

Investigation of transients during start-up of hybrid synchronous electric motor of submersible oil pump with permanent magnets

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Abstract. The results of simulation of transients during the start-up of a hybrid synchronous electric motor with permanent magnets under various loads are presented in this paper. The proposed motor was tested for no-load, full load, and overload using the MATLAB software and Simulink blocks. The model in the Matlab is elaborated using standard blocks library of SimPowerSystems. Also, the possibility of starting the proposed motor at the direct connection to the grid is considered. The velocity-time graphs and electromagnetic torque-time graphs are presented in the paper.

1. Introduction

The development of oil fields is carried out through the construction of oil wells and the mine method. According to the principle of physical impact on the liquid petroleum body, today there are only two main extraction methods: the fountain method and the mechanized method. The mechanized method includes the gas lift method and the pumping method. The pumping method of oil production is the most common in Russia. Pumps are used for the extraction of oil by the pumping method. The electric centrifugal and screw pumps carry out their work by using induction electric motors (IM) [1].

IM have large starting currents, relatively large dimensions and low energy parameters. IM control is implemented using scalar control systems. However, the scalar control systems have several disadvantages, such as the narrow control range and unstable motor operation with dynamically changing load. [2].

Synchronous electric motors with permanent magnets (PMSM) can be used to circumvent these disadvantages. These motors in comparison with IMs have the following advantages: less weight and dimensions at the same power, high energy characteristics. The problems with start-up and the high cost of permanent magnets were usually the disadvantages of PMSM. Nowadays, there is a significant reduction in prices for permanent magnets, which allows the creation of PMSMs, comparable in value to the IM [3]. The use of PMSMs in the oil industry is accompanied by some difficulties. This is due to the need to use complex systems of sensorless vector control. The use of sensor systems of vector control is complicate because of location of an electric motor at a sufficiently great depth to 3000 meters [4], and pulling one more wire leads to a decrease in reliability and an increase in the cost of the system. Therefore, the use of sensorless systems in this case is more preferable. [5].

The main disadvantages of using sensorless vector control systems in the oil industry are long time



setup of the system at the site of the direct operation and a high cost in comparison with scalar control systems. However, the use of the scalar control system with PMSM leads to a number of problems, the most important of which are unstable work, poor start-up and large fluctuations of the electromagnetic torque when the load changes. In work [6] development of PMSM with damper winding (hybrid electric motor) is presented. In this study, the results of the operation of a hybrid electric motor from a scalar control system under various loads are given. The modes of no-load, smooth start-up under pumping load and overload are considered.

2. The model of the hybrid motor in the Matlab/Simulink

The model is created using Matlab/Simulink blocks to simulate the transients of the proposed motor as shown in Figure 1.

