Power Reliability

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Kohler—Power Systems

ABSTRACT

Reliable electrical power is required for safety, security, financial, and many other business reasons. This article will discuss the levels of power continuity, and various methods for making sure that reliable power is available 24 hours a day, 7 days a week. The cost of power continuity is directly related to increased availability, and reliability. The cost of downtime can be measured by the loss of human life, product, equipment, revenue and inconvenience. Uptime cost must be weighed against the cost of providing additional equipment, which can include on-site generation, redundant services, and UPS systems. Equally important for obtaining power reliability are proper design, redundancy, and elimination of single points of failure; training, testing and maintenance.

POWER RELIABILITY

How reliable is your electrical power source?

How important is it to you that you have electricity?

What would the impact be to you, and your business, if there was a power outage that lasted a second, a minute, a day, or longer?

Depending who you ask, you will get different answers to each of the above. If you are a homeowner in a city, chances are that you will experience several short outages every year, live with it, and suffer only the minor inconvenience of resetting some clocks.

If you are a poultry producer, a power outage lasting 15 to 30 minutes in the summer could put you out of business. Loss of power will stop the supply of water and feed, but more importantly it will shut down the ventilation system. Without ventilation you can lose 40,000 chickens per house, and 160,000 chickens on a typical farm due to overheating.

For a manufacturer the outage could run into the millions of dollars per hour, due to lost product, and the loss of production equipment. A power loss could also create a hazardous condition.

A power outage of only a few seconds can be disastrous to a computer center. Uninterruptible power systems (UPS) are used for short-term outages. On-site generation is needed for extended periods to provide electrical power for air conditioning, recharge the UPS batteries, lighting, and system operation.

Needless to say, we expect, and by law, require emergency power for our hospitals, and other life safety applications. We also expect the continuous operation of our 911 centers, police and fire stations, aviation control, water and sewage plants, computers, and telephones, all of which must have electrical power to operate.

My shipboard Navy experience included duty on a guided missile cruiser. The ramifications of not having electrical power on a ship included the loss of the navigation lighting, communications, and the ability to steer. The ship would be vulnerable to attack, and without fuel and water pumps you will stop, dead in the water.

How did the Navy prepare? The ship had 4 × 750 kW steam turbine driven main, and 2 × 250 kW diesel engine driven generators. It had the ability to operate with any two and under extreme cases one generator set. The generators and electrical distribution equipment was installed in four isolated locations. The switchgear was manually operated, quite simple in design, and each generator set was designed for operation either in parallel or as an independently power source. The electrical arrangement was designed to provide power even if the cables are cut, by the use of multiple feeds, and plug-in emergency cabling arrangements. The keys to reliable power were redundancy, flexibility, heavy-duty marine equipment, and well-trained operators.

Nuclear power plants make electricity. Each plant also has standby generators to provide power in the event of an emergency for orderly shut down. The consequences of not having power and the possibility of a melt down are beyond our wildest imagination. Switchgear and generator sets for these applications are certified under IEEE 323 standards, which include testing for aging, nuclear degradation of components, seismic, vibration and shock. All of this testing is in addition to the normal ANSI electrical test for commercial equipment.

The generator sets and switchgear are designed to operate to destruction, since the consequences of not having power is so severe. Other measures used to ensure reliability are the separation of control and communications wiring, the use of the heaviest and nuclear qualified components with documentation tracing the components back to the mill, or mine, extensive system testing, and operator training. The keys to reliability include careful design, close monitoring and testing, and use of the highest quality materials.

Communications and the Internet have pushed the limits for power reliability. While the average utility will provide electrical power 99.9% of the time. That's "three nines" reliability, or about 8 hours of outage a year, and before the "Bit Era," this was good enough. The reliability demands now start at Six Nines for telecom and dot-com world. Six nines (99.9999) of power reliability means that all outages must be held to less than 30 seconds per year. The traditional electrical grid in this country will never be able to provide much better than Three or Four Nines of reliability.

Power reliability involves system design, and the selection of quality products. Reliability also requires redundancy, and the elimination of any single points of failure. While less technical in nature, equipment testing, operator training, and proper maintenance each help to maximize uptime. When discussing reliability and 6-9's we must also remember that equipment must also be capable of being maintained without creating any down time in the true 24/7/365 environment.

