Design Principles for AC Station Service Connections in EHV Substations

Presenter: Prudhvi Bhattiprolu
Co-authors: Matthew Sigg, Manish Thakur
Station Engineering Design Standards

Agenda

- AC Station service challenges in EHV stations
- Station service block diagram
- EHV transformer bank
- Tertiary and distribution structures
- Current limiting reactor sizing
- Grounding transformer
- Voltage drop calculation
- Best practices
- Industry practices
- References

AC Station Service

Highest bus voltage : 765 kV

↓

Utilization voltage : 120/240 V

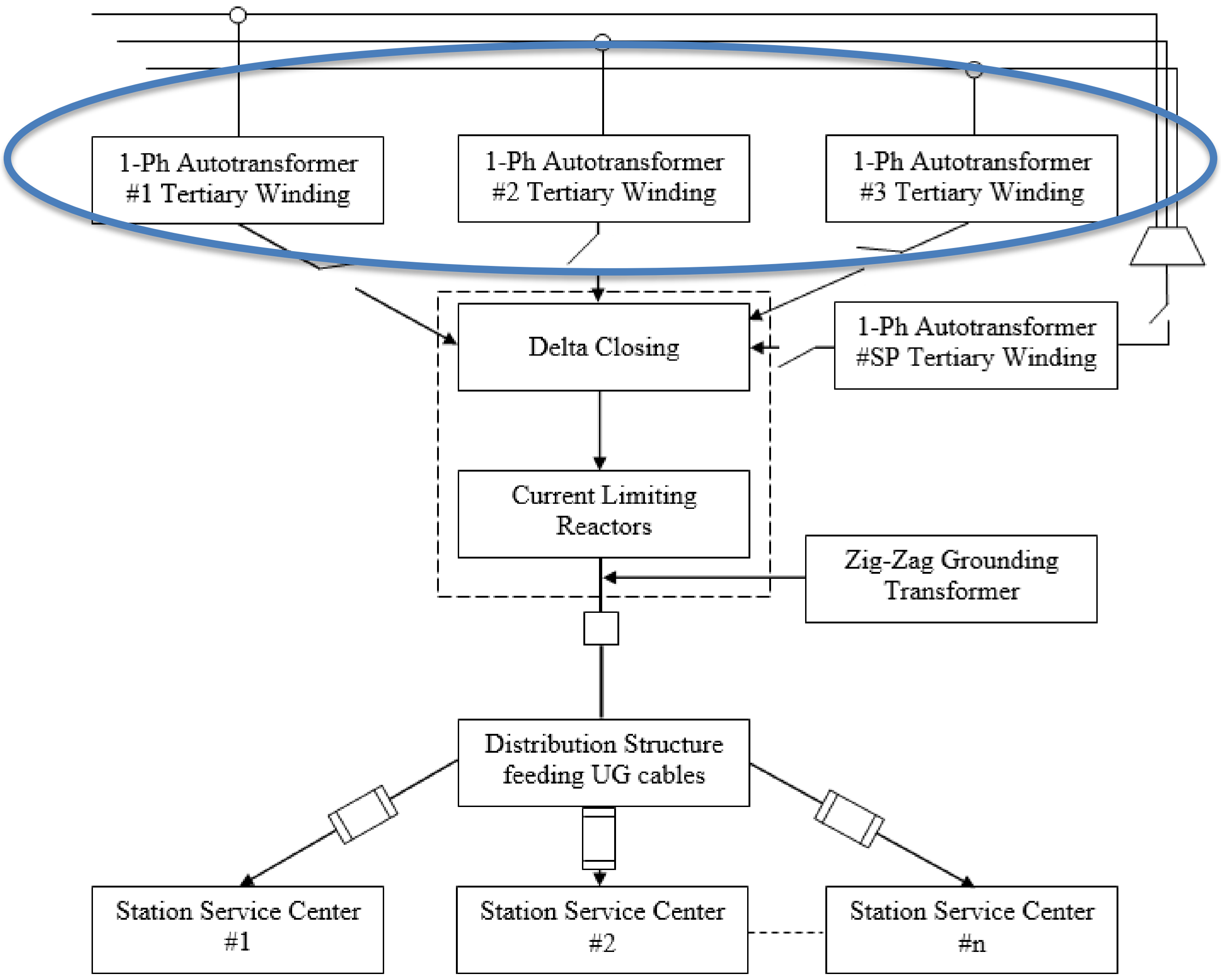
EHV yard, AEP

Challenges in EHV stations

- Need for redundancy (source and equipment)
- Excessive fault currents on tertiary
- Fault selectivity on ungrounded bus
- Increased voltage drops

