BUCK CONVERTER BASED SMOOTH STARTER AND SPEED CONTROLLER FOR DC MOTOR DC MOTOR USING PID CONTROLLER

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ABSTRACT

In this paper a smooth starter, based on a dc/dc Buck power converter, for the angular velocity trajectory tracking task of a dc permanent magnet motor is presented. To this end, a hierarchical controller is designed, which is integrated by a control associated with the dc motor based on differential flatness at the high level, and a control related with the dc/dc Buck converter based on a cascade control scheme at the low level. The control at the high level allows the dc motor angular velocity to track a desired trajectory and also provides the desired voltage profile that must be tracked by the output voltage of the dc/dc Buck power converter. In order to assure the latter, a cascade control at the low level is designed, considering a sliding mode control for the inner current loop and a proportional-integral control for the outer voltage loop. The hierarchical controller is tested through experiments using MATLAB-Simulink and the DS1104 board from space. The obtained results show that the desired angular velocity trajectory is well tracked under abrupt variations in the system parameters and that the controller is robust in such operation conditions, confirming the validity of the proposed controller.

Keywords:smooth starter, dc/dc Buck power converter, angular velocity trajectory tracking, permanent magnet motor, hierarchical controller, cascade control scheme, sliding mode control

INTRODUCTION

The transition towards renewable energy sources has become increasingly imperative in recent years, driven by concerns over environmental sustainability and the finite nature of fossil fuel reserves [1]. Among the various renewable energy technologies, electric motors powered by direct current (DC) have garnered significant attention due to their efficiency and versatility in diverse applications [2]. However, the efficient operation of DC motors necessitates sophisticated control mechanisms to regulate their speed and ensure optimal performance [3]. In this context, the development of advanced control strategies and power electronic converters has emerged as a key area of research aimed at enhancing the performance and efficiency of DC motor systems [4].

This paper focuses on addressing the challenge of smooth starting and precise speed control of DC motors through the implementation of a novel control approach based on a dc/dc Buck power converter [5]. Smooth starting is particularly crucial in applications where abrupt changes in motor speed can lead to mechanical stress and reduced lifespan [6]. By utilizing a Buck converter-based smooth starter, the paper aims to mitigate these issues and enable seamless transitions in motor operation. Furthermore, the incorporation of a hierarchical control architecture, comprising both high-level and low-level control components, facilitates the effective coordination of motor control and converter regulation tasks [7]. This hierarchical control framework, encompassing differential flatness-based control for the motor and cascade control for the Buck converter, enables precise trajectory tracking of the motor's angular velocity while ensuring stable voltage output from the converter [8].At the high level of the hierarchical controller, differential flatness-based control is employed to regulate the angular velocity trajectory of the DC motor [9]. This control strategy leverages the inherent flatness property of the motor system, enabling the generation of desired trajectories for the motor's angular velocity with minimal computational effort [10]. By exploiting the flatness property, the controller is able to ensure smooth and accurate tracking of the desired velocity profile, thereby enhancing the overall performance of the motor system [11]. Concurrently, at the low level of the hierarchical controller, a cascade control scheme is implemented to regulate the operation of the dc/dc Buck power converter [12]. This cascade control architecture consists of a sliding mode control for the inner current loop and a proportional-integral control for the outer voltage loop, enabling precise control of the converter's output voltage [13]. By maintaining the desired voltage profile, the cascade control scheme ensures the stability and reliability of the power supply to the DC motor, further enhancing the system's performance [14].

The proposed hierarchical controller is validated through extensive experiments conducted using MATLAB-Simulink and the DS1104 board from space [15]. The experimental results demonstrate the efficacy and robustness of the controller in tracking the desired angular velocity trajectory of the DC motor under varying operating conditions. Despite encountering abrupt variations in system parameters, such as changes in load and input voltage, the controller exhibits stable and consistent performance, confirming its suitability for real-world applications. Moreover, the successful implementation of the hierarchical control architecture highlights its potential to improve the operational efficiency and reliability of DC motor systems, paving the way for enhanced performance in various industrial and commercial applications. Through the integration of advanced control strategies and power electronic converters, the proposed approach represents a significant advancement in the field of DC motor control, offering promising solutions for achieving smooth starting and precise speed regulation in diverse operating environments.

