Reliability Analysis of the Blow Out Preventer

A comparative study of electro-hydraulic vs. all-electric BOP technology

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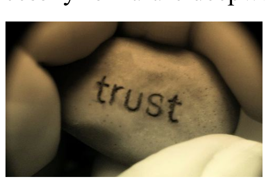
Introduction

The background for this thesis is Odfjell Drilling's experience with downtime on the blow out preventer (BOP) during drilling operations on board their mobile offshore drilling units. Excessive downtime on the BOP is a well-known problem for drilling companies worldwide, which causes increased costs and delays for everyone involved in a drilling project.

The downtime and associated cost due to failure on the BOP increases with the water depth of a drilling project, because the time it takes to recover and re-install the BOP stack will increase. In a deepwater operation, the unproductive downtime from a problem that requires the BOP stack to be recovered to the surface may be 1-2 weeks. The magnitude of the resulting daily loss, both for the owner and the client involved, illustrates how important reliability of the BOP is.

BOPs used for deepwater drilling operations may also experience new challenges compared to operations in more shallow depths. Examples are increased loads on the riser system, higher pressure and temperature in the well, energy loss in subsea accumulators, etc. Today, drilling companies worldwide have a strong focus on reducing BOP downtime. Improved technology and new solutions for subsea BOPs are therefore believed to be a necessity for future deepwater drilling.



Odfjell Drilling is dedicated not only to being a leader in terms of drilling technology and world class operations, but also in the way it adheres to high ethical standards and complies to all applicable laws and regulations.

Objectives

This thesis is a case study of the electro-hydraulic (EH) BOP on board Deepsea Stavanger (DSS), a drilling unit owned and managed by Odfjell Drilling. The first focus is to analyse BOP failures that have led to downtime on this rig, and to relate them to the technical mode of operation on the BOP.

The company Electrical Subsea & Drilling (ESD) is working on developing a fully electrically operated BOP. They claim that their new technology can provide many benefits versus the EH BOP systems, both with respect to environmental and operational safety. Additionally, they claim that their BOP concept is more reliable and less prone to excessive downtime. The second focus is therefore to establish a thorough system description of this concept, to analyse potential failures and to compare them with the failures experienced on board DSS.

Scope

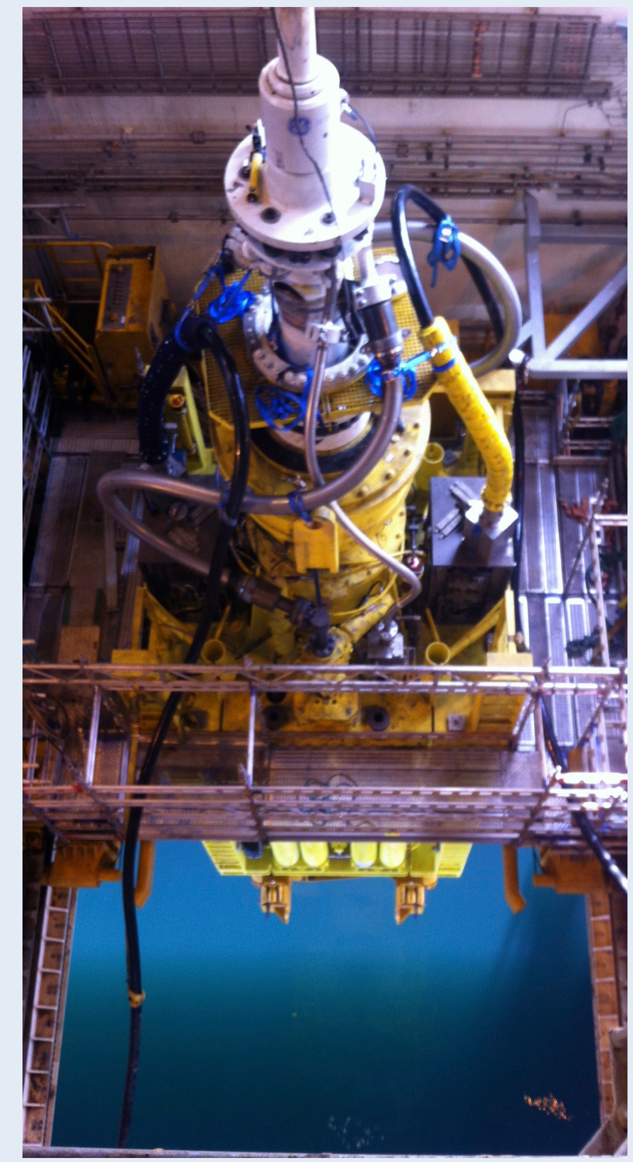
The overall goal is to compare the conventional EH BOP system with the fully electrical BOP concept developed by ESD, with respect to reliability. The purpose of such a comparison is to see if any of the recurring failures Odfjell Drilling experiences on board DSS is less likely to occur if the BOP is electrically operated. Summed up, this thesis addresses the following:

