



Paralleling Switchgear

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What is Paralleling?

Paralleling is the operation in which multiple power sources, usually two or more generators, are synchronized and then connected to a common bus. Some applications require two or more generators to be paralleled with the Utility. The frequency, voltage, phase angle and phase rotation of all the sources must match within prescribed limits before they can be paralleled.

Paralleling multiple sources provides increased reliability, flexibility in load management, uninterrupted maintenance and cost savings during peak rate incentive periods. Multiple generators paralleled to a common bus better serve critical loads. The first generator that reaches the preset operating parameters will power the critical loads with the remaining generators synchronizing and then picking up the lower priority loads. Load management schemes are easier to manage when load demands match the individual generator capacities. It is easy to take one generator off line for maintenance and let the others pick up the slack, especially if a N+1 configuration was adopted. Generators run at their highest efficiency when near full load. Lightly loaded generators are prone to '*wet stacking*' where the temperature at which the engine runs is not high enough to efficiently burn all the fuel, resulting in un-burnt fuel being deposited in the exhaust system.

What is Paralleling Switchgear?

Paralleling Switchgear (PSG) is a combination of protection, metering, control and switching elements acting as an integrated system – to control the distribution of power for the following systems;

- Emergency Systems.
- Legally required standby Systems.
- Critical Operation Power Systems (COPS).
- Optional Standby Systems (emergency transfer and load management systems).

In the first three types of systems, all generators start on a utility power failure. As there is no Utility circuit in the Paralleling Switchgear, an "Engine Start" signal must be sent from the Utility switchgear to the Paralleling Switchgear. The first generator that reaches close to the rated voltage and frequency is connected to a dead bus without having to wait to synchronize and should normally be sized to provide at least power to the critical and life safety loads. For emergency systems this must occur within 10 seconds. A signal is sent to the transfer switch to transfer load to emergency power. The other generators can be synchronized to provide power to the lower priority loads. This must happen within 60 seconds. On return of utility power, most loads will open transition while others may close transition (max 100 msec) to utility power. This would require synchronizing of the two sources of power. Such systems typically consist of Paralleling Switchgear and automatic transfer switches (Fig 1).

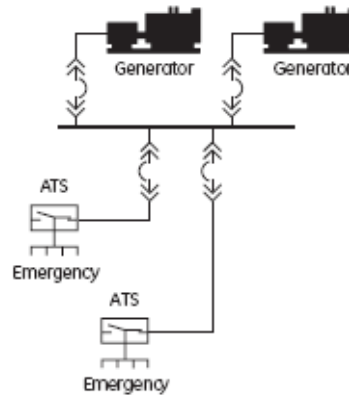


Fig 1: Emergency/Standby/COPS

The last type of system is normally a 'Parallel with Utility' systems (also referred to as "infinite bus" systems). They are the most complex as they require not only the generators to be synchronized between themselves, but the generators must be synchronized with the utility. The generators and utility could be connected together for a short duration (momentary closed, less than 100 msec) or a somewhat longer duration (soft load/unload) or a sustained duration (maintained parallel with the utility, 'Cogen' system).

On receipt of an engine start signal, all engines start and the first generator that reaches near rated voltage and frequency is connected to the dead emergency bus. The utility circuit breaker would be opened and the generator main circuit breaker would close feeding the highest priority loads. Other generators would synchronize and connect to the emergency bus and the load management program would add more loads on the system. The master PLC will now receive demand load and on-line generator capacity information. Based on a preset minimum reserve capacity, it would adjust the number of generators to match the demand load or adjust the loads to match the on-line generating capacity. When the utility voltage returns, the generators would be synchronized with the utility and the loads would be gradually transferred back to the utility. When the generators are unloaded, the generator main circuit breaker and the generator circuit breakers are opened and the generators are allowed to run through the cool down period before being shut down.

Such systems typically consist of Paralleling Switchgear and transfer switches for fine control of load management (Fig 2).

