Integral Group

Deep Green Engineering

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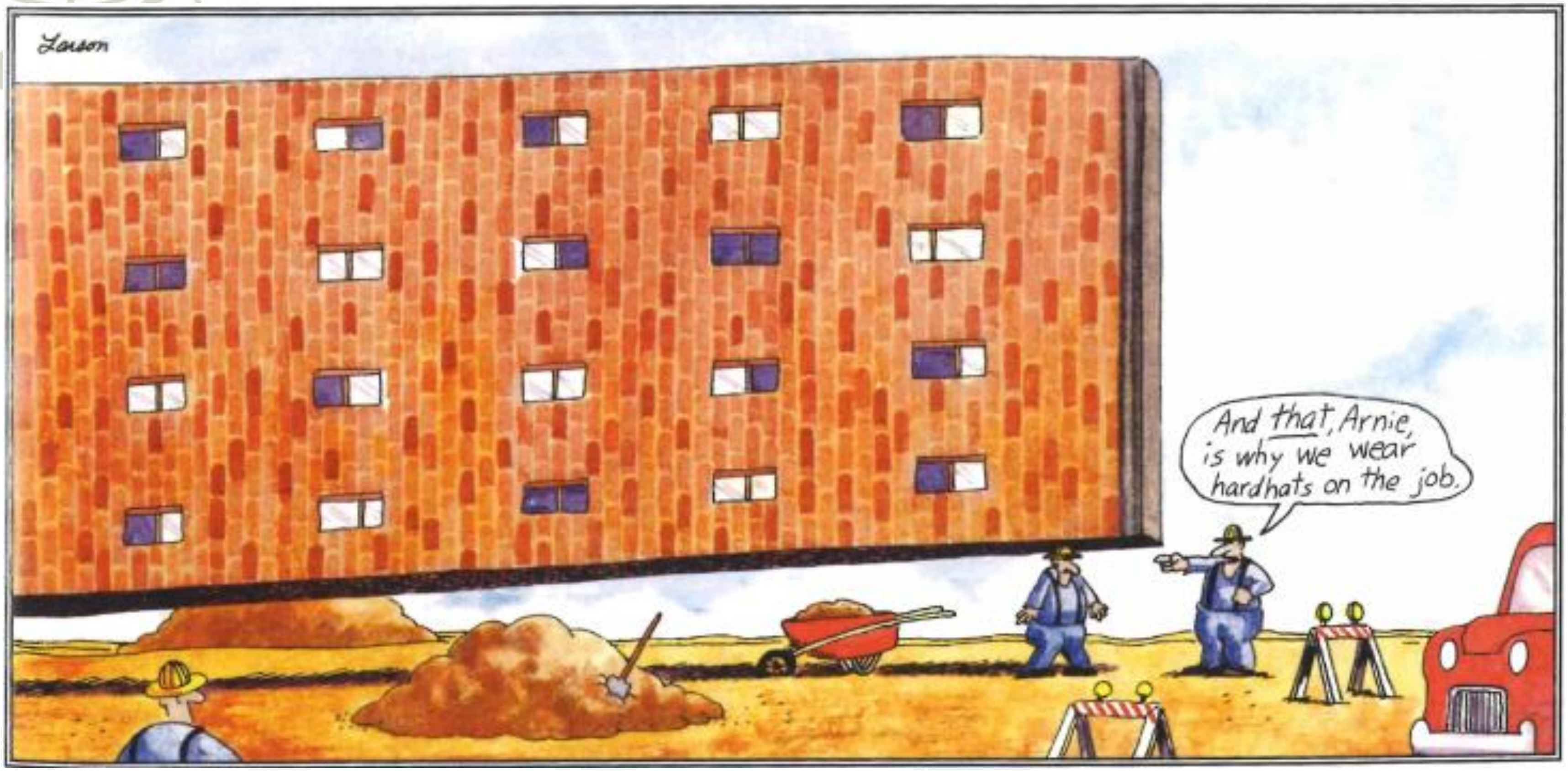
March 18, 2019

Metal-enclosed vs. Metal-clad Switchgear

(…and other observations from an electrical engineer)


Larson
And that, Arnie, is why we wear hardhats on the job.

Objectives

Classifications

Types of Protection

Applications

Considerations

Objectives

- Explain what “metal-clad” means
- Identify what types of protection is used in different types of switchgear
- Understand why this engineer would select metal-clad over other forms of metal-enclosed switchgear

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- Open switchgear has no enclosure as a part of the support structure
- Enclosed switchgear consists of a metal-enclosed supporting structure on the top and all sides (except vents and inspection windows) with access provided by doors or removeable panels

Classifications

Metal-clad Switchgear

Low-voltage Power Circuit Breaker Switchgear

Interrupter Switchgear

Classifications

All metal-clad switchgear is metal-enclosed

Not all metal-enclosed switchgear is metal-clad

What makes it Metal-Clad?

- Main device is draw-out
- Major parts are protected by grounded metal barriers
- Dead front construction
- Insulated primary bus

What makes it Metal-Clad?

