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RISK SESSION

Lessons Learned... or Not

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Abstract

A significant part of the continuing process of DP system verification and checking on board vessels is the requirement to conduct testing on the DP system in a structured way over a regular, defined time period. Although DP systems can be similar between a number of vessels (such as a DP vessel series) very few of these vessels will have identical DP system installations.

As such, the DP system verification and checking process utilizes a formal testing protocol produced specifically for each DP vessel, designed to test the specific DP installation for that vessel in a way appropriate to the philosophy behind the particular type of trials being conducted.

This presentation is aimed at identifying a number of failure effects from MAC's experience of failures identified during recent FMEA Proving trials, 5-Yearly Periodical trials and Annual DP trials which appear to be repetitious in nature, and sometimes surprising, and which may appear to reflect the varying focus the DP industry takes over time on these issues.

Abbreviation / Definition

AC	Alternating Current
AVR	Automatic Voltage Regulator
CB	Circuit Breaker
DG	Diesel Generator
DGPS	Differential Global Positioning System
DP	Dynamic Positioning
DPO	Dynamic Positioning Operator
ECR	Engine Control Room
FMEA	Failure Modes and Effects Analysis
HPR	Hydroacoustic Position Reference
HV	High Voltage
IMCA	International Marine Contractors Association
IMO	International Maritime Organisation
kVA	Kilo Volt Ampere
kW	Kilowatt
mA	Milliamps
MAC	Maritime Assurance & Consulting Ltd
MSC	Maritime Safety Committee
MTS	Marine Technology Society
OEM	Original Equipment Manufacturer
PS	Port Side
PSV	Platform Supply Vessel
RPM	Revolutions Per Minute
SB	Starboard
STBD	Starboard
UPS	Uninterruptable Power Supply
Var	Volt Ampere Reactive
VFD	Variable Frequency Drive
WCFDI	Worst Case Failure Design Intent

Introduction

In the last five years MTS has published several guidance documents related to DP [1-5]. Papers of note include Gap Analysis Proving Trials [2] and Annual Trials [3], as well as guidance on cross connections [4] and auto changeovers [5]. Basically, robust checklists for FMEA practitioners, DP consultancies and vessel owner/operators to assess the quality of their DP documentation, and to make vessel operators aware of fundamental design issues that could affect vessel position-keeping after single failures.

In the last year or so IMCA has been revising key DP documents [6-9], including guidance on preparing FMEAs [7] and DP Annual Trials [8]. On top of that, the DP community has participated in the annual MTS and IMCA conferences, including special workshops or forums on such subjects as live short circuit testing.

This effort has been with the view to make DP operations safer and to take DP documentation to a higher standard. However, as MAC's recent experiences will show, there is still work to be done.

Understanding DP Trials Requirements

See Figure 1 for a pictorial representation of the development of trials programs. According to the new Guidelines for Vessels with DP Systems [9] and Guidance for Developing and Conducting DP Annual Trials Programs [8], excluding the requirements of Class, the initial survey should comprise FMEA proving trials and a complete test of the DP system. MAC's interpretation of this is to have a program that includes testing to verify the FMEA Desktop Analysis and a complete test of the DP system to demonstrate that single failures do not result in exceeding the WCFDI or loss of position.

After this initial survey is completed, the FMEA is then revised as necessary and the analysis is complete.

In one year, the vessel's first set of DP annual trials is due. This time the objective is to demonstrate that the vessel still complies with the requirements of the DP equipment class, that the WCFDI is still intact and that the vessel is being well maintained. With this in mind, the complete DP test, conducted as part of the proving trials, can be used to inform the DP Annual Trials. This DP Annual Trials program is then conducted annually, being sure to keep within the 3-month window of the original proving trials date.

In an effort to be more efficient, the DP Annual Trials can be broken down further into a rolling schedule, conducting only sample tests of equipment of proven reliability (i.e. variable speed thrusters) or of equipment that does not provide critical redundancy. Over the course of the following four years, all equipment has then been tested regularly and the objectives of DP Annual Trials fulfilled.

In year 5 it is then necessary to conduct the complete DP test required of the initial survey and the process continues.

Of course, in the intervening time, the DP system may have been subject to change and so the DP Annual Trials program evolves. Changes will be subject to analysis; a supplementary proving trials program may be required and the FMEA updated. These changes feed back into the system and the DP Annual Trials program evolves. Both documents, FMEA and Trials remain live and accurately reflect the vessel's DP system throughout its lifetime.

