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The Effect of Physical Parameters on the Transient and Steady-State Response of DC Motor Type Moog BN12HS-13AF-01 and Single-Phase AC Motor Type Simtach AC120M-11J30A

Davina Amani Fatihah[1]

[1] **Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Surabaya, Indonesia**

ABSTRACT

A core challenge in electromechanical control systems involves grasping how the physical characteristics of electric motors affect their dynamic behavior, especially in transient and steady-state scenarios. Factors like resistance, inductance, moment of inertia, and torque constant are essential in defining motor performance regarding speed, acceleration, and stability. This research intends to examine the impact of essential physical factors on the transient and steady-state behavior of two types of motors: the DC motor Moog BN12HS-13AF-01 and the single-phase AC motor Simtach AC120M-11J30A. This research's main contribution is the mathematical modeling and numerical simulation of electromechanical systems utilizing actual datasheet specifications. It assesses the time-domain reaction of each motor system to step input signals. The research contrasts open-loop and closed-loop scenarios for the DC motor with PID control and creates a simplified first-order model for the AC motor that accurately depicts its physical characteristics. The approach includes using Laplace transform to represent the continuous-time domain and Z-transform for digital discretization, ensuring compatibility with embedded digital control systems. Simulations utilize MATLAB/Simulink, and system performance is assessed through parameters like rise time, overshoot, settling time, and steady-state error. Findings indicate that parameters like the moment of inertia (J) and the damping coefficient (B) greatly influence the system response. The DC motor utilizing PID control in a closed-loop setup demonstrates significantly enhanced performance, featuring quicker response time and minimal steady-state error in comparison to its open-loop version. Conversely, the AC motor reacts more slowly and with less accuracy, yet maintains stability in uncomplicated scenarios. In summary, the physical traits of motors play a vital role in system performance, and choosing suitable parameters and control methods is crucial for attaining efficient, stable electromechanical systems.

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AUTHOR EMAIL

davinaamani@student.ppns.ac.id

1. INTRODUCTION

Contemporary electromechanical systems, encompassing industrial automation, robotics, and consumer electronics, require accurate regulation of motors. Attaining this level of accuracy greatly depends on comprehending how motors react dynamically to different inputs and environmental factors [5], [6]. The performance of a motor—during both transient and steady-state conditions—is greatly affected by its fundamental physical characteristics like armature resistance, inductance, moment of inertia, and friction coefficient [1], [2]. Nonetheless, because of the intricate characteristics of motor dynamics, forecasting motor performance without a strong mathematical model is typically not dependable [12], [18].

This research centers on two commonly utilized motor types: the DC motor Moog BN12HS-13AF-01 and the single-phase AC motor Simtach AC120M-11J30A. Both are frequently employed in applications that demand either precise positioning or economical speed regulation [14], [15]. Although commonly utilized, the direct influence of physical parameters on their dynamic behaviors—particularly the transient rise time, settling time, and steady-state error—has not been analyzed in a thorough comparative way. Therefore, a research study into how these physical factors influence motor responses is required.

Corresponding author: Davina Amani Fatihah, davinaamani@student.ppns.ac.id, Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Jl. Teknik Kimia, Kampus ITS, Keputih Sukolilo. Surabaya 60111, Indonesia
DOI: XXXX

Different methods have been created to examine and simulate motor systems. Some of the most recognized methods include mathematical modeling with differential equations, application of Laplace and Z-transforms, and computer simulations using MATLAB/SIMULINK [20]. For DC motors, equivalent circuit modeling and function transfer derivations are well-defined, offering a simple method to replicate responses [10], [12]. For single-phase AC motors, the modeling is more intricate because of the magnetic coupling and phase shift in the start and run winding.

Present practices encompass experimental system identification, implementation of PID controllers, and utilization of state-space representation for digital control techniques [3]. These techniques enable the execution of simulations for both open-loop and closed-loop reactions within regulated virtual settings. Nonetheless, although these techniques are effective, they frequently presume fixed or ideal parameters, overlooking how changes in resistance, inductance, or inertia directly impact motor performance in real-world scenarios [7].

