Protect Your Primary Power Lines

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INTRODUCTION

The intent of the authors of this paper is to present ideas, methods and recommendations that will assist in minimizing outage time due to power failures created by faults on power lines. Production is a term understood by all employees of a company. If this paper will help improve production records, then it is well worth the time spent on it.

COOPERATION AND COORDINATION

It is an established practice that each oil company owns its own power lines and the equipment on these lines. The power supplier furnishes a point of service to the oil company. It is from this point of service to the extremities of the oil company lines that this paper will attempt to cover. An assumption is made that the protective equipment of the power supplier is adequate in capability and is coordinated to offer maximum protection and continuity of service to the point where the oil company takes over. From the point of service to the extremities of the oil company lines, it is necessary that the protective equipment be coordinated with that of the supplier. This is a two-way street in which the customer and the supplier must work closely together. If either fails to do his part, there is a loss of production for both.

POWER LINES

There are many ways to design power lines that will transport power from the point of service to the point where it is to be used. No attempt will be made to tell how power lines should be designed and constructed specifically; there are many pole line suppliers and cable manufacturers that have various designs and specifications from which to choose. There are many consulting firms and contractors capable of designing and constructing lines to any desired degree of quality. The best insurance against a loss of production is a well-designed and well-constructed power line. Adequate phase spacing, shielding, proper conductor size, proper pole spacing, a multi-grounded neutral and many other specifications go into the quality of the line. The better the quality of the line, the less protective equipment needed. High winds, lightning and objects coming into contact with lines all contribute to any outages that may occur. Visual inspection, preventive maintenance, quality checking of construction and proper training of personnel lend much to upgrading production records.

FAULT

"Fault" is the common terminology used by the power industry to describe the cause of interruption of power. In general the fault falls into four classifications:

1. Phase-to-ground
2. Double phase-to-ground
3. Phase-to-phase
4. Three-phase

In simple terms, the fault is the shorting out of a circuit to ground or another phase.

Based on experience of the power industry, approximately 95 per cent of the faults on the lines are temporary; of these, 90 per cent are phase-to-ground. This should be kept in mind when designing power lines and selecting protective equipment.

FAULT CURRENT

Each of the type faults described in the previous section produces a corresponding fault current:

1. Phase-to-ground
2. Double phase-to-ground
3. Phase-to-phase
4. Three-phase

The phase-to-ground and the three-phase fault currents are the ones that are normally taken into consideration when calculating fault currents at various points in the system. In general the maximum and minimum fault currents are three-phase and the phase-to-ground. (Near a substation or source of power, the phase-to-ground and the three-phase fault are approximately equal.) The three-phase fault can be calculated to a high degree of accuracy anywhere along the system. However, the minimum fault involving phase-to-ground may vary greatly depending upon the type soil and whether it is wet or dry. At best, phase-to-ground faults are quite difficult to predict with any degree of accuracy. A system neutral that is multigrounded improves the predictability of the minimum fault current in that it gives a far better path of return to the protective equipment.

The purpose of mentioning fault currents is that this is highly important in the selection of protective equipment. One must be certain that the equipment selected can withstand the fault currents imposed upon it. If it is an interrupting device, it must be capable of interrupting the fault current at the point it is in service. The type of system, system voltage and load current must also be considered. It is always advisable to ask the power supplier the maximum and minimum fault currents available at the point of service. Also determine if the supplier has plans to upgrade his system in the area to the extent that fault duty capability of equipment would need to be upgraded.

PROTECTIVE DEVICES

Fuse

The fuse is a protective device that has been used for a long time. In many applications such as distribution transformer and capacitor bank application it works quite well because of its time-current characteristics; however, it should be pointed out that the time current characteristics are not definite as shown in Fig. 1. For example, a 100-amp fault on a 60N fuse would start melting at 15 seconds, but would not clear until 90 seconds. At 1000-amp fault current, the minimum melt time is .045 second and total clearing time is .08 second. The higher the current, the faster the fuse blows. There are many reasons why one might not want to use the fuse for protection of oilfield primary lines. The two most common reasons are:

1. It is a one-operation device which cannot restore service automatically.
2. It permits single-phasing of the primary line.

