Rev. Roum. Sci. Techn.– Électrotechn. et Énerg.
Vol. **71**, *4*, pp. 501–506, Bucarest, 2026

IDENTIFICATION OF SEPARATELY EXCITED DC MOTOR PARAMETERS USING AN AUTOMATED PASEK METHOD

RABAH ROUAS[1], MADJID SI BRAHIM[2], SALAH HADDAD[3]

Keywords: Parameter identification; Separately excited DC machine; Graphical Pasek method; Automated Pasek method.

This article addresses the identification of the parameters of a separately excited DC machine using the Pasek method, which has been modified to make the identification procedure fully automated. Pasek proposed an experimental procedure followed by an identification process that enables the determination, from a single test, of five parameters of a separately excited DC machine under certain simplifying assumptions. The Pasek method significantly reduces the time required for parameter identification; however, it includes a graphical step that requires human intervention and may be subject to measurement errors. In this article, we propose an automated approach that eliminates the graphical step by replacing it with computer-based data processing, thereby further reducing the identification time and making the overall procedure fully automated. The proposed procedure is experimentally implemented, and its results are compared with those of the classical identification method.

1. INTRODUCTION

Separately excited DC machines play a key role in many industrial and robotic electric drive systems due to their linear torque-speed characteristic and the possibility of independently controlling the field flux and the armature current [1]. Their effective control relies on accurate modeling of the electromechanical parameters, including the armature and field resistances and inductances, the torque and electromotive force constants, the rotor inertia, as well as the mechanical loss and friction coefficients. Accurate estimation of these parameters is essential not only for simulation and dynamics analysis of the machine, but also for the implementation of advanced control strategies [2].

The identification of DC machine parameters has traditionally relied on analytical methods combined with standard experimental tests, such as no-load, locked-rotor, and generator tests [1,3–6]. These techniques make it possible to separately determine the electrical and mechanical parameters from measurements of voltage, current, and speed under various operating conditions. Although robust in laboratory settings, they often assume ideal conditions and require multiple experimental tests, which limits their applicability in industrial or embedded environments. Conventional methods are sensitive to measurement errors and temperature variations, which may lead to significant deviations in the estimated parameters, thereby affecting the accuracy of the dynamic models used for control [3,5–7].

To overcome certain limitations of experimental methods, parametric techniques such as least mean squares (LMS) and their recursive variants (RLS) have been widely adopted [8]. These methods estimate parameters by minimizing the squared error between experimental measurements and the responses predicted by the model, thereby providing a trade-off between accuracy and computational simplicity. However, they exhibit limitations when dealing with highly noisy data or when the model is incomplete or poorly specified.

Research has shown that combining RLS with a physics-based approach enables online identification while ensuring the stability and robustness of the estimated parameters even in the presence of disturbances [8].

Several studies aim to improve the accuracy and speed of identification through direct analytical approaches.

A method based on inverse problem theory has been proposed, transforming parameter estimation into a regularized optimization problem that minimizes the discrepancy between the measurements and the model while ensuring stability [9]. Analytical techniques exploiting angular position responses to torque excitations (step or ramp inputs) have been developed to allow direct identification of inertia and friction coefficients. This approach avoids computationally intensive iterative calculations and has been experimentally validated in real time using Hardware-in-the-Loop (HIL) platforms [10]. These methods significantly reduce the number of required tests while ensuring satisfactory accuracy for modeling purposes.

The advent of numerical methods and metaheuristics has revolutionized the parameter identification of DC machines, facilitating the handling of nonlinear models and noisy measurements. A comparative study contrasted analytical and least-squares (LS/RLS) approaches with algorithms such as particle swarm optimization (PSO), genetic algorithms (GA), differential evolution (DE), and cuckoo search (CS) [4,11]. This work demonstrates that metaheuristics provide greater robustness to experimental disturbances compared with conventional methods. The dynamic regressor extension and mixing (DREM) method was introduced to optimize parameter convergence. This approach stabilizes the identification process by significantly reducing the fluctuations and oscillations often encountered with classical methods [12]. The use of the zebra optimization algorithm (ZOA) yields more accurate estimates and faster convergence than other metaheuristics. This approach is distinguished by its high robustness, remaining effective even in the presence of noisy experimental signals [13]. More recently, deep learning-based approaches, particularly artificial neural networks (ANN) and transformer-based models, have paved the way for sensorless estimation capable of modeling complex nonlinearities (saturation, hysteresis) that a classical second-order model cannot capture [14].

