Chapter 13

Standby Power Systems

The term standby power systems describes the equipment interposed between the utility power source and the electrical load to improve the reliability of the electric power supply to the load. In previous chapters, we have described the deficiencies in the electric power supply, such as voltage sags and interruptions, and their effect on individual types of loads. The loads that require standby power can range from a single personal computer supplied by a battery-powered UPS to a large data processing center. In this chapter, we will describe the principal components used in standby power systems—namely, UPSs, transfer switches, and engine-generator (E/G) sets.

Principles: Standby Power System Design

The design of a standby power system for a specific electric-power load requires consideration of the following factors:

- **Reliability:** The questions are
  - What is the power quality of the utility source?
  - What is the cost of a power-quality event?
  - Will the system be required to operate continuously (24/7)?
  - What reliability of the electric power supply is required in terms of MTBF, minutes per year unavailability, Tiers, or other measures?

- **Maintenance:** The questions are
  - Can the load be shut down to perform maintenance or equipment replacement on the standby power system?
  - Can the standby power system be designed as online, or standby-redundant, for reliability or maintenance?
■ **Expansion:** The questions are
  ■ Is expansion or modification of the load planned with or without shutdown?
  ■ Is expansion of the standby power system planned in terms of increased UPS-kVA rating, energy-storage capacity (batteries) or engine-generator kVA?

■ **Personnel:** The questions are
  ■ What type of monitoring system is planned? Onsite, contract-type, alarm equipment?
  ■ What level of training will be given to personnel? Instruction regarding the complexity of the system? Will the training be done by vendors?

■ **Cost:** The questions are
  ■ How much are measures worth for a standby power system over the basic unprotected supply of power to the load?

**Components to Assemble Standby Power Systems**

Components have been described in the previous chapters to correct for utility and internal-plant power deficiencies. These components can be assembled into standby power systems for critical loads and systems. They include the following [13.1]:

■ **Transformers:**
  ■ Constant-voltage (CV) transformers for voltage regulation
  ■ Phase-shifting transformers for harmonic cancellation
  ■ Power distribution unit (PDU) transformers to supply individual loads

■ **Dynamic Voltage Compensators:**
  ■ Compensation for short-time voltage sag and interruption
  ■ Extended time operation
  ■ Single-phase, three-phase loads

■ **Uninterruptible Power Supplies (UPSs):**
  ■ Single-phase, battery support
  ■ Three-phase, battery support
  ■ Flywheel energy storage
  ■ Fuel-cell energy storage

■ **Support Equipment:**
  ■ Engine-generator set
  ■ Gas-turbine generator set
  ■ Transfer switch, E/G set
  ■ Transfer switch, utility feeders
**Sample Standby Power Systems**

The design of practically every standby power system using the preceding list of components is unique. Each design is based upon the total electrical load (kVA), the reliability and number of utility feeders, the space available, the reliability requirements for the load power, the selection of the UPS modules, PDUs, transfer switches and E/G sets, the dollars available, and other factors. Sample basic systems in order of cost and complexity include the following:

1. **Dynamic Voltage Compensator plus a PC**: The simplest combination of a standby power system and a PC is shown in Figure 13.1. The compensator only protects the PC from short-time utility voltage interruptions up to three cycles (50 ms) and sags to 50 percent for up to 2 s.

2. **UPS plus a PC**: This configuration (as shown in Figure 13.2) of a single-phase battery-powered UPS supplying a single personal computer, is the most common arrangement for preventing voltage distortion, sags, surges, and interruptions from affecting the PC. Typical UPSs of 300-W rating, 5-min battery run time, and 120-V terminals in and out are commercially available. The UPSs are line-interactive (Delta) or double-conversion (online). The PC plus UPS can be used in an office, home, factory, or as part of an industrial control or monitoring system.

3. **UPS plus a server and PCs**: The battery-powered UPS can supply multiple PCs from the load terminals of a three-phase UPS, as shown in Figure 13.3, or a local area network (LAN), as shown in Figure 13.4. The UPS would be rated in the 2-to 10-kVA range, typically 208/120-V output, and 10-min battery run time. The UPS must have a sufficient power rating to provide the start-up inrush current to the inputs of the PCs, servers, and printers. The UPS will shut down for utility power interruptions exceeding the battery ampere-hour run time. For maintenance work on the UPS, such as battery replacement or repair, either the UPS is shut down, or the load is transferred to the utility source with a synchronized by-pass switch. Some UPSs utilize “hot swappable batteries.”

