EMERGENCY DIESEL GENERATOR BACKUP POWER SYSTEMS FOR MILITARY BASES

Backup power systems on military installations must provide reliable power during a grid outage. The risks of blackouts and loss of electric power are not new. Outages of just a few hours are well known, but longer duration outages are becoming more frequent. The U.S. Army, Navy, and Air Force now require backup power from one to two weeks. For multiday outages, the reliability of emergency diesel generators will have a significant impact on the installation's backup power system's ability to provide power for critical missions.

Backup Power Systems

The Department of Defense (DoD) has historically relied on stand-alone generators with short-term fuel stockpiles to provide emergency backup power for buildings with critical loads. At every building housing a critical load, a single backup generator is hardwired directly to the building. For the highest priority critical loads, two stand-alone backup generators can be deployed to provide a backup to the backup and a higher degree of reliability. A microgrid is an alternative way to provide resilient power to a military base. A microgrid is a local system of distributed energy resources and electrical loads that can operate as a single entity either in parallel to the commercial (macro) grid or independently ("island" mode). Benefits include being used to provide emergency backup power during commercial grid outages or being a source of revenue and savings when connected to the grid. Any on-site power source can serve as a distributed energy resource, and centralized emergency generators are the most common.

U.S. Department of Defense Energy Policy and Reliability

The U.S. Department of Defense's fixed installations are a critical element of national security. Military bases support the maintenance and deployment of weapons systems, training and mobilization of combat forces, provide direct support to combat operations, play a critical role in homeland defense, and during domestic emergencies provide support to civil authorities. Installations do not operate without energy and are dependent on a commercial grid vulnerable to disruption due to severe weather, physical attacks, and cyberattacks. Military installations must plan and have the capability to ensure available and reliable backup power. Up to now, military installations have lacked the tools and information needed to quantify the reliability of backup power systems. NREL can now provide a quantitative reliability assessment for systems comprised of emergency diesel generators.

