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Investigation, Measurement and Reference Tracking of Dc Motor Using Parameter Variations

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ABSTRACT

Direct current (DC) motor management is crucial, particularly for electronic devices, and efficient DC motor functioning is crucial in most industrial applications, much like it is for any other AC motor. This experiment has demonstrated the impact of compensators on fluctuations in DC motor parameters. The resistance and inductance of a DC motor are the two parameters that will be tracked by this research in order to measure torque. To depict alterations in the motor's properties, the study used the linear time invariant LTI model. Matlab/Simulink greatly aided in the implementation of LTI systems. It has been demonstrated by research how compensators affect fluctuations in DC motor parameters. In order to track the DC motor torque, two DC motor parameters—resistance and inductance—have been selected as references. The study has used the Matlab/Simulink LTI system's ease of implementation, as well as the LTI model to reflect plant change. Furthermore shown is the fact that, although the steady state error is substantially reduced, the lag and lead compensators result in a stable and steady state system, respectively. The compensators that result in a stable system are the most suitable compensators to utilise for appropriate DC motor parameter modification, according to the data presented.

Keywords: DC current, linear Time Invariant, Mat-lab simulink, Reference Tracking, Self-Tuning Control (STC) , Motor Torque

1. Introduction

An exclusive kind of servo drive system are the brushed DC motors. The desire to apply the knowledge that was learned in the Master Course in Automatic Control and Robotics to expand on the field of automation and control research is what inspired this experiment. The comparison of the model with the real model environment through identification, simulation, and verification is the main objective of this project. Using data gathered from the systems, the problem of developing mathematical models of dynamical systems is addressed. The study aims to analyse the motor's estimated data, create models of its electrical and mechanical properties, and then use control systems knowledge to validate these models through simulation. Our world is full of dynamical systems, therefore studying them is essential for scientific inquiry, and there are a lot of applications for system identification approaches. The issue of adaptive control becomes crucial when one has little information of the system. When a controller needs to quickly alter a previously "imprecise" set of controller gains due to an unforeseen system state, adaptive control can be used. For systems whose operating parameters change over time, reference tracking with its variable gain structure is also useful. In industrial control systems, reference tracking techniques are being employed more and more. The concept of adaptive control is not brand-new. Numerous studies on adaptive control were conducted in the early 1950s in order to build autopilots for high performance airplanes.

The utilization of reference tracking can be employed to influence the rotational speed of both DC motors and machinery. Meeting the demands of industrial systems in terms of speed control of DC motors has presented several obstacles in control designs as well as maximizing of productivity. The quality and effectiveness of the work are directly impacted by this and depend on it.

2. A REVIEW

The importance of these qualities and their limitations were explored, which also included a brief summary of some of the DC motor properties. The various drive types employed for trajectory monitoring were specifically emphasized. This chapter summarizes some of the research that has been done in the area of artificial neural networks (ANN) and how they have been used to control DC motors. At the end of the chapter, a quick assessment of the project's contribution to the investigation of reference control of a DC motor via parameter variation is covered.

As robust, easy, and efficient instruments for process control and online adaptation, artificial intelligence technologies are gaining popularity

2.1 Review of related literature

The accomplishments, restrictions, and recommendations of the writers will be discussed in this section, which will also review pertinent literature as it relates to this project.

Sarker and Das (2018) assert that Model Reference Adaptive Control is among several approaches that can be employed to address control issues in situations where the parameters of the controlled process are either unknown or subject to natural variations.Knowing a dc motor's specifications is necessary to comprehend its dynamic behavior. The primary parameters of a dc motor include friction coefficient, armature inductance, armature resistance, rotor inertia, motor constants, and inductance. Some experiments need to be done in order to identify all of these parameters. But as the operation progresses, several factors affect the motor's properties. as a result, the controller's performance, Consequently, when the parameters of a motor exhibit variations, the performance of a controller designed based on constant motor parameters deteriorates. To overcome the need for specific motor parameters in regulating the position of a DC motor, a model reference adaptive control technique is proposed. The effectiveness of this strategy in controlling the motor's position is demonstrated by experimental findings. In a same vein, Schoellig (2012)'s thesis examined trajectory tracking,

