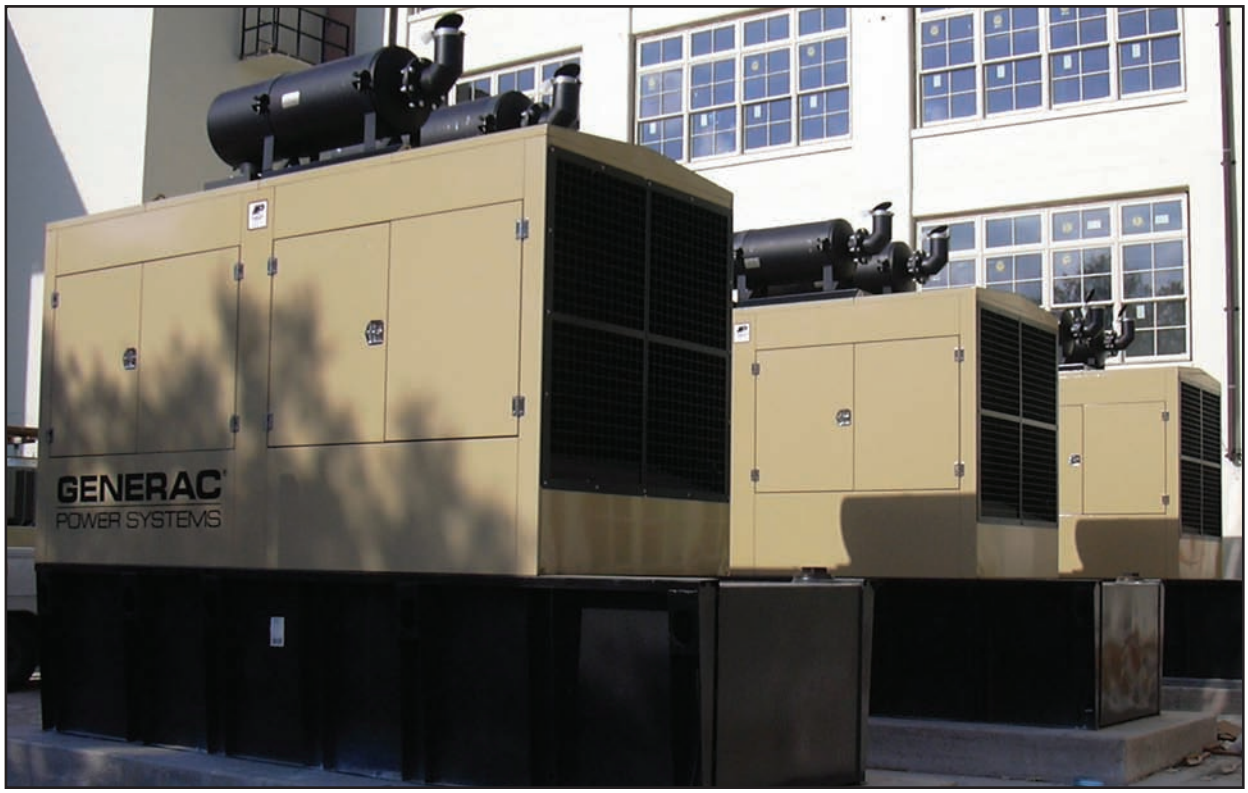
GENERAC®
POWER SYSTEMS, INC.

The Modular Power System (MPS)

WHITE PAPER



INTRODUCTION

When it comes to specifying large projects between 200 kilowatts and 9 megawatts, there is a new alternative solution available right now from Generac Power Systems: the Modular Power System (MPS). For higher kilowatt requirements, the Modular Power System utilizes multiple diesel, bi-fuel or gaseous fueled gensets in a paralleled configuration. This cost-effective solution combines proven high volume engine designs with Generac's own switching and paralleling technology to provide a fully integrated system.

