AN OVERVIEW
OF
TECHOP_ODP_09_(D)
(A METHOD FOR PROVING THE FAULT RIDE-THROUGH CAPABILITY OF DP VESSELS WITH HV POWER PLANT)
OCTOBER 2014

Acknowledgements

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  - ABB
  - GE
  - Siemens
  - AKA

CASE FOR ACTION

- There is a need to improve efficiency and reduce emissions from DP power plants – Operating power plants with closed busties is a means of achieving this.
- Industries experience of loss of position incidents on DP vessels operating with closed busties suggests a lack of sufficient fault ride through capability – Loss of all thrusters or blackout.
- 18 examples of such incidents are given in the Techop.
- Increasingly difficult to get stakeholder concurrence for operation with closed busties.

PURPOSE OF TECHOP

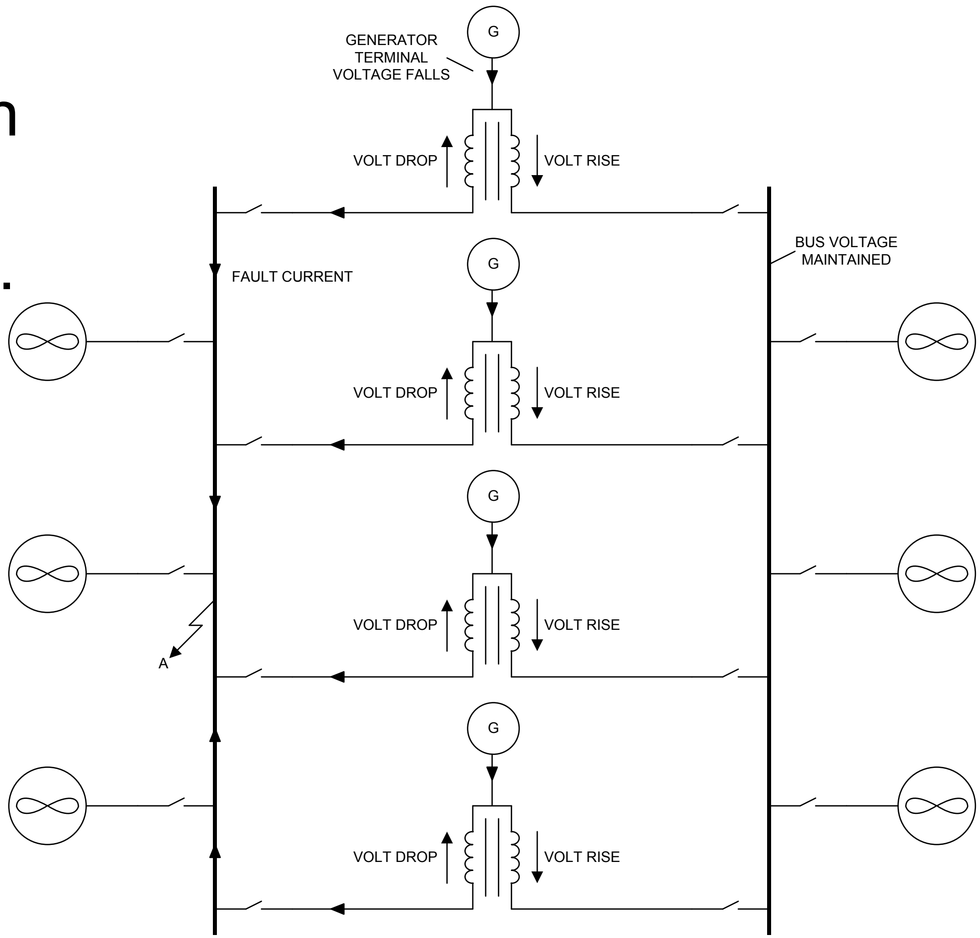
- Build confidence in common power systems by testing fault ride-through capability using an established method.
- Contribute to proof of *equivalent station keeping integrity* for DP class 3 vessels   IMO MSC 645 Section 3.2.4.
- Communicate experience of doing it successfully.
- Enhance the knowledge of stakeholders.
- NOTE: If there is no intention to carry out DP operations with closed busties then <u>you don't need to prove fault ride through capability.</u>

CONTENT OF TECHOP

- Information on one method of proving fault ride-through that has been carried out safely and effectively.
- Practical details on how to carry out the testing.
- Details of the power system attributes to be proven.
- Guidance on computer simulation and preparatory work.
- To provide focus on risk assessment, typical roles and responsibilities for stakeholders.

