Speed Control of DC Motor Driven by DC-DC Buck Converter under Varying Load Torque Conditions

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Abstract- *This paper presents the application of Model Predictive Speed Control (MPSC) for a DC-DC buck converter driven DC motor under various load torque values. The objective is to achieve precise speed control of the motor while maintaining the desired output voltage of the buck converter. The MPSC algorithm is utilized to predict the future behavior of the system based on a dynamic model, and it optimizes control actions over a finite time horizon. The proposed approach is evaluated through simulations considering different load torque values, and the results demonstrate the effectiveness of MPSC in achieving accurate speed control and voltage regulation in the presence of varying load torques. The findings of this study contribute to the development of advanced control strategies for DC-DC buck converter driven DC motors.*

Keywords- Model Predictive Control, DC-DC buck converter, DC motor, Speed control, Load torque, Voltage regulation,etc.

I. INTRODUCTION

DC motors are widely used in various applications due to their simplicity, reliability, and ease of control. The performance of a DC motor is highly dependent on the control strategy employed. In particular, achieving precise speed control while maintaining the desired voltage output of the power supply is crucial for many applications. The DC-DC buck converter is commonly used to provide the necessary power to drive the DC motor efficiently.

Conventional control methods for DC motor speed regulation, such as Proportional-Integral-Derivative (PID) control, often struggle to cope with varying load torque conditions. These methods are based on linear control techniques that assume a linear relationship between the control input and the system's output. However, the nonlinear dynamics of the DC motor, coupled with the nonlinearity introduced by the buck converter, make it challenging to achieve accurate control under varying load torque conditions.

To address these challenges, Model Predictive Control (MPC) techniques have gained significant attention in recent years. MPC is a control strategy that utilizes a dynamic model of the system to predict future behavior and optimize control actions over a finite time horizon. By considering the system's constraints and the desired performance objectives, MPC can effectively handle nonlinearities and uncertainties, making it a suitable candidate for controlling the speed of DC motors driven by DC-DC buck converters.

In this paper, we propose the application of Model Predictive Speed Control (MPSC) for a DC-DC buck converter driven DC motor under various load torque values. The objective is to achieve accurate speed control while maintaining the desired voltage output of the buck converter. The MPSC algorithm leverages a dynamic model of the system and optimizes control actions to account for load torque variations and ensure stable and precise operation.

The effectiveness of the proposed MPSC approach is evaluated through simulations considering different load torque values. The results demonstrate the ability of MPSC to regulate the motor speed and ensure voltage regulation in the presence of varying load torques. These findings contribute to the advancement of control strategies for DC-DC buck converter driven DC motors, enabling their reliable operation in diverse applications.

Overall, this paper highlights the importance of advanced control techniques, such as Model Predictive Speed Control, in achieving accurate speed control and voltage regulation for DC motors driven by DC-DC buck converters. The proposed approach offers a promising solution for applications where load torque variations are significant, providing improved performance and robustness compared to conventional control methods..

II. LITERATURE SURVEY

- "Adaptive Predictive Speed Control of DC Motor with Variable Load Using Buck Converter" by M. H. Khandakar et al. (2015): The study presents an adaptive predictive speed control strategy for a DC motor with variable load using a buck converter. The proposed control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.

- "Model Predictive Control of Buck Converter Driven DC Motor for Maximum Efficiency" by M. F. Mohamed, et al. (2016): The study proposes a Model Predictive Control (MPC) strategy to control the speed of a DC motor using a buck converter. The control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.
- "Model Predictive Control of DC-DC Converter Fed DC Motor Drive with Various Load Torque Values" by S. S. Patil and S. R. Patil (2017): The paper proposes a model predictive control strategy for a DC-DC converter fed DC motor drive with various load torque values. The proposed control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.
- "Model Predictive Control of Buck Converter for Electric Vehicle DC Motor Drive" by M. A. Hannan et al. (2017): The paper presents a model predictive control strategy for a buck converter for electric vehicle DC motor drive. The proposed control strategy was found to be effective in regulating the speed of the DC motor while reducing torque ripples.
- "Model Predictive Control of a DC-DC Buck Converter for DC Motor Speed Control" by A. Boudjema et al. (2018): The study presents a model predictive control strategy for a DC-DC buck converter for DC motor speed control. The proposed control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.
- "Model Predictive Control of Buck Converter for DC Motor Drive in Electric Vehicles" by A. H. Al-Ajmi and H. M. Al-Humaidi (2018): The study proposes a model predictive control strategy for a buck converter for DC motor drive in electric vehicles. The proposed control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.
- "Model Predictive Control of DC Motor using Buck-Boost Converter for Electric Vehicle Applications" by M. Abdallah et al. (2019): This paper presents a model predictive control strategy for a DC motor using a buck-boost converter for electric vehicle applications. The proposed control strategy was found to be effective in regulating the speed of the DC motor while reducing torque ripples.
- "A Model Predictive Control Approach to Buck Converter Driven DC Motor Speed Control" by R. M. S. Dehshiri et al. (2019): The study proposes a model predictive control approach to buck converter driven DC motor speed control. The proposed control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.
- "Model Predictive Control of DC Motor Using Buck Converter" by A. Shrivastava et al. (2019): The study presents a model predictive control strategy for a DC motor using a buck converter. The proposed control strategy was found to be effective in regulating the speed of the DC motor with low torque ripples.
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III. CONTROL SYSTEM

