УДК 621.313

Kvashnin V., PhD
Kosenko V., graduate student

MODELING SYSTEMS DIRECT TORQUE CONTROL USING A THREE-PHASE MATHEMATICAL MODEL

Abstract. *The development in the three-phase model direct torque control system of induction motor has been shown in this article. Obtained and compared the results in the various modes simulation pressure by direct inclusion in the network, using the control system model.*
Keywords: *A three-phase model, the induction motor, control system, the moment, simulation.*

Квашнин В. О., канд. техн. наук
Косенко В. А., аспирант

МОДЕЛИРОВАНИЕ СИСТЕМЫ ПРЯМОГО УПРАВЛЕНИЯ МОМЕНТОМ С ИСПОЛЬЗОВАНИЕМ ТРЕХФАЗНОЙ МАТЕМАТИЧЕСКОЙ МОДЕЛИ

Аннотация. *Приведена разработка трехфазной модели системы прямого управления моментом асинхронного двигателя. Получены и сопоставлены результаты моделирования различных режимов работы АД при прямом включении в сеть и с использованием модели системы управления.*
Ключевые слова: *Трехфазная модель, асинхронный двигатель, система управления, момент, моделирование.*

Квашнін В. О., канд. техн. наук
Косенко В. А., аспірант

МОДЕЛЮВАННЯ СИСТЕМИ ПРЯМОГО КЕРУВАННЯ МОМЕНТОМ З ВИКОРИСТАННЯМ ТРИФАЗНОЇ МАТЕМАТИЧНОЇ МОДЕЛІ

Анотація. *Наведена розробка трифазної моделі системи прямого керування моментом асинхронного двигуна з короткозамкненим ротором. Отримані та зіставлені результати моделювання різних режимів роботи асинхронного двигуна при прямому включенні в мережу і з використанням моделі системи керування.*
Ключові слова: *Трифазна модель, асинхронний двигун, система керування, момент, моделювання.*

Introduction

AC electric motors, in particular asynchronous motors (BP), are very widely used because of their simplicity and reliability. High performance AM impose similar requirements for automatic control systems of them.

To control AC electric motors vector control method are widely spread. At the moment the most promising direction in this area of development is the direct torque control method [1, 2, 3]. Such control systems provide good dynamics (in terms of limiting the dynamic moments) and at the same time show good static characteristics when changing the drive speed within a wide range.

The aim of this work was to develop a mathematical model of AC drive control system with the possibility of direct torque control for asynchronous motor with short circuit rotor.

The main objectives of the study were to develop and direct control system of AM in different modes of operation (starting, idling and operation under nominal load.

The object of investigation was taken asynchronous motor with squirrel-cage given rotor parameters [4].

Development and research

The mathematical asynchronous motor model is taken a two-phase version of the simulation AM model in the rotating frame α-β with a focus on the vector in the rotor flux linkage [5].

Two-phase stator voltages have been converted into three-phase.

The final version of the AM mathematical model, considering you can imagine all the changes in a system equations:

$$\begin{cases} U_{sA} - k_r U_{rA} = R_s \cdot i_{s\alpha} + \sigma L_s p \cdot i_{s\alpha} \\ U_{sB} - k_r U_{rB} = R_s \cdot (-\frac{1}{2} \cdot i_{s\alpha} + \frac{\sqrt{3}}{2} i_{s\beta}) + \sigma L_s p \cdot (-\frac{1}{2} \cdot i_{s\alpha} + \frac{\sqrt{3}}{2} i_{s\beta}) \\ U_{sC} - k_r U_{rC} = R_s \cdot (-\frac{1}{2} \cdot i_{s\alpha} - \frac{\sqrt{3}}{2} i_{s\beta}) + \sigma L_s p \cdot (-\frac{1}{2} \cdot i_{s\alpha} - \frac{\sqrt{3}}{2} i_{s\beta}) \\ 0 = T_r^{-1} \psi_{r\alpha} - k_r R_r \cdot i_{s\alpha} + p\psi_{r\alpha} + \omega_r \cdot \psi_{r\beta} \\ 0 = T_r^{-1} \psi_{r\beta} - k_r R_r \cdot i_{s\beta} + p\psi_{r\beta} - \omega_r \cdot \psi_{r\alpha} \\ \omega = \frac{M}{Jp}. \end{cases} \quad (1)$$

Since most commercially available AM with the rotor short-circuit do not have any internal sensors to build on their basis in a various automated control systems, the development in the control system is necessary to focus primarily on the possible availability engine control parameters that do not lead to their constructive change. These parameters, in this case, may act only current and stator voltage and the rotor angular speed, which can determine the available measuring instruments (sensors current, voltage and speed). Therefore, the development control system was based on the ability to control these variables.

