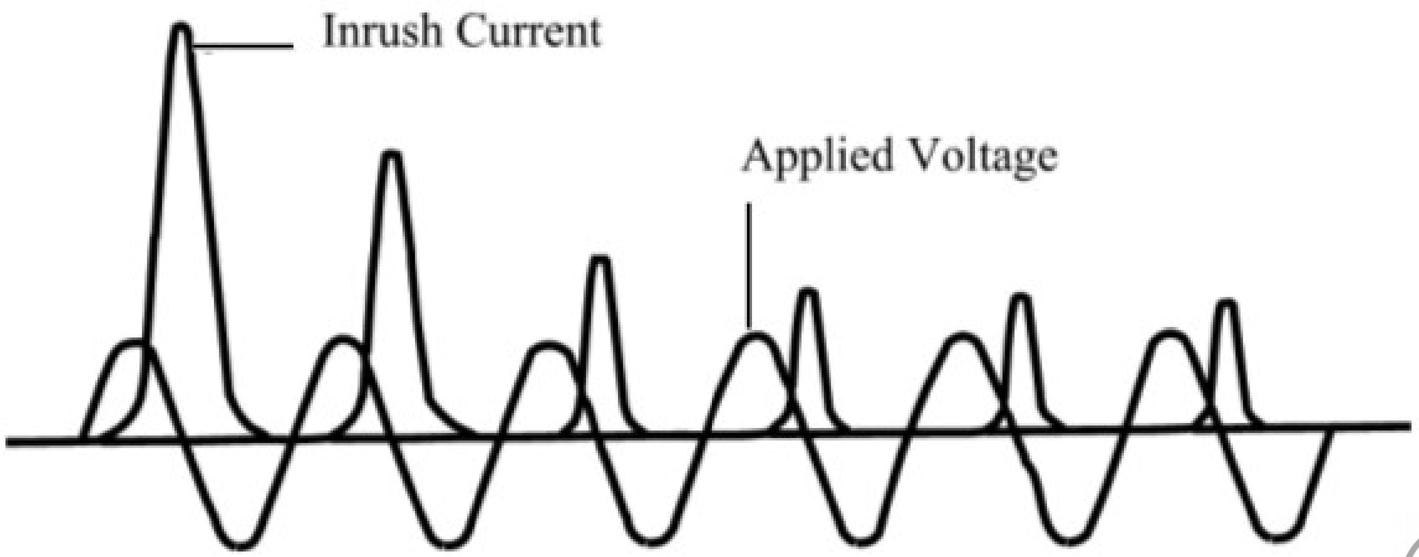
Overview of IEEE Std C37.91 Through Fault Protection

IEEE Guide for Protective Relay Applications to Power Transformers



IEEE Device Numbers

- 24 V/Hz relay
- 26 Thermal device
- 49 Thermal relay
- 50N Instantaneous neutral overcurrent relay
- 51 AC time overcurrent relay
- 51G AC time overcurrent relay
- 51N AC time neutral overcurrent relay
- 51NB AC time neutral overcurrent relay, backup
- 51NT AC time neutral overcurrent relay, torque controlled
- 52 AC circuit breaker
- 59 Overvoltage relay
- 60 Voltage or current balance relay
- 63 Pressure switch or relay
- 67 AC directional overcurrent relay
- 67G AC directional overcurrent relay, neutral
- 86 Lockout relay
- 87 Differential relay
- 87G Ground differential relay

Through Fault Protection

- Overcurrent protective devices such as relays, breakers and fuses have well-defined time current operating characteristics. It is desirable that the characteristic curves for these protective devices be coordinated with the transformer withstand capability curves.
- Category I, II, III, and IV withstand capability curves apply to transformers designed to IEEE Std C57.12.00

Transformer Categories

- Category I transformers (5–500 kVA single-phase, 15–500 kVA three-phase)
- Category II transformers (501–1667 kVA single-phase, 501–5000 kVA three-phase)
- Category III transformers (1668–10 000 kVA single-phase, 5001–30 000 kVA three-phase)
- Category IV transformers (above 10 000 kVA single-phase, and above 30 000 kVA three-phase)