- Mechanical interlocks
- Instrumentation is isolated from primary bus elements
- The door may contain instrumentation

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Types of Protection

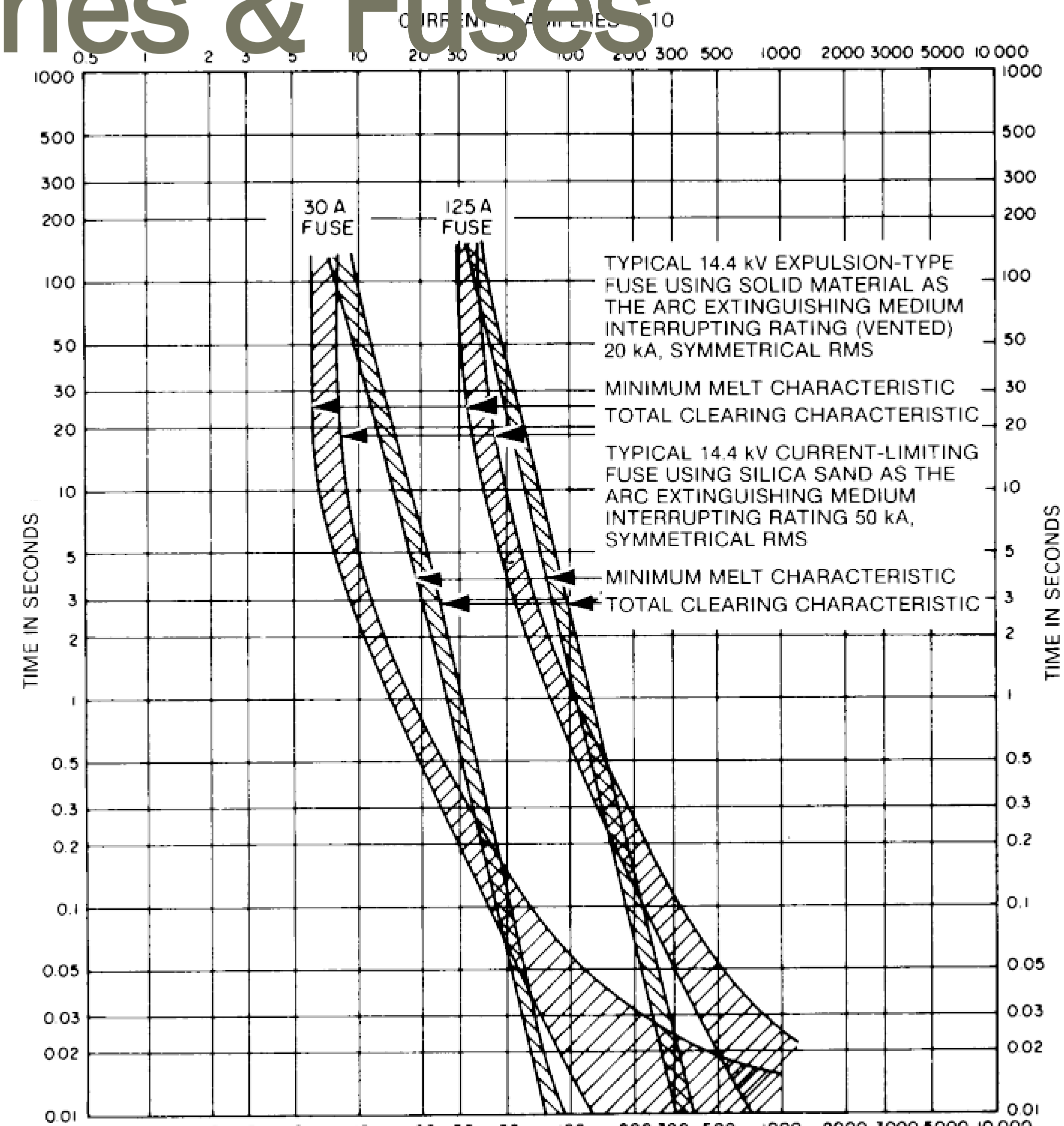
Fuses or Circuit Breakers?

Types of Protection

- Distribute and carry load
- Identify and clear faults quickly enough to minimize damage
- Provide sufficient segmentation of the medium-voltage system