The con’truction of feedback control systems often relies on a mathematical model of the underlying system. However, the accuracy of the dynamics model and the causality of the control action, which only mitigates disturbances as they occur, impose limitations on the effectiveness of these control methods. Recent developments in computing technology have created great opportunities for storing, analyzing, and assessing massive volumes of data. This research is driven by these developments. He aims to take use of these new opportunities with three key contributions: In order to learn to perfectly follow a preset trajectory, he first presents an algorithm that uses data from repeated operations. He customizes the feed-forward reference signal for the system in order to achieve good tracking performance – even in the presence of model flaws and other recurring disruptions. The strategy employs measurements from previous executions to improve tracking performance and is based on a rough model of the system dynamics. To create a learning system that is both successful and computationally efficient, he combines modern optimization techniques with conventional optimal filtering methods. Iterative learning control is the field in which the suggested approach belongs. These additional capabilities will be especially useful when he applies the algorithm to highly agile quadrotor vehicles in the ETH Flying Machine Arena. By improving on time-optimized trajectories, he hopes to fully utilize their dynamic potential. The learning strategy has shown to be successful when used to a quadrocopter system that is directed by a trajectory following controller as well as when applied directly to learning the thrust and rotational rate inputs supplied to the quadrocopter. In the latter instance, a numerical identification method was employed to circumvent a comprehensive analytical modeling process. With regard to the second project, he considers iterative learning control in a multi-agent system, wherein a group of of agents simultaneously and repeatedly perform the same task. The researcher explores the potential improvement in a learner's performance by examining the sharing of information among agents, assuming their similarity. Specifically, the investigation aims to determine whether a specific agent benefits from the collective experience of other agents. Analytical boundaries for the performance enhancement resulting from collaborative learning are derived. Additionally, the third approach employs learning in a different context or environment.Here, he wants to use a quadrocopter to precisely track periodic motions. He creates a learning method that, from a limited number of identification experiments, yields the feedforward correction parameters for a broad class of periodic motions. Our goal of inventing and implementing multi-vehicle flight that is timed to music is what drives our research.

He investigates if information sharing among agents, presuming similarity between them, enhances a learner's performance. The third initiative makes use of learning in an alternative setting. Here, he wants to use a quadrocopter to precisely track periodic motions. He creates a learning method that, from a limited number of identification experiments, yields the feedforward correction parameters for a broad class of periodic motions. Our goal of inventing and implementing multi-vehicle flight that is timed to music is what drives our research, Along with these three key findings, he also investigated the dynamic limits of quadrotor vehicles and created algorithms for both generating and evaluating the viability of potential flight paths.

(Bature et al., 2013)uses a low-cost, straightforward data collecting setup to offer parameter estimates for a class of DC motor. The estimated parameters include the motor armature-winding resistance, back electromotive force (e.m.f) constant, motor torque constant, moment of inertia, and viscous friction. The FIO STD development board acts as the data acquisition device, facilitating interaction between the sensors and computer.Data processing and computations were done in the MATLAB Simulink environment. Through simulations and testing, the accuracy of the calculated parameters is confirmed. Additionally, (Access, n.d.) created a composite Model Reference Adaptive Control (MRAC) of the dc motor using the Matlab/Simulink program. His work aims to act as a tutorial for academics and students in the field by step-by-step linking the offered theory with the Software called Matlab/Simulink. Using the reference adaptive control from the supraunitary relative degree model, a solution to the electric drives' parameter fluctuation is suggested. The results of the numerical simulation demonstrate the viability of the suggested solution in the presence of unexpected dynamics or changes to the process parameter. Also covered in this chapter is the conventional cascading loops-based control of the DC drive.

It is demonstrated that the PI controller, when used in conjunction with an anti-wind up method, provides adequate regulating and tracking performance despite this drawback. It is also demonstrated that the control system can adjust for shifting loads and the counter-electromotive force while using reasonable amounts of current.

