Distribution Single-Phase Tripping and Reclosing: Overcoming Obstacles With Programmable Recloser Controls

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Alabama Power Focus on Improved Customer Service

- Strengthen customer relationship by improving service
- Improve reliability indices
- Take advantage of available technology to improve operation

Indices Measure Performance

- SAIDI
- SAIFI
- MAIFI

Reliability Indices – SAIDI

SAIDI: Minutes per year an average customer does not have electric power

$$\text{SAIDI} = \frac{\text{Total Customer Interruption Duration}}{\text{Total No. of Customers Served}}$$

Reliability Indices – SAIFI

SAIFI: Number of interruptions per year experienced by an average customer

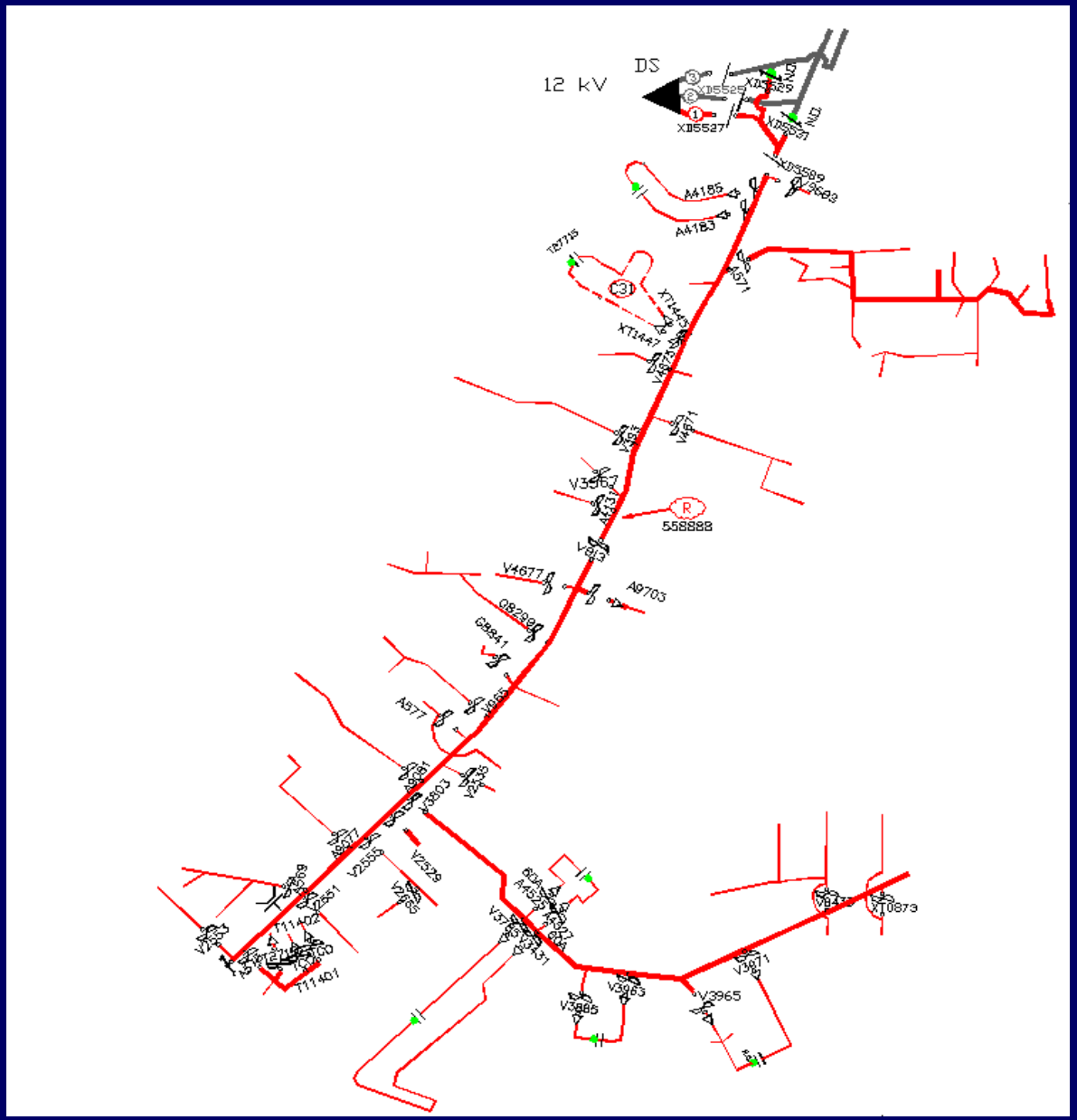
$$\text{SAIFI} = \frac{\text{Total Number of Customer Interruptions}}{\text{Total No. of Customers Served}}$$

Reliability Indices – MAIFI

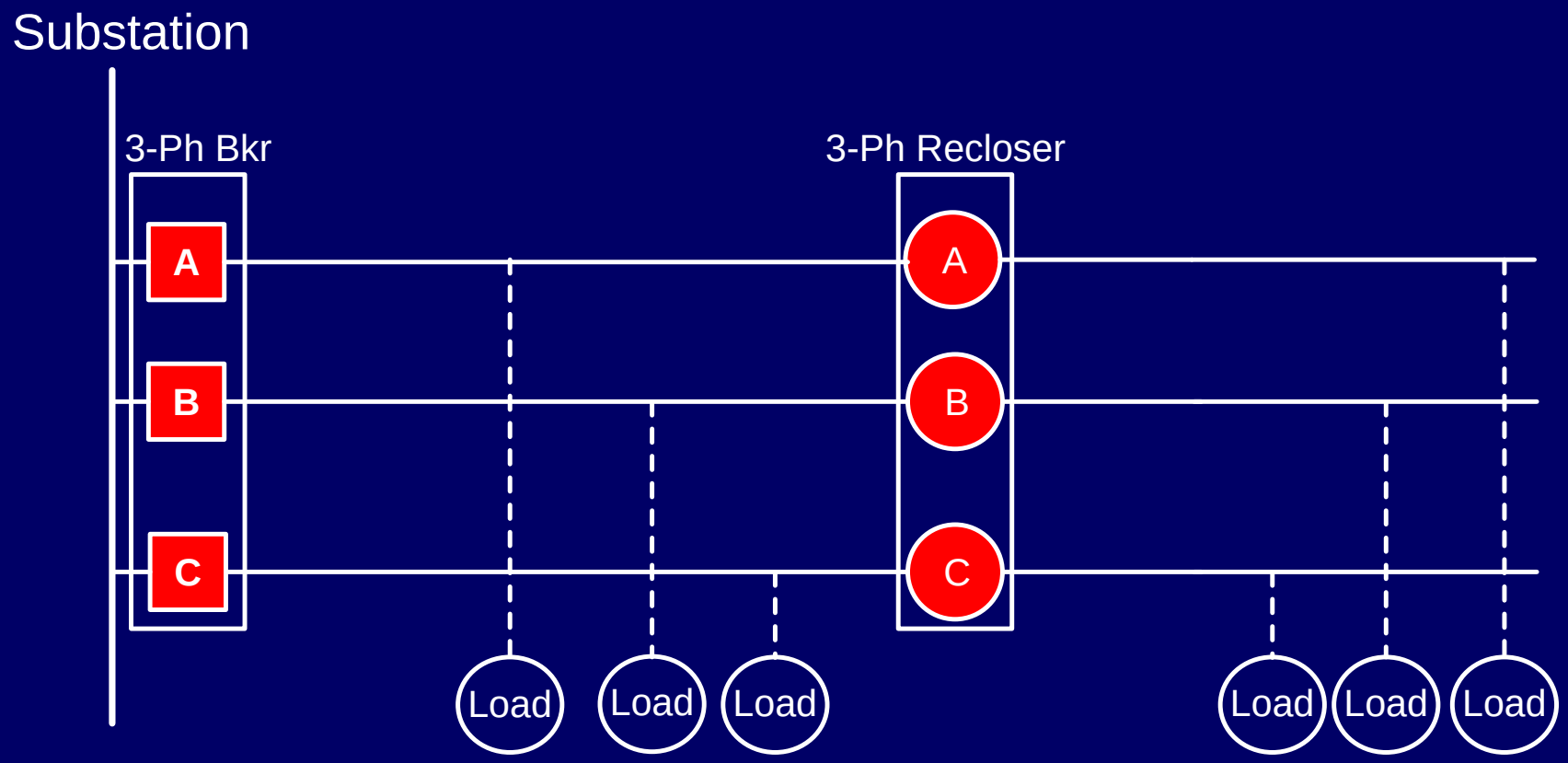
MAIFI: Number of momentary interruptions per year experienced by an average customer

$$\text{MAIFI} = \frac{\text{Total Customer Momentary Interruptions}}{\text{Total No. of Customers Served}}$$