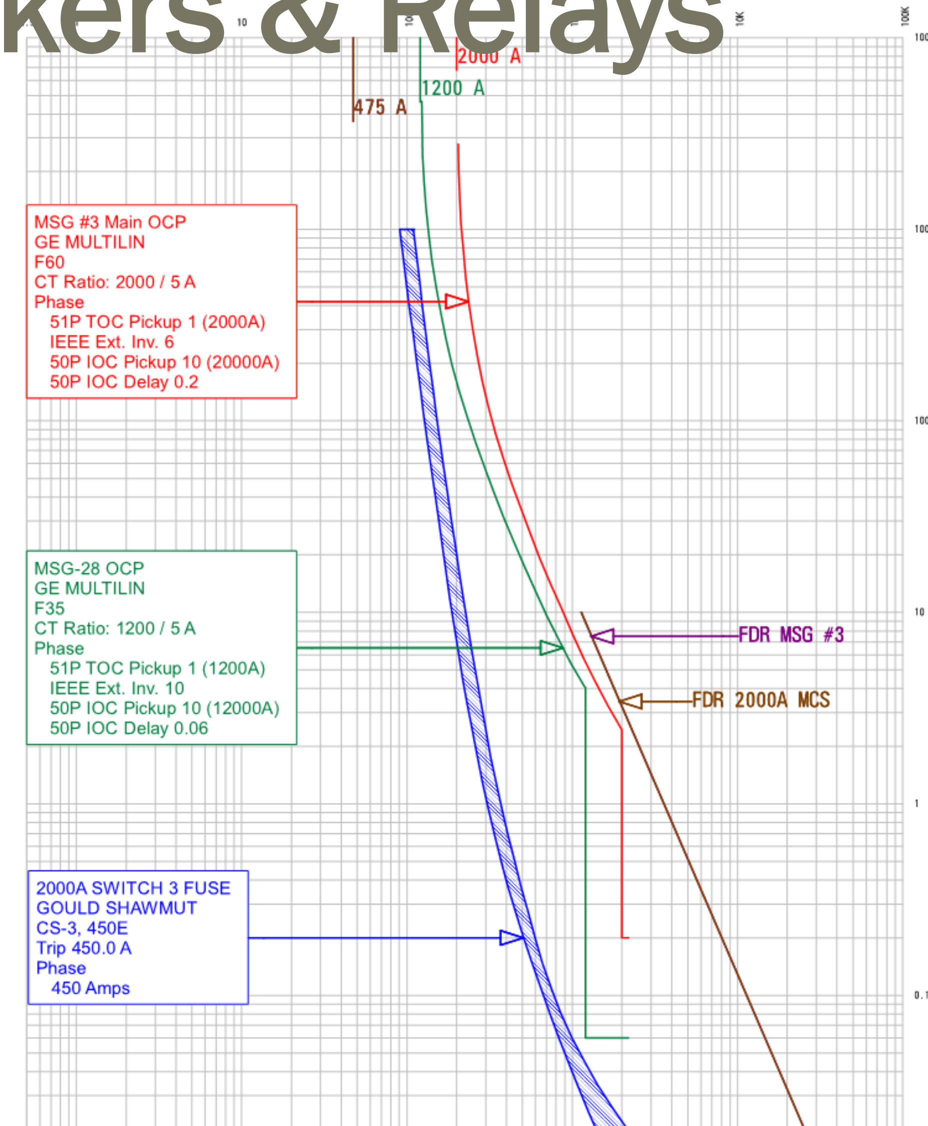
Switches & Fuses

- Simplicity
- Economy
- Fast response characteristics
- Freedom from maintenance



Circuit Breakers & Relays

- Solid state tripping
- Excellent reliability
- Very narrow and predictable tolerances
- Easily selectively coordinated



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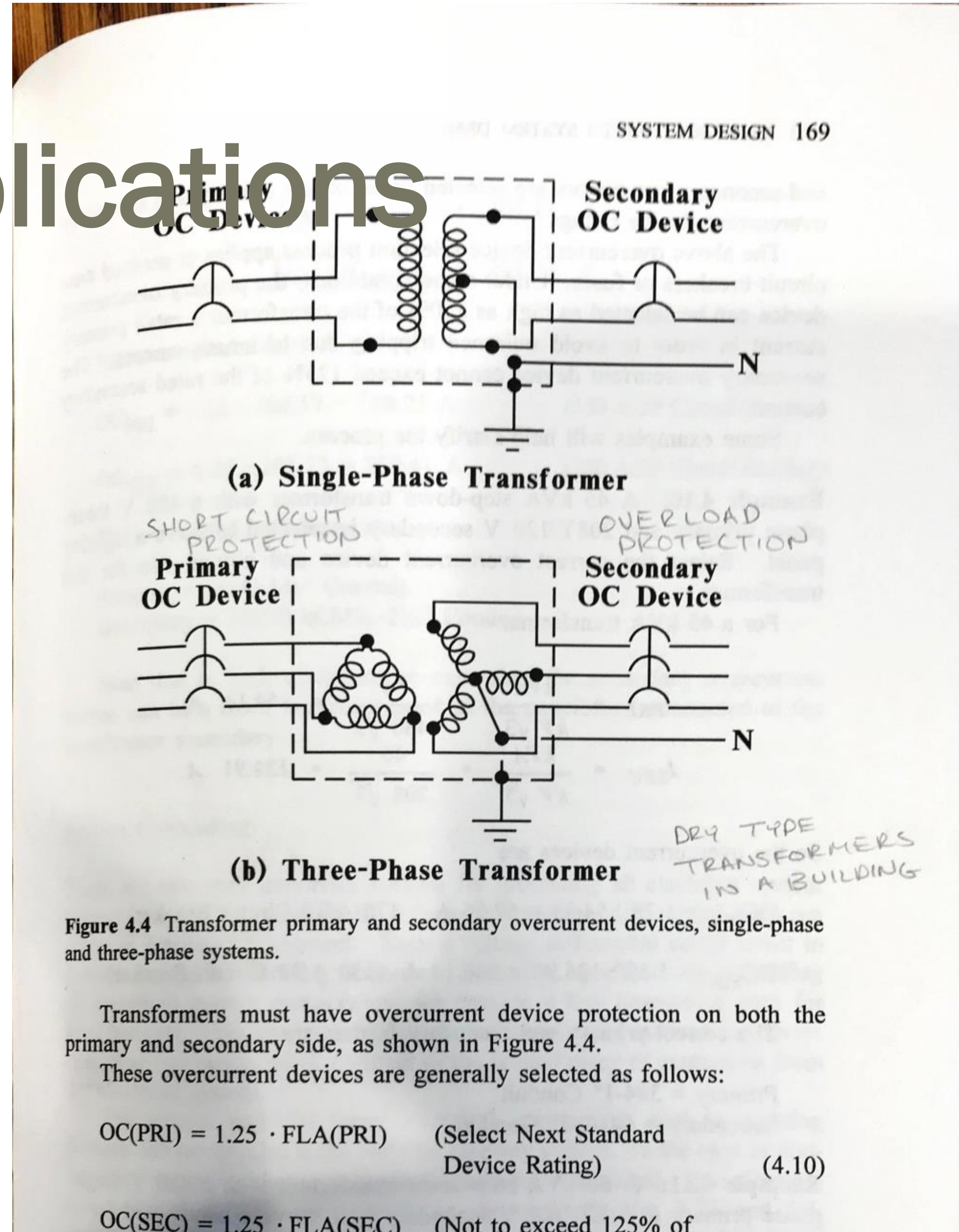
- For this engineer, there is one primary use for fuses and that is short circuit protection



(a) Single-Phase Transformer

(b) Three-Phase Transformer

Figure 4.4 Transformer primary and secondary overcurrent devices, single-phase and three-phase systems.

