PRODUCT INTRODUCTION - Series MG

Power Systems & Controls' *Series MG* represents one of the most effective means of power conditioning where the cost of a full UPS is not justified. The *Series MG* provides all the benefits of a UPS except battery backup.

The *Series MG* consists of a synchronous motor mechanically connected to a synchronous generator. The motor is connected to the utility and the generator to the protected load. Power quality improvement is achieved for both the utility and the customer.

The motor will operate from a utility whose voltage ranges from 10% continuously high to 20% continuously low, and can sag to -60% of nominal for up to 30 seconds. The synchronous motor also presents a unity power factor load to the utility. The generator produces utility grade voltage regulated to within 1%. This combination isolates the customer and the utility from each other.

The customer can no longer be affected by sags, surges, transients, short term power outages. The utility, because of the high power factor and linear current drawn by the motor, can make better use of their transmission lines and is protected for any harmonic currents drawn by the customer's equipment.

Depending on the part of the country, short power outages are a major concern. Short term power losses can be broken down into three classes:

- Instantaneous 5-7 cycles 80 to 120 milliseconds.
- Momentary 100 - 300 cycles 0.05 seconds
- Temporary > 500 cycles >2 seconds

The causes of these outages are the operation of protective devices located on the utility network. Instantaneous outages are caused by a single fast recloser, the momentary outage normally is one fast and two slow reclosures. These are the three tries and out logic where after the third automatic reclosure, a line crew would be dispatched. The temporary outages can have many causes. However, in each case, the only means of a customer isolating themselves from these temporary outages is with a UPS.

Based on a multi-year study conducted by the Electrical Power Research Institute (EPRI), the overwhelming power quality problem found on utility systems is that of voltage sags and short term power loss. This power quality study was conducted by utility companies across the United States. The data collected shows both common power quality problems and the differences in frequency and magnitude dependent on the geographical area studied.

In general, and independent of location, power users have over a 90% probability that the voltage will sag below 80% of rated voltage every month. In industrial environments, this is a major cause of less than expected equipment reliability.

At one manufacturer's plant, the estimated cost for repair of CNC controllers exceeded $5,000 per month. After conducting power quality monitoring, it was determined that the most likely cause of controller failures was the daily sags in the utility voltage caused by motor starting. Dependent on the manufacturing process, voltage dips and switching transients can cause complete process shutdown. In many cases where the production equipment must be cleaned out before the process can be restarted, the cost can be dramatically high.

In these cases, the *Series MG* was a cost effective solution. The true cost of power quality was easily determined. Given a five year lease program, the monthly cost avoidance paid the annual lease payment in five months. The savings over the next seven months represented additional profit for the company.

Series MG Features

Standard Features

- Brushless Synchronous Motor
- Brushless Synchronous Alternator
- Bearing Temperature Sensor
- 10% Output Voltage Adjustment
- Over/Undemgrequency Protection
- Over/Under Output Voltage Protection
- Output Meters (voltage & current)
- Status Indicator Lights
- Auto Bypass Function
- Touch Screen Digital Control Panel

Optional Features

- Remote Annunciator Panel
- Remote Control Panel
- Modem & Serial Port
- Maintenance Bypass
- Paralleling Capability
- Circuit Breaker In Bypass Path
- Outdoor Enclosure
- Sound Enclosure

Packaging

- Integrated, Free Standing Metal
- Maximum Vibration Level 2.0 mils

Touch Screen Digital Control Panel

This panel can be used to control and monitor the MG. All voltages and currents within the MG are available via this panel.

The following metered functions are shown:

- Generator Output Voltages
- Bypass Source Voltages
- Output Currents
- Output Neutral Current
- Input Frequency
- Output Frequency
- Input kVA
- Input kW
- Output kVA
- Output kW

The touch screen control panel can pemgorm the following functions:

- Enable MG
- Lock Generator Breaker Open
- Close Generator Breaker

The touch screen can display the following fault conditions:

- Output Under/Overvoltage
- Overtemperature
- Output Over/Undemgrequency
- PLC Fault
- Phasing Error, Input & Output
- Voltage Configuration
- Power Supply Loss

FEATURE DESCRIPTION

Remote Monitor/Control Panel

This panel can be used to control or monitor the MG. The remote control panel requires the optional RS-485 serial port. All voltages and currents within the MG are available via this panel. All functions of the touch screen control panel are duplicated in the remote monitor/control panel (see above).

Remote Status Panel

This panel is used to give the user an indication of a fault in the motor generator at a remote location. It contains annunciation, alarm reset button and an ESTOP push-button.

Modem

A modem connection is available for users wishing PS&C to monitor the status of their motor-generator. A dedicated telephone line is attached to the modem and data is passed via an RS-232 port in the M-G's PLC to a modem. All vital MG parameters and fault conditions can be monitored by PS&C's Field Service.

Serial Port

The serial port, either RS-485 or RS-232, is available to communicate all pemgormance data, fault and status data to the user's computer monitoring system, SCADA. Monitoring software, sold by PS&C, is required to present this data to the user's computer. The use of PS&C's software, the serial port option and the user's computer, form a powemgul remote monitoring function. The user will need an RS-485 to RS-232 converter for terminating at the computer when the RS-485 connection is used.

Maintenance Bypass Switch

A separately housed bypass switch is available to electrically isolate the MG system. This switch may be electrically or manually operated. The maintenance bypass listed in the price section of this manual is for the electrically operated version of the maintenance bypass. Consult the factory for the price of manual maintenance bypass systems.

Bypass Circuit Breaker

An automatic circuit breaker can be supplied to provide protection for wiring and loads to be connected to the bypass path when other protective elements are inadequate. This optional circuit breaker replaced the standard contactor used for bypass transfers.

Key Features and Benefits From PS&C Design

Feature

The *Series MG* uses synchronous motors and generators.

Benefit

Synchronous motors naturally run at their synchronous speed, which is 1,800 RPM for 60 Hz applications. This constant speed is maintained across a wide range of voltages and independent of load. While synchronous motors cost more than induction motors, the stable output frequency more than compensates for the added cost. If induction motors were used, the M-G would run faster or slower as the utility voltage sagged or surged. The M-G would also speed up or slow down as the customer's load increased or decreased.

The synchronous generator with its 2/3 pitch winding produces utility grade voltage with the ability to cancel the triplen harmonics. This ensures that the customer has the same high grade power their processes were designed to operate on.

Feature

The *Series MG* uses a pony motor starting system.

Benefit

The advantage of a synchronous motor is its constant speed. The disadvantage is that it is very hard to start. If it were placed across the line, it could take as much as ten times its full load current just to get it up to speed. The *Series MG's* pony motor is a small induction motor selected to be large enough to spin the unloaded motor and generator up very close to synchronous speed. The maximum current required for the pony motor is never greater than 1.5 times the full rated current of the main machine. This means that the electrical service does not have to be oversized to allow for starting. Also, using the pony motor prevents voltage sags to other customers on the same service during start-up of the M-G.

The pony motor is connected to the main machine with belts, which are selected to break in the event of a pony motor failure. This is to avoid a standard, off the shelf induction motor being the reason an M-G trips off line. If there were a failure in a pony motor bearing, a new motor could be shipped and installed the next time the M-G was conveniently shut down.

Feature

The *Series MG* has separate motors and generators.

Benefits

When the M-G is used as a power conditioner, the use of separate machines allows the motor to be selected for the real power needed to support the load. The generator can be selected for power quality. In cases where the customer's load is rich in harmonics or has a low power factor, a larger generator is used. The large generator is better able to start motors, furnish nonlinear current, or high reactive power without impacting the voltage quality. This can be thought of in the same way that power customers closer to the power station have better voltage quality than the ones at the far end of the line.

Series MG Motor-Generator

IMMUNITY TO UTILITY DISTURBANCES

Power Systems & Controls' motor-alternator system is the *Series MG* motor-generator. The *Series MG* is an M-G set applied to provide reliable power to critical electrical systems and derives its advantages from a number of characteristics of synchronous machines. First, the load is electrically isolated from the utility and any transient voltage disturbances that occur on the utility are not transmitted to the computer load. Secondly, the inherent ruggedness of the M-G, and specifically the quality of the insulation system, allows the synchronous motor to tolerate induced voltage spikes due to lightning and switching transients with such a high level of immunity that it survives events that damage other connected system loads.