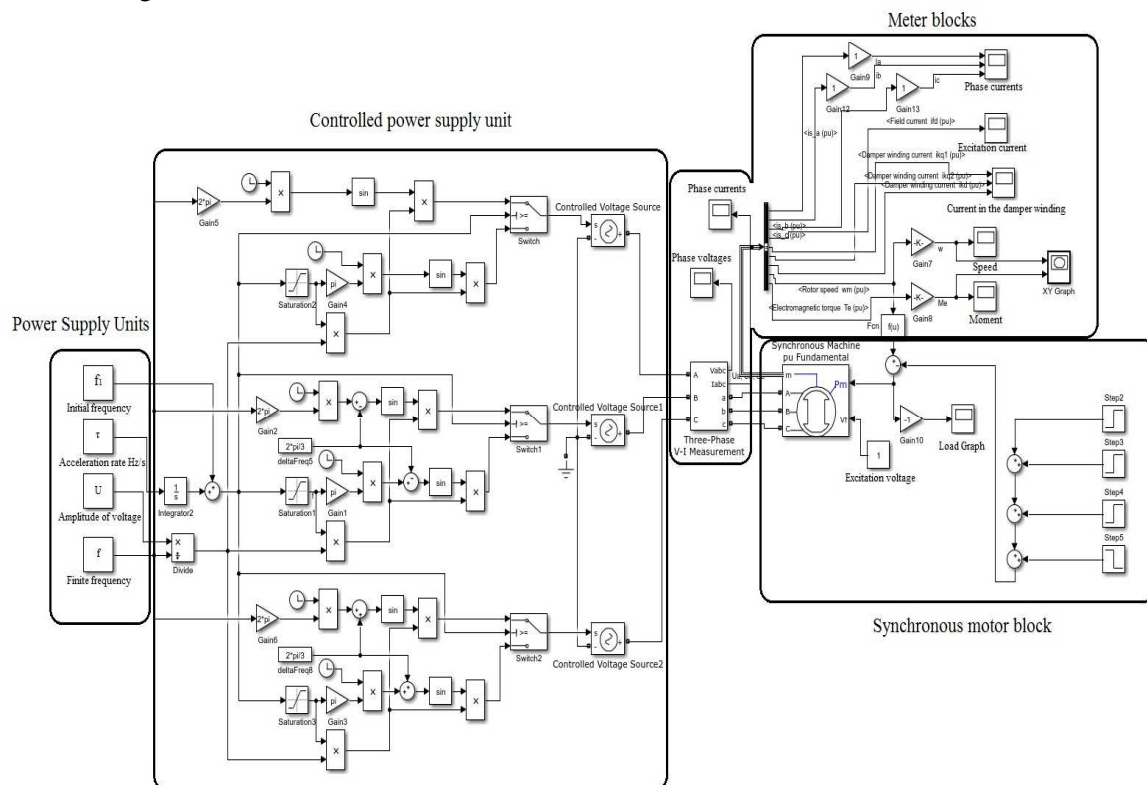


Figure 1. A model in the MATLAB/Simulink program for modeling hybrid motor transients.

The model can be divided into several units: the power supply units, the controlled power supply unit, the synchronous motor block and the meter blocks. The first two blocks allow one to obtain a sinusoidal voltage at the output with a variable frequency f and amplitude U , varying according to the U/f law. The frequency varies from the initial value f_i to the final f according to a linear law with a certain rate of acceleration τ (Hz/sec) [6].

3. Simulation result of the hybrid motor

3.1. Starting of the hybrid motor without load

The hybrid motor is simulated without any load on the rotor shaft. The simulation results are shown in Figure 2 and Figure 3.

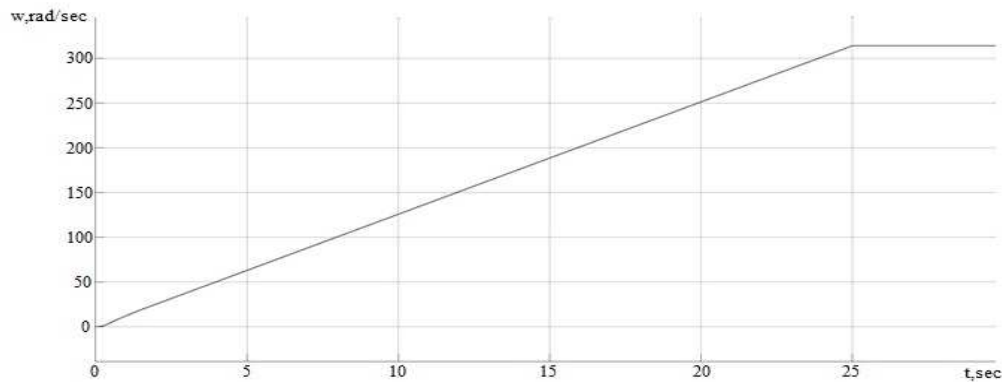


Figure 2. Speed-time graph of motor without load.

