해양 원유/가스 생산플랜트 해저 시스템의 신뢰성, 가용성 및 유지보수성 분석

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RAM Study on a Subsea Production System of an Offshore Oil and Gas Plant

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Introduction

The oil and gas from subsea wellheads are transported via pipelines to an offshore platform. The platform processes and exports them to an onshore terminal or shuttle tankers. In these offshore processes, the process shutdown of the subsea or platform system can cause huge economical damages. So the reliability/availability of the system should be maintained over some critical limits. Especially as the subsea system has bad accessibility and the transportation time of required facilities for maintenance is considerable, the requirement for the subsea system's availability is quite severe. The RAM analysis can be utilized to assess the subsea system's availability and reduce the system's downtime. This study is carried out to assess the availability of the present design and evaluate some recommendations and changes for the design to meet 99% availability of the subsea system.

Overview of Subsea System

Table 1. Subsystems of Subsea System

Sub system	Equipment
Wellhead control system on platform	MCS (Main Control System) HPU (Hydraulic Power Unit) EPU (Electrical Power Unit) DCS (Distributed Control System) ESD (Emergency Shutdown System) UPS (Uninterrupted Power System) Chemical Injection Package TUTU (Topside Umbilical Termination Unit)
Umbilicals	Signal/Power Lines Hydraulic/Chemical Lines
Subsea control system	UTDA (Umbilical Termination & Distribution Assembly) SCM (Subsea Control Module) SCMMB (Subsea Control Module Mounting Base)
Wellhead system	Xmas Tree System Shutdown and Control Valves Flowline System

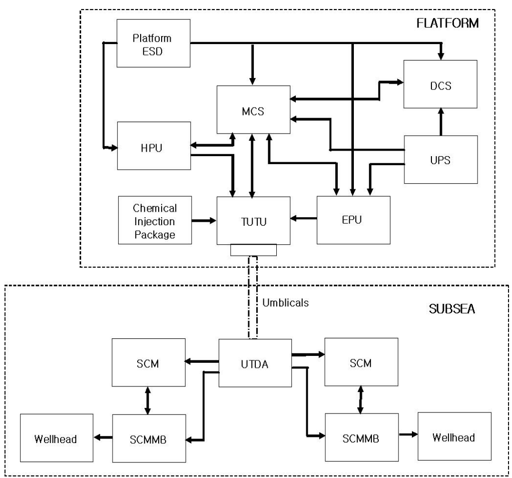

Figure 1. Subsea System Diagram

Theory and Applied Data

1. Failure rate and modes

Failure rate is the average rate at which failures occur, and may be constant or variant with time. The probability of failure of a system is generally dependent on various factors, including the failure characteristics of its components, the operating environment, maintenance and inspection regime, etc. For the purposes of this study, failures of the components comprising the various essential systems will be treated as unrevealed failures. In general, reliability/availability is obtained through statistical analysis of historical failure data (e.g. from maintenance records) from the platform or process. In the absence of site-specific data, data published in OREDA, NPRD are to be used.

A failure mode is defined as the way an item of equipment fails to function as intended. The failure effects describe the loss of required functions that result from failures. The failures considered have been restricted to hardware components and systems. The failure modes are divided into the following three types.

Table 2. Failure Modes

Failure Mode	Description
Critical	A failure that causes sudden cessation of one or more fundamental functions. This failure requires immediate corrective action in order to return the item to a satisfactory condition.
Degraded	A failure that is gradual, partial or both. Such a failure does not cease the fundamental functions, but compromises one or several functions. The function may be compromised by any combination of reduced, increased or erratic out puts. In time, such a failure may develop into a critical failure.
Incipient	An imperfection in the state or condition of an item of equipment that a degraded or critical failure can be expected to result if corrective action is not taken.

2. Reliability

Reliability is defined as the probability that a given system will perform a required function under stated conditions for a stated period of time. The reliability of a system may be viewed as a measure of its quality and performance. Mathematically, it is expressed as follows:

$$R = e^{-\lambda \cdot t}$$

where λ is component failure rate; and t is time period.

3. Availability

Availability is defined as the probability that the system will be in an operational state (i.e. percentage of time a system will be operational relative to the overall time period under consideration). Mathematically, availability can be expressed as follows:

$$Availability,\ A = \frac{u(t)}{u(t) + d(t)}$$

where u(t) is uptime and
d(t) is downtime (proportional to the failure rate and repair time).

4. Maintainability

Maintainability is defined as the probability that a particular repair can be performed within a given time. It is sometimes related to reliability in which the frequency of each repair action is determined by failure rates. Two classes of maintenance are considered in the study, i.e., corrective and preventive maintenance. Corrective maintenance or repair is performed following the occurrence of a failure, the objective being to return the system to a working state as soon as possible. To quantify the effect of corrective maintenance on the availability of the system, repair data can be obtained from various surrogate data such as OREDA.