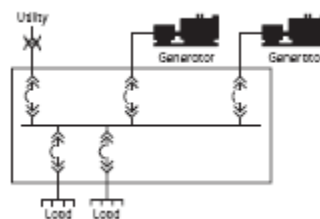


Fig 2: Parallel with Utility



Parallel with Utility systems are brought on line even when the Utility voltage is available. It is called Peak Shaving and is done to avoid the high cost of peak demand charges. The system monitors the utility power usage and when Peak Demand Threshold is approached, they could do either of the following;

- On-Line Peak Shave – the generators supply the excess power demand above the Peak Demand Threshold. The generators could have a ‘wet stacking’ problem if the excess kW requirement is low as compared to the generator capacity. Non-critical loads could be shed to prevent this or the generators could be run at full capacity and the excess generated power could be provided back to the utility.
- Off-Line Peak Shave – the generators supply all the power demand once the demand exceeds the Peak Demand Threshold. This method ensures that the generators are running at near full load. If the generating capacity is less than the load demand, the generators are run at full load and the balance demand is supplied by the utility.

System testing is a very important requirement for emergency/standby systems. ‘No-load’ testing is done, where the generators are started, synchronized and connected to the emergency bus without taking on load. This test will not have any effect on the load fed from the utility and can be scheduled to occur at regular intervals (Engine Exercise setting). ‘On-load’ testing is done where the load is gradually transferred from the utility to the generators, run for a period of time and then transferred back to the utility. Some systems may have load banks for testing the generators and the system controls without impacting the load. Load banks are sometimes used to load the generators when the plant loads are not enough to prevent “wet stacking”.

Prime Power systems are in a category by themselves as they are always on and are the only system supplying power to the site (also referred to as “isolated bus” system). They would consist of a Paralleling Switchgear but no transfer switches.

What are the building blocks of Paralleling Switchgear?

Paralleling Switchgear consists of breaker compartments and control compartments. These can be integrated into one line-up or separately installed. The latter is preferred in order to lower the arc flash hazard risk category (HRC). System operators spend most of their time near control compartments, which can be installed outside the arc flash boundary of the breaker compartments.

Irrespective of the layout of the switchgear the following are the basic breaker compartment requirements for parallel with utility application;

- *Utility Breaker Compartment* – breaker directly fed from utility source.
- *Generator Breaker Compartment* – breaker directly fed from generator source.
- *Tie Breaker Compartment* – breaker in-between similar source breakers. These could be utility tie or generator tie (optional).
- *Generator Main Breaker Compartment* – breaker that ties the generator bus to the utility bus and is used for transfer control between the two sources.
- *Feeder/Distribution Breaker Compartment* – breakers directly feeding loads or transfer switches.

For Emergency, Standby and Prime Power applications there are no Utility and Generator Main breaker compartments.

The following are the basic control compartments;



- *Master/System Control Compartment* – used for controlling the paralleling of generators, generator optimization, load add/shed, system status annunciation, user HMI and local transfer control. One required per system.
- *Generator Control Compartment* – used for starting and stopping of generators, control of voltage, speed and output and provide annunciation of engine and generator status, alarms and shutdowns. One required per generator.
- *Utility Control Compartment* – used for loading control between utility source and generator source, power management and providing transfer device status. One required per utility source.
- *Mimic Panel* – used normally when needed to display system one line status when using a black and white OIP (Operator Interface Panel). This function is incorporated in the ACS (Automatic Control System), which is normally a 15” color touch screen HMI.

Fig 3 shows a single line diagram of a Parallel to Utility system with two generators (Cogen application)

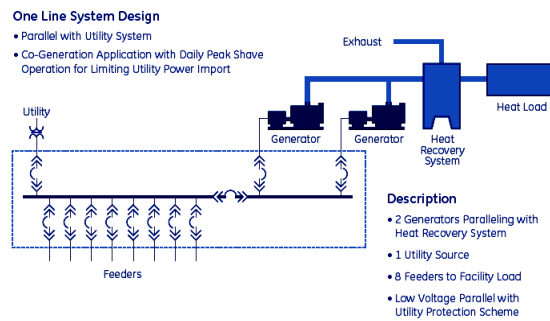


Fig 3: Typical One Line Diagram

Fig 4 shows how this single line diagram would be configured into an integrated switchgear line-up.

