

RAM analysis during design phase: the best Platform offshore configuration case study.

Abstract

The aim of this chapter is to demonstrate the concept of RAM analysis applied to design phase, which supports the asset configuration definition based on sensitivity analysis which enable the cooperation of different asset configuration. In fact the RAM analysis methodology encompasses the scope, lifetime data analysis, modeling, simulation, criticality analysis, sensitivity analysis and conclusion. All those steps will be presented in order to clarify how the RAM analysis can be applied during the design phase to enable the best offshore asset configuration which enable the achievement of high performance.

Key words: RAM analysis, Lifetime data analysis, criticality analysis, sensitivity analysis, redundancies an parallel configuration.

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1. Introduction

Producing hydrocarbons in deepwater offshore requires subsea and Toplevel assets such as different types of platform.

Subsea wells have been used in support of fixed installations as an alternative to satellite or minimum facility platforms for recovering reserves located beyond the reach of the drill string or used in conjunction with floating systems such as FPSOs and FPSs.

Platform applicability should be assessed in the context of field development planning and concept selection for any specific offshore project. Basically the type of the platforms are follows:

- Fixed platform;
- Semi-submersible Platform;
- Floating Production, Storage and Offloading (FPSO);
- Floating Storage and Offloading System (FSO);
- Floating Storage Unit(FSU).
- Floating Liquefied Natural Gas (FLNG)

A fixed platform base under construction on a Louisiana river These platforms are built on concrete or steel legs, or both, anchored directly onto the seabed, supporting a deck with space for drilling rigs, production facilities and crew quarters. Such platforms are, by virtue of their immobility, designed for very long term use (for instance the Hibernia platform). Fixed platforms are economically feasible for installation in water depths up to about 520 m The Semi-submersible platform has hulls (columns and pontoons) of sufficient buoyancy to cause the structure to float, but of weight sufficient to keep the structure upright. Semi-submersible platforms can be moved from place to place and can be ballasted up or down by altering the amount of flooding in buoyancy tanks. Semi-submersibles can be used in water depths from 60 to 3,000 meters (200 to 10,000 ft).

The FPSO consist of large monohull structures, generally (but not always) ship shaped, equipped with processing facilities. These platforms are moored to a location for extended periods, and do not actually drill for oil or gas.

The FSO or FSU (floating storage unit), is used exclusively for storage purposes, and host very little process equipment. This is one of the best sources for having floating production.

The floating liquefied natural gas (FLNG) facility refers to water-based liquefied natural gas (LNG) operations employing technologies designed to enable the development of offshore natural gas resources.

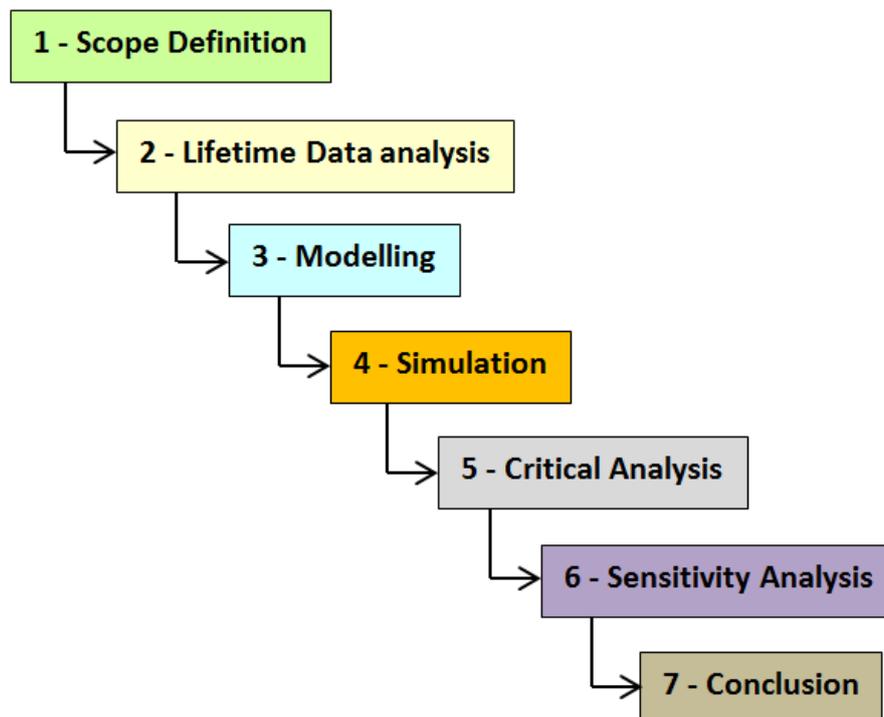
Depends on the type of reservoir, different configuration of platform is required to maximize the production by the asset maximum performance achievement.

