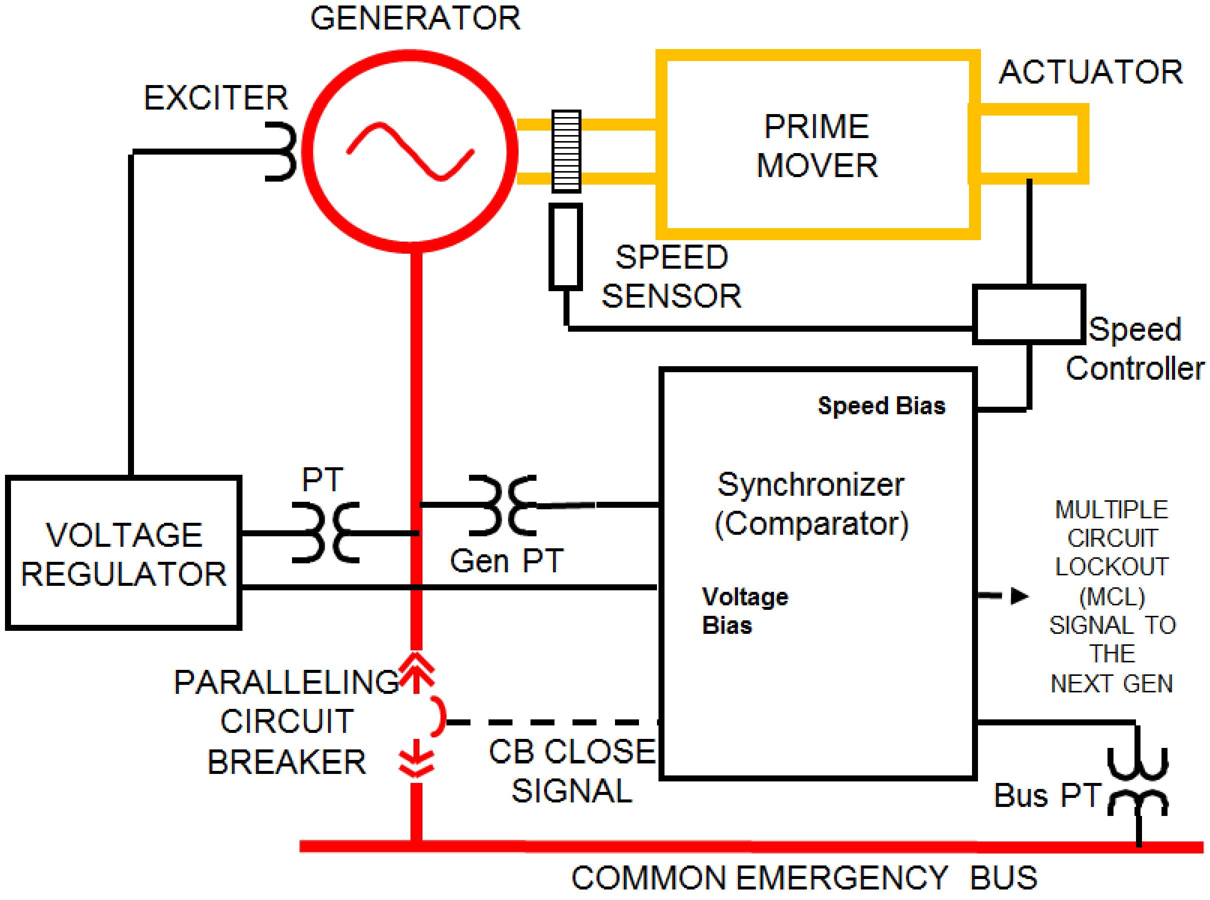
- The oncoming generator frequency is matched to the bus
- Subtle speed changes are made to align the measured voltage sine waves
- Breaker closure is initiated after A dwell time to assure both frequency and phase matching
- Typical of a multi-generator bus where it's used almost exclusively



Phase Match Synchronization

How Does An Automatic Synchronizer Work?

- Voltage from both sides of the generator breaker are brought into a comparator
- The comparator looks at the frequency, phase and voltage differences across the breaker and makes appropriate corrections to the speed control and voltage regulator of the generator
- When the synchronizer determines the phases are matched it allows the generator to be connected to the bus.
- Circuit breaker closure is determined by either phase matching or slip frequency criteria
- For dead bus closure, there must be a multiple circuit interlock to prevent more than one generator closing onto the dead bus at a time, typically provided as part of the synchronizer – Also referred to a “Dead Bus Arbitration” or “First on Sensor”



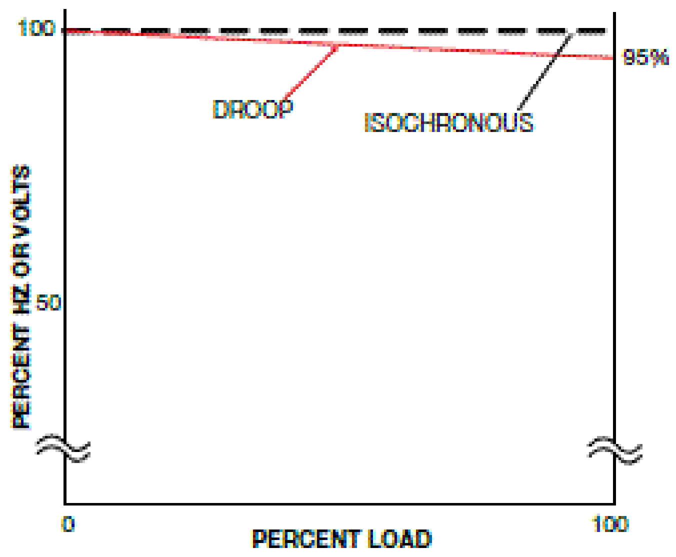
What Types Of Load Sharing Control Methods Are Available?

[Speed] Droop

- In this application, any change in load will result in a frequency (speed) change – As load increase, frequency decrease. As load decreases, frequency increases.
- In applications with (2) or more droop governors, the individual "speed references" will change by the same amount to maintain an even percentage of load
- If the same percent of droop is set on all governors, load will remain balanced under all load conditions
- Frequency (speed) will not stay constant with load variances – There will be transients as a result of frequency change

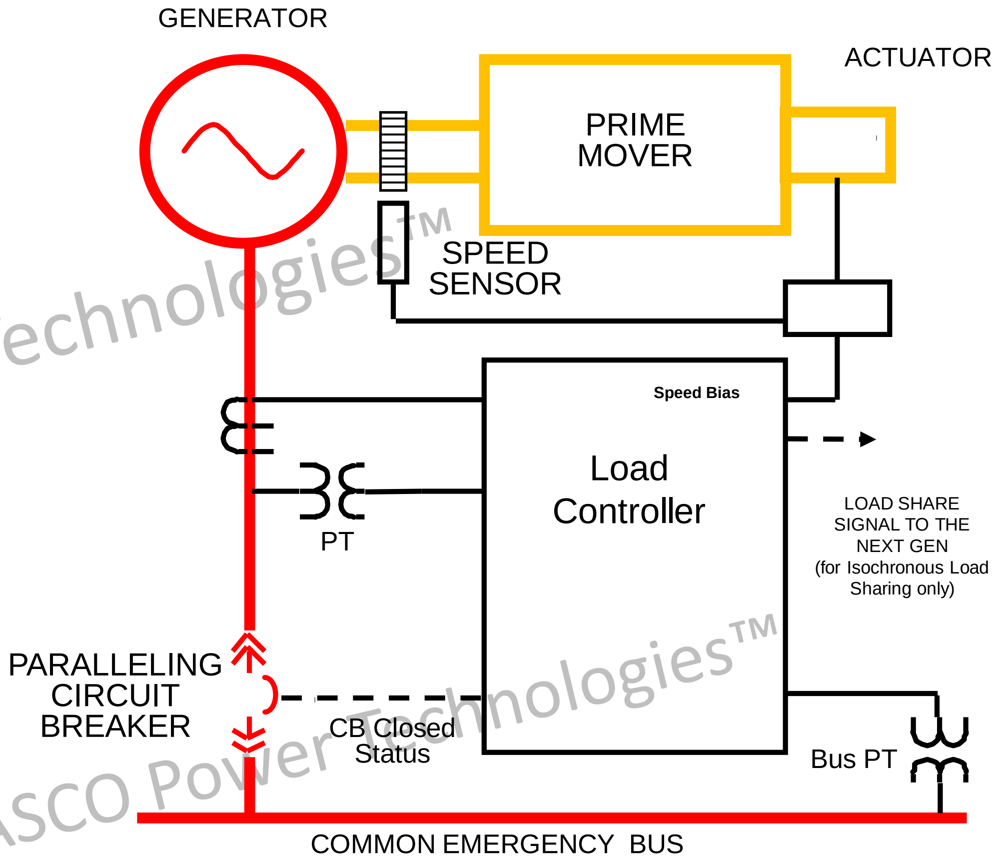
Isochronous

- In this application, frequency (speed) remains constant regardless of the load applied to the generator (within the capacity of the unit)
- This requires an electronic load controller for load signal communications
- Multiple generator sets can be connected together for proportional load sharing between each generator set
- Each generator set will carry a proportional amount of the system load while maintaining constant bus frequency



How Does a Load Share Module Work?

- A Load Share Module is provided for each engine generator and allows for connected load to be shared equally between connected engines (or proportionally for different sized engines)
- The Load Share Module monitors the output power of the generator, total demand of the system as well as the frequency of the bus
- When the Load Share Module confirms the generator paralleling breaker is closed, it adjusts speed up or down depending on the bus frequency and the load on the generator - as load increases, the frequency decreases.
- For isochronous load sharing, the Load Share Module monitors the load on the other generators in the system and can then adjust speed up or down depending on its relative load level



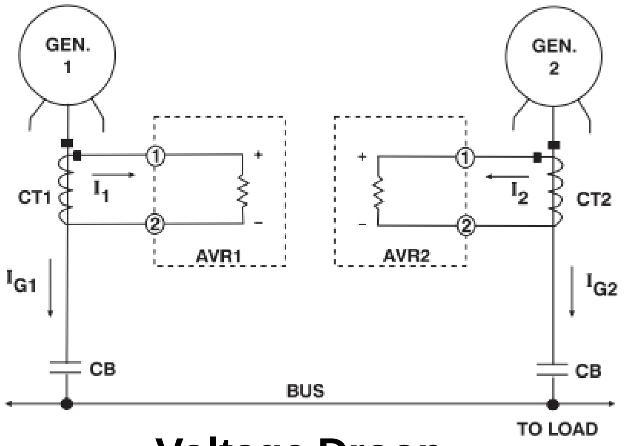
What Types Of VAR Control Methods Are Available?

