SNAME MARITIME 2022 CONVENTION

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Medium Voltage Direct Current (MVDC) Fault Detection, Localization, and Isolation

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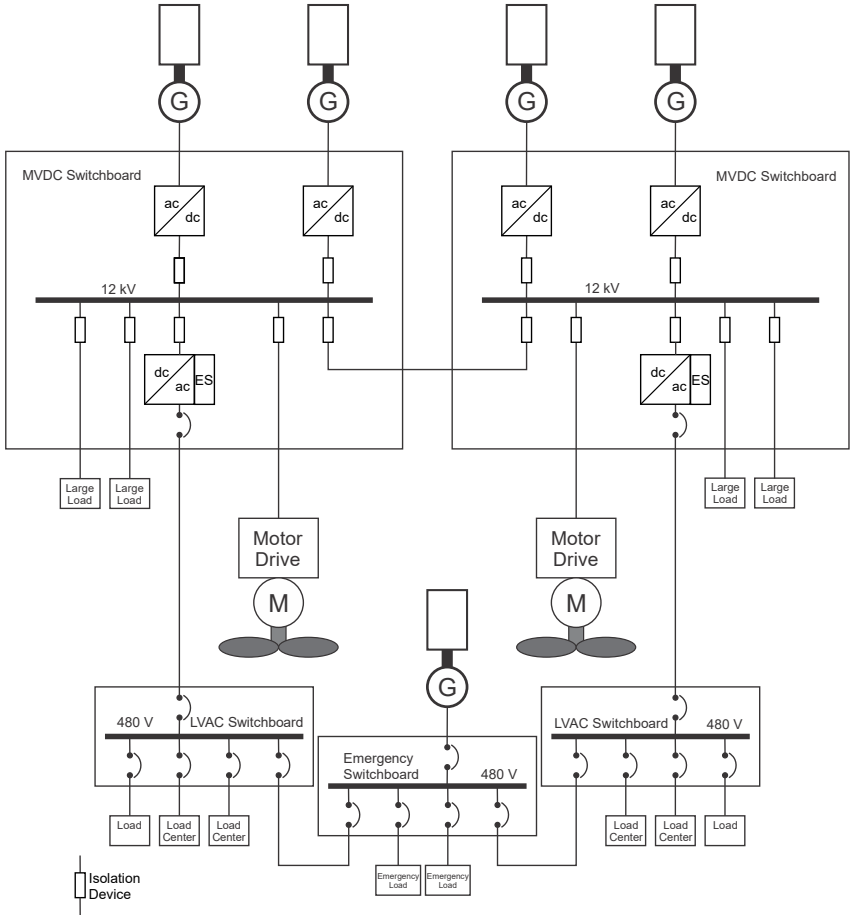
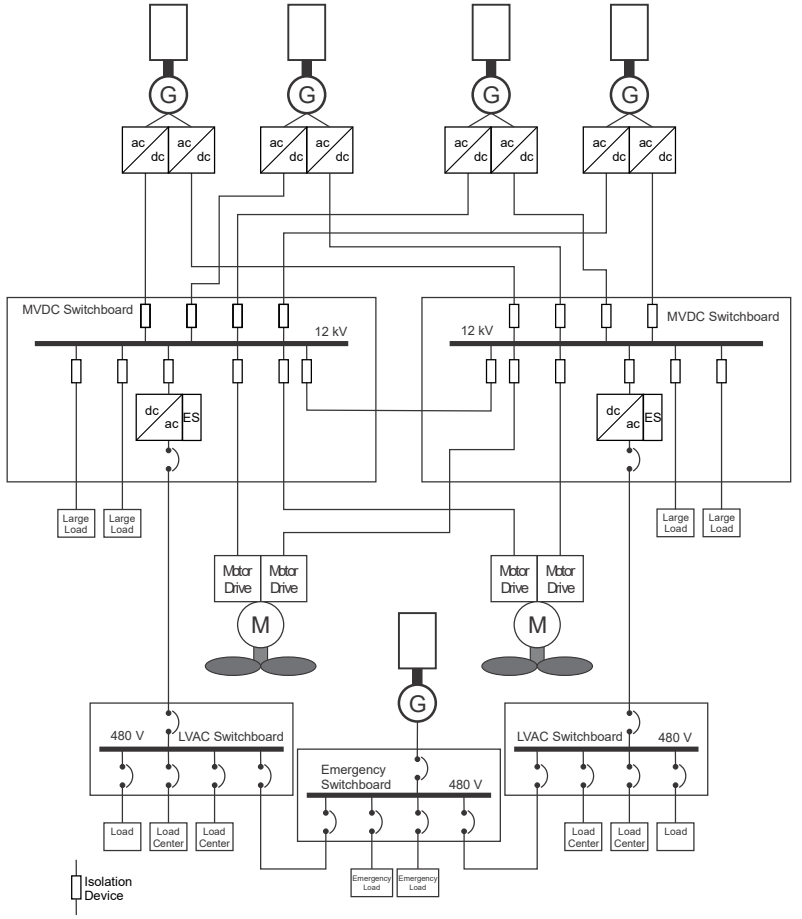
Introduction

