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An American National Standard

IEEE Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers

Sponsor

IEEE Reclosers and Sectionalizers Subcommittee
NEMA Automatic Circuit Recloser Technical Committee

Secretariat

Edison Electric Institute
Institute of Electrical and Electronics Engineers
National Electrical Manufacturers Association

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Foreword

(This Foreword is not a part of American National Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers, C37.61-1973, IEEE Std 321-1973.)

This is a new standard developed to provide information on the selection, application, operation and maintenance of automatic circuit reclosers. It represents current practice on this product in the United States.

The preparation of this standard was the cooperative work of the IEEE Switchgear Committee (Reclosers and Sectionalizers Subcommittee), which prepared this standard, and the NEMA Switchgear Section (SG-13 Automatic Circuit Recloser Technical Committee), and the C37 Subcommittee on Automatic Circuit Reclosers and Line Sectionalizers, which reviewed and approved the document.

Upon recommendation of this latter subcommittee, the proposed American National Standard was voted on by Standards Committee C37 on Power Switchgear, and subsequently approved as an American National Standard.

Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the American National Standards Institute, Inc, 1430 Broadway, New York, N. Y. 10018.

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CLAUSE PAGE

An American National Standard

IEEE Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers

1. Scope

This application guide provides information on the selection, application, operation, and maintenance of single or multi-pole alternating-current automatic circuit reclosers. The guide is for use in conjunction with American National Standard Requirements for Automatic Circuit Reclosers for AC Systems, C37.60-1968, and Supplement C37.60a-1971. The definitions in American National Standard C37.60-1968 apply to this guide.

2. Purpose

This application guide was developed to identify the principle characteristics of reclosers, indicate the system information needed, and give step-by-step procedures used to select reclosers for specific applications.

3. General

Due to the wide variety of operating conditions, many different application and maintenance procedures are employed by users. This guide does not attempt to present all of these and is necessarily limited in scope. Where there are several acceptable procedures, as in the selection of recloser operating sequences, commonly used alternatives are described, with a discussion of their relative advantages. It assumes that the user of this guide will have some experience with fault current calculation procedures and with the application of fuse or relay-controlled circuit breakers to electric power systems. For the user lacking this experience, a list of selected references is included in Section 7.. Sample problems illustrate the procedure followed in selecting single-phase and three-phase reclosers, and in providing coordination with other protective devices in the circuit. Additional information on recloser ratings and the selection of recloser operating sequences is provided in Appendix A.

Section 5, Operation, recommends that operating checks be made on reclosers at the time of installation, and after operation, and discusses the problems associated with reenergizing a circuit which is protected by a recloser.

Section 6, Maintenance, covers the recommended frequency of maintenance, and maintenance procedures. A procedure to determine maintenance according to the number of recloser operations is described in Appendix B.

About 90 percent of all faults on overhead distribution lines are temporary faults caused by lightning, conductor slap, or by animal or tree contact. Early efforts to improve the reliability of service on distribution circuits led to the development of the repeater fuse. With this arrangement, if a fuse were blown, a second and, if necessary, a third fuse, would automatically be inserted into the circuit. Since most faults were temporary in nature, service was usually restored automatically by the replacement fuse, and long service interruptions were avoided.

The success of the repeater fuse led to the development of the automatic circuit recloser, a self-controlled interrupting device which senses fault currents and proceeds through a predetermined sequence of opening and reclosing operations, followed by resetting, hold-closed or lockout. Early reclosers were single-phase, oil-filled, series-trip devices in which main circuit current above a specified value, flowing through a solenoid or operating coil, provided the energy required to open the main contacts.

The first reclosers had relatively low continuous and interrupting current ratings. With load growth, higher continuous and interrupting current ratings have been developed. Modern reclosers are manufactured in single-phase and in three-phase units with mechanical or electronic control. Interruption may be in oil or in a vacuum. Reclosers having higher current ratings may be shunt trip actuated, with operating energy for tripping and contact opening being obtained apart from the main circuit.

4. Application

4.1 Recloser Characteristics

A knowledge of recloser characteristics and standard ratings is a prerequisite to their proper application. The characteristics of importance in application are:

1) Voltage rating
2) Continuous current rating
3) Interrupting current rating
4) Minimum tripping current
5) Operating or time-current characteristic
6) Operating sequence
7) Reclosing interval
8) Reset time

A discussion of recloser characteristics is given in Appendix A. Manufacturers' catalogs provide information on available recloser models, their individual characteristics and optional accessory equipment. Standard ratings and requirements for reclosers are specified in American National Standard C37.60-1968 and Supplement C37.60a-1971.

4.2 Information Needed for Recloser Application

The minimal information given below is needed for recloser selection.

4.2.1

System data and circuit map showing:

1) System voltage
2) System grounding
3) System impulse insulation requirements
4) Tentative recloser location
5) Location of other sectionalizing devices
6) Maximum and minimum fault currents at each sectionalizing device location
7) *X*/*R* ratio at point of application

8) Minimum fault current[1] at end of each circuit or at end of recloser zone of protection
9) Location of major or critical loads and whether they are single- or three-phase

4.2.2

Manufacturers' data on available reclosers:

1) Time-current characteristic (TCC) curves
2) Operating sequence and control
3) Current and voltage ratings
4) Optional accessories

4.2.3

Data on other sectionalizing devices with which the recloser must coordinate:

1) Size or current rating
2) Time-current characteristic (TCC) curves

4.3 Selecting the Recloser

In selecting a recloser it is assumed that the operating sequence will be predetermined by system practice or by the characteristics of other sectionalizing devices with which the recloser must coordinate.

See Tables 2 and 3 of American National Standard Supplement C37.60a-1971. Note that reclosers are classified by "line numbers." This terminology will be used herein to identify or refer to various classes of reclosers.

The following steps are to be followed in selecting a recloser:

Step 1: From Table 2 of American National Standard Supplement C37.60a-1971, identify all recloser line numbers acceptable for the circuit voltage.

1) Line 1 reclosers may be used on circuits of 2.4—15 kV
2) Line 2—8, inclusive, reclosers may be used on circuits of 2.4—15.5 kV
3) Line 9—12, inclusive, reclosers may be used on circuits of 15.5—27 kV
4) Line 13 reclosers may be used on circuits of 27—38 kV
5) Line 14 reclosers may be used on circuits of 38—48.3 kV
6) Line 15 reclosers may be used on circuits of 48.3—72.5 kV

The remaining steps of this procedure assume the use of line reclosers that satisfy this voltage criteria.

Step 2: Determine maximum load current (allowing for some load growth) at the recloser location. From the recloser line numbers of Step 1, note from Table 3 of American National Standard Supplement C37.60a-1971 those that have continuous current rating equal to or greater than the maximum load current.

Step 3: Determine the maximum symmetrical fault current at the recloser location. (Allowing for future increase in fault current.)

[1]See Sample Problems 1 and 2 for typical methods of determining minimum fault current, and Sample Problem 3 for an alternative method of determining the end of the zone of protection.

