Using the PSA to develop a safety case for phase imbalance faults

Rhys Kearney & Becky Mogridge

EDF Energy AGR safety case and PSA SQEPs

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- Why phase imbalances are a problem
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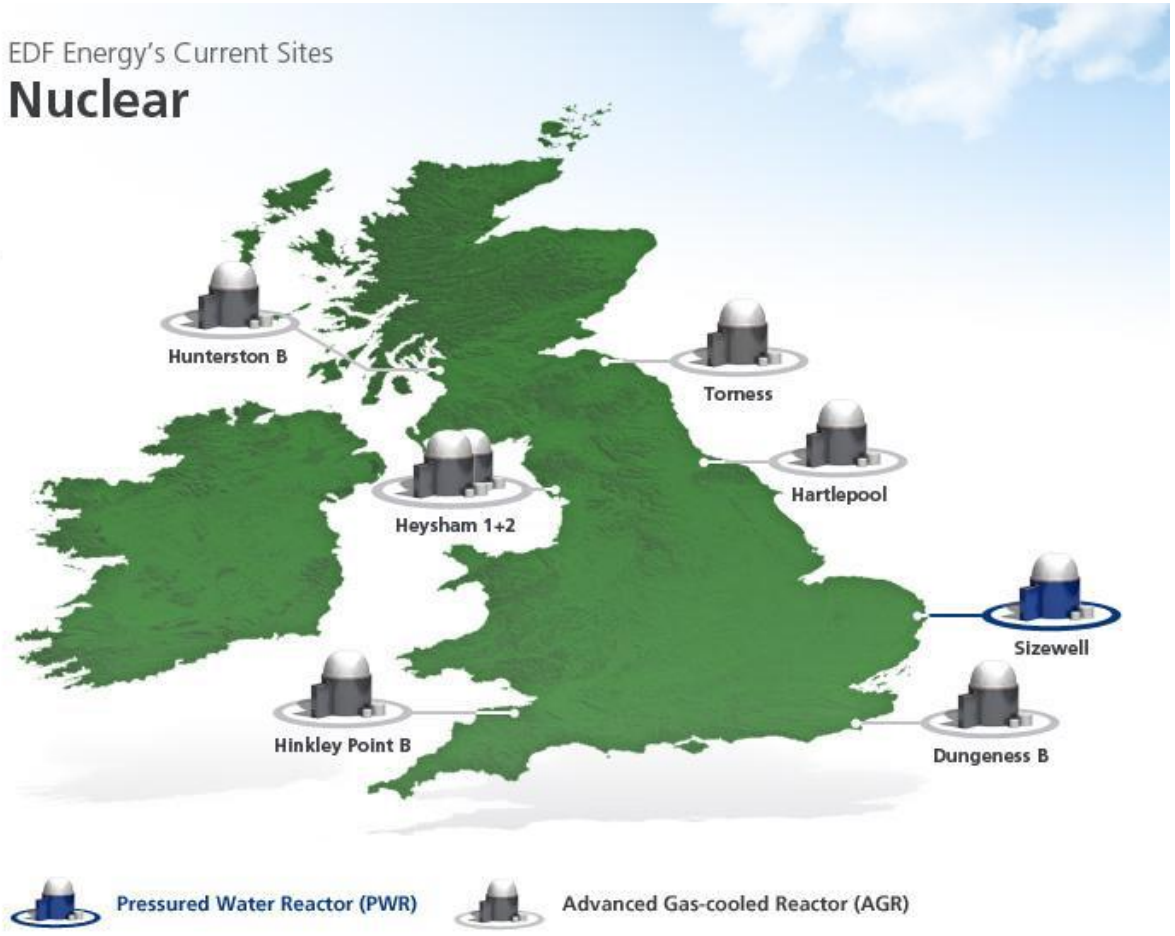
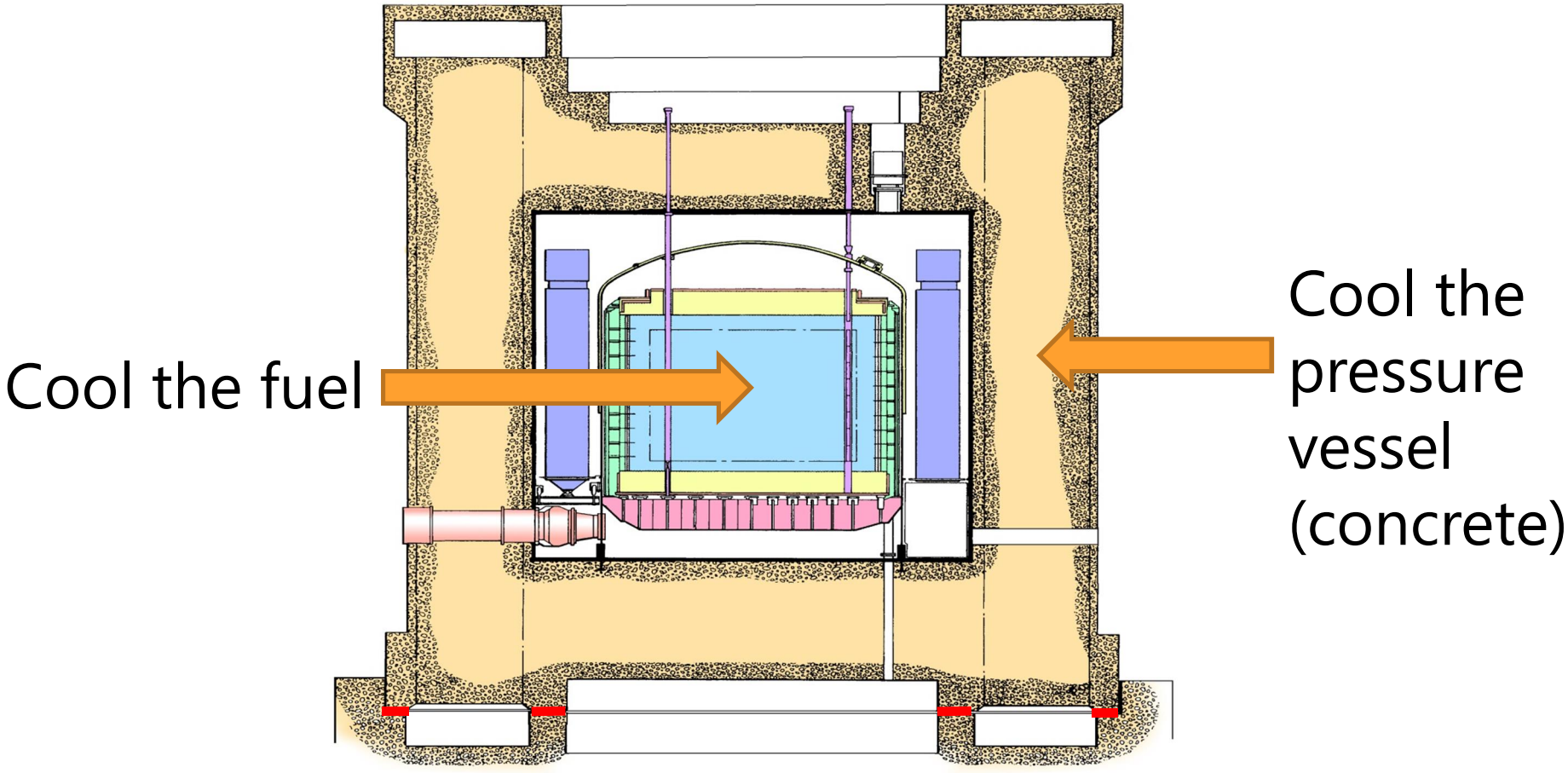
- Questions