The energy stored in the rotating inertia of the M-G set provides *ride-through* allowing the M-G to carry the critical load over many utility disturbances or interruptions. The synchronous motor has substantial ability to continue operation during temporary single phase conditions. In addition, the synchronous motor can carry full load while remaining in synchronism with the utility, even when the utility voltage drops to very low values - levels that the majority of electric power utilization equipment is not expected to, and cannot, tolerate. This means that the M-G set can provide quality power to the protected load during brownouts and for voltage sags to relatively low utility voltage levels. Quality power means that the utilization equipment is provided with rated frequency and voltage, even during a utility brownout and during many utility voltage sags.

Utility disturbances fall into four major categories:

1) Voltage Spikes

2) Single Phase

3) Voltage Droops (including sags and brownouts)

4) Power Loss ("clean break")

In applying the *Series MG*, the voltage droop category is the most important. This is because of the substantial ability of the M-G to tolerate and handle voltage spikes and single phase conditions.

Additionally, the "clean break" power loss is a relatively rare occurrence. The M-G also has significant ability to handle these when they are of short duration, a capability we will expand on later. For very long utility outages, considerably more energy storage is required than an M-G can provide. These situations require battery or fuel energy storage or both. For applications requiring these measures, PS&C can also provide high quality, reliable equipment.

Accordingly, let's talk briefly about the nature of voltage spikes and single phase and the M-G's capability of handling these. Then let's expand and concentrate on a very important area, the voltage droops that frequently plague computer systems. These voltage droops are important because of their frequent occurrence, but more important is the outstanding ability of the M-G to handle them. Lastly, we will cover the shorter duration "clean break" utility power loss, which the M-G also handles while keeping the critical load online.

VOLTAGE SPIKES

Lightning causes voltage spikes by inducing large, but very short overvoltages on the utility. Additionally, when switching events occur on utility distribution systems, longer duration transients occur, which may be a combination of under and overvoltage.

Some types of electrical equipment can tolerate the majority of these transients without malfunction or damage, but not computers. The M-G protects equipment from this type of disturbance because it provides electrical isolation between utility power and the equipment. The motor and generator used are physically separated. Consequently, the protected generator load does not see voltage spike transients.

Distribution systems can usually provide a degree of protection against voltage spikes. The quality of the insulation system of the motor is such that other loads on these utilities are usually affected before the M-G. This is also true if the transient is of excessive duration because the M-G inertial energy has the ability to "soak up" considerable transient energy.

SINGLE PHASE

In a three phase system, one of the three supply lines may be lost through the action of a protective device, e.g., a single fuse opening up. The result is single phase voltage being applied to the motor stator. A lightly loaded system may run undisturbed indefinitely and the synchronous motor may even carry loads approaching full load for some period of time, although it is likely that some motor overheating may result. Correcting the single phase condition will require resetting a protective device or

replacing the fuse up line from the synchronous motor. Single phase conditions are readily detectable. Commercially available devices may be used to detect and enunciate the condition, thus initiating the corrective action. The M-G synchronous motor can, in a great number of cases, provide the time needed for the user to have the single phase condition corrected while still supplying quality power to the critical load.

VOLTAGE DROOP

One variety of a voltage droop is the voltage sag that can occur on a utility distribution system and may persist for a matter of seconds. These may be caused by distribution system faults somewhere other than the user location. This is a prevalent type of utility disturbance and one that the synchronous motor is particularly well qualified to handle. During these kinds of disturbances, a synchronous motor will maintain synchronism with the utility, consequently maintaining speed and the frequency of the generator down to a significantly low voltage. Typically, a fully loaded synchronous machine can maintain rated torque, speed and generator frequency down to at least 60% of nominal applied voltage! A little later in this article, specific evidence of this synchronous motor capability will be furnished in detail.

Another variety of voltage droop is a called a brownout. The utility voltage reduction during a brownout is not as severe in magnitude as that which may occur during a voltage sag. Utility distribution system's protection normally operates if brownout reductions are less than 85% of rated voltage and persist for any significant period of time. Synchronous motors have no trouble providing the torque and speed required for the generator to provide rated quality power to the computer at these voltage reduction levels. The motor draws more current to do this, however, and this must be considered in the selection of input circuit protection for the motor.

POWER LOSS

A rapid drop of utility voltage to near zero is a power loss. An example of such a loss would be the rapid opening of a three phase circuit breaker immediately up line of the synchronous motor. When this happens, utility power flow to the motor is quickly cut off and the energy source necessary for the generator to supply electric power to the computer load is the inertial energy of the M-G set.

This type of utility disturbance is relatively rare as compared to the voltage droop. It usually occurs due to a temporary fault on the utility line, and in response, a protective switchgear briefly opens the line and then tries to reconnect utility power. Utility experience demonstrates that more than 80% of these temporary faults have disappeared by the time utility power is reconnected. The great majority of the interruptions caused by the action of the protective utility switchgear are five cycles or about 80 milliseconds long. In the rarer cases, the protective switchgear may interrupt power for up to 500 milliseconds. As will be explained later in this article, a loaded M-G continues providing power using its inertial energy and doesn't really pull out of synchronism with the utility for the shorter interruptions.

For the maximum interruptions, the energy the M-G delivers to the load reduces its speed and therefore degrades the frequency. However, rated generator voltage is maintained and PS&C's experience shows that computers stay online, even for the longer utility interruptions. What has been shown is that PS&C's M-G provides immunity to a substantial majority of types of utility disturbances. In order to better understand the M-G's capabilities, and in particular, the value of these capabilities in providing reliable power, it is worthwhile to consider further what happens during "voltage droops" and "power losses".

Power Systems & Controls ran a test on an M-G product to determine its tolerance to reduced voltage. The 120 kW M-G set was fully loaded while the input voltage to the motor was decreased in the same fashion that utility voltage would decrease during a voltage droop. The input voltage was reduced to 60% of rated while full load was maintained on the generator. The generator maintained rated voltage and frequency and output power. The motor, which was running at a near unity power factor, increased its current to 167% of rated, in reverse proportion to the reduction in voltage. The motor load angle increased significantly but the motor did not pull out of step with the utility, nor did it give any indication of being close to a pull out condition. Incidentally, this test was run with the motor at approximately a unity power factor. Overexciting the motor to a 0.8 lead power factor could provide an ability to operate at significantly greater reduced voltage, carrying full load while not pulling out of step. In the test described, the M-G operated for 30 seconds, a prescribed test condition, not a machine limitation. The motor could have been run at these conditions for much longer as long as overcurrent protectors did not respond to the 167% rated current by interrupting the motor power.

Motor thermal capacity is also a consideration during such voltage sags. Motor stator conductor losses during this test were almost 280% of rated. Providing adequate thermal overload protection for the motor in such an application would be required if very long voltage sag conditions were likely. For the 85% rated voltage extreme of a brownout condition, the M-G synchronous motor would have the thermal capability of operating for several hours.

