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Field oriented control of PMSM drive with backup power supply

Control de campo orientado de la unidad PMSM con fuente de alimentación de respaldo

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ABSTRACT

The primary purpose of the article is to examine the field oriented control system of permanent magnet synchronous machine (PMSM) electric drive with backup power supply. Authors propose to use bi-directional DC-DC converter to ensure the «hot» backup operation mode in case of grid fault. The change-over switching system, which provide transfer of voltage-source inverter (VSI) from DC link to the backup power source is considered. The presented system provides a good dynamic transient process; the results are confirmed by simulation in Psim software. Moreover, based on the results acquired, an electric drive based on PMSM with field oriented control and a backup power supply system from the battery via a bi-directional DC-DC converter is capable of operating according to the principles of «hot» backup.

Keywords: field oriented control, PMSM, power converter, bi-directional DC-DC converter, transient, simulation.

RESUMEN

El propósito principal del artículo es examinar el sistema de control orientado al campo del accionamiento eléctrico de la máquina síncrona de imanes permanentes (PMSM) con fuente de alimentación de respaldo. Los autores proponen utilizar un convertidor CC-CC bidireccional para garantizar el modo de funcionamiento de respaldo «caliente» en caso de fallo de la red. Se considera el sistema de conmutación de conmutación, que proporciona transferencia de inversor de fuente de voltaje (VSI) desde el enlace de CC a la fuente de energía de respaldo. El sistema presentado proporciona un buen proceso dinámico transitorio, los resultados se confirman mediante simulación en el software Psim. Además, en base a los resultados adquiridos, un accionamiento eléctrico basado en PMSM con control orientado al campo y un sistema de alimentación

de respaldo de la batería a través de un convertidor CC-CC bidireccional es capaz de operar de acuerdo con los principios de respaldo «en caliente».

Palabras clave: control de campo orientado, PMSM, convertidor de potencia, convertidor CC-CC bidireccional, transitorio, simulación.

1. INTRODUCTION

Universal electrification has led to the widespread use of adjustable speed electric drives in a variety of technological processes. Thanks to the principles of field orienred control of the AC electric drive it is possible to reduce energy consumption from 10% to 50%, as well as important advantages are: limitation of starting currents; speed control in wide ranges; full automation of a specific technological process (Mohamadian, 2017; Xin et al., 2016; Mesheryakov & Bezdeneznykh, 2010; Mengoni et al., 2016; Afanas' ev & Glazyrin, 2012; de Oliveira et al., 2015; Tutaev & Bobrov, 2016; Shreiner, 2000; Bezdeneghnyh, 2011; Rudakov et al., 1992; Tutaev & Bobrov, 2018; Díaz et al., 2017; Yang et al., 2012; Tutaev & Bobrov, 2018; Kalachev, 2015; Saihi & Boutera, 2016; Vdovin et al., 2014; Domakhin & Kotin, 2018).

Therefore, the development and improvement of high-performance, compact and economical systems of AC electric drive system is one of the priority directions in the development of science and technology. Currently, the most commonly used AC drives with scalar or field oriented control (Mesheryakov & Bezdeneznykh, 2010; Afanas' ev & Glazyrin, 2012; Tutaev & Bobrov, 2016; Bezdeneghnyh, 2011; Rudakov et al., 1992; Tutaev & Bobrov, 2018; Díaz et al., 2017).

2. MATERIALS AND METHODS

There are a number of industrial areas where the reliability of the electric drive system is paramount. Failure of the electric drive system in such industries as oil production, mining and others can lead to serious economic losses or be a threat to the life of personnel.

Based on the examples presented above, an obvious conclusion follows - the advantages of an adjustable speed AC drive are impossible without a stable power supply. Therefore, the main purpose of introducing backup power supply into a electric drive system is to increase the reliability, which will prevent possible man-made and economic damage in case of instability in the main supply grid.

3. RESULTS AND DISCUSSION

The system, operating on the principle of «hot» backup, transfers to a backup power source within a time interval from 1 ms to 20 ms, avoiding loss of electric drive performance.
Currently, the main technical solutions for matching the DC link of a power converter with a backup DC source is a bi-directional galvanically isolated converter. The structural scheme presented at Figure 1.

