Evaluating Voltage Drop Snapshot and Time Motor Starting Study Methodologies – An Offshore Platform Case Study

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***Abstract*-- This paper presents a comparison between static (*Snapshot*) and dynamic (*Time Study*) motor starting study methodologies in terms of buses voltage drop and power flow, using a case study of an offshore platform. For this purpose, the Power Tools for Windows (PTW) software and the real-time digital simulator (RTDS) were used to performing the analysis of the *Snapshot* and *Time-Domain* methodologies, respectively. The investigation has focused on differences in the parameter requirements necessary for each methodology, with a special application in a complex isolated system, such as the case of an offshore platform typical composed of synchronous generators and the large induction motors. The advantages and disadvantages of each methodology will be analyzed according to the strict operating and handling requirements of an actual offshore platform. Simulation results demonstrated that a motor starting study in the time domain contributes better information than the static one, even more for this type of particular system. This work reveals the need that selection criterias between the two methodologies must be defined in the IEEE 3002.7-2018 standard and for isolated systems is highly recommended to perform an analysis in the time domain.**

***Keywords*: Motor starting, Offshore platform, PTW, RTDS.**

I. Introduction

INDUSTRIAL and commercial electrical systems have grown in capacity and automation in recent decades, this being an important economic contribution that must be guaranteed. Major industries have increasingly demanding requirements for profitability, reliability, power quality, and operational safety. The impact on voltage when starting large high-power induction machines is critical to the reliability and operation of any industry [1].

Manufacturing plants have the induction motor as the main electrical equipment, taking into account the quantity and power. The mining excavation industry has carried out studies regarding the steady state and dynamic behavior of the electric induction motor in order to have the best performance in its operations [2]. The motor starting process has been investigated for decades specifically considering the voltage drop phenomenon [3].

A motor starting analysis includes evaluating the motor starting current and voltage drop. Each motor starting study has an appropriate use and its correct selection is an important step in the solution process. Motor starting studies must determine the variation of voltage as a function of time, reduction of the torque curve and the dynamic analysis of the motor. The study of these effects during the motor start-up will depend on the methodology available in the software to be used, the models used and the information available from the system.

Various mathematical methods can be used to calculate the voltage drop. A typical motor starting analysis methodology is *The Voltage Drop Snapshot*, which aims to evaluate static or instantaneous values of voltage drops in the system for the worst expected scenario. The advantage of this method is that the generator dynamics can be ignored due to the presence of a strong power source and that it can be performed even when dynamic model information, inertia, slip characteristic, and load torque are not available. In turn, given that a dynamic model is not used, one of the disadvantages is that there is not possible to determine the starting time of motors or analyze the impedance variations during the transient. This type of methodology, although it is an approximation, is usually sufficient for most applications.

The Speed – Torque and Acceleration – Time Study methodology performs a more in-depth analysis of the phenomena during motor start-up. This methodology evaluates dynamic information on motor torque, load torque, slip, power factor, currents, and voltages during starting time. It uses models and simulations over time and allows the dynamic analysis of electrical and mechanical phenomena of the system elements (generator, motor and load), thus providing a more precise evaluation of results. The referred methodology needs a larger set of information that must be used for specific applications considering motor start analysis, which may not always be available.

Throughout history the aforementioned methodologies have been developed and studied with the aim of faithfully representing an electrical power system. Studies have determined that all static induction motor models can be divided into two main categories, constant active power and constant rotor slip [4], and that, from a used dynamic model, it is possible to study the variation of voltage, of resistant pair, by some determined laws [5]. In this context, the benefit of choosing a correct motor starting study methodology

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according to the application is high and will avoid wasting money in decision making. For this reason, this paper presents a comparative analysis between motor starting methodologies with a special application in a platform system, whose configuration has interesting characteristics to be analyzed. For this purpose, the Power Tools for Windows (PTW) software and the Real-Time Digital Simulator (RTDS) are used to analyze the two motor starting study methodologies and evaluate their behavior in an offshore platform case study. This analysis is developed within the limits of the applicable standard IEEE std 3002.7-2018 [6], knowing that the load of this system has more than 14% of the total generation, so it is recommended to carry out a time-domine analysis.

II. Motor Starting Study

Modern electrical motors are increasing their capacity where some demand a large amount of installed power. Starting these motors can cause serious disturbances to the motor or any adjacent load. Poor motor starting can cause problems such as voltage drop across the system buses or service interruptions. Depending on the combination of the power supply capacity and the starting motor power, voltage reductions across the buses can be such that they are considered a disturbance in the electrical power quality, called a momentary voltage drop (MVD). MVD can cause malfunctions in the electrical system, due to failures or burns of sensitive devices, as well as anomalies in the production process [7].

