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# DETERMINATION OF THE MAIN PARAMETERS OF A POLE-CHANGING TWO-SPEED INDUCTION MOTOR

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**Abstract.** This article discusses the determination of the main parameters of a pole-changing two-speed induction motor and the issues of improving its energy efficiency. Considering that a large portion of electrical energy is consumed by electric drives, the advantages of using two-speed motors for adjustable electric drives are analyzed.
During the study, a new two-speed induction motor model was developed using the ANSYS Maxwell software, and its operating, mechanical, and dynamic characteristics were determined. According to the calculation results, the efficiency (η) of the motor is 75% at p = 3 (n = 1000 rpm) and 70% at p = 4 (n = 750 rpm). In addition, the dynamics of the starting current and torque over time were studied, confirming the operational stability of the new design.
The results show that the use of pole-changing two-speed induction motors in electric drives makes it possible to save electrical energy and natural resources, increase operational efficiency, and extend the service life of the motor.

**Key words:** asynchronous motor, pole-changing winding, two-speed drive, energy efficiency, ANSYS Maxwell software.

**Аннотация.** В данной статье рассматриваются вопросы определения основных параметров асинхронного двигателя с изменяемым числом полюсов и двумя скоростями, а также пути повышения его энергетической эффективности. Учитывая, что значительная часть электрической энергии потребляется электрическими приводами, проанализированы преимущества использования двухскоростных двигателей в регулируемых электроприводах. В ходе исследования с использованием программного обеспечения ANSYS Maxwell была разработана новая модель двухскоростного асинхронного двигателя, определены его рабочие, механические и динамические характеристики. Согласно результатам расчётов, КПД двигателя (η) составляет 75% при p = 3 (n = 1000 об/мин) и 70% при p = 4 (n = 750 об/мин). Кроме того, были исследованы динамика пускового тока и момента во времени, что подтвердило эксплуатационную устойчивость новой конструкции. Результаты показывают, что использование асинхронных двигателей с изменяемым числом полюсов и двумя скоростями в электроприводах позволяет экономить электрическую энергию и природные ресурсы, повышать эксплуатационную эффективность и продлевать срок службы двигателя.

**Ключевые слова:** асинхронный двигатель, полюсопереключаемая обмотка, двухскоростной привод, энергоэффективность, программное обеспечение ANSYS Maxwell.

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**Annotatsiya.** Ushbu maqolada qutblari o‘zgaruvchan ikki tezlikli asinxron motorning asosiy parametrlarini aniqlash hamda uning energiya samaradorligini oshirish masalalari yoritilgan. Elektr energiyasining katta qismi elektr yuritmalar tomonidan iste’mol qilinishini inobatga olgan holda, boshqariladigan elektr yuritmalar uchun ikki tezlikli motorlardan foydalanishning afzalliklari tahlil qilingan. Tadqiqot davomida ANSYS Maxwell dasturiy ta’minoti yordamida yangi ikki tezlikli asinxron motor modeli ishlab chiqildi va uning ishchi, mexanik hamda dinamik xarakteristikalari aniqlab chiqildi. Hisoblash natijalariga ko‘ra, motorning foydali ish koeffitsiyenti (η) p = 3 (n = 1000 ayl/min) bo‘lganda 75%**,** p = 4 (n = 750 ayl/min) bo‘lganda esa 70% ni tashkil etadi. Shuningdek, ishga tushish toki va momentning vaqt bo‘yicha o‘zgarish dinamikasi o‘rganilib, yangi konstruktsiyaning barqaror ishlashi tasdiqlandi.
Olingan natijalar shuni ko‘rsatadiki, elektr yuritmalarda qutblari o‘zgaruvchan ikki tezlikli asinxron motorlardan foydalanish elektr energiyasi va tabiiy resurslarni tejash, ekspluatatsion samaradorlikni oshirish hamda motorning xizmat muddatini uzaytirish imkonini beradi.

