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IEEE Recommended Practice for Cement Plant Power Distribution

Sponsor
**Distribution Working Group of the
Cement Industry Committee**

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Foreword

(This foreword is not a part of IEEE Std 277-1975, Recommended Practice for Cement Plant Power Distribution.)

The continuing expansion and modernization program in the cement industry has placed an increasing importance on the cement plant power distribution system. Increasing plant capacity accompanied by larger kilns, grinding mills, crushers, and the increasing use of automatic controls has placed greater stress on the adequacy and reliability of the distribution system. Safety, capacity, reliability, and low maintenance — all at a reasonable cost — are the requirements of the cement plant power distribution system.

It was for the purpose of establishing recommended practices for the cement industry to realize these requirements that the Distribution Working Group of the Cement Industry Committee was formed. The Working Group undertook this task in 1959.

The first recommended practice of the Distribution Working Group was titled Report on Preliminary Suggested Recommendations for Cement Plant Power Distribution and was prepared for publication and presentation at the Milwaukee, WI, 1960 Technical Conference sponsored by the AIEE Cement Industry Committee. As a result of the comments received at annual conferences, the report has been revised and expanded each year. It now includes recommendations on the main plant substation, high-voltage distribution, relaying, metering, cables, low-voltage distribution, and quarry distribution.

Since the Federal Government, through its agency the Occupational Safety and Health Administration, has adopted the National Electrical Code, conformance with its requirements is mandatory.

The recommendations given in this recommended practice are those on which the Distribution Working Group could reach an agreement. Certainly, any unusual conditions prevailing in a particular plant may change the advantages or disadvantages usually realized for a particular scheme. The IEEE Std 141-1969, Electric Power Distribution for Industrial Plants, brings to attention the important features of well-designed electric distribution systems that result in satisfactory performance of utilization equipment and efficient operation of plants in general. It is hoped that this recommended practice by the Distribution Working Group of the Cement Industry Committee will be used to augment some of the principles outlined, as they apply particularly to cement plants.

This recommended practice reflects the thinking of members of the Distribution Working Group, consisting of members from cement plants, machinery manufacturers, electric equipment manufacturers, and cement plant designers and builders. Present and past members are:

A. C. Lordi, *Chairman* 1959, 1960, 1961, 1964, 1965,
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C. E. Roberts, *Chairman* 1962, 1963
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Members of the West Coast Subcommittee of the Cement Industry Committee of the IEEE

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IEEE Recommended Practice for Cement Plant Power Distribution

1. Power Distribution for a New Plant

1.1 Main Plant Distribution Substation

1.1.1 Make a Study to Determine the Advisability of Purchasing Electric Power From the Utility or of Generating Power. 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 feel the possible increased production by the use of efficient kilns more than offsets the additional cost of purchased power in most locations in the United States. Other advantages in using utility power are (1) possibly better voltage regulation during the starting of large motors, (2) greater reliability of a larger system, and (3) absence of operating problems associated with power generation.

A trend is indicated here instead of a recommendation as the decision depends much upon local conditions.

1.1.2 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.

1.1.3 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 advantages of choosing the substation equipment and equipment arrangement which best fits its needs. However, utility ownership may enable a quicker restoration of power subsequent to equipment failure since utilities generally stock spare equipment.

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

1.1.4 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 distribution voltage level (2.4 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.

1.1.5 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, or a small-capacity line at some lower voltage, or standby generation, or some combination of these. The use of a loop or alternate transmission line would allow total plant operation, after a short delay, in the event of a transmission line failure. A low-capacity alternate feed or standby generation would allow 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. (See IEEE Std 446-1974, Recommended Practice for Emergency and Standby Power Systems.)

1.1.6 Use a 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 which quickly act to isolate faulted equipment and more easily coordinate with other protective devices used. Also, the use of relays extends the zone of protection against limited

ground faults down to the secondary side of the substation power transformers.

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. 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.

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 switch can be used to effect remote tripping of a circuit breaker to isolate substation faults.

A primary circuit breaker also enables the use of differential relays which 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.

1.1.7 Use a Double-Ended Substation in Sizes Above the 5000 to 7500 kVA Range in Capacity. The double-ended substation as used here is defined as a substation having more than one three-phase stepdown transformer. More than one low side bus may be used where required. See Section 1.1.12.

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 Figs 1 and 2 for the single- and double-ended substations).