The integration of physical knowledge into learning through Physics-Informed Neural Networks (PINN) ensures that the identified parameters comply with Kirchhoff's laws and the electromechanical dynamics equations, even with limited training data [15,16].

Finally, the use of temporal attention mechanisms allows for the isolation of the most informative transient phases of

[1]Laboratory of Advanced Technologies in Electrical Engineering, University Mouloud Mammeri de Tizi Ouzou, Algeria.
E-mails: rabah.rouas@ummto.dz, madjid.sibrahim@ummto.dz, salah.haddad@ummto.dz

DOI: 10.59277/RRST-EE.2026.4.4

the current step, thereby outperforming classical filtering methods in highly noisy environments [17].

Taken together, these studies illustrate a clear progression in the identification of DC machine parameters: from classical analytical and experimental methods, through LS/RLS parametric techniques and advanced analytical approaches, to robust metaheuristics and adaptive methods.

In this context, Pasek's method stands out for its ability to estimate the electrical and mechanical parameters of a separately excited DC machine from a single dynamic test [18,19], thereby reducing the number of experimental tests and providing useful information for modeling, control, and regulation, where parameter identification enables the proper tuning of controllers [5,20,21]. The graphical Pasek's method is particularly attractive due to its simplicity, ease of experimental implementation, and intuitive analytical approach, enabling a practical identification of the machine parameters [22]. In its traditional implementation, the method includes a graphical stage in which key quantities are determined from the experimental curve using graphical charts [18,23–25]. This stage requires manual intervention and may introduce reading errors and affect the repeatability of the identification process [26].

In this article, we propose automating the parameter extraction and calculation stages of Pasek's procedure. The developed program requires only the recorded armature-current transient and two values (initial and final) of the rotational speed as inputs. The characteristic quantities are extracted numerically from the experimental data, while the graphical calculations are replaced by numerical procedures. This automation improves repeatability and reduces the identification time by eliminating manual determination of the characteristic quantities and graphical reading of the Pasek nomograms. The proposed approach therefore provides a practical and efficient alternative to conventional identification procedures while preserving the underlying principle of Pasek's method.

To carry out this study, the paper is organized as follows: Section two represents the theoretical foundations and the operational procedure of the classical Pasek's method. Section three describes the development of the automation scheme leading to a new, fully automated version of Pasek's approach. Section four outlines the experimental setup and the implementation of the automated method. The results are then compared with machine parameters used as reference values, derived from a classical identification method. Finally, the results are discussed in depth, and the paper concludes with a synthesis of the main contributions and perspectives of the study.

2. THEORETICAL FOUNDATIONS OF THE PASEK'S IDENTIFICATION METHOD AND PROCEDURE

The identification method assumes that the excitation current and the load torque remain constant during the identification test. The motor is initially operating at steady speed before the armature-voltage step increase is applied. According to the classical Pasek's model, the friction torque is neglected. However, the automation procedure developed in this work is not intrinsically restricted to the friction-free case and can also be applied when a dynamic viscous friction term is included in the mechanical model.

2.1 THEORETICAL FOUNDATIONS OF PASEK'S METHOD

The model of the separately excited DC machine, under the assumptions stated above, is expressed as follows:

$$V_a = K_m\omega_r + R_a i_a + L_a\frac{\mathrm{d}i_a}{\mathrm{d}t}, \tag{1}$$

$$K_m i_a - C_L = \mathrm{J}\frac{\mathrm{d}\omega_r}{\mathrm{d}t}. \tag{2}$$

The parameters to be identified are the armature resistance R_a and the armature self-inductance L_a, the moment of inertia J, and the torque coefficient K_m.

The model of the separately excited DC machine, expressed in terms of small variations of the variables in the frequency domain, is rewritten as follows:

$$\Delta V_a(p) = K_m\Delta\omega_r(p) + (R_a + L_a p)\Delta i_a(p), \tag{3}$$

$$K_m\Delta i_a(p) = \mathrm{J}p\Delta\omega_r(p). \tag{4}$$

If the variation in armature voltage is a step input of amplitude E, the solutions in the frequency domain are given by:

$$\Delta i_a(p) = \frac{E}{L_a}\frac{1}{p^2 + \frac{1}{T_e}p + \frac{1}{T_e T_{em}}}, \tag{5}$$

$$\Delta\omega_r(p) = \frac{K_m E}{\mathrm{J}L_a}\frac{1}{p\left(p^2 + \frac{1}{T_e}p + \frac{1}{T_e T_{em}}\right)}. \tag{6}$$