**Kalit so‘zlar:** asinxron motor, qutblari o‘zgaruvchan chulg‘am, ikki tezlikli yuritma, energiya samaradorligi, ANSYS Maxwell dasturi.

**Introduction.** Currently, 70–80% of the total electrical energy in our country is consumed by electric drives. Various technological processes are carried out based on these drives. Most of the drives are equipped with single-speed electric motors, and there are several methods available for speed control.
For many years, the majority of electric motors used in electric drives have become technically and morally outdated, often mismatched to the specific requirements of the drives, and the motors used in adjustable electric drives exhibit low efficiency (η). Considering the variable operating modes of adjustable electric drives, selecting single-winding pole-changing electric motors for such systems can lead to significant savings in electrical energy and natural resources.
**Research Methodology.** Replacing two separate-winding electric motors with a single-winding two-speed motor significantly improves the operational performance of adjustable electric drives and increases their productivity, which in turn leads to savings in electrical energy and natural resources**.**
Two-speed electric motors have long been successfully used in various sectors of agriculture and industry, particularly in:

- Lifts and other hoisting mechanisms;
- Chemical and mining-metallurgical machinery;
- Drilling equipment;
- Ventilation systems, pumping units, and several other adjustable drive mechanisms.

In recent years, the analysis of variable operating modes of mechanisms and the use of variable-speed electric motors suited to these conditions have become increasingly important.
The speed control method using two-speed induction motors is considered one of the simplest and most cost-effective approaches. However, direct starting of motors with low network capacity can cause a voltage drop exceeding 30%**.** This results, first, in a decrease in the torque produced by the drive and, second, in disconnection of the drive from the network by electronic or microprocessor-based protective devices that detect voltage drops.

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Using two-speed induction motors in electric drives facilitates the stepwise starting of high-power motors and ensures more efficient operation under partial-load conditions**.**

Two-speed motors can be manufactured with one common winding or two separate windings. A comparison between these two types for the same power shows that two-winding motors require

30–40% more electrical steel and 40–50% more copper**,** and their efficiency (η) and power factor (cosφ) are on average 10–15% lower than those of single-winding motors.

Furthermore, in two-speed motors with separate windings, each speed has its own stator winding, which results in underutilization of the active part (up to 70%)**,** a decrease in energy efficiency**,** and makes their manufacturing and maintenance more complex**.**

These drawbacks hinder the widespread use of two-speed motors instead of single-speed ones in mechanisms operating under variable load conditions, despite their potential for energy and resource savings**.**

Therefore, improving two-speed motors and conducting research in this area is an important task. Replacing two separate windings with a single pole-changing two-speed winding can be considered one of the promising methods for enhancing two-speed induction motors**.**

**Literature reviyew.** A new two-speed induction motor model was developed using the ANSYS Maxwell software. Through the Maxwell program, the operating, mechanical, and dynamic characteristics of the induction motor were obtained.

The results of the calculations for the new two-speed induction motor, performed in the Maxwell environment, are presented in **table 1**, while the operational characteristics are illustrated in the graphs as follows: $I_1=f(P_2)$; $\eta=(f(P_2)$; $\cos\varphi=f(P_2)$; $S=f(P_2)$; $M=f(n_2)$;

