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RELIABILITY

DP FMEA Challenged by Innovative Technologies

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1 Abstract

Innovative Dynamic Positioned (DP) vessels power distribution networks with a complex array of components working independently of each other or interacting with each other are becoming the norm rather than the exception. The accuracy of DP FMEA's for innovative approaches becomes ever more important and inaccuracies in the DP FMEA typically has operational consequences for the DP vessel. A review of a large variety of DP FMEA's suggests that in particular for innovative vessels, DP FMEA's regularly fail in covering all relevant components of an innovative power generation and distribution network. Furthermore with the increased possibilities of operational configurations that comes typically with innovative DP vessels, DP FMEA's regularly fail to specifically state which configuration the DP FMEA was based on, contributing to vessel owners selecting configurations not necessarily providing the most robust set up. Covering all innovative aspects of a power distribution network from a DP vessel in a FMEA requires close cooperation between stakeholders. This paper attempts to increase awareness in the industry that an increased level of detail is required in DP FMEA's when it pertains innovative DP vessels. In order for that to happen we suggest that an increased cooperation is required between DP FMEA providers, manufacturers, shipyards and vessel owners during the DP FMEA process.

2 Introduction

Over the last decade the industry has seen an increase in detail and quality of FMEA's covering DP vessels. The increase in quality can be contributed largely due to an increase of awareness of the importance of DP FMEA's and the availability of DP FMEA guidelines prepared and published by IMCA, industry forums like the Dynamic Positioning subcommittee from the Marine Technology Society and by Classification Societies such as DNV and ABS. DP FMEA quality continues to be challenged, which should be regarded healthy as it continues to raise awareness of the role of the DP FMEA in supporting a DP vessel design and operation. The importance of the DP FMEA not only during the actual design phase, but also during the operational phase of the DP vessel. This last point is sometimes ignored. One still can occasionally perceive the notion that the DP FMEA is something for the design phase, once the vessel is in operation, we can "leave that all behind". DP FMEA's have an even bigger role in innovative power distribution networks when compared to conventional vessels.

The importance of accurate and detailed DP FMEA's is by now well understood amongst quality DP FMEA providers and understood amongst stakeholders which typically utilize "high-end" DP vessels. "Innovative" technologies however are challenging the DP FMEA's process quality.

This paper attempts to highlight that a DP FMEA that does not take into account all components in a power distribution network, or a vessel owner not following the switchboard configuration as defined in the DP FMEA will have consequences during the operational live of a vessel. Typically resulting in a false sense of confidence or a lack of confidence where confidence actually is warranted due to the design.

DP relevant technologies that were introduced on "high-end" DP vessels since recent years can often be regarded innovative, different then what the industry worked with in the two decades prior that. This in particular in the offshore support vessel segment, vessels with limited hull space when compared to for example large deepwater drilling assets. In these vessels, innovative technologies allows for an increase in post failure power generation and thruster availability when compared to conventional designs.

"Innovative" approaches such as Closed Bus Tie operation supported by the use of isolation transformers, thruster drives continuously supplied from two split switchboards (redundancy groups), PLC based Black out Prevention Systems, "islanded" generator and thruster drive protection systems, "islanded" power management systems managing single bus sections and more.

Technical innovation should be embraced as it can result in an increase in reliability and an increase in post failure power generation or post failure propulsion capability and often can result in both when compared with conventional DP vessels.

However innovation will only be embraced if confidence can be instilled in owners and end-users (charterers). Confidence will only be instilled when correct DP FMEA's are produced and appropriate proving trails and subsequent DP annual trials are being defined and when vessel owners operate their vessels as per the DP FMEA.

A review of a large variety of DP FMEA's from a variety of DP FMEA providers and comparing them with the results from the DP FMEA proving trials and the results of subsequent annual DP trials suggest a trend that the quality of DP FMEA's is challenged by innovative technology. Often knowledge about the innovative technology is not readily available with the DP FMEA provider or is available however the functionality incorrectly understood. It was apparent that in the cases where knowledge of functionality of certain relevant components was missing, DP FMEA facilitators typically default back to known systems or ignoring the innovative aspect of the system altogether. This is typically done in order to "stay on the safe side", assuming that the innovative technologies such as for example a Black out Prevention System for a closed bus tie operation is non-existing thus a failure result is as if the innovative technologies were not present.

Ignoring innovative technologies results typically in that the result of failures are incorrectly assessed. A full understanding of all innovative aspects requires the stakeholders to embrace the innovation. In order to have the industry embrace innovative technologies from manufacturers, an increased level of knowledge sharing with the DP FMEA provider is required.

We suggest that well designed and proven innovative vessels typically have a higher post failure capability then a conventional vessel in most but the very worst failures.

This paper also highlights a related topic, the switchboard configuration that the vessel is operating in compared to the configuration as defined in the DP FMEA. The increased modes of operation that innovative power distribution networks typically bring also brings with it more options for a vessel owner to select a mode of operation not necessarily best suited to carry out a specific industrial mission. A DP FMEA that is not clear in the mode of operation the DP FMEA was based, or does not highlight the multiple modes a vessel can operate in, increases the possibility that well-intended changes of configuration take place by vessel crews, which can result in a major change in post failure capability. Even when it remains within the Worst Case Failure Design Intent (WCFDI), vessel owner, crew and charterer should be very much aware of a post failure capability not aligned with the DP FMEA.

3 Conventional versus Innovative DP vessel design

We start by stating what we actually mean with "conventional" and "innovative". We can also say any modification to a previous existing system is already innovation but that is not our definition here. Our interpretation of conventional in this paper is simply the fact that in the period 1980 to 2008 the large majority of DP vessels have somewhat similar power distributions system with similar protection systems. Some vessels were more advanced than others, the reality was that even the most advanced DP vessels were based on similar components and philosophies with regards to protection and distribution. However roughly since 2008 the industry is experiencing a push for innovative DP vessel switchboard designs, with related protection systems in particular in the offshore support vessel segment. This push for innovation is driven typically by the following primary reasons when compared to conventional DP vessels;

1. The need for an increased redundancy in DP vessel power distribution systems.
2. The need for an increase in post failure power and post failure propulsion capability.
3. The need for more efficient (more economical), "greener" power generation.
4. The need for switchboard manufacturers and designer bureau's to distinguish themselves.