This case study will demonstrate the prediction of platform performance based on pre-defined configuration as well as the compression of different possible configurations to maximize the platform performance.

2. Methodology

The RAM analysis methodology can be described step by step. First, the system is modeled considering failure and repair data and later is simulated to evaluate the results. Then improvement solutions are proposed. Based on such considerations, to conduct RAM analysis methodology you must define the scope, perform repair and failure data analysis, model the system RBD (reliability block diagram), conduct direct system simulation, perform critical system analysis, perform system sensitivity analysis, and then draw conclusions. The RAM analysis methodology is shown in Figure 1.

Figure 1 RAM analysis methodology



3. Lifetime data analysis

Life time analysis, regarding historical failure data of operational assets has the advantage of having more realistic data when compared to generics database such as OREDA. Thus, looking at the failure and repair equipment files, it was possible to collect data and perform life cycle analysis in statistic software (Weibull ++ 7 Reliasoft) to define PDF parameters for each failure mode in this case study.

To ensure the accurate representation of such data, maintenance professionals with knowledge of such equipment took part in this stage.

Table 2 shows the some examples of lifetime data analysis results applied in the RBD model.

Table 2 Lifetime data analysis PDF result

| Equipment | Source Information | PDF | Failure (years) | | PDF | Repair (hours) | |
|--|--------------------|--------|-----------------|----------|--------|----------------|----------|
| | | | μ | σ | | μ | σ |
| ESDV | Company Data | Normal | μ | σ | Normal | μ | σ |
| | | | 3.5 | 0.5 | | 8 | 4 |
| Compressors | Company Data | Normal | μ | σ | Normal | μ | σ |
| | | | 3.5 | 0.5 | | 84 | 26 |
| Pumps | Company Data | Normal | μ | σ | Normal | μ | σ |
| | | | 3.0 | 0.5 | | 28 | 4 |
| Vessel (drum, scrubber, column) | Company Data | Gumbel | μ | σ | Normal | μ | σ |
| | | | 25 | 1 | | 136 | 22 |
| Heat Exchanger (air cooler and shell & tube) | Company Data | Normal | μ | σ | Normal | μ | σ |
| | | | 9 | 1 | | 136 | 22 |

4. Modelling

In order to model the offshore system, it's necessary to define the assets boundaries included in such asset management scope. In addition, for each asset life cycle different analysis will require different types of analysis. Therefore, for this case study it will be considering the selection and concept phase where the RAM analysis is carried out in system and equipment level. The asset scope encompasses the offshore platform and utilities systems.

The platform system encompasses the following as:

- Feed.
- Separation.
- Recompression.
- Water treatment

Figure 3 show the separation train represented by RBD configuration.