While earlier research has provided mathematical models for DC and AC motors independently, there is still a gap in targeted analysis regarding the comparative effects of physical parameters on the response characteristics of the system [1]. Additionally, limited research combines both transient and steady-state analysis using actual manufacturer data from particular motor models. The exploration of how altering one parameter (e.g., increasing rotor inertia or inductance) quantitatively affects motor dynamics in simulation is also limited [11], [27]. This gap constrains the practical knowledge required for enhancing motor choice and control methods in real engineering applications.

This study presents an all-encompassing method that integrates traditional control theory with parameter sensitivity analysis based on simulation. The approach consists of: Ableitung mathematischer Modelle (elektrisch, mechanisch und elektromagnetisch) für jeden Motor basierend auf physikalischen Datenblättern und grundlegenden Gesetzen (Kirchhoffsches Gesetz, Newtonsches Gesetz, elektromagnetische Induktion) [5]. Converting these models into transfer functions through the Laplace transform. Executing simulations in MATLAB/SIMULINK for both open-loop and closed-loop systems. Performing studies on parameter variation (e.g., altering inertia, resistance) to examine their influence on time-domain responses like rise time, overshoot, settling time, and steady-state error [28]. This combined method of analytical derivation and numerical simulation enables thorough visualization of the influence of each parameter and assists in confirming theoretical predictions. This research reinforces the essential function of mathematical modeling in the design of control systems and confirms the importance of taking physical parameters into account when analyzing motor behavior [12].

2. MATERIALS AND METHOD

A. Dataset

This research is based on precisely modeling the physical and electrical characteristics of two kinds of electric motors: a DC motor (Moog BN12HS-13AF-01) and a single-phase AC motor (Simtach AC120M-11J30A). Achieving this necessitated a dependable and thorough dataset to provide the foundation for system identification, model development, and simulation evaluation.

This dataset was obtained from official manufacturer datasheets that offered verified and standardized details about the performance attributes of each motor. These datasheets are vital tools in engineering design, as they provide key numerical values obtained from factory testing and typical operating conditions. The retrieved information consists of factors that affect the electrical and mechanical behaviors of the motors. DC Motor – Moog BN12HS-13AF-01The Moog BN12HS-13AF-01 is a precise brushed DC motor frequently utilized in automation, motion control systems, and robotics. The parameters obtained from the datasheet and utilized in modeling consist of:

Table 1. Parameters of DC Motor – Moog BN12HS-13AF-01

Parameter	Symbol	Value	Unit
Armature Resistance	R_a	9.8	Ohms (Ω)
Armature Inductance	L_a	0.00034	Henry (H)
Torque Constant	K_t	0.0031	(Nm/A)
Back EMF Constant	K_e	0.0031	(V·s/rad)
Rotor Inertia	J	2×10^{-8}	(kg·m²)
Viscous Damping Coefficient	B	1.4815×10^{-6}	(Nm·s/rad)

These six factors constitute the foundation of the electromechanical model for the DC motor. The equations that dictate the motor's operation (both electrical and mechanical) are established according to these values and employed to determine the system's transfer function.

The Simtach AC120M-11J30A is a low-capacity induction motor frequently used in HVAC systems, conveyors, and various machinery. While the datasheet for this AC motor lacks the detailed parameters found in the DC motor, some essential data points were gathered and approximated, including:

- Voltage Rating: 220 V (AC)
- Frequent: 50 Hz
- Power Rating and Velocity: Utilized to calculate torque and moment of inertia.
- Count of Poles: Required for computing synchronous speed
- Estimated Inertia and Friction: Based on assumptions of load conditions and empirical models of motors [11], [14].

Given the intricacies of modeling single-phase AC motors, particularly regarding winding asymmetry and non-linear

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torque-speed characteristics, a simplified first-order model was employed. The estimates for rotor inertia and damping were derived from the motor's power rating and mechanical performance spectrum. These simplifications are permissible for general-purpose simulation of both transient and steady-state responses, especially in open-loop settings.

