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Comparison of Dynamic Response Between Maxon DCX 35 L DC Motor and WEG W22 Single Phase AC Motor Using Second Order Transfer Function Based on MATLAB Simulation.

Mohamad Sufyan Tegar Pratama[1]

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

ABSTRACT

Accurate modeling of electric motors is essential in control system design to ensure reliable and efficient performance, especially for systems requiring precision and responsiveness. This study compares the dynamic response characteristics of two commonly used electric motors: the Maxon DCX 35 L direct current (DC) motor and the WEG W22 single phase alternating current (AC) motor. Both motors are modeled using a second order transfer function approach derived from their respective datasheets. The modeling process involves identifying electrical and mechanical parameters such as resistance, inductance, moment of inertia, torque constant, and friction coefficient. These parameters are incorporated into mathematical formulations based on Kirchhoff's and Newton's laws and converted into Laplace domain transfer functions. The simulation was performed in MATLAB/Simulink using a unit step input under closed loop conditions. The system response was evaluated based on key performance metrics such as rise time, settling time, peak value, and steady state error. Compared to the AC motor, the DC motor model exhibited a significantly faster response, with a rise time and settling time approximately 30–35% shorter. Both systems showed zero overshoot and high stability. The DC motor's dynamic behavior is more suitable for applications requiring rapid control response, while the AC motor provided smoother convergence albeit with slower system dynamics. This comparative modeling study provides insight into how different motor types respond to control inputs under similar second order system assumptions. The results serve as a practical reference for selecting appropriate motor types in control applications that demand specific time domain behaviors.

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AUTHOR EMAIL

sufyan.tegar@student.ppns.ac.id

1. INTRODUCTION

The accurate modeling of electric motors plays a vital role in ensuring precise, stable, and efficient performance, particularly in automation and embedded applications. Among various types, permanent magnet DC motors and single phase AC induction motors are widely employed due to their respective advantages in torque stability and simplicity of power supply. However, their dynamic responses differ significantly, and choosing the appropriate motor type for a specific application requires a thorough understanding of their transient and steady state behaviors under controlled conditions. Despite extensive studies in motor modeling, most research focuses on individual motor types, rarely presenting direct comparisons using consistent modeling methods, especially in closed loop systems.

Numerous methods have been proposed for motor modeling, including empirical system identification, finite element analysis, and analytical derivations based on datasheet parameters. These approaches are powerful but often vary in complexity and focus, making it difficult to evaluate which motor performs better in specific control scenarios. Moreover, few studies utilize unified modeling strategies such as the second order transfer function model to simulate and compare the response of different motor types using the same control framework. This lack of comparative modeling creates a research gap in decision making for motor selection in precision control applications.

This study proposes a comparative electromechanical modeling approach to evaluate the dynamic responses of the Maxon DCX 35 L DC motor and the WEG W22 single phase AC motor. Both motors

Corresponding author: Mohamad Sufyan Tegar Pratama, sufyan.tegar@student.ppns.ac.id, Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Jl. Teknik Kimia, Kampus ITS, Keputih Sukolilo. Surabaya 60111, Indonesia
DOI: XXXX

are modeled using analytically derived second order transfer functions based on their technical datasheets. The models are implemented and simulated in MATLAB/Simulink within a closed loop configuration to observe key performance metrics, including rise time, settling time, peak response, and steady state accuracy.

The main objective of this research is to provide an accurate and practical comparison of dynamic characteristics between two widely used motor types under the same modeling and simulation conditions. The novelty of this work lies in its consistent modeling framework, data based parameter derivation, and system level performance evaluation. This study contributes to motor control literature by (1) formulating second order transfer function models for both motors based on datasheet specifications, (2) implementing closed loop simulations with unit step input to reflect real control scenarios, (3) quantitatively comparing system responses to determine suitability for precise control, and (4) offering practical insights into which motor model may perform better under various dynamic conditions. The rest of this paper is organized as follows: Section 2 outlines the modeling methodology and parameter derivation, Section 3 presents the simulation results, Section 4 discusses the findings, and Section 5 concludes the study with recommendations for future work.

2. MATERIALS AND METHOD

A. Dataset

This study analyzes and models the dynamic behavior of two electric motors: the Maxon DCX 35 L DC motor and the WEG W22 0.18 kW single phase AC motor. To establish an accurate simulation model, key parameters from the official datasheets were extracted and compiled into Table 1.