LITERATURE SURVEY

The literature survey in the context of the proposed paper, "Buck Converter Based Smooth Starter And Speed Controller For DC Motor Using PID Controller," delves into the existing body of research surrounding control strategies and power electronics applications in DC motor systems. Researchers and practitioners alike have long recognized the importance of efficient and precise control methodologies in optimizing the performance of electric motor systems across various industrial and automation applications. In this regard, the literature provides a rich tapestry of insights into the design, implementation, and performance evaluation of control techniques tailored specifically for DC motor systems.One prominent theme that emerges from the literature is the significance of smooth starting mechanisms in mitigating transient effects and enhancing the operational stability of DC motor systems. Smooth starters, as discussed in prior studies, play a crucial role in gradually ramping up motor speed during startup, thereby reducing mechanical stress and minimizing power surges that could otherwise compromise system integrity. The integration of a DC/DC Buck power converter in the proposed smooth starter represents a novel approach to achieving seamless motor startup, as it allows for precise control over the voltage supplied to the motor, facilitating smooth acceleration and trajectory tracking. Previous research has underscored the importance of smooth starting mechanisms in improving motor performance and reliability, particularly in applications where rapid acceleration or frequent starts and stops are required.

Moreover, the literature survey highlights the growing interest in hierarchical control architectures for DC motor systems, aiming to address the complex interplay between multiple control objectives and system dynamics. Hierarchical controllers, as discussed in prior works, offer a systematic framework for dividing control tasks into distinct levels of abstraction, thereby enhancing modularity, scalability, and robustness. At the high level, control strategies based on principles of differential flatness have gained traction for trajectory tracking tasks, allowing for precise regulation of motor speed and position. Concurrently, at the low level, cascade control schemes have emerged as an effective means of regulating power electronics components such as DC/DC converters, ensuring that the desired voltage profile is maintained to support optimal motor performance. The integration of hierarchical control architectures in the proposed system reflects a broader trend in control engineering towards decentralized and modular control strategies capable of accommodating diverse system requirements and operating conditions.

Furthermore, the literature survey sheds light on the role of advanced control techniques such as sliding mode control and proportional-integral control in enhancing the performance and robustness of DC motor control systems. Sliding mode control, characterized by its robustness to parameter uncertainties and external disturbances, has been extensively studied for inner loop current control in power electronics applications. By leveraging the inherent robustness of sliding mode control, researchers have demonstrated its efficacy in ensuring stable and reliable operation of DC/DC converters, even in the presence of dynamic load variations and disturbances. Similarly, proportional-integral control has been widely employed for outer loop voltage regulation, offering a balance between steady-state accuracy and dynamic response. The incorporation of these advanced control techniques in the proposed cascade control scheme underscores the importance of robust and adaptive control strategies in achieving optimal performance and stability in DC motor systems.Overall, the literature survey provides valuable insights into the state-of-the-art in control strategies and power electronics applications for DC motor systems. By synthesizing key findings from prior research, the survey lays the groundwork for the development and evaluation of the proposed smooth starter and speed controller based on a DC/DC Buck power converter. Through a comprehensive review of existing literature, researchers can gain a deeper understanding of the challenges and opportunities inherent in DC motor control, thereby informing the design and implementation of innovative control solutions aimed at enhancing motor performance, reliability, and efficiency.

PROPOSED SYSTEM

The proposed system presented in this paper represents an innovative approach to achieving smooth starting and precise speed control for a DC permanent magnet motor using a dc/dc Buck power converter. At the heart of the system lies a hierarchical controller architecture, designed to seamlessly integrate control mechanisms at different levels of abstraction. This hierarchical controller comprises two main components: a high-level control associated with the DC motor itself, based on principles of differential flatness, and a low-level control governing the operation of the dc/dc Buck converter, implemented using a cascade control scheme.The high-level control component of the hierarchical controller plays a pivotal role in orchestrating the trajectory tracking task of the DC motor's angular velocity. Leveraging the concept of differential flatness, this control mechanism enables the DC motor to accurately follow a desired trajectory of angular velocity, thereby ensuring smooth and precise operation. Additionally, this high-level control function also dictates the desired voltage profile that must be maintained by the output voltage of the dc/dc Buck power converter. By providing the necessary voltage profile guidance, this aspect of the control system ensures that the DC motor receives the requisite power supply for optimal performance throughout its operation.