All parameter values were converted into SI units and validated using secondary literature and cross-referencing with comparable motors in academic studies. This guarantees that the dataset both mirrors manufacturer specifications and conforms to control systems modeling standards. Additionally, this dataset was utilized as input to create: Mathematical transfer functions within the Laplace domain, Discrete-time models through Z-transform, Simulink components for the simulation of both open-loop and closed-loop systems.

The validity of this dataset directly affects the precision of the simulations and the insights gained about the characteristics of system responses.

B. Data Collection

In engineering studies related to electromechanical systems, the precision and reliability of the data gathering process are essential for effective system modeling and simulation. This research utilized a systematic data collection approach that integrated secondary data extraction and analytical derivation, aiming to gather precise physical and electrical parameters essential for creating dependable models for the DC and AC motors under examination.

The main data source for the Moog BN12HS-13AF-01 DC motor and the Simtach AC120M-11J30A single-phase AC motor was the technical specifications released by each manufacturer. These datasheets are uniform documents that offer validated specifications obtained from laboratory-quality motor evaluations conducted under typical operating conditions [5], [22NXP]. The information was gathered from: Datasheets officially supplied by Moog and Simtach, Product listings, Technical resources utilized by professionals in electrical engineering

From these documents, a full set of both static and dynamic motor parameters was obtained. For the DC motor, this encompassed resistance and inductance of the armature, torque constant and back EMF coefficient, inertia of the rotor and viscous resistance. The AC motor datasheet included essential specifications like voltage, current, frequency, and rated speed, while mechanical parameters such as inertia and damping needed to be approximated through standard modeling assumptions and comparative analysis.

Since specific motor parameters, especially for the AC motor, were not explicitly stated in the datasheet, additional information was sourced from peer-reviewed articles, textbooks like “Modern Control Engineering” by Katsuhiko Ogata [5], and application notes from motor control toolkits (e.g., MATLAB documentation, NXP Motor Control Library) [3], [20a]. For instance, typical values for moment of inertia J and the damping constant B in small single-phase motors was sourced from empirical data tables and then modified according to the rated power and dimensions of the Simtach AC motor. Likewise, standard dynamic profiles of small industrial motors served as benchmarks to confirm the validity of the estimated values.

Due to the absence of complete experimental testing in this study's scope, specific assumptions were employed to finalize the dataset the two motors were represented as linear time-invariant (LTI) systems. Although actual motors can display saturation, nonlinear friction, and varying loads, this assumption makes the mathematical modeling and simulation easier while still offering valuable insights into both transient and steady-state behavior, no-load operation for response simulation: It was considered that both motors were functioning under a no-load scenario or with a steady nominal load. This enabled the application of classical transfer functions without requiring intricate modeling of torque-load interactions, Optimal control input: A step input was utilized for every simulation, symbolizing an ideal voltage application, to distinctly examine the time-domain behavior free from external disturbances or noise, Consistent environment: Factors like temperature, humidity, and voltage stability were treated as constant, according to the testing conditions outlined in the datasheet. These assumptions were required to ensure modeling feasibility and to concentrate the study on the impact of internal motor parameters instead of external uncertainties.

After gathering and estimating all required parameters, the data was organized into two modeling sections—one for each motor. Every block contained electrical and mechanical subcomponents to create a complete electromechanical depiction. The model for the DC motor was developed using: A circuit illustrating armature resistance and inductance, a mechanical subsystem that includes inertia, damping, and torque production, a rotor speed connected to a back EMF feedback loop.

For the AC motor, given the intricacies of asynchronous dynamics, a simplified first-order model was utilized through: A torque gain indicating the conversion of voltage to speed, a system with aggregated inertia and damping. The organized data was translated into equations for Laplace domain conversion and subsequently transformed into discrete-time models through Z-transform for simulation objectives.