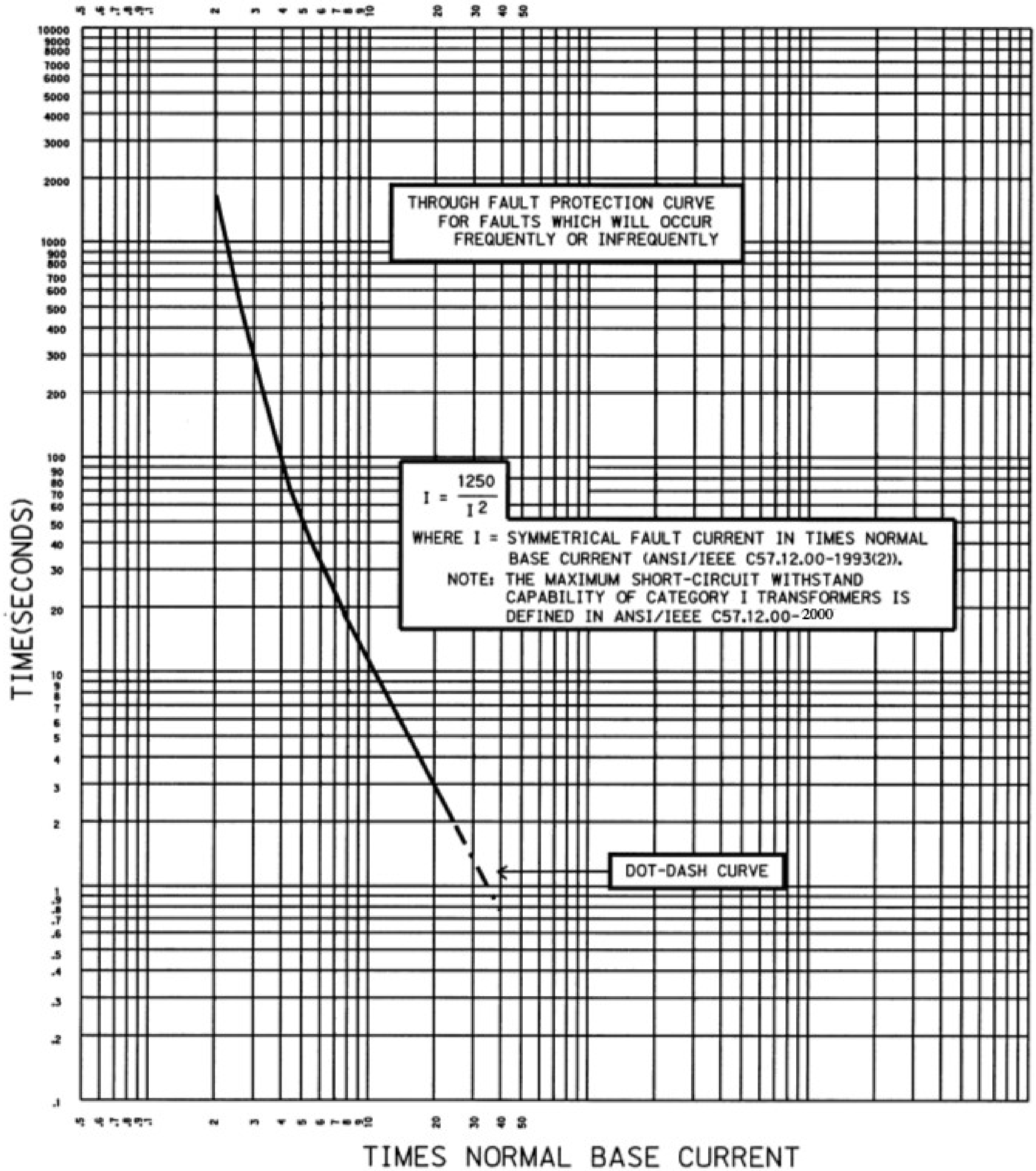


Figure A.1—Category I transformers:
5–500 kVA single-phase;
15–500 kVA three-phase