Figure 3 Separation Train

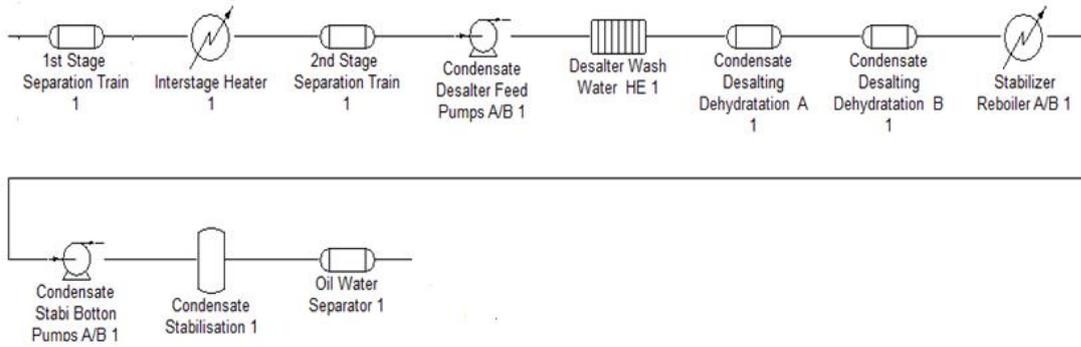


Figure 4 show the recompression train represented by RBD configuration.

Figure 4 Recompression Train

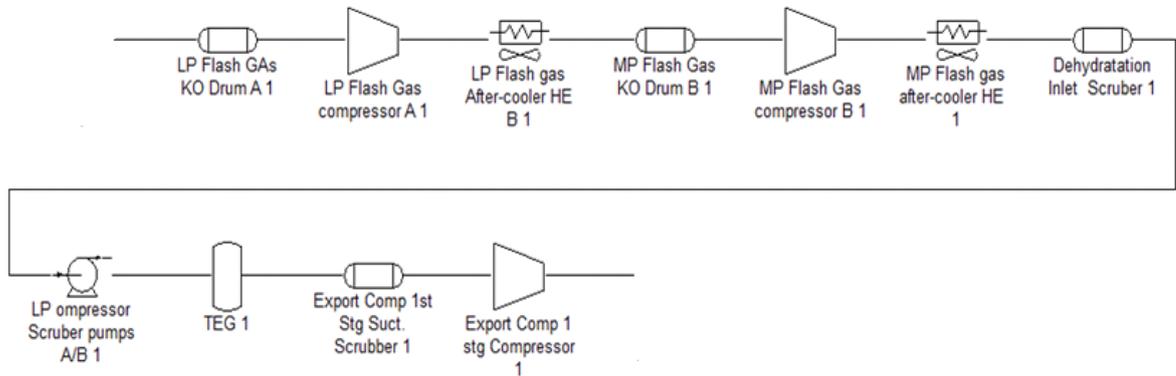
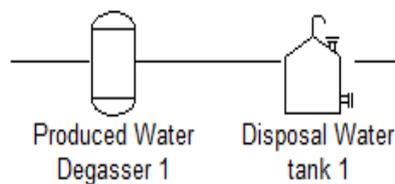


Figure 5 show the water treatment train represented by RBD configuration

Figure 5 Water Treatment



In addition to the platform asset the critical utility system encompasses the following as:

- Flare.
- Medium Heating
- Instrument Air

Figure 6 shows the Flare system represented by RBD configuration

Figure 6 Flare System

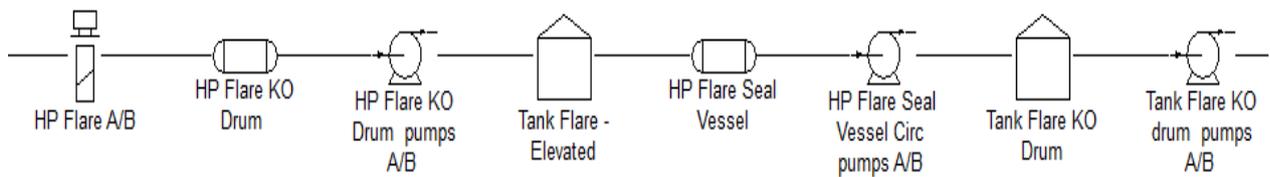


Figure 7 show the Medium Heating represented by RBD configuration

Figure 7 Medium Heating

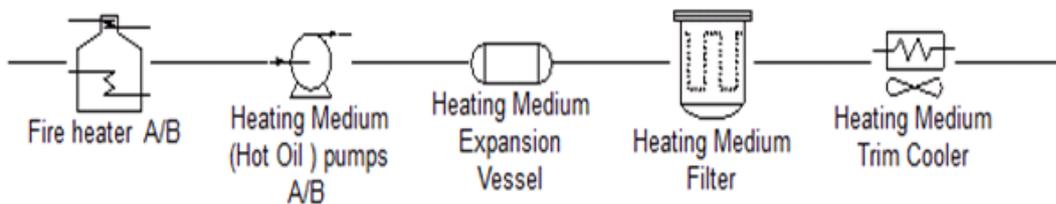
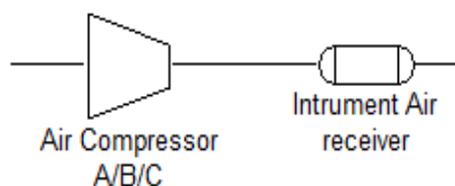


