Closing the Station Keeping Integrity Gap Between DP Power Plant Configurations using Open and Closed Busties

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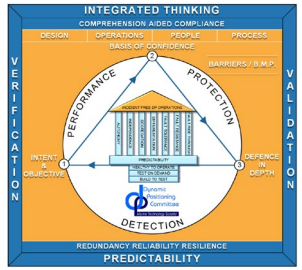


What why when and how

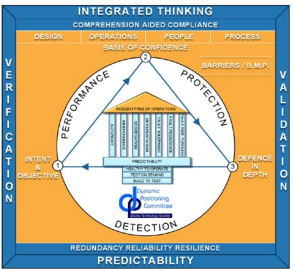
Introduction what why when and how

Closed Busties & SKI – What are they?

- What is station keeping Integrity?
  - Station Keeping Integrity is a subjective and qualitative term used widely in the DP community to describe the reliability, robustness, and resilience of a DP system. That is to say its ability to:
    - Operate predictably on DP without suffering
      - Loss of redundancy
      - Loss of position

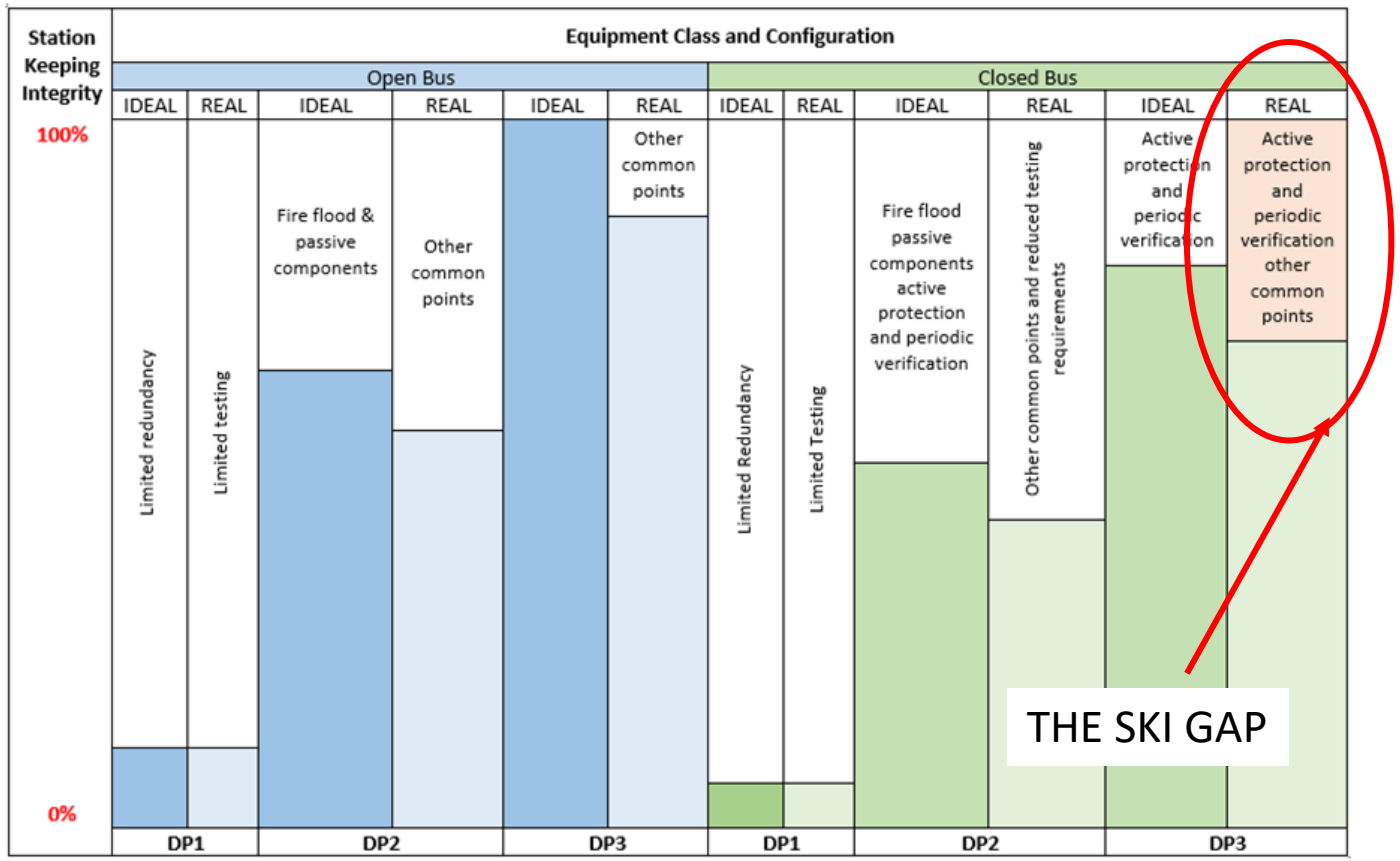
      for an acceptable period of time

      As a minimum, position and heading must be maintained for long enough to safely terminate the DP operation
    - Resist the effects of failures and recover from their effects
    - Demonstrate resilience to failures.

