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Challenges and strategic solutions in commissioning and start-up of subsea production systems

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Abstract

The commissioning and start-up of subsea production systems represent critical phases in offshore oil and gas operations, where meticulous planning and execution are essential for success. This abstract presents an overview of the challenges encountered during these phases and proposes strategic solutions to address them effectively. Environmental factors such as deepwater operations and subsea geology pose significant challenges to commissioning and start-up activities. Technical challenges include ensuring equipment reliability and seamless integration of control systems in harsh underwater conditions. Operational challenges such as remote monitoring and intervention and personnel safety further compound the complexities of these operations. Strategic solutions to mitigate these challenges include advanced planning and simulation using digital twin technology and scenario planning. Enhanced risk management strategies, including contingency planning and early detection systems, are vital to anticipate and manage potential issues effectively. Collaborative partnerships between stakeholders, including suppliers and cross-disciplinary teams, foster innovation and enhance project resilience. Drawing from successful case studies and lessons learned, this abstract emphasizes the importance of proactive planning, risk mitigation, and collaborative approaches in ensuring the successful commissioning and start-up of subsea production systems. By implementing these strategic solutions, operators can enhance operational efficiency, minimize downtime, and improve safety outcomes, ultimately contributing to the long-term viability and sustainability of offshore energy production.

Keywords: Challenges; Strategic Solutions; Commissioning and Start-up; Subsea Production Systems

1. Introduction

Subsea production systems play a pivotal role in offshore oil and gas exploration and production, enabling the extraction of hydrocarbons from beneath the ocean floor (Olajiga et al., 2024). Unlike conventional offshore platforms, which are located above the water surface, subsea production systems are installed on the seabed, typically in deepwater environments. These systems consist of a complex network of equipment and infrastructure designed to facilitate the drilling, production, and transportation of oil and gas from subsea reservoirs to onshore processing facilities (Ani et al., 2024). The key components of subsea production systems include;

Subsea wellheads: These are installed on the seabed and serve as the interface between the reservoir and the production system. They provide access to the hydrocarbons and enable the installation of production tubing and control equipment (Oke et al., 2024).

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Subsea trees: These are valve assemblies mounted on top of the wellheads, which control the flow of oil and gas from the reservoir to the surface. Subsea trees can be equipped with various functionalities, such as production, injection, and monitoring.

Flowlines and umbilicals: Flowlines transport hydrocarbons from the subsea wells to the production facilities onshore or offshore. Umbilicals provide power, communication, and control functions to the subsea equipment (Ogunkeyede et al., 2023).

Subsea processing equipment: This includes pumps, separators, and other equipment installed on the seabed to enhance production and processing capabilities, such as boosting the flow of hydrocarbons or separating water and gas from the oil stream.

Subsea production systems offer several advantages over traditional offshore platforms, including reduced environmental footprint, improved safety, and increased access to remote and deepwater reservoirs (Omole et al., 2024). However, the installation, commissioning, and start-up of these systems present unique challenges due to the harsh operating conditions and remote location, requiring specialized expertise and careful planning.

1.1. Importance of Commissioning and Start-up

The commissioning and start-up phases are critical milestones in the lifecycle of subsea production systems, marking the transition from construction to operational phase (Olatunde et al., 2024). Commissioning involves verifying the functionality and integrity of all components and subsystems of the production system, ensuring that they meet design specifications and regulatory requirements (Olatunde et al., 2024). Start-up, on the other hand, involves gradually ramping up production and initiating the flow of hydrocarbons from the subsea wells to the processing facilities. The importance of commissioning and start-up cannot be overstated, as any errors or malfunctions during these phases can have significant consequences, including costly delays, safety hazards, and environmental damage (Olatunde et al., 2024). Proper commissioning and start-up procedures are essential to identify and rectify potential issues early on, minimize downtime, and ensure the safe and efficient operation of the subsea production system throughout its lifecycle.

