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Direct Torque Control of PMSM Using MATLAB Simulation

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Abstract: This paper involves the application and simulation of Direct Torque Control (DTC) for Permanent Magnet Synchronous Motors (PMSM) using MATLAB. DTC is a robust control strategy known for its capacity to achieve precise control of torque and flux in PMSMs without the need for a complex mathematical model. The primary aims of this investigation are to create a DTC algorithm, conduct simulations using MATLAB, and assess its efficacy in managing PMSM. The research commences with the development of a comprehensive mathematical model for the PMSM, encompassing its electrical and mechanical characteristics. Following that, the DTC algorithm is integrated into the MATLAB environment, enabling real-time control and monitoring. The fundamental principles of the algorithm entail directly governing motor torque and flux by selecting suitable voltage vectors for the inverter based on error calculations

***Keywords* - Direct Torque Control, Permanent Magnet Synchronous Motor, Robust Control.**

1.INTRODUCTION

Permanent Magnet Synchronous Motors (PMSMs) are brushless and have very high reliability and efficiency. Due to their permanent magnet rotor, they also have higher torque with smaller frame size and no rotor current, all of which are advantages over AC Induction Motors (AICMs). With their high power-to-size ratio, PMSMs can help make your design smaller without the loss of torque. Permanent magnet synchronous motors (PMSM) are typically used for high-performance and high-efficiency motor drives. High-performance motor control is characterized by smooth and accurate rotation over the entire speed range of the motor. we offer a comprehensive ecosystem to help you develop advanced PMSM control solutions like sensor-less Field-Oriented Control (FOC) and Direct torque control (DTC) and many other Robust control strategies like sliding mode control and Adaptive sliding mode control. So, permanent magnet synchronous machines have been widely applied in industries due to their advantages they provide. Every control strategy has its own importance. Field-oriented control decouples the air gap-flux and torque channels in the drive system which helps in controlling the PMSM motor. In FOC the instantaneous position of voltage, current and flux space vectors are controlled, ideally giving correct orientation both in steady state and during transients. FOC makes the control accurate in every working operation. The principle of Direct torque control (DTC) is to directly select voltage vectors according to the difference between reference and actual value of torque and flux linkage. Torque and Flux errors are compared in hysteresis comparators. Depending on the comparators a voltage vector is selected from a table. Advantages of DTC are low complexity and that it only need to use of one motor parameter, the stator resistance. No pulse width modulation is needed; instead of six VSI voltage vectors is applied during whole sampling period. All calculations are done in a stationary reference frame which doesn't involve the explicit knowledge of rotor position. The DTC requires less computational power when implemented digitally.

2.Direct Torque Control

[1-15] The Direct Torque Control (DTC) method involves directly managing motor flux and torque, distinguishing it from vector control techniques. DTC dispenses with the need for field orientation, vector transformation, or current control. This simplifies the process by removing complex rotational coordinate transformations, which remain largely unaffected by variations in motor parameters. [15-20] It provides a straightforward calculation procedure, swift torque response, and outstanding dynamic performance [1]. In applications with stringent performance requirements, the use of a robust and reliable control method is imperative. Direct torque control (DTC) has generated considerable interest ever since its initial implementation in PMSM drives. This is owing to its rapid dynamic response, resilience to rotor parameter fluctuations, and inherent sensor less capability [2]. It achieves these control characteristics by directly manipulating the voltage vector applied to the machine's windings through a pulse selector. Direct Torque Control (DTC) of Permanent Magnet Synchronous Motors (PMSM) offers numerous advantages in the