The MPS system consists of diesel-fueled units of 300, 400, 500, or 600 kilowatts (kW) working in concert to offer outputs ranging from 600 to 9000 kW. Spark-ignited gaseous fueled units of 100, 150, 200, 250, or 300 kW produce combined outputs of 200 to 4200 kW. (Generac's 600 kW bi-fuel units can be combined to produce a maximum system size of 9000 kW). Gemini® Twin Pack Solutions, can be combined in a modular fashion to offer from 1000 to 9000 kW of output. The entire MPS product offering uses Generac's PowerManager® Digital Control Platform, which brings a high degree of reliability and flexibility to the control of these systems.

THE RATIONALE

The concept of paralleling multiple gensets in order to produce greater amounts of power is not new. In fact, it is a well-proven method commonly used with large megawatt units in premium installations. Until recently, it has not been economically feasible to combine smaller units in this fashion because of the high cost of traditional paralleling switchgear cabinets. Generac Power Solutions has broken the price barrier by combining its technical expertise, worldwide sources, and vertically integrated manufacturing methods to deliver this capability to an entirely new range of demanding applications, making this a powerful solution over a wide range of output requirements.

MULTIPLE UNITS, MULTIPLE ADVANTAGES

By linking top-quality, long-life gensets with its own paralleling switch technology, Generac has created a cost-effective single-source offering. Combining smaller generator sets is a superior alternative to large, single-engine units for a number of compelling reasons:

- Reliability / Redundancy
- Scalability
- Flexibility
- Serviceability
- Availability
- Reduced cost

RELIABILITY

With multiple generators on call, redundancy is built in and reliability is increased because each generator backs up the other. If the electrical load is divisible, one or more generators can handle a portion of the load while the other redundant gensets are offline.

GENERATOR SYSTEM RELIABILITY

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%

Figure 1

The multiple-genset system provides improved reliability through design:

- Proven high-volume engines
- Integrated system components designed and manufactured to work together
- Redundancy for critical loads
- Coverage available during maintenance
- Backup power even during a unit failure

In many applications, the load requiring the highest degree of reliability is only a small percentage of the total generation capacity. In these situations, the MPS solution automatically backs up the most critical load with the benefits from N+1 to N+Y redundancy. The resulting gain in reliability for the critical loads is significant (Figure 1). For applications in which the critical loads are considerable, the addition of one more smaller generator (N+1) increases reliability for a minimal capital increase when compared to larger generator solutions. To realize the benefits of increased system reliability, it may be necessary to implement load shedding of less critical loads. The MPS system supports this functionality through three load shed contacts. These contacts can be integrated with Generac-supplied transfer switches, facility shunt trip distribution breakers, or integrated into the building management system.

SCALABILITY

Many times when sizing generators, it is difficult to adequately plan for anticipated load growth. If growth projections are too aggressive, precious project capital may be 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.

The MPS system is designed with expandability in mind, allowing multiple generators to be added as needed. MPS modules are designed to simply “plug and play” with existing MPS units of any size. Additional kilowatts can be added at any time. This expandable system can be scaled to more precisely match load requirements as facilities grow or change. Units of different kilowatt ratings can be combined 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, one that can be expanded as necessary. Second, it eliminates the need to estimate ultimate requirements and purchase a large and expensive single-engine unit suited to that projected need — which may or may not develop as anticipated.

With the Modular Power System, dynamic power requirements can be more precisely matched to reflect:

- Lower initial investment
- Budget / capital constraints
- Controlled growth
- Unanticipated growth

FLEXIBILITY

By utilizing multiple generators instead of a large single-unit solution, much greater application flexibility is available. The Modular Power System can present significant advantages in meeting site-specific logistical constraints. Since the MPS generators are lighter, roof-top installations have better weight distribution. The MPS generators are also shorter and lower, providing flexibility in applications with height or depth constraints. In addition, the MPS generators need not be located side by side or even together, thus providing significant installation flexibility for retrofit projects.

The MPS also provides flexibility during service operations. With multiple generators available, units can be taken out of service for repair or scheduled maintenance without complete loss of site standby power. Remaining in-service units can still serve critical site loads, utilizing the priority loading feature included with the MPS system controller. Units can be identified as out of service in the controlling software, and the system adjusts priority loading sequences automatically. Further details of this feature are provided later in this paper.

