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Operational management of offshore energy assets

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Abstract. Energy assets and especially those deployed offshore are subject to a variety of harsh operational and environmental conditions which lead to deterioration of their performance and structural capacity over time. The aim of reduction of CAPEX in new installations shifts focus to operational management to monitor and assess performance of critical assets ensuring their fitness for service throughout their service life and also to provide appropriate and effective information towards requalification or other end of life scenarios, optimizing the OPEX. Over the last decades, the offshore oil & gas industry has developed and applied various approaches in operational management of assets through Structural Health and Condition Monitoring (SHM/CM) systems which can be, at a certain level, transferable to offshore renewable installations. This paper aims to highlight the key differences between offshore oil & gas and renewable energy assets from a structural integrity and reliability perspective, provide a comprehensive overview of different approaches that are available and applicable, and distinguish the benefits of such systems in the efficient operation of offshore energy assets.

1. Introduction

A generic definition of Operations Management refers to the process of maximizing the creation of goods and services in the most efficient and effective way on a business [1] by planning, organizing, coordinating, and controlling all the necessary assets and resources. Therefore, people, equipment, technology, IT and all other assets involved in production are managed always looking for an increase in revenues (or value), a reduction in costs through an improvement of internal effectiveness [2] and at the same time, complying with strict HSE regulations. Operational management (OM) of assets extends this scope to also consider the efficient planning and execution of activities relating to delivery of a service or a process. For this reason, OM can be considered as a critical management function of every business, being its performance determinant for success.

Energy assets, and especially those deployed offshore, are designed for long periods of operation, which often exceed 30 years and during which they are subject to extensive environmental and operational loads. Performance of structures as they age is expected to deteriorate hence decisions need to be taken on how their operational regime should be modified in order to comply with the supply and demand requirements. Especially for renewable energy assets, which contrary to Oil & Gas once have tighter profit constraints and minimization of CAPEX is a fundamental requirement, efficient operational management strategies should be employed towards overall optimization of the return on investment (ROI).

This paper aims to present a review of the current status of operational management for energy assets, particularly distinguishing similarities and differences in approach between Oil & Gas and Renewable Energy assets, identifying common practices, key standards and fundamental characteristics. A discussion and generic presentation of an operational management strategy will also be presented for a



generic offshore structure, highlighting the need for availability of appropriate data and procedures for maximising the information through appropriate post processing frameworks.

2. Comparison between oil and gas and renewable energy assets

Providing a formal definition for the term “asset” it can be defined as “a resource controlled by the enterprise as a result of past events and from which future economic benefits are expected to flow to the enterprise” [3], while [4] introduces to the definition the possibility of having intangible assets by “assets are resources or rights” and [5] goes a bit further introducing the term “probable future economic benefits” allowing consideration of those known but unproduced resources.

Within this paper, two different applications are considered, the offshore Oil & Gas and the offshore Renewables Energy industries and for the latter with a focus to offshore wind energy. Within the Offshore Oil & Gas industry the following assets can be considered: oil and gas platforms, access equipment, onshore facilities, stored gas or fuel, the gas and fuel expected to be extracted, technicians and personnel training programs, warehouses, among others. In the Offshore Wind industry assets can be considered to be: the wind farm structures, taking into account the turbines, submarine cables, offshore and onshore substations, onshore facilities (operations base, warehouses, spares, equipment, technicians and personnel training programs, access equipment, etc. There is an important difference between Oil & Gas and renewables assets, which is that oil and gas can be considered assets when they are in the reservoir, as they are “probable future economic benefits”; and also once they have been extracted and stored or processed. However, wind resource cannot be considered an asset as firstly, it is a renewable source, which means it cannot be depleted and secondly, the electricity produced by it, cannot be stored.

This two applications are governed by different types of risks. In the Offshore Wind industry the most critical risks are the ones related to the integrity of the units, its downtime and the loss of production due to poor availability of the turbines and high maintenance requirement, while in the offshore Oil & Gas industry it is crucial to ensure that the resource can be extracted and stored in the same quality and required quantity; it is also critical to ensure the structural integrity of the platforms as there are manned structures and the loss of lives is a fatality not comparable to the collapse of a wind turbine, which only result to economic losses.

For these risks some mitigation options can be identified: designing platforms complying with up-to-date Health and Safety (H&S) protocols and design standards, continuous investment in personnel’s trainings, development and installation of Structural Health Monitoring systems or a combination of Condition-based with Risk-based maintenance of structural components; the latter constituting proactive operational management approaches. The risk-based methodology presents a cost-effective way of minimising life cycle costs in the management of assets whilst maintaining reliability or availability targets, and operating within safety and environmental regulations [6].

