Power Control System Basics

More than just Paralleling Switchgear

White Paper 127
Rev 1

Life Is On

This document provides an overview of design and features of paralleling switchgear and the systems that control them, also known as Power Control Systems (PCS). Originally issued in 2017, this report has been revised to clarify PCS concepts, reference additional information sources, and further explain how these systems are used in healthcare, commercial, and industrial applications.

INTRODUCTION

Providing reliable backup power requires an ability to connect emergency power sources and equipment loads to and from a facility's electrical system. For a facility with elementary backup power requirements, only an engine-generator and a transfer switch may be necessary. As facility size increases, loads become more critical, systems become more complex, and sophisticated methods for connecting, managing, and disconnecting power sources and loads becomes increasingly important.

REASONS TO CONNECT MULTIPLE POWER SOURCES

There are several reasons to connect, control, and disconnect multiple power sources and loads using a PCS. The most common is to transfer building loads between a utility service and an emergency power source consisting of two or more generators. Power control systems also connect and manage multiple power sources in prime power applications (where utility service is unavailable), and parallel utility and backup power systems to meet operational objectives or control costs. An example of a PCS lineup is shown in Figure 1. Such a lineup includes paralleling switchgear.

Figure 1: A low-voltage Power Control System lineup

Like automatic transfer switches, PCS also provide the essential function of connecting power sources to loads. However, PCS connect multiple power sources to supply the needed amount of power. This requires that the sources be synchronized so that they can connect to a common bus. For more information, review the ASCO Power Technologies brief entitled ***Basic Power Source Synchronization and Paralleling***.[1]

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[1] *Technical Brief: Basic Power Source Synchronization and Paralleling.* ASCO Power Technologies, Inc. 2020. https://www.ascopower.com/us/en/resources/technical-briefs/basic-power-source-synchronization.jsp, accessed February 3, 2021

Once connected, the backup power sources must operate in parallel until those sources are no longer needed. For this reason, PCS are often referred to as paralleling switchgear. However, these systems also provide other benefits:

Redundancy: Connecting redundant power sources to increase reliability and availability

Efficiency: Providing features that optimize generator usage and optimize the connection of loads according to available capacity and facility priorities

Economy:
- Enabling users to connect utility and cogeneration sources
- Generating on-site power to offset use of utility power during periods of high demand
- Responding to utility directives to reduce load in accordance with power contracts

Maintainability: Connecting alternate power sources to facilitate engine-generator maintenance without system downtime.

Scalability: Providing for the future addition of generation and distribution equipment.

PCS HARDWARE OVERVIEW

Most PCS consist of modules, or sections, dedicated to power generation, power distribution, and power system control. These sections are shown in Figure 2, and are the basic building blocks for creating power control switchgear systems. They typically include at least one Master Control Section. The number and types of the other sections depend on the quantity of power sources and the size and complexity of the power distribution system. By arranging sections together with the components and controls they contain, engineers can provide reliable and sophisticated systems for managing power across a wide range of applications.

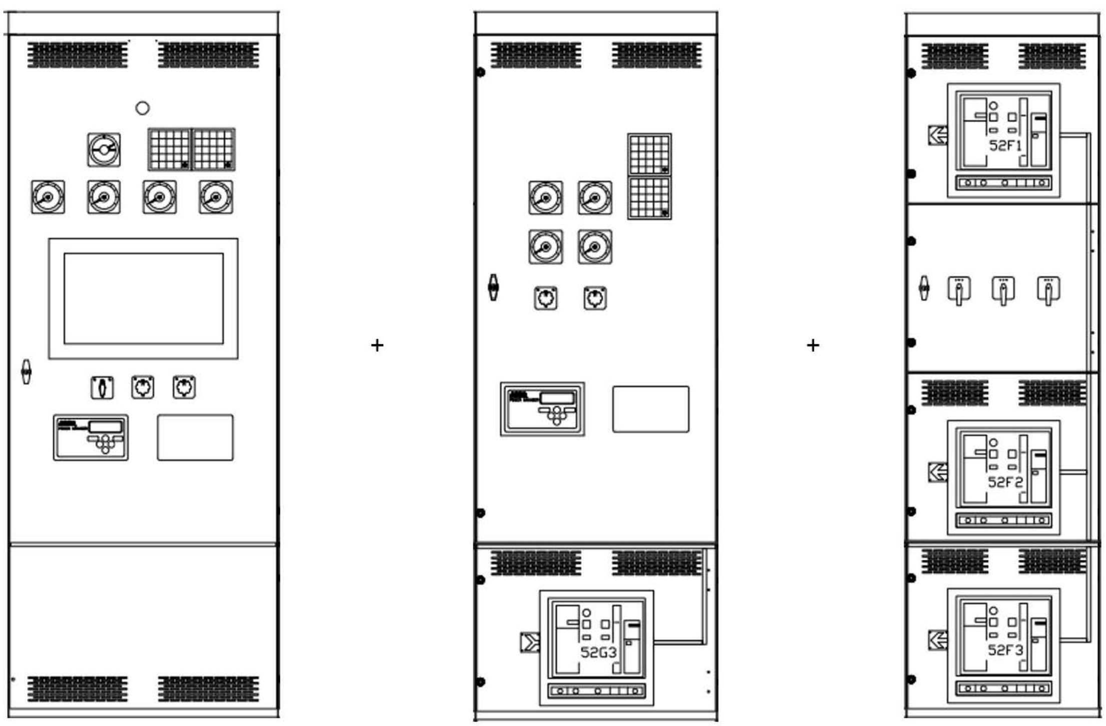
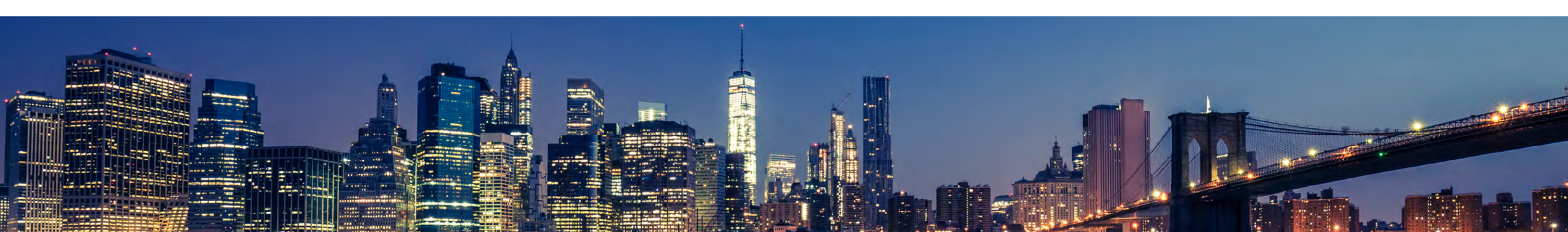


