The following case studies and observations have been compiled from information received by IMCA. All vessel, client, and operational data has been removed from the narrative to ensure anonymity. Case studies are not intended as guidance on the safe conduct of operations, but rather to assist vessel managers, DP operators and DP technical crew in appropriately determining how to safely conduct their own operations. Any queries should be directed to IMCA at dpreports@imca-int.com. Members and non-members alike are welcome to contact IMCA if they have experienced DP events which can be shared anonymously with the DP industry.

The following case studies have been chosen in order to create discussion points for all Key DP personnel. The events have already taken place but, what could have been done differently? Hindsight is a wonderful thing, but these cases allow us to stop, think and positively learn lessons that can be carried into future DP operations.

The IMCA DP Committee has contributed to each of the studies adding their knowledge and experience.

1 Case Study – Closed Bus – Knowing the Risks

1.1 Overview of event

A blackout and subsequent failure of the automatic blackout recovery systems occurred on an offshore construction vessel. The DP system was designed around a three-way split in the redundancy concept which had been certified and tested for closed bus operation by the responsible classification society. At the time of the incident, the vessel was operating in a closed ring configuration with one generator connected to each bus.

The vessel's blackout recovery system was tested on a regular basis. During these tests, it was common to have all six thrusters back into DP Control within 25-30 seconds of a full blackout. Individual bus sections were also tested on a regular basis in order to confirm the recovery of a single blacked out bus (redundancy group).

Prior to the incident, the vessel had been experiencing intermittent neutral to ground overvoltage alarms on one of the offline generators which occurred immediately after the generator was disconnected from the bus and running offline. The event investigation was able to establish a link between the alarms and the effects of one pole of a generator vacuum circuit breaker pole conducting voltage onto the bus (breaking down) while open. The protection system detected the neutral over voltage excursion caused by the faulty circuit breaker and the generator breaker was locked out from reconnection by the protection system, but this action alone was not sufficient to prevent the fault escalating. The situation escalated to a blackout and subsequent failed automatic blackout recovery as follows:

- The faulty generator was disconnected and left running offline. The faulty generator was kept running at rated speed and voltage in an attempt to reconnect to the bus. The control system deemed this generator as healthy even though its protection relay tripped and latched on the neutral overvoltage alarm.
- During this time, the breakdown across the faulty generator circuit breaker single pole caused a steady-state overvoltage condition on the other two healthy phases, saturating the ferro-magnetic core of the two generator Voltage Transformers (VTs) connected to these phases. The sustained operation in the saturation region caused the sequential failures of the two VTs.
- The second VT failure, which occurred while the two phases were in a steady-state overvoltage condition, caused a series of voltage surges that exposed the entire 11kV bus through the conducting faulty circuit breaker pole.

- These voltage surges travelled through all connected generators' VTs as well as to all bus VTs to all voltage sensing circuits within all switchboards in the ring bus. Elements of these control circuits failed, causing an over-current condition which tripped the over-current protection on all the switchboards VTs. This caused all generators and thrusters to trip, disabling automatic blackout recovery and manual control over the switchboards.
- The vessel drifted off station. Manual control over the switchboards was restored by resetting the VT circuit breakers.

1.2 What can be concluded?

- The generator protection relays identified the condition caused by the single pole break down failure in the faulty generator, but the action associated with this condition was not effective in isolating the failure and prevent its propagation.
- There were unidentified failure modes in this vessel design that could cause a blackout and disable both automatic recovery and manual control.
- The damaged controllers for the switchboards could not withstand the over voltages created by this type of failure.

1.3 How can lessons learned from this event be applied to prevent future DP incidents?

- It cannot be assumed that faults detected by the protection system on a generator running offline will be confined to that generator even though its circuit breaker is open. Shutting down a faulty generator will eliminate the risk of fault transfer associated with single pole breakdown in a vacuum circuit breaker, but other mitigating measures may be required to limit fault propagation from all possible causes (example automatically opening the bus ties).
- The main bus ties should be opened and remain open until the true nature of the fault is understood and rectified (if in doubt open the bus ties).
- All parts of a DP system power plant should be rated to withstand the maximum failure effects and conditions that can be experienced during a fault. The maximum conditions should be calculated as part of the design process and the equipment rating selected accordingly or measures to prevent overvoltage reaching damaging levels included in the design, which should be proved through testing.
- Grounding system must be designed to limit steady-state voltage escalation and to effectively dampen voltage oscillations caused by intermittent faults.
- Consideration to install high speed data logger on 11kV power plant protection and control system.