Every parameter was recorded along with its unit, source (datasheet or derived), and any assumptions made during its estimation. This detailed method guaranteed traceability and reproducibility during both the modeling and simulation stages. Ultimately, the data gathering stage created a strong and verified basis for modeling electromechanical systems. By integrating confirmed datasheet data, estimations from literature, and organized assumptions, the research attained the

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necessary precision to model and evaluate how physical motor parameters impact system dynamics.

C. Data Processing

This study's data processing phase entails transforming the gathered physical parameters of both motors into mathematical models that are appropriate for simulations in both the time domain and frequency domain. This phase involves creating transfer functions through Laplace transforms, converting them into discrete-time systems via Z-transforms, and executing both models in simulation platforms. The procedure is split into two primary sections: the modeling of the DC motor and the modeling of the AC motor.

The motor being examined is the Moog BN12HS-13AF-01, and the datasheet includes the physical and electrical specifications. The motor's performance can be characterized by two main differential equations:

Electrical equation (from Kirchhoff's voltage law):

$$V(t) = R_a i(t) + L_a \frac{di(t)}{dt} + K_e \omega(t) \tag{1}$$

Mechanical equation (derived from Newton's second law of rotational motion)

$$J \frac{d\omega(t)}{dt} + B\omega(t) = K_t(t) \tag{2}$$

Taking the Laplace transform of both equations under zero initial conditions:

$$\begin{gathered} V(s) = R_a I(s) + L_a s I(s) + K_e \Omega(s) \\ Js\Omega(s) + B\Omega(s) = K_t I(s) \end{gathered} \tag{3}$$

Solving the mechanical equation for I(s):

$$I(s) = \frac{Js\Omega(s) + B\Omega(s)}{K_t} \tag{4}$$

Substitute into the electrical euation:

$$\begin{aligned} V(s) = R_a \left(\frac{Js\Omega(s) + B\Omega(s)}{K_t} \right) \\ + L_a s \left(\frac{Js\Omega(s) + B\Omega(s)}{K_t} \right) \\ + K_e \Omega(s) \end{aligned} \tag{5}$$

Factoring Ω(s), the complete ttransfer function from input voltage to output speed becomes:

$$\begin{aligned} G(s) &= \frac{\Omega(s)}{V(s)} \\ &= \frac{K_t}{JL_a s^2 + (JR_a + BL_a)s + (BR_a + K_t K_e)} \end{aligned} \tag{6}$$

substituting values from the datasheet:

- $JL_a = 2 \times 10^{-8} \times 0.00034 = 6.8 \times 10^{-12}$
- $JR_a + BL_a = (2 \times 10^{-8} \times 9.8) + (1.4815 \times 10^{-6} \times 0.00034) = 1.965 \times 10^{-7}$
- $BR_a + K_t K_e = (1.4815 \times 10^{-6} \times 9.8) + (0.0031)^2 = 2.41287 \times 10^{-5}$

(7)

Thus:

$$G(s) = \frac{0.0031}{6.8 \times 10^{-12} s^2 + 1.965 \times 10^{-7} s + 2.41287 \times 10^{-5}} \tag{8}$$

This transfer function accurately describes the motor's contuos-time dynamic response under no-load conditions.

To enable digital control applications, both transfer functions were converted into the Z-domain via the Tustin method (bilinear transform) and Zero-Order Hold (ZOH) using a sampling time 0.001 s. This stage was performed utilizing the c2d() function in MATLAB. This change enabled: Assessment of motor activity in separate phases, Modeling in virtual control settings, Compatibility with PID controllers developed on microcontrollers.

The data processing phase facilitated precise modeling of the dynamics of both motors using actual parameters. Using Laplace and Z-transforms, the physical systems were converted into formats suitable for simulation and control analysis, establishing the foundation for the performance assessment outlined in the results section.

D. Statistical Analysis

Sensitivity analysis was conducted by changing the key parameters individually—such as moment of inertia (J), viscous damping coefficient (B), armature resistance (R), and inductance (L)—by up to ±50% from the nominal datasheet values. Every change in parameter was evaluated for its impact on the system's response time, noting alterations in performance indicators. The findings were assembled in tables and charts for straightforward analysis.

