Muhammad Zarkab Farooqi

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I am currently pursuing doctoral degree from the Department of Electrical Engineering at Indian Institute of Technology (IIT), Delhi. I am part of PG Machines Lab, and working under joint supervision of Prof. Bhim Singh and Prof. B.K.Panigrahi. During my Ph.D., my particular emphasis was on development of novel integrated/hybrid converter, aiming to improving power density, reduce reliance on semiconductor switches, and ensure optimal system efficiency, in line with the objectives of Google Little Box Challenge. I have dedicated significant effort in hardware prototype development of front-end AC-DC converters, non-isolated and isolated DC-DC converters, voltage source inverters, dual-active bridge, dual-half bridge, and totem-pole-based series-stacked systems using SiC (Silicon Carbide) and IGBT technologies. Moreover, emphasis was also on implementing soft-switching techniques to improve overall efficiency in electrified propulsion systems and more electric aircraft.

EDUCATION

- [2019(Jan) - 2023(Dec)] Doctor of Philosophy in Electrical Engineering
  Department of Electrical Engineering, Indian Institute of Technology, New Delhi, India
  Advisors: Prof. BHIM SINGH, Prof. B.K.PANIGRAHI
  Thesis Title: **Capacitor-Centric Approaches for Size Reduction and Efficiency Improvement in AC-DC Power Converters** CGPA: 8.75/10

- [2014 - 2018] Bachelor of Technology in ELECTRICAL ENGINEERING
  Department of Electrical Engineering, National Institute of Technology, Srinagar, India
  Advisors: Dr. TABISH NAZIR MIR, Prof. ABDUL HAMID BHAT
  Thesis Title: **Comparative Analysis Of PWM Modulation Strategies For Three-Phase Voltage Source Converters** CGPA: 8.61/10 (4^{th} Position)

RESEARCH INTERESTS

Integrated/ Hybrid Chargers, Voltage Source Inverters for More-electric Aircrafts, Electronic Capacitors for active power buffering, Wide-bandgap Semiconductor based Soft-switched Converters, PWM Techniques for VSI, Planer Inductors, End-to-end product development and debugging, Advance Control Algorithms, C and Embedded C for PE Converters

WORK EXPERIENCE

JAN 2019 ONGOING	TEACHING ASSISTANT PGML Lab IIT Delhi, Delhi, India
DEC 2018 OCT 2021	RESEARCH FELLOW Department of Science and Technology (DST), and IIT Delhi- (Project Code: RP03631)
AUG 2018- DEC 2018	ASST. MANAGER Tata Projects Ltd., Telangana, India
JAN 2017- MAR 2017	RESEARCH INTERN Siemens Healthineers, Gurgaon, India

Professional Experience

2022-23

Development of Hybrid-Isolated DC-DC Converter-**SERB-NSC**

- A single-phase voltage source converter and three-phase phase-modular AC-DC converter have the problem of high DC-link capacitor requirement. In this work, a novel 1 kW SiC-MOSFETs based hybrid isolated DC-DC converter was developed, which is derived from an active power buffer and dual-half bridge and has the ability to reduce the capacitor requirement, while delivering desired output power to load without using any extra switch. Additionally, the converter exhibits the advantage of zero-voltage switching (ZVS) within a specific range. The developed control technique for a hybrid isolated DC-DC converter was verified by using a specially designed low-noise immunity current and voltage sensor board integrated with Texas Instruments microcontroller (TMS320f28379D).
- SiC-based full-bridge based hybrid DC-DC converter was developed to perform active power buffering in multilevel converters, which have applications in ultra-fast EV charging stations, large-scale solar PV systems, railway traction systems and split-battery energy storage systems. With minimal switch requirement and folder/ unfolder concept, the derived output power was maintained with a low DC-link capacitor requirement.

