



IEEE Recommended Practice for Cement Plant Power Distribution

Industry Applications Society

Sponsored by the
Cement Industry Committee

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IEEE Recommended Practice for Cement Plant Power Distribution

Sponsor

**Cement Industry Committee
of the
IEEE Industry Applications Society**

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Abstract: Electrical distribution systems in cement plants that would result in satisfactory equipment utilization, reliability, performance, safety, and low maintenance—all at a reasonable cost—are recommended.

Keywords: alternate power source, power distribution, primary distribution voltage, quarry distribution, secondary unit substation, surge arresters

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Introduction

This introduction is not part of IEEE Std 277-2007, IEEE Recommended Practice for Cement Plant Power Distribution.

This recommended practice has been revised to reflect needed technical changes that have been suggested since the document was last published in 1994.

IEEE Std 277-2007 reflects the thinking of members of the Power Generation and Distribution Working Group, consisting of members from cement plants, machinery manufacturers, electrical equipment manufacturers, and cement plant designers and builders.

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IEEE Recommended Practice for Cement Plant Power Distribution

1. Overview

1.1 Scope

This document has been developed as a recommended practice for electrical distribution systems in cement plants with the objective of satisfactory equipment utilization, reliability, performance, safety, and low maintenance—all at a reasonable cost.

1.2 Purpose

The purpose of this recommended practice is to provide guidance in established practices for the design, application, installation, and protection of electrical distribution systems in cement plants. This recommended practice will be used to augment some of the principles outlined as they apply to cement plants.

2. Normative references

The following referenced documents are indispensable for the application of this recommended practice (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C2-2007, National Electrical Safety Code® (NESC®).¹

IEEE Std 141™-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (*IEEE Red Book*™).^{2, 3}

¹The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

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³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

IEEE Std 142™-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (*IEEE Green Book™*).

IEEE Std 242™-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (*IEEE Buff Book™*).

IEEE Std 446™-1995, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (*IEEE Orange Book™*).

IEEE Std 450™-2002, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-277-1994 Acid Batteries for Stationary Applications.

IEEE Std 519™-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

IEEE Std 625™-2001, IEEE Recommended Practices to Improve Electrical Maintenance and Safety in the Cement Industry Power Distribution for a New Plant.

IEEE Std C37.2™-1996, IEEE Standard Electrical Power System Device Function Numbers and Contact Designations.

NFPA 70, National Electrical Code® (NEC®).⁴

U.S. Department of Labor, Mine Safety and Health Administration (MSHA), CFR 30 Part 56—Safety and Health Standards Surface Metal and Nonmetal Mines.⁵

U.S. Department of Labor, Mine Safety and Health Administration (MSHA), CFR 30 Part 57—Safety and Health Standards Underground Metal and Nonmetal Mines. Subpart K—Electricity.

3. Power distribution for a new plant

Factors to consider in new plant construction include the main plant distribution substation, what cables to use, secondary unit substations, and safety ground check monitoring devices.

3.1 Main plant distribution substation

Source of plant power and the ownership of the main substation can greatly affect both the capital and operating costs of a plant. Type of equipment and substation design will be dependent upon these decisions, as well as selected voltage levels and plant load.

3.1.1 Purchased power vs. on-site generation or co-generation

A study should be performed to determine the economics of purchased power (utility) vs. on-site generation or co-generation. The trend in cement plants is to purchase power from the utility instead of generating power. The decision to purchase or generate power depends primarily upon economics. Many operators believe that the possible increased production by the use of efficient kilns more than offsets the

⁴The NEC is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (<http://www.nfpa.org/>). Copies are also available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁵U.S. Department of Labor Mine Safety and Health Administration (MSHA) publications are available from the U.S. Department of Labor Mine Safety and Health Administration at <http://msha.gov>.

additional cost of purchased power in most locations in the United States. Other advantages in using utility power are:

- Possibly better voltage regulation during the starting of large motors
- Greater reliability of a larger system
- Absence of operating problems associated with power generation

Explore the possibility of a form of co-generation to be operated with a new plant. Available co-generation options include:

- a) Produce electricity for a portion of the plant (no large motors). This portion of the plant would not normally be connected to the utility.
- b) Sell all the electricity the plant produces to the utility and purchase all the electricity the plant uses from the utility. One possible drawback to this would be the cost of transforming the electricity produced to the distribution voltage of the utility.
- c) Produce electricity and tie in with the plant's distribution. This may complicate coordination and protection.
- d) Pursue deregulation opportunities as allowed.