**Table 1. Results obtained using ANSYS Maxwell software.**

**Table 1**

| № | I | $P_2$ | η | cosφ | M | S |
|---|---|---|---|---|---|---|
| | A | W | % | | N·m | % |
| **for the side with p=3p=3p=3 (n = 1000 rpm)** | | | | | | |
| 1 | 1,8 | 140 | 50 | 0,23 | 36 | 0,5 |
| 2 | 1,9 | 274 | 65 | 0,35 | 30 | 1 |
| 3 | 2,1 | 530 | 75 | 0,52 | 20 | 2 |
| 4 | 2,31 | 770 | 76 | 0,63 | 16,5 | 3 |
| 5 | 2,55 | 870 | 77 | 0,67 | 13,5 | 3,5 |
| 6 | 2,7 | 975 | 77 | 0,69 | 12,5 | 4 |
| 7 | 2,9 | 1000 | 76 | 0,73 | 12,5 | 4,5 |
| 8 | 3,2 | 1200 | 75 | 0,76 | 12 | 5 |
| **for the side with p=4p = 4p=4 (n = 750 rpm)** | | | | | | |
| 1 | 1,85 | 78 | 34 | 0,18 | 27,5 | 0,5 |
| 2 | 1,87 | 120 | 44 | 0,22 | 22 | 0,75 |
| 3 | 1,89 | 162 | 50 | 0.25 | 17,5 | 1 |
| 4 | 2 | 320 | 65 | 0,37 | 12,5 | 2 |
| 5 | 2,11 | 430 | 69 | 0,45 | 12 | 3 |
| 6 | 2,32 | 590 | 71 | 0,54 | 11 | 4 |
| 7 | 2,52 | 700 | 71 | 0,59 | 10 | 5 |
| 8 | 2,72 | 810 | 71 | 0,63 | 8,5 | 6 |
| 9 | 2,92 | 900 | 70 | 0,67 | 8,5 | 7 |

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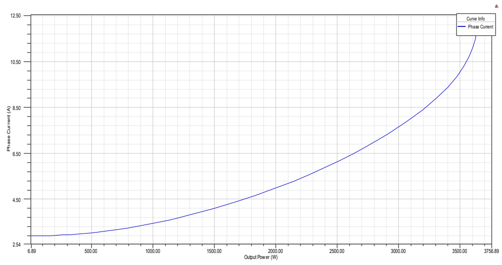