5. Redundancy and voting system

The simplest form of redundant system is the parallel configuration. If the two-component system is redundant (i.e., parallel), it will function if either of the two subsystems function. If we assume constant component failure rates, the time dependence of the reliability is:

$$R = e^{\lambda_1 t} + e^{\lambda_2 t} - e^{(\lambda_1 + \lambda_2)t}$$
$$MTTF = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} - \frac{1}{\lambda_1 + \lambda_2}$$

These results are applicable only to active parallel systems in which all the components are in operation from t=0. For a standby configuration in which the second unit is not turned on until the first fails, the failures are not independent.
The voting system is the variation of redundancy. Here, M is the minimum number of the N units that must function for the system to operate successfully. For example, a 2oo3 voting system shows following availability results.

$$A = 1 - (1 - A_1 \cdot A_2) \cdot (1 - A_2 \cdot A_3) \cdot (1 - A_1 \cdot A_3)$$

<u>Results</u>

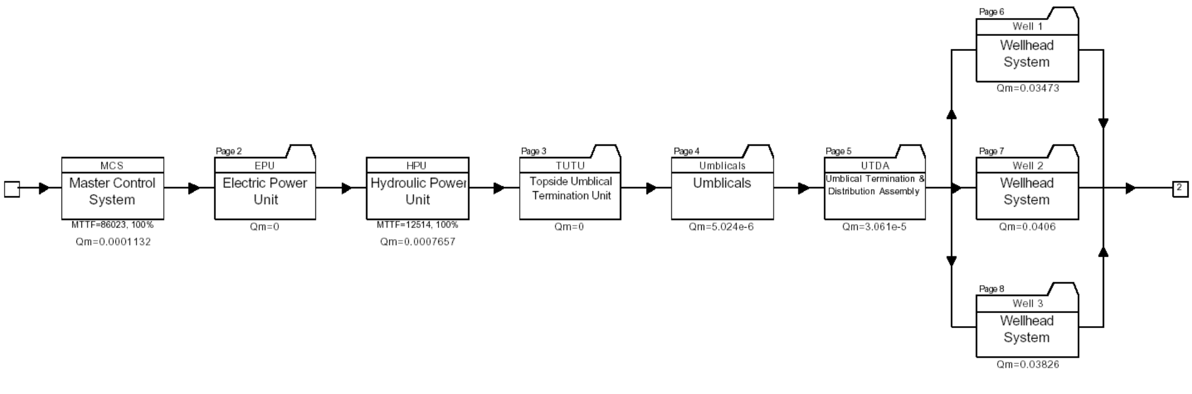

Figure 2. Overall RBD for Subsea System

From the qualitative analysis to identify the critical facilities affecting the system's overall availability, the chemical injection system and the platform DCS system are excluded. Also the results show that dual redundancies should be applied to almost all

Table 3. Availability of Subsystem

Subsystem	Availability
MCS	0.99989
EPU	0.99999
HPU	0.99924
TUTU	0.99999
Umblicals	0.99995
UTDA	0.99997
Wellheads	0.96547

the subsystems. Whether adopting redundancy or not shows significant differences not because the subsystem's original failure rate but because required mobilization time of MODU (Mobile Offshore Drilling Unit: 3 months) or DSV (Diving Support Vessel: 20 days) for repairing.

The RBD (Reliability Block Diagram) such as in Figure 2 is built on these analysis. The RBD assessments show coincident results of the qualitative criticality analysis. For example, a single HPU configuration shows only availability of 0.9717 although a dual HPU redundancy configuration shows availability of 0.9992. Two significant subsystems are identified from RBD analysis; HPU and Wellhead system. Although the Wellhead system itself shows the lowest availability, the total Wellheads system shows 99.993 % availability by adopting a 2oo3 voting system.

On the basis of above results, several operating and maintenance options are applied to optimizing operational cost and system's availability. The final inspection campaign setting and maintainable item's stock strategies show 99.45 % availability

Conclusions

The design of the subsea system can be verified and modified to meet the required availability of 99% via the RAM (Reliability, Availability and Maintainability) study. Qualitative analysis is undertaken to recognize each failure mode and the consequence of events related to the identification of the critical facilities for the subsea system's production efficiency. The RBD method is utilized for the quantitative analysis of the systems reliability. On the basis of the RBD results, the availability and maintainability are assessed using several operating and maintenance strategies. Some configuration of facilities are changed, and inspection intervals for maintenance are set, which results in final 99.45 % availability.

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