Improving BES Reliability at Large Generating Station Locations

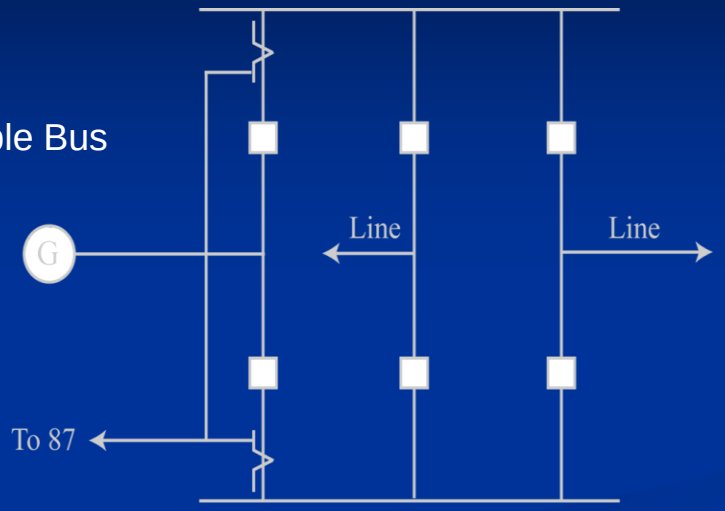
By Thomas E. Baker

Three Areas of Concern at Large Generating Stations

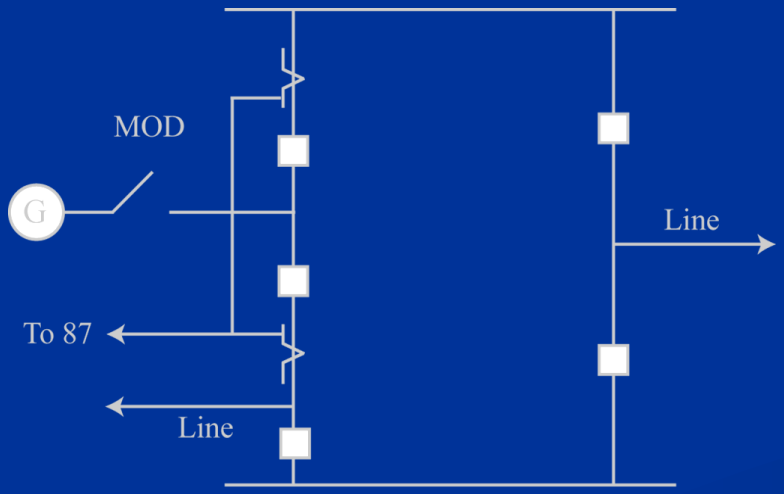
- High voltage switchyard instability
- Many high voltage switchyard schemes not backed-up
- Many important protection functions not applied

