THE TREND OF MIGRATION FROM TOPSIDE TO SUBSEA EQUIPMENT IN MARINE OIL & GAS EXPLORATION UNITS

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ABSTRACT

This work is research that analyse the current trend of migration of the installation of offshore production equipment from the TOPSIDE installation to SUBSEA. Equipment whose technology was traditionally designed to be installed in TOPSIDE, on the surface of oil platforms. The research initially discusses the causes that motivated such technological migration, pointing to the global movement to promote the Green Economy. This movement pushed the offshore oil and gas industry to adapt to sustainability and decarbonization requirements. The impact of the decommissioning law is presented below. Through the creation of government regulatory bodies in countries, stricter regulatory standards were implemented, resulting in increased financial expenses to keep companies running and increased costs to make adaptations and approve new projects, since operating licenses depend on compliance Cool. The study continues by presenting an introductory view of typical SUBSEA and TOPSIDE equipment in offshore production units, which serves as a basis for a better contextual understanding of what the work is about. Next, the challenges and opportunities of migrating from TOPSIDE to SUBSEA are discussed and demonstrated that this is already a reality through the presentation of two real cases of successful migration published in academic literature. Two important conclusions of this study are: the first, to point out the main cause that motivated spending in the search for innovations and development of disruptive technological solutions that present themselves in the current scenario of the offshore industry, which would not be promoted without the revolution caused by the global movement in pursuit of the Green Economy. Due to the comfortable financial situation that the offshore oil exploration and production industry has always had, achieving satisfactory profitability, why spend on innovation? Because she was forced to do it. The second conclusion is that investing in the TOPSIDE-SUBSEA migration is a pressing reality for the offshore industry and is no longer an option to be considered, as it brings a great bonus opportunity for reducing capital (CAPEX) and operational costs (OPEX), both necessary to financially support compliance with new regulatory decommissioning laws. On the other hand, it is important to weigh the challenges to be overcome in the transition.

KEYWORDS: *SUBSEA, TOPSIDE, Offshore Technology, Green Economy, Offshore Equipment.*

I. INTRODUCTION

In recent years, the offshore industry around the world has faced a pressing need to seek innovative technologies to advance their projects. One of the reasons is the increasing depth that we have to drill to find oil in the so-called pre-salt oil fields, located in deep and ultra-deep waters, which require technologies adapted to conditions of high pressure, lack of lighting, kilometric distances to transport production from wells to the exploration unit on the sea surface, among other adverse factors, much more challenging than those found and already overcome in shallow waters, where the oldest exploration fields are located.

The other motivation is to reduce costs for new projects, given the new global operating rules for the offshore industry, which have increased legal requirements to obtain license approval and transferred the so-called environmental cost of their activities to operators, forced to pay for the elimination of waste production and offsetting carbon emissions directly or indirectly linked to its activities. The deactivation of depleted production units, including dismantling, an activity for which expenditure was not foreseen in projects designed 30 or 40 years ago, has also become a driving factor in the search for solutions to reduce capital costs, because regulatory bodies in the sector have established rules that require increasing financial expenses to maintain the integrity of production units and unforeseen expenses with decommissioning at the end of the units' useful life. In short, the need to comply with new legal requirements has made maintaining compliance in operations much more expensive, resulting in new projects that may become unfeasible or unattractive for the private financial institutions that supported the sector.

However, despite the challenges to be faced in the search for innovative and disruptive solutions, which, in principle, can represent an increase in CAPEX AND OPEX, can also bring opportunities precisely to reduce them. Through the analysis of two projects published in academic literature that implemented a change in thinking, we will conclude that there are opportunities for gains in this global scenario that appears to be unfavourable for the offshore oil and gas industry, however, we must focus on innovation as a solution.

Migrating from TOPSIDE to SUBSEA is an alternative that has become increasingly viable from different points of view. The development, adaptation and migration of equipment traditionally installed in plants on the surface of maritime platforms to installations on the seabed, in underwater soil, close to explored wells, is already a reality in the sector. The figure below shows a typical installation of TOPSIDE equipment that can, through technological development, migrate to SUBSEA.