Your site location and how it is supplied will determine the reliability of the electrical utility source. Customers at the end of a radial feeder, miles from the substation are more vulnerable than those located closer. Two utility supplies from separate substations are desirable for large industrial system, as is the use of main-tie-main service equipment. Higher voltage lines have better reliability than a lower voltage system. Your local utility can provide you with specific reliability data for given locations, and supply arrangements.

For some the use of uninterruptible power systems with bypass isolation equipment for service are an integral part of the equation. Kohler can provide the complete solution to on-site power with the ability to provide engine generator sets, automatic transfer switches, switchgear, and UPS systems. In this article, my focus on power reliability will be general in nature, and can be used as a starting point for the proper design and implementation of systems requiring reliable power. I give six examples of various industrial and dotnet installations to show what has been done to obtain extra reliability.

EXAMPLE 1

Typical Emergency Power Application

A typical emergency power installation for a site with a moderate power reliability requirement will include a single generator set providing backup power for all, or only the critical loads, and a single utility feed. Kohler provides the generator set, and an automatic transfer switch for these installations. These installations are covered by the National Electrical Code (NEC-1999, Chapter 7) as adapted into law by the local authority. These systems may be either legally required (Article 701), or optional (Article 702), as required. These type applications constitute the majority of sites supplied. This arrangement has been considered to be adequate for many types of facilities including local police and fire stations, 911 centers, nursing homes, industrial manufacturers, television stations, and telecommunication transmitter sites.

These sites must allow for equipment downtime (power outage) for scheduled maintenance. Since there is a single utility, load panel, transfer switch, and generator set there is no alternate power path. Any failure of the first three items will curtail power to the facility. Some sites only back up a portion of the load, that being the most critical as a means of reducing cost.

A small UPS is typically used to provide power for computers, and control systems during the ten second time that it requires the generator set to start. The major advantages for these systems are simplicity and low first cost. National Fire Prevention Association (NFPA 110—1996) Standard for Emergency and Standby Power Systems provides guidance for these installations.

A simple emergency standby system is shown in Figure 1a.

Variations of this scheme includes the use of several ATS with a single generator set to minimize voltage dip when the load is transferred by moving the load in smaller power blocks.

Currently a very popular product is the Kohler PD-100 series switchgear which functions as an open transition automatic transfer

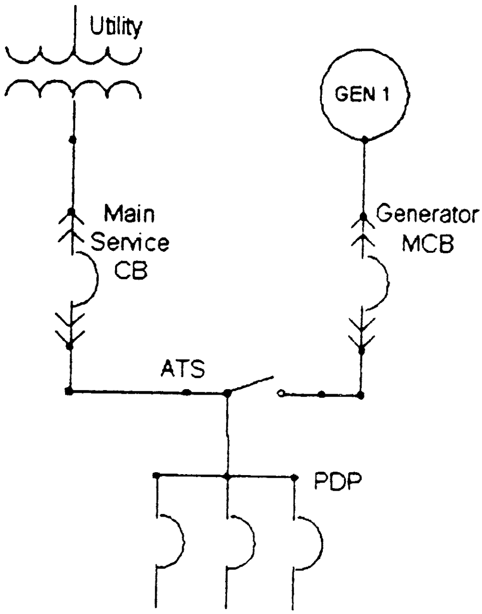

Figure 1a. Basic Emergency Standby System

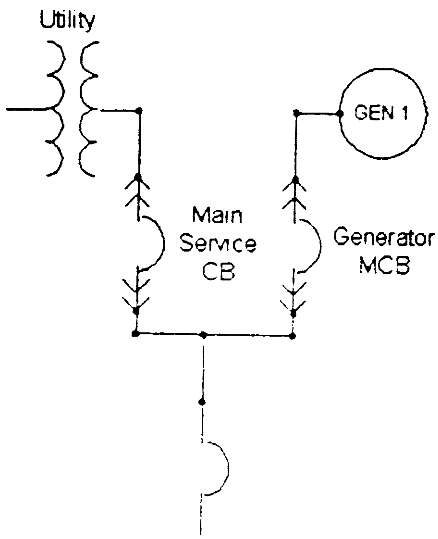

Figure 1b. Kohler PD-100

switch during a power outage, with a ramped (gradual) closed transition return to the utility. This product has the added advantage of having the capability of being used in a closed transition, or continuous parallel with utility modes for peak shaving, interruptible rate, and other utility revenue programs. Application of the Kohler PD-100 switchgear is shown in Figure 1b.

