Electrification of oil platforms through Offshore wind farms: Opportunities and challenges

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ABSTRACT

The present work aims to evaluate the main parameters related to the integration of offshore wind farms with oil platforms for the purpose of generation and consumption of electricity by the oil and gas producing unit, as well as to evaluate their potential contribution to a low carbon economy. To this end, a review of the state of the art on the subject is carried out, in order to identify the main technical, economic and regulatory obstacles to the wide use of offshore wind farms for the electrification of oil platforms.

Keywords: Oil Rigs, Platform Electrification, Offshore Wind Farms, Platform Integration.

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INTRODUCTION

The Despite the fact that oil and its derivatives have shown a percentage reduction in their share of the world energy matrix since the end of the 1980s, their consumption, in absolute terms, is still increasing, leveraged by the economic growth of emerging countries. According to data from the International Energy Agency (2023), there is a tendency to maintain this growth behavior for the next few decades, culminating in stabilization from the 2050s onwards.

This scenario puts pressure on the oil industry to continue expanding its operations to meet the growing global demand for energy. To this end, new exploration and production projects can be initiated, which bring with them high costs and associated risks, or techniques can be applied to enhance the production of oilfields that are already under development or at the end of their useful life.

In both cases, however, the increase in oil production capacity requires an increase in the availability of pumps, compressors, boosters and other productive apparatus that use natural gas from wells or imported from other units as fuel for operation. Said machinery is responsible for a significant portion of greenhouse gas emissions from oil rig operations. An example of this is the Norwegian case, in which 29% of CO2 emissions came from offshore oil platforms in the early years of the 21st century (ARDAL, 2011).

In this context, the generation of electricity for the operation of oil platforms assumes a central role with regard to the consumption of natural gas and the emission of greenhouse gases during oil production. This is due to the fact that the main structures of oil units (processing, injection, export systems, workers' accommodation, etc.) consume electricity from gas turbines. Typically, these turbines operate with an efficiency rate close to only 30% due to area constraints and operational requirements (HE et. al., 2010).

Thus, the generation of electricity from offshore wind farms emerges as a possible alternative to the traditional means of generating electricity on oil platforms. The general advantages of the application of this alternative are: technological robustness of wind turbines, renewable energy source, possibility of economic exploitation of natural gas saved from the non-use of turbines, reduction of taxation for greenhouse gas emissions for companies in the oil and gas sector, compliance with legislation on the subject (existing in several oil-producing countries, such as Brazil), among others.

The main technical challenges of this application are related to the intermittency of the wind source and the main characteristics of the integration of the generation systems present in the wind farms with the consumer systems on the platforms. Thus, the present work aims to present the most relevant parameters to the integration of offshore wind farms with oil platforms, as well as to carry out a survey of the state of the art on the subject.

ELECTRICAL SYSTEMS ON OIL RIGS

Typically, the generation of electricity in large oil platforms comes from up to four synchronous generators that are driven by gas turbines and operated in an open cycle, in the 4 x 33% configuration. The load is divided equally between three generators and the fourth is used as a backup, which gives robustness and reliability to the electrical system, which has several redundancies in order to mitigate the risks of downtime of the oil unit (DIAS, 2018).

The choice of gas turbines is made, among other factors, due to their high reliability, operational flexibility and dimensions and weight appropriate to the constraints imposed by the space limitations on board. In addition, the availability of natural gas from the platform's own production, associated with the lower commercial value of gas in relation to oil, make this generation method even more attractive to operators in the oil sector. It should be noted, however, that the redundancies necessary for the energy security of the platform systems cause the turbines to operate with low efficiency (around 30%, as discussed in the previous topic), which intensifies their pollutant emission rate (PINTO et. al., 2019).

The energy demand of oil platforms presents a high degree of variability depending on the type of platform and the characteristics of the oil field in production. In addition, the demand also usually varies, for the same platform, throughout the production stages of the field (initial production, stabilization and decline of production), and is typically covered by the range of 10 to 100 MW.

Electrical loads on platforms are classified as: non-essential, essential, auxiliary, and emergency. Non-essential loads refer to equipment whose lack does not entail operational or safety risks, unlike essential loads, which are connected to the main bus by different feeders, which allows them to operate through emergency generators. Auxiliary loads, on the other hand, are similar to non-essential loads, except for their fundamental role in the resumption of processes, which requires power supply by an auxiliary generator. Finally, emergency loads concern life-saving equipment on board and the operability of critical equipment to the process. Its bus is powered by emergency and auxiliary generators, in addition to having an uninterruptible power supply system (UPS) for the safety of its operability (OLIVEIRA, 2013).