(Voltage) Droop

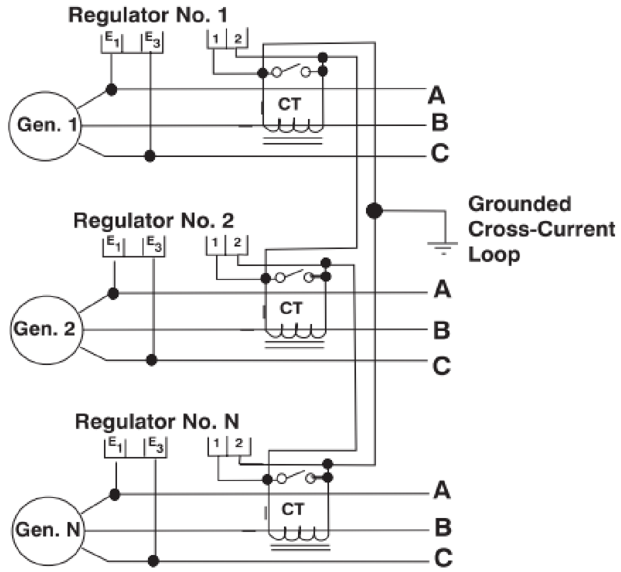
- In this application, any change in current will result in a voltage change
- In applications with two or more voltage regulators, the individual “voltage references” will change by the same amount to maintain an even percentage of vars
- If the same percent of droop is set on all voltage regulators, vars will stay balanced and shared equally under all load conditions
- Voltage will not stay constant with load variances. When load increases voltage decreases, when load decreases voltage increases. Injects transients into the system as a result of load variance.

Cross Current (Reactive Differential Compensation)

- In this application the cross current CT is wired into the regulator, but the CT is also wired out to the other voltage regulators such that an increase on the primary current of the CT will reduce the secondary current on the other CT’s
- If the primary currents are all balanced, the resultant input to the voltage regulators will be zero and the system will stabilize at rated voltage even with load variances
- May be seen on older systems or brownfield sites



Voltage Droop



Cross Current

What Types Of VAR Control Methods Are Available?

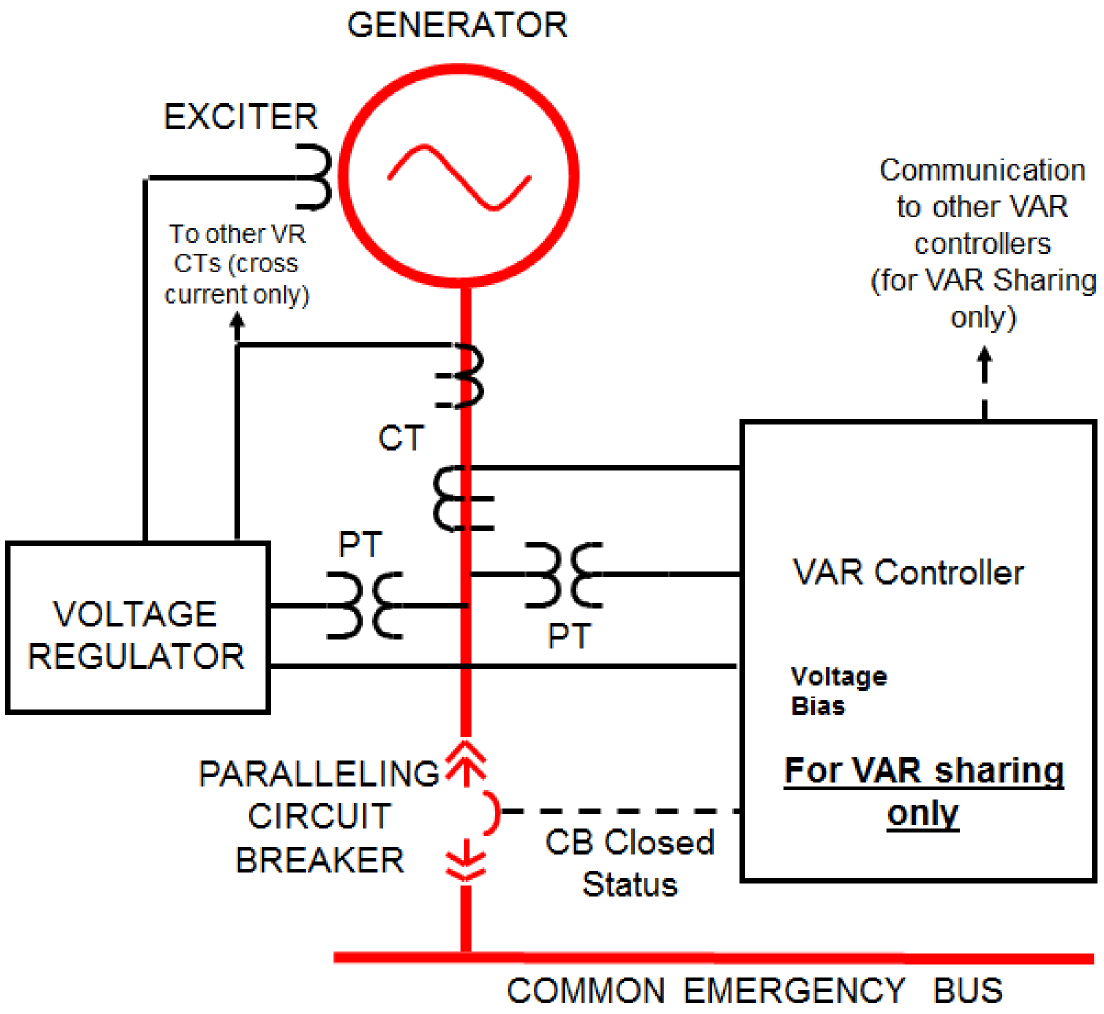
VAR Sharing

- In this application voltage remains constant regardless what the load is on the generator (within the capability of the unit)
- VAR sharing requires electronic voltage control for voltage signal communications
- Multiple generator sets can be connected together for proportional VAR sharing between each generator set
- Each generator set will carry a proportional amount of the system VARs while maintaining constant bus voltage
- VAR sharing is usually integrated into the genset controller (DSLC for example) when provided

VAR Sharing controller

How Does VAR Control Work?

- The voltage regulator monitors the voltage and current of the generator
- The voltage regulator can then adjust the voltage up or down depending on the voltage and current of the generator – as current increases, voltage will be decreased.
- For cross current, the summation of the differential circuit between the CT's will be zero when primary currents are balance – as a result, the voltage regulator will remain at rated voltage as the current changes as long as the current is balanced
- For VAR sharing, the VAR share module will need to know what the VARs are on the other generators in the system.
- Once it confirms the paralleling breaker is closed it can then adjust voltage up or down depending on it's relative var level



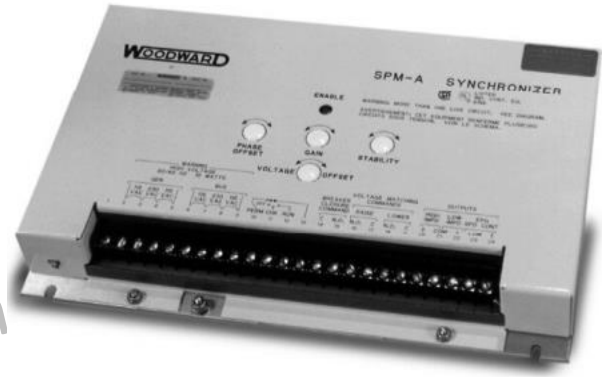
Considerations When Paralleling Multiple Generators

Synchronizing Means (Make/Model Of Synchronizer):

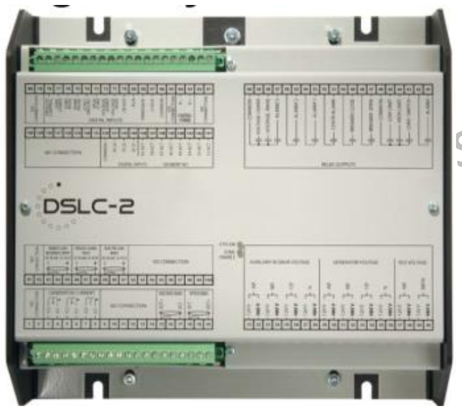
- All synchronizers should be the same make and model because they need to be compatible with a common Multiple Circuit Lockout or Dead Bus Arbitration so that only one generator will connect to the dead bus.

Load Sharing Means And Method (Droop Or Isochronous):

- Most emergency systems run in isochronous load sharing (load sharing at constant frequency). Isochronous load sharing requires compatible controllers that are in ***constant communication*** with each other as they share load proportionally while trimming their individual speed to a specific frequency.
- If the load share modules are not compatible, they can regulate load via the droop method where each controller will adjust speed to a predetermined set point based on the load of the individual engine sets. This will cause bus frequency to change slightly with load.



Analog Synchronizer

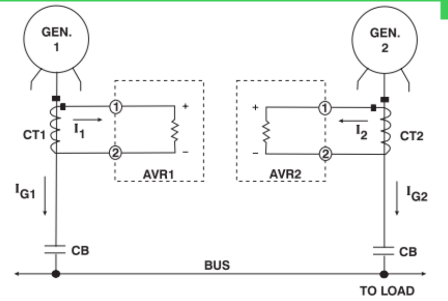


Digital Synchronizer

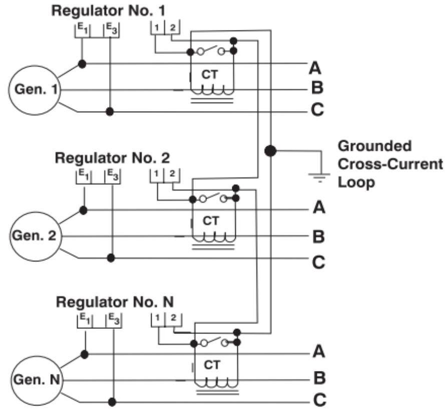
Considerations When Paralleling Multiple Generators

Voltage Control Means And Method (Droop, Cross Current, Or VAR Sharing):

- The simplest method for voltage control is droop. This method raises and lowers voltage based on the current through the voltage regulator CT.
- In order to maintain a constant voltage level, the cross current circuit was developed. With cross current all of the CT's are tied together in so that current contributions from external VR's oppose the current of the local VR, thus allowing VR's with higher reactive component to lower their voltage and VR's with lower reactive component to raise their voltage. Cross current is more accurately referred to as reactive differential compensation.
  - While cross current circuits are effective, they are complicated and the wiring involved is often considered a drawback. Additionally, cross current is incompatible with parallel with utility applications and is therefore limited in it's use.
  - Note: in cross current applications it is crucial that the voltage regulators have compatible input impedances as it is essentially a current divider circuit and any mismatch will almost certainly result in voltage control errors.
- VAR sharing is associated with digital controllers. With VAR sharing, the VR still needs to be connected to a CT and have droop setting, but the digital controller will send a bias signal to the voltage regulator to trim the voltage to a constant set point. In VAR sharing, all of the genset controllers need to ***communicate constantly*** to share vars and therefore all of the genset controllers need to be of the same make and model.
  - Note: a voltage regulator used in a VAR sharing system needs to be able to accept an analog voltage bias signal.



