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**POWER/TESTING**

**Alternative Approaches for Demonstration of Fault Ride-Through  
Capability on DP Vessels with Closed-Bus Operation**

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## Alternative Approaches for Demonstration of Fault Ride-through Capability on DP Vessels with Closed Bus Operation

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# Abstract

- DP-2 and DP-3 vessels must survive a single failure
- Station-keeping must be maintained
- Electrical plant must withstand a fault on main bus
- Fault ride through capability must be demonstrated in closed bus
- Live short circuit testing is one established method
- Marine industry searching for standardized methods
- This paper:
  - Discusses rationale for fault ride through testing
  - Provides overview of the established test method
  - Identifies possible alternative test methodologies

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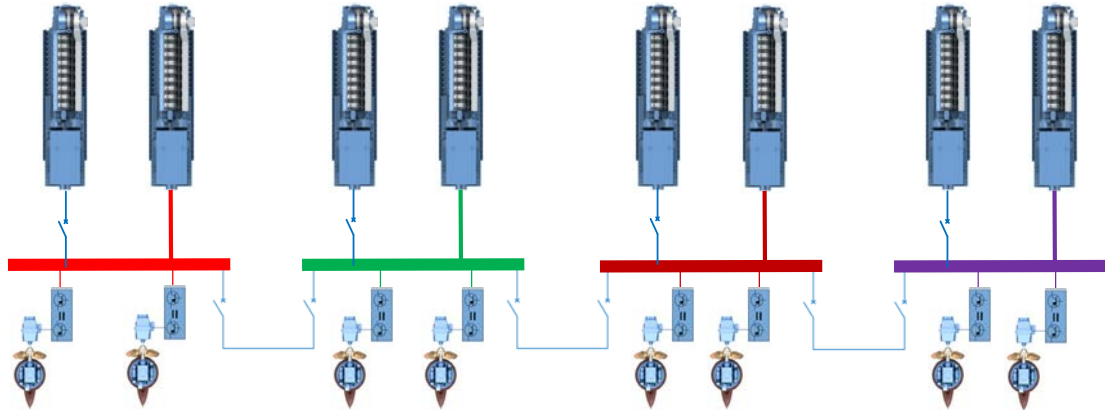
# Introduction and Background

- Traditionally open bus mode is preferred during DP
- Keeps fault isolated to the affected bus
- Operating in closed bus mode:
  - Improves efficiency
  - Reduces fuel consumption
  - Reduces harmful emissions
  - Reduces running hours on engines and life cycle maintenance
- As a result, trend is toward closed bus (common bus) mode
- Allows electrical load to be serviced with less gen-sets online
- However, electrical plant is more susceptible to single failures
- Fault ride-through capability must be demonstrated in closed bus

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# Open Bus

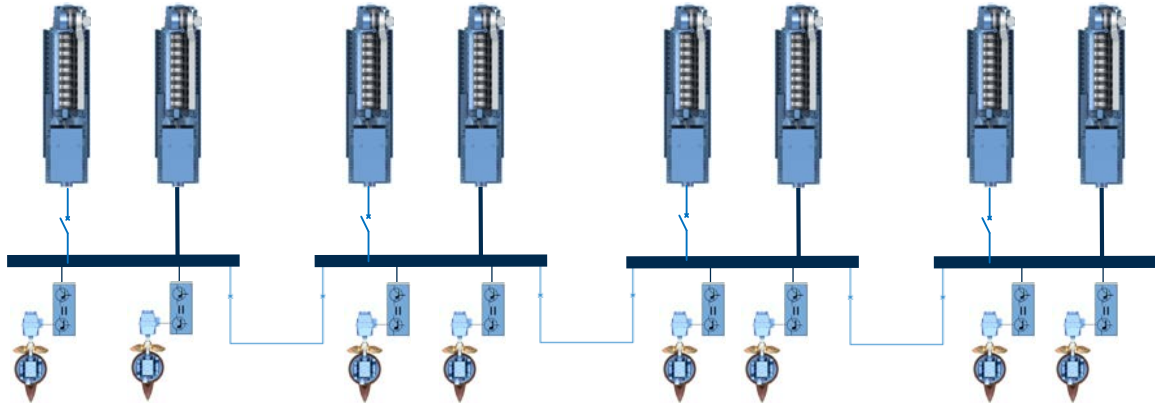
- Eliminates single point of failure
- Disturbance is isolated to the affected side
- Maximized redundancy/fault tolerance
- Each redundancy group works electrically separately and independently from the others