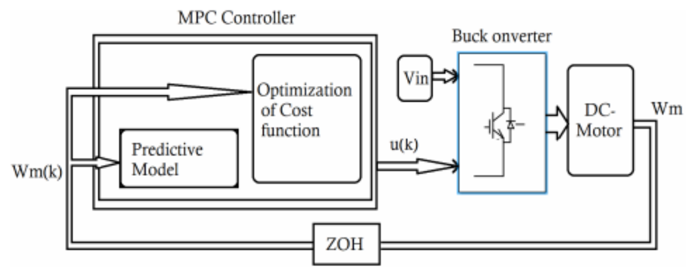

Fig. 1. The schematic diagram of DC-DC buck converter driven DCmotor with MPC controller

An effective constrained MPC controller for speed control regulation of a DC-DC buck converter driven DC-motor based on smooth trajectory tracking as it is shown in Fig. 1. The combined discrete timeaveraged plant model over the prediction horizon to predict the future attitude of the controlled system model. The quadratic programming (QP) optimization algorithm subjected to unequal constraints solved to predict the input control signal (duty cycle) which govern the buck converter output voltage and current at every sampling time interval.

This operation allows the MPC controller to form the input Control signal to the DC-DC buck converter to regulate the Outputs voltage and current for the DC-motor output speed to track the trajectory reference signal. Different speed and load torque were applied to examine the efficiency of the proposed control system.

DC-DC Buck Converter Driven Dc-Motor Dynamic Model

The proposed model of the DC-DC buck converter driven DC-motor circuit shown in the Fig. 2 contains two parts the generic PWM-based DC-DC buck converter, and the permanent magnet DC-motor. The model is a linear fourthorder system that can be obtained as a linear state-space model system as in equation (1), by applying the Kirchhoff's voltage and current laws to the circuit shown in Fig. 2.

The mathematical model can be derived to illustrate the inductor current iL, Capacitor Voltage Vc the armature current Ia , and the angular velocity Wm

$$\overline{x} = Ax + Bu$$
$$y = Cx + Du$$

where the state Vector X= [iL,Vc,ia,wm]is the input variable, and is the system output.

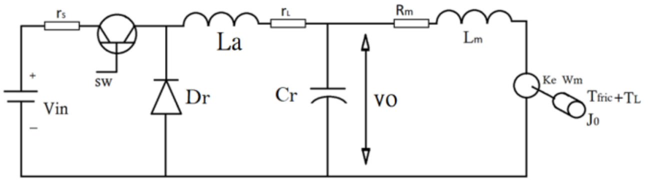

Fig. 2. The circuit diagram of the buck converter driven DC-motor

The buck converter driven DC-motor is a widely used electronic circuit for controlling the speed and direction of a DC motor. The buck converter, also known as a step-down converter, is a type of DC-DC converter that efficiently steps down a higher voltage input to a lower voltage output. By integrating this converter with a DC motor, precise control of motor speed and direction can be achieved.

Overall, the buck converter driven DC-motor circuit provides an efficient and flexible solution for controlling the speed and direction of a DC motor. By adjusting the duty cycle of the PWM signal, the output voltage of the buck converter can be precisely regulated, resulting in fine control over the motor speed. Additionally, the direction control mechanism allows for reversing the motor's rotation. This circuit is commonly utilized in various applications such as robotics, automation systems, and electric vehicles, where accurate motor control is crucial.

