DIRECT-ON-LINE HIGH VOLTAGE MOTOR STARTING CRITERIA FOR ALL-ELECTRIC FPSO

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Abstract - Floating Production, Storage and Offloading (FPSO) remain key assets for meeting the global future energy demands, while alternative energy sources are being developed and made available to global energy supply chains.

The Oil & Gas industry is under increased scrutiny to reduce Greenhouse Gas (GHG) emissions. Hence it is critical that current and future FPSOs are designed to minimize emissions.

Induction motors are the most energy-intensive consumers on an FPSO and shall be designed for the available network supply. Oversizing these motors can result in increased GHG emissions.

Starting criteria of HV direct-on-line motor have significant implications for the size and design of the motor. This paper aims to present the main elements of an all-electric FPSO and investigate, through a case study, the design criteria for a high-power direct-on-line motor.

Index Terms — All-electric, Floating production storage and Offloading (FPSO), Direct-on-line, HV Motor, electrification, GHG reductions.

KEY ABBREVIATIONS

CAPEX Capital Expenditure
CCS: Carbon Capture and Sequestration
DOL: Direct On-line
FPSO: Floating Production Storage and Offloading
GHG: Greenhouse Gas
GTG: Gas Turbine Generator
HRSG: Heat Recovery Steam Generator
HV: High Voltage (>1000V as per IEC)
kbpd: thousand barrels per day.
LIC Low inrush current
OTSG: Once-Through Steam Generator
TCO: Total Cost of Ownership
VSI: Voltage Source Inverter
VLCC: Very Large Crude oil Carrier
VSDS: Variable Speed Drive System
WHRU: Waste Heat Recovery Unit

I. INTRODUCTION

Historically FPSOs were mostly repurposed VLCC tankers which reused the existing steam plant and were supported by dedicated gas turbines to drive directly large pump/compressor equipment installed on the FPSO's topsides. The electrical power plant had limited capacity to supply smaller consumers.

In the context of all-electric FPSO, these dedicated gas turbine drivers are now replaced by electric motors. As a result, the remaining gas turbines are exclusively used for electric power generation. It is noteworthy that approximately 70% of emissions can be attributed to the GHG emissions generated by these turbines, while flaring, contributing up to 30%.

Fig. 1. FPSO GHG emissions sources

Where FPSOs operate, challenges such as local infrastructure development, harsh sea environments or prohibitive initial investments often render access to low carbon power sources from shore-based power plants unfeasible. FPSOs have a large energy demand both for mechanical (drive) power and for heating power. The latter is extracted from exhaust gases from the turbines.

Consequently, commercially viable alternatives to gas turbine generators for FPSO operations are currently limited in many regions. Meanwhile advancements in combined cycle power plants to use the remaining thermal energy available brings the historical steam cycle back to the FPSO. Also, CCS (Carbon Capture, and Sequestration) technologies offer a promising avenue to electrify future FPSOs.

Concomitantly FPSO operations increasingly rely on large electric motors to drive energy-intensive systems like high-pressure pumps and compressors for water and gas injection into the field.

Motor design and utilization directly influence energy efficiency and consequent GHG emissions. Oversizing these motors due to inappropriate process data or electric network supply considerations results in avoidable environmental repercussions, emphasizing the need for a careful approach to their design, starting method and usage.

This paper aims to elucidate the relationship between FPSO electric design, the role of motor selection and GHG emissions.

Specifically, it seeks to explore with an interesting case study the importance of proper motor design concerning the available network supply to avoid oversizing and the subsequent increase in GHG emissions. Moreover, by investigating the starting criteria for large direct-on-line motor this paper highlight the implications for motor size and design within FPSO plants.

II. JOURNEY OF FPSO TOWARD ALL-ELECTRIC DESIGN

The IEA World Energy Outlook 2023 report underscores the crucial role of offshore resources in addressing future energy needs [1]. FPSOs facilitate oil and gas production in remote and challenging offshore locations, where traditional infrastructure might be impractical or cost prohibitive.

Therefore, FPSOs play a key role in meeting global energy demands due to their flexibility, adaptability, and efficiency in offshore energy production. These giant floating plants have the potential to support the development of other offshore resources like ammonia and blue hydrogen. Their ability to accommodate various production scenarios, establishes FPSOs as major assets in ensuring energy security and fulfilling escalating energy demands worldwide.

