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2019 Grid of the Future

Lessons Learned of AC Arc Flash Studies for Station Auxiliary Service Systems

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Date: November 5, 2019

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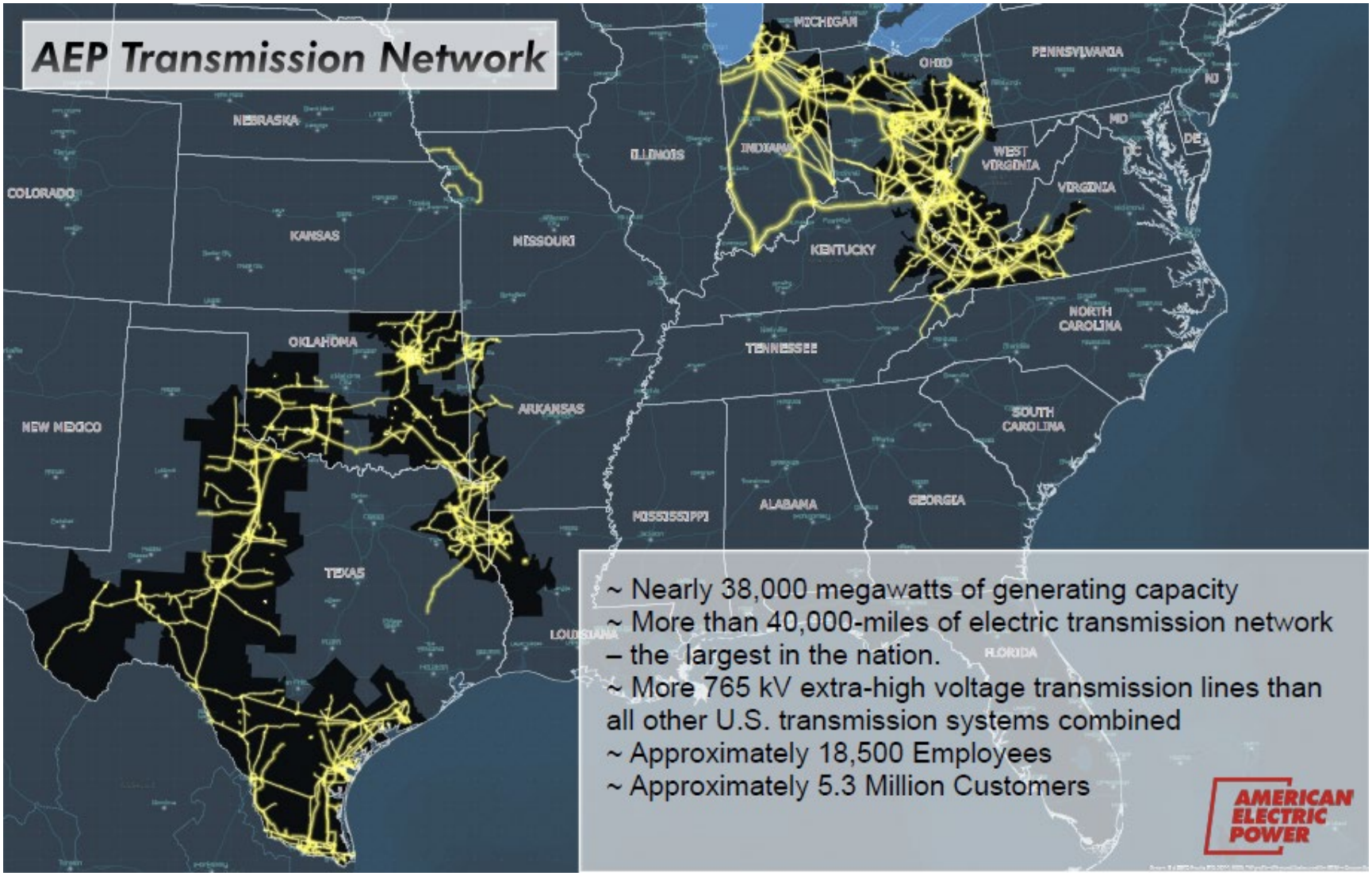
About AEP



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Agenda

- Introduction to Arc Flash in Station Auxiliary Service Systems
- AEP Arc Flash Study Process
  - AEP's Project Process
  - Incorporating Study into Project Timeline
  - Study Workload
- Sensitivity Analysis
  - Procedure
  - Results
- Conclusions

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Arc Flash in AC Station Auxiliary Service Systems

- Faults in AC service circuits (≤480 V) can result in injury or death of station personnel
- Greater risk associated with low-side of Station service (SS) transformers
- Severity affected by:
  - Worker location
  - Fault duration
  - Fault current magnitude
  - Arcing gap width
  - Environmental conditions