From the recloser line numbers meeting the conditions of Steps 1 and 2, identify all those that have an interrupting current rating greater than the maximum fault current. Use the applicable part of Table 3 of American National Standard Supplement C37.60a-1971.

Step 4: Determine the minimum fault current at the end of the zone protected by the recloser.

From the recloser line numbers of Step 3, identify all those with minimum tripping currents less than the minimum fault current.

Refer to Table 3 of American National Standard Supplement C37.60a-1971 which gives minimum trip settings for nonseries coil reclosers. For series coil reclosers, double the continuous current ratings of Table 3 of American National Standard Supplement C37.60a-1971 to obtain the minimum tripping current.

NOTE — Some series coil reclosers are available with nonstandard series coils having a minimum trip value less than 200 percent of the continuous current rating.

An alternative method is to define the end of the zone of protection of a recloser as that point on a circuit having a maximum line to ground fault value of some multiple at least 1.5 times of the recloser minimum pickup current, to ensure that the minimum fault current will be greater than the minimum tripping current.

In the event that no recloser under Steps 2, 3, and 4 can meet this requirement for minimum tripping or pickup, a three-phase recloser with a ground trip auxiliary device may be used effectively on a grounded system. These auxiliaries are available and can detect minimum fault currents of a few amperes. Ground fault sensitivity is limited by the fact that there is load connected from line to neutral, causing some current to flow in the neutral, under normal load conditions.

Step 5: From the recloser line numbers and continuous current ratings that meet the preceding requirements, select those that will coordinate with other devices on the circuit, and coordinate with the damage time current characteristics of circuit elements to be protected.

Device-to-device coordination is done by a comparison of time-current characteristic (TCC) curves, operating sequences, and reset times of the qualifying reclosers with the protective characteristics of other sectionalizing devices on the circuit. Occasionally it may be necessary to change the size, settings, or locations of the other sectionalizing devices where coordination is not obtained with a recloser that is otherwise suitable.

To ensure that circuit elements are adequately protected from exposure to overcurrent, the summation of the clearing times of the TCC of the qualifying recloser should be compared with the damage TCC of the circuit elements, such as switches and conductors, to be protected. This is to ensure that deenergization will occur before damage to the circuit elements takes place.

Step 6: At this point, it is likely that several line number reclosers will meet all the required conditions.

In this case, consider the following in selecting a particular line number:

1) System standards and inventory practices may call for the use of only one recloser line number that will be suitable anywhere on the system within voltage limitations.
2) To minimize investment, the lowest cost recloser line number that qualifies may be the deciding factor.
3) System practice with respect to the use of three-phase or single-phase reclosers may be the deciding factor.
4) Desired flexibility of the recloser control may dictate the use of a particular line number.

Step 7: It is also likely that several continuous current ratings (series coil only) of a given line number may meet all requirements.

The selection will be influenced by the following considerations:

1) The larger rating permits more load growth and will be less sensitive to lockout on inrush and cold-load pickup currents.
2) The smaller rating will be more sensitive in the detection of fault currents below the calculated minimum.

Step 8: After the recloser line number and continuous current rating have been determined, refer to the manufacturer's catalog for the model that corresponds to the selected rating.

Information on optional equipment and accessories can be obtained in the catalog for the specific recloser selected.

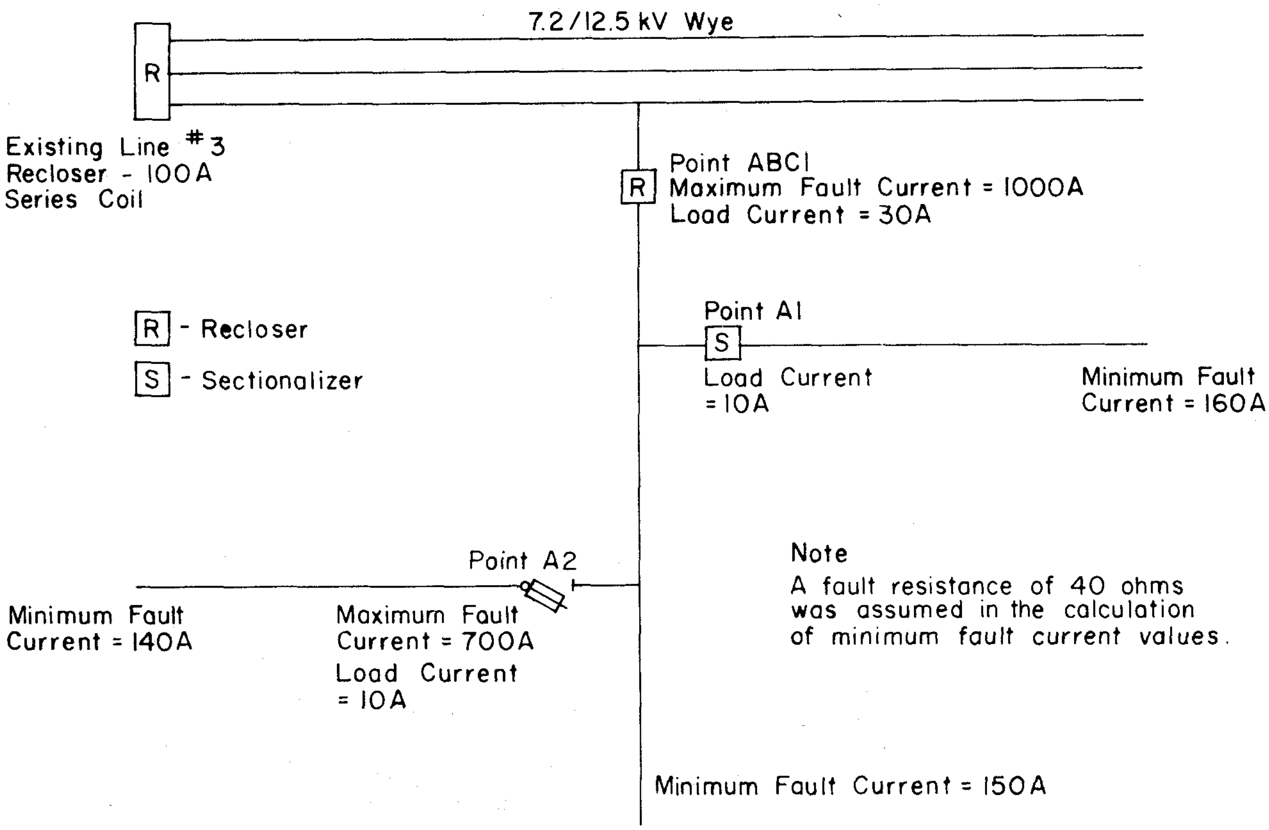

Figure 1— Circuit for Sample Problem 1

4.3.1 *Sample Problem 1*

Select a recloser for use at Point ABC1, given the data in Fig 1.