EXAMPLE 2

Typical Hospital Power Application

A typical hospital emergency power installation will include multiple generator sets operating in parallel to provide backup power, and three or more automatic transfer switches with by-pass isolation features. For these applications Kohler provides the generator sets, automatic transfer switches, and paralleling switchgear.

The transfer switches being located close to the load have two isolated power sources, and often include a bypass isolation feature to permit one switch to be disconnected, and removed without a power loss, for either repairs or maintenance.

A typical paralleling switchgear arrangement is shown in Figure 2a.

Critical power constitutes life safety issues, and the need for power continuity is obvious. Hospital operation has changed considerably in the past ten years, with increased power requirements for sophisticated diagnostic and medical procedures. Besides the more advanced equipment there is also a need for greater power reliability for economic reasons.

Normal power is often supplied from two utility sources via a main-tie-main switchboard with automatic transfer equipment to provide increased reliability. The tie breaker is normally open, and each utility source supplies one side of the switchboard. Each transformer and main breaker is rated to be able to supply the total system, which provides redundancy and the ability to service the equipment.

In the event of a total utility power failure (loss of both power sources) the emergency generator sets are signaled to start. The first generator set closes to the bus in under ten seconds, and provides power to the most important (life safety) load. As additional generator sets are paralleled to the bus, additional loads are added. If there is a generator set failure the least important load is shed or dropped until additional power is available.

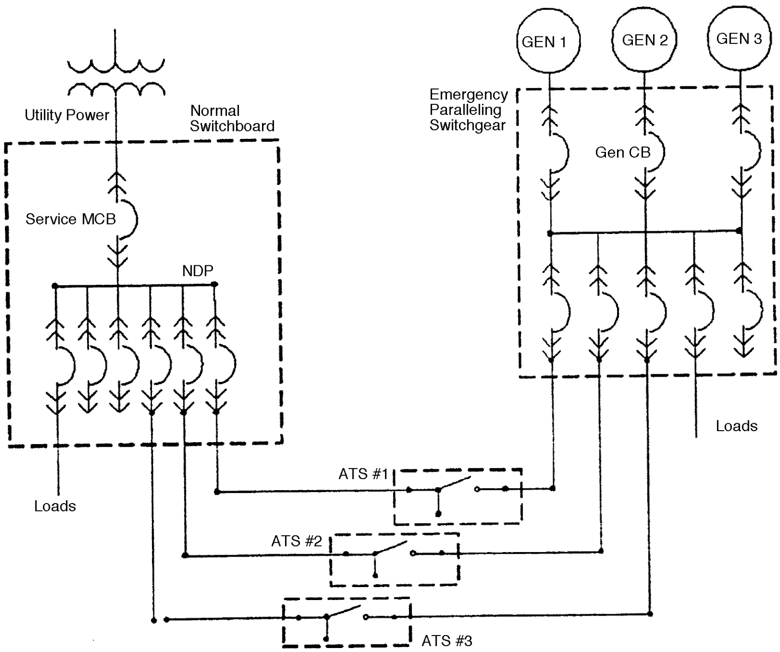

Figure 2a. Typical Hospital System

Figure 2b shows a main-tie-main and emergency system.

These systems often include local uninterruptible power systems (UPS) in addition to provide power during power transfers. The National Fire Prevention Association (NFPA-99, 1996, and NFPA-101-1997) standards provide the minimum basis for these systems.

EXAMPLE 3

Federal Aviation Administration (FAA)-TRACON facilities

Terminal Radar Approach Control Operations Navigation (TRACON) aviation sites are of major importance to the FAA and the flying public for controlling the regional air space in Honolulu, Northern California, Georgia, Washington, DC, and other areas. The diagram below shows how high power reliability was obtained. This system used emergency generation redundancy, multiple utility power sources, and the elimination of single points of failure. The switchgear includes re-