Alabama Power Typical Feeder

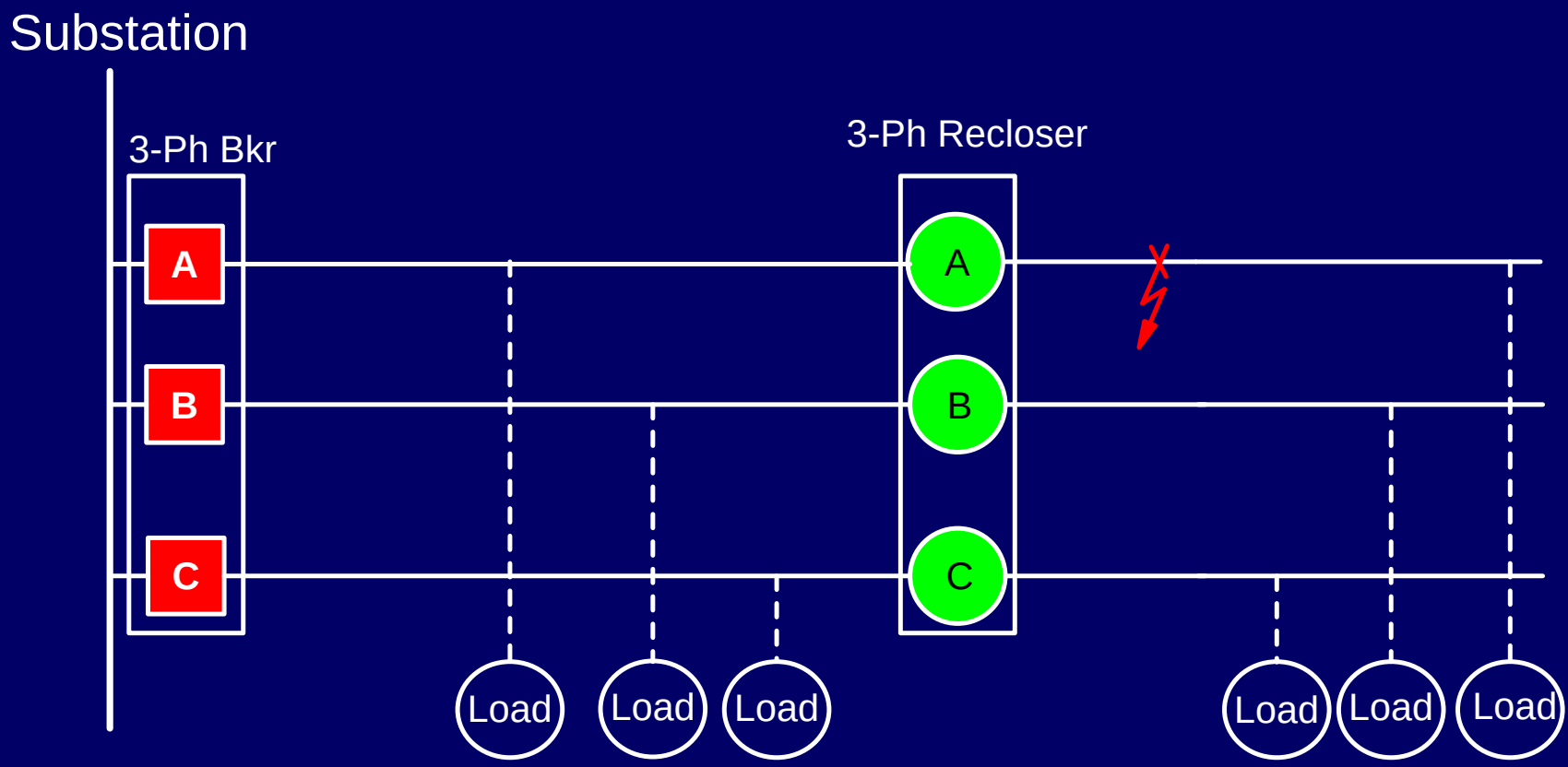


Simplified Typical Circuit



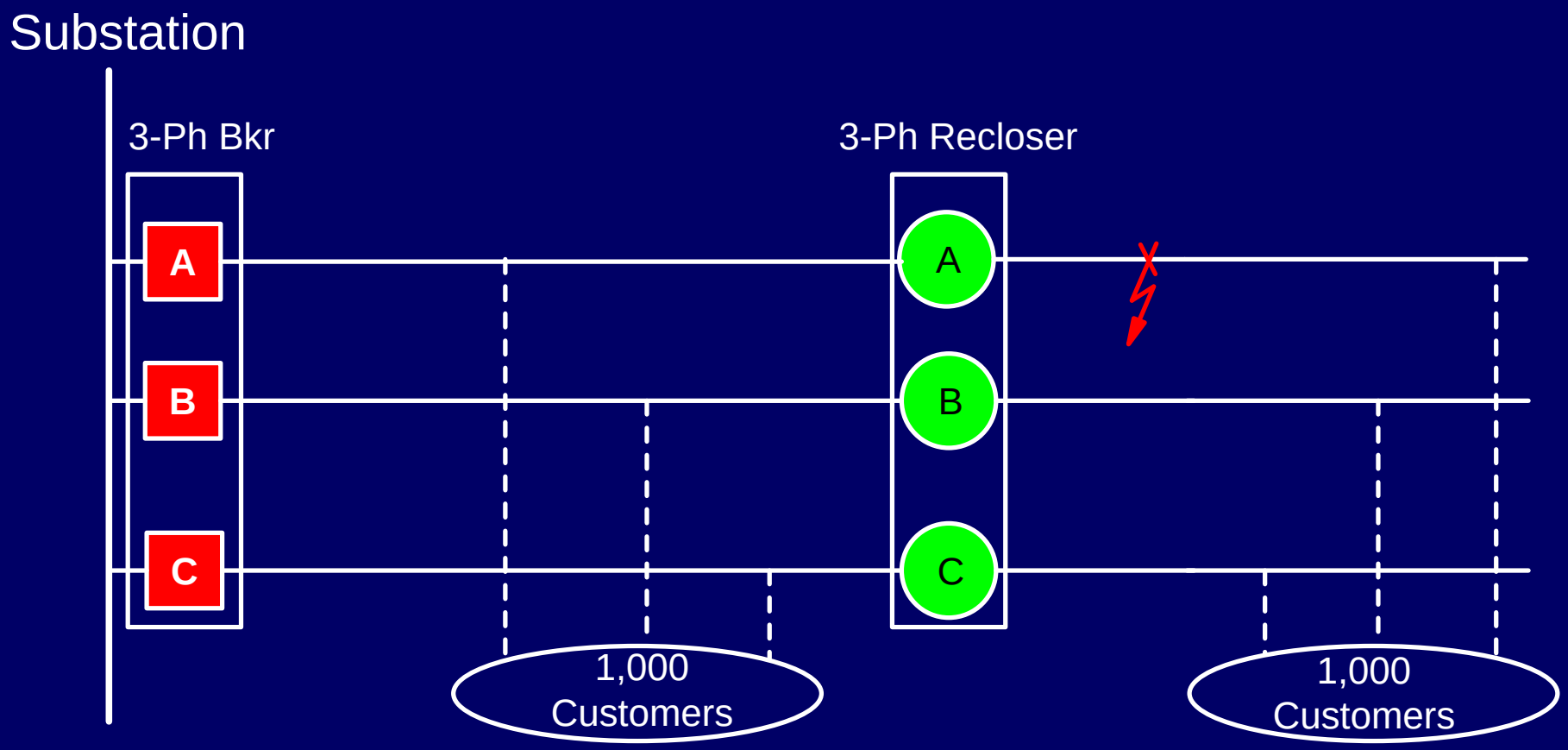
Operation of Three-Pole Tripping Devices

