NEC Mandated Selective Coordination

Challenges and Solutions

IEEE IAS Meeting

May 16, 2011

Powering Business Worldwide

Background and Definitions

Selective Coordination & The National Electrical Code

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

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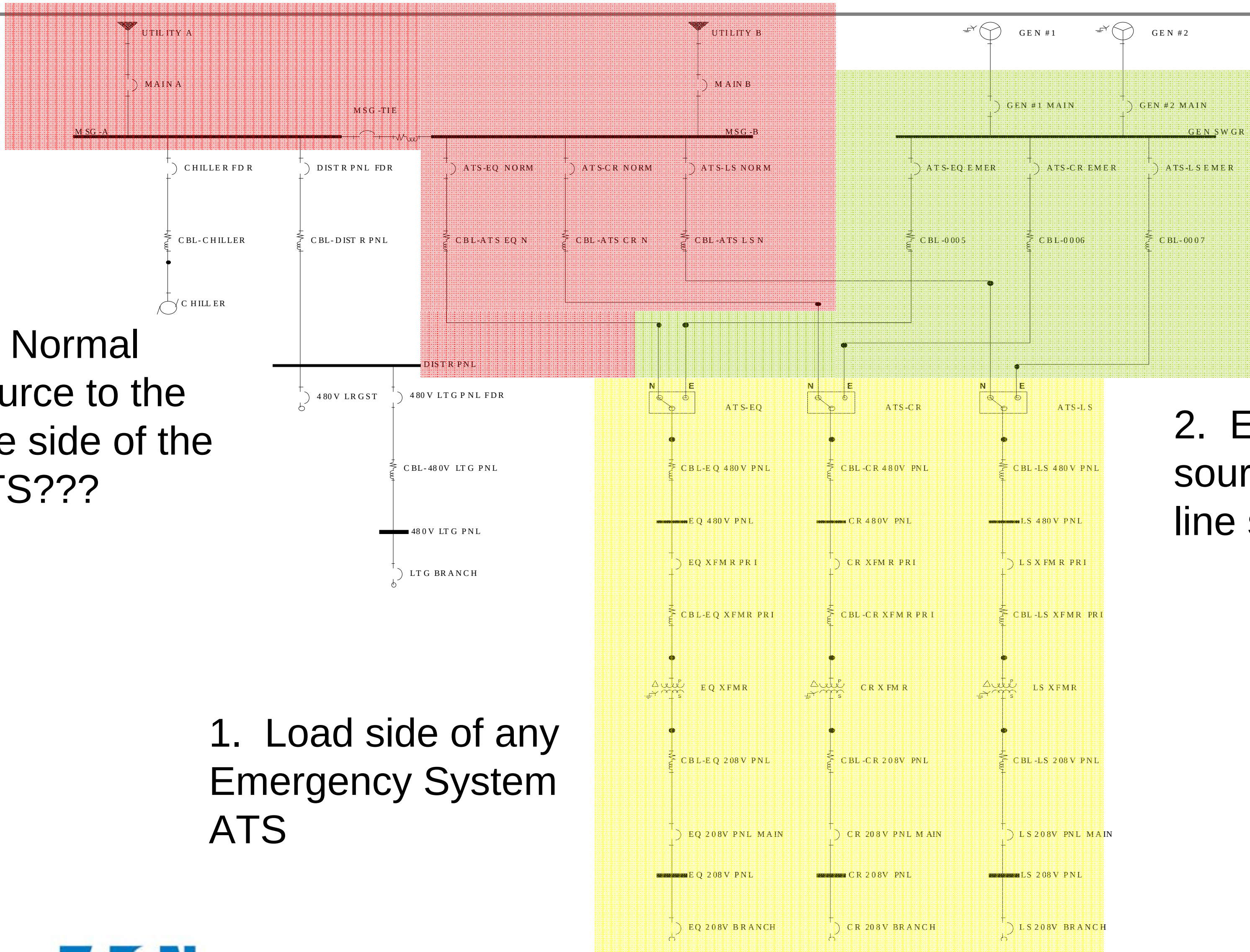
Selective Coordination Challenges

- 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

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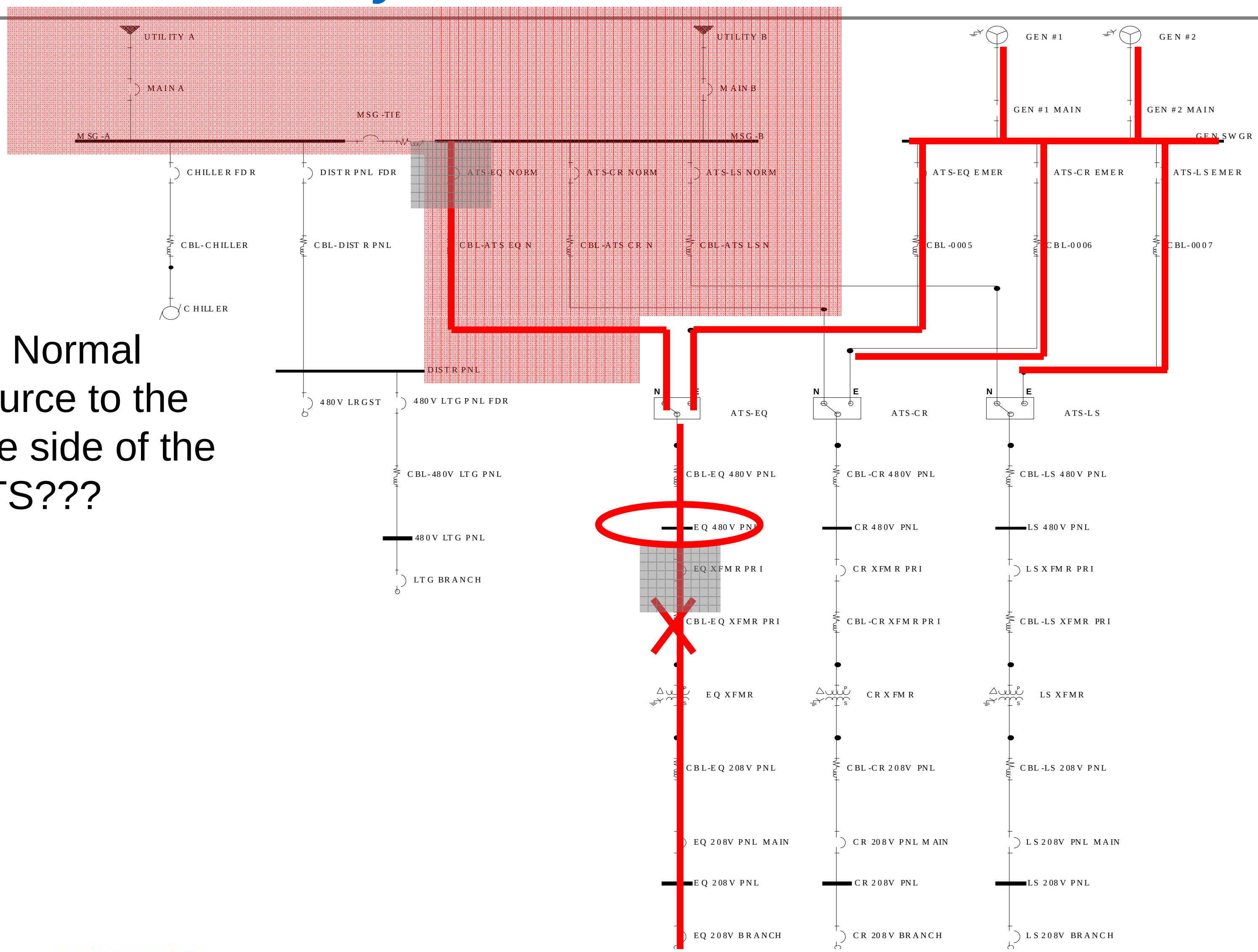
Which devices are required to be Selectively Coordinated?



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?

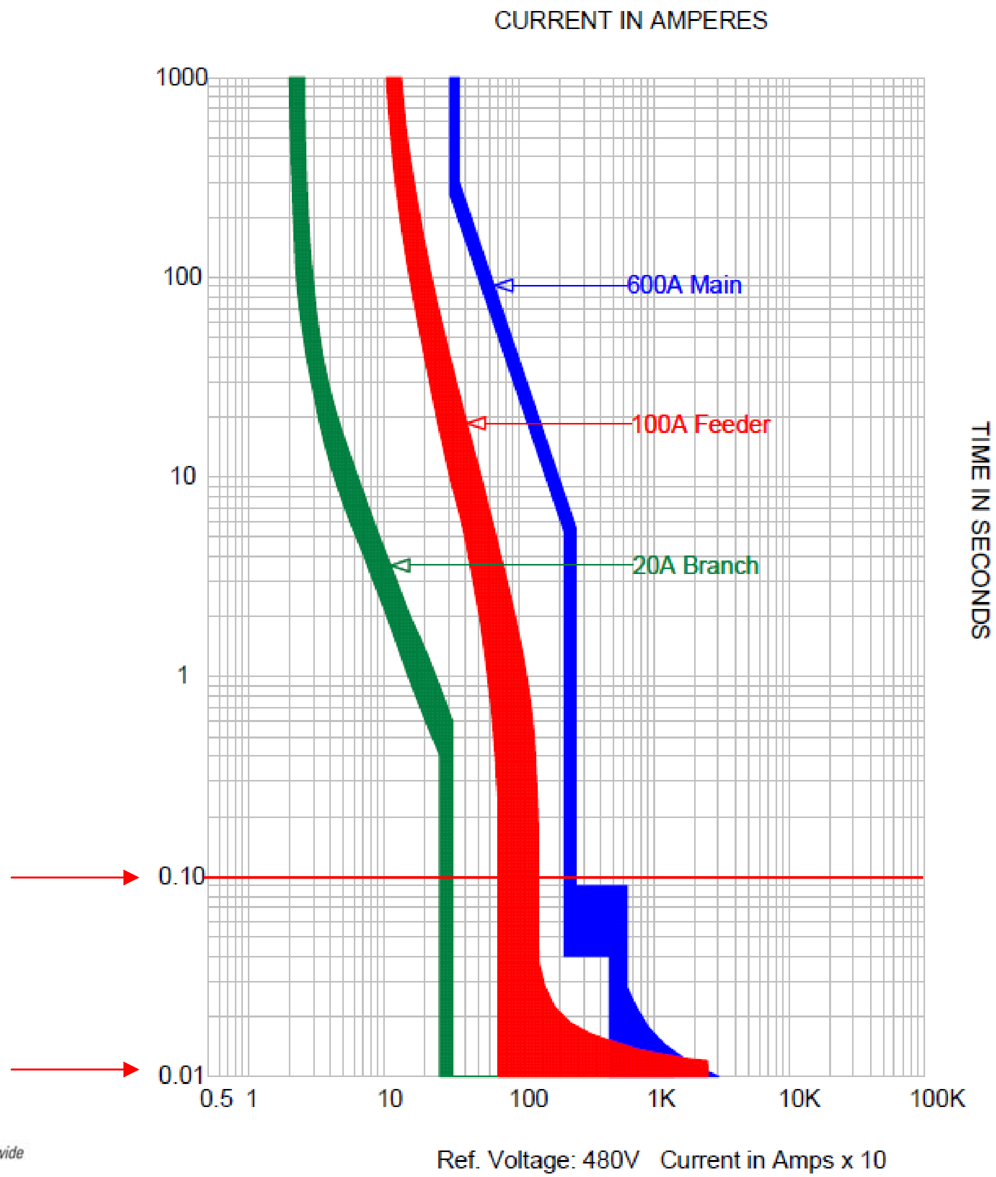
- Some jurisdictions have defined a level of 0.1 or 0.01 for selective coordination*
  - State of California Healthcare (OSHPD) – 0.1
  - State of Florida Healthcare (AHCA) – 0.1
  - City of Memphis – 0.1
  - Las Vegas – 0.01, 0.1 allowable if 0.01 can not be achieved
  - State of Oregon – 0.01
  - City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