Figure 8 shows the Instrument Air represented by RBD configuration

Figure 8 Instrument Air



5. Simulation

The simulation allows creating typical life cycle scenarios for proposed systems, with Monte Carlo simulation methodology. The entire asset was modeled through RBDs, considering the redundancies in each piece of equipment or system configuration. The simulation was conducted for 10 years and 1000 tests were run to converge results. The production efficiency, operational availability and reliability achieved in five years are respectively 98.14%, 99.97% and 17%; In addition there will be 12.52 failures are expected in 5 years, The specific performance of each individual system is demonstrated in the Table 1. This

system configuration considers two trains of separation and two trains of Recopression with 50% of total capacity.

Table 1 Asset Performance Prediction

| Asset Performance prediction (10 years) | | | |
|--|-----------------------|--------------------------|-------------|
| Facility | Production Efficiency | Operational Availability | Reliability |
| Platform | 98.33% | 98.88% | 20% |
| Utilities | Production Efficiency | Operational Availability | Reliability |
| Instrument & Plant Air | 98.78% | 99.99% | 99.99% |
| Heating Medium | 98.64% | 98.89% | 97.5% |
| Flare- Vent System | 99.99% | 99.99% | 99.99% |
| Facility + Utility | 98.14% | 99.97% | 17% |

The production efficiency, operational availability target is respectively 98% and 99%, which requires to analyze the critical equipment and, furthermore, to perform sensitivity analysis to improve the performance indexes if it possible.

6. Criticality analysis

The critical analysis defines which are the most critical subsystems and equipment with the most influence on production losses. The global relative loss means the percentage of total production loss and the downtime impact means the percentage of the total downtime loss. Table 2 shows the critical equipment based on global relative loss and downtime impact

Table 2 Critical equipment

| Equipment | Global Relative Loss (%) | Downtime Impact (%) |
|---------------------------------|--------------------------|---------------------|
| Export Compressor 1 Stg train 2 | 15.75 | 15.87 |
| Export Compressor 1 Stg train 1 | 15.53 | 15.30 |
| LP Flash Gas Compressor Train 1 | 15.83 | 11.60 |
| LP Flash Gas Compressor Train 2 | 15.58 | 11.25 |
| MP Flash Gas Compressor Train 1 | 15.37 | 10.18 |
| MP Flash Gas Compressor Train 2 | 15.38 | 10.53% |
| Total | 93.48% | 64.30% |

The other index that must be used as a reference to define improvement actions in critical equipment is the availability rank index, and in the Platform system case, the equipment configuration in the RBD because the equipment in parallel has no 100% unavailability effect on the whole system. Even in cases of partial effect like the compressors presented in

table 3, this index will indicate critical equipment to be monitored for the achievement of the target.

Table 3 Operational availability Rank

| Equipment | Operational availability Rank (10 years) |
|---------------------------------|---|
| Export Compressor 1 Stg train 1 | 98.69% |
| Export Compressor 1 Stg train 1 | 98.69% |
| LP Flash Gas Compressor Train 1 | 98.69% |
| LP Flash Gas Compressor Train 2 | 98.69% |
| MP Flash Gas Compressor Train 1 | 98.69% |
| MP Flash Gas Compressor Train 2 | 98.69% |

The Table 3 show the equipment with the lowest operational availability. All other equipment has higher operational availability than 98,69%, which shows that the compressor are the most critical equipment.