Moreover, FPSOs can evolve with market dynamics and technological advancements and can already embed “electrification ready” design as per recommendation from IOGP report 653 [2]. This adaptability combined with potential for integration of technologies such as subsea power connection or nearby floating wind farms will diversify the energy mix to meet growing demands while mitigating environmental impacts.

In an all-electric FPSO, electric motors exclusively drive processes including compressors and pumps. This design is not a new concept but has been a significant trend for the last two decades.

Throughout this all-electric journey, we will review the design elements aimed at optimizing advantages and addressing the drawbacks.

A. *Total power demand*

Nowadays with production increasing up to 250kbpd, the FPSO topsides weight is increasing and prebuilt standardized hull able to support up to 45.000 tons of topside has proven to be a successful trend.

Depending on the field specificities, new designed FPSOs may exhibit a **total load demand of 70 to 120 MW** during normal production.

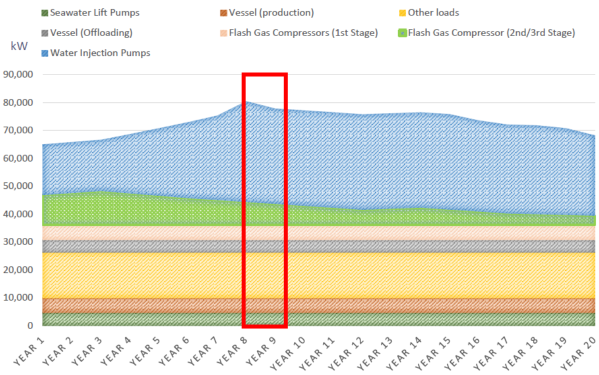

Fig. 2. FPSO load profile

The main consideration for sizing the FPSO power plant is calculating the power peak year in term of water injection and gas compression based on multiple process scenario. For instance, this peak occurs at year 8 as shown in the Figure 2 example.

Additionally, the offloading procedure needs to be considered. This routine involves transferring oil from the FPSO tanks to a nearby tanker the oil while production continues. Intermittent consumers, such as cargo offloading pumps and thrusters for station keeping (if necessary), can add an extra 5MW to 15MW in power demand. Typically, this occurs once or twice a week during the plateau phase of the field's lifespan and should not need load shedding at that time.

B. *GTG selection and combined cycle*

Based on total power demand, GTG are selected with several criteria which can be summarized as follow: -

1. Power and heat capacity including aging and fouling at maximum site temperature.
2. Weight and footprint
3. Reliability and Availability
4. Total cost of ownership
5. GHG emissions

On top of electrical demand, the heat generated by the GTGs via exhaust flue gases can be recovered via Waste Heat Recovery Unit to satisfy the process heating demands. The thermal demand for process varies significantly across different fields, **ranging from 20 to 80MWth**. It is possible to utilize the heat via steam generators (HRSG or OTSG). Unlike WHRU, the hot exhaust flue gases pass through the heating coils to produce steam, which then drives a steam turbine generator (STG) to supply additional electric power and maximize the total efficiency of the GTGs.

With consideration of derating, aging factor of GTGs, the normal production load of FPSO shall not exceed **95% of N+1 generators**. This allowance is required for maintenance of any GTG without affecting on the production.

C. *High Voltage distribution*

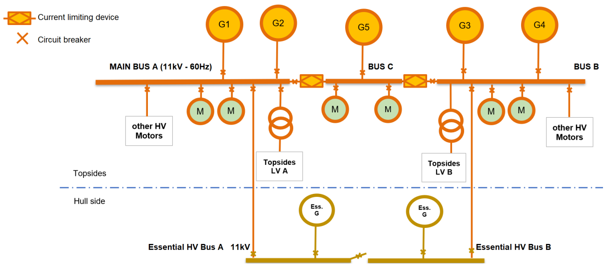

Fig. 3. HV typical single line diagram

To maximize availability and minimize equipment count (hence associated cost and footprint/weight), it is advantageous to connect all Gas Turbine Generators (GTGs) and motors to the same bus and voltage level. The trend is to use **11kV as main voltage** avoiding the use of transformers and intermediate voltage level, connecting directly to the Essential switchgear at 11kV located in the vessel. Although the 13.8kV level is common, it limits availability for motors below 1MW, requiring intermediate voltage switchgears and subsequent stepdown transformers.