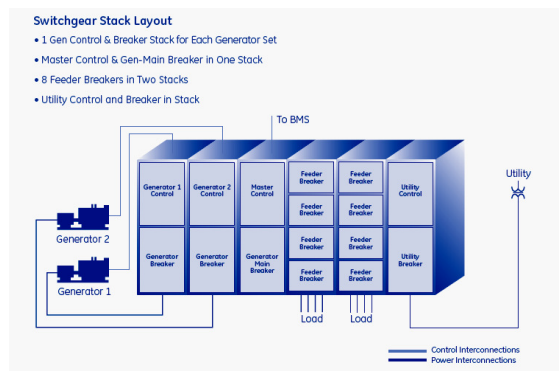


Fig 4: Switchgear Layout for same SLD

Paralleling Switchgear can be low voltage or medium voltage. They can be of switchboard construction, metal-enclosed construction or metal-clad construction. The applicable standards will depend on voltage and type of construction.



For low voltage PSG;

- UL891 – For Dead-Front Switchboards.
- UL1558 and ANSI/IEEE C37.20.1 – For Metal-Enclosed LV Power Circuit Breaker Switchgear.

For medium voltage PSG;

- ANSI/IEEE C37.20.2 – For Metal-Clad and Station Type Cubicle Switchgear.

The equivalent Canadian standard for all the above is CSA C22.2 No. 31.

What are the components of Paralleling Switchgear?

Protection - The protection requirements for Paralleling Switchgear are dependent on the size of the generators and the required level of reliability of the system. Low voltage circuit breakers have built-in trip units and therefore provide all the protection for feeder circuits. Utility and generator circuits require more protection than what low voltage circuit breakers can provide. They have to be provided with separate protective relays. Special selectivity considerations are required when applying LV circuit breakers in conjunction with protective relays, to generator and utility circuits.

Generators would normally require the following protective functions as indicated by ANSI device numbers – 25, 27, 32, 40, 46, 49, 50P, 50/51G, 51V, 59, 67G, 81O/U and 87G. 67G is also available for directional ground alarm. Recommended protection relay that meets all the above functions (except 25) is the GE Multilin SR489 – Generator Protection System Relay. For combined generator – transformer protection, a GE Multilin G30 relay is ideally suited. Large generators may require the GE Multilin G60 relay for proper protection.

Utility circuits normally require the following protective functions – 25, 27, 32, 47, 50/51P, 50/51G, 59, 67 and 81O/U. Recommended protection relay that meets all the above functions is the GE Multilin SR750 – Feeder Protection System Relay. For high speed inter-tripping and communication, utility circuits may require a GE Multilin F60 relay.

For feeder circuits in MV systems, the minimum requirement is 50/51P and 50/51G. The GE Multilin SR735 or MIFII provides all these functions. If metering is required on the feeders, a SR750 can be used. A GE Multilin F35 relay also provides protection and metering for up to 5 feeders in one relay.

Load Management – Load add/shed is controlled by the master PLC and is very important for the efficient operation of the engine-generators. Loads are divided into blocks by the number of generators in parallel and are also given sub-priorities. Loads are added/shed by pre-assigned priorities based on the available on-line capacity. Block shedding is done if a generator fails. Sub-priority load add/shed is done to prevent light loading of the generator. Block and priority settings are done through the ACS.

Certain metered values are required for load management – watts, watt demand, watt-hour and engine run time. SR489 and SR750 provide these metered values via analog signal and/or communication. For precise load management, a GE Multilin PQMII meter may be needed to provide metered values with higher accuracy. Loss of voltage and changes to frequency are captured by the SR750 and SR489 and are used by the Master PLC to transfer/re-transfer, add or shed loads. Engine run time information is used to even the usage of all generators. Generators can be sequentially or randomly loaded and unloaded based on this usage information.



Engine Control - There are two major engine/generator controls that are required by the Paralleling Switchgear for proper functioning:

- An Engine Governor Controller, controls the speed and output of the engine. Most major engine manufacturers have their own matched engine governor controller and prefer to mount it near the engine in the control cabinet. In these cases, the PLCs in the Paralleling Switchgear would only provide the enable signal and the engine governor controller would control the engine-generator.
- A Voltage Regulator, controls the voltage and the reactive power of the generator. They are most often mounted near the generator in the terminal box.

Lastly, there is a need to have an automatic synchronizer to send control signals to the voltage regulator and engine governor controller to bring the generator into synchronism with the generator bus. This device is normally mounted in the Paralleling Switchgear and is shared between generators. Synchronizing switches are used to connect the synchronizing equipment to the correct line and load bus.

Master Control - PLCs are the heart of the Paralleling Switchgear (Fig 5). In order to ensure reliability, the Paralleling Switchgear will have one PLC (GE Fanuc 90/30) per generator and one for the Master Control (GE Fanuc 90/70 or 90/30). All protective, metering, control and display devices are connected to the PLCs and the PLCs are daisy chained to each other.