Given that $T_e=L_a/R_a$ is the electrical time constant, $T_{em}=\mathrm{J}R_a/K_m^2$ is the electromechanical time constant, and setting $T_{em} = \lambda T_e$, eq. (5) and (6) become:

$$\Delta i_a(p) = \frac{E}{L_a}\frac{1}{\left(p + \frac{1}{T_1}\right)\left(p + \frac{1}{T_2}\right)}, \tag{7}$$

$$\Delta\omega_r(p) = \frac{K_m E}{JL_a}\frac{1}{p\left(p + \frac{1}{T_1}\right)\left(p + \frac{1}{T_2}\right)}. \tag{9}$$

with $T_1 = \frac{2T_e}{1+\alpha}$, $T_2 = \frac{2T_e}{1-\alpha}$, $\alpha = \sqrt{1-\frac{4}{\lambda}}$, where $\lambda > 4$.

Applying the inverse Laplace transform to eq. (7) and (8), the corresponding solutions in the time domain are:

$$\Delta i_a(t) = \frac{E}{\alpha R_a}\left(e^{-\frac{t}{T_2}} - e^{-\frac{t}{T_1}}\right), \tag{9}$$

$$\Delta\omega_r(t) = \frac{E}{K_m}\left(1 - \frac{T_1 e^{-\frac{t}{T_1}} - T_2 e^{-\frac{t}{T_2}}}{T_2 - T_1}\right). \tag{10}$$

Considering eq. (9), we observe that the initial and final values of the variation of the armature current $\Delta i_a(t)$ are zero, which suggests that $\Delta i_a(t)$ reaches a maximum. It can be shown that the time t_1 at which $\Delta i_a(t)$ reaches its maximum is given by

$$t_1 = \frac{T_e}{\alpha}\log\frac{1+\alpha}{1-\alpha}. \tag{11}$$

Let us express the quantity $\frac{t_1}{T_e}$ in terms of λ

$$\frac{t_1}{T_e} = \frac{\sqrt{\lambda}}{\sqrt{\lambda-4}}\mathrm{Log}\frac{\sqrt{\lambda}+\sqrt{\lambda-4}}{\sqrt{\lambda}-\sqrt{\lambda-4}}. \tag{12}$$

From eq. (9) and (11), it can also be shown that:

$$\delta = \frac{\Delta i_a(2t_1)}{\Delta i_a(t_1)} = \frac{\Delta i_a(t_1)}{\frac{E}{R_a}}. \tag{13}$$

The quantity δ can be expressed as a function of λ,

$$\delta = \sqrt{\lambda} e^{-\frac{\sqrt{\lambda}}{2\sqrt{\lambda-4}} \log \frac{\sqrt{\lambda}+\sqrt{\lambda-4}}{\sqrt{\lambda}+\sqrt{\lambda-4}}}. \quad (14)$$

Equations (12) and (14) show that two monograms can be constructed, providing, respectively, t_1/T_e and δ as functions of λ. Equations (12), (13), and (14) form the basis for implementing Pasek's identification procedure.

2.2 PROCEDURE OF THE GRAPHICAL PASEK IDENTIFICATION METHOD

Model parameter identification is based on a graphical analysis of the armature current step response. The chronological steps of the identification procedure are as follows:

1. Measure t_1, $\Delta i_a(t_1)$, and $\Delta i_a(2t_1)$ from the recorded experimental armature-current curve as a function of time.
2. Calculate the $\delta = \frac{\Delta i_a(2t_1)}{\Delta i_a(t_1)}$.
3. Calculate the armature resistance $R_a = E\frac{\Delta i_a(2t_1)}{\Delta i_a(t_1)^2}$, knowing the value of E.
4. Extract from the second chart of Fig. 1, the value λ corresponding to the value of δ calculated in step 2.
5. Extract from the first chart of Fig. 1 the value of t_1/T_e corresponding to the value of λ obtained in step 4.
6. Calculate the electrical time constant T_e, knowing the values of t_1 and t_1/T_e.
7. Calculate the armature self-inductance $L_a=T_eR_a$, knowing T_e and R_a.
8. Calculate the electromechanical time constant $T_{em}=\lambda T_e$, knowing λ and T_e.
9. Calculate the torque constant $K_m = \frac{E}{\Delta\omega_r}$, where $\Delta\omega_r = \omega_{r2} - \omega_{r1}$. Given that ω_{r1} and ω_{r2} are the values of the rotational speed before and after the application of the armature voltage step, respectively.
10. Calculate the inertia of the rotating masses $J = \frac{T_{em}K_m^2}{R_a}$.