All Phases Trip for Any Type Fault



Feeder SAIDI Contribution

Customer Distribution



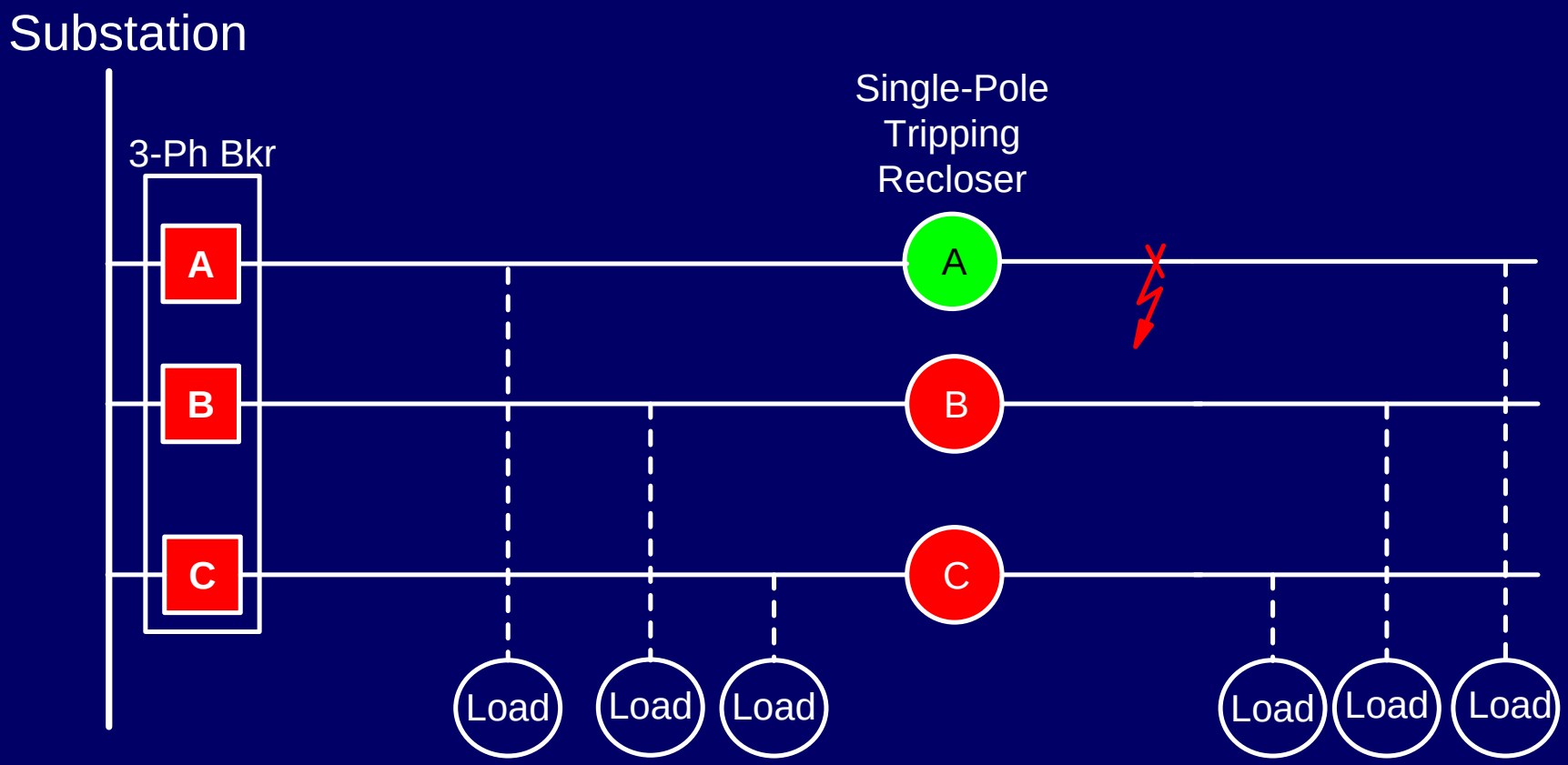
Feeder SAIDI Contribution

Example Calculations

- Assume 1000 customers affected
- Assume 1 hour outage

$$\text{SAIDI Contribution} = \frac{(1000 * 1)\ \text{Cust Hours}}{\text{Total Customers}}$$

Operation of Single-Pole Tripping Device



Feeder SAIDI Contribution

Single-Pole Trip Example Calculations

- Assume 1000 customers affected distributed evenly over phases
- Assume 1 hour outage

$$\text{SAIDI contribution} = \frac{(1000 \bullet 1 \bullet 0.333)\ \text{Cust Hours}}{\text{Total Customers}}$$

Feeder SAIDI Contribution

Single-Pole Trip Improvement

$$\text{SAIDI 3PT contribution} = \frac{1000 \text{ Cust Hours}}{\text{Total Customers}}$$

$$\text{SAIDI SPT contribution} = \frac{333 \text{ Cust Hours}}{\text{Total Customers}}$$

$$\text{Improvement} = \frac{1000 - 333}{1000} = 66.7\ \%$$

Reliability Index Improvements

- 66.7% improvement for single-line-to-ground faults
- 33.3% improvement for two-phase faults
- Improvements for both temporary and permanent faults

Alabama Power Fault Type Distribution Estimate

- 60% involve single-phase only
- 25% involve two phases
- 15% require three-pole tripping to clear

Conservative Estimates

Alabama Power Anticipated Reliability Improvement

66% improvement for 60% of faults

33% improvement for 25% of faults

0% improvement for 15% of faults

$0.66 \bullet 0.60 + 0.33 \bullet 0.25 = 48\%$ improvement

Conservative Estimates

Single-Pole Tripping Concerns

- Tripping / reclosing modes
- Ground-fault sensitivity
- Load unbalance following trip
- Coordination with adjacent devices
- Reclosing difficulties

Tripping / Reclosing Modes

Single-Pole Trip / Single-Pole Lockout (SPTSPLO) – independent tripping, reclosing, and lockout

- Lowest impact to reliability indices
- Results in load unbalance for single- or two-phase event

Tripping / Reclosing Modes

Single-Pole Trip / Three-Pole Lockout (SPT3PLO) – independent tripping, reclosing but three-phase lockout for any permanent fault

- Low impact to MAIFI
- Results in short-term load unbalance for single- or two-phase temporary faults