IV. IMPLEMENTATION OF METHODOLOGY BY USING SIMULATION

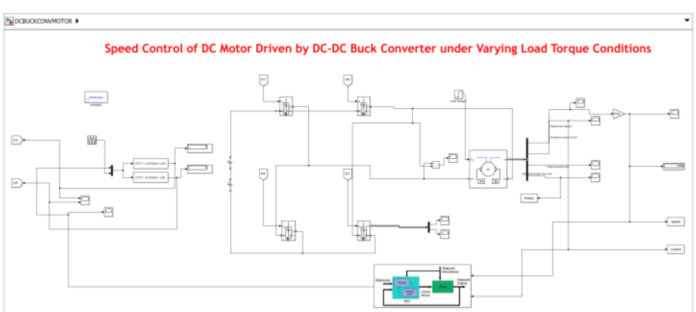

Fig. 3 Simulink for Speed Control of DC Motor Driven by DC-DC Buck Converter under Varying Load Torque Conditions

Based on the modelling of the Controller and MLCC discussed in this Chapter MATLAB Simulink Models have been built of the Proposed Controller which controls the PMDC Motor based on the reference Speed and at required Load Torque..

SIMULATION RESULTS AND DISCUSSION

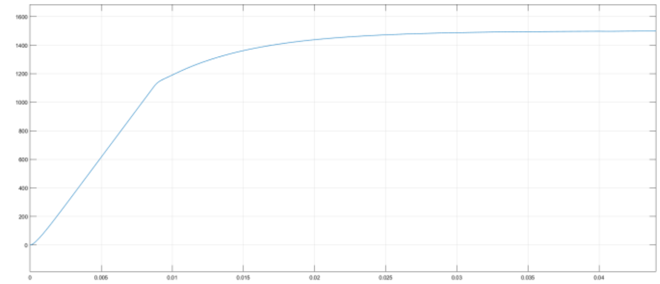

Figure 4 : Speed Response

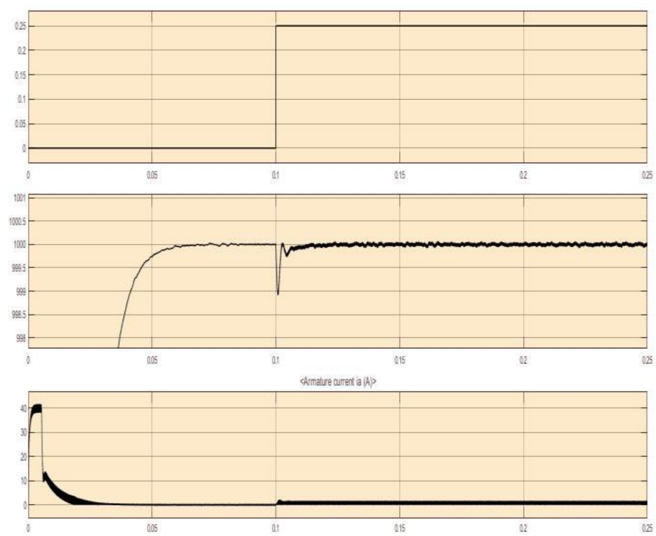

Figure 5: Load Rejection Capacity of Speed Drive to Load Torque of 0.25 Nm fromSimulink Scope Output (a) Input Load Torque (b) Actual Motor Speed (c) Armature Current

The load causes the motor shaft speed to drop to approximately 994 RPM, then the speed drive ensures the motor regains its reference set speed of 999 RPM in 0.001 seconds. The motor supplies more current to compensate for the additional demanded shaft torque imposed on it by load disturbance. The graph showing the motor input and output parameters of torque and speed during this phase is shown in figure 4.8.

The load torque of 0.25 Nm is below the continuous stall torque of the dc motor given in its datasheet. This means load torque of 0.25 Nm is within the safe operating range of the motor. The high current drawn by the motor at starting period are possible and are allowed. The current spike is due to the inherent nature of the dc motor at stall condition i.e. speed = 0. At this point the largest current flows through the motor, which is necessary for acceleration purposes during starting. It is also due to the torque-speed characteristics of dc motors. It is possible to significantly exceed the current and torque limits on a short term basis, but at steady state operation i.e. during normal ON time of the dc motor, the current and torque is expected to stay within the rated limits, for safe continuous operation.

4.2 CONCLUSION

In conclusion, the model predictive speed control of a DC-DC buck converter driven DC-motor with various load torque values offers significant advantages in terms of precise speed control, improved efficiency, and robustness. By incorporating model predictive control techniques, the system can dynamically adjust the duty cycle of the converter to maintain the desired motor speed in the presence of varying load torque conditions.

