Design factors of electrifying brownfield oil and gas facilities

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Abstract - Integrated energy companies see electrification as an opportunity to reduce their operations greenhouse gas emissions, increase reliability and reduce operational costs. This can be achieved by using more fuel-efficient generators, by integrating renewable power generation sources and/or interfacing with an onshore electricity grid. The purpose of this paper is to describe a project concept to improve generation fuel-efficiency through the installation of a 33kV submarine interconnector cable between Platform A (consumer) and Platform B (generator) to enable the decommissioning of existing unreliable and inefficient Platform A generation. This is expected to reduce Platform A carbon intensity, increase power availability, and reduce operational costs. This paper will detail the selection of the submarine cable, the transformers, the electrical protection scheme, the Power Management System integration and describe the main electrical feasibility studies completed. The paper will also highlight some of the challenges when executing brownfield modifications on operating oil and gas assets and provide recommendations for operators considering electrification.

Index Terms — diesel generators, electrification, greenhouse gas emissions, reliability, submarine cable, low carbon projects, net zero aim, brownfield modifications.

I. INTRODUCTION

Electrification of oil, gas and petrochemical assets is a key step to reduce Scope 1 greenhouse gases (GHG) emissions [1]. The use of electric drives and more efficient power generation are among the solutions which can be evaluated to reduce GHG emissions of these assets. On the other hand, the drive for electrification may be due to other factors such as ageing equipment, low reliability, obsolescence, and high operational costs for mechanical drives.

Nevertheless, fully electrifying brownfield assets can impose major challenges to operators. The major modifications required on the asset along with the external infrastructure (e.g., onshore substation) required can have a significant impact on daily operations and will require separate project teams throughout appraisal to execution.

In our example, Platform A started production in 2006. It has five dual fuel reciprocating engine driven generators in a (N+1) configuration with a total installed generating capacity of 13MVA. Since the generator OEM ceased the production of the model in 2007, operational spares are scarce, and the operator expects to exhaust the existing spares stock by the end of 2023. All five generators supply the 6.6 kV/50 Hz main switchboard. In addition, each generator is equipped with a waste heat recovery system connected to the heating medium system which provides heat to the Living Quarters and Hull HVAC systems.

Platform B started production in 2018. It features four dual-fuel gas turbine driven generators in a (N+1) configuration with a total installed generating capacity of 84MVA. All four generators supply the 11kV / 50Hz main switchboard. Again, each generator is equipped with a waste heat recovery system connected to the platform heating medium system.

The operator intends to continue operation of these two assets through the 2030s and for this reason it plans to provide a more robust, long-term, and reliable power supply to Platform A. The project concept is for power to be imported from Platform B via a single, 8km, 33kV (3C x 150mm^2) submarine power and fibre optic cable. Figure 1 illustrates a high-level single line diagram and the interconnection between the two offshore platforms.

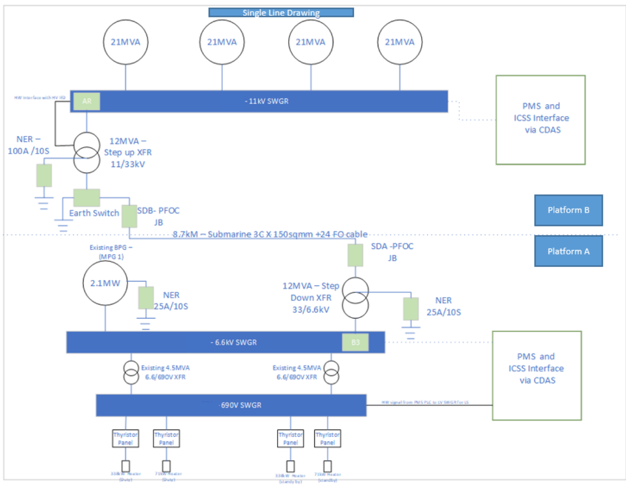

Figure 1. High-level single line diagram and interconnection between Platform A and Platform B.

Through this concept, the operator will reduce direct GHG emissions from Platform A by circa 1000 tonnes of CO_2 equivalent per year. Moreover, the additional load will be handled by the existing generators on Platform B and therefore, they would be run more efficiently. Figure 2 shows the comparison between the emissions with and without electrification in tonnes of CO_2 equivalent per year.

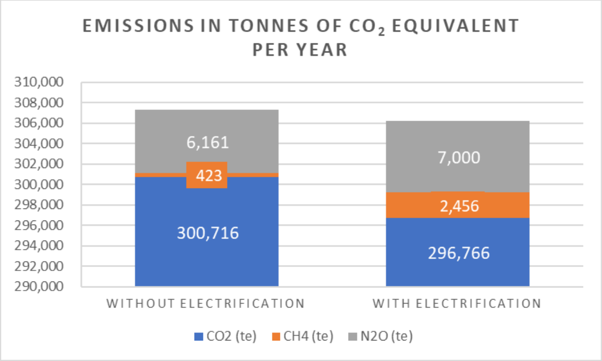

Figure 2. Platform A GHG emissions comparison with and without electrification.