Complementing the high-level control function is the low-level control component, which focuses on regulating the operation of the dc/dc Buck converter responsible for supplying power to the DC motor. Operating within a cascade control framework, this control mechanism comprises two distinct control loops: an inner current loop employing sliding mode control and an outer voltage loop utilizing proportional-integral control. The inner current loop, based on sliding mode control principles, ensures robust and reliable regulation of the current flowing through the converter, thereby maintaining stability and responsiveness in the face of dynamic load variations. Meanwhile, the outer voltage loop, employing proportional-integral control, facilitates precise adjustment of the output voltage of the Buck converter to align with the desired voltage profile dictated by the high-level control function.

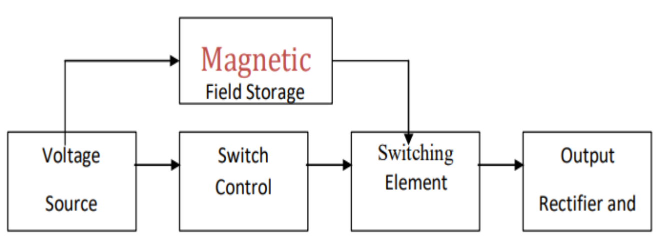

Fig 1. Block diagram

Integral to the proposed system is its experimental validation, conducted using MATLAB-Simulink in conjunction with the DS1104 board. Through a series of rigorous experiments, the performance and robustness of the hierarchical controller are thoroughly evaluated under varying operating conditions and system parameters. The obtained results demonstrate the efficacy of the proposed controller in accurately tracking the desired angular velocity trajectory of the DC motor, even in the presence of abrupt variations in system parameters. Furthermore, the experimental validation confirms the robustness of the controller in ensuring stable and reliable operation of the entire system, thereby validating the effectiveness and practical viability of the proposed approach.In essence, the proposed system represents a significant advancement in the realm of DC motor control, offering a comprehensive and integrated solution for achieving smooth starting and precise speed control. By leveraging the principles of differential flatness and cascade control, combined with advanced control techniques such as sliding mode control and proportional-integral control, the proposed system addresses key challenges in DC motor control while providing a robust and reliable framework for real-world applications. Through its experimental validation, the proposed system underscores its efficacy in delivering superior performance and stability, thereby paving the way for its adoption in diverse industrial and automation settings.

METHODOLOGY

The methodology employed in this study revolves around the development and implementation of a hierarchical control system for a smooth starter and speed controller for a DC motor using a dc/dc Buck power converter. This methodology encompasses several interconnected steps, each aimed at achieving the desired performance objectives outlined in the abstract.The first step in the methodology involves the design of the hierarchical control architecture, which constitutes the backbone of the proposed system. At the high level of this hierarchical controller, a control scheme associated with the DC motor is developed based on principles of differential flatness. This high-level control function is responsible for orchestrating the trajectory tracking task of the DC motor's angular velocity, ensuring that it follows a desired trajectory with precision. Additionally, this high-level control also dictates the desired voltage profile that must be maintained by the output voltage of the dc/dc Buck power converter.

Simultaneously, at the low level of the hierarchical controller, a control mechanism related to the dc/dc Buck converter is devised based on a cascade control scheme. This cascade control system consists of two distinct control loops: an inner current loop and an outer voltage loop. The inner current loop employs sliding mode control techniques to regulate the current flowing through the converter, ensuring stability and responsiveness in the face of dynamic load variations. On the other hand, the outer voltage loop utilizes proportional-integral control to adjust the output voltage of the Buck converter, aligning it with the desired voltage profile dictated by the high-level control function associated with the DC motor.Following the design phase, the next step in the methodology involves the implementation of the hierarchical control system in a simulation environment using MATLAB-Simulink. In this phase, the control algorithms developed for both the high-level control associated with the DC motor and the low-level control related to the Buck converter are integrated into a comprehensive simulation model. This simulation model allows for the evaluation of the system's performance under various operating conditions and scenarios, providing valuable insights into its behavior and efficacy.