Moreover, there is a significant difference in the supply chain of these structures. Taking into account that an offshore wind farm can easily have more than 50 turbines and specially nowadays that the trend is to deploy in more remote locations, it can be concluded that Renewable Energy assets are designed to be fabricated in volumes, while each Oil & Gas structure can be considered as unique. Therefore it is reasonable to consider that maintenance replacements and spares need to be planned efficiently for Oil & Gas assets, as the sudden necessity of a non-predicted spare could take a significant amount of time to be manufactured, with the subsequent loss of revenue.

3. Operational Management of offshore Oil and Gas assets

3.1. Overview

Offshore Oil & Gas assets may have a significant impact on the profits they generate and their efficient operation should constitute a strategic aspect for operators. For that reason, operational management plays an important role not only ensuring the performance and the fitness for service of those assets, but also aiming for Operational Excellence required for maximising profits. Assets performance can be

influenced by numerous factors such as inefficient maintenance planning, communication issues, increased downtime due to extreme weather conditions and unexpected failures, human factors, constant change in operating and environmental conditions, etc. Thus, asset damage, business interruption, pollution, injuries to people, and damage to components are key potential consequences in conventional activities [7].

Whether some of these factors occur due to uncertainties and cannot be controlled, as for example extreme weather or frequent changes in operating conditions, the majority of the rest can be addressed by using appropriate Operational Strategies (OS). This term was defined by [8] as the pattern of decisions that shape the long term capabilities of an operation and their contribution to the overall strategy of the company. These strategies revolve around patterns of choices that usually are from medium to long term nature and to reflect both the core capabilities and competencies of the company [9]. For example, the mature Oil & Gas industry uses Structural Health Monitoring and Condition Monitoring (SHM and CM) Systems combined with the experience developed during the years of operations, and this is recognised as an appropriate and efficient operational management approach.

SHM and CM Systems are important for collecting the data required for carrying out the appropriate risk assessment based on the structures current (and historically recorded) operating conditions, which may vary from the conditions they were initially designed for. Moreover, based on the data collected, several assessments related to the Structural Integrity and Reliability (SI/SR) of the unit can be determinant for both evaluating if the structure's performance degrades as well as establishing a bespoke inspections and maintenance plan. This Operational Risk Assessment is also necessary in case the assets are intended to operate outside normal operating conditions [7]. Furthermore, poor data quality heavily impacts the decision-making process, increasing the risks of operational mistakes. Oil & Gas operators need to carefully tackle this issue to avoid reducing effectiveness of operations. Additionally inconsistent data across systems increase the risk non-compliance to regulators. One of the most significant challenges for the Oil & Gas sector is to manage and post process the huge amount of data and SHM and CM Systems data, and at the same time maximise the information that can be derived from combination of monitoring systems.

3.2. *Legislation and standards*

The main UK legislation related to risk assessment, H&S Management and Installation of offshore Oil and Gas Assets are: Health and Safety at Work etc. Act 1974 [10], Management of Health & Safety at Work Regulations 1999 [11], Offshore Installations (Safety Case) Regulations 2005 [12], Offshore Installations and Wells (Design & Construction etc.) Regulations 1996 [13], Offshore Installations (Prevention of Fire & Explosion, and Emergency Response) Regulations 1995 [14], Pipeline Safety Regulations 1996 [15], Offshore Installations and Pipeline Works (Management and Administration) Regulations 1995 [16], Provision and Use of Work Equipment Regulations 1998 [17], among others.

Further, the most widely used Standards for Offshore Operations are:

- API RP2MET/ISO 19901-1:2006 - Deprivation of Metocean Design and Operating Conditions.
- API RP2MOP/ISO 19901-6:2009 - Marine Operations.
- API RP2SIM: Recommended Practice for Structural Integrity Management of Fixed Offshore Platforms.
- API RP75, Recommended Practice for Development of a Safety and Environmental Management Program (SEMP) for Offshore Operations and Facilities.

Relevant standards developed by British Standards (BSI) are: BS EN ISO 13628 parts 1-11: 1999-2007 [18] and BS 6349-1-1:2013 Maritime works. General. Code of practice for planning and design for operations [19].

Moreover, due to the fact that the presence of ice, snow, extreme cold temperatures, and extremes in daylight hours requires operational procedures for ice management, some Standards for Artic Oil & Gas Operations are currently being developed [20]. These standards aim to regulate the use of specialized equipment and materials, for working in both cold temperatures and long periods of darkness, as well

as how to handle emergencies in these extreme conditions. It is expected that these standards will help to reduce operational costs [21].