Furthermore, the success of commissioning and start-up activities has a direct impact on the overall profitability and sustainability of offshore oil and gas projects. Efficient start-up procedures enable operators to maximize production rates and optimize reservoir recovery, thereby enhancing project economics and maximizing returns on investment (Okwandu et al., 2024). Therefore, investing in thorough planning, execution, and management of commissioning and start-up activities is crucial to the long-term success and viability of subsea production systems.

2. Challenges in commissioning and start-up

2.1. Environmental Factors

Operating in deepwater environments presents unique challenges for the commissioning and start-up of subsea production systems. The extreme water depths increase the complexity and cost of installation and maintenance activities. Deepwater operations require specialized equipment and vessels capable of withstanding high pressures and harsh environmental conditions (Adelani et al., 2024). Additionally, the remoteness of deepwater locations poses logistical challenges, including transportation of personnel, equipment, and supplies to and from the offshore site. The geological characteristics of subsea reservoirs can present challenges during the commissioning and start-up of production systems. Variations in reservoir properties such as fluid composition, pressure, and temperature can impact the performance and reliability of subsea equipment. Furthermore, complex subsea geology, including fault lines, salt domes, and uneven seabed topography, can pose obstacles to the installation and operation of subsea wells and infrastructure (Adelani et al., 2024). Understanding and mitigating geological risks are crucial to the success of commissioning and start-up activities.

2.2. Technical Challenges

Ensuring the reliability and integrity of subsea equipment is essential for the safe and efficient operation of production systems. Subsea components are exposed to harsh environmental conditions, including high pressures, corrosive seawater, and marine fouling, which can degrade equipment performance over time (Adelani et al., 2024). Equipment failures or malfunctions during commissioning and start-up can result in costly downtime and production losses. Therefore, rigorous testing, inspection, and maintenance procedures are necessary to minimize the risk of equipment failure and ensure operational reliability. Integration of control systems is critical for the seamless operation of subsea production systems. Control systems regulate various functions, including wellhead and valve operation, flow control, and safety shutdowns. However, integrating control systems from different manufacturers or suppliers can be challenging due to compatibility issues and communication protocols. Poorly integrated control systems can lead to errors, delays, and safety hazards during commissioning and start-up (Sonko et al., 2024). Therefore, thorough testing and validation of control system interfaces are essential to ensure proper functionality and interoperability.

2.3. Operational Challenges

Operating subsea production systems remotely presents logistical and operational challenges for monitoring and intervention activities. Limited visibility and accessibility to subsea equipment require the use of remote monitoring technologies, such as underwater cameras, sensors, and remotely operated vehicles (ROVs). However, maintaining real-time communication and control of subsea operations from onshore or offshore facilities can be challenging, particularly in deepwater environments with limited infrastructure and connectivity (Sonko et al., 2024). Effective remote monitoring and intervention strategies are essential for detecting and resolving issues during commissioning and start-up. Ensuring the safety of personnel involved in commissioning and start-up activities is paramount, given the inherent risks of working in offshore environments (Sonko et al., 2024). Hazards such as confined spaces, heavy machinery, and high-pressure equipment pose safety risks to workers during installation, testing, and maintenance activities. Furthermore, adverse weather conditions and unpredictable sea states can exacerbate safety hazards, requiring stringent safety protocols and emergency response procedures (Hamdan et al., 2024). Prioritizing personnel training, safety awareness, and adherence to safety regulations are essential for mitigating risks and preventing accidents during commissioning and start-up operations.

3. Strategic solutions

3.1. Advanced Planning and Simulation

Digital twin technology involves creating a virtual replica of the subsea production system, incorporating real-time data from sensors and monitoring systems. This digital representation enables operators to simulate various scenarios, analyze performance, and optimize operations before commissioning and start-up activities begin (Hamdan et al., 2024). By visualizing the system in a virtual environment, operators can identify potential issues, optimize workflows, and make informed decisions to enhance efficiency and safety. Digital twin technology also facilitates predictive maintenance by monitoring equipment health and performance, allowing operators to anticipate and prevent failures before they occur. Scenario planning involves developing and analyzing multiple hypothetical scenarios to anticipate and prepare for different outcomes during commissioning and start-up activities (Etukudoh et al., 2024). By considering various factors such as environmental conditions, equipment performance, and operational constraints, operators can identify potential risks and develop contingency plans to mitigate them effectively. Scenario planning helps operators anticipate challenges, optimize resource allocation, and adapt to changing conditions during commissioning and start-up, reducing the likelihood of costly delays and disruptions (Afolabi et al., 2019).