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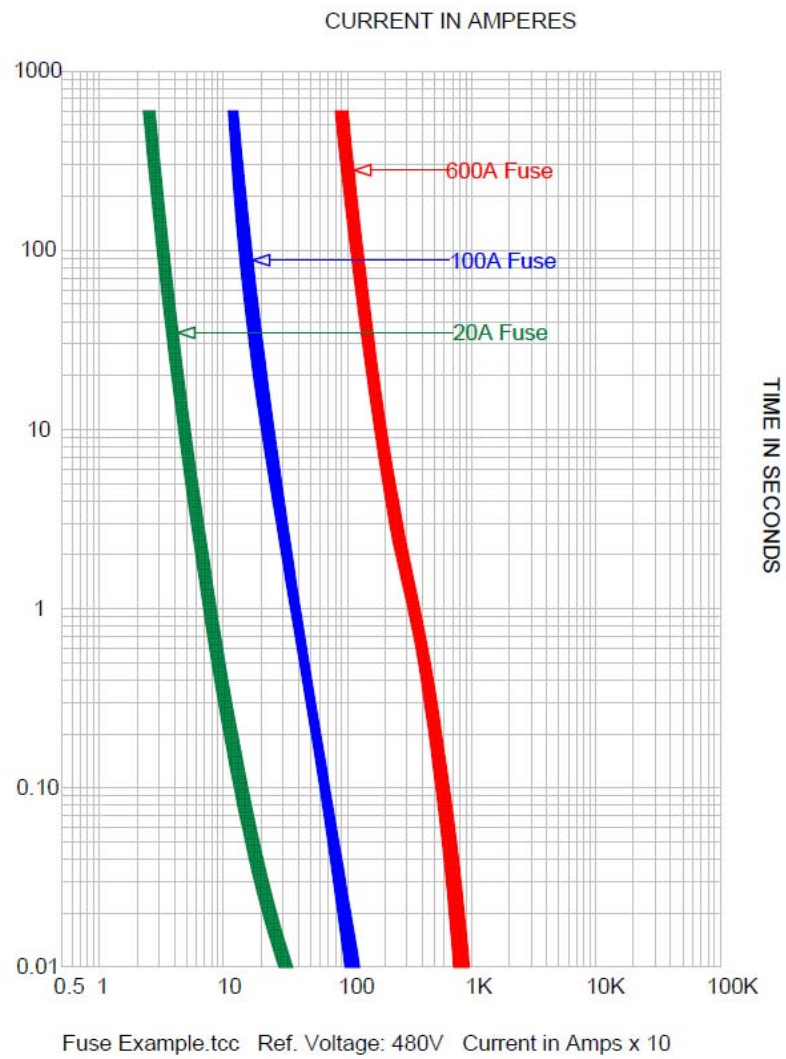
What Do These Time Limits Mean in the Real World?



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Beyond the Curves - Manufacturer's Tables

Challenge - Design

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

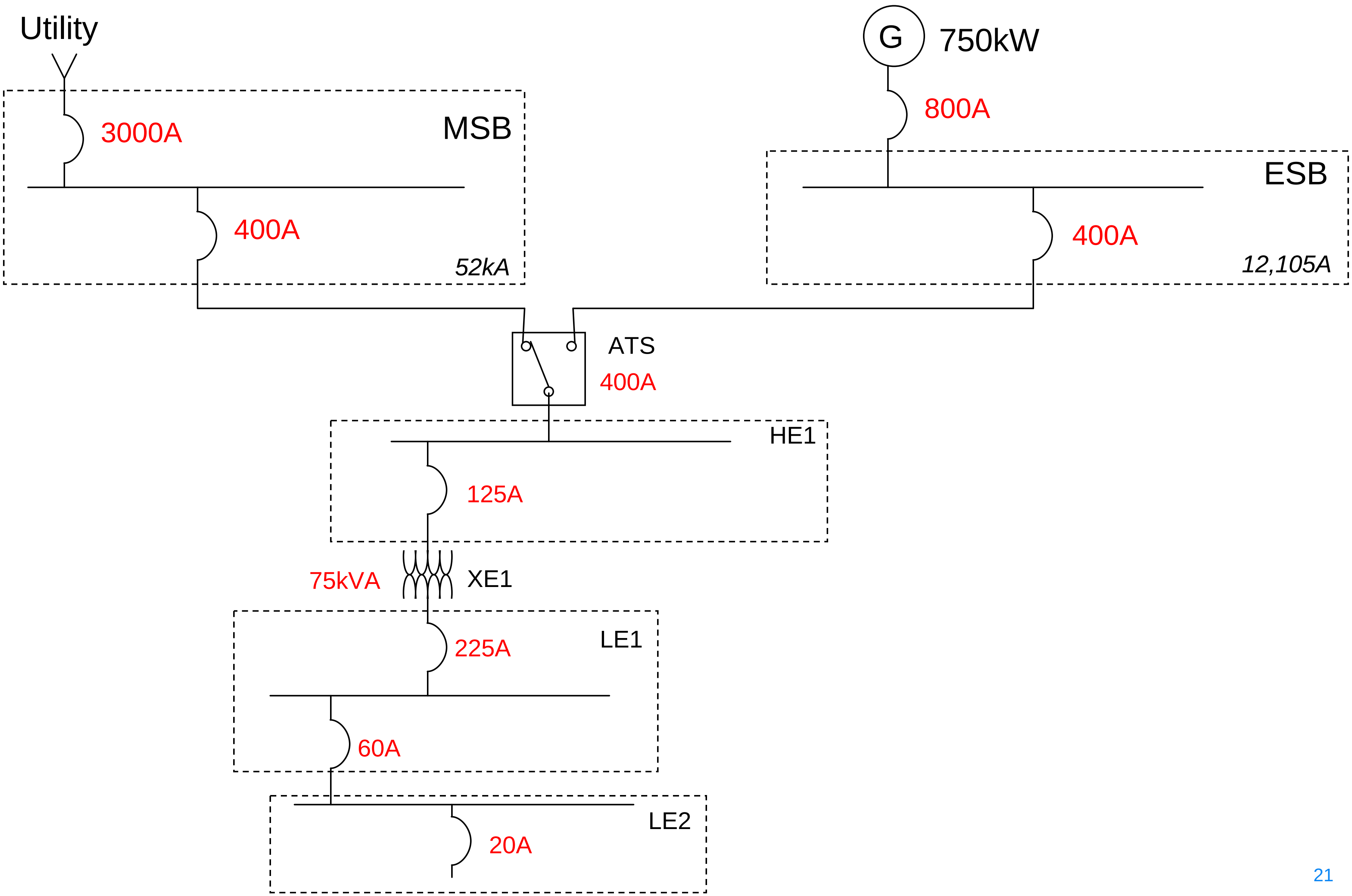
Selective Coordination

- 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, 1^{st} and 2^{nd} 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