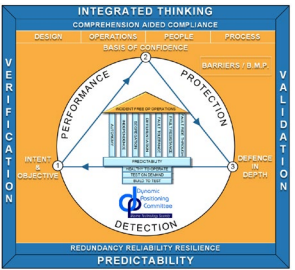


- What is meant by open and closed bus?
  - Open Busties – Two or more independent power systems isolated from each other by open busties – independence based on the passive protection afforded by physical separation.
  - Closed Busties – Two or more independent power systems coupled together through closed busties – Barriers to a common cause of failure are achieved by active protection systems and essential attributes.

Why is there an integrity gap and Why does it need to be closed?



- Corporate and societal expectation for reductions in greenhouse gas emissions.
- Push to find alternate solutions to address spinning reserve requirements in lieu of running additional DGs and at low loads.
- As a means to allow single generator, single BESS configuration in some hybrid DP vessel power plant designs.
- Improved power plant efficiency.
- Reduced wear and tear.

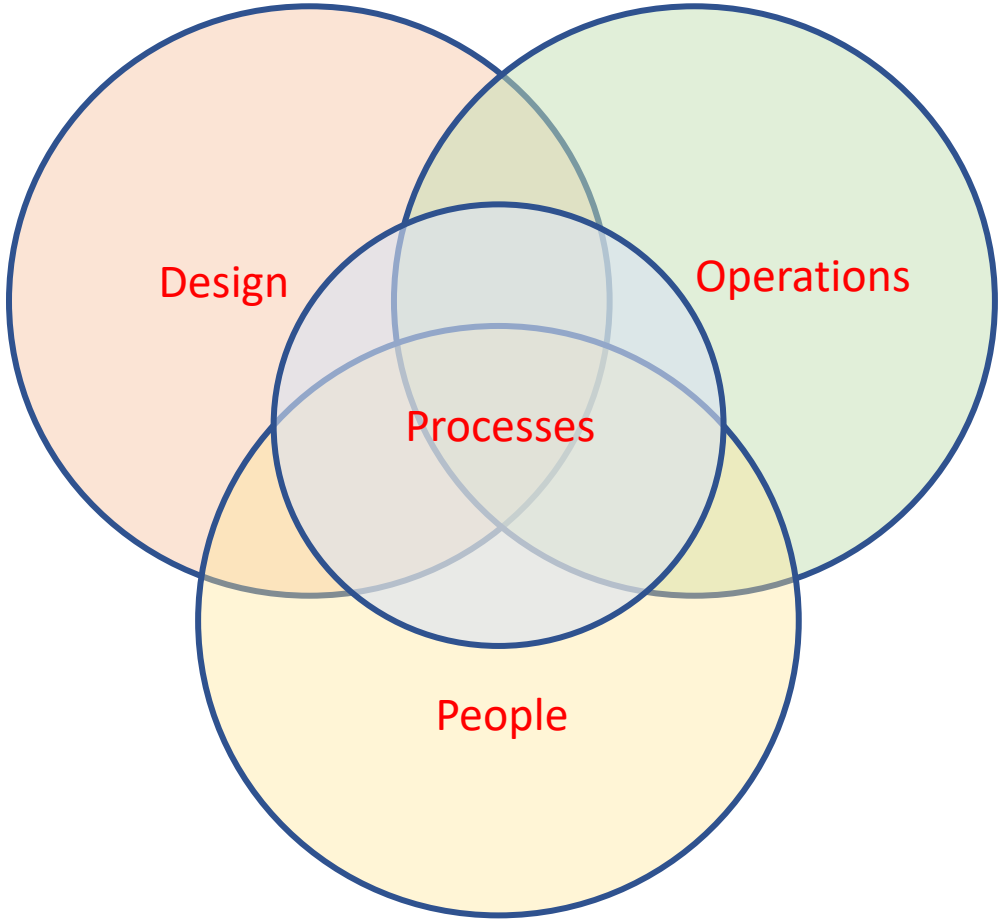


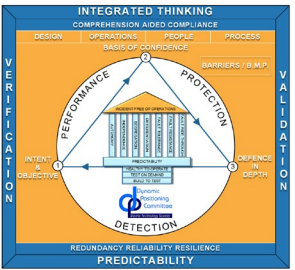
REAL Vs IDEAL - DP2 Vs DP3 - OPEN Vs CLOSED

How do we close the integrity gap?