A motor starting study allows determining voltages, currents, starting times and power flows, taking special care that the generation and voltage drop are adequate, ensuring that the acceleration times are correct and there are no interruptions to any system load. For an isolated system with its own generation, a motor starting study is important when the nominal power of the motor exceeds 10% to 15% of the total available generation capacity [6]. The IEEE std 3002.7-2018 does not mention what kind of methodology to use in this particular case. However, it suggests using a dynamic study in cases where transitory effects are considered important. Therefore, it is suggested that the standard should define a percentage to select a type of study in which synchronous generation is considered.

Reducing of voltage at the motor terminals causes a reduction in the starting torque and, consequently, the acceleration time. High currents in the motor combined with a longer starting time cause excessive temperatures leading to thermal damage and shortened motor life. Therefore, it must be ensured that the voltage drops during motor start-up are within acceptable limits. Depending on the application, voltage drops of 5% to 20% of the nominal voltage of the motor or bus are accepted [6]. Table I presents the allowable voltage values that must be observed at different points of the electrical system.

TABLE I
Critical Voltage Levels When Starting Motor – IEEE std3002.7-2018[6]

Voltage drop location or problem	**Minimum allowable voltage (% rated)**
System Voltage	95% to 105%
At terminals of starting motor	80%
All terminals of other motors that must reaccelerate	70%
AC contactor pick-up (by standard)	85%
DC contactor pick-up (by standard)	80%
Contactor hold-in (average of those in use)	60% to 70%
Solid-state control devices	90%

An important point to consider for a motor starting study is the generation source. The representation of the generator model can be very useful depending on the type of study of starting motors and electrical systems to be used. The transient behavior of the generator and the response of the exciter/regulator under motor-starting conditions can be accurately modeled, providing meaningful results and conclusions. The type of voltage regulator system can dramatically influence motor starting, as illustrated in Fig. 1 [6].

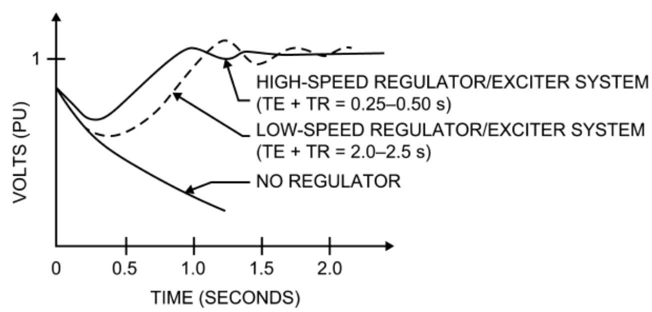

Fig. 1. Typical generator terminal voltage characteristics for various exciter / regulator system [6]

III. Motor Start Study Methodologies

The purpose of motor start analysis is to know if the motor can start successfully under operating conditions of the system and if it will seriously impede the normal operation of other loads in the system, which is why several studies have used these methodologies for years. Studies such as power flow and long-term voltage stability are also developed by this type of methodologies.

Static electrical motor models have been increasingly developed to correctly represent the behavior of the motor in all its operating regions. A case study of paper [8], uses the *Snapshot* methodology by means of a static motor starting simulation, in which it simulates a locked rotor state to determine the worst impact in normal operations. Another case study like [4], presents the use of the induction motor model with constant active power for the stable operating region and with constant rotor slip (s=1) for the stagnation region, behaving as a load with constant impedance characteristic.

For a study of the dynamic starting state of induction motors, where their characteristics are directly related to voltage stability [9], the starting current, torque magnitude, starting time, current variation curves, speed, energy consumed must be considered. According to paper [5], a *Time Study* was carried out where it shows the first starting moments of a low-power motor with and without load, showing oscillations in torque and in the speed curve, as well as a time higher starting compared to no-load starting. In the event of a disturbance, it is stated that induction motors represent the largest portion of load that exhibits a typical dynamic behavior [10]. Developing simulation models of an electrical system becomes a great challenge due to its behavioral nature and the complexity of obtaining information on its parameters. The representation of these models in computer programs demands a great computational effort and the need to obtain more data.

IV. DESCRIPTION OF THE ELECTRICAL SYSTEM

The typically generation system of an off-shore platform is made up of 4 synchronous turbogenerators of 25 MW, 13.8 kV, 60 Hz, of which three synchronous generators are working permanently and one generator is in stand-by mode connected to main bus A and B.

All the buses of the platform's electrical system are divided into two sections “Panel A” and “Panel B” by means of a “Tie” interconnection switch. Fig. 2 shows a simplified one-line diagram of the electrical system platform. Under normal operating conditions, the 13.8 kV panel breaker remains closed (C), while the other breakers remain open (O). Thus, according to the state of the circuit breaker, two connection terminologies are defined on the platform:

• Normal Operation: operation topology in which the MCC (Motor Control Center) or LDC (Load Distribution Center) operates with the two input breakers to each bus closed and the interconnection breaker “Tie” open.

