

There are three camps on this matter of neutral grounding. First, and growing, are those all for it. Second, there's a group against it. They cite better service continuity they feel is inherent in an ungrounded system. Third are engineers who have lived with an ungrounded system but are realizing the advantages of grounding. On a modernization program they'll stick to ungrounded neutrals but will leave the door open for a later switch by specifying Y-connected transformers.

Sound engineering plus solid field experience backs today's

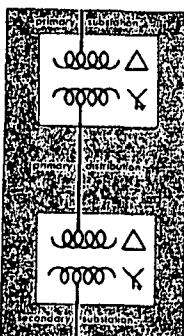
swing to neutral grounding. Most popular method grounds neutral of a Y-connected transformer or generator. Few ground corner or center of phase on 3-phase delta.

In the ungrounded camp there are those who diligently search out each ground as it occurs. They aim to keep the system completely free of accidental grounds. Others still take the shortsighted approach of keeping the system operating with one phase accidentally grounded. They depend on over-current protection to clear the circuit if another phase grounds; in effect, a phase-to-phase short.

If you ground neutrals:

- (1) Ground at each voltage level; only at source. (2) Leave no part ungrounded. Ground each major bus section if you can separate them. (3) Neutral grounding needs three over-current devices, one in each phase. (4) Most systems need only two overload relays for motor running protection whether or not it's neutral grounded. Some need three. Check this. (5) If primary voltage is between 2.4 and 13.8 kv, consider resistance grounding.

Grounded neutrals boost reliability, safety, equipment protection



On Y-grounded low-voltage systems, as on the secondary side of load-center unit substations, line-to-neutral calculated voltage is maximum met either in normal operation or with a ground on one phase. In ungrounded systems, two ungrounded phases are at line-to-line potential measured to third phase when it accidentally grounds. And first fault doesn't automatically clear. If fault occurs on another phase, there's a phase-to-phase short.

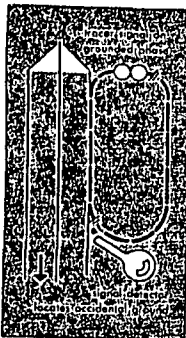
Operating Hazards. When different phases of an ungrounded system accidentally ground in near-by machines, a fire hazard may result. Current path between grounds can include greasy shavings or other material that could be ignited by localized heating or sparks. Impedance of path is high, so current flow may be enough to start a fire but won't blow fuses or trip breakers.

On ungrounded systems, "sputtering"

grounds can cause overvoltages. Circuit formed between system capacitance (mainly cables) and system inductive reactance builds up voltage between phases and ground to several times normal line-to-line. In cases on record such sputtering grounds led to multiple motor faults until located and cleared.

Overvoltages can stem from sources other than sputtering grounds — lightning, contact with higher system voltages, resonance in series inductive-capacitive circuits (POWER, Aug. 1952, pp. 90-92). But a grounded neutral will hold phase-to-neutral voltage constant. **Equipment Protection.** Grounded systems offer better equipment protection. Relays will detect grounds and clear circuit before arcing develops into phase-to-phase faults. On primary voltages of, say, 2.4 to 13.8 kv, resistance grounding is often used to hold down burning at ground point, reduce explosive effects.

If critical loads justify ungrounded operation, here's how you make the best of it



With so many arguments in favor of grounded neutrals, how do today's ungrounded systems manage? Two things are needed: (1) top-notch maintenance to keep circuit insulations in good shape (2) some practical method of quickly locating grounds before they develop into phase-to-phase faults.

That's just about the way many first-rate power engineers handle the problem. They fully realize disadvantages of an ungrounded system. But they believe that, because of critical nature of their loads, demand for continuous service justifies an ungrounded system. **Lamp-Detectors.** Where a simple lamp-detector is used on an ungrounded system it indicates only that a ground does or does not exist. If there is a ground it doesn't tell where. The only available way to find which branch circuit is causing the trouble is to trip the circuit breakers one after another until

the lamp-detector shows the fault is cleared.

This procedure, of course, isn't practical in a modern plant. In lieu of it we now have trouble-sniffing instruments that track down point of fault on an ungrounded system without shutting off power. See sketch, left. **Impulse-Detectors.** A modern ground-detector impulse unit clamps to ungrounded phases at the main bus. A signal current is superimposed on the grounded line all the way down to the trouble point. Then, with a sensitive induction-type impulse receiver, the signal is traced, even through metal-clad switchgear and conduit on the grounded line. The portable detector unit will even pick up an impulse as small as half an ampere. So it readily indicates the point at which signal leaves the power line and enters ground — the fault point. For details of this ground detection procedure, see POWER, May 1952, pp. 132, 133.