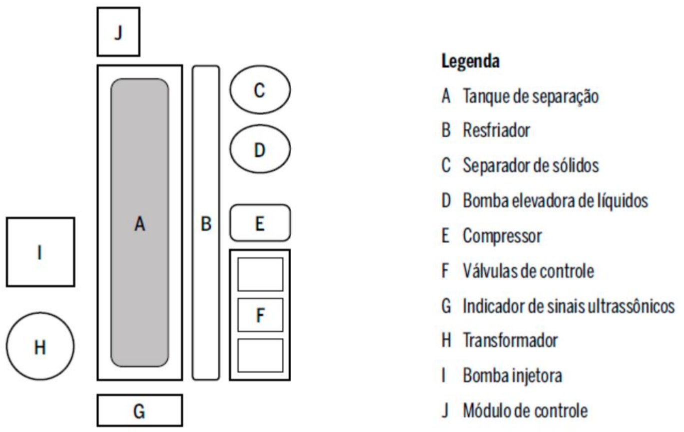

Figure 1: Diagram of typical TOPSIDE equipment. Adapted from [7].

II. THE ERA OF THE GREEN ECONOMY

The Green Economy is a current economic model that aims to improve the well-being of humanity, contribute to the construction of social equality, reduce environmental risks and avoid ecological collapse [1]. The United Nations Environment Program (UNEP) developed the concept in 2008. In the definitions of Green Economy, we always find three main objectives: increasingly reducing carbon emissions, operating efficiently in the use of resources and seek social inclusion [1]. In short, the green economy must provide justice, inclusion and social equity and, at the same time, preserve the environment [2].

2.1. The green industry

Not only governments of nations, but also companies from all types of economic sectors are committed to the purpose of operating sustainably, which is evident in the observation of members of organizations such as the Green Economy Coalition (GEC), founded in European Union (EU) in 2009. This is a coalition formed by organizations from around the world (NGOs, companies, agencies and civil society), which works to accelerate the transformation of current economic systems into Green Economies [1].

2.2. Decommissioning and impact in the offshore industry

In this current GREEN scenario, the oil and gas industry has been one of the most directly affected by new regulatory policies, which has compelled it to seek solutions to adapt to the new market reality. An example of this is the recent implementation of decommissioning policies for Offshore Exploration and Production Units - UEPs, commonly known as oil exploration and production platforms. Today, business operators around the world must comply with a series of requirements and obligations when decommissioning and dismantling UEPs at the end of their useful life. Legislation has sought to transfer to operators the responsibility for the fate of everything that exists in the facilities of an offshore production plant, which means that the industry has to bear high deactivation costs that were not foreseen in projects developed thirty or forty years ago. Therefore, the offshore sector has been actively engaged in recent years in developing innovative technologies for the construction and operation of its new units, seeking to increase production efficiency and optimize performance with lower CAPEX costs. A poorly designed project, which does not address environmental and constructability issues, may become unfeasible for approval by regulatory bodies or due to the high costs required in the current scenario.

III. NEW TRENDS IN SECTOR

Due to the above scenario, the offshore industry has exclusively used FPSOs in its new UEP projects, ships with production and storage capacity of large volumes and high performance. Still, there is a need to provide new, optimized and more robust solutions for the oil and gas treatment plant. Using a fully electrical system to drive large machines brings considerable advantages in terms of increasing plant efficiency and reducing [4].

Company	Head Office	Projects	Suppliers	Head office	Projects
Equinos	Norway	20	TechnipFMC	United Kingdom and NetherLands	32
Petrobras	Brazil	13	Onesubsea	USA	30
Shell	United Kingdom and Netherlands	13	Subsea 7	United Kingdom and Netherlands	16
Total	France	6	Nexans	France	13
Chevron	USA	4	Aker	Norway	11

Figure 2: Implementations of SUBSEA processing projects, 1990-2019. Adapted from [7].

3.1. Paradigm changes to innovate.

The regulations necessary to obtain permission to operate in the offshore sector have become more onerous in all nations due to the need for this industry to adapt to the GREEN, sustainable and clean economy, which implies increased costs of both capital investments (CAPEX) and (OPEX) in new projects. Therefore, to explore resources in increasingly deeper waters there is a great demand for innovative and disruptive solutions. This movement presents numerous technical challenges which, however, are accompanied by many opportunities to expand E&P activities, including the opportunity to reduce costs.

