Dr. Rajesh M. Pindoriya

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Indian Institute of Technology Mandi, India
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EDUCATION

Ph.D. (Electrical Engineering) Indian Institute of Technology Mandi, Himachal Pradesh	2015-2020	8.75 CGPA
M.E. (Electrical Engineering) Gujarat Technological University, Gujarat	2012-2014	8.23 CPI
B. Tech. (Electrical and Electronics Engineering) Rajasthan Technical University, Rajasthan	2008-2012	68%

RESEARCH INTERESTS

- Power Electronics and Electrical Drives
- Control of Electric Motors
- Green Hydrogen Technology for Net Zero Emission Electric and Hybrid Vehicles
- Analysis of Acoustic Noise and Vibration of Permanent Magnet Motors, Switched Reluctance Motor (SRM), Synchronous Reluctance Motor (SynRM) Drives
- Condition Monitoring and Faults Diagnosis of PMSM, BLDC Motor, SRM and SynRM Drives
- Electromagnetic Design of Electric Motors
- Power Electronics Converters for Renewable Energy Generation (Solar PV and Wind)

PROFESSIONAL AND RESEARCH EXPERIENCE

Assistant Professor Department of Electrical & Instrumentation Thapar Institute of Engineering & Technology, Punjab, India	July 2022 – Till now
Project Engineer (Funded by DRDO, India) School of Basic Science Indian Institute of Technology Mandi, India	August 2020 – June 2022
Guest Faculty Department of Electrical and Electronics Engineering National Institute of Technology Delhi, India	September 2021 – December 2021
Ph.D. Candidate & Teaching Assistant School of Computing and Electrical Engineering Indian Institute of Technology Mandi, India	August 2015 – September 2020
Mentorship Design of PMSM/BLDC Motor Drives for Drone Applications Xenhester Innovation Pvt. Ltd., Rajkot, Gujarat, India	October 2019 – Till now
Project Engineer (Funded by NRB, India) School of Computing and Electrical Engineering Indian Institute of Technology Mandi, India	July 2015 - May 2018
Internship Department of Electrical Engineering Indian Institute of Technology Gandhinagar, India	August 2014 - June 2015
Training Gujarat Industrial Power Company Limited (GIPCL), Surat, Gujarat	June 2007 - July 2007

AWARDS AND RECOGNITIONS

- **IEEE Outstanding Volunteer Award** from IEEE India Council in 2023
- **1st Rank in IEEE IAS Global Mentorship Program (GMP) Award** in 2023 (from IEEE IAS CMD, USA)
- **Travel Award** from DST-SERB to attend the IEEE IAS Annual Meeting 2023, 9th Oct.-2nd Nov. 2023, Nashville, Tennessee, USA
- **Global Distinguished Researcher Award** in 2023 (from IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies (GlobConHT 2023), Maldives)
- **1st Rank in IEEE Humanitarian Contest Award** in 2022 (from IEEE IAS Chapters and Membership Department (CMD), USA)
- **Recipient of IEEE IAS Annual Meeting Travel Grant Program (AMTGP-2022),** Detroit, USA
- **1st Rank in IEEE Day Photo Contest 2021** (From IEEE, USA)
- **2nd Rank in IEEE Humanitarian Contest Award** in 2021 (from IEEE IAS Chapters and Membership Department (CMD), USA)
- **2nd Rank in IEEE IAS Global Mentorship Program (GMP) Award** in 2021 (from IEEE IAS CMD, USA)
- **Outstanding IEEE Volunteer Award** in 2021 (from IIT Mandi, India)
- **Best Abstract Award** in 2021 (from IEEE IAS Electrical Safety Workshop, 2021, USA)
- **Darrel Chong Student Activity Award in 2020** (from IEEE MGA Student Activity Committee, USA)
- **2nd Rank in Chapter Web Contest Award** in 2019 and 2020 (from IEEE IAS CMD, USA)
- **Institute of Scholars (InSc) Research Excellence Award** in 2020
- **Continued Outstanding Performance Student Branch Chapter** in 2019 (from IEEE IAS CMD, USA)
- **Outstanding IEEE Student Volunteer Award** in 2019 (from IEEE Delhi Section, India)
- **MHRD Fellowship** during Ph.D., 2018-2020
- **Housing Support Award** in 2018 (from IEEE PES General Meeting 2018, USA)
- **Travel Award** in 2018 (from IIT Mandi to attend the IEEE PES General Meeting 2018, USA)
- **Travel Award** from IIT Mandi to attend the IEEE National/International Conferences (2015-2020), India
- **Travel Award** in 2019 (from IEEE IAS CMD to attend the IEEE IAS Annual Meeting 2019, USA)
- **Best Paper Award** in National Conference on "Emerging Trends in Computer and Electrical Engineering" (ETCEE - 2014) at AITS, Rajkot, March 2014
- **Awarded scholarship** for securing a position of 3rd rank in the 2nd and 3rd year of B. Tech program

PROJECTS UNDERTAKEN

Field Programmable Gate Array (FPGA) Based Speed Control of Brushless Direct Current Motor (BLDC) (M.E. Thesis) **[June 2013- June 2014]**

Advisor: Prof. S. Rajendran, Department of Electrical Engineering, IIT Gandhinagar.

This work presents Field Programmable Gate Array (FPGA) implementation for PWM-based speed control of inverter-fed Brushless DC (BLDC) Motor. The proposed methodology is first simulated for open-loop and closed-loop speed control. These simulation results are further verified through a lab-scale experimental setup. It has been observed that the FPGA-based closed-loop method improves the transient and steady-state response for speed control of BLDC motor. During June 2013-June 2014 of my ME thesis work at IIT Gandhinagar, I have learned about Field Programmable Gate Array (FPGA) based technology, hardware in the loop with MATLAB as well as FPGA, working principle of Intelligent Power Module (IPM), FPGA based speed control of BLDC motor, Induction motor, switched reluctance motor. I have been acquainted with Spartan 3A & Spartan 3E FPGA kit, hardware setup of single-phase, and three-phase inverter and rectifier circuits.

Solar Tracking System (B. Tech Major Project)

Acquire quite good exposure in solar tracking systems in this project. The work was related to designing and implementing a solar tracking system to increase the power generation from the solar PV module.

Power Factor Improvement (B. Tech Minor Project)

Implemented power factor correction for academic institutional load demand and have attempted to demonstrate for lab-scale loading. Acquire knowledge of hardware implementation at B. Tech level.

INDUSTRIAL TRAINING

Summer training (of 55 days) at Gujarat Industrial Power Company Limited (GIPCL), Surat, Gujarat during B. Tech study. Through this training, I have learned some practical aspects of power generation, generating substations, and other technical considerations for the thermal power plant. Also, I have acquired more knowledge of 220 kV substations and power control and management at generating stations.

HIGHLIGHTS OF RESEARCH WORK

1. Design and performance analysis of a low-cost acoustic chamber for electrical machines:
(More details you can find in Appendix 1)

Nowadays consumers demand more smooth and more silent devices, whether it is a computer, power electronics gadget, vacuum cleaner, electric drive, or washing machine. Therefore, for testing all devices one free-field enclosure is required. It provides a free-field environment, which is nearly close to free from background noise and humming noise. An acoustic chamber is a protected chamber designed for Acoustic Noise and Vibration (ANV) measurement under free-field conditions. For the measurement of ANV of electric machines, a highly effective low-cost acoustic chamber has been designed with the highest cut-off frequency of 40 Hz. The design and testing of the acoustic chamber have been done in the laboratory where the calculated transfer function, both in forward and reverse direction has been implemented and further validated with calculated results. This low-cost acoustic chamber is suitable for testing of ANV of all electrical machines.

2. An Experimental Investigation of Acoustic Noise and Vibration of PMSM due to Power Electronics Converters:
(More details you can find in Appendix 2)

In recent years, the market of Permanente Magnet (PM) motors, such as (Permanent Magnet Synchronous Motor (PMSM) and Brushless Direct Current Motor (BLDCM)) drives has become huge due to the demand for electric and hybrid electric vehicles. This work presents an experimental and theoretical investigation of ANV produced by PMSM-based electric drive. The sources of ANV of PMSM drive are discussed in detail, which are physical structural based (mechanical, magnetic, and aerodynamic) and drives based (power electronic converters). Power electronic converter injects the time domain harmonics into the PMSM drives which can be addressed by employing suitable control algorithms. To investigate the ANV of the PMSM drive, a mathematical model of PMSM is developed and analyzed. The physical phenomenon responsible for ANV induced by Maxwell forces in machines has been discussed extensively.

3. A Novel Application of Pseudorandom PWM-Based Technique for Acoustic Noise and Vibration Reduction of PMSM Drive: *(More details you can find in Appendix 3)*

This work presents, a novel application of the Pseudorandom Triangular Pulse Width Modulation (PTPWM) technique on a PMSM drive to reduce ANV. The proposed PTPWM method brings a significant reduction in torque ripples, acoustic noise, and vibrations in the motor, thereby enhancing the performance of the complete drive system under operation. The relationships between the stator current harmonics feed by a drive and non-sinusoidal magnetic field flux distribution, with torque ripples are developed and analyzed in this work. Furthermore, in-depth theoretical background and analysis of how PTPWM improves torque ripples, vibration, and acoustic noise of PMSM drives is presented. Extensive simulation and experimental investigations have been carried out for validation of the proposed control strategy.

4. Design and Implementation of Rotor Position Estimation Scheme for PMSM Drive: *(More details you can find in Appendix 4)*

This work presents, a rotor position estimation scheme for a high-performance PMSM drive. The rotor position of the PMSM drive is estimated by measuring the stator voltage and the current quantity of the PMSM drive. Initially, the PMSM drive run by the V/F control technique. Once the motor reaches up to 10% of synchronous speed, the V/F control technique switches over to the sensorless control algorithm. The sinusoidal Pulse Width Modulation (SPWM) technique has been used to generate three-phase voltages from the dc-link source. The closed-loop speed control is effective from a standstill to a rated speed. Computer simulation and experimental results are presented to demonstrate the effectiveness of the scheme.

