March 2021

Build a Resilient Power System

On-Site Power Reliability Through Advanced Communications Technology

ABOUT BASLER

Basler Electric is a manufacturer of excitation systems, voltage regulators, genset controls, protective relays, and custom transformers. Basler also offers turnkey engineering services through their E^2 Power Systems subsidiary.

Basler products control and manage the delivery of electricity and are commonly found in applications such as power plants, substations, hydro dams, agricultural facilities, airports, refineries, telecom facilities, factories, marine applications, and many others.

Basler has been in business since 1942 and our products are in operation in over 145 countries around the world.

Mission Critical Operations Depend on a Continuous Supply of Electricity to Stay in Business

Any power disruption is a huge cost to consumers and can create unsafe situations. When losing power is not an option, mission critical operations need to rely on dependable on-site power that is automated to eliminate delays and operational errors.

Many recent global events have heightened consumer interest in power security. In the last few years, thermal events on the West Coast of the United States and multiple coastal regions of Australia have resulted in blackouts. Major storms and hurricanes making landfall in the United States and the Caribbean have downed transmission and distribution infrastructure, causing extended forced outages. During the February 2021 North American winter storm, unusually frigid conditions in Texas caused extended power outages, leaving many residents in desperate need of warmth, water, and food. In some regions of the United States, fossil fuel power plants have been decommissioned, but not replaced with equivalent installed capacity. There has been an increase in the number of distributed energy resources (DERs) such as wind and solar, but they are intermittent and not adequately backed up by battery storage systems. All of these circumstances are driving industrial and commercial consumers of electricity to seriously consider investing in their power security to ensure business resilience.

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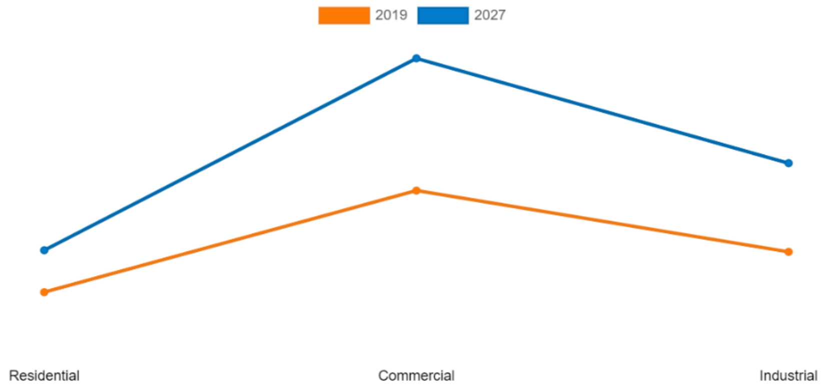
Destroyed transmission tower in Puerto Rico after Hurricane Maria [1]

While several competing distributed energy resources (DERs) are being installed in on-site power systems at commercial, industrial, academic, government, and military facilities, generators driven by reciprocating internal combustion engines (RICE), known as gensets, continue to form a significant portion of installed generation assets. This is largely due to their characteristics which favor backup generation such as low cost per installed kw high power density, fast response to system disturbances, and proven, well-known technology.



Projected Diesel Generator Demand by Industry

Increased Demand for Continuous and Stable Power Supply

On June 16, 2020, Bloomberg News published an article in which the Diesel Generator Market is forecasted to reach $37.1 Bn, globally, by 2027 at 9.8% CAGR. Some of the main drivers of this trend were attributed to increased need for continuous and stable power supply, and rapid industrialization and urbanization. Large diesel generators (> 375 kVA) accounted for nearly 60% of the global diesel generator market in 2019. This trend is expected to continue due to increased demand from large scale industries such as mining, healthcare, commercial centers, manufacturing, and data centers. (Allied Market Research, 2020) These highly sensitive industries are heavily dependent upon a robust power system to maintain operations. A power outage can result in significant revenue loss, exposure to unsafe conditions and even loss of life.

> *While it is important to have a reliable source of onsite power in the event of utility outages, it is just as important to ensure that power sources and the balance of plant are effectively controlled.*

While it is important to have a reliable source of onsite power in the event of utility outages, it is just as important to ensure that power sources and the balance of plant are effectively controlled. One key requirement for mission critical operations as regulated by the NFPA110 code life, is life safety loads must be powered by backup generators within 10 seconds of a utility power outage. In order to meet this requirement consistently, facilities depend heavily on automated control systems. Multiple approaches can be taken in designing the architecture for such systems, taking into account the sequence of operations, generator management, load management, degree of automation, and other factors. Control can be centralized, distributed, or can comprise of elements of both.