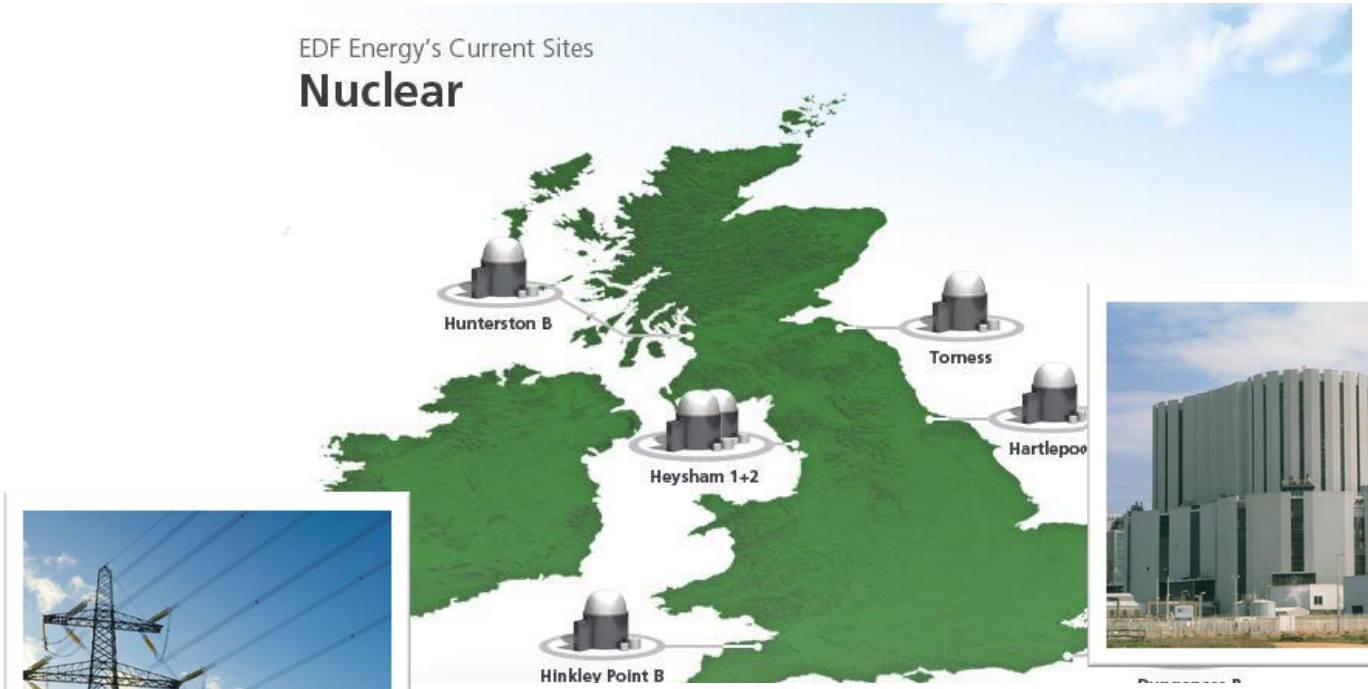
EDF Energy's Nuclear Power Stations

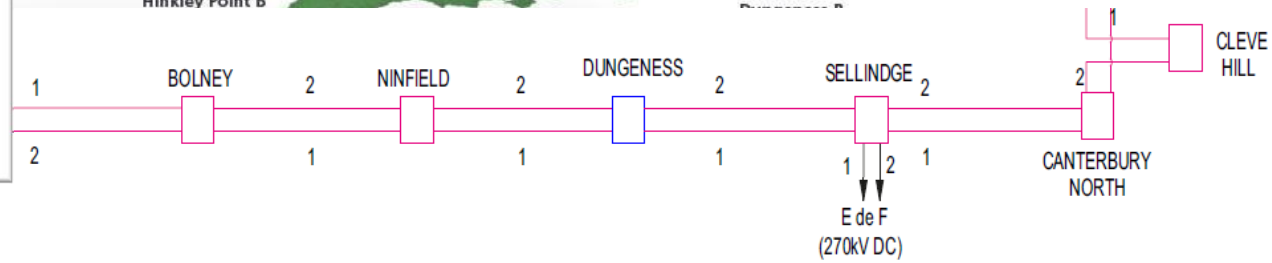


Advanced Gas Cooled (AGR) reactor

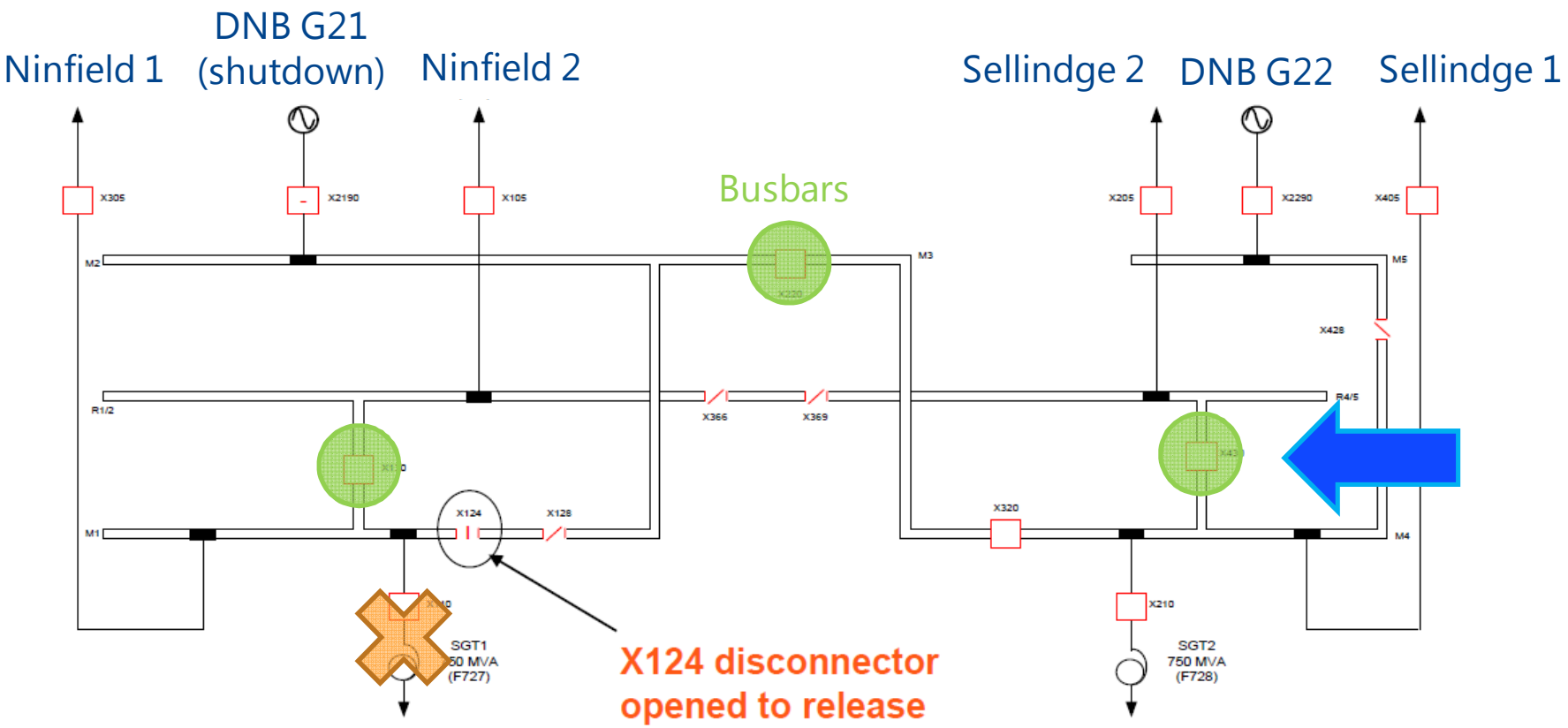


EDF Energy's Nuclear Power Stations

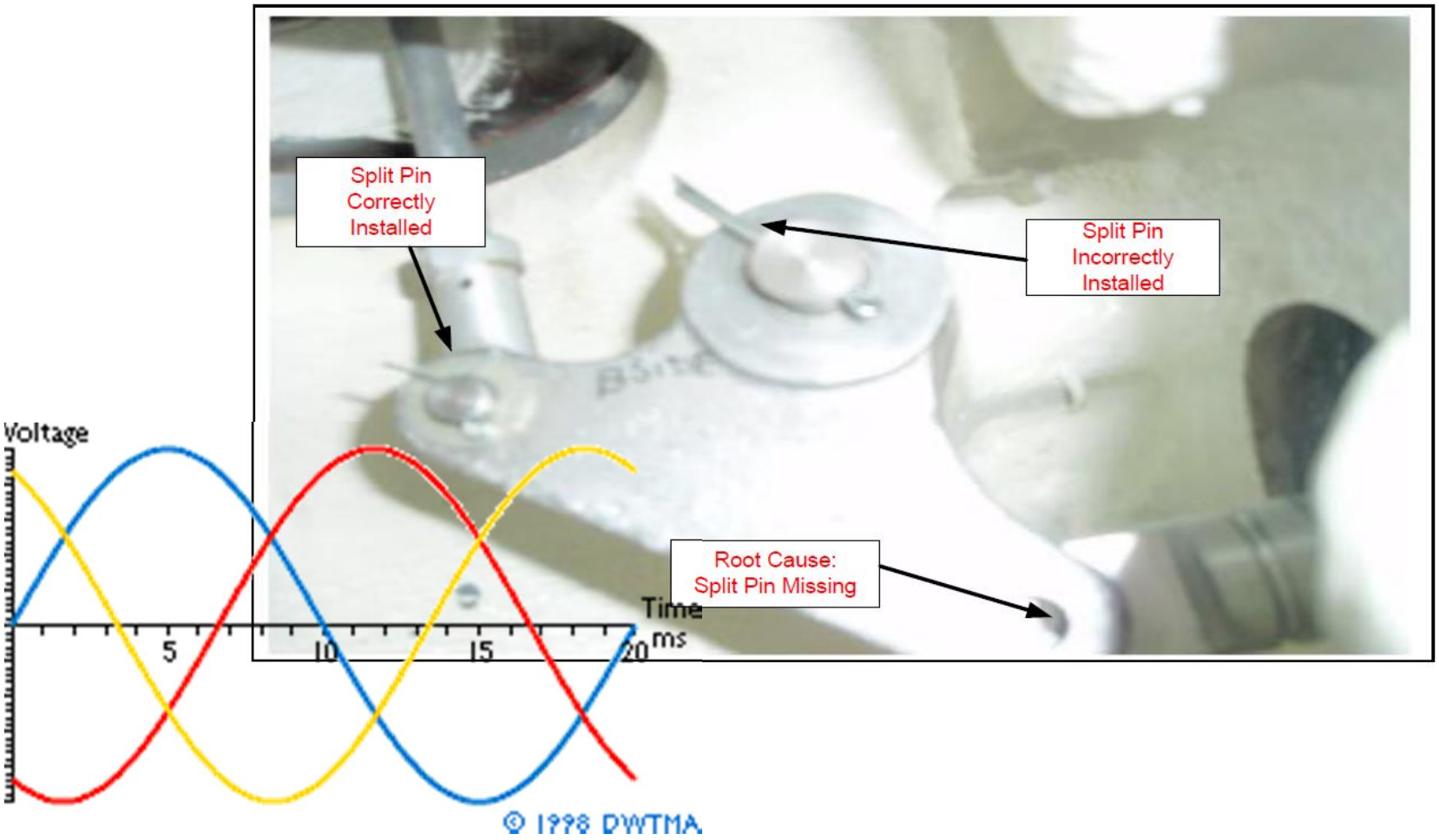




Dungeness 400kV substation: 2014 event

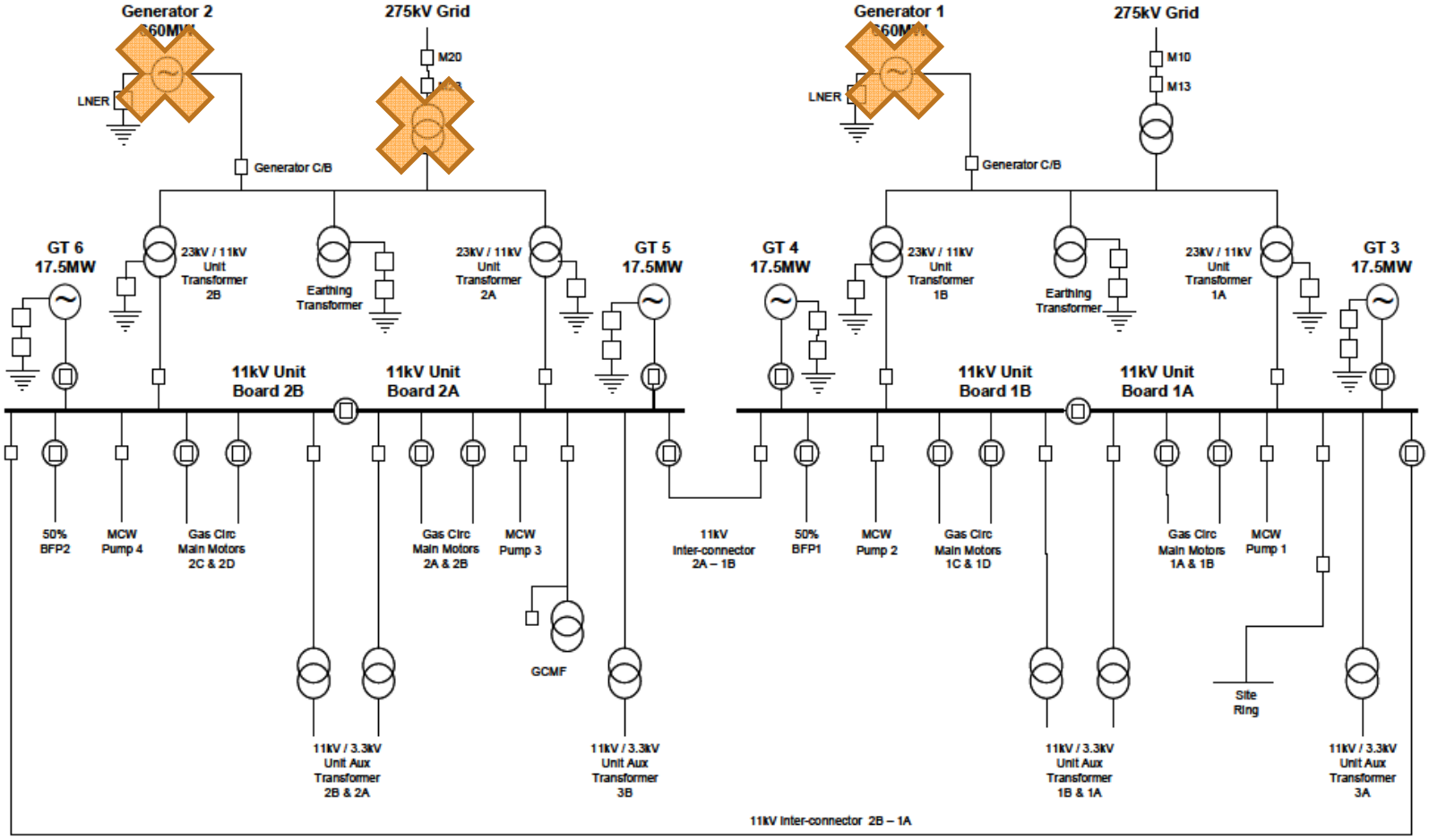


Cause of phase imbalance: failed circuit breaker



Why is phase imbalance a problem?

Phase imbalance is propagated through the electrical distribution system



How the phase imbalance event played out

Time	Dungeness B event
00:00	National Grid switching results in loss of phase
00:02	Generator 22 trips on Negative Phase Sequence protection
00:03	Reactor trips. Automatic-start of systems initiated
00:04	Secondary loop cooling systems pumps trip
00:05	Primary loop cooling water pumps trip
00:06	Main boiler feed pump trips
00:07	Main vessel cooling pumps trip, back-ups auto start
