BOP Risk Model: Experiences and Future Applications

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1. Introduction

Deepwater drilling operations involve a number of critical and complex systems and components. A BOP (Blow Out Preventer) is the most critical safety system associated with drilling operations which is latched onto a wellhead and located on the seabed. BOP facilitates operators to maintain control of the well (pressure control) in normal operation. In accident conditions, it is designed to cope with extreme pressures and reduce damage to lives and environment by preventing a catastrophic blowout (uncontrolled release of reservoir fluids).

When a failure is detected in a certain system or component on the submerged BOP, the industry's typical response is to stop drilling, analyze the possible consequences, perform a risk assessment and determine the risk levels in order to take an appropriate action. These risk assessments typically aid stakeholders, including regulators, in the decision making process by providing insights on whether the fault of the component results in an unacceptable increase in risk level (BOP needs to be pulled to the surface for repair in this case), or if the faulty component has not affected risk level to the point deemed unacceptable for continuing drilling operations (BOP can remain on the wellhead).

To stop drilling and pull the BOP to the surface for manual inspection is a time-consuming operation that results in costly non-productive time. Many of the potential component failures are not critical to safety, as there are - depending on the failed component - often multiple levels of redundancy available. A BOP Failure Decision Model - which can quickly incorporate the failure mode/modes and display the risk impacts of any component failure - is useful and effective for the industry as it facilitates a sound and speedy decision making.

In the recent years, LR has invested large efforts in developing a BOP – Risk Model using LR's own risk monitor software and pooling together the vast experience and expertise from our Risk Consulting and Energy-Drilling divisions. This BOP – Risk Model helps visualize the risk level for any single or combined failures in the BOP system. This model uses concepts from the successful nuclear experiences in probabilistic safety assessment (PSA) and its risk-informed decision-making applications.

The aim of this paper is to present the development of the BOP risk model together with highlights of experiences from projects involving the model and its applications. It also envisions future development of the risk models for other safety critical systems in offshore drilling.

2. BOP RISK MODEL DEVELOPMENT

2.1 Modelling steps

Modeling of the BOP into a risk and reliability model requires several steps:

1. Create a database including all subsystems and components;
2. Identify all functions that are carried out by the BOP;
3. Develop block diagrams describing the logic path by identifying every main component for the function to work. This is further broken down to each component all the way down until every main, minor, and subcomponents needed for the function are identified.
4. Develop fault trees based on the logic block diagrams;
5. Integrate the fault tree model into the risk monitor, to compare the actual status with pre-defined risk levels.

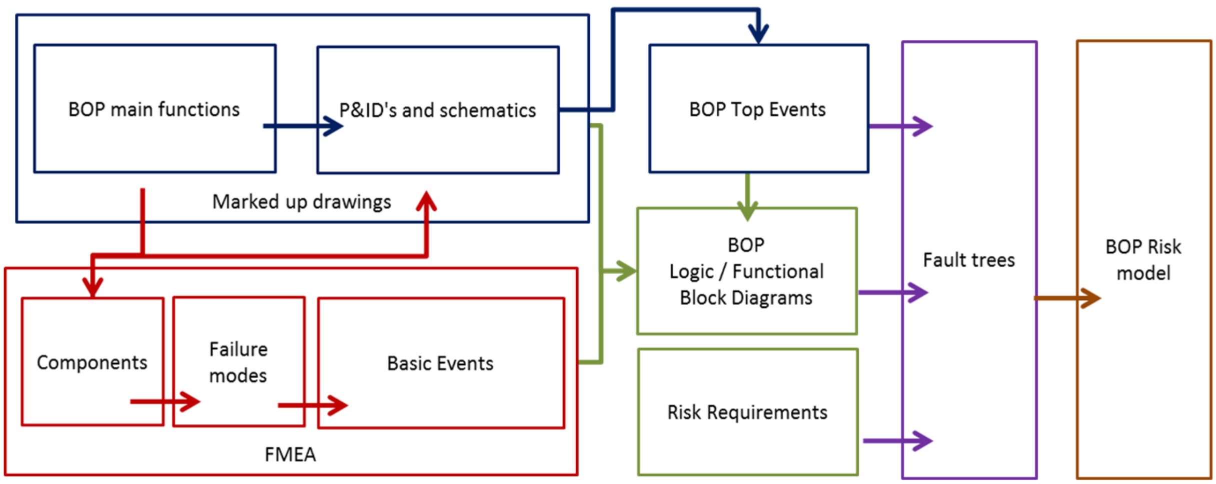

Figure 1 – Modelling of the BOP Risk Model

The risk model is developed using Lloyd's Register Consulting's proprietary RiskSpectrum RiskWatcher; a software product suite licensed for use at 60% of the world's nuclear power plants. Through the model, the risk levels are constantly monitored and based on which, operations are adjusted.