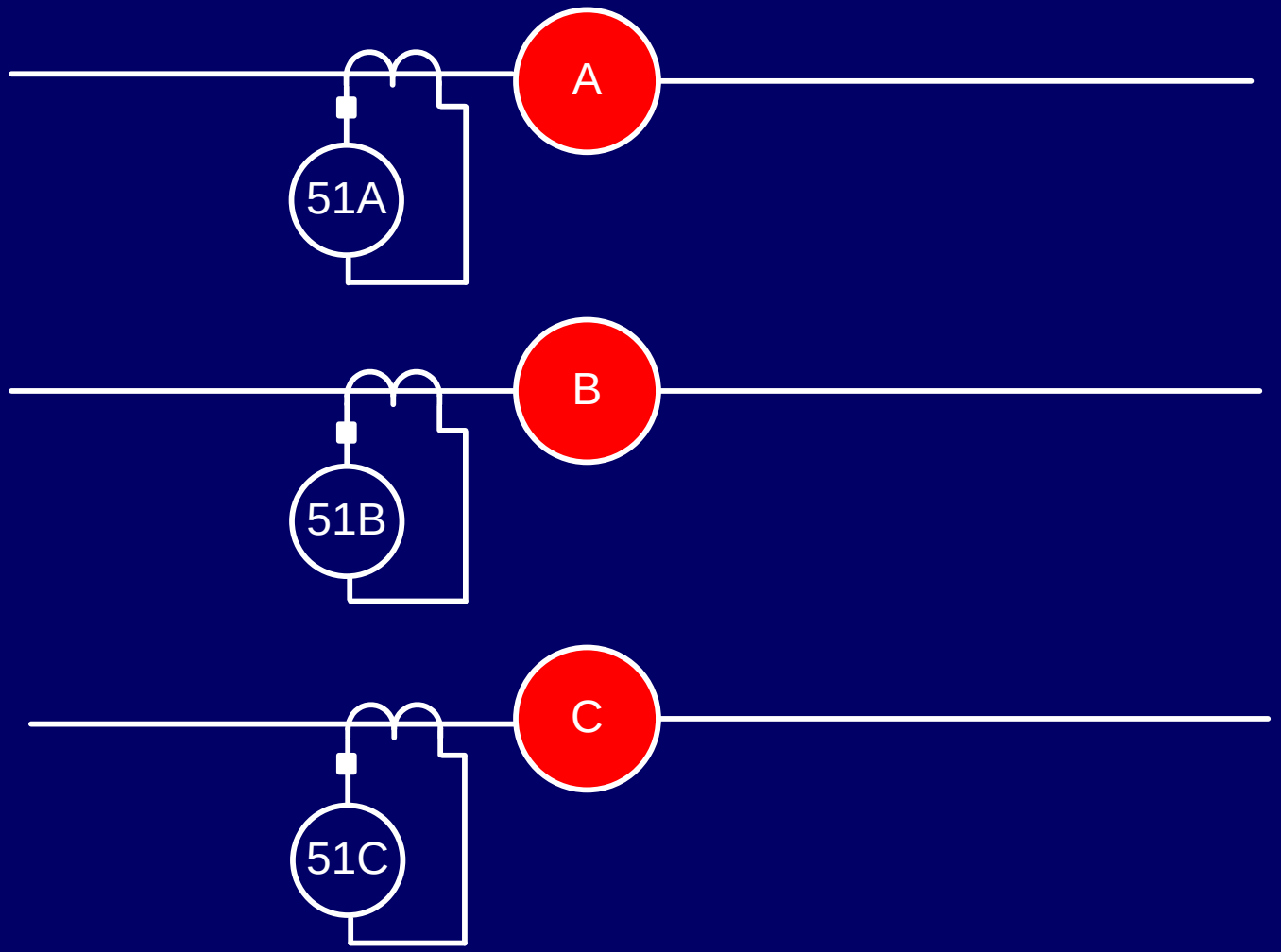
Tripping / Reclosing Modes

Three-Pole Trip / Three-Pole Lockout (3PT3PLO) – three-pole tripping, reclosing, and lockout for any fault

- Traditional operation
- No unbalance following faults

Ground-Fault Sensitivity

Traditional Single-Pole Tripping



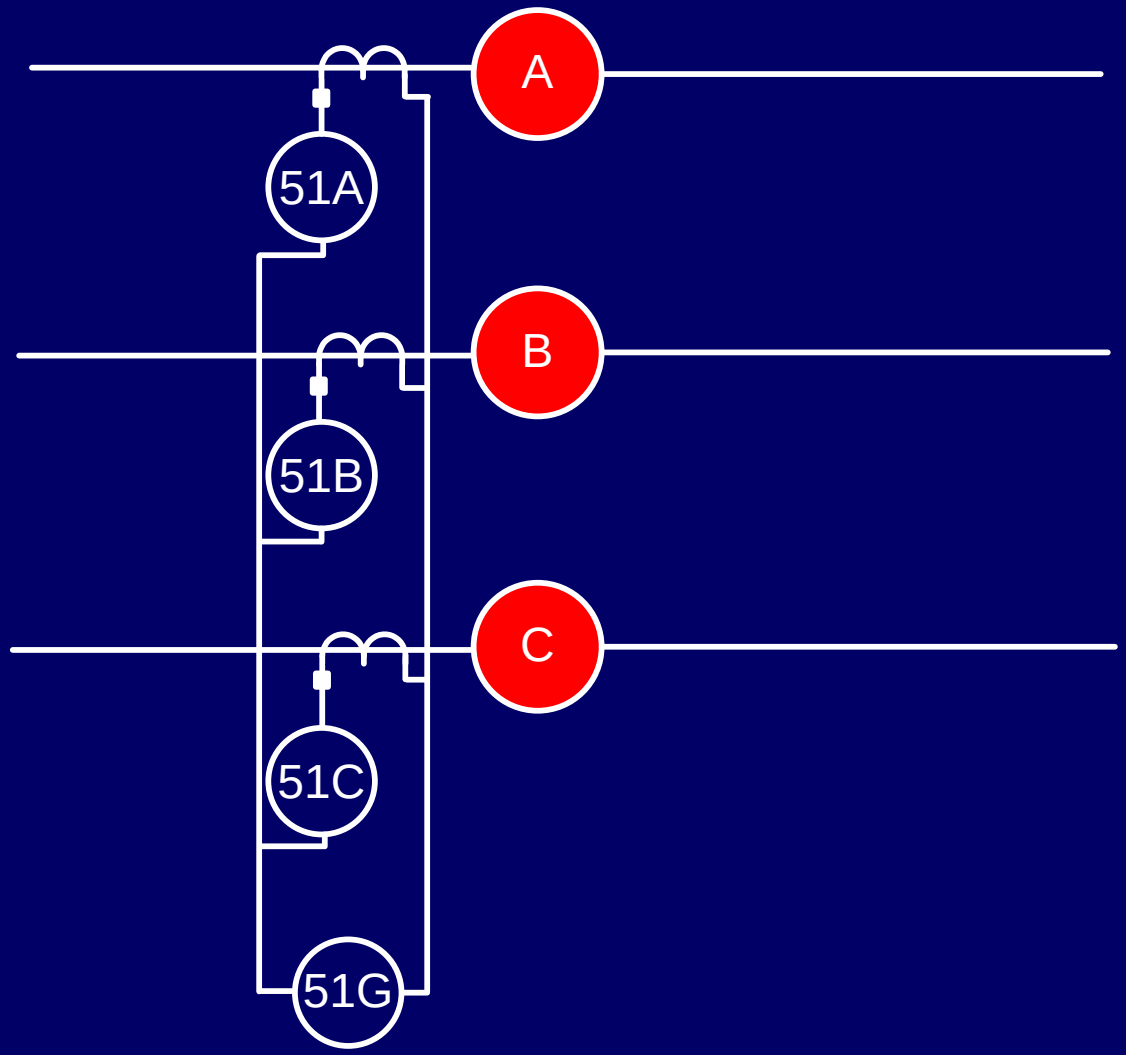
Ground-Fault Sensitivity

Traditional Single-Pole Tripping

- All fault types cleared by phase elements
- Ground-fault sensitivity limited by load carrying requirements
- Ground-fault magnitude may dictate placement of the device