(Bayat & Jalali, 2010)focuses on the issue of linearly limited systems with quick dynamics and constant reference tracking. To guarantee the fulfillment of constraints and tracking objectives, an enhanced servo architecture is introduced, which offers A refined servo architecture is presented, providing an analytical closed-form solution. The proposed approach combines this architecture with explicit model predictive control (eMPC), enabling optimal tracking, constraint satisfaction, and a simultaneous piecewise closed-form solution.

The proposed architecture is characterized by its simplicity, enabling easy comprehension of the physical system's characteristics and practical selection of design parameters. Additionally, the piecewise closed-form solution yields a computationally efficient controller, making it particularly applicable to fast dynamic systems. The explicit MPC solution is significantly simpler due to the constant reference signal assumption. It is demonstrated, however, that the current approach may be used with ease in situations with finite predefined set-points.

3. MATERIALS AND METHOD

Materials used are

1. DC motor design data
2. DC motor controller data
3. Laptop
4. Matlab/simulink for simulation

3.2 A DC motor's transfer function

Because it sheds light on a DC motor's characteristics by taking only the terminal voltage and armature current into account, the trajectory of the spectrum that represents the armature current-to-terminal voltage ratio is very important. It is plausible to infer from this transfer function the precise frequency range point at which excitation becomes advantageous, given that significant parameter alterations occur within this range. An easy-to-understand example should help with this:

In terms of measurement accuracy, it is not practical to find the parameters of an electric low-pass with a cutoff frequency of 10 kHz by using an oscillating quantity that oscillates at 10 Hz as the excitation. This is because there is very little phase-shift and a transfer factor of about 1 between the input and output signals, which show a high degree of resemblance.Only when the excitation frequency roughly approaches the cutoff frequency—a situation that makes the filter characteristics visible—can the filter parameters be determined with accuracy.To find the transfer function, equations (3.1) and (3.2) are translated into the Laplace domain.

$U(s)=k\beta(s)+L.s.I(s) + R.I(s)$ (3.1).

$I(s)-k.\beta(s)-M\_L = J.w.\beta(s)$ (3.2)

3.3 Design of the reference tracking system

A simple implementation of the DC motor reference tracking system on Matlab/simulink would consist of the controller transfer function/Compensator, DC motor transfer function considering the DC motor parameter and the feedback signal (figure 3.1).

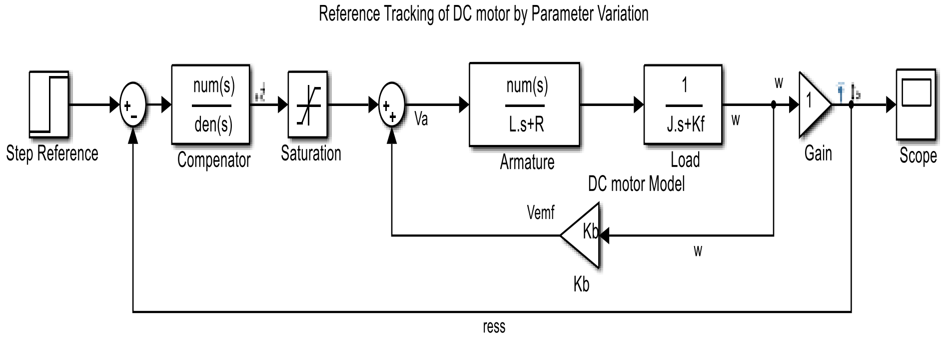

Figure 3.1: The reference tracking system's entire Simulink implementation

Figure 3.2 describes the controller system design environment, the design environment enables the design of the compensator for the DC motor parameter variation