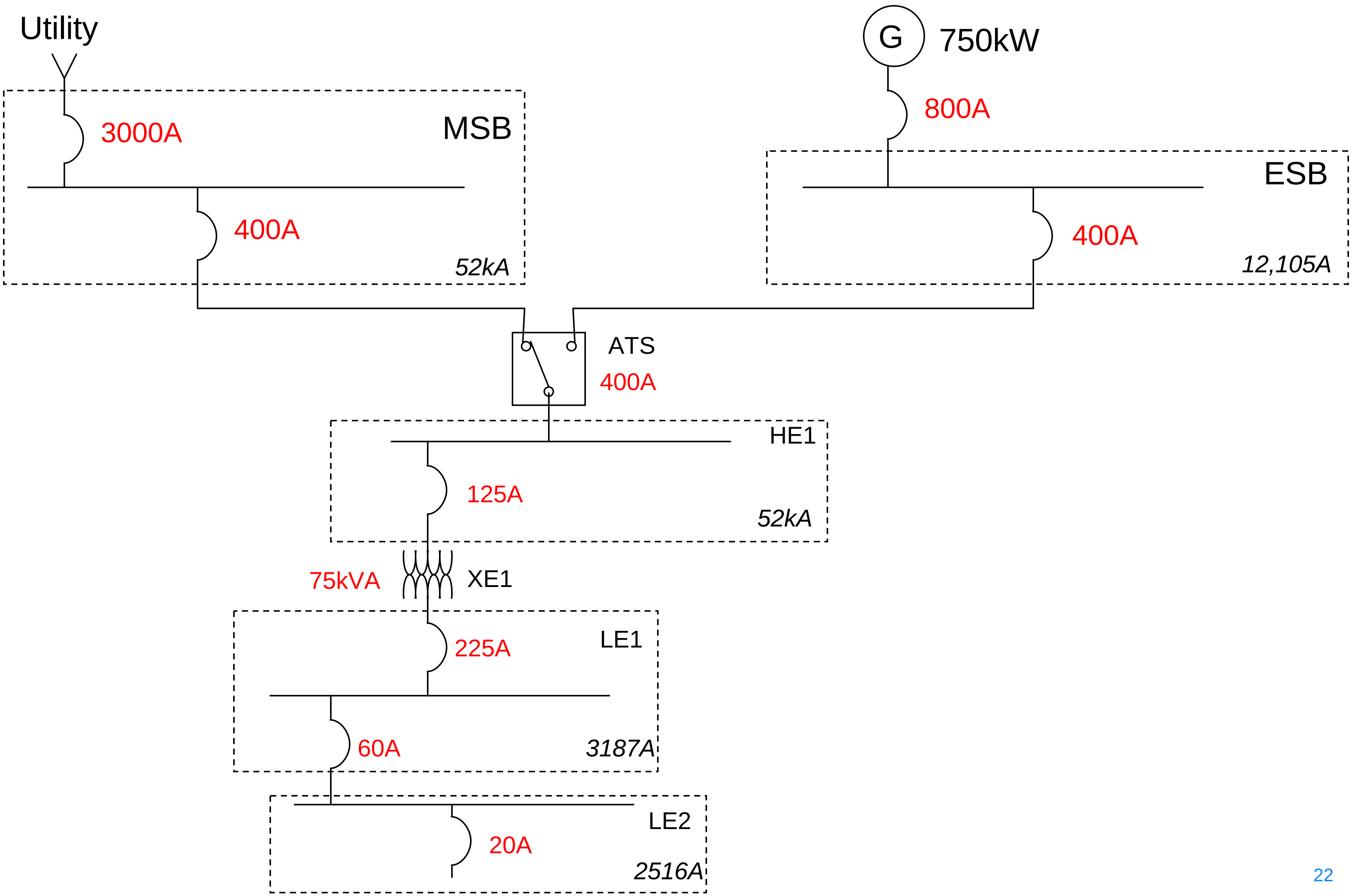
Selective Coordination

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

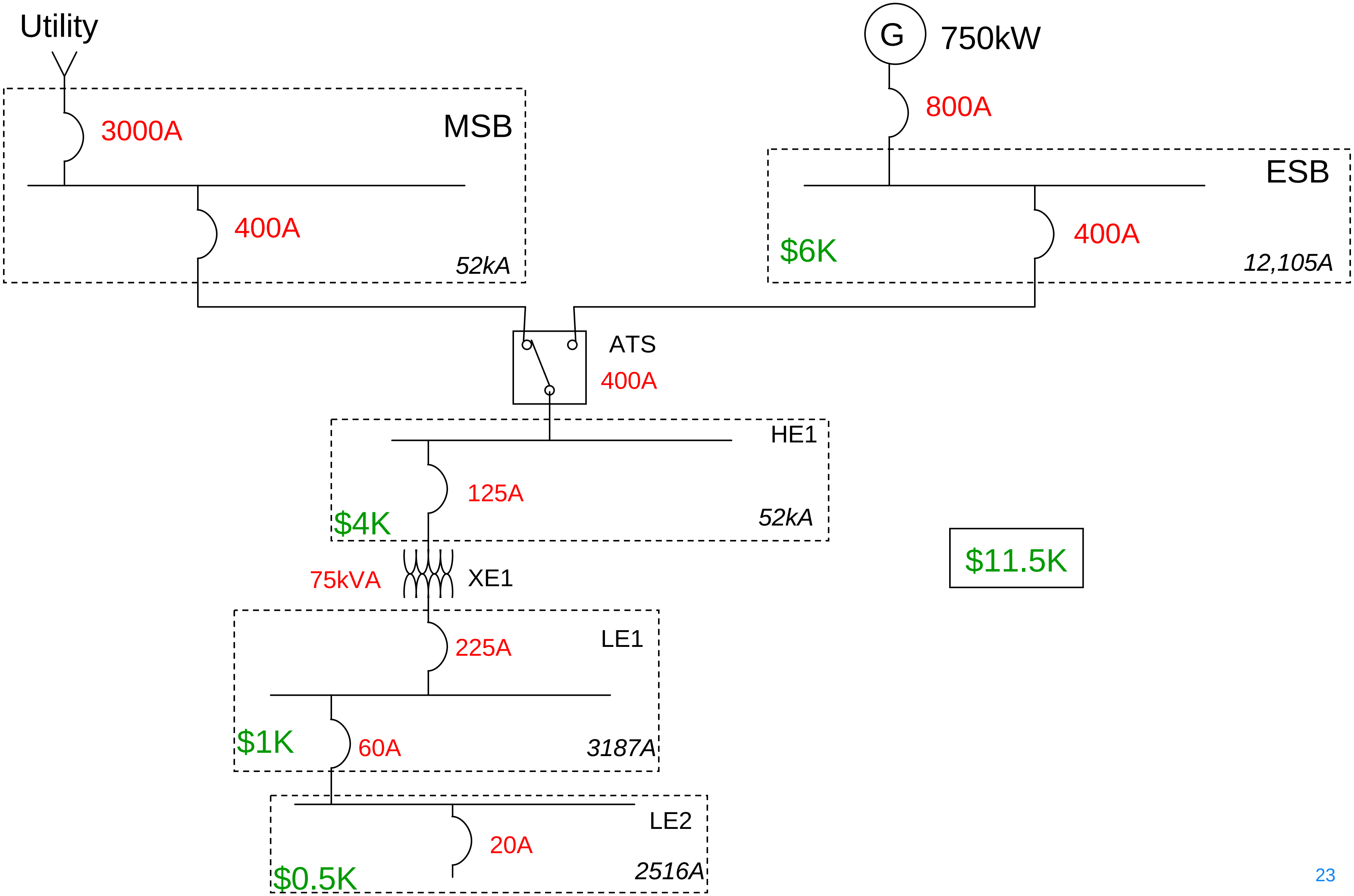
Simplified One-Line



Simplified One-Line – Fault Currents

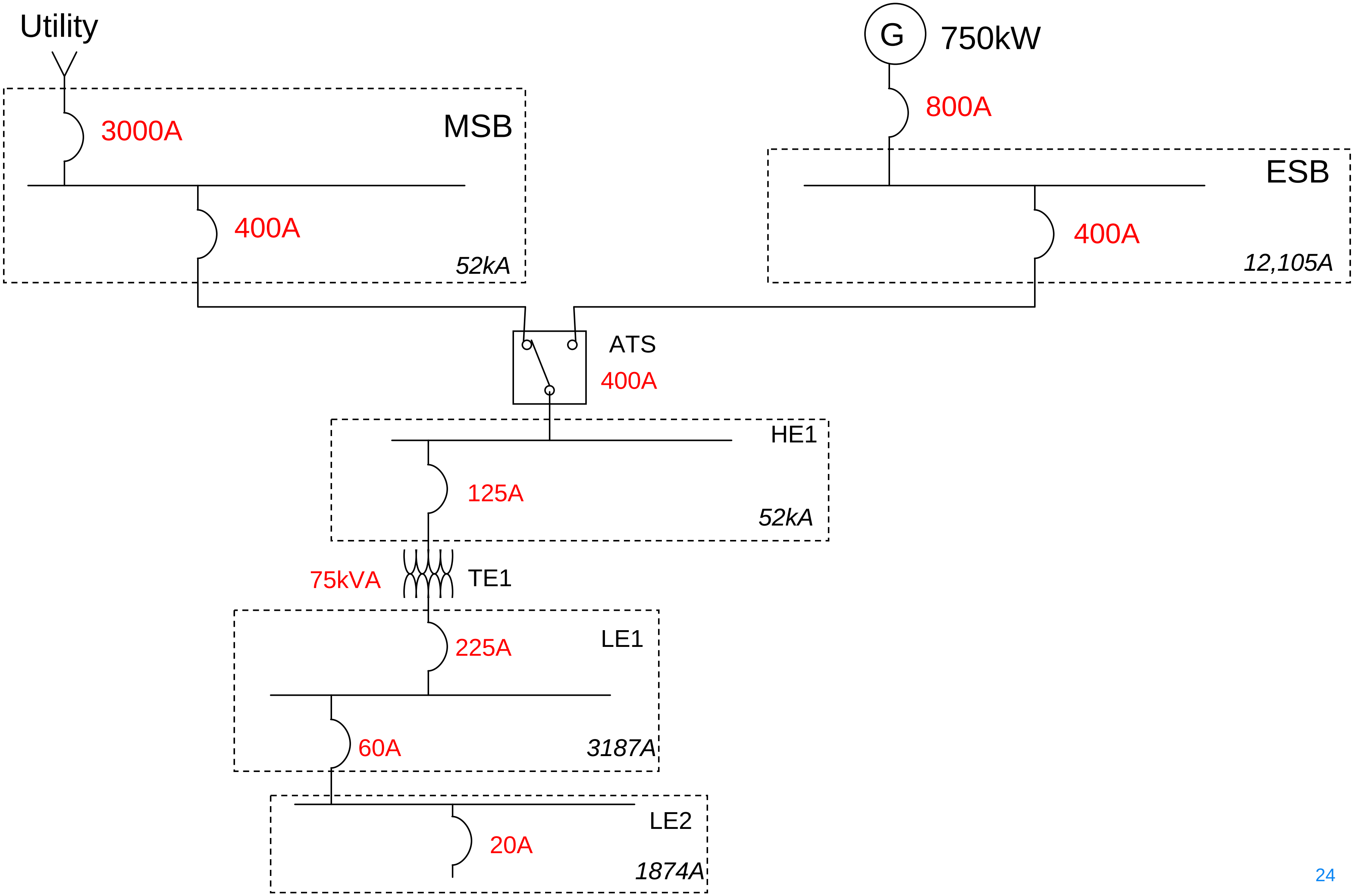


Simplified One-Line – System Cost – Standard Devices



$11.5K

Simplified One-Line – Device Selection



Microsoft Excel - Selective Coordination Tables R3 - 4-1-2011.xls

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)

