



NEC Mandated Selective Coordination

Challenges and Solutions

IEEE IAS Meeting

May 16, 2011





Background and Definitions

Selective Coordination & The National Electrical Code

		NEC VERSIONS					
Article	Title	1993	1996	1999	2002	2005	2008
100	<i>Definitions</i>					★	
517	<i>Healthcare Facilities</i>					517.26	517.26
620	<i>Elevators, Dumbwaiters, Escalators, Moving Walks, Wheel Chair Lifts, and Stairway Chair Lifts</i>	620.51(a)	620.62	620.62	620.62	620.62	620.62
700	<i>Emergency Systems</i>					700.27	700.27 Exception
701	<i>Legally Required Standby Systems</i>					701.18	701.18 Exception
708	<i>Critical Operations Power Systems (COPS)</i>						708.54

No significant changes to Selective Coordination in 2011 National Electrical Code

Selective Coordination - Background

2005 National Electric Code (NEC) Article 100 definition “Coordination (Selective)”:

“Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings.”

Simply stated: When ONLY the overcurrent device protecting the specific circuit that has an overload or fault opens to clear it.

Selective Coordination - Background

- Required for Elevators since 1993 NEC.
- Added to 2005 NEC for Emergency Systems (Art. 700.27) and Legally Required Standby Systems (Art. 701.18).
- When accepted into 2005 NEC Article 700, by omission it became a requirement for “Essential electrical systems” of Health Care Facilities (Art. 517.26) as well.

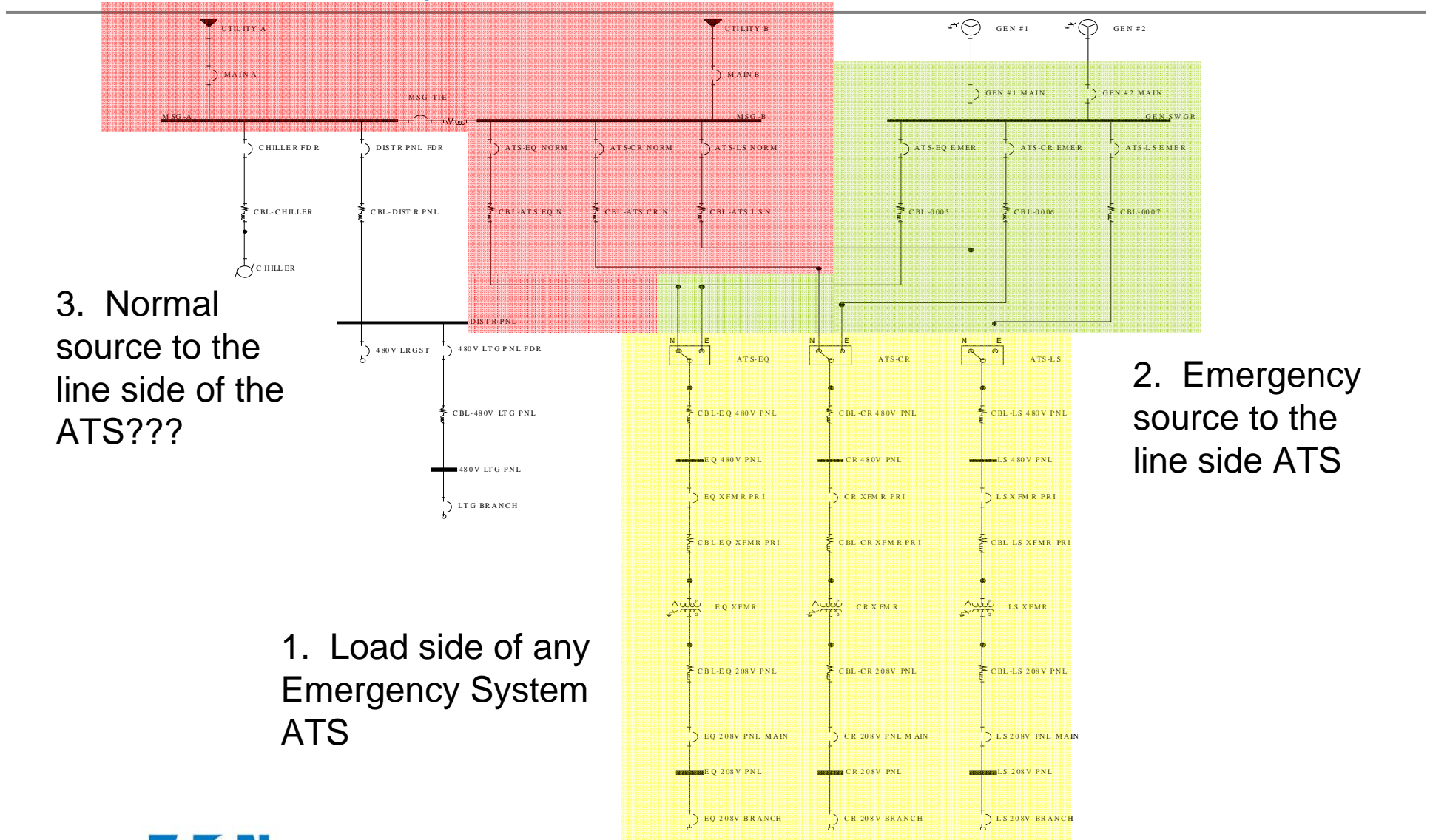
Selective Coordination Challenges

- Interpretation
- Design
- Enforcement

Challenge - Interpretation

- Which Devices are Required to be Selectively Coordinated?
 - 700.27 states, “Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.”
 - Similarly, 701.27 states, “Legally required standby system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.”

Which devices are required to be Selectively Coordinated?



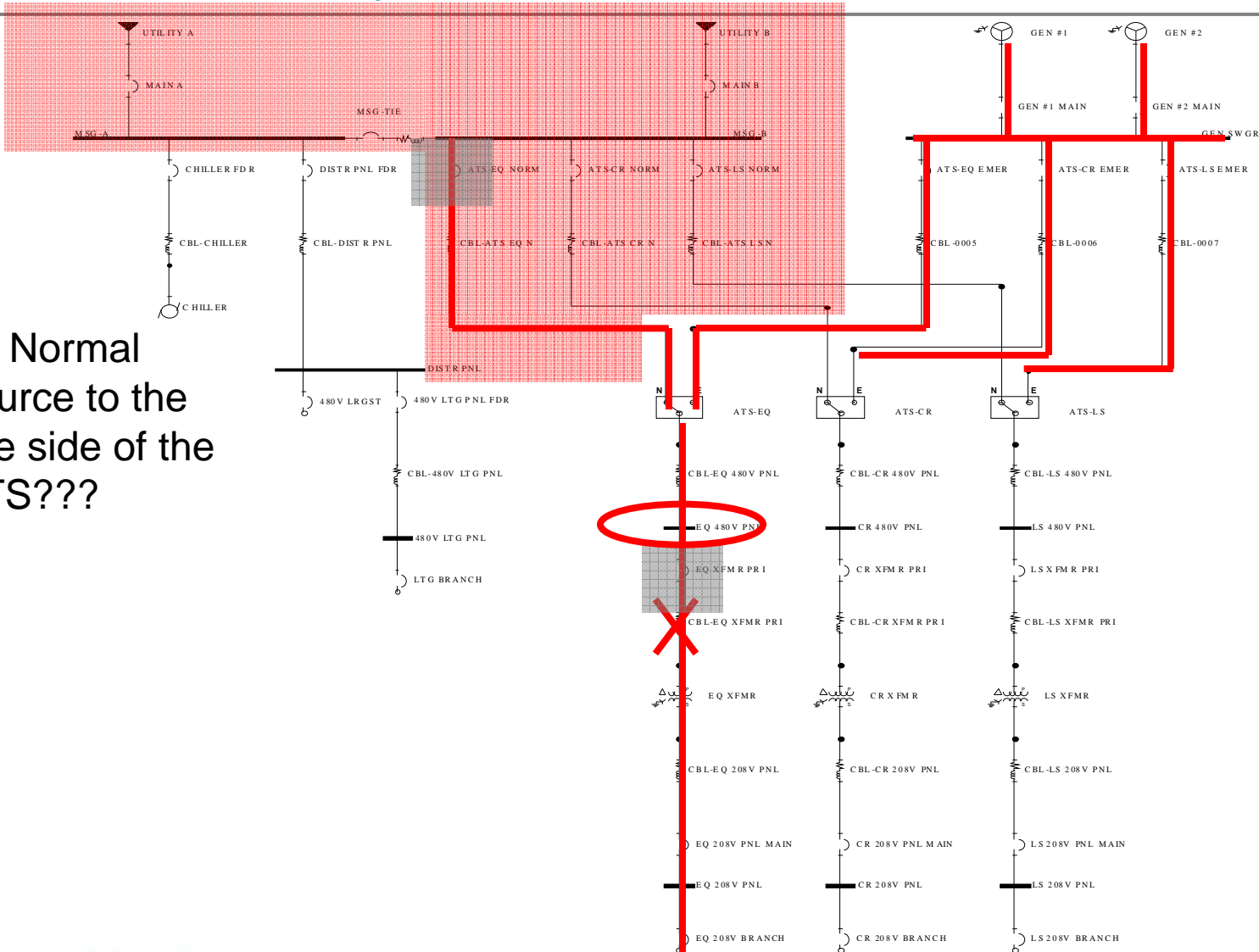
3. Normal source to the line side of the ATS???

2. Emergency source to the line side ATS

1. Load side of any Emergency System ATS

Which devices are required to be Selectively Coordinated?

3. Normal source to the line side of the ATS???



Which devices are required to be Selectively Coordinated?

- Answer: It is up to the Authority Having Jurisdiction (AHJ).
 - Jurisdictions with written clarification for Generator Side only: Chicago, Las Vegas, State of Oregon, State of Washington*, State of Wisconsin
 - Jurisdictions rumored to be requiring coordination up to the Normal Source: Charlotte, NC
 - Actual intent of the NEC is somewhat unclear

Challenge - Interpretation

- What level of Selective Coordination is required?
 - Total Selective Coordination
 - 0.01 seconds
 - 0.1 seconds

What Level of Selective Coordination is Required?

- Reasons for Considering 0.1 or 0.01 seconds instead of Total Selective Coordination*
 - Achieving total selective coordination may be nearly impossible for certain systems
 - Achieving total selective coordination may result in undesirable levels of arc flash energy
 - Verification of total selective coordination is difficult.
 - **Some jurisdictions have defined a time cut-off for selective coordination**

* Choosing a level other than total selective coordination without AHJ approval is risky.

What Level of Selective Coordination is Required?

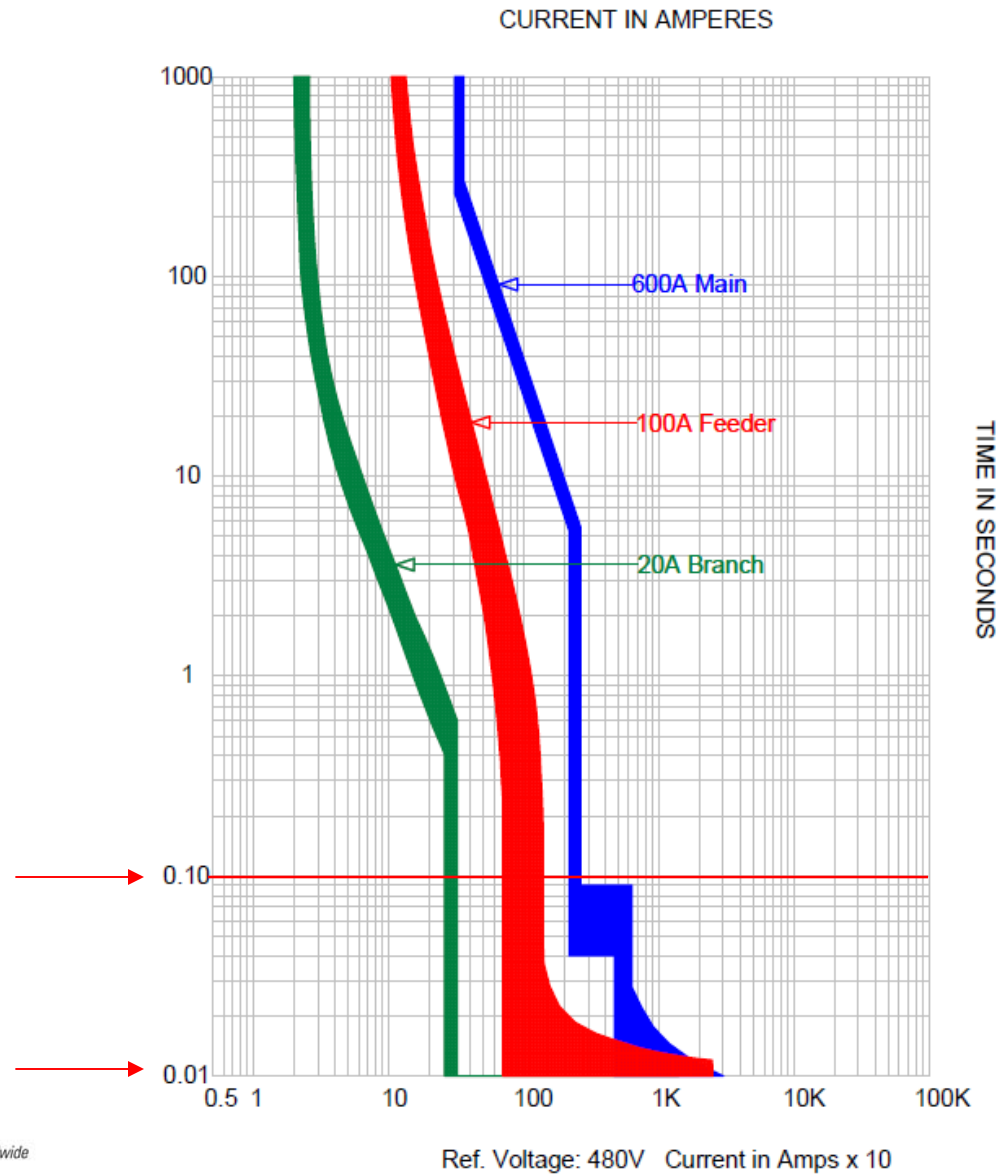
- Some jurisdictions have defined a level of 0.1 or 0.01 for selective coordination*
 - State of California Healthcare (OSHPD) – 0.1
 - State of Florida Healthcare (AHCA) – 0.1
 - City of Memphis – 0.1
 - Las Vegas – 0.01, 0.1 allowable if 0.01 can not be achieved
 - State of Oregon – 0.01
 - City of Seattle – 0.1
 - NFPA 99 (pending) – 0.1
 - But not Georgia...