1.4 Relevant guidance

The following IMCA Guidance would be relevant to this case study:

- IMCA M 220 – *Guidance on Operational Planning*
- IMCA M 103 – *Guidance for the Design and Operation of Dynamically Positioned Vessels*
- IMCA M 166 – *Guidance on Failure Modes and Effects Analysis (FMEA)*

2 Case Study – Vessel Degraded Capability

2.1 Overview

A PSV was conducting DP operations in an open bus 2-way configuration. The vessel had 2 redundant groups, each with 2 generator and 2 azimuth thrusters.

The Worst Case Failure Design Intent (WCFDI), was stated in the FMEA as:

'No single failure as defined for notation XXX will have a greater effect on the vessel's ability to maintain position than the loss of one switchboard (REDUNDANT GROUP), resulting in loss of two thrusters (one fwd and one aft) and two generators. This design intent applies when the power plant is configured as two independent power systems. This design intent applies when each of the two power systems has generators connected.'

The Worst Case Failure (WCF) identified from analysis of the DP system on the vessel is loss of the port engine room due to an auxiliary failure, this would cause the loss of the two generating engines, Switchboard, Azi 2 & BTT1, with BTT1 being the most forward thruster.

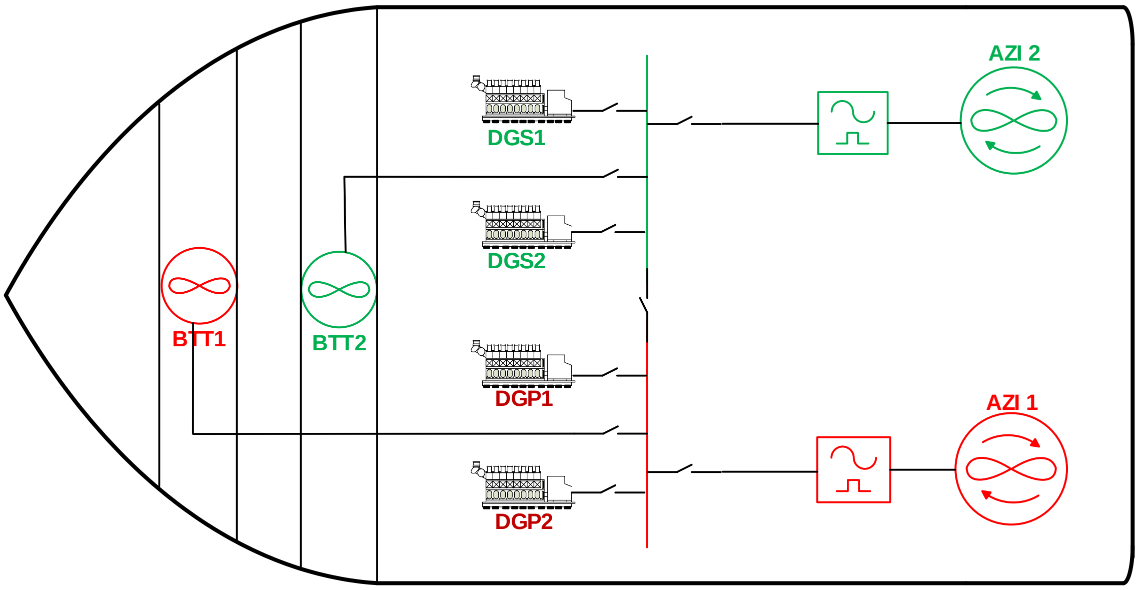

Figure 2-1 Thruster Setup

2.2 Observation – Complacency of redundancy concept

As demonstrated during the DP FMEA Proving Trials and subsequent Annual DP Trials, the vessel is effectively capable of losing one of the two redundant groups after a single failure. The vessel will then be able to maintain its heading and position within the remaining in-tact redundant group.