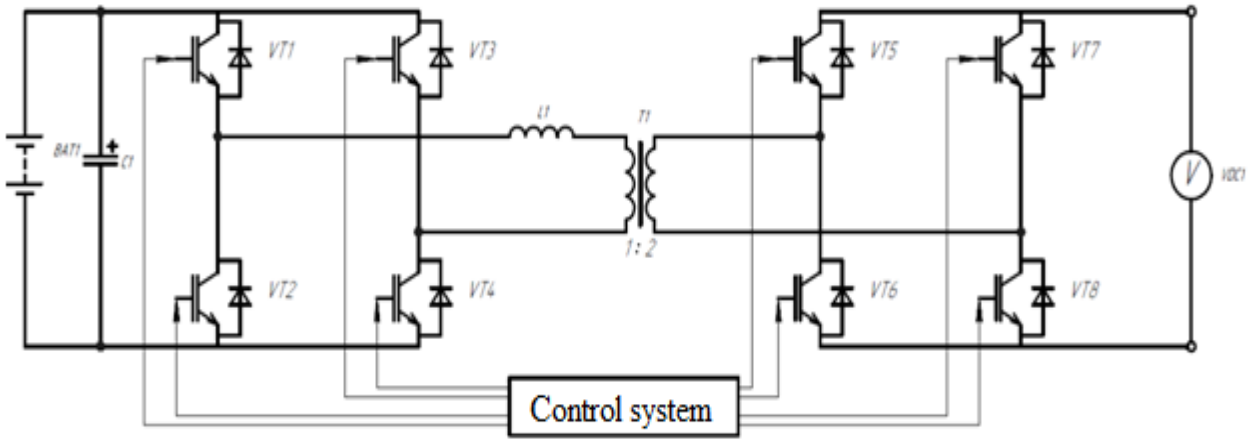

Figure 1. The structural scheme of bi-directional DC-DC converter

Due to its significant advantages, a PMSM with FOC system is often used in electric drives of various industrial facilities (Mohamadian, 2017; de Oliveira et al., 2015; Yang et al., 2012; Saihi & Boutera, 2016).

PMSM drive with FOC and bi-directional DC-DC converter Psim simulation model is presented at Figure 2.

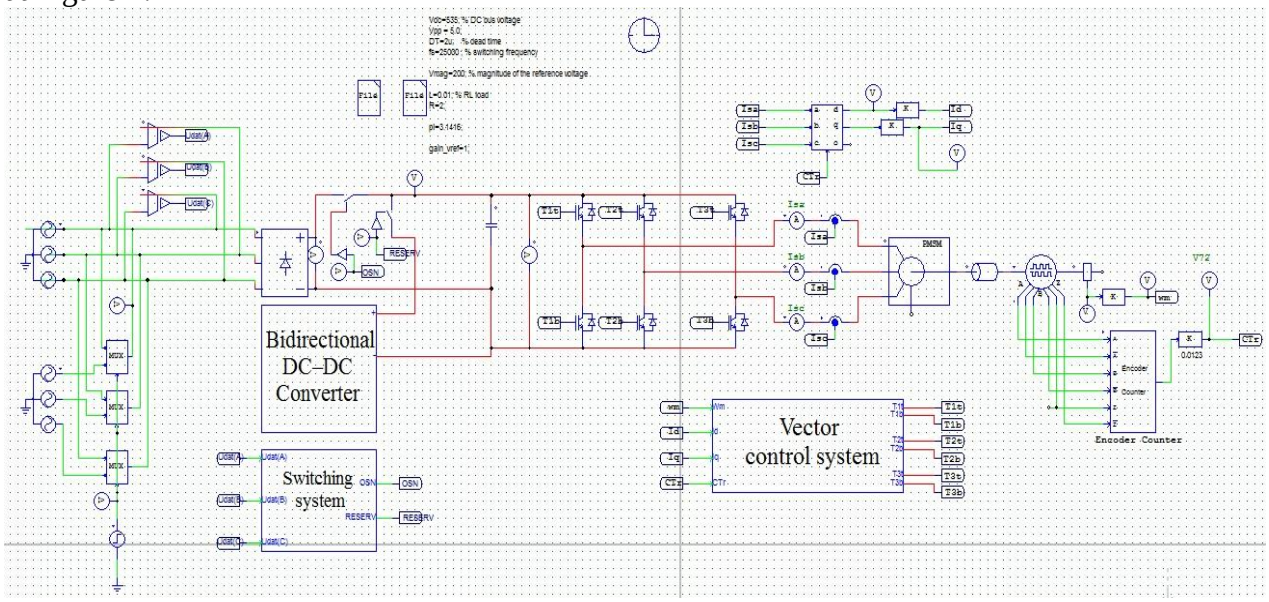

Figure 2. PMSM drive with FOC and bi-directional DC-DC converter Psim simulation model

After simulation it can be concluded that the field oriented control system is synthesized correctly. Results of transients in PMSM drive are presented at Figure 3.