* This list is subject to change and should always be verified with the AHJ

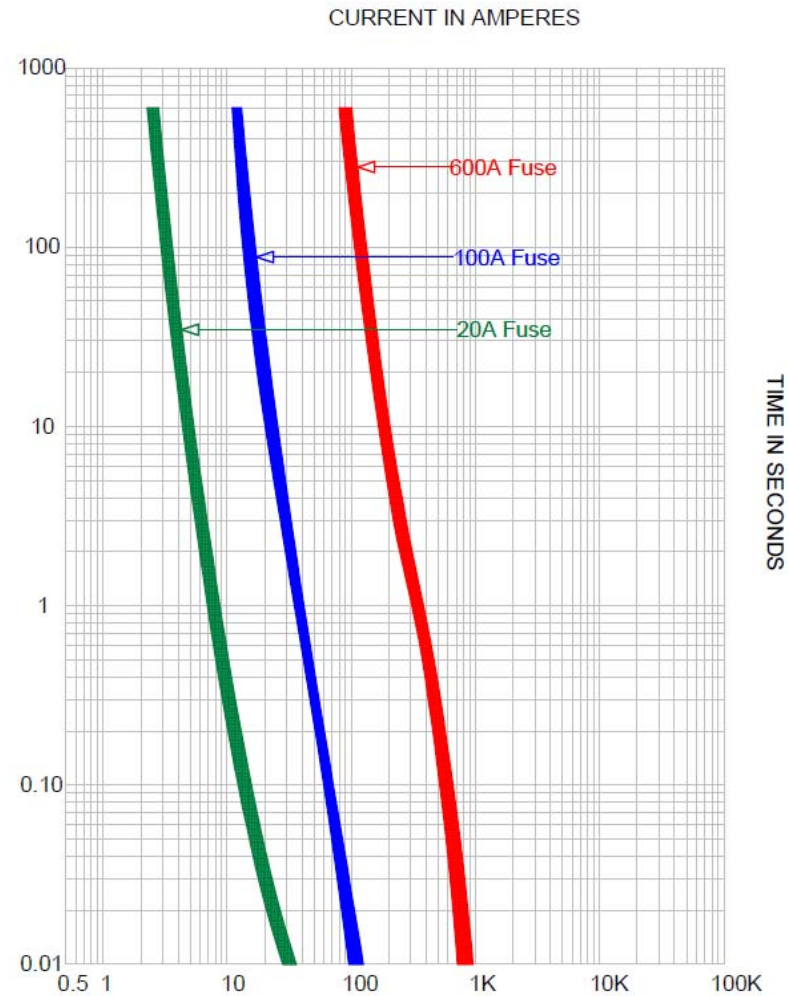
What Level of Selective Coordination is Required?

- What do these time limits mean in the real world?
 - Design to worst case fault currents – bolted fault
 - Most real world faults are lower level arcing faults or ground faults
 - Coordination down to 0.01 seconds allows coordination for all but the highest levels of fault current
 - Coordination down to 0.1 seconds allows coordination for overloads and typical arcing fault levels

What Do These Time Limits Mean in the Real World?



What Do These Time Limits Mean in the Real World?



Fuse Example.tcc Ref. Voltage: 480V Current in Amps x 10

Beyond the Curves - Manufacturer's Tables

Bussmann
Fuse Selectivity Ratio Guide

Simply referring to fuse selectivity ratios makes it easy to design and install fuse systems that are selectively coordinated. See the Catalog Fuse Selectivity Ratio Guide. The top horizontal axis shows busbar fuses and the left vertical axis shows branch fuses. These selectivity ratios are for all levels of overcurrent up to the fuse interrupting rating of 200,000A, whichever is lower. This table is valid only for fuse opening times less than 0.01 second. The breaker part needs to install the proper fuse type and amp rating. It is not necessary to plot time-current curves or a short-circuit current analysis if the available short-circuit current is less than 200,000A at the interrupting rating of the fuse, whichever is less. All that is necessary is to ensure the breaker is rated for the available fault current. If the available fault current is greater than 200,000A, the breaker must be selected for the available fault current.

Selectivity Ratio Guide (A Guide to Loaders)

Line Fuse	Busbar Fuse	Line Fuse	Busbar Fuse	Line Fuse	Busbar Fuse
100A	100A	100A	100A	100A	100A
100A	100A	100A	100A	100A	100A
100A	100A	100A	100A	100A	100A

GE Energy Industrial Solutions
GE Overcurrent Device Instantaneous Selectivity Table

imagination at work

SIEMENS
Techn Journal

480 V Selective Trip Coordination with Modern MCC

Ray Clark, Consulting Application Engineer

The following Selective Trip Coordination Table shows the minimum downstream breaker, that will allow selective trip coordination in industry experience in this area becomes available and further is published. Please contact your Siemens representative for the following steps will assure the best use of the Selective Trip:

1. Conduct a short circuit study to determine the available fault when coordination is critical. This allows the most cost efficient necessary selective trip coordination. A higher available fault current requires a more expensive upstream circuit breaker. Accurate short circuit current calculations.
2. Trip coordination is assumed up to the value shown in the "B" circuit study will be the best source of the maximum available fault value shown in this field. Selective trip coordination is assumed value is less than this "Branch Coordination Level". Faults on very rare so this is a conservative approach. The system design balance the needs of system protection and coordination at various points.

If the branch available fault current is not known, the main bus may be used. This is a very conservative approach and may require many systems the distribution transformer let-through value will be used. The published data for the transformer should be used.

In many cases the minimum frame MCCB will only coordinate level of selective coordination between the two circuit breakers available fault current at that point in the system, the tables may breaker that will allow a higher level of coordination. This will type of circuit breaker such as an insulated case or power break coordination current levels so that by moving down the table it deliver a higher level of selective coordination.

Industry Application IA01200002E (Effective December 2011)

Selective Coordination

EATON
Powering Business Worldwide

Data Bulletin

Short Circuit Selective Coordination for Low Voltage Circuit Breakers

Retain for future use.

INTRODUCTION

The purpose of this data bulletin is to provide coordination data for various circuit breakers. The scope of this data bulletin covers the coordinated region of their time-current curves, based on the protection of motors, branch circuit breakers, and ground fault protection. This data bulletin is a companion to the data bulletin on Short Circuit Selective Coordination with Low Voltage Circuit Breakers.

Appendix Guide

- Appendix A: Mission Critical
- Appendix B: Levels of Short
- Appendix C: Levels of Short
- Appendix D: A Glossary of Terms

SELECTIVE COORDINATION DATA

How Time-Current Curves Are Developed

Time-current curves represent the performance of a circuit breaker at various levels of overcurrent. They are developed from test data and the current level is the time-current curve shows the performance. In the instantaneous region, the clearing time is assumed that the clearing time, hence the curve is linear.

Current-Limiting Circuit Breakers

Many modern circuit breakers have a current-limiting feature that decreases as the current increases. This feature is not shown in the time-current curves and is not shown in the characteristics.

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Fuseology **Littelfuse**

Fuse Application Guide

Overcurrent Protection Fundamentals

Table 2
Fuse Coordination Table

Selecting the Correct Fuse Ampere Rating to Maintain Selectively Coordinated Systems

Amperes Rating	UL Class	Littelfuse Catalog No.	Low Voltage Fuses				High Voltage Fuses				
			100A	150A	200A	250A	100A	150A	200A	250A	
100A	100A	100A	100A	100A	100A	100A	100A	100A	100A	100A	100A
150A	150A	150A	150A	150A	150A	150A	150A	150A	150A	150A	150A
200A	200A	200A	200A	200A	200A	200A	200A	200A	200A	200A	200A
250A	250A	250A	250A	250A	250A	250A	250A	250A	250A	250A	250A

A. General

110-2. Examination, Identification, Installation, and Use of Equipment.

110-2.1 Examination. In judging equipment, consideration shall be given to the following:

- (1) Having effects under normal conditions of use and under abnormal conditions likely to arise in service.
- (2) Insulation and Use. Listed and labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.
- (3) Interrupting Rating. Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the normal circuit voltage and the current that is available at the line terminals of the equipment.
- (4) Equipment intended to interrupt current at other than fault levels shall have an interrupting rating at normal circuit voltage sufficient for the current that must be interrupted.

110-3. Circuit Impedance and Other Characteristics. The manufacturer's protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective device used to clear a fault to do so without excessive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the grounding conductor or enclosing metal enclosure. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section.

ARTICLE 140 - OVERCURRENT PROTECTION

240.1 Scope. Parts I through VII of this article establish the general requirements for overcurrent protection and overcurrent protective devices for more than 600 volts, nominal. Part VIII covers overcurrent protection for three-phase of ungrounded industrial installations operating at voltages of not more than 600 volts, nominal. Part IX covers overcurrent protection over 600 volts, nominal.

(F) Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductive insulation. See also Sections 110.3 for requirements for interrupting ratings and 110.10 for requirements for protection against fault currents.

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Challenge - Design

- How Do I Design a System that can be Coordinated?

Selective Coordination

- Design Tips

1. Flatten the system

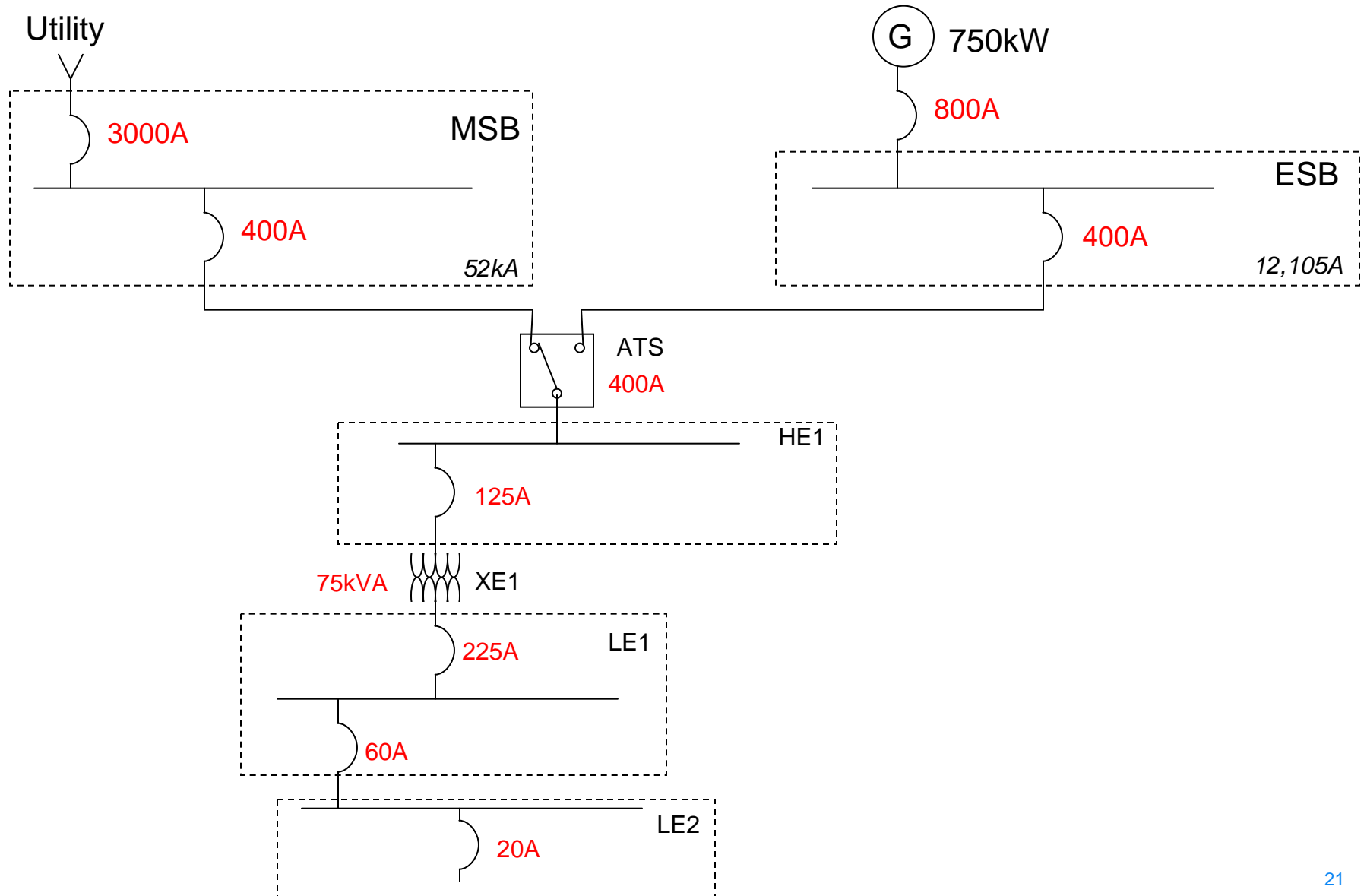
- Limit the number of levels of OCPD's
- Reduces the number of potential coordination problems
- Limit levels of 480v devices to (3)
 - Depending on fault current, 1st and 2nd levels may need to be Power Circuit Breakers (UL1558 Switchgear)
 - Distribution Panels
 - If possible, avoid 277v lighting
 - Otherwise, don't locate lighting panels in same room as Distribution panels
 - Or, utilize isolation transformers to knock down fault current