Sufficient running Gas Turbine Generators (GTGs) allow direct online starting of large motors, yet it introduces two main constraints:

1. Load flow management within busbars

The distribution of loads across 2 or 3 HV buses, along with the bus tie topology may result in current flow surpassing the conventional rating of HV switchgear. It can be avoided with motor sparing and careful repartitions between GTG incomers and other large consumers.

2. Short-circuit contributions

The contribution of two or more GTGs with connected motors onto a bus could exceed HV switchgear short circuit rating (typically 50kA - 1sec for 11kV switchgear). The implementation of fault current limiter between buses offers an effective solution: if the system detects predefined current rise, it triggers a pyrotechnic charge explosion. In conjunction with bus tie breaker, this splits instantly the buses ensuring that any fault is isolated and limit DC current offset from direct generator contribution. This measure prevents widespread damage or disruptions by containing the fault within a bus section of the network.

D. High Voltage Motors or Gas Turbine Drivers?

When the rated power stays below ~23 MWe for rotating equipment, induction motors stand out as an excellent and superior choice compared to synchronous motors. because it does not need any excitation for its rotor. Therefore, the rotor has no components such as insulated windings, exciter, rotating diodes, or permanent magnets. It is only fitted with copper bars short-circuited by rings. Thus, the reliability and the availability of such motors are naturally higher.

In comparison with gas turbine driver, induction motors have a clear advantage of footprint and weight. The size, the weight, and the reduced auxiliaries' equipment and piping are in favor of the motor drive.

Maintenance needs for HV motors are much more limited compared to their driven equipment when gas turbine drivers require regular preventive maintenance. This difference in availability duration may result in production loss.

Without fast-spinning rotor and combustion chamber HV motor's design inherently diminishes the risk of gas ignition, enhancing overall safety.

Determining the rated power of the driver and its margins involves specific considerations. In a traditional gas turbine driven machine, the rated power of compressors or pumps aligns with the power range of gas turbines in the market. This limitation does not apply for HV electric because they are custom designed to suit the requirements of the driven equipment.

In contrast to gas turbine drivers, HV motors do not need margins for derating due to aging and fouling. In an all-electric FPSO where all motors are linked to the same grid as gas turbine generators (GTGs), consolidating those margins allows more precise power generation sizing. This consolidation enhances efficiency and utilization levels.

E. Variable speed drive or Direct-on-line motors?

As a reminder, the concept of an all-electric FPSO with high power motor is not a recent aspiration but a prominent trend that commenced about twenty years ago. The publication *All-Electrical FPSO Scheme with Variable-Speed Drive Systems* [3] issued in 2013 described this approach employing VSDS for FPSO pumps and compressors. The authors presented technical and economical choices and discussed the advantages and drawbacks of this design approach.

The aim of this paper is not to oppose DOL to VSDS type of approach. Both designs have valid reasons and merits:

- On one side, a driven compressor which must start at the settled-out pressure to prevent depressurization or flaring requires a significant starting torque as depicted on figure 4. Consequently, using a Direct-On-Line (DOL) motor might be impossible and potentially necessitating VSDS alternative for starting.

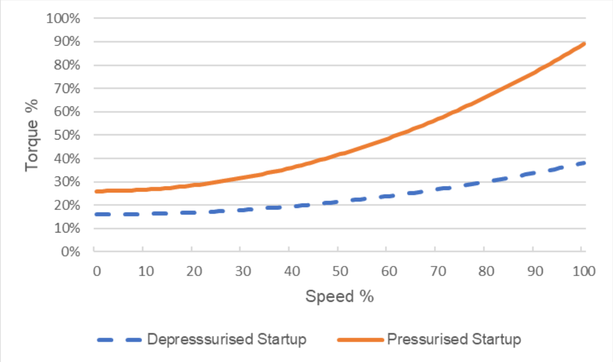

Fig.4. Typical centrifugal compressor torque-speed curve

- On the other side during the production plateau of a 20+ year field life, water injection pumps or gas compressors equipped with VSDS may exhibit lower efficiency compared to Direct Online (DOL) motors. This inefficiency stems from additional losses linked to VSDS. Heat losses in input transformers and converters, are diminishing the overall efficiency. With oil fields exhibiting a declining production profile only in their late years, the reduction in load achievable with variable speed in comparison to gradually shutting off compressors or pumps might not sufficiently offset the power losses caused. As an alternative solution, OEM compressor re-bundling could address these shifting parameters, allowing finer design adjustment. This may become crucial when multiple margins on the process or equipment result in off-design operations.