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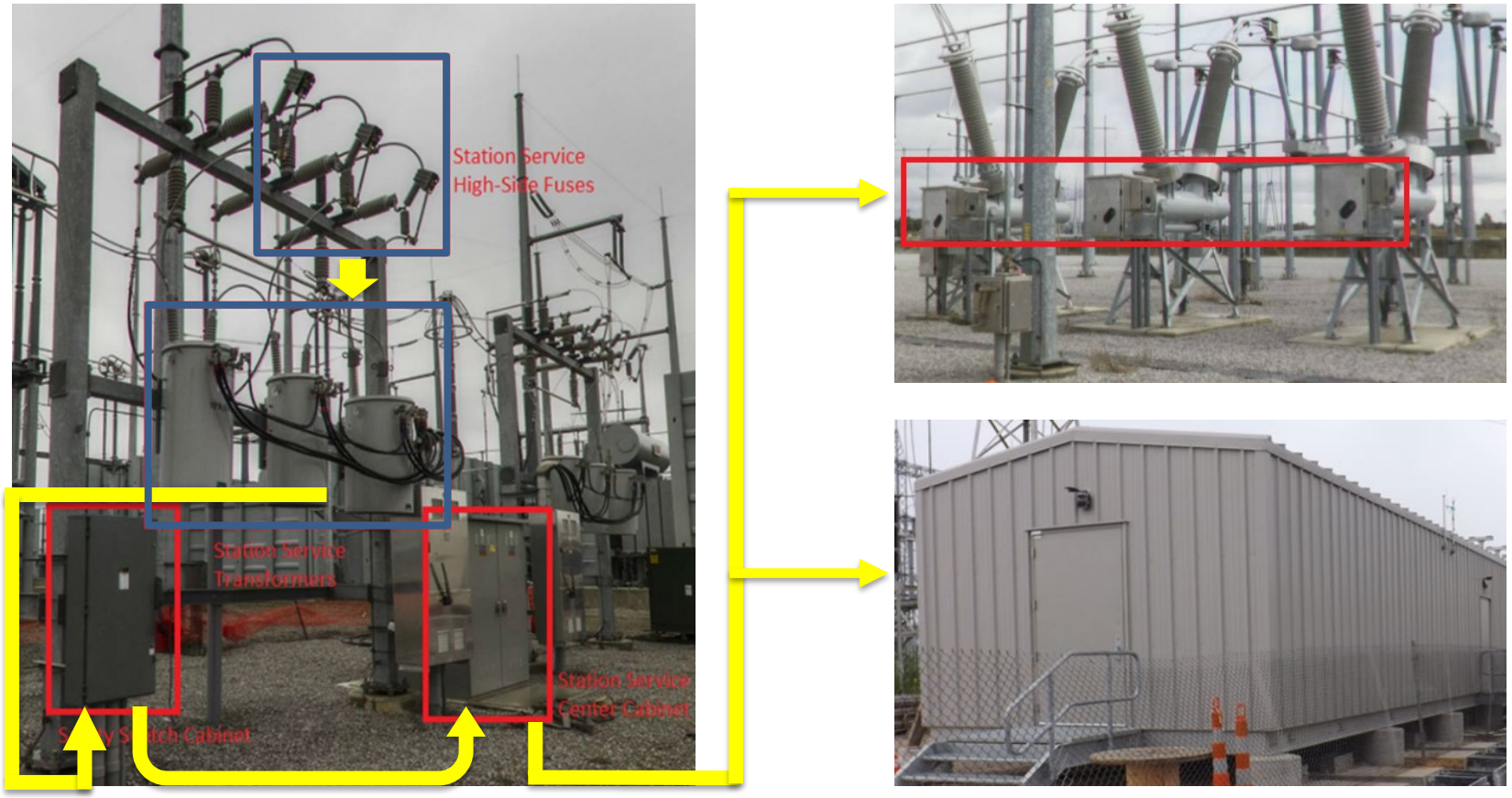
Examples of Risk Locations