Figure 1 shows the two monograms $t_1/T_e(\lambda)$ and δ(λ) derived from eq. (12) and (14) respectively.

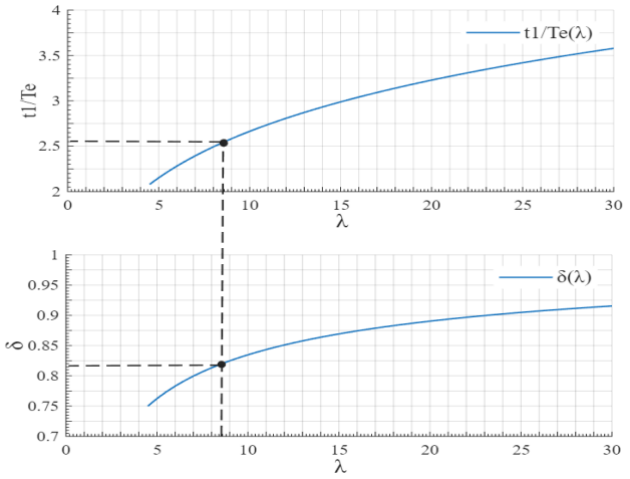


Fig. 1 – Variation of δ and $\frac{t_1}{T_e}$ as a function of λ.

3. PROCEDURE OF THE AUTOMATED PASEK IDENTIFICATION PROCEDURE

The principle behind the automation of the Pasek procedure is based on replacing graphical readings from charts with programmed procedures. In other words, replace steps 1, 4, and 5 of the graphical Pasek method with programmed procedures.

From the measurement taken with a storage oscilloscope connected to a PC, the armature current transient curve as a function of time is recorded in the form of two vectors representing time $t(s)$ and current $i_a(A)$, respectively.

A MATLAB script processes the two vectors t(s) and $i_a(A)$ and:

1. Determine the maximum value of armature current variation, namely $\Delta i_a(t_1)$, while simultaneously determining t_1 and $\Delta i_a(2t_1)$.
2. Calculate $\delta^* = \frac{\Delta i_a(2t_1)}{\Delta i_a(t_1)}$
3. Calculate the armature resistance using the equation: $R_a = E\frac{\Delta i_a(2t_1)}{\Delta i_a(t_1)^2}$, knowing the value of E.
4. Determine the value of λ corresponding to the computed value of δ^* in step 2. Two approaches are possible: find the inverse of eq. (14) or numerically solve the equation $\delta(\lambda) - \delta^* = 0$. These two approaches are explained below.
5. Calculate $\frac{t_1}{T_e} = \frac{\sqrt{\lambda}}{\sqrt{\lambda-4}} \log \frac{\sqrt{\lambda}+\sqrt{\lambda-4}}{\sqrt{\lambda}-\sqrt{\lambda-4}}$, knowing the value of λ from step 4.
6. Calculate the electrical time constant T_e, knowing the values of t_1 and t_1/T_e.
7. Calculate the armature self-inductance L_a using the equation $L_a=T_eR_a$, knowing T_e and R_a.
8. Calculate the electromechanical time constant using the equation: $T_{em}=\lambda T_e$, knowing λ and T_e.
9. Calculate the torque constant $K_m = \frac{E}{\Delta\omega_r}$, where $\Delta\omega_r = \omega_{r2} - \omega_{r1}$. Given that ω_{r1} and ω_{r2} are the values of the rotational speed before and after the application of the armature voltage step, respectively.
10. Calculate the inertia of the rotating masses $J = \frac{T_{em}K_m^2}{R_a}$.

4. CALCULATION APPROACHES FOR λ

4.1 THE INVERSE FUNCTION

The first approach consists of analytically inverting equation (14), but its highly nonlinear nature makes obtaining an exact expression difficult, if not impossible. To overcome this difficulty, the "polyfit" function of MATLAB software is used to find an approximation using polynomial interpolation. After using MATLAB's "polyfit" function, the inverse function λ(δ) is given by

$$\lambda(\delta) = 10^7\left(C_0 + C_1\delta + C_2\delta^2 + C_3\delta^3 + C_4\delta^4 + C_5\delta^5 + C_6\delta^6\right),$$

where: $C_0 = 0.00753$, $C_1 = -0.5575$, $C_2 = 1.7182$, $C_3 = -2.8243$, $C_4 = 2.6115$, $C_5 = -1.2880$, $C_6 = 0.2648$.