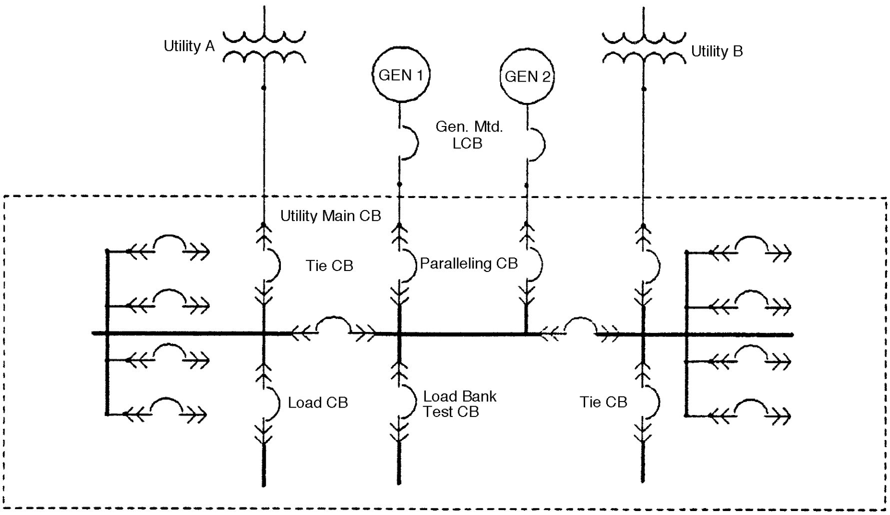

Figure 2b. M-T-M System

dundant "hot bus" PLC for system control. The station battery system was redundant to each power switchboard, and switchgear location. Complementing these systems was a 1) extensive spare parts inventory, 2) a load bank that permitted UPS and generator set testing and 3) extensive training.

The use of two utility power sources increases the normal power availability. The amount of increased reliability depends on if the two sources are fed from the same or from separate substations. In any event the duplication eliminates transformer and main circuit breaker failure problems, and permits servicing of the equipment without a power outage.

Using four generators for an application where two would be adequate provides N+2 redundancy. This permits a generator set to be out of service for overhaul, oil change or other maintenance, and still have a "spare" in the event there would be a failure.

During a single power source outage the system opens the affected utility source and remains connected to the second source. If both sources are lost, all generator sets are signaled to start, and are brought on line, and critical loads are connected within 10 seconds.

An often-specified generator management feature for the control of generator sets to match the connected load was not used on this system. Instead manual shutdown was selected for extended power outages.

This system was also designed for only open transition type operation, with no utility paralleling. These selections were made to ensure system integrity, and increase reliability.

As is common for critical power systems, an extensive supervisory, control, and data acquisition (SCADA) system was included. The normal power switchgear, emergency power switchgear, generator sets, distribution switchboards, and UPS systems were all remotely monitored.

Since an emergency power system is only as reliable as its weakest link, these systems also had an extensive fuel filtering, fuel transfer system with bypass, backup pumps, and redundant fuel tanks.

Going even further: they store all critical spares on site that would be required for the servicing of the equipment, so that a single failure will only minimally effect the redundant units. Training consisted of three levels, being operator, maintenance, and support. Each training class lasted two weeks, and included two instructors for a class size of 8 to 10 students.

This equipment was factory-witness tested as a system. System testing means that the actual generator sets, and switchgear was tested together under actual operating conditions to ensure that all operating and failure modes were properly designed and manufactured.

In conclusion the goal for this facility is to have no power downtime for any reason. It is a true 24/7/365 facility that is operating 24 hours a day, 7 days a week, 365 days a year. We feel that all possible actions were taken to make this a reality.

The paralleling EPS is shown in Figure 3a.

A simplified single line for the emergency power system for the FAA sites is shown in Figure 3b. You will note that multiple power paths are used to supply electrical power from the utility, generators, main switchgear, distribution switchboards, UPS supply switchboard, and multiple UPS to the critical loads.

The load-bank and load-bank switchgear, which is connected to the paralleling switchgear, and the UPS for full load testing are not shown.

EXAMPLE 4

Data Center –A "Dot-Com" Type Company

Typical of many Internet companies, there is a need for heavy power concentration. At this facility there were to be three 5000 Amp 480