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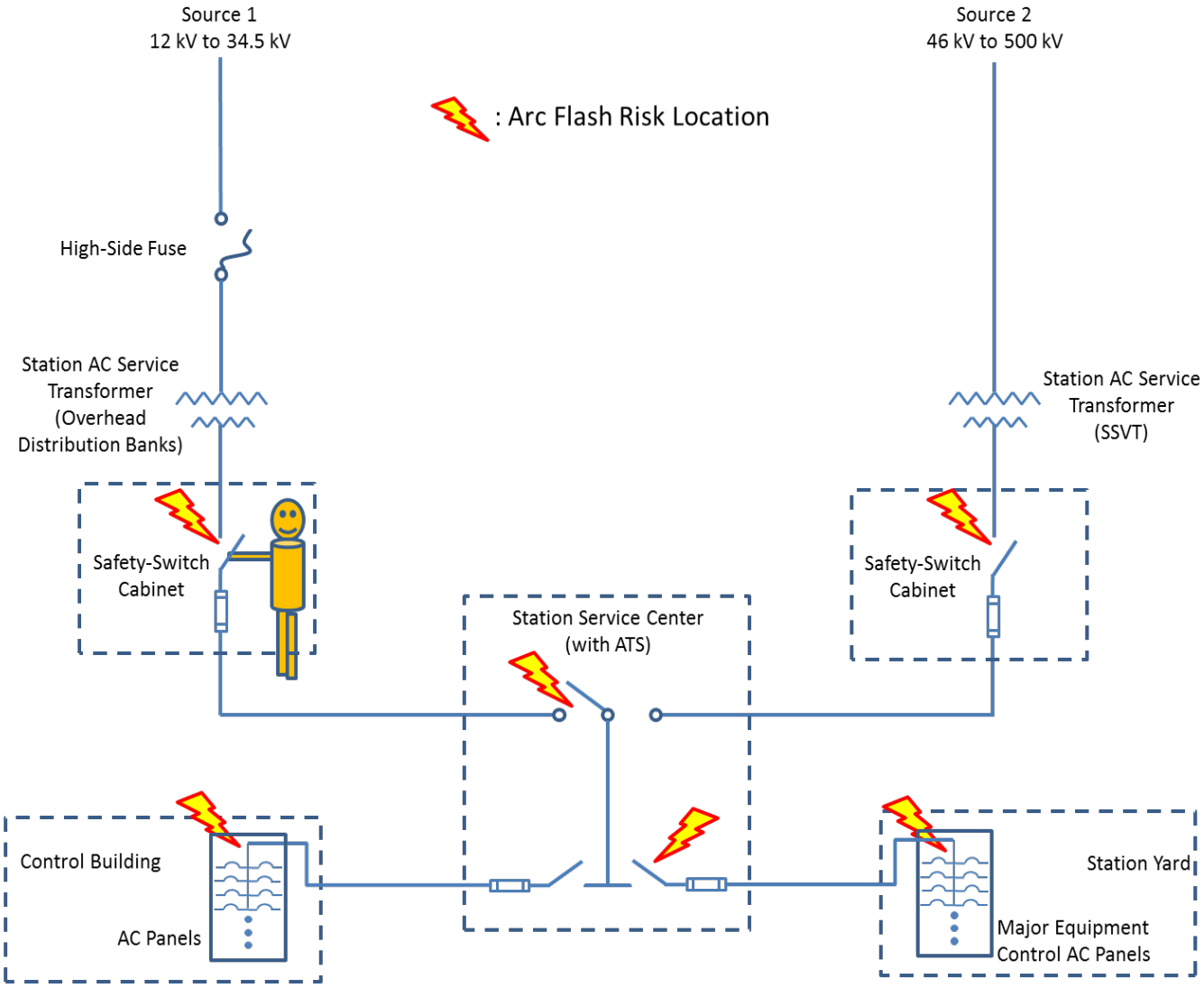
Examples of Risk Locations



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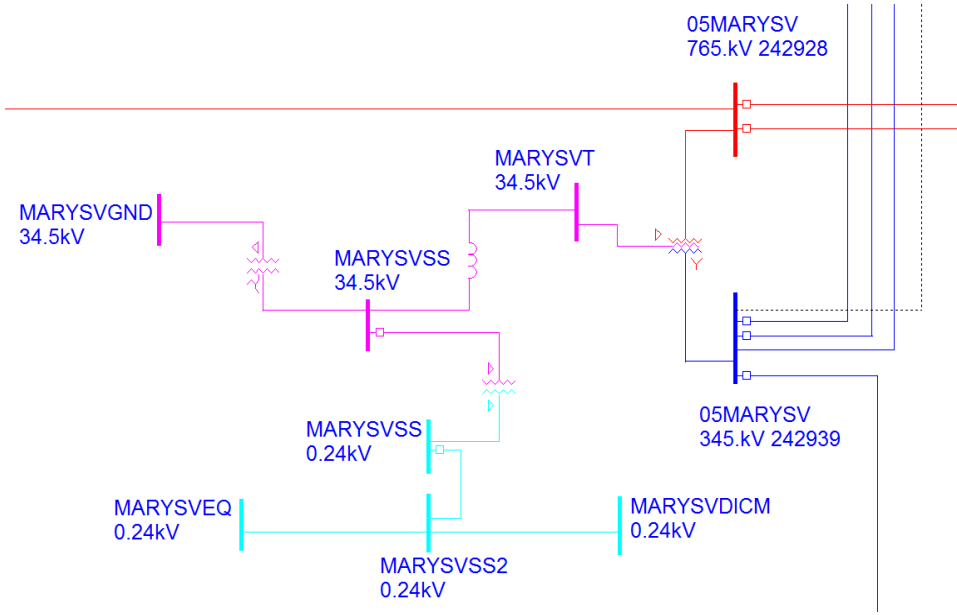
Arc Flash Mitigation Process