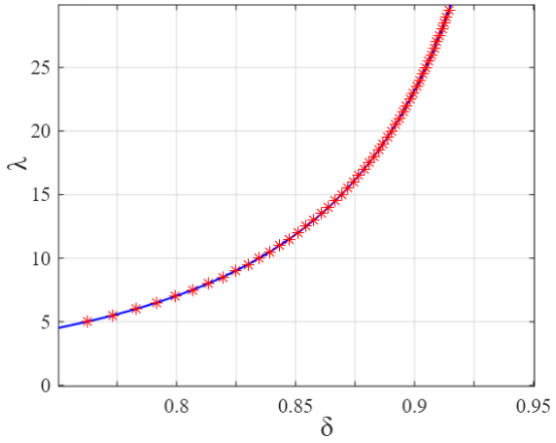


Fig. 2 – Variation of λ as a function of δ and its approximation by a 6th-order polynomial.

Figure 2 shows the inverse function λ(δ) and its polynomial approximation.

4.2 NUMERICAL SOLUTION

Another alternative is to numerically solve the equation: $\delta(\lambda) - \delta^* = 0$ rather than finding an inverse function of δ. This involves finding the specific value of λ corresponding to the computed value of δ. Several numerical methods can be used to find the root of the equation: $\delta(\lambda) - \delta^* = 0$; among them, the bisection method is adopted in this work.

5. EXPERIMENTAL IMPLEMENTATION OF THE PASEK METHOD

To identify the parameters of the DC machine, a specialized test bench was developed, the configuration of which is shown in the schematic diagram of Fig. 3.

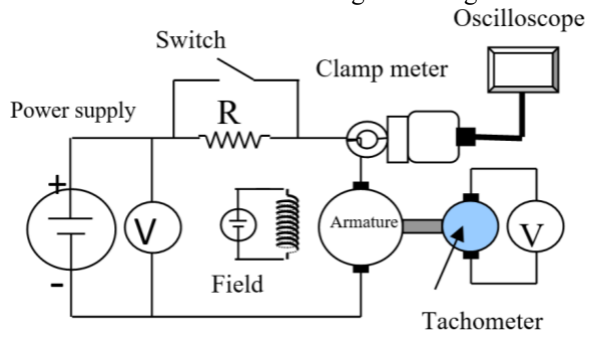


Fig. 3 – Schematic diagram of the experimental test bench for Pasek method.

The machine is first excited by supplying its field winding with a DC voltage source and is started by supplying its armature circuit with a second DC voltage source through a tapped variable starting resistor R. Once the machine reaches its steady-state speed, the starting resistor R is short-circuited, thereby causing a step increase in the armature voltage.

The resistor R is sized so that the amplitude of the step change in armature voltage is sufficient to obtain a usable current waveform. The evolution of the armature current is recorded on a storage oscilloscope, and the two values of rotational speed are measured before and after short-circuiting the resistor R.

Figure 4 presents a photograph of the experimental test bench used for the implementation and validation of the Pasek automated method, including the DC motor, measurement instruments, data acquisition system, and power supply unit.

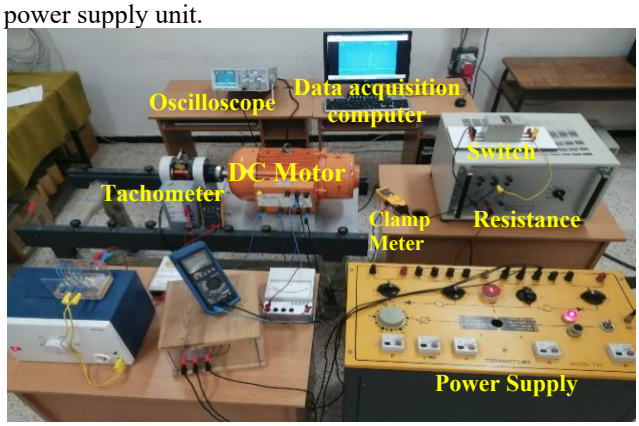


Fig. 4 – Experimental test bench for the Pasek method.

The experiment was conducted by applying an 82 V step increase in the armature voltage.

The two values of the steady-state rotational speed measured before and after closing the switch are, respectively, 880 rpm and 1400 rpm. The variation in speed is then 520 rpm.

Figure 5 shows the experimental recording of the armature current. This figure presents the key results obtained after executing the automated Pasek's procedure.

