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Benefitting from the Use of MTS TECHOPS – A Case Study

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Abstract

The overview of Dynamic Positioning operations throughout the industry has been increasing year on year. As the use of DP for the industrial mission has increased the need for a robust risk mitigation methodology has become higher on the priority list of the risk owners. MTS TECHOP's help meet these increasing demands by providing high level guidance and accessible tools to use during the DP Assurance project cycle.

To this end LOC has seen an increase in requests for, and application of, MTS TECHOP methodologies. With the TECHOP's available the DP systems installed on board a vessel can be more thoroughly vetted, and operations planned with greater detail to ultimately reduce risks to an acceptable level. Further, they help ensure that the DP documentation and testing package are compliant with the latest philosophies and methodologies available, which are often in excess of the vessels original FMEA test procedure. An example of this is the newly released TECHOP on Cross Connections, which is now being applied to help safeguard systems from previously unconsidered potential faults.

It is hoped that this paper will inform stakeholders in the DP industry that the use of MTS TECHOP's, and other available guidance, is beneficial to the DP Assurance process, and demonstrate a practical approach to their application. And further, that they can be performed and delivered in a timely, budget conscious manner to help ensure the continued safe delivery of the specific industrial mission, whatever that may be.

Abbreviation / Definition

ABS – American Bureau of Shipping.
ASOG – Activity Specific Operating Guidelines.
AVM – Automatic Vessel Management.
CAM – Critical Activity Mode.
TECHOP – Issued by MTS and available on the website.

Introduction

The global fleet of Dynamically Positioned vessels has grown in the last few years. From 2010 to 2017 the fleet has more than doubled in size. With orders for vessels placed before the downturn still being delivered through 2017 and beyond.

DP Subsea Vessels (Minimum DP2, 50t crane & 50 berths)				
No. of Units	Fleet at 1/1/10	Fleet at 1/6/17	Order Book at 1/6/17	Delivery over next 6 months
LOA 75-105 meters	111	210	21	13
LOA 105-135 meters	54	104	11	6
LOA 135-225 meters	31	89	13	7
DSV's with integrated sat system	54	64	11	7

Heavy Lift Construction Vessels & Barges				
No. of Units	Fleet at 1/1/10	Fleet at 1/6/17	Order book at 1/6/17	Delivery over next 6 months
With crane size 1,000-2,999 t	31	48	0	0
With crane size 3,000 t+	11	24	3	2

Fig.1 – Figures from "Kennedy Marr – Offshore Industry Market Report - June 2017"

With the increase in fleet size, and the relative speed in which this happened, the expertise and time available to produce well researched and thorough documentation for these vessels could be lacking. Certainly, if a fleet of vessels are built to one design with a single FMEA written to fit all the vessels, errors can be made, systems overlooked or not deemed DP critical or part of the DP system. This is not necessarily the case for all vessels, but a perceived weakness in the requirements, procedures and commercialization of the FMEA methodology.

Prior to the release of the TECHOP by the MTS, gap analyses by LOC were completed using an in-house report template that covered most items based on experience and technical expertise available within the company worldwide. This was a fluid template and well received by the clients, but the reports were inconsistent, making comparisons of like vessels difficult.

The other side of the argument is that an older vessel is assessed based on the latest guidelines from IMO, Flag State, Class, MTS, IMCA, OCIMF and so on. How are the risk owners able to ascertain that the vessel is capable, verified and ready to deliver the industrial mission required for the work scope?

To this end, we offer four case studies, from the experience of a third party marine consultancy, as to the benefit and methodology employed, for utilizing the MTS TECHOP's for risk identification, mitigation and management for the industrial missions of various vessels.

Throughout the case studies the names of the vessel and any identifying information has been removed, as well as client or any other details that may be used to identify the subject vessels.

CASE 1

The FMEA of a DP-2 supply vessel.

The subject vessel was built in 2014, with DP class 2 class notation and a full suite of dynamic positioning documentation provided by a reputable vendor. This was subject to class approval and full testing prior to delivery to the owners in 2015. The vessel had been fully operational from delivery.

A full gap analysis for all documents was requested and completed in Q1, 2017.

The MTS TECHOP_ODP_04_(D)_(FMEA GAP ANALYSIS) dated December 2013 was utilized to produce a report for the client. To both identify any gaps and assist in the closing of those gaps. Further, the MTS TECHOP_ODP_01_(D)_(FMEA TESTING) dated October 2013 was also used to identify any gaps in the FMEA proving trials. It has been noted on previous reviews and analysis that the FMEA Proving trials may include tests that answer some of the questions raised by the gap analysis.