In the proposed control system incorporates the principle direct torque control AM [6, 7, 8, 9] on the basis of the stator current acceleration to idle speed, which reduces the dynamic loads at start-up.

control rotor speed and AM. Structural block diagram in a digital automatic control system model is shown in Figure 1. This structure includes the following blocks:

- Regulator (Regulator);
- PWM generation (PWM);
- The sinusoidal signal formation (SIN);
- Three-phase motor model (Induction Motor).

The control system includes two control loop with negative feedback on the speed in rotor and the stator current. As a result, it becomes possible to separately regulate frequency and voltage amplitude.

Changing the output voltage amplitude is due to changes in the duty ratio (duty cycle) square wave voltage PWM:

$$S = \frac{T}{t} = \frac{1}{D} \quad (2),$$

where S - the pulse duty cycle, T - time clock, t – time during which a signal, D – fill factor (reciprocal of the duty cycle).

Frequency sinusoidal voltage generated is changed by changing the frequency of the modulating signal.

Figure 2 shows the output PWM signal converter.

The control system includes a P-speed controller and the PI-current controller

$$W_{pr}(p) = k_i + \frac{1}{T_i p} \quad (3),$$

where k_i - the controller gain, T_i - Speed time.

As a result, depending on the dynamic modeling the asynchronous motor have been obtained by using the control system and direct its start from the mains supply. [10].

Graphs speed, voltages, currents and torque are shown in Figures 3, 4, 5, 6 respectively.

The rotor angular graph velocity can be seen that in the regulated electric drive as opposed to direct starting AM ensured a smooth