Voltage Droop



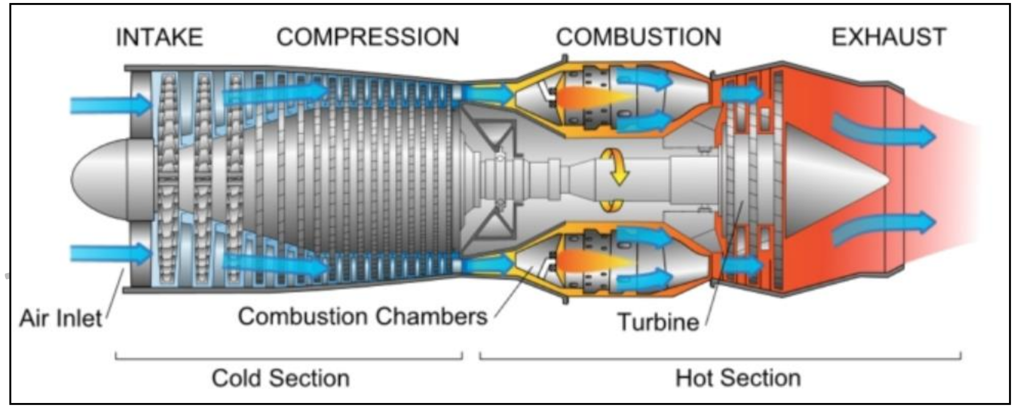
Cross Current

Paralleling Different Engines

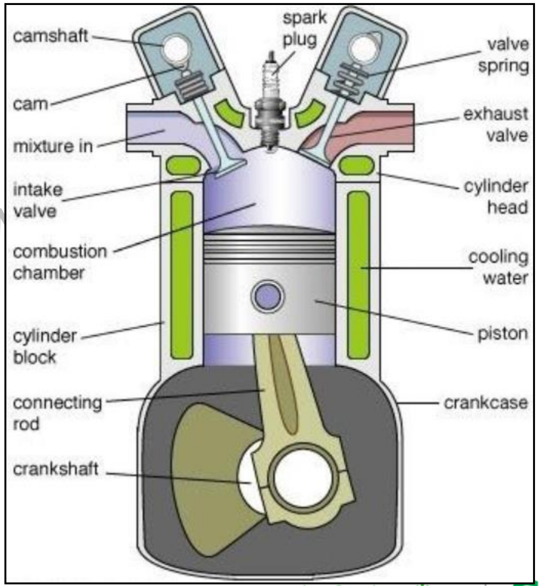
Can I parallel different types of engines?

- The generator and genset controller are only part of the equation when paralleling multiple generators, even if all the controllers are compatible and can communicate effectively. If the mechanical response is different between the different engines, there will be a problem.
- Most notably, this happens when trying to parallel a diesel reciprocating engine with a gas or steam turbine. The turbine's mechanical response is slower than the diesel and load sharing can become greatly imbalanced during block loading/unloading of paralleled devices.
    - Note: this is true (on a somewhat smaller scale) when paralleling diesel and gas engines, even if both are reciprocating (piston driven) engines.

Turbine



Reciprocating Engine



Paralleling Different Generators - Pitch

Can I parallel generators with different pitches?

- What is pitch? Mechanical design that creates a specific voltage waveform output to minimize harmonic distortion.
- Pitch based on the number of slots in the stator coil encompasses in a particular pole of a generator.
- All generators are wound to some fractional pitch. When paralleling different generators, it's important be sure the alternator pitch is matched.
- The most common winding is 2/3 pitch. The 2/3 pitch eliminates 3rd level harmonics but increases 5th level harmonics. Another common pitch is 5/6 which reduces 5th and 7th level harmonics but increases 3rd level harmonics.
- If the pitch is mismatched, instead of reducing harmonics they are increasing as the neutral voltage differences at the 3rd and 5th level harmonics cause increased waveform distortion.
- Mismatched pitch can cause VARs to circulate between generators but only if there is a solid connection on the neutrals with minimal impedance.

Stator coil configurations for 5/6 and 2/3 winding pitches

Each coil spans 10 slots
Winding pitch = 10/12 = 5/6

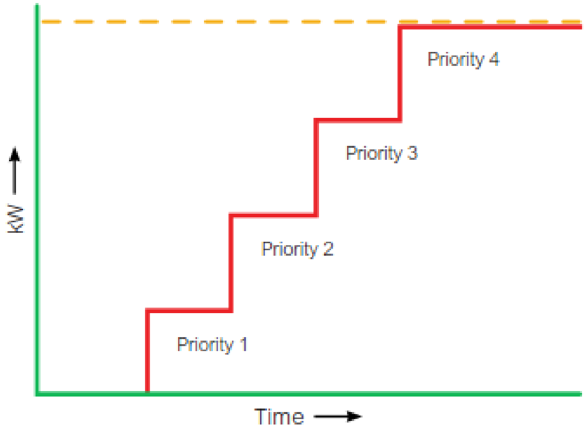
Each coil spans 8 slots
Winding pitch = 8/12 = 2/3

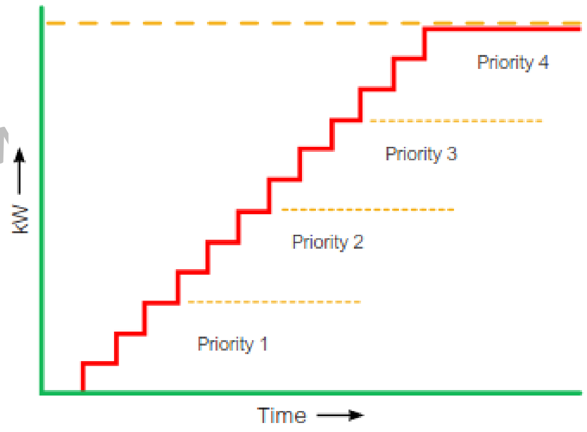
Automatic Priority Load Control

In A Traditional Paralleled Generator Design, All Loads Cannot Be Connect Immediately. They Must Be Prioritized And Connected To The Emergency Bus As The System Connects Generators (Increases In Capacity).

Block Load Add/Shed

- Each block of load (kW) should be sized respectively < the size of each generator (kW)
- Loads are added to the system based on the number of generators on the bus as prioritized blocks and are shed in smaller steps if generator reserve capacity decreases to the point of overload
- Load is typically added/shed in blocks according to their priority values
- Blocks are prioritized from life safety (priority 1) to least important (priority N, where N is the number of generators in the system)
- Shedding of load as a block is generally due to A bus under frequency. This can be caused by a generator failure and/or overload condition, but loss of a generator will not always result in load shed.



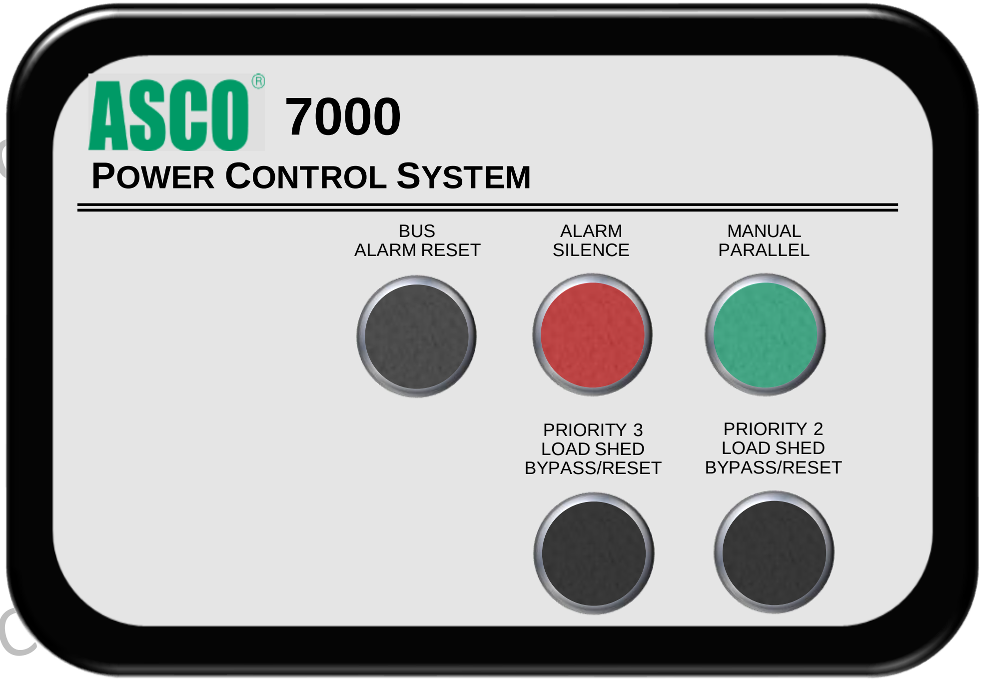


Manual Load Control

Events may occur that require the operator to override the automated load control and manually control the addition of load.

Manual Load Shed Bypass

- Manually re-adding previously shed load
- Operator initiated/deactivated via pushbuttons
- Subsequent overload will re-shed the load
    - Detected bus under frequency relay (81U)
    - Protects system from inadvertent operator error



Priority Load Control With Changing System Conditions

Automated Load Control Must Have The Capability To Account For Changes Or Failures In The System Configuration.

Load Demand

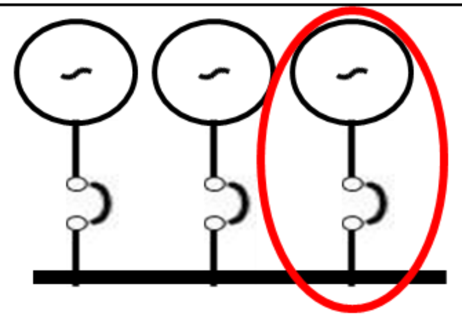
- Controls The Number Of Generators Connected To The Emergency Bus so they operate more efficiently.
- Minimizes runtime by Disconnecting Unnecessary Generators
- Helps balance out maintenance schedules

Bus Optimization

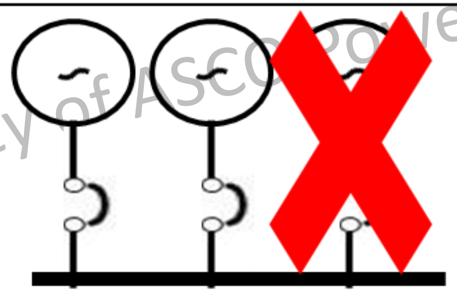
– Controls The Number Of Load Blocks To Be Connected To The Emergency Bus

– Maximize The Load Blocks On The Emergency Bus

– Calculates If The Next Load Block Can Be Connected To The Emergency Bus

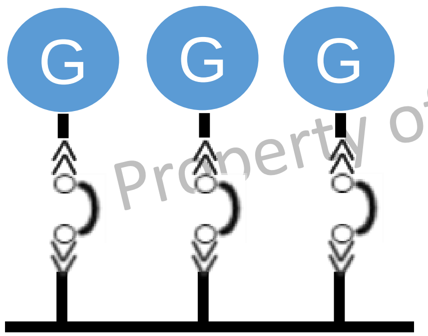


Operates When Excess Capacity is Available



Operates When A Generator Fails

Priority Load Control Example



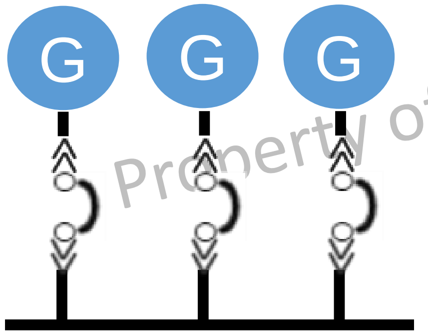
Each Generator Is Rated 1000kw

Priority Block 1	Priority Block 2	Priority Block 3
ATS 101	ATS 201	ATS 301
ATS 102	ATS 202	ATS 302
ATS 103	ATS 203	ATS 303
ATS 104	ATS 204	ATS 304
ATS 105	ATS 205	ATS 305
ATS 106	ATS 206	ATS 306
ATS 107	ATS 207	ATS 307

