ELECTRIC POWER SYSTEM TOPOLOGY FOR HIGH CAPACITY ALL-ELECTRIC FPSO

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Abstract - In the recent years, there is a trend of increasing the oil production capacity of FPSOs. Due to the characteristics of some oil fields, there is a significant increase of associated gas and contaminants to be processed. The search for increased unit efficiency, lower OPEX and lower emissions (Green House Gases - GHG) has led companies to focus on conceiving All-Electric units, in which all dynamic equipment are driven by electric motors. These FPSOs are presenting a large increase in the electric power demand, resulting in increased generation capacity, and culminating in high power density units with more than 150 MW of power demand. This paper studies the technical challenges related to designing the electric power systems for these production units and presents alternative topologies in order to accomplish technical feasibility for the electric power system.

Index Terms — FPSO, Power System, All-Electric.

I. INTRODUCTION

The previous high capacity FPSO project developments have been conceived considering the Brazilian CONAMA nº 382/06 environmental resolution which indicated that that the electric generation of offshore stationary oil production units shall be limited to 100 MW of electric power generation demand. Therefore, former high capacity FPSOs have been designed with the use of gas turbines in order to drive important systems of the FPSO, such as gas injection compressors and CO2 compressors.

The search for reducing GHG emissions led to a change on the regulations through the resolution Conama/MMA nº 501 from 2021 which are now allowing companies to design offshore oil production units with larger electric power generation if the unit is of the all-electric type, which means that the unit is designed considering gas turbines only for electric power generation.

In this context, several studies were performed to determine the electric power demand of high capacity all-electric units to evaluate the impacts of increased electric power demand and of the significant increase on power generation capacity.

In a general point of view, the main impacts on the electric power system when comparing an all-electric unit [1]-[2] with the previous units are:

1. Larger electric power demand.
2. Larger quantity of high-power motors.
3. Increased power rating of high-power electric motors.
4. Increased difficulties on high-power motor starting.
5. Increased short-circuit levels in main switchgears.
6. Increased size and weight of the main switchgear.

This paper studies the possible electric power system topologies for high capacity all-electric FPSOs, in which all dynamic equipment are driven with electric motors [3]. The conducted studies are basically comprised of load balance, short-circuit studies and voltage-drop studies due to largest motors starting.

II. HIGH CAPACITY ALL-ELECTRIC FPSO ELECTRIC POWER DEMAND

The required brake power to drive equipment (bkW) for the highest demanding motors was determined by the process team which defined the premises and conducted simulations for the all-electric production plant design.

During the conceptual design it is common to have different process plant adjustments and, hence, changes in required brake power for each equipment along with the project development. Therefore short-circuit, motor starting and rated current evaluation analysis were conducted with motor power ratings which were valid at the moment in which studies were performed.

With the brake power for each load of the production plant available, the electric power demand was estimated for the studied production plant and the resulting demand was approximately 164 MW. As a reference, the main high-power motors power demand used for the short-circuit and voltage-drop at motor starting are presented in Table I.

One can notice that the development of a high capacity all-electric production unit implies in a significative increase in the power demand, being practically twice of the electric power demand of the latest FPSOs in operation in Brazil and approximately 60% increase in the power demand when compared to standard (non all-electric) high capacity FPSOs to operate in Brazil in the next years.

To supply power to all loads, it was foreseen, initially, a set of 5 x 25% turbine generators with power generation capacity of 43.4 MW each.

TABLE I
HIGH-POWER MOTORS RATED POWER

Description	P (MW)	Configuration
Main Gas Compressor Motor	19.0	3 x 50%
Vapor Recovery Unit Compressor Motor	7.1	2 x 100%
Booster Compressor	17.5	3 x 50%
Injection Compressor	11.0	3 x 50%
CO2 Compressor	16.0	2 x 100%

III. ELECTRIC POWER SYSTEM TOPOLOGY

FPSO electric power systems topology of the production units operating in Brazil have been traditionally conceived by using one main 13.8 kV switchgear comprised of 2 busbar sections interconnected by a tie circuit-breaker and a pyrotechnic fault current limiter to control short-circuit current levels to the ratings of the switchgear, which brings specific characteristics to power system operation [4]. Fig. 1 shows the typical topology for the latest projects under operation In Brazil.