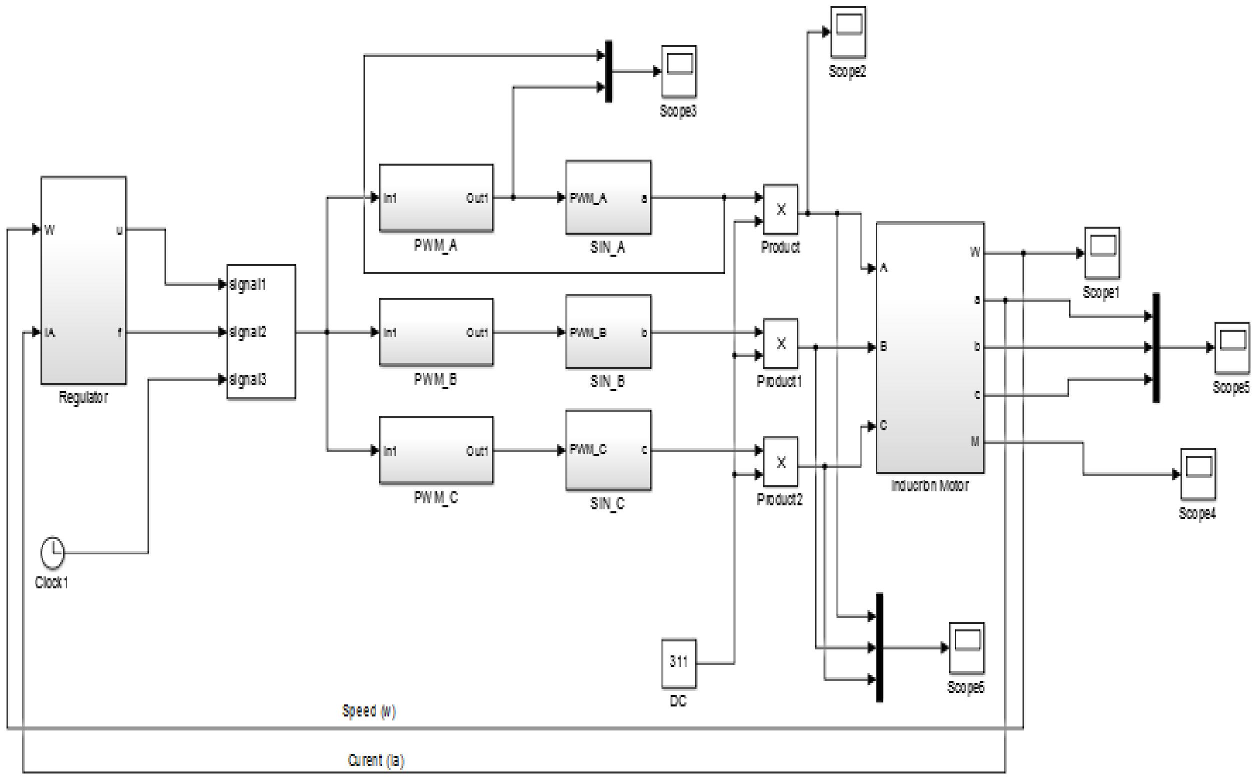

Fig. 1. The structural block diagram of a digital model of the automated control system

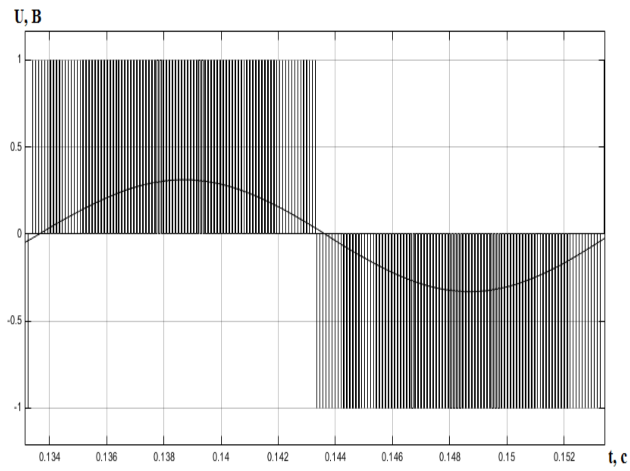

Fig. 2. The output of the PWM

If lashing out nominal load there is minimal static speed error, but there is a dynamic error, which is equal to about 3.5%, which is within acceptable limits and that can be achieved using known settings PI - current controller for symmetrical or modular optima.

In the dynamic it can be seen that it was possible to limit the amount in oscillation and starting torque due to the smooth acceleration AM and control stress in the stator motor winding (see Figure 4, 5).

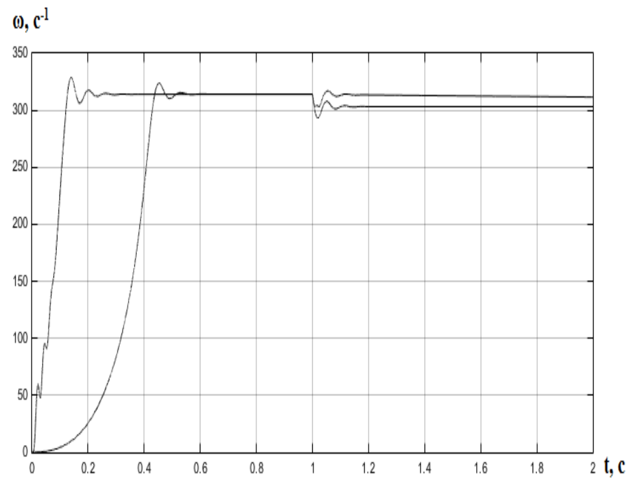

Fig. 3. The transition process for the motor shaft speed

Figure 6 (1, 2) are the stator current diagrams when the engine power directly from the mains (for direct inclusion in the network), and when using the proposed power control system for various operation modes. As seen in