5. An Investigative Study of the PMSG-Based Wind Turbine Using Real-Time Simulation:*(More details you can find in Appendix 5)*

This work presents, the complete control strategy (i.e., transient and steady-state) of a grid-connected direct drive Permanent Magnet Synchronous Generator (PMSG) based Wind Energy Generation System (WEGS) using the mathematical model. A back-to-back power electronic converter has been interfaced with variable speed PMSG-based wind turbine and the power grid. When the faults occur at the grid, the grid-side converter suffers because of a change in the inertia of the prior system due to which the operation of the PMSG gets affected. It is observed that tuning of the grid side converter is required due to the fault that occurred in the grid. Thus, it is observed that maintaining the constant DC link voltage is required for the abrupt-less operation. The simulation results of the faults such as three-phase line-to-line, a line to ground, and realistic grid faults have been discussed in detail. This work also reported the effectiveness of the power quality injected into the grid during the variable wind-speed turbine system. To pursue the above analysis a real-time simulation tool RTDS has been used.

6. Numerical and Experimental Analysis of Torsional Vibration and Acoustic Noise of PMSM Coupled with DC Generator: *(More details you can find in Appendix 6)*

This work presents, the Permanent Magnet Synchronous Motor (PMSM) driven by using Sinusoidal Pulse Width Modulation (SPWM) technique, and then an investigation (cause and effect) of Acoustic Noise and Vibration (ANV) is presented. An equivalent lumped parametric modelling of end-to-end coaxially coupled shafts between PMSM and DC generator along with effective modal mass and modal participation factor accuracy enhancement technique, is presented to predict torsional vibration. The modal analysis approach is used to analyse the torsional vibration response, which is used to estimate the source of acoustic noise, and a mathematical approach is presented at the end to calculate the ANV of electric drives. Theoretical and experimental investigations are carried out on a 1.07- kW, 4-poles, 36-slots, 3-phase PMSM drive. Analytical and numerical results are validated by experimental studies.

RESEARCH PUBLICATIONS

Publications in Journals

1. **R. M. Pindoriya**, Kumar V. Tejan, and B. S. Rajpurohit, "Speed Control of Sensorless PMSM Drive using Adaptive Current Control Prediction Method", *Springer Journal of Electrical Engineering*, vol. 105, pp. 1-13, Jan. 2023, *DOI 10.1007/s00202-022-01725-y (Impact Factor: 1.63)*
2. **R. M. Pindoriya,** K. V. Tejan, and B. S. Rajpurohit and R. Kumar, "Stator Feed-forward Voltage Estimation with MRAS Technique for Position Sensorless PMSM Drive*", Inderscience International Journal of Power Electronics*, vol. 18, no.4, 2023.
3. **R. M. Pindoriya**, R. K. Thakur, B. S. Rajpurohit, and R. Kumar, "Numerical and Experimental Analysis of Torsional Vibration and Acoustic Noise of PMSM Coupled with DC Generator", *IEEE Transactions on Industrial Electronics*, vol. 69, no. 4, pp. 3345-3356, April *2022, DOI: 10.1109/TIE.2021.3076715 (Impact Factor: 9.59)*
4. **R. M. Pindoriya**, A. K. Yadav, B. S. Rajpurohit and R. Kumar, "A Novel Application of Random Hysteresis Current Control Technique for Acoustic Noise and Vibration Reduction of PMSM Drive", *IEEE Magazine on Industry Applications*, vol. 28, issue 6, pp. 27-39, Nov. 2022, *DOI:10.1109/MIAS.2022.3160986 (Impact Factor: 2.38)*
5. **R. M. Pindoriya**, S. Chauhan, B. S. Rajpurohit and R. Arora, "A Critical Evaluation of Safety, Economic and Power Quality Considerations for Single-Phase Power Consumption and Distribution Systems at 120 and 230 V", *The Journal of IEEMA*, vol. 13, issue no. 9, pp. 58-68, May 2022
6. **R. M. Pindoriya**, A. K. Mishra, B. S. Rajpurohit, and R. Kumar, "An Experimental Investigation of Acoustic Noise and Vibration of PMSM due to Power Electronics Converters", *Electric Power Components & Systems, Taylor & Francis Journal*, vol. 48 (19-20), pp. 2005–2018, 2020, *DOI: 10.1080/15325008.2021.1921885 (Impact Factor: 1.38)*
7. **R. M. Pindoriya,** G. Gautam and B. S. Rajpurohit, "A Novel Application of Pseudorandom Based Technique for Acoustic Noise and Vibration Reduction of PMSM Drive," *IEEE Transactions on Industry Applications,* vol. 56, issue. 5, pp. 5511-5522, Sept.-Oct. 2020, *DOI: 10.1109/TIA.2020.2997904 (Impact Factor: 4.38)*
8. **R. M. Pindoriya**, B. S. Rajpurohit, and R. Kumar, "A Novel Application of Harmonics Spread Spectrum Technique for Acoustic Noise and Vibration Reduction of PMSM Drive," *IEEE Access*, vol. 8, pp. 103273-103284, 2020, *DOI:10.1109/ACCESS.2020.2999336 (Impact Factor: 4.098)*

Publications in Book Chapters

1. R. K. Thakur, **R. M. Pindoriya**, R. Kumar, and B. S. Rajpurohit, "Effectiveness Analysis of Control Strategies in Acoustic Noise and Vibration Reduction of PMSM Driven Coupled System for EV and HEV Applications", book entitled *"Transportation Electrification: Breakthroughs in Electrified Vehicles, Aircraft, Rolling Stock, and*

Watercraft", will be published by the IEEE-Wiley, ISBN: 9781119812357, *pp.105-138, DOI: 10.1002/9781119812357.ch5, 2023*

2. **R. M. Pindoriya**, R. K. Thakur, B. S. Rajpurohit, and R. Kumar, *"*Analysis of Acoustic Noise and Vibration of PMSM Coupled with DC Generator for Applications to Electric Vehicles", book entitled *"Planning of Hybrid Renewable Energy Systems, Electric Vehicles and Microgrid: Modeling, Control and Optimization", published by the Springer,* ISBN: 978-981-19-0979-5, pp. 717-757, 2022, *DOI: 10.1007/978-981-19-0979-5*

Publications in Conferences

1. Naman, **R. M. Pindoriya**, and B. S. Rajpurohit, "Cyber Security in the Smart Grid: Challenges and Solutions-A Review", *2043 IEEE 4th International Conference on Sustainable Energy and Future Electric Transportation (SeFeT2024)*, 31 July – 3 August 2024, in Hyderabad, India *(Submitted)*
2. **R. M. Pindoriya**, H. D. Golechha, A. K. Singh, V. Ahuja, A. Sharma, A. Singh, and S. Jain, "A Review of Recent Developments and Challenges in the Selection of Design Parameters for Green Hydrogen Electric Vehicles", *IEEE IAS Annual Meeting 2023,* 29th Oct.-2nd Nov. 2023, Nashville, Tennessee, USA
3. H. D. Golechha, A. K. Singh, and **R. M. Pindoriya**, "State-of-the-Art of Green Hydrogen Fuel Cell Electric Vehicles and Battery Management Systems", *2023 IEEE 3rd International Conference on Sustainable Energy and Future Electric Transportation (SeFeT2023),* 9-12 Aug. 2023, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, India
4. **R. M. Pindoriya**, V. Ahuja, A. Sharma, A. Singh, and S. Jain, "An Analytical Review on State-of-the-Art of Green Hydrogen Technology for Fuel Cell Electric Vehicles Applications", 2023 IEEE 3rd International Conference on Sustainable Energy and Future Electric Transportation (SeFeT2023), 9-12 Aug. 2023, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, India
5. R. K. Thakur, **R. M. Pindoriya**, R. Kumar, and B. S. Rajpurohit, "An MPF method-based Torsional Vibration Analysis of RBHCC-driven PMSM Coupled System in Comparison with SPWM Technique for EV and HEV Transmission", *2023 IEEE IAS Global Conference on Renewable and Hydrogen Technologies (GlobConHT-2023)*, March 11-12, 2023, at The Maldives National University, Male City, Maldives.
6. **R. M. Pindoriya**, Tirupati C. Sharma, Pramod Soni, and Prem F. Siril, "Sensor Assisted Detection of the Explosion During Impact Sensitivity Measurement", *13th International High Energy Material Conference & Exhibits*, 26-28 May 2022, TBRL, Ramgarh, Haryana, India
7. Kumar V. Tejan, **R. M. Pindoriya,** and B. S. Rajpurohit, "Error Reduction in Sensorless Speed Control Technique for PMSM Drive using New Sliding Mode Reaching Law", *IEEE IAS Annual Meeting 2022,* 09-13 Oct. 2022, USA, *doi: 10.1109/IAS54023.2022.9939806.*
8. Kumar V. Tejan, **R. M. Pindoriya,** and B. S. Rajpurohit, "Rotor Position Sensorless Technique using High-Speed Sliding Mode Observer for PMSM Drive", *IEEE IAS Annual Meeting 2021,* 10-14 Oct. 2021, Canada, *doi: 10.1109/IAS48185.2021.9677412.*
9. **R. M. Pindoriya,** A. K. Yadav, and B. S. Rajpurohit, "Current Slope Detection Technique for Estimation of Rotor Position of PMSM Drive*", IEEE 21st National Power Systems Conference (NPSC 2020),* Dec. 17-19, 2020, IIT Gandhinagar, Gujarat, India, *DOI: 10.1109/NPSC49263.2020.9331842*
10. **R. M. Pindoriya**, A. K. Yadav, B. S. Rajpurohit, and R. Kumar "A Novel Application of Random Hysteresis Current Control Technique for Acoustic Noise and Vibration Reduction of PMSM Drive", *IEEE IAS Annual Meeting 2020,* 11-15 Oct. 2020, USA, *DOI:10.1109/IAS44978.2020.9334818*
11. A. K. Yadav, **R. M. Pindoriya**, and B. S. Rajpurohit, "Design and Implementation of Rotor Position Estimation Scheme for PMSM Drive", *IEEE PIICON 2020, 28th Feb.- 1st Mar. 2020,* Sonepat, Haryana, India, *doi: 10.1109/PIICON49524.2020.9113041*
12. Gom Dorji, Jigme Zangpo, **R. M. Pindoriya**, and B. S. Rajpurohit, "A Case Study on Power Quality Analysis for 600 kW Grid Connected Wind Turbine", *IEEE PIICON 2020, 28th Feb- 1st Mar. 2020,* Sonepat, Haryana, India, *doi: 10.1109/PIICON49524.2020.9112867.*
13. **R. M. Pindoriya,** B. S. Rajpurohit, and A. Monti, "An Investigative Study of the PMSG Based Wind Turbine Using Real-Time Simulation", *IEEE ICPS 2019, 20-22 Dec. 2019,* MNIT, Jaipur, Rajasthan, India, *DOI: 10.1109/ICPS48983.2019.9067370*
14. **R. M. Pindoriya,** G. Gautam and B. S. Rajpurohit**, "**A Novel Application of Pseudorandom Based Technique for Acoustic Noise and Vibration Reduction of PMSM Drive", *IEEE IAS Annual Meeting 2019,* Baltimore, USA, 29 Sep. 2019- 03 Oct. 2019, *DOI: 10.1109/IAS.2019.8912467*
15. **R. M. Pindoriya,** B. S. Rajpurohit, and R. Kumar, "Design and Performance Analysis of Low-Cost Acoustic Chamber for Electric Machines", *IEEE Power India International Conference (PIICON-2018),* National Institute of Technology Kurukshetra, Haryana, India, Dec. 10-12, 2018, *DOI: 10.1109/POWERI.2018.8704442*
16. **R. M. Pindoriya**, A. K. Mishra, B. S. Rajpuronit, R. Kumar, "An Analysis of Vibration and Acoustic Noise for BLDC Motor Drive", *IEEE PES GM-2018,* Portland, USA, 05-10 Aug. 2018, *DOI: 10.1109/PESGM.2018.8585750*