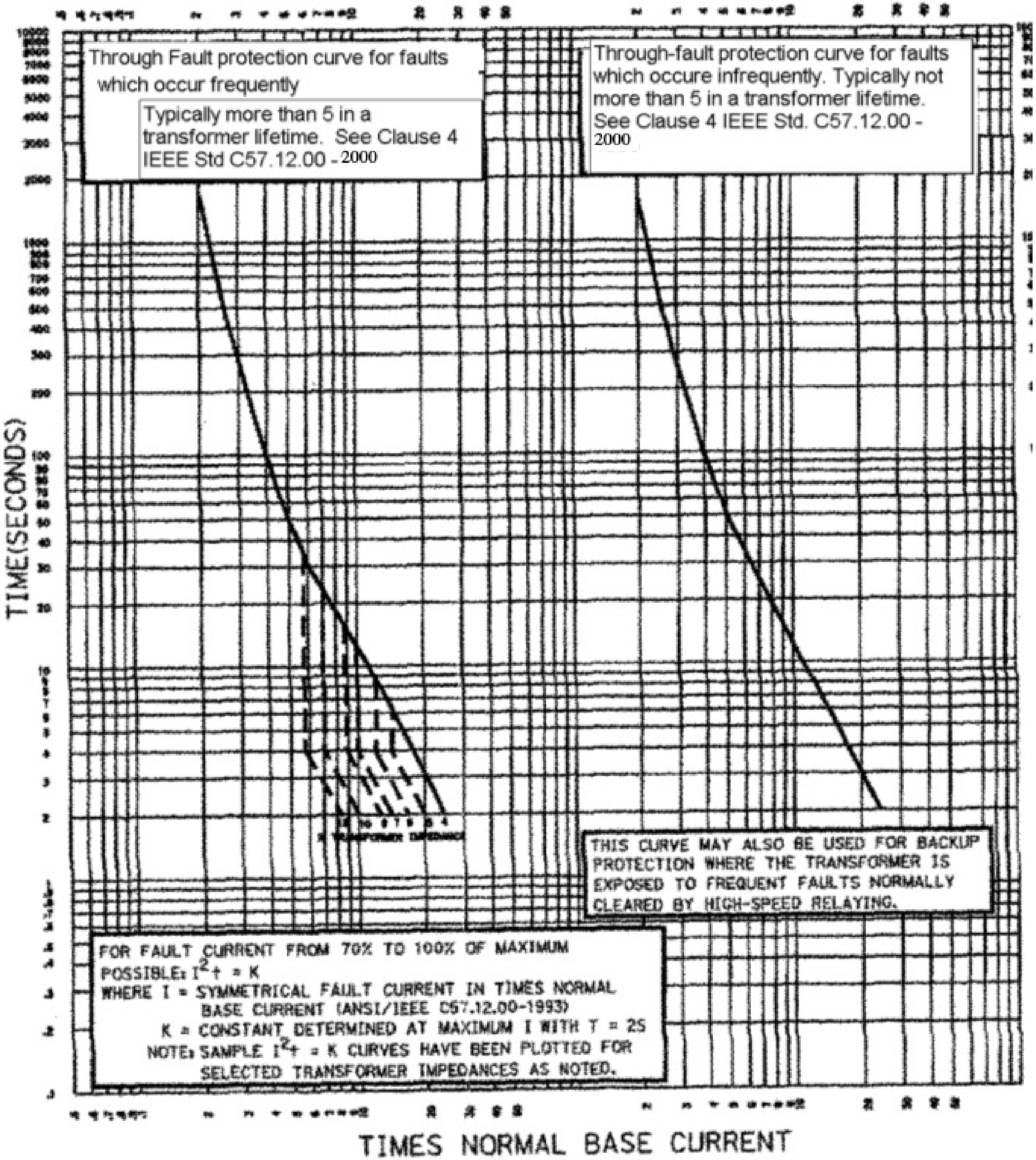


Figure A.2—Category II transformers:
501–1667 kVA single-phase;
501–5000 kVA three-phase

