

WHITE PAPER

Integrated Paralleling Solutions

Generac's Modular Power Systems (MPS)

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EXECUTIVE SUMMARY

Integrated, on-generator paralleling solutions have been available for more than a decade, however, some users are not aware of the many benefits these types of systems offer compared to traditional parallel solutions. As a result, parallel power solutions have been considered solely for large kW and mission critical projects due to the perceived cost, space requirements, and complexity.

With the advent of on-generator controllers, paralleling systems are being used more frequently for low kW projects due to the reliability, redundancy and ease of use offered by these newer systems. Since these integrated generators also tend to be smaller and don't require additional third-party switchgear, they are ideal for projects where space and weight requirements pose challenges for larger generators.

This paper will provide an overview of how traditional parallel systems operate, showcasing the complexities of that type of system, and contrast the traditional systems with the newer, integrated paralleling systems. It will also highlight the benefits of Generac's Modular Power System (MPS) versus other integrated generator systems.

INTRODUCTION

Parallel power solutions have always offered the standby generation marketplace significant advantages; however, the implementation of these solutions has



Generac Industrial Power 3 x 1000 kW Modular Power System (MPS)

been traditionally limited to mission critical applications and large kilowatt projects. This was largely due to the constraints involved with implementing traditional paralleling solutions:

- cost
- space
- lack of single source responsibility
- significant levels of complexity

TRADITIONAL SWITCHGEAR IMPLEMENTATIONS

Cost

The costs associated with traditional paralleled solutions limit their use to mission critical applications in which cost is a secondary concern to power reliability or applications requiring power in excess of 2 MW (historically the largest cost-effective single engine solution). Historically, paralleled power generation was accomplished through utilizing third party vendors that integrated UL891 dead front panel boards into generator paralleling switchgear. Though effective, the cost of this approach is the most notable drawback. The capital cost for low voltage traditional generator switchgear is typically \$25,000 to \$30,000 per section. To parallel two generators (which typically requires a multiple section configuration) would cost \$50,000 to \$75,000. That is just the start of the entire project's expense. Installation and commissioning of the system also add significantly to the cost of most traditional switchgear configurations.

Space

In a traditional system, switchgear needs dedicated floor space inside the building. Plan for each section to be 36" wide by 48" deep and 90" tall. Also plan for a minimum of 3 feet of space in front and 3 feet of space behind the switchgear cabinets. The switchgear lineup needs to be physically located in place which may require on-site assembly and bus work reconnection.



Traditional switchgear line-up with multiple generators.

Integration and Startup Issues

With traditional systems, many different manufacturers are involved in the process, the genset manufacturer as well as the switchgear manufacturers. Should something go wrong, it can difficult to determine which system or OEM is at fault.

In addition, owners should plan on a week for the entire installation process as connecting all these different pieces together takes time. Once installed, it often takes another week or two for startup and commissioning. This process requires the generator and switchgear technicians to be on-site and startup rarely goes smoothly. The only exception to this is for equipment that has been previously tested at the factory as an entire system (generators and switchgear). It soon becomes obvious to anyone running the numbers that the traditional approach to paralleling generators can only be justified for a limited number of high-end applications.

TRADITIONAL PARALLELING CONTROL COMPLEXITY

Let's go a step further and look at the intricacies involved in the traditional paralleling control system.

Each generator in the system typically includes four to six micro-controllers. These controllers are a combination of analog and digital technology from various manufacturers that are hardwired together into an amalgamated system. Add a master control section, and a two generator paralleling system could require between nine to fourteen controllers. Following are the types of controllers and their functions on a traditional parallel system.

Speed and Voltage Control

Each generator in the traditional paralleling system incorporates an electronic governor and voltage regulator. These are simple PID (Proportional / Integrated / Derivative) controls that compare engine speed and alternator voltage to a reference and then ramp the engine fuel rack and alternator excitation open or closed. This control system works fine for a single engine generator.