![Figure 13.1](https://www.digitalengineeringlibrary.com) Block diagram of a dynamic voltage compensator supplying a PC.
AC power Source one-phase

UPS

Battery

Figure 13.2. Block diagram of a single-phase battery-powered UPS supplying a PC.

AC power source three-phase

UPS

Battery

By-pass

PC

PC

PC

Figure 13.3. Block diagram of a three-phase battery-powered UPS supplying multiple PCs.

AC power Source one-phase

UPS

Battery

By-pass

N 6-jack

G

Power cable

Data cable

Clients

Figure 13.4. Battery-powered UPS supplying a PC local area network (LAN).
4. **UPS plus a Transfer Switch and an E/G Set**: An elementary standby power system to withstand long utility power interruptions and long UPS maintenance periods is shown in Figure 13.5. The system operates in the following ways:

- Normal utility service. The UPS receives power from the UPS bus and delivers power to the load. The battery has been charged by utility power.
- Utility service is interrupted. The UPS receives power from its battery and continues to deliver power to the load. The E/G set starts. The transfer switch operates to supply generator power to the UPS. The UPS bus is transferred to the E/G set. The battery recharges. When utility service is restored, the process is reversed.
- UPS must be taken out of service. The E/G set is started. When it is up to speed, voltage, and frequency, the transfer switch operates. The UPS by-pass switch is closed to supply the load from the E/G set. The UPS is taken out of service. When the UPS is to be returned to service, the process is reversed.

![Diagram of UPS system](image)

**Figure 13.5** A battery-powered UPS system: utility source, engine-generator set, transfer switch, and by-pass switch.
5. **UPS plus Two Feeders and a Utility Transfer Switch:** An elementary standby power system utilizing two utility feeders from two substations is shown in Figure 13.6. In case of a feeder fault or failure, the utility transfer switch transfers the service to the alternate feeder. The UPS operates from its battery during the transition. Other loads, such as air conditioning, heating, and lighting, either continue to operate or must be restarted.

**Engine-Generator Sets**

Engine-generator sets (E/G sets) are used in standby power systems to extend the operation time of the UPS beyond the available discharge time of the batteries. For large UPSs (for example, larger than 100 kVA),
the battery time is usually only several minutes. The transfer from utility line to E/G set, including starting and stabilizing the generator for frequency and voltage, can be accomplished in about 10 s. Sometimes a short time delay is introduced in starting to avoid too frequent E/G starts for short-time voltage sags and interruptions that can be handled by the batteries of the UPS.

Engine-generator sets are available from 50 to 2500 kVA. A 218-kVA diesel-engine generator set is shown in Figure 13.7 [13.1]. For larger loads, it is common to employ multiple E/G sets operating in parallel to obtain reliability through redundancy and to have a set available for maintenance. In addition, electric power is required for non-UPS load—that is, air conditioning, lighting, and water pumps. Combustion turbines are also employed to drive generators in standby applications.

**Standards**

The major problem for the installation of E/G sets is environmental. The sets produce noise, exhaust, and vibration; they require coolant air or water, fuel, and fuel systems; they are heavy and require adequate foundations. A list of codes and standards governing E/G sets as an alternative to utility power includes the following:

  ■ Art. 700, “Emergency Systems”
  ■ Art. 701, “Legally Required Standby Power Systems”

Component parts of an E/G set installation

The component parts or subsystems of an E/G set are shown in Figure 13.8. Detailed information is given in On-Site Power Generation: A Reference Book, fourth edition [13.5]. The parts are described as follows:

■ **Engine:** Gasoline, diesel, internal combustion engine, or a combustion gas turbine. Turbine requires minutes to start and acquire load, compared to seconds for an internal combustion engine.

■ **Generator:** Three-phase salient-pole (1800 r/min or 3600 r/min) exciter for field current and damper windings for parallel operation.

■ **Fuel:** Gasoline, diesel oil, natural gas, or another. Requires day tank and offsite tank, pumps, piping, vents, and filters.

■ **Coolant:** Radiator and fan mounted on the engine, or external to the engine, with ducts to the engine.

■ **Exhaust:** Muffler and exhaust piping to discharge gases and control noise.

■ **Starter:** Electric motor, battery, and charger, or pneumatic means and high-pressure air storage. Start initiated by signal from manual switch or transfer switch.