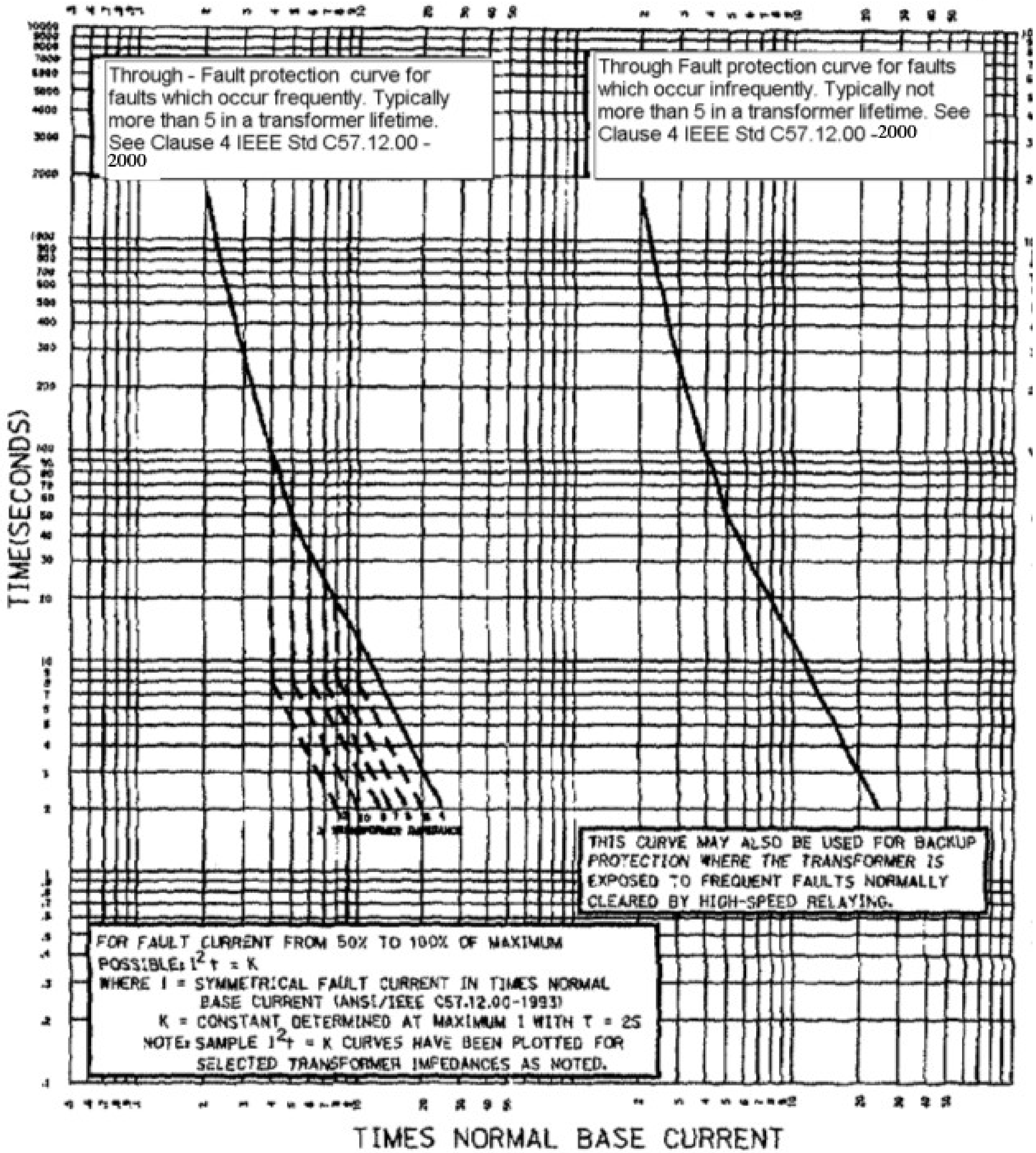


Figure A.3—Category III transformers: 1668–10 000 kVA single-phase; 5001–30 000 kVA three-phase