However, when multiple generators are paralleled together, these control parameters (engine speed and alternator voltage) are locked into the speed and voltage of the other generators in the system, which creates a problem. A generator with a slightly lower speed or voltage set point will integrate its fuel or excitation setting closed and reverse power. The generator with a slightly higher speed or voltage set point will integrate its fuel or excitation

setting open until it is carrying the entire system load or is at full throttle. The generators don't inherently share load. It works like a bicycle built for two where only one person is pushing power into the pedals.

Load Balancing

A third controller is now needed to balance the load. The job of these controllers is to constantly adjust the governor's speed reference for its engine. For this system to work, the load-share controllers are interconnected with a load-share line that shares information about expected load levels. Through constant speed reference changes, this system does balance load between the generators, even though from a control loop standpoint it is inherently unstable. The weakness of this traditional approach is that it requires everything to work perfectly and unfortunately, it tends to be sensitive to electrical noise or equipment failures.

Synchronizing

The fourth controller is an auto synchronizer. This controller matches the sine wave of the generator with the sine wave of the generator bus and issues the command to close the breaker tying them together. This process tends to be very straightforward and easily accomplished. Some manufacturers integrate load-share controllers and synchronizers into a single device.

Genset Control Protection

The fifth and sixth controllers within a traditional paralleling configuration are typically the genset controller and a protective relay. The genset controller is typically manufactured by the genset OEM and it monitors various engine and alternator parameters, and provides alarming per National Fire Protection Association (NFPA) 110 requirements. The protective relay typically performs sync check, voltage and frequency, and reverse power functions. In addition, some third party companies like Beckwith, Basler, and Schweitzer, also manufacture protective relays.

In addition to these genset controllers, the master control section includes a programmable logic controller (PLC) from manufacturers such as Allen Bradley, Modicon, Siemens, and others. This PLC is custom programmed for each project to coordinate relay logic between all the controllers in the system and provide basic communication and control for the system. The switchgear integrator programs the PLC.

Manual Control

As you can see, the traditional approach to paralleling generators does have its challenges. To enhance the reliability of these systems, switchgear is often wired with a manual mode of operation that can be used when things go wrong. In this mode, the load share lines and cross current lines are opened and the control loops are typically placed in an inherently more stable control mode (droop). It should be noted that even in manual control mode, the generator still requires four mission critical controllers to function: governor, regulator, genset controller, and protective relay.

Naturally, the question is — why so many controllers? Why not design the system with a single controller per generator?

HOW INTEGRATED PARALLELING OVERCOMES TRADITIONAL PARALLELING CONTROLLER COMPLEXITY

Integrated parallel systems minimize the number of controls, providing an inherently more reliable system. They also integrate paralleling switchgear into the system, so a third party switchgear solution is not needed.

In 2003, Generac introduced its innovative, integrated paralleling solution, MPS, which offers a single digital controller (G-panel) mounted on the generator to control all genset operations including paralleling. The G-panel is specifically designed to make configuring and commissioning a parallel generation solution as easy as a single genset. Generac's MPS solutions are typically commissioned by distributor technicians within 1 to 3 days versus the traditional market norm of factory technicians taking 1 to 3 weeks.

MPS units include a generator mounted paralleling switch which allows the generators to automatically connect to a common generator bus without the need for external switching devices. With the on-generator integration of the paralleling switching, there is no need for expensive and complicated third party paralleling switchgear. The generators are simply cabled to a common electrical connection point: junction box, large transfer switch, or a distribution panel.

As acceptance of paralleled solutions continued to grow within the market, Generac extended MPS onto its larger 750 to 2000 kW generator line-up. The implementation is conceptually the same but the hardware configuration was revised to align the various features with those needed as the generator and system capacity increases.



Generac 500 kW Bi-Fuel™ generator with integrated paralleling.

Generac's large kW MPS generators utilize the Inteligen controller which increases application flexibility. Where the G-panel was optimized for an easy to implement low voltage generator-to-generator paralleling platform, the Inteligen platform was designed to support more complex configurations seen in large kW applications: main-tie-main, soft-loading, grid paralleling, and medium voltage alternators.