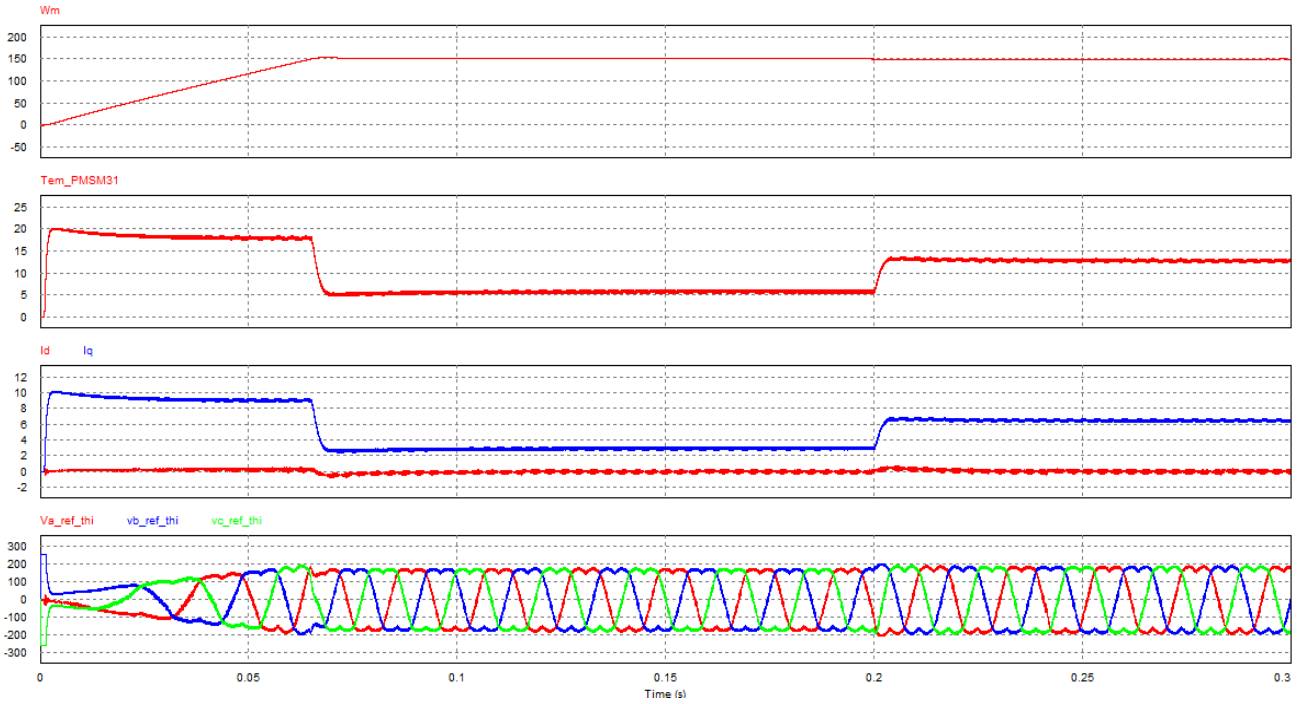

Figure 3. PMSM drive with FOC simulation results. The transient of speed, torque, I_d an I_q current component, voltage with THI

The change-over switching system (Figure 4) is based on tracking the linear rectified voltage from the sensors, each sensor has a divider.

By isolating the DC component using a capacitor, with a resistor connected in parallel and approximating the signal through the «RMS block», it is possible to obtain the fall of the signal edge at the time of the fault operation mode (Figure 5). After filtering the signal and comparing it to the setpoint using a comparator, the change-over switching can be carried out with good dynamic response.