As a periodic compliance check, FMEAs are subject to a five-year review (against latest guidance and industry standards, against industry lessons learned, documentation/drawings against as-built status) and, in some cases, may require a re-write and so the whole process may start again, with proving trials.

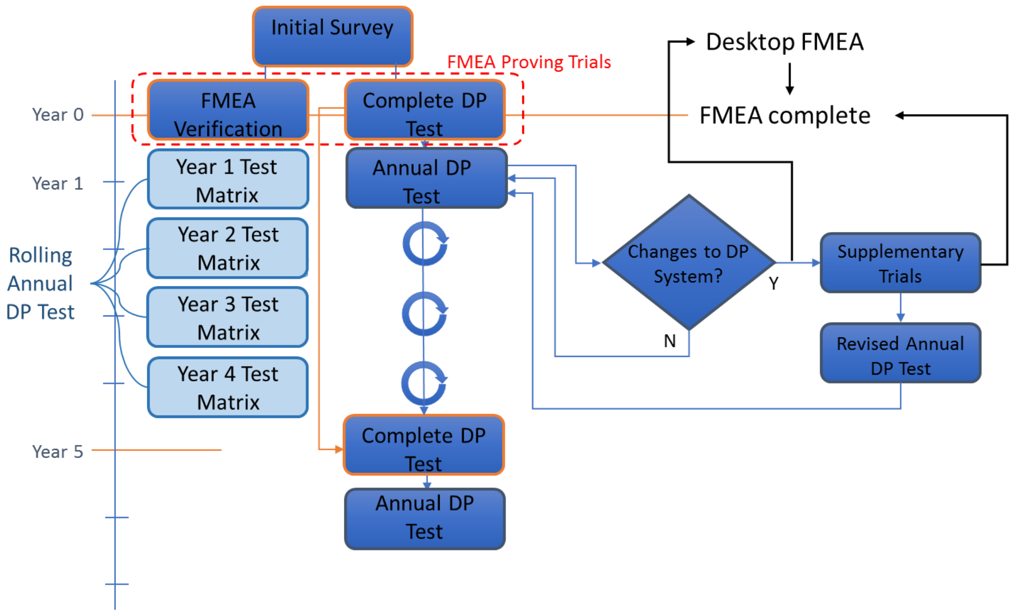

Figure 1 Evolution of DP Trials Throughout Vessel Lifetime

In the last year, MAC has 3 examples of this process being challenged, specifically the interpretation of 5-year periodical survey requirements.

The reason seems to be that the guidance on this matter is open to interpretation. As discussed, the latest IMCA guidance [8 & 9] is more explicit and is aligned with MAC's understanding that a 5-year Periodical Survey does not mean that the Proving Trials are repeated. However, the survey requirements laid out in the original IMO MSC Circular 645 [10], are a little more vague. As such, the MTS guidance on 5-year Periodical Surveys is not so clear – the MTS TECHOP [2] on FMEA testing suggests that the Proving Trials should be repeated after 5 years. To add further confusion, the latest revision of IMCA's Guidance on Developing and Conducting DP Annual Trials Programmes [8], states that IMCA's Guidance on Design and Operation of DP Vessels requires that the DP annual trials program be based on the FMEA proving trials and be repeated every 5 years!

Further difficulty is encountered when determining what constitutes a fair DP Annual Trials program, rolling or otherwise. Industry pressure means there's always a need to minimize cost. There have been various initiatives to realize this that are acceptable; one of which is acceptance of planned maintenance records in lieu of testing. However, this initiative can be problematic; for example, there are occasions when we examine the details of the maintenance work only to find the job is insufficient or doesn't meet the primary objective of the test – demonstrating the elements of performance, protection, detection. Common examples include, auxiliary system pumps only tested in one configuration, UPS endurance only tested for 15 minutes, without proof of alarm, and engine shutdowns only determined by operation of the emergency stop, rather than by the protection criteria we aim to demonstrate.

For some, even rolling annual trials programs are not stripped back enough – MAC has seen requests from some vessel operators to witness testing of only one redundancy group per year!

Net storm and net throughput tests are a requirement of MTS Annual Trials Gap Analysis [8]. Other forms of guidance are not quite so prescriptive. Indeed, the requirement for net storm annual testing was removed from a recent draft of IMCA M103! All network tests require manufacturer support, which has to be paid for by the vessel operator. MAC realizes the cost implications of OEM attendance to conduct this test. Clearer guidance would benefit both the vessel operators and DP practitioners, providing justification for the inclusion of these tests in trials programmes.