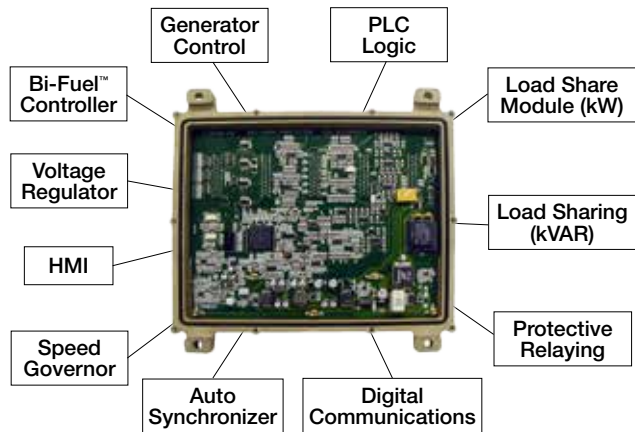
The other key feature is in the implementation of the parallel switching. The Inteligen platform solution utilizes a single power breaker for switching instead of the combination of a molded case breaker feeding a power contactor. Though this solution does not offer the premium cyclic capabilities of power contactor technology, it does mirror the switching configuration used by the traditional switchgear providers. This configuration also offers greater flexibility as the paralleling switching can be located either on the generator or within an external distribution equipment line-up.

Integrated Digital Control

The first step in creating an integrated approach to generator paralleling is to minimize the number of controllers by combining control functions: speed governing, voltage regulation, genset alarm and monitoring, synchronizing, load sharing, and protection.

At Generac, the smaller kW generators utilize a single digital controller (G-panel) mounted on the generator to control all genset operations. With larger kW MPS units (≥ 750 kW), the Inteligen platform is integrated into three controllers that are designed to work together at the factory. This consolidation of functions significantly changes the issues surrounding parallel generation and creates single point OEM responsibility for generator operation. What was a complex system becomes as simple as “plug and play”. No more hardwiring multiple controllers together through third party switchgear. No more difficult calibration processes. No more inherently unstable control loops. No more pulling I/O points back to the master PLC just to secure basic supervisor monitoring capabilities.

Beyond system performance, reliability is significantly enhanced. The maze of analog and digital controllers from different manufacturers hardwired together with complex interconnecting wiring is replaced with simplicity and single source responsibility. The pure reduction in component count increases reliability. Furthermore, since all control functions are contained in fewer devices, it is much easier to harden the control system from the effects of environmental degradation, mechanical stresses, and electrical interference.



Generac G-panel fully integrated controller.

Integrated Paralleling Switching

The second step is to integrate the paralleling switch function into the generator connection box, thus removing the cost and space of external switchgear. Once a generator becomes synchronized, the generator controller issues a close command to a paralleling switch that connects the unit to the generator bus. With an integrated paralleling system, the paralleling switch is typically built into the generator as opposed to a motor operated breaker located in a large metal cabinet, which is connected to a bus bar.

For the smaller Generac MPS units utilizing the G-panel platform, the paralleling switch is a high cyclic operation rated contactor designed specifically for repetitively power switching. The contactor is paired with a shunt trip, molded case breaker that provides overcurrent protection and a completely redundant tripping device. This approach was implemented to exceed the current market norm of using a single electrically operated circuit breaker. For the larger kW MPS units (≥ 750 kW), Generac utilizes a power breaker with an under voltage trip coil to ensure redundant tripping within a single device.



Paralleling Switching Device located on the generator.

The paralleling switching device (contactor or breaker) is mounted on and wired directly to the generator, resulting in a higher degree of system integration. The paralleling switch is then cabled to a common electric point that allows all the generators to come together to form a single system. This common point may be a junction box, larger transfer switch or a power distribution panel.

This cabling replaces the functionality of the generator bus bar inside traditional switchgear. When using a distribution panel, various automatic transfer switches are fed from this combined generator bus. For single transfer switch applications, the wiring from the on-generator paralleling device would be terminated directly to the transfer switch generator terminals. The end result of mounting the paralleling switch / power breaker on the generator is a solution that reduces complexity and cost while maintaining the benefits of a multiple unit system.