Ground-Fault Sensitivity

Common Control Offers Improvement



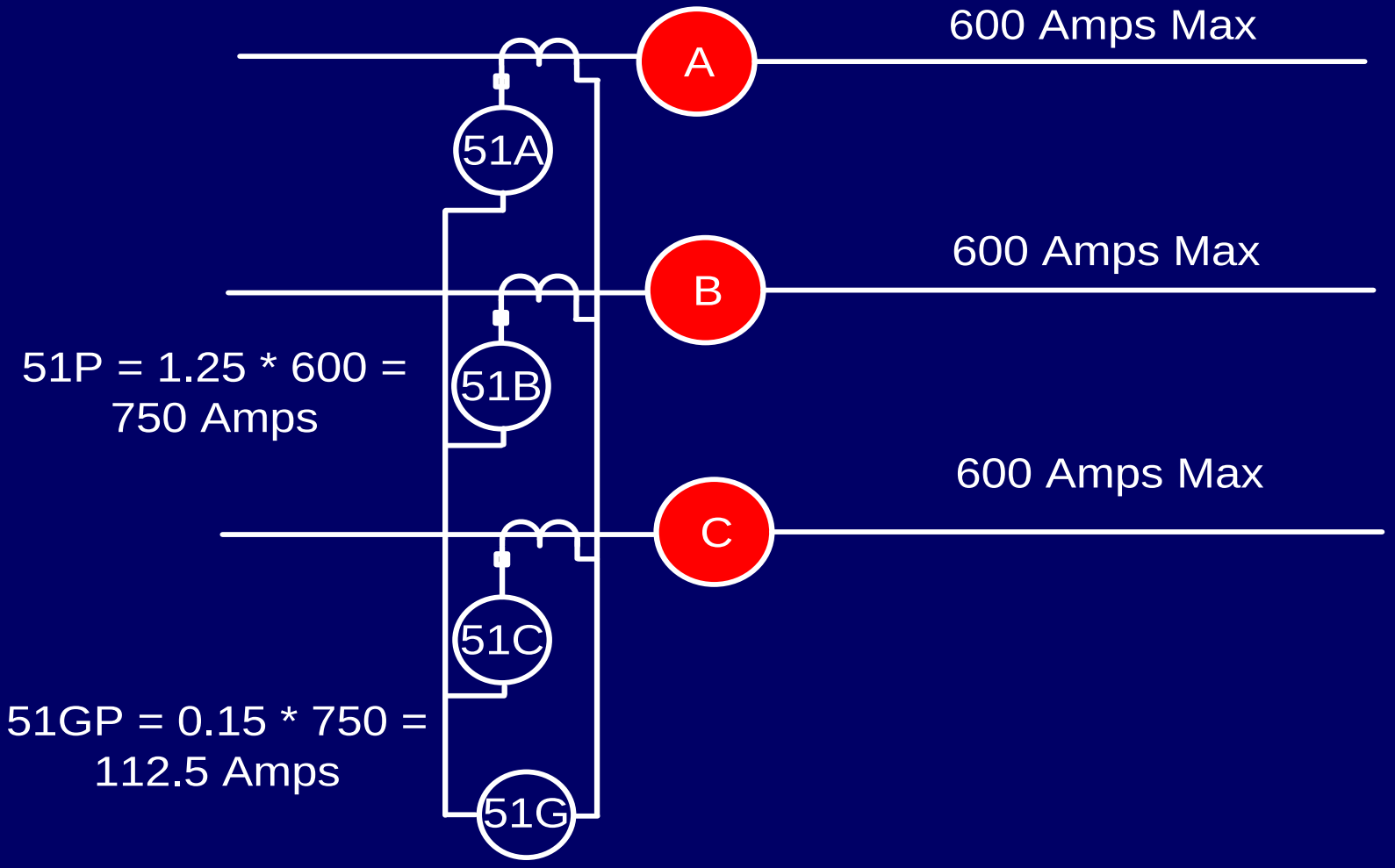
Ground-Fault Sensitivity

Common Control Offers Improvement

- Phase CTs summed to provide residual (3I0) current
- Ground-overcurrent element immune to balanced load
- Ground-overcurrent element offers sensitivity for low-magnitude ground faults

