# Shiladri Chakraborty

Assistant Professor
Department of Electrical Engineering
Indian Institute of Technology Bombay


## PERSONAL DETAILS


**Date of birth** : March 22, 1986
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## ACADEMIC PROFILE

| Degree/Position | Year | Institute | Marks |
|---|---|---|---|
| Post-doctoral Associate | 2018-2021 | University of Maryland, College Park | NA |
| Doctor of Philosophy | 2012-2018 | Indian Institute of Technology Kharagpur | NA |
| Master of Technology | 2010-2012 | Indian Institute of Technology Kanpur | GPA - 9.79/10 |
| Bachelor of Engineering | 2004-2008 | Jadavpur University, Calcutta | GPA - 8.56/10 |
| Higher Secondary | 2004 | South Point High School (W.B Board) | 83.9 % |
| Secondary | 2002 | South Point High School (W.B Board) | 88.1 % |

## AWARDS, ACCOMPLISHMENTS

- Outstanding presentation award at IEEE APEC 2016.
- Student travel grant from IEEE to attend ECCE 2016, APEC 2016 and from DST, Govt. of India to attend IEEE IECON 2017.
- IIT Kanpur Academic Excellence Award, 2012.
- 1st position in M.Tech - Power and Control at IIT Kanpur.
- Jadavpur University Ganesh Janani Devi memorial medal, 2008 for best performance in subjects Electrical Machines II and III.

## RESEARCH EXPERIENCE

### POST-DOCTORAL RESEARCH

Worked on the following projects during my post-doctoral tenure.

- As lead-electrical on an U.S Department of Energy (DOE)-funded project titled "Compact and Low-Cost Microinverter for Residential Systems", which aims to reduce the cost and improve the reliability and performance of residential PV microinverters by developing a **400 W, 240 V ac, grid-tied microinverter** with bill-of-material **cost < $ 0.07/W**, **MTTF > 250,000 hrs**, **CEC efficiency > 97 %** and **power-density > 0.61 kW/litre**. Technical highlights of the work include :
  - Cost-efficiency Pareto-optimal design of a **hybrid Si-GaN**, DAB-based, 200 kHz single-stage, dc-ac topology, includina an auxiliary active power decoupling (APD) circuit to eliminate the use of electrolytic capacitors
  - Design of a novel, low-loss planar transformer with integrated leakage inductance
  - Improved analytical modeling of high-frequency DAB considering transition time effects
  - Control strategy for soft-startup, incorporation of smart grid features ensuring compliance to UL1741 standard
  - Experimental reliability studies to identify failure mechanisms
  - Development of a **1 MHz fully GaN prototype** with ceramic capacitors for APD

  *Progress* : Closed-loop hardware validation of main circuit with APD with efficiency of 96.7 % on a standalone resistive load completed.
  *Publications* : 2 conference papers in ECCE 2020, 3 journal papers in IEEE Trans. on Power Electron., 1 journal paper under preparation for submission to IEEE JESTPE, 1 invention disclosure filed.
- As lead-electrical on an U.S Army Research Lab (ARL) funded-project titled "Thermally Integrated 3D Package for **SiC-based DC-DC** Full Bridge Converter", which aims to build a very high power-density (greater than **25 kW/litre**), **10 kW**, high-voltage (800 V) bidirectional, isolated dc-dc converter for army **electric vehicles** capable of operating at **very high switching frequencies (500 kHz-1 MHz)**. Technical highlights of the work include :
  - **Wire-bondless assembly of bare-die SiC devices** with integrated dc-link capacitors and gate-drive circuitry
  - Compact layout of the switches with better power loop and gate loop inductances than most state-of-the-art solutions
  - Use of **3D-printed multi-functional elements**, serving as both electrical busbars and switch heatsinks
  - Design of a **cooling-system-integrated planar transformer with integrated leakage inductance**, capable of combined core and winding cooling and adoption of **electro-thermal co-design**.

  *Progress* : Experimental electrical characterization of switching behaviour at 600 V, 30 A completed; power testing completed upto 8 kW at 500 kHz, 550 V.
  *Publications* : 4 conference papers - 1 in ASME InterPACK 2019, 2 in ITEC 2020 and 1 in ITherm 2020; 2 journal papers in IEEE Trans. on Transp. Electrific.; 1 conference paper under review; 3 invention disclosures filed.

- As technical support on a JLG Industries-funded project which aims to build a **900 W inductive wireless charger** for charging 24 V battery of electric scissor-lift vehicles, with a target power transfer distance of 20 cm. Contributions limited to analysis and comparison of various compensation networks and topologies.

**DOCTORAL RESEARCH**

*Thesis title* : "Efficiency Optimization and Topological Innovations of **Dual Active Bridge Based Converters**".
*Contributions* : In the first part of the thesis, **hitherto-unexplored, closed-loop realizable, modulation strategies** for both voltage-source and current-source dual active half-bridge dc-dc converter are proposed which reduce conduction and switching losses, thereby improving their power conversion efficiency. In the second part, **two novel DAB-based, fully soft-switched, electrolytic capacitor-less, isolated dc-ac topologies** are developed which lead to potential cost, efficiency and reliability benefits. Battery-integrated forms for both topologies are also proposed. The second topology is extendible for the general case of ac-ac conversion and also scalable to high-voltage applications. Additionally, worked with colleague on ac-side modulation of a phase-modulated, isolated dc-ac converter, which is shown to have better efficiency than conventionally-adopted dc-side modulation, due to reduction in circulating current and extension of ZVS range of primary devices.
*Publications* : 5 in IEEE Trans. on Power Electron., 3 in IEEE APEC, 5 in IEEE ECCE, 1 in IEEE IECON.