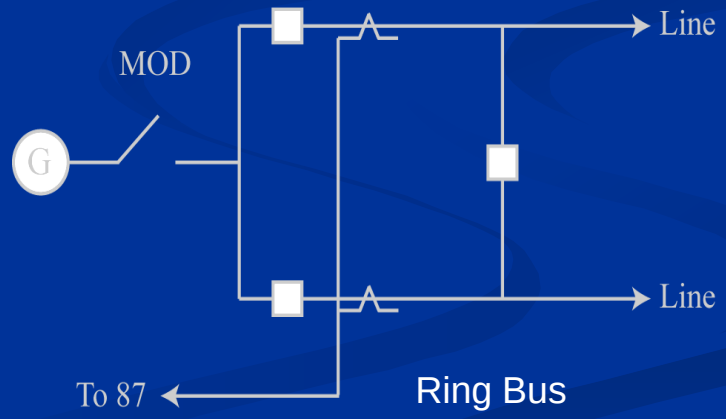
Switchyard Configurations

Double Breaker Double Bus



Breaker & One Half





Ring Bus

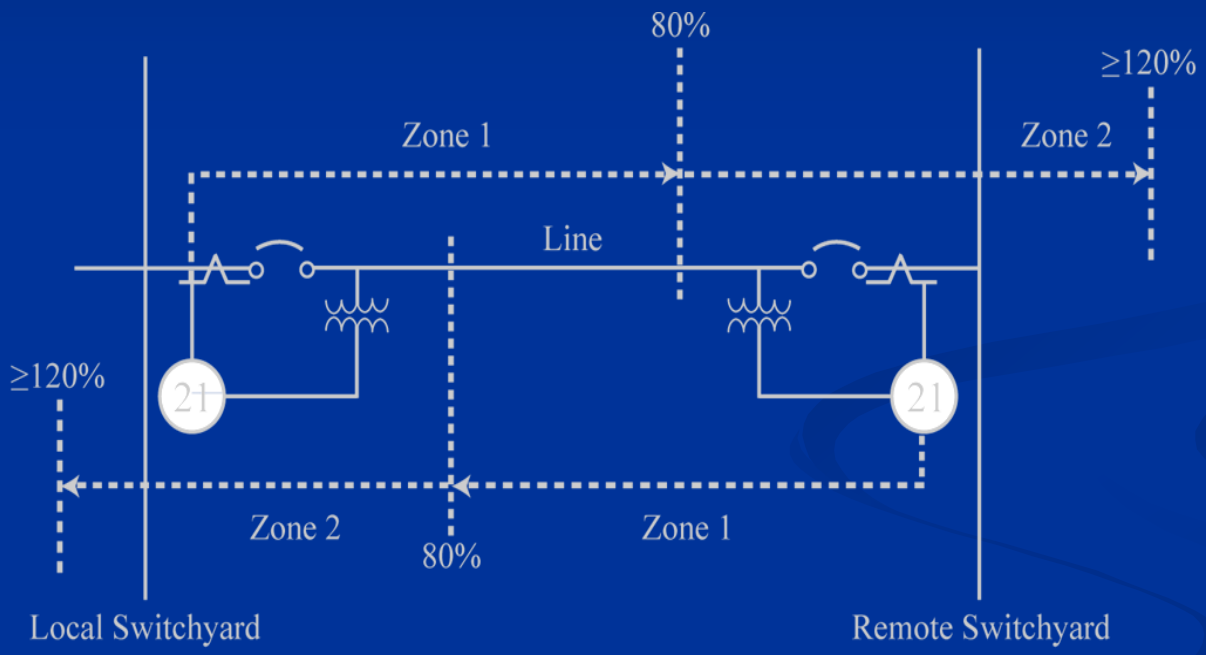
Lack of High Voltage Switchyard Backup protection

- Bus differentials are often not backed up
- Unit, transformer, and feeder differentials are often not backed up
- Breaker failure time delays often exceed critical clearing time

Critical Clearing Times

- Close in 3-phase fault – similar to full load rejection
- Typical clearing times for close in three phase fault:
  - Combustion turbine – as little as 6 cycles
  - 2 pole large coal unit – around 10 cycles
  - 4 pole large nuclear unit – around 12 cycles
  - Ground faults – three times longer
  - Phase-phase & double line to ground cycles less than ground