SYSTEM CONTROL WITH AN INTEGRATED PARALLELING SYSTEM

An integrated paralleling system also typically needs a system controller for coordinating various load circuits in the system. These functions include starting and stopping the generators, priority loading (permissives), load shedding, and data collection for supervisory control by building management systems. A significant

benefit offered by the integrated approach is that most communication to the system controller is digital versus the hardwiring required in many traditional systems. Also, the system controller does not have to perform relay logic to sequence multiple other controllers.

Operationally, each automatic transfer switch (ATS) monitors utility voltage and signals the system controller upon loss of utility supply to sequence the start-up of the system. In addition to sequencing the system through digital commands, a redundant start signal is hardwired to each of the generators to ensure no single point system failures.

Generac has taken great care to ensure that a failure to system communications or the system controller does not interfere with the generators' normal startup, synchronizing, and load-sharing functions. This is not typical of all generator solutions within the market, as a failure of the load-share lines from most manufacturers causes a single point system failure. Generac's MPS products do not share this single point failure issue.

In addition, Generac typically offers a cost effective option for a redundant programmable load sequencer (PLS). This means the load sequencing can also be effectively hardened against a single point failure. Redundant "master" control is not a common feature offered by other generator OEMs.

OPERATING SEQUENCE FOR INTEGRATED SYSTEMS

To understand the sequence of operation for an integrated solution, let's look at an automatic start sequence initiated by a utility failure. For this example, the figure on page 6 shows an emergency power system with two generators and two ATS's. The generators are connected to the system controller via a single RS485 data line. A two-wire start line is run from each ATS, similar to any single engine standby solution, except the connection is made to the system controller. In this illustration, the critical load ATS is configured to pick up load within ten seconds after a power outage.

Upon utility failure, the transfer switches sense loss of utility power and provide a two-wire start signal to the system controller that provides a start command to all the generators in the system. The generators start and accelerate to rated speed. The system controller gives the first generator that reaches rated voltage and frequency permission to close onto the dead generator bus. Upon sensing the energized generator bus, the critical load ATS will transfer onto generator power. At this point, with one generator on the bus, the second ATS for equipment load is prevented from transferring onto the generator bus by a priority loading (permissive contact) feature built into the system controller, thus preventing an overload of the first

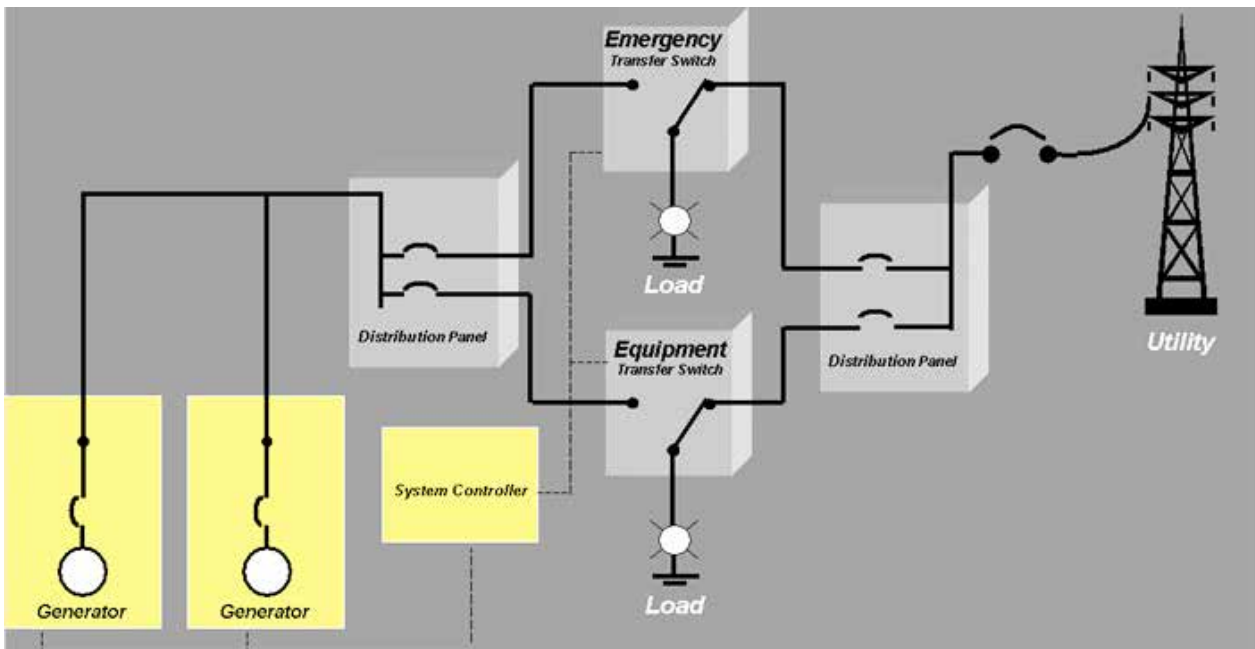
unit onto the generator bus. With the generator bus now energized, the remaining generator must synchronize to this power waveform before it can switch onto the bus for parallel operation. The integrated generator controller controls this process.

