International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

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Substantiation of Energy Performance Indicators of a Pole-Changing Two-Speed Induction Motor

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International Journal of Science and Research Archive, 2026, 18(02), 667-672

Publication history: Received on 04 January 2026; revised on 14 February 2026; accepted on 17 February 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.18.2.0297

Abstract

This article examines the substantiation of the energy performance indicators of a pole-changing two-speed induction motor. The main objective of the study is to develop an energy-efficient electric drive solution for mechanisms operating under variable load conditions, such as pumping units. In the research, the electromagnetic and energy parameters of the two-speed induction motor were initially designed using mathematical methods, and its main operating modes were determined through theoretical calculations.

To verify and refine the obtained theoretical results, a digital model of the motor was developed using the ANSYS Maxwell software environment. During numerical simulation, the magnetic field distribution, flux density, losses, and efficiency were investigated under various speed and load conditions. The simulation results were compared with the outcomes of the mathematical calculations, and a good agreement between them was observed.

The research results showed that the application of a pole-changing two-speed induction motor makes it possible to reduce energy consumption under partial load conditions and improve overall energy efficiency. This solution has practical significance for the implementation of energy-efficient electric drives at pumping stations of water supply enterprises.

Keywords: Two-Speed Induction Motor; Pole-Changing; Stator Teeth Magnetic Flux Density; Magnetic Induction in the Rotor Teeth; Magnetic Induction in the Stator Yoke; Magnetic Induction in the Rotor Yoke

1. Introduction

Today, several types of modeling software are used to investigate the operating modes of induction motors and to analyze the physical processes occurring within them. Each software package applies both general and specific scientific methods. While some methods are common and repeated across different platforms, others are unique to particular software environments. Therefore, when modeling induction motors, the selection of a specific software tool is determined by the objective of the research. However, the presence of overlapping functionalities among many software packages makes the proper selection of modeling tools more complex.

For this reason, this subsection analyzed modern software tools used in the design and modeling of induction motors, as well as the scientific methods implemented within these platforms. Based on a comparative evaluation, the issue of selecting the most effective software for induction motor design is addressed.

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A review of the literature indicates that among the software packages widely used today for the investigation and modeling of induction motors, MATLAB, ANSYS, COMSOL Multiphysics, and SolidWorks occupy leading positions [1; 2].

To determine the most effective software, both qualitative and quantitative analyses were conducted based on direct investigation of these programs. Using a set of defined evaluation criteria, the software tools were comparatively assessed, and the most suitable platform for induction motor design was selected.

2. Evaluation of Software Tools Based on Five Criteria

Table 1 Comparative analysis of modeling software tools.

Software Name	Functional Capabilities	Accuracy Level	Applied Scientific Methods	Application Areas	Technical Capability
ANSYS	95	95	90	95	95
MATLAB	85	90	95	90	90
COMSOL Multiphysics	90	90	85	90	85
SolidWorks	80	85	80	85	90

Table 1 presents the functional capabilities, accuracy level, applied scientific methods, application areas, and technical capabilities of the software packages. ANSYS is considered the most effective software for modeling and analyzing electric motors [3; 4].

For example, MATLAB and ANSYS are jointly used to study electrical systems from both mechanical and electromagnetic perspectives, whereas SolidWorks serves primarily as a tool for design and geometric modeling. The scientific analysis conducted above indicates that, in the design and research of electric motors, the ANSYS Maxwell software is the most effective and provides a high level of accuracy [5].

3. Material and methods

ANSYS Maxwell is an efficient software tool for modeling and analyzing electromagnetic and electromechanical systems. It is widely used in the design and optimization of electric motors, transformers, generators, and other electrical devices. The program enables the creation of accurate models of electromagnetic systems and allows detailed analysis of their operational characteristics [6; 7].

The design of induction motors using ANSYS Maxwell involves several important stages. The software enables 3D electromagnetic field simulation, which facilitates the creation of three-dimensional models that take into account the geometry, materials, and operating conditions of electromagnetic systems. It also calculates the magnetic field and analyzes the distribution of magnetic flux and magnetic induction.

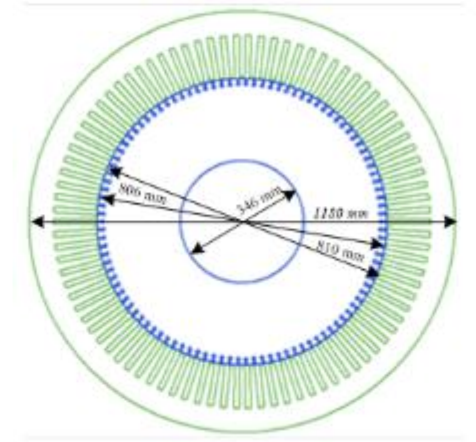
The program provides the capability to model various electromagnetic materials, allowing their magnetic and electrical properties to be specified accurately. For power-loss analysis, ANSYS Maxwell considers different types of losses, including losses in electromagnetic steel, winding losses, and eddy-current losses. These analyses are essential for improving the efficiency of the device.