Selective Coordination

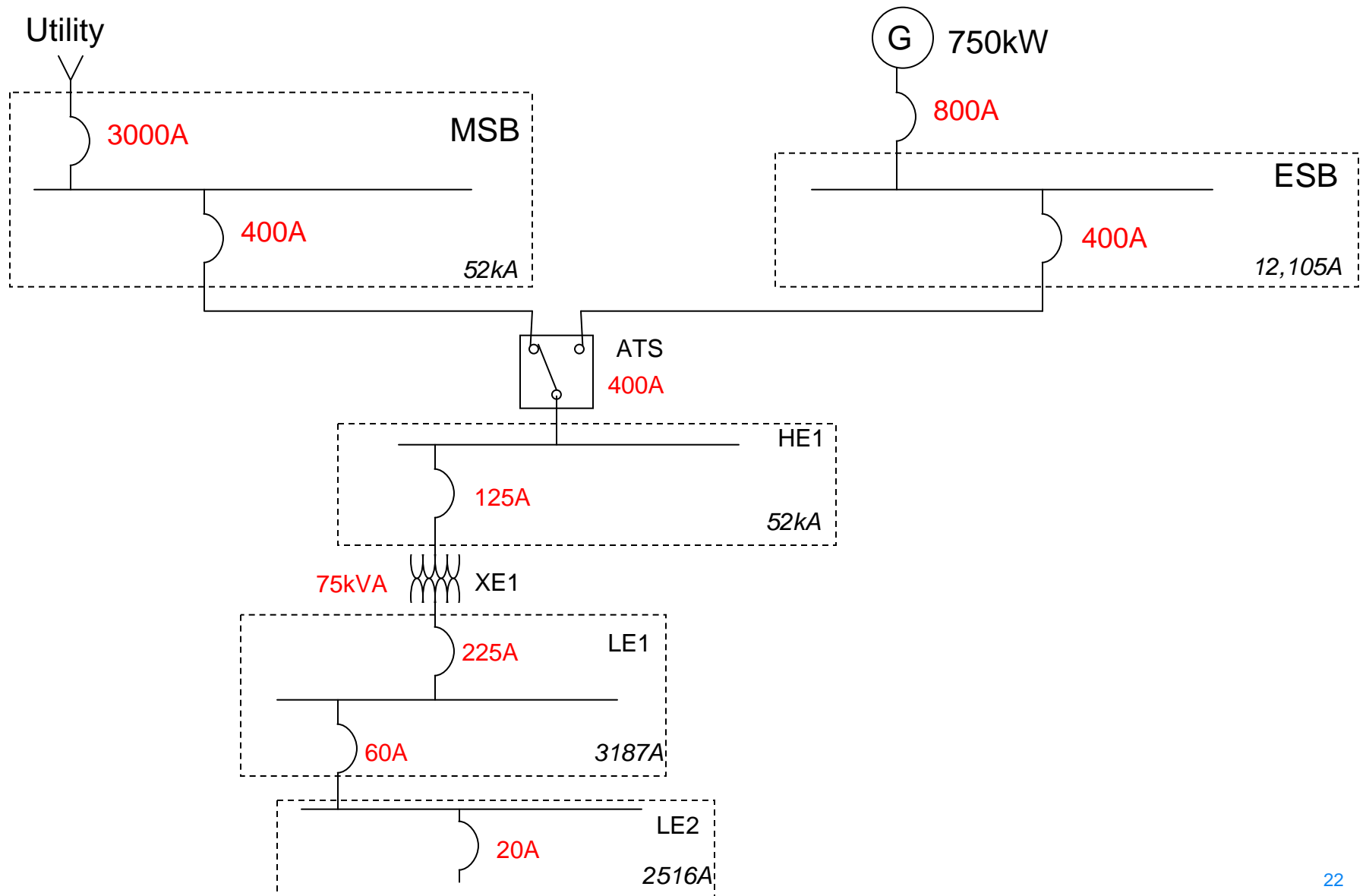
2. Transformer Breakers

- Do not size primary transformer breakers at 125%
- NEC allows primary up to 250%
 - NOTE: This changes the cable size required
- 480v primary breakers need to be sized around 200%
 - Problem is not with 208v secondary breaker, but with the next level branch breakers (BAB)
- Always size secondary breakers to 125% (and round up)
 - NEC 450-3(B) allows you to round up to the next standard rating
 - Needed to allow coordination between secondary main and feeders

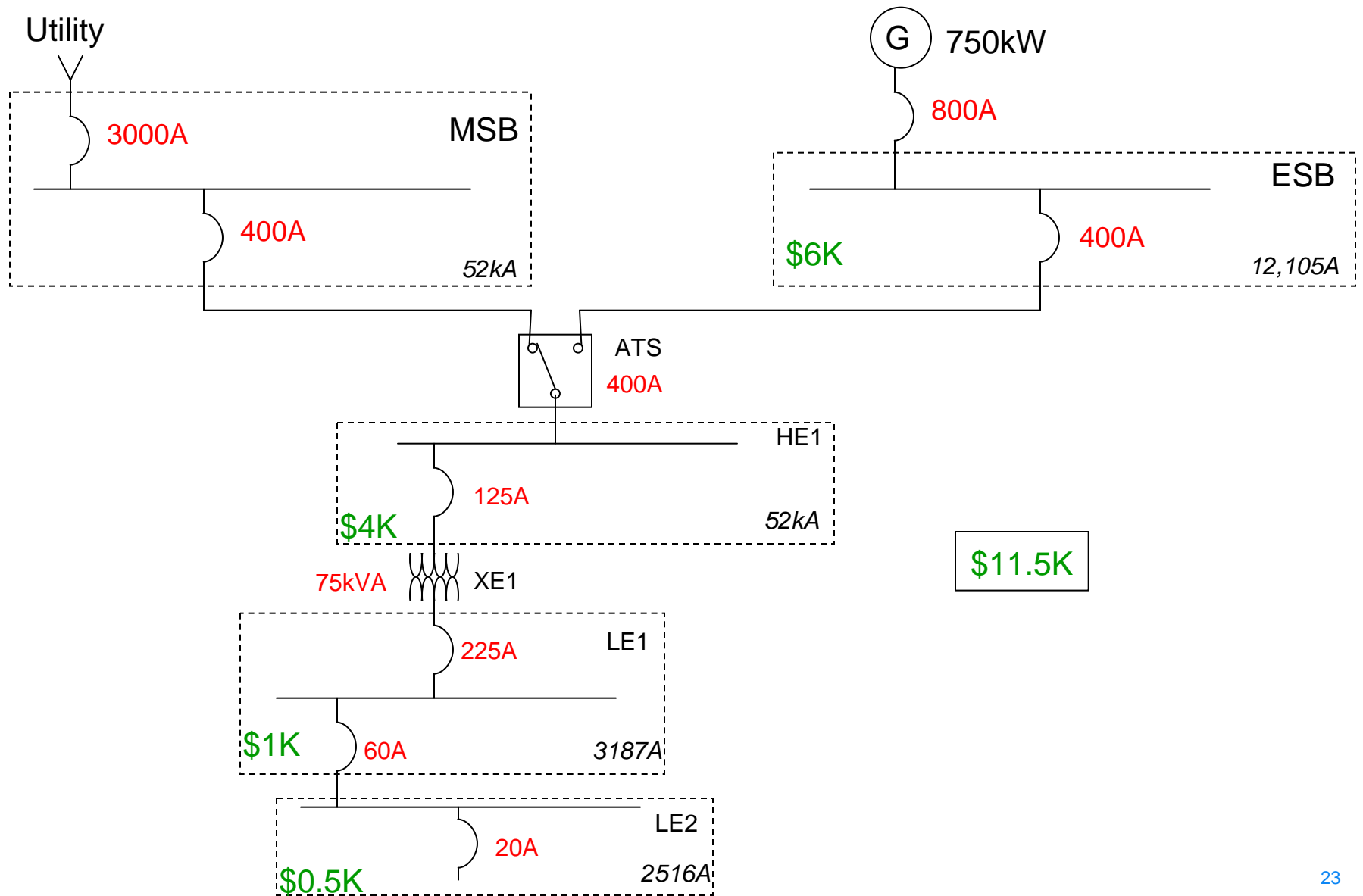
Simplified One-Line



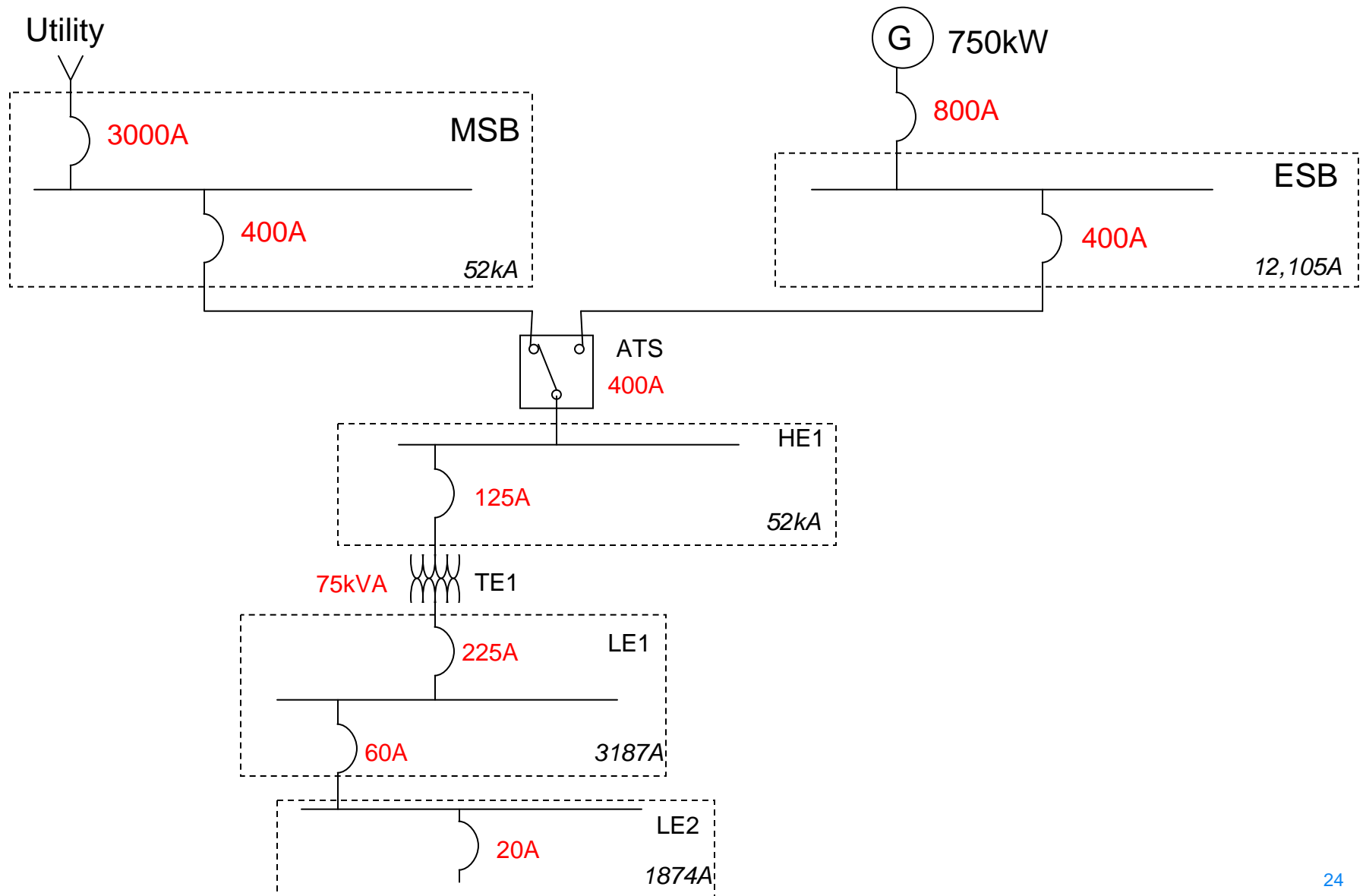
Simplified One-Line – Fault Currents



Simplified One-Line – System Cost – Standard Devices



Simplified One-Line – Device Selection



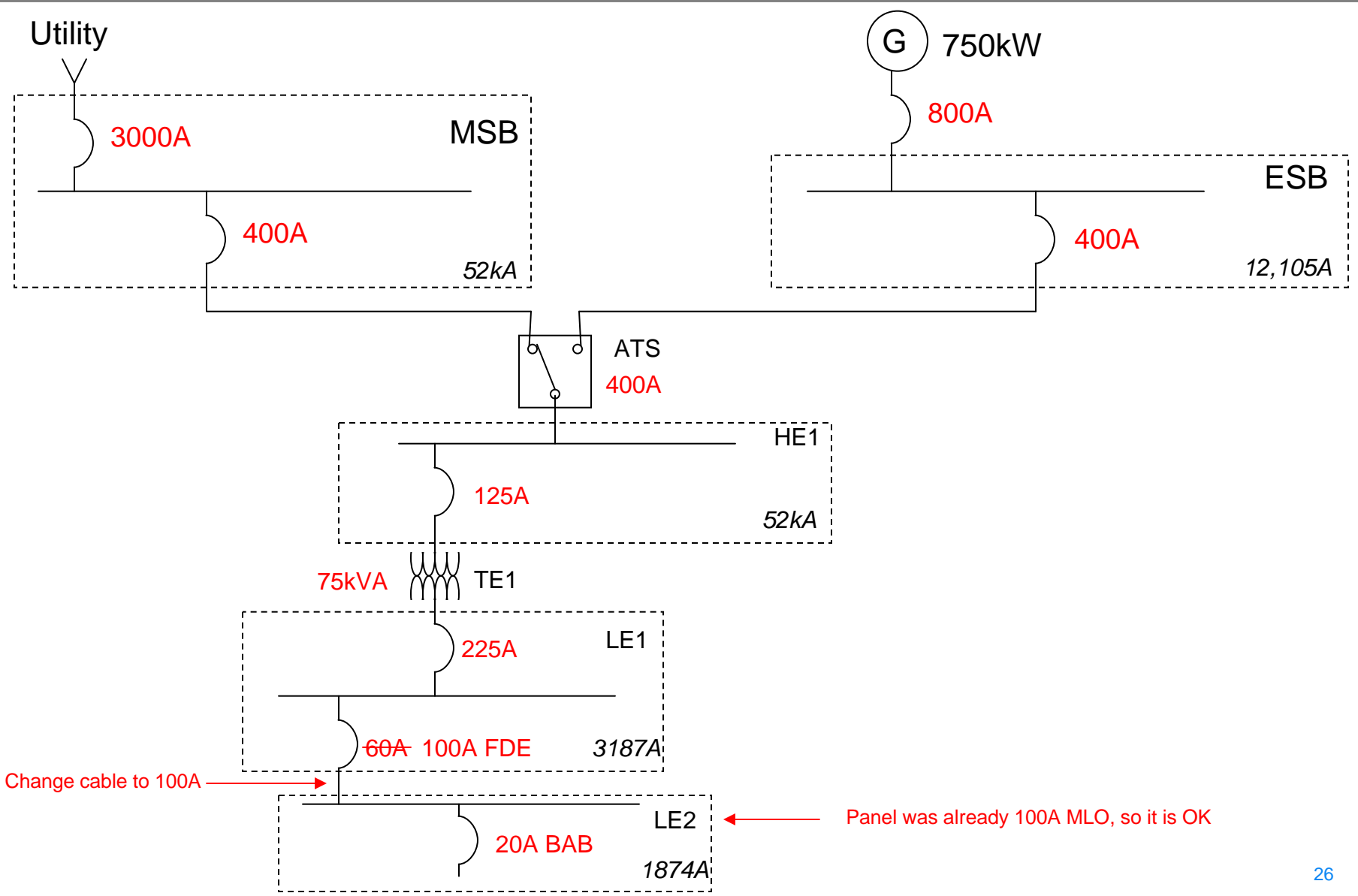
AB50 12
MCCB Selective Coordination Combinations — Test Data (All Values in kAIC rms Current Levels at 480Vac or Less)