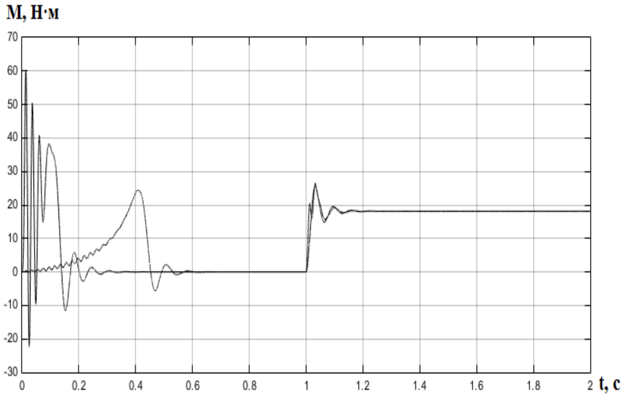

Fig. 4. The transition process at the time of IM

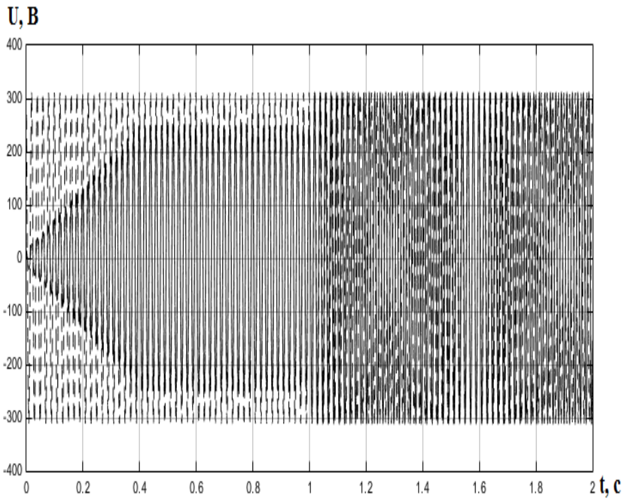

Fig. 5. The transient phase stator voltage A

Figure 6 (1), the obtained values in stator currents IM converter, were lower by about 50% - at start-up, and 14% - when idling, respectively. When loading a rated load (Figure 6 (2)) stator currents are aligned and correspond to their nominal value. Thus, in the case of the proposed power control system increases the frequency in the supply voltage that compensates for subsidence speed which occurs in uncontrolled embodiment. Maximum static speed error is less than 0,5% at the maximum value a steady rate, which corresponds to the nominal.

The voltages oscillograms show that the smooth acceleration and it is provided by consistently growing tension.

Also, studies have been conducted on the subject which provides speed control at lower frequencies (ω = 0,5ω0) Figure 7.