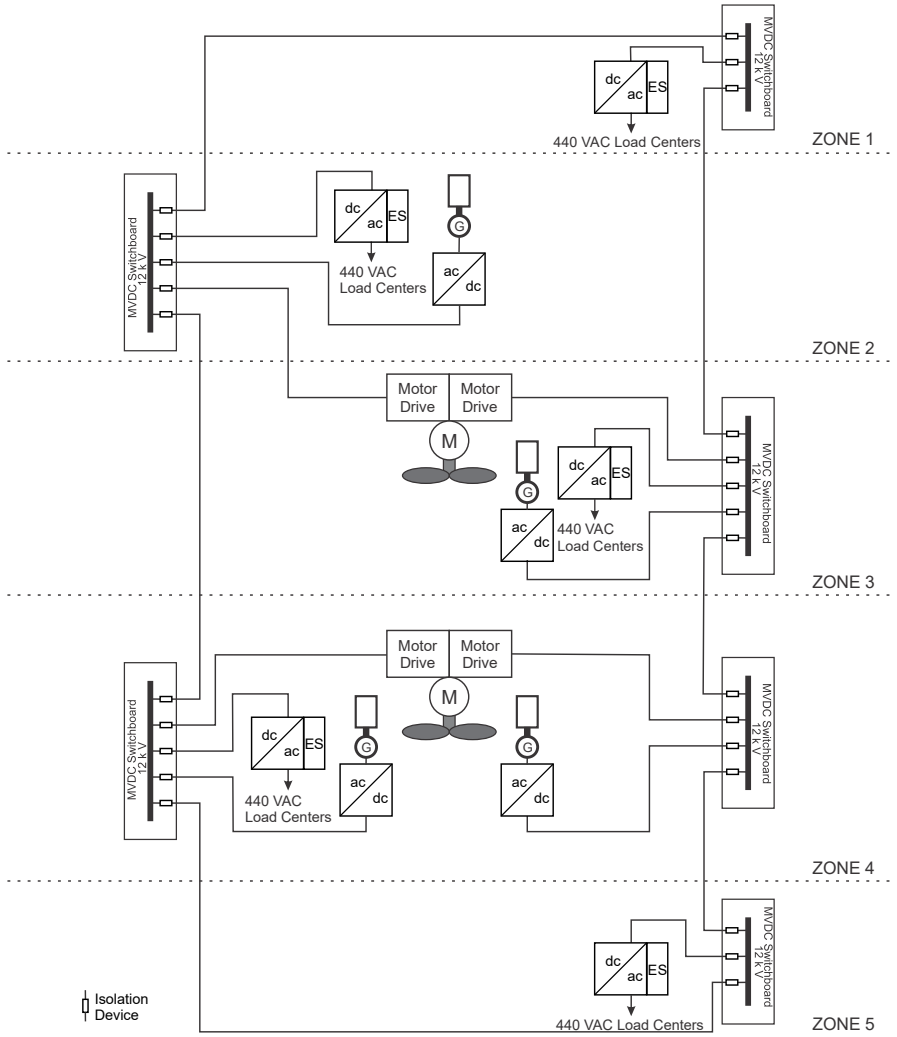
- **Medium Voltage Direct Current (MVDC) between 1 and 18 kV offers advantages to ship power generation and distribution**
  - **Variable Speed operation of prime movers for fuel efficiency**
  - **Faster response to dynamic loads (no need to worry about generator synchronism)**
  - **Some equipment can be smaller (but other equipment can be larger)**
  - **Faster paralleling of generators**
- **Impediments to MVDC adoption**
  - **Lack of available commercial equipment**
  - **Lack of comprehensive design strategy for fault detection, localization and isolation.**