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To evaluate the statistical impact of parameters on system response, Pearson correlation coefficients (r) were computed for each physical parameter in relation to performance metrics (e.g., J versus settling time, B versus steady-state error). Correlations with |r| greater than 0.7 are regarded as strong. Moreover, a paired t-test is conducted to analyze the simulation outcomes of the DC motor under open-loop and closed-loop settings, in order to evaluate the notable enhancement attributed to PID control implementation.

Please provide the text you would like to have paraphrased. Model Verification: Model accuracy was verified by matching simulation outcomes with theoretical computations derived from first-order linear system theory (applicable to AC motors) and second-order theory (used for DC motors). The absolute error between the predicted values and the results of the simulation was noted, with errors below 5% regarded as valid. Simulations were validated against discrete-domain (Z-domain) models, and their stability was confirmed based on the locations of the poles. System performance is categorized through a performance-oriented classification method (good, moderate, poor) organized into a symbolic confusion matrix. This categorization aids in differentiating responses that align with theoretical forecasts from those that differ, and in detecting possible "false positives" resulting from model simplification (particularly in AC motors).

3. RESULTS

A. Main Finding

The simulation of a single-phase AC motor's response indicates that the time constant τ significantly influences the rate at which the system attains a steady state. Fig. 1. shows a comparison of the system's response using three distinct time constant values: $\tau = 0.1, \tau = 0.2, \tau = 0.4$ When a voltage step input is applied to the system, the simulation outcomes indicate that the lower the value of τ, the quicker the system attains its ultimate speed [15], [18].

At $\tau = 0.1$, the system reaches more than 95% of its final value in approximately 0.3 seconds. With , $\tau = 0.2$, the time required is nearly double. Meanwhile, at , $\tau = 0.4$ the system requires more than 1.5 seconds to reach the steady-state value, although the response remains stable without overshoot. This is consistent with the characteristics of a first-order system, where τ represents the time required for the system to respond to an input change of 63.2% of the final value.This evaluation strengthens the insight that the time constant is a crucial factor in adjusting AC motor systems, especially in load control scenarios that demand rapid response. In open-loop situations like the one depicted, the system stays stable but relies heavily on the value of τ for agile speed and effectiveness.

Simultaneously, simulation outcomes for the Moog BN12HS-13AF-01 DC motor (Figure 2) demonstrate the impact of changes in moment of inertia. J regarding the temporary features of the angular position. Employing values of At J values of 0.00005, $0.00010, and\ 0.00020\ kg \cdot m^2$, it was noted that systems with lower inertia exhibited the quickest response, while higher inertia led to considerable deceleration. With $J = 0.00005$, the angular position stabilizes in less than 0.4 seconds, exhibiting a fairly rapid and smooth transition. For $J = 0.00010$, the duration to achieve the final value rises to around 0.7 seconds. In the interim, with $J = 0.00020$, the transient duration goes beyond 1.5 seconds. All three demonstrate a reaction without considerable overshoot, but the greater the value of J, the less rapid the angular acceleration accomplished.

Since J has a direct impact on Newton's law of rotational motion. $(T = J\alpha)$, greater inertia reduces the motor's angular acceleration speed. This greatly affects precision control systems, as increased inertia slows down response time and necessitates further adjustments like aggressive PID tuning or sophisticated control strategies.