Testing relative position references during trials is always a challenge. Finding suitable test locations or acquiring reflectors/transponders incurs additional delays and / or costs in non-project time. Even HPRs can be a problem, in shallow water or without means to deploy the beacon. This then means that the vessel can only demonstrate satisfactory testing of a maximum of two position references (typically DGPS) – not enough to comply with IMO/IMCA/Class rules. According to IMCA [8], an individual position reference not adequately tested constitutes a B finding. No explicit category is given for an insufficient number of suitably tested references.

These issues have provided challenges to MAC in justifying and maintaining an acceptable standard of cost-effective trials programs suitable to all interested parties.

Common Findings from Trials and Assurance Reviews

What follows are some examples of critical findings, most of which are fundamental design issues, demonstrating that, despite a great deal of effort from the DP community, there is still work to be done to help clients improve the safety of their DP operations.

Azimuth thruster failing to uncontrolled rotation: This particular failure effect has been sighted several times in the past few years, including on a DP 3 Dive Vessel (15+ years in service), two DP 3 drilling vessels (8+ years in service), two DP 3 semi-submersibles (newbuild), a DP 2 pipe-layer and a DP 2 PSV. A drawback of older thruster control systems that use +/-10V signals - upon failure of certain thruster command and feedback signals on azimuth thrusters, the thruster rpm will freeze while the azimuth angle rotates to 0° (0V is equivalent to a valid ahead signal). Producing thrust in the ahead direction was traditionally considered a preferred fail-safe; however, failure to uncontrolled rotation is in direct conflict with Class rules and IMO requirements. This takes on added importance when considering that rolling trials programs do not necessarily require variable speed thrusters to be tested annually (azimuthing thrusters are typically of the variable speed type).

Automatic Change-over and Transfer of Fault: This was discovered during trials on a DP 3 pipe-laying vessel. See Figure 2 for an overview of the auto-changeover arrangement. PS3, which feeds retractable thruster 3, does not have its own power generation and therefore relies on an HV feed from main switchboard PS1 or main switchboard PS2. PS1 feeds PS3 through bus tie circuit breaker CB A, whereas PS2 feeds PS3 through bus tie circuit breaker CB B. The feeder circuit breakers to PS3 have individual protection relays for earth fault, under-voltage and short circuit. Circuit breakers CB A and CB B, both PS3 feeders from PS1 and PS2, respectively, are interlocked to create a two-out-of-three scenario whereby circuit breaker CB A cannot be closed whenever circuit breaker CB B is closed and vice versa. There is a blocking system in place where each circuit breaker sensing a short circuit current is sending out a signal to its upstream circuit breaker and thereby blocking the upstream circuit breaker. This means that, in principle, only the circuit breaker nearest to the fault will open.

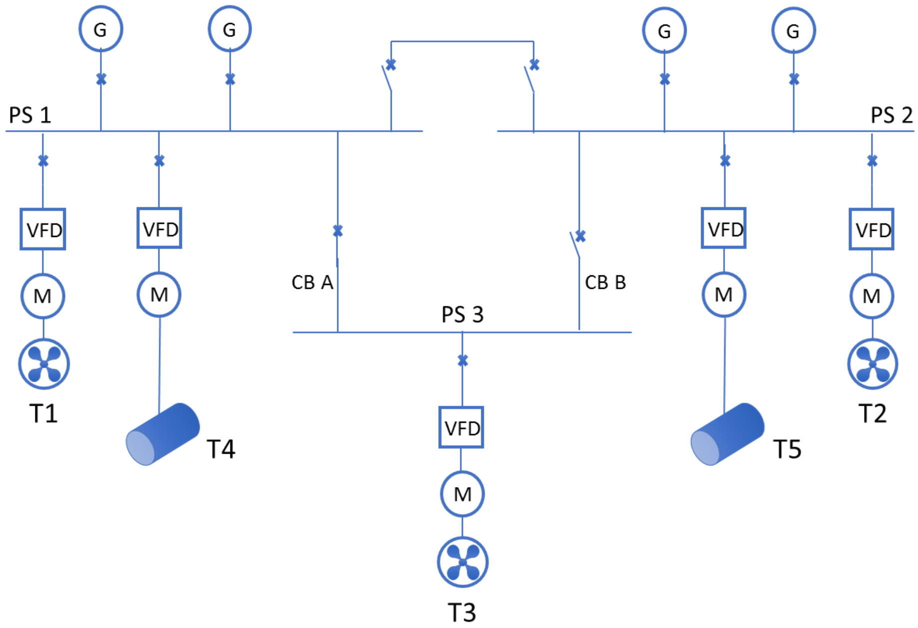

Figure 2 Auto-Changeover and Transfer of Fault

The following conditions need to be met to changeover the feed to PS3 from PS1 to PS2:

- There is a blackout on PS1, no voltage and frequency present.
- PS2 is fully functional with voltage and frequency present.
- Either of the two bus tie circuit breakers between PS1 and PS2 is open (operate open bus tie anyway).
- Circuit breaker CB A is open.

If all conditions are met, circuit breaker CB B, within switchboard PS2, will receive a close command from the power management system.

Now, consider the scenario: on a short circuit downstream of the feeding circuit breaker to Thruster 3, the overcurrent relay associated with the thruster circuit breaker will normally activate a trip of the circuit breaker. Through the blocking system this relay blocks the operation of the overcurrent relays associated with PS3 feeder circuit breakers (CB A and CB B). If, through a hidden failure, the thruster circuit breaker fails to open during a short circuit downstream, as a result of a failing open coil or a mechanical failure of the circuit breaker, then this will result in the generator circuit breakers on PS1 isolating the fault (CBs A and B are blocked from opening on detection of a short circuit). This, however, results in a blackout of PS1 and an under-voltage trip of the PS1 - PS3 feeder breaker, CB A. This provides all conditions for the auto changeover. With the overcurrent protection of PS2 – PS3 circuit breaker, CB B, also blocked, after the auto changeover, this will cause a blackout of PS2. There is therefore reliance on the protection system to prevent cascade failure and a total blackout of the vessel.

<u>UPS Configurations</u>: See Figure 3 for main and bypass UPS configuration. It is not unusual to board a vessel for trials and prepare to witness testing of the UPS systems only to find that the UPS has been left in bypass mode since the last maintenance routine. Often, the bypass supply is configured from the opposite redundancy group and so the designed redundancy concept is defeated. Normally, a robust tool to prevent this particular configuration error is to place checks in the DP checklist; however, having the UPS alarmed for bypass mode is the best course of action and the reason why some Class societies insist upon it in their rules. Of course, a condition of Class rules requires that a DP UPS without a bypass alarm results in an A finding for the client.

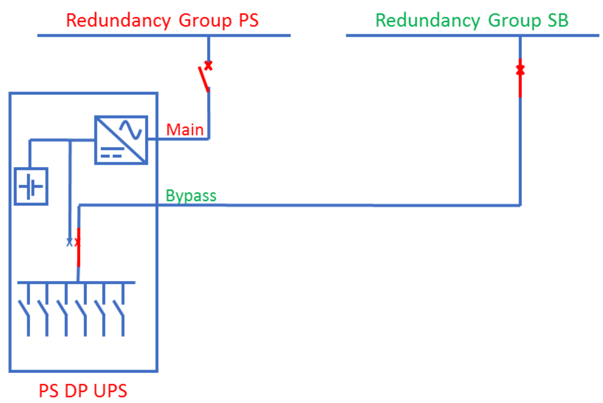

Figure 3 UPS in Bypass Configuration

<u>Control Voltage Cross-Connections</u>: This particular example is from Trials on a DP 3 pipe-laying vessel. See Figure 4 for a simplified overview of the control voltage arrangement. A popular solution to increase redundancy on older vessels was to establish active/online backup supplies on critical control voltages. More recent awareness of cross connections [4] meant that, in this instance, Class insisted that the fuse links be removed to improve redundancy. What was overlooked was that the 110Vdc control voltage systems were cross connected through the consumers, regardless. In addition, during trials, when the fuses were failed to the consumers on one side, no alarm was issued for loss of redundancy. Upon reinstatement, the knife contacts failed on one fuse. This was hidden until fuse failures were attempted on the opposite side, whereupon, opening of the first fuse resulted in the loss of one redundant group.