3.3. *Operational excellence*

Oil & Gas operators are constantly working towards achieving Operational Excellence (OE) required for maximising the profits of the business. This aspiration assures that their assets are operated safely, reliably, sustainably and cost effectively [22]. Many of these companies have high quality management programs, codified manuals and active measurement and training. Top management support, employee training, and employee involvement are some of the key variables that have to be enhanced in order to improve operational performance [23].

The convergence theory [24] states that learning will allow managers to adopt different cultures (and therefore, different ways of doing things) to carry out the same efficient management practices. Moreover [25] agree in the importance of personnel training in increasing productivity, while [26] was able to show empirically how significant is the improvement that quality information and analysis have on process management.

4. **Operational Management of offshore Renewable Energy assets**

Offshore Renewables Energy assets Operation Strategies (OS) are in principle similar to those employed in the Oil & Gas industry. However, due to the differences already mentioned (manned vs unmanned; single vs multiple structures, etc), and the multidisciplinary risks of offshore renewables [27,28], these need to be adapted to the application and optimised to make this industry as efficient as possible, due to its tight economic constraints and related financial risks. This aim will encourage optimisation not only of the design, but also the operation, maintenance and inspection strategies [23]. Design and operation of offshore wind farms is influenced by several factors as have been studied in [29,30,31].

Due to the continuous expansion and development that is currently taking place within the Offshore Wind industry, it had to rapidly adapt OS to the allow deployment further offshore and in larger Wind Farms (WF), without proportionally optimising these strategies, collecting and processing data regarding the structural integrity of units. However, as previously happened with the Oil & Gas industry, it is expected that as soon as the sector gets some experience, OS will tend to become harmonised, following the convergence theory, which mixes both, the Culture Free [32] and the Culture Specific [33] theories in the evolution of management practices [23]. Another important difference between the two applications is the associated level of risks associated with their O&M activities. Therefore, Offshore Wind OS should address this factor adapting, among other things, relevant Health and Safety (H&S) protocols. Some examples of such risks are:

- The permanent personnel on the structure: while Oil and Gas platforms have in average 80 people and possibility of fatalities is completely unacceptable, there is no personnel inside offshore wind turbines during operation; therefore H&S protocols regarding this issue do not need to be as strict as for Oil and Gas platforms.
- The level of exposure the structure has during maintenance activities and H&S protocols required. In case of wind turbines, even though the structures are unmanned and during operations no life is risked, safety during maintenance has to be carefully assessed as a wind turbine is much more exposed to weather conditions than an Oil & Gas platform.
- The level of risk associated with the spares and equipment transport, storage and access to the turbines is significantly more complicated and costly in the Offshore Wind Industry, as inside a nacelle there is not much storage and working space compared to Oil & Gas platforms. This factor makes maintenance costs proportionally higher and an economical risk for the operator that has to be carefully considered and optimised.

According to [34], the cost of offshore O&M activities currently varies from 2 to 5 times the cost onshore. One of the reasons is the increased loading WTs have due to the offshore environment and the variation from the loadings they were initially designed for [35]. Moreover, the additional effort of building wind turbines that resist the environmental harshness of the offshore environment and avoid

hazards such as corrosion, would drive not only CAPEX, but also O&M costs offshore even higher [36,37]. This is the reason why operators are currently looking for strategies that enhance the efficient operation of turbines reducing the O&M costs.

One of the best ways of enhancing efficient operation is by employing SHM/CM systems, as part of a Condition Based Maintenance (CBM) paradigm with smart loads management [35]. CBM consists of preventive maintenance carried out based on the variation of different parameters that are continuously monitored [38]. CBM strategies allow planning of maintenance activities and inspections based on the data of SHM/CM Systems [39].

By constantly monitoring the condition of structural components of every turbine, required maintenance activities can be planned in advance and carried out when necessary offshore rather than in predetermined time intervals [40,41]. Currently, these systems are being adapted to Offshore Wind. SHM/CM systems are already widely used in some subsystems, such as generators and gearboxes, however in others are still waiting for the development of relevant frameworks that will assesses collected data and draw conclusion for the integrity/performance of the subsystem (ie support structures). Therefore, the goal for Operational Management of Renewable Energy assets is to work towards integrating and developing SHM and Structural Health and Prognosis (SHP) Systems for carrying out smart loads management.