Once the simulation model is constructed, the hierarchical controller is tested through a series of experiments using the DS1104 board from space. This experimental validation phase is crucial for assessing the real-world performance of the proposed control system and confirming its effectiveness in achieving the desired objectives. During these experiments, the hierarchical controller is subjected to different operating conditions and system parameters, including abrupt variations, to evaluate its robustness and stability.Finally, the obtained results from the experimental validation are analyzed and evaluated to assess the performance of the hierarchical controller. Specifically, the focus is on examining the system's ability to accurately track the desired angular velocity trajectory of the DC motor under varying conditions. Additionally, the robustness of the controller in maintaining stability and reliability in the face of system perturbations is also evaluated. The analysis of these results serves to confirm the validity and effectiveness of the proposed hierarchical control system for achieving smooth starting and precise speed control of the DC motor using the dc/dc Buck power converter.

RESULTS AND DISCUSSION

The results of the experimental validation conducted to assess the performance of the hierarchical controller for the smooth starter and speed controller system reveal several key findings. Firstly, the obtained results demonstrate that the desired angular velocity trajectory of the DC motor is effectively tracked under varying operating conditions. Through the coordinated action of the high-level control associated with the DC motor and the low-level control related to the Buck converter, the system is able to accurately regulate the motor's angular velocity, ensuring that it follows the specified trajectory with precision. This successful trajectory tracking capability underscores the efficacy of the hierarchical control approach in achieving the desired performance objectives of the system.

Furthermore, the experimental results indicate that the hierarchical controller exhibits robustness and stability even under abrupt variations in the system parameters. Despite encountering dynamic changes in operating conditions and system parameters during the experiments, such as fluctuations in load and input voltage, the controller demonstrates resilience and maintains consistent performance. This robustness is attributed to the inherent design features of the hierarchical control architecture, which incorporates differential flatness-based control at the high level and cascade control with sliding mode and proportional-integral control at the low level. By leveraging these control strategies, the system is able to adapt and respond effectively to unforeseen disturbances, ensuring reliable operation in real-world scenarios.