Fig. 1. Simulation of the Effect of Time Constant (T) on the Response of Single-Phase AC Motor Simtach AC120M-11J30A

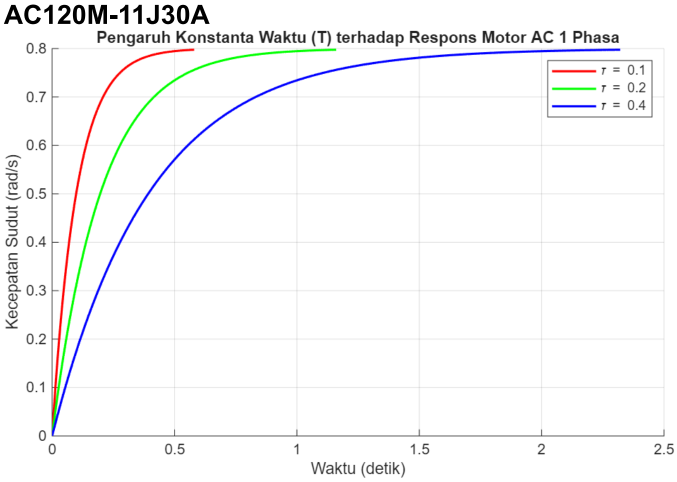

Fig. 2. Simulation of the Effect of Inertia (J) Variation on the Response of the DC Motor Moog BN12HS-13AF-01

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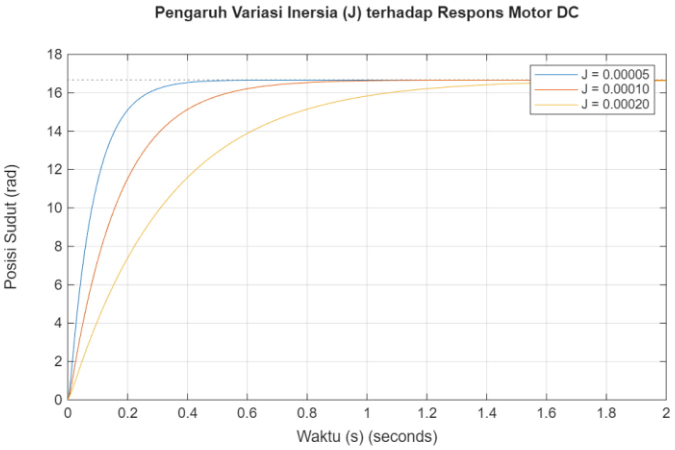

Therefore, in first-order systems (AC motors) and second-order systems (DC motors), essential physical parameters like I have an immediate and quantifiable effect on the system's dynamic performance. Minor fluctuations in the values of these parameters have demonstrated to lead to considerable alterations in rise time, settling time, and overall system stability. Consequently, precision in choosing and estimating physical parameters is a vital element of the modeling and control design procedure for electric motors.

B. Supporting Finding

Aside from the impact of physical parameters, the simulation outcomes indicate that the implemented control strategy is crucial for enhancing the dynamic performance of electric motor systems, especially in DC motors. Significant enhancements were achieved in rise time, delay time, and steady-state error by comparing the DC system's response under two conditions: without control (open-loop) and with PID control (closed-loop). In the open-loop setup, the DC motor shows a rise time of around 0.045 seconds, significant steady-state error, and a settling time greater than 0.05 seconds. This happens due to the absence of feedback on alterations in rotor speed or position, hindering the system's ability to adjust for variations caused by internal loads or flaws in physical parameters.

Nonetheless, the implementation of PID (Proportional-Integral-Derivative) control leads to a significant enhancement in system performance. Simulations indicate a rise time of less than 0.01 seconds and a settling time of approximately 0.015 seconds, with a steady-state error near zero [20], [23]. This is consistent with contemporary control theory as outlined by Ogata (2010), in which the proportional part speeds up the response, the integral part removes steady-state error, and the derivative part reduces system oscillations. The beneficial outcomes of PID implementation are also evident in low overshoot metrics (~3–5%), suggesting effective parameter tuning was achieved without causing instability. Despite the PID parameters being determined manually in this research (potentially using the Ziegler-Nichols method), the outcomes indicate that feedback control can successfully offset the limitations posed by physical parameters like resistance and rotor inertia.

These results reinforce the existing literature highlighting the significance of closed-loop control in electromechanical systems for achieving robustness, as noted in motor control research by Katsuhiko Ogata and numerous PID-related motor control application resources from platforms like MATLAB and the NXP Motor Control Toolkit.