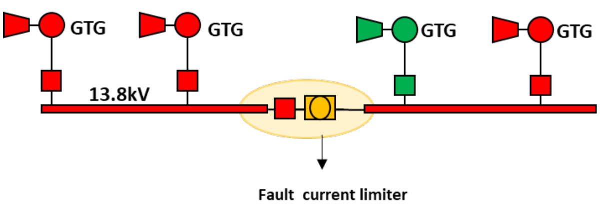

Fig. 1 Typical FPSO electric power system topology

Given the significative raise of electric power demand of the high capacity all-electric FPSO and its respective raise of the power generation capacity, electrical studies were performed to check if the typical topology was suitable for this new condition since it was expected a large increment of short-circuit current levels and rated current levels in the system, particularly at the 13.8 kV switchgear.

Besides the short-circuit current levels and the rated current levels, the starting of the largest motors shall be studied since there was an increment on the quantity of high-power motors and the rated power of the largest motors of the FPSO. Since the FPSO electric power system is typically an isolated system, the starting capacity of large motors is limited, and it is foreseen to have difficulties in starting these motors. There are some ways to mitigate this issue by specifying motors with lower starting current / rated current ratio, however there are also limits for this practice because of its effects on the starting torque of the motor.

In this context, as topology alternatives to deal with the issues presented above, one can mention the addition of more fault current limiters, the use of a synchronizing bus [5], or a hybrid solution. Figs. 2, 3 and 4 present the studied topologies being, respectively, typical linear topology with 2 fault current limiters, synchronizing bus in which each generator and group of loads is connected to a common busbar though fault current limiting reactors, and a hybrid solution considering a common busbar and pyrotechnic fault current limiters denominated as connection bus in this paper. The connection bus topology presented in Fig. 4 is, actually, a simplified version from the connection bus topology concept presented in Fig. 7 in order to provide the least impact when compared to the typical linear topology.

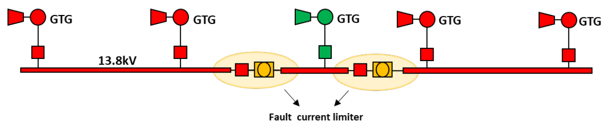

Fig. 2 Linear busbar with 2 fault current limiters

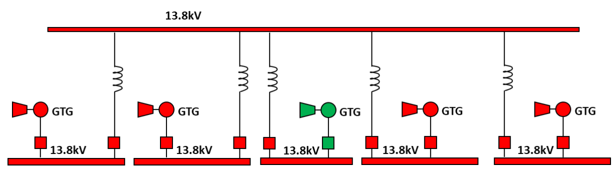

Fig. 3 Synchronizing bus

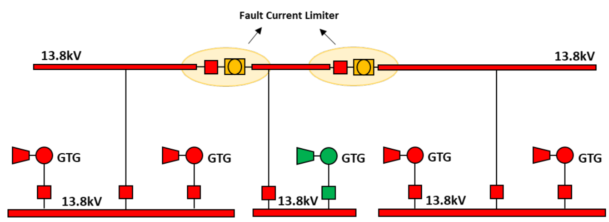

Fig. 4 Connection Bus

The linear topology presented in fig. 2 is directly derived from the topology typically used, in which from the topological point of view, without considering changes of number of generators or motors, the main difference is the additional switchgear columns for tie circuit-breaker and for the pyrotechnical fault current limiter, indicating a low impact in relation to the panels room arrangement and the overall weight of the electric distribution system of the unit.

The synchronizing bus topology presented in fig. 3 requires adding more equipment when compared to the topology with 2 pyrotechnic fault current limiters. The main additional equipment are the fault current limiting reactors which shall be added for each bus containing one generator, the common busbar, and the interconnection columns. One attention point for this topology is that it is expected to present negative impact on high-power motor starting, being necessary to evaluate whether the use of this topology is technically feasible or not due to the voltage-drop on the reactors. This topology is mostly common on onshore industrial plants which are usually connected to the utility. One positive factor of this topology is its scalability, in which additional generator / loads busbars can be included without reaching the withstanding limits of short-circuit currents.