At the time of this particular operation there were deficiencies within both of the redundant groups:

- Azi 1 had hydraulic issues on the azimuth circuit which meant it was required to be in 'Fixed' DP Control mode.
- BTT2 was very sluggish in following the DP Command and was continually activating feedback alarms.
- Due to a leaking turbocharger, Generator DGP2 was only to be used in an emergency, and if used, not to exceed 50% power.

All shore support personnel and vessel personnel were aware of the problems, but the client was unaware. Regardless, the vessel continued to operate in the vicinity of stationary structures.

2.3 What can be concluded?

The vessel is degraded in its intact and post failure capability, and is no longer single fault tolerant.

If the Port redundant group fails, the vessel will be left with a subpar bow thruster that could be lost from DP Control at any time.

If the Starboard redundant group failed, the vessel would be left with a subpar azimuth thruster that could be rejected by DP Control at any time. The port redundant groups generating capacity is severely constrained because there is no confidence in DGP2's ability to supply adequate power.

An in-depth evaluation could have been performed to determine post-failure capability, resulting in an update to ASOG. This would ensure client transparency, and DPOs would be fully aware of the vessel's reduced capability.

2.4 Additional comments

Commercial pressures maybe at play from both the vessel owner and client – Has the vessel been allotted enough time within the contract to carry out routine maintenance?

- Vessel crews should use decision support tools, such as the ASOG to manage station keeping risk.
- Vessel crews and managers should have a full understanding of their vessel's redundancy concept, post failure DP capability and the performance requirements following the worst case failure.
- Vessel crews and managers should be aware that when 100% power is not available from a single bus or generation of a group, the ASOG power limits and thruster percentage limits should be reduced to maintain WCFDI.
- The purpose of field arrival trials is to ensure satisfactory operation of the DP system. The checks should include full functional checks of the operation of the thrusters, power generation, auto DP and IJS and manual controls.

2.5 Relevant guidance

The following IMCA Guidance would be relevant to this case study:

- IMCA M 220 – *Guidance on Operational Planning – the whole* document
- IMCA M 103 – *Guidance for the Design and* Operation *of Dynamically Positioned Vessels* – Sections 2.7, 2.12 (first part), 2.14, 3.44, 3.5 and 3.7
- IMCA M 117 – *The Training and Experience of Key DP Personnel – the whole document*

3 Case Study – Open Bus Saved the Day

3.1 Overview of event

A DP2 vessel was conducting trenching operations within a wind energy field. The vessel was operating open bus with two redundant groups. The vessel has a retractable thruster that can be supplied from either redundant group at this time it was being supplied from the port redundant group. This left the starboard redundant group with on azimuth thruster aft and a bow tunnel thruster.

The port redundant group experienced a blackout during the trenching operation, resulting in the loss of three of the five thrusters. The vessel maintained position on the two remaining thrusters in the starboard redundant group. Once deemed safe to do so, the retractable thruster was reconfigured and re-connected to the starboard switchboard. It has to be noted that the retractable thruster needs to be eliminated as the possible cause of the blackout before it can be re-configured into the healthy redundant group.

The cause of the blackout was traced back to a short circuit within the drive of the aft azimuth thruster, which propagated the fault up to the port switchboard and causing the blackout.

There was no loss of heading or position reported.