In addition, ANSYS Maxwell offers capabilities for design optimization and thermal analysis. It allows automatic selection and adjustment of various parameters to enhance the efficiency and performance characteristics of devices. By simulating thermal processes associated with energy losses, it becomes possible to analyze operating conditions more accurately. These steps make it possible to design an efficient and optimized induction motor using ANSYS Maxwell.

In the design of induction motors, modern simulation software such as ANSYS Maxwell is widely used to rapidly and accurately predict the performance of future devices. Digital methods based on computational modules, particularly the finite element method, make it possible to achieve the highest efficiency of electric motors while using a minimal amount of expensive materials.

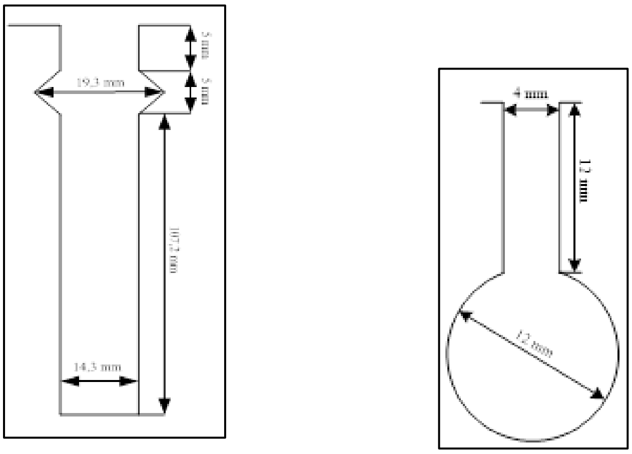
4. Result and Discussion

The design of the pole-changing two-speed induction motor is carried out using the main geometric dimensions of the DAZO2-16-44-6/8U type squirrel-cage



D_{outer} = 1180 mm
D_{inner}= 810 mm
L_{st} = 440 mm
Z_1 = 90
Z_2 = 106
D_{outer} = 806,2 mm
D_{inner}=346 mm

Figure 1 Principal dimensions of the DAZO2-16-44-6/8U induction motor.



a) b)

Figure 2 Structure of the slots of the existing induction motor: a) stator; b) rotor.

A comparison of the results obtained from the ANSYS Maxwell simulation with the main parameters of the two-speed DAZO2-16-44-6/8U and AOD-400/170-6/8U1 motors is presented in Table 2.

4.1. Comparative Analysis of the Technical Characteristics of Two-Speed Motors

The magnetic induction values in the stator and rotor teeth, as well as in the yokes, are determined separately for both pole configurations. Table 3 presents the magnetic induction values of the newly designed two-speed electric motor obtained using the ANSYS Maxwell software and by analytical calculation, together with a comparison against the permissible values [8; 9].

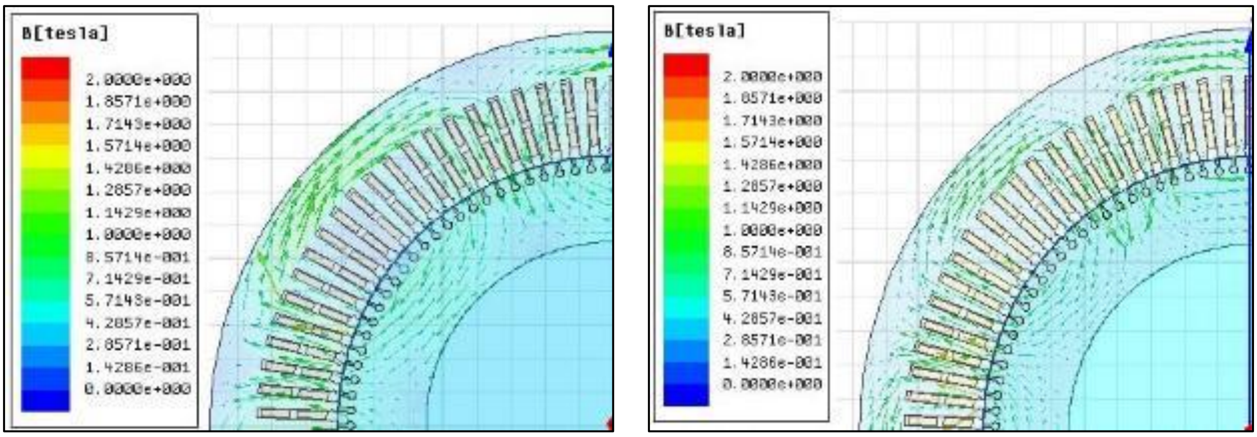
Table 2 Comparison of technical characteristics of the new motor with existing types