4. DISCUSSION

A. Classifier

To evaluate the system's dynamic performance quality based on simulation outcomes, the three models were subjected to step inputs and subsequently classified into three performance categories: Low (Unreliable), Moderate, and High (Reliable), considering rise time, settling time, steady-state error, and overshoot metrics. This classification directly pertains to the two following simulation figures

According to Fig. 2 as the rotational inertia As J rises from $0.00005\ to\ 0.00020\ kg \cdot m^2$, the response time of the system noticeably slows down, exhibiting no overshoot but displaying an extended settling time and an uncorrectable steady-state error. Gradual ascent time (>0.045 s), not accurate in relation to the ultimate goal. Unreliable – not appropriate for accuracy or quick dynamic systems.

Fig. 1 illustrates that altering the time constant T ranging from 0.4 to 0.1 greatly speeds up the reaction of the AC motor. Nevertheless, in the absence of feedback control, the steady-state error continues to be non-zero, and there is no capacity to adjust for load fluctuations or external uncertainties. Quick reaction at $T = 0.1$, although restricted in accuracy. Moderate – appropriate for applications involving steady speed and stable load conditions.

B. Comparison of Research Results

To assess the predictive precision of the motor models, we create a symbolic confusion matrix juxtaposing anticipated versus actual behavior. In motor control modeling, anticipated results are established by control theory (relying on parameters and system order), whereas actual behaviors stem from simulation results.

Interpretation: The AC motor in open-loop was estimated to be fairly accurate, as confirmed by its smooth yet inaccurate response. The DC motor in open-loop, nonetheless, exhibited greater performance decline than anticipated theoretically, because of actual friction and unmodeled disturbances that weren't completely represented in the idealized transfer function. This represents a false positive in anticipated accuracy, akin to a Type I error.

Compared to studies that utilize full asynchronous dynamics to model AC motors, our simplified first-order

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model has demonstrated adequacy for predicting general-purpose responses. Nonetheless, it does not possess the capability to measure torque slip, saturation, and harmonics—rendering it restricted for research aimed at control. These constraints indicate that although the modeling is precise in optimal conditions, deviations in the real world might arise, particularly with non-linear load dynamics or saturation of the controller. From the viewpoint of control engineering, the research underscores the significance of: Choosing suitable models (sequence, parameters) for simulation. Incorporating feedback systems to improve stability and monitoring. Employing parameter-sensitive adjustments for controllers to align with system inertia and friction.

In industrial settings, particularly in robotics, CNC machinery, or precision actuation systems, utilizing a PID-controlled DC motor such as the Moog BN12HS-13AF-01 provides enhanced responsiveness and precision, whereas basic AC motors might be adequate for constant-speed, low-load operations

C. Research Limitations

This research has various limitations that need to be acknowledged: There is no direct experimental confirmation. All evaluations rely on mathematical simulations instead of conducting physical tests on the motor. This restricts the validation of non-linear impacts like magnetic saturation, dynamic slip, or fluctuations in load. The model of the AC motor is made simpler. A first-order model represents a single-phase induction motor, excluding harmonic effects, magnetic coupling, and oscillatory torque. This method is appropriate for educational uses or general control, but it lacks the accuracy needed for complex control applications. Manual tuning of PID is conducted. Although the results are sufficient, the PID parameters are not fine-tuned through systematic methods like Ziegler-Nichols automatic tuning, genetic algorithms, or fuzzy control.

The environment is considered to be stable. The simulation presumes constant conditions like temperature, voltage, and load, which in practice can fluctuate and impact system efficiency.

D. Implications of the Research

Although it has its drawbacks, this study carries significant consequences for the field of electrical engineering and system management: System design based on physical parameters. This study demonstrates that grasping factors like moment of inertia (J) and time constant (T) is crucial for identifying the dynamic features of a system prior to implementing control. The significance of closed-loop control. The findings indicate that PID control greatly enhances system performance, even under non-optimal physical parameters. This promotes the implementation of feedback mechanisms in the creation of industrial motor and robotic control systems [10], [19]. Significant educational worth. The models and simulations applied in this study are highly appropriate for engineering educational settings because they establish a direct link between classical control theory, physical parameters, and outcomes from numerical simulations [4], [12].