Due to the significative raise on the electric power demand, the required rated current of equipment also tends to raise, which may lead to reaching the typical rated current values for commercially available switchgears. In this context, one can observe that the linear topology presents a larger potential of high current values in certain spots of the busbar. This is more evident if it is considered that one extremity of the busbar has more power generation and the other extremity has more high-power loads operating. In this scenario, the current flow will be higher in the middle section of the busbar, which is the only path for the current flow from one extremity to another in addition to the power generated and loads connected at the middle section. Hence, it shall be studied whether the current flow of the linear topology with 2 pyrotechnic fault current limiter is within the limits of the typical rated current levels for the high capacity all-electric FPSO.

The connection bus topology presented in fig. 4 is a potential alternative for the linear topology with 2 pyrotechnic fault current limiters. This topology creates a parallel path for the flow of current from busbar sections independently. Also, for the studied configuration, the only spot that current levels could exceed the rated current level is on the connections from each bus to the common bus. Hence, it is possible to measure and monitor current levels. Once any limit is reached, overcurrent protection could be triggered to avoid any damage to equipment.

This paper proposes the initial configuration of the connection bus topology with only one generator at each generation busbar extremity and the interconnection to the common busbar located at the center of the busbar. This way, loads and generation are distributed between each side of the busbar resulting in lower steady state current levels.

Both linear topology with 2 fault current limiters from fig. 2 and Bus Connection from fig. 4 present some challenges regarding short-circuit current flow and selectivity.

Since each single busbar have high short-circuit levels, already close to switchgear typical withstand limits, the first challenge is regarding the tripping value of the limiter. If the tripping value is near the operating current, unexpected tripping may occur during the FPSO operation. On the other hand, the tripping level shall be limited in order to avoid surpassing the switchgear withstand limits.

The second challenge is to provide reliable selectivity to the operation. When a short-circuit occurs, it is expected that the respective fault current limiter of the protected zone shall trip. According to [4], there might exist a “natural discrimination” of the short-circuit location and a selective tripping of the fault current limiter. For example, fig. 5 presents the connection bus with the fault current limiters FCL 1 and FCL 2 and three short-circuit locations, one at busbar A, one at busbar B, one at busbar C. If a short-circuit occurs at bus A (Fault A), it is expected that the short-circuit contributions flowing through FCL 1 will be higher than through FCL 2, hence the FCL1 could trip earlier and avoiding FCL 2 to trip. The same could be valid for bus C (Fault C). In case of a short-circuit occurring at Bus B (Fault B), both fault current limiters will trip. However, the selective tripping for short-circuits at bus A and bus C is not guaranteed, which could lead to a complete unexpected islanding of the system. Whenever there are no generators operating or not enough power to supply all loads in a particular bus, the fault current limiter tripping will lead to a complete power outage or a load shedding actuation in order to maintain stability, respectively.

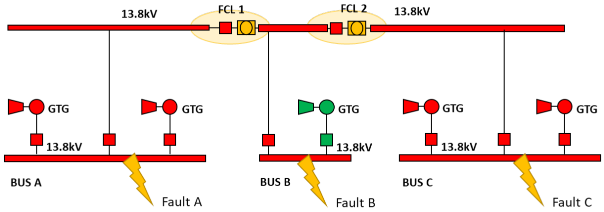

Fig. 5 Example of fault locations in the Connection Bus topology

To overcome these challenges, the topology may be improved by adding one fault current limiter at bus B, having one limiter dedicated to each busbar, defining three protected zones.

Additionally, to provide better tripping selectivity and better fault discrimination, there are fault current limiter solutions in which each generator may have three current transformers in the neutral connections of the generators to provide directional tripping to fault current limiters. In this case, the summation of the short-circuit currents passing through the limiter and through the generators can be used as a tripping criterion. The value can be set as the difference between the switchgear short-circuit withstand current and the loads and transformer contribution of the busbar where the short-circuit occurs. This tripping criterion can replace the challenging fixed tripping value criterion and avoid unexpected tripping when it is necessary to set low values for the fixed tripping value. This solution, however, increase the complexity and costs of the fault current limiter overall solution. Fig. 6 presents the solution.

