2 | utility feed

The primary substation takes in electrical energy in bulk, trims its voltage to proper level and dispenses it. *Transformation is often eliminated where utility voltage is below 15-kv ceiling set by NEC for most installations.* But it may be in order even then, if big motors or other loads operate best at some voltage other than utility's. Three features stand out in any study of primary substations: *location, reliability, and protection.*

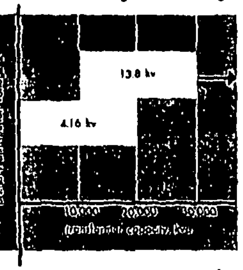
Location, if ideal, would be right in plant load center. But practical *angles and utility requirements* usually put it at edge of plant property. Modern equipment enclosures make outdoor buildingless installation the rule rather than the exception. Additional cost of outdoor gear must be balanced against building costs. Some strive for outdoor location of utility switching and transformers when over 15 kv, put plant primary switchgear indoors.

Where corrosive fumes, residues may settle on high-voltage insulators, study indoor design. Or at least put substation on windward side of source and outline problem to equipment manufacturer.

Reliability of your system can't exceed that of utility supply. So check its adequacy. Ask utility for outage expectancy based on past experience in your area. Underground cable generally fares better than overhead, but faults often take longer to find and fix. Faults on overhead lines are often temporary; can be cleared readily.

Protection starts with pinning down available short-circuit kva the utility can supply. Check if projected utility interconnections will increase this in the future.

Work out with your utility the details on primary substation ownership, number of ... feeders required, voltage



Tie down basic points early. Set number and arrangement of feeds by joint agreement. Decision hinges on: size of load, need for duplicate service, voltage, transmission-feeder capacity and nearness. Incoming feed may vary from 2.4 kv ungrounded to 138 kv with neutral grounded solidly or through resistance.

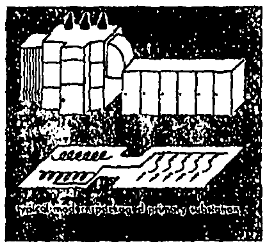
Type of feed and high-voltage switching hangs on supply voltage, service continuity, load size, *short-circuit-current* available, utility relaying, number and size of stepdown transformers, flexibility needed for future load changes.

Utility feed may be a simple tap on a main transmission line, or line may be looped into primary substation, giving, in effect, a 2-circuit feed. More feeds may be brought in, from separate bus sections of utility substation or separate substations. Whether automatic or manual throwover is used depends on continuity required. Short-circuit duty *remains relatively constant regardless of number of lines brought in, if they're not paralleled.*

Who should own the primary substation? There's no *universal answer.* Where a choice is offered, many pros and cons can only be settled by an economic study. Rates are often more favorable where user owns substation. But initial cost and maintenance may offset this. Many large automotive plants set out, where possible, to buy at utility-station voltage, usually 13.8 kv. Other industrials angle for ownership because they want some control of operating reliability. *But remember, if you own, you need manpower versed in high voltage.*

Voltage chart to left isn't a rule, but it's based on good practice today. Note that 4.16 kv is sometimes economical even to 20,000 kva, but 13.8 opens the road to future plant expansion.

Modern packaged substation designs, with single 3-phase transformers, cost less ... than "assembled" stations



Today's packaged unit substation usually proves a better bet than stations assembled on the spot. Equipment cost may run higher but, with proper planning, installed cost shows savings and you have a smart, well-coordinated unit.

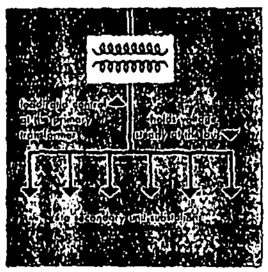
Primary unit substations are made up *of one or more transformers mechanically and electrically coordinated with one or more switchgear assemblies.* Incoming section provides for high-voltage circuits, which may or may not have individual breakers. Transformer is usually oil-filled (see pp 96, 97). Outgoing section handles plant primary feeders with either breakers or load-interrupter switches and power fuses (pp 104, 105).

Weigh advantages of transformer fan cooling. Some engineers peg transformer size on existing load, then provide for later fan cooling. How much extra capacity this gives depends on unit size. *The peak is 67% for 2-stage cooling in transformers over 10,000 kva (p 98).*

Single-phase vs 3-phase transformer question is now pretty well settled. Reliability of today's units makes the single 3-phase transformer the logical and economical choice. Some engineers still feel there are cases, in large substations, where three single-phase units may be best choice. They compare availability problem when replacing a large 3-phase unit against continuing operation with two singles open-delta.