Transformers must have overcurrent device protection on both the primary and secondary side, as shown in Figure 4.4.

These overcurrent devices are generally selected as follows:

OC(PRI) = 1.25 · FLA(PRI) (Select Next Standard Device Rating) (4.10)

OC(SEC) = 1.25 · FLA(SEC) (Not to exceed 125% of

Applications

- For all overload applications, I am selecting a circuit breaker
- For all other applications, circuit breakers seem to be the best choice as well

(to me)

Objectives

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Considerations

Considerations

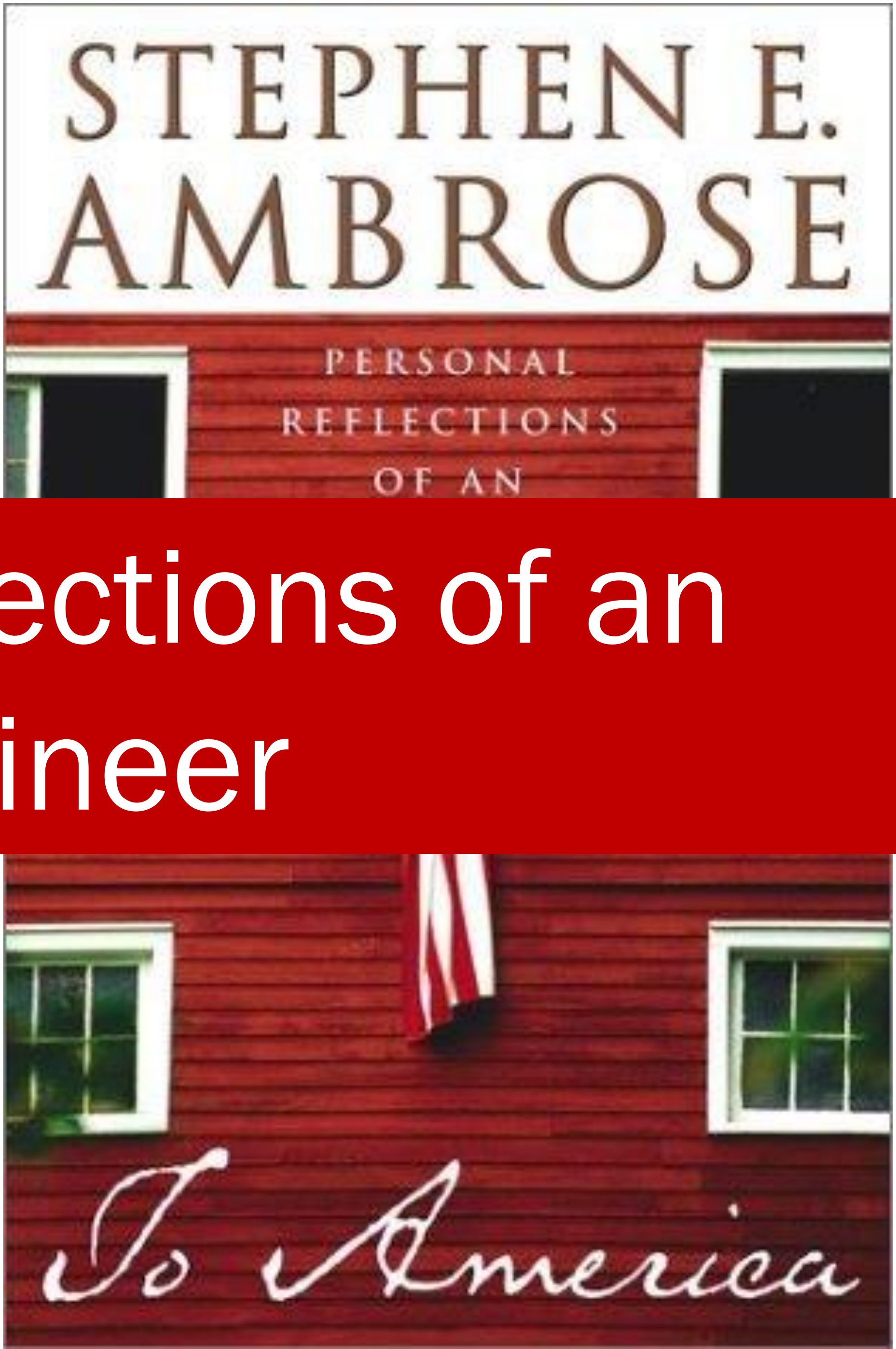
- How many outages can be permitted for maintenance?
- How much load will be interrupted for fault protection or for maintenance?
- Is automatic reclosing necessary?
- Is sophisticated relaying required?

Considerations

- Is DC control power available?
- Is single-phasing a problem?
- Are skilled technicians available?
- Will cable size be based on ampacity?
- What are the economics?