The BOP risk levels can be assessed easily, by comparing the remaining available redundancy of the BOP functions with the minimum requirements in the company policy, industry standards and the regulatory directives. The minimum requirements are identified and verified by experienced BOP experts. These requirements are the basis for the "Pull" or "No Pull" decision from the BOP Risk Model.

For the drilling rigs operated in the Gulf of Mexico, the following regulatory and industry requirements are relevant:

- CFR 250
- API 16D
- API Standard 53

The risk model can be adapted to include location specific requirements applicable to the drilling rigs operated in other areas, e.g. NORSOK requirements for Norwegian Continental Shelf.

2.2 *Software interfaces*

Four colours are introduced in the RiskWatcher software to indicate the different risk levels based on the applicable requirements and the 'real-time' BOP status:

- RED: Red on the top level indicates that critical functions cannot be operated and the BOP is below the minimum requirements. Critical functionality less than 100%.
- ORANGE: Orange indicates loss of redundancy. Detailed risk assessment of the failure taking into account the actual risk of the drilling operation must be performed.
- YELLOW: Yellow indicates that at least one component in the BOP has failed, maintenance is needed at the next available opportunity.
- GREEN: Green indicates proper functioning of all components. This must be the colour when the stack is deployed and after landing.

An example of the defence-in-depth structure can be seen in the pictures below.

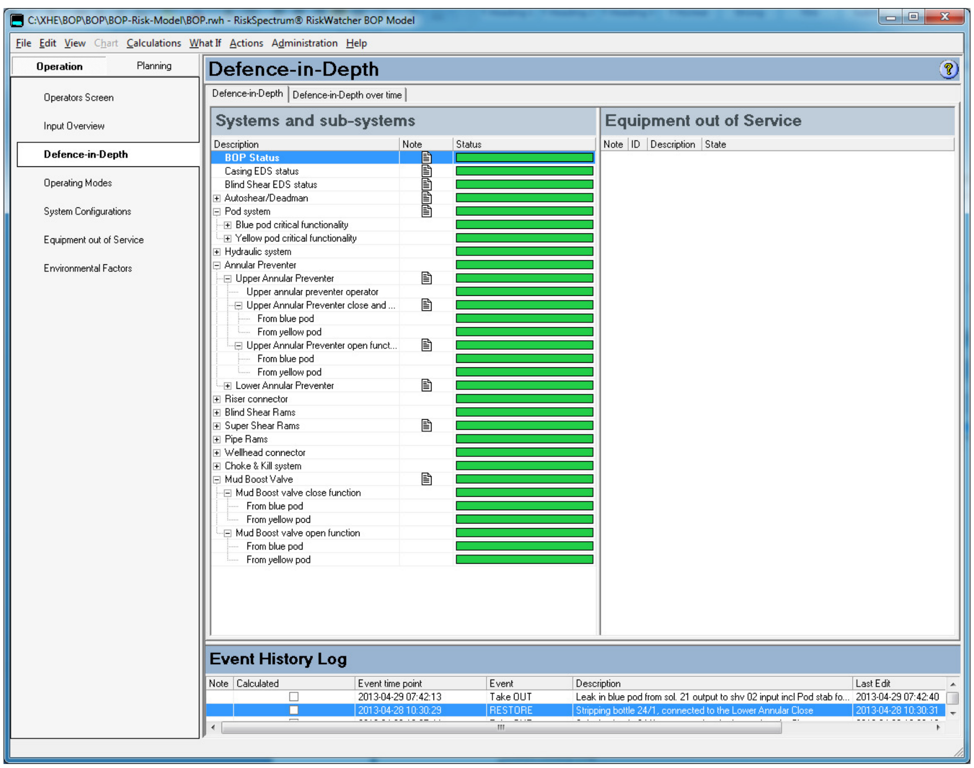

Figure 2 - An example interface in the BOP Risk Model with no failed components

3. BOP RISK MODEL APPLICATIONS

3.1 Pull or no pull decision

Once the risk model is tailored to a specific BOP, risk levels can be assessed within hours. By comparing the remaining available redundancy of the BOP capabilities with the requirements placed by the regulations, the basis for the “Pull” or “No Pull” decision can be established.