Figure 2: Master Control, Generator, and Distribution Sections are arranged to provide sufficient capacity and required features.



Generator Sections

Generator Sections are equipped with components that manage engine-generator startup, connection, disconnection, and shutdown. They can control engine power and the connection and disconnection of generators to and from the main bus. Using Programmable Logic Controllers (PLCs), Generator Sections communicate with generator controllers to affect these operations. Hard-wired backup is provided to ensure engine-generators are started when they are called for, should a PLC become unavailable.

Typical features of generator sections include annunciators that display alarm status, manual generator and synchronizer controls, and paralleling circuit breaker controls. Most often, one section is provided for each generator. In some installations, two generators may be controlled from a single section.

Distribution Sections

Distribution sections contain circuit breakers that connect elements of power distribution systems to an energized bus. They can also be equipped to connect load banks, so that power sources can be tested without transferring live building loads to the backup system. Figure 3 illustrates a PCS with a segmented bus, which offers sophisticated control possibilities for both sources and loads that are further described herein. For a short overview of commonly used breaker types, read the ASCO brief entitled ***Nomenclature for Low-Voltage Circuit Breakers***.[2]

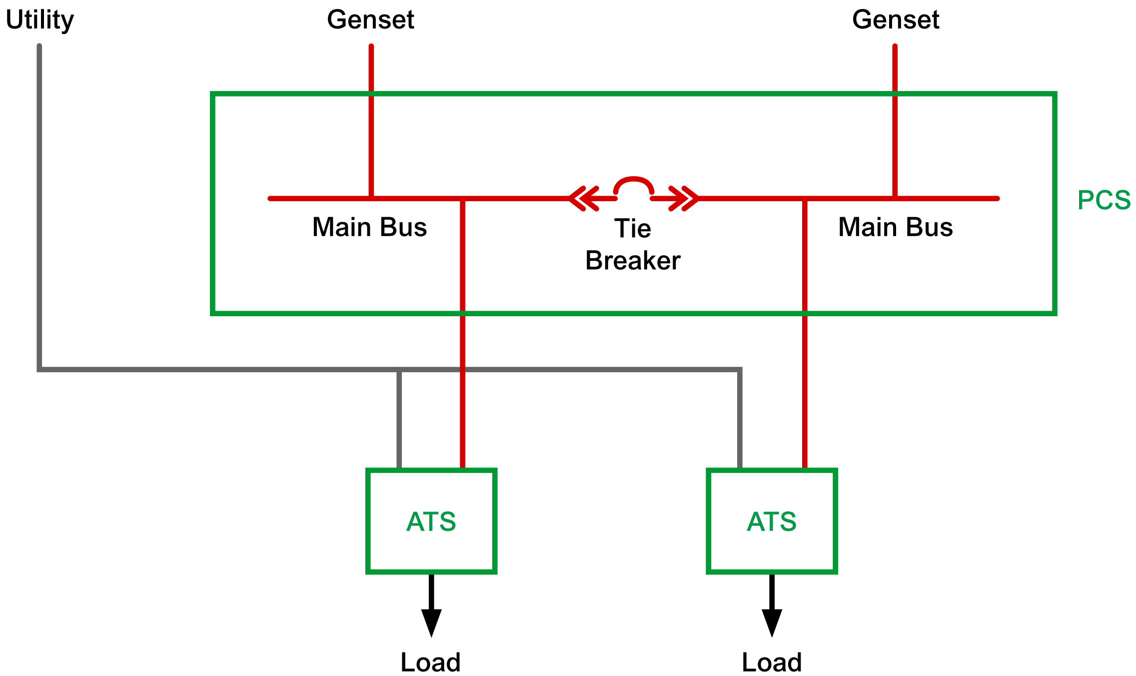


Figure 3: A Power Control System controls how power sources and loads connect to main bus.