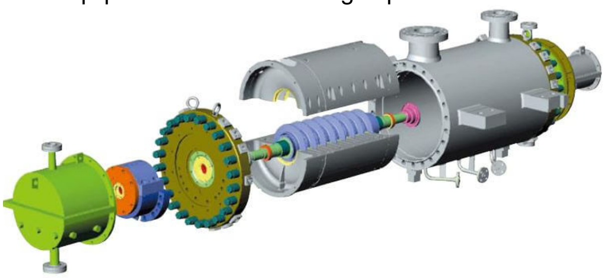

Fig. 5. Compressor re-bunding within main casing

F. Electrical rooms and other constraints

Using a single HV level limits number of transformers However, an all-electric FPSO necessitates large HV switch rooms. For easing the cabling, the commissioning, and the operations, it is advantageous to house all HV & LV switchgears, transformers, and instrumentation panels within a single building. Accommodating VSDS has constraints which shall be considered when overseeing the FPSO electric design.

- Transformers and converters require significant space inside already congested electrical rooms and tackle the need to create additional spaces for instance with dedicated floor for VSDS (Figure 6)

- Ventilation, air conditioning and water cooling should be sized to dissipate additional losses.
- Additional qualified maintenance tasks for electrical operators
- Harmonics used to be a major drawback but thanks to Voltage Source Inverter (VSI) with increased number of pulses the harmonics rejection is a less prominent concern.
- The increased Total Cost of Ownership (TCO) compared to a DOL motor ranges from 5 to 8 times higher. The main factor behind this is the initial investment (CAPEX). Specifically, the cost of energy generated on FPSOs is minimal so not impactful in overall TCO.

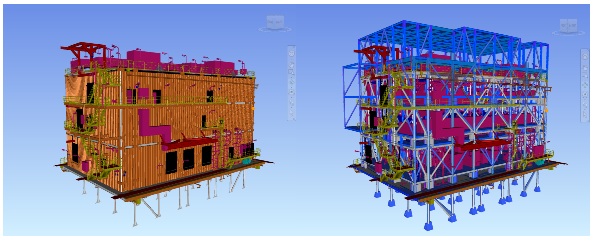

Fig.6. 3D model comparison of electrical building to accommodate VSDS.

G. Summary

The current switchgear and electric motor available today make an all-electric FPSO design cost-effective and a practical choice.

Variable Speed Drive Systems (VSDS) should be evaluated based on process needs or electrical constraints: Where the speed control may not provide significant process or power-saving advantages, VSDs still limit substantial motor inrush current during startup and decrease contributions during short circuits.

However, if an HV motor can be started directly online while tolerating the disadvantages of high starting current, this setup will remain favored due to its reliability, simplicity, and cost-effectiveness. This will be explored further in the following section. Addressing changes in pressure/flow over time in the case of gas compressor, re-bundling could be cost-effective and energy-saving.

III. HV MOTOR DESIGN STUDY CASE

A. Introduction

Among the FPSO fleet, induction motors now reach ratings up to 17.500 kW and can start direct online with low inrush current (LIC) design.

Induction motors qualify as Low Inrush Current (LIC) design if their starting current is limited to below 400% of the full load current (FLC). Their design involves a combination of modifications in the motor's coils and rotor to limit the high inrush current during startup. However, it comes with a degradation of the efficiency, a higher weight, and a higher CAPEX.

This study examines the feasibility of replacing an existing Low Inrush Current (LIC) motor installed on an electric FPSO with a standard induction motor, in collaboration with a motor manufacturer and utilizing operational data. The objective is to evaluate the potential optimization of a 13.8 MW DOL motor design.

B. How low inrush current is achieved?

Various methods are employed in motor design to achieve Low Inrush Current (LIC) characteristics. This paper specifically focuses into rotor design, widely recognized as the primary approach for attaining LIC features. Leveraging the Skin Effect phenomenon, induction motor startup behavior is influenced. During startup, magnetic fields penetrate only the surface (or skin) of the rotor, directing current primarily through the upper part. Adjusting the shape and materials of rotor bars enables control over this behavior. The following three primary methods are commonly utilized:

1. Designing deep rotor bars while modifying slot shapes.
2. Utilizing specialized high-resistance rotor bar materials (Cu-Alloys).
3. Employing a double cage rotor design.

Generally, achieving LIC features involves altering rotor bar shapes and incorporating custom materials such as Cu Brass alloys. For visual representations of various rotor bar shapes, refer to Figure 7, and observe the resulting starting behavior modifications in Figure 8.