BOP Risk Model is different from the traditional BOP monitor. The traditional BOP monitor could be an advanced feature of BOP control system where the real time BOP equipment status could be monitored. BOP Risk Model, on the other hand, is built on logic block diagrams and fault tree models which aids the decision maker to assess the current BOP risk level and make a “Pull” or “No pull” decision.

Figure 3 shows an output of a BOP with three identified component failures. The overall state of the BOP in this particular case is yellow from the BOP Risk Model and drilling can continue without pulling the BOP.

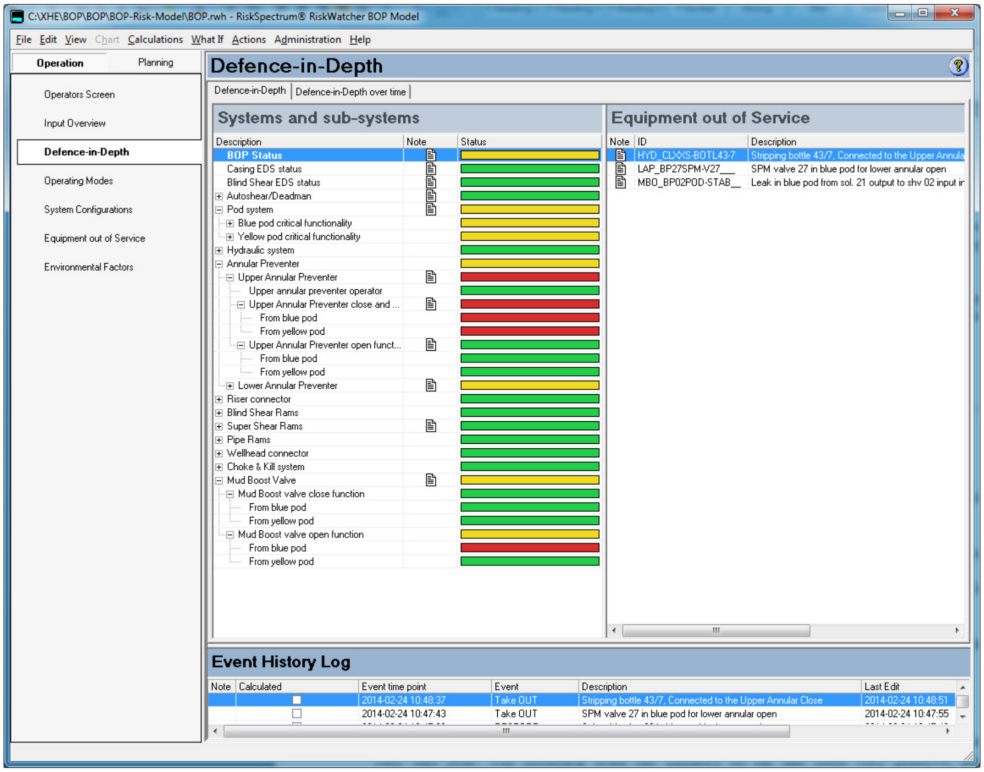

Figure 3 - An example interface in the BOP Risk Model with the identified component failures

3.2 Reliability of the BOP critical functions

In future, BOP Risk Model can also be used to evaluate the reliability of its critical functions. In some countries/regions, there are specific safety integrity level (SIL) requirements for the critical functions in a BOP. Following example is the requirement from a Norwegian guideline:

- As a minimum the SIL for isolation using the annulus function should be SIL 2 and the minimum SIL for closing the blind/shear RAM should be SIL 2

SIL 2 means the probability of failure on demand is between 10^{-3} and 10^{-2}.