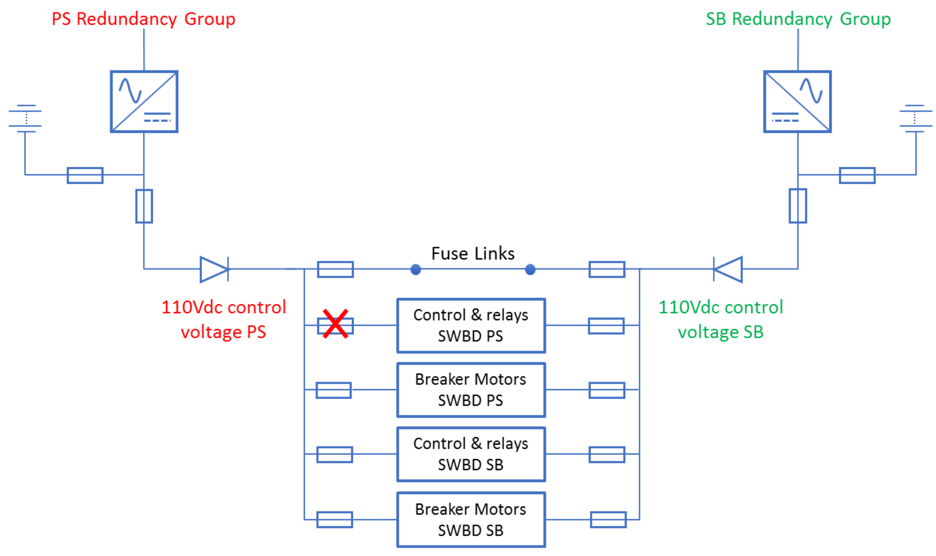

Figure 4 Cross Connections in 110Vdc Switchboard Control Voltages

<u>Closed Bus System Testing</u>: This issue is not to be confused with the live short circuit / voltage dip ride through debate that focuses on meeting Class requirements for DP 3 vessels. This is an issue all too common to DP 2 vessels with closed bus ties as a DP operating mode. Often, there is a misunderstanding among vessel owners and operators that, by definition, DP 3 mode means bus ties open, and so it follows, DP 2 means bus ties closed. Perhaps this is because of the additional prescriptive nature of DP 3 Class rules for closed bus configuration.

As a consequence, little or no consideration has been given to analysis or testing of the numerous active single failures (governor, AVR, load sharing lines), as considered under Equipment Class 2, that can result in failure effects exceeding the WCFDI or indeed blacking out the vessel. Consider the scenario depicted in Figure 5. Three diesel generators on a common bus, one DG fails to full speed and grabs the load from the other parallel generators, tripping them on reverse power, before then tripping itself on overspeed, resulting in a blackout of the switchboard. Often the crew are unwilling to conduct this type of testing as it is seen as destructive. There are many examples of vessels operating closed bus without ever having tested load sharing failures that prove the WCFDI is protected.