Review

Personal Reflections of an Electrical Engineer



Voltage Drop in Conductors

Voltage Drop in Conductors

- NFPA 70 Table 9 (3-phase circuits)

TABLE 9 *Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-Phase, 60 Hz, 75°C (167°F) — Three Single Conductors in Conduit*

	Ohms to Neutral per Kilometer Ohms to Neutral per 1000 Feet														
	X_L (Reactance) for All Wires		**Alternating-Current Resistance for Uncoated Copper Wires**			**Alternating-Current Resistance for Aluminum Wires**			**Effective Z at 0.85 *PF* for Uncoated Copper Wires**			**Effective Z at 0.85 *PF* for Aluminum Wires**			
Size (AWG or kcmil)	**PVC, Aluminum Conduits**	**Steel Conduit**	**PVC Conduit**	**Aluminum Conduit**	**Steel Conduit**	**PVC Conduit**	**Aluminum Conduit**	**Steel Conduit**	**PVC Conduit**	**Aluminum Conduit**	**Steel Conduit**	**PVC Conduit**	**Aluminum Conduit**	**Steel Conduit**	**Size (AWG or kcmil)**
14	0.190 0.058	0.240 0.073	10.2 3.1	10.2 3.1	10.2 3.1	— —	— —	— —	8.9 2.7	8.9 2.7	8.9 2.7	— —	— —	— —	14
12	0.177 0.054	0.223 0.068	6.6 2.0	6.6 2.0	6.6 2.0	10.5 3.2	10.5 3.2	10.5 3.2	5.6 1.7	5.6 1.7	5.6 1.7	9.2 2.8	9.2 2.8	9.2 2.8	12
10	0.164 0.050	0.207 0.063	3.9 1.2	3.9 1.2	3.9 1.2	6.6 2.0	6.6 2.0	6.6 2.0	3.6 1.1	3.6 1.1	3.6 1.1	5.9 1.8	5.9 1.8	5.9 1.8	10
8	0.171 0.052	0.213 0.065	2.56 0.78	2.56 0.78	2.56 0.78	4.3 1.3	4.3 1.3	4.3 1.3	2.26 0.69	2.26 0.69	2.30 0.70	3.6 1.1	3.6 1.1	3.6 1.1	8
6	0.167 0.051	0.210 0.064	1.61 0.49	1.61 0.49	1.61 0.49	2.66 0.81	2.66 0.81	2.66 0.81	1.44 0.44	1.48 0.45	1.48 0.45	2.33 0.71	2.36 0.72	2.36 0.72	6
4	0.157 0.048	0.197 0.060	1.02 0.31	1.02 0.31	1.02 0.31	1.67 0.51	1.67 0.51	1.67 0.51	0.95 0.29	0.95 0.29	0.98 0.30	1.51 0.46	1.51 0.46	1.51 0.46	4

Voltage Drop in Conductors

TABLE 9 Alternating-Current Resistance and Reactance for 600-Volt Cables, 3-Phase, 60 Hz, 75°C (167°F) — Three Single Conductors in Conduit

Ohms to Neutral per Kilometer / Ohms to Neutral per 1000 Feet

Size (AWG or kcmil)	X_L (Reactance) for All Wires: PVC, Aluminum Conduits	X_L (Reactance) for All Wires: Steel Conduit	AC Resistance for Uncoated Copper Wires: PVC Conduit	AC Resistance for Uncoated Copper Wires: Aluminum Conduit	AC Resistance for Uncoated Copper Wires: Steel Conduit	AC Resistance for Aluminum Wires: PVC Conduit	AC Resistance for Aluminum Wires: Aluminum Conduit	AC Resistance for Aluminum Wires: Steel Conduit	Effective Z at 0.85 PF for Uncoated Copper Wires: PVC Conduit	Effective Z at 0.85 PF for Uncoated Copper Wires: Aluminum Conduit	Effective Z at 0.85 PF for Uncoated Copper Wires: Steel Conduit	Effective Z at 0.85 PF for Aluminum Wires: PVC Conduit	Effective Z at 0.85 PF for Aluminum Wires: Aluminum Conduit	Effective Z at 0.85 PF for Aluminum Wires: Steel Conduit	Size (AWG or kcmil)
14	0.190 0.058	0.240 0.073	10.2 3.1	10.2 3.1	10.2 3.1	— —	— —	— —	8.9 2.7	8.9 2.7	8.9 2.7	— —	— —	— —	14
12	0.177 0.054	0.223 0.068	6.6 2.0	6.6 2.0	6.6 2.0	10.5 3.2	10.5 3.2	10.5 3.2	5.6 1.7	5.6 1.7	5.6 1.7	9.2 2.8	9.2 2.8	9.2 2.8	12
10	0.164 0.050	0.207 0.063	3.9 1.2	3.9 1.2	3.9 1.2	6.6 2.0	6.6 2.0	6.6 2.0	3.6 1.1	3.6 1.1	3.6 1.1	5.9 1.8	5.9 1.8	5.9 1.8	10
8	0.171 0.052	0.213 0.065	2.56 0.78	2.56 0.78	2.56 0.78	4.3 1.3	4.3 1.3	4.3 1.3	2.26 0.69	2.26 0.69	2.30 0.70	3.6 1.1	3.6 1.1	3.6 1.1	8
6	0.167 0.051	0.210 0.064	1.61 0.49	1.61 0.49	1.61 0.49	2.66 0.81	2.66 0.81	2.66 0.81	1.44 0.44	1.48 0.45	1.48 0.45	2.33 0.71	2.36 0.72	2.36 0.72	6
4	0.157 0.048	0.197 0.060	1.02 0.31	1.02 0.31	1.02 0.31	1.67 0.51	1.67 0.51	1.67 0.51	0.95 0.29	0.95 0.29	0.98 0.30	1.51 0.46	1.51 0.46	1.51 0.46	4

Solid…

Stranded…

Voltage Drop in Motors

Voltage Drop in Motors

- Starting Currents depend on efficiency of motor
- Premium Efficiency are Type ‘F’ or ‘G’.
- LRA = 3.0 to 6.0 times RLA
- Table 430.52 sets maximum at 800% (8X)
- Watch out for ‘low quality’ motors!