• Contingency operation: topology in which the MCC or LDC panel operates with only one input breaker to each bus closed and the interconnection breaker “Tie” closed.

The distribution system includes most of the electrical system of a platform and is made up of several panels installed at voltage levels of 13.8 kV, 4.16 kV, 690 V and 480 V. The following main motors and transformers are connected at 13.8 kV panel:

- 8 gas compressor motors (11 MW);
- 2 water injection pump motors (5.7 MW);
- 1 vapor recovery unit compressor - VRU (3.4 MW);
- 1 well service pump (1.23 MW);
- 2 sulfate removal unit booster pump motors (1.135 MW);
- 4.16 kV, 690 V and 480 V transformers for powering the panels.

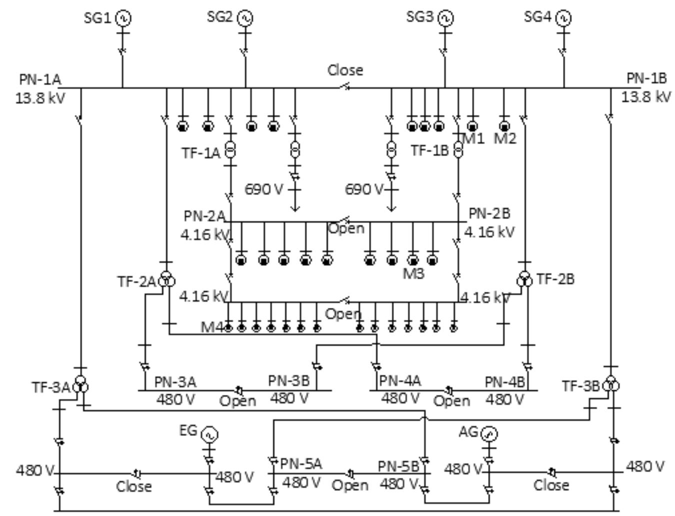

Fig. 2. Offshore platform electrical system topology – Normal Operation

One of the 480V panels can be powered by the three-winding transformer, the emergency generator or the feedback cables, this panel is responsible for supplying power to essential loads and the UPS system. Below is a list of main bus loads representing the normal operating status of the platform.

- 4 main compressors of 11MW in operation and 2 in "stand by";
- 1 gas injection compressor of 11MW in operation and 1 in "stand by";
- 2 main water injection pumps of 5.7 MW in operation;
- 2 booster pumps from the 1.135 MW sulfate removal unit;
- 1 VRU compressor of 3.4 MW in operation;
- 1 well service pump in operation (1.2 MW).

A high-power off-shore platform needs an analysis and technical-economic feasibility study to be implemented. In this context, generators and their excitation controls play an important role in the reactive demand needed during the start-up of the platform motors. Likewise, the importance of the applicable motor starting criteria, in this case, all motors of great magnitude of power and those evaluated here have a direct starting type.

V. DEFINITION OF THE STUDY APPROACH

A. General Information

Various load models are used to accurately represent the characteristics of real loads. The various types of load and the variability of time mean that there is no absolutely accurate load modeling. According to [11], the four most important components in a power system are the generators and their excitation and speed control system, and the load.

For the static load model, a voltage-dependent model is commonly used, such as constant power, constant current, constant impedance, or a model composed of part of each of these types (ZIP model). PTW is software that simulates with static models and examines the effect of instantaneous voltage drop during motor starting. Therefore, the electrical system of the offshore platform will be implemented in PTW to carry out the scenario 1 of analysis and study of voltage drop in motor starting based on the *Snaphot* methodology.

Modern electrical power systems consist of complex nonlinear dynamic systems. The analysis of these systems specifically on the reliability and precision of the results has a strong relationship with computational simulation techniques [11]. For a dynamic behavior analysis, a detailed representation of the electrical system model is necessary, especially of the generation sources and induction motors. This type of study allows a more accurate analysis of the voltage drop situation. Therefore, the electrical system of the offshore platform will be modeled in the RTDS, under the same conditions of scenario 1, to perform scenario 2 of voltage drop analysis at motor starting based on the *Time Study* methodology. In addition, scenario 3 of analysis will be carried out in which the synchronous generators of the offshore platform will be incorporated in order to obtain the dynamic behavior of the voltage during the sub-transient and transient period of the curve.

One of the important operating and maneuvering conditions of the offshore platform is that the voltage on the main bus be adjusted to 1.03 pu in the pre-start of the 13.8 kV motors, the same condition that will be used in the three analysis scenarios to be carried out.

B. Model Used – Snapshot

The PTW software is used to represent motor starts and obtain bus voltage drops based on the *Snapshot* methodology using the load flow study module. The electrical model system of platform used is presented in Fig 2. The most significant loads are on the 13.8 kV bus, as is the generation system.