EHV yard, AEP

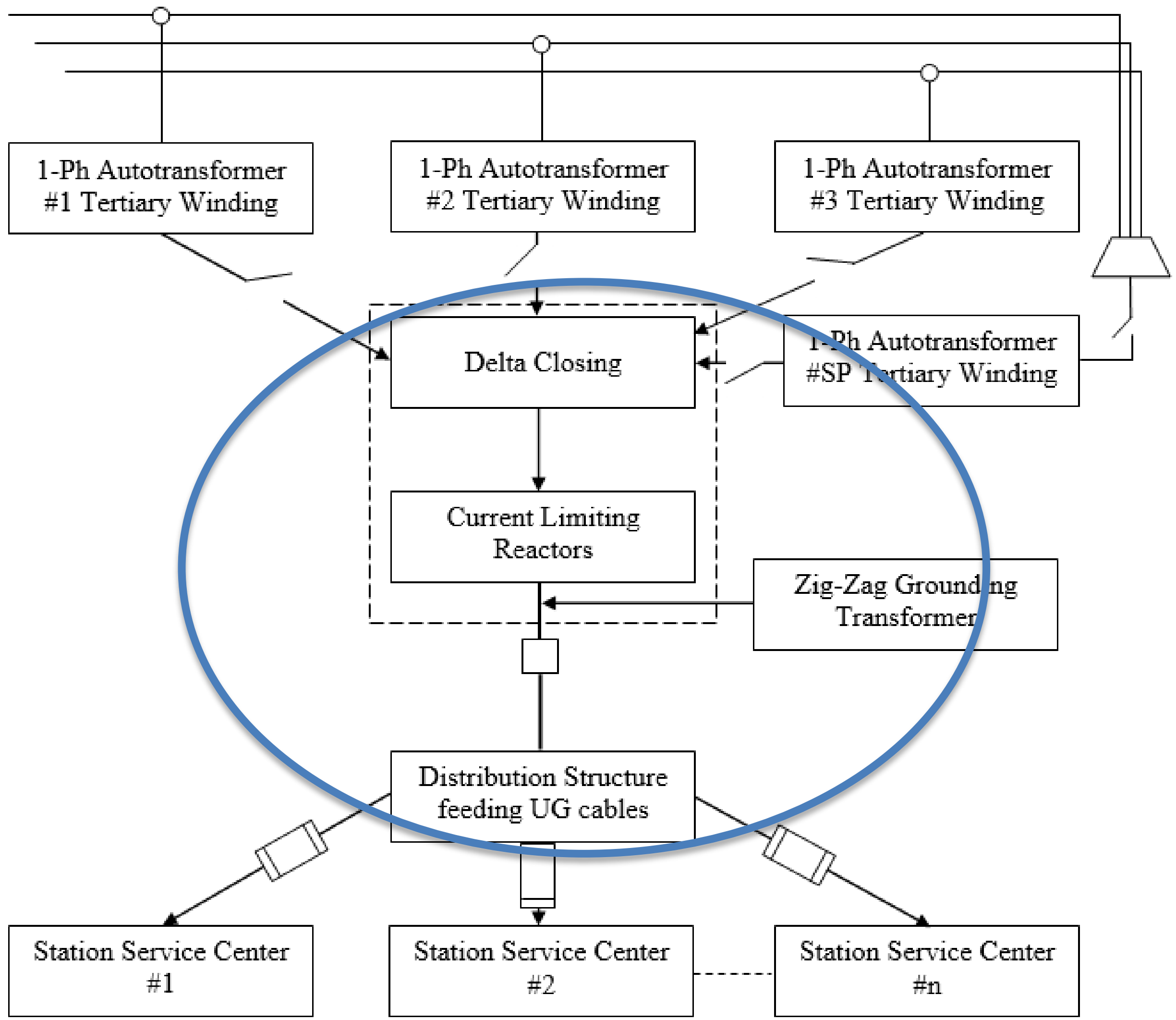
Block diagram



AEP TRANSMISSION
An AEP Company

EHV transformer bank

Block diagram



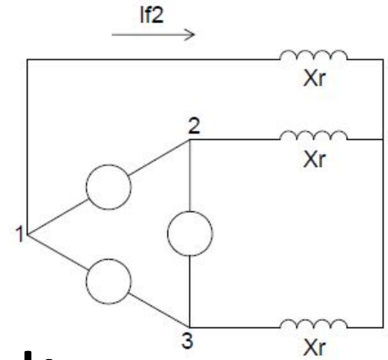
Reactors

- Why?
  - Limit the fault current magnitude on tertiary
    - Sometimes available fault current reaching ~85 kA