3.2. Enhanced Risk Management

Contingency planning involves identifying potential risks and developing strategies to mitigate their impact on commissioning and start-up activities. This includes identifying critical pathways and dependencies, developing alternative solutions, and establishing response protocols for various scenarios (Chukwurah and Aderemi, 2024). Contingency plans should address a range of potential risks, including equipment failures, adverse weather conditions, and logistical challenges. By proactively planning for contingencies, operators can minimize the impact of unforeseen events and maintain project schedules and budgets. Early detection systems utilize sensors, monitoring devices, and predictive analytics to identify and alert operators to potential issues before they escalate into serious problems. These systems continuously monitor key parameters such as equipment performance, fluid levels, and environmental conditions, providing real-time insights into the health and integrity of the subsea production system (Chukwurah, 2024). Early detection of anomalies allows operators to take proactive measures to address issues, such as initiating maintenance activities, adjusting operating parameters, or implementing contingency plans, before they affect production or safety.

3.3. Collaborative Partnerships

Collaborating closely with suppliers and contractors throughout the project lifecycle fosters innovation, enhances communication, and improves project outcomes (Adeleke et al., 2024). Suppliers bring specialized expertise, technologies, and resources to the table, enabling operators to leverage their knowledge and capabilities to address challenges and optimize performance. By involving suppliers early in the planning and design phases, operators can ensure that equipment specifications meet project requirements, streamline procurement processes, and reduce lead times (Ani et al., 2024). Strong supplier collaboration fosters trust, transparency, and accountability, leading to successful commissioning and start-up of subsea production systems. Building cross-disciplinary teams comprising experts from various technical disciplines, including engineering, geology, operations, and safety, facilitates holistic problem-solving and decision-making. Cross-disciplinary teams bring diverse perspectives, skills, and experiences to the table, enabling operators to identify and address complex challenges more effectively (Olu-lawal et al., 2024). By fostering collaboration and communication across different disciplines, teams can leverage collective knowledge and expertise to develop innovative solutions, optimize processes, and mitigate risks during commissioning and start-up activities. Effective teamwork enhances project resilience, efficiency, and success, ultimately delivering value to stakeholders and ensuring the long-term viability of subsea production systems.

3.4. Case studies

Kashagan Field Development, Kazakhstan, the Kashagan field, located in the North Caspian Sea, is one of the largest offshore oil fields in the world (Adeleke et al., 2024). The development of Kashagan involved the installation of a complex subsea production system in a challenging environment characterized by harsh weather conditions, shallow waters, and sensitive ecological concerns. Despite numerous technical and logistical challenges, the project successfully achieved first oil production in 2016 after several years of commissioning and start-up activities. Key factors contributing to the success of the Kashagan project included comprehensive risk management, collaborative partnerships with suppliers and contractors, and advanced planning and simulation techniques.

Ormen Lange Gas Field, Norway, the Ormen Lange gas field, located in the Norwegian Sea, is one of the largest offshore gas fields in Europe. The development of Ormen Lange involved the installation of a subsea production system at water depths exceeding 1,000 meters. The project faced significant technical challenges, including complex geology, high-pressure reservoir conditions, and extreme weather conditions. However, through meticulous planning, innovative engineering solutions, and close collaboration between project stakeholders, the Ormen Lange project achieved successful commissioning and start-up, delivering gas production to the Norwegian continental shelf (Adeleke et al., 2024). Lessons learned from the Ormen Lange project include the importance of early engagement with regulators and stakeholders, proactive risk management, and leveraging advanced technologies for remote monitoring and intervention.