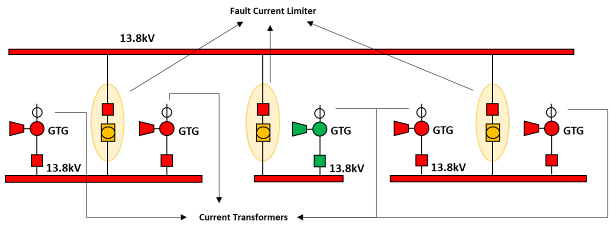

Fig. 6 Connection Bus topology with additional fault current limiter and current transformers at neutral connections of generators

The connection bus topology is also intended to be flexible and scalable. The pyrotechnic fault current limiters can be installed in each generation and loads busbar, and the connection busbar can be just a bus-duct instead of a switchgear. Additional busbars containing generation and loads can be added. If larger generators are considered, one can consider a single generator per busbar, each one with its own fault current limiter. Fig. 7 presents the considerations above. However, for this paper, the considered connection bus topology will be the one presented in fig. 4.

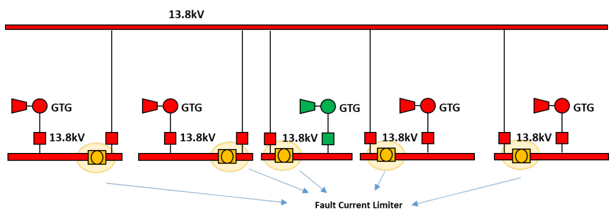

Fig. 7 Connection Bus with single generator per busbar

In order to evaluate the suitability of each topology for the high capacity all-electric FPSO studied in this paper, electrical studies results are presented in the next section.

IV. ELECTRICAL SYSTEM STUDIES RESULTS

This section presents the criteria adopted and the results obtained from the electrical system studies performed for the proposed high capacity all-electric FPSO.

A. Short-circuit Analysis

Due to the significant increase in the motor and generator power ratings, the resulting short-circuit current levels shall be assessed to verify whether the typical topology is adequate or which of the proposed alternatives are suitable for the proposed FPSO to allow the use of typical rated short-circuit withstand levels of commercial switchgear. As a criterion, the maximum short-circuit levels to be allowed for the main 13.8 kV switchgear are 50 kA / 130 kA_{peak}.

The worst-case scenarios were considered for the studies, which have the following characteristics:

1. All generators are operating.
2. The largest number of motors that may operate simultaneously.
3. Other voltage levels are operating under contingency (one feeder of the selective secondary is out of operation and all power is supplied by the other feeder with tie breaker closed).

Studies were conducted following the criteria from the standard IEC 60909 by using commercial digital simulation software.

Considering the possibility of using the typical linear busbar with only one pyrotechnic fault current limiter and with 3 generators at busbar section A and 2 generators at busbar section B, the resulting short-circuit current values are 77.2 kA / 218.3 kA_{peak} for busbar section A and 42.3 kA / 119.6 kA_{peak} for busbar section B. The 50 kA / 130 kA_{peak} considered rated values were already exceeded for busbar section A already considering the actuation of the fault current limiter.

For the linear topology with 2 pyrotechnic fault current limiters, the highest short-circuit current value among the busbar sections was 46.8 kA / 127.1 kA_{peak}, being within the expected rated values. It is suggested to consider the directional actuation of such limiters to allow selective actuation regarding the fault location. One concern that shall be observed is that once the pyrotechnic fault current limiter actuates, maintenance is required for the replacement of blown parts. Hence, particular attention shall be given to the availability of spare parts to avoid plant downtime or production restrictions.

Regarding the synchronizing bus, considering a balanced load distribution among the 5 buses of the 13.8 kV switchgear containing 1 generator each, the highest short-circuit current level assessed was 45 kA / 122.6 kA_{peak} by using reactors with impedance of 10% (generators rated values as the base for the value).

The advantage of such topology is the possibility of controlling short-circuit levels by changing the impedance value of reactors in case there is a need to adjust during design phases, besides the flexibility of adding more generators in new buses still maintaining the limit of 50 kA / 130 kA_{peak}. The disadvantage of this topology is the necessary attention to an eventual short-circuit at the common bus and the need of 5 reactors in the electrical module, increasing footprint and weight, which are two of the major constraints in a FPSO project development.