				Line Side Breaker (Standard and Current Limiting Frames)														
				EG				F			J			K				
				EG T/M	F T/M	F T/M	F T/M	F ETU	F ETU	F ETU	J T/M	J T/M	J T/M	K T/M	K T/M	K T/M	K ETU	K ETU
Breaker Family ->				—				—			—			—				
Type Trip Unit ->				—				—			—			—				
Digitrip RMS Trip Unit ->				—				310+			310+			310				
Optim Trip Unit ->				—				—			—			550, 1050, 550,				
Minimum Trip (Plug/Trip) ->				125A	100A	150A	225A	15A	60A	100A	70A	150A	250A	100A	200A	400A	70A	12
Maximum Trip (Frame) ->				125A	100A	200A	225A	80A	160A	225A	125A	225A	250A	175A	350A	400A	125A	25
Pow-R-Line : Main ->				3E	← 1a,2a,3a,3E →			← 3a →			← 1a,2a,3a,3E,4 →							
Pow-R-Line : Branch ->				3E	← 3a,4,Swbd →			← 4,Swbd →			← 4,Swbd →							
Pow-R-Line : Sub-Feed ->				—	← 1a,2a,3E →			← 3a →			← 1a,2a,3a,3E →							

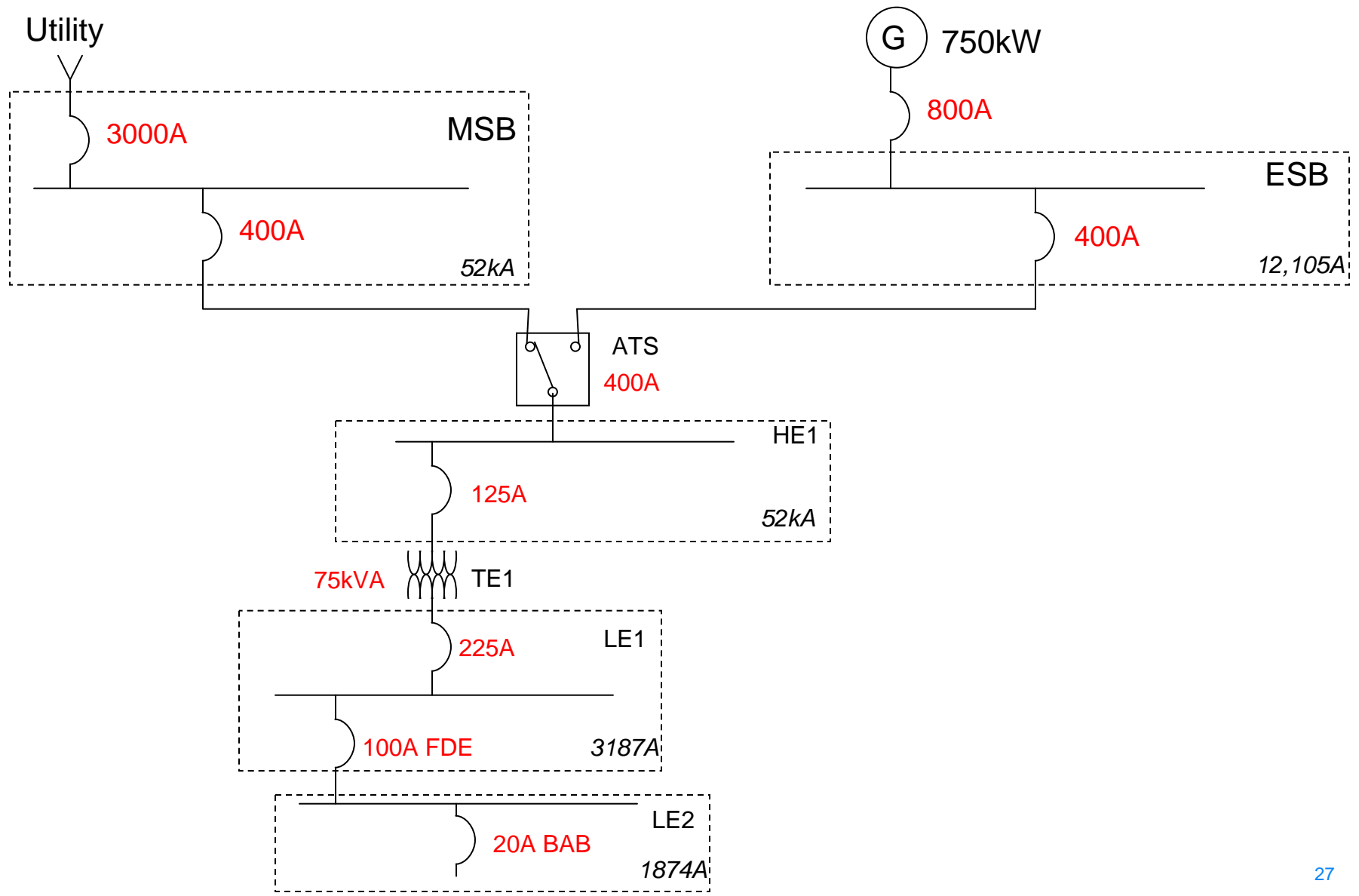
BR, BAB, HQP and QC (10 kA at 240vac) 1, 2 and 3-Pole																		
Pow-R-Line Panelboard / Swbd																		
	Main	Branch	Sub-Feed															
15	—	1a,3a,4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	1.0	2.1	4.0	2.5	5.0	10	3.0	6
20	—	1a,3a,4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	1.0	2.1	3.4	2.0	4.0	8.0	2.5	5
30	—	1a,3a,4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	0.7	2.1	3.4	2.0	4.0	8.0	2.5	5
40	—	1a,3a,4, Swbd	—	0.8	1.0	1.5	2.2	0.6	1.2	2.3	—	1.5	3.4	1.2	3.0	6.0	1.5	4
50	—	1a,3a,4, Swbd	—	0.8	—	1.5	2.2	—	1.2	2.3	—	1.5	2.5	1.2	3.0	6.0	1.5	4
60	1a	1a,3a,4, Swbd	—	0.8	—	1.5	2.2	—	1.2	2.3	—	1.5	2.5	—	3.0	6.0	1.5	4
70	1a	1a,3a,4, Swbd	—	—	—	1.5	2.2	—	1.2	2.3	—	1.5	2.5	—	2.5	5.0	—	3
80	1a	1a,3a,4, Swbd	—	—	—	—	2.2	—	—	2.3	—	—	2.5	—	2.5	5.0	—	3
90	1a	1a,3a,4, Swbd	—	—	—	—	2.2	—	—	2.3	—	—	2.3	—	2.5	5.0	—	3
100	1a	1a,3a,4, Swbd	—	—	—	—	1.8	—	—	2.3	—	—	2.3	—	2.5	5.0	—	3

BRH, QPHW, QBHW and QCHW (22 kA at 240vac) 1, 2 and 3-Pole																		
Pow-R-Line Panelboard / Swbd																		
	Main	Branch	Sub-Feed															
15	—	1a,3a,4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	1.0	2.1	4.0	2.5	5.0	10	3.0	6
20	—	1a,3a,4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	1.0	2.1	3.4	2.0	4.0	8.0	2.5	5
30	—	1a,3a,4, Swbd	—	1.2	1.0	1.5	2.2	0.6	1.2	2.3	0.7	2.1	3.4	2.0	4.0	8.0	2.5	5
40	—	1a,3a,4, Swbd	—	0.8	1.0	1.5	2.2	0.6	1.2	2.3	—	1.5	3.4	1.2	3.0	6.0	1.5	4