Sectionalizer

The sectionalizer is a protective device that automatically isolates faulted sections of line from the distribution system when used in conjunction with a reclosing device protecting the main feeder line. The sectionalizer should not be confused with the Oil Circuit Recloser or OCR that will be taken up in the next section. It is not a fault current interrupting device. It simply counts the number of times the fault current passes through it as the back-up device on the main feeder operates. At a preset number of counts, it opens while the back-up device is open and isolates that faulted section of line from the main feeder. It must be set at less counts than the back-up device. Example: If the back-up device operates four times to lockout, the sectionalizer would be set for three counts. After the third operation of the back-up device, the sectionalizer would open. The back-up device would reclose and the rest of the system would be restored to normal. The sectionalizer opens all three phases simultaneously. It requires no new element and is closed with a hook stick when the fault has been cleared. It is a device that may be used in the place of fuses quite effectively when used properly. It can normally control two to three miles of line. The sectionalizer is a 200-amp device that can control currents from 5 amps to 200 amps based on coil ampere rating. It may be used as a load break oil switch within its load rating.

Oil Circuit Recloser Or OCR

The OCR is a protective device that can distinguish between permanent and temporary faults. It will give temporary faults repeated opportunities to clear or let some protective device down the line clear the fault. If the fault is permanent, the OCR locks open. Oil circuit reclosers are hydraulically or electronically controlled, depending on the type selected. The OCR lends itself well to coordination with other protective equipment such as sectionalizers and fuses down line or another OCR or an oil circuit breaker up the line. The electronic OCR is more versatile in that it has numerous time current curves from which to choose for coordination. It also has the advantage of a far more simple means of changing its protective rating and operating sequence. The hydraulic OCR must be taken down untanked and its coils replaced to change its protective rating. Its sequence of operation is more difficult and time-consuming to change. The electronic OCR's rating is changed by changing out plug-in resistors in the control panel. Its sequence of operations is changed by simply setting a dial. Its time current curve is changed by changing out a plug in the control panel. Either the hydraulic or the electronic OCR is a fine piece of protective equipment when sized and applied properly.

Each of the types of OCR's described above can be equipped with a ground trip device to sense line-to-ground faults that may not be seen by phase trip sensing. The ground trip device is set at a lower value of current than the phase trip due to the lesser magnitude of phase to ground current. As pointed out previously, phase-to-ground fault currents are unpredictable with any degree of accuracy. The ground trip device is another means of having a better opportunity of detecting this type of fault.

The ground trip device works off the current in the neutral. If the current in all three phases is balanced, there is no neutral current. Should one phase current increase due to a fault-to-ground, the system is unbalanced. Under these conditions, the ground trip device senses the unbalance, opens the OCR and clears the fault. The sectionalizer may be coordinated with the OCR in the following manner:

For hydraulic OCR's, match the coil rating of the sectionalizer to the coil rating of the OCR.

For electronic OCR's, match the sectionalizer to the continuous load current of the OCR.

PROPER USAGE OF PROTECTIVE DEVICES

In addition to the fault duty capability, system voltage and etc. mentioned earlier, one must take into consideration two other important conditions:

1. Normal load current
2. Cold load pick up

The first condition is quite easily handled since it involves merely matching the protective device to the load you wish to carry plus a little room for load growth.

The second condition is more complicated and more frustrating if handled improperly. It involves two problems:

1. Transformer inrush current
2. Motor inrush current

The first problem can be controlled by breaking the total system into smaller increments so that the transformer inrush current will not trip out the protective device. The duration of transformer inrush is from 6 to 13 cycles. The magnitide of the current can vary considerably depending on what part of the cycle the line is picked up. Line impedance, transformer impedance, capacitors and other factors can influence the magnitude of the current. According to information available and actual field tests made by authors, the currents involved can vary from 0 to 12 times the full load high side current of the transformer bank. Test experience in one particular field indicated approximately five times transformer full load current. The highest peak of the current occurs in the first few cycles and drops off rapidly. One can readily see that this becomes a severe problem when trying to pick up too much of the total transformer connected load at one time.

The second condition can be controlled to a high degree very simply by sequence starting of motors. In most cases, motor control circuits have timers that permit delay in starting of various motors or groups of motors. By sequence starting 10 per cent of the total load at ten second intervals, the protective equipment rating should not be exceeded at any time. This allows all equipment to be restored to normal within two minutes of a momentary interruption, reducing the possibility of having the protective equipment open again unnecessarily. Many times, an operation due to cold load inrush is misinterpreted as a fault somewhere out on the line.

TYPICAL OIL LEASE PROTECTION

Two proposals for oil lease protection are outlined below. Figures 2 and 3 show the power line schematic and time-current curves for Proposal I. Similarly, Figs. 4 and 5 show the same information for Proposal II.