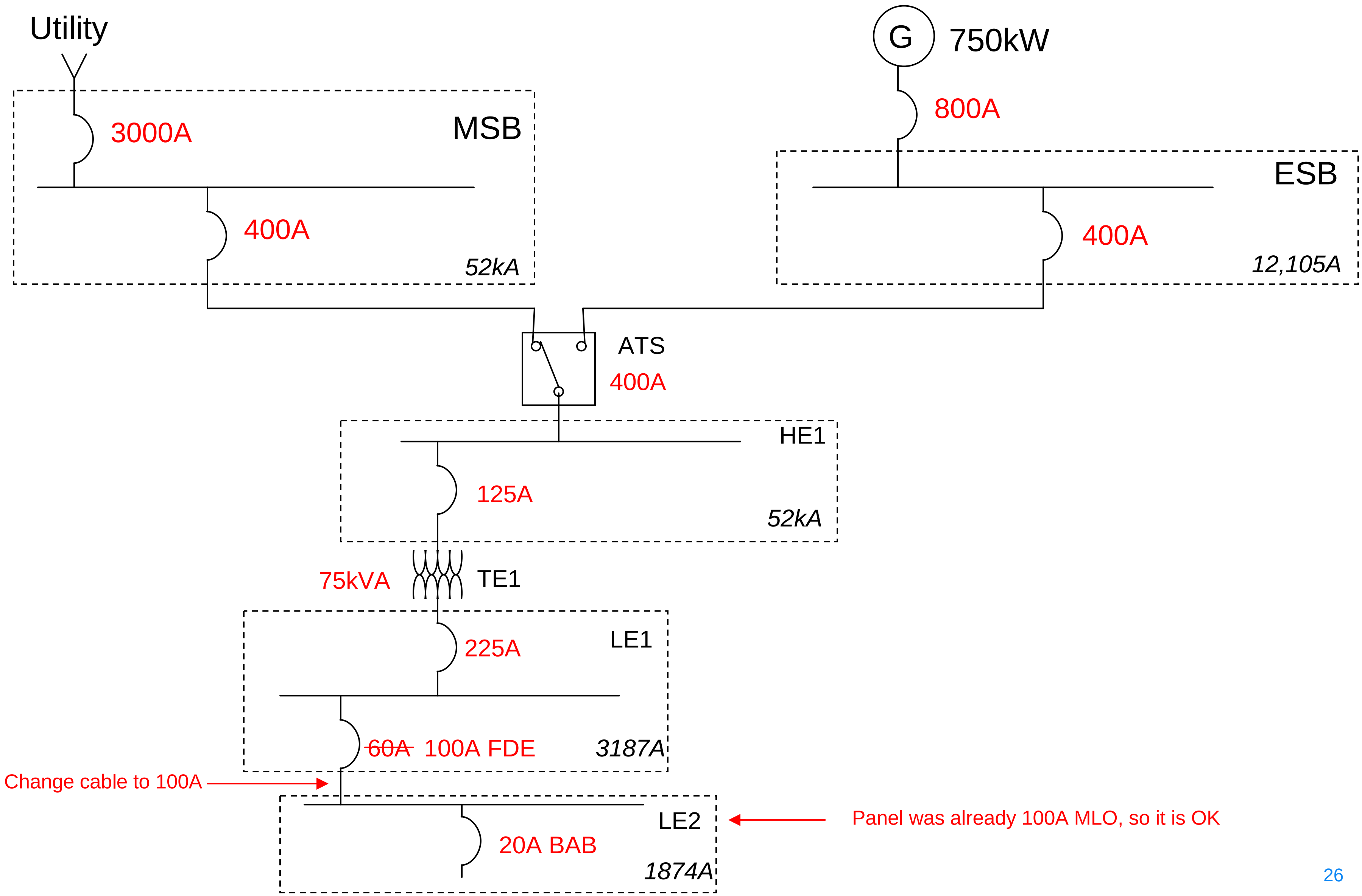

Upstream Breaker →

Downstream Breaker ↓

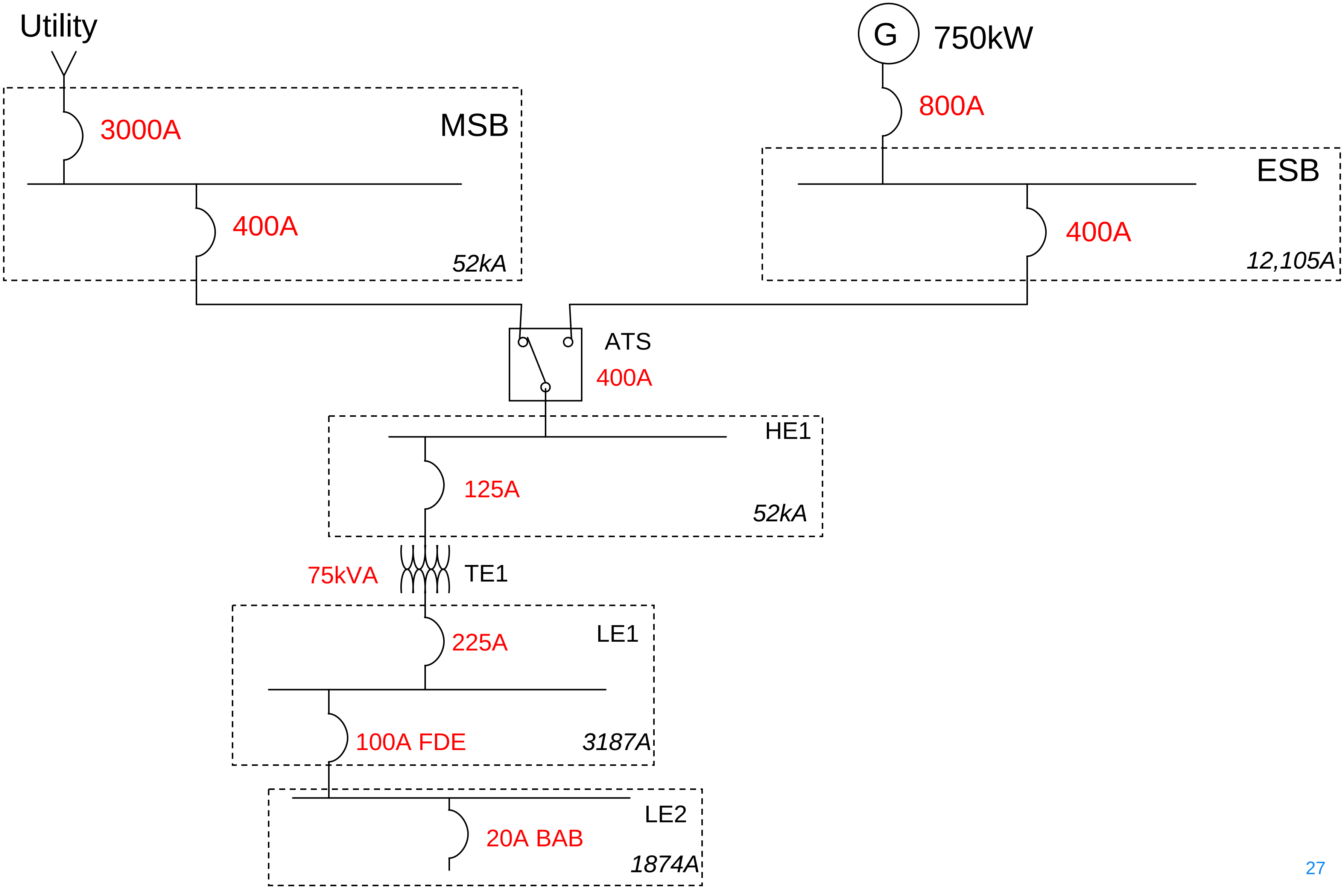
				F	G	H	I	J	K	L	M	N	O	T	U	V	W	X
			Breaker Family ->	EG	F	F	F	F	F	F	J	J	J	K	K	K	K	K
			Type Trip Unit ->	T/M	T /M	T/M	T/M	ETU	ETU	ETU	T/M	T/M	T/M	T/M	T/M	T/M	ETU	ET
			Digitrip RMS Trip Unit ->		—	—	—	310+	310+	310+	—	—	—	—	—	—	310	31
			Optim Trip Unit ->	—	—	—	—	—	—	—	—	—	—	—	—	—	550, 1050	550,
			Minimum 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 —				
			PowR-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

100% Selective / 0.1 Seconds

Simplified One-Line – LE1 Feeder Breaker Change



Simplified One-Line – Device Selection Continued



Microsoft Excel - Selective Coordination Tables R3 - 4-1-2011.xls

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MCCB Selective Coordination Combinations — Te or Less

Upstream Breaker →

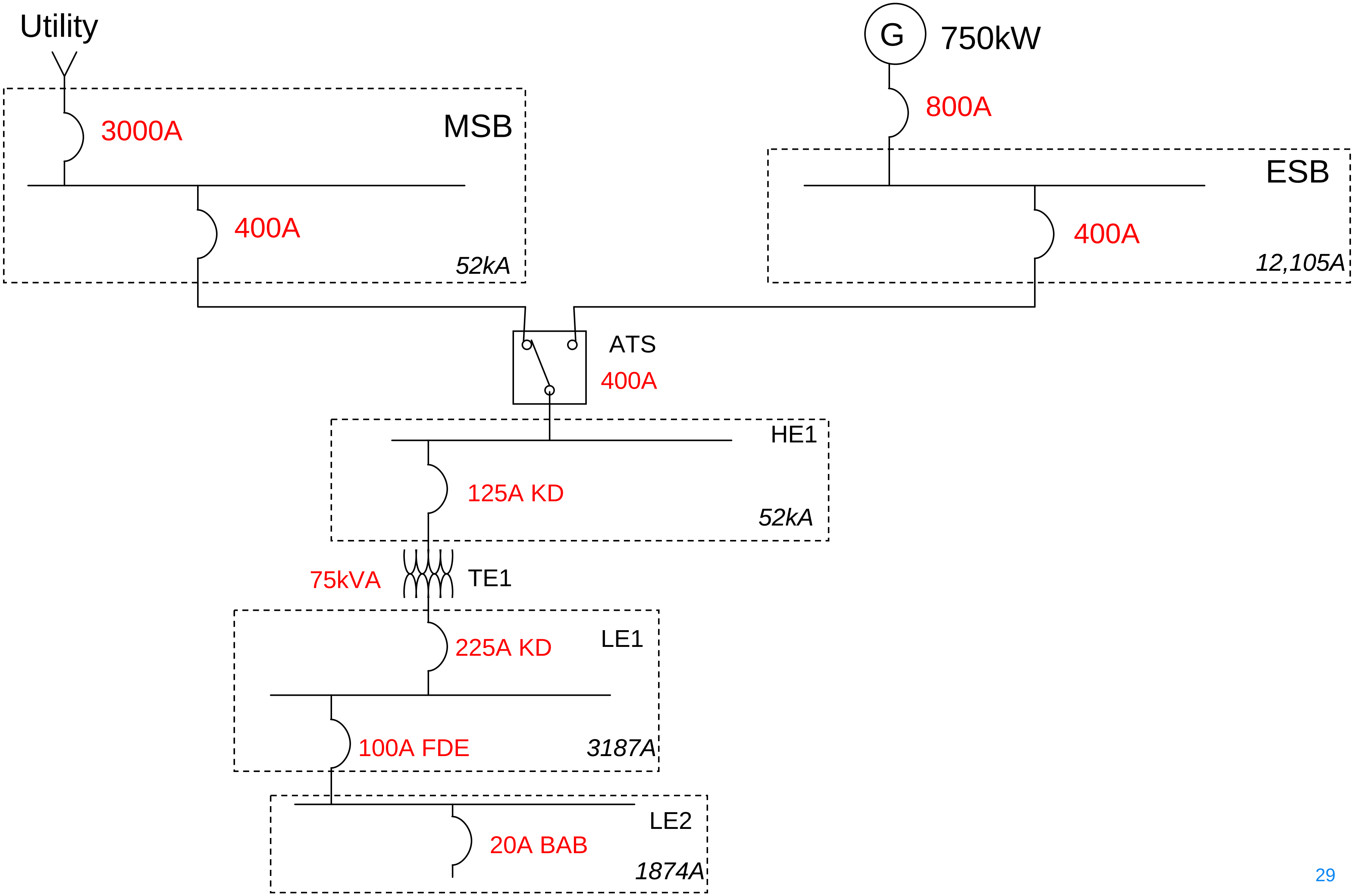
Downstream Breaker ↓

			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 →			← 4,Swb	
			PowR-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	3a,4,Swbd	1a,2a,3a,3E	—	2.3	3.2	—	3.2	4.0	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

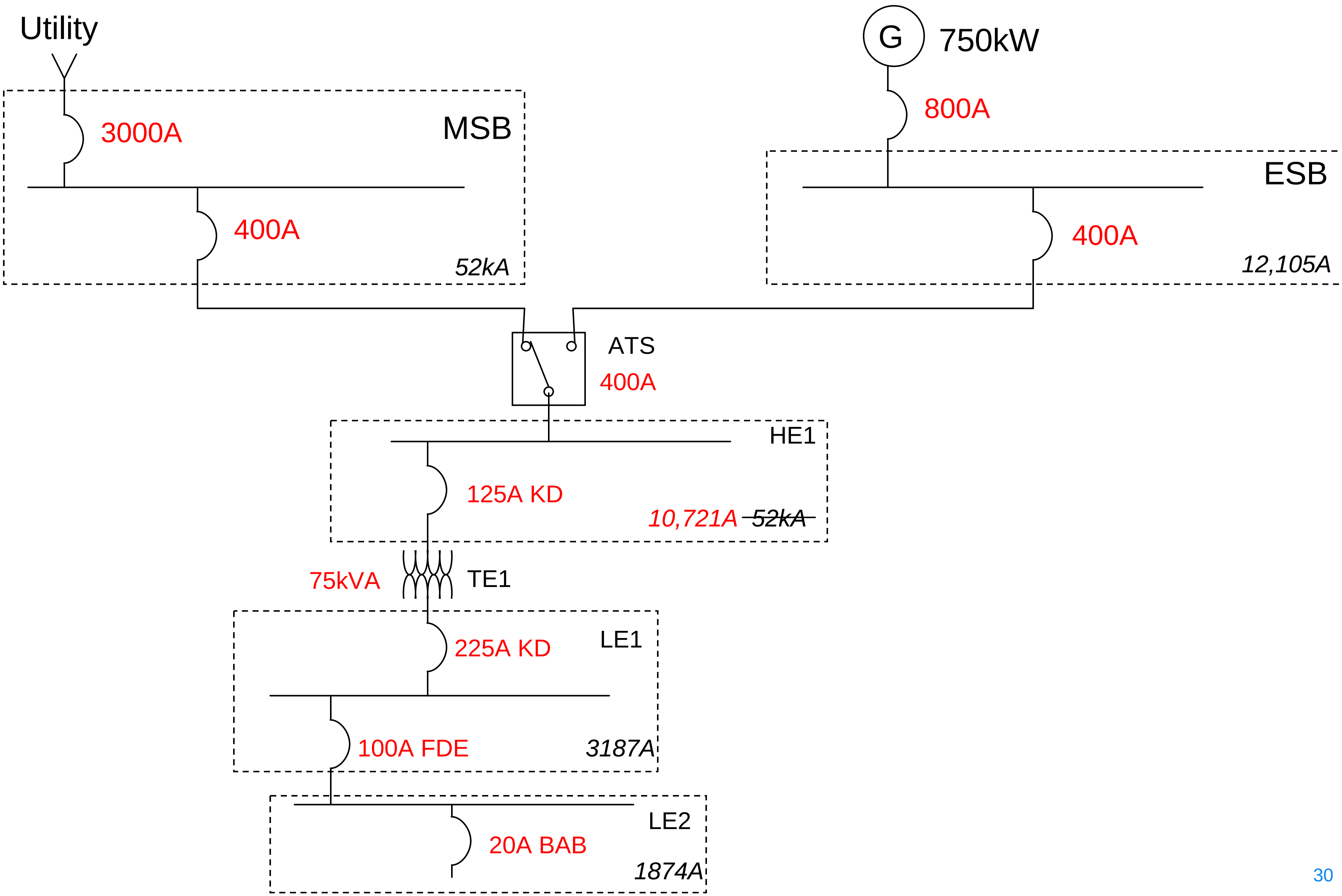
100% Selective / 0.1 Seconds

Ready

Simplified One-Line – Device Selection Continued



Simplified One-Line – Generator Fault Currents



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MCCB Selective Coordination Combinations — Te