In relation to the connection bus topology, it was considered unnecessary to repeat the short-circuit current analysis since, besides visually different, the short-circuit characteristics tend to be the same from the linear topology with 2 pyrotechnic fault current limiters.

Table II summarizes the short-circuit current analysis indicating whether the proposed topology is technically feasible or not regarding the short-circuit values obtained.

TABLE II
Short-circuit analysis summary

Topology	Results	Feasibility
Typical (one pyrotechnic fault current limiter)	77,2 kA / 218,3 kA_{peak}	Not feasible
Two pyrotechnic fault current limiters (Linear and connection bus)	46,8 kA / 127,1 kA_{peak}	Feasible
Synchronizing Bus	45 kA / 122,6 kA_{peak}	Feasible

B. Motor Starting Analysis

After assessing short-circuit levels, it is necessary to evaluate the feasibility of the proposed topologies regarding the starting of the high-power motors of the FPSO.

The criteria used for the design is that during the direct on line starting of the induction motor, the maximum allowed voltage drop in the 13.8 kV switchgear (which feeds high-power motors) is 15% and the voltage drop at the most affected panel is less than 20 %. For these simulations, it was used the static simulation for motor starting.

For the motors to be started, it was considered a motor design with the starting current / rated current ratio of 4. Besides that, it was considered a starting power factor of 0.15. The conventional topology will no longer be studied in this paper since it is not technically feasible because of short-circuit analysis.

Simulations were conducted for the linear topology with 2 pyrotechnic limiters considering the starting of motors with 2 GTGs (gas turbine generators), alternating the other voltage levels in normal and contingency condition (secondary selective fed by both sources or by only one source and tie breaker closed). It was also studied cases with 3 GTGs. All cases were simulated considering a voltage boost at the 13.8 kV (raising the voltage reference of generators) of 6% with generation loading of 65%. Table III and Table IV present the summary of cases and results, respectively.

TABLE III
Motor starting cases for the linear topology with 2 pyrotechnic limiters

Case	Description
1	1st Largest motor started by 2 GTGs / normal condition
2	1st Largest motor started by 2 GTGs / contingency condition
3	1st Largest motor started by 3 GTGs / contingency condition
4	2nd Largest motor started by 2 GTGs / contingency condition
5	3rd Largest motor started by 2 GTGs / contingency condition
6	4th Largest motor started by 2 GTGs / contingency condition

TABLE IV
Motor starting analysis summary for the linear topology with 2 pyrotechnic limiters

Case	Main 13.8 kV switchgear		Most affected panel
	BUS	Volt. drop [%]	Volt. drop [%]
1	B	13.9	19.8
2	B	14.5	26.4
3	B	8.0	17.7
4	B	13.1	24.5
5	B	11.6	22.5
6	A	6.6	15.9

Given the simulation results for the linear topology with 2 pyrotechnic limiters, one can assess that it is possible to start the largest motor of the FPSO with 2 generators when the system is operating without any contingency on the other voltage levels. In case there is any contingency on transformers requiring operating in contingency, a third GTG is required for starting the motor without impairing the electrical system. This premise is, hence, considered acceptable for this design.

During the further stages of the FPSO design, if such high-power motors are still required or if any power increment is needed, alternatives for starting motors may be considered such as variable speed drives to reduce the impact of motor starting on the system.

The motor starting analysis for the synchronizing bus topology presents a higher complexity regarding the direct on line start of motors due to the voltage drop on the current limiting reactors. To evaluate the limitations of the synchronizing bus topology, the cases presented in Table V were studied and results are presented in Table VI. Generation loading is set at 65% and voltage boost at 6%, with exception of cases 2 and 8.

One can assess that the use of the synchronizing bus topology presents a good performance regarding short-circuit levels, however it does not present technical feasibility regarding direct on line motor starting of high-power induction motors.

If VSDs are considered for driving such motors (or only for starting the motors, i.e., pony VSD), the voltage drop stays within the limits and render the synchronizing bus topology technically feasible. However, due to weight and footprint constraints for high capacity all-electric FPSOs, this paper considers that it is not the most adequate solution for this project.