Simplified One-Line – LE1 Feeder Breaker Change



Simplified One-Line – Device Selection Continued

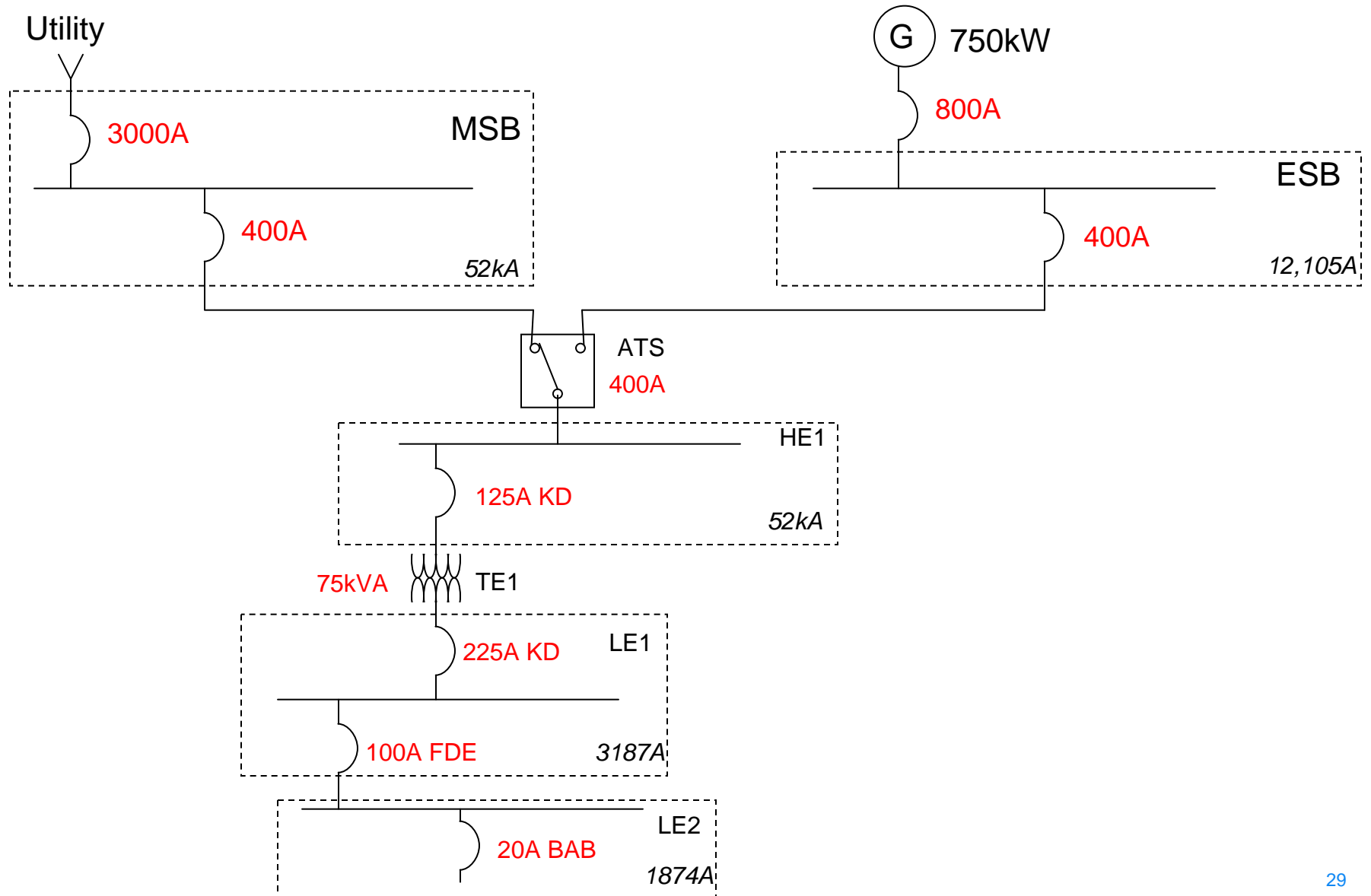


MCCB Selective Coordination Combinations — Test or Less

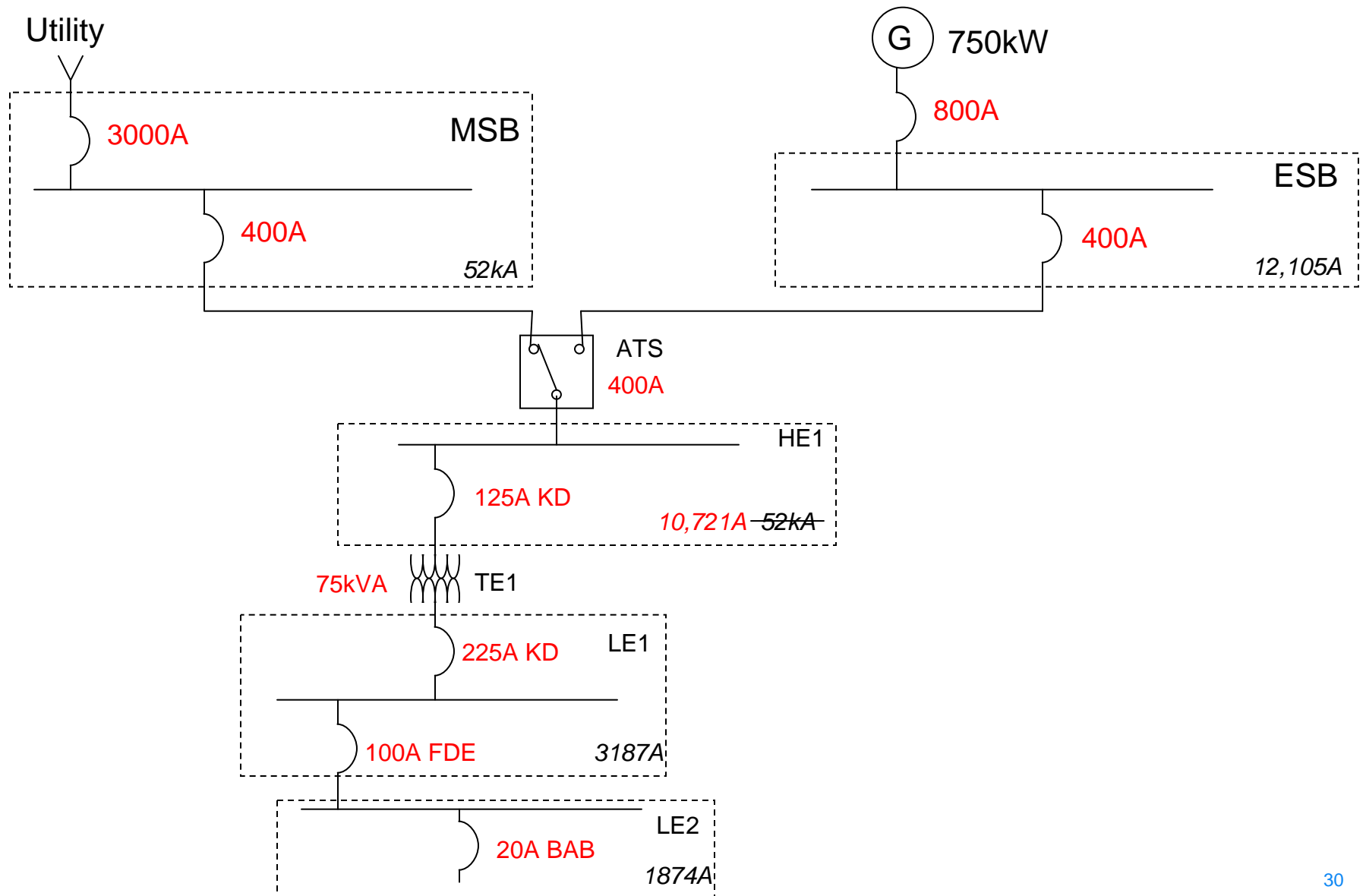
<p style="text-align: center;">Upstream Breaker →</p> <p style="text-align: center;">↓ Downstream Breaker</p>		<p style="text-align: center;"><small>K-Frame Breaker</small></p>	<p style="text-align: center;"><small>L-Frame Breaker</small></p>	<p style="text-align: center;"><small>LG 600 Ampere Breaker</small></p>	<p style="text-align: center;"><small>LG 600 Ampere Breaker</small></p>											
Breaker Family ->		K	K	K	K	K	K	LD	LD	LD	LD	LHH	LHH	LHH	LG	LG
Type Trip Unit ->		T/M	T/M	T/M	ETU	ETU	ETU	T/M	T/M	T/M	ETU	T/M	T/M	T/M	ETU	ETU
Digitrip RMS Trip Unit ->		—	—	—	310	310	310	—	—	—	310	—	—	—	310+	310+
Optim Trip Unit ->		—	—	—	550, 1050	550, 1050	550, 1050	—	—	—	550, 1050	—	—	—	—	—
Minimum Trip (Plug/Trip) ->		100A	200A	400A	70A	125A	200A	300A	400A	600A	200A (Optim) 300A (Digi)	125A	175A	225A	100A	160A
Maximum Trip (Frame) ->		175A	350A	400A	125A	250A	400A	350A	500A	600A	600A	150A	200A	400A	250A	400A
Pow-R-Line : Main ->		←----- 1a,2a,3a,3E,4 ----->					←----- 3a,4,Swbd ----->					←----- 1a,2a,3a,3E,4 ----->				
Pow-R-Line : Branch ->		←----- 4,Swbd ----->					←----- 4,Swbd ----->					←----- 4,Swbd ----->				
Pow-R-Line : Sub-Feed ->		←----- 1a,2a,3a,3E ----->					←----- ----->					←----- ----->				

F Family (FD, HFD, FDC, FDB(150A), EHD(100A), FDE, HFDE, FDCE)																		
Pow-R-Line Panelboard / Swbd																		
Main Branch Sub-Feed																		
15		3a,4,Swbd		2.0	2.5	5.0	2.5	4.0	5.0	10	10	12	12	7.5	14	22	4.0	10
40		3a,4,Swbd		1.6	2.5	5.0	2.5	3.2	4.2	8.3	8.3	12	12	3.2	10	16	3.2	8.3
100	1a,2a,3a,3E		1a,2a,3a,3E	—	—	2.3	3.2	—	3.2	7.0	7.0	12	12	—	10	14	3.2	7.0
225	1a,2a,3a,3E	3a,4,Swbd	1a,2a,3a,3E	—	—	—	3.2	—	4.0	—	7.0	12	12	—	—	12	—	7.0
J Family (JDB, JD, HJD, JDC)																		
Pow-R-Line Panelboard / Swbd																		
Main Branch Sub-Feed																		
70	—	4,Swbd		—	2.0	3.2	—	2.5	4.0	6.0	8.0	12	12	3.2	7.6	12.7	2.8	8.0
125	—	4,Swbd		—	—	3.2	—	2.5	3.7	6.0	7.0	12	12	—	7.6	10	2.8	7.0
250	2a,3a,4	4,Swbd	1a,2a,3a	—	—	—	3.2	—	3.5	—	7.0	10	10	—	—	10	—	7.0
LCL 250 Family Current Limiting																		
Pow-R-Line Panelboard / Swbd																		
Main Branch Sub-Feed																		
125	—	4,Swbd		—	—	3.7	—	2.5	4.2	4.2	4.2	17	17	—	—	12.7	2.8	4.2
200	—	4,Swbd		—	—	3.2	—	—	3.7	—	3.2	17	17	—	—	10	—	3.2
250	—	4,Swbd		—	—	—	—	—	—	—	—	17	17	—	—	—	—	—
LCL 400 Family Current Limiting																		
Pow-R-Line Panelboard / Swbd																		
Main Branch Sub-Feed																		
200	—	4,Swbd		—	—	3.2	—	—	3.2	—	3.2	17	17	—	—	10	—	3.2

Simplified One-Line – Device Selection Continued



Simplified One-Line – Generator Fault Currents



MCCB Selective Coordination Combinations — Test

	Breaker Family ->	LD	LD	LD	LD	LHH	LHH	LHH	LG	LG	LG	LG	NHH	N	N	N
	Type Trip Unit ->	T/M	T/M	T/M	ETU	T/M	T/M	T/M	ETU	ETU	ETU	T/M	ETU	ETU	ETU	ETU
	Digitrip RMS Trip Unit ->	—	—	—	310	—	—	—	310+	310+	310+	—	310	310	310	310
	Optim Trip Unit ->	—	—	—	550, 1050	—	—	—	—	—	—	—	—	550, 1050	550, 1050	550, 1050
	Minimum Trip (Plug/Trip) ->	300A	400A	600A	200A (Optim) 300A (Digi)	125A	175A	225A	100A	160A	250A	600A	150A	400A	400A	600A
	Maximum Trip (Frame) ->	350A	500A	600A	600A	150A	200A	400A	250A	400A	600A	600A	350A	400A	600A	800A
	Pow-R-Line : Main ->	← 3a,4,Swbd →				← 1a,2a,3a,3E,4 →			← 4,Swbd →		← 4,Swbd →		← 4,Swbd →		← 4,Swbd →	
	Pow-R-Line : Branch ->	← 4,Swbd →				← 4,Swbd →			← 4,Swbd →		← 4,Swbd →		← 4,Swbd →		← 4,Swbd →	
	PowR-Line : Sub-Feed ->	—				—			—		—		—		—	

K Family (KDB, KD, CKD, HKD, CHKD, KDC)

	Pow-R-Line Panelboard / Swbd																		
	Main	Branch	Sub-Feed																
100	—	4,Swbd	—	4.2	4.2	10	10	—	5	10	3.5	4.2	10	—	—	22	22	22	22
200	—	4,Swbd	—	—	3.7	10	10	—	—	10	—	3.7	10	—	—	18	18	18	18
400	1a,2a,3a,3E,4	4,Swbd	1a,2a,3a,3E	—	—	10	10	—	—	—	—	—	10	—	—	18	18	18	18

L Family (LDB, LD, CLD, HLD, CHLD, LDC, CLDC)

	Pow-R-Line Panelboard / Swbd																		
	Main	Branch	Sub-Feed																
300	3a,4	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	6.0	—	—	—	18	18	18	18
400	3a,4	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	6.0	—	—	—	18	18	18	18
600	3a,4	4,Swbd	—	—	—	—	—	—	—	—	—	—	—	—	—	18	18	18	18

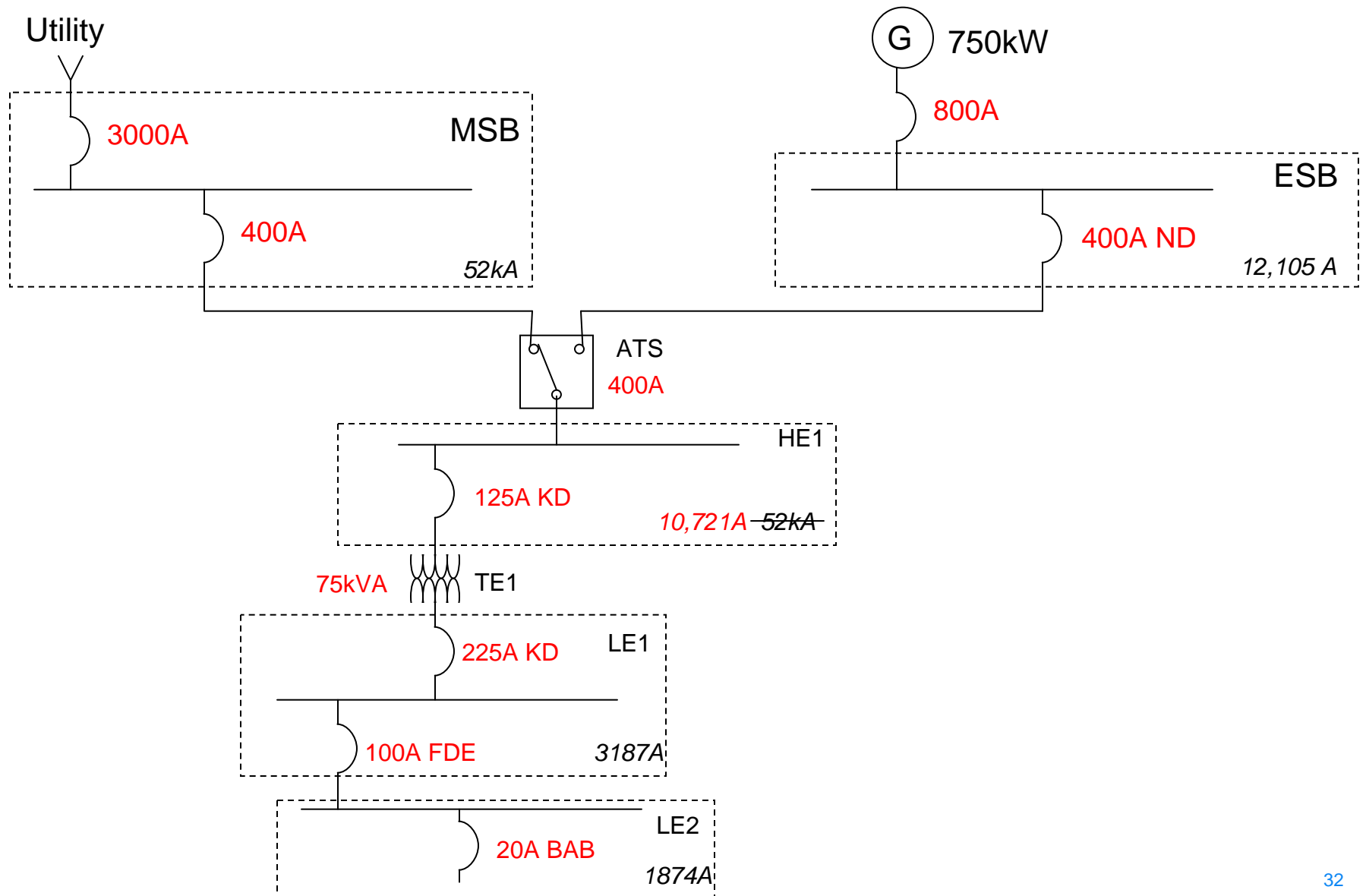
LG Family (LGE, LGS, LGH, LGC)

	Pow-R-Line Panelboard / Swbd																		
	Main	Branch	Sub-Feed																
250	—	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	6.0	—	—	—	10	18	18	18
400	—	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	6.0	—	—	—	18	18	18	18
600	4	4,Swbd	—	—	—	—	—	—	—	—	—	—	—	—	—	18	18	18	18

LG Current Limiting Family

	Pow-R-Line Panelboard / Swbd																		
	Main	Branch	Sub-Feed																
400	—	4,Swbd	—	—	—	6	6	—	—	—	—	6	—	—	—	25	25	25	25
600	4	4,Swbd	—	—	—	—	—	—	—	—	—	—	—	—	—	25	25	25	25