Published in IEEE Transactions on Industrial Electronics, IEEE IAS-2023

2020-23

Control and Modulation Strategies for buck-based electronic capacitor-**GoI-DST**

- In this project, a hybrid continuous and critical conduction mode (HyCCM) modulation technique was developed which minimizes power loss attributed to buck-based electronic capacitor (EC), over a wide power range. While operating the silicon-carbide (SiC) MOSFETs based ECs, the developed HyCCM technique dynamically operates in soft-switched CRM and hard-switching CCM within a one double-line frequency cycle, based on the DC load current. As a result, power loss attributed to EC is minimized over a wide power range, making it suitable for high-power applications.
- In this project, a novel control method for EC converter was developed, which entitles the design of a faster decoupling control, while ensuring the system stability and efficiency during dynamic periods. This control facilitates the rapid adjustment of decoupling capacitor voltage with change in output power. Although the developed control results in higher robustness and improved transient response, the original dynamics of the system remain unaffected.

Published in IEEE Transactions on Industrial Informatics

2021-22

Multi-functional Integrated PMSM based On-board Charger **GoI-DST**

- A higher gravimetric and volumetric power density in the on-board charger was attained by employing a integrating set of components for charging the HV battery, LV battery, and traction purposes. In this project, an integrated on-board charger is presented that maintains input power quality and synchronously performs active power decoupling with same components reutilized for charging LV battery. In order to limit the increase of winding current ripple, grid current total-harmonic distortion, and EMI, the inductance variation behaviour is studied. To mitigate these adverse effects, a variable switching frequency pulse-width modulation (PWM)-based modulation strategy is developed. Moreover, an adaptive PR controller for each motor winding current control is implemented for zero torque production and system stability in charging mode. This control/ modulation approach allows for the stable operation of the integrated on-board charger during the charging process.

Submitted to IEEE ECCE-2021, IEEE Transactions on Transportation Electrification

2019-21 | Current/ Voltage Sensor-less techniques in various Electronic Capacitors.**GoI-DST**

- With the objective to perform decoupling operation under non-ideal grid conditions without sensing the decoupling capacitor voltage, a 1kW IGBT based experimental setup was developed to validate sensorless operation of buck based EC converter using fixed frequency based modulated-model predictive control. With the ease-of-implementation and provision to approach high-switching frequency, in presented MMPC scheme a voltage vector is formulated to directly track the ripple power.
- To achieve improved performance and current-sensorless control, this work presented an adaptive non-linear current observer (ANCO) based control for series-stacked buffer. Without using any differential functions, ANCO based control technique for SSB control is also able to provide disturbance rejection caused by parameter mismatch. Moreover, due ANCO's noise filtering capability, reliable performance of SSB is facilitated.

Published in IEEE Transactions on Transportation Electrification

2020-23 | Mentoring students for Master thesis and Bachelor's projects

- Project 1: Transformer Design using Finite Element Analysis (FEA).
- Project 2: Control and Design of high-frequency unfolder-based Voltage Source converter.
- Project 3: Planer Inductor Design using ANSYS MAXWELL.
- Project 4: Single-stage isolated AC-DC converters for railway traction application

2017-18 | Comparison of Different Modulation Strategies for 3-phase Voltage Source Converter **PE Lab, NIT Srinagar**

- In this project, various modulation techniques of a three-phase voltage source converter have been compared, analyzed and examined for their performance in generation for a sinusoidal output for Variable Voltage, Variable frequency AC based adjustable speed drives. Various modulation techniques include Sine-PWM, Space-vector PWM, Delta-Sigma, Model Predictive Control and Modulated Model Predictive Control.
- MATLAB/Simulink and Hardware implementation of different modulation techniques was verified on 1kW IGBT based 3-Phase VSI using D-Space(RTI 1104)

Individual Projects

- Design and Analysis of Planer Inductor using Ansys Maxwell and KiCad
- Design of Isolation tranfomer for Flyback Converter using Ansys Maxwell (PE-Mag)
- Design of 100kW IPMSM using Ansys Maxwell (RMXpert)
- 1 kW SiC based dual-active bridge for charging a 120V, 24Ahr battery

Patents

- B. Singh, B.K.Panigrahi **M. Z. Farooqi**, *Single phase single stage isolated bidirectional converter for dc-link capacitor reduction*, Indian Patent Application No. 202111058797.
- B. Singh, B.K.Panigrahi **M. Z. Farooqi**, *Electronic Capacitor based Full-bridge Integrated Isolated DC-DC Converter with Power Decoupling Unfolder Circuit*, Indian Patent (Submitted).