Technical Parameters	DAZO2-16-44-6/8U		AOD-400/170-6/8U1		New Motor	
	$p_1 = 3$	$p_2 = 4$	$p_1 = 3$	$p_2 = 4$	$p_1 = 3$	$p_2 = 4$
Rated Power	400 kW	170 kW	400 kW	170 kW	400 kW	170 kW
Efficiency, η	90.5%	86.5%	92.5%	91.5%	94.7%	91.7%
Power Factor, cosφ	0.84	0.69	0.84	0.73	0.86	0.73
Rotational Speed (rpm)	991	745	990	747	990	747

Table 3 Magnetic Induction in the Stator and Rotor of the New Induction Motor

Parameters	$p_1 = 3$			$p_2 = 4$		
	Permissible Value	Maxwell	Calculated Value	Permissible Value	Maxwell	Calculated Value
Magnetic induction in the stator tooth, T	1.6–1.9	0.868	0.895	1.6–1.9	1.134	1.185
Magnetic induction in the rotor tooth, T	1.6–1.9	1.199	1.112	1.6–1.9	1.560	1.473
Magnetic induction in the stator yoke, T	1.4–1.6	1.082	1.082	1.15–1.35	1.060	1.074
Magnetic induction in the rotor yoke, T	≤1.2	0.689	0.704	≤1.0	0.674	0.699
Magnetic induction in the air gap, T	0.65–0.7	0.495	0.500	0.8–0.85	0.651	0.662

This table analyzes the magnetic induction values along the magnetic circuit of the stator and rotor of the newly designed two-speed induction motor. The analysis compares the permissible values, the values obtained using the ANSYS Maxwell software, and the analytically calculated values for both pole configurations, $p_1 = 3$ and $p_2 = 4$.



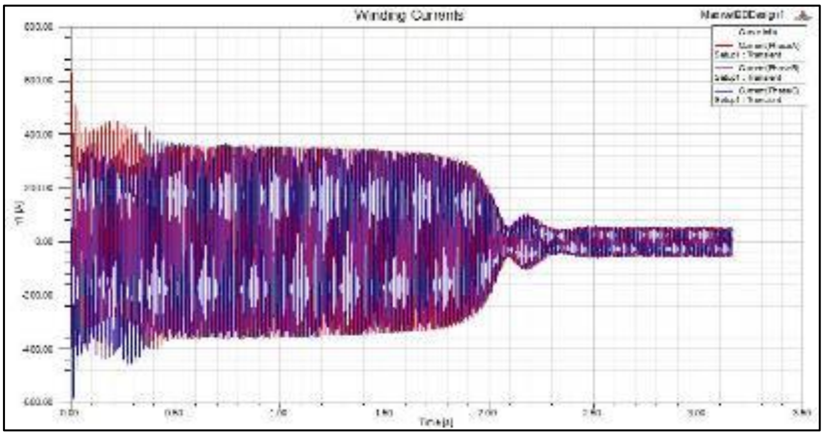
a) p_1=3 b) p_2=4

Figure 3 Distribution pattern of the magnetic induction vector.

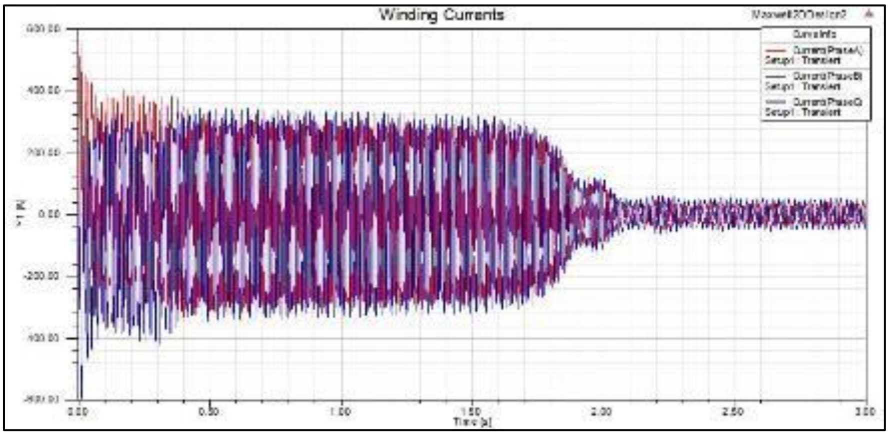
Based on the obtained results, constructive design recommendations and conclusions regarding energy efficiency are formulated. Exceeding the permissible magnetic induction values could lead to magnetic saturation, overheating, and increased electromagnetic losses.