realm of electric motor control. Firstly, it provides exceptionally fast and precise control over motor torque and flux, making it ideal for applications demanding dynamic responsiveness, like robotics and electric vehicles. Additionally, PMSMs inherently possess a high torque-to-inertia ratio, a characteristic further amplified by DTC, leading to superior torque density, vital in scenarios requiring rapid acceleration and deceleration. DTC's ability to minimize torque ripple ensures smoother and quieter motor operation, beneficial in noise-sensitive applications such as electric vehicles and household appliances. Furthermore, it can be implemented in sensor less configurations, eliminating the need for position or speed sensors and reducing system complexity. DTC's robustness to parameter variations is advantageous in scenarios where motor conditions change over time. Its simple implementation, relatively low control bandwidth requirements, and potential for fault tolerance contribute to its appeal. DTC also supports energy-efficient motor operation and finds utility in a wide array of applications, including industrial automation, electric vehicles, and renewable energy systems, owing to its versatility and adaptability. However, it's essential to consider factors like increased switching frequency and electromagnetic interference when choosing DTC for specific applications.

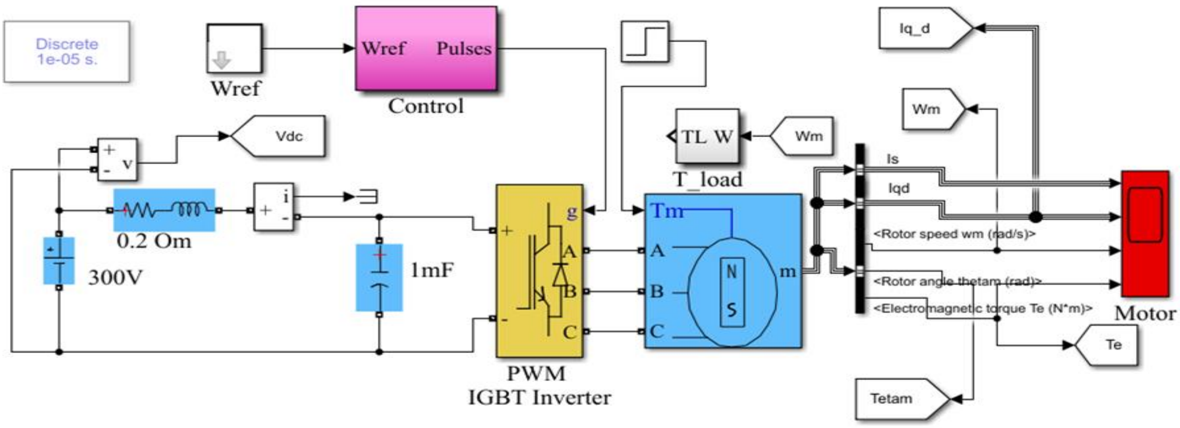
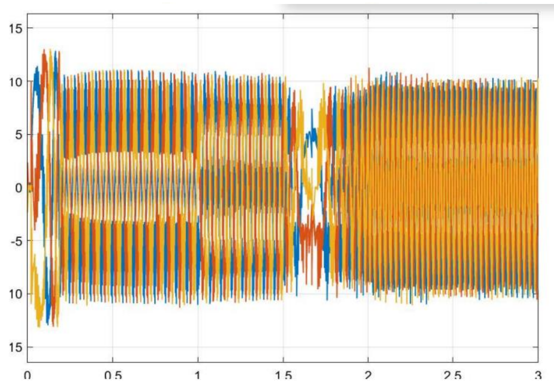