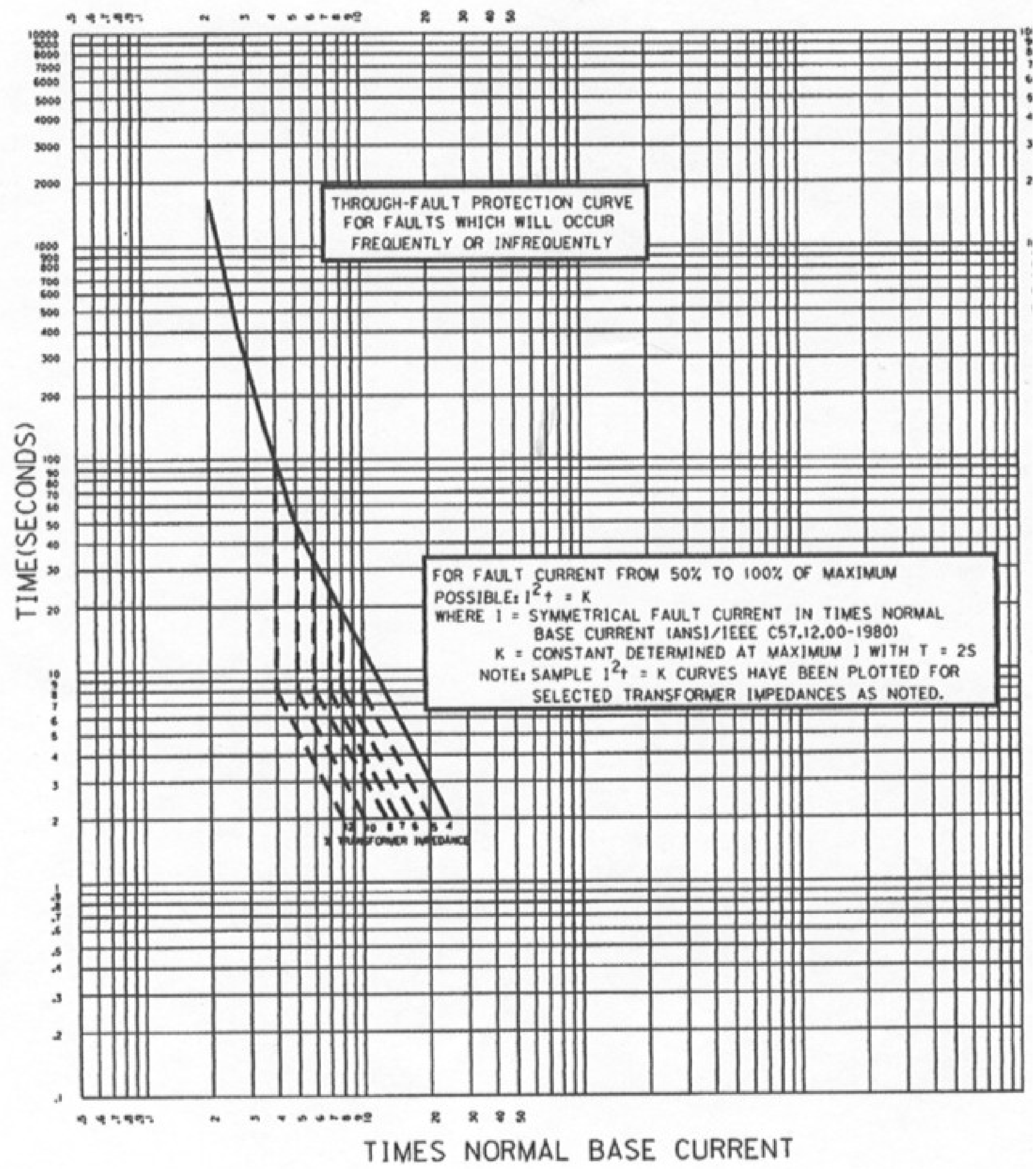


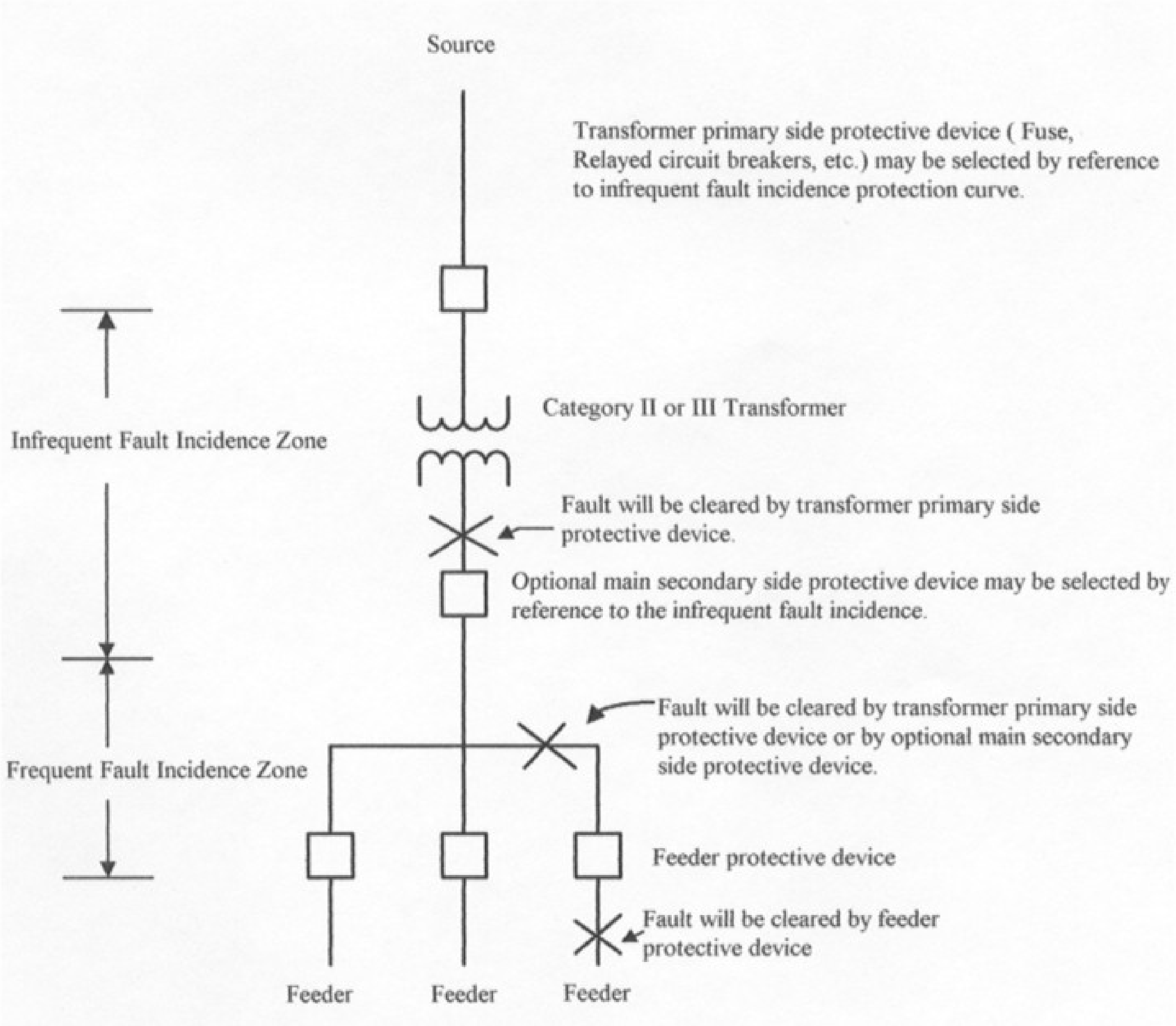
Figure A.4—Category IV transformers: above 10 000 kVA single-phase; above 30 000 kVA three-phase

Damage from Through Faults

- Damage to transformers from through-faults is the result of thermal and mechanical effects. Mechanical effects have recently gained increased recognition as a major concern of transformer failure. Though the temperature rise associated with high magnitude through-faults is typically quite acceptable, the mechanical effects are intolerable if such faults are permitted to occur with any regularity. This results from the cumulative nature of some of the mechanical effects, particularly insulation compression, insulation wear, and friction-induced displacement.
- The damage that occurs as a result of these cumulative effects is a function of not only the magnitude and duration of through-faults, but also the total number of such faults.