FAULT RIDE-THROUGH TESTING IS NOT NEW

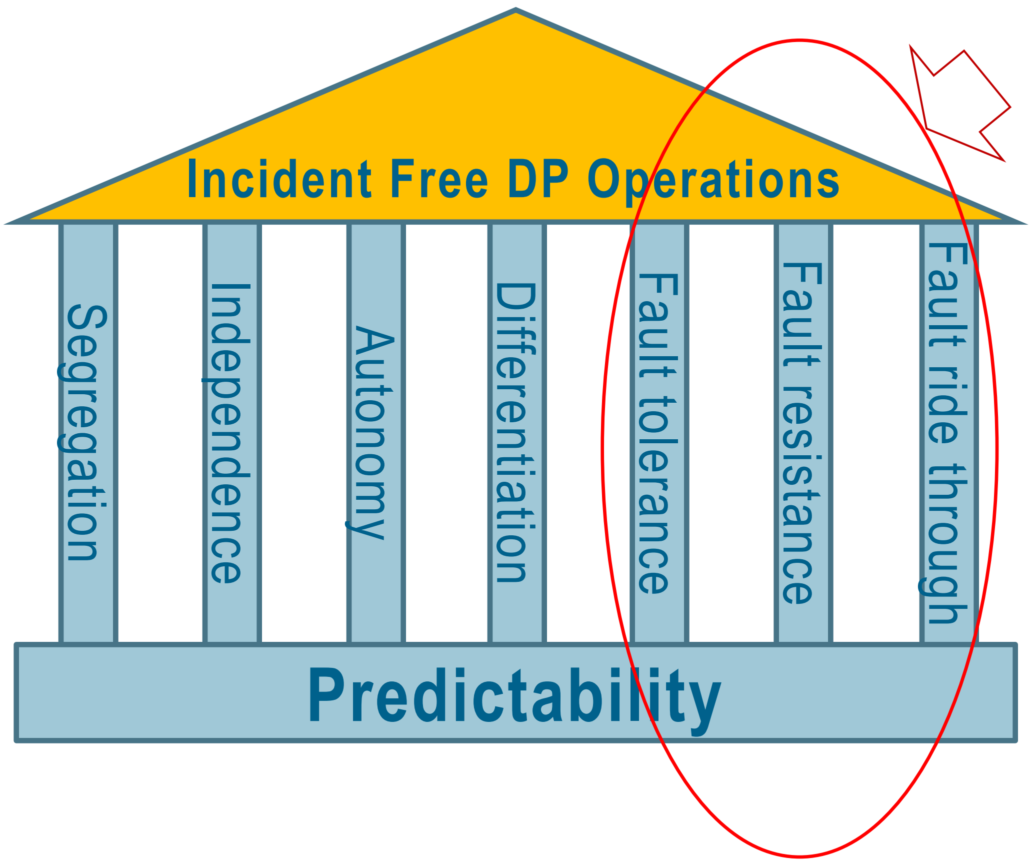
- Fault Ride-Through Testing on LV DP DSVs in the 1980s.
- Built to be tested.
- Tested by application of bolted short circuit to 660V feeder.



FAULT RIDE THROUGH CAPABILITY – A LOOK BACK

- Requirements for fault ride-though capability have always existed based on single failure criteria.
- What has changed is that more focus is now placed on proving this capability by testing.
- Traditional methods inadequate to meet stakeholder expectations:
  - History of too great a reliance on limited analysis only e.g. short circuit calculations.
  - FMEA testing did not create realistic conditions for fault ride through proof.

SEVEN PILLARS



These pillars require more focus when cross-connections are introduced.