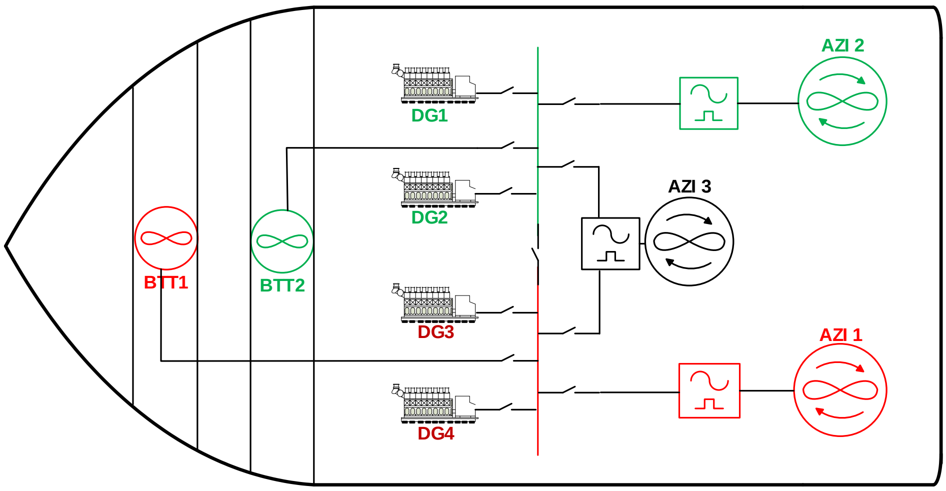

Figure 3-1 Overview

3.2 What can be concluded?

- The vessel operating within its post WCF environmental conditions prior to the loss of a redundant group.
- Had the vessel been operating closed bus can the operator be confident that the bustie would have opened isolating the fault to a single redundant group? Has the vessel been through the prescribed verification and validation in order to allow confidence that the protection systems would have isolated the fault to a single redundant group?

3.3 Relevant guidance

The following IMCA Guidance would be relevant to this case study:

- IMCA M 117 – *The Training and Experience of Key DP Personnel*
- IMCA M 220 – *Guidance on Operational Planning*

4 Case Study – Closed Bus Ruined the Day

4.1 Overview

A DP 2 Cable laying vessel was working closed bus within a wind farm, two out of the four generators were connected to the bus. Each connected generator was loaded to approximately 55% kW load, as stated in the vessels ASOG/TAGOS.

4.2 What happened?

An alarm was activated on the vessel management system indicating to the operator that there was a problem with the power balance on the bus along with bus frequency alarms. The operator in the ECR observed that one generator was at full load while the other generator was at negative load, shortly after this the thrusters started to phase back, causing the vessel to drift off position.

The normal operating frequency of the bus is 50Hz. An observant control room operator would have observed that the frequency on the bus was now reducing to 43Hz, however as the thrusters phased back the frequency would rise and the thrusters would attempt to ramp back up, as they did the frequency would fall again, this cycling effect was causing multiple continuous alarms. The control room operator took the decision to e-stop the highly loaded generator, the vessel immediately blacked out.

The vessel lost heading and position resulting in damage being sustained to the cable, vessel and a monopile when the vessel made contact with one of the monopiles located in the field.

4.3 What can be concluded?

The following can be concluded:

- The vessel did not have the necessary protection that would automatically open the bustie, isolating the fault to a single redundant group. Which would have equaled to the WCFDI.
- The vessel did not have the necessary protection functionality to disconnect the faulted generator, this would have prevented a blackout.
- Operating closed bus within the wind field with fixed structures was clearly not considered a Critical Activity Mode situation and as a result having a closed bus had significant consequences. The vessels FMEA should have guidance as to the limitations of operating in closed bus, the DP operations manual along with the ASOG should give guidance of operations that can be conducted with closed bus configuration.
- The operator should have manually opened the bustie – In case of uncertainty, opening the butie would have averted the blackout by isolating the problem to a single redundant group. If a vessel is operating closed bus it should have the adequate protection in place to isolate a fault and stop it propagating to other redundant groups, it is preferable to have inbuilt automatic functions to perform such actions.

- Why did the operator removed the wrong connected generator? – The operator has decided to remove a generator, they had two options, the question is which generator they should remove at this time. At the time, the root cause of the issue was unknown. The operator was presented with an excessive amount of data and background noise. Upon observing one engine operating at 100% load, they assumed it was the culprit and stopped the engine. If the operator had observed what was occurring with the bus's frequency, they would have recognised that a low frequency was being experienced, this can only occur in one way. Frequency is a function of the rotational speed of the alternator, and the engine governor is responsible for regulating engine speed. In this case, one generator was displaying a negative load on a low frequency bus, indicating that it was the faulty generator because the frequency was being physically lowered – low frequency low load 'must go'. However as stated above it is preferable to have inbuilt automatic functions to perform such actions.

