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Investigating the Utilization of Matlab for Developing Algorithmic-Based Automatic Control Systems

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Abstract: *Investigating the utilization of MATLAB for developing algorithmic-based automatic control systems involves understanding the significance of control systems in various industries such as aerospace, automotive, chemical, and manufacturing. These systems utilize feedback mechanisms to regulate complex system behavior and ensure optimal operation. However, designing control systems becomes challenging when dealing with complex and nonlinear internal dynamics. To address this, researchers have developed automated control system design algorithms using MATLAB.*

The main objective of this investigation is to provide an overview of designing an automated control system using MATLAB. The project aims to develop a reliable and accurate control system algorithm in the frequency domain. This algorithm should be capable of analyzing and shaping the steady-state and transient response of a user-defined plant. The proposed method is easy to understand, versatile, and demonstrates impressive tracking capabilities across systems with different internal dynamics.

To validate the accuracy of the algorithm, simulations and experiments were conducted on electrical plants, manipulating their transient behavior, steady-state response, and stability using the algorithm based on user specifications. The algorithm employs Proportional Controllers, Lead Compensators, Lag Compensators, and Lag Lead Compensators to adjust the gain and phase of the plant's transfer function, achieving the desired response. Its ability to operate in the frequency domain makes it suitable for systems with complex and nonlinear internal dynamics.

Compared to traditional manual design methods, the proposed algorithm offers several advantages. Firstly, it automates the design process, reducing the need for manual intervention. Secondly, it provides accurate and consistent results across multiple experiments. Thirdly, it enables users to design and analyze control systems without specialized knowledge in control theory.

In conclusion, this investigation provides a comprehensive overview of developing an automated control system using MATLAB. The proposed algorithm is reliable, accurate, and independent, operating in the frequency domain while effectively analyzing and shaping the steady-state and transient response of user-defined plants. Its simplicity, versatility, and impressive tracking abilities make it suitable for a wide range of systems with varying internal dynamics. Through simulations and experiments, it has been demonstrated as an efficient and effective approach, offering substantial advantages over traditional manual design methods.

Keywords: Algorithmic-Based Automatic Control Systems

I. INTRODUCTION

Automatic control systems play a vital role in various applications, spanning industries like aerospace, automotive, manufacturing, home automation, energy management, and robotics. These systems employ algorithms to automatically adjust input parameters, achieving desired output responses. Designing such systems requires the selection of appropriate algorithms and parameter tuning for optimal performance. MATLAB, a powerful software tool, offers a comprehensive set of built-in functions and tools for control system analysis and design. This article focuses on algorithmic automatic control system design using MATLAB.

Control systems regulate the behavior of dynamic systems by manipulating input variables. They can be classified as open-loop or closed-loop systems. Open-loop systems lack feedback and rely on predetermined algorithms for input determination, while closed-loop systems continuously measure the output and adjust the input to achieve desired outputs. MATLAB facilitates the design and implementation of control systems, particularly in the continuous-time domain.

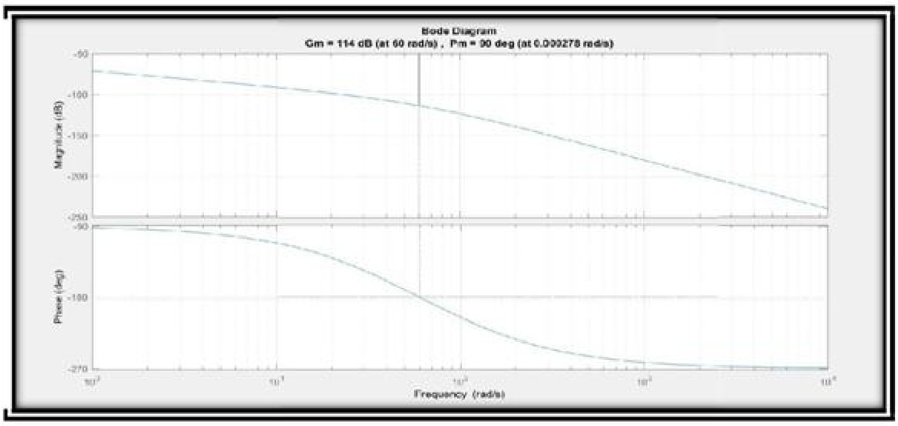
In this article, we explore the use of MATLAB for designing automatic control systems. We discuss the principles of control systems, the difference between open-loop and closed-loop systems, and the advantages of closed-loop systems with feedback. By constantly comparing actual output to desired output, closed-loop control systems offer accuracy, adaptability, and robustness. Their ability to maintain prescribed relationships between system variables makes them indispensable in engineering and automation.