17. **R. M. Pindoriya**, A. K. Mishra, B. S. Rajpuronit, R. Kumar, "FPGA Based Digital Control Technique for BLDC Motor Drive", *IEEE PES General Meeting 2018*, Portland, USA, 05-10 Aug. 2018, *DOI: 10.1109/PESGM.2018.8586472.*
18. **R.M. Pindoriya**, B. S. Rajpurohit, R. Kumar and K. N. Srivastava, "Comparative Analysis of Permanent Magnet Motors and Switched Reluctance Motors Capabilities for Electric and Hybrid Electric Vehicles", *IEEE Engineer Infinite International Conference*, 13-14 Mar. 2018, Greater Noida, Delhi, India, *DOI: 10.1109/ETECHNXT.2018.8385282.*
19. **R. M. Pindoriya**, A. Usman, B. S. Rajpuronit, K. N Srivastava, "Power Maximization of a PMSG Based Wind Energy Generation System and its Control", *IEEE ICPS*, 21-23 Dec. 2017, Pune, India, pp. 1-6, Dec. 2017, *DOI: 10.1109/ICPES.2017.8387323.*
20. **R. M. Pindoriya**, A. K. Mishra, B. S. Rajpuronit, R. Kumar, "Performance Analysis of Control Strategies of Permanent Magnet Synchronous Motor", *IEEE TENCON*-2016, 22-25 Nov. 2016, Singapore, pp. 1-6, Nov. 2016, *DOI: 10.1109/TENCON.2016.7848645.*
21. **R. M. Pindoriya**, A. K. Mishra, B. S. Rajpuronit, R. Kumar, "Analysis of Position and Speed Control of Sensorless BLDC motor using Zero Crossing Back EMF Technique", *IEEE ICPEICES-2016*, 3rd -6th Jul. 2016, Delhi, India, pp. 1-6, Jul. 2016, *DOI: 10.1109/ICPEICES.2016.7853072.*
22. **R. M. Pindoriya,** A. K. Mishra, B. S. Rajpurohit, R. Kumar, "Advance Power Electronics Technology for Renewable Energy System in 21st Century", *NCPS 2015*, September 2015, Visakhapatnam, A.P., India, pp. 43-47, Dec. 2015
23. **R. M. Pindoriya,** S. Rajendran, and P. J. Chauhan, "Field Programmable Gate Array Based Speed Control of BLDC Motor", *IEEE ISGT ASIA 2015*, Bangkok, Thailand, pp. 1-6, 3rd-6th Nov. 2015, *DOI: 10.1109/ISGT-Asia.2015.7387048.*
24. **R. M. Pindoriya,** N. M. Pindoriya, and S. Rajendran, "Simulation of DC/DC Converter for DC Nano Grid Integrated with Solar PV Generation", *IEEE ISGT ASIA 2015*, Bangkok, Thailand, pp. 1-6, 3rd- 6th Nov. 2015, *DOI: 10.1109/ISGT-Asia.2015.7387065.*
25. **R. M. Pindoriya,** S. Rajendran, and P. J. Chauhan, "Speed Control of Brushless Direct Current Motor using PWM method", ETCEE-2014, Rajkot, Gujarat, India, pp.1-6, Mar. 2014 (Best paper award)

SPONSORED PROJECTS/FUNDING RECEIVED

Sr. no.	Name	Sponsored agency	Status/Duration	Amount (Rs)	Team members
1.	Vidhya: STEM for Social Goodwill and Its Impact on Society	IEEE Pre-University STEM	Mar. to Dec. 2024	1,70,000/- ($2000)	Dr. Rajesh M. Pindoriya and Mr. Aryman Mohan
2.	Design and Development of Health Monitoring and Fault Diagnosis for Brushless Motor Drives ln-Wheel Electric Vehicles	Seed Fund, TIET, Patiala, India	Mar. 2023- Mar. 2025	8,00,000/-	Dr. Rajesh M. Pindoriya
3.	Design and Development of an Auto-tuned Ventilator: A Contactless Treatment for COVID-19 Patients	IEEE HAC/SIGHT, USA	15th Jul. 2021- 14th Jan. 2022	3,65,000/- (US $5000)	Dr. Rajesh M. Pindoriya, Dr. Rajeev Kumar, Mr. Rishi Kant Thakur
4.	Auto-tuned Ventilator	IEEE, Region 10 SAC	1st Jul. 2021- 31st Aug. 2021 (Completed)	31,200/- (US $400)	Dr. Rajesh M. Pindoriya, Dr. Rajeev Kumar, Mr. Rishi Kant Thakur
5.	Neoteric Ventilation (NEO): A disruptive innovation in conventional diagnosis procedure	IEEE HAC/SIGHT Region 10	15th Jul. 2021- 31st Dec. 2021	40,000/- (US $500)	Dr. Rajesh M. Pindoriya, Dr. Rajeev Kumar, Mr. Rishi Kant Thakur

ASSOCIATE EDITOR

- Power Electronics Journal, Frontier (Guest Editor) (2023-2024)
- International Journal of Power Electronics, INDERSCIENCE Publishers (2022 - Till now)

PROFESSIONAL MEMBERSHIPS

- Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) (GSM'13, M'20, SM'22) (Membership No. 92994188)
- Life Member of Indian Society for Technical Education (ISTE) (Membership No.139166)
- Member of the Institution of Electronics and Telecommunication Engineers (IETE) (AM'17, M'21) (Membership no. M-500934)
- Member of the Institution of Engineers (IE, India) (AM'17, M'21) (Membership No. M1740398)
- Member of International Association of Engineers (Membership No. 206167)

IEEE PROFESSIONAL EXPERIENCES

- IEEE IAS Chapter Area Chair, R10 East and South Asia (2023-till now)
- Member of IEEE PES YP Professional and Educational Activities (2023- till now)
- Member of IEEE Smart Village South Asia Working Group (2022-till now)
- Member of (IAS-PES Young Professional), IEEE Delhi Section, India (2021- till now)
- Member (IEEE Membership Development), IEEE Delhi Section, India (2021- till now)
- Member of IEEE IAS Electric Machine Committee (2020-till now)
- IEEE PELS Young Professional Executive At-Large Member (2020-till now)
- IEEE PELS Students Activity Committee Member (2019-Till now)
- Mentor of IEEE Student Branch (SB) Chapter IIT Mandi, India (Aug. 2020-till now)
- Founding Chairman of IEEE SIGHT SB Chapter, IIT Mandi, India, (Sept. 2020-Mar. 2021)
- Founding Chairman of IEEE PELS SB Chapter, IIT Mandi, India, (Jul. 2019-Jul. 2020)
- Chairman of the IEEE IAS SB Chapter, IIT Mandi, India, (Apr. 2019- Jul. 2020)
- Treasurer of IEEE SB Chapter, IIT Mandi, India, (Apr. 2019-Jul. 2020)
- IEEE 3rd PES Day celebration section ambassador (22nd Apr. 2020)
- IEEE Xtreme 13.0 public relations team as the student branch ambassador
- IEEE 1st PELS Day celebration ambassador (20th Jun. 2019)
- IEEE 1st PELS Day celebration regional leader (Region 10)
- IEEE 2nd PES Day celebration ambassador (22nd Apr. 2019)

ADMINISTRATIVE EXPERIENCE

- Committee member of reallocating rent of a married apartment, IIT Mandi (2019-20)

INVITED LECTURES

- "Transforming Electric Vehicles to Net Zero Emissions through Green Hydrogen Technology" in Short Term Course on "Power & Control Strategy for Net-Zero Emissions (PCSN- 2023)" organized by SVNIT, Surat from 20th February 2023 to 24th February 2023.
- "Electric and Hybrid Vehicles Technology", Dr. Subhash Technical Campus, Junagadh, Gujarat, India, 06th Jul. 2021
- "IEEE Awareness", IEEE SB Chapter New Horizon College of Engineering, Bangalore, India, 06th May 2021
- IEEE PELS YP, ECCE Asia-2021, Singapore, "IEEE Power Electronics Young Professionals- Activities and Practices", 26th May 2021
- "Introduction to Electric Vehicles, their Major Components, Technologies, Challenges and Future Direction of Development", IEEE SB Chapter Sanjivni College of Engineering, Kopargaon, Maharashtra, India, 10th Mar. 2021
- "Introduction to Electric Vehicles, their Major Components, Technologies, Challenges and Future Direction of Development", IEEE SB Chapter Government Engineering College, Kozhikode, Karela, India, 19th Jan. 2021

- "Main Challenges in Electric Vehicles: Noise and Vibration", *IAS CMD Tuesday virtual meeting series on electrical machines, virtual chapter meeting program*, USA, 08th Sept. 2020.