00:08	Primary coolant (gas circulators) main circulating motors trip
00:12	Decision to disconnect from grid, back-up systems employed

Responding to the phase imbalance risk

- Delivered training to the operators and updated procedures
- Determined the vulnerabilities of our stations to phase imbalance events
- Interim safety cases justifying basis for continued operation
- Installing a dedicated alarm to inform the operator that a phase imbalance event is occurring improving the reliability of operator to disconnect from grid
- Modifications including an auto-disconnect from grid

Human factors aspects

- Significant call on the operator in potentially short timescales hence need for action assessment
  - Diagnosis with no direct indication
  - Grid disconnection
  - Local reset of protection equipment
  - Restart of equipment
- Human factors assessment resulted in improved procedures / training and case clarity.
- Human Error Probabilities an input into the PSA

Using the PSA to understand the risk

- Design characteristics different for each station.
- Modelled the fault as per interim safety case:
  - Operator reliability
  - Phase imbalance a frequent event
  - Assume any motors connected to grid vulnerable
- PSA models the electrical system and its dependencies
- Informed risk position - loss of vessel cooling significant issue

Design characteristics – Heysham 2 / Torness

- Generator trip auto-disconnects grid electrical supplies to half the essential systems
- 2 / 4 quadrants “immune” to phase imbalance and available to cool fuel and provided vessel cooling
- Minimum of 2 quadrants of cooling needed - PSA highlighted that the loss of redundancy had significant impact on risk
- Improved understanding of risk position resulted in changes in maintenance activities and operating procedures

Design characteristics – Dungeness B

- Many cooling systems with inter-dependent electrical supplies (cooling of diesels)
- PSA identified the key systems contributing to risk
- Further investigation identified that some of these systems vulnerable to phase imbalance in the period immediately post-fault
- Significantly impacted risk of loss of vessel cooling
- Risk benefit of additional plant modifications under consideration being informed by the PSA

Summary

- Historically phase imbalance fault not considered significant fault but events have shown otherwise.
- With the help of the PSA, now understand the fault and have implemented measures to ensure the risk position is tolerable
- Additional plant modifications planned to improve the risk position in the future
- Wider recognition of the fault within the nuclear industry (WANO SOER-2015)

THANK YOU

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