![Block diagrams. Functions of E/G set.](image-url)
Control: Electronic isochronous governor for independent operation and when synchronized to other generators and/or to the utility line. Active power load division.

Generator Protection: Relays to monitor load current, terminal voltage, reverse power, frequency, over temperature, to operate alarms and trip the circuit breaker.

Voltage Regulator: Electronic regulator for the exciter or main field current to regulate terminal voltage. Reactive power load division.

Synchronizer: Controls engine speed and circuit breaker closing when the E/G set is to operate in synchronism with the utility line and/or other E/G sets.


Operation. The E/G set is a universal, useful, piece of equipment at a site whose output supplements utility service. Its operation includes the following functions:

Loads: Include UPS, lighting, air conditioning, heating, fans, pumps, electronic equipment, and appliances. To a degree, loads can draw non-sinusoidal current (harmonics) and be unbalanced. The generator must have low subtransient reactance (damper windings) and/or be oversized for harmonic load current.

Emergency Operation: The controls of the transfer switch order the E/G set to start when an interruption in utility voltage is detected (or a manual test signal is entered). When the generator voltage has stabilized at the correct amplitude and frequency, the transfer switch transfers the load to the E/G set. Starting and transfer usually takes about 10 s. When utility power is restored, the controls allow the E/G set to run for about 30 min before the transfer switch transfers the load back to the utility power. Multiple engine-generator sets start in sequence.

Testing: E/G sets for emergency service should be tested about once a week, and allowed to run at least 30 min. The generator can be loaded with one of the following: (1) a dummy load, (2) a facility load, or (3) it can be synchronized to the utility line. The test can be initiated manually or automatically from a programmable controller.

Non-emergency Standby: The E/G can be used to provide power to equipment or facilities when the normal power source is not available—for example, when they are under construction or maintenance work is being done. The UPS can be placed on by-pass. Adequate fuel must be available.
Parallel Operation: Two or more E/G sets can be operated in parallel for redundancy, to secure more than one set’s power, and to handle large motor starting. The governors and voltage regulators must insure parallel operation at the required voltage and frequency, as well as active and reactive power division.

Transfer switches
The purpose for a transfer switch is shown in Figure 13-5. The switch connects the load, in this case a UPS, to either the utility source or to an E/G set. The operation is usually conducted when power from the utility line is interrupted and the output of the E/G set must supplement the capacity of the batteries of the UPS. The transfer switch has other functions, such as transferring between two feeders or transformers, and transferring power to a motor from a failed feeder to an alternate feeder. The subject is covered extensively in reference [13.5].

Standards. Pertinent standards on transfer switches include the following:


Types of transfer switches. Several types of transfer switches are available and include the following:

- Manual: The transfer switch can consist of a double-throw multipole switch, or two mechanically interlocked circuit breakers or contactors.
- Automatic Electromechanical
  - Three-pole or four-pole to switch three phases with or without neutral.
  - Open or closed transition, which usually requires utility permission when switching E/G sets with respect to a utility line.
  - Controls, including voltage sensing, engine starting and shutdowns.
- By-pass: Incorporates a by pass switch section that can connect the preferred line to the load while the transfer switch is removed for maintenance, as shown in Figure 13.9 [13.5].
Solid State: Utilizes thyristor or GTO AC switches in each leg, as shown in Figure 13-6. Transfer switches have been built for switching utility feeders rated up to 34 kV.

Applications. Applications for transfer switches include nearly every area of electrical application, particularly those devoted to high reliability and safety. These include the following:

- Utility to E/G Set: A generic diagram is shown in Figure 13.10. The shape of the movable contact is typical to obtain a short travel distance and no ambiguity of contact positions.
- UPS Supply: Transfer from a utility line to an E/G set to supplement the UPS battery. Data centers employ up to 10,000 kVA of E/G sets and suitable transfer switches.
- Electric-Motor Transfers: For large induction motor–driven fans and pumps, as in power plants, transfer switches are employed where two alternate transformers or feeders are provided.
- Lighting: Alternate and emergency lighting systems supplied by transfer switches from batteries, inverters, and alternate feeders.
Summary

Standby power equipment provides the means to improve the reliability of the utility electric power supply to critical load equipment. Alternate feeders and E/G sets utilizing transfer switches are the principal means of providing both power and standby power to UPSs, health care facilities, and telecommunications systems. The design requires consideration of all aspects of the existing utility supply and the desired objectives of the high-reliability system.

References