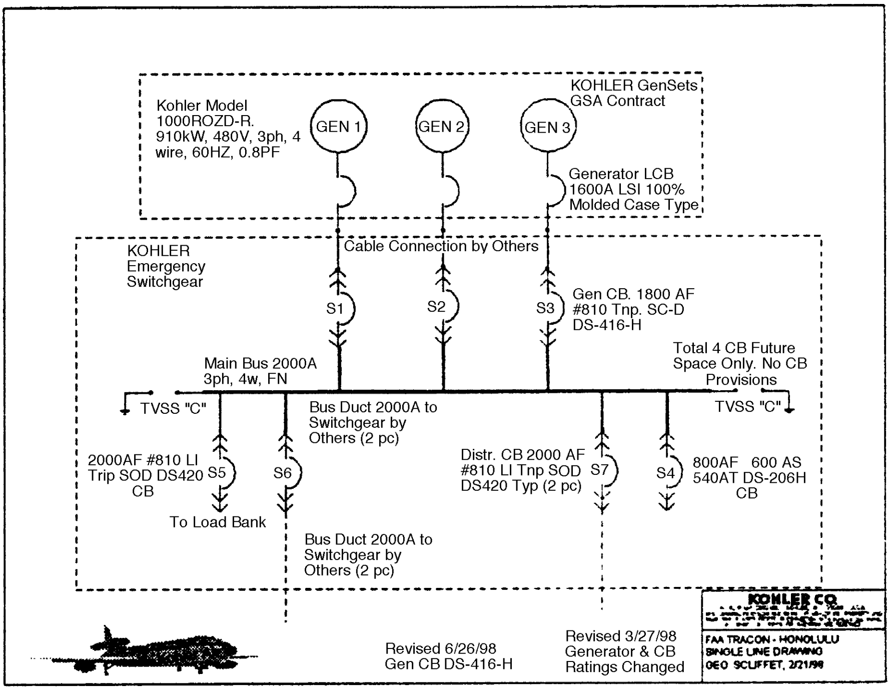

Figure 3a. Paralleling Switchgear

volt utility services, supplying three dedicated loads, each connected via bus duct. Due to space limitations this project was to be located on the top of a high rise in Atlanta. I stated, "was," since as a part of the business adjustment this equipment has not been installed and is in storage. We provided three 2000 kW generator sets each rated 2000 kW, the generator sets, and other equipment and services.

The design philosophy behind this arrangement is that any generator could be used to supply any load. Generators can be paralleled with each utility for testing, with a no-break load transfer. The switchgear included redundant master PLC controls, and other safeguards to eliminate any single point of failure, and provide the maximum of system flexibility. This facility utilized UPS as further power protection to override any momentary power sags, or outages. Data centers cannot lose power for even a second, without major economic losses.

Three utility, three generators, three-load system is shown in Figure 4.

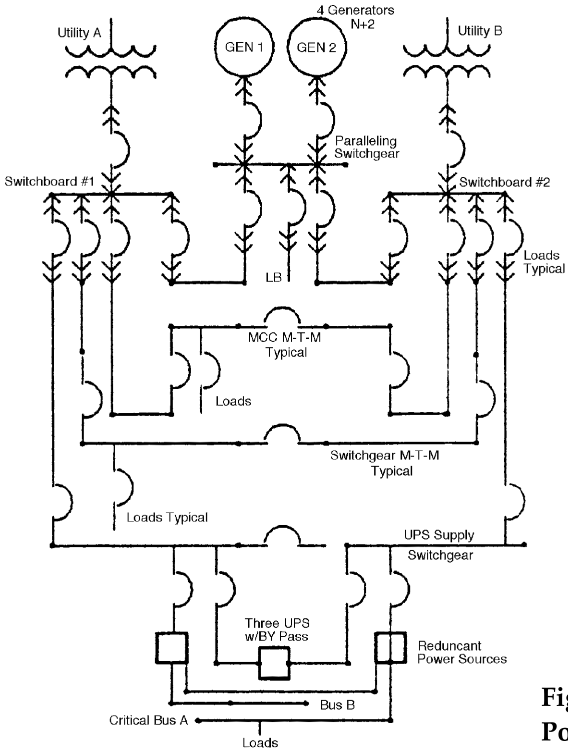

Figure 3b. Redundant Power System

EXAMPLE 5

Industrial Manufacturer

Loss of electrical power at this manufacturer will result in a loss of product, and production valued at millions of dollar per hour. The complete loss of power for 15 minutes will cause the loss of production equipment. This facility utilizes two utility supplies from separate substations. It also uses 5 × 2000 kW diesel engine driven emergency generator sets to provide long term back up power. This system is somewhat unique in that generation is at 480 volts, paralleling is at 15 kV, and the utility is 127 kV. Extensive monitoring and control are incorporated for system operation.

Paralleling with the utility for testing and load transfer are incorporated. This would be typical of some larger industrial facilities. UPS are used to backup data gathering, and control equipment.