SERVICEABILITY

Rather than using one large industrial-class engine, Modular Power System gensets use high-volume, mass-produced, over-the-road truck engines. These prime movers are more readily serviceable by on-road diesel technicians. Likewise, maintenance and replacement parts tend to be much less expensive for this category of engine. When compared on a kilowatt basis, the maintenance cost for the MPS system is slightly less than the single-engine solution. This is due to lower parts costs, easier to handle components and fluid quantities, and a more readily available pool of technicians.

Though catastrophic failures of standby generators are not common, the MPS solution significantly mitigates the effects of such an event. The inherent redundancy of the system ensures backup power even during equipment failure. The capital cost to replace a unit is a fraction of the single-engine approach. Finally, the smaller modular units are also easier to move and place on site. Instead of requiring a heavy-duty crane, the MPS units can be handled with a forklift or a much smaller crane.

AVAILABILITY (SHORT LEAD TIMES)

Generac's Modular Power System Solution uses a variety of its most popular genset models. Using readily available high-volume engines, these units can typically ship with shorter lead times than single-engine, large-kilowatt generators. Because Generac is a vertically integrated manufacturer, each MPS unit's key components are Generac designed and built, including the alternator, engine cooling system, gear drive, digital controls, automatic transfer switch, standard or sound-attenuated enclosure, and sub-base fuel tank. Generac is the single-source supplier of the entire package, and warrants all elements of the Modular Power System.

COST EFFECTIVE

The MPS product is a high-value, cost-effective alternative to large, single-engine gensets. It is a viable option that will produce the power of similarly rated individual units, with much greater benefits.

One look at dollar-cost-per-kilowatt for engines with different power outputs will show why the multiple-generator concept works so well. The engines utilized are mass-produced, over-the-road truck engines, which cost less due to economies of scale. Larger, specialized engines that produce above 600 kW are built in fewer numbers, making them more costly to manufacture. Figure 2 shows relative dollar cost per kW for diesel engine gensets, with MPS engines falling in the most cost-effective range of 300 to 600 kW.

Installation costs for a Modular Power System are generally comparable to a large, single-engine genset of equivalent output.

- Smaller units are easier to transport
- Smaller units are easier to handle at site
- Both are terminating the same number of amps
- Cabling is easier to terminate (lower amp density)
- Single RS485 line is used for control wiring
- Units can be placed and commissioned in 1-2 days

The net result is a typical cost savings to the end user.

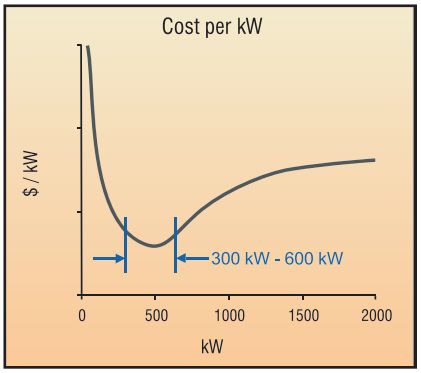


Figure 2

THE GEMINI® TWIN PACK OPTION

Generac's Gemini® Twin Pack Solution, featuring dual gensets in a single package, is an even more powerful MPS option. Gemini's unique design offers numerous benefits, which are multiplied in an MPS arrangement:

- Higher power density
- Built-in redundancy (one unit backs up the other)
- Greatest value on a dollar-cost-per-kilowatt basis
- High production volume 16L engine (assures product availability)

Combining multiple units in 1000 kW increments up to 9000 kW, Gemini-based Modular Power Systems offer another scalable, redundant power solution. Gemini units can also be combined with other MPS capable units.

BI-FUEL™ ENGINE OPTIONS

The new Generac Bi-Fuel™ option provides even more benefits. This innovative technology uses a combination of diesel and natural gas to take advantage of the best qualities of each fuel (more power from diesel, lower emissions from natural gas). The Bi-Fuel option is available at 600 kW for both stand-alone and MPS applications.