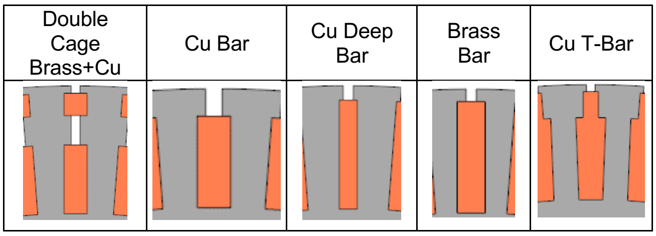

Fig.7. Rotor slot and bar shapes

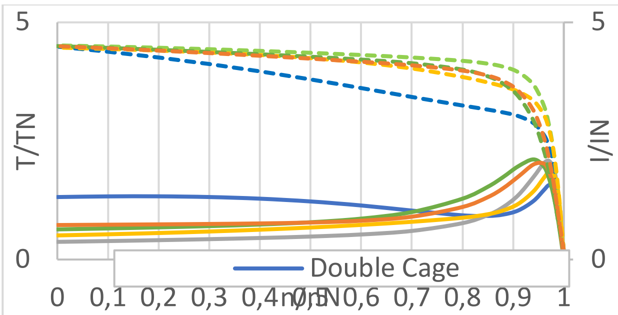

Fig.8. Torque-Current vs speed curves for different rotor designs

C. DOL motor main selection criteria on FPSO

When selecting an HV motor, the following requirements must be considered:

1. Torque speed characteristic of the driven load:

The accelerating torque of the motor should always exceed the load torque, even if there is a voltage reduction. This is typically represented by a quadratic curve for devices like centrifugal pumps, fans, and compressors illustrated in yellow on Figure 9 for the studied motor.

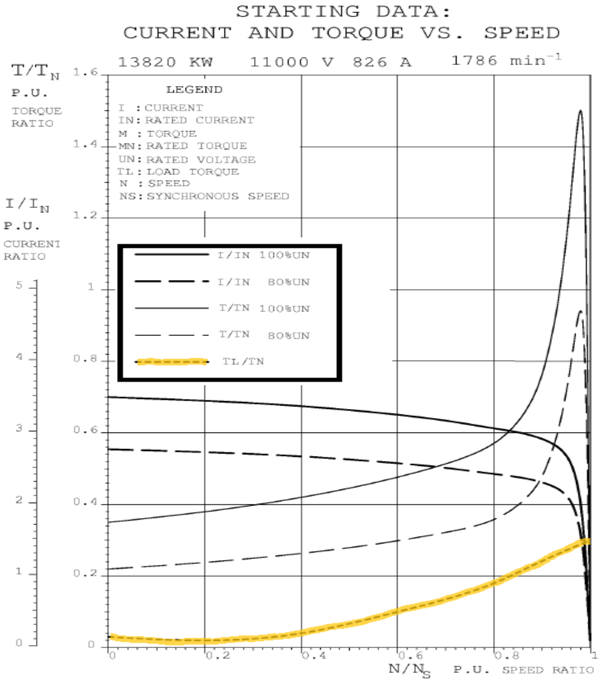

Fig. 9. Actual motor load torque curve

2. *Electric supply capacity*

The motor expected short circuit contribution is related with starting current ratio and shall be adequate with supply network.

3. *Reliability and Availability*

Mean time between failure (MTBF) and preventive maintenance schedule shall be in line with process and overall FPSO maintenance program.

4. *Efficiency of the overall system*

Higher efficiency means that losses are reduced, typically this is a reduction in thermal losses from energy conversion. This implies minimization of operating losses effectively reducing GHG emissions.

5. *Total cost of ownership*

TCO Consideration of initial CAPEX investment and OPEX expenditure of the motor and associated equipment.

6. *Footprint and weight*

Footprint-on topsides for the HV motor but also electrical rooms in case of VSDS.

D. *DOL Motor starting criteria*

1. *Voltage drop*

When a large HV motor is started, large instantaneous amounts of reactive power are required. This depletion of reactive power from the power generation system can cause disturbances on the buses. An all-electric FPSO power plant has restrictions on the allowable voltage drop. These restrictions are set regardless of the plant conditions or loading profiles. Those are necessary to ensure the quality of the power for other consumers and minimize effect for other motors and loads using the same bus. During start-up, the total voltage drop, including all upstream network impedance, at motor terminals shall be less than 20 % according to IEC 61892 part 1 section 4.5.2.5 [4].