Upstream Breaker →

Downstream Breaker ↓


L-Frame Breaker


LG 600 Ampere Breaker


LG 600 Ampere Breaker


N-Frame Breaker


N-Frame Breaker

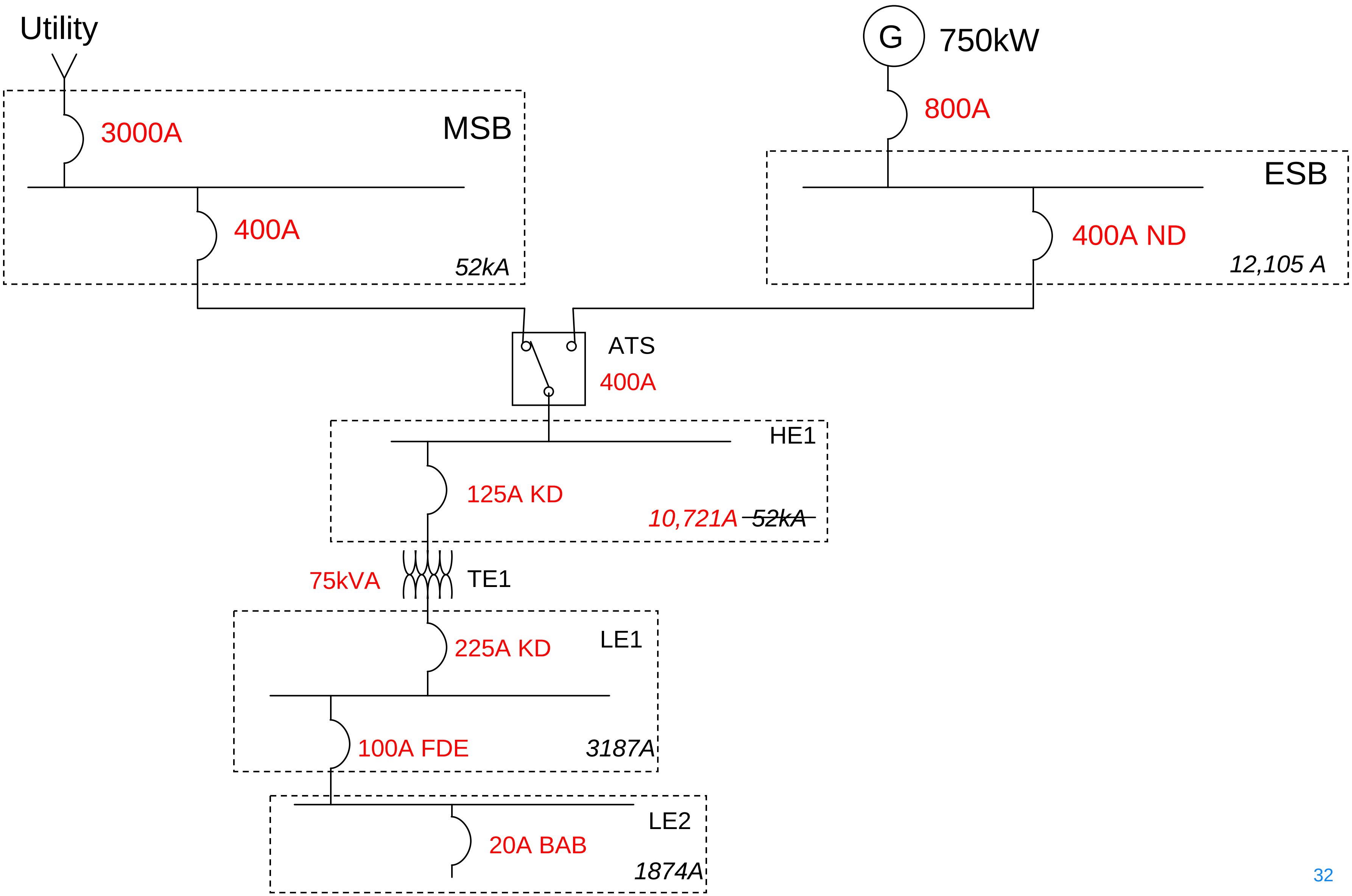
	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
Breaker Family ->	LD	LD	LD	LD	LHH	LHH	LHH	LG	LG	LG	LG	NHH	N	N	N	N
Type Trip Unit ->	T/M	T/M	T/M	ETU	T/M	T/M	T/M	ETU	ETU	ETU	T/M	ETU	ETU	ETU	ETU	ETU
Digitrip RMS Trip Unit ->	—	—	—	310	—	—	—	310+	310+	310+	—	310	310	310	310	310
Optim Trip Unit ->	—	—	—	550, 1050	—	—	—	—	—	—	—	—	550, 1050	550, 1050	550, 1050	550, 1
Minimum Trip (Plug/Trip) ->	300A	400A	600A	200A (Optim) 300A (Digi)	125A	175A	225A	100A	160A	250A	600A	150A	400A	400A	400A	600
Maximum Trip (Frame) ->	350A	500A	600A	600A	150A	200A	400A	250A	400A	600A	600A	350A	400A	600A	800A	1200
Pow-R-Line : Main ->	← 3a,4,Swbd →				← 1a,2a,3a,3E,4 →			—	—	4,Swbd	4,Swbd	4	—	—	4,Swbd	4,Swb
Pow-R-Line : Branch ->	← 4,Swbd →				← 4,Swbd →			← 4,Swbd →				4,Swbd	← 4,Swbd →			
PowR-Line : Sub-Feed ->	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Row	Downstream	Main	Branch	Sub-Feed	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
123	**K Family (KDB, KD, CKD, HKD, CHKD, KDC)**																			
124		**Pow-R-Line Panelboard / Swbd**																		
125		**Main**	**Branch**	**Sub-Feed**																
126	100	—	4,Swbd	—	4.2	4.2	10	10	—	5	10	3.5	4.2	10	—	—	22	22	22	22
127	200	—	4,Swbd	—	—	3.7	10	10	—	—	10	—	3.7	10	—	—	18	18	18	18
128	400	1a,2a,3a,3E,4	4,Swbd	1a,2a,3a,3E	—	—	10	10	—	—	—	—	—	10	—	—	—	—	18	18
129	**L Family (LDB, LD, CLD, HLD, CHLD, LDC, CLDC)**																			
130		**Pow-R-Line Panelboard / Swbd**																		
131		**Main**	**Branch**	**Sub-Feed**																
132	300	3a,4	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	—	6.0	—	—	—	18	18	18
133	400	3a,4	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	—	6.0	—	—	—	—	18	18
134	600	3a,4	4,Swbd	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18
135	**LG Family (LGE, LGS, LGH, LGC)**																			
136		**Pow-R-Line Panelboard / Swbd**																		
137		**Main**	**Branch**	**Sub-Feed**																
138	250	—	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	—	6.0	—	—	10	18	18	18
139	400	—	4,Swbd	—	—	—	6.0	6.0	—	—	—	—	—	6.0	—	—	—	—	18	18
140	600	4	4,Swbd	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18
141	**LG Current Limiting Family**																			
142		**Pow-R-Line Panelboard / Swbd**																		
143		**Main**	**Branch**	**Sub-Feed**																
145	400	—	4,Swbd	—	—	—	6	6	—	—	—	—	—	6	—	—	—	—	25	25
146	600	4	4,Swbd	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25

100% Selective / 0.1 Seconds

Ready

Simplified One-Line – Device Selection Continued



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MCCB Selective Coordination Combinations — Te

Upstream Breaker →

Downstream Breaker ↓

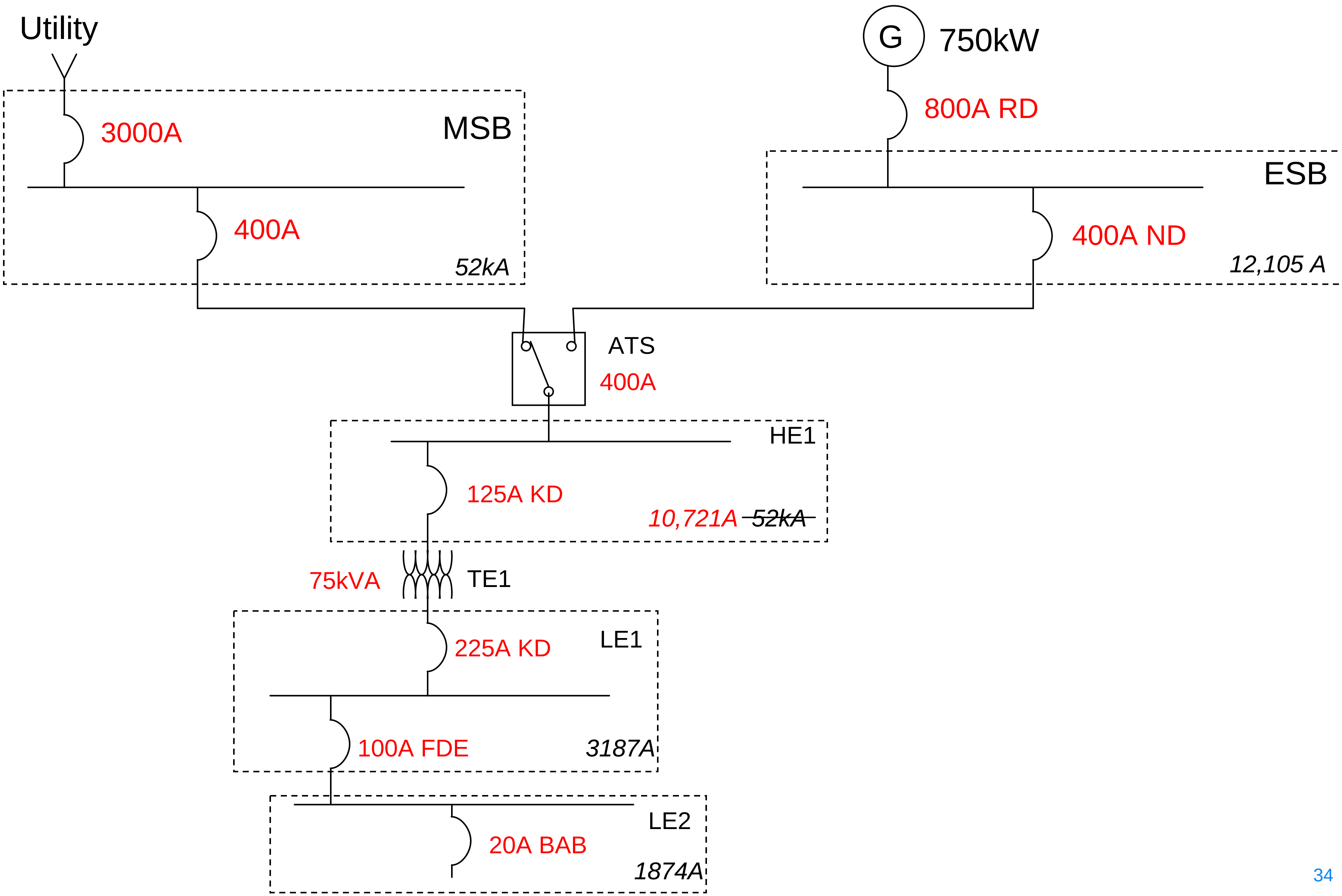


				AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
			Breaker Family ->	NHH	N	N	N	N	R	R	R	R	R	R
			Type Trip Unit ->	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU	ETU
			Digitrip RMS Trip Unit ->	310	310	310	310	310	310	310	310	310	310	310
			Optim Trip Unit ->	—	550, 1050	550, 1050	550, 1050	550, 1050	510, 610, 810, 910, 1050	510, 610, 810, 910, 1050	510, 610, 810, 910, 1050	510, 610, 810, 910, 1050	510, 610, 810, 910, 1050	510, 610, 810, 910, 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	16	22	25
600	—	4,Swbd	—	—	—	—	—	12		—	16	16	22	25
800	4,Swbd	4,Swbd	—	—	—	—	—	—	—	—	—	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