  - Enable use of commonly used distribution structure and equipment.

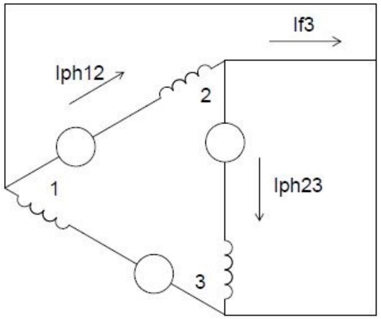
- Inside vs Outside the delta
  - L-L fault on the tertiary structure bus work

Reactor sizing

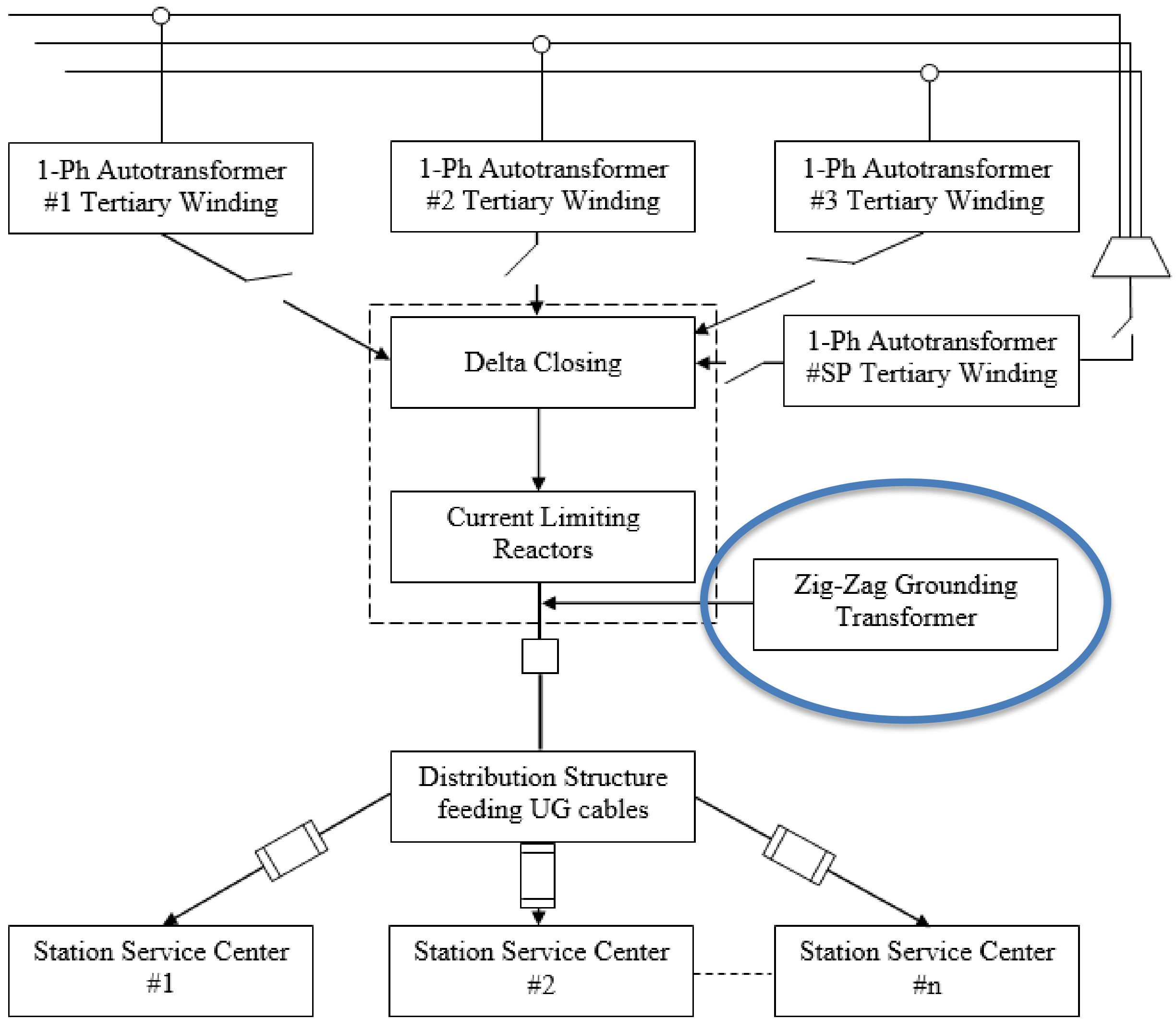
- Reactors outside delta
  - $X_r = V * [(1/I_{f2}) - (1/I_{f1})]$