The electrification of Platform A will not only reduce its annual GHG emissions, but it will also significantly reduce the emission of other gases such as carbon monoxide, nitrogen oxides (NOx), sulphur dioxide (SO_2) and volatile organic compounds (VOCs) as shown in Table 1 below. Maintenance and fuel costs are also expected to be reduced when 4 out of the 5 generators are decommissioned.

	Using EEMS Default EFs			
	CO (te)	NOx (te)	SO_2 (te)	VOC (te)
Without electrification	1475.4	5582	375.9	187.9
With electrification	640.6	32	1.4	3.8
reduction	56.6%	99.4%	99.6%	98.0%

Table 1. Other gases emission comparison with and without electrification.

II. BROWNFIELD PROJECT DESIGN OVERVIEW

A. Concept Studies and Planning

As part of concept studies, a few major decisions had to be made:

1. *Transmission voltage:* Platform B high voltage level is 11kV and, therefore, it would have been preferrable to transfer power at 11kV between both platforms. However, there is a risk of excessive voltage drop upon starting the largest motor. After conducting a dynamic motor starting study, it was determined that the voltage drop was greater than 20% and beyond recommended levels as per IEC 60364 [2]. To overcome this problem without installing variable speed drives or motor soft-starters, the project decided to select 33kV for the transmission voltage between the platforms. This led to the requirement for a step-up transformer on Platform B and step-down transformer on Platform A.

2. *Back-up generator:* the project had considered purchasing a back-up generator to supply habitation and life support loads for periods of prolonged import power outages. This generator would not replace the emergency generator, which automatically starts in the event of a power loss, supplying critical life support loads on the platform and blackstart capability.

3. *Submarine cable redundancy:* The redundancy of the interconnector was one of the key design considerations the project had to evaluate. Since the project opted to procure a back-up power generator, the project decided against installing a second submarine cable. This decision led to a significant reduction in the capital cost of the project.

B. Front End Engineering and Design (FEED)

1. *Power and Fibre Optic Cable (PFOC): a* 33kV 7.956km 150mm*2* submarine power and fibre optic cable was chosen and procured early in FEED to secure production and delivery times. The subsea PFOC is to be routed between A and B platforms and pulled through existing J-tubes (risers) at both ends. Besides avoiding existing and future subsea infrastructures and dropped objects where possible, the cable route shall avoid geohazard threats as well. To address this requirement, geophysical route survey was performed, and the cable route design avoids seabed features identified from the geophysical survey result and GIS (Geographic Information System) data base, including areas with steep seabed slopes. The cable design was also checked to ensure its robustness and stability on the seabed in the event of seabed displacements due to a seismic event.

2. *Back-up generator:* the project decided during FEED to repurpose one of the existing main power generators in Platform A instead of procuring a new back-up generator. With the decommissioning of the other generators, this should provide required spares to maintain the remaining generator for the foreseeable future.

3. *Neutral Earthing Resistor (NER) and Transformers*: Calculations which considered the submarine cable capacitance, leakage current and maximum power generation were completed to specify the NER rating. During the concept studies, it was decided to install the NERs outdoors on both platforms to minimise potential heat load impact on HVAC. However, to comply with Platform A requirement for all electrical equipment outdoors to be Ex certified to a minimum Zone 2 and temperature class T3 (even if installed in non-hazardous areas), the transformer on Platform A will be Ex rated whereas the NER will be placed inside the switchroom. On Platform B, the transformer and the NER will be inside the switchroom. The NER has a 10A continuous current rating and is IP54. Since vendors were unable to provide an NER that met the IP requirement, a canopy will be provided for weather protection.

4. *Power system studies:* As part of the FEED, a power system model including both platforms was created and studies such as load flow, short circuit and motor starting were completed. The load flow, short circuit, and motor starting showed that there were no significant

changes to the existing Platform A and B electrical designs. The results were within the defined equipment ratings, voltage, and frequency tolerances. Moreover, the project conducted a transformer energisation study. This study was required to ensure that the inrush current would not cause a substantial voltage drop. The study confirmed that upon energisation of the transformer, the voltage drop did not exceed 20% [2]. Therefore, a Pre-Insertion Resistor (PIR) is not required.

5. *Earthing Switch:* An earthing switch will be required to earth the 33kV submarine cable during maintenance. Since Platform B highest voltage is 11kV, a standalone earthing switch is required. Manufacturers do not offer a standalone earthing switch, this led to a bespoke design involving the modification of two switchgear cubicles, which will be placed inside of a container. The cable on the secondary of the transformer will be terminated into the first cubicle bus bar, which is then connected to the second cubicle where the earthing switch is housed. Since current will be flowing continuously in the first cubicle, HVAC requirements for the container had to be considered and the project considered two options: Air Insulated or Gas Insulated Earthing Switch. The project opted for an air insulated switch (AIS) instead of a gas insulated switch (GIS), due to economic and environmental reasons.