Proposal I

Power supplier is to install a 400-amp Type RE electronic OCR with 400-amp phase trip and 200-amp ground trip. Phase and ground trip sequence of operation is to be one instantaneous operation for lightning and other momentary faults and three time delay operation for permanent faults and coordination.

Oil company to install two 400-amp hydraulically operated Type R OCR's with 100-amp coils, 200-amp trip. One OCR to look at main feeder line of east portion of the lease and the other OCR to look at main feeder of west portion of lease. Both OCR's set on time delay curve C-4 trip operations to lockout.

Eight 200-amp three-phase sectionalizers with 140-amp coils, 225-amp pick up and set for three counts to lockout. Each sectionalizer to be placed in a branch feed off the main #2ACSR east-west feeder as shown in Fig. 3. (Note: The coil rating of the above sectionalizers is one rating above normally recommended matching of OCR coils. This was checked out with the manufacturer and was recommended to permit a little higher inrush current without sectionalizer counting. *Never* size sectionalizer coil below OCR coil rating.)

Condition 1. Permanent three-phase fault at X in SW Corner of lease.

1. Power supplier OCR trips once on instantaneous trip and recloses in ½ second or 30 cycles.
2. Sectionalizer 1 will make one count.
3. Oil company west OCR will trip two times.
4. Sectionalizer 1 will count two more times and lock out while west OCR is open on its second shot.

Sectionalizers 2 and 3 not likely to count if motors are sequence started.

Condition 2. Temporary phase-to-phase fault caused by lightning or phases getting together.

1. Power supplier OCR trips out on instantaneous one time, recloses and resets.
2. Sectionalizer 1 counts one time and resets.

Condition 3. Permanent phase-to-ground fault. Again this is indefinite depending on soil conditions, but assuming that the fault current is of proper magnitude, the following sequence of events takes place:

1. Power supplier OCR trips on ground trip instantaneous and resets.
2. Sectionalizer 1 counts one time.
3. West OCR operates two times on time curve and resets.
4. Sectionalizer 1 counts two more times to lock out.

If the magnitude of the fault current is too small to trip any protective device, the line will eventually burn in the clear, maybe. It is highly possible for a phase to lie on the ground in this area, crystallize the sand, insulate itself and remain on the ground indefinitely without tripping any protective device.

Condition 4. Temporary phase-to-ground fault.

1. Power supplier OCR trips on ground trip instantaneous one time and resets.
2. Sectionalizer 1 counts one time and resets.

Condition 5. Permanent phase-to-phase or three-phase fault on West #ACSR feeder.

1. Power supplier OCR trips one time on instantaneous phase trip.
2. West OCR trips four times to lockout.

Condition 6. Permanent or temporary phase-to-ground fault on West #2ACSR feeder.

Same result as in conditions 3 or 4 but more reliable since the fault is closer to the protecting OCR's. A multigrounded neutral would improve the dependability of protective devices on phase-to-ground faults.

Proposal II

Power supplier to install a 400-amp Type RE OCR with 340-amp phase trip and 140-amp ground trip. One instantaneous shot on ground and phase 3 time shots on ground and phase.

Oil company to install eight 400-amp hydraulically operated Type R OCR's with 50 or 70-amp coils as shown on Fig. 4. Three time shots to lockout. This proposal is more desirable since it permits better coordination and protection to various parts of the lease. Each OCR has a time current characteristic that permits it to sense a fault current and act accordingly. The oil company OCR is far less likely to trip out on transformer inrush current due to its time current characteristics which would permit the current to go to a relatively high value and drop off before the OCR would trip. On temporary phase or ground faults, only the power supplier OCR would trip on instantaneous on phase or ground trip. On permanent phase-to-ground faults, if the fault current is of sufficient magnitude, the power supplier OCR would trip one time on ground trip, one time on phase trip and then the oil company OCR would take that section of line out on phase trip.

Any temporary fault on the east-west feeder would operate the power supplier OCR only. A permanent fault would lock out the power supplier OCR and shut the entire lease down until the fault could be cleared. Proposal I is the least expensive, but in turn, it does not offer the protection that Proposal II does. Proposal II could be improved even more with OCRs in main east-west feeder.

The reader should realize that there are many more possible arrangements and combinations of protection than offered in Proposals I or II. Each oil lease has its own problems and should be studied individually.

SUMMARY

As pointed out, there are numerous aspects to primary line protection; this paper does not cover every possibility. The key to a better production record is:

1. Good primary lines
2. Proper protective devices and proper usage
3. Break areas to be protected into smaller units
4. Sequence start motors
5. Close coordination between the power supplier and the oil company.