*Figure 1 : **Simulation Diagram of Direct Torque Control***

3. RESULTS



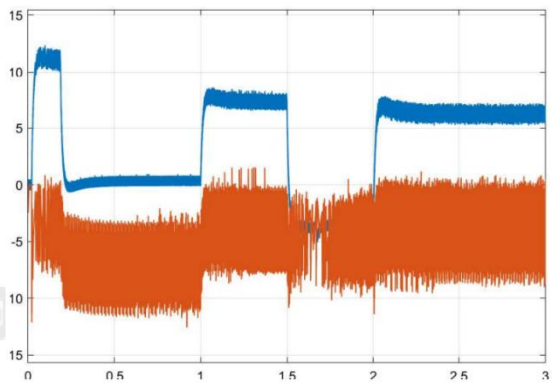


Figure 2 : current response curve

Figure 3 : control voltage response curve

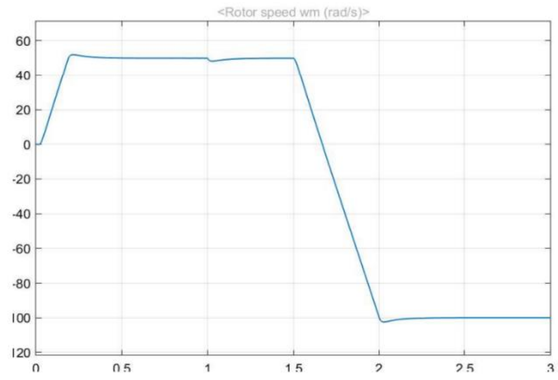


Figure 5 : Speed response curve

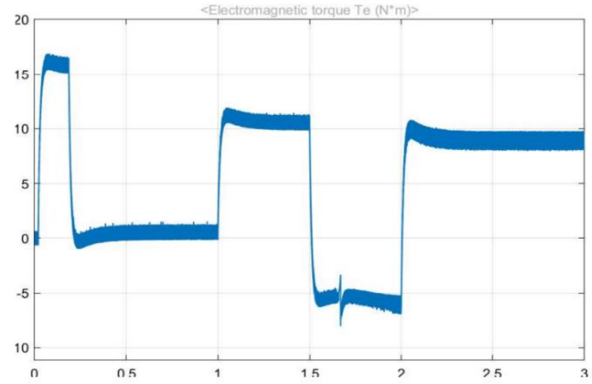


Figure 6 : Torque response curve

The findings indicate that when subjected to identical load conditions, Direct Torque Control exhibits faster and more stable current responses and speed control in comparison to the integer order controller. However, the fractional order controller demonstrates superior performance in scenarios involving load variations or disturbances. The fractional order control exhibits greater adaptability and recovery capabilities, resulting in minimal speed fluctuation when the load undergoes changes.

4.CONCLUSION

Direct torque control (DTC) for permanent magnet synchronous motors (PMSMs) is a promising technique due to its good dynamic torque response and low complexity. It controls the torque and flux of the PMSM directly, enabling operation over a wide speed range, from zero to rated speed. Additionally, DTC does not require any sensors, reducing system cost and complexity. Its fast torque response, wide speed range, and sensor less operation make DTC suitable for many real-life applications, such as electric vehicles and aircraft engines. DTC is a versatile and useful technique for controlling PMSMs.

REFERENCES

[1]. Ayyarao, Tummala SLV, N. S. S. Ramakrishna, Rajvikram Madurai Elavarasan, Nishanth Polumahanthi, M. Rambabu, Gaurav Saini, Baseem Khan, and Bilal Alatas. "War strategy optimization algorithm: a new effective metaheuristic algorithm for global optimization." IEEE Access 10 (2022): 25073-25105.

[2]. Hemanthakumar Chappa, Tripta Thakur, "Voltage instability detection using synchrophasor measurements: A review", Vol. 30 No. 6, International Transactions on Electrical Energy Systems, 2020.

[3]. Kishore T S, Singal S K, "Design economics of EHV power lines", IEEE International Conference on Advances in Electrical Engineering (ICAEE 2014), pp.1-4, 9-11 Jan. 2014, VIT University, Vellore, India.

[4]. Potnuru, Devendra, T. S. L. V. Ayyarao, Lagudu Venkata Suresh Kumar, Yellapragada Venkata Pavan Kumar, Darsy John Pradeep, and Challa Pradeep Reddy. "Salp swarm algorithm based optimal speed control for electric vehicles." Int. J. Power Electron. Drive Syst 13 (2022): 755-763.

[5]. HK Chappa, T Thakur, SC Srivastava, "Reactive power loss based voltage instability detection using synchrophasor technology", IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), 2015.