IEEE REVIEWER COMMITTEE

Journals

- IEEE Open Access
- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Energy Conversion
- IEEE Transactions on Power Electronics
- IEEE Transactions on Industry Applications and Industry Applications Magazine
- IEEE Transactions on Transportation Electrification
- Taylor & Francis Group: Journal for Control, Measurement, Electronics, Computing and Communications
- IEEE Transactions on Mechatronics

Conferences

- IEEE Autumn Meeting on Power Electronics and Computing (ROPEC2020), 13-15 Nov. 2019, Mexico
- IEEE Texas Power and Energy Conference (TPEC2020), 6-7 Feb. 2020, Texas A&M Engineering, US
- IEEE Power Electronics Drives and Energy System Conference (PEDES-2018), 18-21 Dec. 2018, IIT Madras, India
- IEEE International Conference on Sustainable Energy Technologies and Systems, 26 Feb. -01 Mar. 2019, Bhubaneswar, Odisha, India
- IEEE International Conference on Electrical Engineering, Computer Science, and Informatics (EECSI 2017), 19-21, Sept. 2017, Yogyakarta, Indonesia
- IEEE Global Humanitarian Technology Conference (GHTC 2017, 2018, 2019), USA
- IEEE Technical Conference (TENCON 2016), 22-25 Nov. 2016, Marina Bay Sands, Singapore
- IEEE International Conference on Control, Electronics Renewable Energy and Communication 2016, Indonesia

MAJOR SUBJECTS STUDIES AND TECHNICAL SKILLS

- Power Electronics, Electrical machines, Solid State DC Drives, and Control systems during the Ph.D. and M.E. period
- Quite a comfort with a real-time platform like; OPALRT, RTDS, and dSPACE
- Quite a comfort with MATLAB/Simulink platform, LabView, C, Verilog and VHDL programming, FPGA with system generator toolbox
- Quite a comfort with FEM software tools such as Maxwell, Ansys Maxwell, RM Expert, Altair Flux, Altair Flux Motor, JMAG and Magnetic Acoustic Noise Analysis Tool for Electrical Engineering (MANATEE)

CONFERENCES ATTENDED

1. IEEE IAS Global Conference on Renewable and Hydrogen Technologies (GlobConHT-2023), March 11-12, 2023, at The Maldives National University, Male City, Maldives
2. 21st National Power Systems Conference (NPSC 2020), Dec. 17th -19th, 2020, IIT Gandhinagar, Gujarat, India
3. IEEE IAS Annual Meeting 2020, 11th -15th Oct. 2020, USA
4. IEEE IAS Annual Meeting 2019, 28th Sep- 3rd Oct. 2019, Baltimore, US
5. IEEE PES General Meeting 2018, 5th -10th Aug. 2018, Portland, USA
6. National Conference on Power Electronics (NPEC-2017), 18-20, Dec. 2017, College of Engineering Pune, India.
7. IEEE Innovative Smart Grid Technologies (ISGT) ASIA 2015, 3rd - 6th Nov. 2015, Bangkok, Thailand
8. National Conference on Emerging Trends in Computer & Electrical Engineering (ETCEE - 2014) Mar. 7th - 8th, 2014, Organized by Atmiya Institute of Technology and Science, Rajkot, Gujarat, India

WORKSHOP ATTENDED

1. A National Workshop on Real-Time Digital Simulation for Power Engineering Applications, 13th -16th Jun. 2019, IIT Mandi, H. P., India

2. A Global Initiative of Academic Networks (GIAN) course on Active Shape Control, Active Vibration Control, Active Noise Reduction, and Structural Health Monitoring (Adaptronics) from 4th – 9th Feb. 2019, IIT Mandi, H.P., India
3. Training on "Embedded System and Power Electronics and Electrical Drives", Vi Microsystem, 26th Dec. 2017 – 8th Jan. 2018, Chennai, India
4. Short Term Course on "*Modelling and Simulation Using Finite Element Method for Engineering Applications - 2017 (Msfemea-2017)*", 19th – 23rd Jun. 2017, IIT Mandi, Himachal Pradesh, India
5. One-week GIAN course on "*Advanced Adjustable Speed AC Motor Drive Systems: Applications, Problems & Solutions (ASMDS- 2017)", 15th* - 20th May 2017, NIT Goa, India
6. TEQIP sponsored 3 Day Workshop on *"National Workshop on Digital Controllers for Power Electronics Converters &Systems",* 11th -13th, Apr. 2016 PES Institute of Technology, Bangalore, India

APPENDIX

1. Design and Performance Analysis of Low-Cost Acoustic Chamber for Electric Machines:

The schematic layout of the acoustic transfer function model is shown in Fig. 1. Here we have used two microphones, an amplifier, an acoustic chamber, DAQ, and of course host PC for record and analysis of data. An experimental setup for characterization and performance analysis of the acoustic chamber is shown in Fig. 2. An external amplifier is utilized to generate a sound signal of 6 kHz with an 80-dB amplitude. An acoustic chamber has been designed and assembled at IIT Mandi, as shown in Fig. 3 and Fig. 4, to perform suitable studies on the vibration and acoustic noise of electric machines/drives. The frequency spectrum of the forward transfer function of the acoustic chamber is shown in Fig. 5. It is showing the cut-off frequency of the acoustic chamber is 40 Hz.

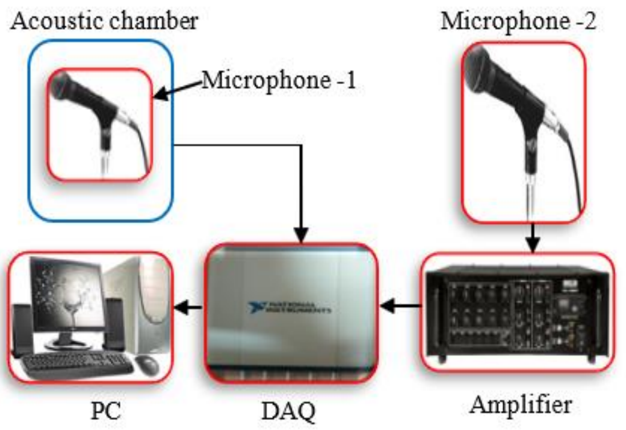


Fig. 1. Schematic diagram of acoustic transfer function method.

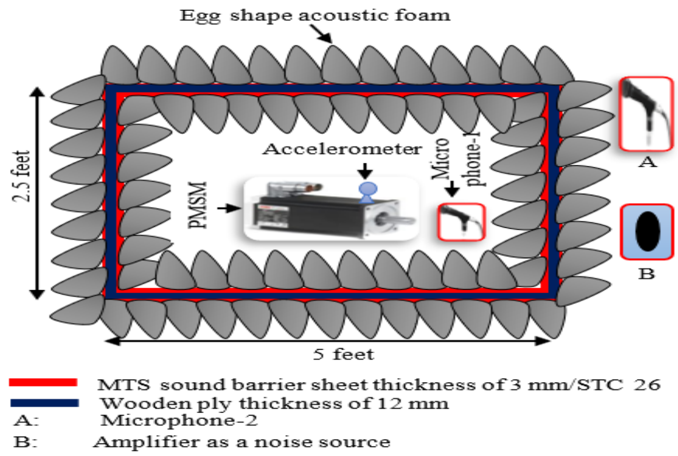


Fig. 2. Schematic layout for testing of acoustic chamber.

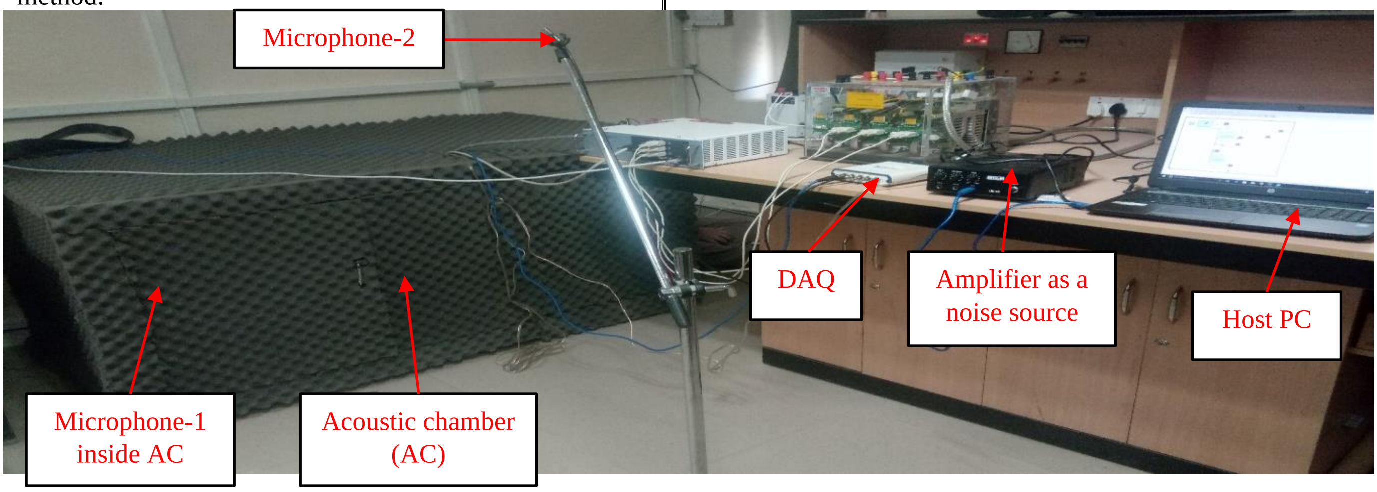


Fig. 3. An experimental setup for the characterizing of acoustic chamber.

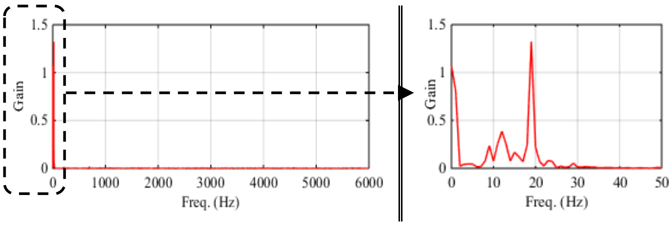


Fig. 4. The frequency spectrum of a forward transfer function.

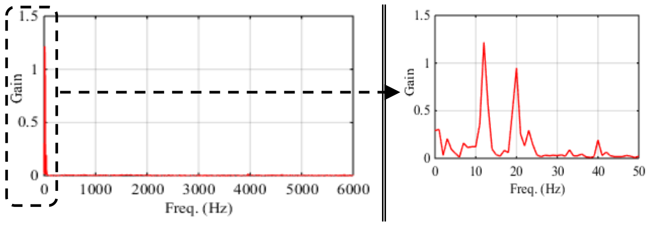


Fig. 5. The frequency spectrum of a reverse transfer function.