- BOP reliability literature study.
- Description of the technical mode of operation of the BOP, both electro-hydraulic system and all-electric concept.
- Analysis of BOP failures.
- Demonstration of how BOP failures relate to the technical mode of operation.
- Qualitative analysis of the faults.
- Comparison of the electro-hydraulic BOP system and the electrically operated system.
- Conclusions and recommendations for further work

Method

To compare the two BOP concepts, a reliability analysis has been performed on each system. The reliability analyses have been performed in the following steps:

1. Functional analysis
2. FMECA
3. Reliability block diagram analysis
4. Fault tree analysis



BOP seen from above, on deck in moonpool area on board Island Innovator.

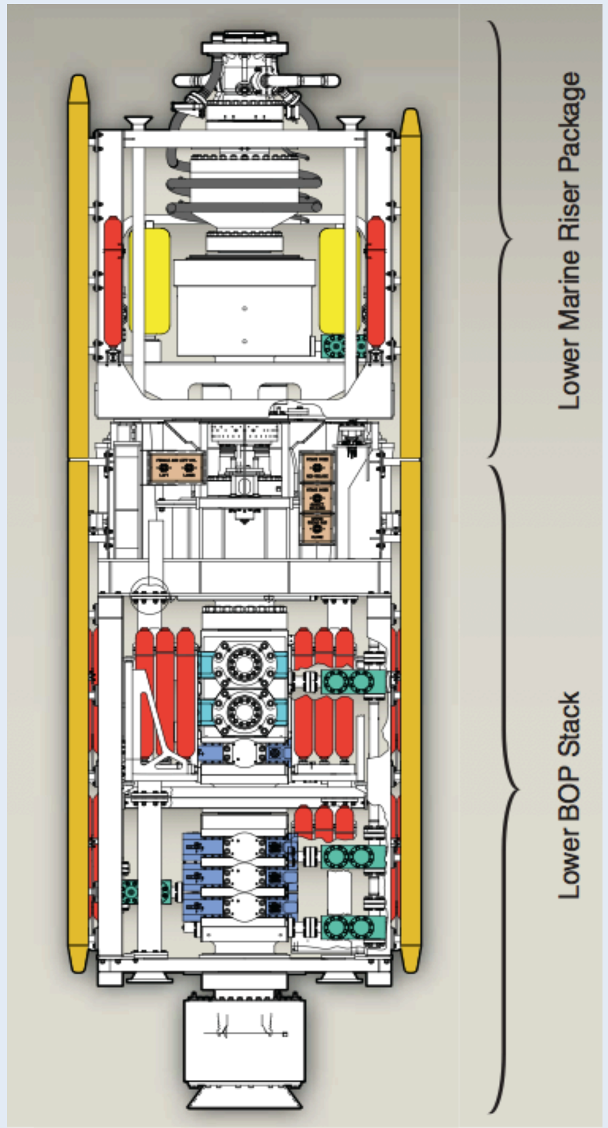
Macondo Blowout

History shows that uncontrolled releases of hydrocarbons have caused several major accidents. The Macondo blowout, also referred to as the Deepwater Horizon accident, claimed eleven lives and is considered the largest accidental marine oil spill in the history of petroleum industry.

On the evening of 20th April 2010 control of the well was lost, allowing hydrocarbons to enter the drilling riser and reach the Deepwater Horizon, resulting in explosions and subsequent fires. The fires continued to burn for approximately 36 hours. The rig sank on 22nd April 2010. Over the next 87 days, almost 5 million barrels of oil were discharged to the Gulf of Mexico, before the well was permanently plugged with cement and "killed" on 19th September 2010.

The primary cause of failure was by DNV identified as the BSRs failing to fully close and seal due to a portion of drill pipe trapped between the blocks. Contributing causes to the primary cause included:

- The BSRs were not able to move the entire pipe cross section into the shearing area.
- Drill pipe in process of shearing was deformed outside the shearing blade surfaces.
- The drill pipe elastically buckled within the wellbore due to forces induced on the drill pipe during loss of well control.
- The position of the tool joint at or below the closed Upper Annular prevented upward movement of the drill pipe.
- The Upper VBRs were closed.
- The flow of well fluids was uncontrolled from downhole of the Upper VBRs.