The compression ignited, gas powered technology used in these Bi-Fuel generators offers numerous advantages:

- Greatly extended run time
- Lower particulate and NOx emissions
- Redundant on-site fuel supply
- Longer maintenance cycles
- Historically lower fuel costs

While operating under load, Bi-Fuel units can operate on up to 70% natural gas. If conditions dictate, the unit can revert to 100% diesel fuel with a no-break, automatic fuel changeover. The on-site diesel fuel tank required for Bi-Fuel units can also be smaller, if desired, to save on space, cost, and fuel maintenance.

GENERAC DESIGNED & BUILT

The Modular Power System is a fully integrated product that encompasses an array of components designed and manufactured by Generac:

- UL 2200 Listed & NFPA 110 compliant generators
- Weather and sound-attenuated enclosures
- UL 142 Listed double-walled base tanks
- PowerManager® Digital Control Platform
- UL 1008 Listed automatic transfer switches
- GenLink® communications software

INTEGRATED CONTROL SYSTEM

Generac has integrated its transfer switch, paralleling, and control expertise to create a solid package that will excel in the most demanding applications. Generac's own PowerManager® Digital Control Platform integrates all generator and paralleling functions into a single control solution.

The PowerManager® Digital Control Platform features advanced communications capabilities, making remote operation easy via GenLink® software or third-party interface equipment utilizing the Modbus protocol (Figure 3). Using a PC, it is possible to see the entire system, or focus on the operation of an individual generator. In addition to viewing the operation of an individual unit, the servicing dealer can set and adjust operating parameters remotely.

For MPS applications, two configurations of PowerManager® controllers are used in concert to accomplish system control:

- The PowerManager® – Parallel Controller (PM-PC), located on each generator in the parallel system, controls generator operating functions along with synchronizing to a common generator power bus.
- The PowerManager® – System Controller (PM-SC) interfaces with each generator and automatic transfer switch (ATS) connected in the system to provide supervisory level control of system functions.

By loading product-specific software into the PowerManager® Digital Control Platform, it's possible to create either the PM-PC or PM-SC. This multi-purpose controller approach allows for commonality of hardware using a robust, powerful and highly reliable control module that provides advanced diagnostic capabilities and can be easily serviced.

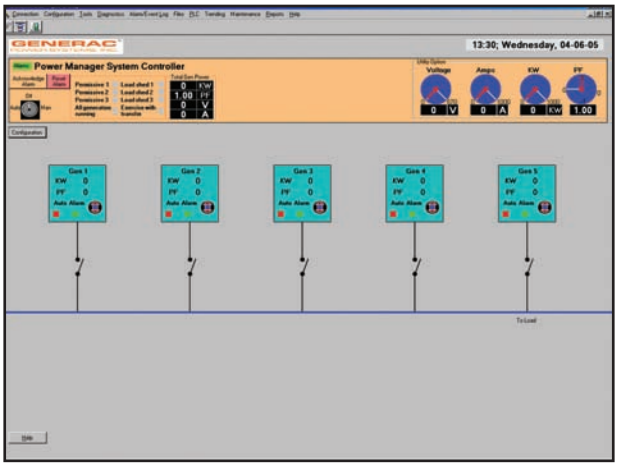


Figure 3

POWERMANAGER® PARALLEL CONTROLLER

The PowerManager® - Parallel Controller (PM-PC) is an integrated control system that combines various control functions into one digital device. Historically, switchgear providers would use separate discrete control devices and hardwire these devices together to form a system for generator paralleling. These systems tended to be complicated, sensitive to calibration errors, hard to troubleshoot, and expensive. By integrating all control functions into a single device, what was a complex system becomes a simple "plug and play" module. In addition to paralleling, the PM-PC digitally controls the engine and alternator for genset operation:

- Speed governor
- Voltage regulator
- Engine controller
- Auto-synchronizer
- Load sharing (kW and kVAR)
- Protection

The speed governor and voltage regulator are no longer discrete devices, but rather integral functions inside the PM-PC. The speed governor function provides digital frequency regulation to 0.25%, and the voltage regulator function provides voltage regulation to 0.25% stand-alone and 1% during parallel operation.