Knowledge of the severity and duration of utility voltage droops is valuable information in the application of M-G’s to a customer’s facility. PS&C’s successful experience in M-G applications can be put to optimum use when such utility information is available. It is useful to have a physical picture of what happens in the synchronous motor as the motor is loaded and as motor terminal voltage is reduced at a constant load. If it were possible to ride the peak of the synchronous motor stator flux wave, which rotates at the motor synchronous speed locked to the utility frequency, we would find ourselves looking at the center of the rotor field pole. From our position on the stator flux wave, the rotor pole would appear stationary. As full load torque was applied to the synchronous motor rotor, we would see the center of the rotor pull falling back approximately 15-20 electrical degrees just as if the rotor were connected to the stator flux wave by strong rubber bands. This rubber band connection is the effect provided by the flux coupling between the synchronous motor rotor and the stator flux wave. Under normal conditions, the 15-20 electrical degree fall back, called the synchronous motor load angle, is maintained and the rotor operates in synchronism with the stator flux wave, which is itself in synchronism with the utility frequency. Now let’s “turn down” the utility voltage in the same manner that takes place during a voltage sag. As the utility voltage decreases, the spring constant of the flux rubber bands between the stator flux wave and the rotor is reduced. We could say that these flux rubber bands become more springy. As a result, they are stretched and the motor load angle increases. As we sit on the peak of the stator flux wave, we see the center of the rotor pull falling back further behind us but still staying stationary and in synchronism with the stator flux wave once the load angle adjustment for lower utility voltage has taken place. The synchronous generator, which the synchronous motor drives, is still supplying rated voltage, frequency and power to the protected load. It still requires rated torque from the synchronous motor to do this and the motor responds by increasing its stator current to adjust for the reduction in utility voltage.

The protected load is totally unaffected by these extreme events. The synchronous motor can maintain this condition for a long period of time, as long as its thermal capacity is not exceeded. Another requirement is that protective devices are not triggered by the higher synchronous motor current levels. We can simulate the end of the voltage sag by "turning up" the motor voltage. In this case, the flux rubber bands become less springy, thus pulling the motor towards us as we ride the peak of the stator flux wave, reducing the motor load angle. As we reach rated utility voltage, normal operation is restored with no disturbance to the critical load's power.
What if the utility voltage drops too low? If this occurs, we can visualize the flux rubber bands becoming so springy that they "break". This is called pulling out of step. For all practical purposes, when the utility voltage is low, we can say that the utility power can no longer support the computer load. As a matter of fact, the utility would not have supported the critical load at a considerably higher voltage level were it not for the presence of the synchronous motor and generator applied in the M-G.

To summarize the above, the synchronous motor flux rubber bands keep the synchronous motor synchronized with the utility line down to voltages of 60% of rated or less while the M-G supplies rated voltage frequency and power to an uninterrupted computer operation.

Now let's see what happens in the synchronous motor during a power loss. Once again, we are operating under rated conditions and riding the peak of the stator flux wave. Our hypothetical circuit breaker opens and suddenly, both the flux rubber bands and the stator flux wave we were riding are gone. To really follow what goes on, we also need a hypo-thetical reference stator flux wave to tell us where the utility frequency and phase will be whenever it comes back. We know that electrical utilities are linked in a network that stretches across the United States. Consequently, when power is reconnected, it will come back at exactly a standard 60 Hz frequency and in phase with our hypothetical reference stator flux wave, which has been rotating at synchronous speed during the interruption just as though nothing <u>had</u> happened. For all practical purposes, we are now riding the peak of the reference stator flux wave. We note that the rotor is falling away behind us but not very rapidly. We know that it didn't stop instantly because it has rotating inertial energy (I/2 x I x Omega squared that describes rotating flywheel action) and that it is now supplying the energy needed by the generator by slowing down. This rotating inertial energy is the other tool in the kit we referred to in the paragraph above for the five cycles or 80 millisecond interruption described earlier and which is most prevalent on utility systems.

The rotor fall back is typically about 60° or less when the input voltage returns. Under these conditions, the rotor quickly pulls forward as the flux rubber bands are reestablished, returning to a normal load angle for rated utility voltage. A substantial surge in input current was needed to accelerate the rotor to the normal load angle. This current surge is roughly proportional to the angle the rotor slipped back, which in turn is a function of the machine inertia divided by the load on the machine, and of course, the duration of the power loss. Typically, if the rotor fall back is 60°, the magnitude of the inrush current may be seven times its full load operating current. However, the acceleration is very rapid and the higher current level persists only for a few cycles.

What we have just described is known as synchronous ride-through. The rotor has slowed down to supply the energy needed by the generator, but not rapidly, and the fall back angle only reached 60 electrical degrees or less. While mathematically we can say that a change of the angle in a period of time is a frequency change, for all practical purposes, the generator frequency never really deviated from synchronous, rated voltage and power was delivered and the load was never interrupted.

Now let's suppose the power loss period is longer, up to 500 milliseconds. For full load on the generator, we will have exceeded a 60^o fall back. Additionally, the synchronous motor rotor speed will be noticeably below synchronous at the time of the return of utility voltage. Under these circumstances, the synchronous motor operates as an induction motor utilizing its amortiser windings, which are "cage windings" like those utilized on induction motors. PS&C installs a device that protects the synchronous motor field during this mode of operation. The synchronous motor accelerates as an induction motor to a near synchronous speed. At this point, the protective device re-enables the synchronous motor field and the motor quickly pulls into a surge of synchronous motor current approaching the motor locked rotor current has occurred during the induction motor acceleration, but as before, this is a relatively brief period of time.

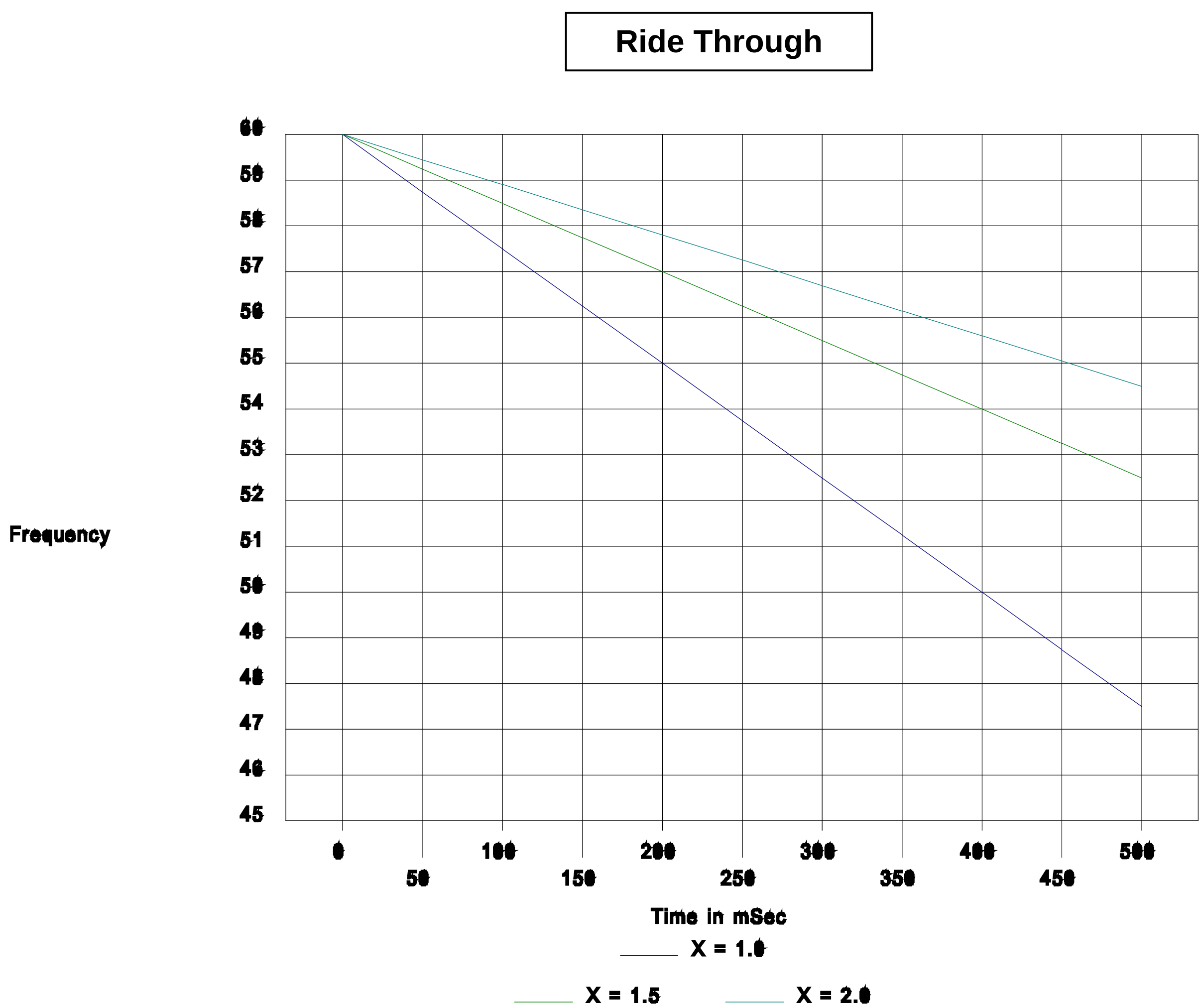
Generator voltage and power output have been maintained at rated during this long utility power loss disturbance, and although the generator frequency has decreased during this time, PS&C has ample experience showing that the M-G's maintain computers online up to 500 milliseconds with full load maintained on the generators.

