The Use of Computer Modelling in the Context of Sustainable Development Strategy in Power Engineering

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Abstract: This paper considers the application of computer modelling tools to improve the reliability of power supply systems in the context of ESG - strategy. The possibility of using special software packages to improve stability of an oil and gas production offshore platform is being estimated. Large induction motor acceleration transient processes in an isolated power system are being analyzed. A comparative analysis of asynchronous motor starting conditions is being performed depending on the system configuration and the generating equipment composition. Recommendations on changing the starting procedure for large induction machines in order to decrease the number of switching operations are being prepared. The effect of computer modelling tools on ecology and fuel efficiency of the existing power supply system is being determined. The importance of dynamic modelling of transients for modern power engineering industry in the context of ESG - concept is evaluated.

1 INTRODUCTION

Issues of sustainable development, including the ESG strategy, are now on the agenda of all global companies, primarily related to the environmental situation and global warming. The main task of the global energy community is the rational consumption of resources and minimization of production waste for the environment.

Today, the topic of "green" responsible investment is gaining momentum every year and it is important for business to demonstrate its attitude and policy on this issue to stakeholders. Following the ESG principles directly affects the competitiveness, financial performance and stable economic growth of the company.

2 PROBLEM STATEMENT

The development of energy today is impossible without following trends such as the concept of sustainable development and ESG strategies in particular. ESG covers issues of environmental safety, social responsibility and corporate governance. Large companies around the world conduct ESG reporting, disclosing their non–financial component of activities in order to attract stakeholders and demonstrate their level of reliability. ESG is a trend that has taken root in recent years in all areas, including energy, which cannot be ignored. Responsible execution of activities in the ESG aspects is undoubtedly a competitive advantage of companies (Murzintseva, 2022).

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When considering the ESG concept within the energy industry, we are talking primarily about resource-saving production, which consumes less fuel, thereby reducing the amount of emissions into the environment. It is also worth noting the use of digital tools, for example, digital modeling, which allows minimizing and avoiding errors caused by the human factor, leading to undesirable environmental incidents (Degtyareva, 2021).

In the context of the "S" aspect of the ESG concept, the first priority is the safety of employees and compliance with their working conditions. This article is about minimizing the use of drilling platform generators in order to reduce the number of operational switches, fuel consumption and increase the overall reliability of the electrical installation, thereby ensuring a high level of safety for production employees.

The corporate governance aspect of the ESG strategy develops the theme of high-quality energy management in companies, which allows rational use of human capital and reduces the time for interaction between people, which in turn means high efficiency of the company as a whole (Moki, 2022). The corporate governance aspect also includes the issues of developing the company's philosophy and strategy, business ethics, the composition and role of the board of directors.

Separately, it is worth paying attention to the issue of evaluating business activities in the field of ESG. This requires an accurate ESG evaluation system, which determines the criteria for the successful implementation of the ESG strategy by the company. It is definitely necessary to talk about an individual approach to assessing ESG activities and results for each industry in the context of the specifics of a particular branch of the economy. It is necessary to modernize and improve the existing assessment and rating systems, adapt them in the ESG key.

Due to the specifics of the companies in the energy industry, it is worth noting their significant impact on the overall environmental situation in the world. It is extremely important for the energy sector to follow the ESG principles, as this is directly related to their efficiency, the final product and the impact on the environment (Degtyareva, 2022).

Asynchronous machines acceleration causes serious effect on the power system where they are located. In order to make motor acceleration easier and to reduce their effect on the power system a number of techniques was developed. These techniques include reduced-voltage starts using additional impedance in stator circuit or using step-down transformer; starts with star-delta connection switch are also considered to be a part of these techniques (Mahmood, Hashjin, 2022; Falahi, Butler-Purry, Ehsani, 2013). Another approach is to use variable frequency drives and soft starters (Islam, 2019). The latter methods cause a negative effect on the power systems' reliability and considered to be too expensive at the design stage, thus greatly improving starting conditions. Reduced voltage starts decrease machines' mechanical characteristics considerably, which is undesirable as well. As a result, there is a tendency to use direct-on-line induction motor starting techniques.