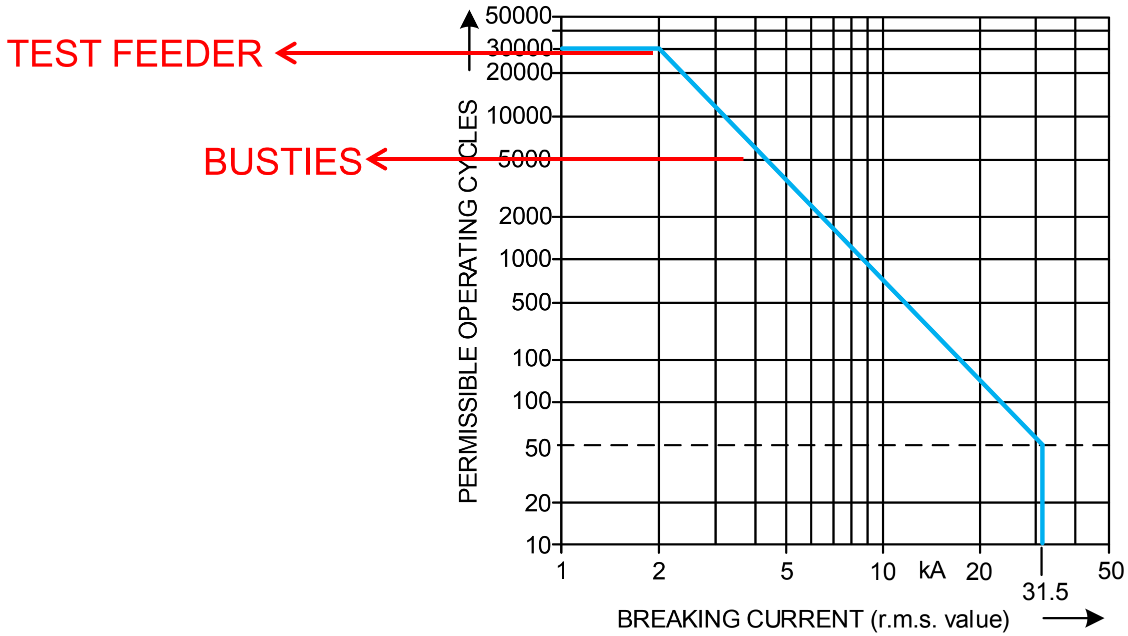
PRE-REQUISITES FOR CARRYING OUT FAULT RIDE - THROUGH TESTING

- Expertise - Already available from several well known sources.
- Qualification and approval – Early engagement with class.
- Roles and responsibilities – Agree in advance.
- Action in the event of unsuccessful tests – Agree in advance.

INDUSTRY READINESS FOR TESTING

- Recent experiences of successful testing.
- More than 10 tests carried out - plus experience of real short circuits on DP vessels.
- Initial apprehension overcome:
  - Crew safety.
  - Test personnel safety.
  - Risk assessment.
  - Equipment damage – leaving hidden failures (weakness) – actually helps reveal them.

EFFECT ON CIRCUIT BREAKER LIFE



Build to test

You need to check what your circuit breakers are rated for.

EFFECT ON BUSBARS

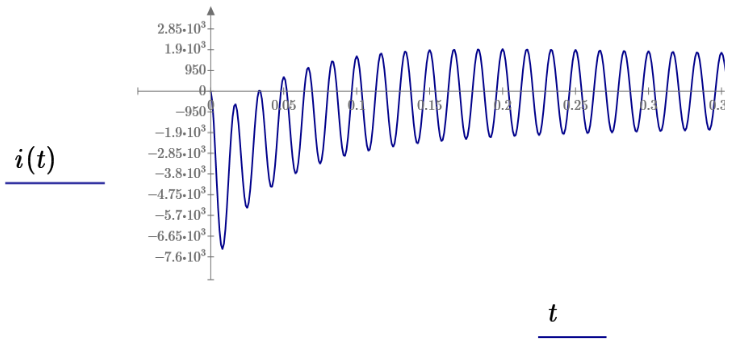
- Forces on bus bars are proportional to the square of the current.
- As peak test current in the example in the Techop is around 1/3rd of rating.
- Forces are around 1/10th of rating.

EFFECT ON GENERATORS

- Generators rated for a defined number of short circuits – for example 3.
- Generator sees ‘almost’ a full short – there is some impedance – more could be added but considered unnecessary on HV systems by manufacturers – no reports of damage.

PRACTICAL CONSIDERATIONS FOR CARRYING OUT TESTING

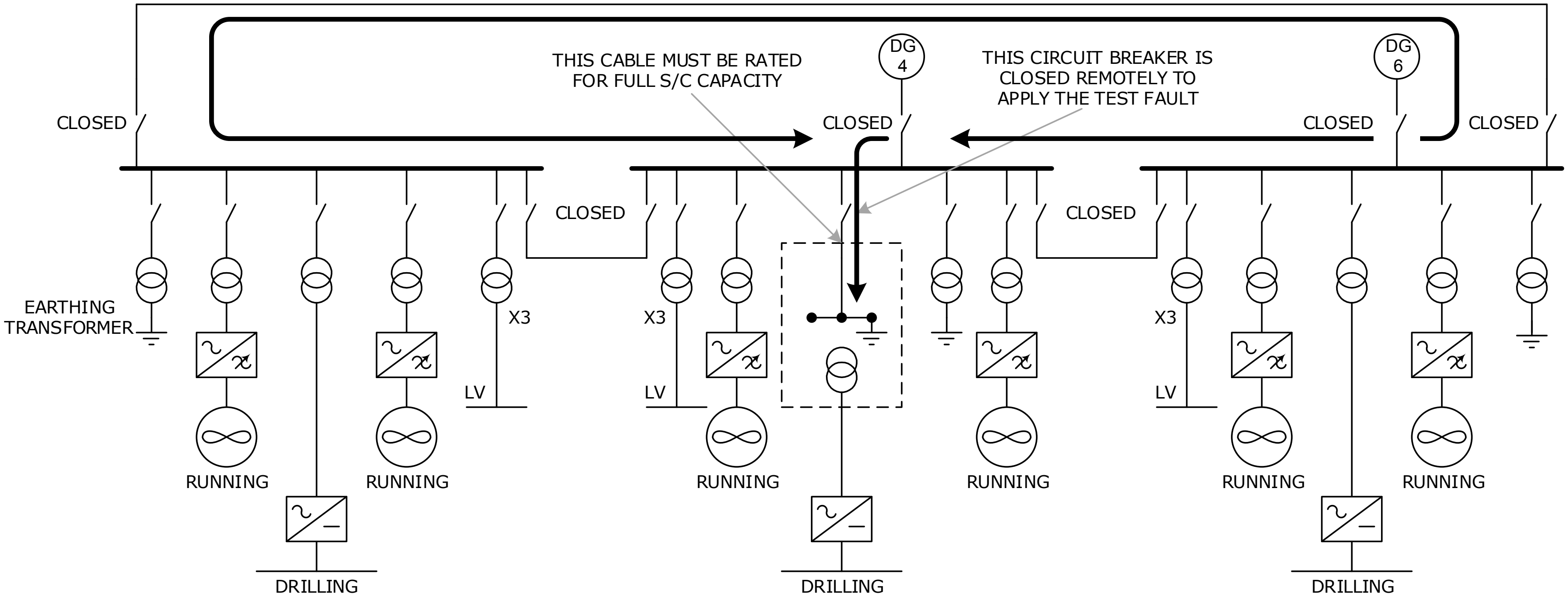
1. Advance modelling.
2. Building confidence for the fault ride-through test – commissioning.
3. Fault ride-through test.
4. Earth fault test.