Where in the past integrated alarm systems monitor the power distribution network, in innovative designs we find localized controller's managing the protection of individual components such as a generator, a thruster or a switchboard section by monitoring the individual components and by monitoring its surroundings. Where in conventional systems we find thrusters with options to be supplied from different sides of the switchboard, in innovative designs we see thrusters permanently supplied from split switchboards, protected by advanced protection systems and isolation transformers. Where we rely in conventional designs on selective coordination in circuit breakers and power management systems for switchboard protection, in innovative designs we rely on micro controllers (PLC) managing high speed black out prevention systems to action prior a breaker setting is triggered. Centralized power management systems versus localized power management systems for each specific bus section in innovative designs.

This innovation is good, as it eventually will drive DP vessel designs with robust power distribution networks, high post failure capability and improved economic and environmental operation.

4 The challenge

The review of DP FMEA's and a comparison with the results from DP FMEA proving trials and annual DP trials on innovative vessel designs (typical construction later then 2010) shows that regularly the innovative functionality is not clearly understood by DP FMEA providers or by vessel owners (or both). In addition, occasionally the functionality of innovative components were completely omitted in the DP FMEA. The reason for not having the knowledge of the innovative technologies within DP FMEA providers is often driven by the fact that manufactures are not forthcoming in distributing the details or the FMEA provider is not investing in staff embracing innovative technologies and often it is as simple as not having communication protocols established between DP FMEA providers and manufacturers in the case of shipyard turnkey projects.

A default back to conventional rationalizing in a DP FMEA is often obvious in the cases where an innovative design aspect is not clearly understood thereby omitting the innovative components and their effects in the power distribution network.

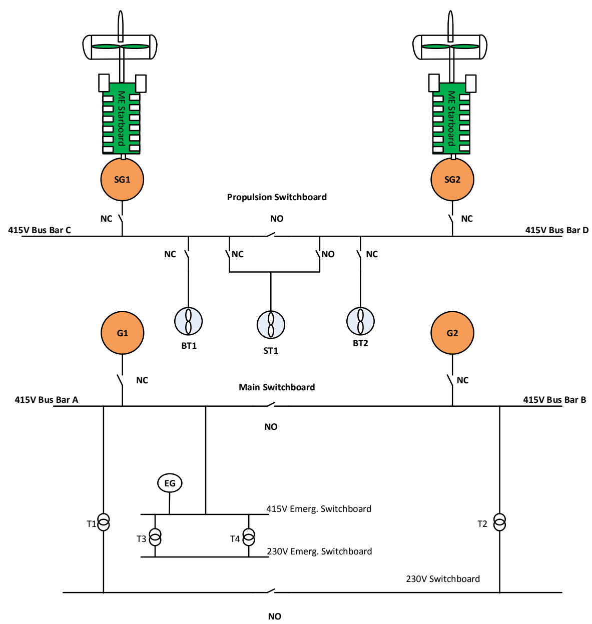
The conventional designs of power distribution networks and related components typically are clearly understood in all aspects by the majority of DP FMEA providers, in where the WCFDI and the Worst Case Failure (WCF) result can relative easily be verified or established in a DP FMEA exercise and confirmed in subsequent DP proving trials. In innovative DP vessel design this is not always clearly identifiable. It typically requires experienced DP FMEA providers that have the capability and knowledge in house to ensure a detailed understanding of all the components used and the control logics in place behind these components and how these systems interact with each other.

The importance of fully understanding the purpose and interaction of components in DP vessels is illustrated in several examples of "high-end" DP vessels that are currently in operation. Where incorrect interpretation of an innovative design intent or not understanding innovative operational modes resulted in either not "fully proven" DP vessels, DP vessels not operating as per design intent or a post failure capability that is different than as described in the DP FMEA. Cases were observed where the true post failure capability of a DP vessel was higher than the post failure capability as was described in the DP FMEA. In these vessels the DP FMEA presented a vessel in a lower operational capability (post failure) then they are actually operating in.

5 DP Vessel Switchboard Configuration and Innovative Components

In this chapter we highlight a few conventional and innovative power distribution designs currently in place on DP support vessels in operation.

5.1 Illustration (1) shows a conventional common DP vessel switchboard design. This vessel has no power management and the switchboard protection is by the selective coordination of circuit breakers. A DP FMEA facilitator with minimal experience will have no trouble identifying or verifying the WCFDI and the post WCF vessel capability and apply the relevant failure modes to this design.



The propulsion switchboard which supplies all electrical driven thrusters is separated from the main switchboard, which supplies all low power consumables including DP critical ones.

This is what we consider a conventional switchboard configuration and relative "easy to analyze" from a DP FMEA perspective.

The disadvantage of this set up is that both the shaft generators and auxiliary generators are required to operate while in DP mode. This is not very economical nor "green", it is however regarded a "robust" DP set up.

Illustration (1) – Conventional DP vessel power distribution network.

In illustration (2) below we can see a similar switchboard design as in illustration (1) with the addition that bus ties are in place between the propulsion switchboard and the main switchboard. The design intent becomes more important to describe and it should clearly state in the DP FMEA which vessel configuration should be operated in while on DP. In the case of more operational configurations, the results of WCF should be listed for all DP operational configurations.

Without going into the details of how a FMEA process is managed, it is obvious that this configuration requires a more detailed understanding with the FMEA facilitator of what the effect is of relevant failure modes in the relevant configurations and which mode or modes of operation the vessel will be operating in. Selective coordination of breakers becomes more critical in isolating faults and a good understanding of how Voltage and Current transients can affect other switchboards and connected consumers.

Many varieties exist of this switchboard design all with different levels of protection and control.