Voltage Drop in Motors

"Energy Efficient is 2 steps below "Premium Efficient"

Fire Pump Motors

For fire pump applications per NFPA®† 20 where contaminants are minimal.

Horsepower: 7.5 – 250 HP

Phase: Three Phase

RPM: 1800 and 3600 RPM

Voltage:
- 575
- 208-230/460
- 200/400
- 230/460 Volts

Efficiency: Energy Efficient

Enclosure:
- Open Dripproof (ODP)

Mounting:
- Footed and Footless
- Vertical and Horizontal

Vertical Shaft Type:
JP Close Coupled Pump Mounting

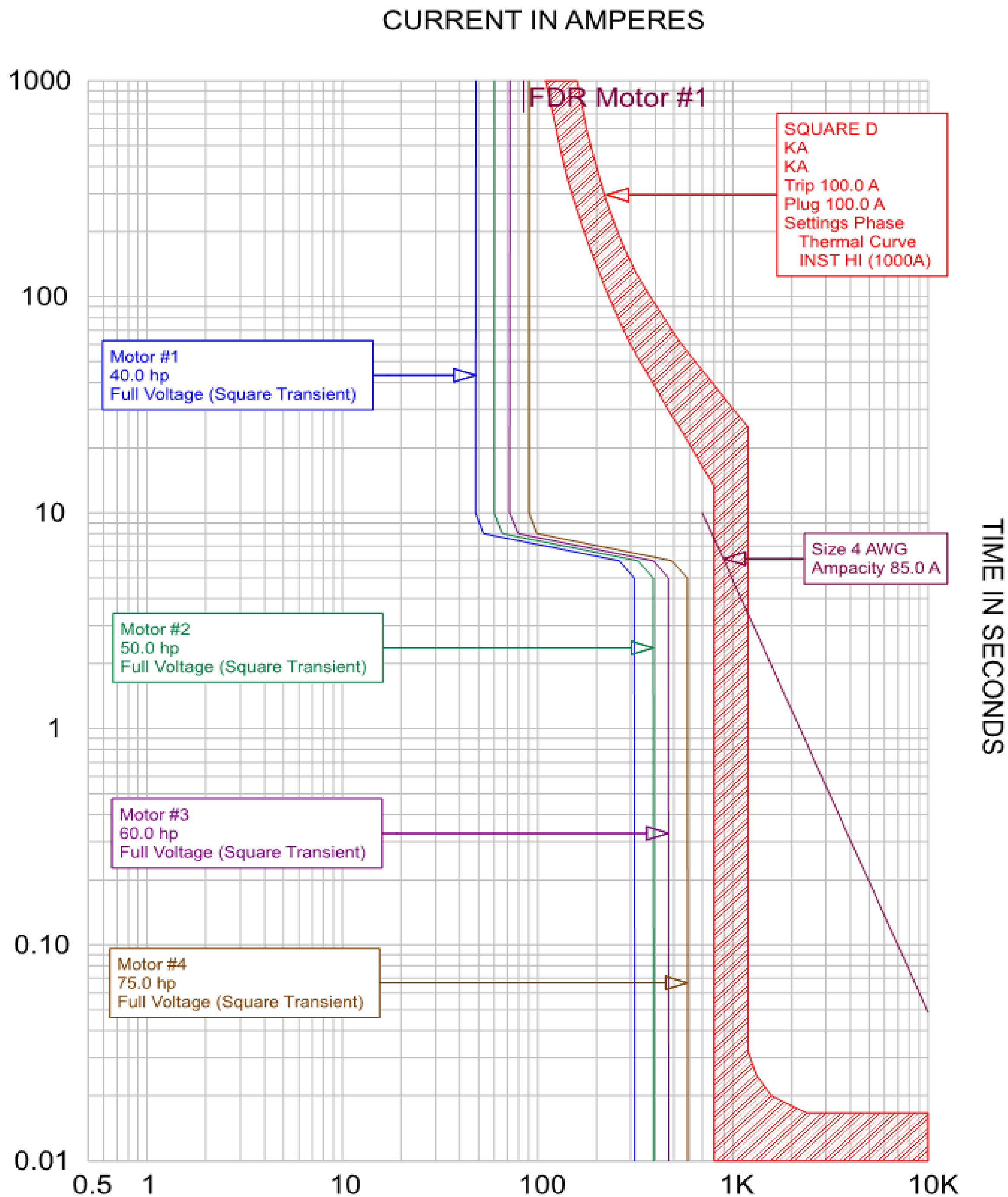
Prescriptive v. Performance

- Circuit breaker (and fuse) sizing calculations are prescriptive in NFPA 70

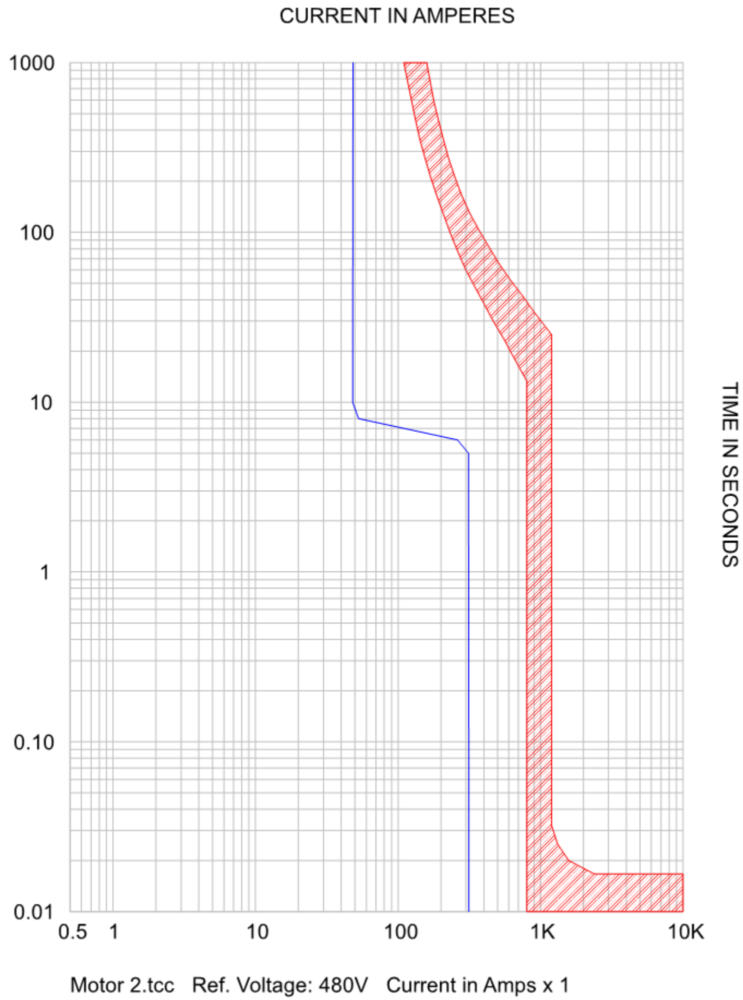
Prescriptive v. Performance

50 hp, I_{fla}=65 A @ 480v, 3 ph

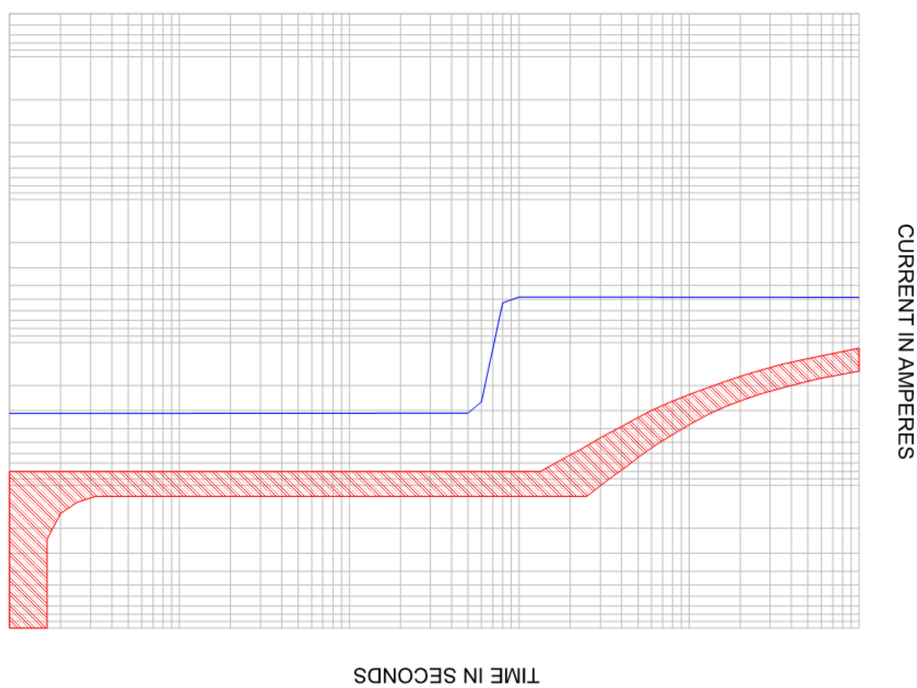