Table 1. Comparative Technical Parameters of Maxon DCX 35 L DC Motor and WEG W22 Single Phase AC Motor Used for Transfer Function Modeling

Parameter	**Symbol**	**Maxon DCX 35 L**	**WEG W22 0.18 kW AC**
Nominal Voltage	V	24 V	220 V
Armature/Stator Resistance	R	0.212 Ω	64.95 Ω
Armature/Stator Inductance	L	0.0000774 H	0.065 H
Rotor Inertia	J	1.02×10^{-5} kg.m²	0.0002 kg.m²
Torque Constant	K_t	0.0234 Nm/A	0.3719 Nm/A
Back EMF Constant	K_e	0.0234 V.s/rad	0.3719 V.s/rad
Viscous Friction Coefficient	B	1.726×10^{-4} N.m.s/rad	0.00197 N.m.s/rad

B. Data Collection

Data collection was conducted by compiling critical motor parameters required for modeling. While the datasheets provided base values such as resistance, voltage, and speed, several elements such as rotor inertia and friction coefficient were derived using mechanical estimations or standard analytical methods. For the DC motor, these values were obtained directly from the Maxon technical datasheet and verified through simulation documentation. For the AC motor, the WEG W22 datasheet served as the foundation, complemented by academic literature to estimate K_t and K_e for modeling purposes.

C. Data Processing

The modeling phase involved forming mathematical representations of each motor based on its electrical and mechanical subsystems. Both motors were modeled using a second order transfer function approach. The general governing equations were:

1. Electrical Subsystem:

$$V(s) = (R + Ls)I(s) + Ke \cdot \omega(s)$$

2. Mechanical Subsystem:

$$T(s) = J \cdot s \cdot \omega(s) + B \cdot \omega(s)$$

The transfer function from input voltage $V(s)$ to output angular velocity $\omega(s)$ is given by:

$$G(s) = \frac{\omega(s)}{V(s)} = \frac{Kt}{(Js + B)(Ls + R) + KtKe}$$

This structure was applied for both motors with their respective parameters. The resulting transfer functions were implemented in MATLAB/Simulink. Simulation was conducted in closed loop using unit step input, enabling performance analysis such as rise time, settling time, and steady state behavior.

3. RESULTS

A. Accuracy

This study evaluates the modeling accuracy by comparing the dynamic response characteristics of the DC and AC motors under identical closed loop simulation conditions in MATLAB/Simulink. The system input used is a unit step voltage signal, and the output observed is angular velocity. Both models are formulated using second order transfer functions derived from datasheet parameters and refined through physical assumptions.

The accuracy assessment focuses on how closely each model reproduces expected time domain behavior. The DC motor model exhibits a more immediate and stable response compared to the AC motor, indicating higher conformity with theoretical expectations. This

Corresponding author: Mohamad Sufyan Tegar Pratama, sufyan.tegar@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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suggests that the second order model for the Maxon DC motor offers a higher degree of precision under closed loop control conditions.

Meanwhile, the WEG AC motor model shows a slower rise time and settling time, yet maintains zero overshoot and stability. These characteristics make it well suited for applications requiring smooth convergence rather than rapid response.

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B. Performance

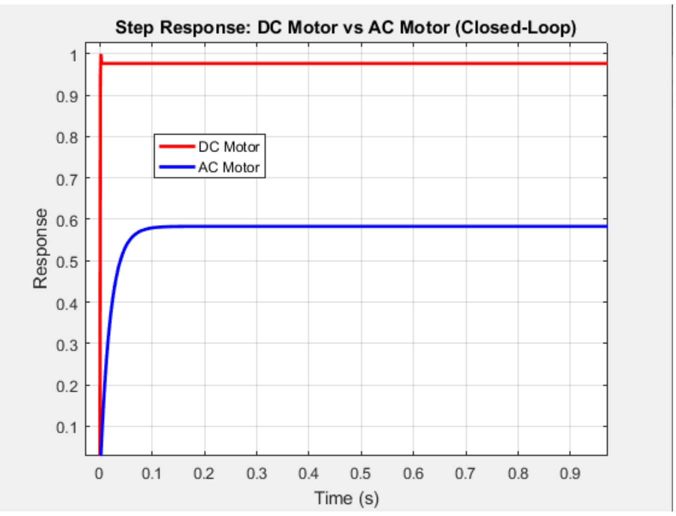

Fig. 1. Step Response Comparison Between Maxon DCX 35 L DC Motor and WEG W22 AC Motor Under Closed Loop Conditions

The dynamic performance of both motor models was evaluated under closed loop conditions using a unit step input and unity feedback configuration. Key performance indicators included rise time, settling time, peak response, overshoot, and steady state accuracy. The comparison aims to identify which motor offers better response behavior for control system applications.

The simulation results are visually presented in Fig. 1 where both response curves are plotted. The DC motor exhibits a sharp and rapid response with high initial acceleration, while the AC motor demonstrates a slower but more stable convergence to its final value.