Publications

Selected Publications

[**J5**] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Integrated Electronic Capacitors based Split BES-assisted Modular Multi-Port Power Electronic Transformer for Fast EV Charging Station," in *IEEE Transactions on Industrial Electronics.* **(IF:7.7**)(Early Access).Link

[**J1**] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Robust Control for Enhanced Dynamic Performance of CRM based Active Power Decoupling Circuit," in *IEEE Transactions on Industrial Informatics*, vol. 20, no. 3, pp. 3685-3694, March 2024 **(IF:12.3**). Link

[J2] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Reduced Sensor-Based Model Predictive Control of Power Decoupling Circuit for On-Board EV Charger," in *IEEE Transactions on Transportation Electrification*, vol. 9, no. 2, pp. 2104-2114, June 2023. **(IF:7.0**). Link

[J3] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Performance Enhancement of Single-Phase Two-stage AC-DC Converter with Reduced DC-link Capacitance," in *IEEE Transactions on Industry Applications,*, vol. 59, no. 5, pp. 5739-5748, Sept.-Oct. 2023.. **(IF:4.4**). Link

Journal papers

[J4] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Enhanced Control and Modulation of On-Board Integrated EV Charger with Active Power Decoupling Capability," in *IEEE Transactions on Transportation Electrification.* **(IF:7.0**)(Under Review: TTE-Reg-2023-03-0514.R2)

Conferences Papers

[C1] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "A Multiport EV-Fleet Charging Station Based on Modular Multilevel Converter," in *2021 IEEE 12th Energy Conversion Congress & Exposition - Asia (ECCE-Asia)*, Singapore, Singapore, 2021, pp. 1765-1770. Link

[C2] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Model Predictive Control for Modular Electric Vehicle Charger," in *2020 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES)*, Jaipur, India, 2020, pp. 1-6. Link

[C3] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, "Input Power Quality Control of Integrated On-Board Charger with Reduced DC-link Capacitance," in *2021 IEEE Energy Conversion Congress and Exposition (ECCE)*, Vancouver, BC, Canada, 2021, pp. 1669-1674. Link

[C4] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, Rohit Kumar, "Single-Stage Isolated Bidirectional Soft-Switched AC-to-DC Converter with Active Power Decoupling," in 14^{th} *IEEE Energy Conversion Congress and Exposition (ECCE)*, Nashville, TN, USA, 2023.

[C5] **M. Z. Farooqi**, Bhim Singh, B. K. Panigrahi, Rohit Kumar, "Active Power Decoupling in Cascaded H-Bridge Converter using Secondary-Stage Isolated DC-DC Converters," in *IEEE IAS Annual Meeting 2023 (IASAM)*, Omni Nashville, TN, USA, 2023.Link

Courses Taken

- Switched-Mode Power Conversion [Spring 2019]
- Computer-Aided Design of Electric Machines [Spring 2019]
- Dynamic Modelling and Control of Grid Connetced Converters [Spring 2019]
- High Power Converters [Fall 2019]
- Selected Topics in Power Electronics [Fall 2019]
- Selected Topics in Control Systems [Fall 2019]
- WBG based Soft-Switching Converters [Spring 2020]
- Resonant Power Conversion and Wireless Power Transfer [Fall 2023]

Course Projects

- Hardware Implementation and associated Control of Solar PV based Single-Phase Grid Connected DC-AC Inverter [2019]
  Hardware Design, and Micro-controller Coding of wide-band based d 2kW DC-AC Grid Connected Inverter with improved performance under weak grid conditions

Advisor: Prof. Ramkrishan Maheshwari,

- Comparison of different modulation strategies for enhanced DC utilization [2018]
  Different modulation techniques such as SPWM, SVMPWM, Hysteresis modulation technique, 3rd harmonic injection, Delta Sigma Modulation, Predictive Control Modulation & Modified Predictive Control Modulation implementation and verification on 1 kW IGBT based hardware prototype.
  Advisor: Prof. T.N.Mir

