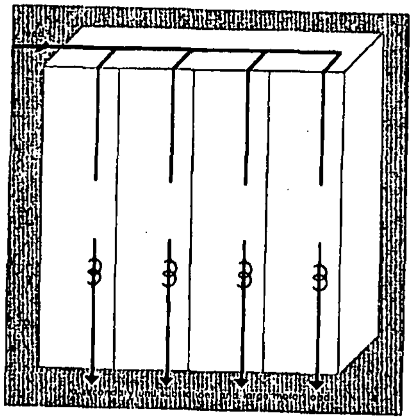


Mainstay in most protection plans, today's circuit breaker keeps pace with growing demands for more reliable protection, minimum downtime on faults.

Industrial-plant breakers, on secondary of primary substation transformer and in secondary substations, use air rather than oil in contact-breaking chamber. In modern switchgear, individual *breakers* (also meters and instruments) are removable so maintenance can be done with equipment deenergized.

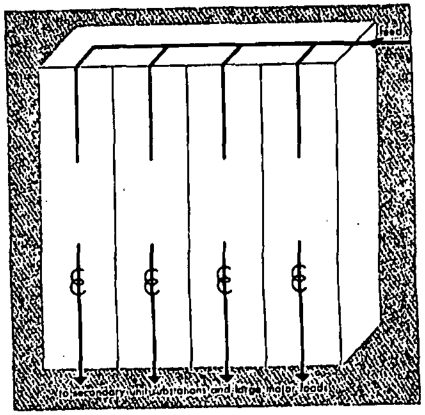
The few cycles needed for breakers to trip allows protective relay to close contacts, breaker trip coil to move plunger releasing breaker operating mechanism, and opening contacts to interrupt current.

Short-circuit current is maximum during first few cycles because of dc component and peak contribution from motors on line. Thus, there are two bases for short-circuit-current ratings of circuit breakers: (1) *momentary rating*—ability to stand mechanical stresses which are maximum during early cycles (2) *interrupting rating*—ability to break circuit safely.

Filling gap between simple air-break switches and circuit breakers, modern load-interrupter switches find use where main need is switching. Where fast resetting of breakers isn't required, where possible single-phasing can be tolerated, combination interrupter switch and fuse serves as economical alternative for more complete service given by *breakers*.

In industrial primary substations, typical units are able to interrupt 600 amp of load plus magnetizing current. Sizing to interrupt station load means switching can be done without mechanical and electrical interlocking with secondary breakers. Some engineers specify combination interrupter switches and power fuses to give short-circuit protection for primary feeders and secondary transformers. Fuses are usually high-voltage boric-acid type.

Switching centers in large industrial plants, where power is distributed over a series of high-voltage feeders to unit subs, use interrupter switches as an economical means of switching under load.



Here's how circuit breakers are now being applied in primary and secondary unit substations, and on incoming utility-power feeders

On the preceding page we stressed the importance of adequate interrupting capacity in today's protective equipment. Now let's look at some of the practices being followed by power engineers in applying this equipment.

Primary Substation. If a main transformer breaker (in unit's secondary leads) is used in the simple-radial system, overcurrent relaying can be applied to trip this breaker as backup protection for plant primary-feeder breakers. Main job of this breaker, from system-protection standpoint, is to detect and isolate faults on primary substation bus. Relaying for breakers, however, must be coordinated with other protective devices in system. Thermal overload protection for primary-substation transformer can also *control this breaker*.

With modern unit-substation construction, however, it is now general practice to eliminate the transformer breaker. This can be justified by the compactness and extreme reliability of unit-type equipment, which makes possibility of a primary-substation-bus fault remote. In large primary substations, possible use of bus and transformer differential protection should be considered. Additional insurance provided must justify premium paid. In some special cases, differential schemes combining transformer and bus protection can be devised with a saving in cost of protective features.

If the utility sub-transmission system supplying plant primary substation consists of a single radial line, no protection is ordinarily provided at *substation high-voltage terminals*, with possible exception of a high-voltage fuse in combination with a switch. In cases where other independent loads are supplied over the same single radial line, however, the utility may call for an automatic switching device, a circuit breaker, at primary-substation high-voltage terminals. This protects incoming line against outage caused by faults in the industrial-plant system. Such a breaker is generally relayed by overcurrent units, coordinated so that it doesn't trip for faults that should be cleared by primary-feeder breakers or other protective devices in the industrial-plant system.

The high-voltage breaker can provide backup protection for faults on the plant system, and where transformer or bus differential *protection is used*, the breaker can be controlled by the differential relays.