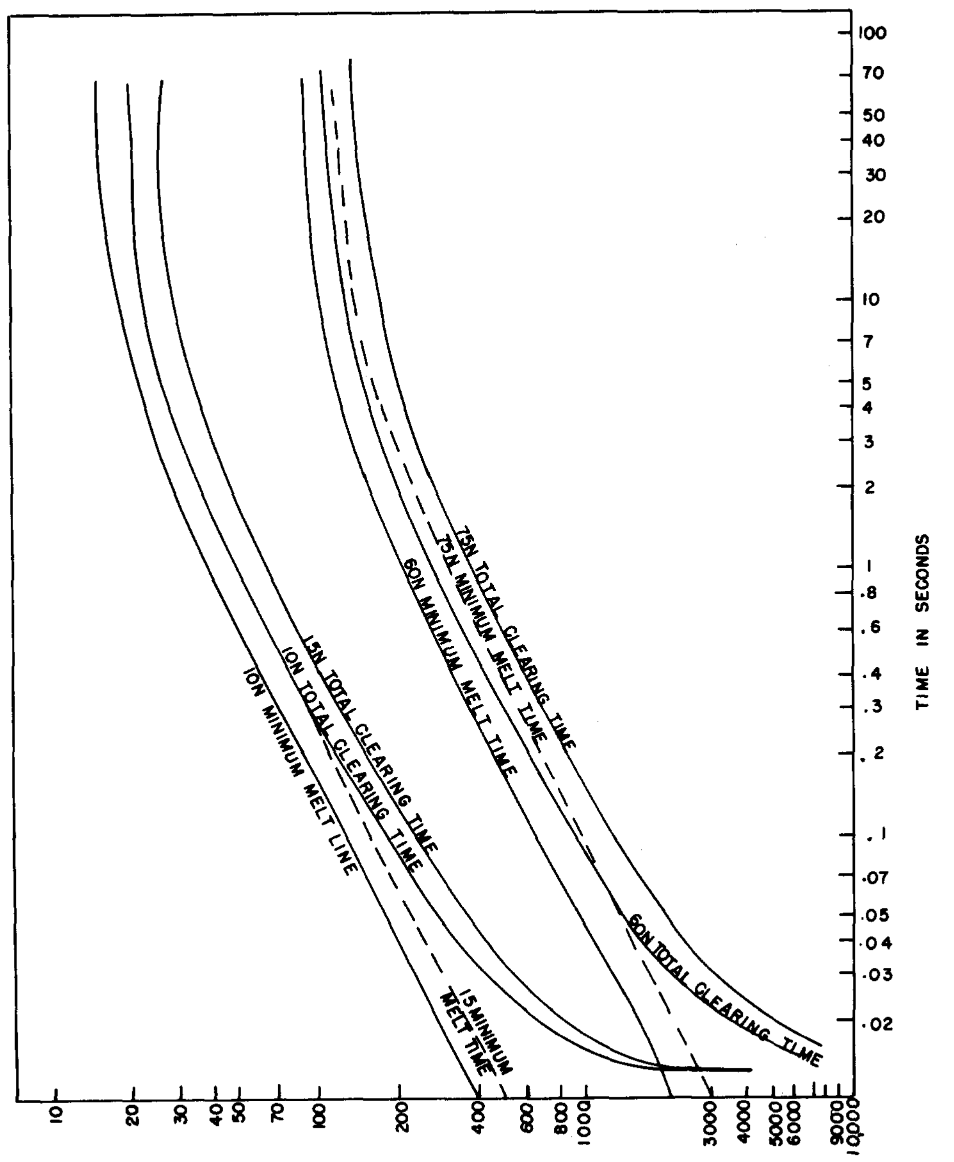