The best way to represent synchronous generators is by considering them as a swing bar “SB”, because PTW uses a model composed of an ideal voltage source in series with a certain impedance for each one of them. For this, the rms values of the internal voltage of the machine and its respective phase angle must be adjusted. The value of the serie impedance can be obtained from the resistance of the windings and the reactances of the direct axis in the subtransient (Xd') or transient (Xd”) condition. Table II presents the active and reactive power flow (PF) values of the synchronous generators in the normal operation scenario obtained through the model as Swing bar “SB” through Xd' and Xd”, the modulus and angle values of Internal voltage phase (Vg) of each generator are also displayed.

The internal voltages of the generators should be a little higher than 10% of the nominal voltage so that the voltage in the main bus is close to 13.8 kV. This is necessary, since there is a voltage drop in the internal impedance in the three generators due to the circulation of load currents demanded by the platform. It can be verified that the modulus and angle values of the internal voltages of each generator are lower when Xd” is used in the simulation, confirming that there is less internal drop in the machines when Xd” is used".

TABLE II
COMPARISON OF POWER FLOW, CONSIDERING XD’ AND XD”

		UNIT	GS1	GS2	GS3
Xd'	PF	MVA	24.3	24.4	24.3
		MW	21.5	21.6	21.5
		Mvar	11.4	11.4	11.3
	VG MOD	pu	1.103	1.103	1.102
	VG ANGLE	°	8.66	8.69	8.66
Xd”	PF	MVA	24.4	24.5	24.1
		MW	21.5	21.7	21.3
		Mvar	11.6	11.4	11.2
	VG MOD	pu	1.071	1.070	1.069
	VG ANGLE	°	6.22	6.30	6.19

The execution parameters of the power flow can be seen in Fig. 3, in which the model of the generators and the internal impedance considered are highlighted. As suggested by the IEEE std3002.7-2018 standard, the direct axis transient reactance (Xd') was selected to compose the representation impedance of the oscillating buses of synchronous generators considering that there are higher internal voltage drops in synchronous generators.

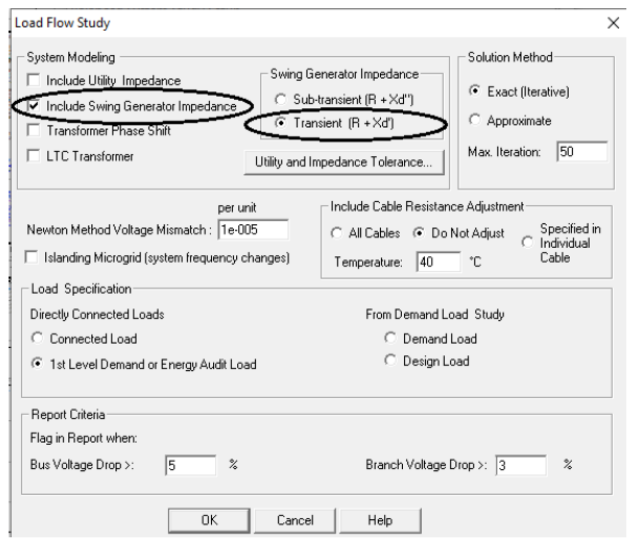

Fig. 3. Load flow calculation parameters in PTW

The motor parameters entered in the PTW to perform a Snapshot start are presented in Fig. 4, where it was indicated that the load flow uses the RLA/FLA contribution and the starting power factor to calculate an equivalent starting current. This model used a constant impedance to better represent the starting characteristics of the motor.

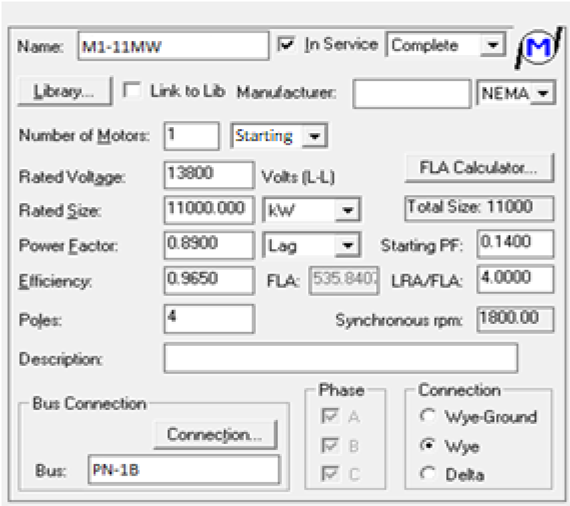

Fig. 4. Gas compressor motor parameters (11MW) – PTW

C. Model Used – Time Study

RTDS is a set of hardware and software exclusively for simulated studies of transient electromagnetic phenomena in real time. For the modeling effect of induction motor loads, RTDS is a very important tool to know the behavior of the motor and specifically in its starting process. One of the characteristics of this dynamic motor starting model is that the equivalent circuit of the motor is used to simulate the behavior in all its stages. The parameters of a motor are calculated from performance tests such as no-load and locked rotor tests that are regulated by international standards. However, this information is not always available to the final user or it is not correct. There are other alternatives that are evaluated to estimate the equivalent circuit parameters based on the motor information provided by the manufacturer. This is the case of [12], which presents an iterative method for estimating these parameters using only the motor nameplate data.