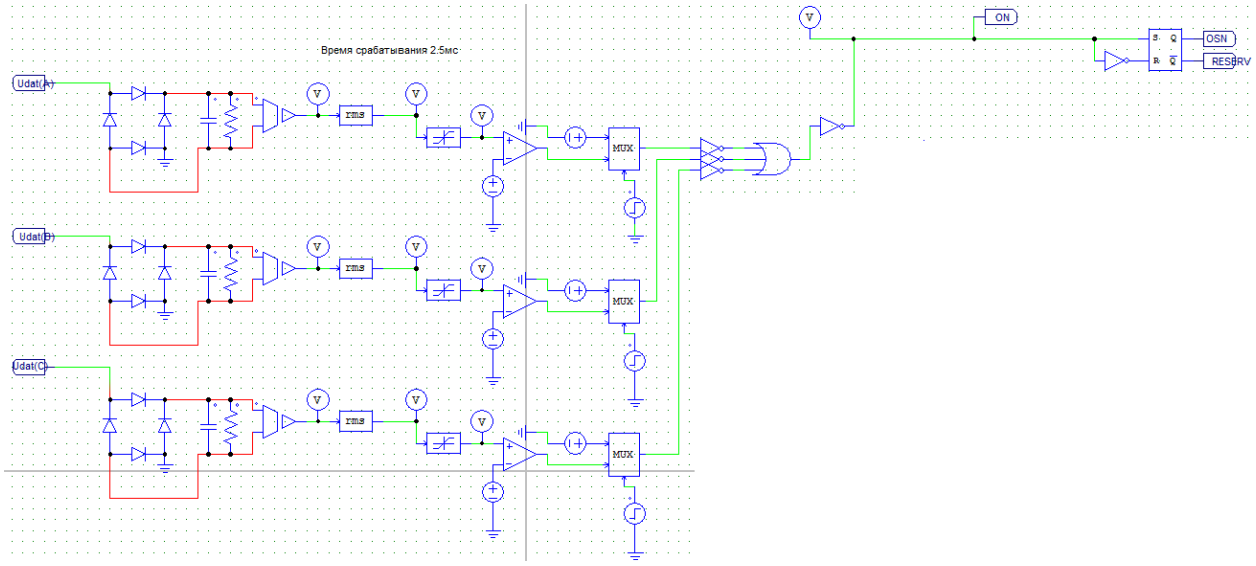

Figure 4. Change-over switching system simulation model

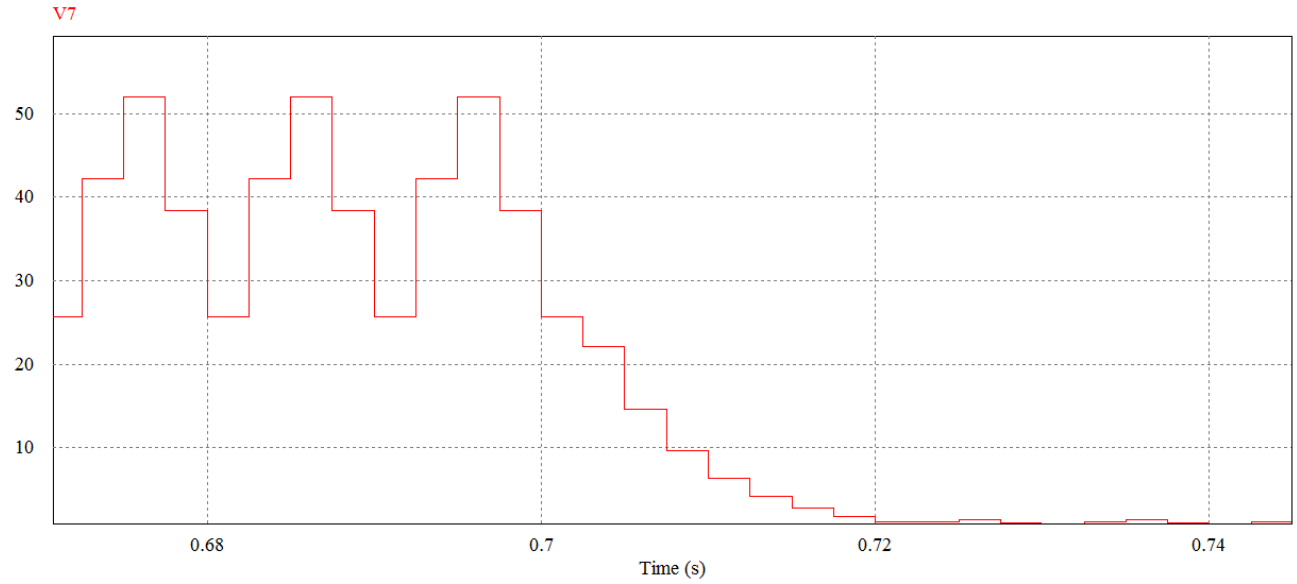

Figure 5. Signal from voltage sensor

Figure 6 shows the transient of the input phase voltage and the enable signal for switching from the main source to the backup supply. The control signal was issued within 2.5 ms after the occurrence of the fault operation mode.