2. An Experimental Investigation of Acoustic Noise and Vibration of PMSM due to Power Electronics Converters:

The Field Programmable Gate Array (FPGA) architecture of hall sensor-based control system for PMSM drive is shown in Fig. 6. The control system features the cascaded control principle included as the inner loop current controller and outer loop speed controller with a sinusoidal PWM technique for voltage source inverter fed PMSM drive. The schematic diagram and pictorial view of the experimental set-up for analysis of ANV of PMSM drive are shown in Figs. 7 and 8, respectively.

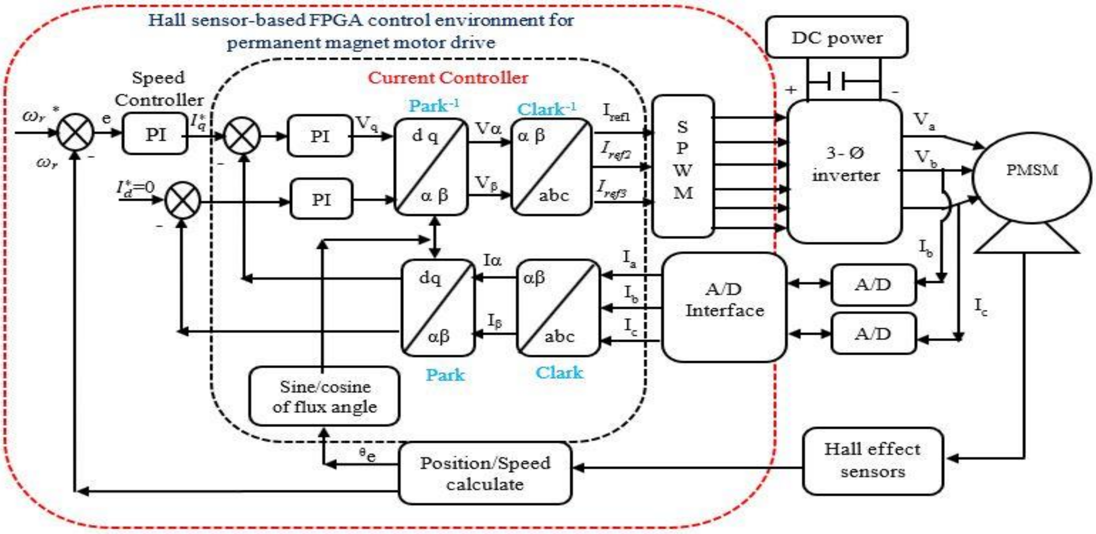


Fig. 6. The control block diagram of a hall sensor-based PMSM drive.

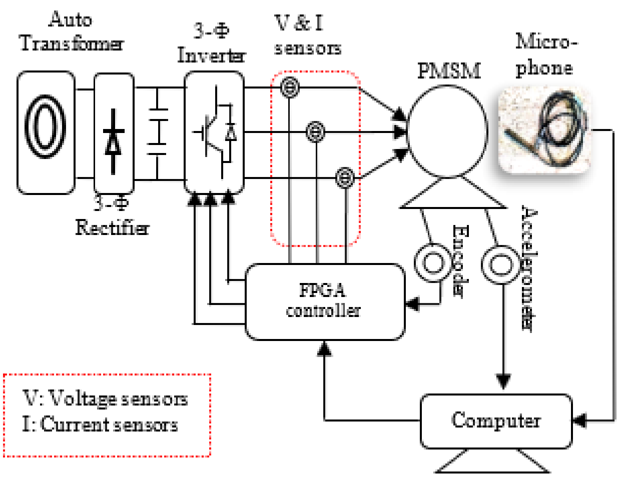


Fig. 7. Schematic diagram of the experimental setup.

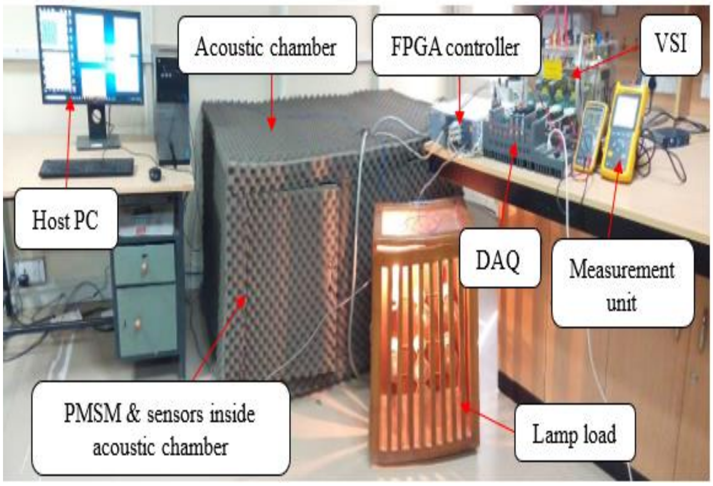


Fig. 8. An experimental setup for analysis of ANV of PMSM drive.

The simulation studies have been performed using MATLAB/Simulink and Magnetic Acoustic Noise Analysis Tool for Electrical Engineering (MANATEE) software. The analysis of vibration and acoustic noise of the PMSM drive is not feasible in MATLAB/Simulink software. Analysis of acoustic noise of PMSM drive has been simulated in MANATEE. Fig. 9 shows the MANATEE simulation flow which contains four modules as Electrical, Electromagnetic, Structural, and Acoustic module. To analyse the machine acoustic behaviour; computed noise power level spectrum at variable speed, along with a sonogram is shown in Fig. 10.

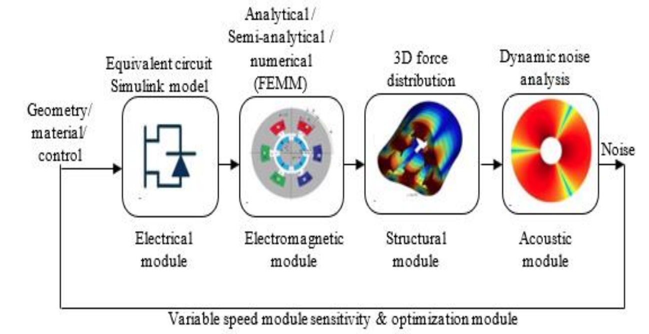


Fig. 9. Pictorial view of the MANATEE simulation process.

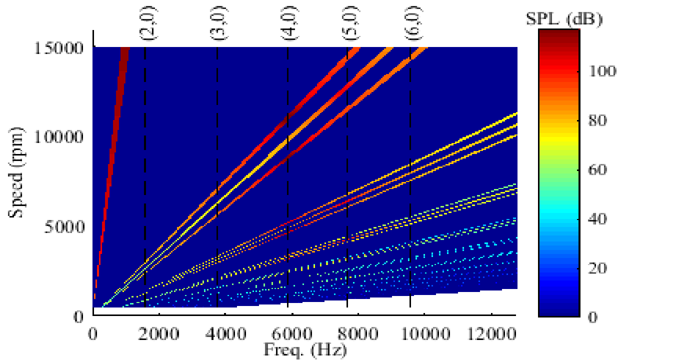
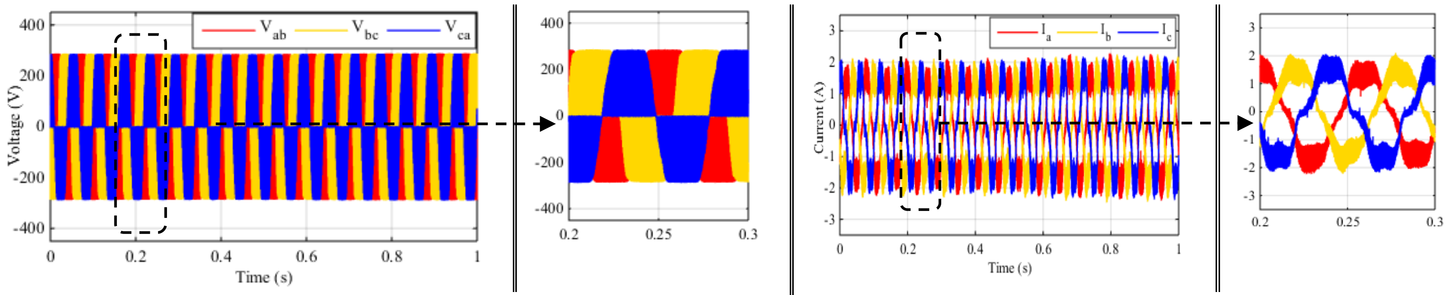


Fig. 10. Simulation results of sound power spectrogram of PMSM drive.

The experimental results of the three-phase stator input voltage with the amplitude of 300 V of PMSM drive are shown in Fig. 11 (a). The three-phase stator current with the amplitude of 2. 1 A of PMSM drive is shown in Fig. 11 (b). The waveforms of stator current are sine waves with a 120º phase shift to each other. But the three-phase stator current contained too much ripple due to Maxwell forces.

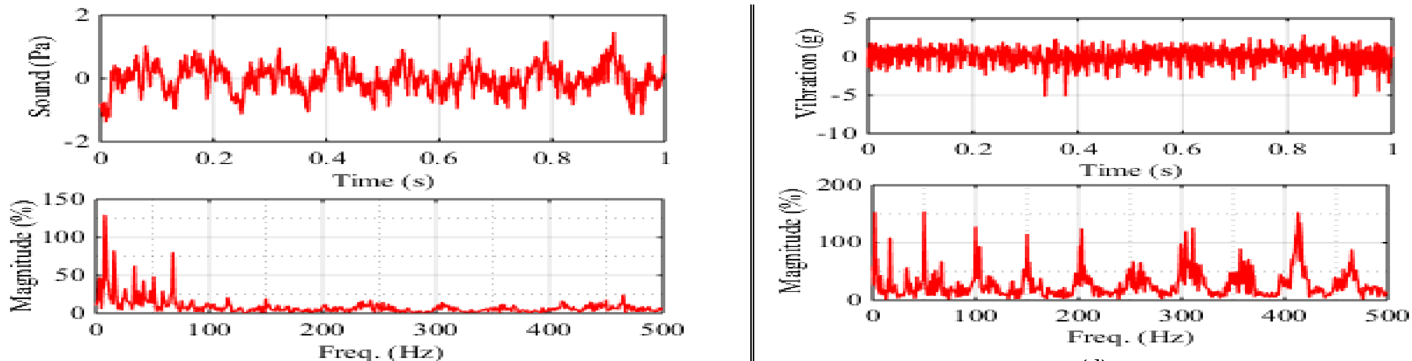


(a) (b)

Fig. 11. Experimental results of PMSM drive: (a) rated input supply voltage and (b) current response.