For application purposes, we can quantify the effect of a flywheel or inertial energy. This is true because the product of the real load on the M-G set and the time period of a power loss interruption is proportional to the product of the rotor RPM2 and the inertia or WK^2 of the M-G rotors. The power x time product is normally expressed in kilowatt seconds. We can make a ratio of the rotor WK^2 to the generator load kilowatts. We also need to account for the M-G losses and thus need to reduce the effect of the WK^2 by the efficiency of the M-G. Taking into account these three parameters, we can define an X factor as shown above.

$$\text{X } Factor = \frac{WK^2}{KW\ \eta} = \frac{\eta\ WK^2}{KW}$$

$$\begin{aligned} &Where \\ \eta &= efficiency \\ WK^2 &= Rotor\ inertia \\ KW &= \Re\ Load \end{aligned}$$

Figure 1, which is an M-G application aid, shows the average generator frequency



during a power loss interruption vs. the interruption time in milliseconds for X factor ratios of 1, 12 and 2.

Incidentally, the M-G's represented on this curve will hold a rotor fall back angle of less than 60° for interruptions six cycles long with full load on the generators.

To complete our discussion of utility disturbances, it is important to consider power feedback. Power feedback is easiest to visualize in a power loss situation. When utility voltage quickly disappears during a power loss, terminal voltages of rotating machines, either synchronous or induction, do not disappear. This is because the flux in the rotating field that has been established during normal operation is "locked" in the rotor for a period of time or time constant that is typically longer than the duration of the transient disturbance that the M-G is designed to ride-through.

When the utility line opens, this rotor locked flux generates a voltage at a frequency corresponding to the speed of the motor rotor. If there is load on the utility lines up-line of the motor, but down-line of the power break that has occurred, the motor acting as a generator may supply this load from its store of inertial energy. When this happens, energy that was intended to keep the critical load online is diverted to an up line load; the result is that the effective ride-through of the unit is reduced. For a synchronous motor whose field is typically excited during the power disturbance, this power feedback can be greater and last longer. For voltage droop, voltage or power feedback is not a significant factor. Only the voltage that the utility can't maintain during this situation determines the ability of the M-G to keep the critical load online. As previously stated, the M-G tolerance for low voltage operation is significant.

In those unusual applications where power loss occurrences are significant, power feedback has the capability of reducing effective ride-through and therefore the length of power disturbance that the M-G can tolerate. For those applications, PS&C can apply a device that will effectively detect reverse power flow, thus allowing the application of a fast power switch to quickly interrupt the power diverted by these parasitic up-line loads.

In summary, M-G's have the ability to immunize sensitive electrical loads from the four major categories of utility disturbances: voltage spikes, single phasing, voltage droops (including sags and brownouts) and power losses. The M-G's are particularly effective against the most common of these disturbances, the voltage droop. Drawing on a wealth of successful experiences with motor-generators, PS&C can supply valuable application information and also assist in the application of these economical and effective UPS system power continuity problems. PS&C also has the capability to detect power feedback and to provide corrective control action in situations where power feedback is a significant factor.

SERIES MG SPECIFICATIONS(example-375kVA Series MG)

Power Systems & Controls will furnish one *Series MG* 375/480/60, 375 kVA motor-generator (M-G) sets that are designed to the following specifications.

FUNCTIONAL DESCRIPTION: The M-G set and associated controls shall provide a means of electromechanically isolating, and filtering disturbances in the AC power source from the electronic data processing systems.

PHYSICAL DESCRIPTION: The M-G set shall consist of the following elements:

- Brushless, Two Bearing Synchronous Motor With Brushless Exciter
- Reduced Current Motor Starter
- Motor Controls
- Motor Input Circuit Interrupter
- Brushless, Two-Bearing Synchronous Generator With Paralleling Capability
- Brushless Direct Connected AC Exciter With Rotating Rectifiers
- Bolted Steel Coupling Between Motor & Generator Adjustable To Match Input & Output Phases
- Generator Controls
- Generator Output Circuit Breaker
- Common Mounting Steel Base With Spring Type Vibration Isolators

CONTROLS: The M-G set shall be equipped with the following controls:

1. Motor Control: START switch at the M-G set, which activates the reduced current motor starter.

2. Motor Starter: Reduced current motor starting shall be accomplished by the following method:

   The M-G set shall be equipped with a pony motor type starter that reduces the starter that reduces the starting inrush to less than 1.5 x nameplate amperage.

3. Instruments: Metering shall be provided to monitor the following conditions:

AC Input Voltmeter	-	Each Line Voltage
AC Input Current	-	Each Phase
AC Output Voltage	-	Each Line To Line Voltage
AC Output Current	-	Each Phase

4. Voltage Adjustment Range: Output voltage control shall provide up to a ± 10% adjustment range from nominal.

5. Fault Detectors: The M-G set shall be equipped with protective devices that shut the unit down and activate internal latched indicators. These indicators shall retain the fault indication after the M-G set has stopped to simplify troubleshooting.

   - Output Overvoltage/Undervoltage
   - Starter Overload
   - Output Undemgrequency - Shutdown Only
   - Motor Overload
   - Motor Overtemperature
   - Motor and Generator Bearing Overtemperature

6. Status: The touch screen operator intemgace shall indicate the following conditions:

   - Motor On
   - Load On
   - System Bypass
   - System Fault

7. Uninterrupted Bypass: The internal bypass will transfer the critical load from the M-G set back to the utility without interruption. The bypass can be initiated either manually by a switch or automatically by the standard fault detectors listed above. There will be no more than ± 8% voltage transient during bypass.

8. Cycle-On-Line: The M-G systems will be capable of operating the critical load equipment directly on the utility, starting the M-G set, synchronizing the M-G with utility and transferring the critical load to the M-G without interrupting the operation of critical load equipment. The starting sequence will be automatic after initiation by the start switch. The cycle-on-line sequence will be automatic after closing the generator circuit breaker. The transition shall be without interruption of the critical load.

9. E.P.O.: This feature provides for the intemgace of the customer supplied “Emergency Power Off” via a set of switchable normally closed/normally open dry contacts.

10. Controls: The controls of the motor and generator shall be mounted in separate floor standing cabinets.

11. Power Outage Protector: The M-G set shall be equipped with protector circuits, and, in the event of a sustained power outage, the output breaker will be tripped when the output frequency decays to a preset level. Furthermore, the motor shall be protected from return of utility power before the M-G has coasted to a stop.

ELECTRICAL CHARACTERISTICS (example 375kVA *Series MG*):

INPUT:

Voltage	480 VAC, ± 10%, 3 phase, 4 wire, wye
Frequency	60 Hz
Power Factor	Adjustable from 0.8 leading to 1.0
Ride-Through	200 ms for usual power disturbances
Voltage Impulse	To 1500 volts for not more than 1 ms
Brownout	20% continuously low input voltage

OUTPUT:

Power	375 kVA at 0.8 lagging power factor continuous duty, _ 300 kW
Voltage	480 VAC, 3 phase, 4 wire, wye
Frequency	Same as utility
Steady State Voltage Regulation	± 1%
Transient Voltage Regulation 50 step load	± 8%
Harmonic Distortion	5% maximum total RMS harmonic distortion, 3% maximum single at full load
Phase Displacement	120 degrees ± 1 degree balanced load 120 degrees ± 3 degree for 25% unbalance
Overload	110% of nominal for 2 hours 125% for 10 minutes 150% for nominal for 1 minute

ENVIRONMENTAL CHARACTERISTICS

Ambient temperature	0 to 40 degrees C
Relative humidity	0 to 95% non-condensing
Altitude	0 to 3300 feet
Construction	Suitable for interior use
Bearings	Grease lubricated, antifriciton type
Service factor	Continuous duty, 24 hour service
RPM	1800 for 60 Hz

MOTOR-GENERATOR BEARINGS

Power Systems & Controls *Series MG* motor generator contains four (4) bearings. Each bearing requires annual lubrication to insure maximum bearing life. Our Standard Warranty provides replacement of any failed component during that period.