[6]. Patro ER, Kishore TS, Haghighi AT, "Levelized Cost of Electricity Generation by Small Hydropower Projects under Clean Development Mechanism in India", Energies, 2022, Volume 15, Issue 4, 1473. https://doi.org/10.3390/en15041473

[7]. Tummala, Ayyarao SLV, and Ravi Kiran Inapakurthi. "A two-stage Kalman filter for cyber-attack detection in automatic generation control system." Journal of Modern Power Systems and Clean Energy 10, no. 1 (2021): 50-59.

[8]. Thakur T Chappa H., "A novel load shedding methodology to mitigate voltage instability in power system" no.3, Pp 63-70, Electrical Engineering & Electromechanics 2022.

[9]. Kishore T S, Koushik S D, Venu Madhavi Y, "Modelling, Simulation and Analysis of PI and FL Controlled Microgrid System", 3rd IEEE International Conference on Electrical, Computer and Communications Technologies (ICECCT 2019), 20-22 Feb, 2019, SVS College of Engineering, Coimbatore, India.

[10]. Ayyarao, Tummala SLV. "Parameter estimation of solar PV models with quantum-based avian navigation optimizer and Newton–Raphson method." Journal of Computational Electronics 21, no. 6 (2022): 1338-1356.

[11]. Hemanthakumar Chappa, Tripta Thakur, "Power System Voltage Stability", Novel Advancements in Electrical Power Planning and Performance pp 283-299, IGI Globa, 2020.

[12]. Nuvvula, R.S.S.; Elangovan D.; Teegala, K.S.; Madurai Elavarasan, R.; Islam, M.R.; Inapakurthi, R. Optimal Sizing of Battery Integrated Hybrid Renewable Energy Sources with Ramp-Rate Limitations on Grid Using ALA-QPSO. Energies 2021, Volume 14, Issue 17, 5368. https://doi.org/10.3390/en14175368

[13]. Tummala, Ayyarao SLV. "A robust composite wide area control of a DFIG wind energy system for damping inter-area oscillations." Protection and Control of Modern Power Systems 5, no. 1 (2020): 25.

[14]. Hemanthakumar Chappa, Tripta Thakur, "A fast online voltage instability detection in power transmission system using wide-area measurements", vol. 43,pp 427-438, Iranian Journal of Science and Technology, Transactions of Electrical Engineering, 2019.

[15]. Bade Venkata Suresh, Yegireddi Shireesha, Teegala Srinivasa Kishore, Gaurav Dwivedi, Ali Torabi Haghighi, Epari Ritesh Patro, "Natural energy materials and storage systems for solar dryers: State of the art", Solar Energy Materials and Solar Cells, Volume 255, 2023, 112276, ISSN 0927-0248, https://doi.org/10.1016/j.solmat.2023.112276.

[16].G. I. Kishore and R. K. Tripathi, "Single-phase PFC converter using switched capacitor for high voltage DC applications," IEEE Trans. Ind. Appl., vol. 54, no. 3, pp. 2560–2567, 2018.

[17].G. I. Kishore and R. K. Tripathi, "3-phase high gain PFC converter implementing switched capacitors," in 2019 International Conference on Computing, Power and Communication Technologies (GUCON), IEEE, 2019, pp. 551–556.

[18].G. I. Kishore and R. K. Tripathi, "Single-phase PFC converter using modified multiplier SEPIC converter for high voltage DC applications," in 2017 4th IEEE Uttar Pradesh Section International Conference on Electrical, Computer and Electronics (UPCON), IEEE, 2017, pp. 598–603.

[19].C. Ravikiran, G. I. Kishore, T. A. Rao, and M. Rambabu, "Effective elimination of harmonics by means of a hybrid series active filter (HSAF)," Int. J. Eng. Res. Appl., vol. 2, no. 5, pp. 96–101, 2012.

[20].T. Ayyarao, G. I. Kishore, and M. Rambabu, "Adaptive control of saturated induction motor with uncertain load torque," Int. J. Recent Trends Eng. Technol., vol. 3, no. 4, 2010.