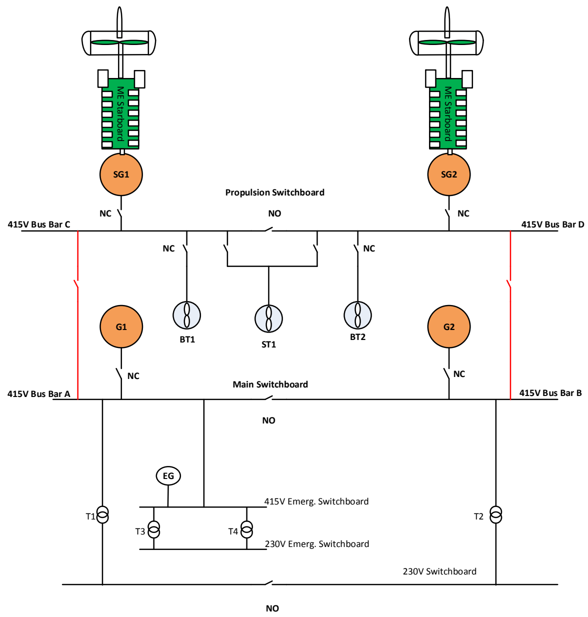


Illustration (2) – Conventional DP vessel power distribution network with variety of operational modes.

We note here that by connecting multiple switchboards, the full understanding of the functionality of each component in the power distribution network becomes much more critical as more than one switchboard with its associated consumers section can now be affected in the case of a fault.

5.2 The importance of a DP FMEA and the DP annual trials clearly stating in what switchboard configuration basis the DP FMEA or DP annual trials is prepared and thus in what configuration the vessel should operate in is well illustrated by the following example in where a power failure caused a greater loss of vessel capability then was anticipated by the vessel owner and charterer who were referring to the vessel's DP FMEA.

This DP incident caused a loss of position of approximately 6 meters prior the vessels remaining thrusters were able to recover to her pre-set position.

The DP FMEA produced for this offshore support vessel with a power distribution network as shown in illustration (3) was based on the highest possible "post failure thrust capability". The vessel DP FMEA did not consider an alternative mode of operation. We wish to highlight that a DP FMEA provider also will not consider alternative modes of operation then specifically is requested in the scope of work. We do suggest DP FMEA providers to advice and recommend to vessel owners that alternative modes of operation can and should be analyzed and incorporated into the DP FMEA.

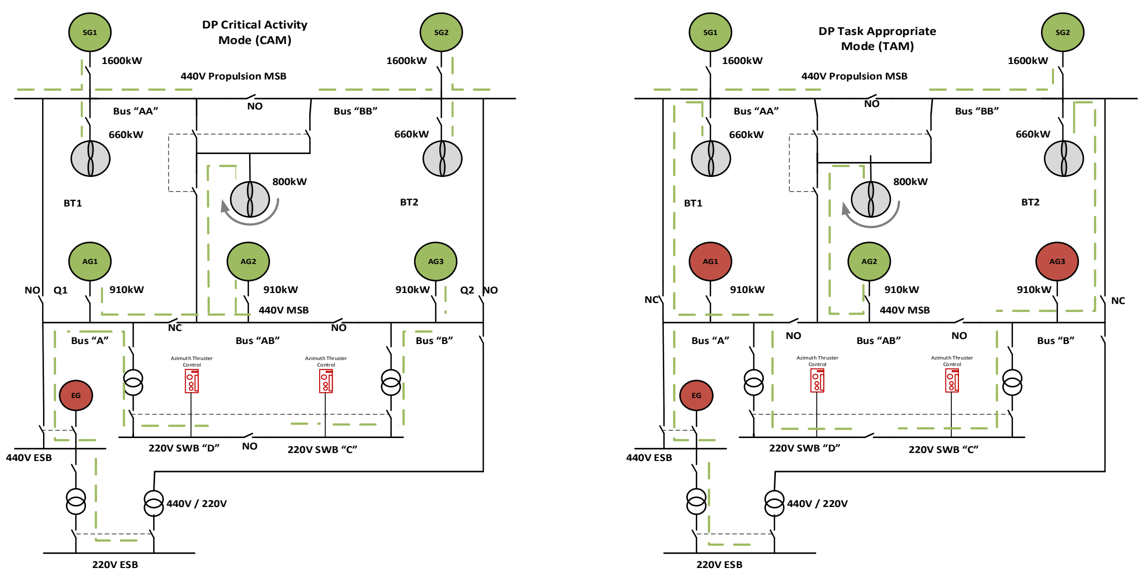


Illustration (3) – Construction vessel with two DP operational modes

The highest level of post failure capability is achieved in a configuration where the main switchboard "A", "AB" and "B" is supplied by 2 Diesel Generators and one in standby. The Bus Ties Q1 and Q2 between the propulsion switchboard (AA and BB) and main switchboard (A, AB and B) would remain open while on DP. (CAM in illustration 4). The annual DP trials for this vessel were also based on this configuration, annually proving a robust DP configuration to stakeholders.

The vessel is outfitted with two azimuth propulsion thrusters aft, directly driven by the main engines via a mechanical drive shaft. Two transverse bow tunnel thrusters are supplied from shaft generators coupled to the main engines. In addition there is a bow mounted azimuth thruster which is typically supplied from the main switchboard AB and can be supplied from either side of the propulsion switchboard.

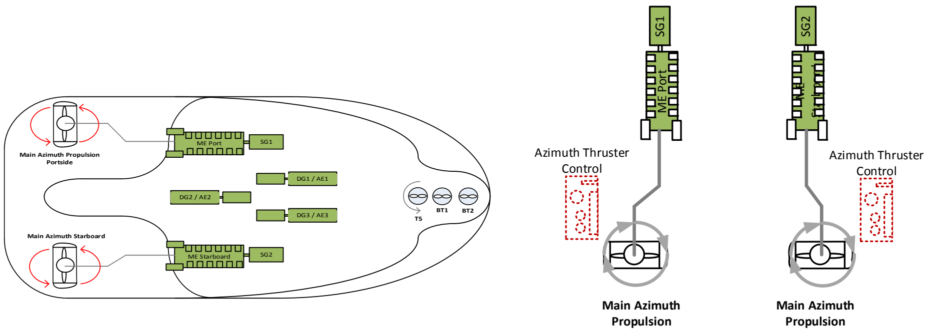


Illustration (4) – Mechanical driven azimuth thrusters with electric azimuth thruster controls.