[2] *Technical Brief - Nomenclature for Low-Voltage Circuit Breakers*. ASCO Power Technologies, Inc. 2020. https://www.ascopower.com/us/en/resources/technical-briefs/nomenclature-for-low-voltage-circuit-breakers.jsp, accessed February 3, 2021.

Master Control Section

The Master Control Section provides overall system control as well as direct control of specific equipment. This section contains PLCs that coordinate system-level actions and features. Master Control Sections provide the following functions:

- Automatic and manual system operation
- Utility circuit breaker control
- Tie circuit breaker control
- Transfer switch operation
- Distribution circuit breaker control
- Adding and shedding of loads

Master Control Section hardware can be enhanced to perform at the highest levels of reliability and availability by providing redundant PLCs and redundant control circuits. ASCO's document entitled ***Redundant Control and Communication for Power Control Systems*** explains redundant features that are available for mission-critical facilities.[3]

Section Integration

The PCS generator, distribution, and control sections are typically installed in one or more equipment lineups within a facility's power control area. Figure 4 shows the relationship of each section to the overall power system.

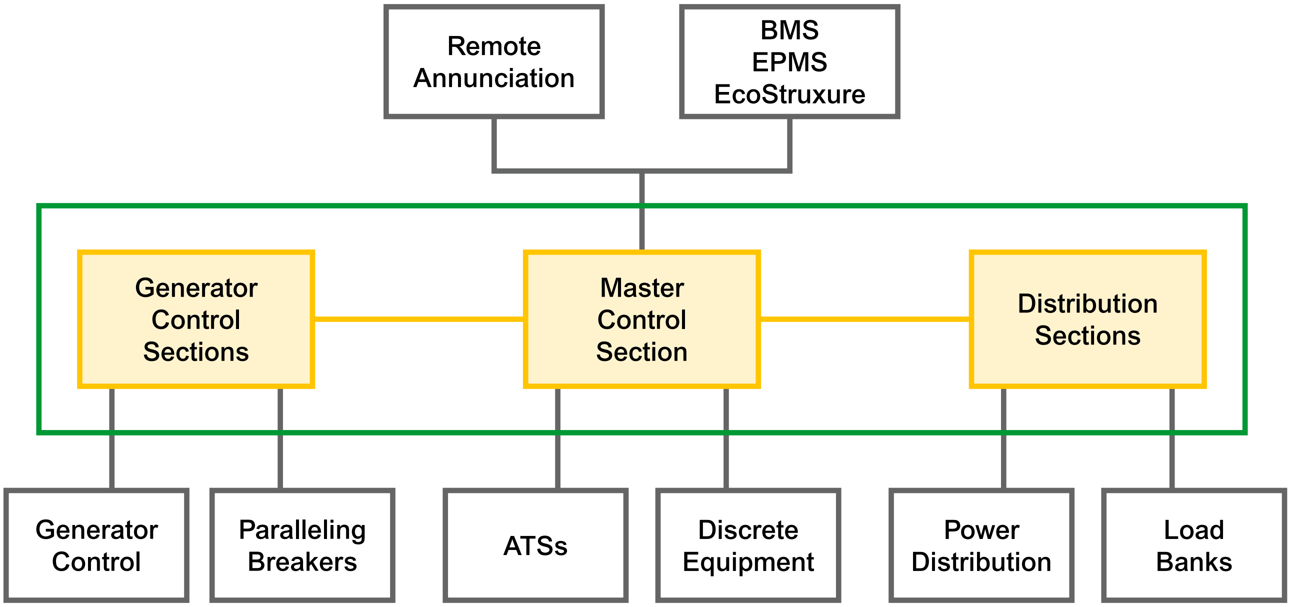


Figure 4: A typical PCS configuration

[3] *Redundant Control and Communication for Power Control Systems.* ASCO Power Technologies, Inc. 2018. https://www.ascopower.com/us/en/download/document/PCM-WP-REDCONT/, accessed February 3, 2021.

Figure 5 shows a PCS lineup that features a Master Control Section, sections for three engine-generators, plus two Distribution sections.

Figure 5: A PCS with a Master Control Section, three Generator Sections, and two Distribution Sections

MEDIUM VOLTAGE PCS

Power Control Systems can also serve medium voltage loads where facilities require large amounts of generation capacity, or where operating at higher voltages enable cost-effective use of smaller conductors and/or can reduce power losses over longer distances.

Like low voltage PCS, medium voltage PCS use similar controls for synchronizing and paralleling. They offer similar load control capabilities, such as load adding and shedding, load demand response, and bus optimization. Likewise, they offer similar connectivity for communicating with remote devices and commercially available Building Management Systems and Emergency Power Management Systems.

Medium voltage PCS differ from low voltage systems in multiple ways. While low voltage systems are built to UL 1558 or UL 891 standards, medium voltage PCS are designed to ANSI 37.20.2.[4,5,6] Medium voltage PCS equipment is typically larger overall, even while using smaller bus sizes – medium voltage bus typically carries up to 3000 Amps, while low voltage bus must sometimes carry up to 10,000 Amps. Where low voltage PCS typically uses circuit breakers with electronic trip units, medium voltage applications typically utilize vacuum-type circuit breakers that are tripped by protective relays.