Successful commissioning and start-up projects prioritize comprehensive risk management strategies to identify, assess, and mitigate potential risks effectively. This includes conducting thorough risk assessments, developing contingency plans, and implementing early detection systems to monitor key parameters and anticipate issues before they escalate (Odedeyi et al., 2020). Lessons learned from past projects underscore the importance of proactive risk management in minimizing project delays, reducing costs, and ensuring safety and environmental compliance. Building collaborative partnerships with suppliers, contractors, regulators, and other stakeholders is essential for the success of commissioning and start-up projects (Olowe et al., 2015). Effective communication, transparency, and trust are key principles that underpin successful partnerships, enabling stakeholders to align objectives, share knowledge, and resolve challenges collectively. Lessons learned from successful projects highlight the importance of early engagement with stakeholders, fostering a culture of collaboration and innovation, and leveraging the expertise and resources of all parties involved. Utilizing advanced planning and simulation techniques, such as digital twin technology and scenario planning, enhances the predictability and efficiency of commissioning and start-up activities (Olowe, 2018). Lessons learned from past projects emphasize the benefits of creating virtual replicas of subsea production systems, simulating various scenarios, and optimizing workflows before execution (Kayode and Kumarasamy, 2020). By leveraging advanced planning and simulation tools, operators can identify potential issues, optimize resource allocation, and make informed decisions to improve project outcomes and minimize risks during commissioning and start-up.

4. Conclusion

In conclusion, the commissioning and start-up of subsea production systems represent critical phases in offshore oil and gas operations, requiring meticulous planning, execution, and management. Subsea production systems play a crucial role in offshore oil and gas exploration and production, enabling the extraction of hydrocarbons from beneath the ocean floor. Challenges in commissioning and start-up arise from environmental factors such as deepwater operations and subsea geology, technical challenges including equipment reliability and control systems integration, and operational challenges such as remote monitoring and personnel safety. Strategic solutions to address these challenges include advanced planning and simulation techniques such as digital twin technology and scenario planning, enhanced risk management strategies including contingency planning and early detection systems, and fostering collaborative partnerships with suppliers and cross-disciplinary teams (Owoola et al., 2019). Successful case studies such as the Kashagan field development in Kazakhstan and the Ormen Lange gas field in Norway demonstrate the importance of comprehensive risk management, collaborative partnerships, and advanced planning and simulation in achieving successful commissioning and start-up of subsea production systems. Lessons learned from past projects highlight the importance of proactive risk management, collaborative partnerships, and leveraging advanced technologies to optimize project outcomes and ensure the long-term viability and sustainability of offshore energy production.

Looking ahead, the future of commissioning and start-up of subsea production systems will be shaped by emerging technologies and industry trends. Advances in digitalization, automation, and robotics are transforming the way offshore operations are conducted, enabling operators to improve efficiency, reduce costs, and enhance safety. For example, the adoption of artificial intelligence (AI) and machine learning algorithms for predictive maintenance and real-time monitoring will enable operators to optimize equipment performance and prevent unplanned downtime. Furthermore, the development of next-generation subsea technologies, such as subsea processing and subsea storage systems, holds promise for unlocking new resources and enhancing production capabilities in challenging environments. These technologies enable operators to process and store hydrocarbons on the seabed, reducing the need for surface infrastructure and minimizing environmental impact. In addition, the industry is increasingly focusing on sustainability and environmental stewardship, driving innovation in renewable energy sources and carbon capture and storage (CCS) technologies. As the demand for clean energy continues to grow, there will be opportunities to leverage subsea production systems for the development of offshore wind farms, wave energy converters, and other renewable energy projects. In conclusion, while challenges persist, the future of commissioning and start-up of subsea production systems is bright, fueled by innovation, collaboration, and a commitment to sustainable development. By embracing emerging technologies and best practices, operators can navigate challenges effectively, maximize production efficiency, and contribute to the transition to a more sustainable energy future.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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