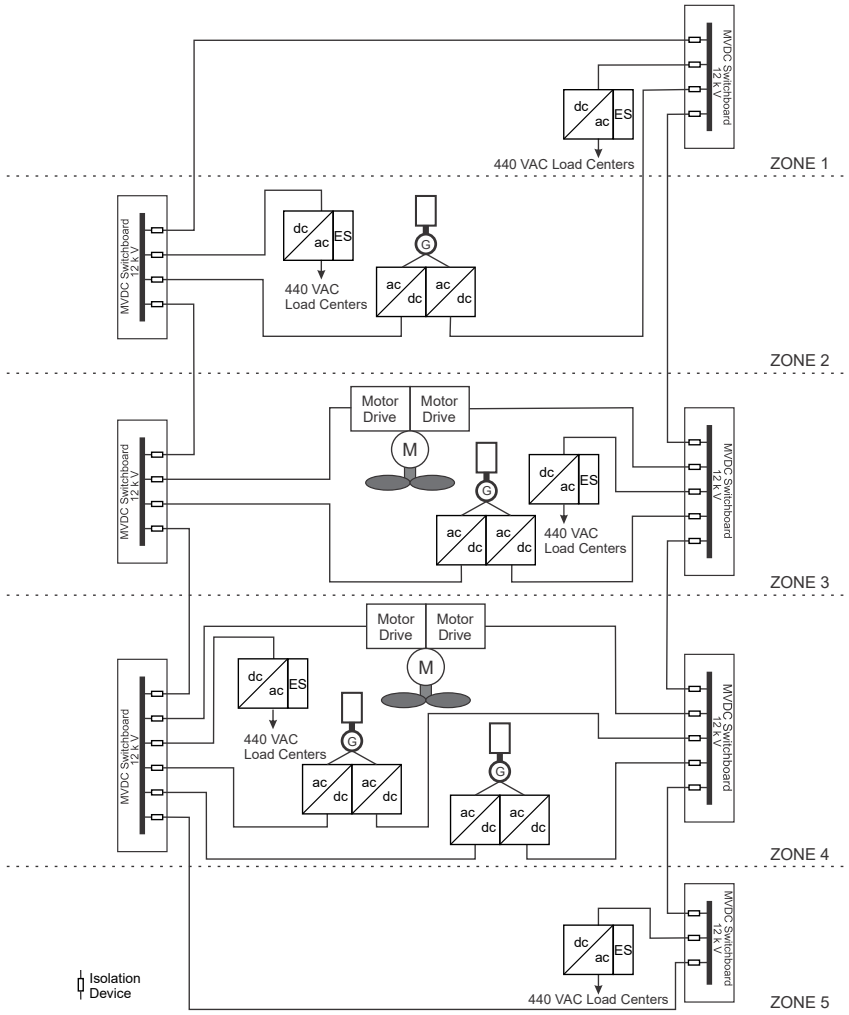
Radial Distribution Systems





Zonal Distribution Systems





Fault Detection

- First Indication of a line-to-line fault is a drop in the line-to-line voltage to below the normal range.
  - Requires a definition of the normal range.
- In a line-to-line fault, current will ramp up at a rate inversely proportional to the system inductance
  - A current ramp rate faster than normal is also an indication of a fault.
  - Requires a definition of normal.
- Arc Faults can be detected by spectral content of the current waveform.
- Ground faults can be detected by measuring the neutral to ground voltage.