At the time of conducting the study in RTDS, it was detected that the parameters provided by the datasheet did not respond adequately. The datasheet presents two different parameters one for full load and one for locked rotor condition. However, the model in RTDS requires a unique set of parameters for both conditions. Therefore, this section presents a parameter estimation resource where an algorithm was implemented to obtain the optimized equivalent circuit parameters and introduce them into the motor model in RTDS. The motor data that was used as objective function to the optimization algorithm implemented are: nominal voltage and power, efficiency, starting power factor, torque curve characteristics, and nominal speed. Table III shows the values of the induction motor parameters provided by the data sheet and the results obtained from the estimation and optimization, the latter were used for the simulation in the RTDS as shown in Fig. 5.

TABLE III
PARAMETERS OF INDUCTION MOTOR (11MW) IN PU

	Datasheet		
Parameters	**Full load**	**Starting**	**Optimized**
rs	0.006188	0.012713	0.0273774
Xs	0.162042	0.162042	0.1361842
rr	0.00787	0.023072	0.0079613
Xr	0.159082	0.101705	0.1137893
Xm	6.861059	8.260176	5.1790769

For the simulation in RTDS, the optimized information of the parameters of all the motors of the system was used. Unlike PTW, RTDS allows starting maneuvers to be carried out in real time during the simulation and obtaining the various information required from the system.

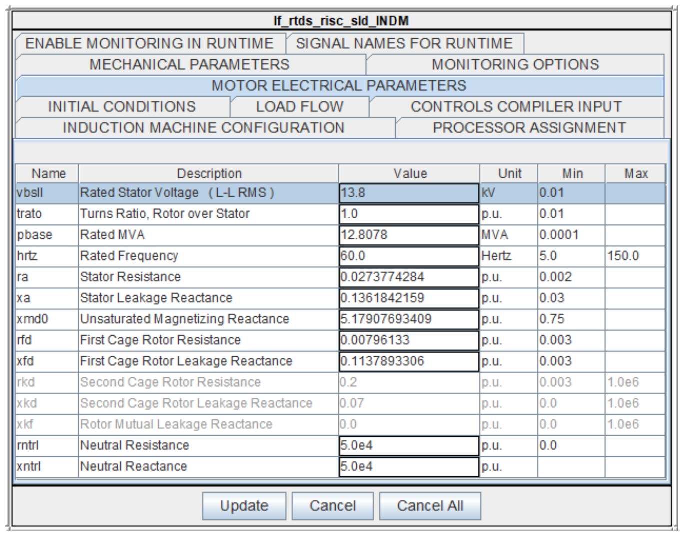

Fig. 5. Gas compressor motor parameters (11MW) – RTDS

1. Scenerio 2

In this analysis an ideal source was used in series with an impedance adjusting the internal voltage value and its respective phase angle in such a way as to ensure the pre-start voltage in the main bus of the system in accordance with the regulations platform operating and maneuvering.

2. Scenerio 3

For this analysis, a more complete model of the generation system is implemented, which includes the Synchronous Generation block, the multi-mass block that represents the inertia of the turbine, reducer and couplings. In addition to the power equipment, the speed/frequency control meshes and the excitation system are modeled.

According to the information from the platform, the excitation system follows the IEEE AC5A design used for brushless systems illustrated in Fig. 6. While the speed control follows the Woodward controller layout illustrated in Fig. 7.

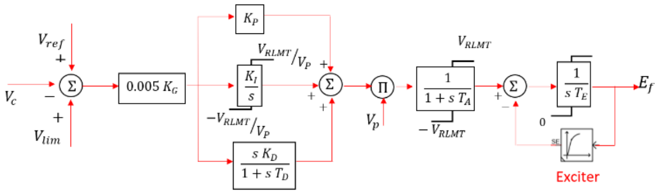

Fig. 6. Main control block diagram of the platform´s Voltage Regulator

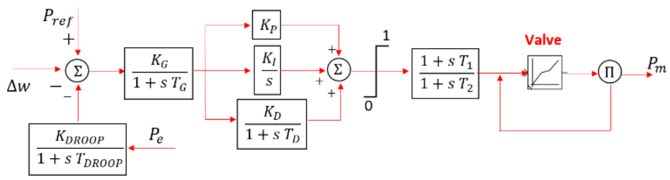

Fig. 7. Speed Governor block diagram

VI. RESULTS (PERFORMANCE EVALUATION)

Table IV shows the results of scenario 1 of voltage drop analysis scenario obtained using the *Snapshot* methodology. The motors with the highest power (11MW) are those that cause the greatest voltage drop in the own and continuous buses of each motor due to the high demand for reactive power during start-up. In PN-2A bus it can be observed that the worst values obtained are 13.28% and 13.29% when the M1-11MW and M2-11MW motor start, respectively.