The amplitude of acoustic noise is 1.2 Pa measured at I = 2.1 A and N = 1000 rpm is shown in Fig. 12 (c). The generated acoustic noise is directly proportional to the electromagnetic torque ripple of PMSM drive. Also, it is depending on the switching frequency of the power electronics converters. Here, measured acoustic noise at a frequency range of 500 Hz. But the magnitude of acoustic noise varies according to switching frequency of power electronics.

The time and frequency spectrum of vibration signal for PMSM drive are shown in Fig. 12 (d). Vibration sensors were located horizontally at the end of the body of the PMSM. One accelerometer with an output sensitivity of 10 mV/g was attached with beeswax at a point directly behind any stator poles to measure vibration. Fig. 12 (d) presents a time and frequency domain vibration spectrum of the PMSM drive at I = 2.00 A, N = 1000 rpm with vibration magnitude of 2.13 gravitation (2.1 * 9.8 = 20.58 m/s^2) and maximum vibration occurs at 50 Hz with magnitude 150 % gravitation, it could be due to mechanical resonance of mechanical parts like fan blades or the end cap.



(c) (d)

Fig. 12. Experimental results of PMSM drive: (a) steady-state speed response (refer. speed 1000 rpm), (b) torque response, (c) time and frequency domain response of acoustic noise, and (d) time and frequency domain response of vibration.

3. A Novel Application of Pseudorandom-Based Technique for Acoustic Noise and Vibration Reduction of PMSM Drive:

The Block diagram of the proposed PTPWM technique is shown in Fig. 13. Random bit generator as shown in Fig. 13, consists of EXCLUSIVE OR (XOR) gates and linear shift registers that help in generating Pseudo-Random Bit System (PRBS). A clock is used to give a switching signal to shift register with f_{clock} switching frequency. Eight shift registers are connected in cascaded form, where the output of one shift register is an input to the second. The output of 4, 5, 6, and 8-bit shift register combine to be fed as an input to the XOR gates.

An intermediate waveform for PTPWM technique is shown in Fig. 14. Two carrier waves with a 180º phase shift to each other as given in Fig. 14. (a)-(b) are processed in the multiplexer with the random bits produced by the random bit-generator as given in Fig. 14 (c). For a time period of (0.1210 to 0.1225 s), the carrier wave is selected according to the random bit, and accordingly the multiplexer gives a pseudorandom triangular carrier frequency signal as shown in Fig. 14 (d).

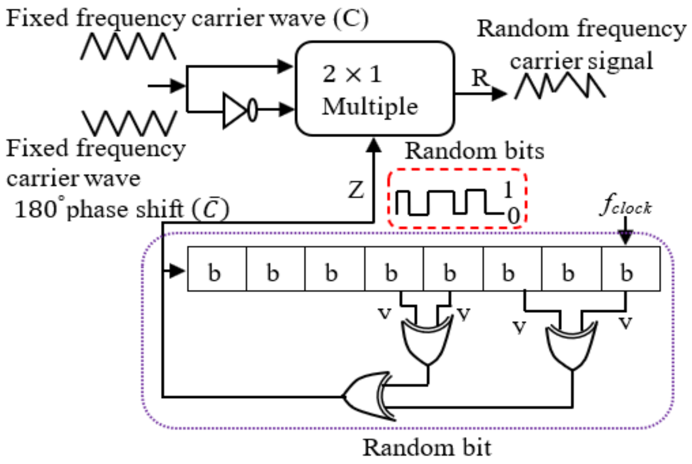


Fig. 13. Block diagram of the proposed PTPWM technique.

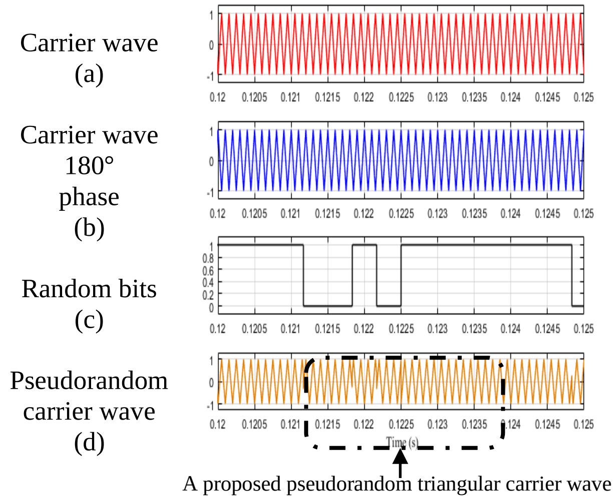


Fig. 14. Intermediate waveforms for PTPWM technique.

The time and frequency domain sound spectrum as Sound Pressure Level (SPL) of SPWM and PTPWM techniques for PMSM drive (during steady-state speed response) are shown in Figs. 15 and 16, respectively. The maximum amplitude of the sound spectrum is observed around 48 dB and 37 dB for SPWM and PTPWM techniques, respectively as shown in Fig. 15. That means acoustic noise survived is around 10% by using PTPWM as compared to SPWM. As stated earlier, randomization results in shifting part of the harmonic power to a continuous spectrum and markedly levelling the discrete spectrum, as clearly visible from Fig. 16. This leads to spreading out of noise spectrum over the wide range and hence a significant reduction in overall noise. The maximum sound spectrum of PMSM drive observed near frequency range of 73 Hz of the rotor frequency with the amplitude of 0.058 and 0.03 for the SPWM and PTPWM techniques respectively as shown in Fig. 16.

The maximum amplitude of vibration is observed around 1.8 and 0.9 gravitation for SPWM and PTPWM techniques, respectively, as shown in Fig. 17. PMSM drive exhibits twice the magnitude of vibration for SPWM as compared to PTPWM technique for PMSM drive. The maximum vibration spectrum of PMSM drive observed near the frequency range of 27 Hz of the rotor frequency for the SPWM and PTPWM techniques is shown in Fig. 18.

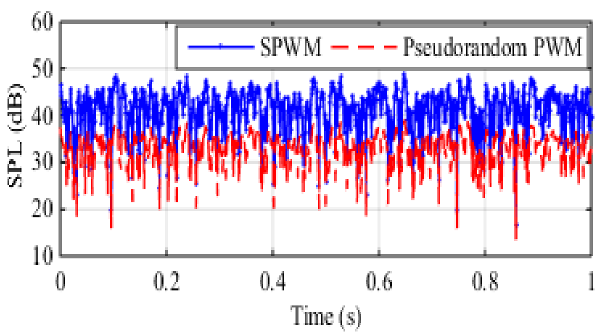


Fig. 15. Experimental result of time-domain acoustic noise of PMSM drive.

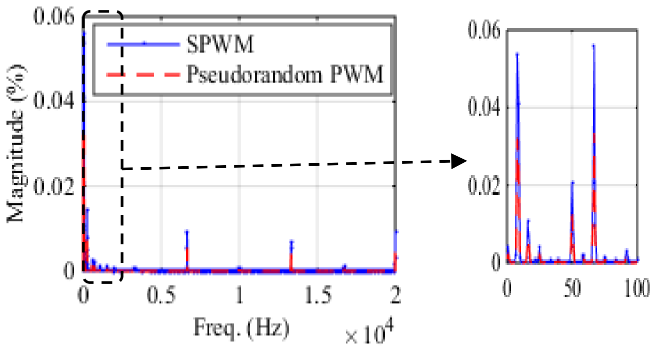


Fig. 16. Experimental result of a frequency-domain spectrum of the sound of PMSM drive.

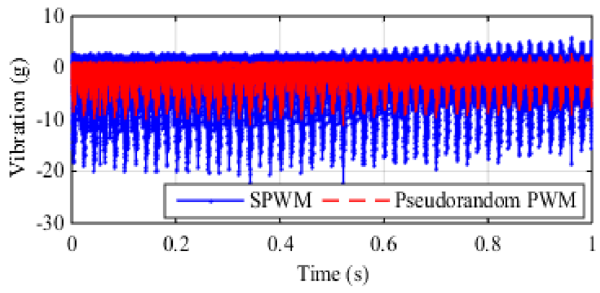


Fig. 17. Experimental result of time-domain vibration of PMSM drive.

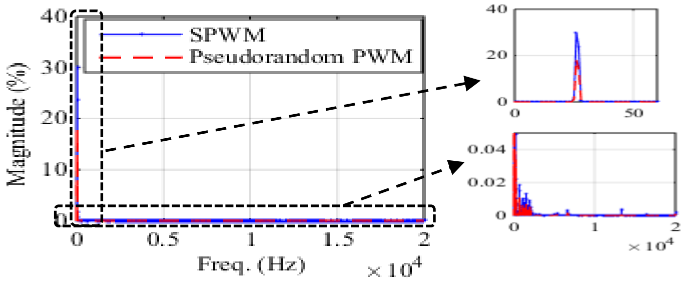


Fig. 18. Experimental result of a frequency-domain spectrum of vibration of PMSM drive.

Comparison of acoustic noise of PMSM drive (in percentage) with SPWM and PTPWM technique are given in Table I. Substantial reduction of acoustic noise is observed with PTPWM technique. For applied load torque of 1 N-m, the reduction in acoustic noise is found to be 22.92 % less in PTPWM technique as compared to SPWM. A comparison of vibration of PMSM drive with SPWM and PTPWM technique is given in Table II. A substantial reduction of vibration of PMSM drive is observed with PTPWM technique. For applied load torque of 1 N-m, the reduction in vibration of PMSM drive is found to be 40.12 % less in PTPWM technique as compared to SPWM.

TABLE I. Comparison of Acoustic Noise of PMSM Drive

S. No.	T_m (N-m)	SPL (dB)		% of reduction of acoustic noise
		SPWM technique	PTPWM technique	
1	1	48	37	22.92
2	1.5	52	42.23	18.79
3	2	59.5	48.45	18.57

TABLE II. Comparison of Vibration of PMSM Drive

S. No	T_m (N-m)	Vibration (g)		% of reduction of vibration
		SPWM technique	PTPWM technique	
1	1	1.8	0.9	40.12
2	1.5	2.8	1.2	53.4
3	2	3.2	1.7	46.2

4. Design and Implementation of Rotor Position Estimation Scheme for PMSM Drive:

The rotor position information is mandatory to operate the PMSM drive. Normally rotor position information sense by hall effect, encoder, and proximately sensors. But these types of sensors have certain disadvantages such as reduces reliability, increase weight, complexity, cost, and size of PMSM drive. Estimation of the rotor position by measuring the stator voltages and currents in each phase is shown in Fig. 19. The estimated rotor position as shown in Fig. 19 is plotted between $-\pi$ to $+\pi$ instead of plotting between 0-2π. The estimated and measured unit vectors are shown in Fig. 20. These unit vectors are used in the algorithm of vector control for the transformation of 2∅- 3∅. Reference speed is compared with estimated speed and sensor based PMSM drive speed as shown in Fig. 21.