Fault Localization

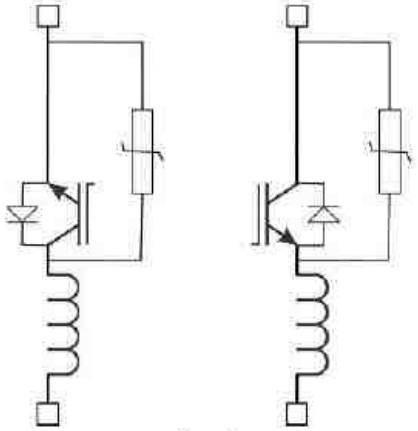
- **Line-to-line Faults**
  - **Loads and load feeder cables: overcurrent or excessive current ramp rate**
  - **Sources and source feeder cables: Lack of delivered power, or reverse current**
  - **Bus-ties and Switchboards: Differential Protection Zones and directional protection. Kirchhoff's Current Law used to identify current taking an unintended path**
- **Ground Faults**
  - **Current signal injection at the grounding resistor with current sensors on cables**
  - **Feature extraction from relatively few sensors**
- **Arc Faults**
  - **Feature extraction from relatively few sensors**

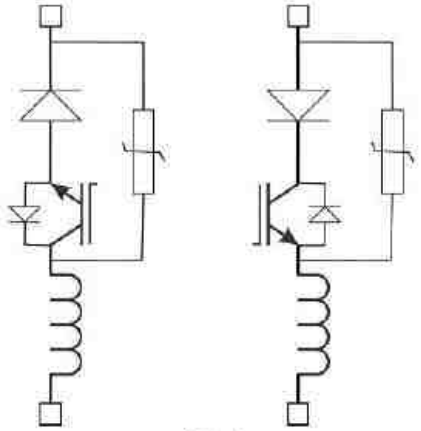
Fault Isolation

- **Disconnect Switches**
  - **Bus de-energized, switches reconfigured, bus re-energized.**
  - **Energy Storage may be used to power mission critical equipment until fault is removed and system re-energized.**
  - **T1 time of 20 to 100 milliseconds likely achievable.**
- **Solid State Circuit Breakers (SSCB) including Hybrid Circuit Breakers**
  - **May trip all breakers with an overcurrent, then once the fault has been localized, selectively close breakers.**
  - **May trip only those breakers nearest the fault**
  - **T1 time of 10 to 100 microseconds likely achievable – generally tolerated by most loads.**

SSCB Directional Functionality

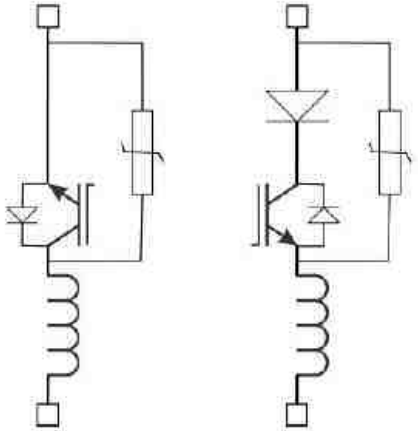
Unidirectional
without
Reverse Blocking

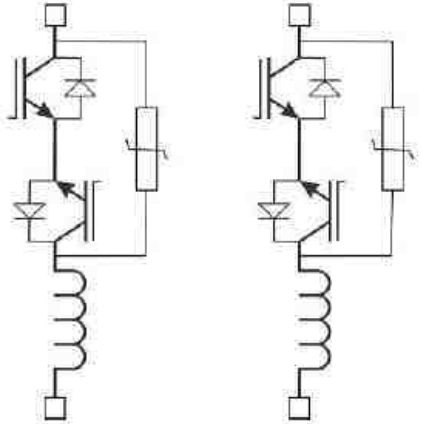




Unidirectional
with
Reverse Blocking

Unidirectional
With one pole
Reverse Blocking





Bidirectional

Recommended Symbols

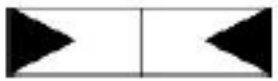
Uni-Directional Without Reverse Blocking