Solution: The load current and available fault current at Point ABC1 permits the use of a single-phase series coil recloser. Referring to Table 3 of American National Standard Supplement C37.60a-1971, continuous current rating must be at least 35 A, but for load growth a 50 A, or even a 70 A, rating should be considered. Checking the interrupting rating for these sizes shows that a 50 A Line 1 recloser or 35, 50, or 70 A Line 2, 3, and 4 reclosers would meet the interrupting requirements. The minimum calculated fault current of 140 A at the end of the zone of protection based on an assumed fault resistance of 40 Ω should be detected by any of the foregoing coil sizes of 35, 50, or 70 A. Detection of the minimum fault by the 70 A recloser (140 A ± 10 percent pickup) would, however, be marginal and therefore this recloser size probably would not be considered. To determine whether these various reclosers will coordinate with the substation recloser, the TCC curves may be compared as shown in Fig 2. In practice, it is often assumed that a lower continuous current rated series coil recloser will coordinate with a larger continuous current rating series coil recloser, particularly if they are of the same make. This is not true for certain older reclosers. Also, at locations where the fault current is high relative to the recloser ratings, the separation of adjacent rated recloser TCC curves may not provide positive coordination.

In such cases, it is advisable not to use adjacent coil ratings. Until experience is gained with the various recloser characteristics, it is advisable to compare TCC curves.

Since Fig 2 shows that coordination will be obtained with any of the possible reclosers, the selection must be based on the considerations discussed earlier. For this example, it is most probable that the 50 A Line 1 recloser would be selected since it meets all requirements adequately and has the lowest first cost.

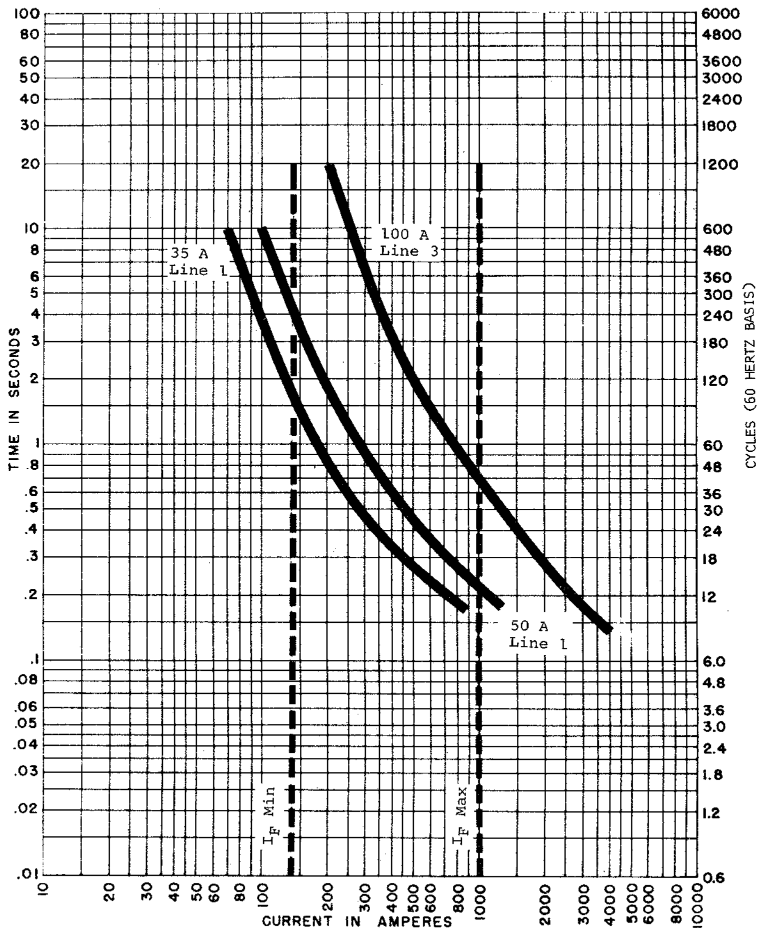

Figure 2— Comparison of Time-Delay or Retarded Curves

4.3.1.1 Coordination with Load Side Devices

When a recloser is installed in a circuit, the coordination of load side devices must also be checked. The continuous current rating of the automatic line sectionalizer[2] at Point A1 should be 50 A, the same as that of the recloser at Point ABC1. Coordination will be obtained with smaller ratings, but in this case it will be necessary to check the short time currentratings of the sectionalizer to be sure that they are adequate for the maximum system fault currents at the sectionalizer location.

[2]An automatic line sectionalizer is a self-contained circuit opening device that automatically opens the main electrical circuit through it after sensing and responding to a predetermined number of successive main circuit impulses of predetermined or greater magnitude. It opens while the main circuit is de-energized.

The selection of the load side fuse at Point A2 is determined by plotting the TCC characteristics of the 50 A Line 1 recloser on logarithmic paper or using transparent overlays and selecting a fuse size in accordance with system coordination practices.

Fig 3 shows that a 20 A fuse will be satisfactory for use at Point A2.

4.3.2 Sample Problem 2 — Selection of Three-Phase Reclosers

A three-phase recloser may be installed instead of single-phase reclosers for any of the following basic reasons:

1) The circuit load exceeds the maximum current rating available in single-phase reclosers.
2) The maximum short-circuit current exceeds the maximum interrupting rating available in single-phase reclosers.

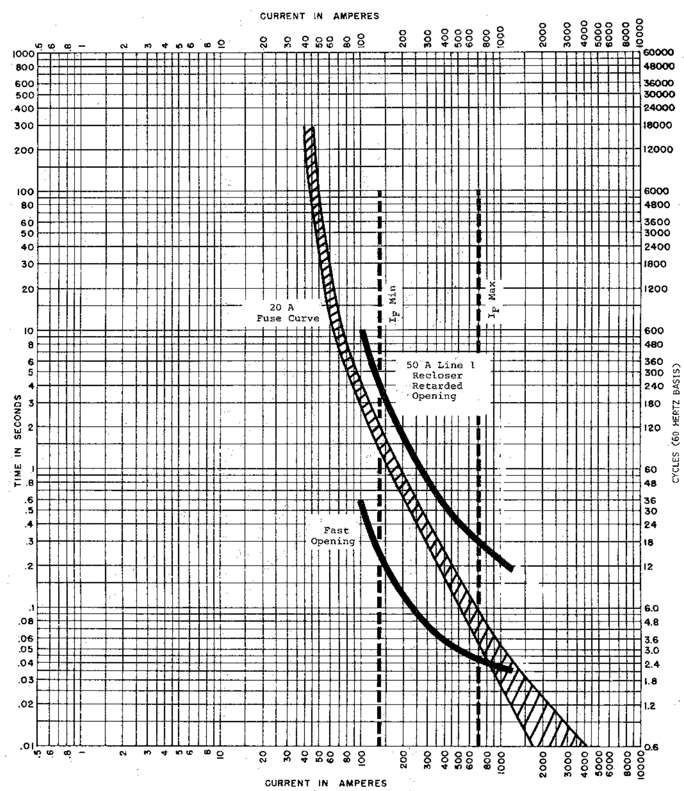

Figure 3— Sample Recloser — Fuse Coordination Chart

3) The load is critical to single phasing, and requires a three-phase switching device.
4) Less investment may be required compared to the use of three single-phase reclosers.
5) It may be preferable for a particular substation design.

Example: The procedure used in selecting a recloser for Point A, Fig 4, is as follows: Nominal voltage 7.2/12.5 kV Wye.