1. Identify risk locations
2. Quantify severity by determining incident energy (IE)
3. Mitigate high IE through various techniques:
   - Add low-side fuse
   - Adjust fuse type/speed/amperage rating
   - Other considerations:
     - Reduce cable length
     - Increase cable size



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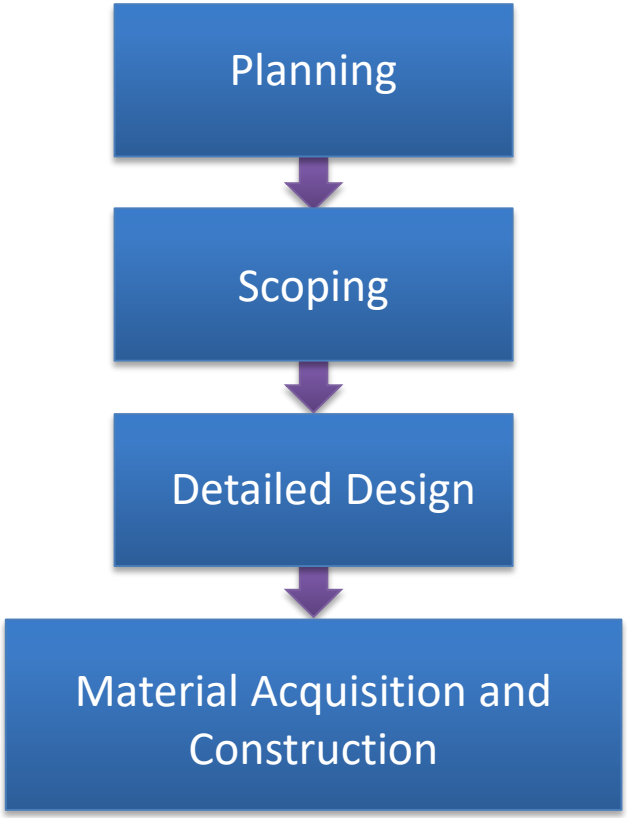
Incorporating Study into Project Timeline



- Identifying projects requiring costly mitigation strategies before funding a scope is critical
- Primary concern: Distribution transformers protected by high-side fuses
- Studies for all other situations can be performed during Detailed Design stage

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Study Workload

- New task for AEP
  - Identified subject matter experts (SMEs) trained to perform studies
- One SME assigned for each region
- Study Time Requirement: 30 min. to 4 hours
- Developed spreadsheet to facilitate data collection and completion of studies

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Example of Arc Flash Analysis Form

Arc Flash Analysis Form

Station Name	BRIDGMAN
Station Service Install BPID	A15041132

Instructions:

Fill out this table for the proposed station service changes during the design phase of a project.
If there are additional station service sources, copy this sheet as needed.
Send this sheet to the regional arc flash SME when complete.
The arc flash SME will send back this form with the results, and any recommendations for equipment upgrades.

If the station service transformers tap a distribution bus, fill out this section for each distribution bus.

	Name of D bus the SS transformer taps	Name of the D transformer that feeds the D bus	Transformer Base MVA	Transformer %Z	Name of transmission bus that feeds the distribution transformer
Preferred Source	12KV MAIN BUS #1	XF #1	7.5	7.5	69KV BUS #1
Alternate Source	12KV MAIN BUS #2	XF #2	7.5	7.2	69KV BUS #1

Fill out this section for each station service transformer, safety switch, and transfer switch.

	Station service xfmr KVA (each)	Station service xfmr %Z If unknown, put "Unknown"	Station service xfmr hi-side fuse type (6A K, 8A K, etc.)	Low-Side Has 240V Safety Switch?	Safety Switch 240V Fuse Size (A)	Conductor length from safety switch to transfer switch (ft)	Conductor Gauge to Transfer Switch
Preferred Source	50	Unknown	12A K	Y	100	15	4/0
Alternate Source	50	Unknown	12A K	Y	100	35	4/0

Fill out this section for each 240V panel that is fed by a fuse or wire, including all sub-panels and the main panel fed from a safety switch or transfer switch. Don't include panels fed from a CB.