Uni-Directional With Reverse Blocking

Uni-Directional With One-Pole Reverse Blocking

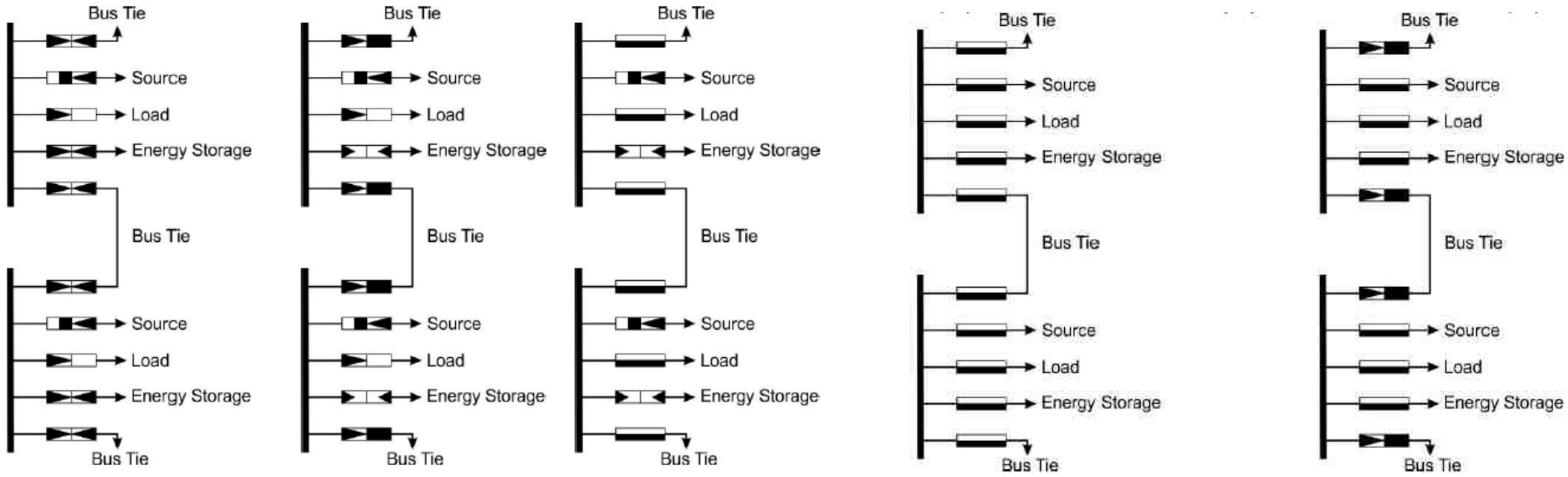
Bi-Directional

Disconnect Switch



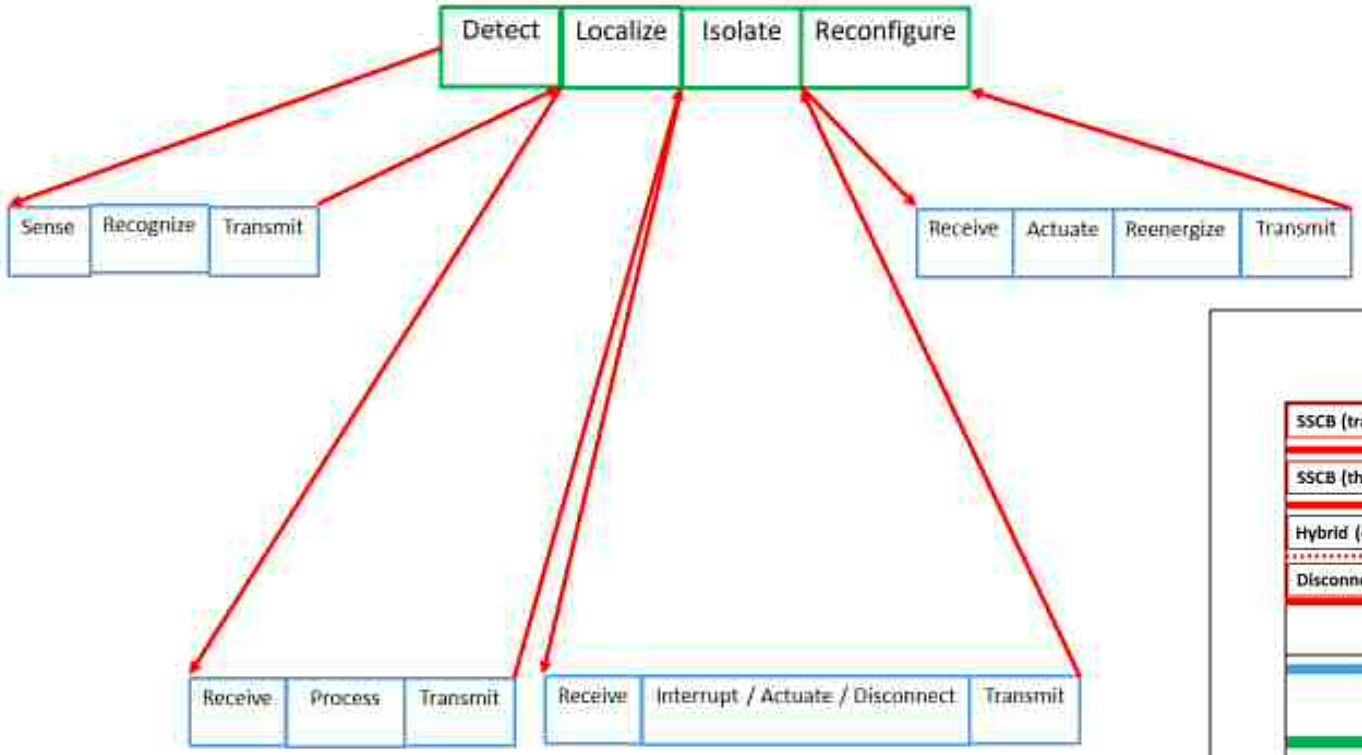
Bi-Directional - independent directional control