The engine controller function of the PM-PC protects the system and provides information at a glance. Its protective functions are annunciated by an audible alarm covering numerous types of conditions. The PM-PC monitors and protects all engine, alternator, and paralleling functions:

- Engine (NFPA 110, Level 1)
- Over current
- Over / under voltage
- Over / under frequency
- Sync check
- Reverse power
- Over-speed (independent)

Besides providing protective functions, the PM-PC displays various system data during generator operation:

- Volts and amps
- kW, kVAR, and power factor
- Engine speed and alternator frequency
- Oil pressure and temperature
- Coolant temperature
- Battery voltage
- Fuel level
- Run hours

In addition, the PM-PC performs the synchronizing function, which enables the generator to parallel onto a generator bus. Slip frequency, phase angle, and voltage are verified to be within acceptable windows prior to the generator closing onto the bus. Dynamic frequency slip algorithms drive engine speed changes proportional to phase differences to ensure rapid and reliable synchronizing.

Once a generator becomes synchronized, the PM-PC issues a close command to the paralleling switch that connects the unit to the generator bus. Historically, this switch is a motor-operated breaker located in a large metal cabinet and connected to a bus bar. With the MPS system, the paralleling switch is a high cycle rated contactor specifically designed for switching power circuits, not a breaker which is designed as an overcurrent protective device. The paralleling switch is mounted on and wired directly to the generator, resulting in a higher degree of system integration (Figure 4).

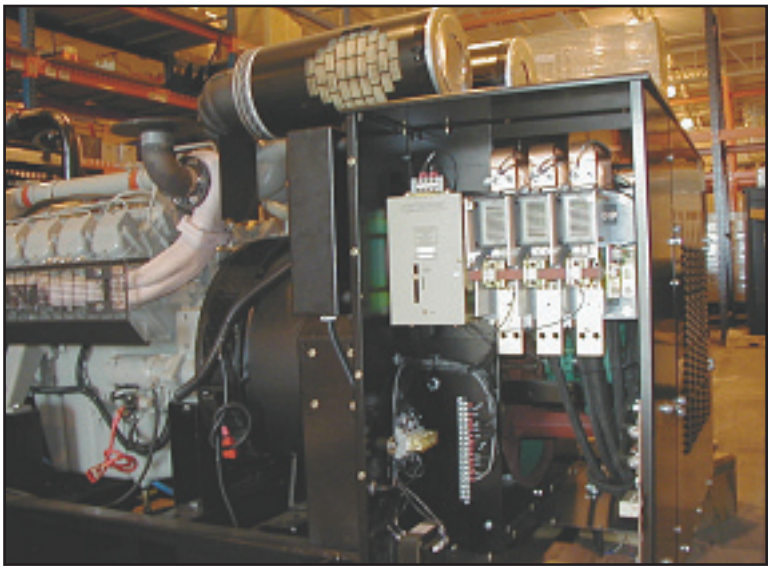


Figure 4

The PM-PC also performs load balancing functions. This allows kW and kVAR load to be shared on a percentage basis across all generators on the bus, while maintaining rated voltage and frequency. While other digital controllers use isochronous load sharing and reactive cross current, these methods are inherently unstable, relying on continuous correction to maintain stability. The PM-PC load-share function combines the accuracy and repeatability of digital control with inherently stable control algorithms for load balancing.

POWERMANAGER® SYSTEM CONTROLLER

The PowerManager® – System Controller (PM-SC) coordinates the operation of every generator and ATS in the emergency power system. Each ATS monitors utility voltage and signals the PM-SC upon loss of utility supply. The PM-SC in turn communicates with the PM-PC on each generator to control unit starting and stopping, along with sequencing for paralleling to the generator bus.