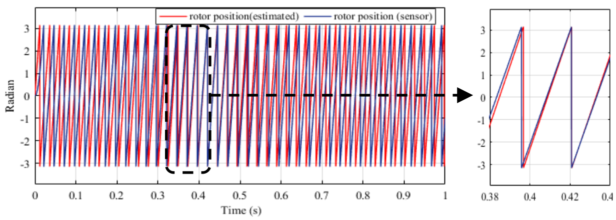


Fig. 19. Estimated and measured PMSM rotor position.

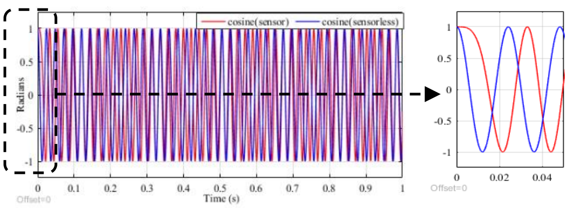


Fig. 20. Measured and estimated sine waveform.

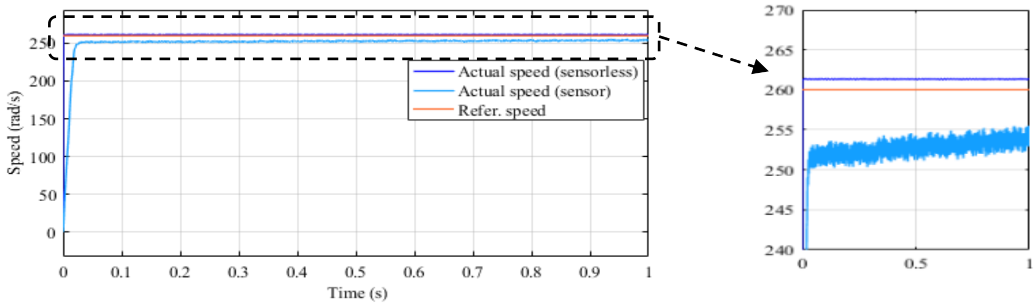


Fig. 21. Steady-state speed response of PMSM drive.

5. An Investigative Study of the PMSG-Based Wind Turbine Using Real-Time Simulation

A schematic layout of the direct-drive PMSG-based wind turbine is shown in Fig. 22. The control algorithm for direct-drive PMSG-based wind turbines has been implemented in the Real-Time Digital Simulator (RTDS) is shown in Fig. 23. The RSCAD model of direct-drive PMSG based wind turbine is shown in Fig. 24. It has been modelled in a real-time RSCAD environment platform.

The three-phase stator current of PMSG is shown in Fig. 25. The waveform of a three-phase stator current of PMSG is pure sinusoidal and without any type of harmonics. The generated active and reactive power of the direct-drive PMSG-based wind turbine is shown in Fig. 26. The magnitude of generated active power is 1.5 MW and reactive power is 0.5 MVAR. The active and reactive power of the wind turbine is shown in Fig. 27 during the three-phase line-to-line fault occurred in the grid. The dynamic speed response of the PMSG is shown in Fig. 28.

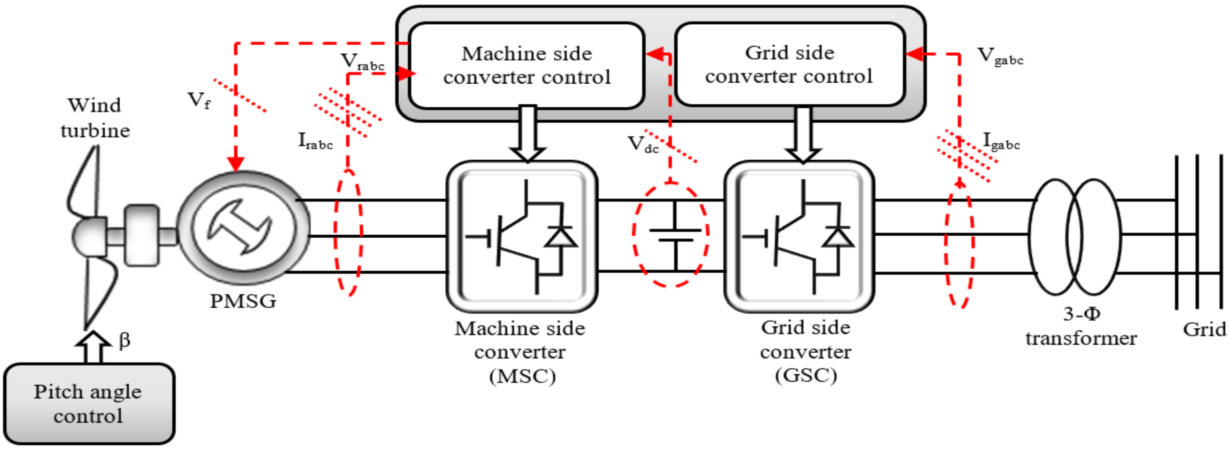


Fig. 22. A schematic layout of the direct-drive PMSG-based wind turbine system.

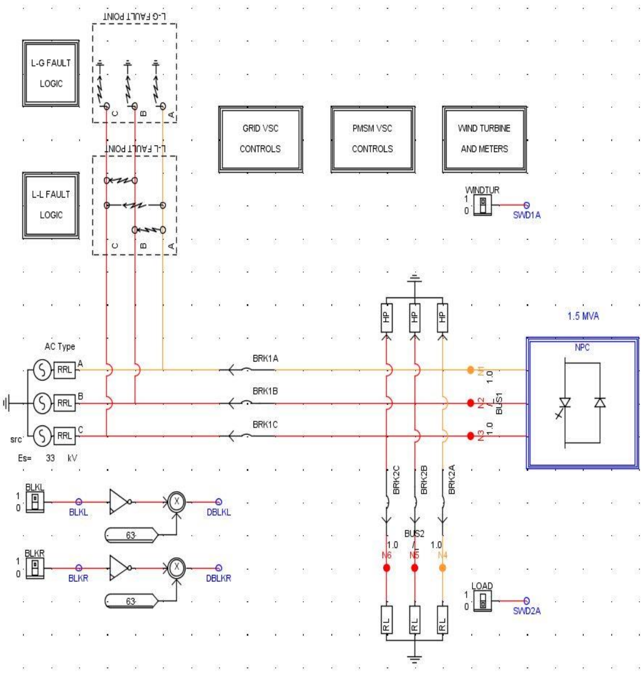


Fig. 23. RSCAD block diagram of direct drive PMSG based wind turbine.

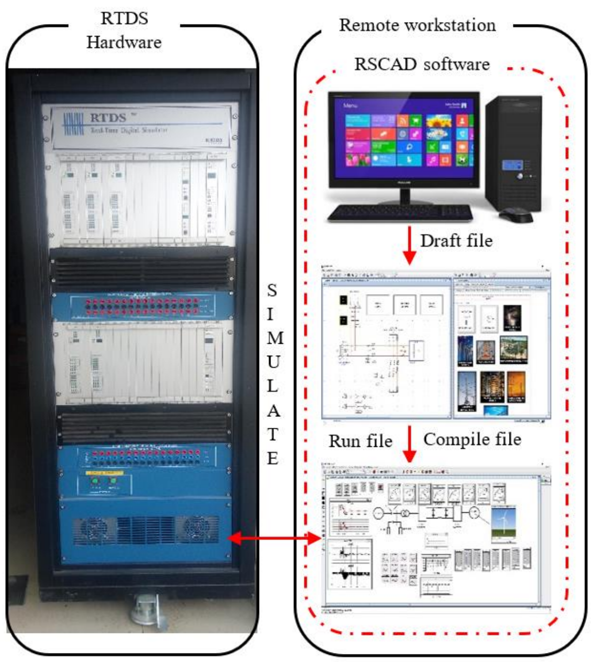


Fig. 24. Implementation in the Real-Time Digital Simulator (RTDS).

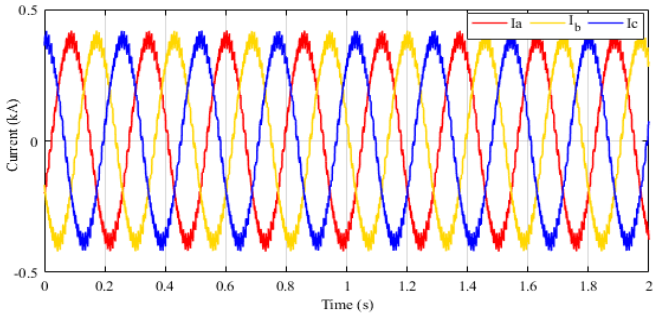


Fig. 25. Three-phase stator current of PMSG.

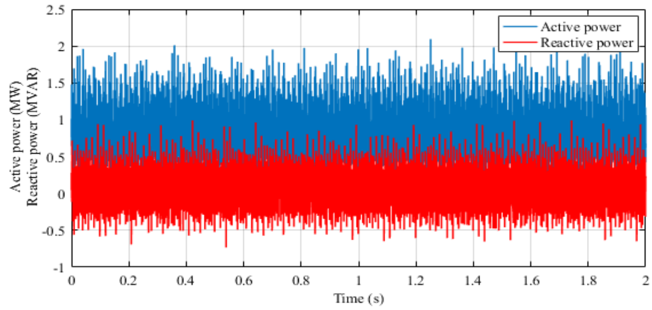


Fig. 26. Active and reactive power.

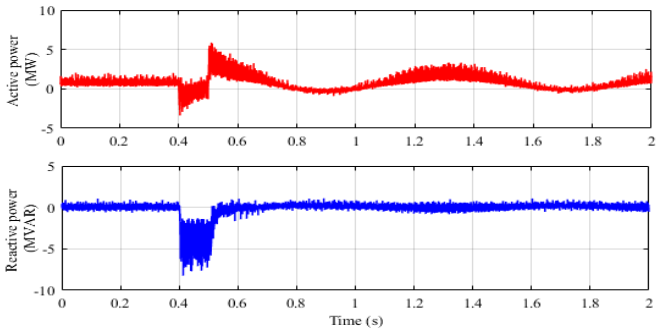


Fig. 27. Active and reactive power during the three-phase line-to-line fault.