For overhead structures, look into use of aluminum, especially where corrosive atmospheres may cut through galvanized steel. When steel coating is gone, painting must start. This usually calls for killing all or part of substation and forms just another maintenance headache. In a few industries aluminum may not stand up; some chemical and petroleum plants reported trouble.

Today's critical loads generally dictate need for load-ratio control or regulators to ... hold down voltage swings

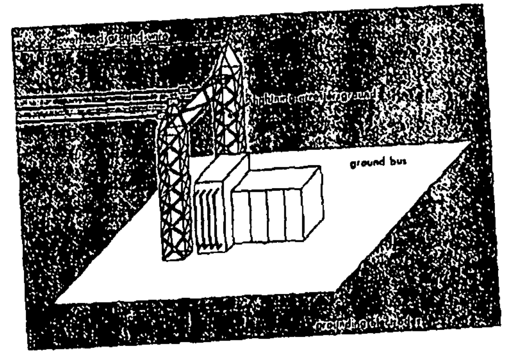


Motors, lamps, heating equipment are all designed to operate best at rated voltage. Distribution systems aim to provide this but the best system suffers *unavoidable fluctuations in supply voltage and voltage drop.*

Today's industrial plant aims to hold substantially constant bus voltage—within ±3 to 5%. It sometimes is done with load-ratio control, generally built into the primary transformer to change taps under load. There are usually 16 steps above and 16 below rated secondary voltage. In some cases, it may prove economical to regulate specific loads instead of voltage for entire plant. This decision depends on voltage limits of supply and required regulation of the specific loads.

Figure cost of load-ratio control at *roughly \$2.75 per kva of transformer capacity for loads in the 10,000-kva range.* Engineers now give more thought to selecting voltage control when designing the primary substation, rather than later at greater cost. Many feel it is justified in nearly every installation where voltages above 15 kv are stepped down to the 2.4 to 13.8 range. Control can be set to hold voltage constant or to raise it slightly as load increases, to compensate for drop in plant system.

What's answer where supply is below 15 kv and carried directly to secondary *unit substations?* Load-ratio control in each secondary substation is generally uneconomical and often impractical. The solution is either *step voltage regulators or induction voltage regulators* in the primary supply. Their standard regulating range is ±10%. Can you save by hooking two induction regulators open-delta? Dollarwise, yes, but open-delta connection creates unbalanced voltage that may affect heating in fully loaded polyphase *induction motors.* Best practice avoids open-delta in favor of straight 3-phase regulation.



Plant safety needs good equipment grounding

Equipment grounding is important in primary substation design as well as throughout entire distribution system. *It means connecting to ground all noncurrent-carrying metal parts:* conduit, raceways, transformer cases, switchgear enclosures.

Prime object is to limit voltage between these metal parts and earth to a safe value under all operating conditions. Three components are used: *Grounding electrode* is a conductor embedded in the earth. *Ground bus* is a network that ties solidly to grounding electrodes. *Grounding conductor* connects equipment and wiring enclosures to the ground bus.

Ground bus should surround building or structure. Grounding electrodes should connect to bus at two or more points. With a double path to earth, a single broken tie won't open the connection. *Size of ground bus* is based on how much current may flow through it and for how long. For mechanical strength, aside from current-carrying capacity, keep ground bus No. 2 awg, or larger. Modern practice may dictate cable sizes to one million cm for a sound equi-potential grounding scheme.

Local grounding connections for lightning arresters are made by driving rods into earth near arresters. *In addition,* tie lightning-arrester conductor to common station ground bus.

Where it's exposed to possible mechanical injury, ground bus should be protected, generally by conduit. Connect both ends of conduit to ground bus to avoid inductive effect.

New portable welding device offers a promising way of joining grounding electrodes, bus and conductors (POWER, March, 1953, pp 123-125). Basic elements are *powdered metal,* firing charge, small crucible. Result is a high-current-capacity joint.

General Pointers: Equipment frames are considered grounded if they're bolted or welded to properly grounded structural steel. Rigid conduit systems by themselves aren't usually considered good grounding connections, but NEC accepts at 600 v. or less. A grounding connection run inside conduit or raceway through which power flows must be insulated, equal in size to largest line conductor but generally not larger than No. 4.