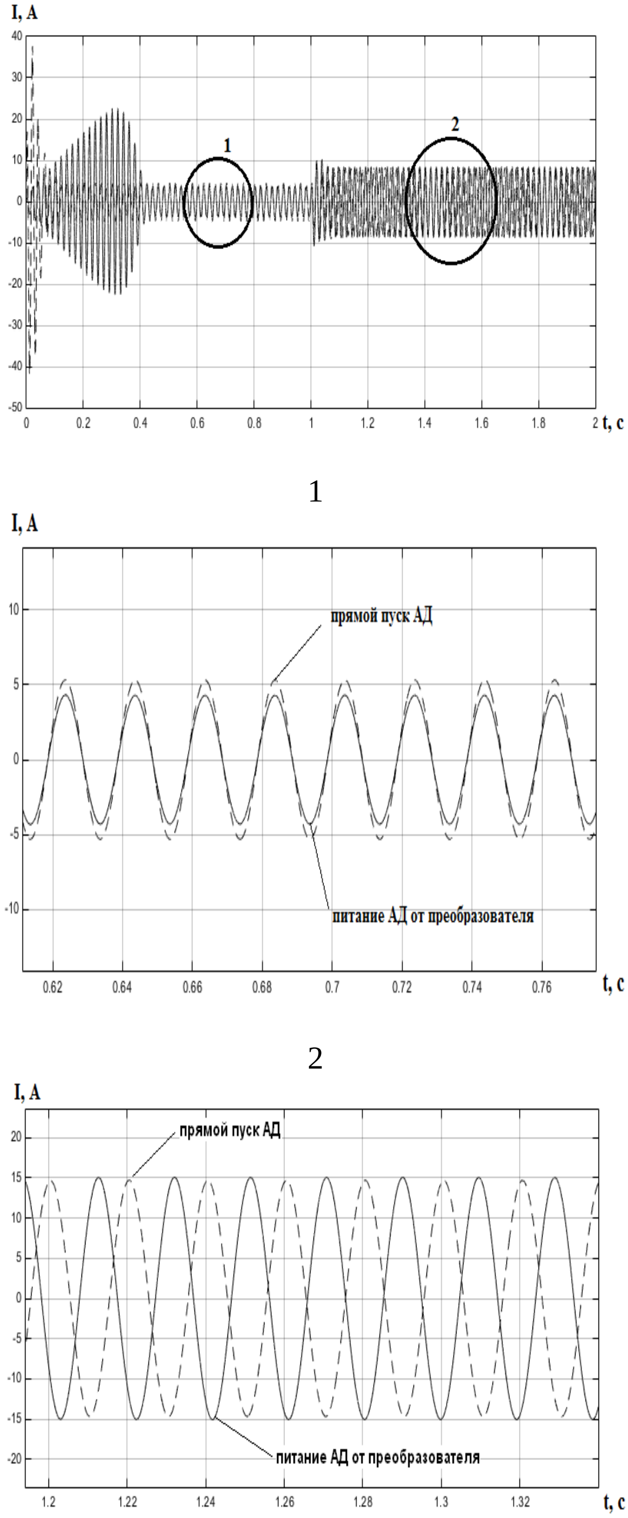

Fig. 6. The transient currents and phase stator voltage A

Plot speed (Figure 7) shows that the designed control system at a lower speed provides higher accuracy rate stabilization.

However, the dynamic error increases during acceleration and lashed the nominal load.

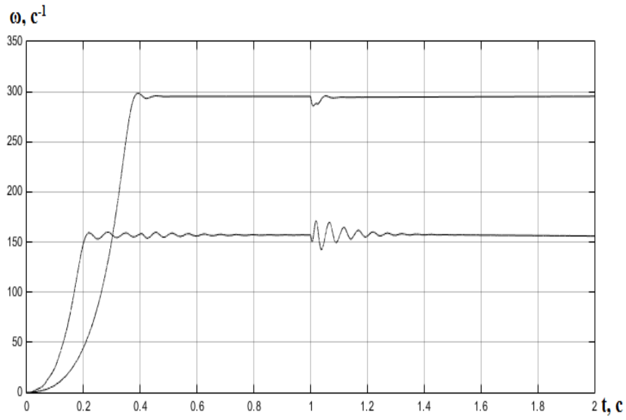

Fig. 7. The angular speed of the rotor at a different frequency voltage

Conclusions

Thus, the model has been developed a three-phase induction motor control system with a squirrel cage.

As shown by the simulation results, the proposed system provides adjustment control in the motor speed for different operating modes and at different frequencies.

Thus, at start-up provides inrush current limiting and develop starting torque, thus limiting the dynamic overload during acceleration.

Idling is performed at lower values of the stator current in comparison with the embodiment in the engine power directly from the mains.

The nominal load condition is provided by droop of less than 1% error in speed to the maximum steady speed.

References

1. Kvashnin V.O., Cherednik U.N. Postroenie I isledovanie modeli sistemi pryamogo upravleniya momentom dlya minimizacii pulsacii elektromagnitnogo momenta [Construction and research of direct torque control system model to minimize the electromagnetic torque ripple] // Elektromehanichni ta elektrosberigauchi sistemi, 2012, Sbornik 3, pp. 382-384 (in Russian).

2. Kozyaruk A.E., Rudakov V.V. Sistemy pryamogo upravleniya momentom i tokom dvigatelej peremennogo toka [Direct Control Systems Torque and current AC motors] // Harkov: Osnova. – 2004. p. 210 (in Russian).

3. Volkov A.V. Issledovanie energeticheskix pokazatelej asinxronnogo elektroprivoda na osnove avtonomnogo invertora toka [The study of energy performance asynchronous electric drive based on a stand-alone inverter] // Elektrotexnichni ta komp'yuterni sistemi. – K: «Tehnika». – 2011.- №(03) 79. – pp. 40-41 (in Russian).

4. V. O. Kvashnin razrabotka dinamicheskoj modeli asinxronnogo dvigatelya [Development of a dynamic model of an induction motor] // Visnik: sxidnoukraïnskogo nacionalnogo universitetu: naukovij zhurnal: Lugansk. -2006: vipusk №1(95).- pp.87-91. (in Russian).