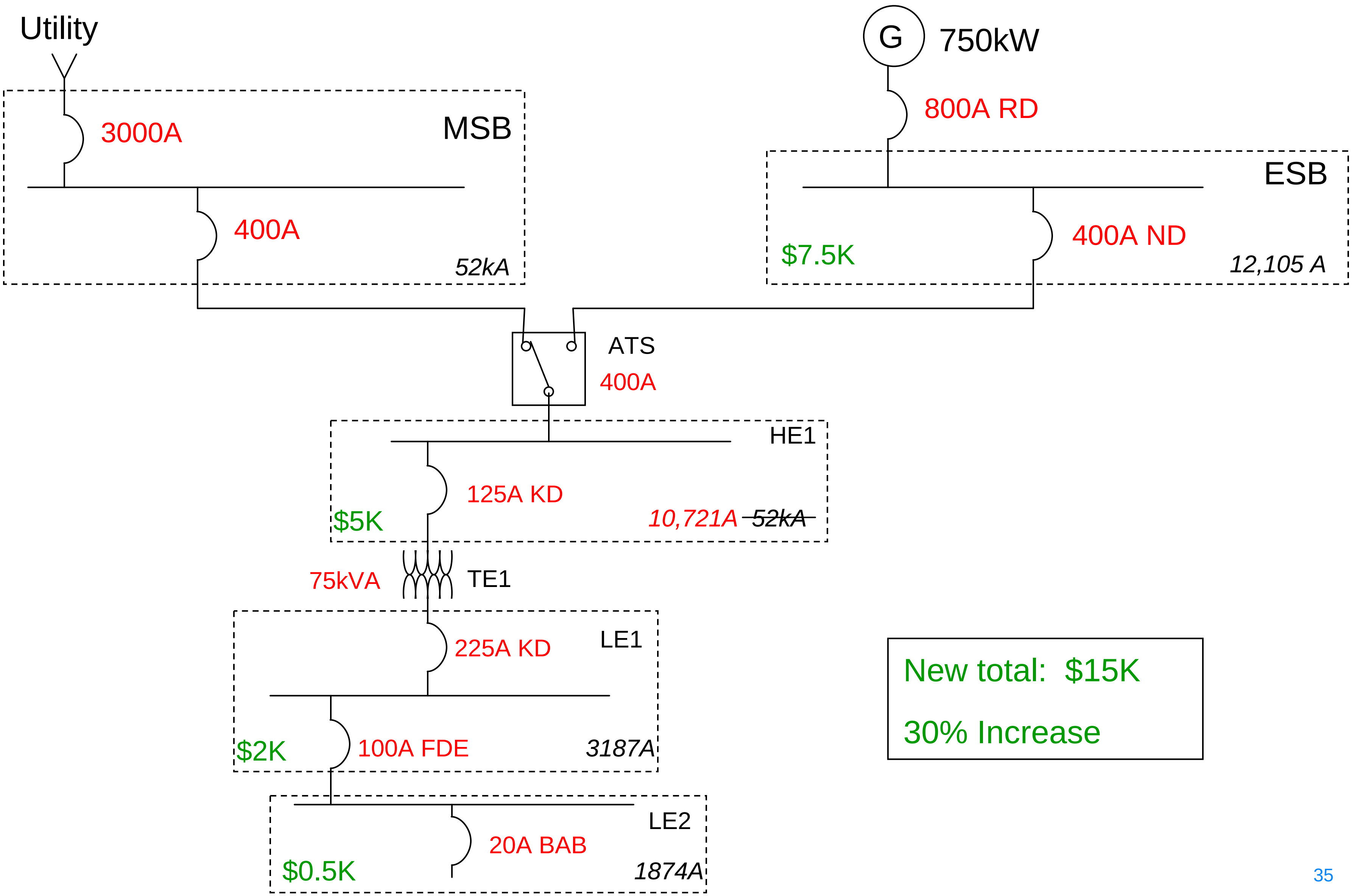
100% Selective / 0.1 Seconds

Ready

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



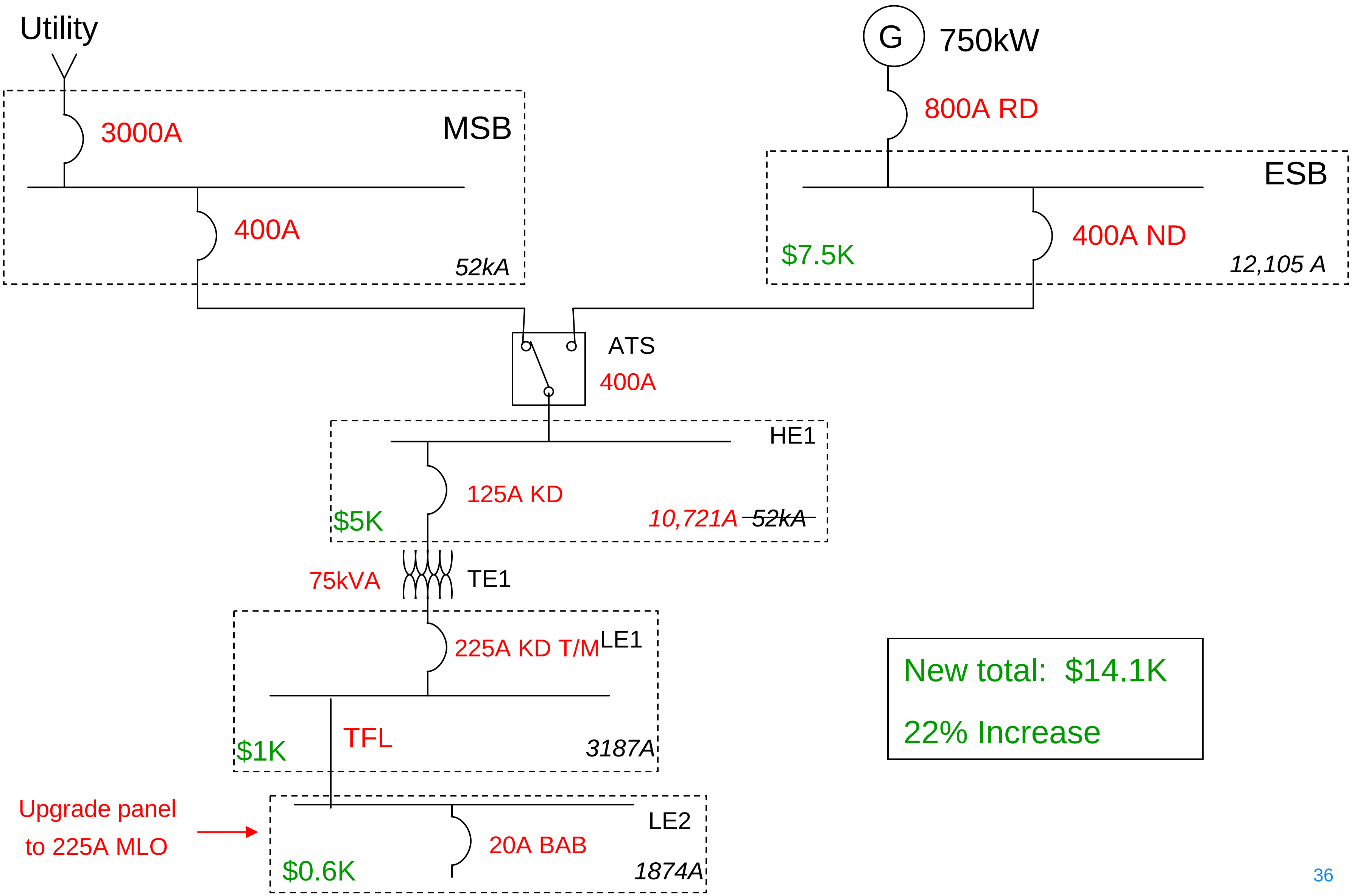
Simplified One-Line – Equipment Costs – Selectively Coordinated System



New total: $15K

30% Increase

Simplified One-Line – Flatten the System



New total: $14.1K

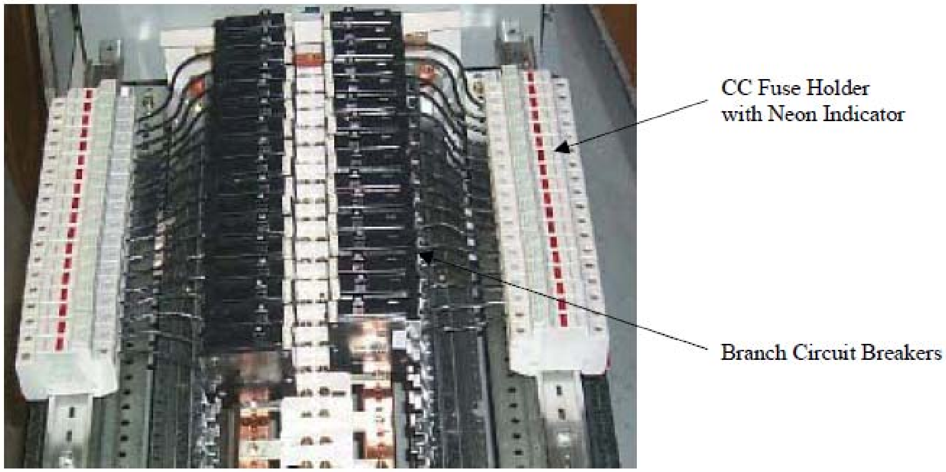
22% Increase

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

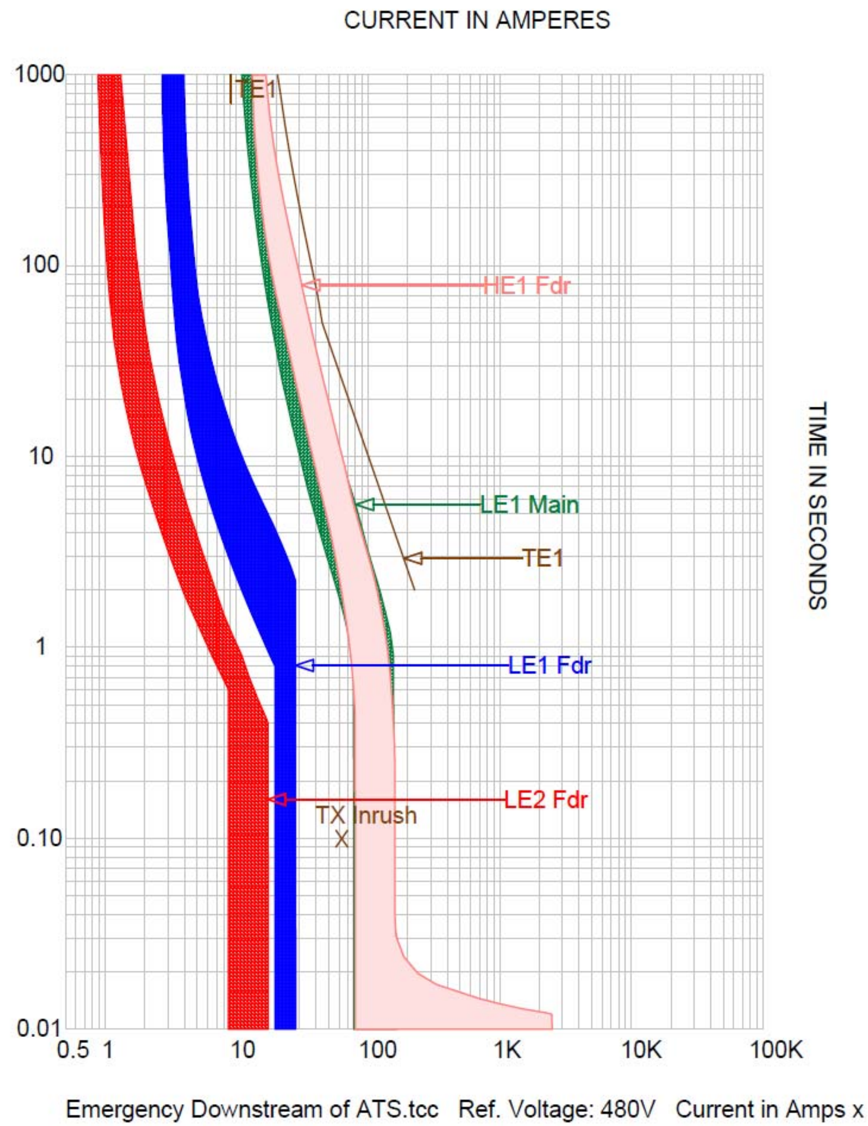


Total Selective Coordination Summary

- 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?