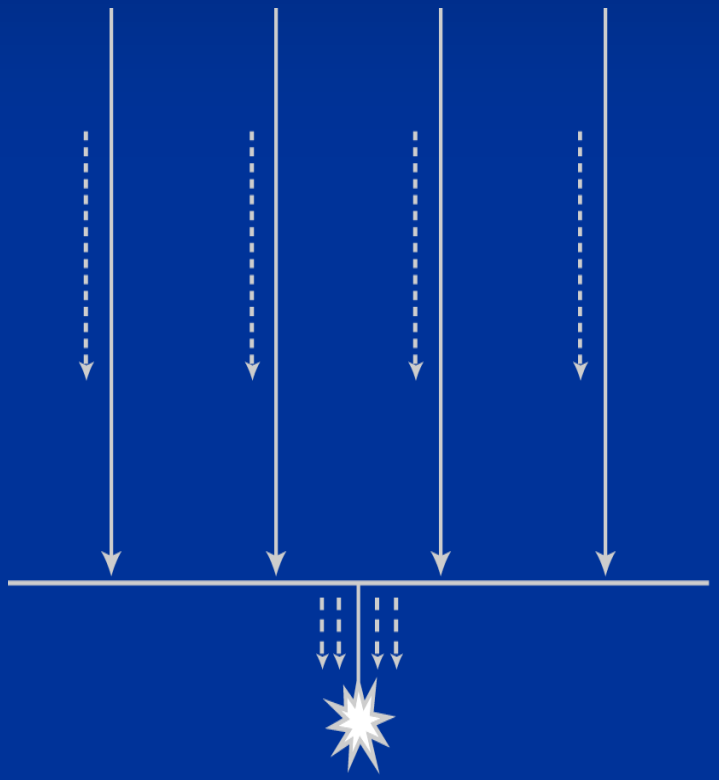
Line protection is normally backed-up



Single Relay Scheme Backup Clearing

- Zone 2 line relays normally set for 24 cycles.
- Transformer bank high side overcurrent usually have more than 1.0 seconds of time delay.
- Breaker failure time delays may be longer than the critical clearing times.
- Generator negative phase sequence and backup impedance have long time delays that may not prevent instability.
- Remote zone 2 and directional ground overcurrent protection may not have the sensitivity to detect the fault depending on the number of lines and sources.

Current Distribution & Infeed Ohms



Infeed Ohms

Pu Z_A .5

Pu Z_B .5

A

B

Base Amps 5000

Pu Z_C .5

$$Z_T = \frac{(Z_A \times Z_B)}{(Z_A + Z_B)} + Z_C \qquad I_T = \frac{Base\ I}{Z_T}$$

$$Amps\ from\ A(I_A) = \frac{Z_B}{(Z_A + Z_B)} \times I_T \quad 3333.333$$

$$Ohms\ from\ A = Z_A + \left(Z_C \times \frac{I_T}{I_A}\right) \quad 1.5$$

Notes:

Useful for setting impedance relays functions involved with multiple sources.

Proposed Switchyard Zone 1 Impedance Schemes

For GSU Differential:

- Looks from the switchyard to the unit.
- Provides backup for the unit differential protection.
- If the unit differential fails to clear faults properly, there may be a collapse of the electrical system or islanding.
- Should not be able to see unit auxiliary transformer low side faults and generator under excitation events.

For RAT Transformer Differential:

- Looks from the switchyard to the RAT
- Provides backup for the differential protection.
- If the RAT transformer differential fails to clear faults properly, there may be a collapse of the electrical system or islanding.
- Should not be able to see RAT transformer low side faults.

For Bus Differentials:

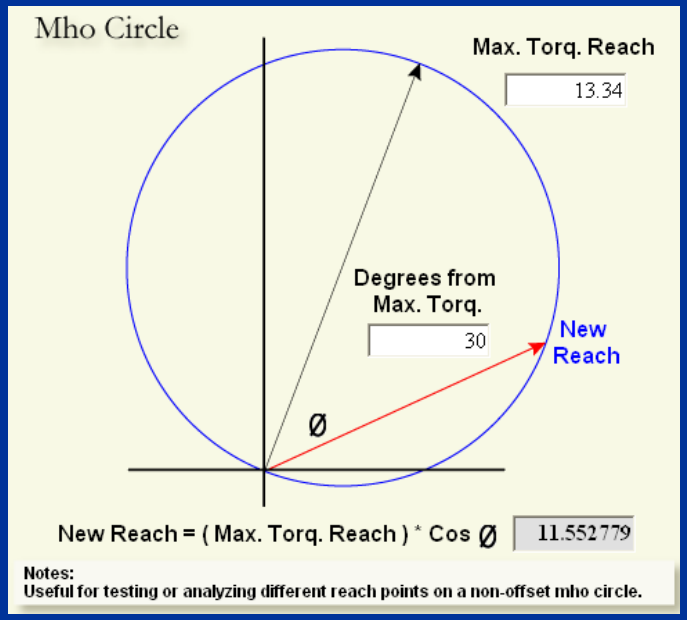
- Use line CTs to feed digital current differential
- Does not overlap, but line protection includes breaker and is backed up