**Figure 1. Relationship between stator current $I_{nom}$ (A) and shaft power $P_2$ (W)**

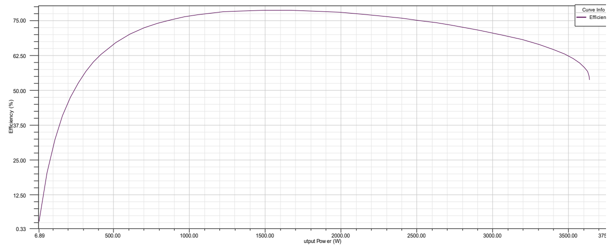

**Figure 2. Relationship between efficiency η(%) and shaft power $P_2$ (W).**

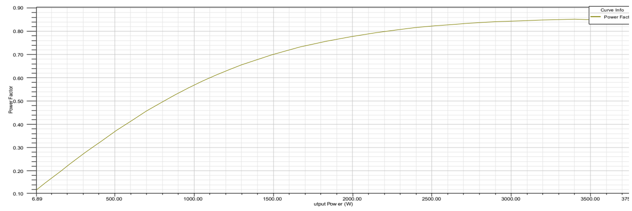

**Figure 3. Relationship between power factor cosϕ and shaft power $P_2$ (W).**

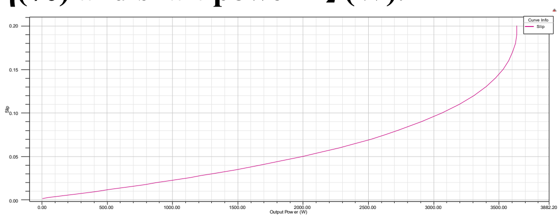

**Figure 4. Relationship between slip S and shaft power $P_2$ (W).**

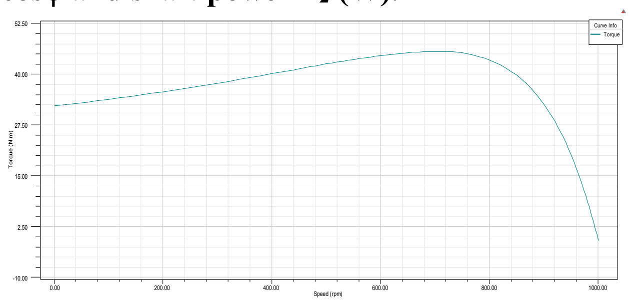

**Figure 5. Relationship between torque M (N·m) and shaft speed $n_2$ (rpm).**

**Analysis and results.** The research results show that for the side with p = 3 (n = 1000 rpm), when the shaft power $P_2$=1.2 kW, the efficiency is η=75%, the power factor is cosφ=0.76, the current is $I_2$=3.2 A, and the slip is s=5%. For the side with p = 4 (n = 750 rpm), when $P_2$=0.9 kW, the efficiency is η=70%, the power factor is cosφ=0.67, the current is $I_2$=2.92 A, and the slip is s=7%. When applying the newly designed 4A90L6/8Y3 type induction motor to electric drives, starting operation at a lower speed of n = 750 rpm and then switching to n = 1000 rpm ensures the long-term reliable performance of the motor. By analyzing the graph showing the relationship between current I (A) and time t (s) during direct-on-line starting of the pole-changing two-speed induction motor, the starting current $I_{start}$ and its duration can be determined.

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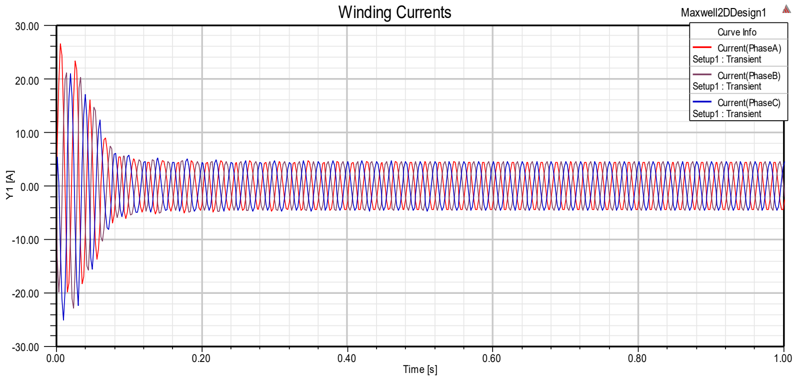


**Figure 6. Dynamics of the stator current I (A) versus time t (s) for the newly designed motor with p=3 (n = 1000 rpm).**

The graph shows that the starting current lasts for **0.08 s**; during this time the starting current $I_{start}$ is **16 A**, while the nominal current $I_{nom}$ is **2.8 A**.

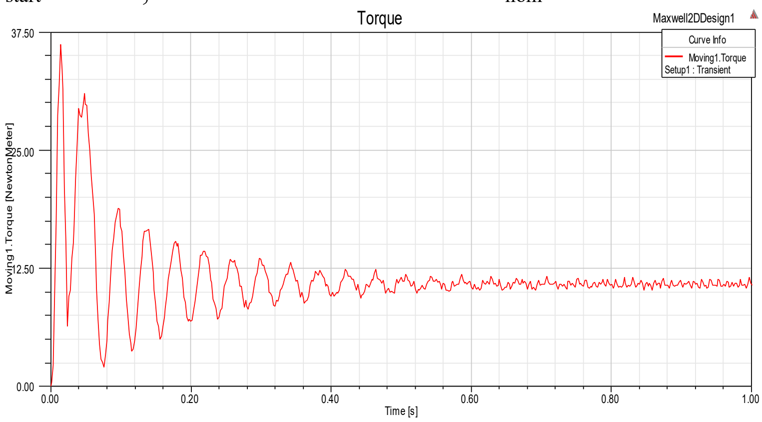


**Figure 7. Relationship between torque M (N·m) and time t (s).**

**Conclusion.** In conclusion, it can be seen that for the side with p = 3 (n = 1000 rpm), the starting current $I_{start}$=16 A, while for the side with p = 4 (n = 750 rpm), $I_{start}$=13 A. The obtained results show that when the load of the adjustable electric drive is low, operating at a speed of n = 750 rpm (with a power of P = 900 W) allows for significant savings in electrical energy and natural resources.

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