The PM-SC (Figure 5) is housed in a wall-mountable NEMA 1 cabinet that can be located some distance from the generators and transfer switches for convenient access. The PM-SC can operate with transfer switches of any manufacture and design that use the standard two-wire start feature. In order to perform priority load sequencing as discussed below, the ATS must also be equipped with a transfer inhibit/permissive feature controlled by a contact closure. This feature is available on all sizes of Generac ATS's and some third-party units. The MPS system utilizing the PM-SC can easily integrate emergency-load transfer switches that require ten-second transfer time or less per NFPA 99 and NFPA 110 requirements. The only requirement is that the sum total of ten-second loads be no more than the smallest generator in the MPS system, to allow each load to be powered by the first generator that closes onto the common bus.

Figure 5

To understand the sequence of operation for the PM-SC, let's look at an automatic start sequence initiated by a utility failure. For this example, Figure 6 shows an emergency power system with two generators and two ATS's. The generators are connected to the PM-SC via a single RS485 data line. A two-wire start line is run from each ATS, as it would be to any single-engine standby solution, except the connection is made to the PM-SC.

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 PM-SC. The PM-SC then provides a start command to all the generators in the system. The generators start and accelerate to rated speed. The PM-SC gives the first generator to reach 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 feature built into the PM-SC (Figure 6 depicts the system in this state). The PM-SC has three priority loading steps that manage ATS load sequencing, thus preventing an overload of the first unit onto the generator bus.

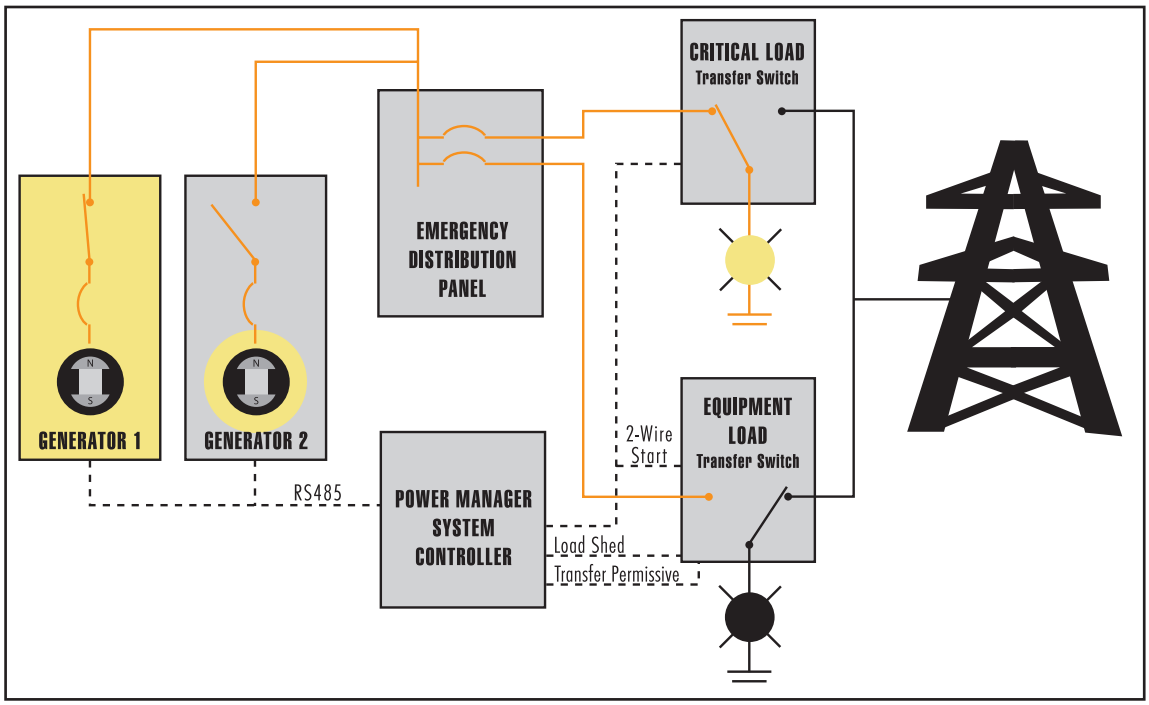


Figure 6

Each priority load step is assigned an expected kilowatt value, referenced “ATS Load 1” to “ATS Load 3” (Figure 7). Relays associated with the priority load steps operate load-permissive contacts. For this example, the load-permissive contacts for “ATS Load 1” are wired into the transfer-permissive circuit on the ATS serving the non-critical equipment load.