Although single-phase reclosers are available which will satisfy the load and short-circuit requirements at "A," assume that a three-phase switching device is preferred for one of the other reasons noted above. Based on the maximum fault current at Point A, a recloser having an interrupting rating of 8000 A or greater is required. From Table 2 of American National Standard Supplement C37.60a-1971, this requirement would be satisfied by any of the Line 5, 6, 7, or 8 reclosers. Since some margin above interrupting rating is usually desired by users, it is probable that the Line 5 recloser rated at 8000 A would not be considered. Tables 2 and 3 of American National Standard Supplement C37.60a-1971 show that the Lines 6, 7, and 8 reclosers are all nonseries coil reclosers with continuous current ratings of 560 and 1120 A, respectively. In view of the present maximum load current of 200 A and making allowance for load growth, it appears that the 560 A continuous current rating is adequate and therefore only the Lines 6 and 7 reclosers will be considered.

Note that for nonseries coil reclosers, there is only one continuous current rating. Minimum phase current trip setting is variable, however, and as indicated by Table 3 of American National Standard Supplement C37.60a-1971, a Line 6 or 7 recloser may be obtained with trip settings of 200, 280, 400, 560, 800, and 1120 A.

Assume that for coordination with the source side device, a 400 A phase trip current is the maximum setting that can be tolerated. For load growth purposes this also seems to be a reasonable choice.

The data given on the sketch of Fig 4 shows a minimum calculated fault current[3](line-to-ground) of 250 A at Point E. Since this current will not cause phase current tripping at the selected rating, it is necessary to install ground tripping to detect the minimum fault current. These accessories are not standardized, but reference to manufacturers' catalogs show minimum ground tripping ratings of 50, 70, 100, 140, and 200 A. Any of these will detect the minimum fault current.

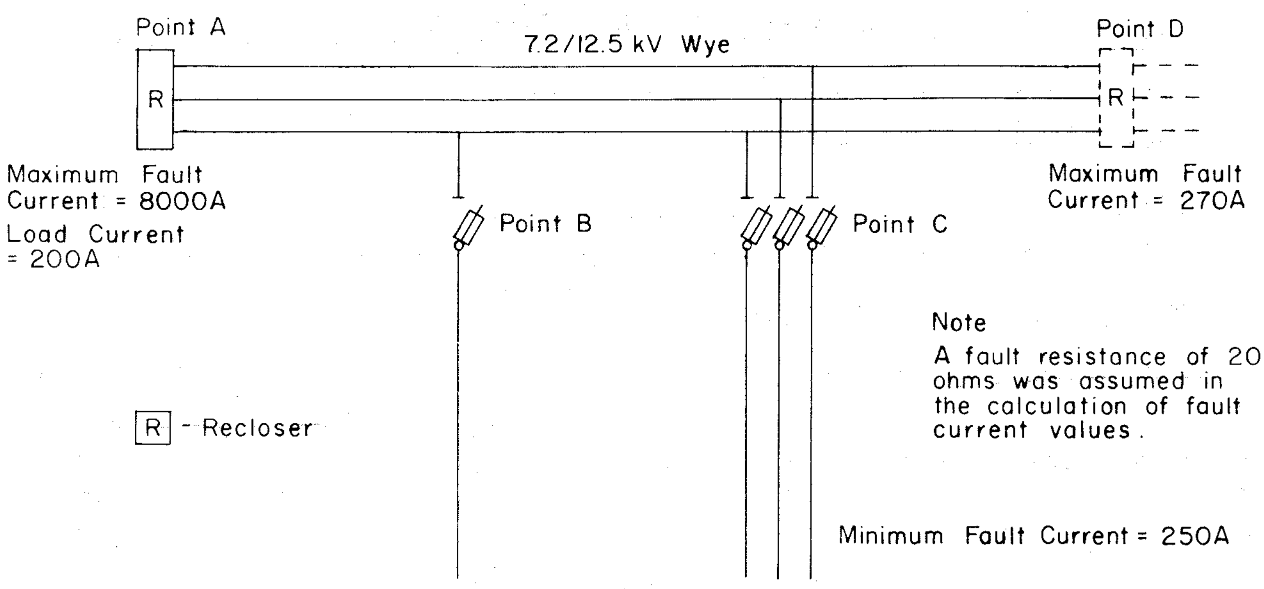

Figure 4— Circuit for Sample Problem 2

The criteria for phase current unbalance on this system is based on a maximum of 20 percent of the maximum load current of the three phases. Using the phase tripping current setting as the maximum possible load current and taking 20 percent of this value gives a tentative minimum ground trip of 80 A. After considering the possible unbalanced current through the recloser in the event of the opening of the most heavily loaded single-phase branch circuit, it appears that a 100 A ground trip setting would be satisfactory. The recloser selected for use at Point A would have the following characteristics:

1) Line 6 or 7
2) Continuous current rating, 560 A
3) Minimum-phase tripping current, 400 A

[3]In this example, the minimum fault current was determined by assuming a fault resistance to ground of 20 Ω

4) Minimum ground tripping current, 100 A
5) Time-current characteristics to coordinate with the source and load side devices

(See sample problem 1 for illustration)

In checking the catalog data of the manufacturer whose recloser has been chosen for general use, it is found that a Line 6 recloser is not offered. Therefore, the Line 7 recloser is selected.

4.3.3 Sample Problem 3 — Selection of Three-Phase Reclosers (Alternative Method)

As an alternative to calculating minimum fault current at a predetermined zone end, with an assumed value of fault impedance, the zone end can be defined as that point where the maximum fault current is some multiple (say 1.5 × or 2.0 ×) of the recloser coil minimum pickup value. This method takes into account the probability of the occurrence of some fault impedance, while somewhat simplifying the calculations required. This method is illustrated in Fig 5.

In selecting a recloser for Point A, a review of Tables 2 and 3 of American National Standard Supplement C37.60a-1971 reveals the following:

Voltage Rating: Voltage rating lines 1–8 are acceptable.

NOTE — Lines 9–15 are for higher voltage systems and will not necessarily work properly on 7.2/12.5 kV lines.

Interrupting Rating: Lines 1 and 2 are not acceptable; the remainder are acceptable.

Continuous Current Rating: Lines 1 and 2 are not acceptable; the remainder are acceptable.