TEST CONDITIONS

- Vessel at sea trials location.
- DP system in full auto DP.
- Two generators online (on different busses). supplying DP & Hotel.
- All transformers connected.
- All busties closed.
- Instrumentation and logging facilities operating.
- Carry out test.

FAULT RIDE-THROUGH TEST



EXPECTED RESULT

- Test fault applied.
- Busties open to isolate switchboard with fault.
- All thrusters stay online and selected to DP.
- All DP essential systems continue to operate without malfunction.
- Feeder removes test fault.
- Both generators remain on line.
- All buses healthy.

TEST DATA AQUISITION

Signal sources that can be instrumented (Build to Test) or used to collect data include:

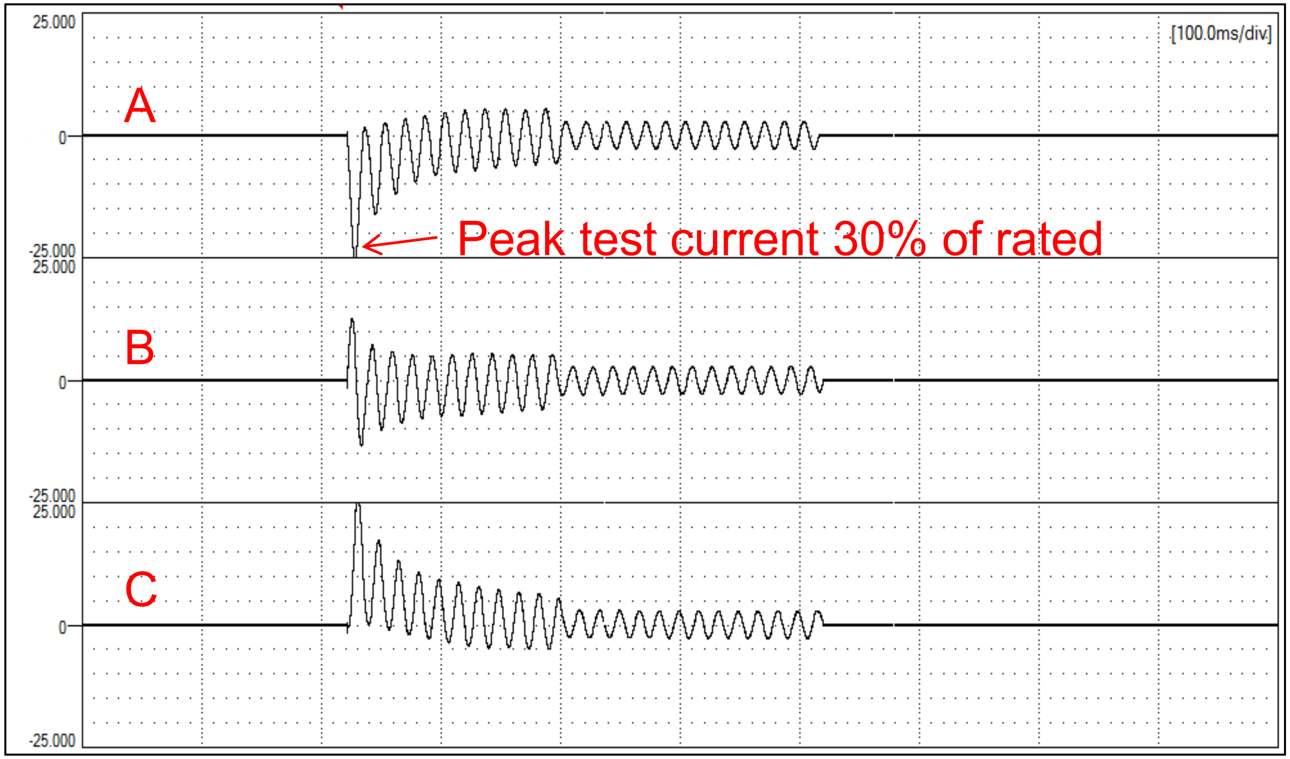
- Generator VTs and protection & measuring CTs.
- Bus VTs and protection & measuring CTs.
- Feeder protection and measuring CTs.
- Serial links from protection relays.
- Serial links from governors and AVRs.
- Serial links from thruster drives.