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. Note that, as discussed earlier, the PM-PC on each generator controls this synchronizing function. Once a generator achieves synchronicity, a request and permission exchange takes place with the PM-SC before it switches onto the bus. Through this communication process over the RS485 data line, the PM-SC knows which generators are paralleled on the common bus.

As additional generators parallel to the bus, the PM-SC compares available generation capacity to expected load. Load is added in order of priority only when sufficient capacity is available. This is accomplished by activating the load-permissive relay, which in turn closes the ATS load-permissive circuit to allow load transfer. Although this example used only one load step, three prioritized steps are available with the PM-SC for use with multiple transfer switches feeding branch load circuits.

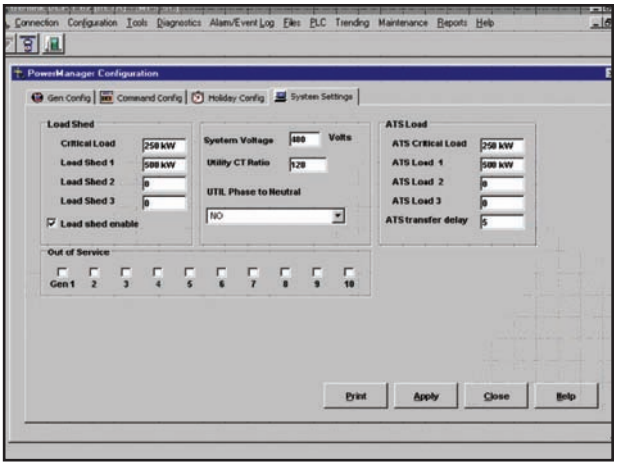


Figure 7

Another feature of the PM-SC is priority load shedding. Three load-shedding steps are available to manage load during a generator failure. If a generator fails to start or fails during operation, load equal to the lost generator capacity is removed from the system. Similar to priority loading, each load-shed step is assigned an expected kilowatt value (Figure 7). The PM-SC compares lost generation capacity to load assigned for shedding and then sheds the appropriate number of steps. Load shedding can be performed with a Generac-supplied ATS or a shunt trip circuit breaker within the facility’s distribution system. Some third-party ATS’s also have load-shedding features. As with priority loading, load-shed contacts are activated using relays in the PM-SC.

ENHANCED INTERFACE

In the Modular Power System, the PM-SC provides a single point of communication for the system. The PM-SC utilizes the RS485 data line to communicate with each PM-PC generator controller. This allows the PM-SC to easily control basic system operation as well as gather detailed information from each PM-PC in the system.

The PM-SC can easily provide generator and system status information upstream to a building management system or an operator interface. For easy system integration, the PM-SC supports Siemens PPI, Modbus, and CANbus protocols and has various communication options:

- (2) RS232 ports
- (2) RS485 ports
- CANbus port (J1939)
- Internal modem
- Touch-screen interface

A touch-screen interface is provided on each generator with the PM-PC, as well as on the PM-SC. With intuitive, easy-to-navigate screens, this interface allows local access to monitor key system parameters and perform basic diagnostics.