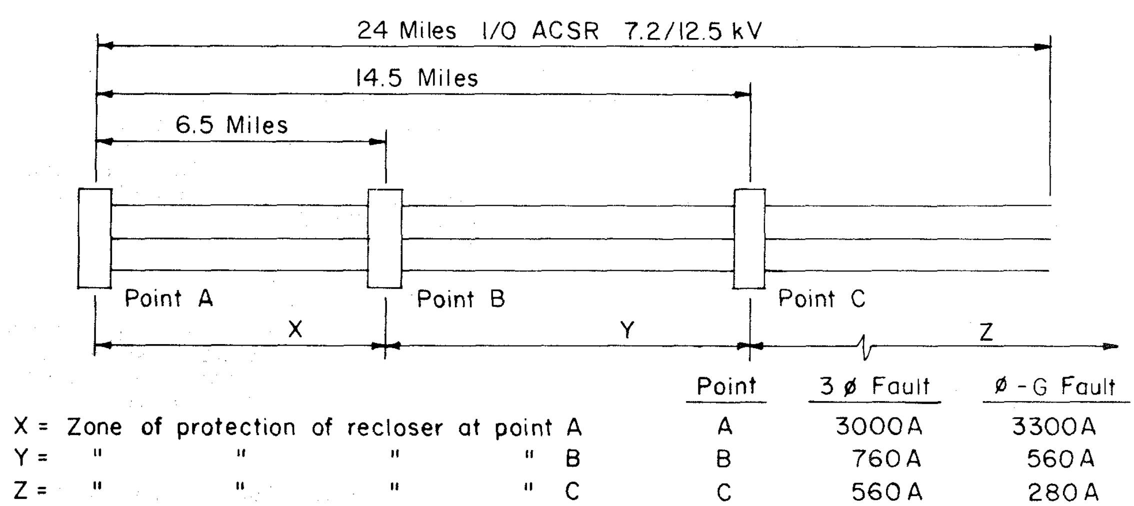

Figure 5— Circuit for Sample Problem 3

A Line 3 recloser is adequate in all respects, and should be a good economic choice for application at Point A. The coil should have a continuous current capability equivalent to the largest load expected, and desirably a minimum rated coil size.[4] A 140 A coil could be selected, and with the desired operating sequence, if coordination with source side devices exists, this recloser would be installed at Point A.

[4]Minimizing the coil size has the advantages of:
1) Providing faster clearing of faults, reducing the probability of damage to circuit elements.
2) Extending the zone of protection to optimum value. An excessive number of units is avoided, while maintaining adequate protection.

In this example, it is assumed that the end of the zone of protection for any recloser is that point where the maximum phase to ground fault current is equal to twice the recloser pickup current. Therefore, the zone end for the recloser at Point A is that point where the maximum phase to ground fault current is $140 \times 2 \times 2 = 560$ A. Calculations show that this occurs 6.5 miles from Point A. A second recloser is required at this point (B).

By again employing the selection process described for A, it is established that a Line 2 recloser with a 70 A coil can be applied at Point B. The end of the zone of protection for the recloser at B will be the point where the phase-to-ground fault current is $70 \times 2 \times 2 = 280$ A, or 14.5 miles from Point A. Similarly, at Point C (14.5 miles from Point A), a Line 1 recloser with a 35 A coil can be applied. The Line 1 recloser zone end will be at a point where the phase-to-ground fault current is $35 \times 2 \times 2 = 140$ A. This point is beyond the end of the circuit. In every case, the recloser selected conforms to requirements for:

1) Voltage rating
2) Interrupting capability
3) Continuous capability
4) Coordination with adjacent devices

This alternate method can be applied to branch lines as well. It can also be used in those situations where reclosers must be applied at specific locations (junctions, etc) dictated by operating requirements.

5. Operation

5.1 Installation

All personnel responsible for supervision and operation should become familiar with reclosers and their function before placing equipment in operation. This can be accomplished by studying the manufacturer's instruction book and diagrams.

Before installation:

1) Check for external mechanical damage
2) Check oil level of oil-filled reclosers
3) Check the operating sequence to determine that the recloser operates as specified
4) Check the operation counter (Record its reading when installation is completed)

A record card for each recloser should be kept on file to show the make, type, size, and serial number of the unit, and the date of purchase and date and location of the installation, counter reading, settings, and sequences of operation.

Additional data should include dates of inspection and maintenance, nature of maintenance, oil test data, and reassignment to other locations.

5.2 Reclosing After Lockout

If the recloser has operated to lockout, the operator should first make a complete visual inspection of the recloser for evidence of external damage such as broken or cracked bushings, thrown oil, etc. After the fault has been removed from the line and inspection indicates that everything is in order, the recloser may be closed.

5.3 Cold-Load Pickup

Excessive currents experienced on circuit reenergization may cause operation of the recloser to lockout. The excessive currents are caused by two phenomena; both are likely to occur:

1) Inrush currents associated with motor starting, transformers, and the like. The duration of this component of cold-load pickup is quite short, a matter of several cycles.
2) An increase in the post interruption load value relative to the pre-interruption load value due to loss of diversity of cycling loads (electric heating, air conditioners, etc). The ratio of the post interruption load to preinterruption load varies with the length of interruption but can be as high as 2. Due to this effect excessive currents may persist for tens of minutes.

If cold load cannot be picked up, the circuit may be sectionalized to disconnect part of the load, or the recloser may be by-passed temporarily. Nonseries coil reclosers may have special control provisions to allow for the inrush component of cold-load pickup.

CAUTION — Do not hold the operating lever of series coil reclosers in a closed position in an attempt to pick up cold load.

6. Maintenance

6.1 Frequency of Maintenance

All reclosers should be maintained after a number of operations, or after a time interval, in accordance with the manufacturer's recommendations or operating experience.

6.1.1 Maintenance Based on Elapsed Time

The frequency of inspection and maintenance will vary with the operating service and with local conditions. Initial inspections should be made in accordance with the manufacturer's recommendations. Local conditions of humidity and temperature may affect the frequency of maintenance necessary. Study of maintenance records extending over several years will be helpful in determining proper maintenance schedules.

6.1.2 Maintenance Based on Number of Operations

Reclosers may be maintained after a certain number of operations, determined from the recloser operation counter readings. A procedure for evaluating useful life of a recloser based on standard duty is presented in Appendix B.

6.1.3 Maintenance Based on Elapsed Time and Number of Operations

In recloser maintenance; the use of time interval alone as a basis for servicing does not take into account the frequency and severity of the recloser operations. On the other hand, use of the number of operations alone ignores elapsed time during which the oil may have deteriorated.

A suggested method of combining the elapsed time and operation factors is as follows: Maintenance and internal inspection of reclosers should be performed at 100 operations or every three years, whichever occurs first. However, operating experience with particular designs is the best basis for establishment of maintenance schedules.

6.2 Procedures

6.2.1 Field Inspection

After installation, a recloser should be carefully inspected at established intervals, which may be seasonal, monthly, or quarterly, or even less frequently. The inspection should include checking the tank for oil leakage and examining the bushings for cracks, as well as the coverage of other items recommended by the manufacturer. The counter reading should be recorded at the time of inspection. When the inspection is made, it is recommended that the recloser be bypassed by suitable means, and isolated, and that an operating test be performed. The recloser should be manually operated several times to the lockout position by means of a switch stick, or other control. Operating tests may disclose possible sources of trouble and are also of value in preventing the accumulation of high-resistance oxides on the contact surfaces.