At some point in the operational life of the vessel, the common mode of operation for DP was changed by the vessel crew, a change supported by vessel management. In the new mode the main switchboard was supplied by the shaft generators while on DP, thus the bus tie Q1 and Q2 closed between Bus AA and A and bus BB and B (TAM in illustration 4). This change was implemented without updating the DP FMEA, hence without knowledge to charterers. The charterer assumed, as per DP FMEA that upon the loss of a switchboard section AA or BB due to whichever reason, the loss would not exceed the loss of one tunnel thruster as the main engine would continue to mechanically drive the main azimuth thruster with the main azimuth control and pitch and steering hydraulics being supplied by the main switchboard.

While operating in the revised mode a minor failure in the air supply to the clutch on the gearbox between the shaft generator and main engine resulted in the loss of the associated shaft generator. This now resulted not only in the loss of one bow transverse thruster as in the DP FMEA described configuration, but also in the loss of one main azimuth propulsion thruster even while the main propulsion engine remained fully functional. The main azimuth functionality was lost due to the fact that the main azimuth control and hydraulics were supplied by the main switchboard section A and B. The loss of one main propulsion azimuth thruster is a significant decrease in post failure capability compared to the loss of only a single bow tunnel thruster upon the same failure mode.

The loss equals (does not exceed) the WCFDI for this vessel of not more than 50% of the installed main propulsion capability, hence one can argue it is an acceptable post failure capability. However by changing the configuration the vessel had changed from a "robust" DP vessel in where post failure capability typically was higher than the WCFDI to a vessel in where a major failure quickly resulted in a capability equaling the WCFDI.

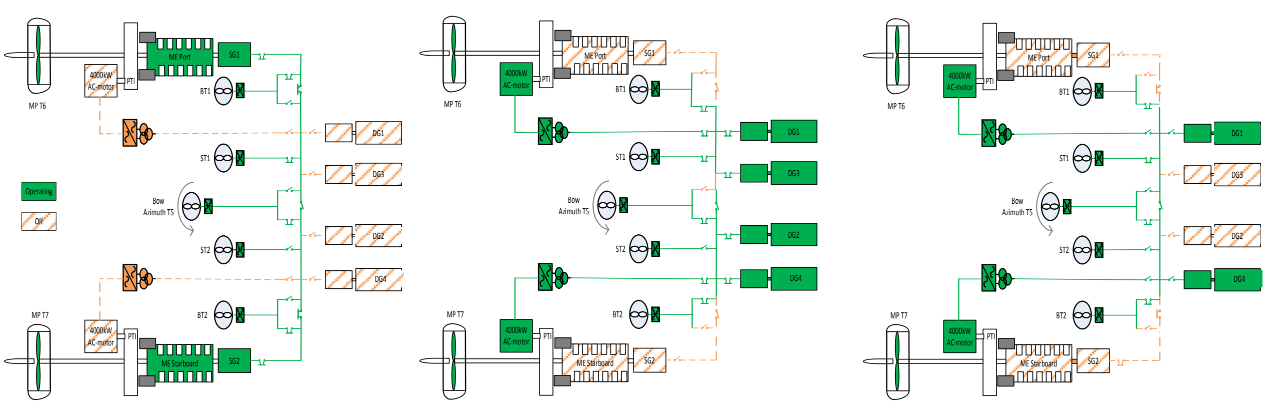
Important to note that in this particular case the charterer had an incorrect understanding of the true post failure capability, based on the original DP FMEA. It illustrates the importance to operate the vessel in the configuration as described in the DP FMEA or alter the DP FMEA to reflect the change or add additional configurations with the relevant WCF results and post failure thrust capability.

Vessel owners and charterers alike should welcome multiple operational modes for DP vessels where the design allows this. However DP FMEA's must be revised in order to accurately reflect all configurations and annual DP trials must be adjusted to proof the various operational modes. DP FMEA providers must embrace this innovation by advising clients of the various operational modes available for the vessel under review.

IMCA M220 describes well defined methods to manage a variety of vessel configurations such as Critical Activity Mode (CAM), Task Appropriate Mode (TAM) and Activity Specific Operational Guidelines (ASOG). In the above example, dual configurations were subsequently incorporated into the DP FMEA and managed operationally by the CAM and TAM guidelines.

5.3 In the next example an offshore support vessel has an innovative power distribution network with multiple options for power distribution configurations, depending the electrical power and bollard pull demand. The vessels switchboard design philosophy list six specific modes of operation of which two are specific for DP operations. The two "DP modes of operation" are shown below in illustration 5, configurations "A" and "B". The DP FMEA fails to list one specific configuration, nor does the DP annual trials program. The DP FMEA and annual DP trials not specifically detailing the vessel configuration for DP operations was a major contributing factor for the vessel crew to select a configuration not aligned with any of the six configurations in the design philosophy as the vessel crew worked after the DP FMEA and not after the lengthy and detailed design philosophy document. The configuration the vessel was operating in DP typically was configuration "C" as is illustrated below.

In configuration "C" two diesel generators supply power to all thrusters, including the main propulsion thrusters, in a split configuration. In this configuration the vessel crew relied on the power management system (PMS) to start a subsequent diesel generator at 85% of the switchboard coupled generator capacity. The 85% start limit setting was imbedded in the PMS and could not be altered by the vessel crew. During on-hire DP trials the fact was highlighted that it was not realized with the vessel crew that the loss of one diesel generator would place the remaining single diesel generator in an overload situation in conditions where the two diesel generators were operating above 50% of their rated load during DP operations. The DP system, upon loss of the thrusters associated with the failed switchboard side, will compensate the demanded thrust vector by ramping up the thrusters allocated to the remaining healthy side. However in order to prevent an overload situation the power management system would use phase back on the remaining thruster drives until a stand-by generator starts and is coupled to the switchboard. For this duration a position excursion or heading loss can be expected as the required thrust vector to compensate the environmental forces is not met.



Configuration "A" Configuration "B" Configuration "C"

Illustration (5) – Construction vessel with two DP operational modes.