Attention to elements of:

- Design
- Operations
- People
- Processes





Design

Design Operations People & Process

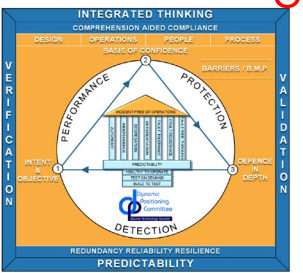
Vulnerabilities in closed bus power systems

Not a **comprehensive list** but some of the better and less-well known issues and limitations:

- Generator fuel control and excitation failures
- Lack of fault ride through capability

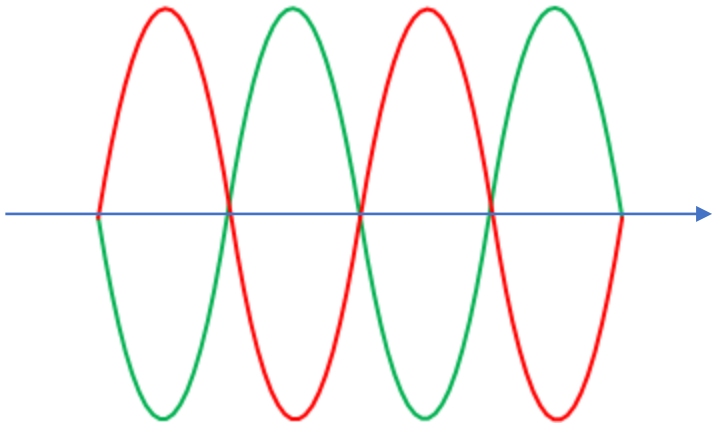
} Well known - See paper

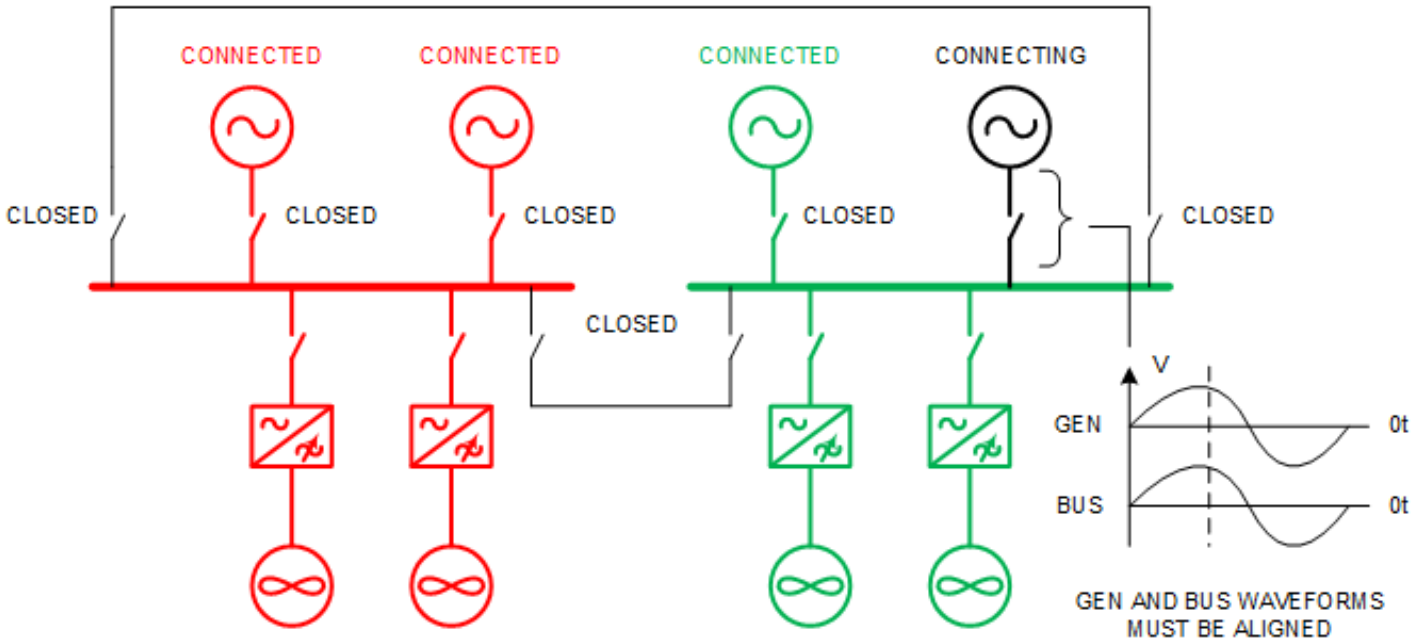
- Crash synchronizing of generators and busties Inadvertent connection of stopped generators.
- Intermittent ground faults, transient phenomena and arcing faults.
- Logical links dependencies in software.
- Vertical dependencies within redundant groups associated with common modes of failure.