Total Demand On The Emergency Bus: 0kw

- Each ATS Load Is Equal To 100kw
- Each Generator Is 1000kw
- Bus Optimization Is Set To Allow Load Connection Of 90% In The Event Of A Generator Failure
- The Utility Source Is Available
- All ATSs Are Connected To The Utility Source

Priority Load Control Example



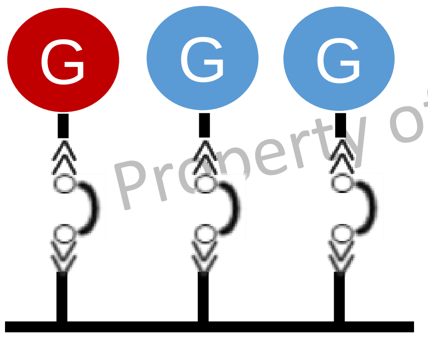
All Generators Are Signaled To Start

- The Utility Source Is Lost
- All ATSs Are De-energized
- All ATSs Send A Start Signal To The Generator Control System
- All Generators Are Signaled To Start

Priority Block 1	Priority Block 2	Priority Block 3
ATS 101	ATS 201	ATS 301
ATS 102	ATS 202	ATS 302
ATS 103	ATS 203	ATS 303
ATS 104	ATS 204	ATS 304
ATS 105	ATS 205	ATS 305
ATS 106	ATS 206	ATS 306
ATS 107	ATS 207	ATS 307

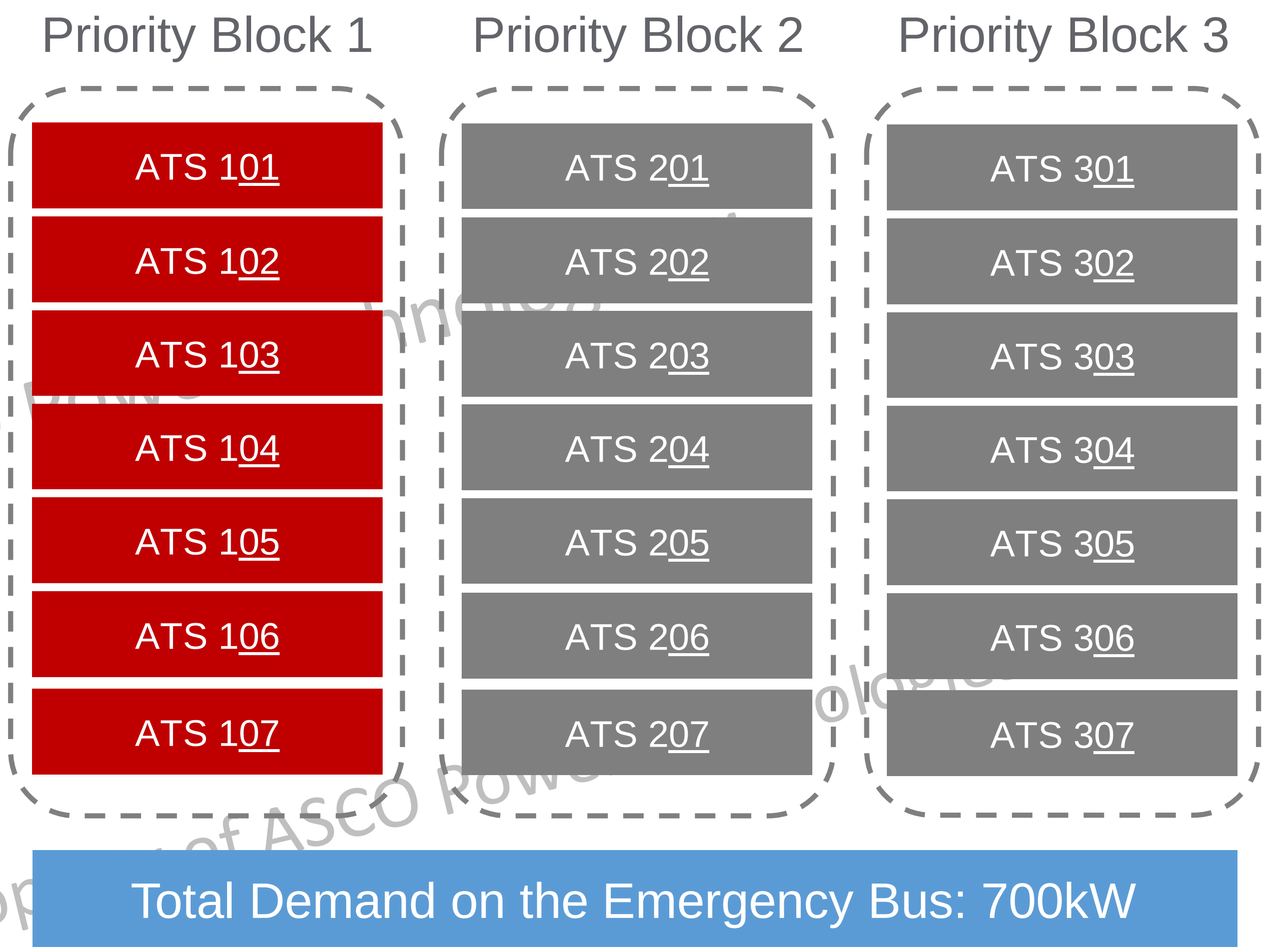
Total Demand on the Emergency Bus: 0kw

Priority Load Control Example

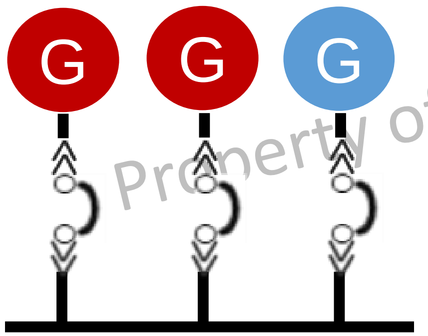


The 1st Generator Is Connected To the Bus

- The first generator to achieve nominal speed and voltage is connected to the emergency bus
- The system allows the connection of priority load block 1 to the emergency bus
- The total demand on the emergency bus is 700kW



Priority Load Control Example



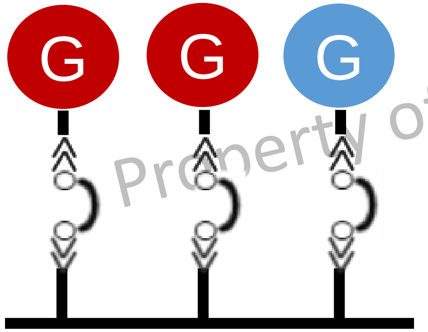
The 2nd Generator Is Connected To the Bus

- The second generator to achieve nominal speed and voltage is connected to the emergency bus
- The system allows the connection of priority load block 2 to the emergency bus
- The total demand on the emergency bus is 1400kW

Priority Block 1	Priority Block 2	Priority Block 3
ATS 101	ATS 201	ATS 301
ATS 102	ATS 202	ATS 302
ATS 103	ATS 203	ATS 303
ATS 104	ATS 204	ATS 304
ATS 105	ATS 205	ATS 305
ATS 106	ATS 206	ATS 306
ATS 107	ATS 207	ATS 307

Total Demand on the Emergency Bus: 1400kW

Priority Load Control Example



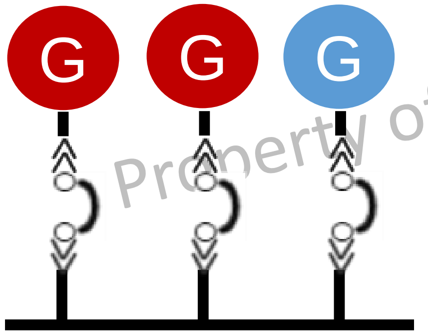
The 3rd Generator Fails To Connect To the Bus

- The third generator fails to connect to the bus
- Priority load block 3 remains de-energized
- The bus optimization time delay begins to count down

Priority Block 1	Priority Block 2	Priority Block 3
ATS 101	ATS 201	ATS 301
ATS 102	ATS 202	ATS 302
ATS 103	ATS 203	ATS 303
ATS 104	ATS 204	ATS 304
ATS 105	ATS 205	ATS 305
ATS 106	ATS 206	ATS 306
ATS 107	ATS 207	ATS 307

Total Demand on the Emergency Bus: 1400kW

Priority Load Control Example



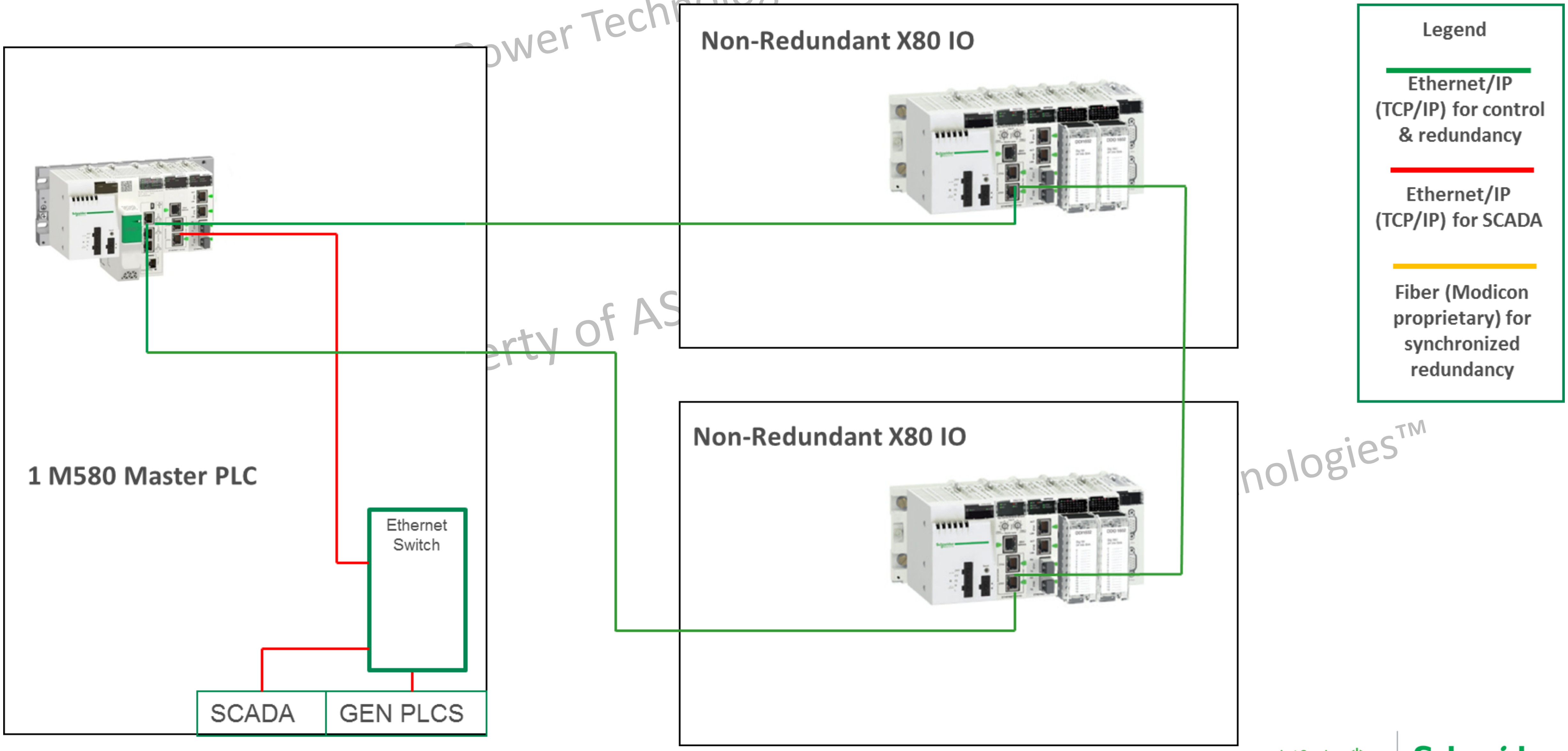
The System Allows 90% Total Capacity To Connect To the Bus

