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Recommended Practice for

CEMENT PLANT

POWER DISTRIBUTION

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FOREWORD

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 report 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, Wisconsin 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.

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 Standards Publication, No. 141, titled "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 report 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:

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C. LOW-VOLTAGE DISTRIBUTION

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Recommended Practice for **CEMENT PLANT POWER DISTRIBUTION**

PART I **POWER DISTRIBUTION FOR A NEW PLANT**

A. MAIN PLANT SUBSTATION

I-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 longer kilns more than offsets the additional cost of purchased power in most locations in the United States. Other advantages in using utility power are (a) possibly better voltage regulation during starting large motors, (b) greater reliability of a larger system, and (c) 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.

I-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. Use the prevailing winds to help keep substation insulators clean between regular cleaning times.

I-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 must 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.

I-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.

I-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. See Figure 1.

I-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 breaker cannot be isolated by the main secondary 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.

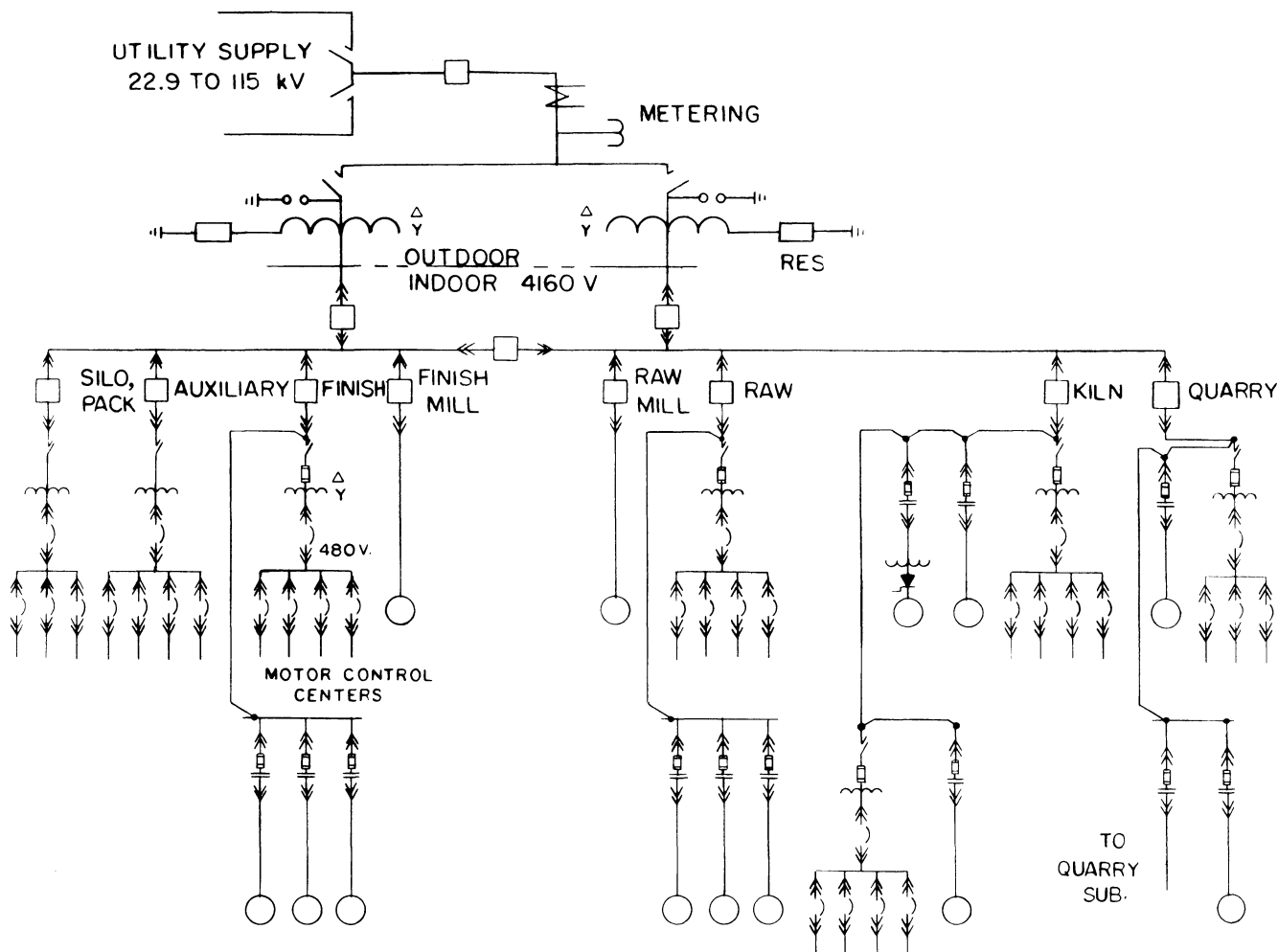


FIGURE 1
Typical Cement-Plant Distribution System.

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 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 breaker.