Voltages continue to climb. Power engineers and makers of equipment come closer to agreeing on "ideal" voltages, so we move toward lower levels. **Selecting Voltages.** Plant safety and local codes enter but three main factors are: load size, distance and equipment ratings. Bigger loads and longer distances point to higher voltages. And, of course, voltage ratings of using equipment must match feeds. Power engineers no longer consider 4.16 or 13.8 kv too dangerous to have around. Greater safety of to-

day's equipment, both in insulation and mechanical enclosure, makes high voltage nothing to fear. **Primary Voltage.** Here higher levels mean lower cost, greater flexibility and expansion margin. Savings increase as plants spread out and loads get bigger.

On the secondary side, apparent advantages of higher voltage point to making it as high as possible, up to limit of 600 v. Actually, 480 v is becoming the byword for new load areas because of ready availability of utilization equipment for it.

Higher voltage levels offer economies, flexibility for expansion

Each of many voltages available for primary distribution — 2.4, 4.16, 13.8 and 63 kv — has its place. But today's thinking points to two: 4.16 kv for plants having a supply transformer and/or generating capacity of 10,000 kva, or less, and 13.8 kv where there's a supply transformer and/or generating capacity of 20,000 kva, or more. So for range between, either of two voltages may be most economical. In choosing, don't forget your plant will probably grow. While 4.16 kv might possibly be slightly less expensive now, if plant should require sizable expansion 13.8 kv would be more economical.

2.4 or 4.16 kv? With all factors included — switchgear, motors, starters — costs generally favor 4.16 kv. In addition, there's greater allowance for expansion at 4.16. In small plants (say 2000 kva) differential may be small but in larger plants (up around 15,000 kva) saving

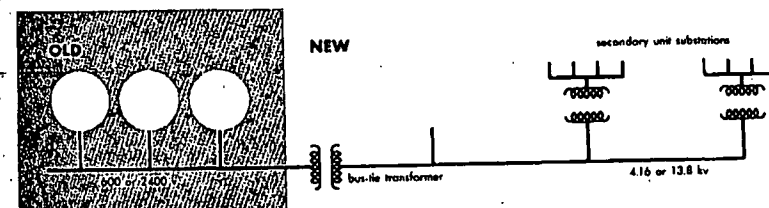
can be several dollars per kva for 4.16 kv. Feeder costs usually dip as voltage rises. Data for a modern armored high-voltage primary-feeder layout points to a saving of about \$1.00 per circuit kva per 1000 ft. for 4.16 over 2.4 kv. Operating at 13.8 offers an additional saving over 4.16 of about \$0.50 per circuit kva per 1000 ft., where individual circuit loads can be kept in the 3000-kva range. Cost of terminating may detract from economy of 13.8 kv if average length of runs is low and there are many small loads or substations per feeder. But more kva can be carried at higher voltage; fewer lines may be needed.

At 4.16 kv, switchgear for a given interrupting capacity costs less than at 2.4. And in a 4.16-kv system, if a 1200-amp breaker is needed, a more expensive 2000-amp job would be required in a 2.4-kv system.

What about expansion? Largest metal-

clad breaker for 2.4 kv is 150 mva maximum interrupting rating. For 4.16 kv, maximum is 250 mva. This allows a much larger system without synchronizing buses, current-limiting reactors, or other means of cutting fault current. **Secondary Voltages.** Today's practice puts spotlight on 480 v; forward-looking power engineers seldom find good reason for selecting 240 v. Coarsely, 240-v systems run higher than 480; heavier current means larger cable, breakers.

It used to be argued that 240 v is required for areas with heavy electric furnace loads. Today most large furnaces can operate directly from 480 v. Even though a sizable portion of load is at 240 v for small furnaces, it's seldom economical to adapt 240 for general distribution. Select 480 and step it down to 240 for specialized loads. Another point favoring 480 v is ease of getting 277 v for plant lighting (see pp. 122, 123).



In modernizing, present voltages needn't limit you, higher ones can be worked in

Electrical modernization plans may involve: (1) replacement of some unsafe or obsolete part of the system, with little or no expansion of capacity, or (2) expansion to boost capacity for growing loads. In either case, biggest gain can be made by changing to a load-center system and higher voltage. **Best Approach.** Start by laying out a complete ideal power system of type and voltage desired. Plan it as if you were building the entire plant new. Then see what modifications of the plan are needed to use serviceable existing equipment. From then on, every step should be based on the ideal plan. Too often, power engineers spoil good intentions by letting the existing setup influence future plans too greatly. This is

especially bad if the old system isn't right for plant conditions. **Higher Voltage.** Always check this when expanding or modernizing an existing system. Converting a low-voltage system to a higher voltage is a simple procedure. As sketch shows, it merely requires addition of a bus-tie transformer between the buses. Then expansion can be to higher voltage as if lower voltage system didn't exist. Old low-voltage and new high-voltage system can be tied in several other ways.

Many plants using a 2.4-kv system are facing expansion, yet want to hold onto 2.4 already installed. This can be done by working in a 13.8-kv system to serve new loads and also areas of 2.4 kv through appropriate transformers.