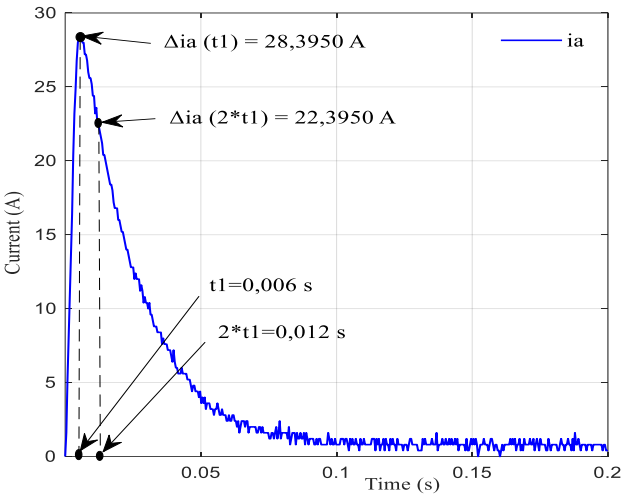


Fig. 5 – Experimental armature current i_a as a function of time.

6. RESULTS AND DISCUSSION

The identification of the DC machine parameters was carried out using the automated Pasek method proposed in this work. The experimental armature-current transient response was processed numerically in MATLAB in order to extract the characteristic quantities required by Pasek's identification procedure. The resulting values of the motor parameters were subsequently compared with those obtained using a classical identification method. In the latter, an experimental test is required for each parameter (L_a and R_a using the volt-ampere method, K_m using the open-circuit electromotive force characteristic as a function of rotational speed at a constant excitation current, and J using the deceleration test). The classical method is considered as a reference for assessing the accuracy of the proposed automated procedure.

Table 1

Characteristic quantities obtained by the automated Pasek's procedure.

Quantities	Value obtained by automated Pasek procedure	
t_1 (s)	0.006	
$\Delta i_a(t_1)$ (A)	28.395	
$\Delta i_a(2t_1)$ (A)	22.395	
T_e (s)	0.0026	
δ	0.788	
	Analytical Inversion	Bisection Method
λ	6.330	6.322

Table 1 summarizes the characteristic quantities automatically extracted from the experimental armature-current transient. The MATLAB-based procedure determines the current peak and its corresponding time t_1 directly from the sampled experimental data. The time $2t_1$ is calculated, and the corresponding value of the armature current $\Delta i_a(2t_1)$ is then automatically extracted. These quantities are subsequently used to calculate the electrical time constant T_e and the parameter δ required by the Pasek automated method.

The results demonstrate that the characteristic quantities required by the identification procedure can be obtained directly from the experimental data without manual extraction from the response curve. This eliminates the

subjectivity associated with graphical determination of the characteristic points and provides a reproducible numerical procedure.

The determination of λ, which is traditionally obtained from the graphical representation of the δ(λ) relationship, is also performed numerically in the proposed automated procedure. For this purpose, two numerical approaches are considered: polynomial approximation of the inverse relationship and numerical solution using the bisection method. As shown in Table 1, the two approaches produce very similar results. However, it should be noted that the inverse function method provides a result instantaneously, whereas the bisection method converges after 23 iterations. This agreement confirms the consistency of the numerical implementation and demonstrates that the graphical reading of Pasek's nomograms can be effectively replaced by an automated numerical calculation.

Table 2 presents the electromechanical parameters identified using the proposed automated Pasek method and those obtained using the classical identification method.

Table 2

Comparison of the parameters identified by the classical method and the automated Pasek method.

Parameters	Classical method	Automated Pasek method	
		Analytical Inversion	Bisection Method
Armature Resistance R_a [Ω]	2,274	2,277	2.277
Armature Inductance L_a [H]	0,0059	0,0058	0.0058
Electromagnetic Torque Constant K_m [N·m·A^{-1}]	1,50	1,50	1.50
Total Moment of Inertia J [kg·m²]	0,016	0,0163	0.0162

The results presented in Table 2 show a close agreement between the parameters identified using the automated Pasek method and those obtained using the classical identification method.

The armature resistance is estimated as 2.277 Ω by the automated procedure, compared with 2.274 Ω obtained using the classical method. For the armature inductance, the automated procedure gives 0.0058 H, while the classical method gives 0.0059 H. Similarly, the electromagnetic torque constant is estimated at 1.50 N·m·A−1 by both methods. The moment of inertia is evaluated at 0.0162 kg·m2 and 0.0163 kg·m2 using the inverse function method and the bisection method, respectively, compared with 0.016 kg·m2 obtained from the classical identification.