For technological reasons induction machines in this power system require direct-on-line starting as well, which causes supply voltage and frequency to drop on load busbars. Supply voltage decrease can cause motor start failure, according to the following expressions:

$$T(s) = \frac{3 \cdot U_G^2 \cdot {R_R}/{s}}{2\pi f_C \cdot \left(R_C + K_C \cdot {R_R}/{s}\right)^2 + (X_C + K_C \cdot X_R)^2}$$

$$J\frac{d\omega}{dt} = T - T_L, where:$$

T - induction motor electromagnetic torque;

T_L - load torque;

U_G - grid voltage;

R_R, X_R, R_C, X_C - rotor and stator resistances and reactances respectively;

J - induction machine moment of inertia;

$\frac{d\omega}{dt}$ - induction machine rotating speed derivative (Ansuj, Shokooh, Schinzinger, 1988; Eremia, Shahidehpour, 2013).

According to the given expressions it is safe to say that voltage drop causes motor starting torque to decrease (Rajinder, Singh, 2016). Taking into account the load torque, there is a danger of motor start failure during decreased voltage mode. Also, there is a risk of minimum voltage protection tripping is present due to voltage drop.

3 POWER SYSTEM EFFICIENCY IMPROVEMENT USING COMPUTER MODELLING

It was computer modelling with special software which allowed to achieve the result decreasing modelling time as well.

An oil and gas production offshore platform with own generation was chosen as a study case. The platform power supply system is considered to be an isolated power system with 6 kV and 0.4 kV switchgears. Most of the load is represented with induction machines with nominal voltage of 6 kV. These motors considered to be the most important power consumers, as the platform technological process heavily depends on their continuous operation. The platform auxiliary load is concentrated on the 0.4 kV switchgear and modelled with lumped loads. The largest motors have a rated power of 5 MW each, transients involving such powerful motors in an isolated power system considered to be the most severe cases. In case of these processes failure, stability of entire power system is decreased, which can result in blackout. Generation is represented with two gas turbine generators with a rated voltage of 6 kV and lesser diesel units with a rated voltage of 0.4 kV which are distributed to the downstream 0.4 kV switchgears. These diesel units do not take part in the normal operating mode, thus they provide power supply to the most important auxiliary systems during emergency and maintenance operating modes. The detailed equipment parameters are shown in tables 1 and 2.

Table 1: Gas turbine generators characteristics.

P rated, MW	S rated, MVA	Rated kV	Rated PF	η, %	x_d”, %	Rated speed, rpm	Exciter	Governor
24	30	6	0.8	95	23.1	1500	AC2	LM2500

Table 2: Induction machines characteristics.

P rated, MW	Rated kV	Rated PF	η, %	Rated speed, rpm	T_{lr}, p.u.	T_{max}, p.u.	I_{lr}, p.u.	Rated slip, %
5.1	6	0.91	96.5	2976	0.5	1.8	4.5	0.8

The platform technological process implies the 5 MW induction machine direct-on-line starting with the same machine in operation. At the design stage it was determined that this mode should be carried out with both gas turbine units in operation. This decision significantly increases the number of operational switchings, furthermore, it causes negative effect on equipment, as the generators parallel operation is undesirable. In this case the generators will be operating in isochronous mode, as a result, synchronous machine oscillations and load “dragging” will take place. This will result in decrease of synchronous machines transient stability and power system reliability reduction as a whole.

During the platform power supply system complex study, the platform power system was modelled with ETAP software package and transient stability simulations were carried out. During the experiments not only the equations of the electrical part of the machines were dynamically solved, but also the motion equation for induction machines:

$$J\frac{d\omega}{dt} = \sum T$$

The simulation also takes into account the change in load torque depending on the rotation speed.

As a result of simulation, it was discovered that 5 MW motor acceleration with two generators in operation is successful: the starting time does not exceed 5 seconds, the voltage drop does not exceed 12% and the frequency drop is about 0.3 Hz. During the transient, the operating parameters do not decrease below the permissible values. There is no risk of minimum voltage protection or generator overcurrent protection tripping during this mode. After successful motor acceleration there is an overvoltage of 106 % of nominal value on the supply busbars. This effect is a result of generator exciter operation, but this effect is not a cause for concern, as the value does not exceed permissible threshold for this equipment type and the duration is rather small. The same effect can be observed with system frequency, but in this case the overshoot is negligible. Transient plots are shown in Figures 1 - 3.