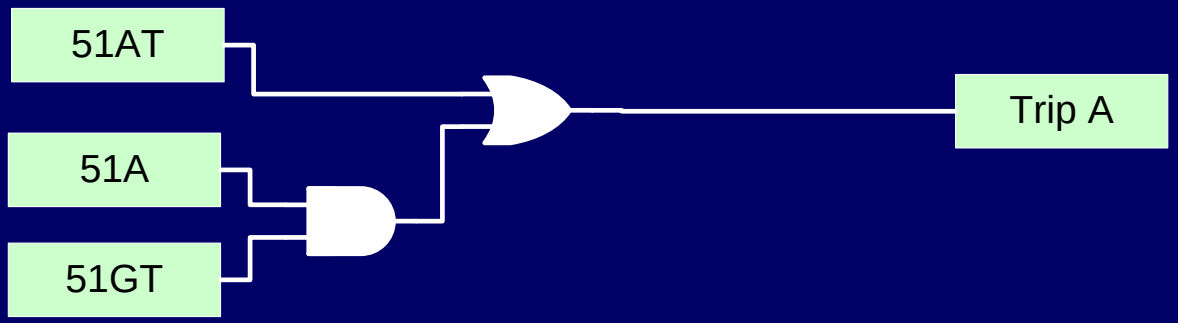
Ground-Fault Sensitivity

Common Control Offers Improvement

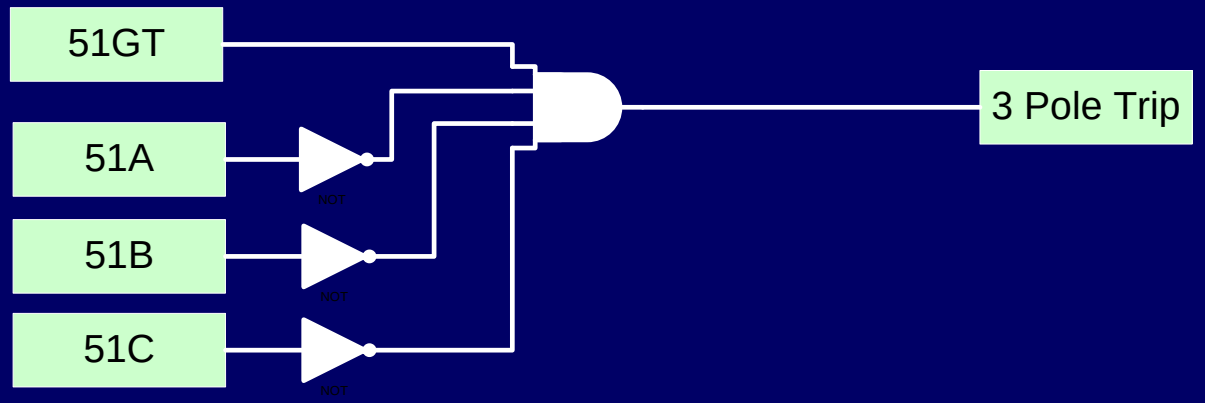


Ground-Fault Sensitivity

Sensitive Fault Tripping

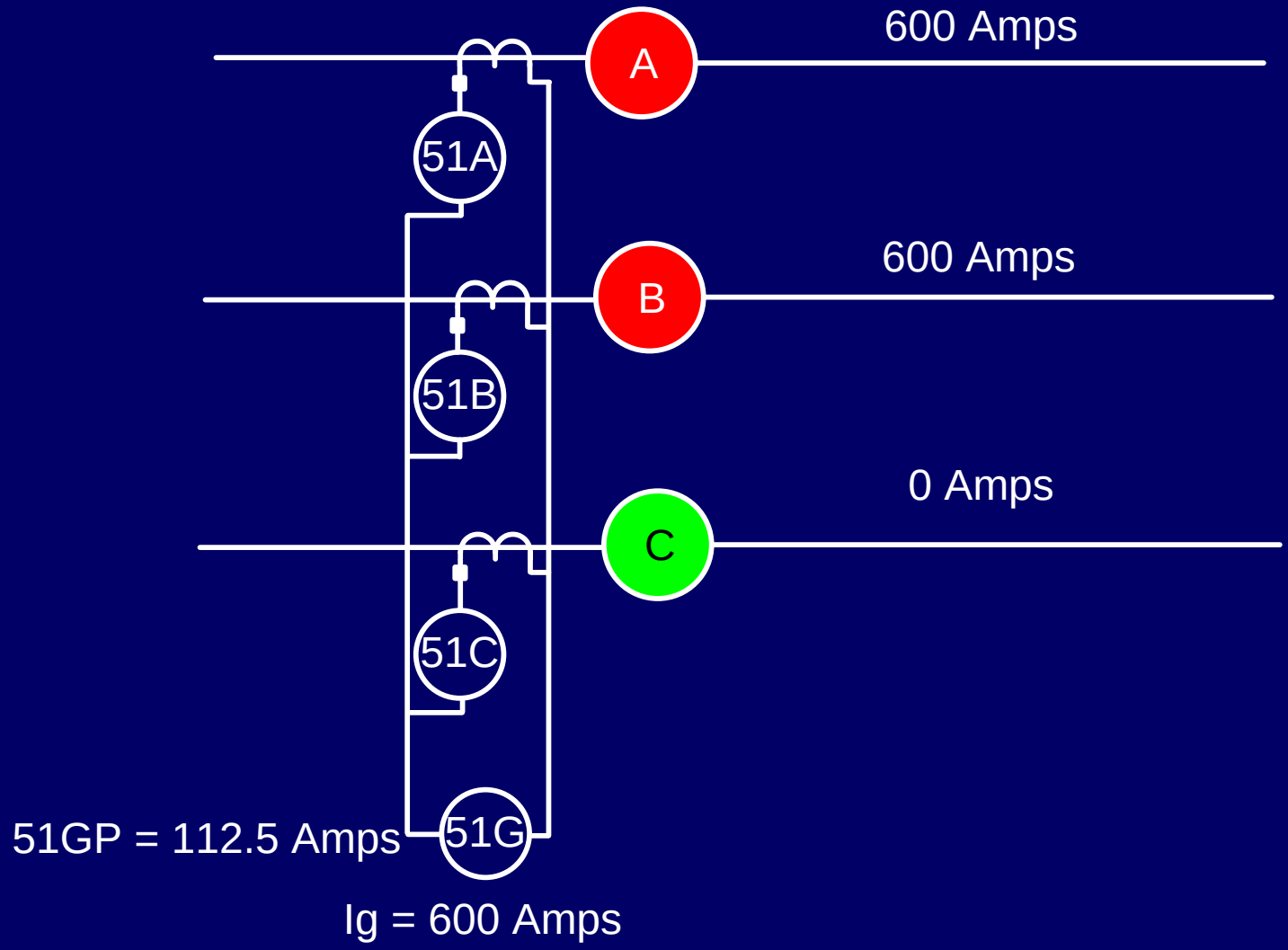


Similar Logic for B & C Phases



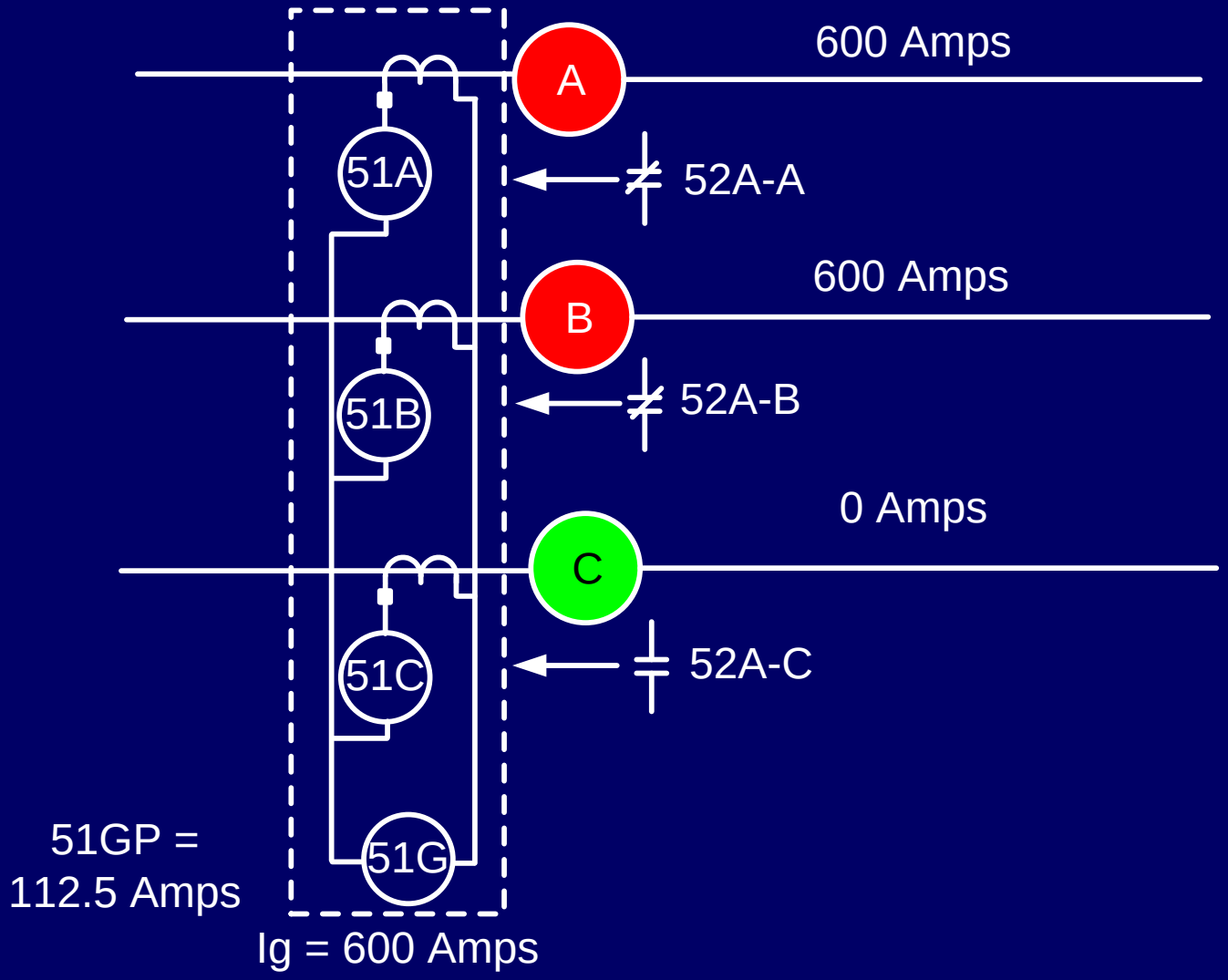
Load Unbalance Following Trip

Effect on Ground Element



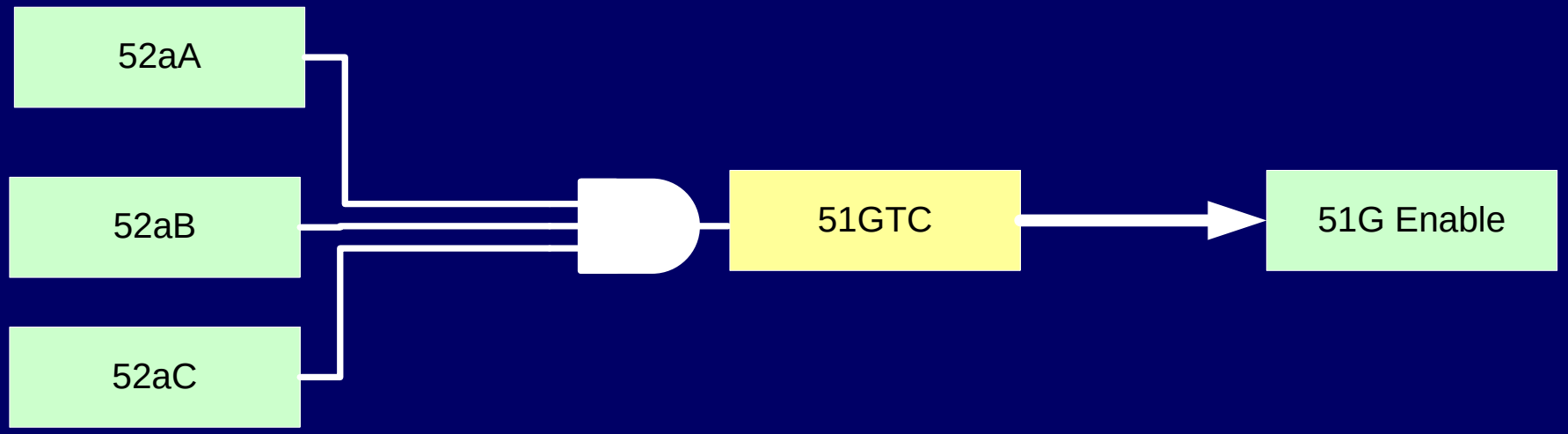
Load Unbalance Following Trip

Common Control Adapts to Unbalance



Load Unbalance Following Trip

Ground Enable Logic



Ground Disabled for Pole-Open Condition