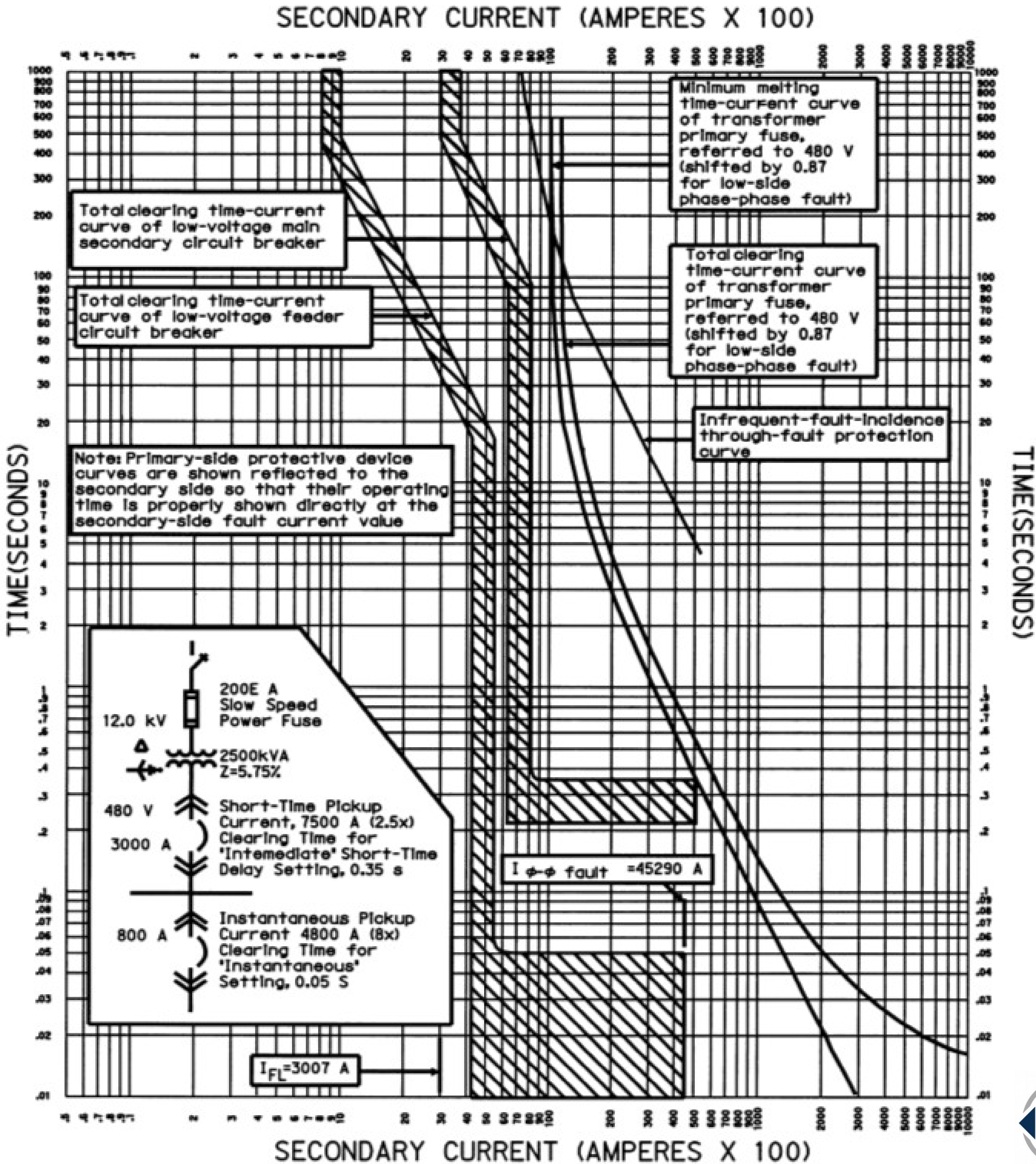
Through Fault Protection Zones

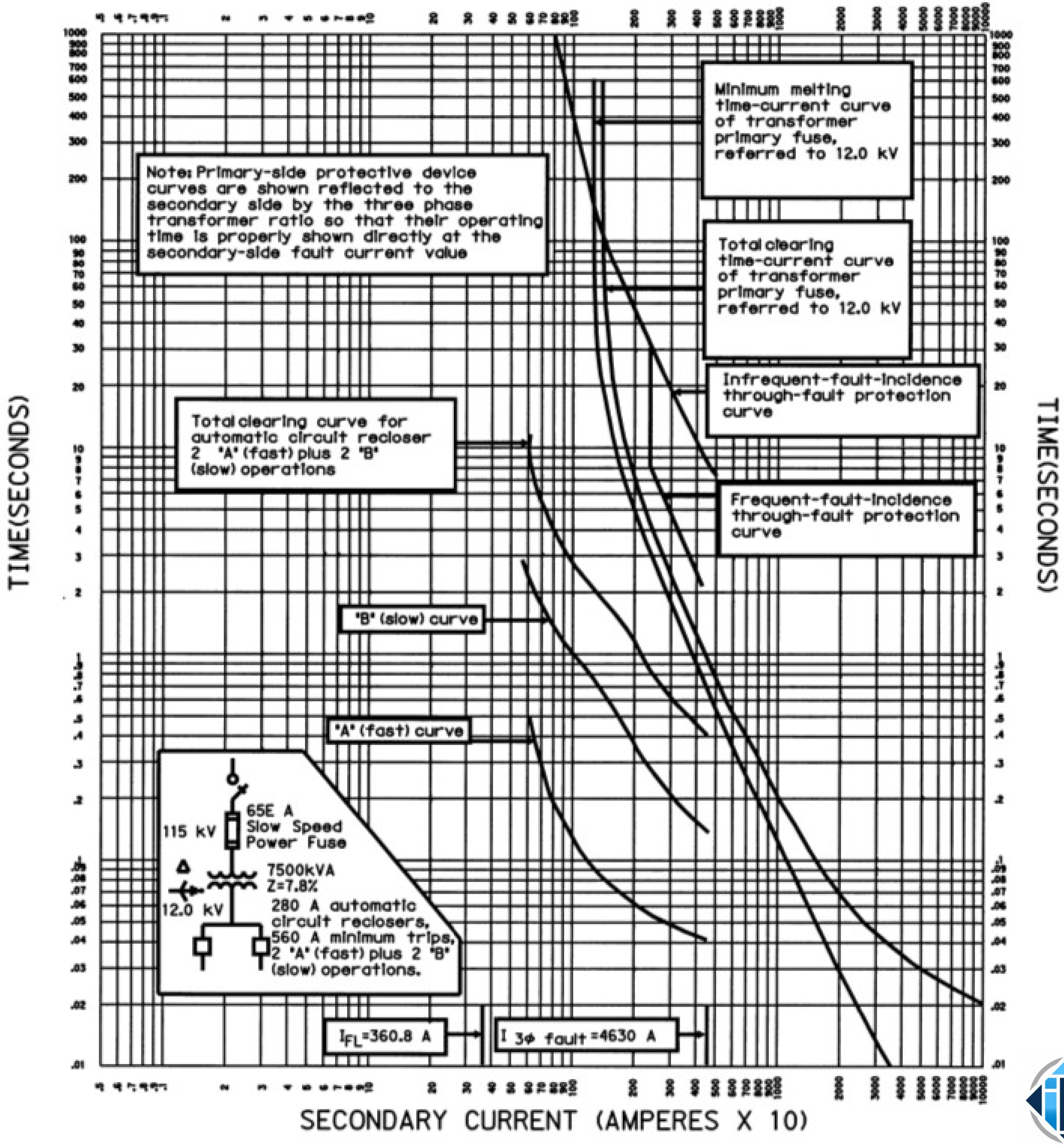