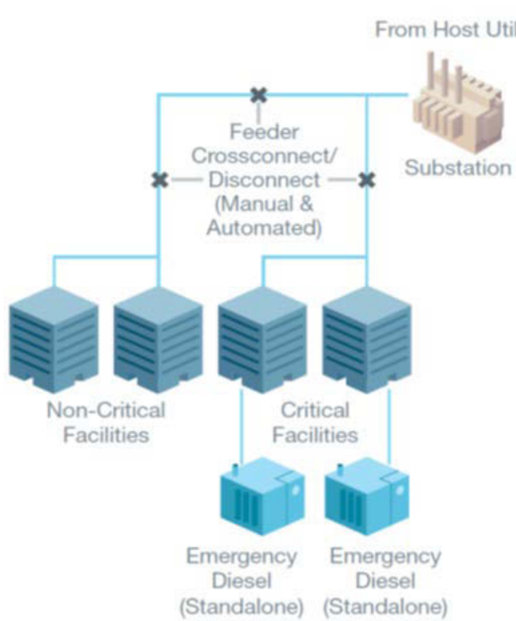

Figure 1. Stand-alone generators tied to individual buildings

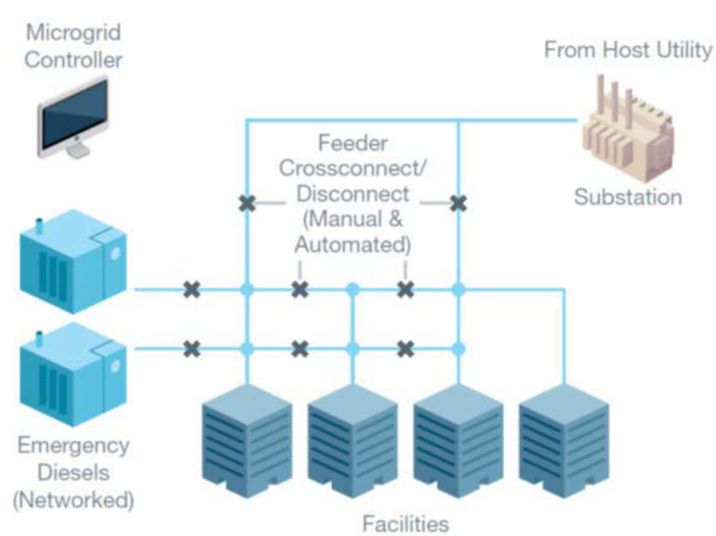

Figure 2. Microgrid with larger networked generators

Emergency Diesel Generator Reliability

Reliability is the probability that an item will perform its required function for a stated time interval. Figure 3 shows the reliability of an emergency diesel generator as a function of outage duration and quality of maintenance. These results are derived from large data sets for emergency diesel generators typically used on military installations.[1] A poorly maintained generator is unlikely to provide power for durations longer than a few days and has a reliability of only 80% at 12 hours. This figure reinforces the importance of following the current guidance on generator maintenance. But even well-maintained generators have a reliability of only 80% at two weeks. Thus, a single well-maintained emergency diesel generator cannot guarantee emergency power for critical loads over multiday outages.

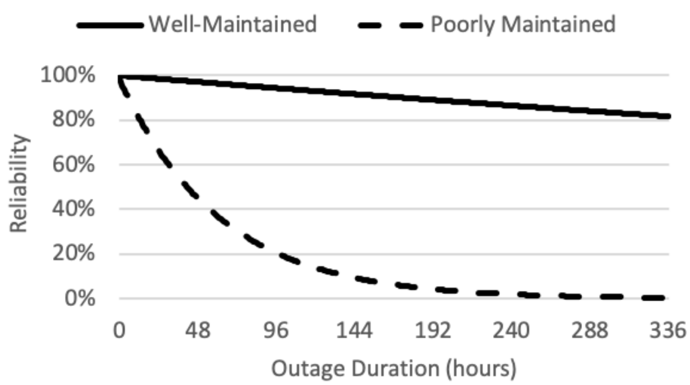

Figure 3. The reliability of a single emergency diesel generator over two weeks (336 hours)

Quantifying System-Level Reliability[2]

A military base's critical mission depends on having power across multiple buildings. Three base level reliability metrics are illustrated below for well-maintained emergency diesel generators for a small base (1 MW peak critical load) and a large base (20 MW peak critical load). Poorly maintained generators do not meet the needs of military installations independent of how they are arranged.

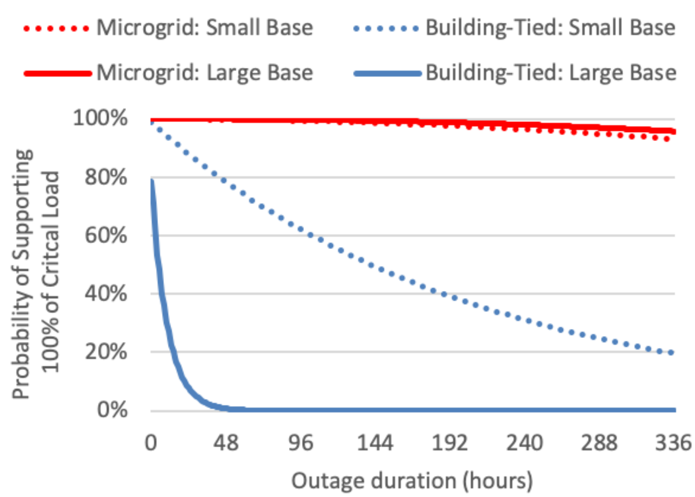

Figure 4. The probability of a microgrid and a single generator per building architecture meeting 100% of the critical load requirement for outages up to 14 days (336 hours)

The probability that all critical loads will be 100% supported as a function of outage duration up to two weeks for a microgrid and one emergency diesel generator tied to each building is shown in Figure 4 for a small and large base. Due to the ability of a generators to share load in a microgrid, this backup power architecture maintains a high probability of meeting nearly a 100% of the critical load for two weeks for both bases. Stand-alone generators have a small probability of providing power for all buildings with a critical load for a multiday outage. The fraction of lost load shows a similar pattern. The microgrid fraction of lost load is less than 1% for the large base and less than 2% for the small base, while the fraction of buildings without power is nearly 20% for a building tied system at fourteen days. The small loss of load can be compensated by the microgrid shedding lower priority critical loads. For generators tied to individual buildings, there is no such opportunity. By the end of a two-week outage one should expect to lose the ability to provide electric power to one or two buildings on a small base. On a very large base, one will lose the ability to provide power to 30-31 buildings.

The highest priority critical loads are typically only a fraction of the total critical load. These are loads that are required to support high priority critical missions that must be sustained. For this case, we will compare a microgrid architecture to two generators per building. Figure 5 shows the probability of meeting the highest priority load for situations where the highest priority load is 25% of the total critical load for a microgrid and two building-tied generators per building.