As an example of the main loads existing in oil platforms, the pumps and compressors necessary for the operation of the plant stand out, which are the largest consumers of electricity. Pumps are necessary to maintain the appropriate pressures at each stage of the process, while compressors play a central role in the pumping, injection and export systems of hydrocarbons.

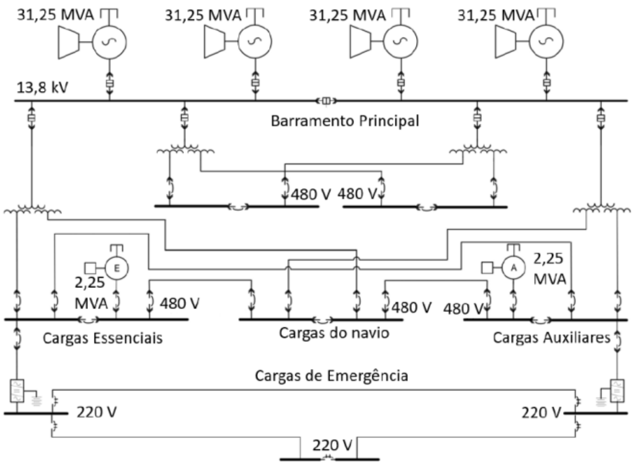
Fresky et. al. (2023) categorized the main challenges related to the generation of electricity on platforms and the transition to less emission-intensive models:

- Technical: The equipment is designed for operation under peak production conditions and its significant variation over time contributes to the reduction of the efficiency of the systems for most of the life of the platform.

- Business: the transfer of ownership of the platform between different operators implies loss of information and application of different construction standards, in addition to the change of suppliers and in the supply chain.
- Financial: the search for renewable alternatives to traditional generation systems on platforms is not yet attractive to investors, in addition to having limited government support.
- Socio-environmental: a possible decrease in operational efficiency for the sake of environmental gain may generate a public perception of the oil sector's lack of commitment to social issues.
- Regulatory: some countries, such as Norway, already have a specific tax regime for the emission of pollutants from electricity generation systems on offshore platforms.

Figure 1 illustrates, in a simplified way, the typical electrical system of a Floating Production Storage and Offloading (FPSO) platform and its main parameters of electricity generation and consumption. Table 1 shows the common quantitative distribution of loads for this type of platform, which is usually close to 70 MW.

Fig. 1. Simplification of the Electrical System of an FPSO



Source: Dias, 2018.

TABLE I: Types of Loads in FPSOs

Kind	Load (kW)
Non-Essentials	66440
Essential	1396
Auxiliary	1752
Emergency	785
Total	**70373**

Source: Adapted from (Dias, 2018.)

OFFSHORE WIND FARMS

Wind farms are sets of interconnected wind turbines in order to supply electricity to a main system. Its installation, both onshore and offshore, presents a greater degree of simplicity compared to other renewable energy sources, such as hydroelectric power. The choice for offshore installation is made due, among other factors, to the higher wind potential found at sea, the lower risks arising from the visual impact and noise emission by the wind turbines (since there is no population in nearby areas) and the absence of environmental restrictions regarding land use (NUNES, 2010).

Due to their geographical particularity, however, offshore parks have special construction and installation needs, since they must be transported to the place of operation with most of their components assembled (SILVEIRA, 2015). In addition, the need for special corrosion protection, dehumidification support systems and metal coating reinforcements in machine housings can be highlighted. It is also important to highlight the need to assess the depth, characteristics of the seabed and sea current regimes at the installation site (TAVARES, 2010).

Once installed and put into operation, this equipment must have a rigorous maintenance plan that considers, in addition to the technical specificities of the generator components, the climatic conditions, the location of the wind farm and the availability of the necessary resources (support boats, qualified labor, spare parts, etc.). Failure to comply with these criteria can lead to interruption of power generation and other technical, operational, and socioeconomic consequences associated with it (IRAWAN et al., 2022).

As an example of the relevance of the maintenance efficiency of offshore wind farms, Khalid et. al. (2023) state that costs related to this step can reach up to 29.5% of all costs over the life cycle of these facilities. In this context, several applications in automation and robotics have been gaining notoriety in the offshore wind market as an attempt to mitigate risks to human life and raise the quality of data obtained during operations to better support decision analysis.