- Reactors inside delta
  - $X_r = 3*V * [(1/I_{f2}) - (1/I_{f1})]$



Block diagram

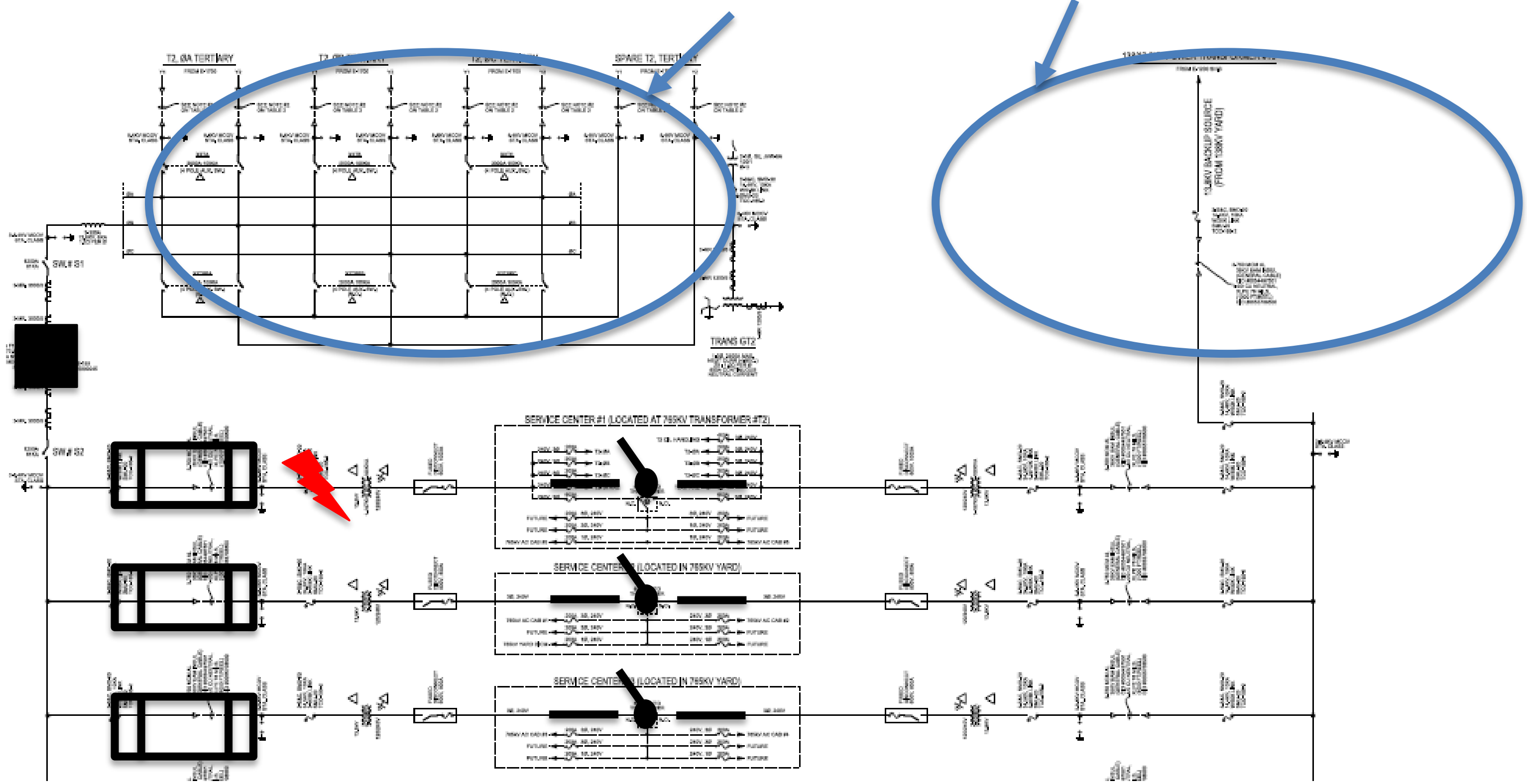


Grounding transformer

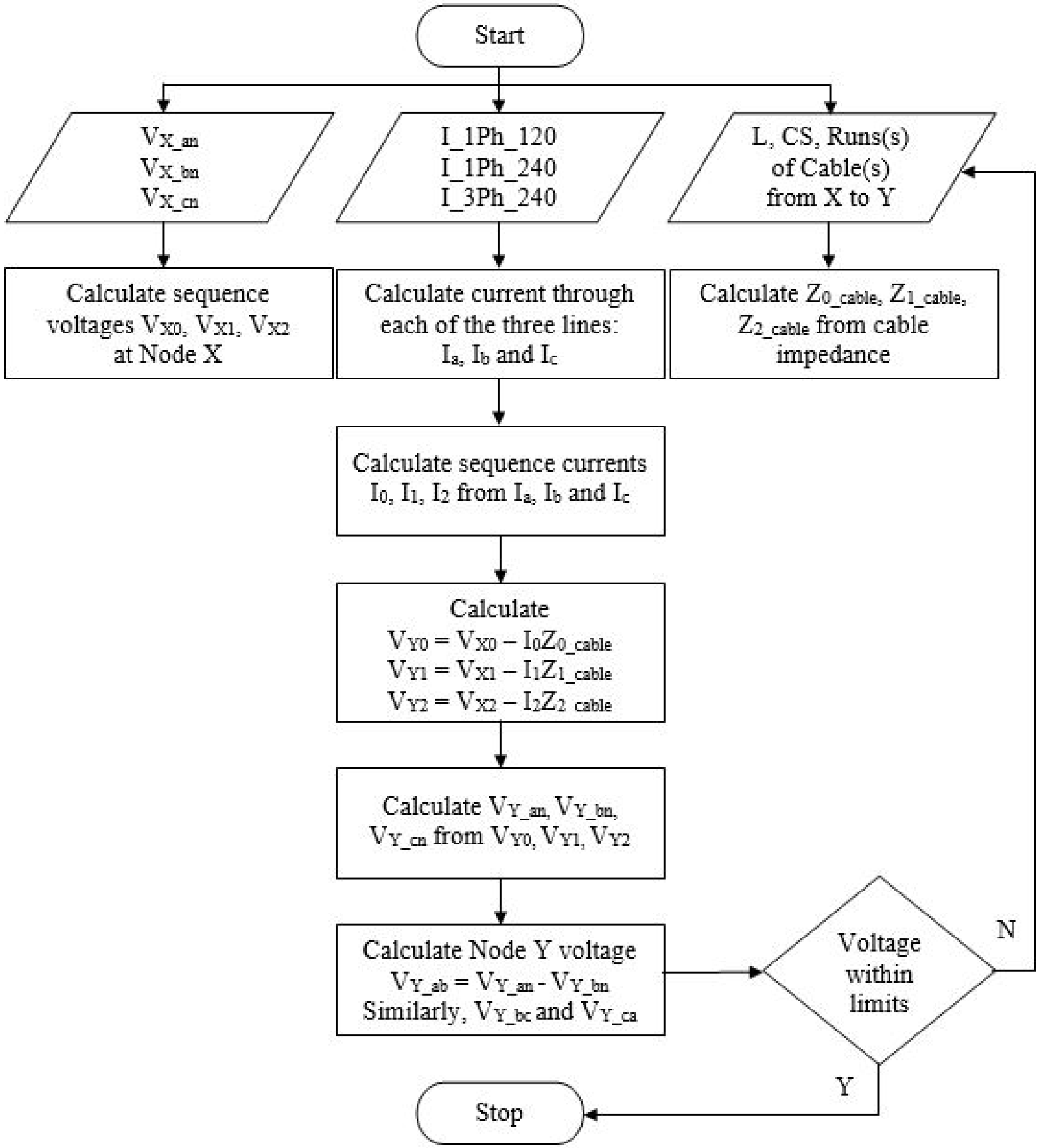