Name of 240V AC panel	Panel is fed from which panel/device?	Fuse size the panel is fed from (A)	Conductor length (ft)	Conductor gauge	Does this panel feed individual circuits (not panels) with fuses?	Largest fuse size feeding an individual circuit (A)
Main fuse cab	Manual Transfer Switch	N/A	15	4/0	N	N/A
Bus 2 AC panel (CAB #2)	Main Fuse Cab	60	35	4/0	Y	60
Bus 1 AC panel (CAB #1)	Main Fuse Cab	60	15	4/0	Y	60
OUTDOOR AC PANELBOARD	Main Fuse Cab	100	35	4/0	N	N/A
Indoor 240V AC Cab	Bus 1 AC Panel	100	180	12/C 7/18	N	N/A

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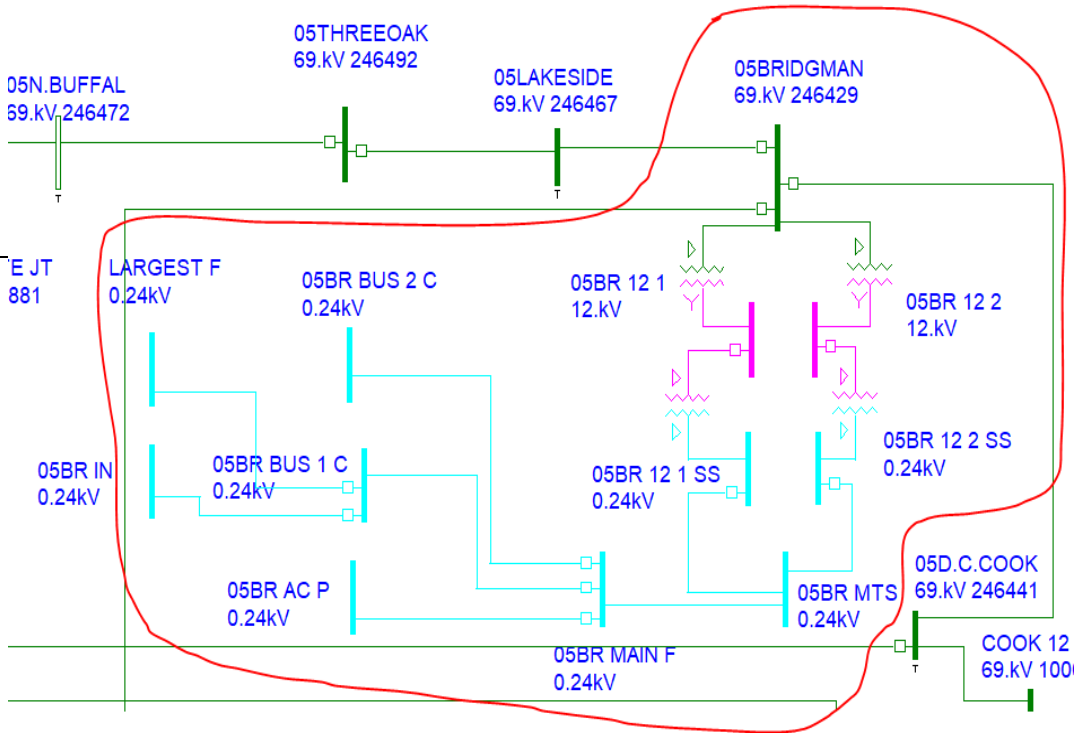
Example of Completed Study and Results Table

Buses	Incident Energy	Incident Energy @ 85% Current
Bus 1 SS	1.555	1.774
Bus 2 SS	1.557	1.776
Manual Trans. Sw.	1.390	1.607
Main Fuse Cab	1.436	1.646
Bus 1 AC Cab	0.170	0.143
Bus 2 AC Cab	0.162	0.136
AC Panelboard	0.380	0.438
Indoor AC Panelboard	0.103	0.146
Bus 1 AC Cab Greatest Load Hazard	< .2	< .2
Bus 2 AC Cab Greatest Load Hazard	< .2	< .2