- Analysis & Design of Interleaved Boost Converter for Electric Vehicle Charging [2019]
  Controller Design of 10kW EV charger operating at 100kHz in discrete-time domain
  Advisor: Prof. S.S. Nag

Teaching experience

- Introduction to Electrical Engineering (ELL101)
- Introduction to Electrical Engineering Lab (ELP101)
- Electromechanics Laboratory Lab (ELP203)
- Electric Drive Systems (ELL752)
- Electrical Machines Lab (ELP850)
- Electric Drives Lab (ELP852)

Affiliations

- IEEE *Member*
- IEEE IAS *Member*
- IEEE PES *Member*
- IEEE Young Professional *Member*
- Reviewer *IEEE Transactions on Power Electronics*
- Reviewer *IEEE Transactions on Industrial Electronics*
- Reviewer *IEEE Transactions on Industry Applications*
- Reviewer *IET Power Electronics*
- Reviewer for Conferences: *APEC-2022, ITEC-2023, ECCE-2022-23.*

Talks and Seminars

Oct, 2023	*Poster Presentation at IEEE IAS-AM 2023* on Integrated-Isolated Electronic Capacitor for DC-DC Power Conversion in Muli-level AC-DC-DC Converters.
April, 2023	*Invited talk at JNTU, Kakinada, AP* on Implementation and Design of Isolated DC-DC Converters.
Feb, 2023	*Invited talk at JNTU, Kakinada, AP* on Design and Implementation of Digital Controller for DC-DC & AC-DC Converters.
Oct, 2022	*Invited talk at NITTTR, Chandigarh* on Control and Stability Analysis of Switched Mode Power Converters.
Oct, 2021	*Paper Presentation at IEEE ECCE-US 2021* on Reducing DC-Link Capacitance in EV Chargers.
May, 2021	*Paper Presentation at IEEE ECCE-Asia 2021* on Isolated Multilevel EV Chargers.
Dec, 2020	*Paper Presentation at IEEE PEDES 2020* on Model Predictive Control in Multilevel EV *Chargers.*

Awards and Certificates

2023 *Graduate Student Grant* in IEEE Industry Applications Society (IAS) Annual Meeting 2023.
2023 *Research Excellence Travel award (RETA)* in IIT Delhi-2023.
2021 *Research Scholar Travel Award (RSTA)* in IIT Delhi-2021.
2018 4^{th} *Rank* in the class of 75 students (B.Tech) in NIT Srinagar-2018.
2023 *Ansys Maxwell: High Frequency Power Magnetics* by Udemy (Online)

Technical Skills

Silicon Carbide based PE Converters	*Single-phase PFC based AC-DC Converter for bidirectional Power Flow* *Dual-Active Bridge for EV Charging* *Power Electronics based Capacitors* *Soft-switched AC-DC & DC-DC Converters for Improved Efficiency* *Improved PWM Techniques for motors using 3-phase inverters*
Gate Driver Design	*Gate Driver Design with De-saturation, and Over-current Protection* *Triggering 5kW SiC based Converter with 100kHz Switching Frequency*
Micro-controllers	*DSP (Peripherals - ADC, DAC, PWM, GPIO), FPGA (Communication protocols), Dspace, Opal-Rt, Typhoon HiL (Implementation of PWM modulation techniques for voltage source inverters applied to 3-phase motors*
Current/Voltage Sensor	*Sensors with 1MHz bandwidth for controlling PE Converters*
Modelling and Design	Multiphyscics modelling ANSYS MAXWELL, PEMag, RMXprt, Simplorer, Study of EMI (CM & DM) and Thermal Issues
Circuit and PCB	Circut design & verification in MATLAB, Simplis, PLECS, LT-spice. PCB designing in KiCad, Altium Designer, Design Spark.
Programming	Proficient in C & Embedded C, Intermediate knowledge of Python

References

- **Prof. Bhim Singh (Ph.D. Supervisor)**
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  Department of Electrical Engineering
  Indian Institute of Technology Delhi, India
- **Prof. Bijaya Ketan Panigrahi (Ph.D. Supervisor)**
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  Indian Institute of Technology Delhi, India
- **Dr. Tabish Nazir Mir (B.Tech Supervisor)**
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