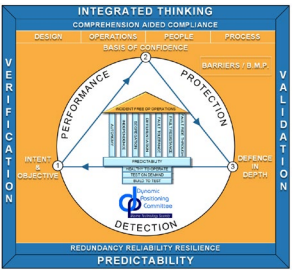


Generator connection faults (synchronisation & dead bus)

- Crash Synchronisation
- Inadvertent connection
- Dead bus closure (tokens)



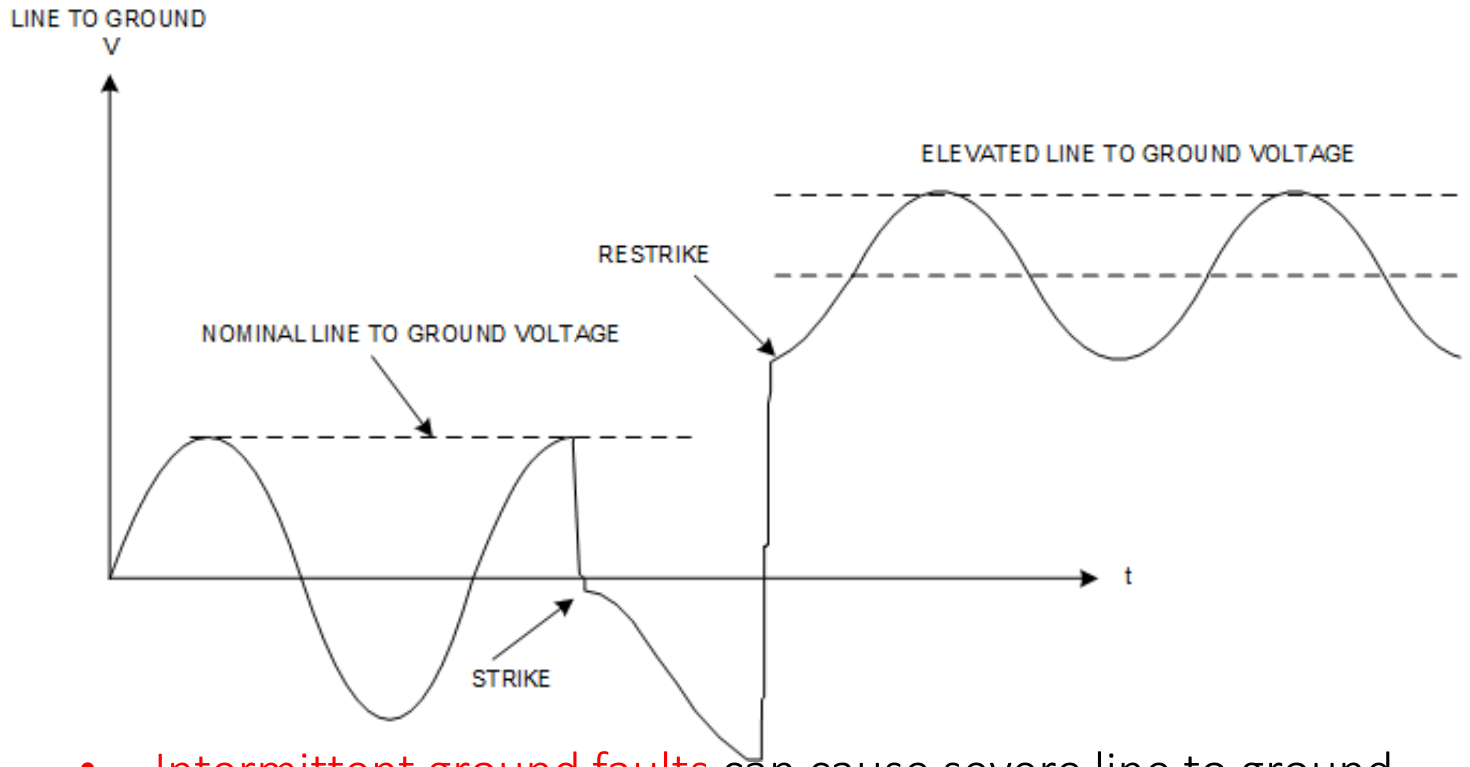




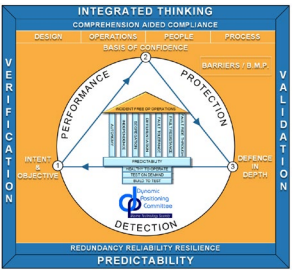
Worst case – completely out of sync – damage may ensue – power system must withstand effects

Line to ground overvoltage

- In a three-phase power system, quantities such as:
  - Voltage
    (line to line & line to ground)
  - Current
  - Frequency
- Must be kept within a nominal range of values or protection operates to isolate the cause of the power system upset.
- Line to ground voltage is the voltage from any one the three phases to the ship's hull.