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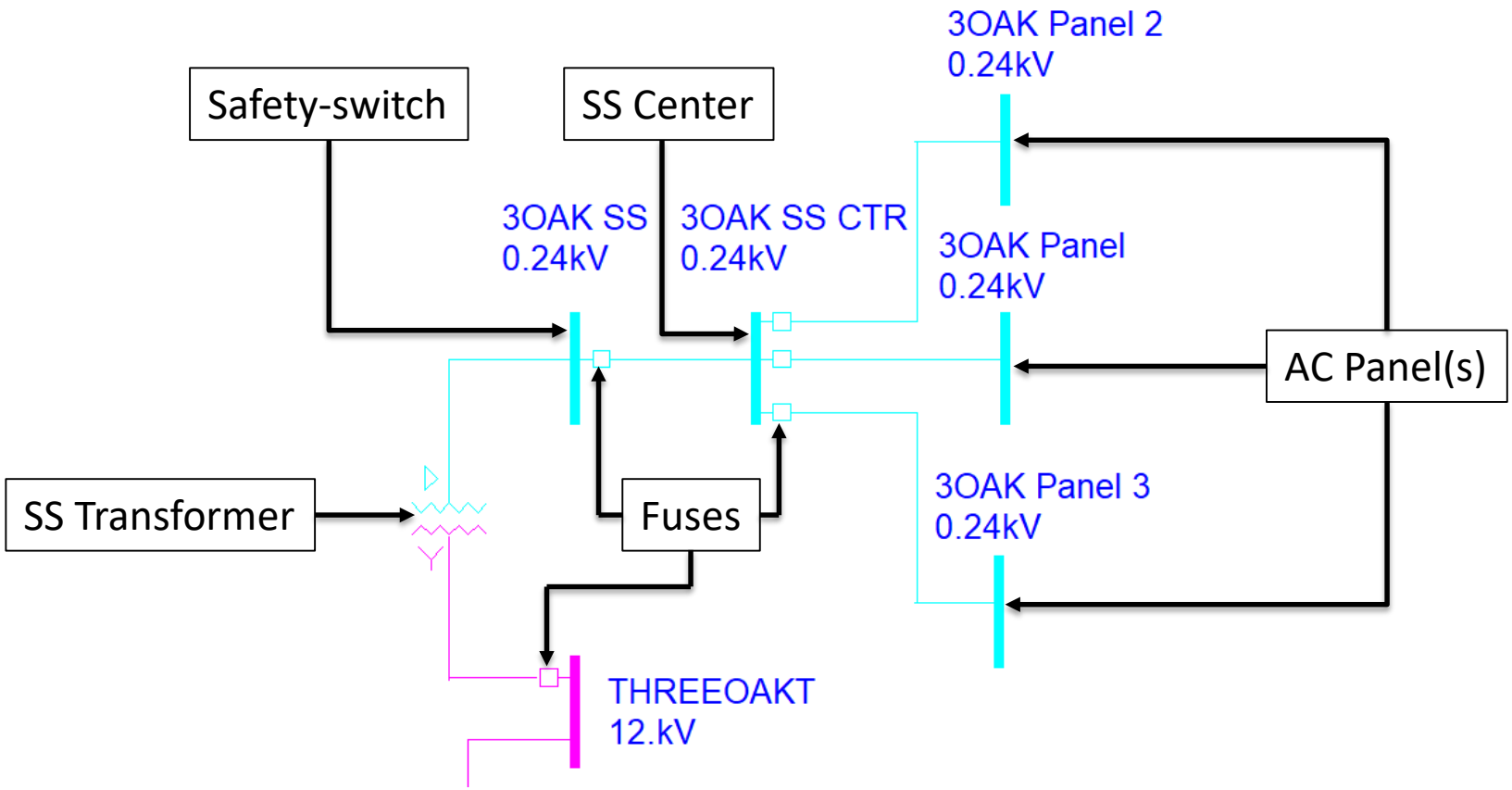
Background for Sensitivity Study

- Objective:
  - Identify design parameters critical in determining potential arc flash hazard within a station
- Compiled list of study parameters
- Established Base Case
- Focused on simple station service system:
  - Safety-switch Cabinet
  - SS Center Cabinet
  - AC Panel(s)

Parameter	Range			
High-Side Bus Three-Phase Fault Current (A)	1678	**3158**	4626	5750
SS Transformer Configuration	**Y-Δ**	Δ-Δ	---	---
SS Transformer Positive-Sequence Impedance (p.u.)	1.50%	**2.00%**	2.50%	---
SS Transformer Capacity (kVA)	10	**25**	50	---
High-Side Fuse	K-TIN-006K	**K-TIN-008K**	K-TIN-010K	K-TIN-012K
Safety-switch Fuse	KTN-R-100	**NON-250-100**	KTN-R-200	NON-250-200
SS Center Fuse	**LPN-RK-100**	LPN-RK-200	LPN-RK-400	LPN-RK-600
Cable Size between Safety-switch and SS Center Cabinets	1/0	2/0	**4/0**	---
Length of Cable between Safety-switch and SS Center Cabinets (ft)	**5**	10	15	---
Cable Size between SS Center and AC Panel Cabinets	#12	**#10**	#6	---
Length of Cable between SS Center and AC Panel Cabinets (ft)	25	**50**	75	---
Number of AC Panel Circuits	**1**	2	3	---

Example of Simple System used in Sensitivity Study



Procedure

1. Select high-side bus
2. Generate required components
3. Calculate short circuit current on low-side bus
4. Perform hazard calculations for each component
5. Record results (IE, Arcing Current, Clearing Time)
6. Adjust single parameter and repeat calculations
7. Determine percent differences
8. Assign parameter impact levels

Percent Difference	Color
Equal to -100%	
Between -10% and -100%	
-10 % to 10%	
Between 10% and 100%	
Greater than or Equal to 100%	