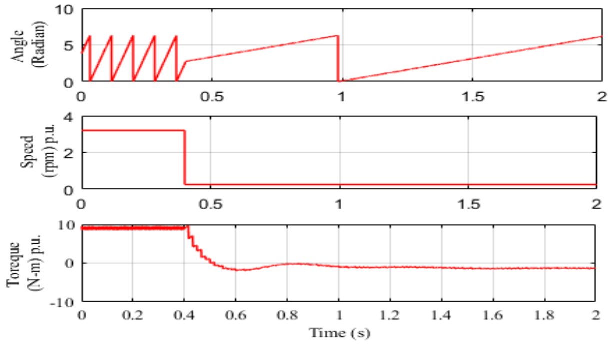


Fig. 28. Dynamic response of PMSG.

6. Numerical and Experimental Analysis of Torsional Vibration and Acoustic Noise of PMSM Coupled with DC Generator

Schematic diagram of PMSM coupled with DC generator is shown in Fig. 29. Power is transmitted from driving shaft (S_1) to drive shaft (S_3) through transmission shaft (S_2). Roller support (B_2) is provided at midspan of S_2, to avoid whirling motion which usually takes place, where the length to diameter ratio between support is high, hence transverse vibration is negligible. Oldham coupling (A) having discs (C_1) and (C_2) are pinned with shaft S_1 and S_2, respectively. Similarly, oldham coupling (B) having disc (C_3) and (C_4) are attached with shaft S_2 and S_3, respectively. Oldham couplings are used to transmit power between shafts of different diameters and different axis of rotation (in Fig. 3 all shafts are coaxial). Roller contact bearing (B_1) is provided in between S_1 and motor stator, similarly, at generator end, B_3 is in between S_3 and generator hub. An equivalent five DOF torsional lumped model is shown in Fig. 30. Five degrees of freedom are chosen using effective modal mass and modal participation factor.

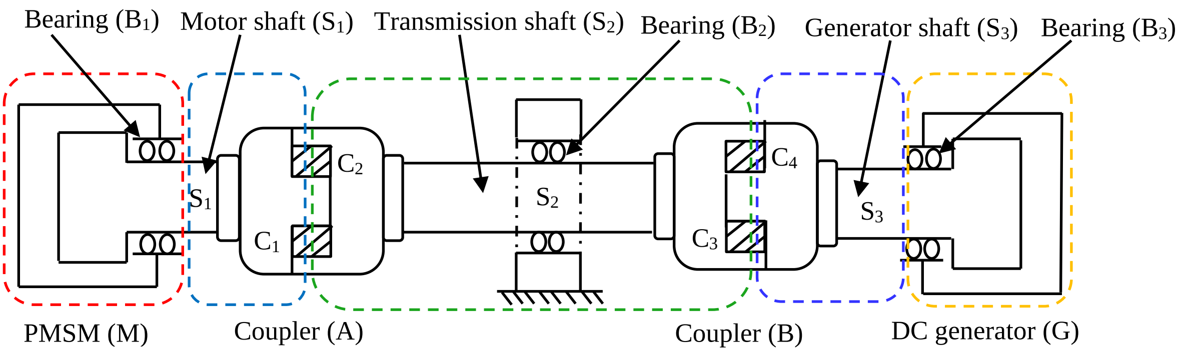


Fig. 29. Schematic diagram of PMSM coupled with DC generator.

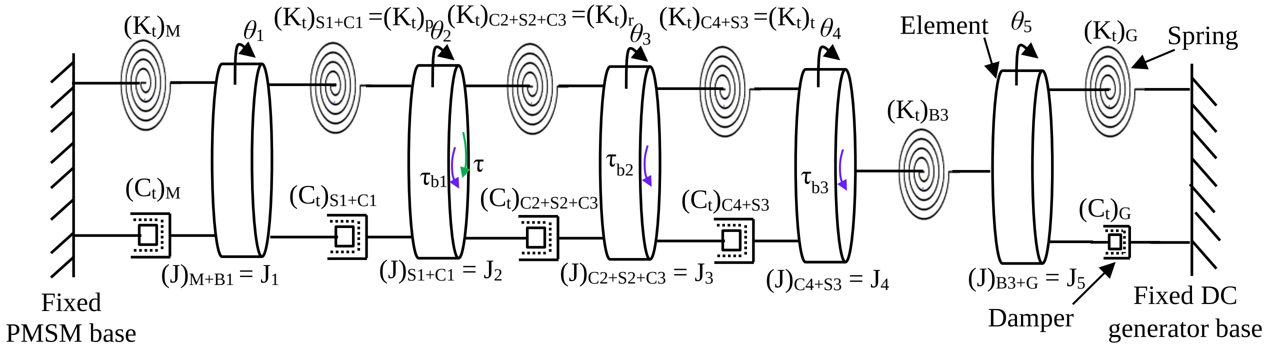


Fig. 30. Equivalent lumped parametric modelling of torsional vibration induced in PMSM drive coupled with DC generator.

As the maximum rated speed of setup is 3000 rpm (50 Hz), the lowest two natural frequencies are within range (the effect comes during starting and stopping of the motor). Modes shape corresponding to these frequencies are under concern. It is found from Fig. 31, at a frequency 23.78 Hz, the motor hub has the highest amplitude of vibration, and the motor shaft has 97.7% of the amplitude of vibration relative to the motor hub. Also, at a frequency 34.64 Hz, the generator hub has the highest amplitude of vibration, with the generator shaft and transmission shaft having 97.86% and 90.84% amplitude of vibration relative to the generator hub, respectively. Hence generator and motor fixtures are more likely to damage under dynamic loading due to vibration at resonance. Also, from Fig. 32, at the beginning of power transmission (t = 0), the angle of twist of PMSM, element-2, element-3, element-4 & DC generator are 10-6×{8.7285; 8.2589; 2.232; 1.88; 1.78}radian, respectively, with a maximum difference of angle in between element 2 and 3.

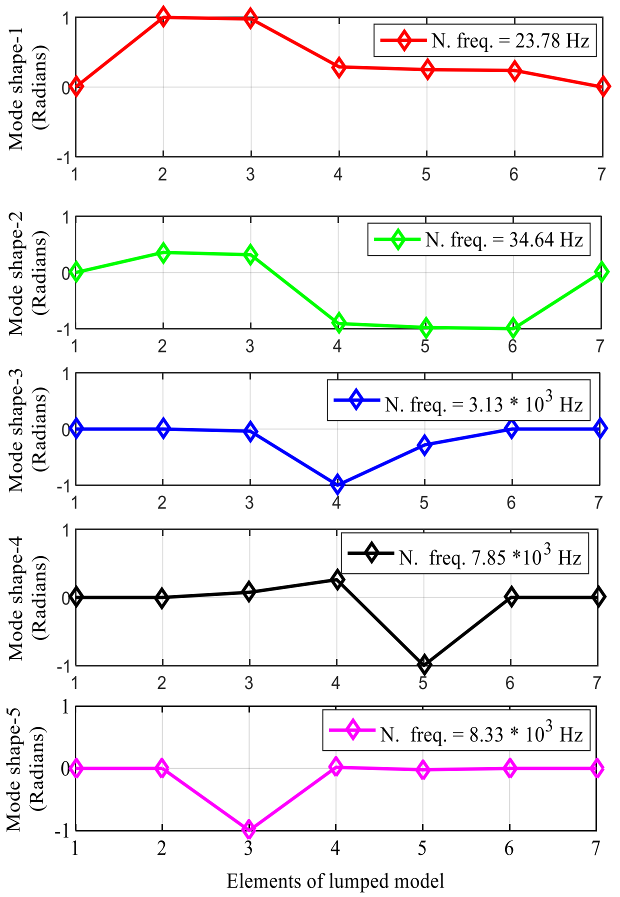


Fig. 31. Simulation results of PMSM drive coupled with DC generator: Mode shapes response of corresponding elements at various natural frequencies.

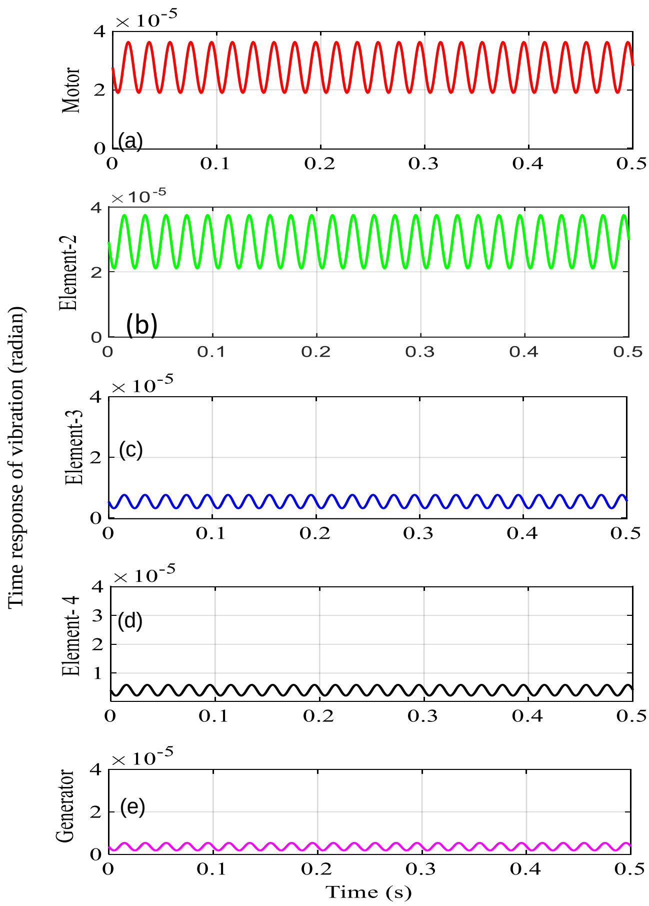


Fig. 32. Vibration response of the PMSM drive coupled with the DC generator obtained by lumped parameter analysis: (a) PMSM Drive, (b) shaft-S1, (c) shaft-S2, (d) shaft-S3, and (e) DC generator.

REFERENCES

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SCEE, IIT Mandi,
Himachal Pradesh, India
Email: ravindra.arora@gmail.com

I declare that the information given above is true to the best of my knowledge.

Place: Patiala, India

Dr. Rajesh M. Pindoriya