3.1.2 Locating plant substations above 15 kV

Locate the high-voltage (above 15 kV) part of the main substation outdoors on the windward side of the plant. The costly practice of locating plant substations (above 15 kV) indoors or under a roof to minimize dust settlement is no longer considered necessary.

3.1.3 Ownership of outdoor part of main plant substation

Make a study to determine whether the outdoor part of the main plant substation is to be owned by the plant or by the utility. Here again, economics, including initial, operational, and maintenance costs, should be compared with local utility rates at different voltages to determine who should own the outdoor substation. Excluding economics, the plant purchasing the substation has the advantage of choosing the substation equipment arrangement that best fits its needs. However, utility ownership may enable a quicker restoration of power subsequent to equipment failure since utilities generally stock spare equipment.

Wherever the substation is located, make sure the plant has access to the main metering equipment (computer capture of utility pulses) so that the plant knows instantaneous kilowatt usage. Time of use and level of use are important economic considerations.

A study is indicated instead of a recommendation because of the wide variation of utility rates and policies.

3.1.4 Extra-creepage insulators and bushings

Use extra-creepage insulators and bushings on the exposed electric equipment in the outdoor substation. The use of extra-creepage porcelain in the outdoor substation extends the time between cleaning periods and helps keep flashovers to a minimum. Many operators use silicone waxes or greases to facilitate the periodic cleaning of exposed insulators and bushings.

Bushings at the medium voltage level (2.4 kV to 13.8 kV) are best kept enclosed in terminal chambers. It is also desirable to keep the number of bushings to a minimum by the use of three-phase instead of single-phase transformers.

3.1.5 Alternate power source

Provide for an alternate power source to the plant, especially for critical loads. This power source could be a full-capacity transmission line to the plant, a small-capacity line at some lower voltage, standby generation, or some combination of these. The use of a loop or alternate transmission line allows total plant operation, after a short delay, in the event of a transmission line failure. A low-capacity alternate feed or standby generation allows operation of critical loads during the line failure outages. Standby generation should be exercised under load once a week to help ensure its availability when needed. If possible, standby generators should also be exercised once a year under full load conditions by means of an external resistive load bank [see IEEE Std 446-1995 (*IEEE Orange Book*)]⁶.

Some utilities offer rebates for remote interruption of plant power. If this is the case, and if economically viable, then provisions should be made for this interruption in the system design. This could include putting the shipping department and plant offices on a separate meter. Also, some utilities offer rebates for shedding a portion of the plant load on notification. In this case, no separate meter is needed.

3.1.6 Use of circuit breakers

Use circuit breaker or circuit breakers for primary protection of substation apparatus. Circuit breakers are preferred over fuses for substation primary protection as they allow the use of fast, sensitive relays that quickly act to isolate faulted equipment and more easily coordinate with other protective devices used. When using a circuit breaker on the primary of a substation transformer, it is possible to extend the zone of protection to include the transformer secondary winding and the secondary main breaker. This would be done by including a ground current transformer with ground relay (50G, 51G, or 50/51G) and/or transformer differential relaying for transformer protection. This additional relaying would supplement the primary over-current relaying to protect against ground faults and high impedance phase-to-phase faults occurring in the transformer secondary winding or between the transformer secondary winding and the main secondary breaker. Fuses' or circuit breakers' primary overcurrent relaying (50/51G) would be insensitive to faults occurring in this zone and would not clear the fault until considerable damage had been done to the transformer.

Ground faults occurring in the substation transformer secondary or between the transformer secondary and the main secondary circuit breaker cannot be isolated by the main secondary circuit breaker located on the load side of the ground fault.

