The methodologies employed in the conception of Digital Twins in the Oil & Gas Industry

Guido Vaz Silva[1]; Dalton Garcia Borges de Souza[1]; Rodolfo Cardoso[1]; Iara Tammela[1] and Danilo Colombo[2]

[1] Department of Engineering, Fluminense Federal University (UFF), Brazil.
[2] Cenpes, Petrobras, Brazil.

Abstract. The Oil and Gas (O&G) industry operates in a highly regulated environment due to the inherent health, safety, and environmental risks associated with its activities. Recently, it has been under increasing pressure to optimize its operations in pursuit of better economic performance, as lower oil prices have been in effect for a considerable period. This scenario has led to emerging technologies, associated with Industry 4.0, being perceived as important solutions to improve the relations between revenues, risks, and operational costs. One of the technologies that promises more benefits and, consequently, generates more expectations is the Digital Twin (DTs). DTs are digital models of physical assets resulting from integration that allows the mirroring between the physical and digital worlds to collect, process, visually display, simulate data to improve or automate decisions in pursuit of improvement in operational and strategic results (WANASINGHE, et al., 2020).

The present article analyzed methodological approaches for the conception of DTs within the scope of the main activities of the O&G industry - exploration, drilling, production, processing, and distribution -, based on articles found in academic and non-academic databases using a systematic literature review that adopts the PRISMA framework, in search of a synthesis of generic stages for its conception (ROWLEY & SLACK, 2004).

The article search was conducted from August 1 to December 31, 2023. This process began with a search for publications that included keywords related to "Digital Twin," "Digital Model," and "Environment Model," along with specific terms to the oil, petroleum, and gas sector. This process culminated in the filtering of 66 articles with relevant content on the development or application of DTs. Among these articles reviewed, a high diversity of strategies and approaches in the conception of DTs was identified, with low detail. Some articles prioritize presenting the final architecture diagram, structure or model of the conceived DT over the sequence of steps for its construction. Among these, only 6 articles scrutinize more clearly the step-by-step construction of the DT, enabling a panoramic view of the main stages.

Several factors may explain the diversity of observed approaches. Firstly, the relative novelty of the DT research and application domain may contribute to the lack of established reference methods. Secondly, within the examined sample, a significant number of articles authored by individuals of the O&G industry were identified, with a greater emphasis on presenting the final solution rather than delving into methodological details related to the design of the DT solution. Thirdly, the sample revealed variations in DT types and application objectives, naturally leading to differing working methods.

The primary aspects outlined in the analyzed articles facilitate a more detailed delineation of the main stages, aiming to propose a methodological sequence for the development of a DT for oil well completion systems (CAMARA DIT PINTO et al., 2021; LIANG et aL., 2023; SINGH, et al. 2019; MENDOZA, et al., 2021): (i) *Diagnosis and Architecture Design:* specific objectives for the DT in well completion are identified, along with functional and non-functional requirements necessary to achieve these objectives. The processes involved in well completion are understood and documented, and physical assets such as valves, pipes, and equipment that will be digitally represented are identified. Digital assets are developed using 3D modeling software, which is employed to create precise digital representations of the physical assets involved in well completion; *(ii) Contextual Data Integration and Processing:* the types of sensors required to collect real-time data are determined, and these sensors are integrated with physical assets to monitor relevant parameters. The connectivity infrastructure is established to enable communication between sensors, physical assets, and the DT system. Data from existing systems is integrated; *(iii) Development of Analytical Models:* machine learning techniques and data analysis are utilized to develop

analytical models that can predict future behaviors based on collected data. Simulations are implemented to replicate the behavior of the well completion system in different scenarios. These simulations are used to optimize system performance and test different control strategies. A user-friendly interface is created for interacting with the DT, ensuring users can view real-time data, access reports, and control the system. *(iv) Assessment and Control*: extensive tests are conducted to ensure the DT functions as expected. DT results are validated by comparing them with real data obtained in the field. The DT is implemented in the operational environment, and continuous monitoring processes are established to ensure its accuracy and effectiveness over time. Adjustments and improvements to the DT are made based on feedback, new data, and changes in operational conditions. It is important to remember that the development of a DT is an iterative process, and collaboration among engineering, data, and operational experts is crucial for project success.

Finally, the sequence of stages derived from the literature can be a valuable resource for researchers and professionals engaged in digital twin development initiatives. Nevertheless, there is a pressing need for further studies that delve into the step-by-step process, particularly concerning various types of digital twins and their respective objectives and maturity levels.

Keywords: Industry 4.0; Digital Twin, Oil and Gas Industry.

References

1. CAMARA DIT PINTO, S.; VILLENEUVE, E.; MASSON, D.; BOY, G.; BARON, T. & URFELS, L. Digital twin design requirements in downgraded situations management. IFAC Papers On Line 54(1), 869–873 (2021).
2. LIANG, J.; MA, L.; LIANG, S.; ZHANG, H.; ZUO, Z. & DAI, J. Data-driven digital twin method for leak detection in natural gas pipelines. Computers and Electrical Engineering 110 (2023).
3. ROWLEY, J.; SLACK, F. Conducting a literature review. Management research news, v. 27 (6), 31-39 (2004).
4. WANASINGHE, T. R. et al.: DT for the O&G Industry: Overview, Research Trends, Opportunities, and Challenges. IEEE Access, v. 8, 104175–104197 (2020).
5. SINGH, A.; SANKARAN, S.; AMBRE, S.; SRIKONDA, R. & HOUSTON, Z. Improving Deepwater Facility Uptime Using Machine Learning Approach. In: SPE Annual Technical Conference and Exhibition, Calgary, Alberta, Canada, September (2019).
6. MENDOZA, J.; TARIQ, R.; ESPINOSA, L.; ANGUEBES, F., BASSAM, A. Soft Computing Tools for Multiobjective Optimization of Offshore Crude Oil and Gas Separation Plant for the Best Operational Condition. In: 18th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), Mexico City, Mexico (2021).