Load Unbalance Solution

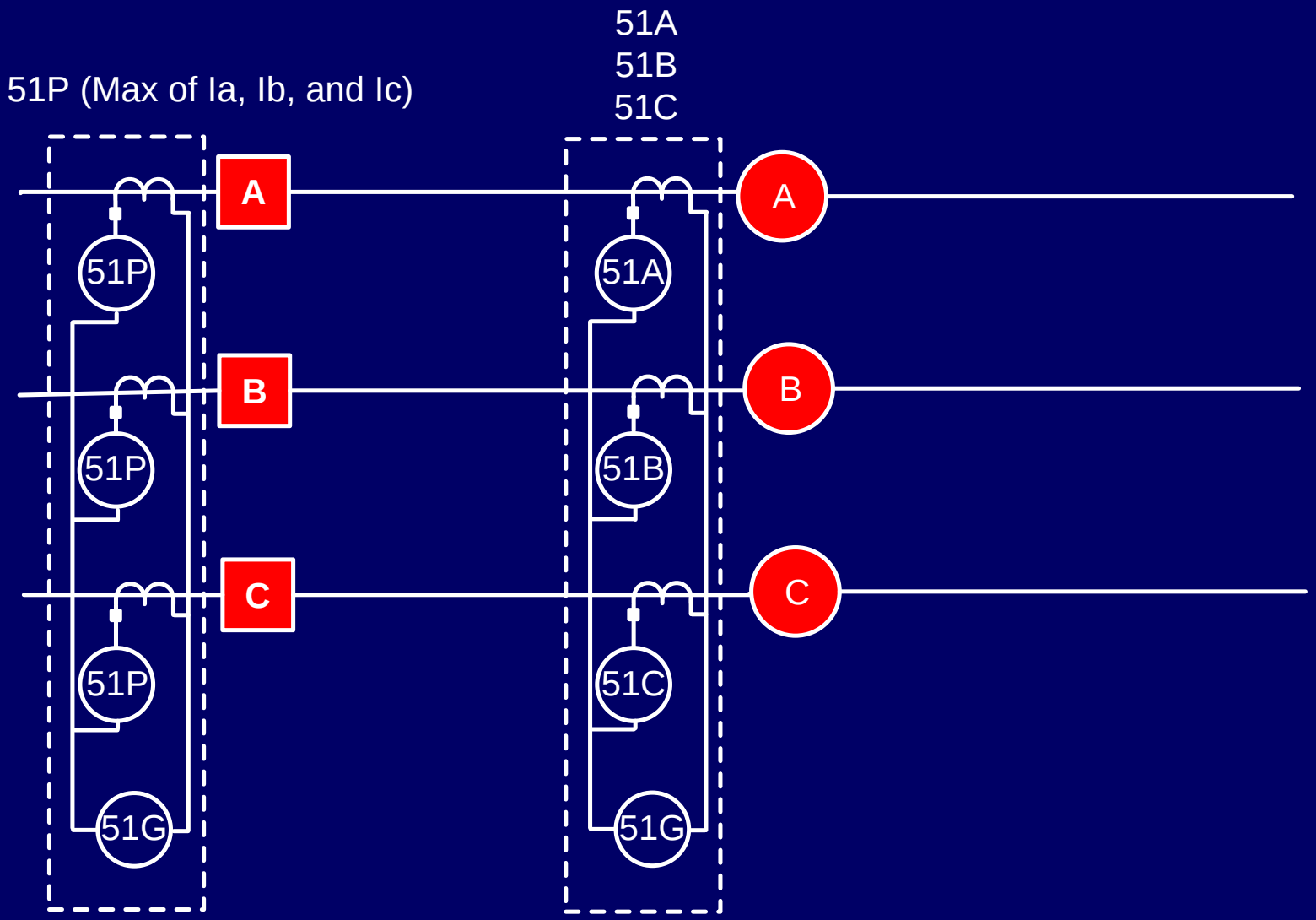
Summary

- Unbalanced pole open condition creates residual current
- Supervise ground element with pole status

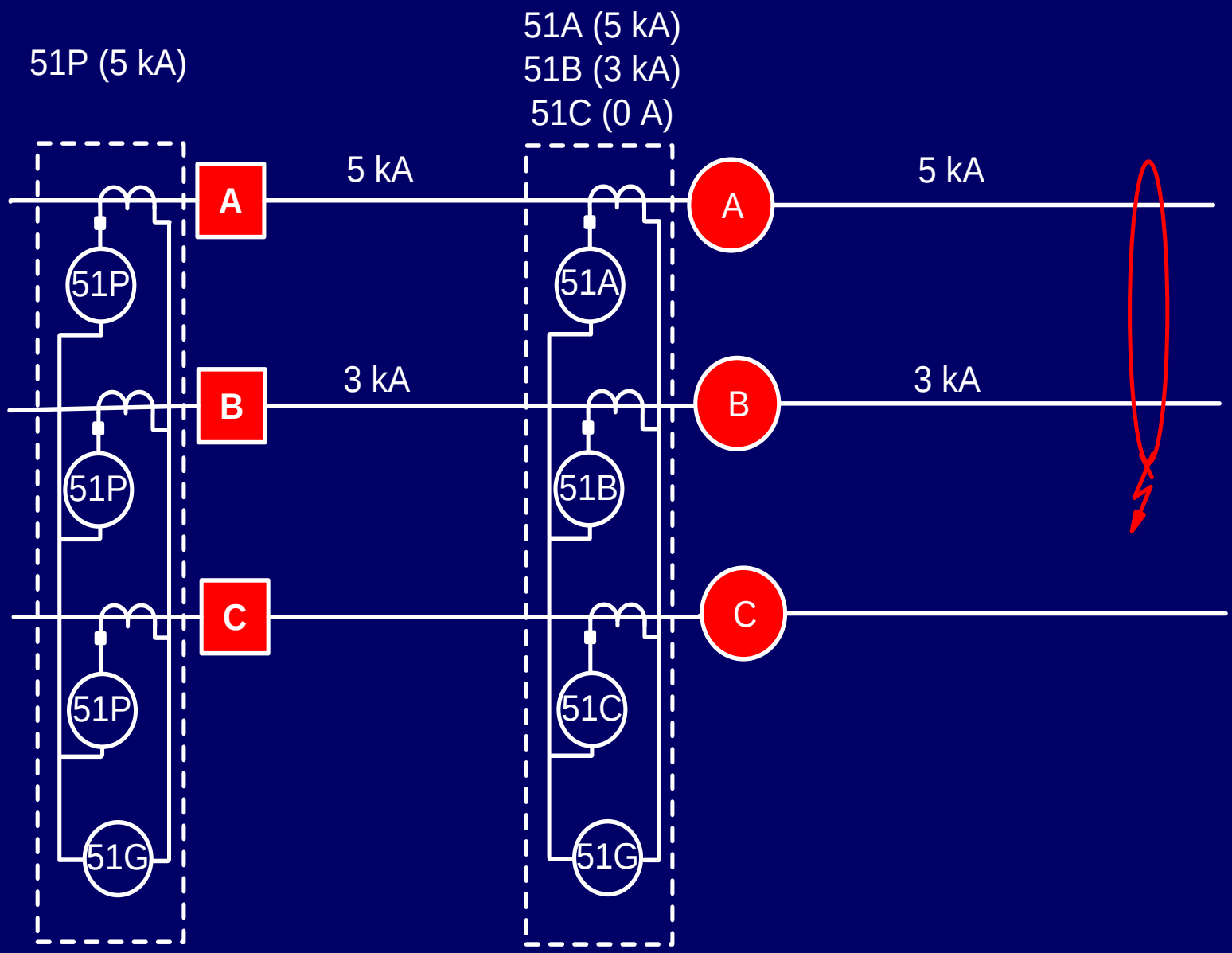
Coordination With Upline Three-Phase Maximum Overcurrent Devices

- Maximum overcurrent element times on highest of three-phase inputs
- Multiphase faults may present coordination problem
- Evolving faults may present coordination problem

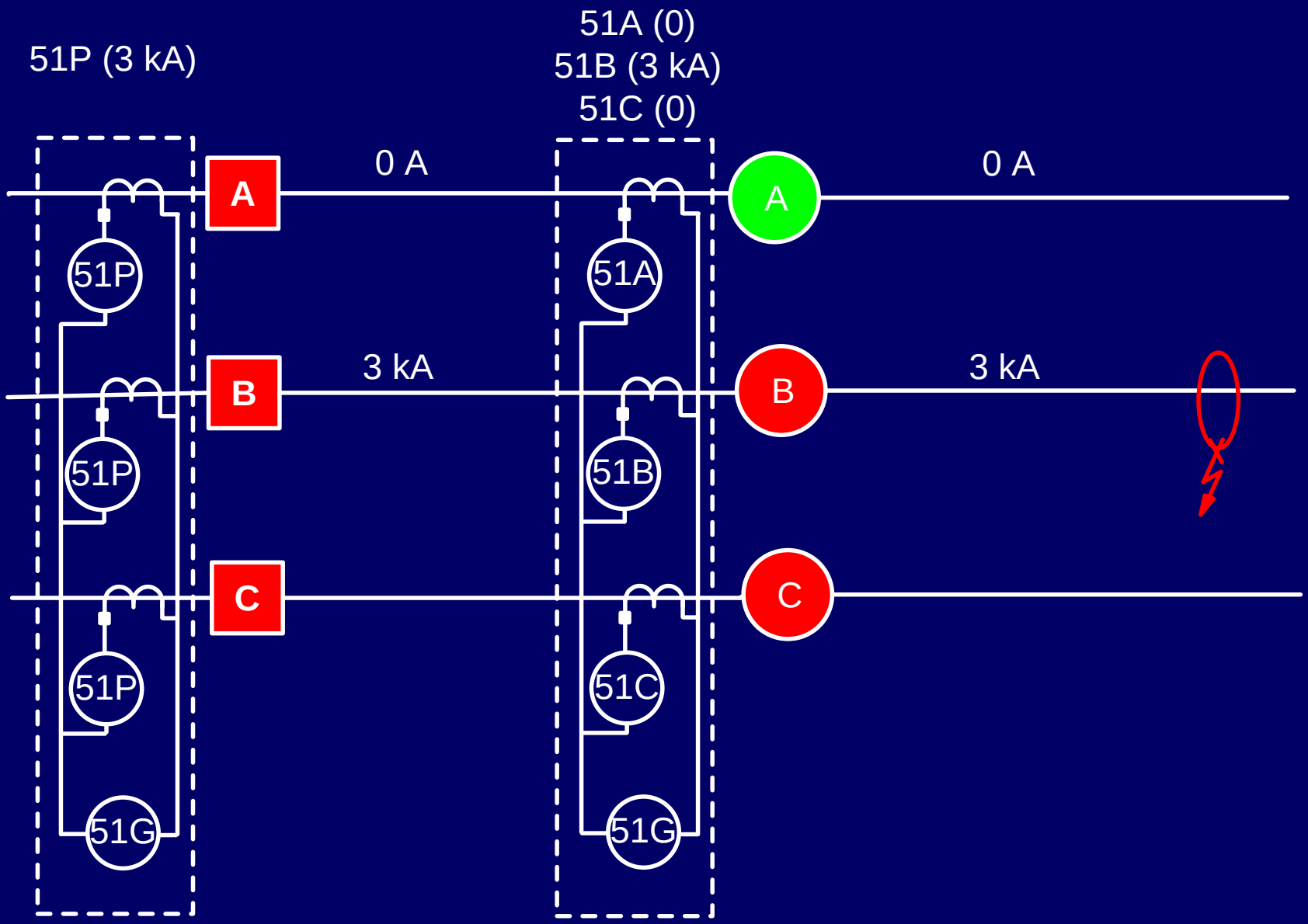
Coordination With Upline Three-Phase Maximum Overcurrent Devices