CAPABILITIES AND ADVANTAGES

Power Control Systems offer sophisticated options for managing and optimizing power in complex electrical systems. The following paragraphs describe key capabilities.

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[4] *UL 1558 – Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear*. Edition 5. Underwriters Laboratories, Inc. Northbrook, Illinois, USA. 2016.

[5] *UL 891 – Standard for Switchboards*. Edition 12. Underwriters Laboratories, Inc. Northbrook, Illinois, USA. 2019.

[6] *C37.20.2-2015 - IEEE Standard for Metal-Clad Switchgear.* Institute of Electrical and Electronics Engineers. Piscataway, New Jersey, USA. 2015.

Bus Optimization

Most backup power systems are sized to provide backup power to a facility's most important loads, but not all of its normal operating loads. Consequently, loads are categorized by their relative priority, and those of highest priority are connected first to the backup power system. Consequently, loads of lesser priority can remain unpowered if the total demand would exceed generation capacity.

However, not all equipment necessarily operates at full power at any given time. By measuring the real-time demand of each load, PCS that feature Bus Optimization can add loads of lower priority according to actual real-time generator capacity, maximizing the amount of equipment the backup sources can power. Figure 6 shows how ATSs may be added to maximize usage of available generation capacity. For additional information, refer to the ASCO document entitled ***PCS Load Management*** and the ASCO video by the same title.[7]

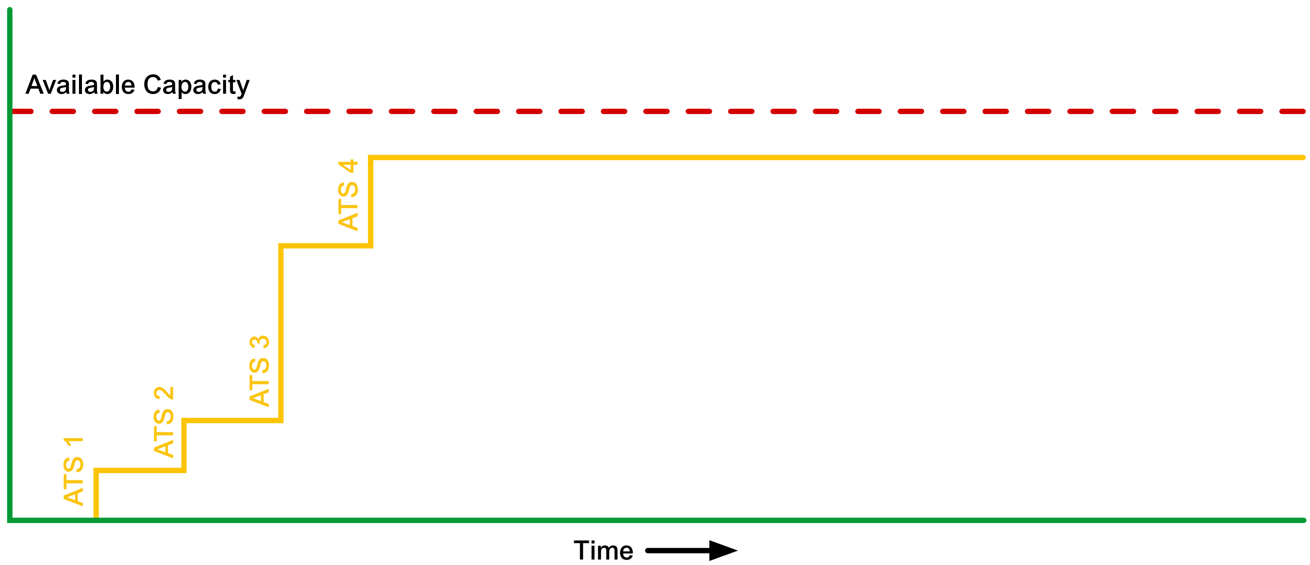

Figure 5: A PCS with a Master Control Section, three Generator Sections, and two Distribution Sections

Generator Load Demand

Whereas Bus Optimization connects the largest amounts of load to power, PCS that feature Generator Load Demand maximize efficiency by serving real-time loads using the fewest generators. For instance, if a facility with three 500 kW generators is operating at 60% of total load, power demand can be met by running only two of the generators at levels nearer their rated capacity. While starting all three generators assured maximum power availability on transfer to backup power, shedding one generator after backup power becomes stable saves fuel and avoids wear-and-tear, which increases efficiency and reduces costs. This sequence is shown in Figure 7.