Extended Warranties assume normal mandatory maintenance is being pemgormed. Systems not receiving required lubrication of bearings and couplings are being subjected to misuse. A failure under these circumstances is not covered by the Power Systems & Controls Extended warranty. This is consistent with products from all manufactures.

Bearings supplied by Power Systems & Controls are expected to provide trouble free Service for a minimum of ten (10) years. Average bearing life exceeds twelve (12) years, and we do not recommend a replacement of bearings at any fixed time. Our *Series MG* motor-generator has temperature monitors installed in each bearing chase, and will give notice of bearing problems long before a failure. Only when detected should bearings be replaced.

The Power Systems & Controls Total Maintenance Contract will cover replacement of a failed bearing, provided the system has been under our Maintenance contract for at least three years prior to a failure. We will provide bearing replacements under a Time And Materials Contract for systems not under contract.

Ride-Through for Series SMG & Series IMG

Basic Equation Development

$$\text{Energy Initial} = \text{Energy lost} + \text{Energy Remaining}$$

$$\text{Energy Initial} \quad E_I = \text{‰}\ J_{MG}\ \omega_I^2 \quad \_\text{System rotational energy}$$
$$\text{Losses} \quad E_L = (P_L + P_P + P_I)\ t \quad \_\text{Watts delivered to load, internal losses, parasitic losses}$$
$$\text{Remaining} \quad E_R = \text{‰}\ J_{MG}\ \omega_2^2 \quad \_\text{System rotational energy at the end of the period of interest}$$

Where

$$J_{MG} = \text{Combinded Motor - Generator Inerria } (lb - ft^2)$$
$$\omega_I = \text{Initial rotational velocity (radians)}$$
$$P_l = \text{Power load}$$
$$P_P = \text{Parasitic load (kW)}$$
$$P_I = \text{Internal losses (kW)}$$
$$P_T = P_L + P_P + P_I \text{ (kW)}$$
$$\text{Assume } P_I = 10\% \bullet P_L \text{ or actual losses}$$
$$\omega_2 = \text{End of event velocity}$$

Assembling the Equation

$$\text{‰}\ J_{MG}\ \omega_I^2 = K_1\ P_T\ t + \text{‰}\ J_{MG}\ \omega_2^2 \qquad K_1 = 0.7376 \text{ ft - lb / watt seconds}$$
$$J_{MG}\ (\omega_I^2 - \omega_2^2) = 1.475\ P_T\ t \qquad \text{converts watt - seconds to rotational energy}$$
$$\omega_I^2 - \omega_2^2 = \frac{1.475\ P_T\ t}{J_{MG}}$$

Where

$$\omega_{electrical} = 2\pi f\ (\ ^2\_\#\text{ poles}) \qquad \text{Solve for four pole machine}$$
$$\omega_e = \pi fe$$

Converting mechanical to electrical

$$(\pi f_1)^2 - (\pi ft_2)^2 = \frac{1.475\ P_T\ t}{J_{MG}}$$ *Substituting electrical frequency for mechanical frequency*

$$f_1^2 - f_2^2 = \frac{0.1495\ P_T\ t}{J_{MG}}$$ J_{MG} *supplies by vendor in lb - ft²*

lb - ft² must be converted into lb - ft² _32.2

$$f_2^2 - f_1^2 = \frac{4.814\ P_T\ t}{J_{MG}}$$ *Equation is now dimensionally correct*

$$f_2^2 = f_1^2 - \frac{4.814\ P_T\ t}{J_{MG}}$$

and

$$T = J_{MG}\ \alpha = J_{MG}\ \frac{\Delta\omega}{\Delta t} = J_{MG}\ \frac{\Delta^2\omega}{\Delta t^2}$$

$$\Theta = \Theta_0 + \omega t + ‰\alpha t^2$$ *Equation of Motion*

$$\phi = \frac{T}{J_{MG}}\ t^2$$

$$\Theta = \phi / 2$$ *Mechanical to electrical*

$$\Theta = ‰\frac{T}{\phi} = \frac{737.6 \bullet 32.2}{2\pi 30}\left(\frac{P_T}{J_{MG}}\right)t^2 \qquad J_{MG} = J_{MGOVER}32.2$$

$$\phi = \frac{126\ P_T\ t^2}{J_{MG}}$$

$$T = \frac{737.6\ P_T}{2\pi I30}$$

$2\pi I30$ = *1800 RPM converted to milliseconds*

$\phi = 1.26 \bullet 10^{-4}\ P_T\ t^2 \_ J_{MG}$ *converts t to milliseconds*

Where:

ϕ = *Resultant electrical phase displacement*

t = *milliseconds*

P_T = *Killowatts*

J_{MG} = *lb - ft²*

$$f_2 = \sqrt{f_1^2 - \frac{4.814\ P_T\ t}{J_{MG}}}$$

Where:
t = *milliseconds*
P_T = *Killowatts*
J_{MG} = *lb - ft*^{2}
f = *electrical frequency*

The above equation defines the end frequency from the generator, but is not in a form that leads to a solution.

$$f_2 = \sqrt{f_1^2 - \frac{4.814\ P_T\ t}{J_{MG}}}$$

$$\text{Recall } \phi = \frac{1.26 \bullet 10^{-4}\ P_T\ t^2}{J_{MG}}$$

$$\text{Rewrite } \frac{P_T}{J_{MG}} = \frac{\phi}{1.26 \bullet 10^{-4}\ t^2}$$

$$f_2 = \sqrt{f_1^2 - \frac{38.206\ \phi}{t}}$$ *Equation used to determine ride-through for motor-generator*

Recall

$$\phi = \frac{1.26 \bullet 10^{-4}\ P_T\ t^2}{J_{MG}}$$

Solve for ride-through time (t)

$$t = \sqrt{\frac{\phi\ J_{MG}}{1.26 \bullet 10^{-4}\ P_T}}$$ *Equation used to determine ride-through for motor generator*

Sample Ride-Through Calculations

Timing

Shunt Trip = 15 - 20 mSec
PLC Scan _ 10 mSec
Detection Time = 9 mSec

Total delay time & reaction time = 37 mSec nominally

t_1 = *Ride-through time before circuit must begin to detect*

$$t_1 = t - 37 \text{ mSec}$$

t_2 = *Ride-through time before decision is made to open input*

$t_2 = t - 28$ *mSec* *Note: Detection must occur before reaction*

Using previous example detection begins at

$$t_1 = 112.3 - 37 = 75.3 \text{ mSec}$$

$$f'_2 = \sqrt{3600 - \frac{4.814 \bullet 880 \bullet 75.3}{1399}}$$

$f'_2 = 58.07$ *hz* *Generator output frequency when detection begins.*

Worst case considerations with parasitic loads

Given:

$$J_{MG} = 1399\ lb - ft^2$$

$$P_L = 800\ kW$$

$$P_P = 0$$

$$P_I = 80\ kW$$

$\phi \leq 1$ *Radian, limit imposed by surge current upon return of utility voltage*

$$F_1 = 60\ hz$$

Note: Inertia values for pony motor and miscellaneous are not included.