As additional generators parallel to the bus, the system controller compares available generation capacity to expected load. Load is added in order of priority only when sufficient capacity is available.

Another function of the system controller is load shedding. If a generator fails to start or fails during operation, load equal to the lost generator capacity remains offline or is removed (shed) from the system. Load shedding can be performed within the ATS or a shunt trip circuit breaker within the facility's distribution system.

ADDITIONAL ADVANTAGES OF PARALLEL GENERATION CONFIGURATIONS

Parallel generation offers many advantages versus single genset configuration including better reliability, redundancy, reduced cost and space requirements, and the flexibility to add or subtract generators from the system depending on growth and usage.



Example configuration of an integrated paralleling system.

Redundancy

Parallel power generation is simply more reliable than single engine generator solutions. With multiple generators on call, redundancy is built-in and reliability is increased because each generator backs up the other. The resulting gains in reliability for the critical loads are significant. For example, if a standby generator has an assumed reliability of 98%, an N+1 configuration has a reliability of 99.96% and an N+2 configuration has a reliability of five nines (99.999%). Some might interpret that to mean that redundancy is only gained with the additional cost of under-utilized additional generators, but that is not the case. Most applications have real world load factors that place the typical load level at 50 to 60%. With no to minimum load shedding, most applications are able to achieve N+1 redundancy for the application’s mission critical load. For ground up designs, mission critical loads are often separated onto their own circuits. In these configurations, typical load factors may even be higher and still maintain N+1 or N+2 redundancy for the most critical loads through the ability to shed less critical loads. Load shedding may be implemented through shunt tripping distribution breakers, driving transfer switches to a disconnected position, or interacting with building management systems.

Number of Generators in the System	Level of redundancy for Critical Loads			
	None	N+1	N+2	N+3
1	98.0%	–	–	–
2	96.0%	99.96%	–	–
3	94.1%	99.92%	99.999%	–
4	92.2%	99.88%	99.998%	99.9999%

Expandability

Many times when sizing generators, it is difficult to adequately plan for anticipated load growth. If growth projections are too aggressive, precious project capital is expended before it is necessary. If growth projections are too low, the facility may be left without reliable standby power or require expensive generator upgrades. An integrated approach to paralleling generators allows generators to be added as needed.

Paralleling solutions allow users to simply “plug and play” additional generation modules anytime they are required. Generation is scaled to more precisely match load requirements as facilities grow or change. Smaller units of different kilowatt ratings could be used in any combination to meet a particular load profile. For a growing facility, this expandability has two advantages. First, it reduces the initial cost by allowing purchase of a more modest system that is scaled to initial needs and can be expanded as necessary. Second, it eliminates the need to estimate



Pads poured for planned future expansion.

ultimate requirements and purchase a large and very expensive single engine unit suited to that projected need – which may or may not develop as anticipated.