Thus, the use of unmanned aerial vehicles and remotely operated underwater vehicles have contributed to the access and maintenance of equipment whose location or operating characteristics pose specific risks to workers. Through a survey of the state of the art on the subject, Khalid et. al. (2022) identified the main parameters for the evaluation of the use of automata in offshore wind farm maintenance operations, namely:

- Equipment Mobility: Hydro or aerodynamic characteristics that impact locomotion and access to the main components of wind turbines;
- Sensory Capacity: Support for the control and navigation of the equipment, in addition to the quality of the inspections and interventions carried out and the acquisition of relevant data for decision making during the process.
- Dimensions and Weight: They must be optimized in order to accommodate as many

instruments as possible, without compromising the mobility and accessibility of the equipment.

- Level of Automation: Degree of human support required for efficient operation of the equipment.

Figure 2 illustrates an offshore wind farm.

Fig. 2. Burberry London Wind Farm

Source: Silveira, 2015

The wind turbines typically used in offshore wind farms are composed of propeller-type horizontal shaft rotors (usually with three blades) and moved by aerodynamic forces of lift and drag from the obstruction of wind movement. In addition, it is common for these structures to have mechanisms that allow their positioning to always be perpendicular to the direction of the wind.

According to Dutra (2008), a typical offshore wind turbine is composed of the association of the following structures:

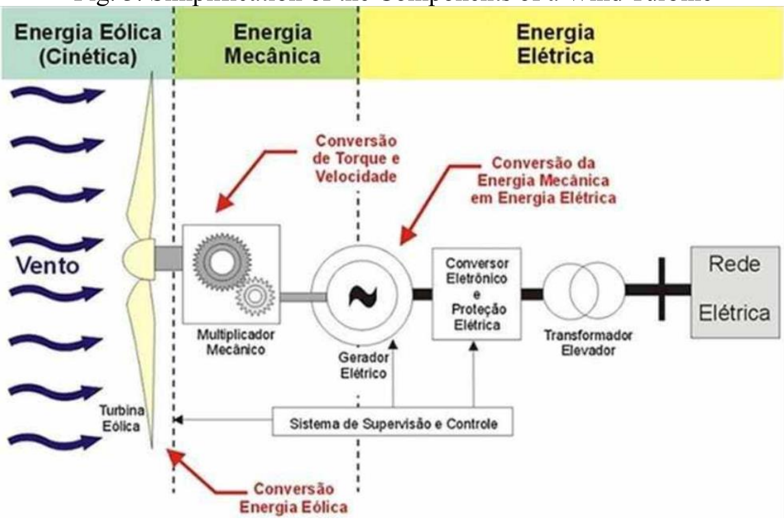
- Nacelle: housing mounted on the tower and housing the main components of the generation system;
- Blades, Hub and Shaft: Blades are responsible for converting the kinetic energy of the wind into mechanical work. The hub is positioned in front of the generator and is composed of the bearings for fixing the blades, while the shaft is responsible for coupling the hub to the generator, allowing the transfer of mechanical energy;
- Transmission and Gearbox: composed of shafts, bearings, transmission gears and couplings whose function is to transmit the mechanical energy delivered by the rotor shaft to the generator;
- Generator: equipment responsible for converting mechanical energy into electrical energy;
- Tower: support structure and positioning of the wind generation system.

Also according to the author, the main operational challenges for the generation of electricity by wind turbines are due to the following parameters:

- Oscillations in wind speeds, which imply variable rotation ranges for generation;
- Oscillations in the input torque of the generator (whose variation in the power available on the shaft is induced by the previously mentioned parameter);
- Geographical isolation of the systems, which incurs difficulty in installation, operation and maintenance, making it necessary to have a high reliability of operation.

Figure 3 presents the simplified schematic of a typical wind turbine and its power conversion and transmission flow. The types of existing turbines and generators and their forms of connection to the power grid will not be addressed because they are beyond the objectives of this work.

Fig. 3. Simplification of the Components of a Wind Turbine



Source: Picolo, 2014

INTEGRATION BETWEEN PLATFORMS AND WIND FARMS

As discussed in topic 1, the generation of electricity for oil platforms from offshore wind farms has been gaining notoriety in recent decades due to its environmental, economic and regulatory benefit. An example of this growth is the recent implementation of the Hywind Tampen wind farm in the Norwegian portion of the North Sea, which has 11 floating wind turbines of 8.6 MW anchored in water depths of up to 300m.