The Master PLC controls the transfer switches for load add/shed. The generator PLCs communicate with the engine/generator's controllers via specific gateways. If reliability needs to be enhanced, redundant Master PLC can be employed. Alternatively, complete manual control could be employed as backup for the PLC. Critical start/stop, alarm and shutdown signals can be hardwired to meet the requirements of NFPA 110. On master PLC failure, the generator PLC will

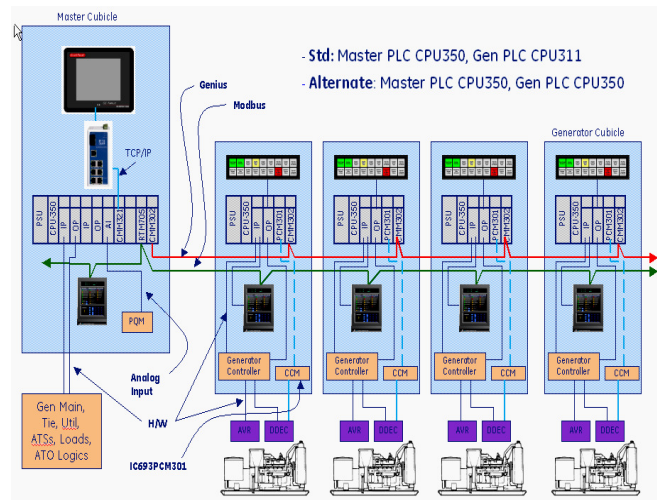


Fig 5: Typical PLC Architecture

provide the generator start signals, automatically synchronize all generators and connect the first priority loads. The lower priority loads will have to be connected manually.



HMI - A master HMI is provided on all Paralleling Switchgear. This can be a simple 5" black and white OIP or a 12", 15", 17", 19" or 42" high resolution, touch screen color ACS (Fig 6). Front views, single line diagrams and various other information and control screens can be incorporated in the ACS. OIPs may need a separate mimic panel to complete the visual display of the overall system. ACS will incorporate the mimic and provides the interface for control, option settings (time delays, transition mode selections etc), soft switching and load management. Advanced diagnostics such as fault monitoring, alarming, shutdown, event recording and trending can be done on the local ACS or even remotely.

Some users prefer to have discrete meters such as ammeters, voltmeters, wattmeters etc. This option is normally selected with the OIP option. The ACS can provide this same information either in tabular format or as digitized analog meters on the screen. As the ACS is only an input device, failure of this device will not effect the switchgear operation. Redundant ACS or remote ACS can

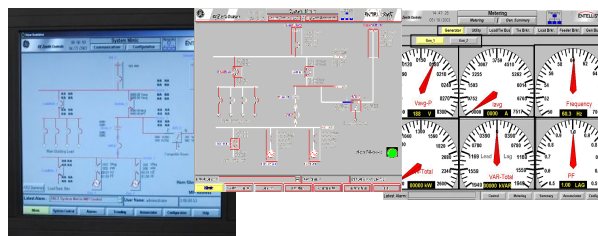


Fig 6: ACS with Typical Screens

be provided as an option.

Annunciators, (2x9 windows) can be provided for users that appreciate the standard annunciator displays or the ACS can have screens that depict the discrete annunciators and replicate the operation.

24VDC is provided to the Paralleling Switchgear from the best starting battery available and is controlled by an automatic 24VDC Control Voltage Sensor system. This system ensures a stable 24VDC supply.



Fig 7: GE Paralleling Switchgear

Conclusion - Paralleling Switchgear can be built as simple as possible with minimal control or as complex as possible with complete control, load management and redundancy. At the lower



end, hardwired relays are used but at the higher end, complete digital control is adopted. Redundancy is achieved by having hot synched PLCs in lieu of hardwired switches and meters. The trend is towards Digital Control as it can handle complex algorithms that enable multiple scenarios for load management and redundancy. It provides flexibility for system upgrades and enhancements. It also permits operational modifications to be done outside the equipment and then uploaded after complete testing. Digital controls have extensive diagnostics that can enhance reliability.

Reference:

Energy Commander™ Paralleling Switchgear- Application Guide. GE Consumer & Industrial, Power Quality – TB-2103.