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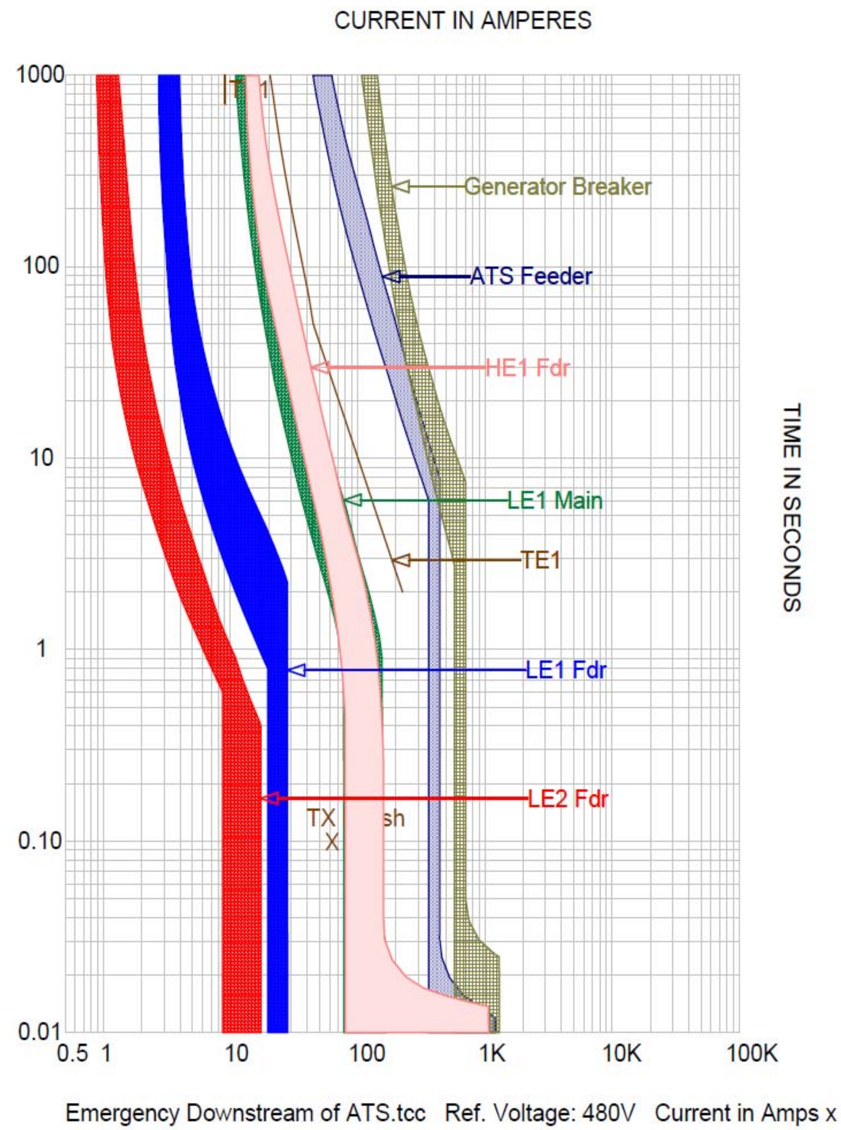
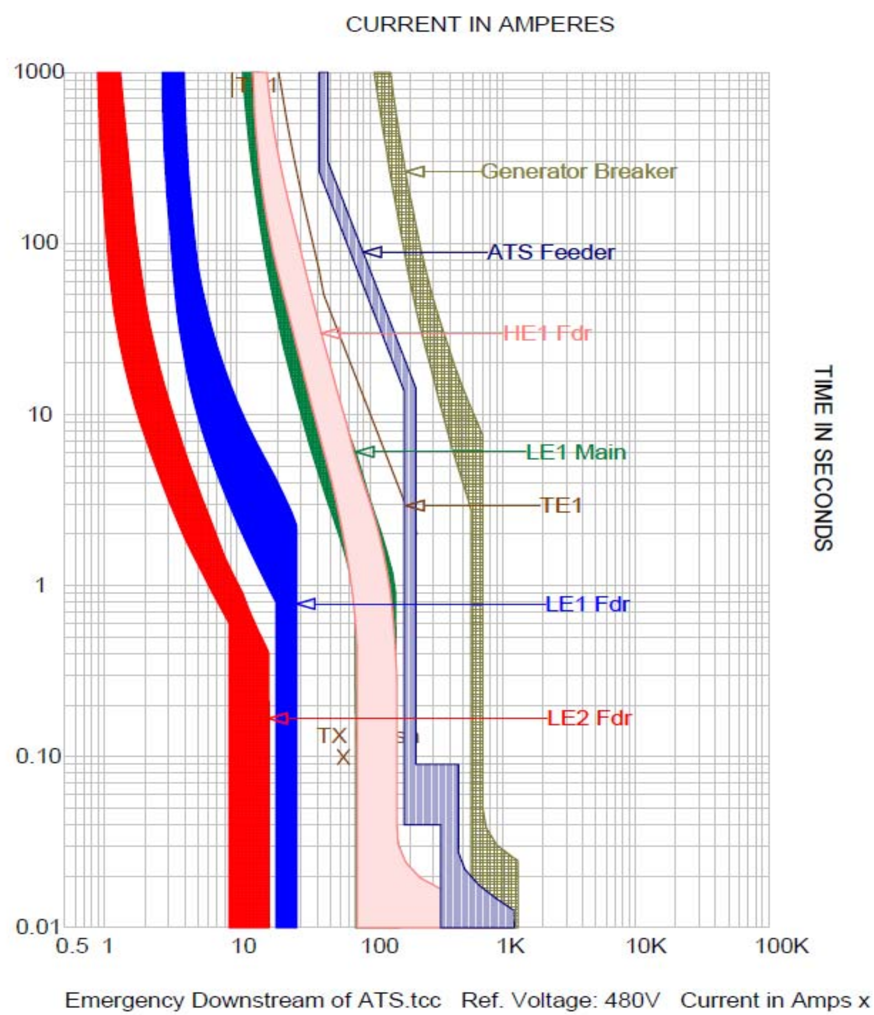
Coordination at 0.01 and 0.1 Seconds

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



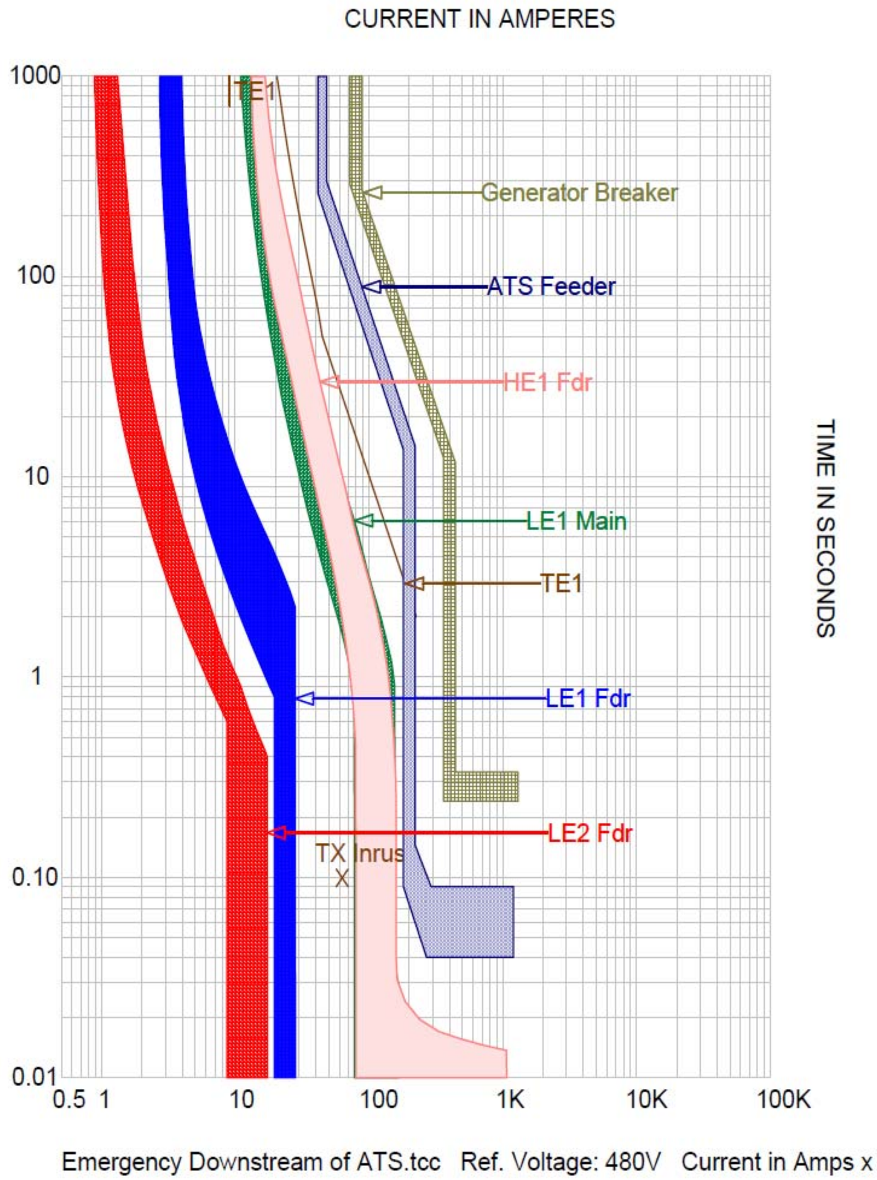
Coordination at 0.1 Seconds

- 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)



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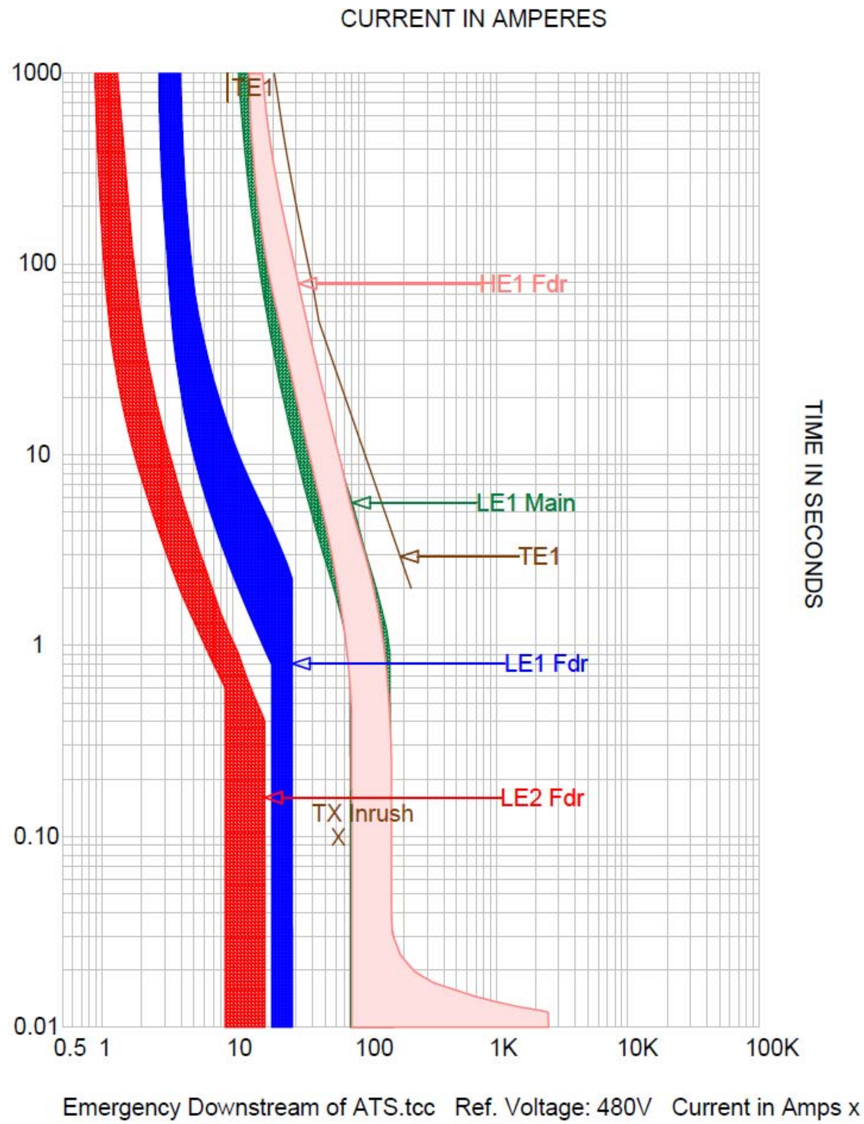
Challenge - Enforcement