2. *Frequency stability*

On the islanded network of FPSO, the frequency is dependent of GTG speed hence the fuel gas injection control. When HV motor is starting, gas turbine shall be able to provide instantaneous active power without control upset. The criteria are ±10% max excursion during transient and recovering ±1% within 5s as per IEC 61892 part 1 section 4.5.2.4 [4].

In the event of an overload (i.e., if the exhaust temperature exceeds safe levels), Dry Low Emission (DLE) turbine control may reduce fuel intake hence decreasing speed and potentially leading to a shutdown of the power plant.

3. *Generator Load acceptance*

The capability of GTG to quickly and effectively manage a sudden load increase depends on their preloading level, rotating inertia and GTG fuel gas control dynamic..

4. *Acceleration duration*

The time for acceleration is linked to the voltage level and the inertia of the rotor along with the driven load. At startup, the rotor heats up more than the stator, and a prolonged start can lead to overheating and potential damage to the rotor.

E. *Description of the motor and starting performance*

The case study focuses on parameter of an HV motor driving the injection gas compressor on an all-electric FPSO equipped with 4 HV generators driven with GTG connected on 11kV bus as represented in Figure 10 with the following generator characteristics:

HV generator data	
Parameter	Value
Rated power	26.500 kW
Current	1739 A
Speed	1800 rpm
Power Factor	0.8
Transient reactance X'd	28.8%
Sub-transient reactance X''d	14.7%

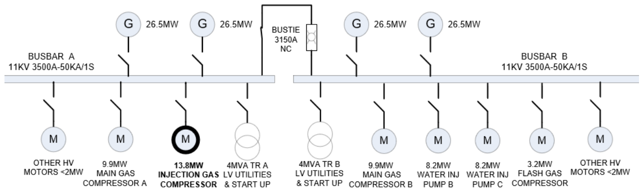

Fig 10 . Single line diagram of the HV bus

Following initial compression boosting the produced gas flows to the injection gas compressor. This component allows to reintroduce gas back into the reservoir through risers preserving pressure levels, and curbing depletion of the reservoir.

The single stage centrifugal compressor spinning at 12900rpm due to the gearbox and boosts pressure from 200 to 580 bara. It can be started direct online with surge control valve fully open enabling full recycling.

Actual HV motor nameplate	
Parameter	Value
Rated power	13820 kW
Current	826 A
Speed	1786 rpm
Power Factor	0.89
Locked rotor current	350%
Motor inertia	1133 kg.m²
Locked Rotor PF	0.15
Locked rotor torque	35%
Maximum torque	150%
Efficiency @100%	97.1%
Cold/hot start	3/2

During the design phase, motor selection addressed concerns about inrush current by opting for a 350% Low Inrush Current (LIC) design, complying also with the generic requirement of three cold and two hot starts (3/2) capacity.

With three operational generators and one standby (3+1 GTG configuration), the motor shall be able to start with three generators online. During startup, the voltage drop at the motor terminals should not exceed 20%, factoring in all impedance along the network, which significantly relies on the transient reactance (X'd) of the generators.

During motor startup, the sudden surge in current causes a momentary voltage drop across the bus system, leading to a reduction in the supplied voltage to the motor and other connected loads. This decrease significantly affects the available torque for acceleration, bearing in mind that torque capability is directly proportional to the square of the applied voltage.

When a large motor connects to the grid, the generator's reactance combines with the load impedance, lowering the voltage until the regulator can boost the internal excitation voltage to balance it out. Similarly, at the end of the run-up time when the motor moves over its maximum torque point or when a load is removed, the voltage rises to the level of the increased internal excitation voltage. This voltage drop and rise during motor startup can be simulated in a power systems analysis software as shown below:

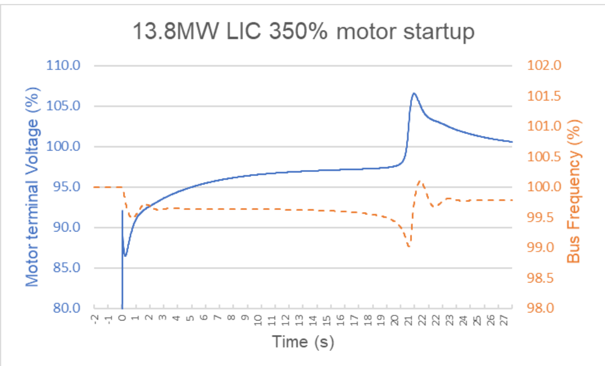

Fig. 11 Actual motor voltage drop with simulation model

Actual motor startup evaluation	
Parameter	Value
Starting time	20.6s
Starting current	2629A = 322%
Starting reactive power	46.6MVAR
Starting active power	17.9MW
Voltage at motor terminal	86.5%
Bus frequency	99.1% - 59.46Hz