Centralized control is more traditional, based on a client-server architecture, and is typically associated with Programmable Logic Controller (PLC) programming. The PLC controller is usually the client sending instructions to and requesting data from multiple server devices throughout the network. This established approach to networking seems well understood from an operational standpoint. PLCs are very flexible because a programmer can create logic to tailor the system to meet site specific requirements. PLCs also come with their challenges. They introduce a single point of failure, such that if the master PLC controller fails, the entire system malfunctions.

Secondly, a centralized node in the network creates a bottleneck, through which all network traffic must be transmitted. Lastly, writing PLC logic is a specialized skill typically performed by an expert. Because experts have their individualistic programming styles, it is difficult to transfer knowledge from one PLC programmer to another, and there is an industry-wide gap created as PLC programmers retire from the workforce. This ongoing trend is creating significant challenges for younger field technicians.

The alternative to centralized control is distributed control. Modern genset controllers have adopted such architectures, including peer-to-peer networking that allows a different controller to be in command of the operation depending on the situation. Peer-to-peer networking allows for multiple topologies, including mesh, ring, and star.

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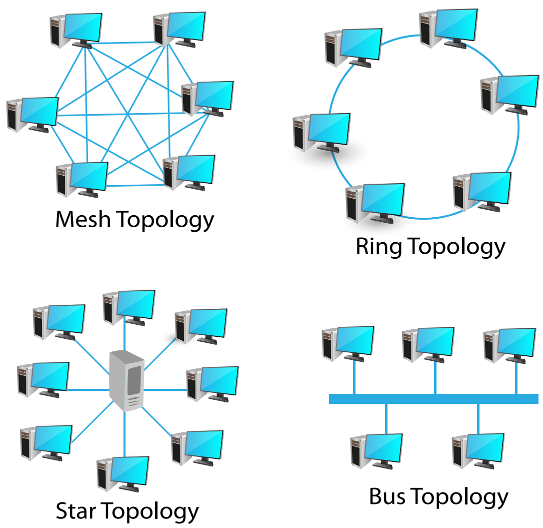
Network Topologies

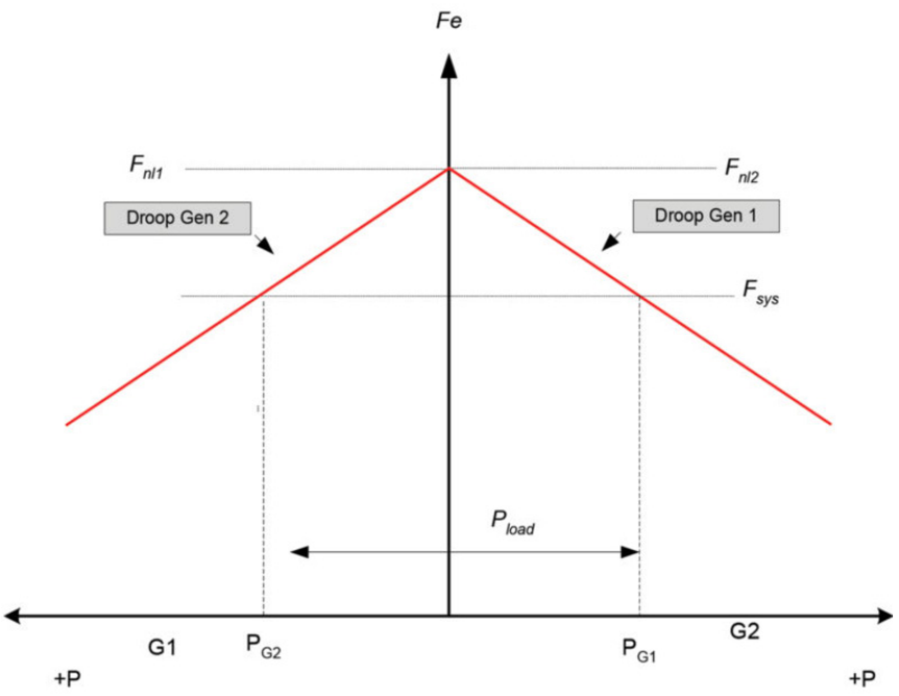


An Inter-genset Communications Network is the Backbone of all Advanced Automated System Level Control

Controllers on gensets, breakers, and balance of plant equipment communicate directly with each other to coordinate their decision making. The benefits of such technology are countless. Inter-genset communications provide an easy and efficient medium to support load sharing, reactive power sharing, generator management, load management, paralleling, system level coordination, and communication with external systems.

In the past, operators depended strictly on the speed droop and voltage droop characteristics of a genset to control load (kW) and reactive power (kvar) sharing. During commissioning, the droop settings would be adjusted to optimize load and reactive power sharing. As the kW on each machine increased from no load (NL) to full load (FL), the generator frequency would decrease. Likewise, as the kvar on each machine increased from NL to FL, the voltage would decrease. Hence, it was not possible to maintain consistent voltages and frequencies throughout each machine's load profile.