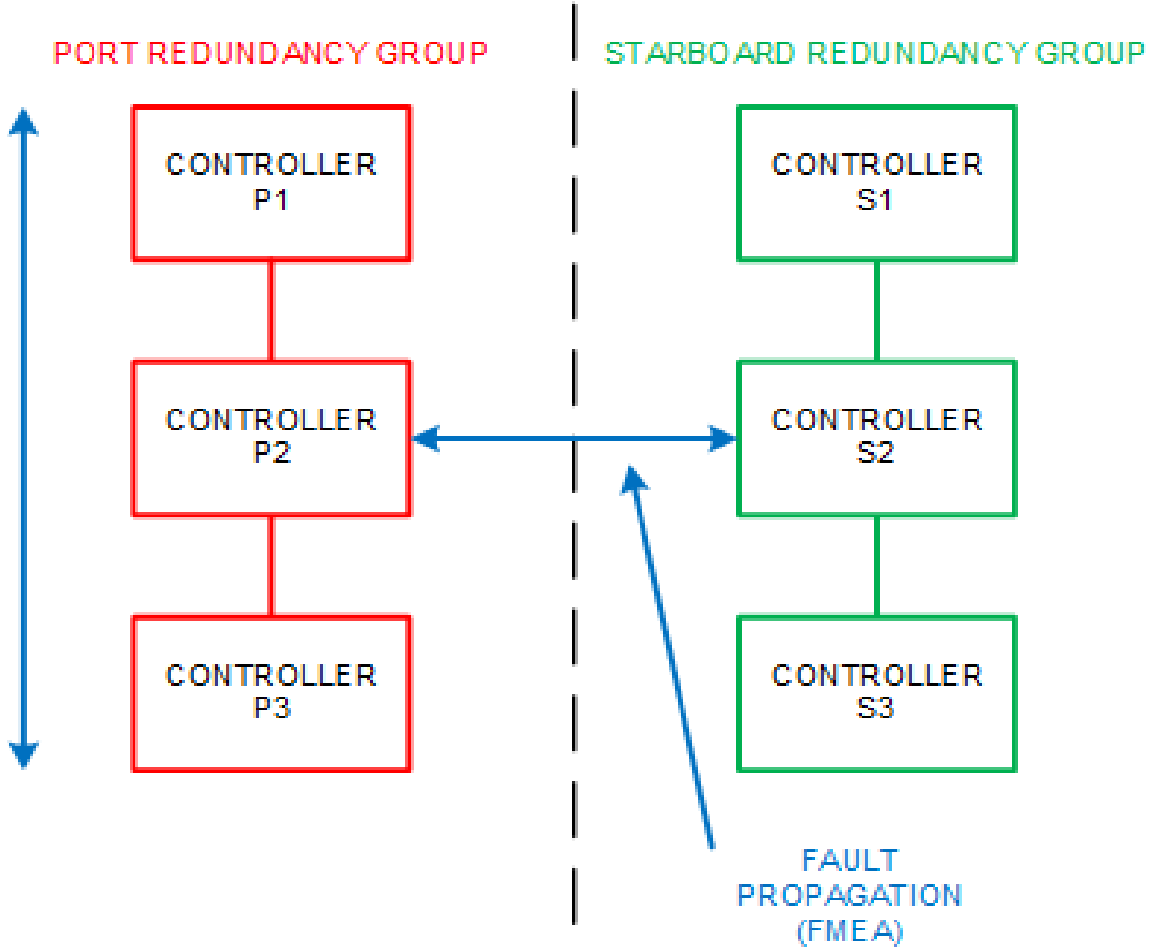


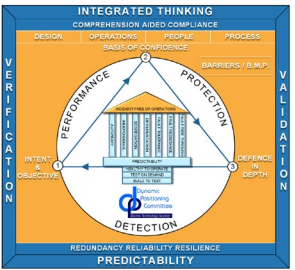
- Intermittent ground faults can cause severe line to ground overvoltage.
- Capable of destroying insulation and power components that are ground referenced – Also control power consumers derived from main bus.



Software – Vertical dependencies & analysis methods

- DP FMEA is heavily focused on fault propagation between redundant DP equipment groups.
- Limitations of DP System FMEA:
  - Software not considered
  - Not every unsafe condition results from a failure (e.g. design flaws & software errors)
- Other methods better suited to analyzing control functionality – Example - System Theoretic Process Analysis – STPA – JDP on DP System Integration