Vessel management systems, history stations, data loggers can be used to record any changes in plant status.

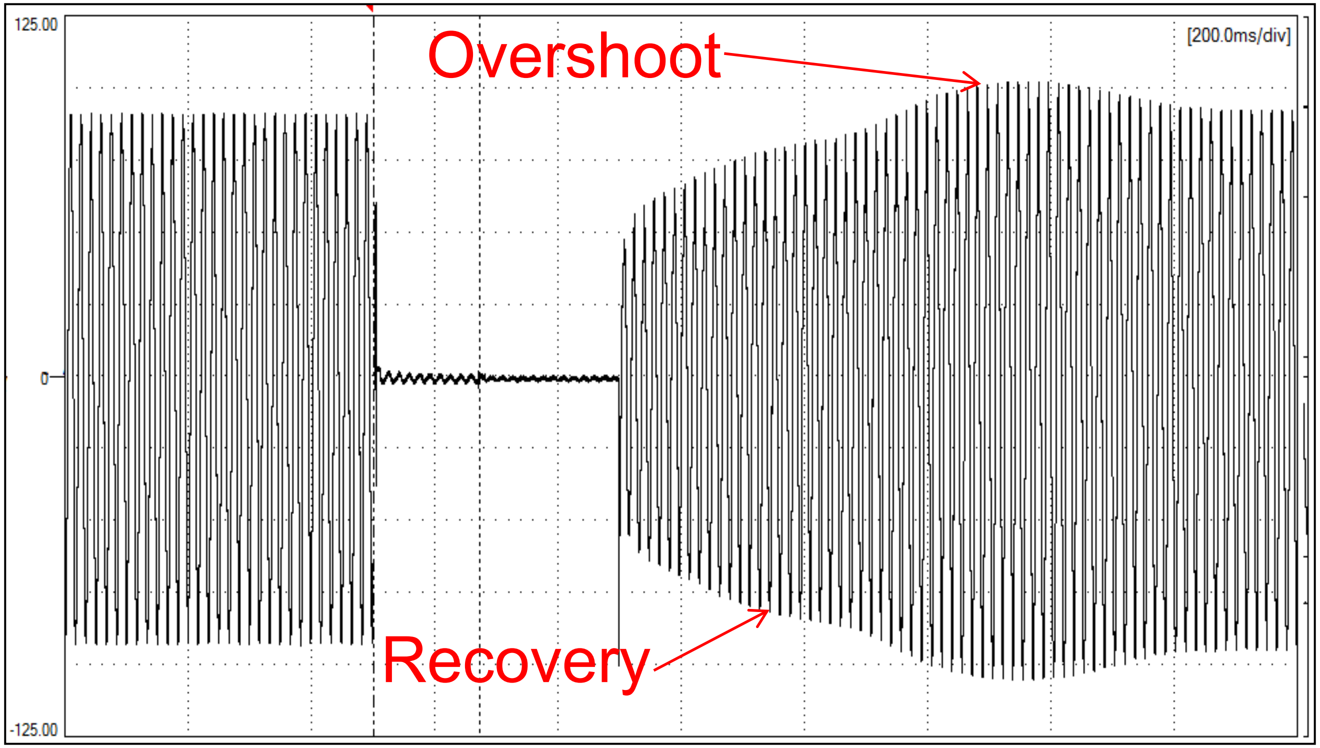
POWER SYSTEM ATTRIBUTES TO BE VERIFIED

- This section of the Techop deals with various functions and features to be verified as part of the analysis and testing process:
  - Fault cleared by busties.
  - Voltage dip ride-through.
  - No protection operation on plant recovery current.
  - No protection operation on plant recovery over voltage.
  - Model mal-synchronisation and inadvertent gen CB closure.
  - Decrement curve and model validated.