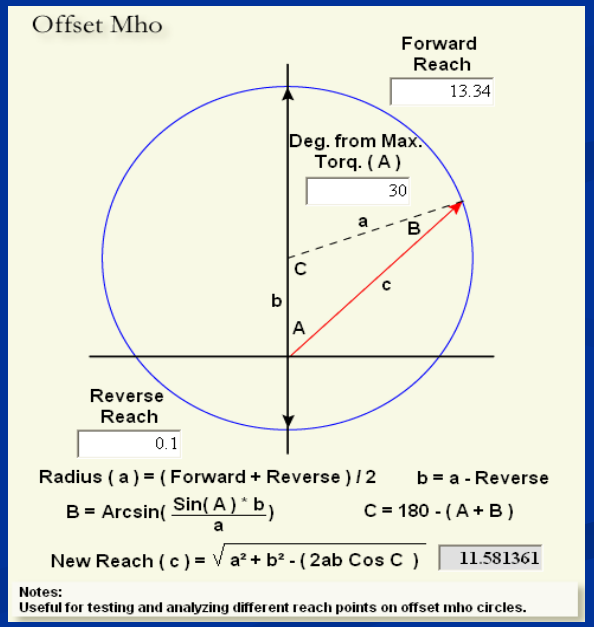
For Breaker Failure Schemes:

- Usually enough margin to reduce time delays

Generator Backup Impedance
No Industry Consensus

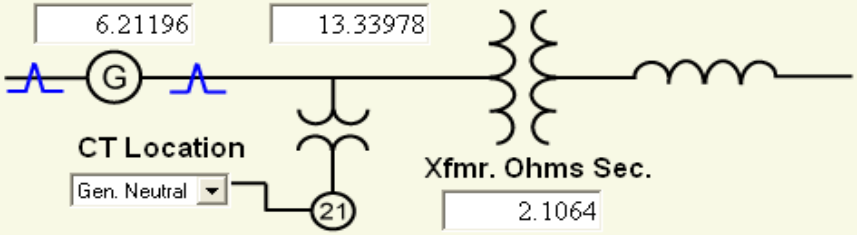
- Thermally protects generators from 3-phase transmission system faults and disturbances that do not clear properly.
- Provides backup for generator and transformer 3-phase short circuits.





(21) Backup Impedance

X_d' Ohms Sec.	.67 pu Ohms Sec.
6.21196	13.33978



Zone 1 Forward = 0.5 * Xfmr. Ohms Sec.	1.053200
Zone 1 Offset = 0.1 Ohms (neutral CT) / X_d' Ohms Sec. (output CT)	0.1
Zone 1 Angle	75
Zone 1 Time Delay Seconds	0.1
Zone 2 Forward = 0.67 per unit	13.339780
Zone 2 Offset = 0.1 Ohms (neutral CT) / X_d' Ohms Sec. (output CT)	0.1
Zone 2 Angle	75
Zone 2 Time Delay Seconds	2.0

Notes:
All ohms are generator base secondary.
Z1 Forward reaches halfway into transformer.
Z1 Time ensures differential targets.
Z2 Forward = 150% rated MVA = .67 pu.
Z2 Time ensures downstream coordination and thermal protection.
Z2 is a 3-Phase setting (Xfmr. comp. not necessary) and relies on (46) function to protect the machine from prolonged unbalanced faults.

Important Functions Often Not Applied

- Out-Step
- Inadvertent Energization
- Pole Flashover
- Slow-Breaker Closing During Synchronizing