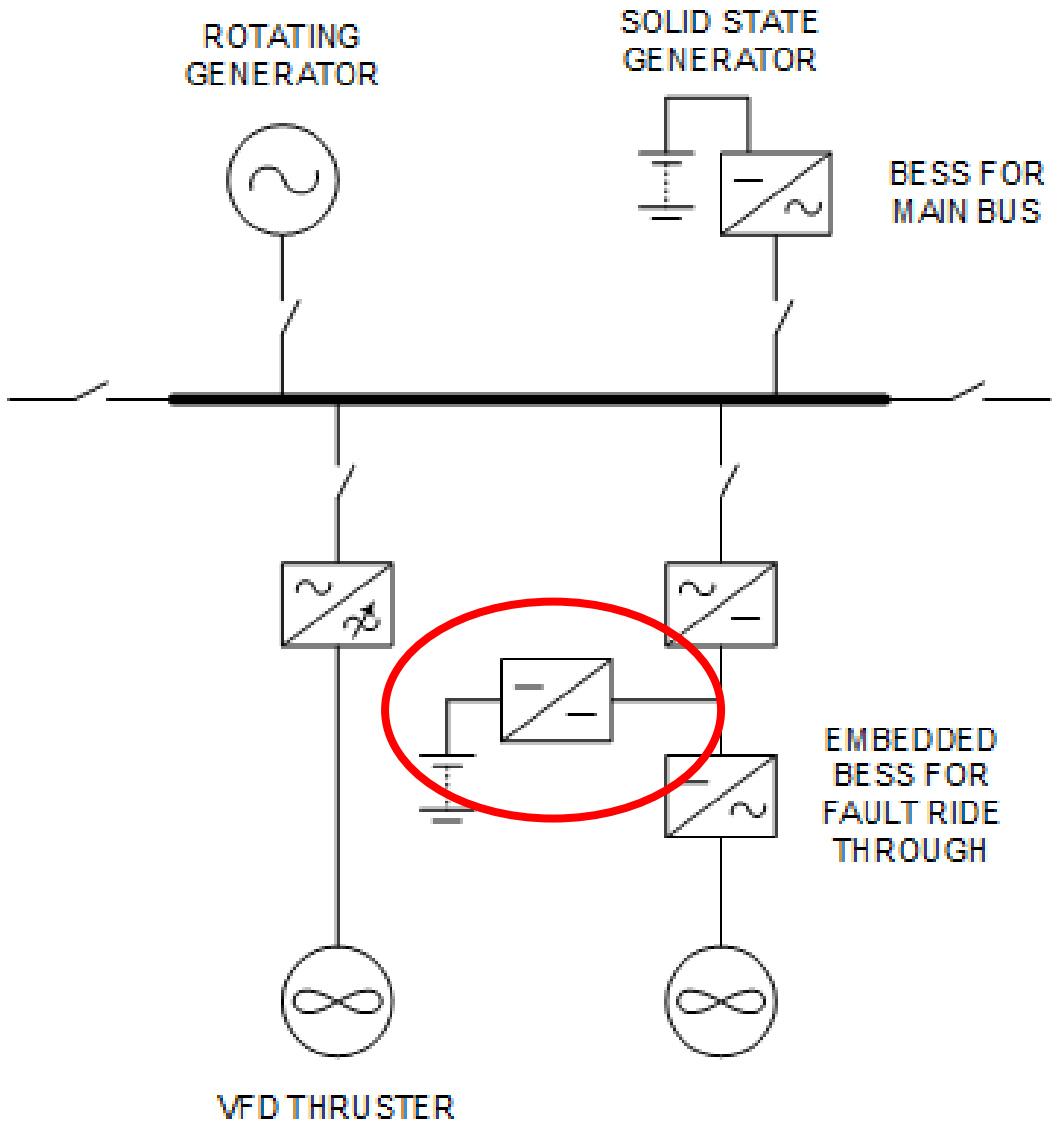


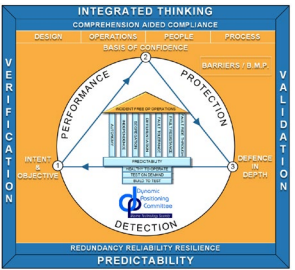


BESS

Battery Energy Storage Systems (BESS)

- BESS added to power system for various reasons:
  - Electronic spinning reserve (redundancy)
  - Peak shaving
  - Load acceptance
  - Ride Through capability
- BESS introduce their own modes of failure to a power system.
- BESS must be located at the thruster level to provide thruster ride through capability.