TABLE IV
DROP VOLTAGE IN % - PTW (SCENARIO 1)

	MOTOR		M1-11MW	M2-11MW	M3-960KW	M4-740KVA
	BUS		PN-1B	PN-1B	PN-2B	PN-3A
	BUS	Nominal Voltage [kV]				
1	PN-1A	13.8	10.08	10.09	2.05	-0.09
2	PN-1B	13.8	10.08	10.09	2.05	-0.09
3	PN-2A	4.16	13.28	13.29	4.94	2.54
4	PN-2B	4.16	12.33	12.33	9.34	1.90
5	PN-3A	0.48	12.27	12.27	4.03	1.85
6	PN-3B	0.48	12.77	12.77	4.94	2.87
7	PN-4A	0.48	13.04	13.04	4.73	2.53
8	PN-4B	0.48	11.72	11.73	3.59	1.43
9	PN-5A	0.48	10.30	10.31	1.84	-0.41
10	PN-5B	0.48	9.81	9.82	1.39	-0.81

Table V shows the voltage drop analysis scenario 2 results obtained using *The speed – Torque and acceleration – Time Study* methodology through RTDS. It is observed that the same phenomenon occurs in scenario 1 of the *Snapshot* methodology, the motors with the highest power are those that cause the worst scenarios. The PN-3B bus has the highest voltage drops of 13.42% and 13.46% when the M1-11MW and M2-11MW motor start, respectively.

The simulation results obtained by RTDS and RSCAD software significantly demonstrate what happens to the motor throughout the starting process. Fig. 8 shows the behavior of the active and reactive powers, as well as the power factor and electromagnetic torque of the 11MW motor. The active and reactive power registered when starting the motor were 5.86 MW and 38.6 Mvar respectively, stabilizing in the operating area with the values of 6.47 MW and 3.16 Mvar respectively. It can be seen that the initial power factor is 0.149 stabilizing at 0.898 at the end of the starting process.

TABLE V
DROP VOLTAGE IN % - RTDS (SCENARIO 2)

	MOTOR		M1-11MW	M2-11MW	M3-960KW	M4-740KVA
	BUS		PN-1B	PN-1B	PN-2B	PN-3A
	BUS	Nominal Voltage [kV]				
1	PN-1A	13.8	9.41	9.44	1.62	1.08
2	PN-1B	13.8	10.04	10.07	1.74	1.03
3	PN-2A	4.16	12.20	12.24	4.46	6.85
4	PN-2B	4.16	12.13	12.16	8.22	3.10
5	PN-3A	0.48	11.98	12.02	4.08	3.54
6	PN-3B	0.48	13.42	13.46	4.79	4.10
7	PN-4A	0.48	12.25	12.29	4.33	3.77
8	PN-4B	0.48	12.02	12.06	3.54	2.88
9	PN-5A	0.48	10.31	10.33	1.56	0.85
10	PN-5B	0.48	8.81	8.83	0.79	0.23

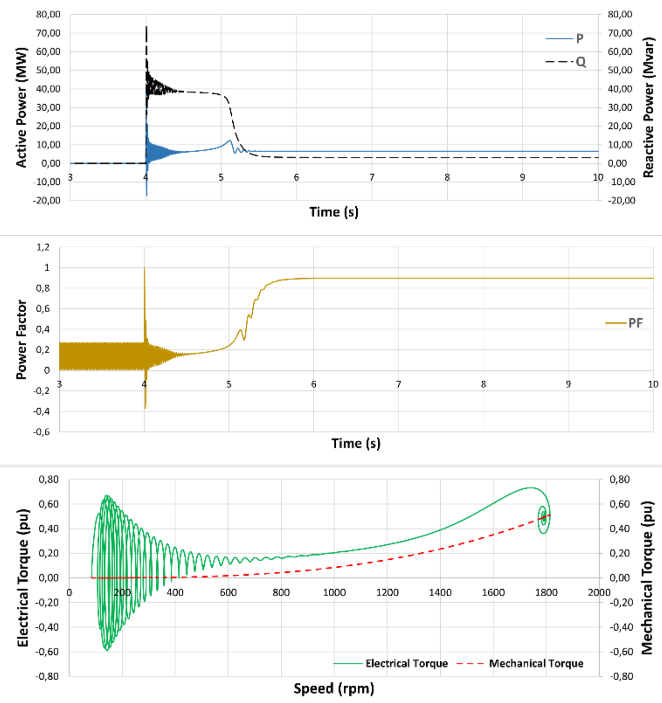

Fig. 8. Powers, Power Factor and Electromagnetic Torque during starting 11MW Motor – Scenario 2, RTDS

The two methodologies presented are capable of providing information on the behavior of voltage and power flow during the worst case of starting a motor. However, in an offshore platform with its own generation as is the case studied here, this is not so much the case. PTW does not provide information on starting time, speed or torque dynamics.