I-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 paragraph I-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 Figures 2 and 3 for the single- and double-ended substations).

I-8. Use station or intermediate type lightning arresters selected to coordinate with equipment insulation levels to protect exposed outdoor substation equipment against lightning surges.

Lightning 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 impedance (less than 5 ohms) discharge path to ground. More effective protection is obtained if the arrester ground lead is connected to the ground lead of the protected equipment.

Protection against lightning is usually provided at the outdoor substation by station or intermediate type lightning 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 impulse levels than liquid-filled transformers, switchgear, etc. Thus, it is recommended that all rotating machines connected to exposed circuits be protected by rotating machine arresters and surge protective capacitors at or very near to [less than 3 feet (1 meter) from] the machine terminals. Even though large important rotating machines are not connected directly to exposed lines, it is still desirable to use arresters and surge capacitors to reduce the effects of induced lightning and switching surges. Arresters capable of operating in the contaminants around the cement plant should be used.

Arresters for the resistance-grounded systems usually used in cement plants are rated for line-to-line voltage.*

I-9. Ground the power system through a neutral-grounding resistor or resistors at the 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-second resistor 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 ade-

quate margin. Ground-fault current should not be limited to less than the system charging current (usually less than 15 amperes). Generally speaking, 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.

I-10. Use a feeder breaker (or 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. Sometimes it is desirable to use an additional 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 breakers. The tripping voltage should be at least 125 volts to minimize relay contact continuity failures due to dust.

I-11. Allow for margin in substation capacity.

Approximately one-third extra kVA capacity 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-year 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 paragraph I-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 million barrel per year plant capacity. The use or provision for future use of fans on the substation transformers should be considered.

* Arresters for line-to-line voltage are used on systems that are not effectively grounded as defined by EEl-NEMA Publication No. 117, Appendix B, dated May 1949.

I-12. Use 4160 volts as the distribution voltage for plants of 20,000 kVA and below. Above 20,000 kVA, either use the split-bus 4160-volt system or the 13,800-volt system.

The interrupting and momentary current capacity of the 4160-volt circuit breakers and motor controls limits the allowable short-circuit capacity and thus substation kVA on a bus. However, most existing plants have short-circuit capacities within the limits of 4160-volt equipment.

When short-circuit capacities are above the limits of 4160-volt equipment, the 4160-volt 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 distribution voltage may require an additional transformation to 4160 or 2400 volts to enable the economical use of large motors at the lower 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.

Figures 2 through 7 show relative costs for the electric apparatus at several distribution-voltage levels.

I-13. Design the power system to limit voltage drop during starting large motors (at the distribution voltage) to a maximum of 15 percent of system voltage at the motor terminals.

The possibility of equipment malfunctioning becomes real when a greater than 15 percent voltage drop is realized. Special precautions to maintain control voltage may be required where greater than a 15 percent drop in system voltage is anticipated.

During normal running, voltage at the large motors at the distribution voltage should not vary more than plus or minus 5 percent of rated motor voltage.

I-14. Isolate synchronous machines from the utility system prior to any reclosing action, subsequent to a plant power outage due to the utility system.

A power outage allows the synchronous machines to shift in phase position in respect to

the utility system. Subsequent re-application of power to the machines when out of synchronism may result in inrushes and torques well above drive mechanical limits. High-speed underfrequency relays without any intentional time delay can usually act to isolate loaded synchronous motors prior to a reclosing action. Note that lightly loaded motors and/or motors connected to high inertia loads may not decelerate in time to allow underfrequency relay action prior to utility reclosing.

Coordination with the utility to block or delay reclosing is suggested.

I-15. Choose and set protective relays to selectively initiate the isolation of faults on the distribution system. Periodically check relays to insure proper operation.

A relay coordination study should be made to enable selective isolation of both phase and ground overcurrents for the load on each feeder back to the utility system.

Suggested relaying is outlined as follows: See Figure 1. Note: Specific relay choices cannot be made as relay curves vary with different manufacturers. Care must be exercised to ensure that the proper curve is specified.

I-15.1 Department Feeder Breakers at the Distribution Voltage Level.

Phase — Inverse time, moderately inverse time, very inverse time, or extremely inverse time relays, or equivalent, as required to properly coordinate with the connected load protective devices. The extremely or very inverse time relay may be required to coordinate with fuses in the high-voltage motor starters and when used on the primaries of the low-voltage substation transformers. If the feeder breaker feeds directly to an unfused low-voltage substation transformer, the phase relays should also have instantaneous trip attachments set above the maximum asymmetrical fault expected at the connected low-voltage substation secondary.

Refer to paragraph I-32 for recommended use of low-voltage substation fuses.

Set phase relays to pick up as low a value of current and to operate at as fast a time as feasible and yet still maintain selectivity with the connected equipment. The relays should initiate clearing of faults on equipment directly connected to the feeder breaker within the thermal capacity of the connected cable and equipment. See Figures 10 and 11.