The vessel DP FMEA should clearly specify which configuration to select for DP operations, which configuration was used for the DP FMEA analysis. In this case the vessel DP FMEA failed to highlight the mode of operation for DP activities and failed to highlight the fact that start settings for subsequent diesel generators were "factory" set at 85%. These were contributing factors for the vessel crew to select a mode of operation not compliant with the vessel design intent.

5.4 Illustration (6) shows a power distribution network with a bow azimuth thruster continuously being supplied by both sides of a split switchboard. In order to analyze the system's ability to isolate faults to one side of the switchboard, it clearly requires a detailed understanding of all aspects of the switchboard. The DP FMEA facilitator must embrace innovation in order to delve into the details. This case will highlight two specific important aspects; (1) the functionality of one specific innovative component was not incorporated into the DP FMEA and (2) protection barriers in the dual supplied azimuth had not been reviewed in detail.

The fact that a certain component had been omitted from the DP FMEA resulted that an incorrect conclusion was drawn during annual DP trials and "A" recommendations were raised, which as we shall see, was for a non-existing issue. The "A" recommendations raised, resulted quickly in a vessel owner and a charterer losing confidence in the vessel, albeit not warranted.

The normal mode of DP operation of the power distribution network in illustration (6) is the bus tie between the main switchboards open and thruster 3 is being supplied by both sides (Q1 and Q2 closed) thus having a common point between the switchboards at Thruster 3 (T3). The 230V switchboard is supplied by both sides with the bus tie Q3 open. The 690V emergency switchboard is supplied by Bus 2 (Q4 closed) and Q7 open.

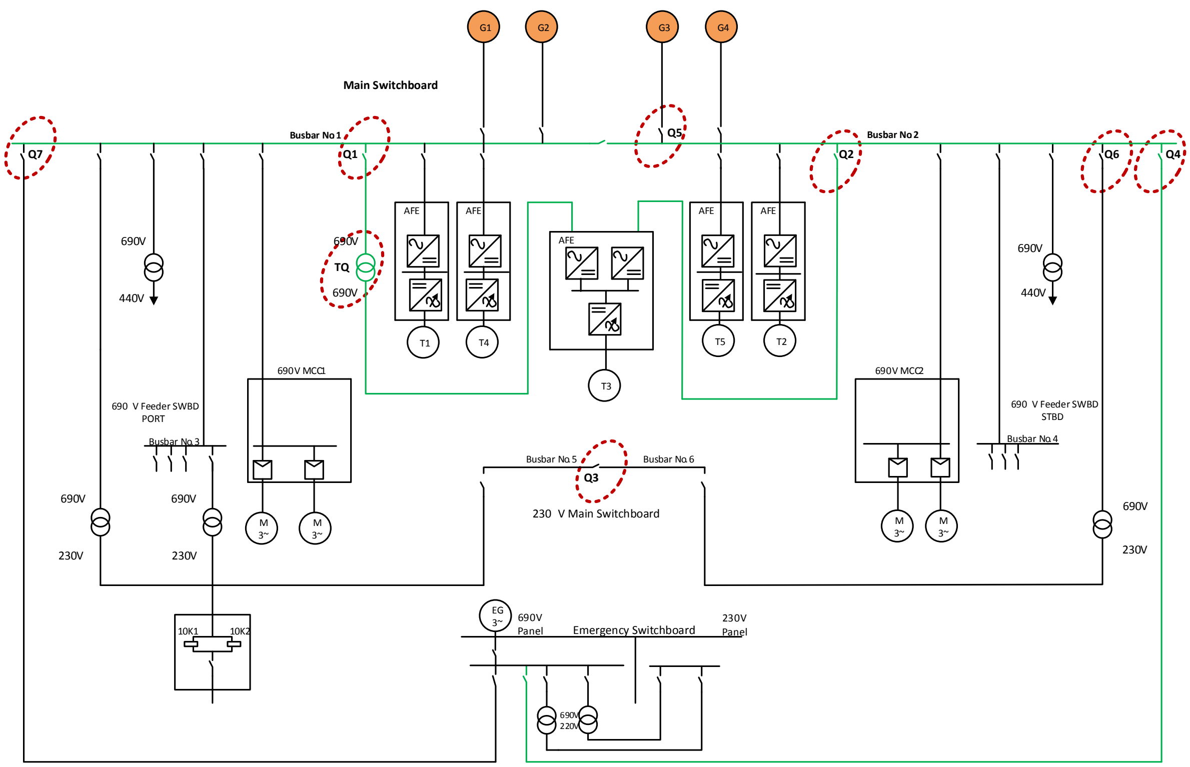


Illustration (6) – Power distribution network of offshore construction vessel

The vessel switchboard is outfitted with a late generation Black out Prevention System (BPS). A PLC based module located in the switchboard panel. A standalone unit which is monitoring the switchboard “health” at multiple locations. The vessels DP FMEA omits this component and its functionality nor analyzed the component and work it into the tabulated failure modes.

The DP annual trials called for an Automatic Voltage Regulator (AVR) failure test on the generators. The expected result of the AVR failure was the opening of the G3 main breaker Q5. This did indeed occur upon failure of the AVR, but also the breakers Q2 and Q6 and Q4 opened. The opening of these additional breakers, beyond the main breaker for G3 was quickly contributed (incorrectly as we shall see) to incorrect selective coordination of circuit breakers and “A” recommendations were raised to review the selective coordination of all breakers in the entire switchboard. It was assumed that the AVR failure caused a Voltage transient on the bus bar, resulting in the trip of these breakers.

Subsequent review by the switchboard manufacturer showed that no breaker had tripped on its own protection settings. The breakers had been correctly tripped by the BPS. The BPS measured the generator (G3) Voltage accurately at a high sample rate. Upon measuring a spike of 720V caused by the purposely failed AVR of G3, the BPS philosophy is to assume that the G3 main breaker contains a hidden failure, it assumes it fails to trip and the BPS starts to work its designed sequence to isolate the failure to one side of the switchboard by issuing the following commands;

- Opening Q2, T3 now continuous to be supplied by Bus 1.
- Opening Q6 and closing Q3, now we have 230V main switchboard supplied by Bus 1.
- Opening Q4 and closing Q7, now we have the emergency switchboard supplied by Bus 1.