With an integrated paralleling system, generation capacity can be managed to match business realities. A lower initial investment can help meet budget or capital constraints while offering the flexibility to add onto the system quickly due to unexpected growth.

Location Flexibility

Utilizing multiple smaller generators instead of a single large unit solution offers greater application flexibility. This can be a significant advantage in meeting many



4 Generac generators stacked to meet tight footprint requirements.

site-specific logistical constraints. Multiple smaller generators offer greater weight distribution making rooftop installations more feasible. This provides a compelling option versus installing a larger generator into the building requiring the use of a complex remote cooling scheme.

Smaller generators are also shorter and lower, providing flexibility in applications with height or depth constraints. This often opens up the parking garage as another location possibility for the generators. In addition, the generators do not need to be located side by side or even together, thus providing significant installation flexibility for retrofit projects.

Serviceability

Multiple generator solutions also provide enhanced reliability during normal preventative maintenance. With multiple generators available, unit(s) can be taken out of service for repair or scheduled maintenance without complete loss of a site's standby power. Remaining in-service units can still serve the critical site loads. In addition, while catastrophic failures of standby generators are not common, multiple generator solutions significantly mitigate the effects of such an event. The inherent redundancy of the system ensures backup power even during equipment failure and the capital cost to replace a smaller unit is a fraction of the large, single generator expense.

Cost Effectiveness

An ancillary benefit of using multiple smaller gensets is derived from the engine classification. Smaller generators use high volume, mass-produced over-the-road truck engines. These prime movers tend to be of extremely high quality and very reliable due to the level of tooling and plant automation utilized in their manufacture. This same automation, along with market pressures and economies of scale, make this engine class the lowest cost per kW for prime movers. When these high-value engines are combined with internally integrated paralleling technology, paralleled generation systems can compete dollar for dollar against monolithic single engine solutions. In addition to capital cost, this engine class tends to be less expensive to maintain, replacement parts are easily available and on-road diesel technicians have ample experience servicing these engines.

GENERAC'S MODULAR POWER SYSTEM BENEFITS

Generac has taken a market leading position in advocating and positioning integrated paralleling solutions. With more than a decade of experience in on-generator paralleling, Generac has been able to offer thousands of parallel solutions at the price point of single larger capacity generator (i.e. 3 x 500 kW for the same cost as a 1 x 1500 kW).

This paralleling solution is available on diesel generators 175 kW to 2 MW, Generac's Gemini (2 x 500 kW twin pack) and on spark-ignited generators 130 to 500 kW.

Generac's commitment to removing single point system level failures is also unique in the market. Generac's MPS product offers enhanced reliability against the market alternatives while maintaining cost effectiveness.

In addition, the demand is growing for higher power nodes to meet the demands of an always "online" world. Generac's range of MPS products allows managers and engineers more choices in optimizing the types and sizes of gensets for specific applications.

SUMMARY

The benefits of parallel generation are widely accepted in the marketplace; however, the implementation of these solutions has been traditionally limited due to the constraints in implementing traditional paralleling solutions.

Parallel on generation products offers many advantages versus single genset configurations including:

- Redundancy – N+1, N+2 and more offering up to 99.999% reliability,
- Cost Savings – readily available diesel engines are highly reliable and manufactured in large quantities.
- Reduced Space Requirements – generators can be located on rooftops or in parking garages to offer more options to owners.
- Serviceability – a single unit can be taken out of service for maintenance or repair while other units remain available should an outage occur.
- Flexibility – gensets can be added or subtracted from the system depending on growth. This allows owners to make a smaller initial investment as various size generators can be added only when needed.
- Ease of Integration – third party switchgear is not needed as controls are part of the genset.

The use of integrated systems will no doubt continue to grow exponentially as more owners and engineers become aware of the many advantages of these products.

For more information about these concepts or the variety of Generac MPS products available, contact Generac Power Systems at www.generac.com or toll free at 1-844-ASK-GNRC.