Simplified One-Line – Device Selection Continued

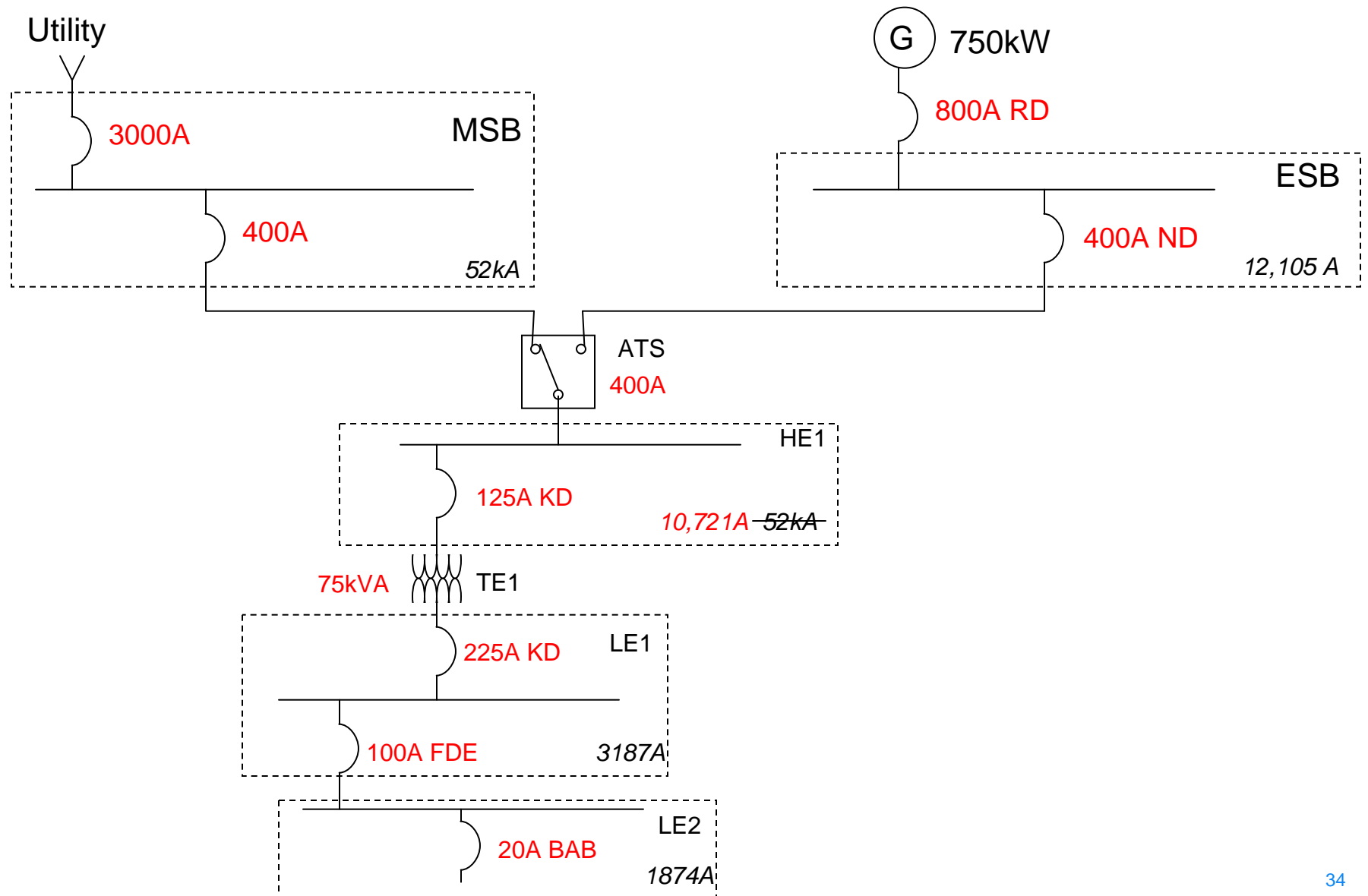


MCCB Selective Coordination Combinations — Test													
		N-Frame Breaker			N-Frame Breaker			R-Frame Breaker					
		Breaker Family ->	NHH	N	N	N	N	R	R	R	R	R	
		Type Trip Unit ->	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU	
		Digitrip RMS Trip Unit ->	310	310	310	310	310	310	310	310	310	310	
		Optim Trip Unit ->	—	550, 1050	550, 1050	550, 1050	550, 1050	510, 810, 1050	510, 810, 1050	510, 810, 1050	510, 810, 1050	510, 810, 1050	
		Minimum Trip (Plug/Trip) ->	150A	400A	400A	400A	600A	800A	800A	800A	800A	1000A	1200A
		Maximum Trip (Frame) ->	350A	400A	600A	800A	1200A	800A	1000A	1200A	1600A	2000A	2500A
		Pow-R-Line : Main ->	4	—	—	4,Swbd	4,Swbd	← Swbd →					
		Pow-R-Line : Branch ->	4,Swbd	← 4,Swbd →			← Swbd →						
		PowR-Line : Sub-Feed ->	—	—	—	—	—	—	—	—	—	—	

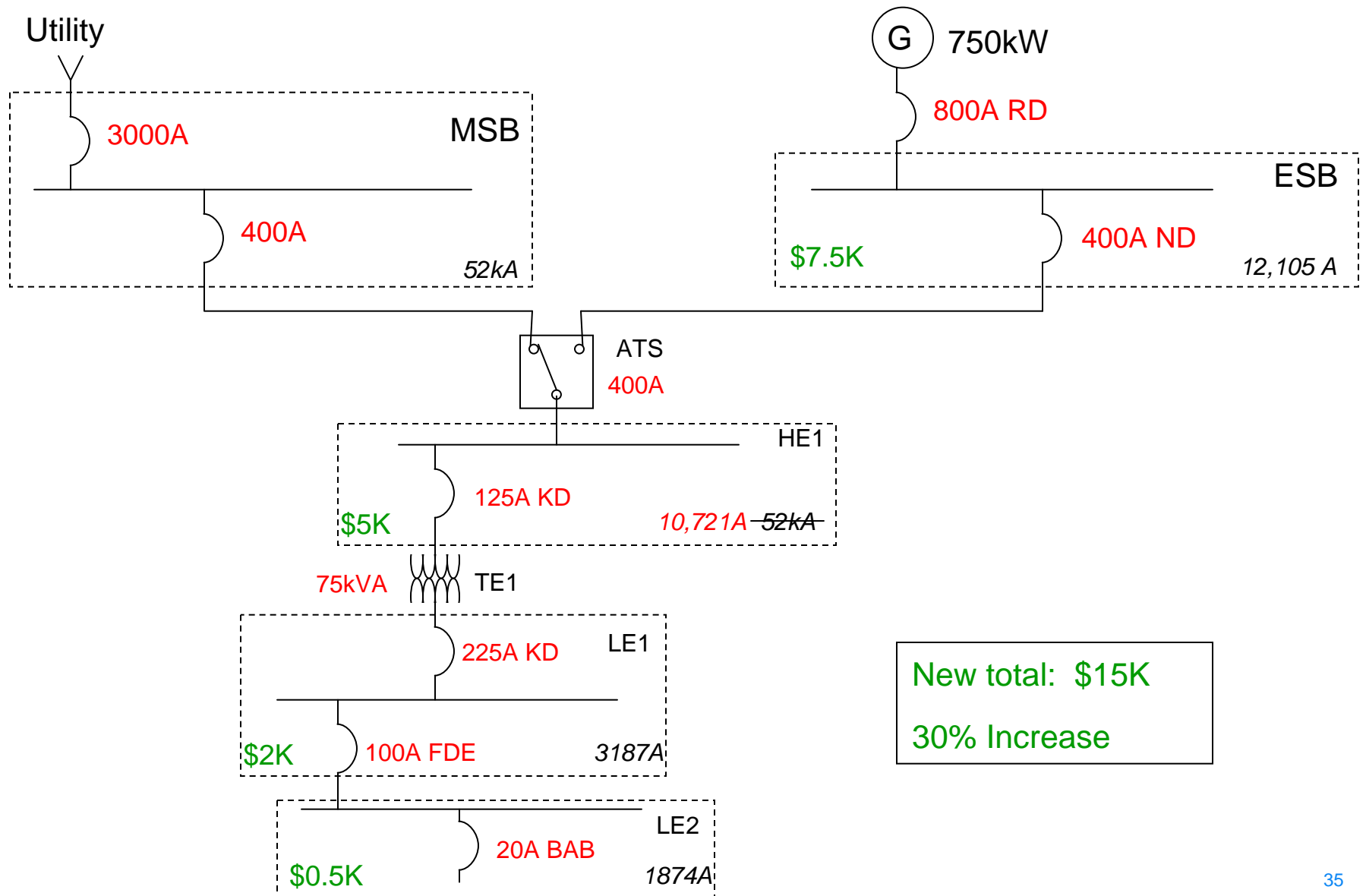
N Family (ND, CND, HND, CHND, NDC, CNDC, NGS, NGH, NGC)												
Pow-R-Line Panelboard / Swbd												
	Main	Branch	Sub-Feed									
400	—	4,Swbd	—	—	—	—	12	16	16	16	22	25
600	—	4,Swbd	—	—	—	—	12	—	16	16	22	25
800	4,Swbd	4,Swbd	—	—	—	—	—	—	16	16	22	25
1200	4,Swbd	4,Swbd	—	—	—	—	—	—	—	18	18	—

NHH Family													
Pow-R-Line Panelboard / Swbd													
	Main	Branch	Sub-Feed										
350	4	4,Swbd	—	—	—	—	12	16	16	16	16	22	25

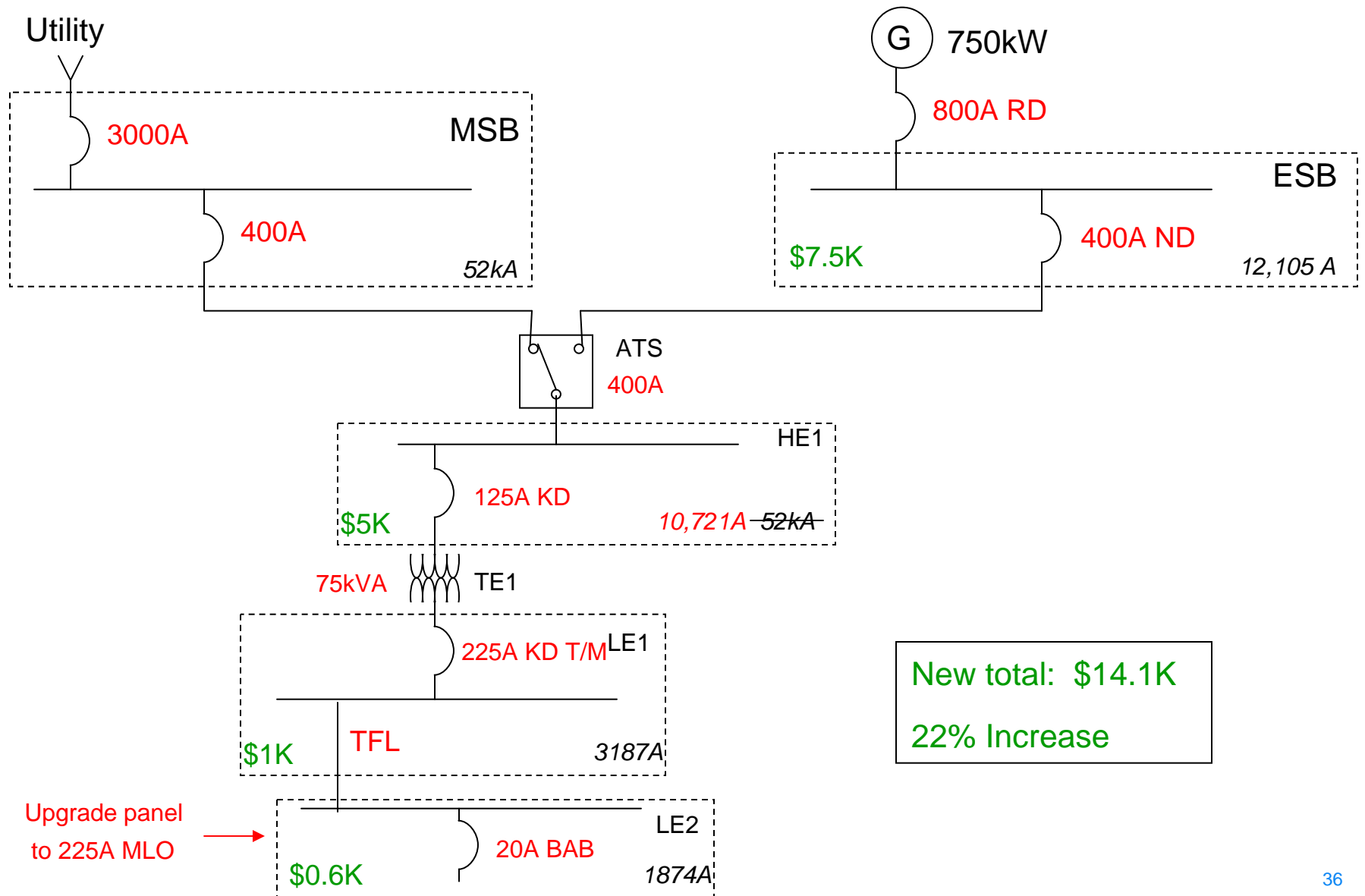
Simplified One-Line With Total Selective Coordination Up to the Generator



Simplified One-Line – Equipment Costs – Selectively Coordinated System



Simplified One-Line – Flatten the System

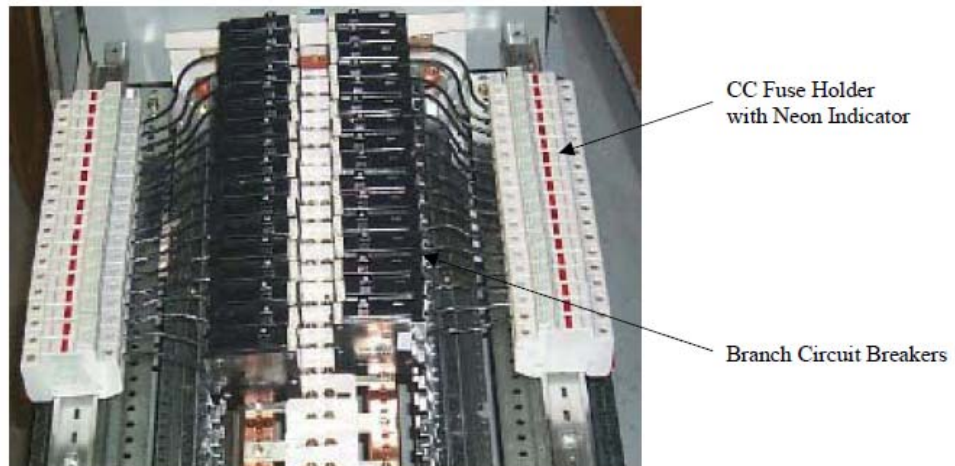


Total Selective Coordination Summary

- Flatten the system
- Broaden your ideas on transformer protection
- Check ATS withstand ratings with chosen breakers
- Tables represent a single manufacturer's equipment

Total Selective Coordination Summary

- Fusible Devices
 - Especially with high fault currents
 - New fusible panelboards available
 - Physical sizes for fusible equipment is typically larger than breaker designs