1.1 Objectives of the Study

- Determine if the system is stable and how stable it is.
- Predict the system's performance through analysis that doesn't require solving differential equations.
- Identify how to adjust or compensate the system to produce the desired performance characteristic easily.

II. RESULTS

Proportional Controller



Graph: Bode of User-Defined Plant

The above graph is the bode magnitude and phase plot of the with an extremely low value of Gain cross over frequency (Wgc) user-defined plant, and ahigh phase margin (PM), thus being sluggish; though stable. This sluggishness is over come by the help of a Proportional Controller It increases system's Wgc (at the cost of decreasing PM and damping ratio, due to higher resonance peak), thus increasing its band width and hence the speed of response of the system, as shown in the graph below. The system loses robustness and stability, corresponding to the decrease in its PM and increase in its resonance peak.

Graph: Bode of Proportional Compensated Plant

The effect of the Proportional Controller (red) on user-defined plant (blue) can be verified from the comparison graph below. It is clear that the Controller doesn't affect the Bode phase plot while changing the parameter so if the magnitude plots as explained above.

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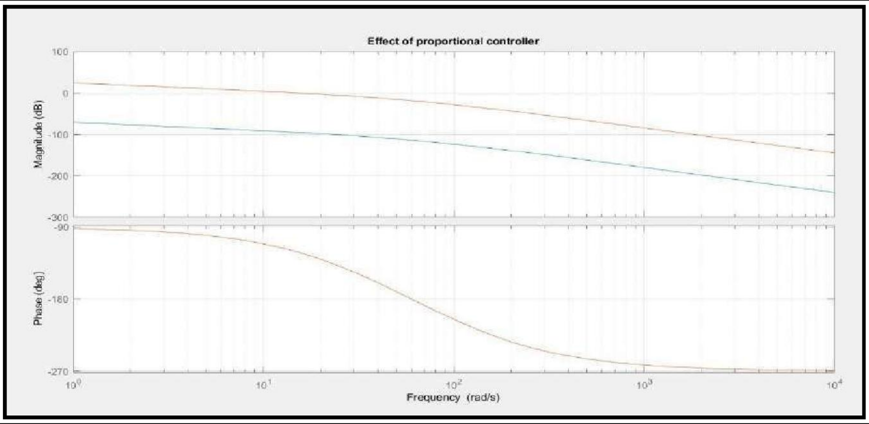
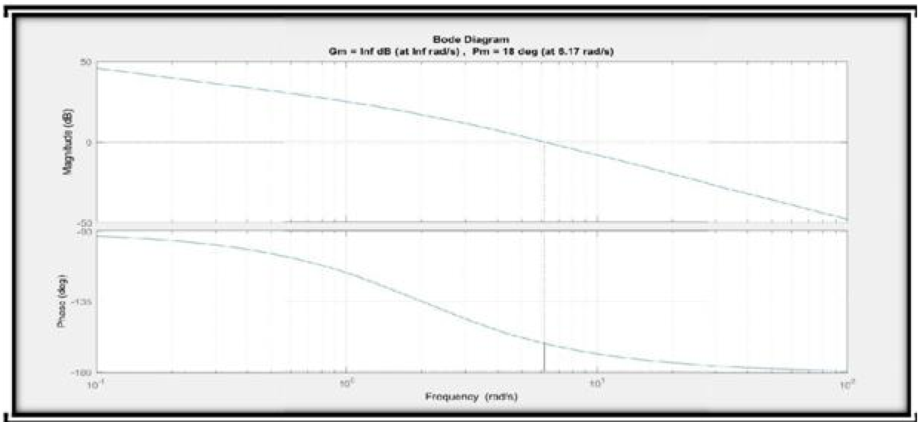