These results support the validity and reproducibility of the proposed automated Pasek's identification procedure. The close agreement with the classical reference method demonstrates that the proposed numerical implementation can reliably determine the electromechanical parameters of the separately excited DC motor while avoiding the manual determination of the characteristic quantities required in the graphical procedure.

7. **CONCLUSION**

This study focused on the automation of the Pasek method for identifying the electromechanical parameters of a separately excited DC machine, with the primary objective of eliminating the subjectivity associated with the graphical determination of the characteristic quantities. This objective was achieved through the development of a numerical procedure that automatically extracts the characteristic quantities from the experimental armature-current transient and replaces the manual graphical determination of the characteristic quantities required by the Pasek method with numerical calculations. We implemented polynomial interpolation and the bisection method to numerically determine the parameter λ, yielding consistent results.

The identified parameters were validated by comparison with a classical identification method based on independent experimental tests. The close agreement obtained for the armature resistance, armature inductance, electromagnetic torque constant, and total moment of inertia demonstrates the reliability of the proposed automated procedure. The relative differences between the automated and classical methods remained below 2%, confirming the good consistency of the proposed numerical implementation with the reference identification results.

More broadly, this work demonstrates the potential of numerical tools for automating traditional analytical identification methods. By eliminating manual determination of the characteristic quantities and graphical reading of Pasek's nomograms, the proposed procedure improves the repeatability and practicality of the identification process while preserving the underlying principle of the Pasek method. This approach offers promising prospects for the implementation of automated parameter identification procedures in applications such as the commissioning and self-tuning of industrial variable-speed drives. The proposed automation principle can also be extended to motor models incorporating additional mechanical effects, including dynamic viscous friction. The development and experimental validation of such an extended model constitute a promising direction for future work.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Laboratory of Advanced Technologies in Electrical Engineering (LATAGE).

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Rabah ROUAS: Programming, test bench implementation, results processing, writing.

Madjid Si BRAHIM: test bench implementation, results acquisition, writing.

Salah HADDAD: supervision, review, test bench design.

ANNEXE

Table 3

Nominal characteristics of a separately excited DC motor.

Parameters	Value
Rated output power, P_{mec} [kW]	3
Rated rotational speed, n [rpm]	1500
Field rated voltage, U_f [V]	120
Field rated electrical current strength, I_f [A]	1,33
Armature rated voltage V_a [V]	220
Armature rated current I_a [A]	16

SYMBOLS AND ABBREVIATIONS

V_a: armature voltage
C_L: load torque
i_a : armature current
ω_r: rotor angular speed
R_a: armature resistance
L_a: armature self-inductance

J: total moment of inertia referred to the rotor
K_m: electromagnetic torque constant
T_e: electrical time constant
T_{em}: electromechanical time constant
t_1: time corresponding to the maximum current.