- Infrequent- and frequent-fault incidence zones



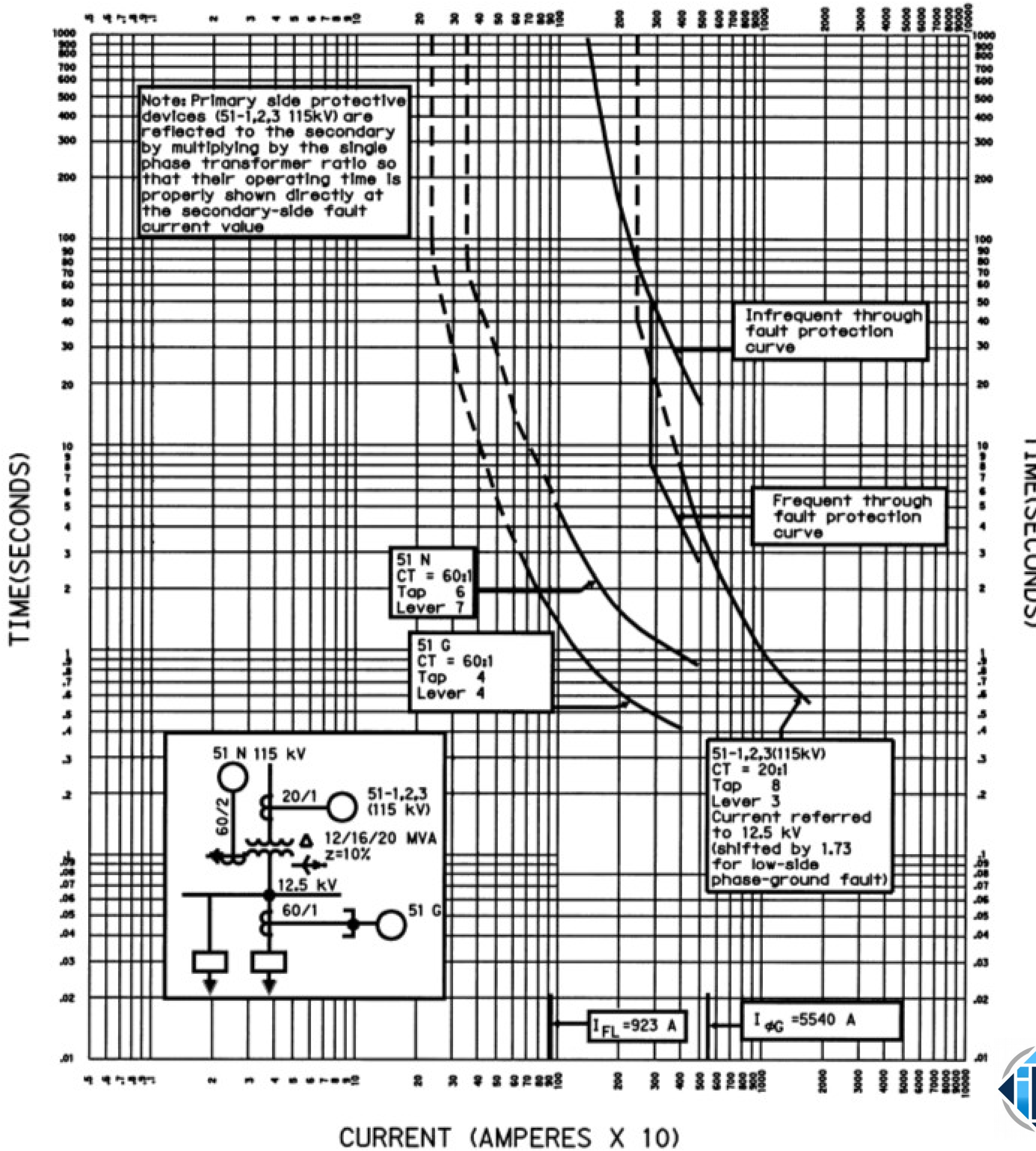
Infrequent vs. Frequent Fault Protection of Transformers