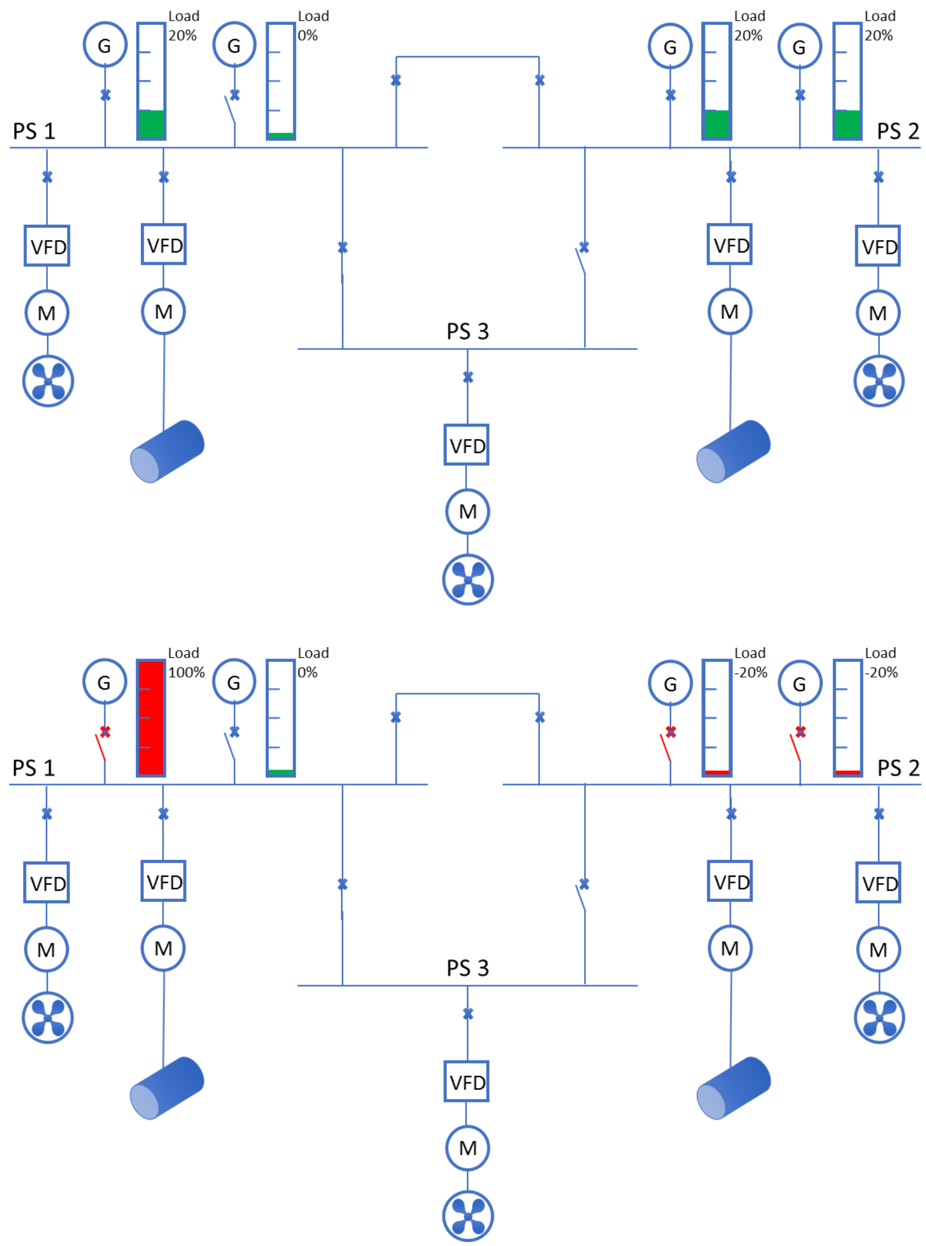

Figure 5 Closed Bus System Testing

Conclusion

All cases presented are representative of issues already well understood within the DP community. The current industry climate dictates cost reductions but of course that should never be at the expense of safety and a diligent approach to DP operations. DP vessel assurance reviews have suggested that approaches to minimising DP trials programs have resulted in critical aspects of testing being overlooked. In some instances, ambiguity in the guidance can lead to differing interpretations of the requirements for testing and so clients are unclear on how to meet expectations. Finally, fundamental design issues remain prevalent as vessel operators are unaware that traditional approaches to maintaining DP critical equipment are in direct conflict with Class rules and industry guidance.

MAC is one of many DP consultancies and we consider our experiences as a small sample in the industry, indicative of a more widespread phenomenon. Moving forward, with continuing subdued oil price and industry pressure to reduce costs, how do we deliver consistent and thorough trials programs that meet the expectations of all interested parties? It begs the question, are we learning from our lessons?

Acknowledgements

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References

1. TECHOP_GEN_01, “POWER PLANT COMMON CAUSE FAILURES”, Sep. 2012
2. TECHOP_ODP_01_(D), “FMEA TESTING”, Oct. 2013
3. TECHOP_ODP_08_(O), “ANNUAL DP TRIALS AND GAP ANALYSIS”, Sep. 2014
4. TECHOP_ODP_11_(D), “CROSS_CONNECTIONS”, May 2015
5. TECHOP_ODP_13_(D), “CONTROL POWER SUPPLIES AND AUTO CHANGEOVERS”, Sep. 2016
6. IMCA M103, “Guidelines for The Design and Operation of Dynamically Positioned Vessels”, Feb. 2017.
7. IMCA M166, “Guidance on Failure Modes and Effects Analysis (FMEA)”, Apr. 2016.
8. IMCA M190, “Guidance for Developing and Conducting DP Annual Trials Programmes”, Mar. 2017
9. IMCA M245, “International Maritime Organization Guidelines for Vessels and Units with Dynamic Positioning (DP) Systems”, Aug. 2017
10. IMCA 113 IMO, “Guidelines for Vessels with Dynamic Positioning Systems, MSC Circular 645”, Jun. 1994