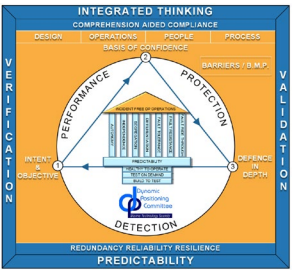


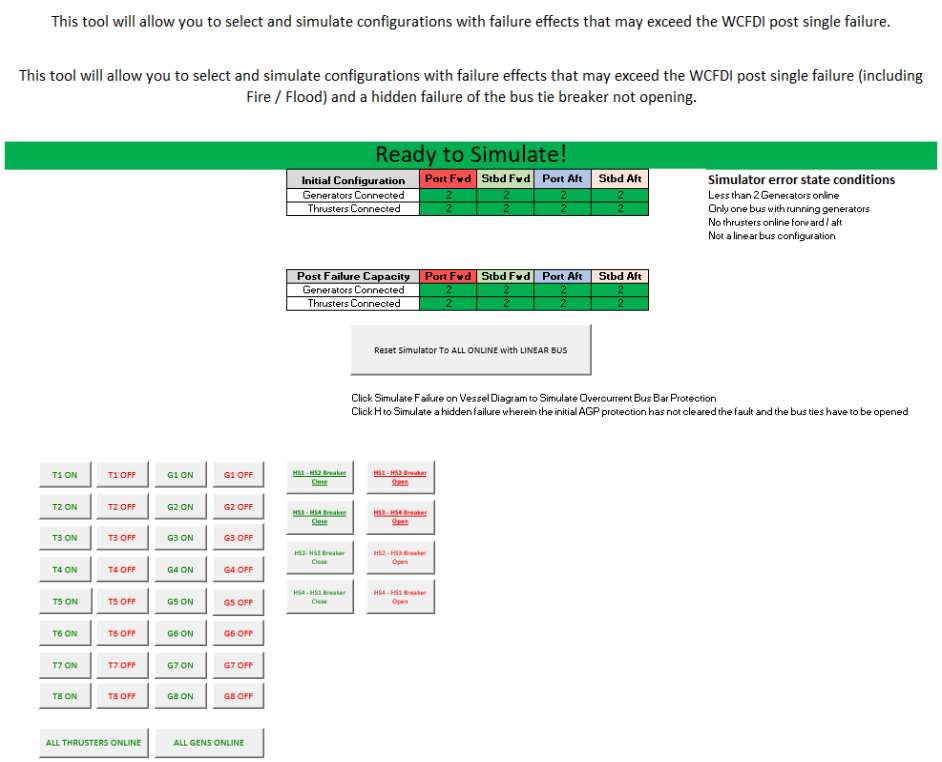
Operations

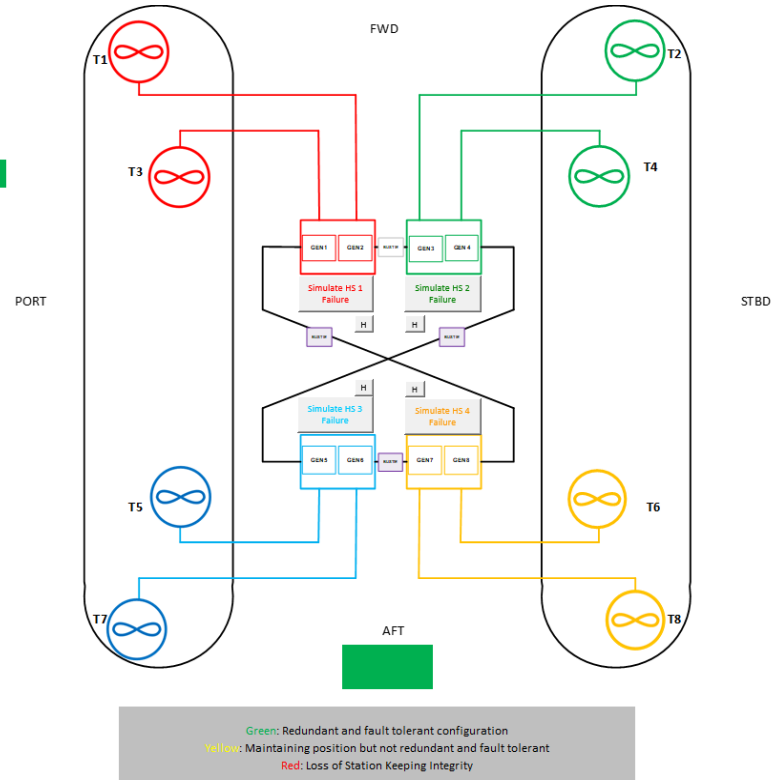
Design Operations People & Process

Operations Planning - When

- The process of DP operations planning should not be dissimilar to that for operations planning with open busties (when there is full confidence)
- ASOG / WSOG: A more granular approach may be taken to identifying activities which have high consequences on position loss where there may be value in taking a pragmatic approach and operating with all generators & thrusters online and the busties open.
- Decision Support Tools can help the crew visualise the vulnerability that arises from operating multi bus systems with one bus powered by its tie lines.







People & Process

Design Operations People & Process

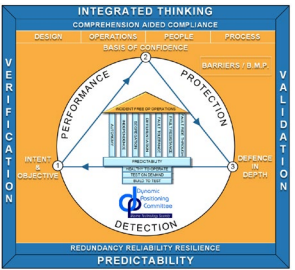
People & Processes

Development and validation of DP system design philosophy (RCPD)

- **Build to Test** – Reduced test anxiety (adequate margins for testing established).
- **Test on Demand** – Reduce test burden. associated with complex protection systems.
- **Healthy to Operate** – Ease burden of detecting degradation and hidden failures.

Verification and validation of design and build

- Mathematical modelling.
- Validated models.
- Extend test capability – Cascade Waveform Injection Testing – Independent Performance Verification.



People

- Critical alarms.
- Awareness of:
  - degradation of performance.
  - Hidden failure of on-demand functions.