TABLE V
Motor starting cases for the synchronizing bus topology

Case	Description
1	1st Largest motor started by 2 GTGs / normal condition / no generation running at motor busbar
2	1st Largest motor started by a VSD with 2 GTGs / contingency condition / no generation running at motor busbar
3	2nd Largest motor started by 2 GTGs / normal condition / no generation running at motor busbar
4	3rd Largest motor started by 2 GTGs / normal condition / no generation running at motor busbar
5	4th Largest motor started by 2 GTGs / normal condition / no generation running at motor busbar
6	4th Largest motor started by 2 GTGs / contingency condition / no generation running at motor busbar
7	1st Largest motor started by 2 GTGs / contingency condition / with 1 generator running at motor busbar
8	1st Largest motor started by 2 GTGs / normal condition / with 1 generator running at motor busbar

TABLE VI
Motor starting analysis summary for the synchronizing bus topology

Caso	Main 13.8 kV switchgear		Most Affected Panel
	BUS	Volt. drop [%]	Volt. drop [%]
1	B	30.5	33.7
2	B	7.8	13.4
3	D	28.7	34.6
4	D	26.6	32.1
5	D	18.9	22.8
6	D	21.9	37.6
7	A	17.9	29.1
8	A	17.8	24.1

Regarding the connection bus topology, besides visually different from the linear topology, it was considered unnecessary to perform the analysis since the electrical characteristics tend to be the same between the topologies for this specific analysis.

For further studies, the synchronizing bus will be disregarded for this work since it does not allow direct on line starting of high-power motors for this project.

C. Steady State Current Distribution Analysis

As mentioned previously in this work, the typical electric power system topology shall be reassessed to comply with rated levels of electric equipment due to the increment on the demanded load, quantity of high-power motors and generation capacity.

Additionally, with such increment of the demanded load, the steady state current distributed over the switchgear equipment also tend to raise significantly. Since the demanded load can reach values of 160% of the non all-electric high capacity unit, it is necessary to evaluate whether the typical rated current of switchgear equipment of 4,000 A is exceeded or not.

In this context, it is necessary to evaluate the performance of the linear topology with 2 pyrotechnic limiters and the connection bus topology to assess if the current distribution is within the typical rated values of switchgear equipment for the high capacity all-electric FPSO.

To be able to perform the current distribution analysis, the loads and generators were distributed along the busbars of the switchgear for the linear topology and between the extremities of each generation busbars for the connection bus topology.

Therefore, for the linear topology with 2 pyrotechnic limiters, the total load for bus A was divided in 3 groups of equal value (LA1, LA2 and LA3), total load for bus B was divided in 2 groups of equal value (LB1 and LB2) and total load for bus C was divided in 3 groups of equal value (LC1, LC2 and LC3). The current distribution is calculated in each segment between load groups or between a load group and a generator (IA1, IA2, IA3, IA4, IB2, IB3, IC1, IC2, IC3, IC4 and IC5). Fig. 8 presents the proposed configuration for the analysis.

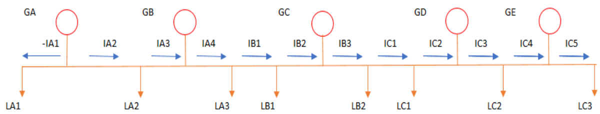

Fig. 8 Current distribution configuration for the linear topology with 2 pyrotechnic fault current limiters

For the connection bus topology, the total loads for each generation busbar were condensed at the center of each busbar which it is connected to (LA, LB and LC). Each generator is at one extremity of the respective busbar. The current is calculated from each generator to the load and from the connections to the common busbar also in the center of the busbar (IX1, IX2 and1 IX3). Fig. 9 presents the proposed configuration for the analysis.

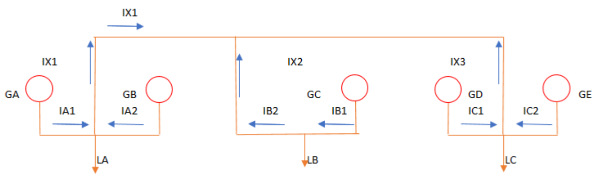

Fig. 9 Current distribution configuration for the connection bus topology

Simulations were performed considering a series of scenarios in which the status of each group of redundant equipment are turned on and off (i.e., 2 x 100%, 3 x 50%, 4 x 33%, 5 x 25%) in order to find the largest quantity of possible plant configurations during the operation phase of the unit. Simulations considered also 4, 3 and 2 generators in operation with respective on/off status switched between simulations.