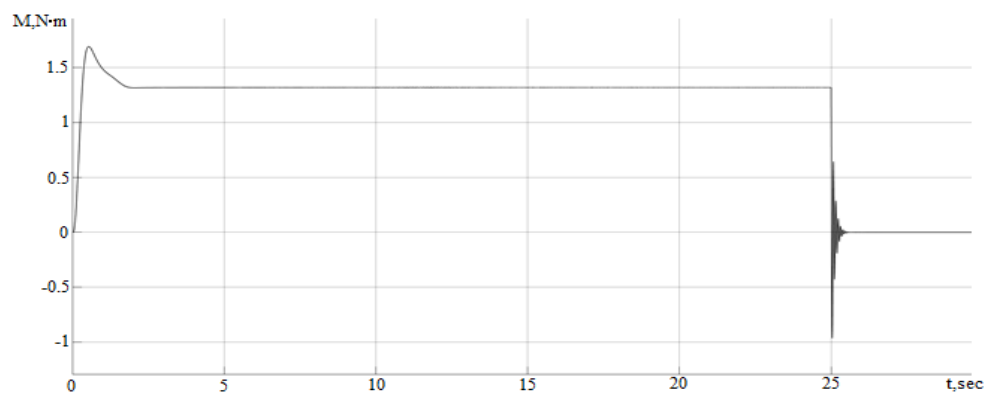


Figure 3. Electromagnetic torque-time graph of motor without load.

As can be seen from Figure 2, the motor's rotor accelerates smoothly without any fluctuations over the entire range of acceleration when the rated speed is reached, small oscillations are observed. These oscillations are caused by the inertia of the rotor.

3.2. Starting of the hybrid motor with pumping load and short-term overload

The hybrid electric motor is simulated during a soft start under a pumping load and short-time overload. The load graph is shown in Figure 4. As can be seen from Figure 4, the motor accelerates under the pumping load to the rated speed, and then there is a stepwise load surge equal to half of the rated torque M_n .

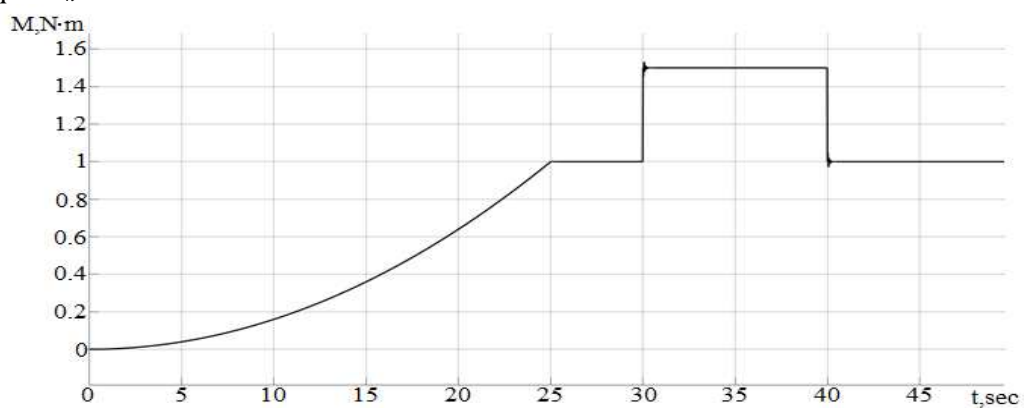


Figure 4. Motor load graph.

Figure 5 and Figure 6 show the speed-time and electromagnetic torque-time graphs of the proposed motor.