$$t = \sqrt{\frac{\phi\ J_{MG}}{1.26 \bullet 10^{-4}\ P_T}}$$

$$t = \sqrt{\frac{1 \bullet 1399}{1.26 \bullet 10^{-4} \bullet 880}}$$

$t = 112.3$ *mSec for* ϕ _ 1 *Radian*

$$F_2 = \sqrt{f^2 - \frac{4.814\ P_T\ t}{J_{MG}}}$$

$$F_2 = \sqrt{3600 - \frac{4.814 \bullet 880 \bullet 112.3}{1399}}$$

$F_2 = 57.1\ hz$ *Generator frequency at* $t = 112.3$ *mSec* ϕ _ 1 *Radian*

$$t_{\min} + 37 = \sqrt{\frac{\phi \bullet J_{MG}}{1.26 \bullet 10^{-4} \; P_{\max}}}$$

$$f_{2\,\min} = 58 = \sqrt{3600 - \frac{4.814 \; P_{\max} \; t_{\min}}{J_{MG}}}$$

$$3364 = 3600 - \frac{4.814 \; P_{\max} \; t_{\min}}{J_{MG}}$$

$P_{\max} \; t_{\min} = 49 \; J_{MG}$ *Solution is found by iteratively solving* $T_{\min}$ & $f_2 \min$ *equations*

Using previous example

$t_{\min}$ *to 58 hz = 20 mSec*

$P_{\max} = 3429 \, kW$

$P_L = 800 \, kW, \quad P_I = 80 \, kW, \quad P_P = 2549$

Note: The maximum parasitic load (P_P) is found by this method. Larger parasitic loads will cause the frequency of the generator to be below our imposed limit of 57 hz. Larger parasitic loads cause the input circuit breaker to the motor-generator to trip on return of the utility voltage.

OPTIONAL FEATURES

1. Bypass Inhibit: In the event that utility input voltage is outside of ± 10% of nominal, the bypass shall be inhibited.

2. Remote Monitor: System package has a separate desk top alarm panel which includes the following monitoring and alarm functions:

   - Load On
   - System Bypass
   - System Fault
   - Audible Alarm (sounds when any of the above fault conditions occur)

3. Split Voltage: System package includes a dry-type, fully isolated transformer, rated for full load continuous duty with two taps, (1) above and (1) below nominal. All equipment will be in a NEMA-1 enclosure. NEMA standards for noise and temperature shall apply.

4. Sound Enclosure: The M-G set will be equipped with a sound attenuation device to reduce noise emission to less than 65 dBa at 2 meters free field. The enclosure will be modular and supplied in a disassembled condition to facilitate installation. The enclosure will be equipped with a means to remove the waste heat produced by the M-G set for the enclosure.

5. Exhaust Silencer: The M-G set will be equipped with a sound attenuation device to reduce exhaust noise emission to less than 78 dBa at 2 meters. The device will be an integral part of the M-G assembly.

QUALITY

All materials, parts, and components used will be new and of high grade.

TESTING

The total system will be exposed to a functional and load test and will be subject to a factory full load test prior to shipment. Tests conducted at 1.0 P.F.

MAINTAINABILITY

No regular maintenance service operations are required at less than one-year intervals. At installations where unusual concentrations of moisture, vapors, dust and other particles may impinge upon windings, maintenance may be done at more frequent intervals, but without shutdown.

DUAL SOURCE MOTOR-GENERATOR SYSTEM SPECIFICATION (example 750 kVA)

Power Systems & Controls will furnish dual input synchronous isolation system(s) with a 900 amp (750 kVA, 600 kW) continuous rating.

FUNCTIONAL DESCRIPTION:

This system shall provide continuous, isolated and filtered power to the protected load with two (2) synchronous motor-generators. These machines will each be connected to different utility feeds. During normal operation, the motor-generators will operate in parallel, sharing the load and drawing equal amounts of energy from each utility source. The motor-generators will each be rated at 750 kVA.

In the event of a failure of one of the two sources, the system logic will detect reverse power from the motor connected to the failed feeder. The system control will, within 40 sec., open (trip) the electrically operated input circuit breaker preventing back feed to the failed source. Transfer control logic will then close an alternate source circuit breaker, connecting both motor-generators to the remaining feeder. During the detection and transfer time, the machine connected to the remaining utility source assumes 100 % of rated system load (900 amps). This places a worst case overload equal to 150% of the rated continuos capacity of one motor-generator.

The second motor-generator, on loss of its input, begins to motor. Motoring is the condition where the system's generator draws energy from the systems common output bus acting as a motor driving the now unloaded main motor. The energy drawn from the system is limited to that needed to overcome the mechanical losses system. During this period, the motor-generator naturally maintains 1800 RPM in synchronism with the remaining machine and its input source.

On closure of the alternate feed tie circuit breaker, the second system draws a small additional current to reaccelerate the motor to reach the same power angle as the loaded system. The detection, opening, and reclosure/transfer time is less than two seconds. The total overload time for the loaded machine is less than two seconds, which is well within the thermal limits of the machine that is rated for 150% for 30 seconds.

During the time of the source transfer, the motor-generator uses its mass and inertia to buffer the protected load from any variations in voltage or frequency during the input source transfer.

PHYSICAL DESCRIPTION:

The dual feed synchronous isolation system shall consist of the following self contained elements:

- Automatic electromechanical Open Transition Transfer System With Operator Selected Source Automatic Bypass
- System Control Console
- Shaft Coupled Motor-Generator Sets

Each element of the system shall be capable of being installed separately from the other components of the system to facilitate system installation and maintenance in existing facilities.

ELECTRICAL CHARACTERISTICS:

INPUT:

A.	Voltage -	480 VAC + 10%, - 20% 3 Phase, 4 Wire
B.	Power Factor	Unity to 0.95 leading
C.	Voltage Impulse	1500 volts for not more than 1 ms.
D.	Brownout	-20% continuous -60% for 30 seconds

OUTPUT:

A.	Voltage -	480 VAC, 3 Phase, 4 Wire
B.	Power -	750 kVA at 0.8 lagging , 600 kW
C.	Current -	902 Amperes per phase
D.	Power Rating -	Each machine 750 kVA
E.	Overload Rating	110% of nominal for 2 hours 125% for 10 minutes 150% of nominal for 1 minute 200% of nominal for 30 seconds
F.	Frequency	Same as utility

G.	Steady State Voltage Regulation	± 0.5%
H.	Transient Voltage Regulation 50% step load	± 8%
I.	Harmonic Distortion - distortion, load	5% maximum total RMS harmonic 3% maximum single at full
J.	Phase Displacement	120 degrees ± 1 degree balanced load 120 degrees ± 3 degree for 25% unbalance
K.	Ride-Through	500 ms for usual power disturbances
L.	Overcurrent power	Electronic solid state detection of reverse and extended overcurrent.

TRANSFER CONDITIONS:

The system shall transfer from the preferred power source to the alternate power source for the following conditions:

1. Unacceptable reverse power

2. Preferred source overvoltage:

   a. >110% of nominal (adjustable).
   b. Loss of continuity in preferred source.
   c. Loss of phase in preferred source.
   d. Manual signal.

The system shall inhibit transfer to the alternate source for the following conditions:

1. Alternate source under voltage:

2. Less than approximately 80% of nominal.

RETRANSFER CONDITIONS:

Automatic Retransfer Conditions - The system shall automatically retransfer the load to the preferred source provided all of the following conditions are met:

1. The sources are in-phase.

2. Preferred source voltage is within ± 10% of nominal for more than two seconds. Separate adjustable under voltage return level, normally set at -5%.

3. Manual/automatic return selector switch is in the automatic position.

4. Transfer was not caused by loss of phase.

TRANSFER TIME:

Transfer Sensing Time - Maximum transfer sensing time for loss of preferred source voltage shall be 2 seconds or less.

CONTROLS:

The following controls shall be furnished on the front of transfer system cabinet:

1. Transfer Test Switch - Allows transfer to be manually initiated.

2. Manual Reset Switch - Allows each machine to return to the preferred source when the Manual/Automatic Return Selector Switch is in the manual position if phasing and voltages are correct. Also resets the loss of continuity latch after repairs.

3. Manual/Automatic Return Selector Switch - Selects either manual or automatic mode for retransfer to preferred source after a transfer to alternate source.