6. *Enabling construction works*: Brownfield modification projects are complex and must deal with constraints such as logistics, space availability and constructability. This is the reason constructability reviews are important. The offshore execution of the project will be completed in three phases. In the first phase, one of the existing diesel generators will be removed to provide space to build a structure to house the transformer and NER on Platform A. Other enabling works will be the removal of cable trays and bulk items to enable installation of the new equipment.

7. *Power Management System (PMS):* another design decision was whether the independent PMS of the two assets needed to be integrated. Since the back-up generator will not run in parallel with the new cable supply during normal operation, it was decided not to integrate the systems. Any momentary synchronisation of the back-up generator would be done manually. Moreover, Platform A load will be seen as a single load on Platform B without the requirement for individual load shedding of individual Platform A loads. The only data required by Platform A for drilling activities is the Platform B spinning reserve value which will be sent from Platform B to Platform A, to inform drilling operator in support of decision to commence critical operations.

8. Protection, inter-trips, and interlocks: The Intelligent Electronic Device (IED) on the feeder / incomer from Platform B to Platform A will have the following protection schemes:

- Instantaneous Overcurrent(50)
- AC Time Overcurrent(51)
- Transformer Differential protection(87T)
- Restricted Earth Fault(64)
- Undervoltage protection(27)
- Directional Overcurrent(67)

The IEDs are connected via a fibre optic core within the PFOC, which will be used to inter-trip both IEDs in the case of an electrical fault. The IEDs are time synced using an IRIG-B signal sent via the fibre optic cable.

Mechanical interlocking between circuit breakers is installed to avoid closing the earthing switch whilst busbar or import cable are still energised and vice-versa.

9. *Switchboard modification*: The project is procuring a new circuit breaker for the incomer cubical on Platform A, as the existing circuit breaker is only rated for 630A whereas a 1250A is required for the interconnection. For Platform B, an existing spare cubicle will be modified to accommodate a transformer feeder. The equipment in these assets were supplied by different OEM / vendors and this creates some interface challenges. Lastly, the switchboard modifications will be executed whilst the platforms are operating.

10. Waste Heat Recovery Demand: As the project is decommissioning four out of the five existing generators, the WHRU can no longer supply the heating demand (circa 410kW) for the HVAC system on Platform A. Since, the HVAC is the only user of the wasted heat, the project is installing two redundant electric heaters to compensate for the loss of WHRU. These heaters will be thyristor controlled and supplied from the low voltage switchboard on Platform A.

III. CONCLUSION

Operators considering electrifying brownfield assets shall not only be clear what is driving the project, but also understand which modifications are required to the asset and other interfacing systems. Where the site being electrified is powered from an adjacent facility, operators shall consider the interface design between platforms, the management of different technology suppliers, the use of different specifications and finally the impact on operations that the modifications will cause.

When estimating the GHG impact of electrification projects, Operators shall consider short and long-term carbon intensity at the different modes of operations, for instance normal, future, and peak power. Generation, transmission, and distribution losses should also be carefully considered in the GHG estimation since they can influence the result significantly. Moreover, one should also quantity the emissions of other gases such as NOx and

SO_2 since reducing their emissions will have a positive impact on improving the air quality.

Once the gas emissions are understood, Operators should not underestimate the complexity of the modifications required for electrification on brownfield offshore assets. Existing emergency shutdown and hazardous area philosophies, heating medium and HVAC demand are some of the design aspects which will need to be considered during FEED. Generally, a multi-discipline team will be assembled to assess and identify all system which will be impacted by the electrification of the asset.

Finally, besides completing a fair and unbiased assessment of the GHG emissions of their facilities, Operators should also evaluate means to reduce waste and increase process and equipment efficiencies in line with their electrification projects.

IV. NOMENCLATURE

CB: Circuit Breaker
CDAS: Control and Data Acquisition System
EEMS: Environmental Emissions Monitoring System
EF: Emissions Factor
FEED: Front End Engineering Design
GHG: Green House Gas
GIS: Geographic Information System
HVAC: Heating, Ventilation and Air Conditioning
ICSS: Integrated Controls and Safety System
IED: Intelligent Electronic Device
IP: Ingress Protection
NER: Neutral Earthing Resistor
OEM: Original Equipment Manufacturer
PFOC: Power and Fibre Optic Cable
PIR: Pre-Insertion Resistor
PMS: Power Management System
WHRU: Waste Heat Recovery Unit

V. ACKNOWLEDGEMENT

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VI. REFERENCES

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VII. VITA

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