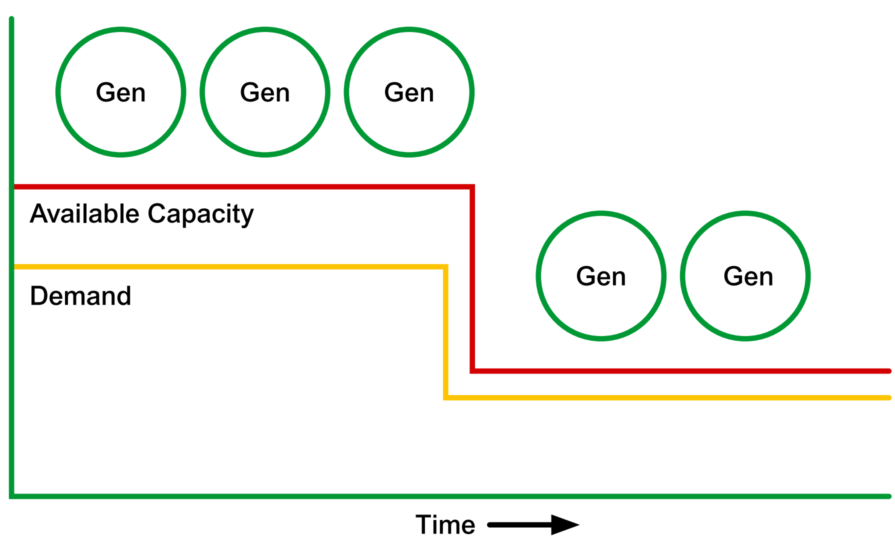

Figure 7: Generator Load Demand can shed generators according to real-time power needs.

[7] *PCS Load Management.* ASCO Power Technologies, Inc. 2019. https://www.ascopower.com/us/en/download/document/PCM-WP-LOADMNGMT/, accessed February 3, 2021.

Bus Segmentation

Within a PCS, electrical bus can be segmented to connect discrete groups of devices. Placing a tie breaker (a circuit breaker that allows power to flow in either direction between adjacent bus) between the segments offers operational benefits. Multiple engine-generators can be concurrently started and connected to their respective loads without waiting for all of the power sources to synchronize and connect, thus reducing time to bring backup power online.

For example, Figure 8 illustrates a split bus arrangement that can connect feeds from a utility, another from on-site renewable power sources, and four generators to a power distribution system. This arrangement offers source flexibility, and can bring backup power to loads faster than an equivalent single bus system. Figure 9 shows a ring bus system. If a bus or tie breaker fails, this system can still carry power from any remaining source to any remaining load.