6.2.2 Servicing

When reclosers are serviced, the following items should be given particular attention:

1) Oil — Never assume that new oil is free of moisture. It should be tested for dielectric strength before using, with breakdown across a standard 0.1 in gap occurring at not less than 26 kV rms, the minimum acceptable dielectric strength for new oil. Breakdown at a lower test voltage usually indicates excessive moisture in the oil. This moisture should be removed by filtering before the oil is used in any type of electrical equipment.
   When reclosers are temporarily removed from service for minor repair work prior to their scheduled servicing, test the oil before putting the recloser back in service. If the dielectric strength of the oil is less than 22 kV rms, it should be replaced with clean dry oil.
   NOTE — See American National Standard Methods of Testing Electrical Insulating Oils, C59.2-1970 (ASTM D117-69) for approved test methods.
2) Vacuum Interrupting Modules — These modules may lose dielectric strength from leaks caused by excessive mechanical strain, insufficiently degassed contact materials, or other causes. Vacuum gap dielectric strength can be tested with a 60 Hz high-potential test at the manufacturer's recommended voltage.
   Vacuum contacts should be adjusted for proper contact opening travel, contact closing over-travel and contact closing force according to manufacturer's recommended procedure.

WARNING: VACUUM INTERRUPTERS MAY PRODUCE X-RADIATION WHEN ENERGIZED ABOVE MAXIMUM RATED VOLTAGE. READ MANUFACTURER'S INSTRUCTIONS CAREFULLY FOR REQUIRED PRECAUTIONS.*

*See American National Standards C37.85-1972 and C37.85a-1972 which establish X-radiation limits for power vacuum interrupters.

3) Insulation - The insulation of fiber parts and of electrical wiring may deteriorate due to aging, moisture, and the accumulation of sludge deposits. The insulation can be tested by a 60 Hz high-potential test, by power factor measurement, or by dc insulation tests. The 60 Hz high-potential test voltage should be 75 percent of the 1 minute dry withstand voltage shown in Table 2, Column 5, of American National Standard Supplement C37.60a-1971.
4) Minimum Tripping Current — The minimum tripping current test is made to determine the recloser trips at the proper current value. This test is described in Section 5.5 of American National Standard Supplement C37.60a-1971.
   When conducting low-voltage, high-current tests for determining minimum trip, follow recommendations of the recloser manufacturer.
5) Time-Current Characteristics — Manufacturer's maintenance manuals usually contain instructions for this type of test. Test conditions and procedure are described in Section 5.10 of American National Standard C37.60-1968.

6) Lockout — New or reconditioned reclosers should be checked by operating them through their sequence to lockout before they are placed in service. The procedure for this test varies with the make and type of recloser. The manufacturer’s instruction manual will usually describe the procedure for the specific recloser.
7) Reset — The resetting time of a recloser should be checked during the lockout test and should be within the limits set by the manufacturer.

7. References

ANSI C37.010-1972, Application Guide for AC High-Voltage Circuit Breakers (IEEE Std 320-1972)

ANSI C37.60-1968, Requirements for Automatic Circuit Reclosers for Alternating-Current Systems

ANSI C37.60a-1971, Supplement to C37.60-1968

ANSI C37.85-1972, Safety Requirements for Automatic Line Sectionalizers for AC Systems

Wagner and Evans, *Symmetrical Components,* New York: McGraw Hill Book Company, 1933.

Coordination of protection and construction of distribution circuits, AIEE Committee Report, *AIEE Transactions*, vol 73, part IIIB, 1954, pp 1609–1624.

Electrical Transmission and Distribution Reference Book, Pittsburgh, Pennsylvania: Westinghouse Electric Corporation, 1950, 4th ed, chapter II.

8. Revision of American National Standards Referred to in This Document

When the American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, Inc., the revision shall apply.

Annex A

Recloser Characteristics

(Informative)

(These Appendixes are not a part of American National Standard and IEEE Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers, C37.61-1973, IEEE Std 321-1973.)

A general understanding of standard ratings and operating characteristics and available accessories is necessary for the proper application of automatic circuit reclosers.

A.1 Standard Ratings

A.1.1 Voltage Rating

The maximum voltage ratings for various classes of reclosers are given in Column 3 of Table 2 of American National Standard Supplement C37.60a-1971.

A.1.2 Interrupting Current Rating

The interrupting current ratings of the various classes of reclosers are given in Table 3 of American National Standard Supplement C37.60a-1971. Note that the interrupting rating of a given line or class recloser is not the same for all continuous current ratings in that line. Reclosers are rated in symmetrical amperes with test power factors as indicated by the X/R ratios in Columns 9, 11, and 13 of Table 2 of American National Standard Supplement C37.60a-1971. These test power factors generally will be more severe than those encountered on systems where the reclosers are applied within the ratings.

The recloser is not a constant kilovolt-ampere device, and its interrupting rating does not vary with voltage or X/R ratio. Therefore, if the applied voltage or the X/R ratio is less than rating, no increase in interrupting current capability should be assumed unless indicated in published data or approved by the manufacturer.

A.1.3 Minimum Tripping Current

For series trip reclosers this is standardized at two times the continuous current rating. The minimum tripping current for shunt trip reclosers is adjustable and has no standard relation to the rated continuous current. Information for specific reclosers should be obtained from the manufacturer.

A.1.4 Continuous Current Ratings

These ratings are given in Table 3 of American National Standard Supplement C37.60a-1971.

NOTE — Since reclosers are designed to trip at a current that may be substantially in excess of the continuous current rating, they may carry an overload for which they are not self-protecting. Information as to operation in this region should be obtained from the manufacturer.

A.2 Operating Characteristics

A.2.1 Tripping and Control

Reclosers are classified as series trip or nonseries trip devices.

A series trip recloser obtains the energy to trip its main contacts from the system fault current flowing through a solenoid or operating coil which is electrically in series with the line. Since the operating coil carries main line current at all times, it produces a magnetic force proportional to the product of the coil turns and line current (NI). Consequently, there is a definite relationship between continuous current rating, minimum tripping current rating, and maximum interrupting current rating.

The control for series trip coil reclosers is actuated by the operating coil solenoid. This provides reliability and simplicity, but limits the choice of operating characteristics. The fast and time-delayed curves of the series trip recloser are not adjustable.

A nonseries coil recloser may derive its energy for operating the tripping mechanism and opening the main contacts from a source other than the main circuit; for example, a battery. Consequently, there is no definite relationship between continuous current rating, maximum interrupting current rating, and minimum tripping current rating. Fault current is sensed usually by current transformers, and the control is actuated by the resulting signal. The control may be electromechanical, hydraulic, pneumatic, or electronic in nature. It is typically very flexible providing the user with a wide choice of operating characteristics.

A.2.2 Recloser Functions

Reclosers may have either a lock-open or a hold-closed function.

A.2.2.1 Lock-Open Function

A recloser with this function opens and recloses its contacts on sensing fault current. If the fault is sustained in nature, the recloser proceeds to operate to a final contact-open position. To restore service, the recloser must be closed by the action of an operator.

Typical operating sequences for lock-open reclosers include:

1) Two fast and two time-delay operations
2) One fast and two time-delay operations
3) One fast and three time-delay operations
4) Three fast and one time-delay operations
5) Two fast and one time-delay operations

All of these sequences provide a high degree of protection against the effects of transient and sustained faults. They also permit ready coordination with other sectionalizing devices such as fuses and automatic line sectionalizers. While reclosers may be set for all fast or slow operations, these sequences are seldom used in practice primarily because of coordination difficulties.

