How to Use Coordinaide™ to Protect Transformers Against Secondary-Side Arcing Faults.

This is the second in a series of articles describing how Coordinaide™ — The S&C Protection and Coordination Assistant can be used to select the optimal S&C fuse or Vista® Underground Distribution Switchgear TCC curve to protect transformers, capacitor units, lines, cables, or motors, or to selectively coordinate with one or more protective devices in series.

This installment explains how to select a transformer-primary fuse to protect against arcing secondary-side faults. Two properly selected fuses, a solid-material power fuse and a current-limiting power fuse, will be considered.

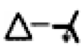
A Brief Discussion of Transformer Protection

The most important principle to be considered when selecting a primary fuse for a three-phase power transformer is that it must protect the transformer against damage from mechanical as well as thermal stresses resulting from secondary-side faults that are not promptly interrupted. A properly selected primary fuse will operate to clear such a fault before the magnitude and duration of the overcurrent exceed the through-fault current duration limits recommended by the transformer manufacturer, or published in the standards. Curves representing these limits can be found in the latest issue of ANSI/IEEE Standard C37.91, "Guide for Protective Relay Applications to Power Transformers," and ANSI/IEEE C57.109, "Guide for Transformer Through-Fault Current Duration."

Although the through-fault protection curves are only a guide, they are nonetheless recommended as a criterion against which to measure the degree of transformer protection provided by the primary fuse. To meet this criterion for high-magnitude secondary-side faults, the total-clearing curve of the primary fuse should pass below the point on the appropriate through-fault protection curve (commonly called the "ANSI" Point) at the current level corresponding to a maximum three-phase secondary-side fault based solely on the transformer impedance (i.e., a "bolted" fault assuming an infinite source). In addition, to provide maximum protection for the transformer against faults located between the transformer and the nearest secondary-side overcurrent protective device — as well as maximum backup protection for the transformer in the event the secondary-side overcurrent protective device fails to operate, or operates too slowly due to an incorrect (higher) rating or setting — the total clearing curve of the primary fuse should intersect the appropriate through-fault protection curve at the lowest possible value of current.

The results of published studies [1] [2] [3] indicate that, under arcing conditions, secondary-switchboard and other nearby faults on 480/277Y-volt circuits may have magnitudes as low as 40% of the maximum available phase-to-ground fault current level at the point of the fault. You can determine if the transformer-primary fuse will protect against an arcing secondary-side fault by referring to Table 1 (below) which lists primary-side line current values for various types of secondary-side faults and for various transformer connections and impedances, expressed in percent of the transformer full-load current. The desired protection is obtained if the current value at which the total-clearing curve of the primary fuse intersects the transformer through-fault protection curve is less than the values shown in Table 1.

Table 1. Secondary Fault Currents Reflected to Primary Lines

Transformer Connection	Impedance	Arcing Phase-to-Ground Fault①	Maximum Primary-Side Line Current for Various Types of Secondary Faults, Percent of Transformer Full-Load Current		
			Three-Phase	Phase-to-Phase	Phase-to-Ground
	4% 5.5% 5.75% 6.5% 8%	1000% ■ 700 ■ 500	2500% 1820 1740 1540 1250	2180% 1580 1510 1340 1090	2500% 1820 1740 1540 1250
	4% 5.5% 5.75% 6.5% 8%	NA	2500 1820 1740 1540 1250	2180 1580 1510 1340 1090	NA
	4% 5.5% 5.75% 6.5% 8%	580 ■ 400 ■ 290	2500 1820 1740 1540 1250	2500 1820 1740 1540 1250	1450 1050 1010 890 730

NA – Not Applicable

①Commonly accepted arcing-fault-current values for secondary-switchboard and other nearby faults.

■For transformers with medium-voltage secondaries (2.4 kV or 4.16 kV), the entries in the "Phase-to-Ground" column apply.

REFERENCES

1. J. R. Dunki-Jacobs, "The Effects of Arcing Ground Faults on Low-Voltage System Design," article reprinted from the May/June 1972 issue of IEEE Transactions on Industry and General Application.
2. J. R. Dunki-Jacobs, "State of the Art of Grounding and Ground Fault Protection," article reprinted from the 1977 Conference Record of the IEEE 24th Annual Petroleum and Chemical Industry Conference, September 13-14, 1977, Dallas, Texas, Catalog No. 77CH1229-4-IA.
3. L. E. Fisher, "Resistance of Low-Voltage Alternating Current Arcs," IEEE Transactions on Industry and General Applications, Vol. IGA-6, November/December 1970, pages 607-616.