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

Results and Discussion I

- High-Side Bus Three-Phase Fault Current:
  - Affected all downstream buses
  - Minor effect
  - **Decreased current → Increased IE**

High-Side Bus Three-Phase Fault Current Results

Case	Base	1	2	3
High-Side Bus Three-Phase Fault Current (A)	**3158**	**4626**	**1678**	**5750**
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	0.9920	1.0293	0.9897
Incident Thermal Energy @ SS Center Cabinet (%)	1	0.9972	1.0138	0.9959
Incident Thermal Energy @ AC Panel (%)	1	1.0000	1.0092	1.0000
Arcing Current @ Safety-switch Cabinet (%)	1	1.0042	0.9864	1.0052
Arcing Current @ SS Center Cabinet (%)	1	1.0037	0.9864	1.0047
Arcing Current @ AC Panel (%)	1	1.0016	0.9899	1.0008
Clearing Time @ Safety-switch Cabinet (%)	1	0.9879	1.0445	0.9844
Clearing Time @ SS Center Cabinet (%)	1	0.9918	1.0278	0.9897
Clearing Time @ AC Panel (%)	1	0.9955	1.0223	0.9955

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

Results and Discussion II

- SS Transformer Parameters:
  - Affected all downstream buses
  - Configuration: Negligible effect
  - Positive-Sequence Impedance:
    - **Increased impedance → Increased IE**
  - Capacity:
    - **Decreased capacity → Increased IE**
    - More sensitive to decreases in capacity than increases

SS Transformer Pos.-Seq. Impedance Results

Case	Base	1	2
Positive-Sequence Impedance (p.u.)	2.0%	1.5%	2.5%
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	0.6838	1.4554
Incident Thermal Energy @ SS Center Cabinet (%)	1	0.8278	1.1212
Incident Thermal Energy @ AC Panel (%)	1	0.9450	1.0826
Arcing Current @ Safety-switch Cabinet (%)	1	1.2251	0.8543
Arcing Current @ SS Center Cabinet (%)	1	1.2226	0.8544
Arcing Current @ AC Panel (%)	1	1.0707	0.9325
Clearing Time @ Safety-switch Cabinet (%)	1	0.5493	1.7263
Clearing Time @ SS Center Cabinet (%)	1	0.6656	1.3292
Clearing Time @ AC Panel (%)	1	0.8750	1.1607

SS Transformer Capacity Results

Case	Base	1	2
Transformer Capacity (kVA)	25	50	10
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	0.4649	43.9864
Incident Thermal Energy @ SS Center Cabinet (%)	1	0.6061	1.7355
Incident Thermal Energy @ AC Panel (%)	1	0.8991	2.1009
Arcing Current @ Safety-switch Cabinet (%)	1	1.6256	0.5211
Arcing Current @ SS Center Cabinet (%)	1	1.6192	0.5223
Arcing Current @ AC Panel (%)	1	1.1413	0.6832
Clearing Time @ Safety-switch Cabinet (%)	1	0.2750	88.9645
Clearing Time @ SS Center Cabinet (%)	1	0.3591	3.5010
Clearing Time @ AC Panel (%)	1	0.7813	3.1518

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

Results and Discussion III

- Fuse Parameters:
  - Three fuse locations:
    - High-side
    - Safety-switch
    - SS Center
  - Only affected bus immediately downstream
  - **Increased fuse size → Increased IE**

High-Side Fuse Results

Case	Base	1	2	3
High-Side Fuse	K-TIN-008K	K-TIN-006K	K-TIN-010K	K-TIN-012K
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	0.3958	2.5190	15.4284
Incident Thermal Energy @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Incident Thermal Energy @ AC Panel (%)	1	1.0000	1.0000	1.0000
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Arcing Current @ AC Panel (%)	1	1.0000	1.0000	1.0000
Clearing Time @ Safety-switch Cabinet (%)	1	0.3958	2.5190	15.4281
Clearing Time @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Clearing Time @ AC Panel (%)	1	1.0000	1.0000	1.0000

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

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Fuse Parameter Results Continued

Safety-switch Fuse Results

Case	Base	1	2	3
Safety-switch Fuse	NON-250-100	KTN-R-100	KTN-R-200	NON-250-200
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Incident Thermal Energy @ SS Center Cabinet (%)	1	0.1019	0.5165	5.7796
Incident Thermal Energy @ AC Panel (%)	1	0.4404	1.0000	1.0000
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Arcing Current @ AC Panel (%)	1	1.0000	1.0000	1.0000
Clearing Time @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Clearing Time @ SS Center Cabinet (%)	1	0.1019	0.5154	5.7778
Clearing Time @ AC Panel (%)	1	0.4420	1.0000	1.0000