Although this is relative easy to understand with the schematics in front of you in a white paper, in reality this takes place in milliseconds while simulating an AVR failure test and typically challenges the understanding of the events by all stakeholders. Here comes the importance of a DP FMEA clearly incorporating the functionality of all components in a switchboard and DP trials program correctly based on the relevant vessel DP FMEA.

To illustrate the complexity a DP FMEA provider will have to embrace when analyzing innovative power distribution designs, we show the thruster drive that is supplied from two split switchboards on this vessel in illustration 7. The DP FMEA mentions the protection settings of the breakers Q1 and Q2 and states the isolation transformer TQ provides the required protection from a fault transferring from a faulty switchboard section to a healthy switchboard section or from a fault originating in the thruster drive transferring to one or both switchboards. The barriers in the redundant drives had not been listed. This raised concern with charterers as the isolation transformer alone was not deemed sufficient protection to allow for a common connection between the switchboards at this thruster drive. Subsequently the charterer suggested to supply the thruster from one side of the switchboard only. This would defeat the design intent of the power distribution network and as we will see not necessary.

Subsequent review showed the details of the additional barriers in the redundant drive. The following illustration shows the additional barriers present in late generation drives, which should be incorporated into a DP FMEA. It also illustrates the multiple failure modes that were analyzed. A DP FMEA omitting these details will leave significant gaps in the DP FMEA process, particular in a crucial aspect as a common point between two split switchboards. Only the subsequent review showed there were sufficient barriers in place and raised the confidence amongst stakeholders to allow the vessel to operate with a common point between split switchboards (two redundancy groups).

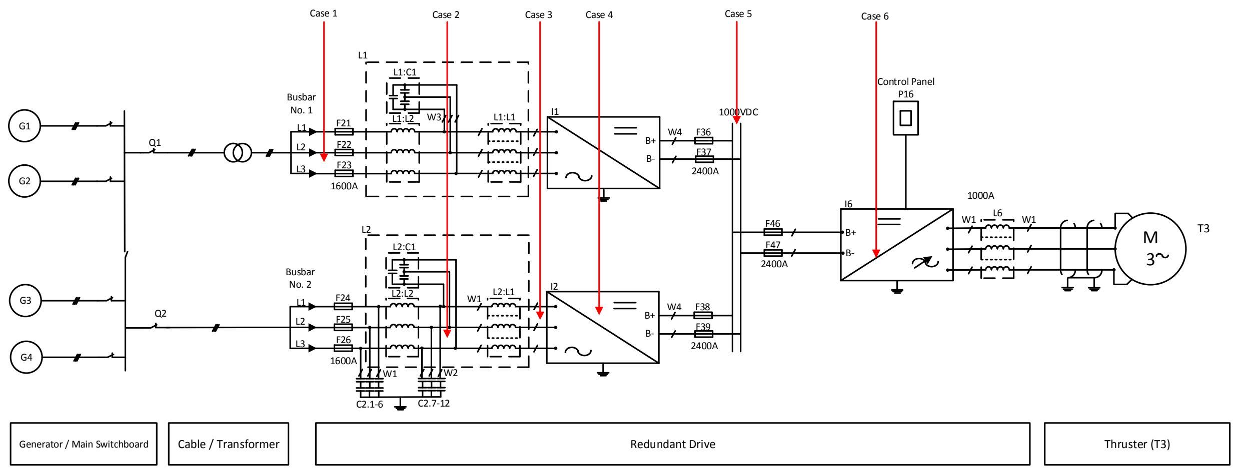


Illustration 7 – Protection barriers in dual supplied drive from illustration 5.

5.5 The next two examples were highlighted in reviews of DP FMEA's after annual DP trials had taken place. Illustration 8, figure "A" shows a Wartsila Low Loss Concept (LLC) switchboard design. The DP FMEA review showed an understating of the vessel's post failure capability in one vessel. In another vessel the thruster capacity was not correctly described in the DP FMEA.

In the first case the original vessel DP FMEA had completely omitted any ability of the LLC 1 & 2 transformers and its associated circuit breakers to isolate failures, isolate large Voltage and Current transients typically associated with failures in electrical components. By omitting the LLC transformers and their associated breakers from the DP FMEA, Bus A1 and A2 were regarded as a common Bus, similar for Bus B1 and B2. The DP FMEA described as post failure thruster availability being 50% for many failure modes (losing one side of the switchboard). However the DP annual trials and on-hire acceptance trials clearly showed the system's ability to isolate most faults to only one bus section and actually maintaining all thrusters available for DP albeit two thrusters only at 50% of their rated capacity. Although 50% of power generation and thrust capability as described in the original DP FMEA was within this vessels WCFDI, it does not do justice to the design. An ability to maintain all thrusters operational upon a variety of failure modes compared to the loss of 50% of the thrusters as described in the DP FMEA is a significant improvement. In reality this vessel is likely to perform with a higher power generation and thrust capacity than conventional vessels after certain failure modes.

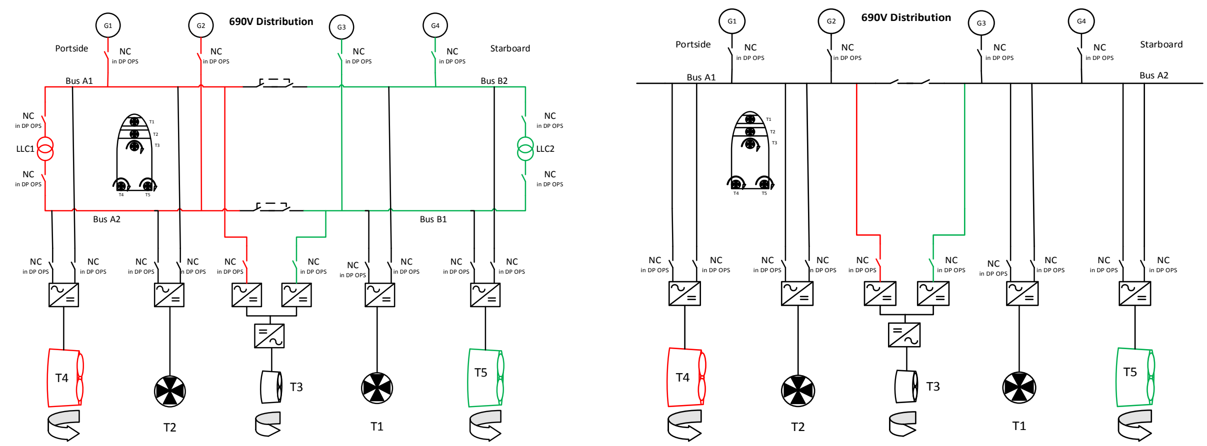


Figure "A" **Figure "B"**

Illustration 8;

- **Figure "A" Innovative power distribution network Wartsila LLC.**
- **Figure "B" how power distribution network was analyzed in the DP FMEA**

5.6 A DP FMEA of a different vessel with this same switchboard design was not covering all technical aspects. This created the situation where the vessel operated below a known capability.