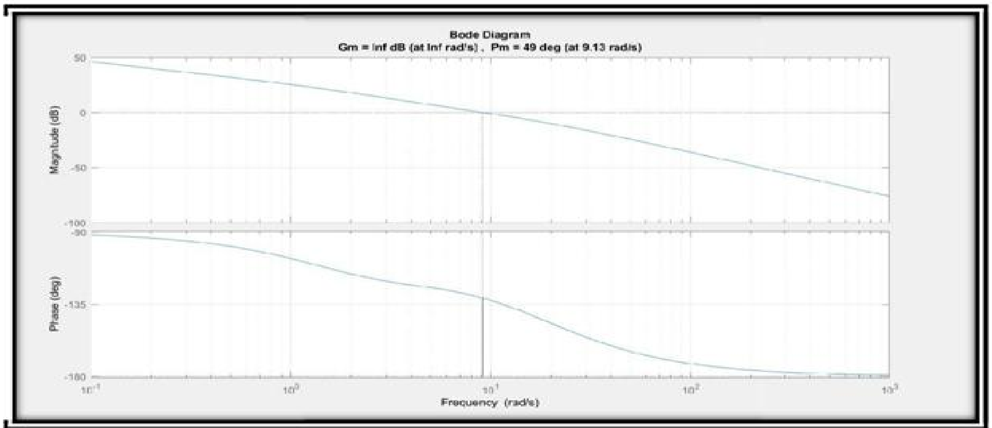
Graph: Effect of Proportional Controller

Lead Compensator:



Graph: Bode of lead compensator Input

This graph has already appreciable value of gain satisfactory stability of the undergone proportional compensation and hence has an crossover frequency, but the phase margin is too low for system. The phase margin is increased by the addition of a lead compensator, along with an increase in the gain cross over frequency; hence an improvement in both, stability and transient response, as seen in the plot below:



Graph: Bode of Lead Compensated Plant

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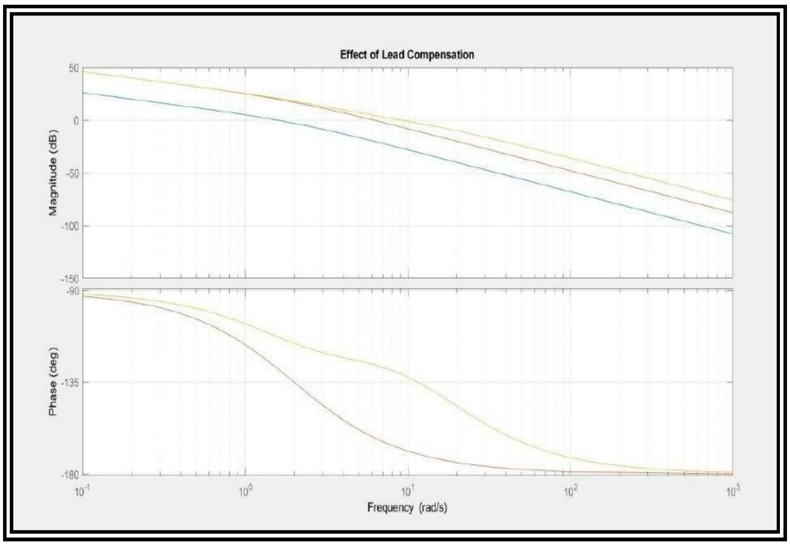
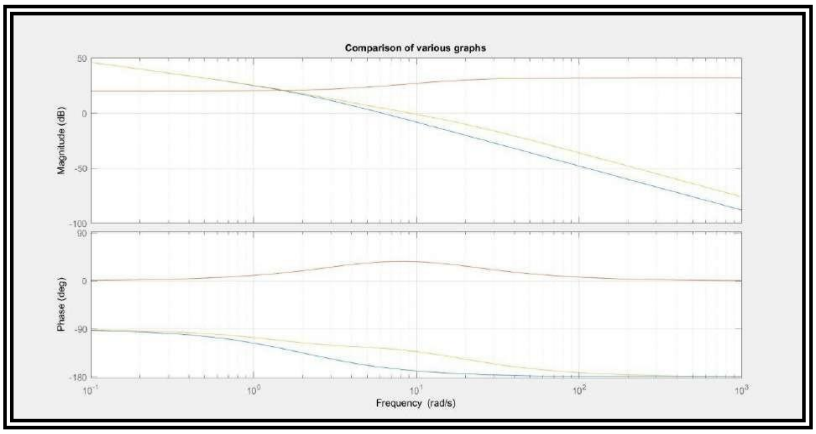
The comparative effects of Proportional Controller (red) and Lead Compensator (yellow), on the user-defined plant (blue), are depicted below:



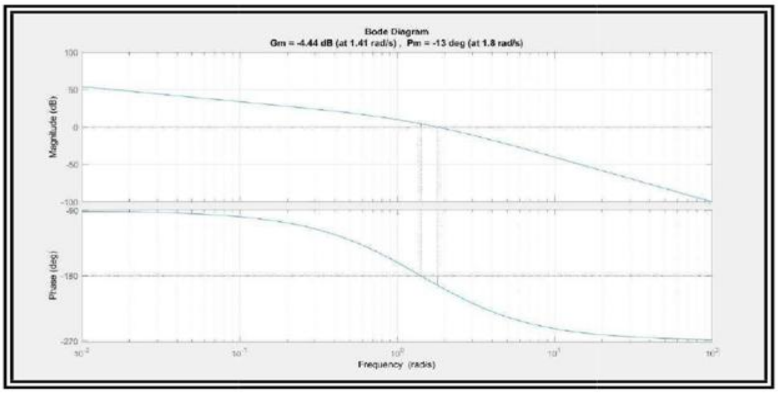
Graph: Effect of Lead Compensation

Similarly, the comparison of Proportional Compensated plant (blue), Lead Compensator (red) and Lead Compensated System (yellow) is depicted below:



Graph: Comparison of various Bode plots

Lag b Compensator:



Graph: Bode of Lag Compensator Input

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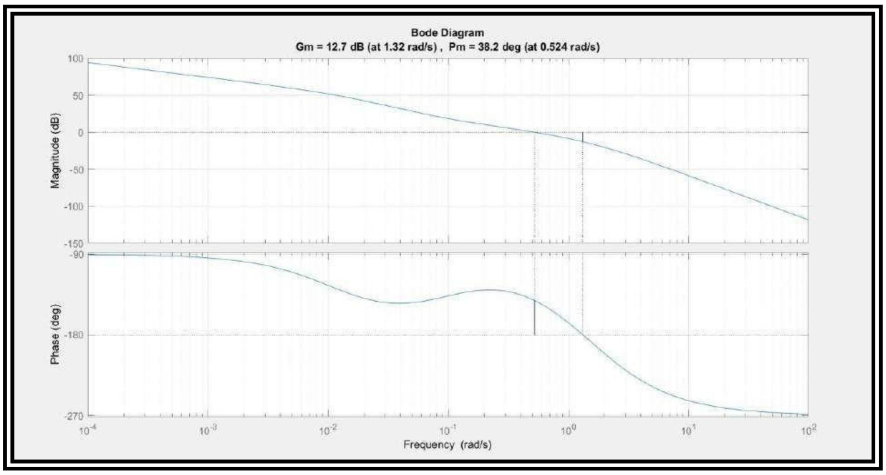
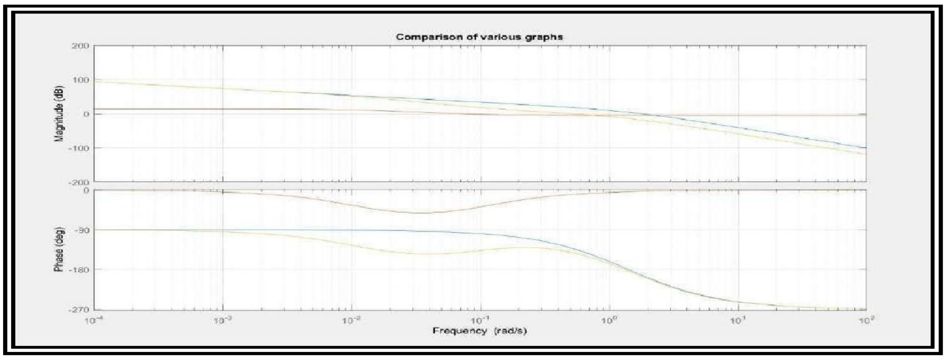
The gain cross over frequency of the above system is n't enough and the phase margin is too low for satisfactory stability of the system. Hence to develop both ,a lag compensator is used.