- The bus optimization time delays expires
- The priority 3 atss are allowed to connect to the emergency bus by sub-priority
- The system allows 1800kw to connect to the bus
- Four additional ATS are allowed to connect to the bus

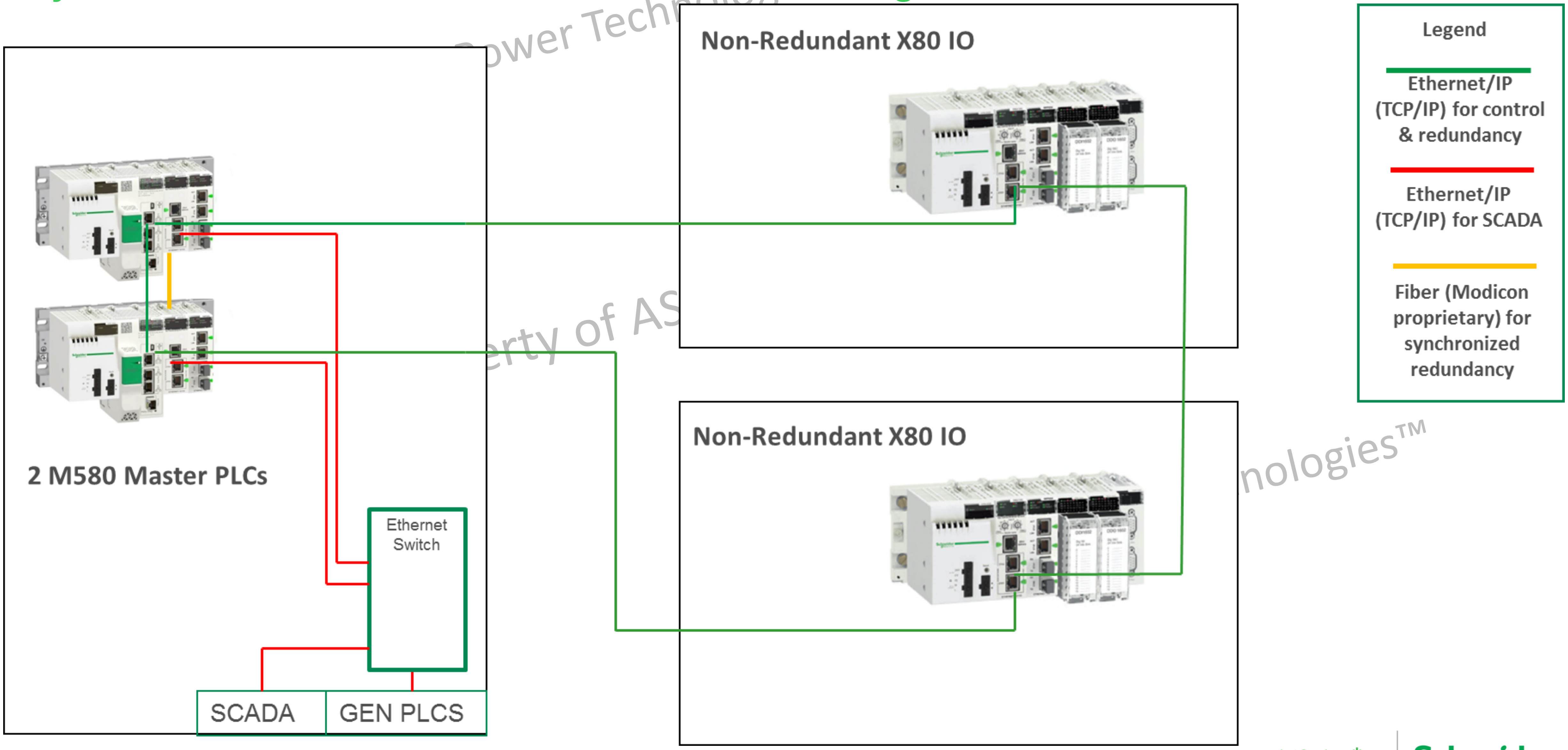
Priority Block 1	Priority Block 2	Priority Block 3
ATS 101	ATS 201	ATS 301
ATS 102	ATS 202	ATS 302
ATS 103	ATS 203	ATS 303
ATS 104	ATS 204	ATS 304
ATS 105	ATS 205	ATS 305
ATS 106	ATS 206	ATS 306
ATS 107	ATS 207	ATS 307

Total Demand on the Emergency Bus: 1800kW

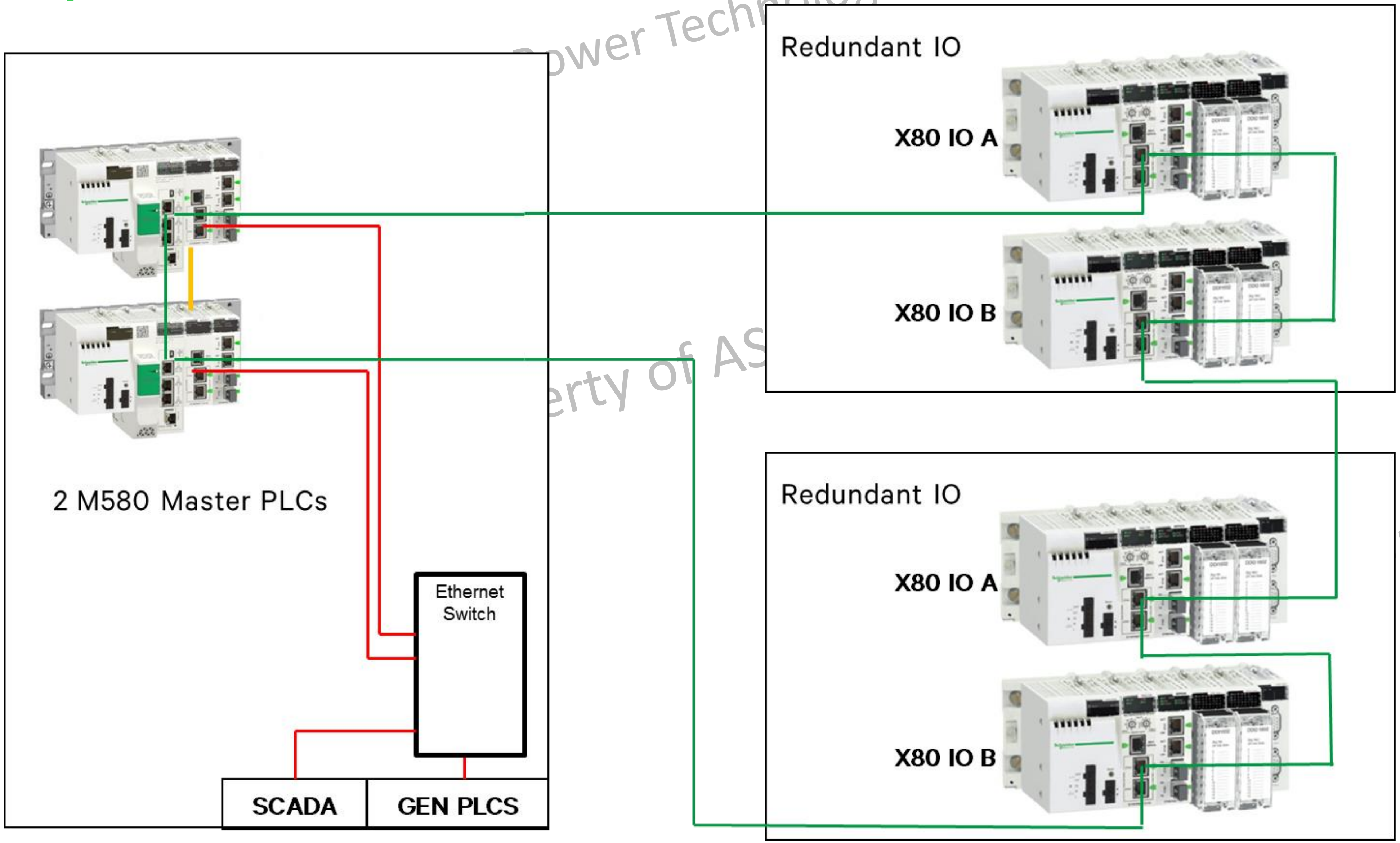
System Architecture – Single PLC, Single I/O



System Architecture – Redundant PLC, Single I/O



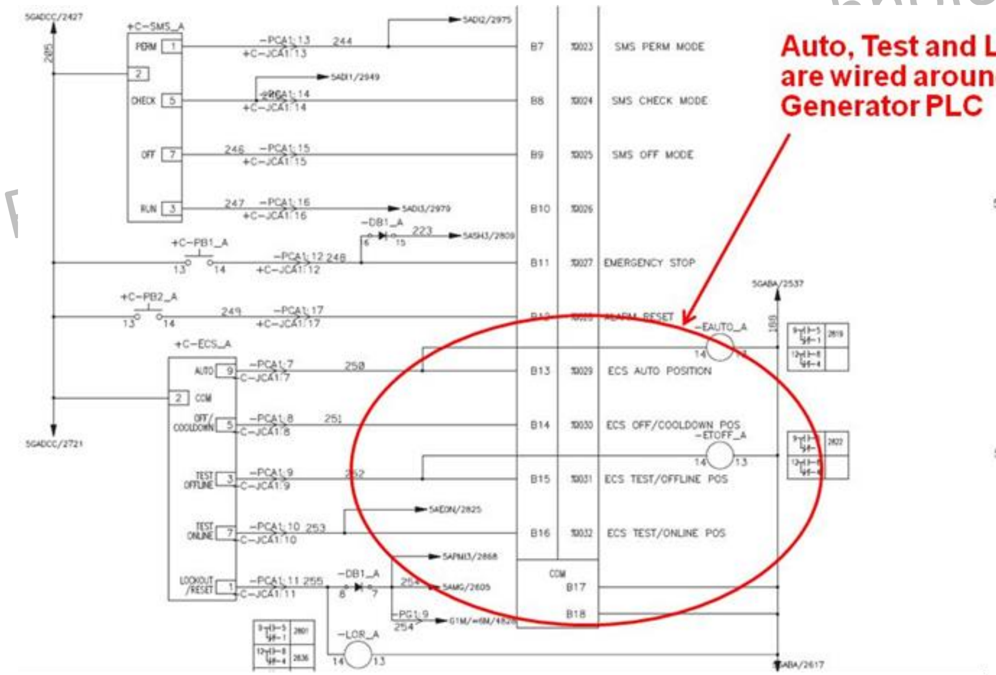
System Architecture – Redundant PLC, Redundant I/O