FIGURE 1

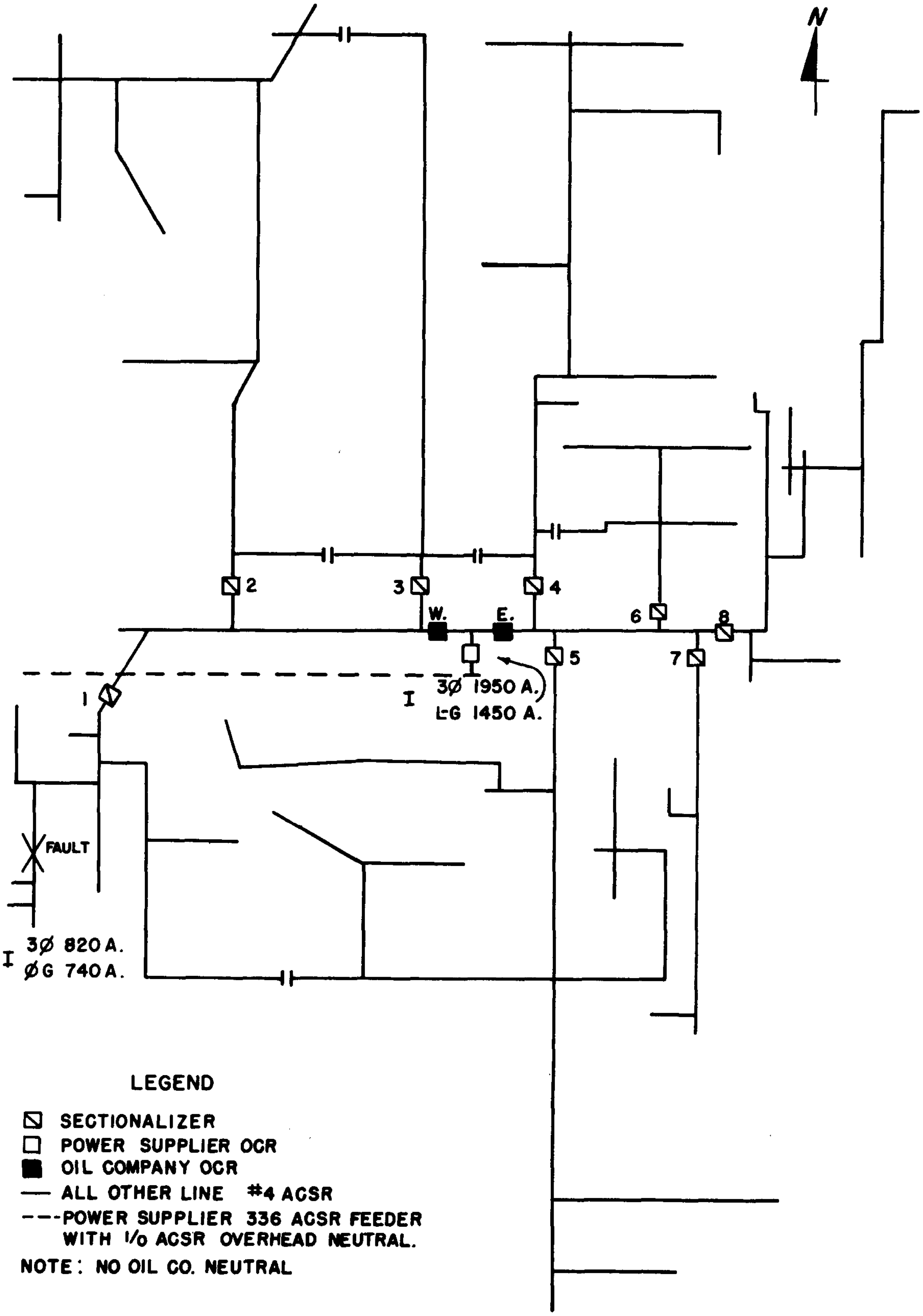