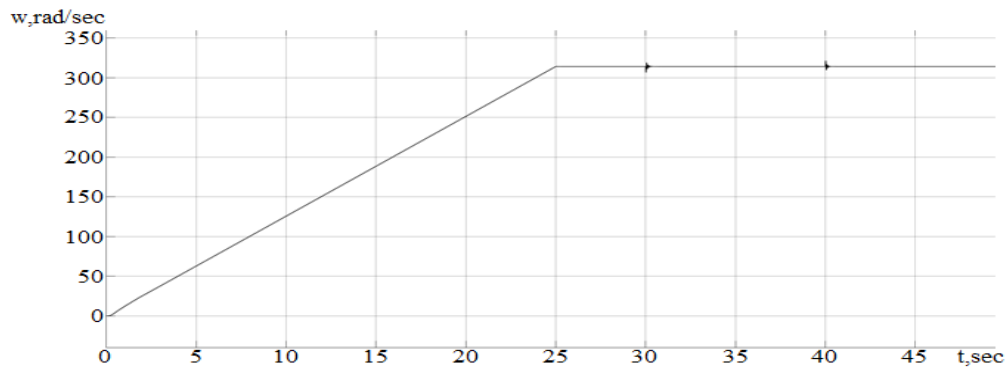


Figure 5. Speed-time graph for given load.

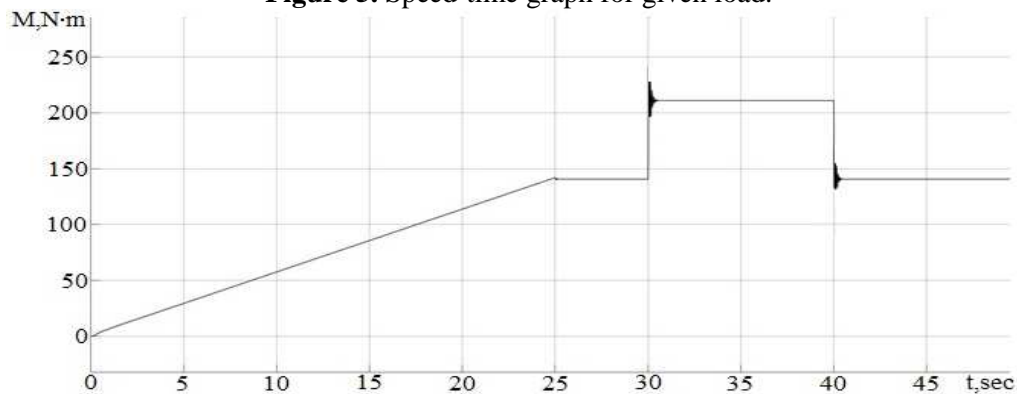


Figure 6. Electromagnetic torque-time graph for given load.

From Figure 5 and Figure 6, it can be seen that the hybrid motor accelerates without any speed and electromagnetic torque fluctuations, up to the rated speed. A rapidly damped oscillating process is observed when overloading, as well as load shedding the maximum amplitude of velocity oscillations does not exceed 2% of the rated speed and the maximum amplitude of the electromagnetic moment does not exceed 12% of the steady-state value, which is acceptable.

3.3. Starting of the hybrid motor when directly connected to the grid.

The study is made of the possibility of direct starting of a hybrid electric motor at a rated voltage U_r and a rated frequency f_r . The simulation results are shown in Figure 7 and Figure 8.

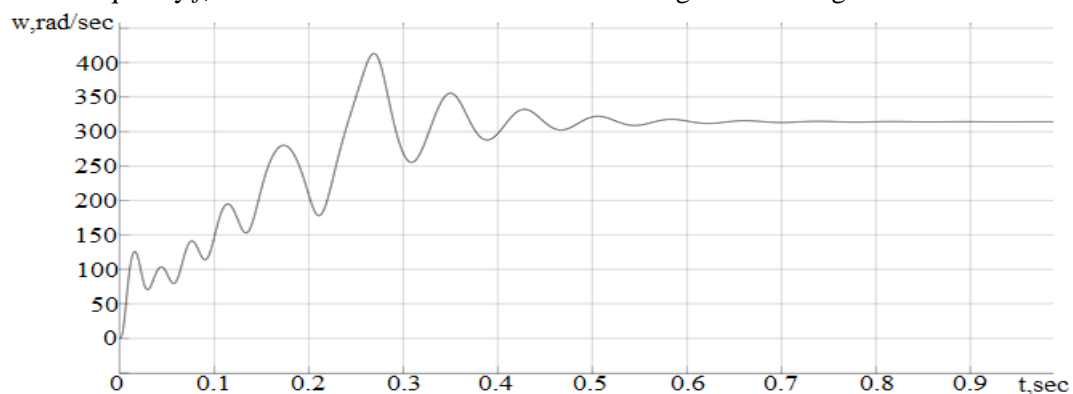


Figure 7. A speed-time graph at a direct start-up the motor.