$V := 480$	$ph := 3$	$I_{fla} := 65$	
$I_{cb} := 1.75 \cdot I_{fla}$	$I_{cb} = 113.75$	CB= 125A/3P	
$I_f := 1.25 \cdot I_{fla}$	$I_f = 81.25$	Fuse= 90A	
$I_w := 1.25 \cdot I_{fla}$	$I_w = 81.25$	WIRE = 3 #3, 1 #6 G., 1 1/4" C. (Copper) WIRE = 3 #1, 1 #4 G., 1 1/2" C. (Aluminum)	
$kVa := I_{fla} \cdot \frac{V \cdot \sqrt{ph}}{1000}$	$kVa = 54.04$	$kVa_{3ph} := \frac{kVa}{3}$	$kVa_{3ph} = 18.01$


CURRENT IN AMPERES
TIME IN SECONDS
1000
100
10
1
0.10
0.01
0.5
1
10
100
1K
10K
FDR Motor #1
SQUARE D
KA
KA
Trip 100.0 A
Plug 100.0 A
Settings Phase
Thermal Curve
INST HI (1000A)
Motor #1
40.0 hp
Full Voltage (Square Transient)
Size 4 AWG
Ampacity 85.0 A
Motor #2
50.0 hp
Full Voltage (Square Transient)
Motor #3
60.0 hp
Full Voltage (Square Transient)
Motor #4
75.0 hp
Full Voltage (Square Transient)