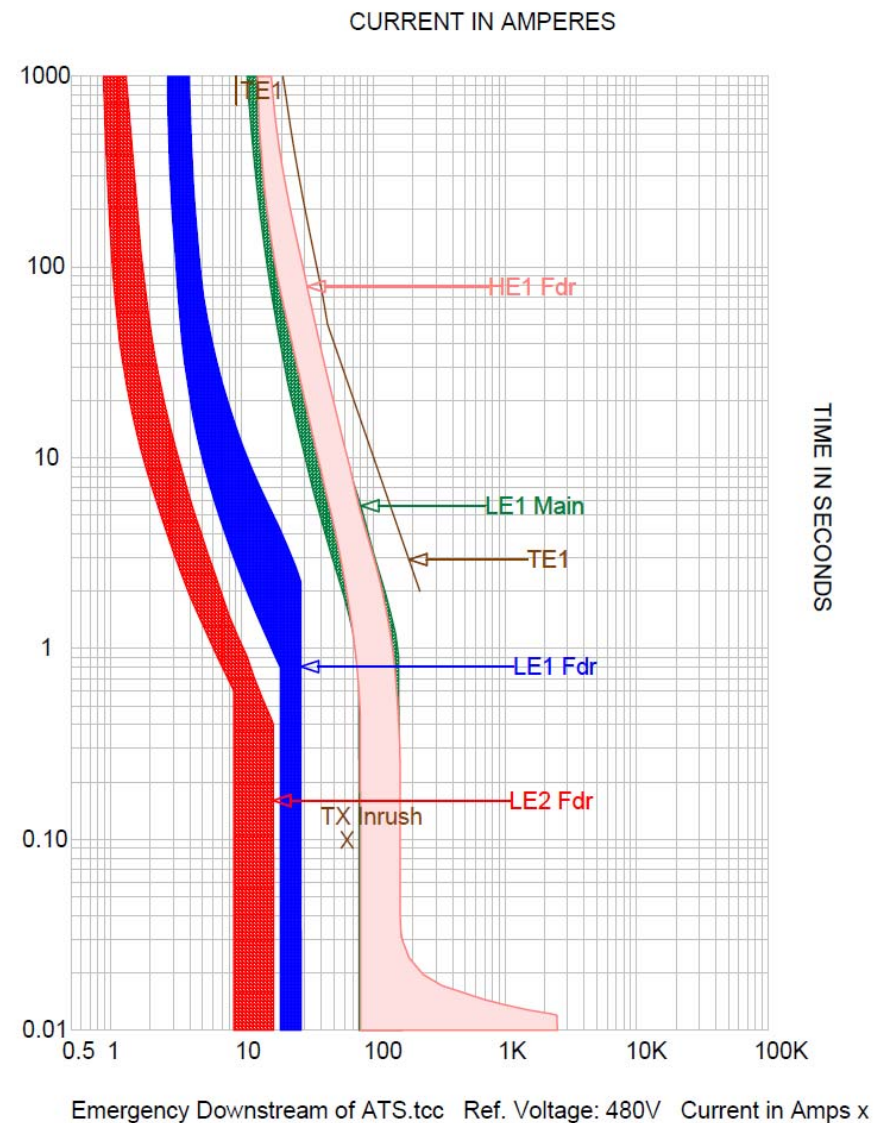


Total Selective Coordination Summary

- Can't I just put in my specs that the switchgear manufacturer must provide a selectively coordinated system?
- Yes, but please don't!
 - Our salesmen won't necessarily know which circuits need to be coordinated
 - Cable sizes may need to be increased, depending on which breakers are required
 - ATS sizes may need to be increased – not in our package
 - Generator breaker sizes may need to increase – not in our package
 - Distribution equipment size may increase and no longer fit in the room
 - Who pays for all of the above?

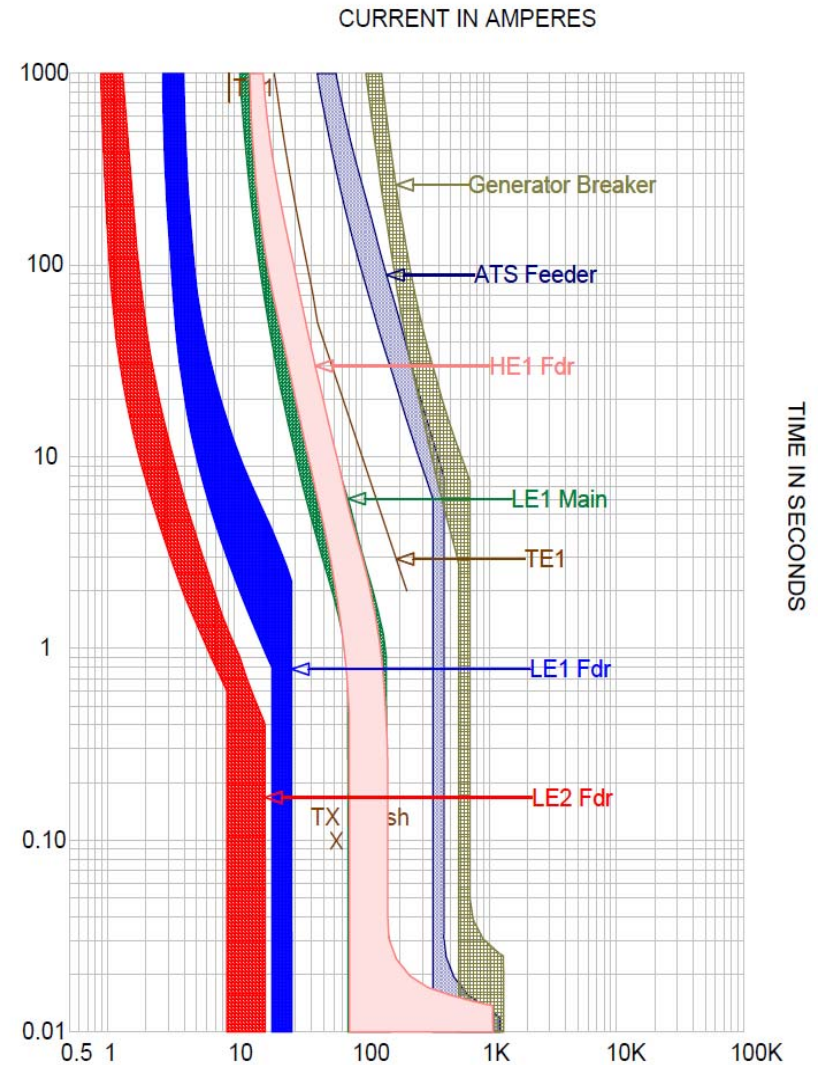
Coordination at 0.01 and 0.1 Seconds

- Here's our original equipment (downstream of the ATS) selected without selective coordination in mind
- Do we coordinate at the 0.01 level?
- How about at 0.1 seconds?



Coordination at 0.01 and 0.1 Seconds

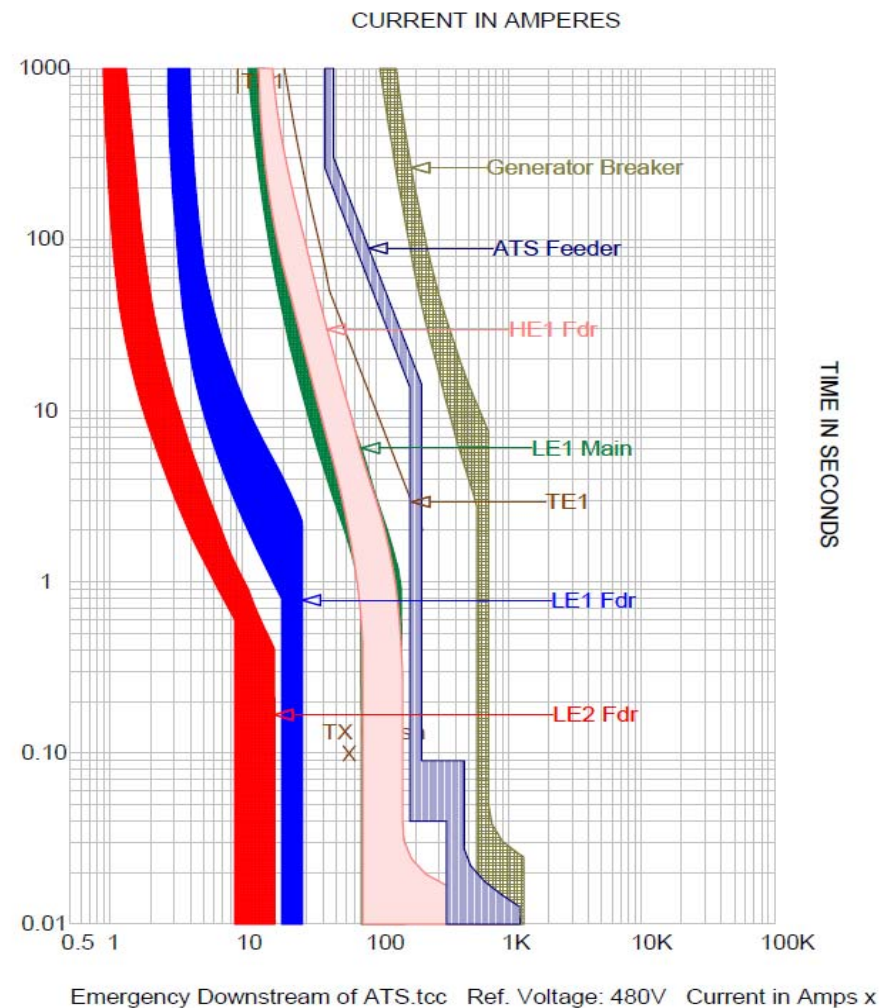
- But we have a little bit of work to do upstream of the ATS on the Generator Side.



Emergency Downstream of ATS.tcc Ref. Voltage: 480V Current in Amps x

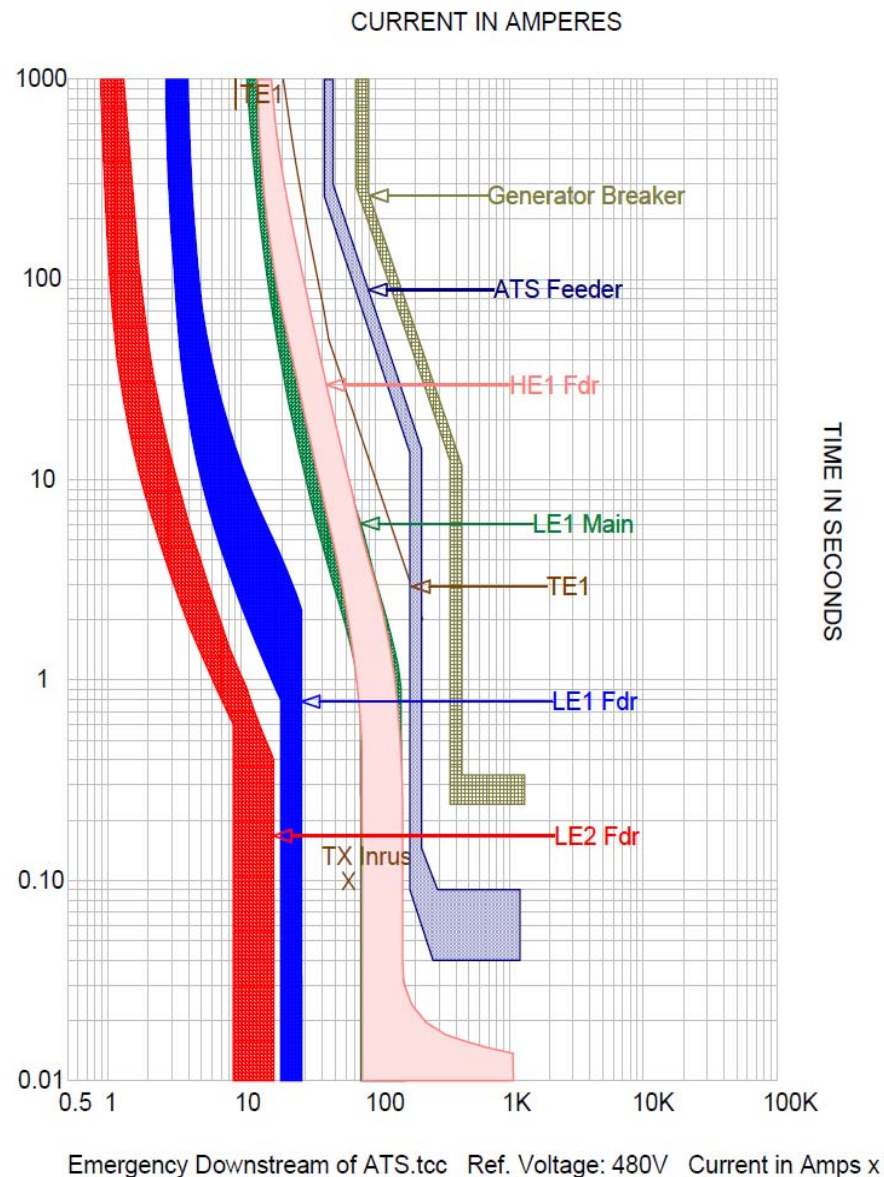
Coordination at 0.1 Seconds

- We can make one small change and get coordination at 0.1 second – change the ATS feeder to an electronic trip.
- Total adder from our original \$11.5K cost estimate - <\$500, 4% adder.