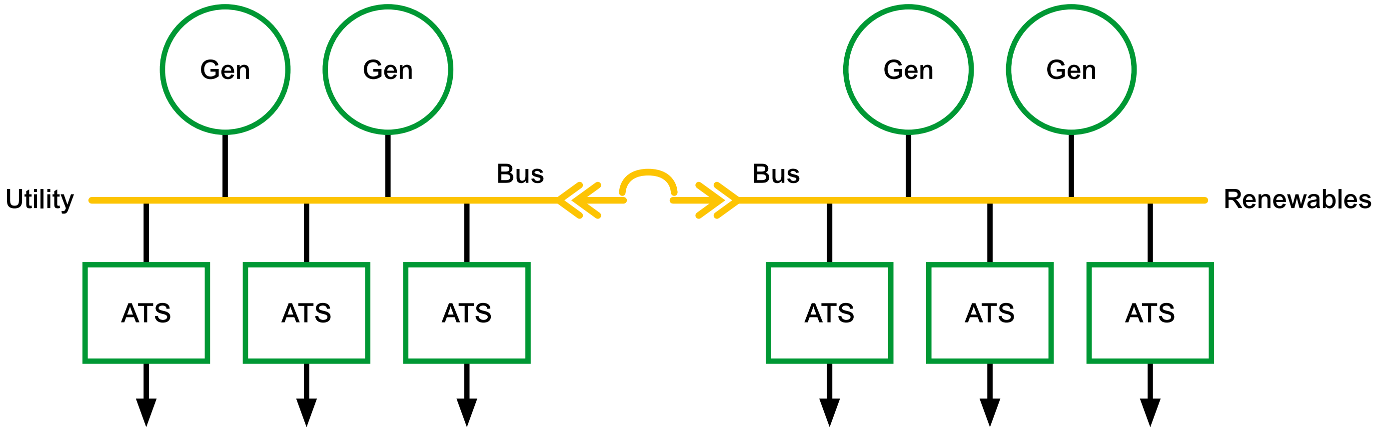

Figure 8: A segmented bus arrangement

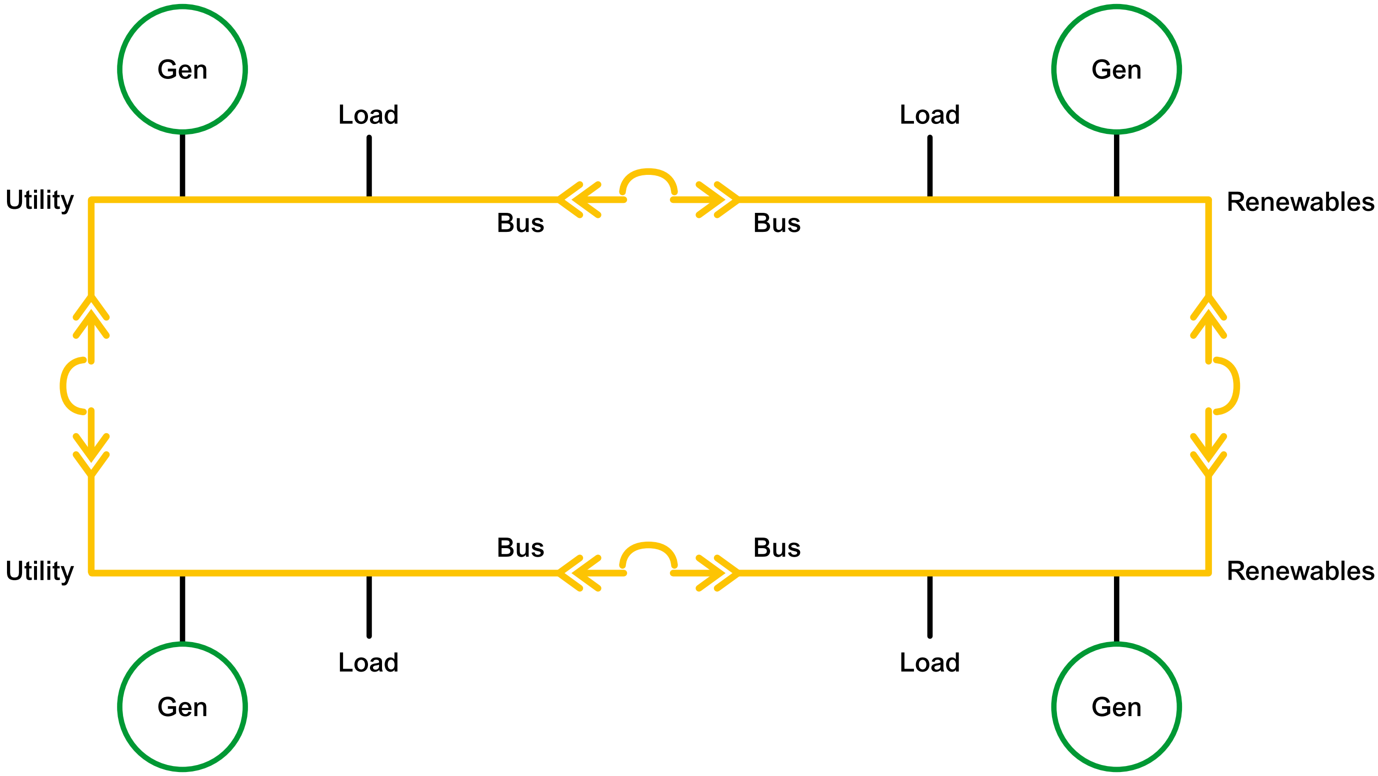

Figure 9: A segmented bus in ring configuration offers additional redundancy.

Custom Operating Sequences

Power Control Systems employ custom operating sequences that are key to meeting unique facility requirements. For example, a facility's two utility power sources may each feed separate bus connected by a tie breaker. If Source 1 fails, a tie breaker will close between the two sections of bus and Source 2 will supply all loads. This is possible when manufacturers develop custom operating sequences to respond to a loss of Source 1, a loss of Source 2, a loss of both sources, and the return of each source. In addition, sequences can ensure sufficient power capacity by paralleling an on-site generator with one of the utility sources when the other utility source fails. Custom operating sequences can maximize the redundancy and availability benefits that PCS can offer.

In another example, healthcare facilities are required to connect life safety and critical loads to backup power within 10 seconds of a utility outage.[8] In many applications, these loads exceed the capacity of any single generator in a paralleled-generator backup power system. In most examples, the ability to comply with the 10-second requirement is based on the response capabilities of the engine-generator sets. PCS that feature segregated bus with tie breakers together with facility-optimized event sequences can connect all life safety and critical loads to backup power even before all of a facility's generators are synchronized together. This decreases the time required to connect these loads and enables facilities to comply with the 10-second requirement.

Automated Testing and Reporting

Power Control Systems can be configured to simplify testing of critical power equipment. By connecting a load bank to a power control system, backup power testing can be completed without having to engage live loads. In addition, custom sequences can be used to schedule and automate tests ranging from simple generator exercises that ensure power source readiness to system-wide tests that simulate performance during utility outages. Reporting systems can record and compile operational information collected during a test into automatically generated test reports that document compliance status (Figure 10). For more on this capability, review the ASCO Power Technologies document entitled [*The Value of Automated Power Compliance Reporting*].[9]