Legend

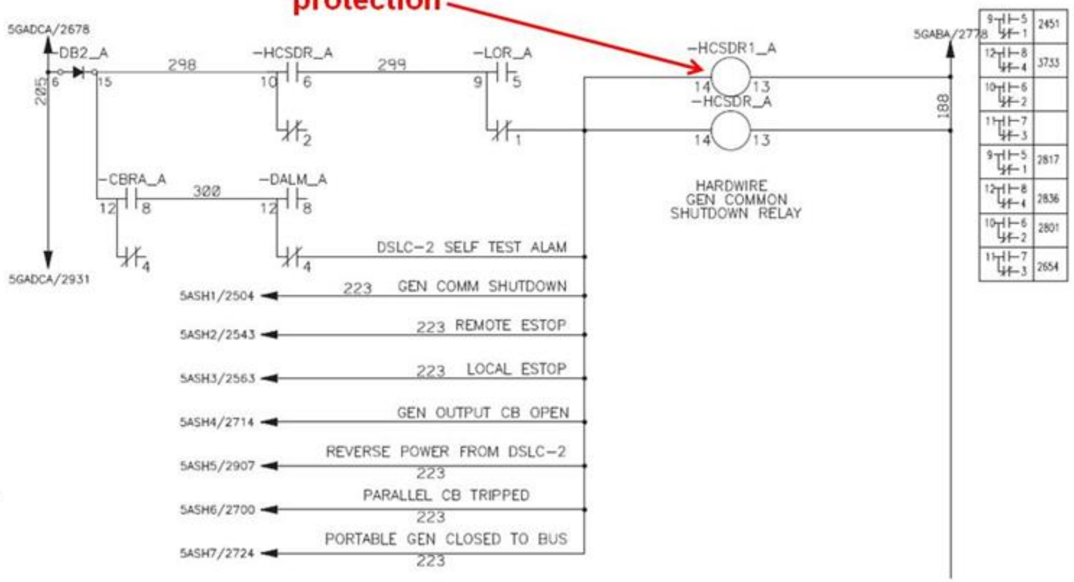
- Ethernet/IP (TCP/IP) for control & redundancy
- Ethernet/IP (TCP/IP) for SCADA
- Fiber (Modicon proprietary) for synchronized redundancy

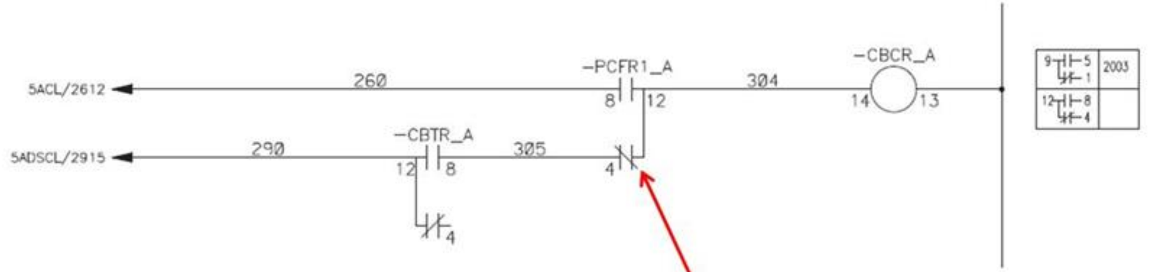
Hard-wired Backup Circuits



Auto, Test and Lockout are wired around the Generator PLC

The DSLC-2 provides protection





Close relay can be activated on generator PLC failure.

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User Management & System Monitoring

An Operator Interface Panel (8” – 42” Touch Screen) Should Be Provided To Allow Modification Of User-Adjustable Settings And System Monitoring And Control

Generator Controls Station

Breaker Controls

Master Control Operation

Generator Menu

Load/Gen Priorities

Status One-Line

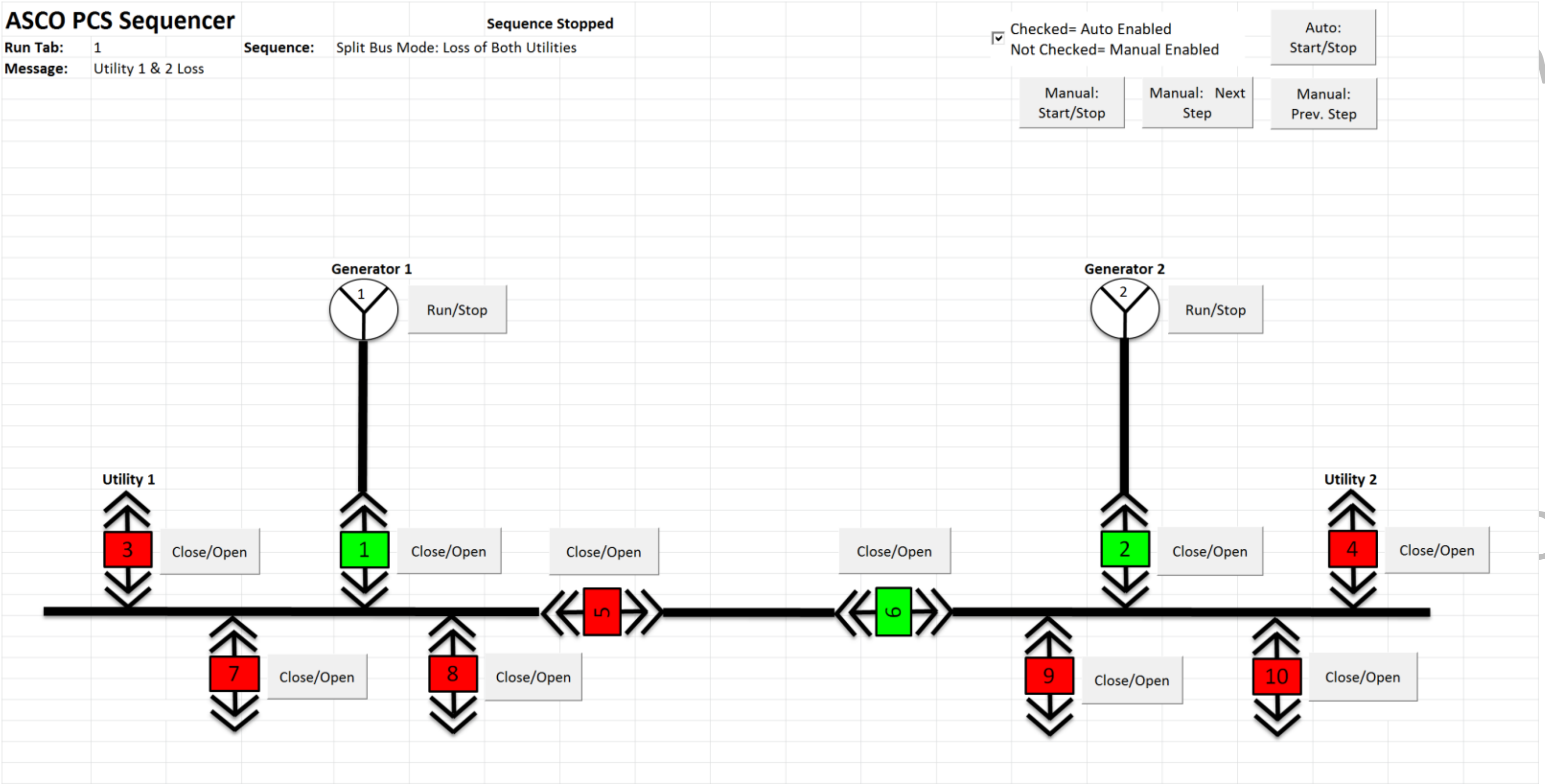
Additional Control And Monitoring Hardware Considerations

Consider Additional Monitoring And Control Nodes To Allow User Interface Outside the Arcflash Zone

Consider Including A Power Control Systems Simulator For PLC Modification Testing And Operator Training

System Failure Analysis

Failure Recovery Sequences Should Be Included In All Power Control Systems For Critical Applications, Allowing Automated Multi-Failure Recovery Whenever Possible