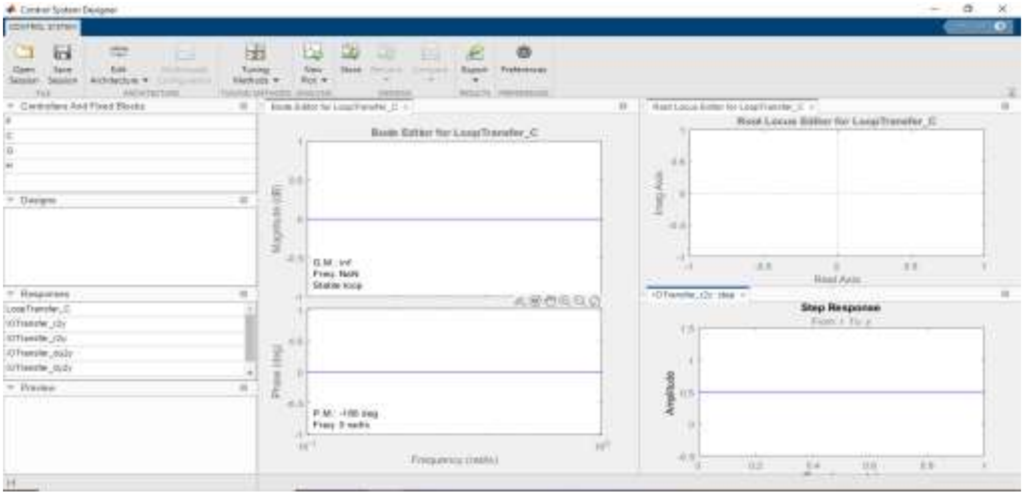

Figure 3.2 control system design main window

4.1: RESULTS AND DISCUSSION

4.2 True poles compensator

The following can be used to create a compensator with real poles gain: C=C×1/(1+s).

As seen in figure 4.1, a controller with this design may be created using the controller designer. The real pole compensator produces a stable step response for the DC motor torque by operating at a phase magnitude (PM) of 91.6 degrees and 36 rad/s.

intricate pole

The following formula can be used to create a compensator with real poles gain: C=C×1/((1+1s+(0.71s)^2))

The complex pole compensator operates at a phase magnitude (PM) of 13.6 degrees and 8.45 rad/s, producing a distorted and transient step response for the DC motor torque at first, but eventually becoming stable, as shown in figure 4.1. A controller with such a design can be implemented using the controller designer, as in figure 4.1 below.

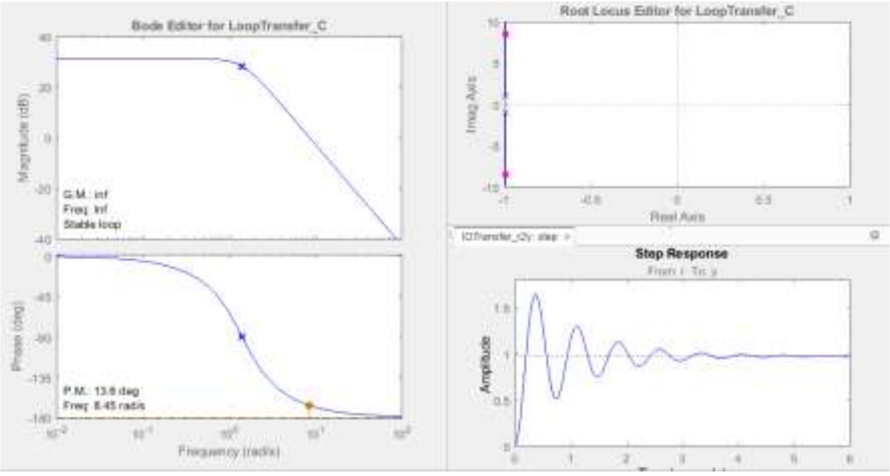

Figure 4.1: system reaction step under intricate control of a pole compensator

4.3 Differentiator

The compensator C=C×((s))/1 can be designed with differentiator poles and zeros gain.

Figure 4.2 illustrates how a controller with this design can be created using the controller designer. The differentiator compensator produces a damping step response for the DC motor torque by operating at a phase magnitude (PM) of -90 degrees and 0.0278 (rad/s).