From previous use of the DP FMEA Proving trials gap analysis check sheet, an excel file downloaded directly from the MTS website, it was noted that when selecting some of the variations, for example DP3 or closed bustie operations some pertinent line items can be removed. This was corrected early in the use of the document by including all parts of the document, per Appendix A: FMEA Gap Analysis Table of the TECHOP. This was also noted to be a very helpful in this case, as the change in status of the bustie directly affects the number of applicable line items and additional protections were in place even though the vessel may not be operated with a closed bustie.

The standard routine we have found that works best for completing the gap analysis is to read the FMEA, noting any obvious omissions or mistakes. Then go through the FMEA with direct reference to each line item on the Gap Analysis Table. The review the FMEA Proving trials to see if testing has closed any further parts of the analysis. As each FMEA and proving trial is different, this can be time consuming and leads to a desire for a more industry-wide, formalized, FMEA template for the main sections of analysis. For example a list of headers for an FMEA with a top down approach starting at the bridge?

Each line item of the FMEA Gap Analysis Table is generally an aide-memoire, with no guidance or details on what would be an acceptable level of detail. This was noted during this FMEA Gap Analysis as the document vendor had attempted to close some self-identified gaps from their own analysis by inserting keywords from the gap analysis table into the FMEA.

But, this leads to confusion. Attempting to close the gap for ID No. 192 in the Gap Analysis Table "Power Management / Power Management Scope / Auto reconfiguration"

The FMEA states:

> "All of the bus tie circuit breakers are operated manually, with the exception of automatic tripping due to overcurrent. The Power Management System is not capable of auto reconfiguring the circuit breakers or reducing power transfer across bus tie."

Yet, the next paragraph states:

> "If an on-line generator should fail or its circuit breaker should trip, the PMS will automatically start a standby generator, place it on the bus and automatically open and close bus tie circuit breakers to reconfigure the electric plant as necessary to meet the ship's electrical demand."

The Gap Analysis Table and guidelines from the TECHOP, have greatly assisted in bringing together a comprehensive, and repeatable, report for the many sub standard FMEAs.

From the gap analysis and review of all the dynamic positioning documentation on board the vessel, further testing was carried out to prove that the systems were as redundant and fault tolerant as expected. This resulted in a conclusion that the FMEA should be updated, along with the trials program, to reflect the as built status of the vessel.

Just because a gap analysis is completed, and maybe extra testing undertaken, does not mean that there are no hidden failures, faults or other issues that could arise. The gap analysis allows the vessel operator, charterer and end client to fully assess the systems against a known standard, giving consistent results that are reliable when correctly implemented.

CASE 2

Identification and mitigation of cross connections.

The vessel in question was delivered in early 2016 and is fitted with a 930Vdc main switchboard controlled via a Siemens Bluedrive Plus C. Power generation is provided by four main generators, and thrust provided by two bow thrusters and two stern thrusters. A technologically advanced vessel, it is fitted out to a high standard by a reputable yard. FMEA and proving trials documentation were found to be well written and comprehensive.

LOC attended the initial proving trials as witnesses on behalf of the chartering company.

The power distribution layout makes use of a 600A Automatic Breaker Transfer (ABT) switch that provides power to the 480V Emergency Switchboard from either the port or starboard 480V switchboard. The switch controller sees the starboard bus as the main supply, with the port bus as the secondary. The theory behind it is that in case of a loss of the starboard MSB, resulting in a further loss of the starboard 480V switchboard, the ABT will sense that loss of voltage and automatically switch over to the port 480V switchboard. Further, the ships service lighting panel was designed to be fed from either side of the 480V port and starboard switchboards via a 400A ABT, with the port side as primary.

These cross connections were obviously installed as a means to increase redundancy, however as stated in section 2.1.3 of Techop_ODP_11_(D):

"A common misconception is to confuse cross-connections with added redundancy, without recognizing that such cross connections have the potential to defeat the redundancy concept by introducing vulnerabilities in fault resistance, fault tolerance and fault ride-through"

This type of fault propagation is specifically addressed in section 3.9 of the TECHOP – Auto Changeovers – Between Redundant Groups – and details four risks associated with using auto changeovers:

1. The potential for hidden failure
2. The potential for fault transfer
3. The changeover creates a common point
4. Transient position excursions

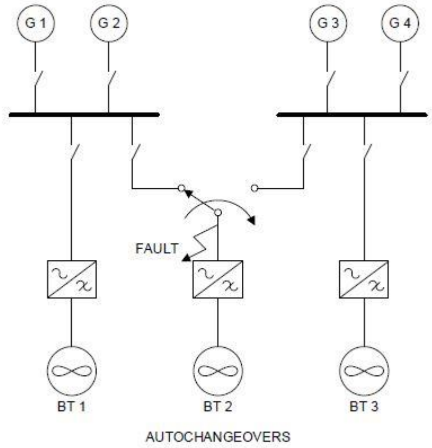

Figure 3-7 Auto Changeover

Section 3.9.6 states:

"Providing the auto changeover with greater intelligence can help to reduce the risk. In particular, including the ability to determine the location of the fault and lock-out the changeover if the fault is downstream"

In this case however, the logic provided by the ABT controllers was unable to determine the location of the fault. Also, the switch configuration was not user selectable – only a loss of voltage on the primary side could trigger the changeover to the secondary feed. Because of this it was determined that the risk of a fault transfer was too great, and mitigation options were considered. Section 3.9.6 goes on to further state:

"Other options include disabling the changeover during operations in CAM and accepting a lower post failure DP capability and operating the vessel within it."

Analysis was made of the system and it was decided to lock out the secondary feeds to each ABT, by isolating the associated output breakers on the 480V switchboards. Both ABT's were then tested to ensure they were fed from the appropriate side, that they allowed power to pass normally, and that no switching would occur upon loss of the main voltage supply. Finally, the breakers were labelled for isolation during DP operations and a recommendation was issued, stating that the vessels Critical Activity Mode be updated to include the breaker isolations. This was all completed prior to the trials starting in earnest.

Having the TECHOP on Cross Connections available onsite proved invaluable, both in coming to the final decision to include the ABT isolations in the vessels CAM, and for illustrating to the shipyard why this was required. The logic behind the as-built configuration was evident, however it was effectively downrated for DP operations, making these switches an expensive addition that was ultimately not required. This could have been prevented by the inclusion of the FMEA provider in the design stage.

CASE 3

Blackout Recovery – A System Protecting Itself

The case study vessel is a DP-2 classed diesel electric vessel, delivered in 2016, with 4 generators providing power to two tunnel thrusters and two azimuth propulsion drives with a conventional 50/50 split design. Power Management and DP Control were provided by respected manufacturers with robust integrated systems.

At the time, the vessel was being tested in the TAM configuration for a specific operation. Aside from the obvious debate this ignites, TECHOP_ODP_12_(O) states e*xamples of non-critical activities carried out on DP by logistics vessels include: operations down wind and down current within the 500m zone of an asset with a short time to terminate (2.11.7).*

Upon testing a partial blackout scenario, it was evident the vessel was not in conformance with one of the two design objectives of TECHOP_ODP_02_(D)_(BLACKOUT RECOVERY): *Robustness – The blackout recovery system should be able to return to operational status as much of the power plant as can be made available following the incident and be able to do so regardless of the manner in which the power plant failed (4.2.2).*

The vessel was in an open bus configuration with one generator online on each side of the bus with the others in standby; and both sides of the bus PMS in 'Auto' mode. Upon loss of power on the port bus by pressing the emergency stop of the online engine, the PMS began immediate automatic blackout recovery, starting the generator that was in standby on the port side. However, the starboard side's mode of operation was changed from 'Auto' to 'Semi-Auto' (operator dependent Auto mode) as per the software; thus preventing the standby generator on the starboard from being started and requiring manual intervention.

While the effects of the partial blackout could have been minimized by having a second generator immediately online to provide additional power to the two remaining thrusters, the opposite occurred. As the vessel began to drift and thruster power requirements increased, the PMS began phase back of the thrusters as a protection method, while at the same time disabling the load depending start function of the standby engine on the starboard side as it was now in 'Semi-auto.' While the operator was eventually able to manually start the standby generator and essentially restore the vessel to WCF in CAM mode, the approximate time of 80 seconds had passed; wherein the port switchboard and associated thrusters were now restored and the vessel attempting to recover from an excessive position excursion.

Multiple desirable features from the TECHOP could have been coupled together and implemented to prevent this scenario.

Autonomy in machinery control – If the PMS were able to *distribute the blackout recovery function to the control system of the major machinery such as thruster and generators such that each unit is responsible for detecting blackout and making itself ready for reconnection*, the time to recovery would have been significantly less (4.3.8).

Thrusters automatically recovered to DP system control – While the recommendation is that *following a blackout…DPOs should only need to supervise the system as it recovers control,* the change in semi-auto mode required manual intervention to regain thrusters into the DP system (4.3.21)

While the automatic change in PMS control mode appears to be a possibly useful self-preservation function if operating in closed bus, the effect in other modes of operation should be considered. While the PMS performed in line with some of the TECHOP, such as not tripping online generators in response to blackout indication, the vessel operators were left with a situation equivalent to blackout recovery hindering functions such as *protective functions that lock out healthy equipment from reconnection, the overuse of unnecessary permissive for generator and thruster connection, and the unnecessary use of local reset functions (4.4.1),* all of which are advised against. While none of these existed exclusively, the same outcome was achieved.