- Infrequent - Protected secondary-side conductors. Transformers with protected secondary conductors (for example, cable, bus duct, or switchgear), experience an extremely low incidence of through-faults. Hence, the main secondary, the primary-side and feeder protective devices may be selected by reference to the infrequent-fault-incidence protection curve.
- Frequent – Overhead lines – Substation transformers with secondary-side overhead lines have a relatively high incidence of through-faults. The secondary-side feeder protective equipment is the first line of defense against through-faults, and their time-current characteristics should be selected by reference to the frequent-fault-incidence protection curves.


SECONDARY CURRENT (AMPERES X 100)
TIME(SECONDS)
Minimum melting time-current curve of transformer primary fuse, referred to 480 V (shifted by 0.87 for low-side phase-phase fault)
Total clearing time-current curve of low-voltage main secondary circuit breaker
Total clearing time-current curve of transformer primary fuse, referred to 480 V (shifted by 0.87 for low-side phase-phase fault)
Total clearing time-current curve of low-voltage feeder circuit breaker
Infrequent-fault-incidence through-fault protection curve
Note: Primary-side protective device curves are shown reflected to the secondary side so that their operating time is properly shown directly at the secondary-side fault current value
200E A Slow Speed Power Fuse
12.0 kV
2500kVA Z=5.75%
480 V
Short-Time Pickup Current, 7500 A (2.5x) Clearing Time for 'Intemediate' Short-Time Delay Setting, 0.35 s
3000 A
800 A
Instantaneous Pickup Current 4800 A (8x) Clearing Time for 'Instantaneous' Setting, 0.05 S
I φ-φ fault =45290 A
I_FL=3007 A
SECONDARY CURRENT (AMPERES X 100)



TIME(SECONDS)
Note: Primary-side protective device curves are shown reflected to the secondary side by the three phase transformer ratio so that their operating time is properly shown directly at the secondary-side fault current value
Minimum melting time-current curve of transformer primary fuse, referred to 12.0 kV
Total clearing time-current curve of transformer primary fuse, referred to 12.0 kV
Infrequent-fault-incidence through-fault protection curve
Frequent-fault-incidence through-fault protection curve
Total clearing curve for automatic circuit recloser 2 "A" (fast) plus 2 "B" (slow) operations
"B" (slow) curve
"A" (fast) curve
115 kV
65E A Slow Speed Power Fuse
7500kVA Z=7.8%
12.0 kV
280 A automatic circuit reclosers, 560 A minimum trips, 2 "A" (fast) plus 2 "B" (slow) operations.
I_FL=360.8 A
I 3φ fault=4630 A
SECONDARY CURRENT (AMPERES X 10)



Note: Primary side protective devices (51-1,2,3 115kV) are reflected to the secondary by multiplying by the single phase transformer ratio so that their operating time is properly shown directly at the secondary-side fault current value
Infrequent through fault protection curve
Frequent through fault protection curve
51 N CT = 60:1 Tap 6 Lever 7
51 G CT = 60:1 Tap 4 Lever 4
51-1,2,3(115kV) CT = 20:1 Tap 8 Lever 3 Current referred to 12.5 kV (shifted by 1.73 for low-side phase-ground fault)
51 N 115 kV
20/1
51-1,2,3 (115 kV)
60/2
12/16/20 MVA Z=10%
12.5 kV
60/1
51 G
I_{FL} =923 A
$I_{\phi G}$ =5540 A
TIME(SECONDS)
CURRENT (AMPERES X 10)