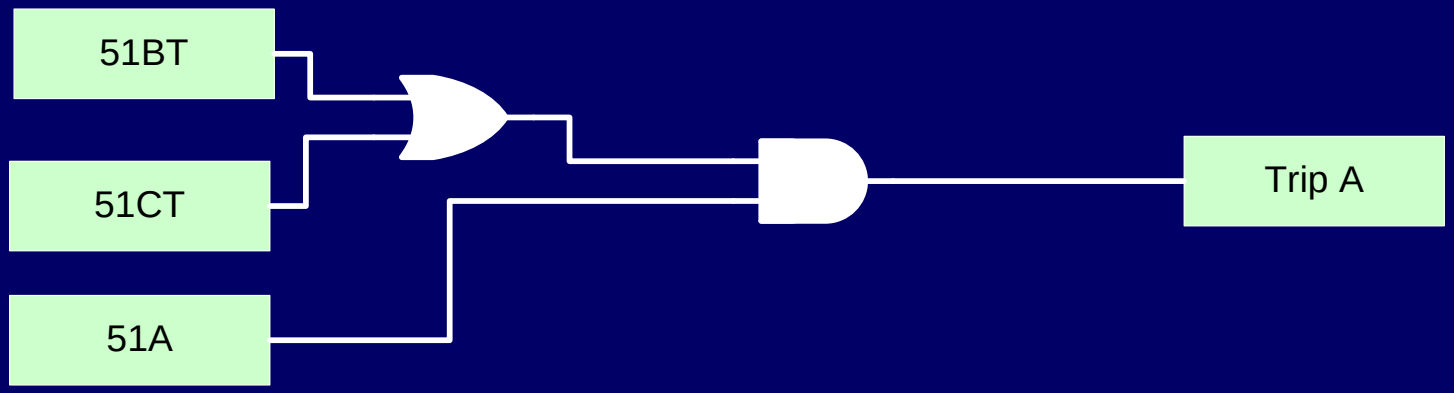
Multiphase and Evolving Faults



Multiphase and Evolving Faults



Multiphase and Evolving Faults Solution



Similar Logic for B & C Phases

Multiphase and Evolving Faults

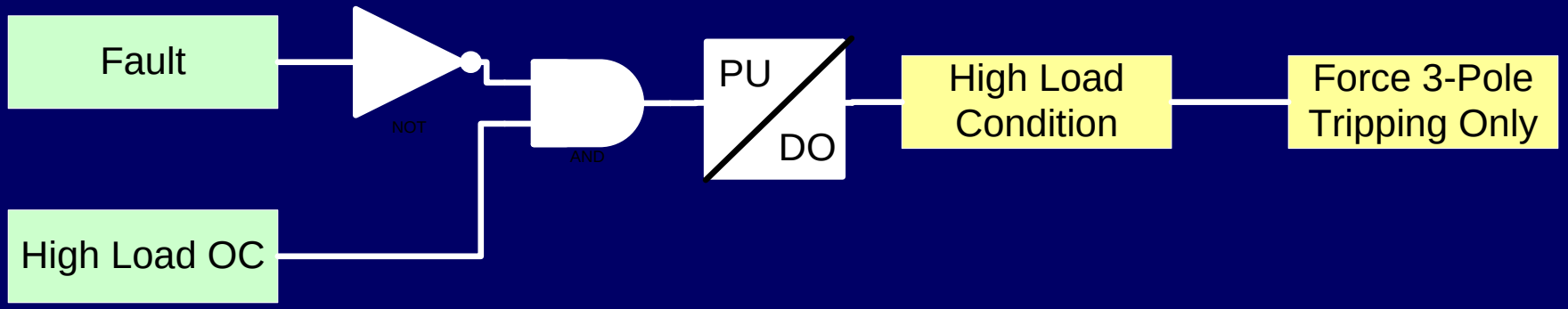
Summary

- Multi-phase and evolving faults may complicate coordination with maximum phase overcurrent elements
- Trip all phases picked up when any element times out in individual phase devices

Alabama Power Field Experience Lessons

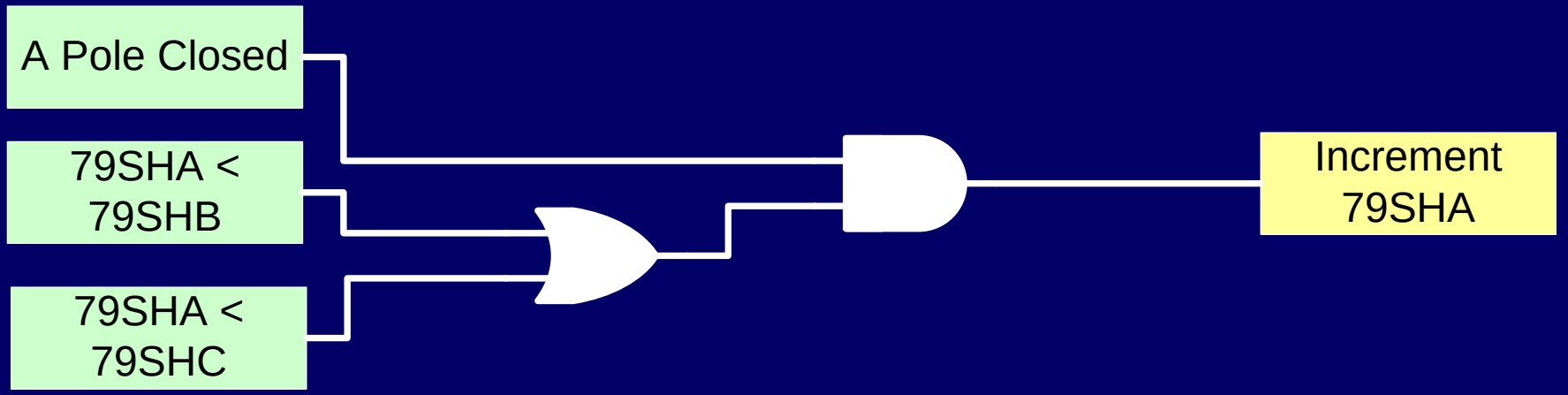
- Implement load-based automatic mode selection of device to maximize usefulness
- Synchronize individual phase reclosing counters to avoid excessive reclosing

Load-Based Automatic Mode Selection Logic



- Maximizes availability of single-pole tripping to gain maximum benefit
- Allows implementation on feeders previously not considered

Reclosing Shot Counter Synch Logic



Similar Logic for B & C Phases

Conclusions

- Opportunity to improve reliability dramatically
- Must consider resulting operating conditions
- Flexibility of today’s technology offers solutions to many potential problems