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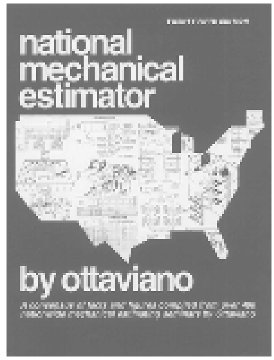

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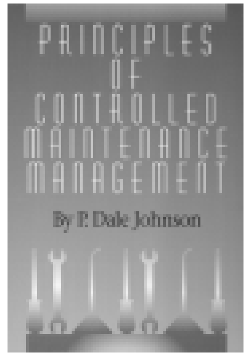

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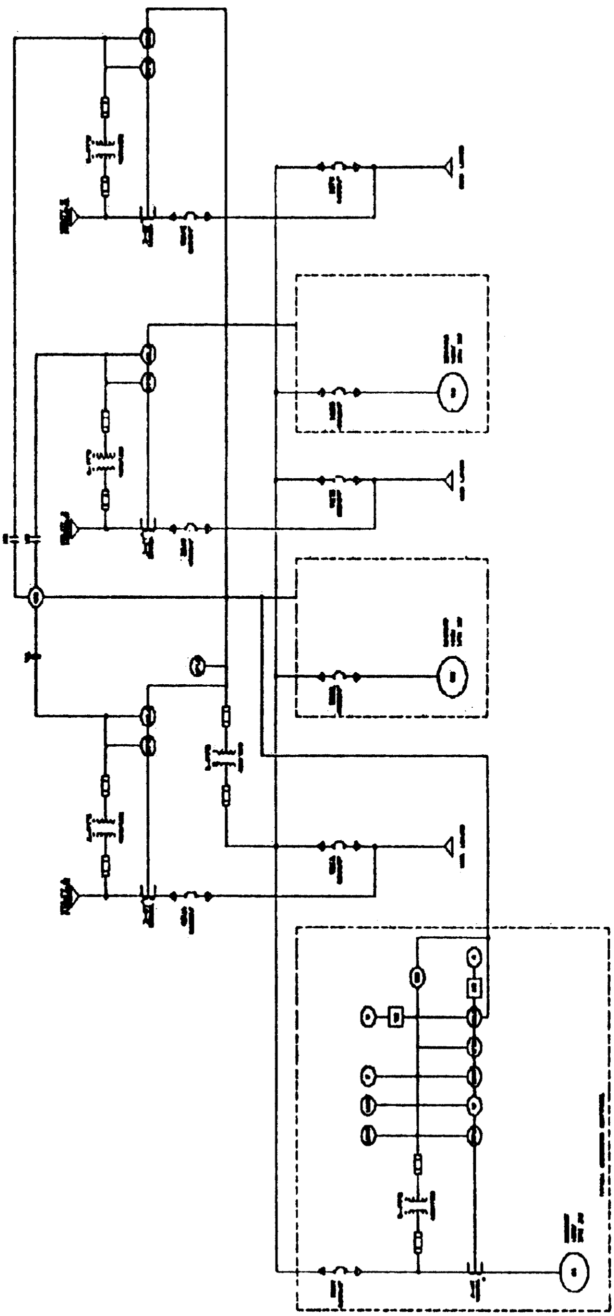