- Why?
  - Fault selectivity

Primary Source

Backup Source



Voltage drop calculations



Example for 100 ft 6 AWG

- 1-Ph 240V 60A: V_{load} = 234.12 V
  - 2 * I * Z
- 3-Ph 240V 60A: V_{load} = 234.91 V
  - Sqrt(3) * I * Z

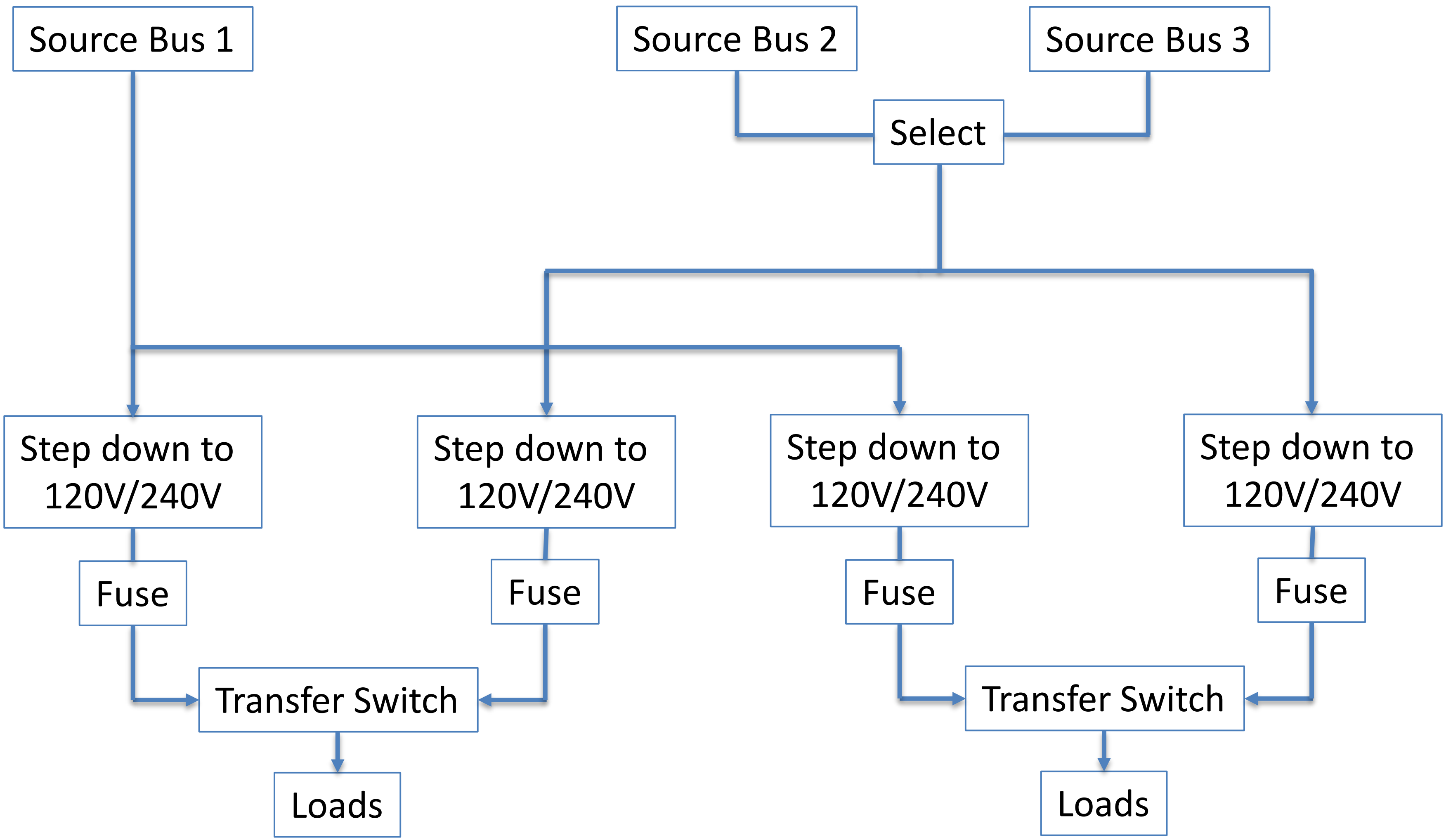
- 1-Ph 240V 35A + 3-Ph 240V 25A
  - ???
  - V_{load} = 234.45 V at UPF load
- Ability to include power factor as input ☺