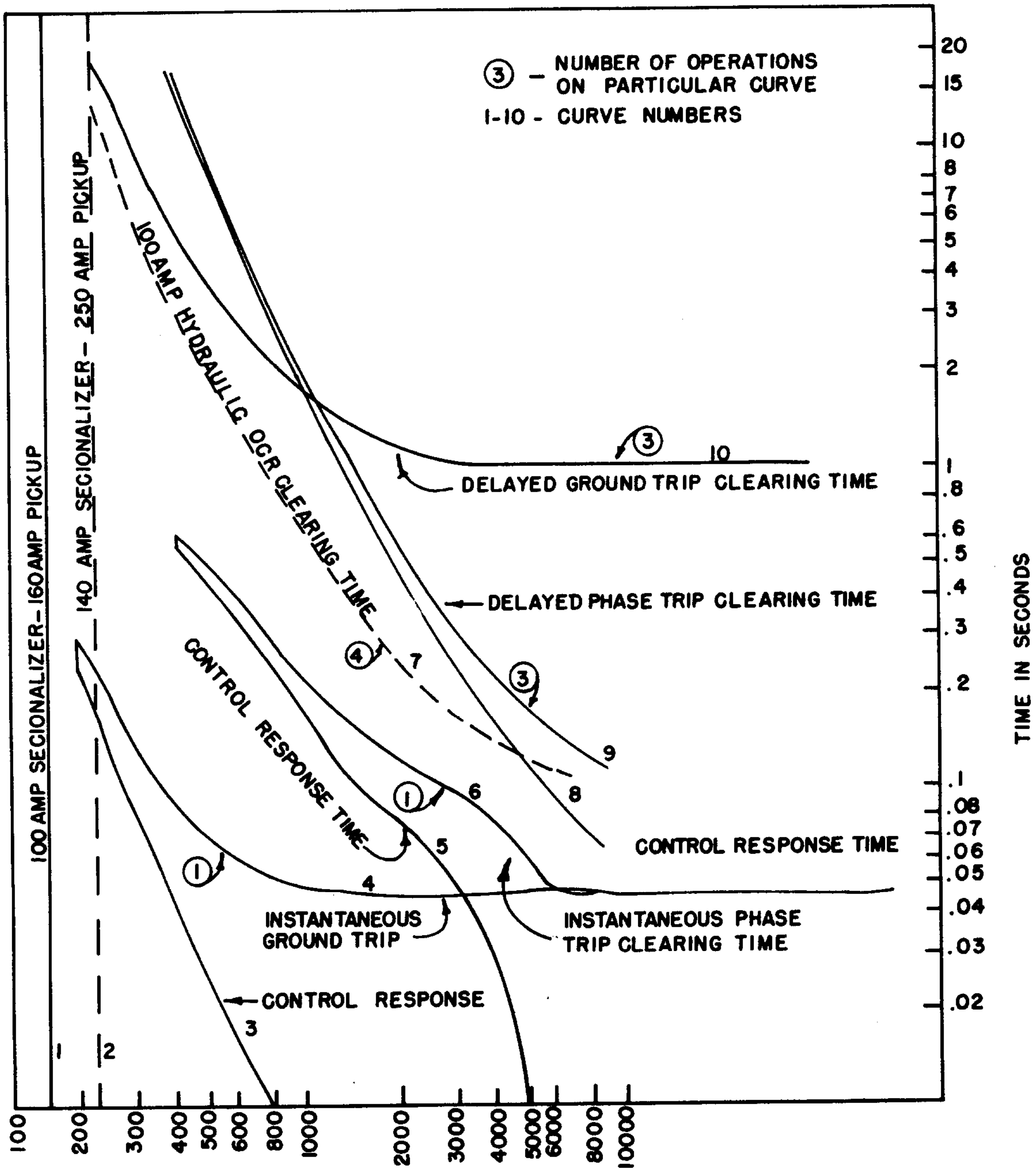