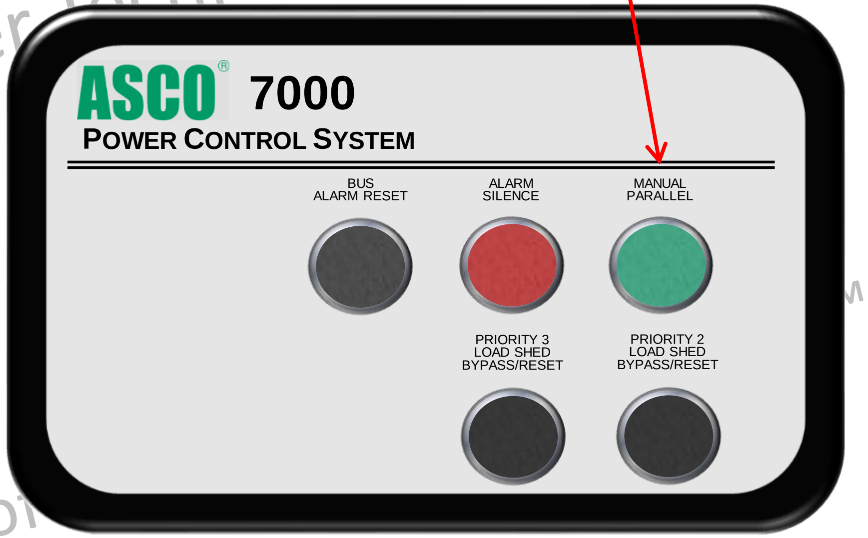


	MODE	TRANSITION TYPE	PREFERRED UTILITY	PREFERRED BACKUP	SEQUENCE	FAILURE
Sequence 1	Split Bus	Any	Any	Any	Loss of Both Utilities	None
Sequence 2	Split Bus	Any	Any	Any	Loss of Both Utilities	Generator 2 Failure
Sequence 3	Split Bus	Any	Any	Any	Loss of Both Utilities	Generator 1 Failure
Sequence 4	Split Bus	Any	Any	Any	Loss of Both Utilities	Generator 2 Main Circuit Breaker Fail to Close
Sequence 5	Split Bus	Any	Any	Any	Loss of Both Utilities	Generator 1 Main Circuit Breaker Fail to Close
Sequence 6	Split Bus	Any	Any	Any	Loss of Both Utilities	Utility 1 Main Circuit Breaker Fail to Open
Sequence 7	Split Bus	Any	Any	Any	Loss of Both Utilities	Utility 2 Main Circuit Breaker Fail to Open
Sequence 8	Split Bus	Softload	Any	Any	Return of Both Utilities	None
Sequence 9	Split Bus	Softload	Any	Any	Return of Both Utilities	Utility 1 Main Circuit Breaker Fail to Close
Sequence 10	Split Bus	Softload	Any	Any	Return of Both Utilities	Utility 2 Main Circuit Breaker Fail to Close
Sequence 11	Split Bus	Softload	Any	Any	Return of Both Utilities	Generator 1 Main Circuit Breaker Fail to Open
Sequence 12	Split Bus	Softload	Any	Any	Return of Both Utilities	Generator 2 Main Circuit Breaker Fail to Open
Sequence 13	Split Bus	Open	Any	Any	Return of Both Utilities	None
Sequence 14	Split Bus	Open	Any	Any	Return of Both Utilities	Utility 1 Main Circuit Breaker Fail to Close
Sequence 15	Split Bus	Open	Any	Any	Return of Both Utilities	Utility 2 Main Circuit Breaker Fail to Close
Sequence 16	Split Bus	Open	Any	Any	Return of Both Utilities	Generator 1 Main Circuit Breaker Fail to Open
Sequence 17	Split Bus	Open	Any	Any	Return of Both Utilities	Generator 2 Main Circuit Breaker Fail to Open
Sequence 18	Split Bus	Any	Any	Generator	Loss of Single Utility 1	None
Sequence 19	Split Bus	Any	Any	Generator	Loss of Single Utility 1	Utility 1 Main Circuit Breaker Fail to Open
Sequence 20	Split Bus	Any	Any	Generator	Loss of Single Utility 1	Generator 1 Failure
Sequence 21	Split Bus	Any	Any	Generator	Loss of Single Utility 1	Generator 1 Main Circuit Breaker Fail to Close
Sequence 22	Split Bus	Any	Any	Generator	Loss of Single Utility 2	None
Sequence 23	Split Bus	Any	Any	Generator	Loss of Single Utility 2	Utility 2 Main Circuit Breaker Fail to Open
Sequence 24	Split Bus	Any	Any	Generator	Loss of Single Utility 2	Generator 2 Failure
Sequence 25	Split Bus	Any	Any	Generator	Loss of Single Utility 2	Generator 2 Main Circuit Breaker Fail to Close
Sequence 26	Split Bus	Any	Any	Utility	Loss of Single Utility 1	None
Sequence 27	Split Bus	Any	Any	Utility	Loss of Single Utility 1	Utility 1 Main Circuit Breaker Fail to Open
Sequence 28	Split Bus	Any	Any	Utility	Loss of Single Utility 1	Tie Circuit Breaker Fail to Close
Sequence 29	Split Bus	Any	Any	Utility	Loss of Single Utility 2	None
Sequence 30	Split Bus	Any	Any	Utility	Loss of Single Utility 2	Utility 1 Main Circuit Breaker Fail to Open
Sequence 31	Split Bus	Any	Any	Utility	Loss of Single Utility 2	Tie Circuit Breaker Fail to Close
Sequence 32	Split Bus	Softload	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	None
Sequence 33	Split Bus	Softload	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Generator 1 Failure
Sequence 34	Split Bus	Softload	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Generator 1 Main Circuit Breaker Fail to Close
Sequence 35	Split Bus	Softload	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Tie Circuit Breaker Fail to Open
Sequence 36	Split Bus	Softload	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 37	Split Bus	Softload	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 38	Split Bus	Open	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	None
Sequence 39	Split Bus	Open	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Tie Circuit Breaker Fail to Open
Sequence 40	Split Bus	Open	Any	Any	Return of Utility 1 (Bus Energized by Utility 2)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 41	Split Bus	Softload	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	None
Sequence 42	Split Bus	Softload	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Generator 2 Failure
Sequence 43	Split Bus	Softload	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Generator 2 Main Circuit Breaker Fail to Close
Sequence 44	Split Bus	Softload	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Tie Circuit Breaker Fail to Open
Sequence 45	Split Bus	Softload	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Utility Main Circuit Breaker Fail to Open
Sequence 46	Split Bus	Softload	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Generator 2 Main Circuit Breaker Fail to Open
Sequence 47	Split Bus	Open	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	None
Sequence 48	Split Bus	Open	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Tie Circuit Breaker Fail to Open
Sequence 49	Split Bus	Open	Any	Any	Return of Utility 2 (Bus Energized by Utility 1)	Utility 2 Main Circuit Breaker Fail to Close
Sequence 50	Common	Any	Utility 1	Any	Loss of Utility 1	None
Sequence 51	Common	Any	Utility 1	Any	Loss of Utility 1	Utility 1 Main Circuit Breaker Fail to Open
Sequence 52	Common	Any	Utility 1	Any	Loss of Utility 1	Utility 2 Main Circuit Breaker Fail to Close
Sequence 53	Common	Any	Utility 2	Any	Loss of Utility 2	None
Sequence 54	Common	Any	Utility 2	Any	Loss of Utility 2	Utility 2 Main Circuit Breaker Fail to Open
Sequence 55	Common	Any	Utility 2	Any	Loss of Utility 2	Utility 1 Main Circuit Breaker Fail to Close
Sequence 56	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	None
Sequence 57	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Generator 1 Failure
Sequence 58	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Generator 1 Main Circuit Breaker Fail to Close
Sequence 59	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Utility 2 Main Circuit Breaker Fail to Open
Sequence 60	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 61	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 62	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	None
Sequence 63	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Utility 2 Main Circuit Breaker Fail to Open
Sequence 64	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Utility 2)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 65	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 1)	None
Sequence 66	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 1)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 67	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 1)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 68	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 1)	None
Sequence 69	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 1)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 70	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 1)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 71	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 2)	None
Sequence 72	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 2)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 73	Common	Softload	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 2)	Generator 2 Main Circuit Breaker Fail to Open
Sequence 74	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 2)	None
Sequence 75	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 2)	Generator 2 Main Circuit Breaker Fail to Open
Sequence 76	Common	Open	Utility 1	Any	Return of Utility 1 (Bus Energized by Generator 2)	Utility 1 Main Circuit Breaker Fail to Close
Sequence 77	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	None
Sequence 78	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Generator 1 Failure
Sequence 79	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Generator 1 Main Circuit Breaker Fail to Close
Sequence 80	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Utility 1 Main Circuit Breaker Fail to Open
Sequence 81	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Utility 2 Main Circuit Breaker Fail to Close
Sequence 82	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 83	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	None
Sequence 84	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Utility 1 Main Circuit Breaker Fail to Open
Sequence 85	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Utility 1)	Utility 2 Main Circuit Breaker Fail to Close
Sequence 86	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 1)	None
Sequence 87	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 1)	Utility 2 Main Circuit Breaker Fail to Close
Sequence 88	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 1)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 89	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 1)	None
Sequence 90	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 1)	Generator 1 Main Circuit Breaker Fail to Open
Sequence 91	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 1)	Utility 2 Main Circuit Breaker Fail to Close
Sequence 92	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 2)	None
Sequence 93	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 2)	Utility 2 Main Circuit Breaker Fail to Close
Sequence 94	Common	Softload	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 2)	Generator 2 Main Circuit Breaker Fail to Open
Sequence 95	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 2)	None
Sequence 96	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 2)	Generator 2 Main Circuit Breaker Fail to Open
Sequence 97	Common	Open	Utility 2	Any	Return of Utility 2 (Bus Energized by Generator 2)	Utility 2 Main Circuit Breaker Fail to Close

Manual Paralleling

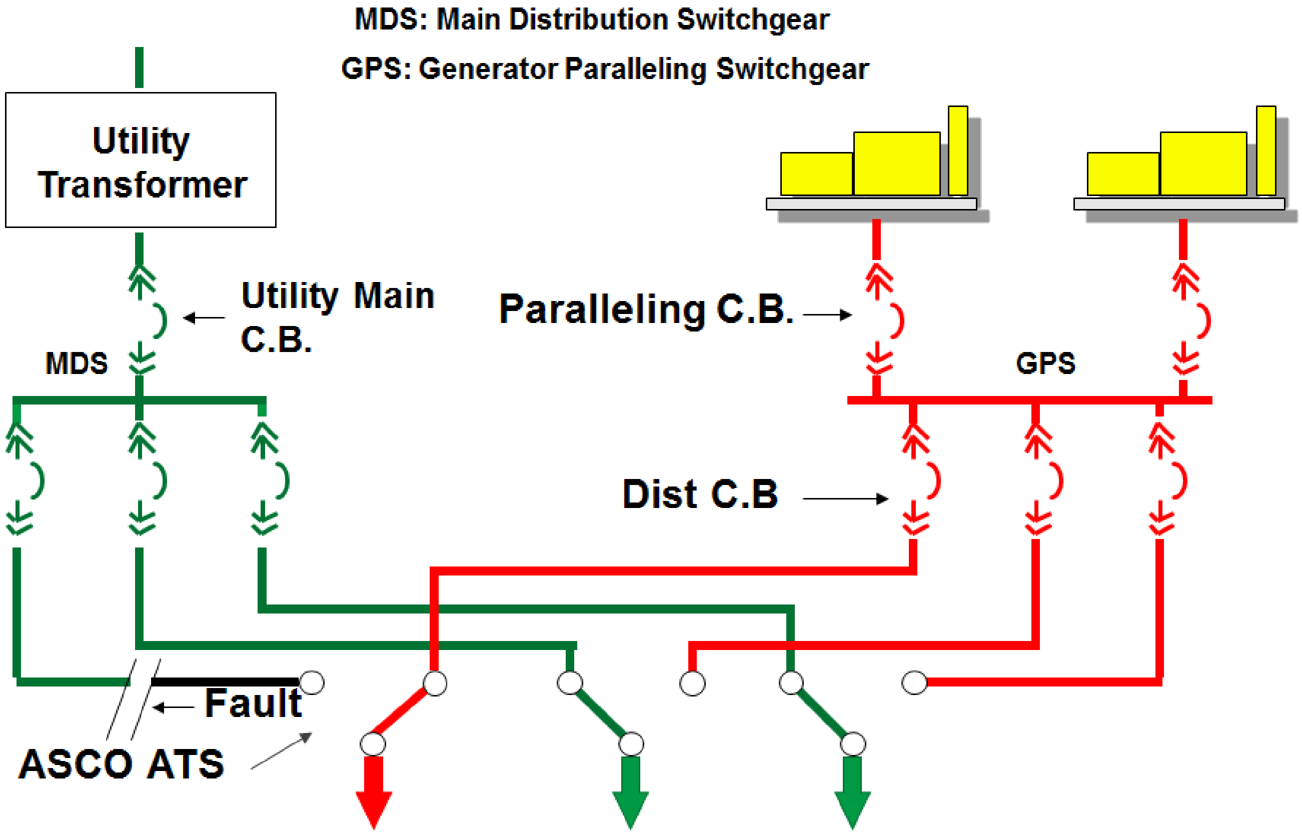
- This provides A means to manually close the generator breakers in-phase if one or more automatic synchronizers are not functioning properly
- Used to verify automatic synchronization before paralleling generators.
- All of the generator breakers can be closed from one location at the master
- A synchroscope, plant selector switch and synch check relay aid the operator in the control and prevent out of phase closures
- A hardwired manual parallel ckt provides an alternate manual close path in case the automatic control relay fails.
- True manual paralleling is designed to operate in the absence of automation

1. Observe Synchroscope
2. Manual Parallel Pushbutton is illuminated
3. When Light *goes out* chosen gen is in sync
4. Press manual parallel pushbutton initiating breaker close for effected generator.
5. Manual breaker close is hardwired around the automatic close relay and through a discrete sync check relay, ensuring breaker is not closed out of sync.



Emergency Standby System

- In An Emergency Standby System, A Signal Must Be Received That Indicates Normal (Utility) Power Has Been Lost.
- The Emergency Power System Will Then Start One Or More Generators, Connect Them To A Distribution Bus, And Control Downstream Loads To Allow Loading Based On The Capacity Of Emergency Power Available.
- An Emergency Standby System Needs Both Generator Controls And Master (Or System) Control, Which Includes Load Control (Via ATS Or Distribution Breakers).