4. Maintenance Bypass Switch - Allows load to be connected directly to the preferred source. The maintenance bypass switch shall have overlapping contacts so as to prevent interruption of power to the loads during switching.

5. Isolation Switches - Removes power from the system for maintenance purposes. The isolation switches may be incorporated in the maintenance bypass switch.

The Rotary Filter shall be equipped with the following controls:

1. Motor Control: START switch at the M-G set which activates the reduced current motor starter.

2. Motor Starter: Reduced current motor starting shall be accomplished by the following method:
The M-G set shall be equipped with a pony motor type starter that reduces the starter that reduces the starting inrush to less than 1.5 x nameplate amperage.

3. Bypass Inhibit: In the event that utility input voltage is outside of $\pm$ 10% of nominal, the bypass shall be inhibited.

4. Instruments: Digital metering shall be provided to monitor the following conditions:

AC Input Voltmeter	-	Each Line Voltage
AC Input Current	-	Each Phase
AC Output Voltage	-	Each Line To Line Voltage
AC Output Current	-	Each Phase

5. Voltage Adjustment Range: Output voltage control shall provide up to a $\pm$ 10% adjustment range from nominal.

6. Fault Detectors: The M-G set shall be equipped with protective devices which shut the unit down.

7. Indicators - These indicators shall retain the fault indication after the M-G set has stopped to simplify troubleshooting.

   a. Output Overvoltage/Undervoltage
   b. Starter Overload
   c. Output Under Frequency - Shutdown Only
   d. Motor Overload
   e. Motor Overtemperature
   f. Motor and Generator Bearing Overtemperature

8. Uninterrupted Bypass: The maintenance bypass will transfer the critical load from the motor-generator system back to the utility without interruption. The bypass can be initiated either manually by a switch or automatically by the standard fault detectors listed above. There will be no more than $\pm$ 8% voltage transient during bypass.

9. Cycle-On-Line: The system will be capable of operating the critical load equipment directly on the utility, starting the system, synchronizing with utility and transferring the critical load to the system without interrupting the operation of

critical load equipment. The starting sequence will be automatic after initiation by the start switch. The cycle-on-line sequence will be automatic after closing the generator circuit breaker(s). The transition shall be without interruption of the critical load.

10. E.P.O.: This feature provides for the intemgace of the customer supplied “Emergency Power Off” via a set of switchable normally closed/normally open dry contacts.

11. Controls: The controls of the motors and generators shall be mounted in separate floor standing cabinets.

12. Power Outage Protector: The M-G set shall be equipped with protector circuits, and, in the event of a sustained power outage, the output breaker will be tripped when the output frequency decays to a preset level. Furthermore, the motor shall be protected from return of utility power before the M-G’s have coasted to a stop.

INDICATORS:

The following functions shall be monitored and indicated with lights on the front panel of the system control console:

- Source One and/or Source Two Available
- Automatic Bypass Available
- Loss Of Source One Or Two
- Synchronization Monitor

The following functions shall be monitored and indicated with lights on the front of the control console:

- Motor On
- Load On
- System Bypass
- System Fault

Remote Monitor: The system shall have a separate desk top alarm panel which includes the following monitoring and alarm functions:

- Load On
- System Bypass
- System Fault
- Audible Alarm (sounds when any of the above fault conditions occur)

ALARM CONTACTS:

The following functions of the system shall have alarm contacts (SPDT 2 Ampere rating) available for connection to purchaser's alarm system:

- Loss Of Source One
- Loss Of Source Two

DESIGN:

System Controls:

1. Life - The system shall use components of adequate rating to provide an expected service life of twenty years (20) continuous duty and ten years (10) without component replacement. The system shall contain no continuously moving parts other than cooling fans, which shall have permanently lubricated bearings.

2. Maintenance - Provisions shall be provided for testing the control circuits while the critical loads are bypassed to one of the power sources. All adjustments and tests shall be possible with the use of a standard metering and oscilloscope. Test points and diagnostic lights shall be provided to allow easy adjustment of the controls. Control circuits shall be mounted on etched circuit boards with plug-in connections for ease and speed of repairs.

Motor-Generator (M-G):

1. The M-G sets shall consist of the following elements:

    a. Brushless, two bearing synchronous motor with brushless exciter
    b. Reduced current motor starter and motor controls
    c. Motor input circuit interrupter
    d. Brushless, two-bearing synchronous generator with paralleling capability
    e. Brushless direct connected AC exciter with rotating rectifiers
    f. Bolted steel coupling between motor and generator adjustable to match input and output phases
    g. Generator controls
    h. Generator output circuit breaker
    i. Common mounting steel base with spring type vibration isolators

2. The motor-generator shall require no regular maintenance service operations at less than one year intervals. At installations where unusual concentrations of moisture, vapors, dust and other particles may impinge upon windings, maintenance may be done at more frequent intervals, but without shutting down.

CONSTRUCTION:

Enclosure: The transfer system shall be housed in a code gauge steel, NEMA 1 enclosure requiring access from the front for all servicing adjustments. Access shall be through a hinged door with a tumbler lock and latch handle. The enclosure shall be primed and painted inside and outside with a suitable semi-gloss enamel. The enclosure shall be either of the wall mount or free-standing floor mount design.

Layout: Modules and subassemblies shall be mounted in open construction style so that each may be easily replaced. The equipment shall be constructed so that each power component can be replaced without a soldering iron or special tools. Cable and conduit connections shall be through the top of the cabinet.

Material & Workmanship:

1. Workmanship shall be first class in every respect.
2. All material shall be new and of high commercial grade.
3. Brackets and securing hardware shall be electroplated with corrosion resistant material.
4. Internal wiring conductors shall be combined into cables, or bundles, and shall be tied securely together.

COOLING:

Cooling shall be by natural convection or forced air by fans. If forced air cooling is used, then the fans shall be protected with individual fuses so that if a problem develops in one, it will not affect others. Natural convection cooled modules may require rear clearance for adequate air flow.

ENVIRONMENTAL CHARACTERISTICS:

A.	Ambient temperature	0 to 40 degrees C
B.	Relative humidity	0 to 95% non-condensing
C.	Altitude	0 to 3200 feet

D. Construction — Suitable for interior use

E. Bearings — Grease lubricated, antifriction type

F. Service factor — Continuous duty, 24 hour service

G. RPM — 1800 for 60 Hz

OPTIONAL FEATURES:

Sound Enclosure: The M-G sets will be equipped with a sound attenuation device to reduce noise emission to less than 65 dBa at 2 meters free field. The

enclosure will be modular and supplied in a disassembled condition to facilitate installation. The enclosure will be equipped with a means to remove the waste heat produced by the M-G set for the enclosure.

Exhaust Silencer: The M-G sets will be equipped with a sound attenuation device to reduce exhaust noise emission to less than 78 dBa at 2 meters. The device will be an integral part of the M-G assembly.

TESTING:

The total system will be exposed to a functional and load test and will be subject to a factory full load test prior to shipment. Tests conducted at 1.0 P.F.

Applications Considerations

This section has been intentionally left blank. This section will be completed in accordance with the specific requirements set forth by NIPSCO.

Installation Considerations

This section has been intentionally left blank. This section will be completed in accordance with the specific requirements set forth by NIPSCO.

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Product Services

Service & Warranty

Local Service

Power Systems & Controls maintains a factory technical support service center in Richmond, VA and local first response via ____________

This operation is on call and available 24 hours a day, seven days a week, 365 days a year. This organization has the ability, training and over sixty years of experience servicing PS&C UPS systems to insure that this site will receive the best possible service. PS&C also maintains a local service operation in which is able to respond on-site to needs within four hours. Service descriptions are as follows:

Power Systems & Controls' provides seven days a week, 24 hour a day hotline support for any PS&C customer whether covered by Power Systems & Controls' warranty or a service contract.

Power Systems & Controls' service mission is to respond to all trouble calls with a trained technician/engineer within 30 minutes of the time the call is received. The technician returning the customer's phone call will be fully trained and versed in the customer's equipment.