Operation based on their integrity status can potentially allow the control variation of a wind turbine when a certain level of damage is detected in an early stage by the SHM/SHP System. This may lead to reduction in the power production but at the same time it will delay damage propagation, increase their service life, and allow for multiple turbines to be serviced during the same visit to the plant in order to maximize the overall profit of the WF, decreasing maintenance costs and increasing operational efficiency. Some simulations carried out by [34] showed that according to this practice reducing the power production by 5%, fatigue life extension in blades would increase by a factor of 3 due to a decrease of a 10% in the corresponding loading.

5. Discussion

As mentioned earlier, the transition from Oil & Gas to Renewable Energy applications (unmanned structures and hence lower risk profile, volume production, and significant operational loads) bring a great motivation for further studies in Operational Management. The fact that renewables are forced to reduce CAPEX as much as possible, considering that their payoff period is longer, introduce the challenge of optimization of the CAPEX/OPEX ratio, transferring expenditure in later periods of operation of the units and more specifically when they will be generating profit. Further with the introduction of new materials (of higher compositional consistency and lower variation of mechanical properties), consideration of new operational conditions and hence new prevailing failure modes and mechanisms constitute efficient operational management as pertinent towards increased cost competitiveness of the industry. Further, information gathered throughout the asset's service life will provide valuable input towards requalification and more well informed selection of the most appropriate End of Life (EOL) scenario.

Ability to reassess the performance and integrity of the structure is driven by its structural deterioration, accidental damage due to impact, changing demands and regulations, life extension, deployment conditions etc. More specifically, aging mechanisms in offshore assets can be considered fatigue, corrosion, accumulated damage, scour etc. Based on the above a justified requirement becomes the development and application of a widely accepted framework for the adequate evaluation of the condition of a structure throughout its service life, considering updated data from real operations.

Design standards have evolved over the last decades including general information regarding the design, maintenance and operation of structures. Based on the provisions of API RP-2A Section 17, the key aspects of reassessment should include: Inspections, surveys and data management, Environmental conditions and forces, Structural elements, systems and analysis, Foundation elements, systems and analysis, Operational considerations, Policy considerations and consequences. The aforementioned

provisions yield for a strong requirement for sufficient data and appropriate processing methodologies, however generic methodologies for the latter tasks are not available.

Data collected should adequately inform Structural Integrity Management (SIM) or Structural Reliability Assessment (SRA), in order to allow assessment of the current status and contribute to a cost effective inspection and maintenance strategy. Concepts of SRA have been successfully applied to other engineering systems of increased complexity such as manufacturing, power generation and offshore environmental loading [42, 43, 44]. Figure 1, illustrates a framework for Integrity/Reliability Re-Assessment of Offshore Support Structures. An important element that should be considered, is the calibration of the initial simulation models (stresses, reliability estimations) after installation in order to take into consideration the actual deployment conditions (ie geotechnical conditions, and particularly for wind turbines operational loads). This activity will allow for more realistic assessment for critical parameters, such as fatigue life (deterministically calculated or through reliability analysis), to be determined, allowing for a more efficient operational management and planning. Further, collecting information during the structure's service life, will allow for tailored interventions (with effective scheduling), rather than in regular intervals, utilising the residual resistance of the structure.

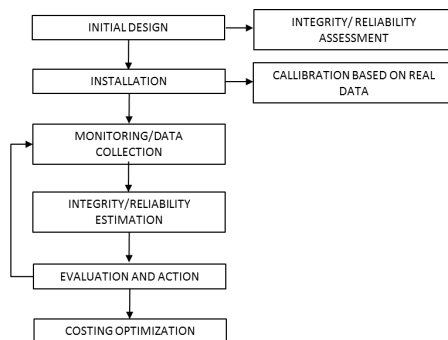


Figure 1. Integrity/reliability assessment of offshore support structures.

Collection of data in the most efficient way, is a challenge of great research priority, in order to ensure that sufficient information is collected potentially from multiple monitoring systems (such as accelerometers, strain gauges) etc, focusing more on the quality of data rather than in the (often unnecessarily) increased resolution. Another challenge, specifically applicable to offshore wind farms, is that of the increased cost of installation of SHM systems, as the number of units increases. The ability to extrapolate information from a limited number of instrumented units to the entirety of the wind farm, will allow customised inspection and maintenance planning and well informed EOL scenario selection for each unit or group of units.

6. Conclusions

This paper has presented a review of asset operational management approaches for the offshore Oil & Gas and Renewable Energy sectors, in order to highlight similarities, differences and influential parameters. Moving towards a broader deployment of offshore wind farms, with thousands of units already installed or planned to be installed over the next few years, provides a great motivation for further research in the efficient collection and processing of data in order to optimise OPEX through optimised planning of inspection and maintenance activities as well as well informed decisions for the most profitable End of Life scenario.

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