5. Kvashnin V. O., Kosenko V. A. Udoskonalennya metodiki viznachennya energetichnih harakteristik asinhronnogo dviguna z vikoristannyam yogo matematichnoi modeli [Improved methods of determining the energy characteristics of induction motor using his mathematical model] // Sbornik trudov XX mejdunarodnoy nauchno-tehnicheskoy konferencii, g. Sevastopol 2013, 3-y tom 302p, pp. 274 – 277 (in Ukrainian).

6. Lazarev G. Preobrazovateli dlya chastotno-reguliruemogo elektroprivoda [Converters for variable frequency drive] // Silovaya Elektronika.- 2008.- №8(132).- pp.14-23. (in Russian).

7. Shavyolkin A. A. Avtonomnyj invertor toka v kachestve istochnika sinusoidalnogo napryazheniya [Independent current source inverter sinusoidal voltage] // Naukovi praci Doneckogo nacionalnogo texnichnogo universitetu. Seriya: "Elektrotexnika i energetika". - Doneck: dvnz «DonNTU». – vip. 1(14) – 2013. – pp. 304–307 (in Russian).

8. Z. Boudries, D. Rekioua Ziani, M. Sellami Direct power control of a PWM rectifier fed autonomous induction generator for wind energy applications // Energy Procedia 36 (2013) pp. 391 – 400

9. K.Veena, K.Roopa A New Rv Multilevel Inverter For Induction Motor Drive Applications // The International Journal Of Engineering And Science, 2014, pp. 69-77.

10. Chernih I. V. Modelirovanie elektrotehnicheskih ustroystv v Matlab, SimPowerSystems i Simulink [Modeling of electrical devices in Matlab, SimPowerSystems and Simulink] // M. DMK Press; SPb.: Piter, 2008. -288p.: il.

Список использованной литературы

1. Квашнин В.О., Чередник Ю.Н. Построение и исследование модели системы прямого управления моментом для минимизации пульсаций электромагнитного момента // Електромеханічні і енергосберігаючі системи 2012 г, Сборник 3, с. 382-384.

2. Козярук А.Е., Рудаков В.В. Системы прямого управления моментом и током двигателей переменного тока. – Харьков: Основа, 2004. – 210 с.

3. Волков А.В. Исследование энергетических показателей асинхронного электропривода на основе автономного инвертора тока // Електротехнічні та комп'ютерні системи. – К: "Техніка". – 2011.- №(03) 79. – С. 40-41

4. В. О. Квашнин Разработка динамической модели асинхронного двигателя// Вісник: Східноукраїнського Національного університету: Науковий журнал: Луганськ. -2006: Випуск №1(95).- С.87-91.

5. Квашнин В. О., Косенко В. А. Удосконалення методики визначення енергетичних характеристик асинхронного двигуна з використанням його математичної моделі // Сборник трудов XX международной научно-технической конференции г. Севастополь 2013, 3-й том 302с, с. 274 – 277.

6. Лазарев Г. Преобразователи для частотно-регулируемого электропривода // Силовая Электроника.- 2008.- №8(132).- С.14-23.

7. Шавёлкин А. А. Автономный инвертор тока в качестве источника синусоидального напряжения // Наукові праці Донецького національного технічного університету. Серія: "Електротехніка і енергетика". - Донецьк: ДВНЗ «ДонНТУ». – вип. 1(14) – 2013. – С. 304–307.

8. Z. Boudries, D. Rekioua Ziani, M. Sellami Direct power control of a PWM rectifier fed autonomous induction generator for wind energy applications // Energy Procedia 36 (2013) pp. 391 – 400

9. K.Veena, K.Roopa A New Rv Multilevel Inverter For Induction Motor Drive Applications // The International Journal Of Engineering And Science, 2014, pp. 69-77

10. Черных И. В. Моделирование электротехнических устройств в Matlab, SimPowerSystems и Simulink. – М. ДМК Пресс; СПб.: Питер, 2008. – 288 с.: ил.

Kvashnin Valeriy
PhD Associate Professor of the department «Electromechanical systems of automation and electric drive» Donbass State Engineering Academy

Phone: 0626 41-68-93,
+38 (050) 989-77-01
E-Mail: v.kvashnin@mail.ru

Kosenko Vladislav
Graduate student of the department «Electromechanical systems of automation and electric drive» Donbass State Engineering Academy
Phone: +38 (099) 709-57-84,
E-Mail: vladislavart44@mail.ru