The mission of the technical support is:

1. Define the nature of the customer problem and to talk customer personnel through any procedures required to insure the power is returned to the critical bus.

2. Ascertain the technical ability of the person requesting technical support. If this person is qualified to work on the power conditioning system, the technical support engineer will work with the customer's personnel to provide complete repair of the equipment.

3. If the customer is not capable of servicing the power conditioning system, then an on call field engineer is dispatched to the customers site.

4. Should the customer attempt to repair the unit in conjunction with Power Systems & Controls' technical support engineer and no progress is made for a period of two hours; PS&C would then recommend a field engineer respond to the site to assist in the repair. The Power Systems & Controls field engineer would then

be dispatched either from the factory location or the closest local service center.

Power Systems & Controls provides technical support services at no additional charge to all of our customers. Power Systems & Controls' warranty will cover the on-site response of a field engineer should it be required. Power Systems & Controls does not limit its on-site response to Monday through Friday, from 8 to 5 pm. However, the necessity for an on-site field engineer is dictated by two criteria:

1. Should the system fail in a catastrophic manner in which power is lost to the critical bus - under this condition a field engineer is immediately dispatched.

2. The power conditioning system has indicated an alarm condition indicating there is a problem with the equipment; however the equipment is on line and supporting the critical load. Under this particular condition, the nature of the problem is ascertained and Power Systems & Controls' field engineer will be dispatched at the next convenient time in order to make the repair. Typically, this type of repair is pemgormed Monday through Friday from 8 to 5 pm. However, should the customers operational circumstance dictate otherwise, Power Systems & Controls will respond at an appropriate time.

In all cases, Power Systems & Controls' customers are directly in the decision making loop as to what is an appropriate response and the time in which service can be delivered which best serves Power Systems & Controls and our customers.

Warranty

Power Systems & Controls warrants its equipment to be free from manufacturing defects for a period of 12 months from date of bring-up or 18 months from date of shipment for all commercial sales. Standard warranty statements from PS&C are contained in this section.

In addition to the base warranty, PS&C provides two types of product support for its systems.

Preventative Maintenance (PM)
Full Service Maintenance (FSM)

PM

Our recommendation for PM involves a qualified service man checking key operational electronic and mechanical settings every six months. Annually (and during a 6 month PM service) more intensive operational checks and lubrications are pemgormed.

The majority of the PM work required to maintain the reliability of your system can be pemgormed by your staff if they are properly trained. Training is available at our Richmond VA factory at a nominal charge. Our belief is regular PM service by a factory field engineer is best for critical power systems. In addition to the inspections and actions listed above, our factory representative brings with him years of experience with similar systems. His on site knowledge of PS&C equipment and its operational characteristics is invaluable in spotting problems and equipment trends. With this in mind, we have priced our PM service aggressively to encourage all owners of our power conditioning systems to take advantage of factory PM service.

Additional PM service is available on a contract basis for a long as the equipment is in service. Pricing for PM service will be reviewed every three years and will remain firm during the period of coverage. Contract periods as short as one year are available.

FSM

Full Service Maintenance of your system provides you with factory service and repair of any component for the contract period. Should any component fail it will be replaced at no additional charge to you. Emergency service is provided 24 hours per day, 7 days per week at no additional charge. Scheduled repairs will be made during normal business hours. No additional charges for travel, parts or shipping will accrue. As a part of the FSM program, PM services are also included. The goal is to provide you factory service to assure reliability at a fixed cost.

Exclusions from our FSM program are simple. They include Acts of God, abuse, severe overload, environmental events (such as earthquake, flood, temperature, etc.), manmade disaster (war, riot, etc.) and lightning.

FSM contract periods are available on a contract basis for a long as the equipment is in service. Pricing for FSM service will be reviewed every three years and will remain firm during the period of coverage. Contract periods as short as one year are available.

TRAINING

Power Systems & Controls training department has several levels of classes available to purchasers of our equipment.

The courses range from basic system operation for your facilities personnel to operation theory for your engineering department. We also offer a short course for your computer operation personnel.

The computer operator course is geared to educate your personnel on the system which will be protecting your critical load. Instruction is given on the remote monitor and what actions are required for each alarm, who to contact and what information they should gather prior to calling for assistance.

PS&C's field engineers will work with your operations staff to develop an emergency procedure tailored to both your operation and the qualifications of your personnel.

The second level of training offered, is geared towards the people who will operate the power system.

This course communicates the operating plan developed by your staff. This opens lines of communications between your people and PS&C's field service group. Equipment operators are instructed in transferring the critical load from protection power to normal utility for equipment maintenance. Upon completion your staff should be able to:

1. Start up system from a cold powered down status
2. Transfer (uninterrupted) critical equipment to protected power
3. Secure the system after a failure
4. Interpret system flags and alarms
5. Pemgorm inspections of system between normal factory maintenance calls
6. Define the % of system capacity remaining (to allow power planning when adding additional critical equipment)
7. Communicate with PS&C's 24 hour, 7 day a week technical support hotline
8. Pemgorm minor repairs and maintenance

This course is held in your facility on your equipment, and allows your people to develop procedures and check lists during the course which will be used during the equipment service life. PS&C offers this training on completion of system start-up, before committing systems to critical load.

This allows your people to operate the equipment without endangering your critical load.
The third level of training PS&C can provide is an in depth course on the equipment. This course covers all the fundamentals for the circuits and systems contained in your system. Each major section is broken down and explained.

Upon completion your personnel will be able to:

1. Replace components
2. Pemgorm electrical maintenance
3. Pemgorm all function presented in the level 2 course

NOTE: Level 3 training requires electrical/electronic background and associate experience with oscilloscope's, DFM's and high power electrical circuit breakers and contactors.

FACTORY TRAINING

The goal of this program is to explain the operation of the system to computer room personnel and operational requirements to the facilities department. Site personnel who will be operating the system should have a basic understanding of electrical systems
and circuit breaker operation.

Instruction on the system will include:

1. Theory of operation
2. Correct operating practices
3. Trouble shooting procedures
4. Preventive Maintenance procedures
5. The system as installed for the customers project

This course may be adapted to the type of personnel the customer elects to send to the course or the depth that the customer would like to train their personnel.

SITE TRAINING

The goal of this program is to explain the operation of the system to computer room personnel and operational requirement to the facilities department. Site personnel who will be operating the system should have a basic understanding of electrical systems
and circuit breaker operation.

Instruction on the system will include:

1. Theory of operation

2. Correct operating practices

3. Trouble shooting procedures

4. Preventive Maintenance procedures

5. The system as installed for the customers project

The course is intended to fill the needs of the customers project, and may be adapted to the type of personnel the customer elects to send to the course or the depth that the customer would like to train their personnel.

CUSTOMER TRAINING AGENDA- FACTORY CHARGEABLE PER SCHEDULE A-S

I. Classroom Work

I. Review of one-line drawing
II. Review of System Basics
III. Review relay logic
IV. Review of drawings
  A. Review list of functions pemgormed by relay logic
  B. Review list of symbols
  C. Review list of relay ID versus function
  D. Review schematic
  E. Review bypass detectors
  F. Review under frequency detector
V. Review M-G Function
  A. Why an M-G?
  B. Why a synchronous motor?
  C. Review generator and regulation
VI. Review purpose of customer weekly report sent to PS&C
VII. Review PM form
VIII. Review operating procedure
  A. How to start
  B. How to bypass
  C. How to stop
  D. How to cycle-on-line
  E. How to emergency stop
  F. Review fault and status panel
    1. Function of lights
    2. Alarm and silence PB

II. Training at Unit

I. Review safety procedures
II. Customer starts, stops, bypasses, cycles-on-line
III. Review again bypass detectors
IV. Review how to "set-up" unit
V. System operational demonstration
VI. Fault and minor maintenance review
  A. Review troubleshooting procedure
  B. Bug equipment: allow customer to troubleshoot
  C. Review and set up other problems

III. Return to Classroom

I. General Summary
II. Customer Questions

Drawings-Series MG