7. Sensitivity analysis

After critical analysis, it becomes clear that it is mandatory to implement the improvements in some equipment to achieve the performance indexes target whenever it's possible. In addition, the other possibility is to test different system configuration. The tradeoff of the reliability improvement need spares configuration need to take into account the impact of LCC, the feasibility of performance achievement and the time to implement and develop more reliable equipment. In this specific case, the reliability index definition for each equipment is considered very high based on company database which shows the highest reliability performance for each equipment. Therefore, the solution was to model different asset configuration in order to compare the performance achieved in 10 years. The following cases were considered as baseline to decide the best configuration as:

- Two separations and decompression trains with 50% of capacity each one.
- Three separations and decompression trains with 33.33% of capacity each one.
- One separations and decompression trains with 100% of capacity each one.

Table 4-32 show the asset performance sensitivity case comparison.

Table 4 Asset Performance by year

| Asset Performance prediction (10 years) | | | |
|--|--|--------|--------|
| Year | Production efficiency by configuration | | |
| | 1 x 100 | 2 x 50 | 3 x 50 |
| 1 | 98.89% | 99.99% | 98.79% |
| 2 | 98.87% | 98.88% | 98.88% |
| 3 | 98.09% | 98.55% | 98.77% |
| 4 | 95.62% | 96.35% | 98.49% |
| 5 | 97.67% | 97.83% | 98.43% |
| 6 | 97.47% | 97.94% | 98.41% |
| 7 | 97.13% | 97.98% | 99.99% |
| 8 | 96.34% | 98.97% | 98.89% |
| 9 | 96.81% | 97.88% | 98.89% |
| 10 | 96.11% | 98.89% | 98.89% |
| Average production Efficiency | 97.30% | 98.33% | 98.84% |

Based on the result of Table 4 the best result is achieved by the configuration 3 x 50% trains (Separation and Recompression). Even though, such configuration increases the operational cost by increasing the maintenance and inspection cost as well as the acquisition cost. In order to improve the configuration 2 x 50%, the preventive maintenance will be implemented. Some of the preventive maintenance applied to the platform equipment is defined as follows:

- Test and Inspection for all vessels and tanks in each 5 years.
- Schedule Maintenance for compressor in each 3 years.
- Schedule Maintenance for critical valves for each 2.5 years.
- Predictive maintenance and monitoring online for all pumps during the lifecycle operation. It's expected to detect pump failures in over 2,5 years.
- Monitoring online for all compressors. It's expected to detect compressor failures after 3 years.

Based on the limitation of the RAM analysis softwares by simulating the effect of predictive maintenance and online monitoring, the main assumption considered in the model is that all equipment will achieve the warranty target which enable to have no failure before the defined schedule maintenance.

By implementing such preventive maintenance policies, the effect of asset performance is to increase the production efficiency, operational availability and maintain high reliability. The