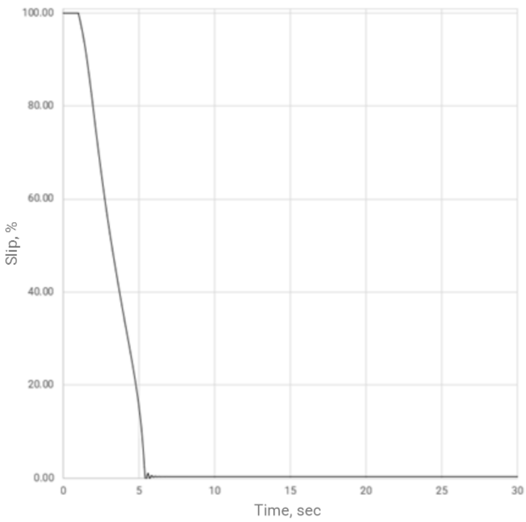

Figure 1: Starting motor slip.

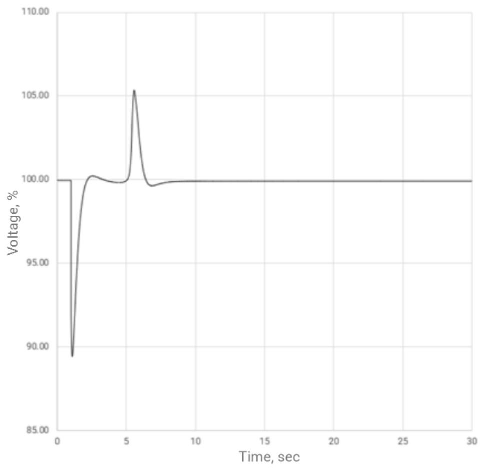

Figure 2: Voltage plot.

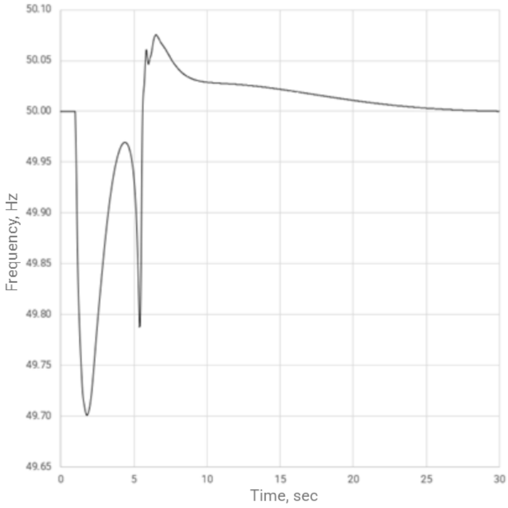

Figure 3: Frequency plot.

Thus, considered operating mode involves both main generators to be in operation, which is undesirable. Simulation of the similar operating mode but with only one generator in operation was carried out as well, the results show that it is impossible to provide the induction machine acceleration, as the voltage drops by 24 % during the transient. Beside the severe voltage drop, there is also an overvoltage of 111 % of rated value is observed after the acceleration. This value is unacceptable during normal operating mode and its' prolonged duration can cause damage to the platform equipment. The result also show that after acceleration the system frequency stays at the point of 47.6 Hz. This value allows us to say, that even when an induction machine acceleration is carried out under such conditions, the other motors are going to decelerate. Such state can result in platform technological process disruption, as this deviation from rated values is considered to be unacceptable.

The complexity of the acceleration is due to the high-power induction machine starting effect. During the acceleration the supply voltage decreases and the other motors in operation start to decelerate. With the deceleration the induction motors start to move on their current characteristics, their consumed currents increase resulting in the acceleration extension and power system load increase. Thus, the considered mode is not only unacceptable due to the deviation in operating parameters, but due to the risk of motor in operation disturbance.

As a result, minimum voltage protection will be tripped. Furthermore, generator overload protection can be tripped as well. It is clear that certain measures should be taken in order to provide safe motor acceleration. Transient plots for this simulation are shown in Figures 4 - 6.

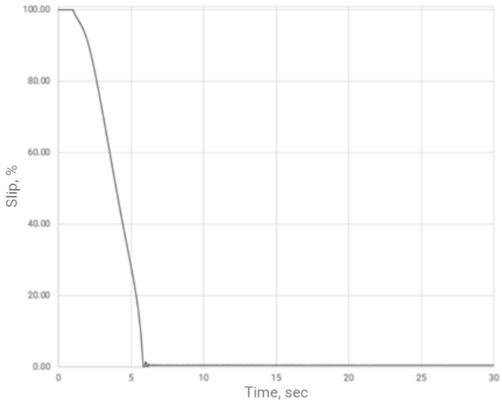

Figure 4: Starting motor slip.