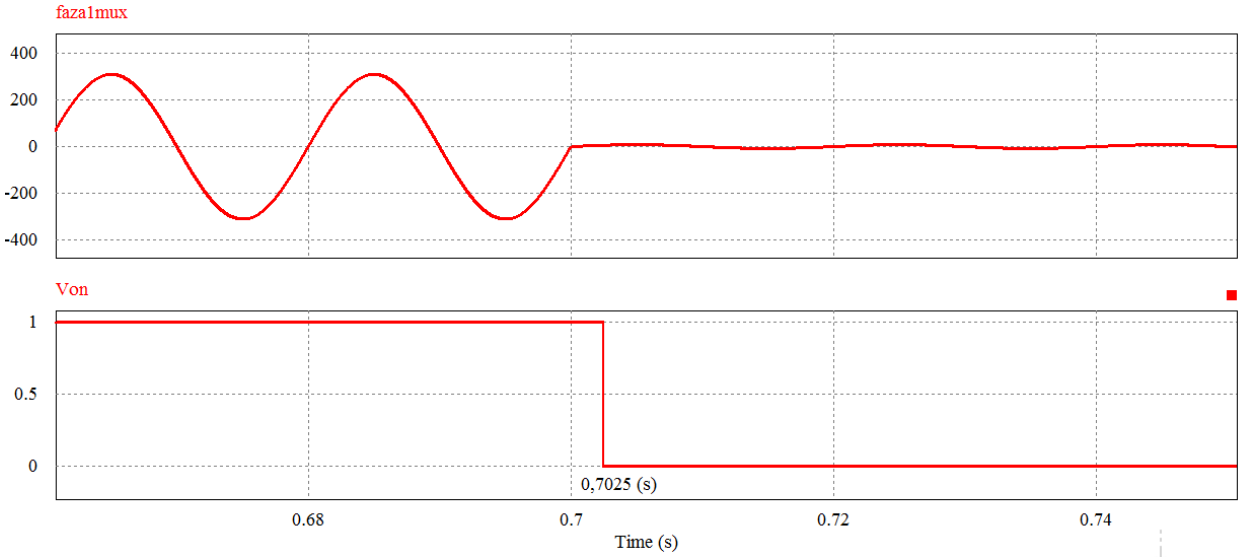

Figure 6. Transient of input phase voltage and switching over enable signal

An assessment of the transient process response and belonging to one of the principles of redundancy can be made from the graphs of torque, speed, voltage in the DC link and the curve of the current of one of the motor phases. Figure 7 shows the speed and torque transients at the time of transfer to backup power supply.