Table VI shows the results of scenario 3 of the voltage drop analysis obtained, at the same sub-transient time instant as in scenarios 1 and 2, using the speed study methodology - Torque and acceleration - Time through RTDS with the platform's own generation and its respective speed and excitation controllers. The PN-5A bus has the highest voltage drops of 14.38% and 14.82% when starting the M1-11MW and M2-11MW motors, respectively.

TABLE VI
DROP VOLTAGE IN % - RTDS (SCENARIO 3)

	MOTOR		M1-11MW	M2-11MW	M3-960KW	M4-740KVA
	BUS		PN-1B	PN-1B	PN-2B	PN-3A
	BUS	Nominal Tensión [kV]				
1	PN-1A	13.8	9.75	9.44	1.56	0.84
2	PN-1B	13.8	9.63	10.14	1.63	0.88
3	PN-2A	4.16	9.62	9.44	2.91	3.78
4	PN-2B	4.16	12.13	10.22	3.61	1.46
5	PN-3A	0.48	12.31	12.05	4.00	3.27
6	PN-3B	0.48	12.75	13.24	4.66	3.90
7	PN-4A	0.48	12.62	12.30	4.24	3.52
8	PN-4B	0.48	11.48	11.94	3.43	2.66
9	PN-5A	0.48	14.38	14.82	6.54	5.79
10	PN-5B	0.48	9.44	9.19	0.90	0.16

Table VII shows the absolute differences in voltage drops between the two methodologies (scenario 1 y 2). A particular case is observed where there are differences of -1.08% and -1.05% in the PN-2A bus of 4.16 kV when the 11 MW motors of the PN-1B bus are started. Another specific case presents the greatest difference between methodologies of 4.31%, this error may have occurred due to the equivalent loads created in the respective buses. However, the voltage drop in this case is less than 10%, relatively far from the recommended limit of 15%.

TABLE VII
DIFFERENCE BETWEEN METHODOLOGIES (SCENARIO 1 AND 2)

ABSOLUTE DIFFERENCE IN % - PTW VS. RTDS						
	MOTOR		M1-11MW	M2-11MW	M3-960KW	M4-740KVA
	BUS		PN-1B	PN-1B	PN-2B	PN-3A
	BUS	Nominal Voltage [kV]				
1	PN-1A	13.8	-0.67	-0.65	-0.43	0.99
2	PN-1B	13.8	-0.04	-0.02	-0.31	0.94
3	PN-2A	4.16	-1.08	-1.05	-0.48	4.31
4	PN-2B	4.16	-0.20	-0.17	-1.12	1.20
5	PN-3A	0.48	-0.29	-0.25	0.05	1.69
6	PN-3B	0.48	0.65	0.69	-0.15	1.23
7	PN-4A	0.48	-0.79	-0.75	-0.40	1.24
8	PN-4B	0.48	0.30	0.33	-0.05	1.45
9	PN-5A	0.48	0.01	0.02	-0.28	0.44
10	PN-5B	0.48	-1.00	-0.99	-0.60	-0.58

Fig. 9 shows the differences in the behavior of the PN-1A bus voltage when the M1-11MW motor starts in scenarios 2 and 3 of the speed - torque and acceleration - Time study methodology. The solid line curve presents scenario 2 of motor starting analysis emulating the behavior of the system with ideal sources, that is, under the same conditions of scenario 1 of analysis in PTW. It can be seen that the post-transient voltage stabilizes at 1,016 pu, additional information that was obtained thanks to this methodology.

The dashed line curve presents scenario 3 of motor starting analysis, the voltage variation caused by the voltage regulator that is implemented in the RTDS as part of the synchronous generator set is observed. In both scenarios, the test was performed with a reference voltage of 1.03 pu, respecting the operating and maneuvering premises of the platform, to then proceed with the start-up of the 11 MW motor. However, it can be observed that the post-transient voltage stabilizes at a different level, this is due to the fact that in scenario 3 the voltage regulator acts so that the voltage does not drop as much as scenario 2. Furthermore, it is observed that the response of the voltage regulator causes the voltage to recover faster than in a system with ideal sources.