Best practices

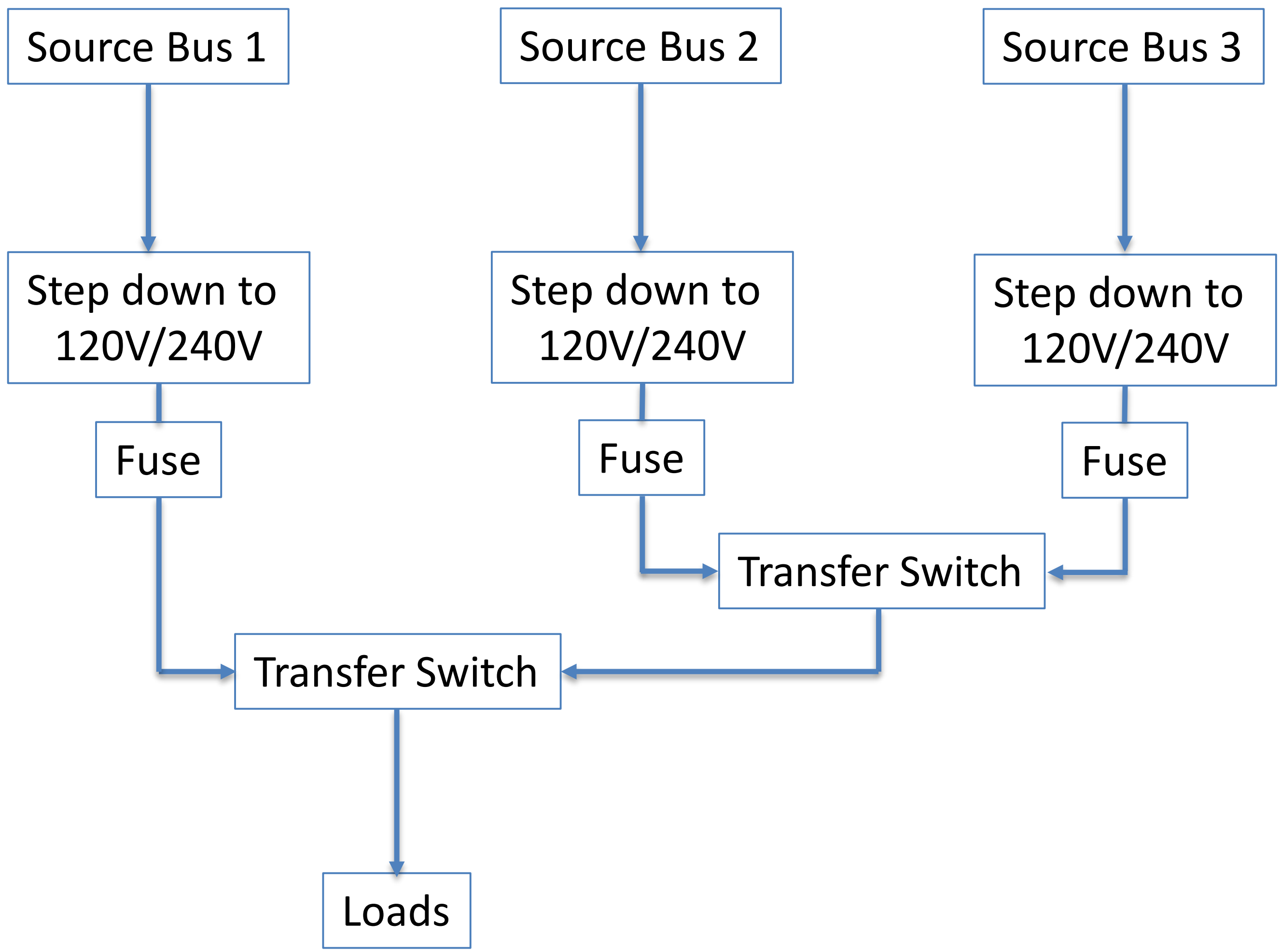
- Arc flash analysis
  - PPE requirements
  - Minimum working distance
- Single vs Three-phase station service
  - SSVT costs
- Animal mitigation
- Second backup source
- Vector diagrams