N
W.
E.
2
3
4
5
6
7
8
1
3Ø 1950 A.
L-G 1450 A.
I
FAULT
I
3Ø 820 A.
ØG 740 A.
LEGEND
SECTIONALIZER
POWER SUPPLIER OCR
OIL COMPANY OCR
— ALL OTHER LINE #4 ACSR
---POWER SUPPLIER 336 ACSR FEEDER
WITH 1/0 ACSR OVERHEAD NEUTRAL.
NOTE: NO OIL CO. NEUTRAL

FIGURE 2

FIGURE 3



EXPLANATION OF FIG. 3 CURVES

SECTIONALIZER CURVES

1 100 amp coil - 160 amp pickup
2 140 amp coil - 225 amp pickup

ELECTRONIC OCR CURVES

3 Instantaneous ground trip control response time
4 Instantaneous ground trip recloser clearing time
5 Instantaneous phase trip control response time
6 Instantaneous phase trip recloser clearing time
8 Delayed phase trip control response time
9 Delayed phase trip recloser clearing time
10 Delayed ground trip recloser clearing time

HYDRAULIC OCR

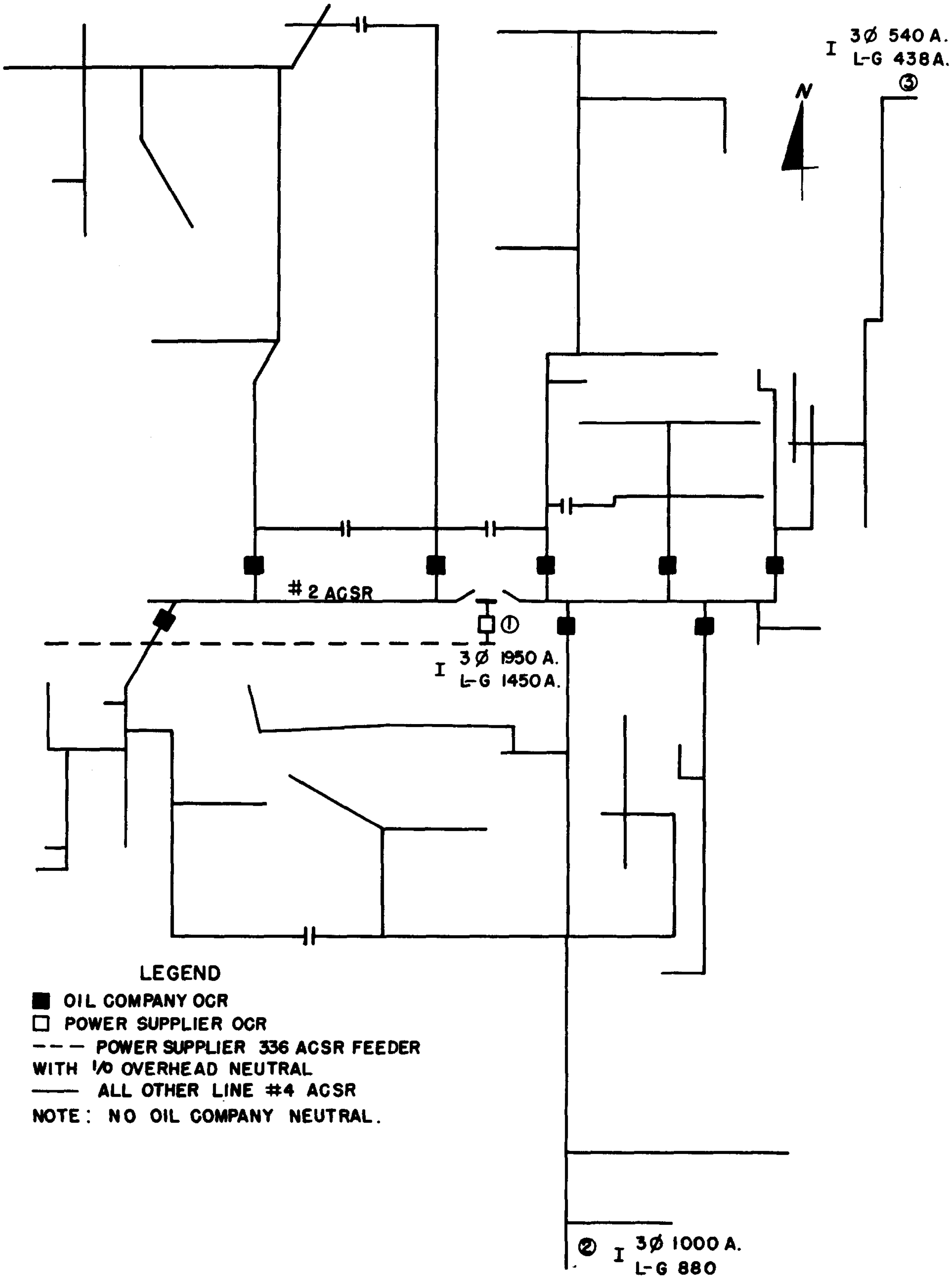
7 Delayed phase trip recloser clearing time

ELECTRONIC OCR

Ground trip 1 instantaneous and 3 delayed shots to lockout
Phase trip 1 instantaneous and 3 delayed shots to lockout