Since, through spot manual simulations, it could be verified some scenarios in which currents above 4,000 A were found in segments of the busbar that are not monitored by any device, it was developed an algorithm in Python capable of estimating a large quantity of scenarios in which the current in any segment exceeds the value of 4,000 A in the main 13.8 kV switchgear.

For each simulation, the algorithm randomly alternates the on/off status of the redundant group of equipment respecting the redundancy criteria of each group to achieve all operational conditions possible. The algorithm also has the flexibility of limiting the redundancy criteria for lower demand and generation scenarios (i.e., 1 x 50%, 2 x 33%, etc.). A large quantity of iterations was performed to try to exhaust all possible scenarios statistically. Hence, each case was iterated 10 million times, being recorded each unique case and whether this case exceeds 4,000 A or not. The results from the algorithm can be found in Table VII.

TABLE VII
Steady State Current Distribution Analysis Summary

Case	Scenarios exceeding 4,000 A				Total number of Scenarios
	Linear Topology		Connection Bus Topology		
	Total	%	Total	%	
2 GTGs / 2 Transformers in contingency	0	0.000	0	0.000	6.480
2 GTGs / 3 Transformers in contingency	80	0.617	80	0.617	12.960
2 GTGs / All Transformers in contingency	292	0.563	192	0.370	51.840
3 GTGs / Normal condition	6	0.556	0	0.000	1.080
3 GTGs / All Transformers in contingency	744	2.153	144	0.417	34.560
4 GTGs / 3 Transformers in contingency	26	0.008	0	0.000	311.040
4 GTGs / 4 Transformers in contingency	48	0.008	0	0.000	622.080
4 GTGs / All Transformers in contingency	294	0.024	84	0.007	1.243.752
Total	1.490	0.065	500	0.022	2.283.792

From Table VII, it is possible to assess that there are 1490 total scenarios with steady state current values exceeding 4,000 A for the linear topology with 2 pyrotechnic fault current limiters. Despite of being a low percentage of the total number of unique scenarios for the studied cases, some of these scenarios can occur in segments of the busbar without any monitoring, leading to a failure of the switchgear and associated operational losses.

The proposed connection bus topology with generators at extremity of each generation busbar presented 500 scenarios exceeding 4,000 A. These values occurred in the connection points to the common busbar. Besides a smaller quantity of scenarios when compared to the linear topology, the interconnection feeders to the common busbar can be monitored and protected by overcurrent relays. Therefore, when the limit is about to be reached, an alarm can be issued to the operation team to try to act on the plant configuration to avoid tripping the feeders. In last case, the overcurrent trip will protect the equipment and avoid damages.

V. CONCLUSIONS

This work presented the main challenges of conceiving a high capacity all-electric FPSO, proposing possible topologies to be considered in the design and evaluating their advantages, disadvantages, and limitations for this specific unit.

As discussed in the Item IV of this paper, the connection bus topology proposed and presented in Fig. 4 presented more advantages and full technical feasibility when compared to the linear busbar with 2 fault current limiters and to the synchronizing bus topology. Hence, it was considered the most adequate topology for this specific production unit since it is capable of controlling short-circuit levels to within the typical rated values of 50 kA / 130 kA_{peak}, capable of direct on line starting of high-power motors and presenting lower quantity of cases exceeding 4,000 A of steady state current on segments of the busbar, presenting larger availability than the linear topology from Fig. 2 and the possibility of monitoring and protecting when an overcurrent occurs. It is expected adjustments in the topology during the various design phases, however the connection bus is flexible enough to accommodate such adjustments, i.e., using busducts at common busbar, addition of pyrotechnic fault current limiters, installation of current transformers at neutral connections of generators and different generator positions, according to the necessity of the unit. Therefore, this paper indicates the bus connection topology for the high capacity all-electric FPSO studied.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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