Animal mitigation

Second backup – Scheme 1

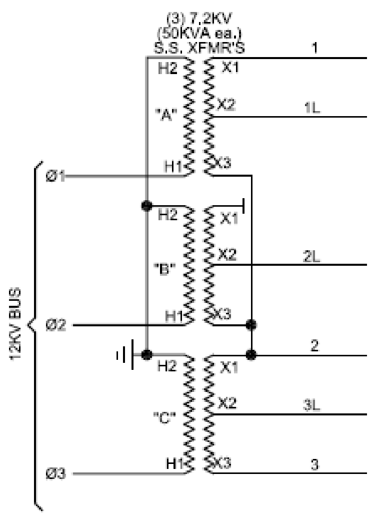


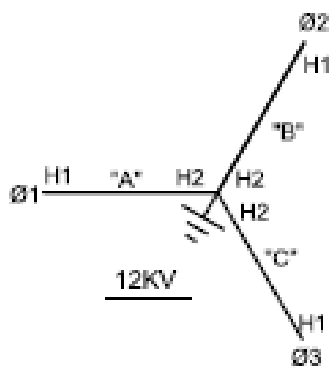
Second backup – Scheme 2

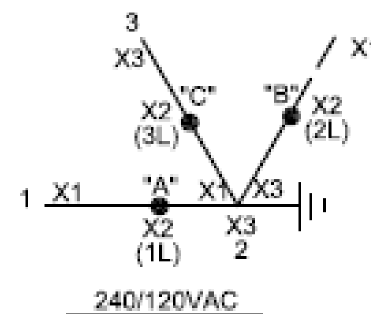


Importance of vector diagrams

- Example: Chicken-foot
- L-L voltages: 120V, 120V and 120*1.732V
  - ATS concludes the source to be heavily unbalanced. Proceed with a manual transfer or custom auto transfer switch.







AEP TRANSMISSION
An AEP Company

Industry practices

AC Station Service Designs in other Utilities for EHV Stations				
S. No.	Name of Utility	Primary Source for Station Service	Backup Source for Station Service	Second Backup for Station Service
1	Utility 1	Autotransformer Tertiary	Autotransformer Tertiary SSVT vs Local Distribution (cost based)	NA
2	Utility 2	Autotransformer Tertiary	Local Distribution	Generator
3	Utility 3	Autotransformer Tertiary	Local Distribution (SSVT if no availability of Local Distribution)	NA
4	Utility 4	Local Distribution	Autotransformer Tertiary	NA
5	Utility 5	Distribution Bus in Station	Distribution Line	Generator

Questions ?

References

- [1] Belknap et al., CIGRE US National Committee 2015 Grid of the Future Symposium, “Increased Reliability of EHV Systems through Station Switchable Spare Transformer and Shunt Reactor Design and Operation”

- [2] Xuan Wu et al., CIGRE US National Committee 2017 Grid of the Future Symposium, “Arc Flash Study Principles & Procedures for below 15 kV AC Systems”