HYDRAULIC OCR

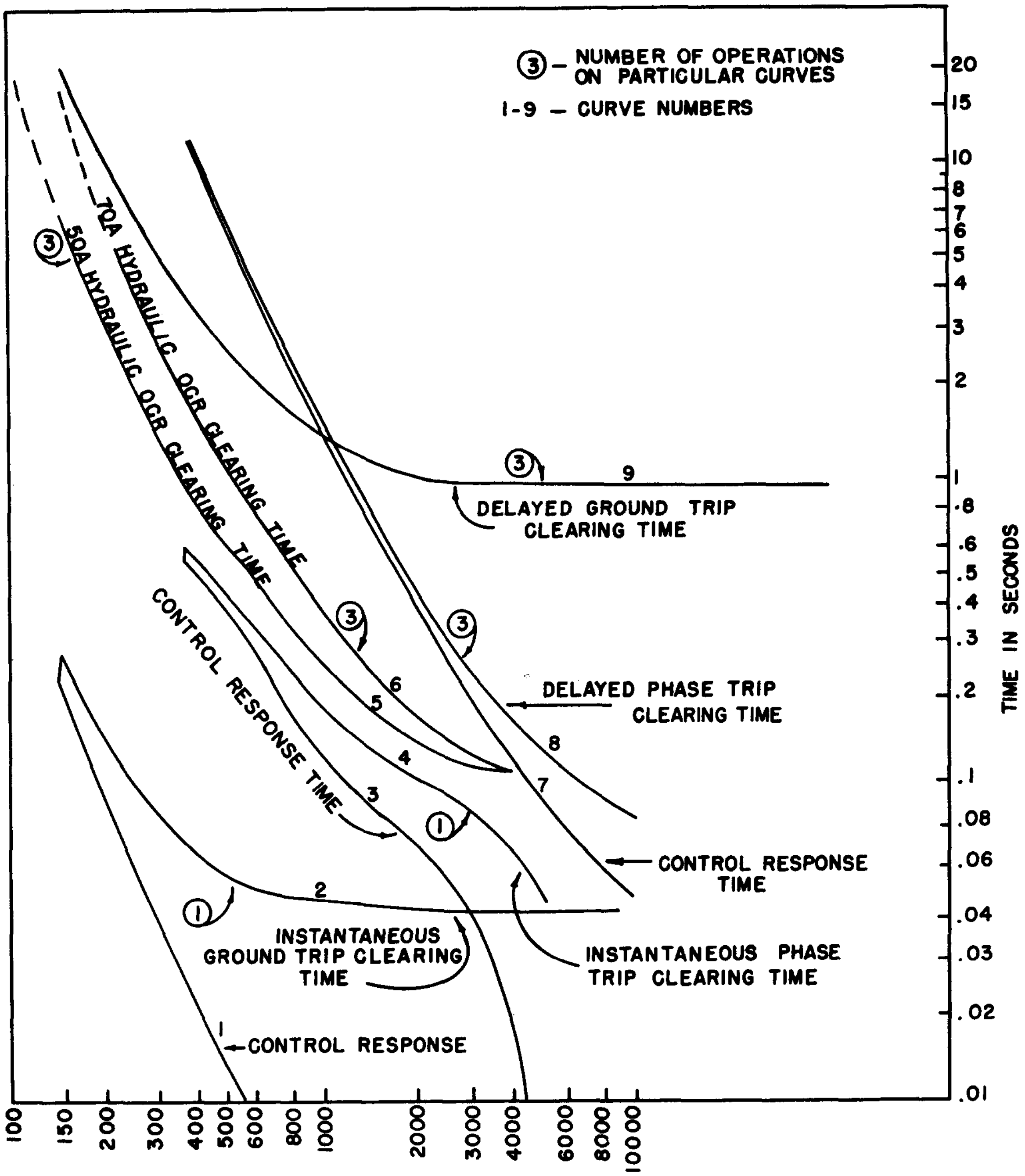
Phase trip 4 delayed shots to lockout
100 amp coil
Sectionalizer 3 counts to lockout



I 3Ø 540 A.
L-G 438A.
③
N
2 ACSR
①
I 3Ø 1950 A.
L-G 1450 A.
② I 3Ø 1000 A.
L-G 880
LEGEND
■ OIL COMPANY OCR
□ POWER SUPPLIER OCR
--- POWER SUPPLIER 336 ACSR FEEDER WITH 1/0 OVERHEAD NEUTRAL
—— ALL OTHER LINE #4 ACSR
NOTE: NO OIL COMPANY NEUTRAL.

FIGURE 4

FIGURE 5



EXPLANATION OF FIG. 5 CURVES

ELECTRONIC OCR

1 Instantaneous ground trip control response time
2 Instantaneous ground trip recloser clearing time
3 Instantaneous phase trip control response time
4 Instantaneous phase trip recloser clearing time
7 Delayed phase trip control response time
8 Delayed phase trip recloser clearing time
9 Delayed ground trip recloser clearing time

HYDRAULIC OCR

5 Delayed phase trip recloser clearing time 50 amp
6 Delayed phase trip recloser clearing time 70 amp

ELECTRONIC OCR

Ground trip 1 instantaneous and 3 delayed shots to lockout
Phase trip 1 instantaneous and 3 delayed shots to lockout
Hydraulic OCR's 50 and 70 amp coils, 3 delayed shots to lockout