

Secondary unit substations, placed close to load centers, take primary distribution voltage, transform it to lower secondary value (usually 480 v today) and, through a system of circuit breakers, start it on its way to nearby load areas. Standard factory-assembled units offer (1) fast delivery, skipping drafting-room time needed with "specials" (2) top interchangeability and flexibility when future changes are necessary (3) quick replacement of any elements damaged during equipment life (4) lower cost than field-assembled substations.

Strive for uniformity in your substations. Group loads so substations of equivalent kva can be used. Aim for interchangeability of transformers and switchgear. Then one spare is spare for all. **Future Growth.** Sizable load additions usually call for new substations. But small new loads can often be tacked on existing units, provided spare capacity was incorporated when originally selected. In modern units, switchgear is so designed that complete new feeder sections may be added with ease. During design stage, check that enough floor space is available

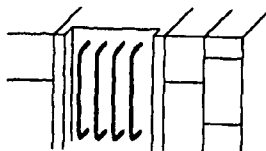
to take additional switchgear at low-voltage end of substations. Since breakers in the same interrupting class are interchangeable, you can increase breaker size without structural change. **Substation Size.** For each plant there is generally an optimum size giving lowest cost per kva. With many small units, more primary cable is required, boosting installed cost. But small units reduce the amount of secondary cable. On the other hand, when substations are large, switchgear and secondary-feeder-cable costs climb.

**Location.** First determine where the substation would fit best in an ideal situation — indoors or out. Modern practice includes the plant roof as well as space alongside the building in the term "outdoors". Another out-of-the-way spot is in balcony areas. Such location offers savings in valuable floor area and in additional costs of outdoor roof equipment.

Unit substations are available in double-ended designs as well as the familiar single-ended type. Weigh well the economics of double-ended designs before ruling out straight singles across the board.

## Single-ended unit substations satisfy the needs of most plants

Incoming section between primary feeder and transformer may have circuit breaker, load-interrupter switch, oil-fuse cutoff, selector switch, or a solid connection. Where switches selected interrupt transformer magnetizing current only, a keyed interlock is usually used, tied in with main secondary breaker. Load-interrupter switches are available with or without power fuses for transformer protection. Switch and fuse combination is economical, effective. With two incoming lines, a 3-position selector switch is used. Make sure there's enough space to throw switch without hazard.

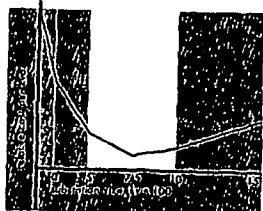


Transformer can be oil-filled, askarel, vented or sealed dry type (pp 95, 97). Askarel offers high impulse strength, can be put indoors or out. Sealed dry type combines some advantages of liquid units (sealed against outside dirt) yet needs no maintenance other than occasional inspection, external cleaning.

Secondary switchgear now makes wide use of drawout breakers. Molded-case breakers can be used with substations up to about 300 kva, have widest use where operation is infrequent and drawout feature is not necessary (lighting substations, for example). Breakers may be manually or electrically operated. Control centers may be used where you want to centralize motor starters, lighting panels and associated controls in one spot. Provide spare breaker position when you want secondary-selective layout. Run cable between this point and bus of nearby substation.

## Interrupting capacity of secondary switchgear is important in substation sizing

To arrive at most economical substation size for any plant, study the factors that directly affect installed cost: length and size of both primary and secondary cables, primary voltage, heavy spot loads, required interrupting capacity for secondary switchgear, primary short-circuit protection. Curve, below, was prepared on a basis of 480-v secondary



distribution, after considering above factors in a typical plant. Curve changes if 208 v is used; economical size then falls around 300 kva.

**Substation Costs.** For small units, costs climb mainly because of higher transformer cost in smaller kva ratings. At other end of scale, costs climb with bigger units mainly because of greater available short-circuit currents, calling for more expensive secondary switchgear. And since larger subs usually serve larger plants, secondary cable cost mounts fast with station size.

With 13.8 kv on primary feeders, aim for 4000 to 7500 kva per feeder. Then 750-, 1000- and 1500-kva units can usually be applied without individual primary overcurrent protection (NEC, paragraph 4512b). Such protection would be needed with 500-kva substations and some primary voltage and loads.

If primary voltages fall between 2.4

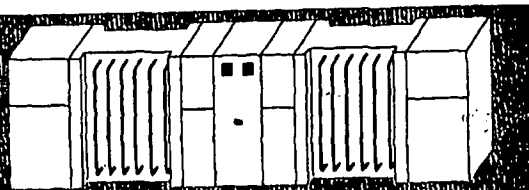
and 4.16 kv, most economical primary feeder loadings are between 1000 and 3000 kva per feeder. In this range, smaller substations can be used without the added primary protection.

**Heavy spot loads** often justify larger substations. Typical are furnaces, ovens, large welders — these might call for 2000-2500-kva subs at 480 v.

**Interrupting Rating.** There are three common short-circuit-rating brackets in the low-voltage range: 15,000, 25,000 and 50,000 amp, all rms asymmetrical. Assuming a 480-v secondary, largest sub generally used within 15,000 amp is 300 kva. If 25,000-amp figure isn't to be exceeded, 750 kva would be top practical limit. Where substations larger than 750 kva are used, secondary switchgear generally carries a 50,000-amp interrupting rating. This last requirement alone often dictates two 750-kva substations rather than a single 1500-kva unit.

## double-ended units may prove best bet in concentrated load areas

Two transformers feed two sections of low-voltage gear with a normally open breaker between. Unit provides service if transformer or incoming line fails.



Double-ended substations go hand in hand with secondary-selective and network arrangements. If either of these layouts looks best for your plant, you then need to weigh single against double units. With doubles, maintenance and testing of transformers can be done without service interruption. But they cost more, mainly because of the need for two main secondary breakers and a tie breaker, not necessary with single

units. Main secondary breakers are necessarily large to carry full transformer load current.

Where loads are heavily concentrated in one area and the choice is between two economically sized smaller substations and one single large unit, double-ended design may prove best. Spare Transformer. Some power engineers buy a spare transformer as a replacement for many similar-size units

throughout the plant, and stick to single-ended substations. In an emergency, spare can be put to work quickly.

There are times when each transformer of a double-ended unit must be sized to carry total substation load so no load need be dropped if a feeder or single transformer fails. More typically, load diversity and judicious emergency operation are counted on to hold normal rating for both transformers.

## Secondary unit substation location affects costs and efficiency of distribution system

**building roof** This location proves popular where primary distribution is overhead and bus duct is used. Then short secondary runs drop direct to bus duct. Roof location often sidesteps high ambient temperatures, dirt and fumes in plant; it also fits well where load areas change frequently. Remote tripping and closing of breakers is usually needed.

**balcony areas** Steel structure with expanded-metal or sheet-steel floor is placed high enough so space below is usable, often as a washroom. Balconies keep substations out of normal traffic and, in food plants, out of range of splash from equipment hoses. Substations are also suspended in roof trusses, just above lowest structural members.

**floor level** Check plant layout for low-value areas indoors at centers of load. Consider, too, putting substation immediately outside. And where buildings are long and narrow, study areas between them if cable runs can be kept short. Avoid spitting all equipment at a single transformer bank; stick to load centers and short secondary runs.