Test anxiety (clipboard syndrome!)

- Initial verification
- Periodic verification.

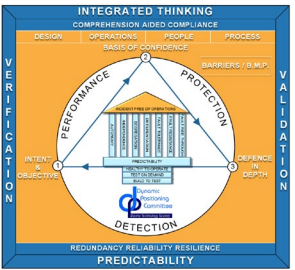
Countering test anxiety

- Design and build power and control systems that are designed for the test conditions to which they must be periodically subjected.
- Design closed bus power, control and protection systems that do not require aggressive testing to prove their fault tolerance
- Make use of power system test-lab facilities for aggressive testing of protection systems where not required to use vessel power plant.
- Develop alternative test methods that provide the same level of confidence as a more realistic test.

Conclusions

Delivering on societal expectations (GHGER & SKI)

- All themes require focus - **Design Operations People and Process**.
- Minimise fault propagation paths.
- Deploy advanced verification and validation tools.
- Maintain a learner mindset – be aware of developments in other industries and new rules (lessons learned).
- Extend V&V to software and control functionality (JDP).
- Design for the rigours of initial and periodic testing.
- Reduce the periodic test burden – CWIT & IPV (previous MTS papers).
- Provide redundant protection systems – SKI is heavily dependent on active protection and protection system are all potential hidden failures.
- Relieve the cognitive burden through DSTs.



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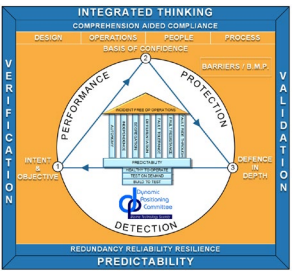

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