Shaffer BOP

The 18 ¾", 15,000 psi (1,034 bar) electro-hydraulic Shaffer BOP installed on DSS is one of the most commonly used subsea BOPs in the world today. The BOP is shown in the figure above.

The total height of the combined BOP stack and LMRP is 15.473 metres, and the total weight is estimated to 371,728 kg. All functions on the LMRP and BOP stack are electro-hydraulically controlled from control panels located at the surface on the unit. The BOP system consists of two annular preventers (Spherical BOPs) and six ram preventers.

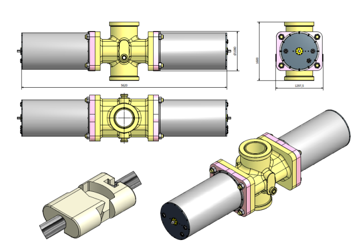
Electro-hydraulic vs. fully-electric BOP technology

The equipment delivered by any of the three big BOP manufacturers worldwide today is considered to be conservative, not very user- or service-friendly and fitted with somewhat old and out-dated technology and solutions. Some examples from DSS are listed below.

- Many screwed fittings on the hydraulic system, rather than welded and bent tubes.
- Heavy use of hoses instead of bent and welded tubes.
- Gnarled placement of typical service points on the BOP stack makes access very difficult.
- Not enough spare parts on stock/ on board and long delivery time on spare parts from BOP suppliers.

Other factors resulting in increased downtime of BOP equipment during drilling is deeper waters and wells with higher pressures and temperatures (HP/HT wells). Additionally, problems with subsea BOP control systems are a significant contributor to the non-productive time of drilling rigs.

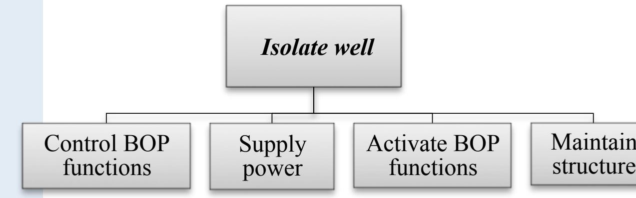
The main focus for ESD is development of a light concept, with electrical actuation and control. Additionally, the emphasis is on improved water depth capability, safety features and no release of hydraulic fluid to the environment. Their devices are made compatible for existing electro-hydraulic system, only by replacing the hydraulics with electrical power. The mechanical construction of the BOP system (sealing/ cutting devices, etc.) is, in other words, (almost) similar to excising systems. The main difference will be the actuation element on each preventer that is run by an electric motor, and subsea batteries instead of accumulators. The equipment uses the same topside infrastructure, communication systems and backup control as an existing electro-hydraulic control system.



The power actuator device can be developed for use in a ram preventer. A ring motor, with internal planetary gear, drives the ram.

External dimensions and interfaces shall as far as possible be adapted to existing BOP technology.

Results



The functional failure analysis was performed as a basis for the FMECA. The results from the **FMECA** highlight the components and functions in the BOP systems that are most exposed to failure/ downtime – and therefore critical with respect to reliability of the system, as shown in tables below:

Electro-hydraulic MUX system		
PRIORITY	**COMPONENT**	**POTENTIAL FAILURE MODE**
1	Hydraulic lines on BOP stack	Internal leakage
2	Blind shear ram preventer	Fail to shear pipe
3	Shuttle valve	Fail to move (stuck in position)
4	Subsea accumulators	Burst bladder
	Flange and gasket	External leakage

All-electic system		
PRIORITY	**COMPONENT**	**POTENTIAL FAILURE MODE**
1	Blind shear ram preventer	Fail to shear pipe
2	Actuator element	Fail to move
3	Electrical power cable	Transmission failure
	Flange and gasket	External leakage

Failure of the BSR was further studied in **fault tree analyses** of both systems, providing the following probabilities of failure:

TOP event: Failure to shear pipe and seal off well		
Electro-hydraulic MUX system	8,83438E-05	[occ.per h.]
All-electric system	1,83423E-05	[occ.per h.]

Conclusion

The results show that the all-electric BOP concept has a lower probability of failure than the electro-hydraulic system. This is based on the fact that electric components are considered more reliable than hydraulic ones. Other benefits are listed below

- Improved HSE.
- Improved monitoring and shorter repair time
- Reduced costs. Umbilicals are simplified without hydraulics.
- The all-electric equipment is less sensitive to water depth and long distances

The all-electric concept has a great potential, but there is still uncertainty associated with the implementation of such technology.

Acknowledgements

Odfjell Drilling and Electrical Subsea & Drilling have been priceless contributors to this work

NTNU – Trondheim
Norwegian University of Science and Technology

ODFJELL DRILLING

Electrical Subsea S E D Drilling