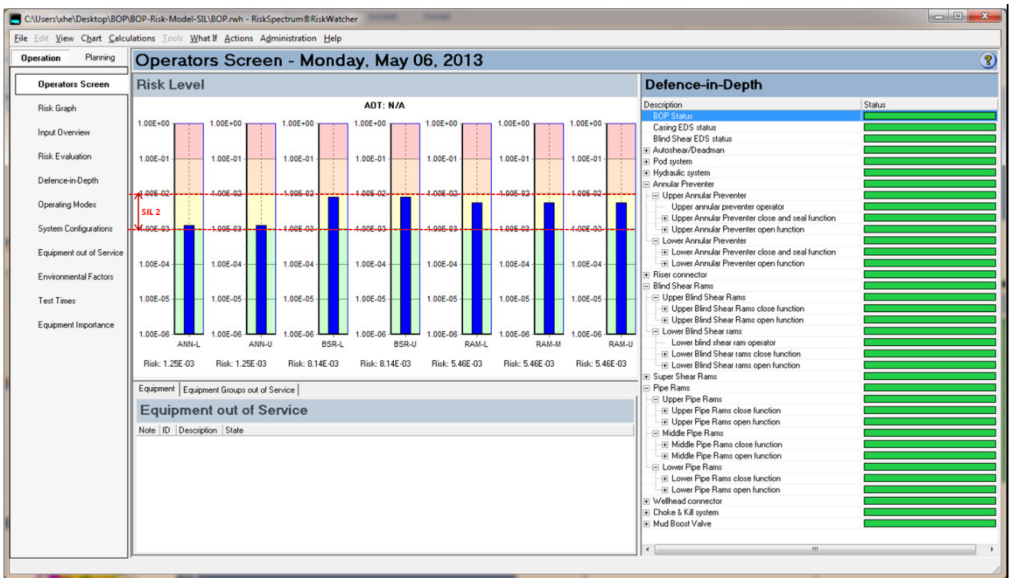

Figure 4 - Reliability of the BOP critical functions (example)

With the component reliability data included, BOP Risk Model can calculate:

- The ‘real time’ reliability level (Safety Integrity Level) of the critical BOP functions, e.g. annulus close function, blind shear RAM close function.
- The model can take into account the test interval of the BOP components. When a scheduled periodic test is extended, BOP Risk Model can be used to check if the reliablity level is still within the accepted limits.
- Component importance measures: The risk model will rank the components based on their importance.

A challenge in the reliablity calculation is the lack of BOP failure data. As a solution, we can use Bayesian approach to improve the data in the model. Firstly, the model uses generic data from offshore industry. The generic data can then be updated when enough system specific data is available, e.g. enough events stored in the software event history.

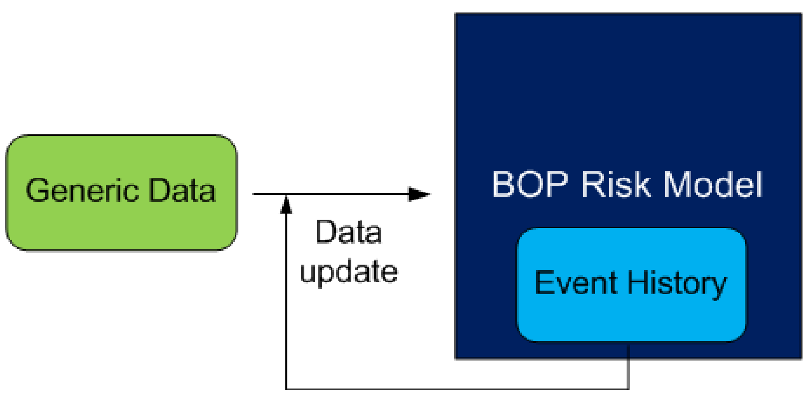

Figure 5 – Failure data collection and treatment

3.3 Application to other critical systems

BOP Risk Model is built for BOPs in the offshore drilling rigs. The same process and software can be used to build other critical systems or even the whole rig/installation. In general, risk model is suitable for a system when it satisfies one or more of the following conditions:

- system is critical to safety
- the system is complex but its component failures can be monitored/detected/evaluated and the effects can be modelled in the logics
- has some levels of redundance and needs a 'realtime' risk-based decision making
- possesses costly downtime
- has a performance/reliability target (through risk model quantitative assessment)

A good example would be an offshore subsea production system. Poor reliablity can have a major financial impact for all organizations involved in design, manufacturing, installation and operation of subsea equipment. To achieve high reliability performance, continual attention is needed to manage and minimize the potential for equipment failure. A Risk Model implemented in RiskWatcher can play an important role in this process.

4. CONCLUSIONS

BOP Risk Model projects have been successfully implemented in a number of offshore drilling rigs. Positive feedbacks are also received from the regulatory body. The model provides a good common platform for different parties including operator, drilling company, regulatory body to look at real-time BOP risk level. It helps to get accurate logical decisions and accelerates the decision making process.

The Risk Model can also be used for reliability and integrity management optimization, maintenance and spare parts management optimization.

Currently similar applications to other critical systems are being investigated. Expriences gained in the BOP applications are valuable in this process.

5. REFERÊNCIAS

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[2] I. A. Alme, X. He, T. B. Fylking, et, al. "BOP risk and reliability model to give critical decision support for offshore drilling operations", 11th International Probabilistic Safety Assessment and Management Conference and The Annual European Safety and Reliability Conference, Helsinki, Finland, 25–29 June 2012.