4.4 Relevant guidance

The following IMCA Guidance would be relevant to this case study:

- IMCA M 117 – *The Training and Experience of Key DP personnel*
- IMCA M 220 – *Guidance on Operational Planning*
- IMCA M 252 – *Guidance on Position Reference Systems and Sensors For DP Operations*

5 DP Drill Scenario

DP emergency drill scenarios are included to assist DP vessel management and DPOs/Engineers and ETOs to conduct DP drills onboard. The intent is that the template can be used on any DP vessel so specific details regarding the technical outcome are not included. The benefit from using this template is to monitor and learn from the human reactions of key DP personnel. It is also important that the crew are familiar with various DP system setups including their failure modes.

5.1 Relevant guidance

The following IMCA Guidance would be relevant to this case study:

- IMCA M 117 – *The Training and Experience of Key DP Personnel*

EXERCISE SCENARIO	LOSS OF REDUNDANT GROUP (E.G. PORT SW/BD)

Objective:

To observe the reaction of the crew and verify vessel's remaining capability following loss of any one redundant group.

Method:

With the vessel in full auto DP control; power plant configured according to the vessel's DP FMEA and DP operations Manual (and respective decision support tool); all other vessel equipment and systems set up in accordance with applicable DP checklists:

1. Vessel in a safe location. Simulated location and activities agreed and communicated to all participants.
2. Simulate the failure by tripping online generators on the applicable redundant group.
3. Observe reaction of DPO crew, DP technical personnel, the equipment, DP system behaviour and potential vessel position/heading excursions

Prior to executing, discuss the expected results:

- Is the methodology appropriate to gain the best outcome of the exercise?
- Who will be involved with the exercise and what roles will individuals have?
- What equipment will be impacted?
- What are the risks of the exercise?
- Is the exercise scenario appropriately documented?
- Who will observe and accurately record exercise data including the DP system configuration pre exercise?

Observations During Exercise:

- Is the drill procedure being followed?
- Is the equipment reacting as expected?
- Are those individuals directly involved in the exercise reacting appropriately given their assigned duties?
- Are those individuals indirectly involved reacting in an appropriate manner?
- Is the degree of participation and diligence as expected?
- What is the duration from commencement to concluding a safe outcome for the vessel?
- Bridge team should take the opportunity to take 'Footprint' plots

Actual results witnessed:

1. EXAMPLE: DP system loses redundant group thrusters. System allocates thrust so there is no loss of heading or surge control, the vessel maintains position with remaining thrusters. If vessel is set up with due regard to applicable ASOG parameters thruster and generator loads are within acceptable limits.

EXERCISE SCENARIO	LOSS OF REDUNDANT GROUP (E.G. PORT SW/BD)

Discussion Points (Post exercise):

Human Factors

- What are the potential risks due to “multi-tasking” during DP operations that may directly lead to the scenario outlined during this drill? (Examples include managing / monitoring deck operations, radio traffic, etc.)
- What are the potential risks due to distractions in the workspace (i.e., Bridge, Engine Room) that may directly lead to the scenario outlined during this drill? (Examples include routine maintenance procedures, social media, personnel interactions, etc.)
- Discuss the alternative actions / reactions that may occur in response to a similar scenario. Are there multiple paths to a successful resolution or is there a preferred solution? Why?
- Following a review of the simulated exercise and the vessel and crew’s reaction, what different operator (Bridge and/or ECR) reaction(s) might be warranted if faced with a similar situation during operation?

Review of DPO and other key DP personnel reaction

- What potential gaps in the existing DP Familiarisation program have been highlighted as a result of the exercise?
- What changes / revisions should be considered for the training and familiarisation procedures?

Review the applicable checklists (ASOG CAM / TAM / DP operations Manual / bridge & engine room checklists / FMEA / DP Annual Trials programmes / etc.)