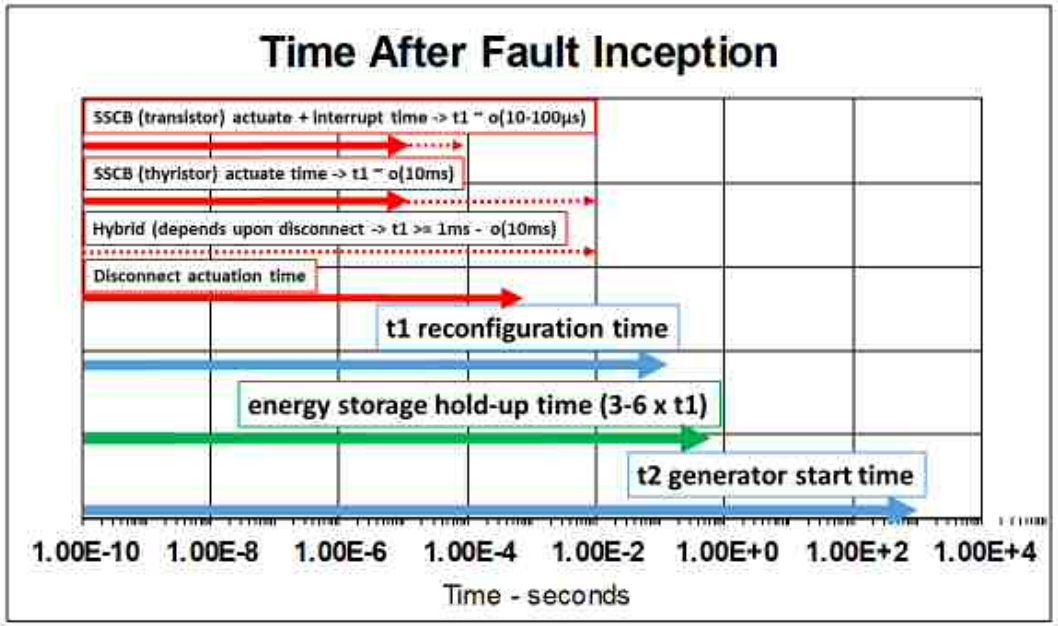
Isolation Device Strategies



Each strategy can work acceptably – Enables trade off in size, weight, and cost.
First challenge is commercial availability of Isolation Devices.

MVDC Fault Protection Timeline





Conclusions

- **The Technology for implementing MVDC system protection exists**
  - **Multiple system solutions are acceptable**
- **Commercial Products generally do not exist**
  - **System solutions will depend on the products that are offered by industry**

Thank you for your attention this concludes the presentation

Questions?