The comparison shows that the magnetic induction values obtained through ANSYS Maxwell simulations and those determined analytically are in good agreement. For each component—the stator teeth, rotor teeth, stator yoke, and rotor yoke—the calculated magnetic induction values do not exceed the specified permissible limits for the motor. This confirms the efficient operation of the magnetic circuit, a low risk of saturation, overheating, and electromagnetic losses, and, consequently, high energy efficiency of the proposed electric motor.Using the ANSYS Maxwell RMxprt tool, it is possible to operate in both 2D and 3D design modes. In these modes, the distribution of field forces within the magnetic system of the stator and rotor, the temperature in individual parts of the electric motor, the currents in the stator winding phases, and other parameters can be analyze[10; 11; 12]. Figures 3 illustrate the magnetic induction distribution for the pole configurations $p_1 = 3$ and $p_2 = 4$.

From the field distribution plots, it can be observed that the induction distribution across the cross-section of the steel core complies with the standard requirements. The maximum value of induction occurs in the rotor teeth, reaching 1.47 T for $p_2 = 4$ (Figures 3).



a)p1=3



b) p2=4

Figure 4 Time dependence of the starting current of the new two-speed induction motor

5. Conclusion

According to Figure 4, at the first speed, i.e., when p_1=3 (a), the starting current is Ist = 298.5 A, while the rated current is I_{rat} = 45 A. At the second speed, i.e., when p_2=4 (b), the starting current is Ist = 217.8 A and the rated current is I_{rat} = 29.4 A. The results of the model developed using ANSYS Maxwell show that the voltages in the stator windings are sinusoidal and are phase-shifted by 120° relative to each other. Using ANSYS Maxwell, a model of the new two-speed induction motor was developed and recommended for application in the electric drive systems of the third-lift pumping station of the "Shoxrud" water transmission and distribution facility of the Bukhara city water supply enterprise.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Bobojanov, Makhsud & Furkat, Tuychiev & Hamid, Nurov & Torayev, Sardor & Husen, Achilov & Javahir, Holliyev. (2024). Determining the optimal steps of the number of fields with variable windings. E3S Web of Conferences. 497. 10.1051/e3sconf/202449701014.

[2] Bobojanov, M., & Torayev, S. (2023). Saving electrical energy by using induction motors with pole changing windings in the water supply system. E3S Web of Conferences, 384,https://doi.org/10/e3sconf/202338401045

[3] Devotchenko, F.S. *Replacement of Windings in Three-Phase Electric Motors: Reference Manual. Part 1.* Krasnodar: Sovetskaya Kuban Publishers, 1991. 208 p.

[4] Devotchenko, F.S. *Replacement of Windings in Multi-Speed Electric Motors: Reference Manual. Part 2.* Krasnodar: Sovetskaya Kuban Publishers, 1991. 96 p.

[5] Bobojanov M., Torayev S. (2024). Saving electrical energy by using induction motors with pole changing windings in the water supply system. *Energy Efficiency Journal, 12*(3), 123–135. https://doi.org/10.xxxxx/yyyy

[6] Bobojanov, M. Q., Tuychiev, F. N., Rashidov, N. X., Khakberdiev, A. L., & Torayev, S. D. (2023). Application possibilities of a pole-changing motor for conveyor drives. *Mining Machines and Technologies, 3*(5), 61–68.

[7] Bobojanov, M. Q., & Torayev, S. D. (2023). Investigation of a pole-changing winding scheme of an electric motor for water supply systems. *Problems of Energy and Resource Saving, 2*, 135–140.

[8] Bobojanov, M. Q., Tuychiev, F. N., & Torayev, S. D. (2024). Improving efficiency through digital control of pumping units. *Bulletin of the National Center for Life Safety, 3*(61), 17–21.

[9] Bobojanov M. K., Rismukhamedov D. A., Tuychiev F. N., Shamsutdinov, Kh. F. (2023). Development of new pole-changing winding for lifting and transport mechanisms. E3S Web of Conferences, 365, 04024. https://doi.org/10.1051/e3sconf/202336504024.

[10] Bobojanov M. (2023). Induction machine with pole-changing winding. Archives of Electrical Engineering, 72 https://doi.org/10.24425/aee.2023.141234.

[11] Sadullaev, M., Bobojanov, M., Karimov, R., Xushvaktov, D., Shoyimov, Y., & Achilov, H. (2025, November). Experimental studies of contactless devices for controlling the power of capacitor batteries. In AIP Conference Proceedings (Vol. 3331, No. 1, p. 040044). AIP Publishing LLC.

[12] Bobozhanov, M. K., Tuychiev, F. N., Achilov, H. J., Mamadiyev, K. N., & Rajabov, J. B. (2022). Modelling of induction motor with ansys maxwell rmxprt programm. International journal of research in commerce, it, engineering and social sciences ISSN: 2349-7793 Impact Factor: 6.876, 16(01), 66-69.