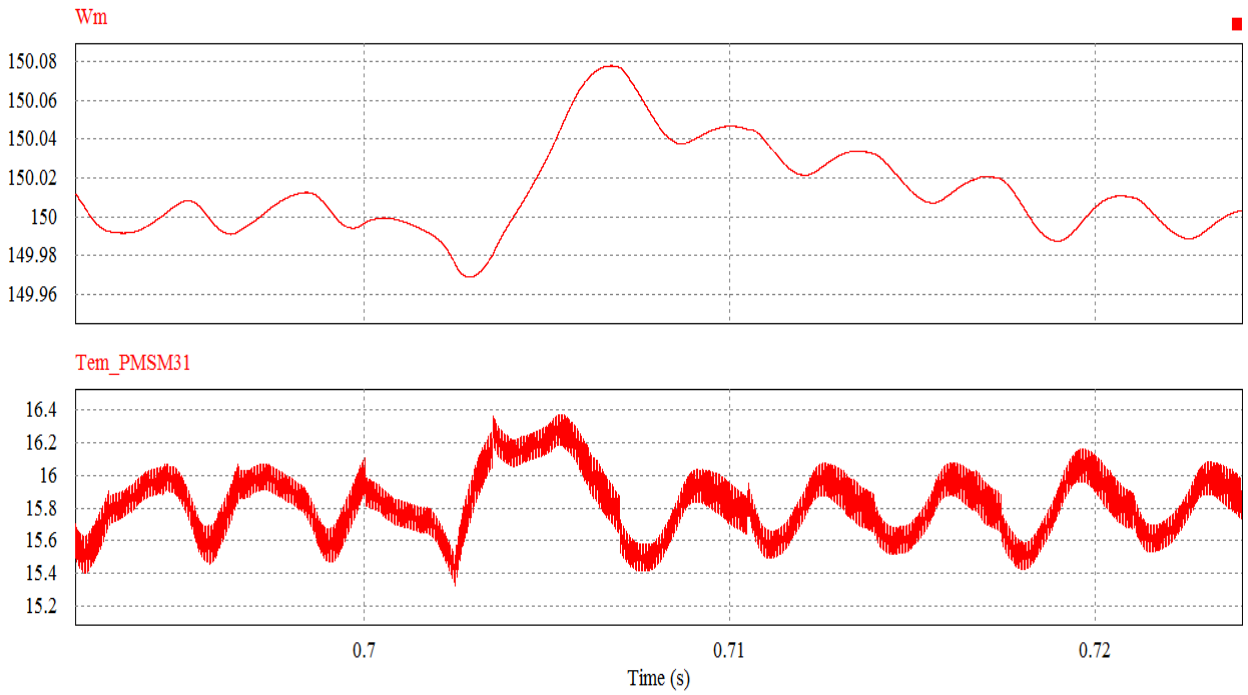

Figure 7. Transients of speed and torque at fault operation mode

Based on the obtained result, it is obviously, that the system implements the principles of «hot» backup. Moreover, the amplitudes of the values of speed and torque at the moment of switching over are insignificant, and they are unable to influence the actuator, which means that switching over to the backup supply is performed without significant ripples. Figure 8 shows the graphs of phase A current and DC link voltage at the moment of switching over to backup supply.

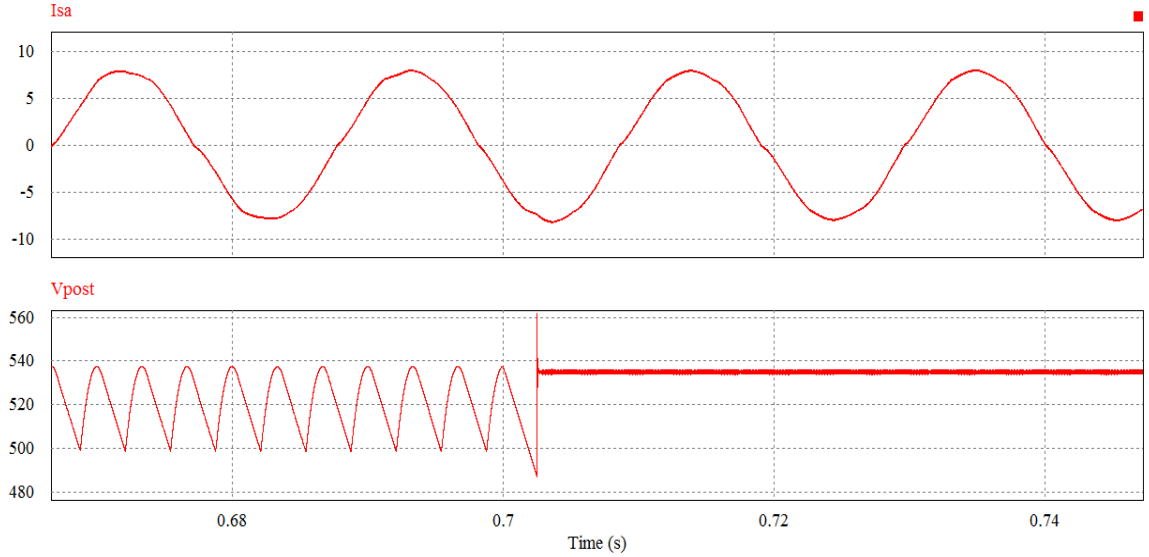

Figure 8. Transient of phase current and DC link voltage

4. CONCLUSION

Based on the results of simulation and analysis of the operation of circuitry solutions, the final conclusion can be drawn - an electric drive based on PMSM with field oriented control and a backup power supply system from the battery via a bi-directional DC-DC converter is capable of operating according to the principles of «hot» backup. Moreover, the course of the transient process, based on the simulation data, occurs without a sharp increase in the amplitudes of the torque and speed, and, therefore, there are no ripples and vibrations in the mechanical part when switching over to backup DC supply. Sometimes this requirement is fundamental in the construction of low-inertia systems with backup power. The presented system provides a good dynamic transient process; the results were confirmed by simulation in Psim software.

CONFLICT OF INTEREST

The authors confirm that the information provided in the article does not contain a conflict of interest.

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