Ultimately, the vessel is left with excessive protection and lessened system reliability in this particular mode. This is an example of how a limited number of functions contradicting the TECHOP can be catastrophic to the operation.

CASE 4

Evaluation of Protection Systems: Investigation through an Annual Gap Analysis

The subject vessel is classed DP-3, diesel electric propulsion, completed FMEA Proving Trials in 2016 and Annual Trials completed in 2017, both by separate reputable companies. LOC performed a Gap Analysis on the Trials Document in 2017 using TECHOP_ODP_08_(O)_(ANNUAL DP TRIALS AND GAP ANALYSIS).

Gaps were identified that warranted further investigation and additional testing of the DP system was recommended, where it soon became apparent that TECHOP_ODP_03_(D)_(EVALUATION OF PROTECTION SYSTEM) would be relevant.

From the Gap Analysis of the previous Trial documents, a lack of sufficient testing was identified on the UPS systems and Diesel Generator Monitoring System (DGMS), a type of advanced generator protection.

Firstly, it was discovered when focusing on *Performance – UPS battery endurance and UPS distribution included in group redundancy test (TECHOP_ODP_08)*, that the Integrated Bridge System UPS's were not tested to include verification of outputs in the previous trial documents. As part of this testing proceeded, thruster card outputs were found to be supplied from the UPS, resulting in loss of associated thrusters upon opening of output breakers.

Secondly, the DGMS raised concerns as each engine's DGMS was noted to only have a small percentage of wire pulls tested in both previous Proving and Annual Trials documents, which is in direct opposition of accepted FMEA testing methods. This was confirmed and further testing was completed to include all wire pulls on all units.

Furthermore, DGMS testing led to an investigation of the associated 110Vdc UPS units, which were also noted not to have undergone endurance testing. Upon further review, the failure of each DGMS UPS caused a complete blackout of the associated switchboard, which is equivalent to the vessel's WCFDI, albeit a different cause than what was recognized in FMEA.

"DP vessel designers should carefully evaluate protective functions upon which redundancy depends to determine whether the required level of protection is actually achieved and that the protective function does not represent a single point failure." (TECHOP_ODP_03_(D) 3.2.1)

As warned by the TECHOP, protection is achieved, however at the cost of introducing a second single point source of Worst Case Failure.

FMEA TECHOP also applies indirectly, as the system intended to mitigate a fault causes a more severe fault than what it is designed to protect: *Where protective functions are used to moderate failure effects their use for this purpose will only be accepted as contributing to redundancy if it can be demonstrated that they are independent of the control system to a degree which ensures that a single failure cannot create a fault condition requiring the protective function to act and disable the protective functioning intended to detect and isolate that fault (TECHOP_ODP_01_(D) 4.6.1)*

When protection becomes inadvertent control, the intent of the system has transitioned from a tool to a liability, especially when not identified. Assuming a protection function to be fault tolerant and not tested as an independent system, can lead to *failures in control systems rendering ineffective protective functions specifically designed to deal with the effects of such control system failures. TECHOP_ODP_03_(D) 4.2.2)*

While the failure is not necessarily allowing vulnerabilities worse than the protection, this is not the intent of the system.

Multiple lessons can be learned from this example, starting with fundamental aspects of FMEA's mentioned in Case Study 1 and expanding to the mitigations and hidden faults that can be detected when not just one TECHOP is considered, but the compounding effects of their combined use.

Conclusion

The FMEA Gap Analysis TECHOP allows us to create consistent reports to a defined scope. Allowing all parties involved in the industrial mission delivery to have a level of trust in the documentation.

However, the correctly qualified personnel completing the any Dynamic Positioning work scopes, whether review, analysis, testing or operational, is required to prevent a delivery of poor documentation and the possibility of un-identified issues remaining in the system.

The TECHOP's are not the only available guidelines and should be read in conjunction with those available and relevant to the work being carried out. The TECHOP's do a good job of referencing other documentation that may be pertinent to the operation in hand.

The analysis can also assist on a desktop review for acceptance of the vessel, allowing for direct testing of specific groups of machinery and systems installed on board.

The numbering of TECHOP's is cumbersome, as can be seen from this paper, referencing back to the documents should be easier, and knowing which edition is in use. For example MTS TECHOP_ODP_04_(D)_(FMEA GAP ANALYSIS) does not show which revision or date unless you open the document.

The release of TECHOP's is quietly accomplished. If you are subscribed then you will get an email, however some professionals within the industry may not be aware of the tools being made available. Other methods for announcing the release could be looked into.

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References

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