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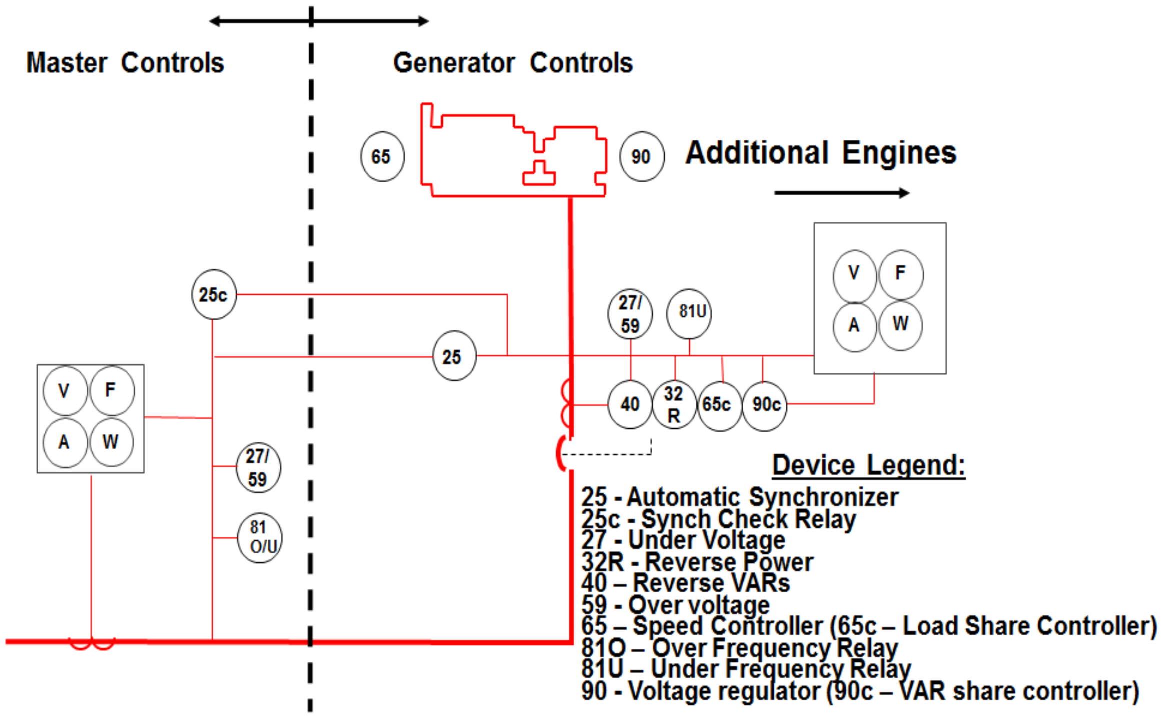
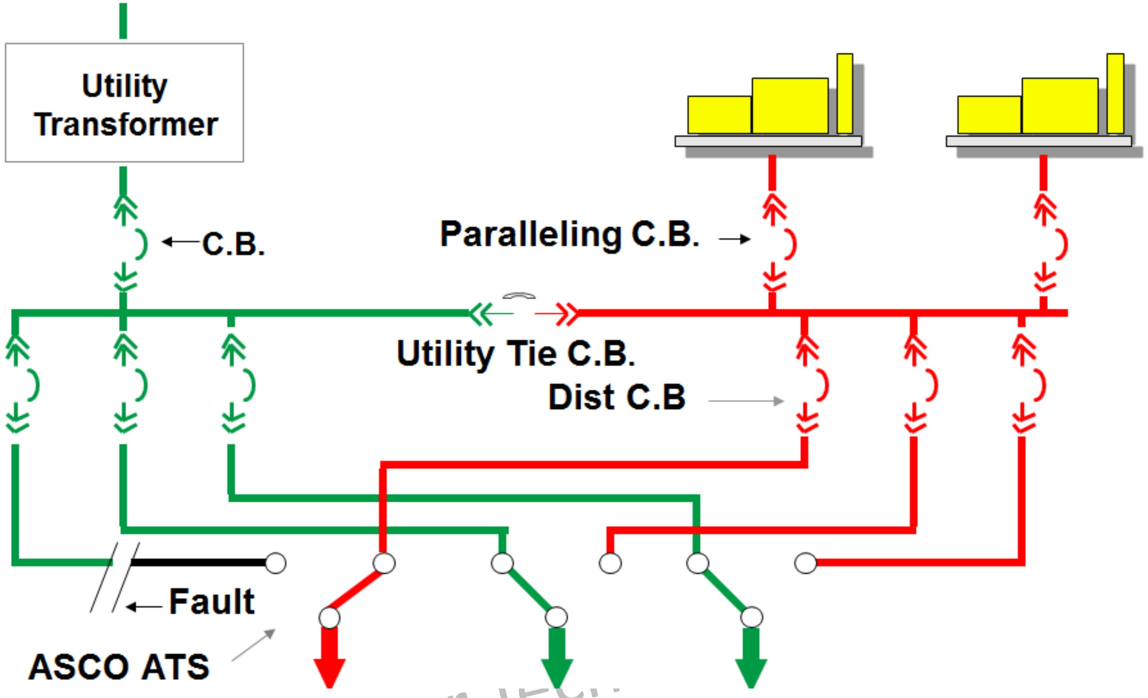
Emergency Standby System

- The controls for emergency power systems are divided into Master (or System) controls and generator controls.
- Master controls
  - These provide overall system control and therefore monitor the system (or bus) voltage, frequency, current and power. Bus voltage and frequency are monitored via protective relays to facilitate load add/shed . A hardwired sync check relay is provided to permit manual parallel operations as A back up to the generator controls.
- Generator controls
  - Automatic synchronization, load and VAR sharing, as well as generator protection are provided in the generator control section. Voltage, frequency, current and power are monitored at A minimum. Voltage and speed control are required for VAR and load sharing between paralleled units. Reverse power and reverse VAR protection are needed for protection while paralleled with other generators. Voltage and frequency monitoring are required to verify the generator can be synchronized to the bus. And the synchronizer is needed to actively synchronize and parallel the generator to the bus.



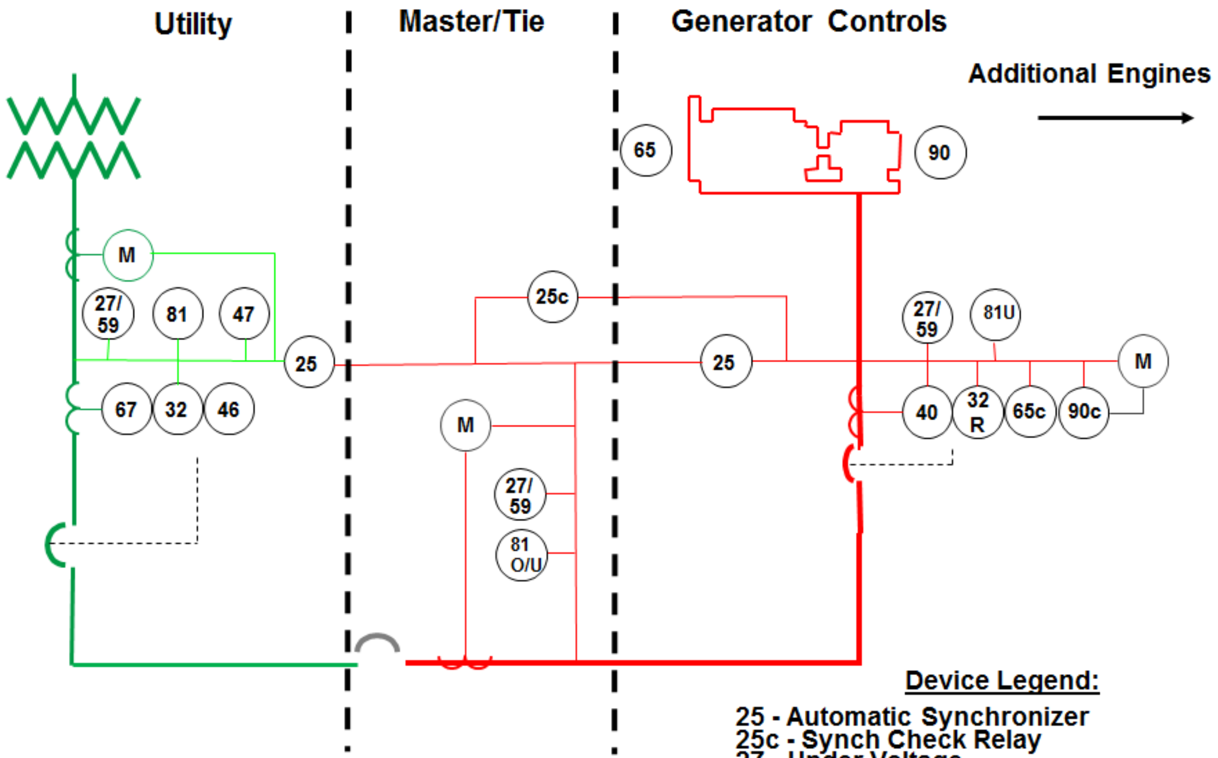
Parallel With Utility System

- Soft load parallel with utility applications are often found in mission critical facilities or sites where utilities offer peak shaving credits.
- The following are some of the benefits of a soft load parallel with utility design:
  - No interruption of load when retransferring to utility from generator.
    - Saves wear and tear on circuit breakers and ups's.
  - No interruption of load when transferring from good utility to generator for maintenance or peak shave.
  - Provides opportunity for revenue via utility import/export control.
- In a parallel with utility system, there is often a means of back feeding the ATS from the generator source. ATS need to be fitted with special accessories (transfer test for ex.) To prevent the engine start signal from being removed while generators are connected to the normal source of the ATS.



Parallel With Utility System

- In this example, the controls for parallel with utility systems are divided into Utility, Master/Tie, and Generator Controls.
- Utility – this is where the utility main circuit breaker resides. Control is from the master controller via distributed IO. Utility metering and protection are typically provided in this section as well. Protection requirements are defined by the local utility company and are in place to ensure that the generators do not inadvertently back feed the utility grid when the grid is down. A master synchronizer is provided to synchronize and parallel the generator plant with the utility.
- Master/Tie – as with any system, the Master provides overall system control. This section will have all the same functions and protection of the emergency backup system, but additional control will be required for the tie breaker. The tie can be viewed as the generator main input breaker to the critical load bus. Note: in certain applications one master synchronizer may be used to synchronize across both the utility main and the tie breaker.
- Generator Controls – The controls will have the same functions as the generator controls for an emergency backup system, however Cross Current VAR control and Isochronous load control cannot be used on a generator while in parallel with utility. A VAR/PF controller is required to ensure that the generator can maintain constant and steady VAR output. Baseload and/or import/export functionality are required to maintain constant and steady load (kw) output while in parallel with utility.



Device Legend:

25 - Automatic Synchronizer
25c - Synch Check Relay
27 - Under Voltage
32R - Reverse Power
40 – Reverse VARs
46 – Negative Sequence Current
47 – Negative Sequence Voltage
59 - Over voltage
65 – Speed Controller (65c – Load Share Controller)
67 – Directional Overcurrent
81U – Under Frequency Relay
81O – Over Frequency Relay
90 - Voltage regulator (90c – VAR share controller)

For further information

- CEU and PDH Certificates

- All attendees will receive an email tomorrow March 5th with instructions regarding the link to download your PDH certificate and the CEU exam.

- **Speaker's contact**
  Feel free to reach out to the speaker by email should you have any questions

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Thank You!

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