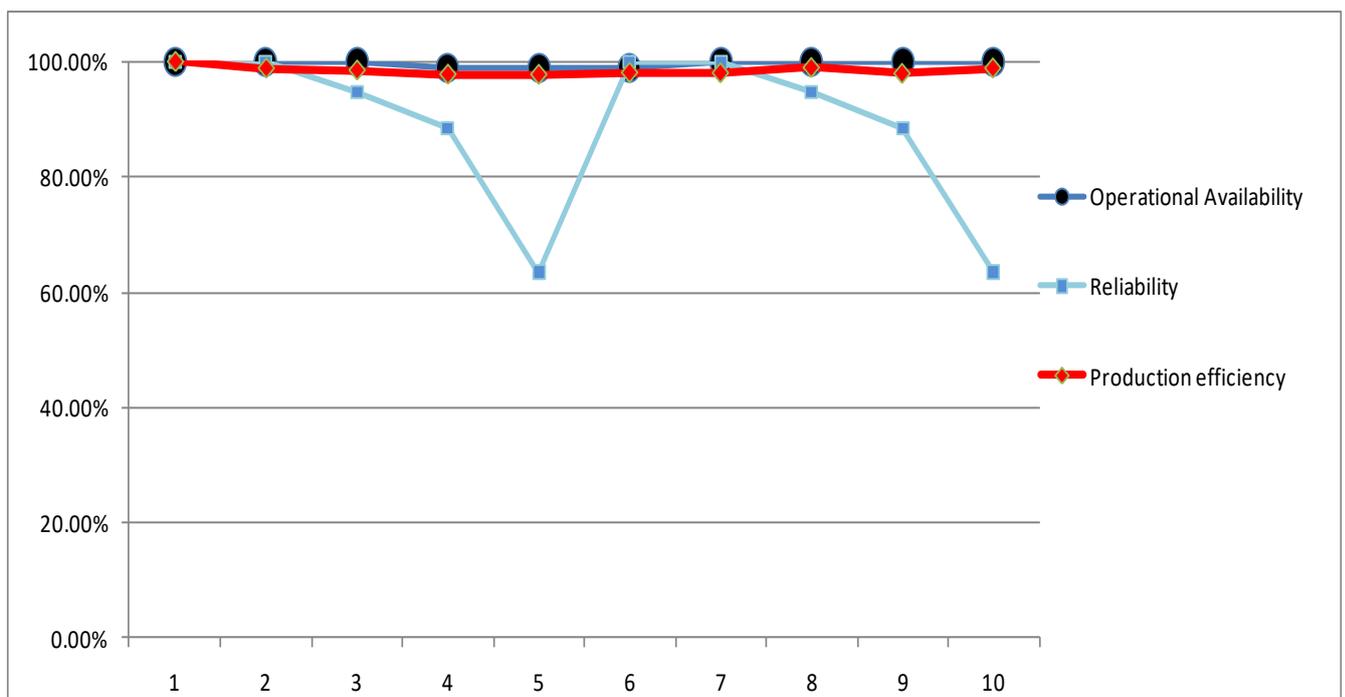
performance of the asset after the implementation of preventive maintenance is described in Table 5.

Table 5 Asset Performance after preventive maintenance

| Years | Operational Availability | R(t) | Production Efficiency |
|-------|--------------------------|--------|-----------------------|
| 1 | 99.99% | 100% | 99.99% |
| 2 | 99.99% | 99.90% | 98.88% |
| 3 | 99.99% | 94.80% | 98.55% |
| 4 | 98.98% | 88.50% | 97.85% |
| 5 | 98.98% | 63.40% | 97.83% |
| 6 | 98.99% | 100% | 98.14% |
| 7 | 99.99% | 99.90% | 98.08% |
| 8 | 99.98% | 94.80% | 98.97% |
| 9 | 99.98% | 88.50% | 97.98% |
| 10 | 99.98% | 63.40% | 98.89% |

The average operational availability and production efficiency are 99.69% and 98.52% respectively. Such positive effect of preventive maintenance on asset performance, enable the improvement of performance by reducing the downtime caused by corrective maintenance. In fact, the downtime related to preventive maintenance in many cases is similar to the downtime caused by the corrective maintenance. What is avoided by preventive maintenance is the logistic delays caused when corrective maintenance need to be implemented. The additional positive effect of preventive maintenance is the reliability recovery, which reduces the risk of failure and unexpected system shutdown as shows the Figure 9.

Figure 9 Asset performance after preventive maintenance by years



8. Conclusion

The RAM analysis is a powerful reliability engineering, quantitative method which supports Oil and Gas asset projects in taking a better decision about the asset configuration and the effect of such configuration in the asset performance. The main advantages demonstrated in this case study to implement RAM analysis during the design phase in Oil and Gas industry were:

- To predict asset performance, such as production efficiency, operational availability and reliability
- To define the critical equipment which impact on asset performance
- To define the minimum reliability requirement to be achieved during warranty time in order to enable the asset to achieve the performance target.
- To enable the different asset configuration, performance
- To analyze the effect of preventive maintenance policy on asset performance.

As far as the design specification of different equipment are defined, a more detailed RAM analysis must be performed based on the top level RAM analysis one. In addition, once the equipment configuration is defined, the maintenance policies in component level must be in fact, the RCM analysis is a very good approach to define the maintenance policies based on component failure modes. The result of the preventive maintenance tasks must be input in the RAM analysis in order to predict the effect of such tasks in the System performance.

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