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# Closed Bus

- Reduced emissions, reduced fuel consumption
- Improved efficiency, reduced running hours & lifecycle cost
- Each redundancy group is electrically joined with all the others -> **Susceptible to single failures**



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# Recent Incidents

- DP Drillship Incidents
  - Single electrical disturbance caused loss of all thrust
  - Online thrusters did not “ride through” the disturbance
  - Loss of station keeping, emergency disconnect sequence
- Consequence
  - DP Failure Modes and Effects Analysis (FMEA) proving trials and annual trials methods needed improvement
  - Must verify and validate a fault ride through capability
  - Industry implementing more robust testing methodologies

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# Discussion

- Effects of a Fault on Common Closed Bus:
  - Severe voltage transient may cause equipment to trip
  - Upstream loads may trip if fault not isolated quickly
  - Large variations in kW load may occur
- Traditional Evaluation Methods
  - Short circuit study
  - Coordination study
  - Voltage dip calculations
  - Stability study
- Compliance is not normally verified by shipboard testing
- **On a DP-2 or DP-3 vessel, it must be verified that the electrical systems can be safely operated in a closed bus and can withstand a single main bus fault**



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## Industry Guidance Established

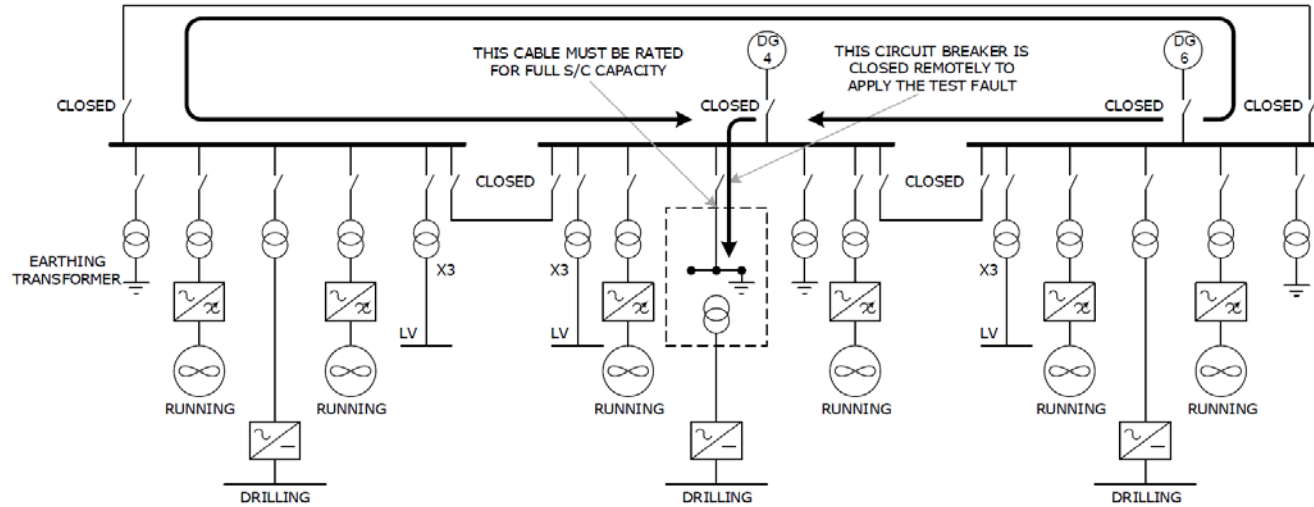
- USCG Safety Bulletin: Where ride-through capability is an essential part of the DP redundancy concept it should be proven by live short circuit testing
- Marine Technology Society (MTS) Techop: Method for Proving the Fault ride-through Capability of DP Vessels with HV power plant
- ABS Guide for Dynamic Positioning - The test procedures are to be based on the simulation of failures and is to be carried out under as realistic conditions as practicable
- IMCA Information Note IMCA M 06/16, DP2 and DP3 Common Power Bus Operation – Identifies Available Guidance for Demonstrating the Dependability of Common Power Bus Arrangements

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## Live Short Circuit Testing per MTS Techop 09

- Apply a low impedance connection on a major feeder
- Close test breaker to simulate a short circuit fault
- Overcurrent protection opens the bus-tie
- Fault isolated to one redundant machinery group
- Healthy part of the plant continues without malfunction
- Proves that system can ride through a major fault