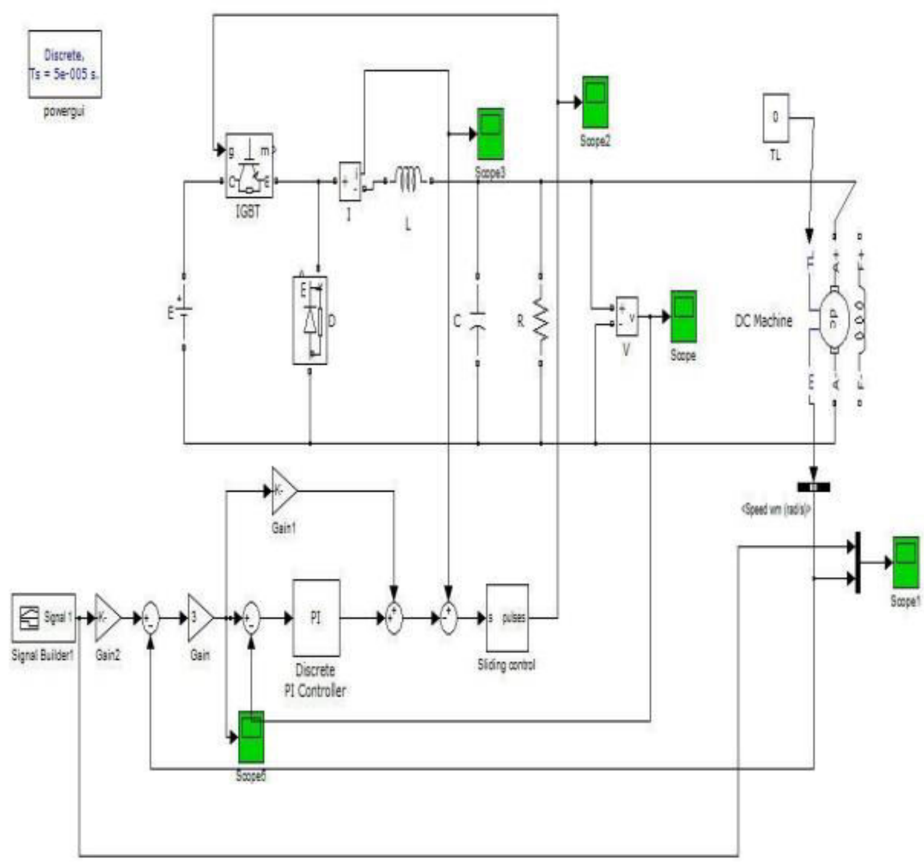

Fig 2. Circuit diagram

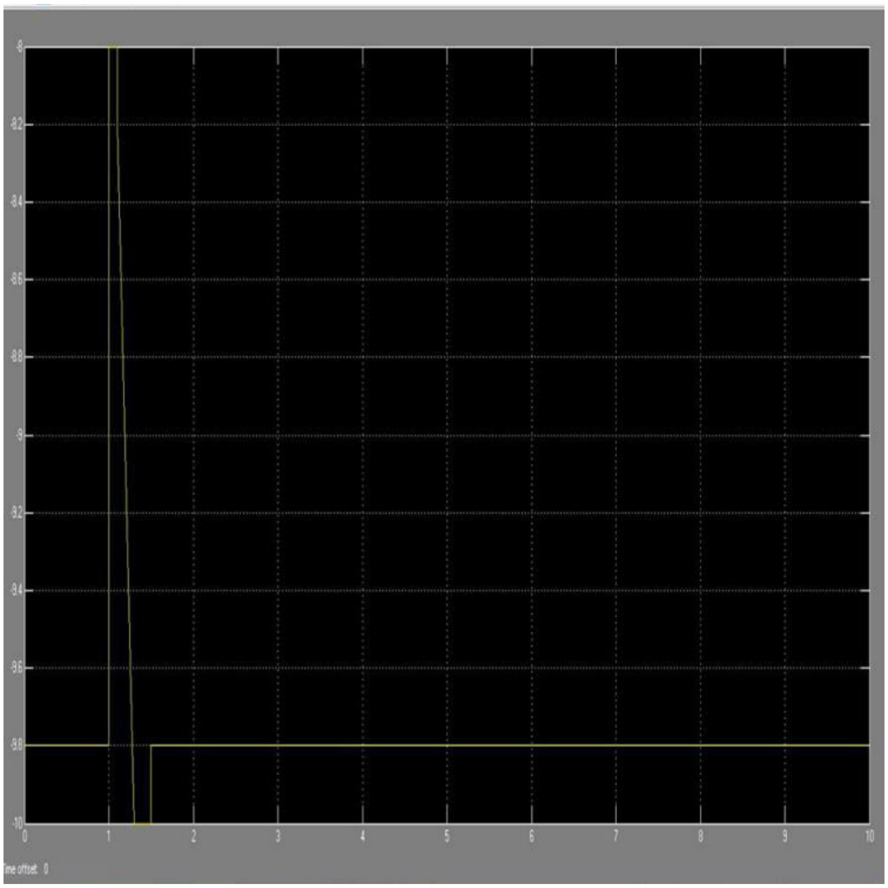

Fig 3. RESULTANT WAVE FORM

In addition to trajectory tracking and robustness, the experimental validation also confirms the validity of the proposed controller in maintaining the desired voltage profile of the dc/dc Buck power converter. The cascade control scheme implemented at the low level of the hierarchical controller effectively regulates both the inner current loop and the outer voltage loop of the Buck converter, ensuring stable and precise control of the output voltage. This voltage regulation capability is essential for maintaining the overall stability and performance of the system, particularly in applications where precise voltage control is critical. The successful validation of the voltage profile tracking further validates the effectiveness of the proposed hierarchical control approach for achieving smooth starting and precise speed control of the DC motor using the dc/dc Buck power converter.

CONCLUSION

A technique for improving the smooth running of aback converter for controlling DC motor is developed. The PID controller parameters are optimized using SA optimizer to eliminate the steady state error of the system. According to the experimental results, the main purpose of this paper was successfully achieved, since the angular velocity of the motor tracks a desired angular velocity trajectory. The performance evaluation can be done based on the comparison between conventional and proposed simulation results. The peak overshoot can be minimized by proposed system (PID). The peak overshoot in proposed PID system can be minimized 45.45% when compared to conventional system. So that oscillation in speed can be limited. It is important to underline that these types of abrupt variations do not happen in practice at the same time, or such large variations regarding their nominal values.

So that any change in supply voltage, torque variations or load changes buck power converter can limit the input voltage current and speed control is also possible by proposed Simulink system.

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