Time-current characteristic curves for lock-open reclosers are not standardized and must be obtained from the manufacturer.

Characteristic curves for reclosers usually begin at 200 percent of the full-load rating of the unit and extend to the maximum interrupting rating. Fast or instantaneous curves are plotted to the maximum clearing time for one opening, and all variations are negative, or to the faster side. Time-delay curves are plotted to the average clearing time for one opening and have a ± 10 percent tolerance.

Recloser operating times may vary with temperature. When oil or other liquid is used as the timing means, operation at sub-zero temperatures has been found to be slower than shown by the published curves.

A typical time-current characteristic curve for a series trip, lock-open recloser is shown in Fig A.1.

A.2.2.2 Hold-Closed Function

An alternative recloser operating scheme uses reclosers having a hold-closed function. The reclosers are set for a sequence of two instantaneous operations and then hold closed. The contacts are held closed as long as fault current flows through the recloser, the permissible duration limited only by the thermal time-current characteristics of the series coil. When some other device on the load side of the circuit (usually a fuse) interrupts the fault current, the recloser automatically resets to the normal operating position. As with the lock-open function, the two instantaneous hold-closed sequences provide for clearing temporary faults without a prolonged interruption. The thermal time-load characteristics of the series coil provide additional time for a wide range of sectionalizing fuse ratings to operate. Thus, within fuse coordination capabilities, more sectionalizing points can be used within the zone of protection of each recloser.

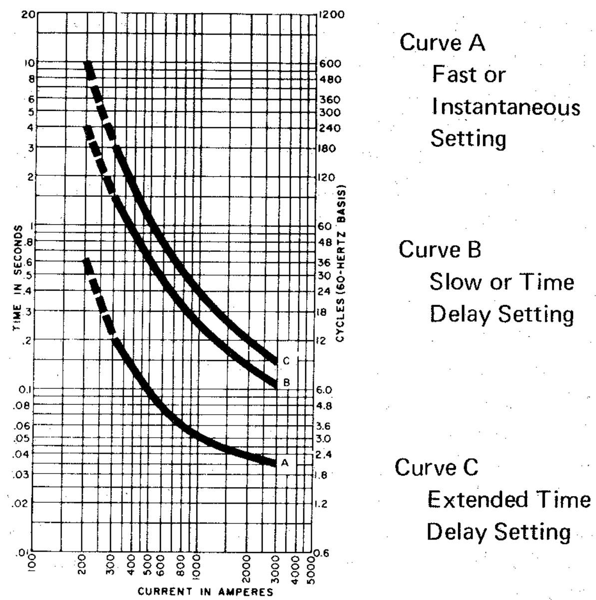

Figure A.1—Typical Time-Current Curves of a Single-Phase, Hydraulically-Controlled Recloser Rated 100 A Continuous Current

A.2.3 Reclosing Interval

The reclosing interval is the open-circuit time between an automatic opening and the succeeding automatic reclosing. On most single-phase reclosers this time is fixed and cannot be adjusted. However, on some reclosers the reclosing interval can be adjusted over a wide range. The minimum reclosing interval must be long enough to allow the arc path to deionize. This interval, where used, is normally applied as the first reclosing operation and is considered fast or instantaneous reclosing.

Reclosers having solid state or static electronic controls have independent adjustments for each reclosing interval. This offers the advantage of flexibility for considerations such as relay resetting times and fuse cooling periods.

A.2.4 Reset Interval

The time required for the recloser to return to its initial operating condition. The reset interval may be initiated from fault inception or from successful reclose. On series trip and some shunt trip reclosers, the reset interval is a fixed time. On reclosers having solid state or static electronic controls, the reset time is adjustable to a very short interval when initiated by successful reclose.

The optimum reset time setting is one which is as fast as possible without allowing resetting during the reclosing periods to prevent reclosing and trip operations or “pumping.” In practice, this optimum setting is difficult to obtain except with reclosers having reset from successful reclose, in which resetting is blocked in the presence of current above the minimum pickup level. When long resetting times are used, multiple lightning strokes to a feeder, repetitive conductor slap due to wind, or other fault may cause recloser lockout, even though these repeating faults are of a temporary nature.

A.3 Accessory Equipment

Manufacturers provide accessory equipment for use with reclosers which serve to increase the operational flexibility of this equipment and whose use frequently provides the solution to an operating or application problem. These accessories are not standardized and may not be available for all recloser classes or makes.

While the following list is not all inclusive, it is representative of the accessories that are available:

1) Ground tripping accessory
2) Remote operating mechanism
3) Current transformers
4) Current metering
5) Target accessory
6) Nonreclose attachment
7) Loop automatic sectionalizing equipment

Annex B

Procedure To Determine Maintenance Basis on Number of Operations of Oil-Filled Reclosers

(Informative)

If desired, the standard operating duty shown in Table 2 of American National Standard Supplement C37.60a-1971 provides a means for evaluating the useful life of a recloser under standardized conditions. Since the fault duty is dependent on the location of each fault, it is necessary to assume typical fault conditions to use the recloser counter reading to indicate the total number of operations.

Example: Consider a recloser of 4000 A interrupting capacity, as shown on Line 3, Table 2, American National Standard Supplement C37.60a-1971 with test currents of 4000, 2000, and 800 A, which are 90–100 percent, 45–55 percent, and 15–20 percent, respectively, of the interrupting rating. Since the standard operating duty is based on the empirical formula: Operating duty = (Interrupted current)$^{1.5}$ × (Number of operations), the total operating duty factor for the recloser can be calculated as follows:

$$\begin{aligned} 4000^{1.5} \times 12 \text{ Operations} &= 303.6 \times 10^4 \\ 2000^{1.5} \times 20 \text{ Operations} &= 180.0 \times 10^4 \\ 800^{1.5} \times 32 \text{ Operations} &= 72.0 \times 10^4 \\ \hline \text{Total} \quad 64 \text{ Operations} &= 555.6 \times 10^4 \end{aligned}$$

NOTE — $I^{1.5} = I \times \sqrt{I}$

The duty factor for each of the recloser ratings shown in Table 2 of American National Standard Supplement C37.60a-1971, using the standard duty cycle and calculated as shown above, is shown in Table B.1.

NOTE — Refer to Appendix C, Basis of Derivation of Duty Factors and Standard Operating Duties.

Table B.1—Recloser Duty Factors

Recloser Line No of Table 2 of American National Standard Supplement C37.60a-1971	Duty Factors × 10^4
1	165
2	209
3	556
4	556
5	1399
6	1685
7	3510
8	3510
9	291
10	975
11	1399
12	1399
13	2573
14	1958
15	1399

Using the duty factors shown in Table B.1, it is possible to calculate the total number of interruptions permissible for any combination of fault currents.

Example: How many operations can a recloser perform if all of the faults are at 75 percent of maximum interrupting rating?

Assume a Line 3 recloser having a 4000 A interrupting rating and having a duty factor of 555.6×10^4.