- 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

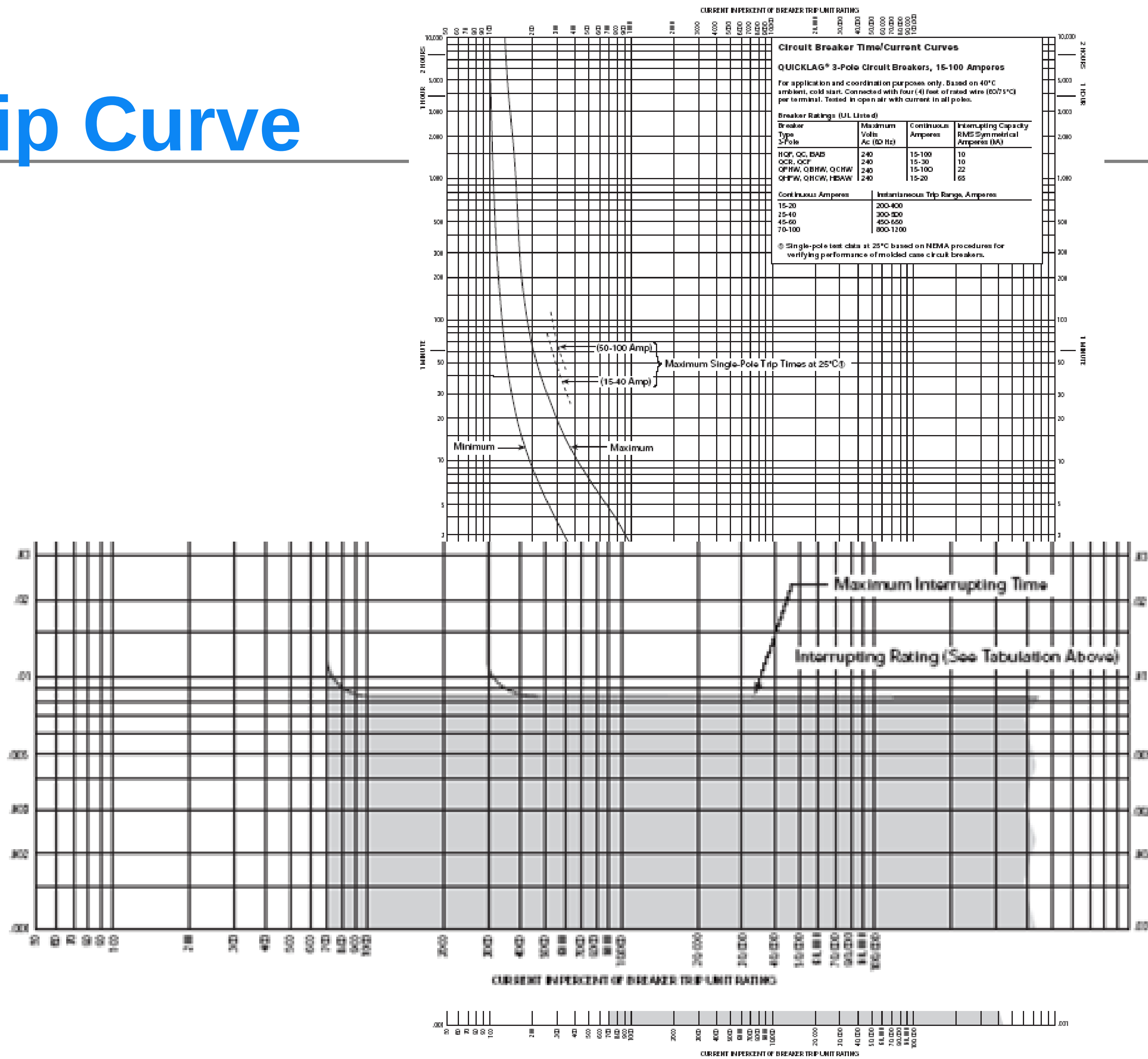
- Breaker Curves
  - No standardized method for representing time current curves



BAB Trip Curve

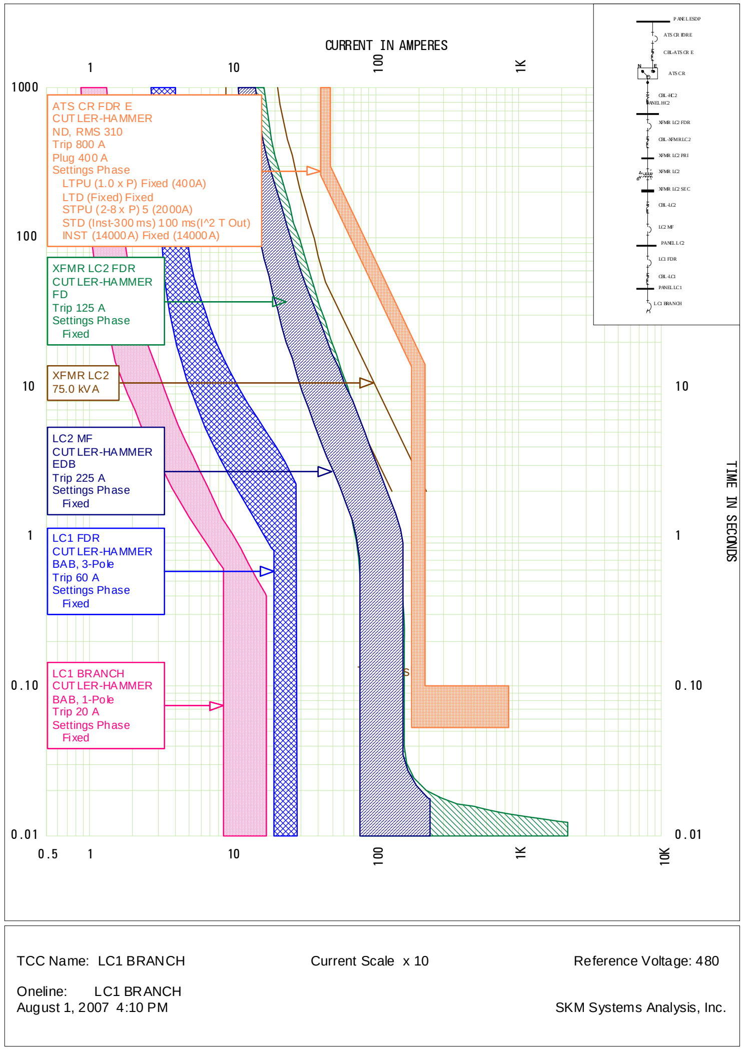
.01 Sec

QUICKLAG 3-Pole Circuit Breakers, 15-100 Amperes



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



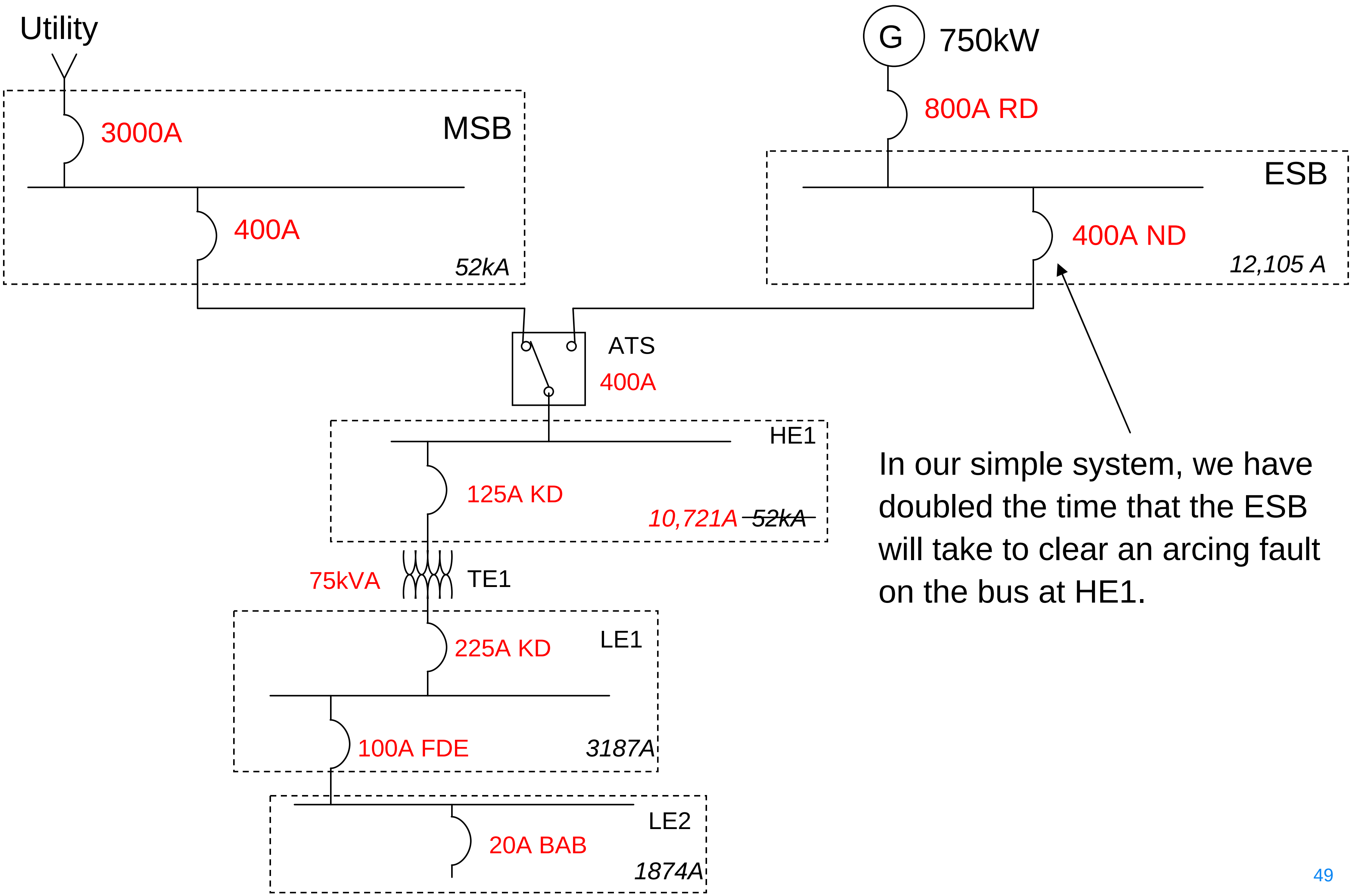
Challenge - Design

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.

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Questions?

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