One of the challenges to overcome is the generation and transport of energy to power this innovative equipment, however, the search to replace fossil fuels in generation with clean sources, such as wind energy from maritime structures, offers a convenient and attractive option.

The installation of underwater equipment has undergone a significant technological transition in recent years, as a legal obligation, companies need to maintain and account for the integrity of submerged assets and to achieve this it is necessary to seek more efficient and safe operations, improving methods and developing new equipment that allow evaluating the conditions of equipment in a safe way for professionals who work operationally. Performing preventive maintenance of subsea subsystems then becomes a common practice to identify potential problems before they cause operational failures [5].

To achieve the objective of effective and efficient maintenance, without compromising safety, innovations present solutions, but they also bring new challenges, such as the need for specialized training and adaptation to innovative technologies.

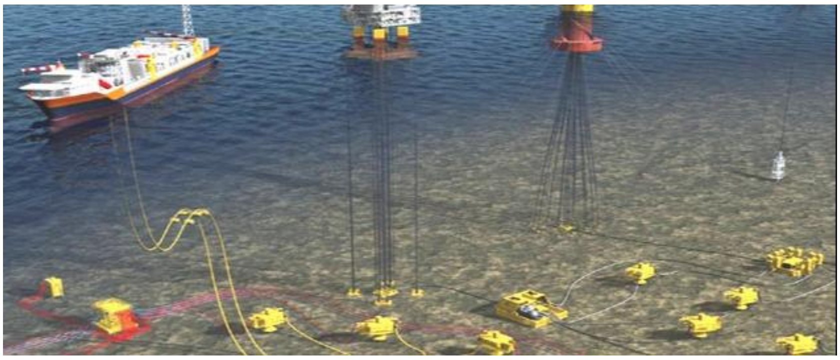

Figure 3: Typical offshore production system. Adapted from [8].

3.2. Power generation in UEP

An oil platform can make use of many forms of energy generation to meet its operational demands. Turbines powered by gas produced by explored wells and are therefore convenient from a fuel economic point of view. There are also aero derivative models, these turbines are adaptations of the traditional equipment that powers jet planes. Other sources of power generation include steam turbines or reciprocating engines, which burn gas, diesel or crude oil1. In Brazil, the typical application is 25 MW turbines.

• Generators, for feed submersible oil production pumps and critical systems, such as data processing.

• Reciprocating engines burn gas, diesel, or crude oil to generate power.

• Steam turbines, give power energy, although they are less common than gas turbines.

• The electricity generating plant normally is feed by the gas extracted from the field.

There are studies on the generation of electrical energy through sea waves applied to underwater platforms, the technology consists of using the rise and fall of waves to generate energy.

3.3. Submerged Centrifugal Pumping (BCS)

The production of an oil well occurs in two ways, the first when the well is "emerging", meaning that it has sufficient reservoir pressure (PR) to raise the fluid to the surface without the help of equipment. it is the natural elevation. The second way is when the reservoir has oil, but it lacks PR (this happens as the useful life runs out) we call this well "non-rising" and to produce it will be necessary to use one of the artificial lift methods, Submerged Centrifugal Pumping (BCS) is one of them.

Submerged Centrifugal Pumping (BCS), also known as Electrical Submersible Pumping, is a technology that has revolutionized the oil and gas industry. This technique consists of using a submerged centrifugal pump to extract oil from deep wells, increasing productivity and production efficiency. The BCS is made up of three main parts: the pump, the electric motor and the production head. The pump is responsible for extracting the oil from the well, while the electric motor provides the energy necessary for the pump to operate. The production head is responsible for controlling the flow of oil and separating it from the fluids produced along with it [3].

The installation of a BCS pump uses an electrical cable that connects the pump to the electric motor on the surface. The installation of a BCS pump uses an electrical cable covered with insulating materials to protect against damage, which connects the pump to the electric motor on the surface. Automation in oil wells that use BCS can lead the company to reduce maintenance and electrical energy costs, in addition to improving the reliability of information collected from the process.