CAUTION

These ground faults, when limited by a neutral-grounding resistor, are not seen by transformer primary fuses and must be isolated by a primary circuit breaker. If not isolated, these ground faults create a safety hazard and may result in the destruction of the faulted substation equipment and the grounding resistor.

A primary circuit breaker also enables the use of differential relays that quickly initiate action to clear faults, keeping fault damage to a minimum. The unfaulted half of a double-ended substation can usually be quickly restored to service subsequent to an outage initiated by a properly relayed substation using a primary circuit breaker. Where cost prohibits the use of a local primary circuit breaker, a means of remote tripping through a pilot scheme, carrier scheme, or a grounding relay can be used to affect remote tripping of a circuit breaker to isolate substation faults. When the transformer primary protection are switch and fuses, a grounding switch may be employed to place an intentional ground fault on the system to cause the upstream breaker to open, thus isolating the fault.

⁶Information on references can be found in Clause 2.

3.1.7 Double-ended substation

Use a double-ended substation in sizes above the 5000 kVA to 7500 kVA capacity range. The double-ended substation, as used here, is defined as a substation having more than one three-phase step-down transformer. More than one low-side bus may be used where required (see Figure 1 and Figure 2 in Clause 7).

The double-ended substation allows for greater reliability and flexibility. Double-ended substations permit insulator cleaning, no-load tap changing, and reduced-capacity operation without a power outage. The double-ended arrangement is desirable at lower capacities, but the additional cost of the double-ended arrangement usually does not justify its use in sizes below 5000 kVA. (Substation costs may be estimated from Figure 1 and Figure 2 for the single-ended and double-ended substations.)

3.1.8 Surge arresters

Use station or intermediate-type surge arresters selected to coordinate with equipment insulation levels to protect exposed substation equipment and rotating machines against lightning surges. Surge protection is most effective when applied at the terminals of the apparatus to be protected. Equipment connected by cable to an exposed (outdoor lines subject to lightning strokes) power source or directly to an exposed source generally requires lightning protection. Effective arrester protection requires that the arresters be installed with a low-surge impedance discharge path to ground. Where feasible, connect the arrester ground lead to the ground lead of the protected equipment. Leads should be kept as short as possible.

Protection against lightning is usually provided at the outdoor substation by station or intermediate-type surge arresters and overhead ground wires. Apparatus energized from exposed circuits should have arrester protection at the terminals of the apparatus to be protected. Apparatus energized through cables from exposed circuits should usually have arrester protection at the junction of the cable and the exposed source. If cables connect to the outdoor transformer terminal chamber, and the transformer primary source is exposed, the transformer should have primary arrester protection.

Rotating machines have lower basic impulse insulation levels (BIL) than liquid-filled transformers, switchgear, etc. Thus, all rotating machines connected to exposed circuits should be protected by lightning arresters and surge capacitors at or very near to [less than 1 m (3 ft) from] the machine terminals. The lightning arrester limits the surge level while the capacitor reduces the slope to prevent any possible motor winding damage. Both are required for proper protection. Even though large important rotating machines are not connected directly to exposed lines, it is still desirable to use surge arresters and surge capacitors to reduce the effects of induced lightning and switching surges. Extra creepage bushings capable of operating in the contaminants around the cement plant should be used.

Surge arresters for resistance-grounded systems usually used in cement plants are rated for line-to-line voltage [see IEEE Std 142-1991 (*IEEE Green Book*)].

3.1.9 Grounding the power system

Grounding the power system through a neutral-grounding resistor or resistors at the primary medium voltage level (2.4 kV to 13.8 kV) is recommended. Power systems are grounded to minimize the magnitude of the transient overvoltages that occur in ungrounded systems during ground faults. To minimize the damage due to the ground-fault current that flows in a solidly grounded system during a ground fault, a neutral-grounding resistor should be used. Limiting the ground-fault current will minimize the damage to the large motors used in the plant at the distribution-voltage level.

A 10 s resistor rating is satisfactory for plant distribution service, when ground faults are relayed to trip the faulted circuit.