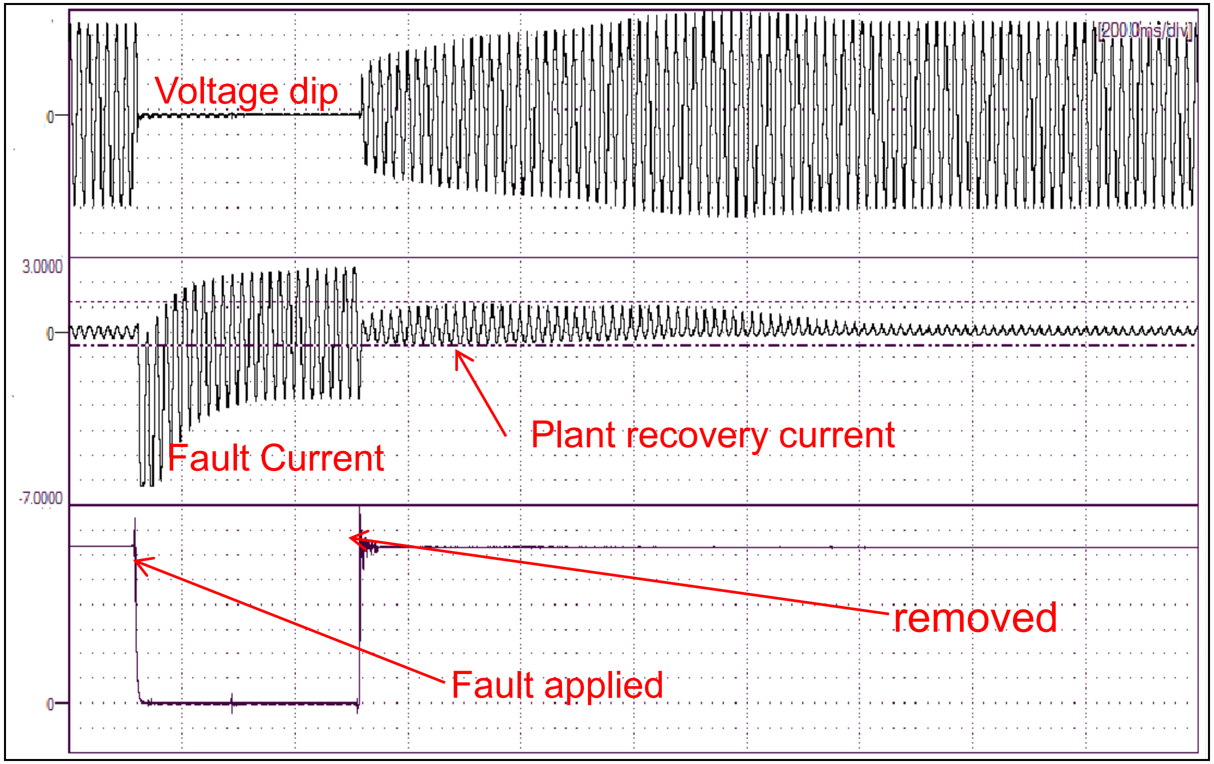
FAULT CURRENT RECORDINGS



MAIN BUS VOLTAGE RECOVERY & OVERSHOOT



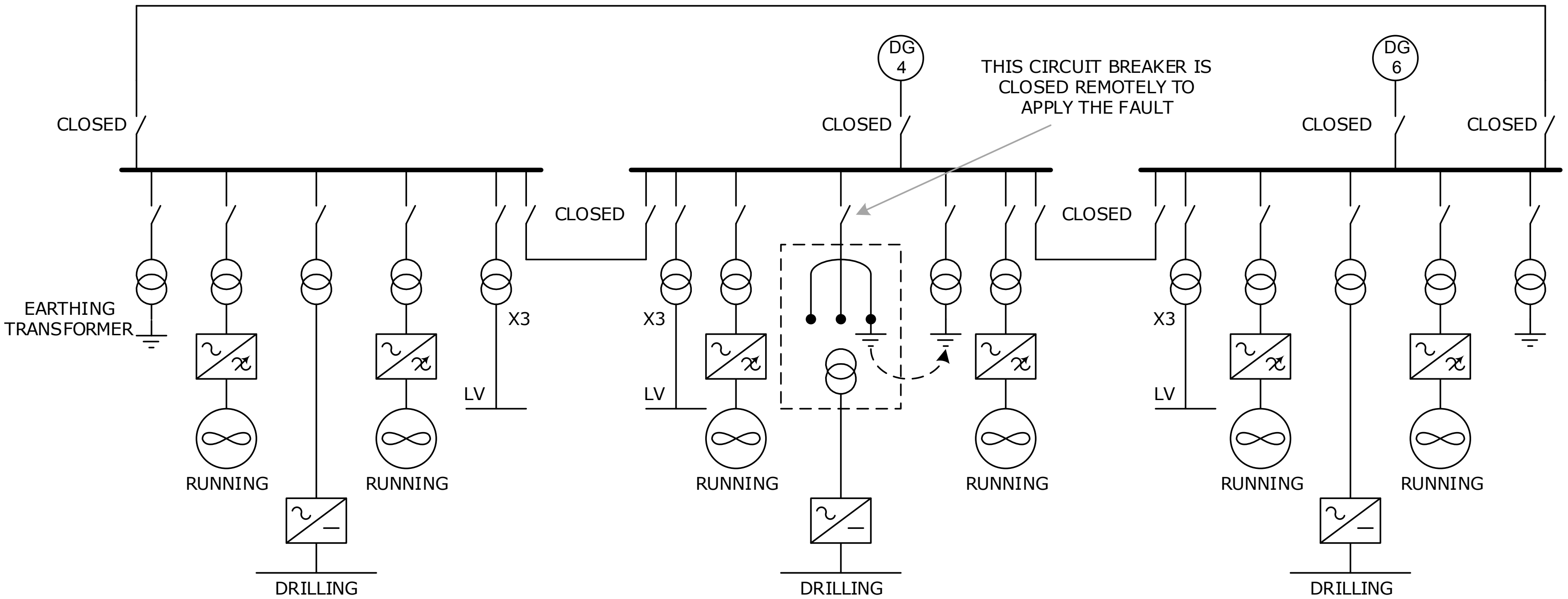
PLANT RECOVERY



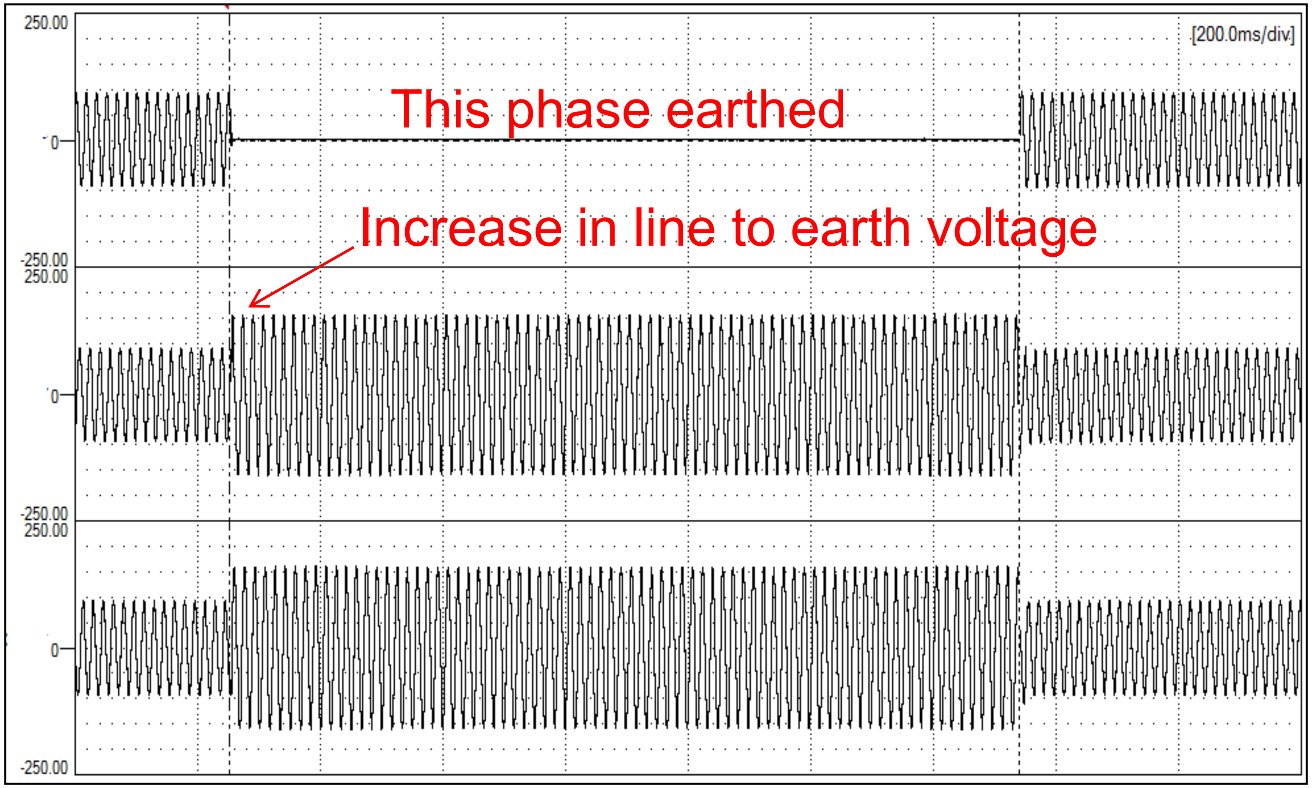
COMPUTER SIMULATION

- Time Domain Modelling – e.g. Matlab^{TM} Simulink^{TM} or equivalent.
- Real Time Digital Simulation or similar.
  - Protection relays.
  - Enhanced generator protection.
  - Drive controllers.
- Use test data to validate model predictions.