A robust inter-genset communications network is key to reassuring customers that their generation assets will be available during power outages.



Generator Frequency Drops from NL to FL When Load Sharing Using Droop [3]

With the introduction of advanced Proportional-Integral-Derivative (PID) controllers in genset controllers, network load sharing resolved this problem by allowing multiple machines to loadshare while maintaining the system frequency. Controllers are able to communicate among themselves to determine how much load is on the network, how many machines are online, and share kW proportionally among the machines. kvar is shared in a similar manner. Because the frequencies and voltages are kept consistent, power quality is maintained.

Besides making kW and kvar sharing a lot easier and more reliable, advanced genset controller networking allows gensets to be dispatched according to their assigned priority. Generators can be prioritized to maximize fuel efficiency, for balanced service intervals, to minimize emissions, etc. Automating generation dispatch in such a customized fashion is very valuable to customers who do not have personnel available to attend to standby generators. Such customers are consumed with their business operations, and not with generator operation. They need the reassurance that their generation assets will be available during power outages. A robust inter-genset communications network is a key element in satisfying that need. End users are able to keep just enough generators running with sufficient spinning reserve to maintain a stable system, while avoiding the wastage associated with running more gensets than necessary. Generators are automatically cycled online and offline as loads increase and decrease, thus optimizing generation dispatch. Automating this process delivers a more consistent result by eliminating human error.

The integrity of the Inter-genset Communications Network is a Vital Link in Creating a Reliable Power System

In as much as the gensets, balance of plant equipment, and control systems may be of superior quality, the integrity of the inter-genset communications network is a vital link in creating a reliable power system. If communication with a controller is lost, the genset controlled by that device will no longer participate in load sharing. This can result in severe problems if the remaining generators on the network are incapable of carrying the loads. Overload conditions can arise, and the entire system can cascade very quickly. One method of mitigating this risk is to provide a redundant network communication line to each controller, so that if the primary line fails, there is an automatic failover to the redundant line. This level of redundancy allows kW and kvar sharing to continue seamlessly in the event of a communication failure.

> *Programmable logic gives integrators the flexibility to optimize the startup process.*

An alternative risk mitigation approach is to set up a droop override condition that will be initiated by a communication loss. This would force machines into droop once they are off the load sharing network, so that the remaining machines on the network would not get overloaded. Once the machines with failed communications are restored onto the network, they can participate in network load sharing as before.

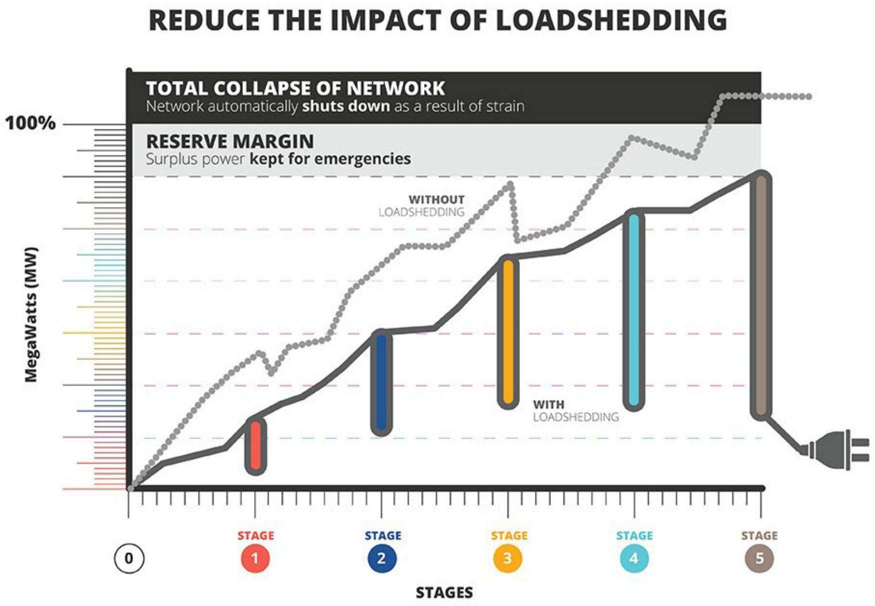
Oftentimes, a load bus is dead after a power outage and multiple generators need to be brought online quickly to meet the NFPA110 10-second start regulation. However, if multiple generator breakers are closed to a dead bus simultaneously, they can be closed out of synchronization, posing a major threat to personnel safety, and causing catastrophic generator damage. To avoid this, multiple genset controllers communicate with each other over the inter-genset communications network, and arbitrate among themselves to determine which genset closes onto the dead bus first. Once the bus is energized, the other gensets are synchronized to it before their breakers are closed.