- What additional necessary actions and considerations should be addressed?
- What potential changes should be made to make the checklists more appropriate?
- What additional necessary operating conditions and parameters should be considered?
- What potential changes should be considered to make Decision Support Tools more applicable to the vessel and her equipment?
- How would these changes improve / affect the vessel’s capabilities and limitations?

Conclusion:

Based on the results of the exercise and related discussions before and after, any suggestions for follow up including any corrective actions deemed appropriate should be accurately detailed and managed to close out.

6 News in Brief

IMCA published IMCA M 259 – *Guidelines for the Management of DP System Network Storms* in September 2022.

Station Keeping Events STATS:

The information below is a snapshot of the DP Station Keeping events to date for 2022.

How many in 2022

- Total 170 Reported to date

What type

- 35 Observation
- 89 Undesired Event
- 76 Incident

Bus Configuration

- 199 Open
- 25 Closed

Main Cause (Overall Effect)

- 0 Human
- 67 Thruster/Propulsion
- 11 Position References
- 33 Power
- 1 Electrical
- 1 Environmental
- 5 Sensors
- 51 Computer
- 1 Mechanical

Secondary (Root) Cause

- 31 Human
- 0 Thruster/Propulsion
- 9 Position References
- 1 Power
- 45 Electrical
- 12 Environmental
- 5 Sensors
- 36 Computer
- 28 Mechanical

Figure 6-1 Event Stats

The percentage of DP Incidents reported per year has increased since 2019, a year before the pandemic, which is a concerning trend; however, this year's figures show that the percentage of incidents has decreased, which is encouraging. See the graph below:

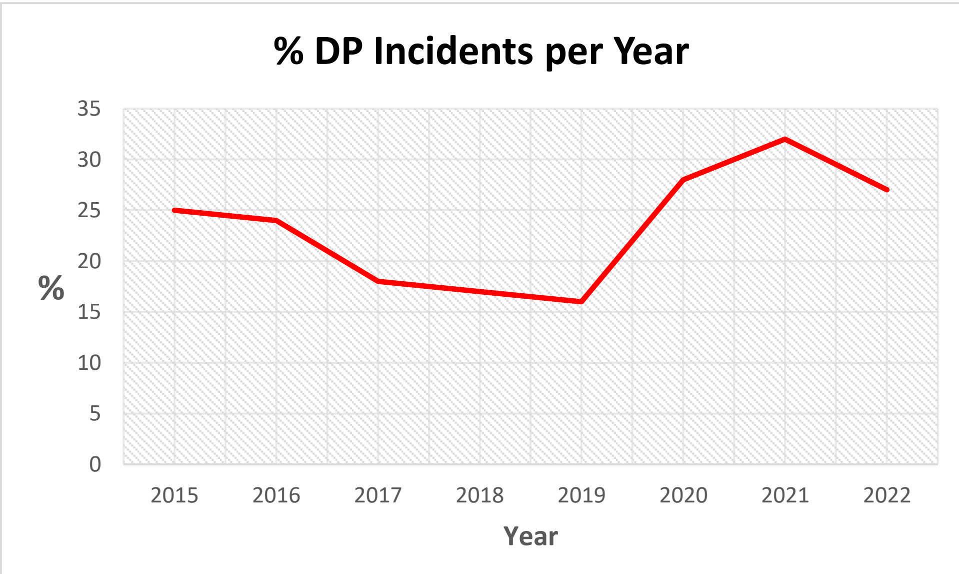

Figure 6-2 Percentage of DP Incidents per year of Reporting

Dynamic Positioning Station Keeping Review – Incidents and Events Reported for 2021 can be downloaded here.

The 2022 review will be available shortly.

If you are employed by an IMCA member company, you can register on the website using your company domain email address. Once registered, you will be given direct access to the members area including all guidance and publications. This also applies to Bridge, ECR or Rank email addresses onboard vessels.

IMCA has a new DP reporting form available here. You may want to consider using this form for your vessels.

Please forward reports to dpreports@imca-int.com.