SS Center Fuse Results

Case	Base	1	2	3
SS Center Fuse	LPN-RK-100	LPN-RK-200	LPN-RK-400	LPN-RK-600
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Incident Thermal Energy @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Incident Thermal Energy @ AC Panel (%)	1	9.0917	9.0917	9.0917
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Arcing Current @ AC Panel (%)	1	1.0000	1.0000	1.0000
Clearing Time @ Safety-switch Cabinet (%)	1	1.0000	1.0000	1.0000
Clearing Time @ SS Center Cabinet (%)	1	1.0000	1.0000	1.0000
Clearing Time @ AC Panel (%)	1	9.0580	9.0580	9.0580

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

Results and Discussion IV

- Cable Parameters:
  - Affected all downstream buses
  - Size:
    - **Decreased size → Increased IE**
  - Length:
    - **Increased length → Increased IE**
  - Percent difference variation between cable locations likely due to different ranges of length
- Number of AC Panels:
  - Negligible effect

Cable Size Results between Safety-switch and SS Center

Case	Base	1	2
Cable Type between Safety-switch and SS Center Cabinets	4/0	1/0	2/0
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Incident Thermal Energy @ SS Center Cabinet (%)	1	1.0014	1.0014
Incident Thermal Energy @ AC Panel (%)	1	1.0092	1.0000
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	0.9990	0.9995
Arcing Current @ AC Panel (%)	1	0.9977	0.9984
Clearing Time @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Clearing Time @ SS Center Cabinet (%)	1	1.0010	1.0010
Clearing Time @ AC Panel (%)	1	1.0045	1.0045

Cable Size Results between SS Center and AC Panel

Case	Base	1	2
Cable Type between SS Center and AC Panel Cabinets	#10	#12	#6
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Incident Thermal Energy @ SS Center Cabinet (%)	1	1.0000	1.0000
Incident Thermal Energy @ AC Panel (%)	1	1.4587	0.8349
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	1.0000	1.0000
Arcing Current @ AC Panel (%)	1	0.7772	1.2842
Clearing Time @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Clearing Time @ SS Center Cabinet (%)	1	1.0000	1.0000
Clearing Time @ AC Panel (%)	1	1.9107	0.6384

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

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Cable Parameter Results Continued

Cable Length Results between Safety-switch and SS Center

Case	Base	1	2
Cable Length between Safety-switch and SS Center Cabinets (ft)	5	10	15
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Incident Thermal Energy @ SS Center Cabinet (%)	1	1.0041	1.0069
Incident Thermal Energy @ AC Panel (%)	1	1.0092	1.0092
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	0.9963	0.9927
Arcing Current @ AC Panel (%)	1	0.9969	0.9930
Clearing Time @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Clearing Time @ SS Center Cabinet (%)	1	1.0072	1.0144
Clearing Time @ AC Panel (%)	1	1.0045	1.0134

Cable Length Results between SS Center and AC Panel

Case	Base	1	2
Cable Length between SS Center and AC Panel Cabinets (ft)	50	25	75
Incident Thermal Energy @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Incident Thermal Energy @ SS Center Cabinet (%)	1	1.0000	1.0000
Incident Thermal Energy @ AC Panel (%)	1	0.8532	1.3119
Arcing Current @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Arcing Current @ SS Center Cabinet (%)	1	1.0000	1.0000
Arcing Current @ AC Panel (%)	1	1.2539	0.8199
Clearing Time @ Safety-switch Cabinet (%)	1	1.0000	1.0000
Clearing Time @ SS Center Cabinet (%)	1	1.0000	1.0000
Clearing Time @ AC Panel (%)	1	0.6652	1.6205

Large Decrease	Moderate Decrease	Minor Effect	Moderate Increase	Large Increase

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Sensitivity Study Results Summary

- Parameters greatly affecting system impedance are critical
- **Increased impedance → Increased IE**
  - Greater clearing times from reduced arcing current
- Arcing current and clearing time influence IE
  - Clearing time shows greater influence
- Emphasizes importance of fuses and need to track system changes that affect impedance for downstream components

Parameter	Impact
High-Side Bus Three-Phase Fault Current	Low
SS Transformer Configuration	Negligible
SS Transformer Positive-Sequence Impedance	High
SS Transformer Capacity	High
High-Side Fuse Curve	Moderate
Safety-switch Fuse Curve	Moderate
SS Center Fuse Curve	Moderate
Cable Size	Moderate
Cable Length	Moderate
Number of AC Panel Circuits	Negligible

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Conclusions

- Arc flash studies are preferably performed after Scoping stage
- A dedicated SME team is responsible for studies with project engineers supplying required information
- Arc flash study results are used to develop mitigation plan
- For arc flash studies, emphasis should be placed on:
  1. Transformers
  2. Fuses
  3. Cable parameters

Thank You