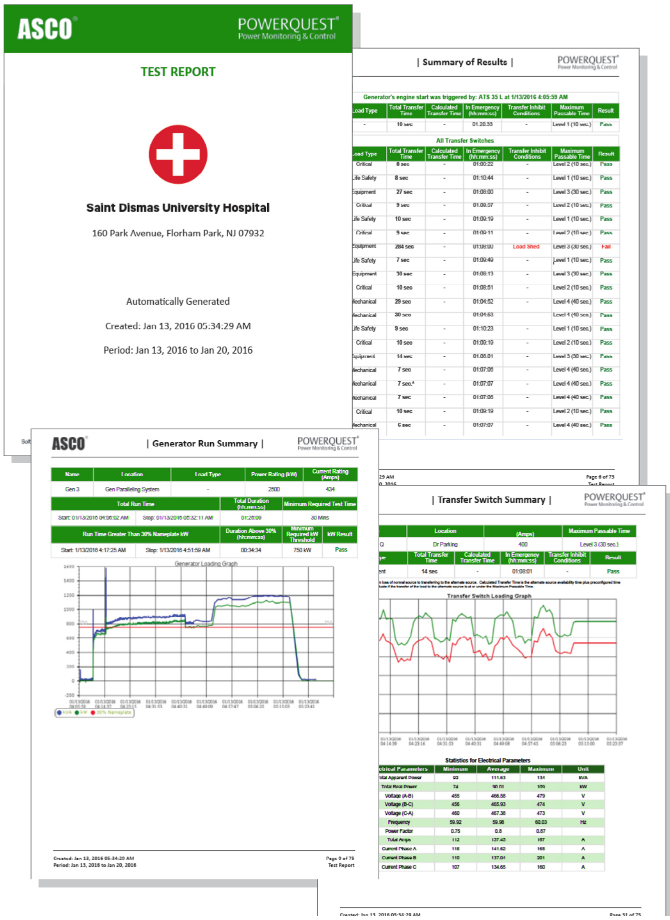

Figure 10: PCS can be equipped to automatically generate compliance test reports.

[8] *NFPA 70 – National Electrical Code*. 2020 Edition. National Fire Protection Agency. Quincy, Massachusetts, USA. 2019.

[9] *The Value of Automated Power Compliance Reporting*. ASCO Power Technologies, Inc. 2019. https://www.ascopower.com/us/en/download/document/PCM-WP-AUTO-POWER-REPORT/, accessed February 3, 2021.

Vendor and Fuel Neutrality

Power control systems provide signals to engine-generator controls to adjust power output. Power control systems can control engine-generator sets from a variety of manufacturers (Figure 11). This provides flexibility when adding generators to existing systems, and avoids compelling users to acquire additional units from manufacturers of previously purchased engine-generators.

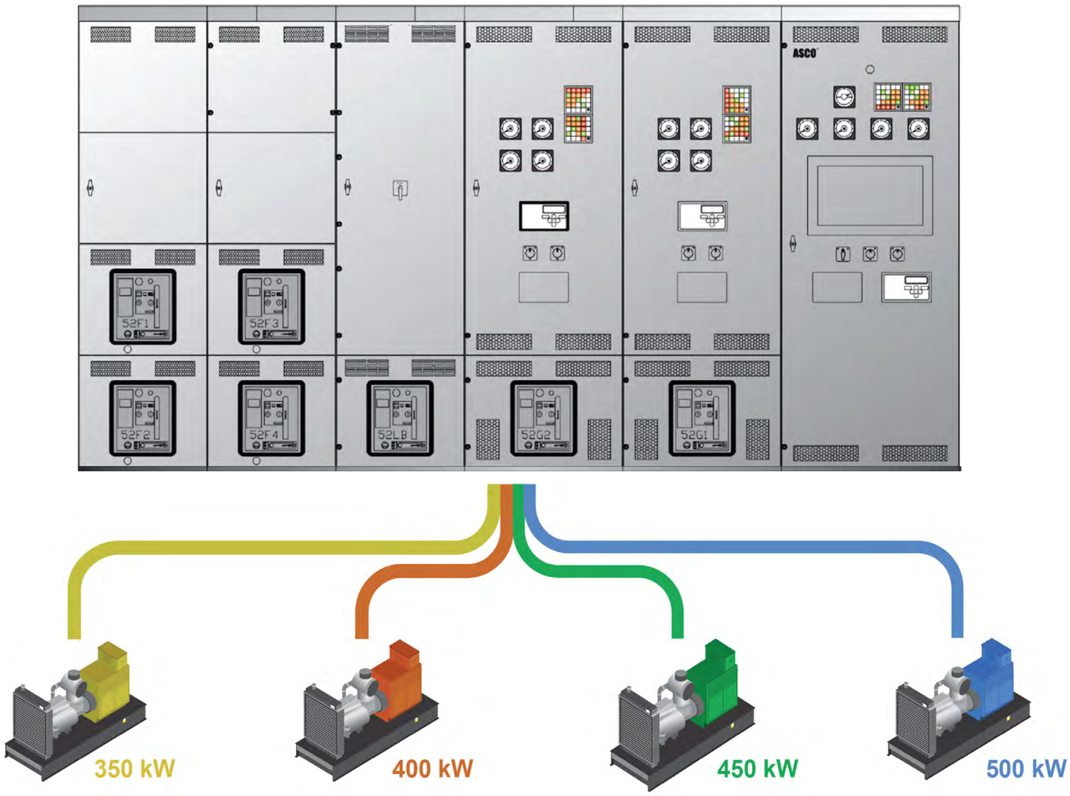

Figure 11: Power Control Systems can integrate engine-generators from different manufacturers.

Power control systems can also accommodate multiple fuel types. Diesel and natural gas engines offer different operating characteristics and respond to changes in load at different rates. Power control systems can be configured to successfully control equipment fired by diesel and/or natural gas by adding or shedding loads in ways that minimize engine stress, regardless of fuel type.

System Modifications

Power Control Systems employ custom operating sequences that are key to meeting unique facility requirements. For example, a facility's two utility power sources may each feed separate bus connected by a tie breaker. If Source 1 fails, a tie breaker will close between the two sections of bus and Source 2 will supply all loads. This is possible when manufacturers develop custom operating sequences to respond to a loss of Source 1, a loss of Source 2, a loss of both sources, and the return of each source. In addition, sequences can ensure sufficient power capacity by paralleling an on-site generator with one of the utility sources when the other utility source fails. Custom operating sequences can maximize the redundancy and availability benefits that PCS can offer.