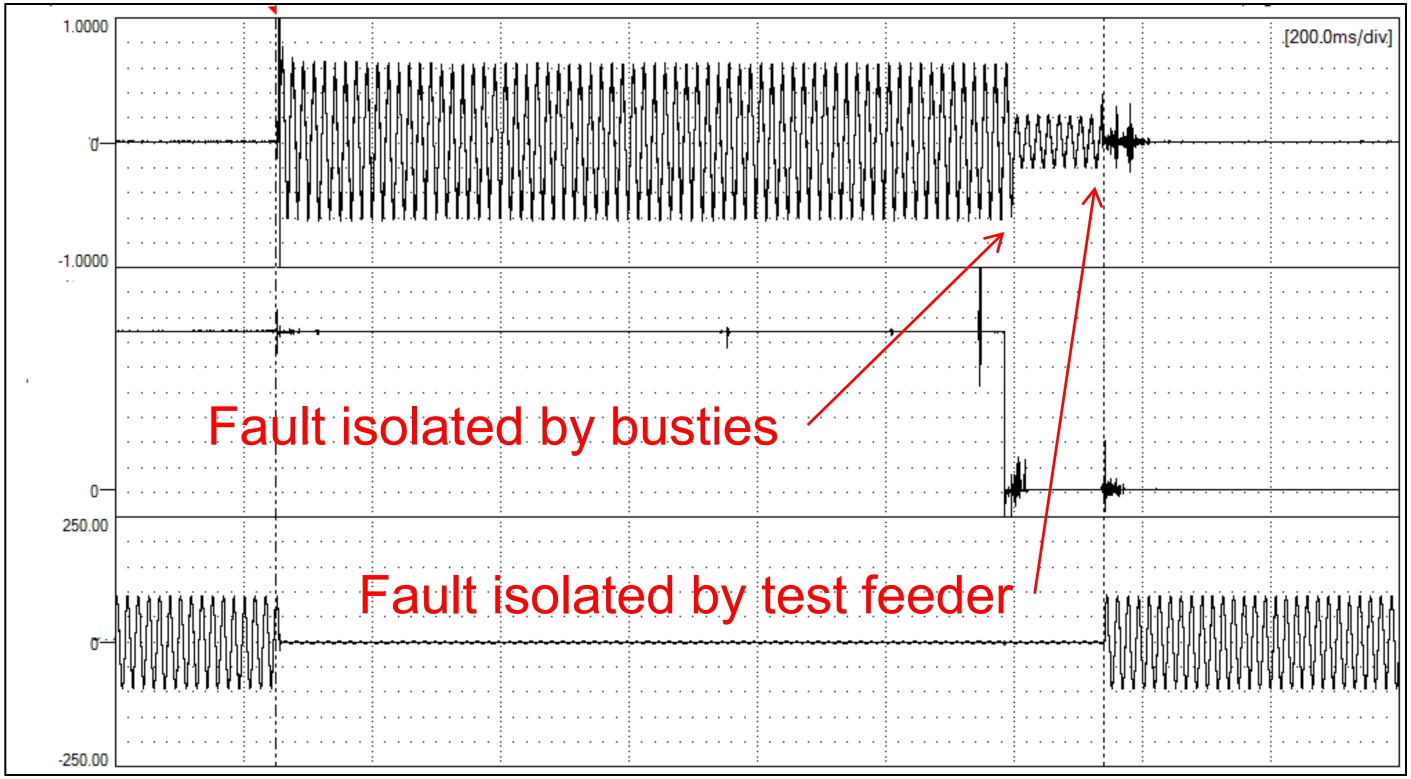
EARTH FAULT TEST



EFFECT ON LINE TO EARTH VOLTAGE



EARTH FAULT CURRENT



TEST REPORT

INTRODUCTION

- Vessel, DP system and power systems description.
- Redundancy design intent and worst case failure design intent.
- Power plant configurations and fault types to be modelled and tested.

APPLICABLE RULES, STANDARDS AND CLASS NOTATION.

TEST METHODOLOGY

- Description of test method with supporting sketches.

DISCUSSION OF SIMULATION METHODOLOGY

- Simulation package, TDS, RTDS, HIL etc. Discussion of any assumptions made in modelling of configurations which were not tested. Means by which the worst case conditions were identified.

TEST REPORT - CONT

RESULTS

- Comparison of measured and modelled waveforms.
- Comparison with the results of static studies such as short circuit calculations.
- Results of RTDS or HIL demonstrating that actual protection and control systems respond correctly.
- Presentation of worst case conditions and confirmation that the severity of the failure effect does not exceed the DP system's worst case failure design intent.

CONCLUSIONS

- Compliance with the applicable rules & requirements.

INSPECTION AFTER TEST

- Removal of test equipment.
- A general inspection of the generators used for testing could include visual inspection of:
  - End winding.
  - Auxiliary components, AVRs, CTs etc.
  - Cable terminations.

CHALLENGES

- Build to Test
  - Thruster drives may need braking resistors.
- Special cases
  - HV power plant with limitations which make it more difficult to test.
  - Older power plants – Uncertainty in relation equipment spec.
  - LV power plant.
- Complementary methods for periodic testing where required.

CONCLUSIONS

- There is a case for action.
- It is possible to carry out fault ride through testing with acceptably low risk when properly executed.
- A combination of design requirements, computer simulation and testing, produces common power systems with comparable integrity to independent power systems.