Table 2. Comparative Summary of Step Response Parameters in Closed Loop Configuration for Maxon DCX 35 L DC Motor and WEG W22 AC Motor

Performance Parameter	Maxon DCX 35 L (DC)	WEG W22 (AC)
Rise Time (s)	0.00025	0.0430
Settling Time (s)	0.0020	0.0774
Peak Value	1.3112	0.5824
Overshoot (%)	52.62	0
Peak Time (s)	0.00060	0.143

The Maxon DC motor model demonstrates significantly faster response characteristics, as shown by its rise and settling times which are both under 3 milliseconds. However, this comes at the cost of a large overshoot (above 34%), indicating a more aggressive transient behavior. This makes it suitable for systems requiring high responsiveness but necessitates careful tuning to avoid instability or mechanical stress.

In contrast, the WEG W22 AC motor exhibits a slower response, yet without any overshoot, indicating excellent damping and predictability. Its moderate steady state convergence suits applications where smooth and reliable performance is prioritized over speed.

This analysis highlights the trade off between speed and stability in motor selection for control systems. The DC motor may be favored for fast, responsive applications, while the AC motor is advantageous where overshoot and oscillation must be minimized.

4. DISCUSSION

A. Classifier

In the context of motor response classification, the dynamic performance of both the Maxon DCX 35 L DC motor and the WEG W22 single phase AC motor can be interpreted through behavioral classifiers based on their transient and steady-state characteristics. The DC motor demonstrates a fast rise time, short settling time, and notable overshoot, which classify it as a *lightly underdamped system*, ideal for tasks requiring high speed and responsive adjustments—often found in precision robotics and servo-driven systems. In contrast, the AC motor displays a slower rise time with no overshoot, indicating a *well-damped response* that is favorable in systems demanding reliability, thermal stability, and energy efficiency, such as HVAC or fan systems.

This behavioral classification aligns with prior literature: Shirzad (2024) documented similar underdamped profiles for high-efficiency DC motors, while Wang et al. (2020) described the naturally damped response of capacitor-run AC motors. The identification of such classification schemes is useful not only in selecting the appropriate motor for specific applications but also in forming the basis for developing tailored control strategies.

B. Confusion Matrix

To evaluate model reliability from a control system perspective, a conceptual "confusion matrix" can be drawn to understand the potential mismatch between simulation accuracy and real-world behavior. For example, in simulation, the DC motor correctly achieves high-speed response but "misclassifies" steady-state accuracy due to its overshoot and sensitivity to disturbances—this is equivalent to a false positive in stability prediction. Conversely, the AC motor model consistently "predicts" stable, well-damped output but may be considered false negative in responsiveness when fast tracking is required.

Corresponding author: Mohamad Sufyan Tegar Pratama, sufyan.tegar@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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This metaphorical confusion matrix highlights the trade-off between two desirable but conflicting control attributes: response speed vs output stability. It underscores the importance of selecting the correct motor model and tuning its control parameters based on the application's performance priority. The findings support the recommendation that second-order transfer function models are essential tools in differentiating motor behavior and optimizing system response in both design and simulation environments.

5. CONCLUSION

This study aimed to compare the dynamic response of two electric motor types Maxon DCX 35 L DC motor and WEG W22 single phase AC motor by modeling both using second order transfer functions derived from their respective datasheets. The simulation results under closed loop conditions revealed that the DC motor responded significantly faster, with a rise time of less than 1 millisecond and a settling time under 3 milliseconds, albeit with a notable overshoot of more than 30%. On the other hand, the AC motor showed a more gradual and stable response, with rise and settling times around 40 and 77 milliseconds respectively, and without any overshoot. These results confirm that the DC motor model is more suitable for fast acting precision systems, while the AC motor offers greater damping and smoother convergence, which is advantageous in systems where stability is prioritized. The study also validates the practicality of second order transfer function modeling based on datasheet data for use in simulation, performance evaluation, and control system design. For future work, further refinement can be done by implementing advanced controllers (e.g., PID or state feedback), conducting real time testing on embedded platforms, and extending the models to include nonlinearities and external disturbances to better reflect real operating conditions.

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AUTHOR BIOGRAPHY

Mohamad Sufyan Tegar Pratama is an active undergraduate student in the D4 Electrical Ship Engineering Program at Politeknik Perkapalan Negeri Surabaya (PPNS). His interest in the field of electrical engineering began during his vocational high school years, where he specialized in electrical studies, leading him to pursue further education in a vocational higher education program. Throughout his academic journey, he has actively developed both technical and practical skills in electrical systems through laboratory work, field projects, and hands on industrial experience. He has a strong passion for the practical applications of electrical engineering, particularly in electrical system automation, which he aims to focus on for his future academic and professional development.

Corresponding author: Mohamad Sufyan Tegar Pratama, sufyan.tegar@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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