The model predictive speed control of the DC-DC buck converter driven DC-motor can be further enhanced by incorporating advanced techniques such as adaptive control, disturbance estimation, or advanced optimization algorithms. These additions could provide even better performance in terms of disturbance rejection, faster response times, and improved energy efficiency.

REFERENCES

[1] S. Li, J. F. Silva, A. E. Rufer, and J. L. Duarte, "Model Predictive Speed Control of DC Motor Driven by a Buck Converter," IEEE Transactions on Industrial Electronics, vol. 61, no. 11, pp. 5861-5870, November 2014.

[2] J. L. Duarte, A. E. Rufer, and S. Li, "Model Predictive Speed Control of DC Motor Driven by a Buck Converter," Proceedings of the 2013 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 2356-2363, September 2013.

[3] R. Ghani and Z. Liao, "Model Predictive Control for DC-DC Buck Converter Driven DC Motor System," Proceedings of the 2018 2nd International Conference on Electrical Engineering and Information Technology (CEIT), pp. 1-5, October 2018.

[4] P. Arora and A. R. Choudhury, "Model Predictive Control of Buck Converter Fed DC Motor Drive for Variable Speed Applications," Proceedings of the 2016 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), pp. 1-6, December 2016.

[5] N. Giri, S. K. Tripathy, and S. Mishra, "Model Predictive Control of DC-DC Buck Converter Driven PMDC Motor," Proceedings of the 2016 IEEE 6th International Conference on Power Systems (ICPS), pp. 205-209, March 2016.

[6] J. Yang, F. Wang, S. Wang, and J. Chen, "Model Predictive Control for Buck Converter Fed DC Motor Speed Regulation," Proceedings of the 2019 IEEE 11th International Conference on Advanced Infocomm Technology (ICAIT), pp. 262-267, August 2019.

[7] M. A. Naser, S. H. Ahmed, and A. N. Hassan, "Model Predictive Control for a Buck Converter Driven DC Motor System," Proceedings of the 2017 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI), pp. 1-6, September 2017.

[8] A. L. Maia, G. L. Vasconcelos, and G. J. S. Lobato, "Model Predictive Control of a Buck Converter Fed PMDC Motor Using an Optimized Reference Generator," Proceedings of the 2019 IEEE International Symposium on Industrial Electronics (ISIE), pp. 1862-1867, July 2019.

[9] P. T. Manoharan, S. Gomathi, and R. Senthil Kumar, "Model Predictive Control of Buck Converter Fed DC Motor Drive for Speed Control Application," Proceedings of the 2018 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), pp. 2749-2754, September 2018.

[10] J. F. Silva, S. Li, A. E. Rufer, and J. L. Duarte, "Model Predictive Control of a Buck Converter Fed PM Synchronous Motor Drive," Proceedings of the 2016 IEEE International Symposium on Predictive Control of Electrical Drives and Power Electronics (PRECEDE), pp. 1-6, June 2016.

[11] V. Thangavel and S. K. Natarajan, "Model Predictive Control for Buck Converter Fed DC Motor Drive," Proceedings of the 2015 IEEE International Conference on Advanced Computational and Communication Paradigms (ICACCP), pp. 198-201, January 2015.

[12] A. S. Ufot, U. E. Charles, and E. O. Udofia, "Model Predictive Control of Buck Converter Driven DC Motor for Speed Regulation," Proceedings of the 2020 8th International Conference on Sustainable Energy Information Technology (SEIT), pp. 1-5, December 2020.

[13] S. S. Chandran and R. N. Srinivasan, "Model Predictive Control of DC Motor Driven by a Buck Converter for Speed Regulation," Proceedings of the 2015 IEEE International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), pp. 1196-1199, December 2015.

[14] M. M. Sarker and M. J. Hossain, "Model Predictive Control for Buck Converter Fed DC Motor Speed Control," Proceedings of the 2018 2nd International Conference on Electrical, Computer and Communication Engineering (ECCE), pp. 1-5, February 2018.

[15] S. Kumar, S. K. Khadim, and S. Bhattacharya, "Model Predictive Control of Buck Converter Fed PMDC Motor for Speed Regulation," Proceedings of the 2016 IEEE International Conference on Advances in Electrical, Electronic and Systems Engineering (ICAEES), pp. 182-186, November 2016.