When a high-voltage breaker is used in the primary substation, there is little justification for using a breaker in transformer secondary leads. Protection normally supplied by secondary breaker can be provided by high-voltage breaker, making one less step in relay coordination.

Secondary Substations. In simple-radial *systems, secondary* subs are protected in one of two ways. A main breaker can be used between stepdown transformer and secondary bus. If so, breaker permits not more than 2.5 times normal rate of current to the substation transformer. More usually, trip setting of this main breaker is closer to rated current of transformer, common trip setting being 1.25 times rated current.

In the second case, the main breaker is omitted, but sum of trip settings of low-voltage feeder breakers is less than 2.5 times rated transformer current Transformer thermal overcurrent protection can be supplied by some manufacturers.

NEC sets limits within which individual overcurrent protection on primary side of secondary-substation transformers can be omitted (1953 edition, Section 4512). *Basically, the Code* permits leaving out individual primary overcurrent protection when there is adequate secondary overload protection for the transformer. Also, when primary-feeder relaying can be said to detect faults in low-voltage side of the transformer. If you interpret the Code literally, it permits connecting only 5 identical transformers to the same primary feeder without use of individual overcurrent protection on the primary side of the transformers, when *transformer impedance is 6% or less*. If transformer impedance is between 6% and 10%, it is permissible to connect only three transformers of like size to the same primary feeder.

While the code requirement is generally accepted by power engineers today as being approximately correct at 6% and 10% transformer impedance, the regulation is unnecessarily restrictive for other values of impedance. In many cases today, the oversimplification of the Code rule imposes an economic penalty on the *industrial-plant* distribution system.

Breaker Coordination. Protection at load points must coordinate with breakers at supply end or low-voltage side of secondary substation. This coordination between protective elements depends mainly on the low-voltage-feeder breakers carrying current to supply several branch feeders. Even though ampere-time characteristics of two devices have dissimilar shapes, coordination is generally obtainable because of differences in normal current ratings.

When breakers operate up near point of maximum interrupting duty, opening times of both low-voltage-feeder and branch-circuit protection may be so nearly instantaneous that coordination is impossible. It is for this reason that various schemes have been worked up to provide selective tripping of such devices. For example: A definite time delay is often introduced into the opening of a low-voltage breaker at a high fault-current level to give branch-circuit device enough time to open if fault is in branch.

It was specifically this problem that resulted in recent development of more accurate adjustable series-trip elements for low-voltage air breakers. Since their entry into breaker field, it is usually easier to coordinate characteristics.

Tripping characteristics of a breaker necessarily form a band rather than a line. It's defined by a lower ampere-time value below which the breaker will reset and not trip, and an upper value representing maximum time required for breaker to open circuit for a given flow of current. Usually, if a ratio of 2:1 exists between tripping-current value of larger breaker and smaller, the smaller trips before larger breaker is unlatched.

Network Protection. In a secondary network system, main *substation breaker* is the *network* protector. This automatically opens only on reverse power flow. To get backup protection for network protector in case it fails to open, fuses are usually incorporated as part of the network protector. Three fuses generally provide overcurrent protection against currents greater than 2.5 times transformer rated current.

Network relay that trips protector is an induction-type 3-phase directional power relay. An overvoltage reclosing feature is generally incorporated in modern network relays to initiate automatic reclosing of protector when proper voltage supply is restored to secondary substation.

Secondary-Selective Systems. Coordination of tripping characteristics of low-voltage feeder breakers and those in transformer leads is exactly the same *as problem met in simple* radials. Exception may come when all load is carried by one transformer, as would be the case with a single-ended secondary unit substation.

When substation is operated with one transformer, an added breaker is often placed between main primary breaker and low-voltage feeder breakers. Then if bus-tie trips automatically on overcurrent you avoid difficulty of getting selective operation of main, bus-tie, and low-voltage-feeder breakers.

short-circuit currents theoretically possible at various voltages

short-circuit energy 3-phase kva	short-circuit amp per phase 15,000 v	2500 v	480 v	208 v
25,000	1000	5,800	31,000	70,000
50,000	2000	11,500	63,000	140,000
100,000	4000	23,000	125,000	280,000

Note: The above are calculated values discounting impedance that may be met in the typical plant system on secondaries of unit substations

This is modern metalclad switchgear:

An assembly of main units and auxiliary compartments with: (1) all parts enclosed in grounded metal (2) grounded *metal barriers* to isolate secondary controls and wiring from high-voltage primary devices, and primary units from each other (3) removable-type circuit breaker having self-coupling primary and secondary disconnecting contacts and a mechanism for moving it physically between connected and disconnected positions (4) interlocks for safe operation, proper sequence.