Coordination at 0.01 Seconds

- To achieve coordination to 0.01 seconds above the ATS on the generator side, we have to:
 - Provide an 800AF/400AT electronic trip breaker to feed the ATS
 - Use a Power Circuit Breaker on the Generator
- Cost adder over base case for our equipment: \$1.5K (not including generator breaker)

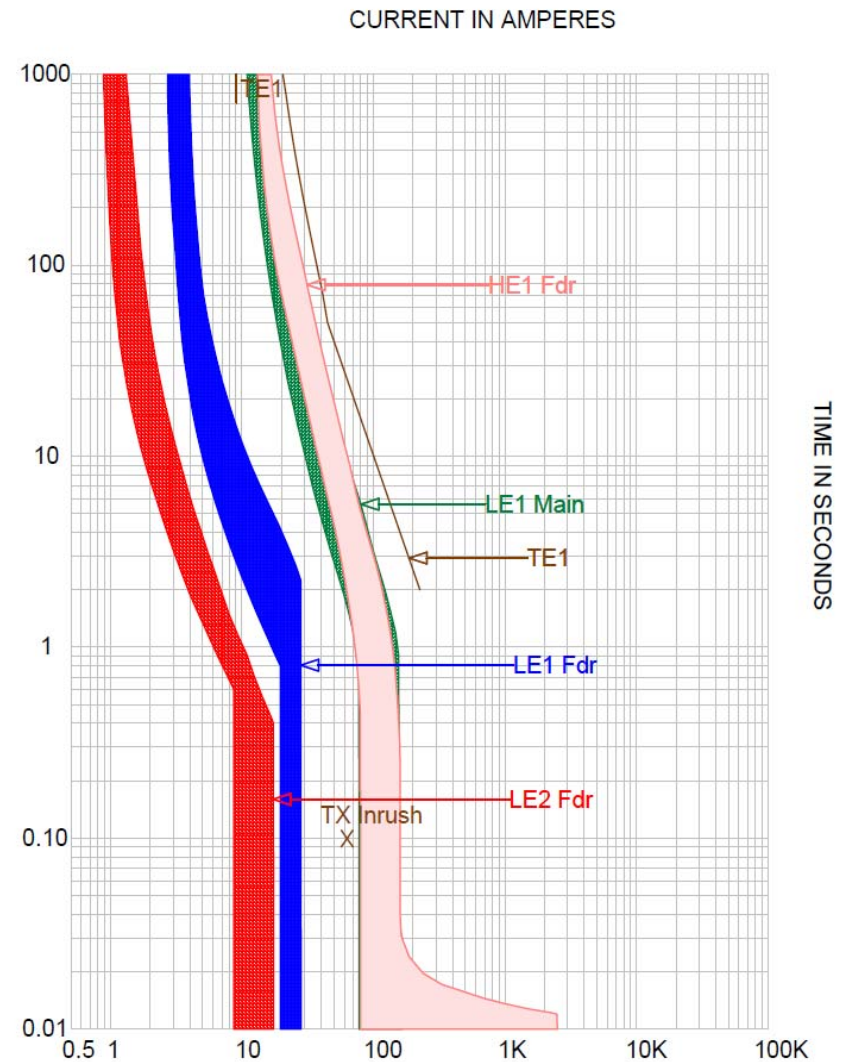


Challenge - Enforcement

- How is Selective Coordination Evaluated?
 - Some jurisdictions are looking at curves
 - Some jurisdictions require a stamped letter from the engineer of record
 - In some jurisdictions, it has yet to be defined

Challenge - Enforcement

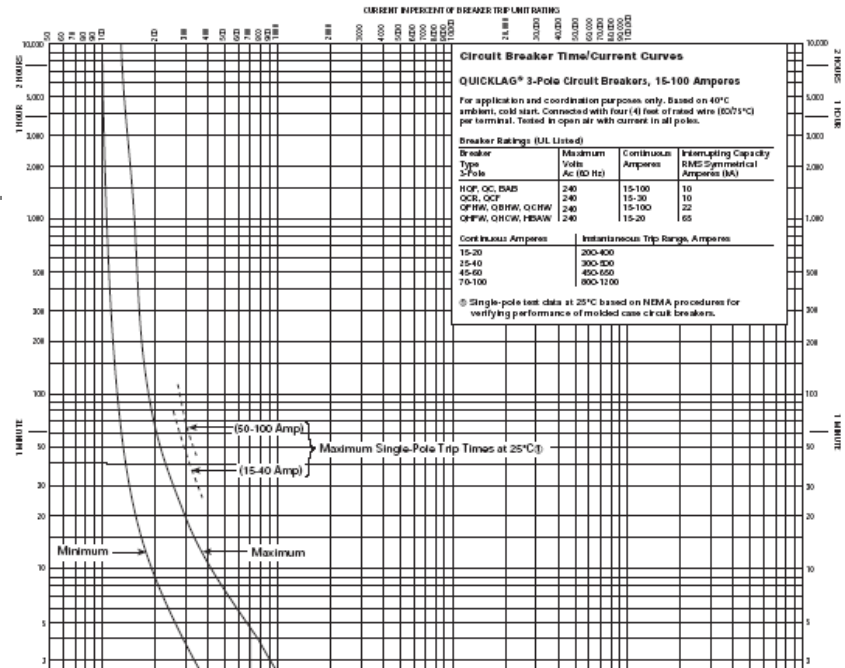
- Breaker Curves
 - No standardized method for representing time current curves



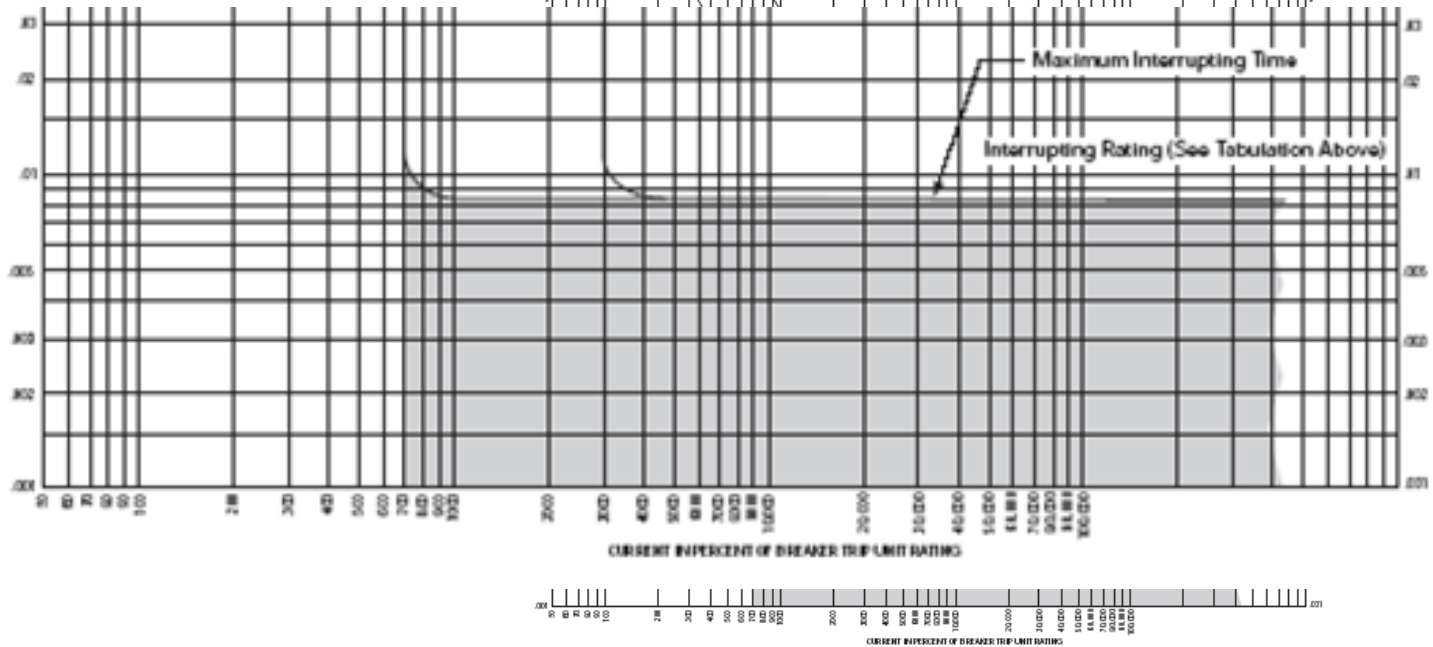
Emergency Downstream of ATS.tcc Ref. Voltage: 480V Current in Amps x

BAB Trip Curve

QUICKLAG 3-Pole Circuit Breakers, 15-100 Amperes

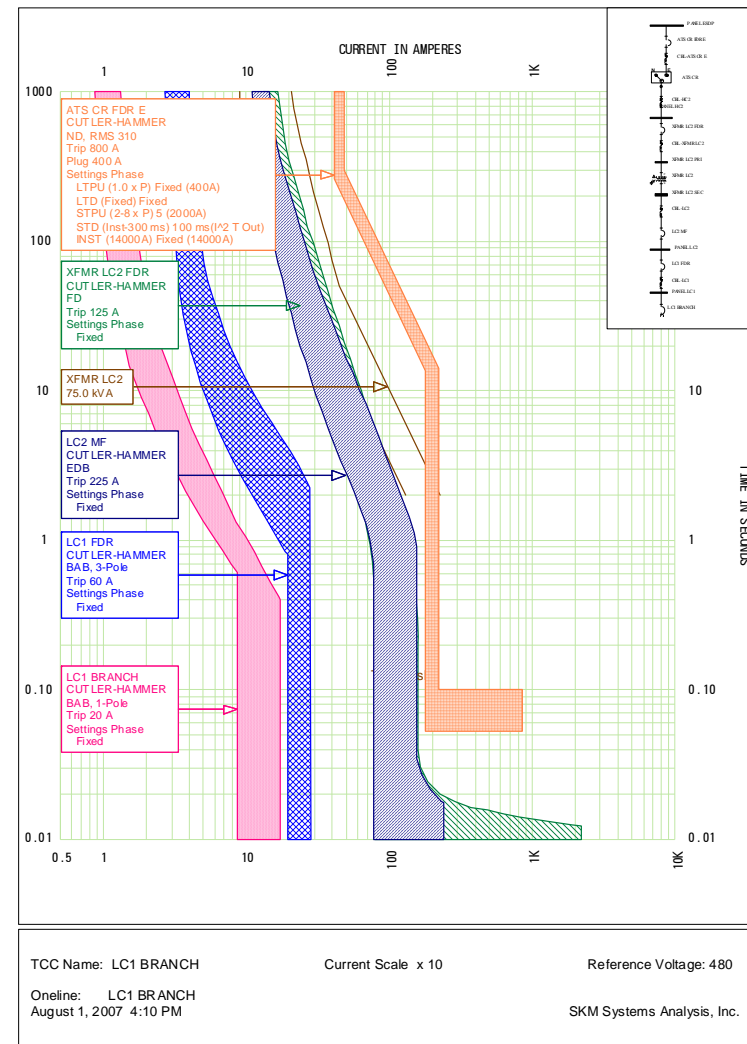


.01 Sec →



How is Selective Coordination evaluated?

- The SKM (and all coordination software) plots cut off at 0.01 second
- If coordination to 0.01 seconds is acceptable, be aware that this will be contradicted by our 100% Selective Coordination Tables



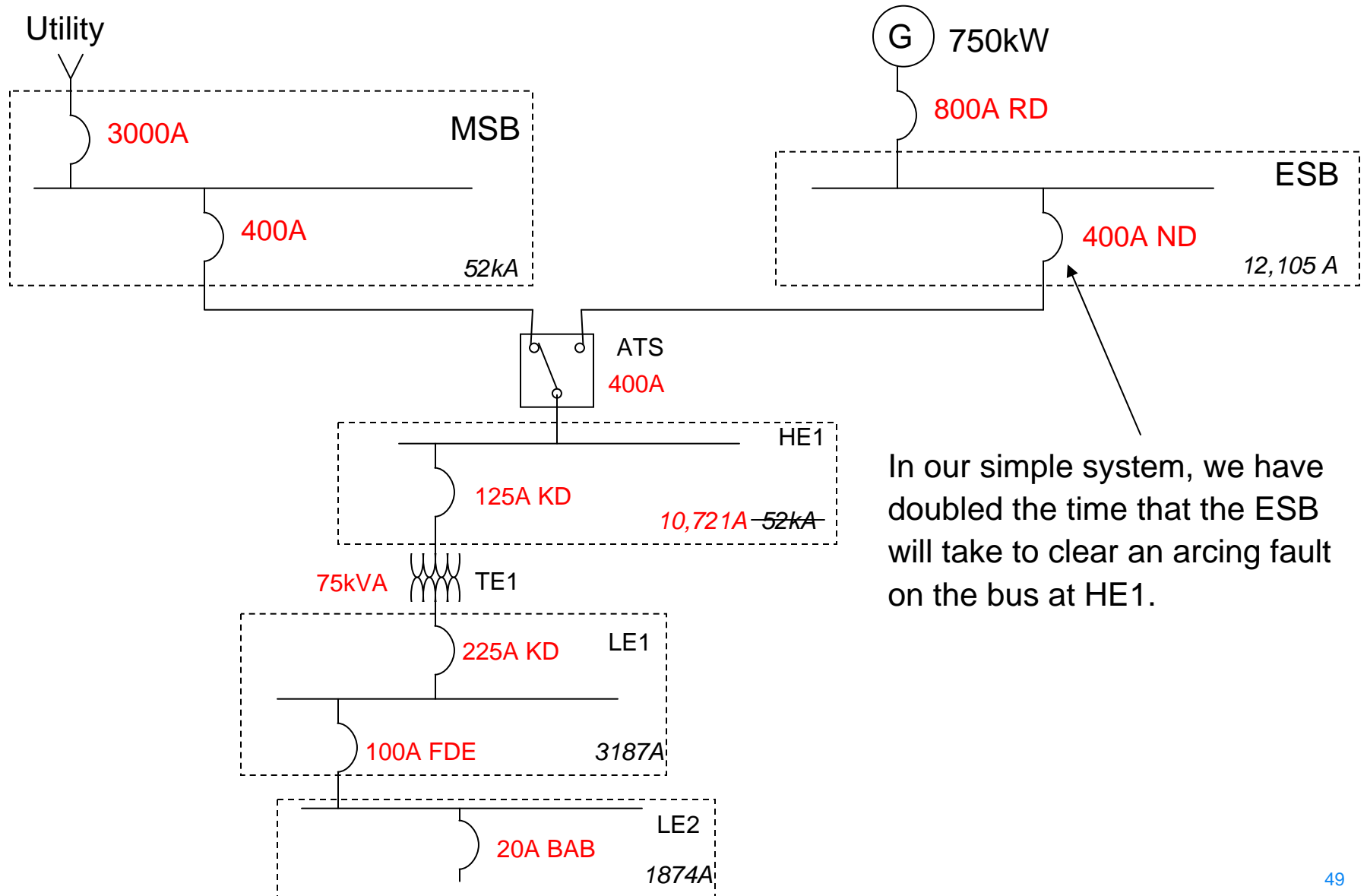
Challenge - Design

What about Arc Flash?

- Arc Flash Energy is dependent upon:
 - Actual magnitude of the fault energy
 - ***Time that the arc is allowed to propagate***

When we select devices to selectively coordinate, we are purposefully introducing time delays by selecting larger and/or more adjustable devices upstream.

Simplified One-Line – Arc Flash



In our simple system, we have doubled the time that the ESB will take to clear an arcing fault on the bus at HE1.

Challenge – Arc Flash

Techniques for dealing with the Arc Flash Challenge:

- Zone Selective Interlocking
- Arc Flash Reduction Maintenance Switches

Note: 2011 NEC 240.87 mandates one of the above or differential protection when circuit breakers are used without instantaneous protection.



Questions?