It is estimated that the wind farm is capable of supplying 35% of the annual energy demand of five platforms operating in the Snorre and Gulfaks fields, and this figure can be significantly exceeded at times of the year when the incidence of winds is more significant in the region. In addition, its implementation is expected to contribute to the reduction of two hundred thousand tons of carbon dioxide and one thousand tons of nitrogen oxides per year (EQUINOR, 2023).

Despite the great potential exemplified, the supply of electricity from wind farms to oil platforms still faces several technical and regulatory challenges so that its implementation can be expanded to other traditional regions of the oil industry. Ardal et. al. (2014) analyzed methods that could provide greater reliability to the interconnection systems between wind sources and consumer platforms and, according to the authors, the main challenges to interconnection are related to the following aspects:

- The intermittent nature of wind sources makes it mandatory to have additional electricity generation and/or great operational flexibility related to non-essential loads;
- The interconnection of the platforms with other sources of electricity has not been planned since the development process of the oil fields, which imposes restrictions on the feasibility of control and balance between generation and load and ends up compromising the stability of the system;
- Possibility of negative impacts on the platform's electrical systems, such as compromising the stability and design of the control and protection systems;
- Lack of specific regulation for interconnection projects.

In order to analyze the impact of these issues, Kolstad et al. (2013) simulated the interconnection of an offshore wind farm to five oil platforms. During the simulations, the authors reinforced the understanding that the biggest challenge for the implementation of projects of this kind is the need for a backup system that compensates for the intermittency of the wind source. As a solution, it was proposed to interconnect to the onshore power grid through a High Voltage Direct Current (HDVC) transmission system, 220 km long.

This interconnection presented satisfactory answers in the simulated scenarios (complete loss of wind generation and abrupt start-up of one of the five platforms), since it enabled the rapid recovery of the grid due to the short response time of the HDVC system. As there is usually no connection between the electrical systems of platforms and the onshore grid, the restoration of power in cases similar to those simulated would depend on the response time of the gas turbine controllers, which are usually slower than the HDVC converter (DIAS, 2018).

Ardal et al. (2011) applied sensitivity analysis in the evaluation of the main parameters affecting the interconnection between wind farms and platforms. To this end, three phenomena were simulated: large engine starting on the platform, short circuit lasting 30 ms on the platform and abrupt variation in wind speed.

In the case of the start-up of the large engine, the variables that showed sensitivity to voltage and frequency variations were: permanent reactance and transient reactance, in the case of the wind generator, and rotor inertia, governor's droop constant and gas injection time constant, in the case of the gas turbine.

The short-circuit simulation pointed out greater relevance for the parameters related to the wind generator, such as: reactances and synchronous and transient constants, as well as subtransient ones. In the case of the gas turbine, the parameters that showed sensitivity to the short-circuit scenario were: rotor inertia and governor's droop constant. The wind speed variation affects only the wind generator and the main parameters sensitive to this scenario are: rotor inertia and wind turbine speed controller variables.

Despite the existence of work similar to those mentioned above, the implementation of wind farms interconnected to oil platforms still comes up against the lack of consolidation of the proposed models, especially in the case of operations in deep and ultra-deep waters, which require greater electricity generation capacity (SILVA et. al., 2023).

CONCLUSION

The objective of this article was to present the most relevant parameters for the interconnection of oil platforms and offshore wind farms and their relevance for the transition to a less carbon-intensive economy. To this end, the main concepts of electricity generation and consumption on oil platforms were addressed, followed by the concepts pertinent to the installation, operation and maintenance of offshore wind farms. Finally, the growing relevance of the theme for the oil industry was presented through examples of applications currently in practice and studies in which the feasibility of the interconnection was tested through simulations of everyday operational situations that may present high demands to the system interconnected to the wind farm.

The literature review allowed us to conclude that, despite the efforts to reduce greenhouse gas emissions and the central role of the oil industry in achieving this objective, both the state of the art and the technique regarding the use of renewable energies for the electrification of oil platforms still need more attention in order to achieve the systematic feasibility of the method. Currently, the broad application of these concepts comes up against the technical challenge imposed by the nature of wind generation, the lack of economies of scale, which reduces the investment portfolio and the absence of specific regulation combined with the lack of government support to carry out the activities.

It should be noted, however, that due to the high impact of the oil industry in terms of pollutant emissions, this method of energy generation has high potential for the contribution of the oil and gas sector in the transition to a low-carbon economy. Thus, it is necessary to unite efforts from academia, industry and regulatory bodies to overcome the main challenges for the electrification of oil platforms through wind energy.

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