$(4000 \times 0.75)^{1.5} = 16.4 \times 10^4$ per operation

$$\text{Permissible number of operations} = \frac{\text{Recloser duty factor}}{\text{Duty factor per operation}}$$

$$= \frac{555.6 \times 10^4}{16.4 \times 10^4} = 34 \text{ operations at 3000 A}$$

If other fault currents have occurred, the accumulated effect, or sum of these operations, can be calculated.

Example: Again using a Line 3 recloser having a duty factor of 555.6×10^4, assume faults have occurred, as follows:

Number of Operations	Fault Currents	Calculation	Calculated Duty
10	800 A	$10 \times 800^{1.5}$	22.5×10^4
12	1000 A	$12 \times 1000^{1.5}$	37.8×10^4
20	2500 A	$20 \times 2500^{1.5}$	250.0×10^4
10	4000 A	$10 \times 4000^{1.5}$	253.6×10^4
		Total	563.6×10^4

In the above example, the cumulative duty exceeds the duty factor for the rating. This indicates that recloser maintenance should be performed.

Annex C

Basis of Derivation of Duty Factors and Standard Operating Duties

(Informative)

The total operating duty factor for automatic circuit reclosers listed in Table B.1 is a function of the interrupting rating and is normally established on the basis of the curve shown in Fig C.1.

The operating duty at the three test currents used in the standard operating duty tests are apportioned as follows:

Duty-Cycle Test Current — Percent of Symmetrical Interrupting Current Rating	**Percent of Total Duty Factor**
100	50
50	37.5
20	12.5
	100.0

The number of unit operations at each test current of the standard operating duty test is calculated by dividing the total duty factor at the test current by the operating duty per interruption, where the operating duty per interruption is equal to $I^{1.5}$.

NOTE — $I^{1.5} = I \times \sqrt{I}$

This number is rounded off to the nearest multiple of four operations, except at maximum interrupting rating, when this approximation may distort the distribution greatly. At maximum interrupting, the nearest even number of operations should be used.

After the unit operations at each test current have been determined, the total standard duty cycle is recalculated. If necessary, adjustments in the number of unit operations (in multiples of four operations) at the 20 percent and 50 percent test currents may be made to bring the total duty factor close to the empirical value determined from the curve of Fig C.1.

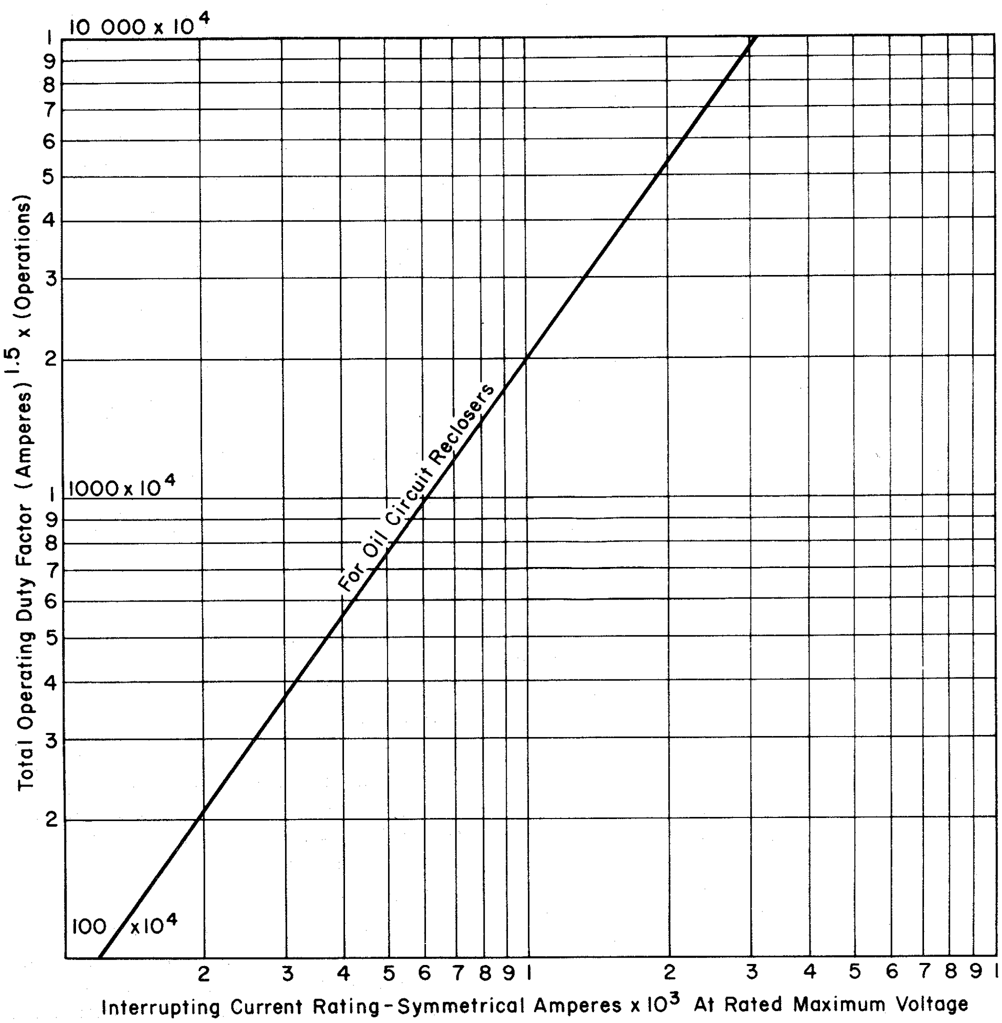

Figure C.1—Recloser Duty Factor Versus Interrupting Current Rating

Example: Assume an oil circuit recloser having a symmetrical interrupting rating of 8000 A at rated maximum voltage. From the curve of Fig C.1, the total duty factor should be 1470×10^4.

The duty factor apportioned to each test current will be as follows:

Duty Cycle Test Current (Amperes)	Operating Duty
8000 (100%)	735×10^4 (50%)
4000 (50%)	551×10^4 (37.5%)
1600 (20%)	184×10^4 (12.5%)
	1470×10^4 (100%)

Calculate the operating duty per interruption as follows:

Test Current (Amperes)	**Calculation**	**Operating Duty per Unit Operation**
8000	$8000 \times \sqrt{8000}$	71.5×10^4
4000	$4000 \times \sqrt{4000}$	25.3×10^4
1600	$1600 \times \sqrt{1600}$	6.4×10^4

Determine the number of unit operations at each test current as follows:

$$\text{No of unit operations} = \frac{\text{Total duty factor at the test current}}{\text{Duty factor per operation}}$$

Test Current (Amperes)	**Calculated No of Unit Operations**	**Unit Operations Rounded Off**
8000	10.3	10
4000	21.8	20
1600	28.8	28

Recalculate the total duty factor as follows:

Test Current (Amperes)	**Duty Factor per Operation $\times 10^4$**	**No of Operations**	**Duty Factor $\times 10^4$**
8000	71.5	10	715
4000	25.3	20	505
1600	6.4	28	179
			Total Duty Factor = 1399*

*This value is shown in Table B.1 of Appendix B.