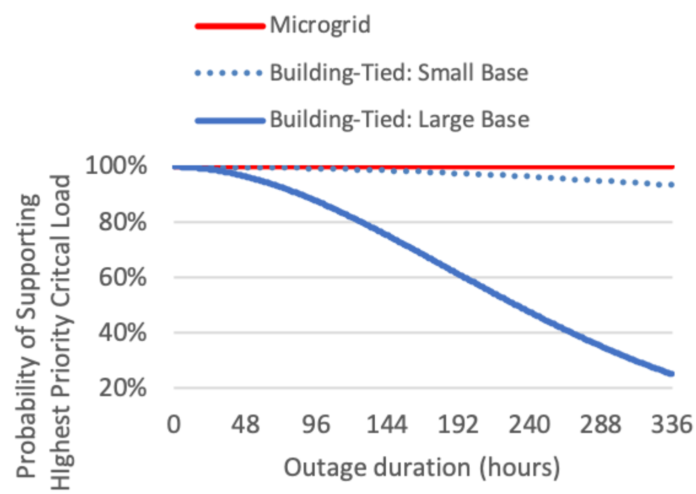

Figure 5. Probability of meeting 25% of highest priority critical load for small and large bases. Building-tied systems have two generators per building. A small base has only two buildings and the large base has 40 buildings with high priority loads.

The microgrid essentially has a 100% probability for both bases because it can prioritize which loads are the most important and preferentially send power to those loads. Stand-alone building-tied systems, even when two generators are tied to each building, cannot provide high confidence that the highest priority loads will be supported. The situation is worse for the highest priority critical mission loads. All three metrics examined provide evidence that stand-alone building-tied systems, even when two generators are used, cannot provide the level of confidence required by DoD installations for power to be available to support critical missions during a multiday grid outage. Diesel generator-based microgrid configurations provide a robust source of power for critical loads due to their network configuration and ability to share load. But microgrid architectures do introduce other vulnerabilities that must be managed, including cyber vulnerabilities and dependence on the on-base distribution system.

[1] Marqusee, Jeffrey, and Don Jenket. "Reliability of Emergency and Standby Diesel Generators: Impact on Energy Resiliency Solutions." 2020. Applied Energy, *Vol. 268*. 15 June 2020, 114918.

[2] Marqusee, Jeffrey, Sean Ericson, and Don Jenket. 2020. Emergency Diesel Generator: Reliability and Installation Energy Security. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5C00-76553. *https://www.nrel.gov/docs/fy20osti/76553.pdf*.

Modern mobile diesel generator for emergency electric power

Environmental Security Technology Certification Program

Environmental Security Technology Certification Program is DoD's environmental and energy technology demonstration and validation program. The Environmental Security Technology Certification Program harnesses the latest science and technology to demonstrate innovative, cost-effective, and sustainable solutions to meet DoD's installation energy challenges.

Conclusions

The reliability of emergency diesel generators has a significant impact on a military installation's energy resilience. They must be well-maintained if they are to be relied on for providing power longer than a few hours. Single stand-alone generators tied to individual buildings with critical loads, even if well-maintained, are unlikely to have power for all these loads over a multi-day outage. Over a two-week outage it is likely that a small base will lose power to a few buildings while larger bases will lose power to dozens of buildings. A microgrid, which is composed of a network of centralized generators, has a high probability that all buildings with critical loads can be supported throughout a two-week outage. The expected microgrid lost load is very small and can be managed by shedding lower priority loads. Of greatest concern is power for the highest priority critical loads. Stand-alone building tied emergency diesel generator systems often manage this by placing two emergency generators per building (a backup to the backup). Although this improves the likelihood of having power, it does not provide the level of power reliability DoD needs. Even a system that deploys two generators per building will have less than a 50% probability of supporting the highest priority critical loads for a two-week grid outage on larger bases. Microgrid systems can prioritize loads in real time and guarantee power availability for the highest priory critical load. If backup power is required for multiple days, stand-alone building-tied emergency diesel generators cannot be relied on by themselves to provide backup power for critical loads, and a microgrid should be considered. Microgrid introduce other vulnerabilities, cyber and dependence on the on-campus distribution system, that can and must be managed.

Learn More

For more information about the impact of emergency diesel generator reliability, visit www.nrel.gov/docs/fy20osti/76553.pdf

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