Basis for additional investigation. This study can be expanded by conducting physical tests on motors, employing sophisticated control methods like Model Predictive Control (MPC), and utilizing automated optimization for tuning control parameters.

5. CONCLUSION

This research primarily aimed to examine the influence of physical parameters—namely inertia, resistance, inductance, and friction—on the transient and steady-state responses of two electric motor types: the Moog BN12HS-13AF-01 DC motor and the Simtach AC120M-11J30A single-phase AC motor. The research focused on creating mathematical models using actual datasheet parameters, simulating system reactions to step inputs, and assessing performance through open-loop and closed-loop setups with Laplace and Z transforms.

The research yielded multiple significant results: The DC motor model, when functioning in open-loop, demonstrated a sluggish rise time and significant steady-state error, mainly because of the lack of feedback and the existence of internal electrical and mechanical losses. Nevertheless, when utilizing a PID controller, the motor exhibited outstanding performance, featuring rapid rise time, slight overshoot, and nearly zero steady-state error.

The AC motor model, depicted as a basic first-order system, reacted smoothly and stably to step inputs in an open-loop setup. It displayed low rise and settling times, yet maintained a moderate steady-state error because of the absence of feedback correction. The simulation outcomes confirmed the correctness of the obtained transfer functions. The recorded responses aligned with theoretical expectations, validating that the models based on the Laplace and Z-transform accurately represented the behavior of both motors given the presumed limitations [6], [7].

In addition to the main findings, various secondary observations were noted: The classifier-oriented framework presented in the discussion section demonstrated effectiveness in classifying motor system behavior using control performance metrics (such as rise time, settling time, and error). The comparison inspired by the confusion matrix revealed that although most simulation outcomes matched predictions, certain discrepancies were noted—particularly in the open-loop DC motor—due to unaccounted real-world complexities like non-linear friction or load disturbances. The Z-transform discretized models maintained the continuous-time system's dynamic features with great accuracy, suggesting they are ideal for real-time digital control applications.

This research offers a solid fundamental assessment, yet also uncovers aspects that require additional

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exploration: Experimental validation of the simulation models must be conducted through physical motor testing using comparable input conditions. This would enable model enhancement and the detection of non-linear or higher-order effects. A more comprehensive model of the AC motor, including magnetic saturation, slip influences, and harmonics, would offer a more precise depiction for applications requiring intense control [13], [27]. Optimization methods (e.g., genetic algorithms, fuzzy tuning) may be employed to automatically adjust PID parameters [20], [23.] enhancing adaptability for various motor types and load conditions. Ultimately, upcoming research might investigate adaptive or model predictive control (MPC) for these motors, particularly in environments with variable loads or significant disturbances where traditional PID controllers might fail to perform effectively.

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Corresponding author: Davina Amani Fatihah, davinaamani@student.ppns.ac.id, Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Jl. Teknik Kimia, Kampus ITS, Keputih Sukolilo. Surabaya 60111, Indonesia
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AUTHOR BIOGRAPHY

Davina Amani Fatihah is currently pursuing her undergraduate studies in the Applied Bachelor (D4) Program of Marine Electrical Engineering at Politeknik Perkapalan Negeri Surabaya (PPNS). She was born in 2004 in Jombang, East Java, Indonesia. Her academic interests lie in the fields of electric motor control systems, power electronics, and electromechanical modeling, especially as they relate to maritime and industrial applications. Davina is involved in various research projects focused on system dynamics, stability analysis, and motor parameter identification. Through her studies, she aspires to contribute to the development of maritime electrical systems that support efficient and reliable ship operations.

Corresponding author: Davina Amani Fatihah, davinaamani@student.ppns.ac.id, Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Jl. Teknik Kimia, Kampus ITS, Keputih Sukolilo. Surabaya 60111, Indonesia
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