Doing the Exercise

To complete the transformer protection exercise describe above, you'll need to launch Coordinaide.

Then you'll be directed to the Coordinaide opening page, which contains a brief description of the protective applications Coordinaide is designed to handle. When you launch the program, you'll be directed to a second page that contains a brief "Conditions of Use" disclaimer, followed by a short note detailing minimum web browser requirements and a link to a

“Helpful Hints” page. One final click launches the program and takes you to the “General Information” page. Please follow these directions to select the lateral (section-alizing) fuse, the transformer fuse, and, finally, to determine the value of current up to which the two fuses coordinate. Values in *italics* are to be entered into Coordinaide.

Enter the Project’s General Information

- Project Name: *Transformer Protection Exercise*
- Date: [provided by Coordinaide]
- By: *Optional*
- Voltage, kV (Three-Phase): *12.47* (default value)
- Available Fault Current (RMS Symmetrical Amperes): *15000* (no comma)

Select Device #1 Type

- *Power Fuse*

Select Device #2 Type

- *Transformer*

Click “Continue” after specifying Devices #1 and #2.

Select Parameters for Device #1

- Manufacturer: *S&C*
- Type: *SMU-20*
- Speed: *Standard*
- kV range: *7.2-14.4*
- Rating: *65E*
- Preload Adjustment, Percent: 0 (default value)
- Ambient Temperature Adjustment: 25 Degrees Celsius (default value)

Click “Continue” after selecting the parameters for Device #1. The time-current characteristic curve for Device #1 will display.

Select Parameters for Device #2

- 3-Phase Primary kV: *12.47* (default)
- 3-Phase Secondary kV: *0.48*
- 3-Phase Rating kVA: 1000
- Impedance in Percent (1% - 15%): *5.75*
- Fault Current in Sym RMS Amps: 15000 (from General Information Page)

- Connection: *Delta / Grounded-Wye*

Click “Continue” after selecting the parameters for Device #2. The time-current characteristic curve for Device #2 will display.

Results Page

Click on the tab at the top labeled “Results”.

If desired, you can change the current scale of the grid from the default, 5 to 100,000 amperes, to 0.5 to 10,000 amperes. You can also zoom in on a particular section of the grid by entering the upper and lower current and time values into the appropriate cells.

To determine the exact value of current **down** to which the 65E-ampere Standard Speed solid-material power fuse will protect the transformer, place the “cross hair” cursor over the intersection of the *total-clearing curve* of the 65E-ampere primary fuse, and either one of the two transformer through-fault protection curves, and click once. The current value down to which the fuse will protect the transformer is displayed at the top of the grid, approximately 140 amperes for a three-phase secondary-side fault, and approximately 150 amperes for a phase-to-ground secondary-side fault. For convenience, these values are automatically computed by Coordinaide, expressed as a percentage of the transformer’s full-load (i.e., nameplate) current, and are displayed on the summary page. They are given the name Transformer Protection Indices (TPIs).

For a three-phase secondary-side fault, the 65E-ampere Standard Speed fuse will protect the transformer down to 305% of its full-load current. Referring to Table 1, for a bolted three-phase secondary-side fault on this transformer (5.75% impedance, delta / grounded-wye connection), the maximum value is 1740% of the nameplate current. Clearly, the 65E-ampere primary fuse will protect against this type of fault. It will also protect against a bolted phase-to-ground secondary-side fault since the TPI is 322%, whereas the maximum index value for this fault, shown in Table 1, is 1010% of nameplate. In fact, the subject fuse will also protect against an *arcing* phase-to-ground secondary-side fault since the TPI is less than the maximum value for an arcing fault shown in Table 1, which is 400% of the transformer’s nameplate current. See Figure 1. The excellent protection provided by the solid material power fuse is due, in large part, to its tight tolerances and also because of the inverse-time “shape” of its time-current characteristic curve. As you will discover in short order, because of its broad tolerances and very steep time-current characteristic curve, a current-limiting fuse having a similar ampere rating will not provide much in the way of transformer protection, all other factors being equal.