Received on 26 April 2026

REFERENCES

1. M. Kuczmann, "Review of DC motor modeling and linear control: theory with laboratory tests," Electronics, **13**, *11*, Art. no. 2225 (2024).
2. R. Belal, M. Flitti, M.L. Zegai, "Tuning of PI speed controller in direct torque control of dual star induction motor based on genetic algorithms and neuro-fuzzy schemes," Rev. Roum. Sci. Techn. – Électrotechn. et Énerg., **69**, *1*, pp. 9–14 (2024).
3. D.I. Völlmecke, "Parameter identification of DC motors," Technical report, IMC Berlin (2013).
4. M.F. Fazdi, P.-W. Hsueh, "Parameter identification of a permanent magnet DC motor: a review," Electronics, **12**, *12*, Art. no. 2559 (2023).
5. S.S. Saab, R. Abi Kaed-Bey, "Parameter identification of a DC motor: an experimental approach," Proc. 8th IEEE Int. Conf. Electronics, Circuits and Systems (ICECS), **2**, pp. 981–984 (2001).
6. G.Á. Szíki, A. Szántó, É. Csernusné Ádámkó, "Review of methods for determining the moment of inertia and friction torque of electric motors," Acta Polytech. Hung., **21**, *4*, pp. 203–218 (2024).
7. C.O. Gökçe, M.E. İpek, M. Dayıoğlu, R. Ünal, "Parameter estimation and speed control of a real DC motor with a low-resolution encoder," Results Control Optim., **19**, Art. no. 100549 (2025).
8. R. Majdoubi, L. Masmoudi, M. Bakhti, A. Elharif, B. Jabri, "Parameter estimation of BLDC motor based on physical approach and weighted recursive least squares algorithm," Int. J. Electrical and Computer Engineering, **11**, *1*, pp. 133–145 (2021).
9. M. Hadef, M.R. Mekideche, "Parameter identification of a separately excited DC motor via inverse problem methodology," Turkish J. Electr. Eng. Comput. Sci., **17**, *2*, pp. 99–106 (2009).
10. J.A. Cardona Soto, I.U. Ponce, I. Soto, M.A. García, G. Mejía, "Identification of dynamic parameters in a DC motor using step and ramp torque response methods," Sensors, **26**, *1*, Art. no. 78 (2025).
11. N. Khac Tung, S.M. Vlasov, "Algorithm for identification of DC motor parameters by method of dynamic expansion of regressor and mixing," J. Sci. Tech. Inf. Technol., Mech. Opt., **21**, *1*, pp. 130–134 (2021).
12. A. Sebhi, A.C. Megherbi, A. Dendouga, A. Zitouni, "Identification of DC motor parameters using the ZOA metaheuristic algorithm with comparative study," J. Electr. Eng. Renew. Energy Dev., **1**, *1*, pp. 1–8 (2025).
13. K.H. Chao, K.H. Huang, Y.H. Guo, "Design of a brushless DC motor drive system controller integrating the Zebra Optimization Algorithm and sliding mode theory," Electronics, **14**, *17*, Art. no. 3353 (2025).
14. J.C. Gamazo-Real, V. Martínez-Martínez, J. Gomez-Gil, "ANN-based position and speed sensorless estimation for BLDC motors," Measurement, **188**, Art. no. 110602 (2022).
15. M. Raissi, P. Perdikaris, G.E. Karniadakis, "Physics-informed neural networks: a deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations," J. Comput. Phys., **378**, pp. 686–707 (2019).
16. J. Stiasny, G.S. Misyris, S. Chatzivasileiadis, "Physics-informed neural networks for non-linear system identification for power system dynamics," Proc. 2021 IEEE Madrid PowerTech, Madrid, Spain, pp. 1–6 (2021).
17. S. Ayankoso, P. Olejnik, "Time-series machine learning techniques for modeling and identification of mechatronic systems with friction: a review and real application," Electronics, **12**, *17*, Art. no. 3669 (2023).
18. Z. Pásek, "Nový způsob určení základních dynamických parametrů stejnosměrného motoru" ["A new method for determining the basic dynamic parameters of a DC motor"] (in Czech), Elektrotechnický Obzor, **51**, pp. 109–114. https://fliphtml5.com/xgdg/ihme/Elektrotechnick%C3%BD_obzor_1958_-_1969/ (1962).
19. H.A. Toliyat, G.B. Kliman, "Handbook of electric motors," 2nd ed., CRC Press (2018).
20. K.J. Åström, T. Hägglund, "Advanced PID control," ISA – The Instrumentation, Systems, and Automation Society. https://www.semanticscholar.org/paper/Advanced-PID-Control-%C3%85str%C3%B6m-Hagglund/be4405ec46a026a6f602a260765d794a55f0b951 (2006).
21. J.G. Ziegler, N.B. Nichols, "Optimum settings for automatic controllers," Trans. ASME, **64**, *8*, pp. 759–765 (1942).
22. A. Batool, N. ul Ain, A.A. Amin, M. Adnan, M.H. Shahbaz, "A comparative study of DC servo motor parameter estimation using various techniques," Automatika, **63**, *2*, pp. 303–312 (2022).
23. S.P. Perumalsamy, V. Narayanasamy, K.P. Arunachalam, P. Balasubramanian, "Evaluation for thermal analysis of DC motors in electric vehicles," Rev. Roum. Sci. Techn. – Électrotechn. et Énerg., **71**, *1*, pp. 151–156 (2026).
24. M.M. Rădulescu, A.A. Pop, "Experimental determination of linear dynamic model parameters of the separately excited brushed DC motor by modified Pásek's method," Rev. Roum. Sci. Techn. – Électrotechn. et Énerg., **67**, *3*, pp. 271–274 (2022).
25. M.M. Rădulescu, "Transient processes in classical rotating electric machines I" (in Romanian), Casa Cărții de Știință (Science Book Publishing House), Cluj-Napoca, pp. 475–480 (2022).
26. M. Jesenik, M. Ravber, M. Trbušić, "Innovative approach for the determination of a DC motor's and drive's parameters using evolutionary methods and different measured current and angular speed responses," Mathematics, **12**, *1*, Art. no. 42 (2023).