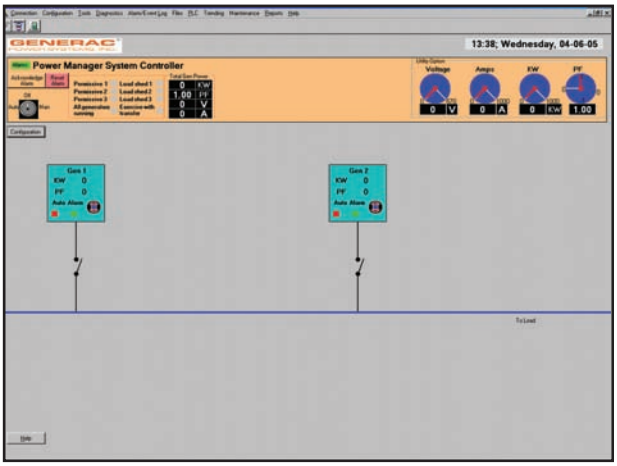


Figure 8

For full access to configuration, monitoring, diagnostic, and reporting capabilities of the PowerManager control system, Generac provides its GenLink® communications software. This Windows-based operator interface program can be connected to the PM-SC either locally with an RS232 serial cable or remotely via modem. Figure 8 illustrates a PM-SC configuration with two generators that are currently shut down and disconnected from the generator bus.

In addition to monitoring the overall system, it is very easy to drill down from the system level to any given unit's generator controller by double-clicking on the generator icon. This allows full viewing of all engine and alternator operating parameters, as shown in Figure 9. This shows the generator running, voltage at 480 volts, power at 316 kW, oil pressure at 54 psi, coolant temperature at 190 degrees, etc. Note that all data is communicated digitally, from the generator (PM-PC) to the system controller (PM-SC), to GenLink on a remote computer. Traditional systems often used discrete interconnect wiring for each function, with analog information unavailable remotely.

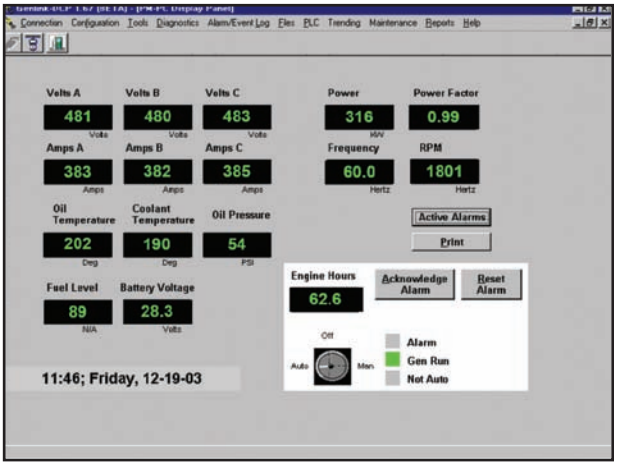


Figure 9

Furthermore, this system also provides the local Generac dealer (as well as the factory) the ability to remotely support the product in the field. It is possible — with appropriate safeguards — to drill down one more level to the setpoint parameters of any of the PM-PC controllers. Figure 10 shows one of the setup screens for internal control parameters — in this case governor settings — on a given generator. Similar setup screens exist for engine, voltage regulator, and generator functions, along with Bi-Fuel functions if applicable.

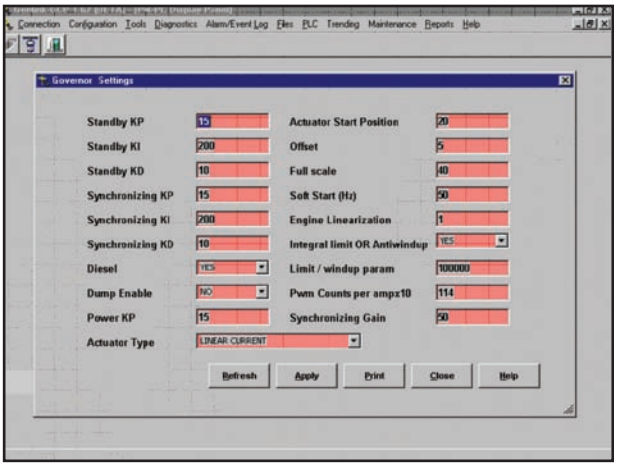


Figure 10

CONCLUSION

The MPS alternative to traditional large-engine gensets offers increased benefits at a lower cost. From a benefit standpoint, MPS offers built-in redundancy, increased reliability, expandability, enhanced communication and control, flexible installation options, better availability, and provisions for future closed-transition offerings. From a cost standpoint, MPS often provides a savings over traditional single-engine solutions. For numerous reasons, it is a compelling solution to large kilowatt requirements.

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