Figure 4. Three utility, three generator, three load system

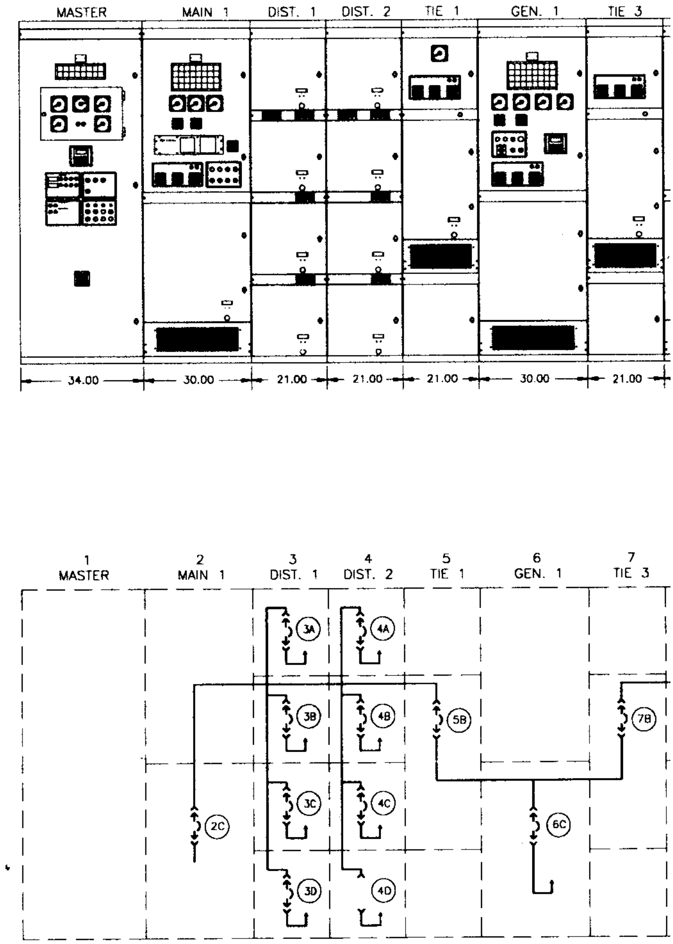
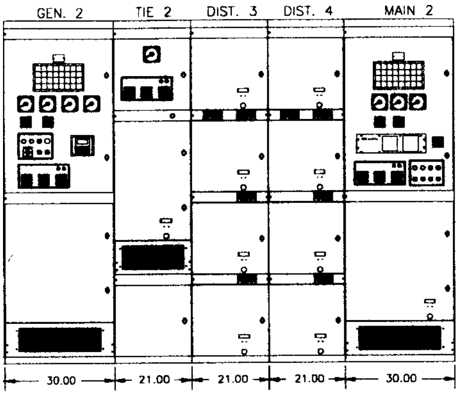


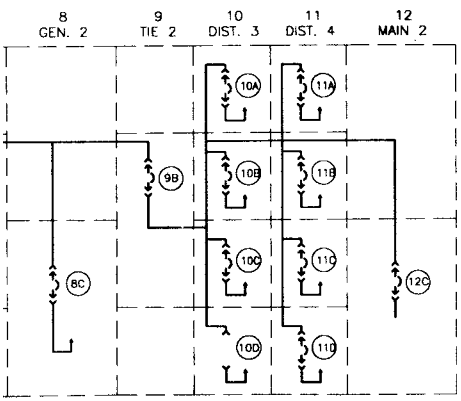
Figure 5.

EXAMPLE 6

Kohler Co. Hattiesburg Engine Manufacturing Plant

Using our equipment in our own facilities would be expected. We also had an opportunity to participate in the electrical utility peak rate program, which reduces our electrical cost, and assist the utility with their peak demand energy problems. This switchgear was UL-1558 listed and labeled, and used with two Kohler generator sets each rated





SYSTEM SPECIFICATIONS

VOLTS: 480VAC
PHASE: 3ø, 4 WIRE
FREQUENCY: 60Hz
MAIN BUS: 3200A
BUS BRACING: 100KA

2000 kW, 480 Volt, 3 phase, 4 wire, 60 HZ @ 0.8 PF. This system also has two utility main sources, and two tie circuit breakers. The system is designed to automatically switch from Main #1 to Main #2, to signal starting of engine generator sets upon the loss of both utility sources. For return to utility after an outage, system testing, and peak rate operation the generator sets parallel with the utility source, load is gradually added "ramped" in each direction, and the generator sets run in parallel with the utility.

CONCLUSION

You will note that there are many different approaches to power reliability. The various schemes rely on redundancy of components, multiple power paths, and the elimination of single points of failure in their designs. Quality materials, good documentation, factory and site testing, a good start-up, and on going testing and maintenance are also required.

ABOUT THE AUTHOR

George Scliffet is a switchgear expert, with wide experience in low and medium voltage emergency power systems. His experience includes cogeneration (CHP), distributed generation, and distribution switchgear. His background includes application engineering and the sales of generator systems, electrical controls, and power switchgear. Switchgear projects have included commercial, industrial, nuclear, marine, military, and aviation. applications. Scliffet has been. a guest speaker at AEE, EGSA, IEEE, and US Army Corp of Engineers conferences, and has been published in many technical journals. His education includes a BS in Industrial Technology, and many specialized programs. Scliffet has been a Senior Sales Engineer with Kohler Co., Power Systems Group, Generator Division, Sheboygan, Wisconsin, for the past 12 years.

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