During the initial phases of a project, acquiring and fine-tuning electrical parameters can pose challenges, often necessitating the inclusion of margins where uncertainties exist. In this process, the supplied values have undergone verification and validation against recorded in-service data. Ensuring precision and reliability in the model parameters is crucial for fine-tuning the motor design.

F. Evaluation of an alternative motor design

It is noted that load inertia in this case study is a significantly higher value, and it has major implications on the motors starting behavior notably impacting the need for 3/2 starts and the adherence to thermal limits for both stator and rotor.

Following an analysis of on-site operational data, it was concluded that 3/2 starts are unnecessary. In rare instances of an unsuccessful start, the operator allows the motor to cool before retrying. Thus, in real-life scenarios, a reduced number of starts, specifically 2/1, is deemed acceptable, while 3/2 starts are not frequent practice. Consequently, the alternative motor case study is based on a 2/1 start configuration.

The design of the alternative motor was completed in simulation, considering the required ratings and load conditions adhering to standard motor design for starting current (exceeding 400% FLC). The starting current for this alternative motor design is calculated at 430%, with a maximum of 490% including tolerances.

Alternative HV motor nameplate	
Parameter	Value
Rated power	13820 kW
Current	833 A
Speed	1791 rpm
Power Factor	0.90
Locked rotor current	**430%**
Motor inertia	780 kg.m²
Locked Rotor PF	0.085
Locked rotor torque	36%
Maximum torque	170%
Efficiency @100%	**97.5%**
Cold/hot start	**2/1**

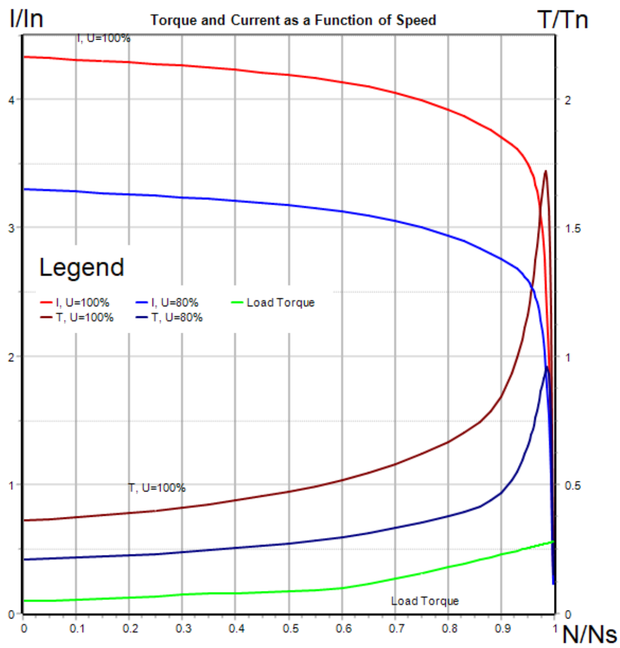

Fig. 12 Torque-Speed vs speed of alternative motor

G. Electrical performance comparison

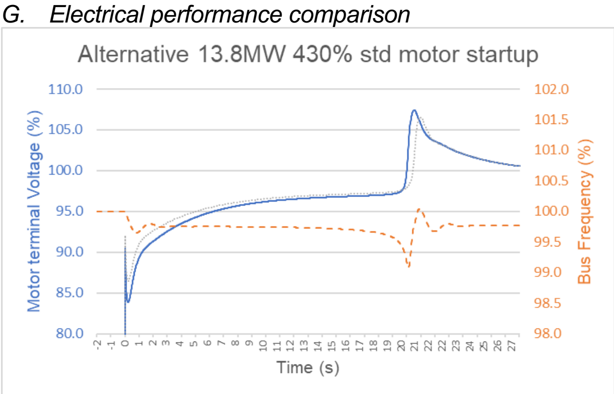

Fig. 13 Alternative motor voltage drop with simulation model

Alternative motor startup evaluation	
Parameter	Value
Starting time	20s
Starting current	3124A = 375%%
Starting reactive power	54.5Mvar
Starting active power	16.8MW
Voltage at motor terminal	**83.9%**
Bus frequency	99.1% - 59.46Hz
Bus voltage	84.7%

Despite having an equivalent starting time, the alternative motor demonstrates superior performance data due to lower losses. The alternative motor exhibits a 0.4% increase in efficiency while providing a higher power factor. Notably, the motor's efficiency directly influences the GHG footprint of the energy consumed. The effect of efficiency in terms of GHG footprint is calculated in the next section.