This vessel, shown in illustration 9 operates as follows; Bus A1 & A2 are connected as are Bus B1 & B2. Bus A1 & A2 is split from Bus B1 & B2. The feeders supplying T2 remain BOTH connected (both breakers closed) to the dual drives of T2 even in case of a split switchboard configuration (open bus tie). The common point is on the DC bus between the thruster drives of T2. The system philosophy on this vessel is for the T2 drive PLC to control this aspect and will only choose one drive to generate DC power for the common DC bus on the T2 drive. The supply cables to each drive on this vessel were rated for 50% of the thruster capacity. Meaning effectively in open bus tie configuration, the thrusters T2 is "only" rated for 750kW instead of the listed 1500kW in closed bus configuration. For this vessel the open bus configuration results in a 23% reduction of bow mounted thrust capability. The DP FMEA fails to highlight this fact and subsequently vessel operation took place for several years in the assumption that T2 is able to deliver 1500kW.

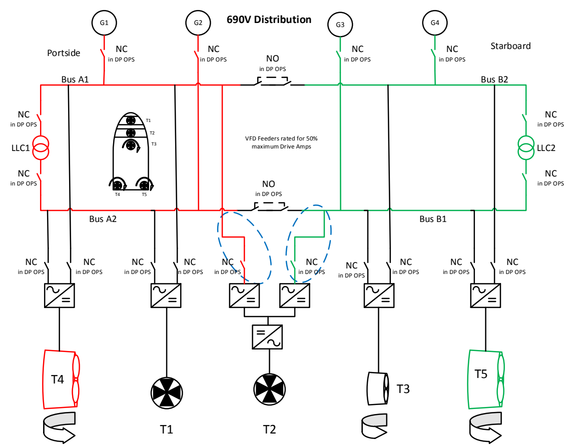


Illustration 9 –LLC Concept operating with open bus tie, 50% capacity of T1.

The vessel has been operating with good performance due to having sufficient thrust capability overall, however the fact is that the vessel was performing with the assumption amongst owner and charterer that thrust capabilities where at 100% just as described in the DP FMEA.

Note that it was actually the vessel DPO's who initially pointed out the slightly lower performance in maintaining heading while working close to the maximum environmental envelop in open bus configuration compared to closed bus configuration.

This is an important aspect a DP FMEA should cover as it directly affects the station keeping ability. It requires the availability of all relevant technical data of all switchboard components and the subsequent full understanding of all these components to come to the relevant conclusion in the DP FMEA process.

5.7 In our final example we conclude with an offshore support vessel of recent construction which was outfitted with a variety of "late generation" protection systems. The relevant switchboard is shown in illustration 10, however the components and their set up we will discuss are fitted in several different switchboard designs.

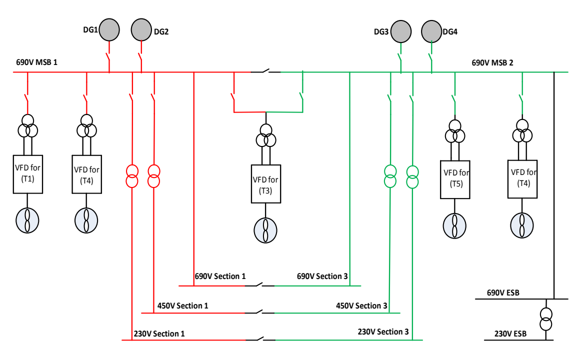


Illustration 10 –Power distribution network with "mis-matched" power management modules.

In addition to a power management system, the vessel DP FMEA describes that the switchboard is outfitted with a "Switchboard Protection Module" with no further details. Nor is the Switchboard Protection Module listed in the tabulated failure modes. The DP FMEA does not describe the component functional description or the design philosophy of the component.

The FMEA proving trial results did not highlight anything abnormal (casting doubt about the quality of the FMEA proving trials).

The vessel had been three years in operation when Global Maritime performed the vessel's first DP annual trials. During these trials the vessel systems were unable to synchronize a stand-by generator to the switchboard while the remaining three coupled generators were operating at high loads (open bus ties).

The failure to synchronize and connect resulted after 7 minutes in a High Temperature Cooling Water (HT CW) shutdown on one DG which subsequently resulted in the loss of one side of the switchboard with its related consumers. The ability of synchronizing generators with a highly loaded switchboard is a typical real world scenario which occurs for example when the vessel is making a position "step" on DP, is operating in "follow sub" mode, the usages of large consumers such as deepwater cranes or is exposed by sudden changing environmental forces due to a squall. In this case the partial black out resulted in the charterer rejecting the DP vessel temporarily from charter, loss of confidence with vessel owner and with charterer and downtime involved for all stakeholders.

A subsequent review by the switchboard manufacturer quickly identified that the DP system was limiting power by phasing back of the thruster drives at 95% of the switchboard loading in order to prevent overload of the switchboard. The innovative Switchboard Protection Module which was mentioned but not described in the DP FMEA phased back thruster power when it measured a load of 97% of the switchboard load. The fact that two overload protection systems commenced to phase back power on heavy consumers near simultaneously resulted in switchboard load variations. This prevented subsequent generators to synchronize and connect with the end result of one diesel generator tripping. As a solution the DP system power limitation was adjusted to 105% of the switchboard loading. Subsequent DP trials proved the switchboard protection module being fully capable of preventing an overload situation while simultaneously synchronizing and connecting additional generators to the switchboard.