In addition, modern control and communication functions can be added to existing systems by installing the latest metering, monitoring, and control solutions using Modbus, BACnet, and TCIP protocols. These communication protocols enable connection to commercial building and emergency power monitoring systems and to Schneider Electric EcoStruxure™ solutions. For more information on modernizing paralleling switchgear and power control systems, review the ASCO document entitled ***Modernizing Existing Power Control Systems***.[10]

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[10] *Modernizing Existing Power Control Systems.* ASCO Power Technologies, Inc. 2018. https://www.ascopower.com/us/en/download/document/PCM-WP-MODPOWER/, accessed February 3, 2021.

APPLICATIONS

Power Control Systems are highly configurable and multiple sections can be integrated according to exact capacity and functional requirements for specific facilities. As a result, PCS offer great flexibility to meet nearly any power system need. The following paragraphs explain how PCS can commonly be configured in healthcare, information technology, and utility applications.

Hospitals

Hospitals provide life-saving services, and as such, must provide reliable backup power to loads in timeframes prescribed by industry codes and governmental regulations. While the configuration of their power distribution systems is highly variable, ASCO has observed that the following features are commonly specified for PCS:

Connection of All Life Safety and Critical Loads within 10 Seconds of Loss of Normal Power

- This enables all life safety and critical loads to connect to backup power within the timeframe required by regulations.
- This presents direct safety benefits to building occupants as well as to personnel who must recover building operations following power or emergency events.

Redundant Master Programmable Logic Controllers

- This enables a secondary PLC to offer continued control of the PCS if a primary PLC becomes unavailable.
- It provides customers with a "bumpless" transfer to a secondary PLC when a primary PLC becomes unavailable.

To see a PCS in a healthcare application, review the ***ASCO 3D Healthcare Facility Tool***.

Data Centers

The rapid and secure exchange of business data is vital to both a functioning economy and the revenue of corporations. Enterprise-Scale Tier IV Data Centers thus provide mission-critical services that require reliable backup power to avoid profound financial losses that result from business interruption. In ASCO's experience, the following features are commonly specified for PCS for these facilities:

Redundant Emergency Power Sources

- Providing more engine generators than required to support their loads makes redundant units available if one genset should fail. Most commonly, one additional engine is used (N+1), and sometimes more (N+2).In these configurations, a genset can fail or be shut down for maintenance without impacting loads.
- Sometimes completely redundant engine capacity (2N) is provided. 2N configurations provide two entirely independent power source systems with no single points of failure. 2N systems are more robust than N+1 or N+2 systems because they are fully redundant and can be maintained without interrupting power to mission-critical loads.

Redundant Master Programmable Logic Controllers with Redundant I/O Networks

- By providing redundant master PLC controls and networks, system control is maintained even with the loss of a PLC, I/O, or network connection.
- These arrangements provide "bumpless" transfer of control functions to a secondary PLC when a primary PLC becomes unavailable, without interrupting operating sequences.
- The loss of an I/O pathway to controlled devices, such as circuit breakers and automatic transfer switches, would result in loss of control. A redundant I/O system would retain device control in the event of loss of a single I/O pathway. These features ensure maximum uptime in mission-critical applications.

To see a PCS in a data center application, review the ***ASCO 3D Data Center Facility Tool***.

Water and Wastewater Treatment Facilities

Water and waste water treatment plants are vital to public health and personal convenience. They are also always "on", operating 24 hours per day, 365 days per year. Because large treatment plants operate very large motor loads, many of these facilities rely on medium voltage systems. A power outage here can impact human health and the environment, so reliable backup power is a critical element to successful operation. Over the years, ASCO has noted that these facilities commonly use the following features to their advantage:

Redundant PLCs with Redundant I/O, such as that described for data centers above.

Arc Mitigation Capability:

- Water Treatment facilities generate backup power at 5kV or 15kV voltage levels and specify Arc Resistant Switchgear to mitigate associated arc flash risks.
- Arc Resistant Type 2B switchgear mitigates risk to personnel near the front, sides, and rear of the switchgear sections.

SUMMARY

The most common reason to use a PCS is to transfer building loads between a utility service and an emergency power source consisting of two or more generators that are synchronized and connected to a common bus. These systems are comprised of power generation, power distribution, and power system control sections, that are arranged to provide the required emergency power capacity and functionality. They are available for low-voltage and medium-voltage applications.

Power control systems offer a range of functions that can benefit facilities and end users. These include:

Bus Optimization that maximizes the amount of load that can be supplied with existing generator capacity

Generator Load Demand to minimize the number of operating generators to only those needed to supply actual loads

Bus Segmentation to provide redundant configurations and reduce time required to connect the most important loads to backup power

Custom Operating Sequences to maximize configurability and end user benefits for any application

Automated Testing and Reporting to streamline backup power compliance testing programs

Power Control Systems also enable facilities to seamlessly operate, monitor, and control a range of backup power sources, transfer switches, and distribution equipment from different manufacturers; and to utilize power sources powered by different fuels. Power Control Systems can often be updated and expanded to meet changing facility power needs, without requiring the replacement of entire PCS systems. While PCS are used across a wide range of industries, this report describes examples configured for select healthcare, data center, and water treatment facilities.

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