# Typical Arrangement Fault Ride-Through Test



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# Advantages

- This test induces a short circuit with the minimum impedance possible so as not to limit the short circuit current and so demonstrates the capabilities of the system to ride through this condition without losing power to the propulsion systems
- The main advantage of this test method is that the test results may be used to validate the analysis provided by advanced computer modelling and simulation
- It is important to understand that this test supports the model and associated simulations by demonstrating an actual fault ride through and that it is not to be used in isolation from modelling and simulation

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## Disadvantages

- The disadvantages are that the test needs to be carefully managed to avoid exposing persons to danger and the risk of damaging equipment, inducing potential latent equipment failures thus reducing its expected life
- Some equipment manufacturers may not honor the terms of their warranties if such testing is carried out
- There is no certainty that the short circuit created is the condition most likely to result in a loss of power
- Operators need to be aware that equipment is only capable of accommodating a limited number of short circuit tests before needing replacement, this is particularly pertinent if the initial testing is not seen as validating the expected modelled and simulated analysis

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# What are we really trying to verify?

- Voltage transient ride through:
  - No electrical equipment required to maintain station-keeping will trip off-line when a system-wide momentary voltage transient occurs under short circuit conditions
- Selectivity/Discrimination:
  - Protective devices closest to the fault will trip in a coordinated manner thereby isolating the fault to the affected circuit
- System Stability:
  - Once the fault has been cleared, the remaining generators will remain on-line and recover from the system-wide disturbance to maintain power to all loads required for stationkeeping

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# Live Short Circuit Test Limitations

System Attribute	Fully Tested?	Explanation
Voltage transient ride through	Yes	Since voltage transient occurs throughout the plant, all devices will be proven to ride through the fault
Selectivity	No	Only the devices nearest to the test circuit are tested for proper selectivity
Stability	No	Only demonstrated for one configuration with limited number of generators online

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## Alternative Methods to Consider

- Effort has been made to identify viable alternative tests or simulation methods to demonstrate fault ride through
- These methods should be considered as possible alternatives for fault ride through testing on DP vessels
- While some of these methods have advantages over others, and some are not complete tests of all three characteristics, they may be used in different combinations to achieve the same purpose as live short circuit testing
- International Marine Contractors Association (IMCA) has developed an information note (per reference 3) that provides a list of alternative testing and analysis methodologies that can be used to establish the dependability of a common power bus arrangement



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# Alternative Methodologies

Alternative Methods to Demonstrate the Dependability of Common Power Bus	
Formal risk assessment	Inducing a voltage dip by automatic cycling circuit breakers
Advanced computer modelling and simulation	Simulate circuit breaker fault response by injecting a measured control signal into the breaker controller/programmable logic controller (PLC)
Simulating a voltage transient by starting a large load	Use of a load bank to simulate short circuit conditions
Creating a voltage dip using the automatic voltage regulator (AVR)	Construct a replica switchboard in a testing facility
Use of variable speed/frequency drives to simulate bus fault conditions	

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## Closed Bus Notation

- Another proposal that has been considered is to assign a special “Closed Bus” notation to represent the type and level of testing/studies to be performed and then leaving it up to the vessel owner to select the desired notation as appropriate for the specific vessel design and level of redundancy
- The notation would represent the type and level of testing and analysis to be performed
- This may range from the normal DP FMEA and DP FMEA Proving Trials, to special studies and simulations in a controlled environment, to full scale fault ride through (live short circuit testing) on the ship as per the MTS Techop with built-in, full scale (full voltage, full current) test capability for periodic testing. arrangement

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## SV and ISQM Notations

- Lastly, for DP vessels where electrical systems that rely on software based safety functions there are rigorous software verification and validation procedures that can be adopted (i.e. Hardware in the Loop (HIL) testing, Software in the Loop (SIL) testing) as outlined in the ABS Guide for Systems Verification (SV) to enhance safety for safety critical functions (Safety Integrity Level 2 or 3)
- Additionally, rigorous software quality assurance procedures can be adopted as outlined in the ABS Guide for Integrated Software Quality Management (ISQM) in order to enhance the reliability of safety critical software based functions on DP vessels

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## Conclusion

- Live short circuit testing in tandem with advanced computer modelling and simulation has been established as one standardized method of verifying and validating fault ride through capability of DP-2 and DP-3 class vessels operating in a closed bus configuration
- In response to queries for possible alternative approaches to live short circuit testing, viable alternative testing methodologies have been proposed and are being considered by industry

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# Recommendations

- Standardized test methods should be discussed further with industry and regulatory agencies
- A definitive list of alternative standardized test methods should be fully developed and distributed for industry comments
- Once consensus is reached, the list acceptable methods for testing or simulating fault ride through should be published for guidance