One can argue that this is the vessel designer (switchboard designer) and shipyard responsibility to properly set this up. We suggest however that it is the role of the DP FMEA facilitator to list and analyze the functionality of all components in a power distribution network and warn if clashes between these systems are present as was the case in above example. In conventional vessels this has been rather straight forward. In innovative vessels this can be challenging due to the many components involved, all with their own role and functionality. It really drives the need for DP FMEA providers to embrace innovation in order to capture all functionality of all components typically found in innovative power distribution networks. If components functionality are missed the result will likely affect operations eventually. By merely stating the system contained a Switchboard Protection Module and not analyzing the functionality and settings of this module and its possible interaction with other systems the DP FMEA failed to highlight crucial functionality which eventually allowed the loss of one switchboard section to occur.

6 Conclusion

It is the DP FMEA provider's role to identify the systems and their functionalities that possible can "clash" with each other to the extent that it will endanger the station keeping ability. This is relative straight forward and well established in conventional vessel design with for example a dual 24V supply for an engine control module or a something like a DP UPS. However our review showed it is not well established when it comes to innovative power distribution networks the offshore vessel segment has only started to use in recent years.

We have attempted to illustrate the importance to incorporate all components into a vessel DP FMEA, their functionality and their ability to isolate faults. In order for DP FMEA providers to be able to do that, embracing innovation is first of all required by these same providers. Next the information of these components must be forthcoming from manufacturers. The DP FMEA provider has a role to embrace innovation and detail the relevant data that is required in the DP FMEA process in order to allow for full understanding of the functionality of a component and the relation to other systems.

Not incorporating these innovative technologies into the DP FMEA will result, as we have illustrated with these examples, in vessels operating with different post failure results as described in the DP FMEA or can result in a DP FMEA describing a vessel with a post failure capacity typical being equal as conventional vessels, while in reality the vessel has a better post failure capability than conventional vessels in most but the worst failure modes. In these cases, owners spending significant capex investment for innovative power distribution systems will not find the rewards of this investment such as an increased marketability through a DP FMEA reflecting the details. Nor do charterers who typically rely on DP FMEA's find an increased comfort in the actual vessel capability when compared to a conventional vessel.

Innovation will not be stopped by regulation, industry guidelines or a conservative culture. History has proven that. Stifling innovation by outdated regulations, culture or industry guidelines is not healthy. More than ever current high-end DP vessel power distribution network designs and all of its related components require a full integral understanding by DP FMEA providers in order to perform a detailed DP FMEA and prepare the subsequent proving trials, which in turn typically provides the basis for the annual DP trial program. To achieve this, a closer cooperation between DP FMEA providers, manufacturers, shipyards and vessel owners is required then currently often is the case. The typical turn-key contract approach between vessel owner and shipyard is not readily facilitating this with the shipyard managing the documentation flow to the DP FMEA provider. Even where best intent leads the way, unfamiliarity with the DP FMEA process typically places a low focus on the flow of documentation between manufactures, designers and DP FMEA providers. Turnkey DP vessel construction contracts should have the terms incorporated for the provision of all relevant DP FMEA documentation. Simultaneously DP FMEA providers have an equal significant responsibility to request and specify in detail the correct relevant data they require. Guidelines for the actual execution of DP FMEA's are now well defined in a variety of industry documents such as IMCA M166, IMCA M178, IMCA M219 and DNV-RP-D102.

The guidance is there, however we suggest that what really is required is DP FMEA providers embracing innovation and closer cooperation between DP FMEA providers, manufacturers and designers. Vessel owners with innovative vessels will require more than ever to operate their vessels as per DP FMEA defined configuration(s) and when that mode is changed a DP FMEA update is required to incorporate the change or to incorporate the additional mode of operation. Where in the past a variety of companies, DP FMEA providers were available to produce the required level of detail in the DP FMEA's, it appears with high end innovative vessels, the availability is limited and it is suggested that vessel owners and charterers verify that the selected DP FMEA provider has the capability in house to perform DP FMEA's on their high-end offshore vessels loaded with innovative components.

The crucial key and the sole condition to industry wide acceptance of innovative DP vessels is the way the industry will be proving these DP vessels to confirm post failure thruster and power generation capability in DP mode are similar or elevated compared to traditional power distribution systems.

We suggest that this will require an adjustment of commonly accepted DP FMEA practice and DP FMEA proving schemes. Increased interaction between DP FMEA providers and manufacturers will have to become the norm rather than the exception. Tests to simulate faults typically resulting in significant voltage and current transients will have to become standard activity and we argue can be done successfully when manufactures are introduced to test requirements early in the process. A revision of test schemes for common control systems capabilities to isolate faults will be required. Network storms to become standard test requirements.

DP FMEA providers will have to challenge themselves more than ever; "do we fully understand what each component is doing and the control logic behind it?"

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References

IMCA M178 FMEA Management guide

IMCA M166 Guidance on Failure Mode and Effect Analysis

IMCA M206 A Guide to DP Electrical Power and Control Systems

IMCA M220 Guidance on Operational Activity Planning

Marine Technology Society DP Vessel Design Philosophy Guidelines PART 1 & PART 2

Marine Technology Society TECHOP FMEA GAP ANALYSIS

Marine Technology Society TECHOP FMEA Testing

Marine Technology Society TECHOP Power plant common cause failures

Egil Hystad, Wartsila - Energy Efficient Concepts & Advanced Power Distribution Systems

Alek Karlsen and Stian Ruud, DNV – New initiatives related to classification of DP systems

Saurabh Shah and Kamal Garg, Schweitzer Engineering Laboratories – DP Powerplant Open Bus Redundancy with Reliable Closed Bus Operation

Doug Phillips, Brian Haycock, Steven Cargill - FMEA Failed to Meet Expectations Again (Again?)

Jan Fredrik Hansen, Frank Wendt, Jaroslaw Nowak, Kai Hansem, Kjetil Stenersen, ABB – Integrated power and automation system for enhanced performance of DP class drilling vessels.