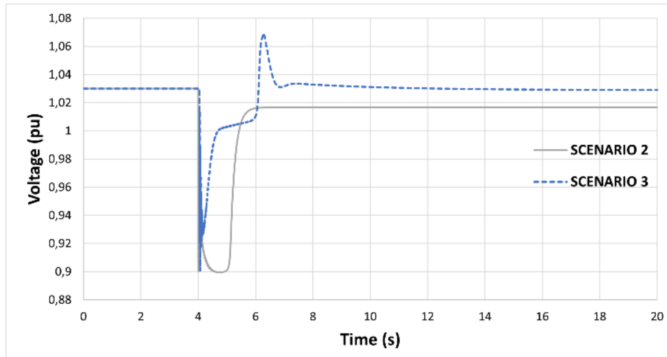

Fig. 9. Voltage profile at the main bus during 11 MW motor starting – RTDS

Fig. 10 presents the behavior of the starting speed of the M1-11MW motor. The solid line curve presents scenario 2 of motor starting analysis with ideal sources and the dashed line curve presents scenario 3 of motor starting analysis where it is observed that the starting speed of the motor in scenario 3 has a more real performance than what happens with the motor, using the offshore platform's own generation.

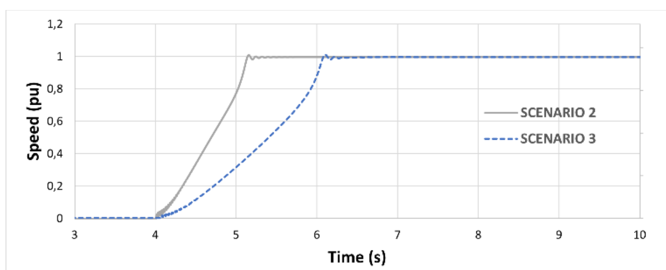

Fig. 10. 11MW motor starting speed – RTDS

The results obtained by the two methodologies through PTW for the analysis scenario 1 and RTDS for analysis scenario 2 are adequate in the first instance, according to the limits defined by the IEEE standard std3002.7-2018. The voltage drop values are very similar, since the vast majority of the absolute differences obtained were less than ± 0.5%, indicating good adherence between the results of the *Snapshot* and *Time Study* methodology. However, in scenario 2 of the analysis of Time Study methodology, more information was obtained on the dynamic behavior of the voltage and on the induction motor, an analysis that PTW will never show.

In scenario 3, the RTDS analysis considering the set of synchronous generators resulted in sub-transient voltage drops like scenarios 1 and 2, as expected. However, the voltage can be reestablished immediately because the voltage controller directly influences the bus supplying more reactive. Unlike PTW, which uses static models for a motor starting study with the particularity that its generation system does not have the dynamics of the voltage controllers of synchronous generators, making it impossible to observe this phenomenon, which is why it represents a problem in motor starting analysis in an isolated system. That is why the importance of carrying out studies in real time since it considers the dynamics of all the elements involved in the system.

VII. Conclusions

Voltage drops due to motor starting events on an offshore platform can present unique challenges for the system, especially if this is an isolated system. Although solutions based on simulations represent a type of technology or methodology, it is important to define conditions and criteria for which they can be applied.

In the case study presented, detailed simulations were performed to first compare the motor starting voltage drops based on the *Snapshot* and *Time Study* methodology under the same conditions (Analysis scenario 1 and 2). Then a motor start-up simulation was carried out considering the synchronous generation set as an offshore platform works (Analysis scenario 3).

Static studies help to have a rough analysis of what can be expected in the behavior of a system. However, it does not consider many variables because it makes a linear approximation of what is expected from the behavior of the machine. A dynamic study carried out in RTDS, which is an analysis in the time domain, considers the behavior of the other variables of the system such as the voltage regulator that allows observing the restoration of the voltage. Due to the generators are working at 1.03 pu as initial condition, the starting of the motor causes the subtransient voltage to drop to 12.42 kV as in scenarios 1 and 2 of 12.41kV in PTW and 12.5kV in RTDS respectively, but immediately reestablish itself and try to reach 14.214kV, which is the reference value being used.

Therefore, this study recommends that for isolated systems like an offshore platform that has synchronous generation with excitation and speed controls, a study of motor starting should be carried out in the time domain, since a static study with the Snapshot methodology it does not provide all the necessary information like the Time Study methodology. Therefore, it is important that the standard IEEE std 3002.7-2018 specifies that for isolated systems the Time Study methodology should be used, with which more real information about the system would be obtained and thus avoid making bad decisions.

The solutions evaluated here according to the operation and maneuvering requirements of the platform to meet the voltage drop criteria are satisfactory, in such a way that this study can be used for future investigations of alternative power generation topologies in an offshore platform.

VIII. References

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