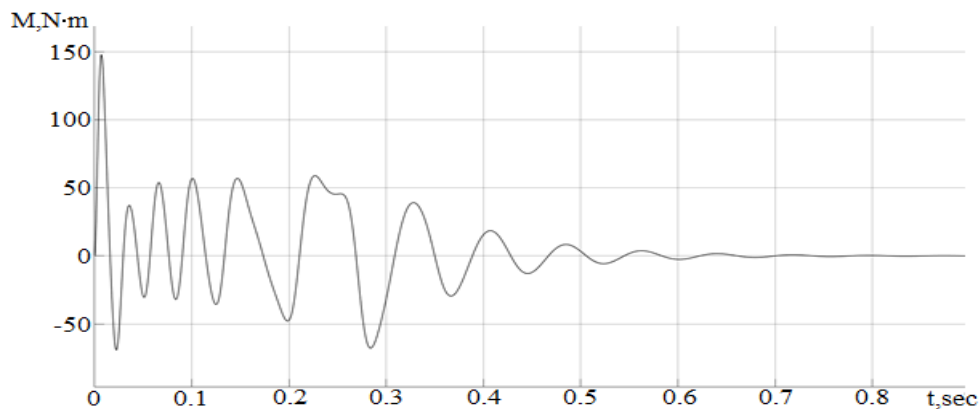


Figure 8. Electromagnetic torque-time at direct start-up.

From Figure 7 and Figure 8 it can be seen that oscillations of both the speed and the electromagnetic torque are observed when the hybrid motor starts directly. However, the oscillations decrease and the hybrid motor accelerates to the rated rotational speed. Thus, the theoretically investigated hybrid electric motor can be started directly connected to the grid, which is a important advantage, since during direct start no start-up procedures and measurement of the rotor position are needed.

4. Conclusion

It can be concluded that the motor after carrying out the simulation can work stably when starting without load, pumping load and overload.

It was found out that the hybrid electric motor can theoretically start-up directly connected to the grid at the rated voltage and rated frequency. This is a very significant advantage over PMSM, since no start-up procedures and knowledge of the rotor position of the electric motor are required.

References

- [1] EHliyashvskij I V 1985 *Technology of oil and gas production (Uchebnik dlya tekhnikumov vol 2)* (Moscow: Nedra)
- [2] Makarov V G 2011 *Actual problems of an asynchronous electric drive and methods for their solution* (Krasnoyarsk: Vestnik Kazanskogo tekhnologicheskogo universiteta)
- [3] Shevchenko A F and Pristup A G 2016 *Electric machines with permanent magnets* (Novosibirsk: Novosibirsk State Technical University Press)
- [4] Korshak A A, SHammazov A M 2005 *Basics of oil and gas business* (Ufa: DizajnPoligrafServis)
- [5] Shevchenko A F, Abdel Maksud Selim S A 2011 Vector control of the stator current of a synchronous motor with permanent of the submersible pump drive *Nauchnyj vestnik Novosibirsk State Technical University NSTU* (Novosibirsk: Novosibirsk State Technical University Press) chapter 2 pp 168-177
- [6] Bانشchikov N A, Babickij D YU 2017 Synchronous submersible motor of oil pump with damper winding with excitation from permanent magnets *MNSK: sbornik nauchnyh trudov NSTU* (Novosibirsk: Novosibirsk State Technical University Press) chapter 20 pp 10-14