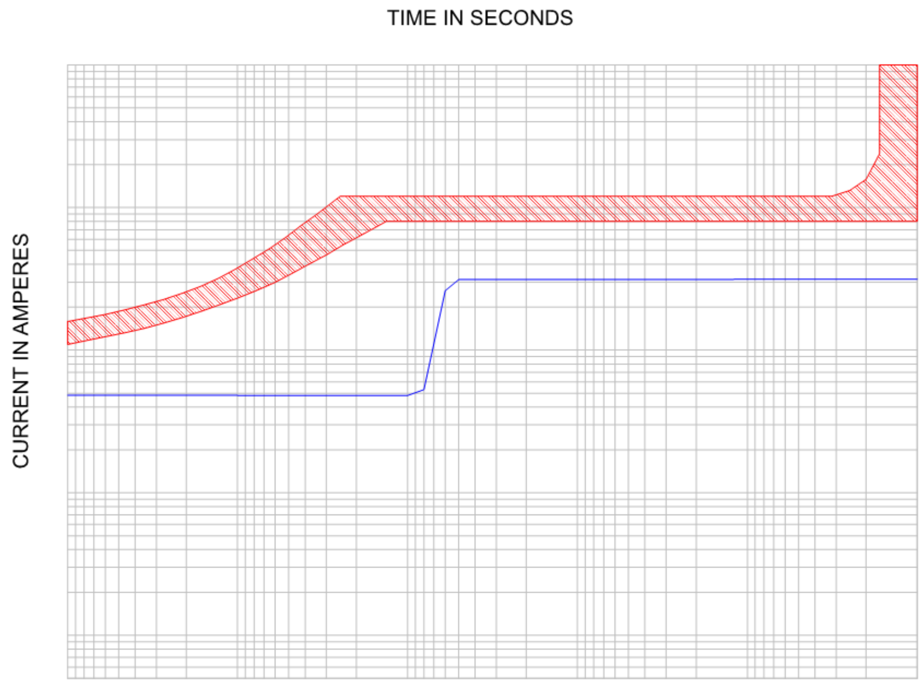
Motor Starting

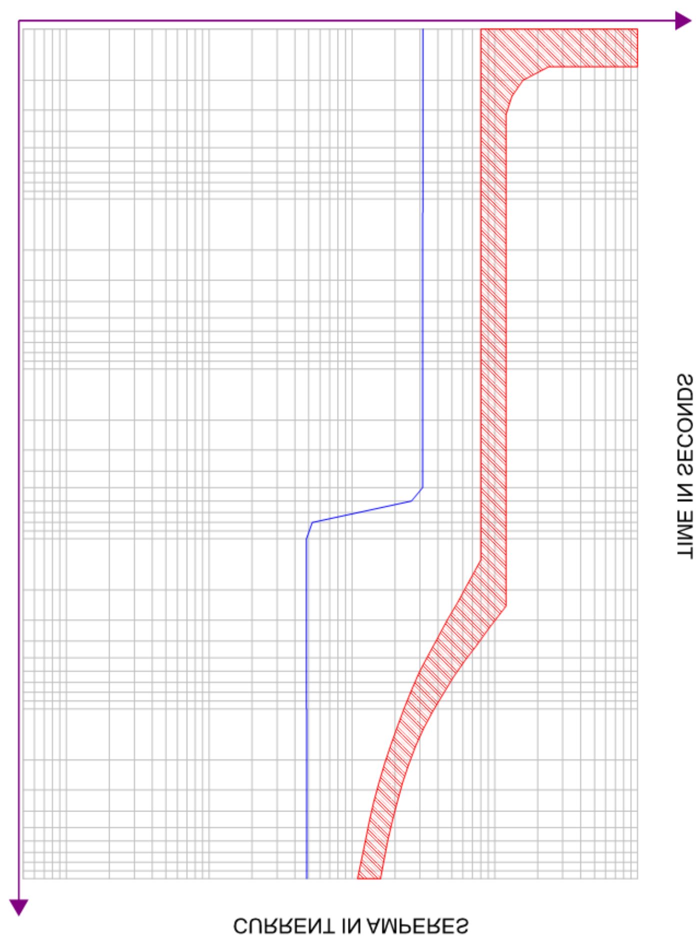


Motor Starting



Motor Starting





Motor Starting

Industry Consolidation

Industry Consolidation

Industry Consolidation

- Products benefitting from consolidation:
  - Variable Frequency Drives
  - Metering
  - TVSS/SPDs

Short Circuit Current in VFD

- Most modern VFDs will not allow current to reverse power flow
- This means that a VFD can act as a gate valve preventing motor contribution in short circuit conditions…

  … as long as the motor is not in bypass.
- Some newer VFDs do not act this way, however, so called Matrix Drives – AC-AC conversion drives

Regenerative Drives

- When ascending, elevators consume power, when descending, they are capable to regenerating power
- Some manufacturers will put this power back on to the ‘grid’
- May cause issues of reverse power flow when on emergency power or when the distribution system is small

Reverse Power Flow

- Reverse power flow is becoming more of a challenge as buildings become more energy efficient and on-site generation becomes larger and more prevalent

No Such Thing as a Sucker's Steak

- If you are good a it; stick to it
- If not; leave it to the other guys

I’m No Contractor… No Contractor is an Engineer

- If you are good a it; stick to it
- If not; leave it to the other guys

International Building Code

- Are we better off?
- Local jurisdictions should not amend Codes. Except on the issue of selective coordination, of course!
- City of Atlanta ordinance on above ground fuel storage is a great (horrible) example
- The line item veto

Calling all Developers!

- Get your lease language updated
- Just because you are flipping a property does not mean that you can't do something special

THANK YOU