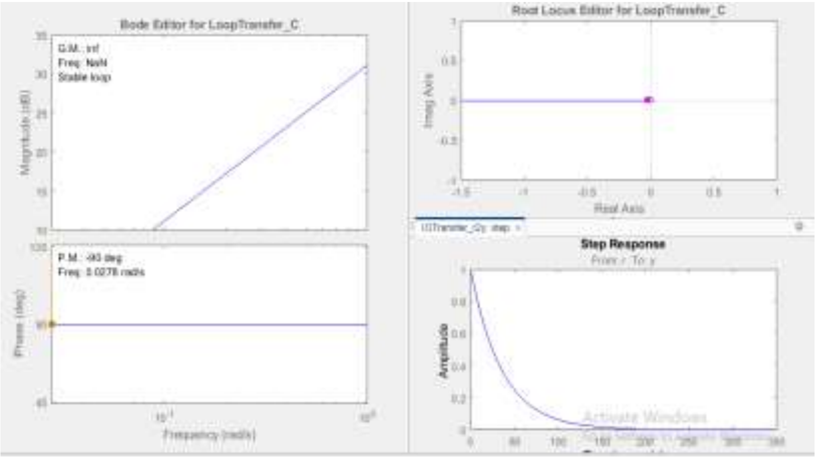

Figure 4.2: system step response under differentiator compensator control

The compensator shown above demonstrates how each type of compensation generates a distinct variation of the DC motor parameters. The real poles and zeroes compensators use variations in R and L to generate a stable torque for the DC motor, while the complex poles and zeroes contribute to the achievement of a steady state system. Additionally, the lag and lead compensators, on the other hand, produce stable and achieve a steady state system, respectively, but with much lower steady state error. The compensators from the preceding results that result in a stable system are the ideal compensators to utilise for suitable modulation of the DC motor parameters.

4.4 Lag

A compensator with lag poles and zeros gain can be design as shown,

$$\mathrm{C} = C \times \frac{(1 + 0.1s)}{(1 + s)}$$

Controller with such design can be implemented using the controller designer as shown in figure 4.3, the complex zero compensator operates on a phase magnitude (PM) of infinite degree and nil value (rad/s) to produce a stable step response for the DC motor torque, as shown in figure 4.3

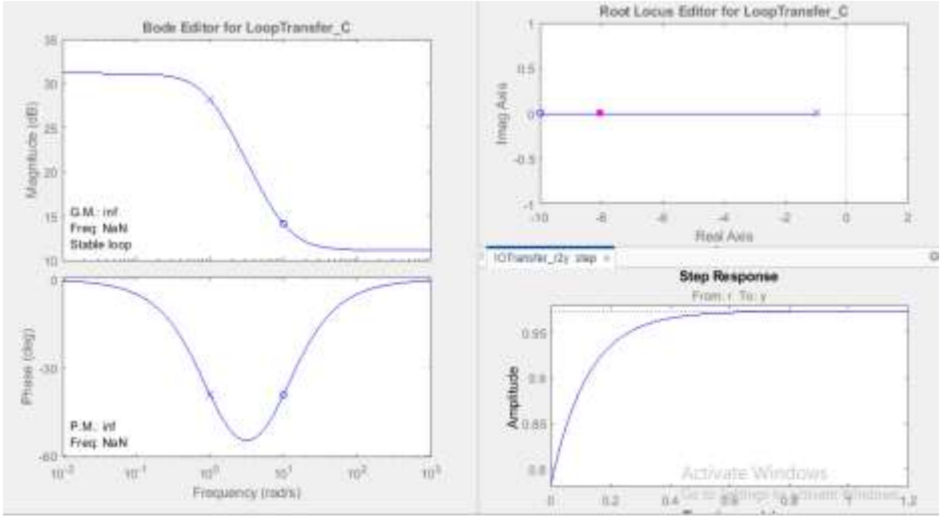

Figure 4.3: system step response under lag compensator control

CONCLUSION

In conclusion, in order to depict plant variation, the study used the LTI model. Because Matlab/Simulink makes it simple to design LTI systems, the study investigated several compensator system controllers for tracking the DC motor characteristics.

The stdy's findings demonstrate that it is possible to reduce the steady state inaccuracy and response time of LTI systems (DC motors) while still maintaining tracking of the motor's characteristics. As demonstrated in chapter 3 of the project, linearization has also made the DC motor model easier to track parameters. The closed loop step response of the resulting design indicates that, for the majority of the compensators that were checked for control, the reference tracking goal is achieved with zero steady state error.

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