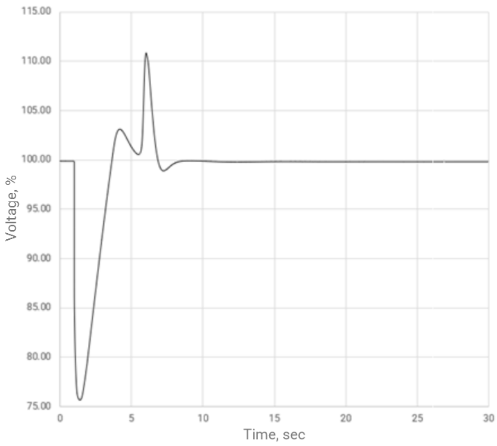

Figure 5: Voltage plot.

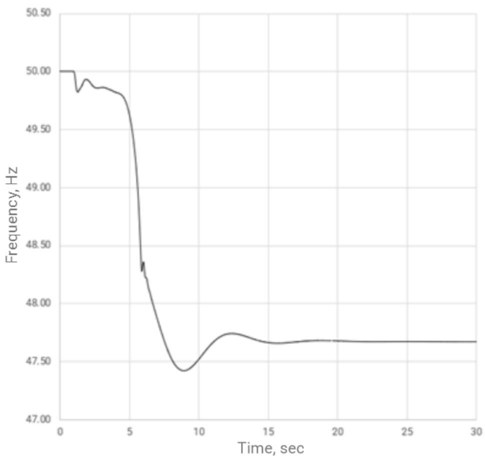

Figure 6: Frequency plot.

In order to decrease the number of operational switchings and simplify the acceleration procedure, a number of calculations and subsequent modelling were carried out to make up a set of measures, required to ensure successful motor acceleration with one generator in operation. The engineering solutions resulted in the following measures:

- Partial platform power supply system unloading to the point, when the overall load does not exceed 16 MW;
- Generator terminal voltage increase up to 105% of nominal value during the transient.

The suggested measures do not interfere in the technological process of the platform, which allows them to be executed with no visible problems.

The results of transient modelling with the mentioned measures taken into account show, that acceleration takes 4 seconds, and there is no risk of relay protection tripping as well. No unacceptable equipment load values were detected during the transient as well.

These results show that the acceleration time is equal to the one, obtained during the simulation with two generators in operation. The voltage drop still exceeds to value obtained in the mentioned simulation, but given the fact that it does not drop below the tripping setting value and the duration is short, the acceleration is not dangerous for the platform power system stability. It is also worth noting the overvoltage after the acceleration, which is 116 % of rated value. In this case an additional check for potential overvoltage protection tripping is required, but the duration is rather short and the overvoltage protection setting usually exceed these values. This allows us to conclude that this overvoltage is not dangerous for the power system. It is also worth noting the significant improvement in terms of frequency deviation during the transient. In the considered simulation the frequency deviation does not exceed 0.5 Hz, this result is similar to the one, obtained during the first simulation. Transient plots are shown in figures 7 - 9.

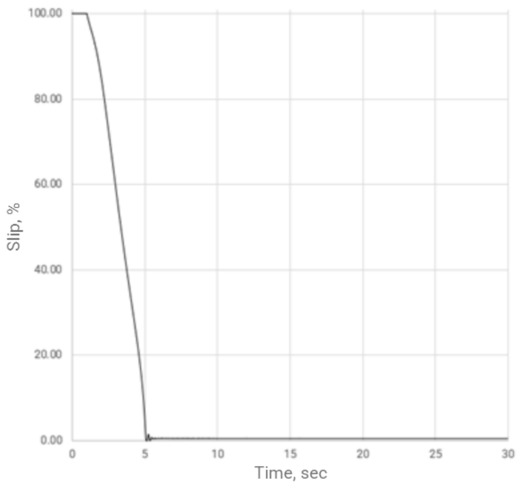

Figure 7: Starting motor slip.

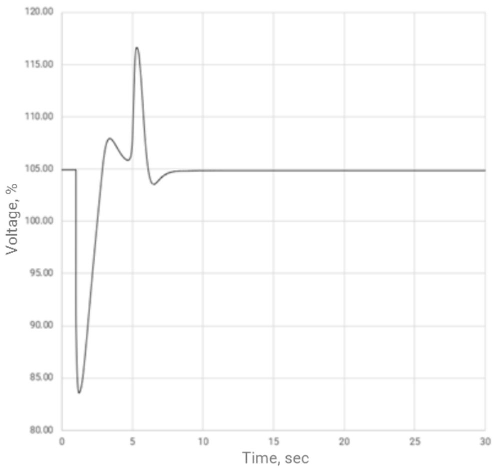

Figure 8: Voltage plot.