Another means of starting up multiple generators to power life safety loads in less than 10 seconds involves synchronizing generators before turning on excitation. This method of bringing generators online in a rapid fashion is also known as close before excitation, dead field paralleling, and run up synchronization. Programmable logic gives integrators the flexibility to optimize the startup process to achieve various functions such as turning off specific PID controllers, and turning on excitation in multiple machines at once. Once all generators are synchronized and are ready to accept load, the generator management system controls the dispatch of generators as needed, according to assigned priorities. This level of automated control is achieved through the inter-genset communications network.

While it is important to control generator dispatch, in some applications it is equally important to prioritize and control loads, particularly in situations where there is not always sufficient installed generation capacity to support the loads. This situation can arise during a genset outage. In these circumstances, loads must be prioritized and controlled according to the amount of available generation capacity.

Lower priority loads are shed when the amount of load exceeds the amount of available generation, so that the higher priority loads are not compromised.

As more generation becomes available, lower priority loads are restored, until all installed generation is made available again. The inter-genset communications network can be used to detect the amount of available generation versus load, and make decisions to optimize the site. This ensures that generators do not get overloaded and high priority loads are not interrupted.



Load shedding as implemented by the city of Johannesburg. More aggressive load shedding needs to be implemented when the spinning reserve is lower. Loads are shed from the lowest priority (stage 1) to the highest (stage 5). [4]

Control Area Networks (CAN bus) vs. Ethernet Networks

Inter-genset communications work on various infrastructure. Two of the most common are Control Area Networks (CAN bus) and Ethernet communications. CAN bus is well-established in multiple industries, particularly automotive. It is highly used in engine ECU to controller communications in the genset industry. The CAN layer comprises a two wire main trunk line, with one device forming each end of the bus, and all other devices on stubs connected in parallel with the main bus. It is essential that a 120-ohm resistor is connected in parallel with each end of the main trunk line for the CAN network to function correctly. The wiring is fairly simple, whereby each device needs to be connected to a CAN high and a CAN low wire. A shield wire is run the full length of each twisted pair and is terminated at one end. The shield wire is needed because CAN communication is susceptible to electromagnetic interference (EMI). Noise signals from nearby ac wiring and other sources can cause communication disturbances and errors in equipment operation. CAN bus networks typically transmit data at speeds less than 1 Mbps.

Ethernet cables typically consist of eight small copper wires terminated with RJ45 connectors. Installers must ensure that the wires are terminated in the correct orientation in the connectors. Ethernet networks can transport data at much higher speeds than CAN bus, up to 100 mbps.

Modern Ethernet networks use switched connections, allowing point-to-point network architectures, thus moving away from bus topologies where one cable is shared by all devices on the network. In Ethernet networks, ring topologies can be built by incorporating network switches with ring management capability, thereby increasing network redundancy. In a ring network, each device is connected to two other devices. Therefore, if there is a single point of failure in the communications network, inter-genset communications will continue without interruption.

With the internet of things (IOT) being incorporated into smart building management systems (BMS), genset and balance of plant data is often transmitted to a separate BMS network. Ethernet communications on genset controllers are essential for transmitting power system data to the BMS. In addition, multiple external devices and systems such as SCADA and PLC get integrated with genset controllers through an Ethernet interface.

> *Ethernet networks can transport data at much higher speeds than CAN bus, up to 100 Mbps.*

Special Considerations for Rental Power and Military Installations

Portable power applications, such as rental power for events and military installations, require that gensets be moved frequently from site to site. These applications require that multiple machines be set up and disconnected quickly and easily. In such operations, it is common for operators to randomly choose a genset from inventory and install it in an existing fleet of gensets in service. The setup needs to be plug-and-play. In order to achieve this, the communications settings cannot be static. To solve this problem, automatic configuration of Internet Protocol (IP) addresses, subnet masks, and default gateways has been implemented in advanced genset and power management controllers. Automatic configuration of multiple controllers can be achieved using a DHCP server, or controllers can obtain IP addresses within a designated range if no DHCP server is available. This feature saves time and increases the ease of setup for large fleets of gensets.

In conclusion, the reliable operation of gensets at mission critical sites is key to business continuity. No power-no business! A vital aspect of modern genset operation is a robust communications network, without which the onsite power system will not function as it should. The type of communications infrastructure used, data transmission speeds, network topology, and ease of setup are key factors that determine the reliability of the network. Apart from having power available when needed, an effective inter-genset communications network also has ancillary benefits such as intelligent generator management, load management, system control, and communication with external systems.

To learn more, visit https://www.basler.com/Product/DGC-2020HD-Digital-Genset-Controller and download the application note: **Improve On-Site Power Reliability with Redundant Ethernet Communications.**

To learn more, please email usatechsupport@basler.com or call 618.654.2341 to speak with a Basler representative.

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About the Author:

Denny Raymond is a Senior Application Engineer at Basler Electric and has over 15 years of power systems experience. Denny provides control and voltage regulation solutions for genset systems.