Below we list the use of the elevation technique using BCS:

• Increased production: BCS allows the extraction of oil and gas from deeper wells with greater efficiency, increasing production.

• Reduced operating costs: The BCS is more efficient and requires less maintenance than other pumping systems, resulting in a significant reduction in operating costs.

• Greater durability: The BCS pump are made from corrosion-resistant materials and can operate for a prolonged period without the need for maintenance.

The BCS pumping method is common in high-flow wells, from medium depth to ultra-deep, and implemented with the reinjection of water produced during oil extraction, taking advantage of a waste product, which solves another problem.

IV. TRANSFER OF EQUIPMENT FROM TOPSIDE TO SUBSEA

The transition from surface equipment to underwater environments presents a series of technical challenges in different disciplines.

4.1. Challengers

To overcome technical challenges, engineers and researchers involved with offshore oil and gas production have constantly sought innovations that provide a reduction in operational costs involved and maximize equipment performance. Some examples are underwater renewable energy installations, oceanographic research, use of drones in dangerous activities and advanced robotics to carry out operations in deep and ultra-deep waters. Lets see now some technical challengers:

1. Pressure and Depth: significantly higher pressures compared to surface environments, which can affect the structural integrity of equipment, which require robust designs and resistant materials, external pressure forces have extreme values and require design considerations to ensure the equipment durability and safety.

2. Corrosion from salt water: sea water is highly corrosive and constant exposure leads to accelerated deterioration of equipment, which compromises the efficiency and useful life of components, this requires the use of new materials, with greater resistance to corrosion , such as stainless steel alloys and special coatings, also require the implementation of monitoring and maintenance systems adapted to the submerged environment, allowing corrosion problems to be detected in advance.

3. Underwater Communication: data transmission and communication are different in the underwater environment when compared to the AR transmission medium, as its properties are different, the conduction of electromagnetic signals, for example, in water is impaired, affecting the transmission range, the acoustic and fiber optic transmission are effectively an option for controlling equipment and receiving signals from remote sensors, but must be adapted to new operating conditions.

4. Underwater Installation and Maintenance: the installation and maintenance of underwater equipment are complex tasks and at great depths must only be carried out by Remotely Operated Vehicles (ROV) robotic equipment.

5. Power supply: Providing power to subsea equipment and autonomous systems to ensure operation requires long autonomy, which requires long-term storage elements, whether batteries, underwater fuel cells or, alternatively, wireless power transmission systems .

6. Environmental Monitoring: monitoring environmental conditions, such as temperature, pressure and water quality, are essential to maintain the enterprise's legal compliance, anticipating equipment failures and accidents, but this can be difficult in underwater environments and requires sensors and monitoring systems. Advanced remote monitoring, to collect real-time environmental data and facilitate rapid decision-making.

From all this we can infer that the sector has adapted quickly by investing and adopting disruptive solutions and everything leads us to believe that it will continue to be a great business investment option and return.

V. EMERGING TECHNOLOGIES CASES PUBLISHED IN RECENT ACADEMIC LITERATURE

In this topic we will show two cases published in recent academic literature demonstrating applications of innovative solutions that have achieved success and are already a reality in the offshore industry.

5.1. Thickness measurement in subsea pipelines

Thickness measurement in pipelines using Acoustic Resonance Technology (ART): One of the maintenance operations for subsea equipment is measuring the thickness of submerged product transport pipelines, which connect production wells to platforms. Pipelines must have integrity control that requires periodic inspections, where measuring their thickness is an item to check. This operation was initially carried out by divers, however, with the increasing water depth between the wells and the platform, and the need to eliminate diving activities due to the risk involved, it is now carried out almost exclusively by robotics, ROVs [6].

Figure 4: ROV measuring the thickness of a duct using ART. Adapted from [6].

Although robotic systems use increasingly effectively, traditional methods of ultrasonic thickness reading are not possible through a wide variety of subsea pipeline linings, including unwanted fouling from the marine environment.

Figure 5: Elements of riser fouling from marine life. Adapted from [6].