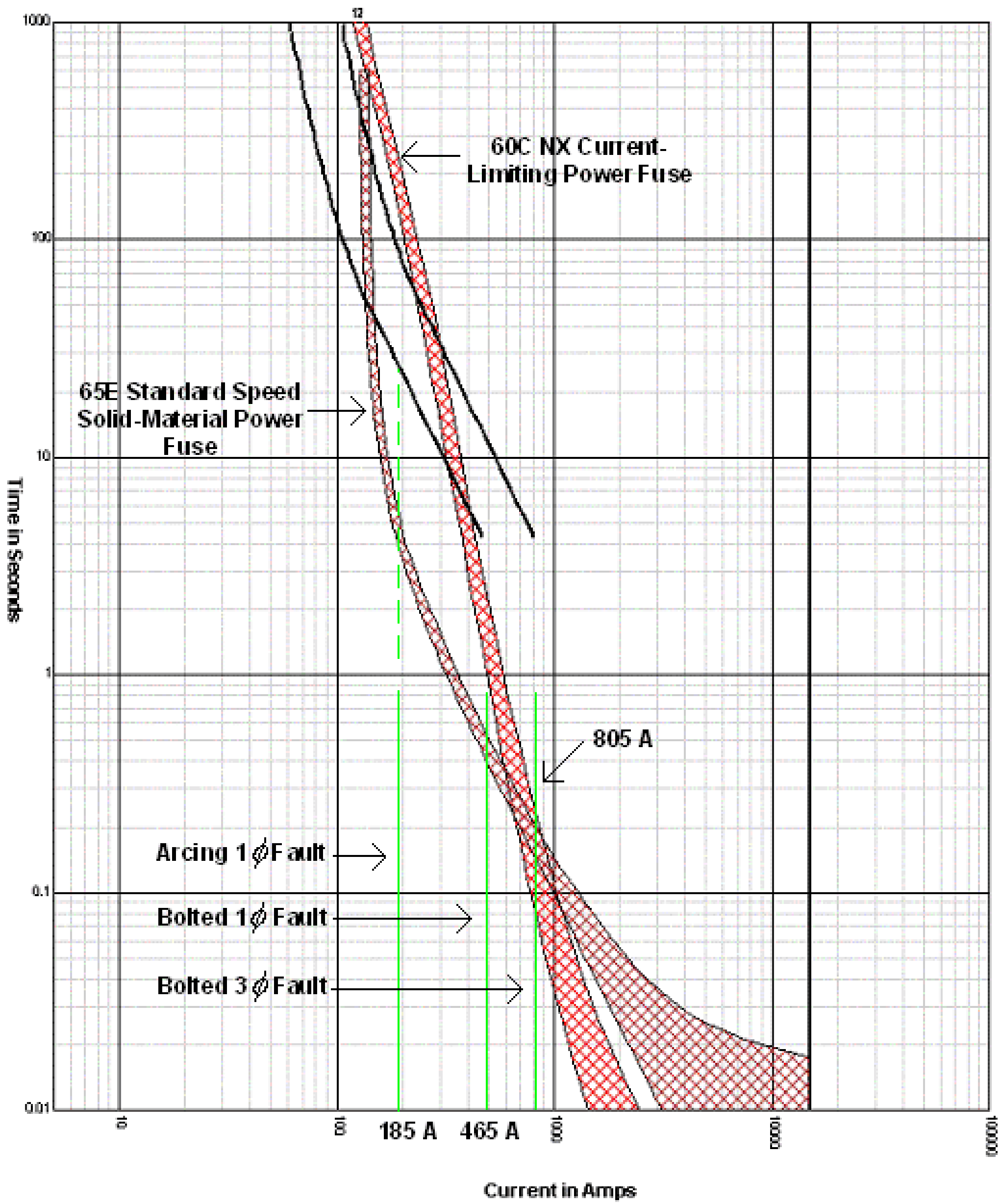


Figure 1.

Now repeat this exercise using a Cooper Power Systems NX style current-limiting fuse rated 60C amperes for Device #1. As you will see, this fuse barely protects against a bolted phase-to-ground secondary-side fault, and it will not protect against an arcing secondary-side fault. Clearly, a fuse that can protect against arcing secondary-side faults would be preferred over one that cannot provide such protection.