Graph: Bode of Lag Compensated Plant

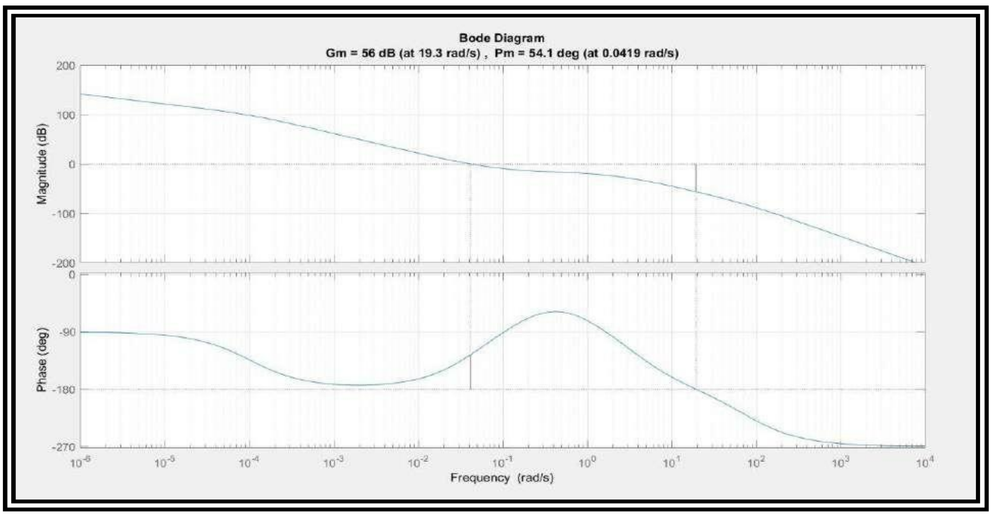
The comparative effects of Proportional Compensated plant (blue), Lead Compensator (red) and Lead Compensated System (yellow) is depicted below:



Graph: Comparison of various Bode plots

Lag and Lead Compensators in Combination

The plot of the final compensated system is shown below:



Graph: Bode of Lag-Lead Compensated Plant

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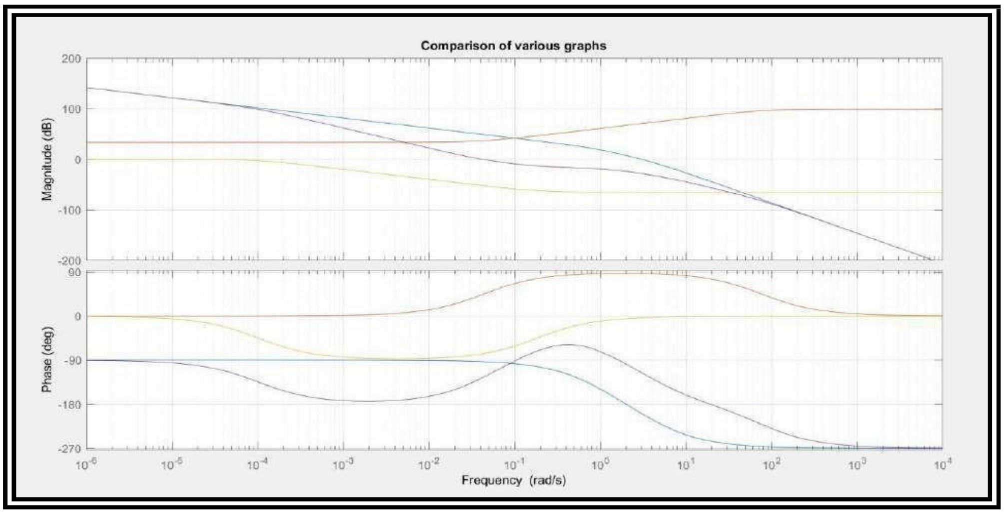
The comparison of various plots shows how the Lead (red) and the Lag (yellow) portions try to manipulate the original plant (blue) according to their characteristics, and the net effect that occurs in the compensated system (purple):



Graph: Comparison of various Bode plots

III. CONCLUSION

The conclusion of this study highlights several key findings. Firstly, the analysis of time specifications in the frequency domain is a more straightforward approach compared to previous methods. Consequently, it has become the preferred method for such analyses. Secondly, the Proportional Compensator has proven effective in enhancing transient response and overall performance. Thirdly, the Lead Compensator has been successfully employed to reduce time response while increasing stability margin, mainly due to its advantageous phase lead contribution. Moreover, the Lead Compensator facilitates rapid responses by achieving a higher gain crossover frequency, resulting in broader bandwidth and reduced settling time. Fourthly, the Lag Compensator aims to enhance steady-state characteristics and minimize steady-state error by attenuating high-frequency components. It is particularly suitable when noise signals are present and a broader bandwidth may not be desirable. Lastly, the Lag-Lead compensation strategy is recommended when both fast responses and precise static accuracy are required. In summary, all three compensators, individually or in combination, can be utilized to fulfill specific requirements and preferences.

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