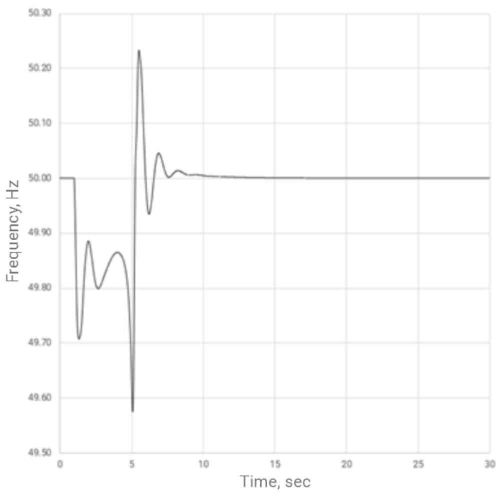

Figure 9: Frequency plot.

This case shows that with help of special software package modelling it was possible to reduce the number of operational switchings and the complexity itself of the induction machine acceleration process. In addition, these changes lead to the platform power system operation simplification along with its' reliability and energy efficiency increase.

5 CONCLUSION

Considering also the fact, that it was possible to reduce the number of gas turbine generators, involved in the motor acceleration process, reduction in fuel consumption of the platform and overall power efficiency increase can be considered as the result of the simulation.

The number of operational switchings reduction results in number of operations decrease, that are needed to be performed by the personnel to carry out the motor acceleration. This reduces the human factor in the production process on the considered platform.

The dynamic modelling of transients using modern software can increase the accuracy of the calculations, since it is possible to analyze the processes in the plant in detail. As a result, the cost of the equipment can be decreased in the design stage and increase in efficiency of the existing equipment. the introduction of computer modelling to the modern energy industry makes it possible to increase the flexibility and capacity of the existing power installations and the ones under construction. Thus, the implementation of computer modelling provides an opportunity to get a more complete picture of the processes occurring int the power system.

Also, the use of special software packages can significantly reduce the influence of human factor on the calculation processes. When such software is used, calculation accuracy is significantly higher to the other methods, and the number of steps, where mistakes can be done, is significantly reduced if the model and initial data are properly checked.

Based on the given example, we can conclude that the use of computer modelling in the context of the ESG concept can increase the resource capacity, energy efficiency and environmental friendliness of existing production or the ones under the construction, as well as maintain the safety of personnel at the facility at high level.

REFERENCES

Murzintseva, D. A., 2022. Digital development of Rosatom State Corporation as the implementation of the ESG strategy. Priority and promising directions of scientific and technical development of the Russian Federation : materials of the V-th All-Russian Scientific and Practical Conference, Moscow, February 16, 2022 / Ministry of Science and Higher Education of the Russian Federation, State university of Management. Moscow: State University of Management. pages 246-248.

Degtyareva, V. V., 2021. Digitalization as a competitive advantage of Rosatom State Corporation. *Bulletin of the University,* 12:34-39.

Moki, M. S., 2022. Managing the economic development of the country on the principles of ESG and digitalization. *Bulletin of the University*, 4: 114-121.

Degtyareva, V. V., 2022. Analysis of the influence of ESG factors on corporate innovation and investment management. *Modern Economy: problems and solutions,* 4: 82-93.

Mahmood, F., Hashjin, R., 2022. Starting Analysis of Squirrel Cage Induction Motors 1000 kW by Variable Frequency Drive in Power System, Case study: Tabriz Pump station. *NTU Journal of Engineering and Technology*, 1.

Falahi, M., Butler-Purry, K. L., Ehsani, M., 2013. "Induction Motor Starting in Islanded Microgrids". in *IEEE Transactions on Smart Grid*, vol. 4, no. 3, pp. 1323-1331.

Islam, M., 2019. VFD Motor Controller for Ship Service Auxiliaries.

Ansuj, S., Shokooh, F., Schinzinger, R., 1988. Parameter estimation for induction machines based on sensitivity analysis. *Record of Conference Papers., Industrial Applications Society 35th Annual Petroleum and Chemical Industry Conference,* pp. 35-40.

Eremia, M., Shahidehpour, M., 2013.Handbook of Electrical Power System Dynamics, IEEE Press.

Rajinder, M. S., Singh, M., 2016."Sensitivity analysis of induction motor performance variables. *2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES),* pp. 1-6.