Around 2017, a partnership between an E&P company and another specialist in underwater inspection services investigated the applicability of Acoustic Resonance Technology (ART) for thickness measurement. The project was successful and since 2020 the method has replaced the old one in the process and continues to evolve. Nowadays, in 2023, acoustic resonance technology is becoming prevalent for insulated or lined pipelines in subsea infrastructure. As added advantages, the method provides fully quantitative information, does not contain radiation, and can collect large areas of data points extremely quickly [6].

5.2. Oil and water separation process equipment. SUBSEA installation

SUBSEA Water and Oil Separation: Subsea separation systems are increasingly being studied and applied in various fields around the world and have already proven to be viable alternatives for the development of fields far from a UEP or that present other challenges associated with ensuring flow, such as low reservoir pressure, high viscosity of the fluids produced, or a large amount of water dissolved in the oil. As these migratory technologies become more well-known, reliable, and compact, the tendency is for them to become competitive to adopt for various applications. SUBSEA processing can be an alternative to the traditional TOPSIDE structure. The work of DA SILVA et.al. (2015) conducted a literature review and comparison of technologies, their conclusions highlighted the technical-economic challenges faced in conventional TOPSIDE processing systems and the advantages of processing entirely on the seabed, considering this a viable alternative, depending on specific circumstances.

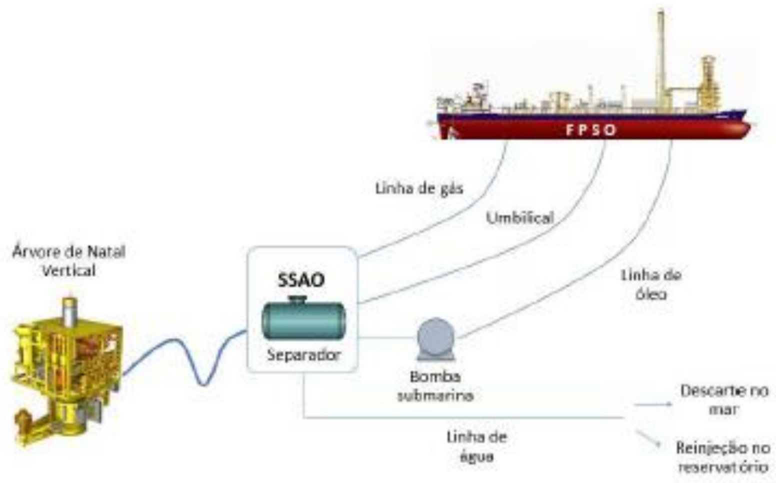

Figure 6: Submerged water-oil separation system. Adapted from [9].

The work is structured into the following sections:

1. The first one draws attention to the global pressure for the Green Economy and how the movement has advanced strongly to impact industrial activities, reflected in the offshore sector, mainly through Decommissioning rules.

2. The second section highlights the sector's tendency to face breaking paradigms to innovate and two examples of real cases illustrating the topic.

3. The third topic presents the migration of TOPSIDE equipment to SUBSEA as a current option in the search for reducing operational costs and its inherent challenges.

4. This last part of the text shows that emerging technologies are already a reality, presenting two recent real case studies of disruptive solutions.

Finally, of all that has been exposed, the work records its conclusions, two of which are considered the most significant.

VI. CONCLUSIONS

It is possible to highlight that the search for innovations emerged in the offshore E&P industry to meet the pressure for the Green Industry, as the sector has always had financial comfort in its ventures, despite the risk involved in the activities inherent to the processes of this industry. Another plausible conclusion is that in the search for innovation, the TOPSIDE to SUBSEA migration solution has proven to be efficient from the point of view of implementation and reduction of CAPEX and OPEX costs, examples are innovations in anchoring systems, underwater communication, and remote maintenance, in However, the environmental impacts associated with this project alternative must always be evaluated in multidisciplinary discussions. We must pay attention to the fact that the installation of equipment on the seabed may be rejected from the point of view of compliance with environmental legislation in the view of the regulatory body, when evaluating the projects submitted to it, however, if there is technically exposure based, considering sustainable practices and mitigating measures to be adopted by the industry, this can be essential to favourably reverse a decision on project approval.

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