1.1.8 Use Station or Intermediate-Type Surge Arresters Selected to Coordinate With Equipment Insulation Levels to Protect Exposed Outdoor Substation Equipment 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 usually should 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 than liquid-filled transformers, switchgear, etc. Thus, all rotating machines connected to exposed circuits should be protected by rotating machine surge arresters and surge protective capacitors at or very near to [less than 1 m (3 ft) from] the machine terminals. 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. Surge arresters 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 142-1972 (ANSI C114.1-1973), Recommended Practice for Grounding of Industrial and Commercial Power Systems.]

1.1.9 Ground the Power System Through a Neutral-Grounding Resistor or Resistors at the Primary Distribution Voltage Level (2.4 to 13.8 kV). Limiting ground-fault current by a resistor is desirable to minimize ground-fault damage to the large motors used in the plant at the distribution-voltage level. A 10 s resis-

tor rating is satisfactory for plant distribution service, when ground faults are relayed to trip the faulted circuit.

The value of resistance used should be low enough to allow the flow of sufficient ground-fault current to be selectively relayed with adequate margin. Ground-fault current should not be limited to less than the system charging current (usually less than 15 A). Generally, the combination of grounding resistor and ground relaying used should result in the protection of 90 percent of the windings of motors and transformers. This protection is effected if ground relays pick up at 10 percent or less of the maximum ground-fault current.

1.1.10 Use one or more Feeder Circuit Breakers for Each Operating Department at the Distribution-Voltage Level. This sectionalizing of loads allows independent departmental (or production unit) operation and facilitates the metering of each department. The trend is toward the universal use of metal-clad switchgear with removable-type air circuit breakers. A tie breaker is desirable in the double-ended metalclad lineup for increased flexibility. It is desirable to use an additional circuit breaker to separate the large mill motors on the raw and finish mills from the raw and finish mill auxiliaries, to facilitate relay coordination and to allow closer protection of the connected equipment. A kiln unit with all its auxiliaries should be connected to the same circuit breaker.

Either indoor or outdoor metalclad air circuit breakers are used, depending upon available plant area. The preference is toward using indoor metalclad air circuit breakers located in clean pressurized rooms, rather than outdoor circuit breakers. The tripping voltage should be at least 125 V to minimize relay contact continuity failures due to dust. [See IEEE Std 142-1972 (ANSI C114.1-1974).]

1.1.11 Allow for Margin in Substation Capacity. Approximately one-third extra apparent power capacity (in kilovolt-amperes) over that needed for present plant operation is desirable in the initial substation installation. Circuit breakers also should allow for anticipated increase in utility short-circuit capacity for an approximate 10 yr period. Consideration should be given to the providing of features in the substation to facilitate subsequent expansion.

It is desirable to choose the size of transformers for double-ended substations of sufficient size to enable starting of the large mill motors on a single transformer within tolerable voltage regulation. (See Section 1.1.13.) Mill torque limits should be observed both on single- and two-transformer operation.

A typical suggested substation size is 5000 kVA (with fans for 6250 kVA capacity) for each 200 000 ton per year plant capacity. The use or provision for future use of fans on the substation transformers should be considered.

1.1.12 Use 4160 V as the Primary Distribution Voltage for Plants of 20 000 kVA and Below. Above 20 000 kVA, Either Use the Split-Bus 4160 V System or the 13 800 V System. The interrupting and momentary current capacity of the 4160 V circuit breakers and motor controls limits the allowable short-circuit capacity and thus substation apparent power on a bus. However, most existing plants have short-circuit capacities within the limits of 4160 V equipment.

When short-circuit capacities are above the limits of 4160 V equipment, the 4160 V bus can be split to keep short-circuit capacities within equipment ratings. Or, a higher distribution voltage can be used, with the available equipment having higher short-circuit capacities. The next economical voltage choice is usually 13.8 kV.

The use of 13.8 kV as a primary distribution voltage may require an additional transformation to 4160 or 2400 V to enable the economical use of large motors at the lower primary distribution voltages. However, the double transformation increases system impedance and voltage drop during starting the large grinding-mill motors, and should be taken into account. It is recommended a study be made to determine the economic motor voltage for plants of 20 000 kVA and above.

Figs 1-6 show relative costs for the electric apparatus at several distribution-voltage levels. [See American National Standards Institute C2 (1973 Edition) National Electrical Safety Code.] (Also see IEEE Std 141-1969, Recommended Practice for Electric Power Distribution for Industrial Plants.)

1.1.13 Design the Power System to Limit Voltage Drop During Starting Large Motors (at the Distribution Voltage) to a Maximum of