H. Material and GHG footprint

Large motors require significant amount of material utilization to meet the required performances. In this case, alternative motor design meets the required operational performance while requiring less material such as copper, iron, and steel as shown in below table:

	Actual Motor	Alternative Motor	Difference
Rotor Weight	9799kg	8220kg	1579kg
Stator Weight	13700kg	9348kg	4352kg
MTB Weight	957kg	510kg	447kg
Total machine weight	**38000kg**	**26510kg**	**11490kg**
Total weight difference			**30.2%**

The current motor design weighs 38 tons, whereas the newly designed motor weighs 26.5 tons, presenting an 11.5-ton difference. It results in a 30% reduction in material usage while enhancing efficiency and power factor. Additionally, the lighter standard motor permits a smaller skid platform, contributing to overall material savings and a reduced GHG footprint (estimated reduction due to material change: 21.9 tons CO2eq)

With regards to efficiency gain:

	Actual Motor	Alternative Motor	Difference
Annual energy consumption	124,678,888 kWh	124,167,385 kWh	511,503 kWh
Est. GHG emissions [tons CO2 eq./year]	74,807 tons	74,500 tons	307 tons

Total GHG estimated reduction per year: 307 tons of CO2eq. Over a 20-year lifespan, this accumulates to 6,140 tons of CO2eq.

I. Mechanical Dimensions Comparison

Total Rotor Weight	Actual motor (mm)	Alternative Motor (mm)	Difference (mm)
Total Length	4617	4275	**342**
Total Width	4802	3875	**927**
Total Height	4422	2945	**1477**

A notable dimensional contrast exists between LIC motors and standard motors with potentially 30% height reduction. In offshore applications, particularly on FPSOs, optimizing space is critical. Standard motors offer significantly compact dimensions while delivering superior electrical performance, addressing this space utilization challenge effectively.

In addition, mechanical handling and lifting offshore pose formidable challenges, primarily hinging on the weight and dimension of the motor. These challenges extend beyond mere spatial considerations and delve into the intricacies of crane capacity, route structural reinforcement, and motor dismantling.

In scenarios where structure load performance and lifting capacity is a decisive factor, the challenges are accentuated. The LIC motor, due to its weight, necessitates a meticulous disassembly process, involving the dismounting of the cooler and the extraction of the rotor, over the disassembly of the main terminal box(es). This meticulous approach is necessitated by crane and structure limitations capped at 24 tons. In contrast, the Standard motor, with its more manageable weight, may require a less extensive dismounting process, involving only the removal of the terminal box and coolers.

IV. CONCLUSIONS

When conceptualizing an all-electric FPSO, early-phase parameters have a pivotal role, starting with defining the total load and subsequently determining the primary generators and main voltage level. Those details are crucial for assessing the starting capacity of large motors, which can also support the choice between Direct-On-Line (DOL) and Variable Speed Drive Systems (VSDS) where applicable.

Regarding motor selection, during the initial phase of a project, the design typically involves collaboration with compressor or pump manufacturers, often excluding engagement with motor manufacturers. This paper asserts that involving motor manufacturers at an early stage offers significant advantages. Closer collaboration facilitates streamlined model simulations, ensures motors are designed with precision, eliminating unnecessary margins or uncertainties. It also prevents the use of Low Inrush Current construction where it is unwarranted. Revisiting the design with actual operational data simplifies the process, unveiling initial uncertainties.

Underlining the criticality of early motor design, particularly in terms of starting capability and contributions to short-circuit scenarios, this case study highlights various advantages:

- Decreased motor weight and frame size
- Reduced material usage and associated emissions
- Lower initial capital expenditure (CAPEX)
- Enhanced efficiency resulting in greenhouse gas (GHG) reductions
- Compliance with lifting capacity of a FPSO without major disassembly

V. REFERENCES

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VI. VITA

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