**MASTER'S RESEARCH**

*Thesis title* : "Design and Control Of High-Gain Isolated **Resonant Boost Converter** For PV Microinverter Application".
*Contributions* : Developed a novel LLC resonant tank-based, high-voltage-gain dc-dc converter with load-independent ZVS property using planar magnetics for use as the dc-dc front-end of a two-stage PV microinverter.
*Publications* : 1 in IEEE Trans. on Power Electron., 1 in IEEE ECCE, 1 in NPEC.

## INDUSTRIAL EXPERIENCE

| Year | Organization | Designation | Responsibility |
|---|---|---|---|
| 2008-2010 | Tata Motors Ltd. | Assistant Manager | Decommissioning, planning, maintenance |

## TEACHING EXPERIENCE

At IIT Bombay, instructor for

- "Technical Communication" (EE 350) - Spring 2022.

At the University of Maryland

- Developed lab experiments for "Introduction to Electrical & Computer Engineering" (ENEE101) on 1) Energy harvesting from solar cell, piezoelectric and thermoelectric generators and 2) Operation of boost and buck-boost converters.
- **Instructor for "Renewable Energy" (ENEE476)** - Fall 2020.

At IIT Kharagpur, served as teaching assistant for the following courses.

- Tutorial class for "Electrical Machines" (EE21002).
- Tutorial class for "Power System and Apparatus Design" (EE49004).
- Laboratory class for "Power Electronics and Machine Lab".
- Tutorial class for "Signals and Networks" (EE21101).
- Tutorial and laboratory classes for "Electrical Technology" (EE11101).

## PUBLICATION LIST

**Journals**

**J11.** Y. Shen, M. D'Antonio, **S. Chakraborty**, A Hasnain and A. Khaligh, "Comparison of CCM and CRM-based Boost Parallel Active Power Decoupler for PV Microinverter," *IEEE Trans. on Power Electron.*, Early Access.

**J10.** Y. Park, **S. Chakraborty** and A. Khaligh, "Characterization of a Bare-die SiC-based, Wirebond-less, Integrated Half-bridge with Multi-functional Bus-Bars," *IEEE Trans. on Transp. Electrific.*, Early Access.

**J9.** Y. Park, **S. Chakraborty** and A. Khaligh, "DAB Converter for EV On-Board Chargers Using Bare-die SiC MOSFETs and Leakage-Integrated Planar Transformer," *IEEE Trans. on Transp. Electrific.*, 8 (1), pp. 209-224, Mar. 2022.

**J8.** M. D'Antonio, **S. Chakraborty** and A. Khaligh, "Planar Transformer with Asymmetric Integrated Leakage Inductance Using Horizontal Air Gap," *IEEE Trans. on Power Electron.*, 36 (12), pp. 14014-14028, Dec. 2021.

**J7.** M. D'Antonio, **S. Chakraborty** and A. Khaligh, "Improved Frequency-Domain Steady-State Modeling of the Dual-Active-Bridge Converter Considering Finite ZVS Transition Time Effects," *IEEE Trans. on Power Electron.*, pp. 7880-7891, July 2021.

**J6. S. Chakraborty** and S. Chattopadhyay, "A Dual-Active-Bridge-based Fully-ZVS HF-isolated Inverter With Low Decoupling Capacitance," *IEEE Trans. on Power Electron.*, 35 (3), pp. 2615-2628, Mar. 2020.

**J5. S. Chakraborty** and S. Chattopadhyay, "A Dual-Active-Bridge-Based Novel Single-Stage Low Device Count DC-AC Converter," *IEEE Trans. on Power Electron.*, 34 (13), pp. 2339-2354, Mar. 2019.

**J4. S. Chakraborty** and S. Chattopadhyay, "Fully-ZVS, Minimum RMS Current Operation of the Dual-Active Half-Bridge Converter using Closed-loop Three Degree of Freedom Control," *IEEE Trans. on Power Electron.*, 33 (12), pp. 10188-10199, Dec. 2018.

**J3.** N. K. Kummari, **S. Chakraborty** and S. Chattopadhyay, "An Isolated High-frequency Link Microinverter Operated with Secondary-Side-Modulation for Efficiency Improvement," *IEEE Trans. on Power Electron.*, 33 (3), pp. 2187-2200, Mar. 2018.

**J2. S. Chakraborty** and S. Chattopadhyay, "Minimum-RMS-Current Operation of Asymmetric Dual Active Half-Bridge Converters with and without ZVS," *IEEE Trans. on Power Electron.*, 32 (7), pp. 5132-5145, July 2017.

**J1.** U. Kundu, **S. Chakraborty** and P. Sensarma, "Automatic Resonant Frequency Tracking in Parallel LLC Boost DC-DC Converter," *IEEE Trans. on Power Electron.*, 30 (7), pp. 3925-3933, July 2015.

**Conferences**

**C23.** M. D'Antonio, **S. Chakraborty** and A. Khaligh, "Design Optimization for Weighted Conduction Loss Minimization in a Dual-Active-Bridge-Based PV Microinverter," *IEEE IEEE Energy Conversion Congress and Exposition (ECCE), Oct. 2020.*

**C22.** Y. Shen, M. D'Antonio, **S. Chakraborty** and A. Khaligh, "CCM vs. CRM Design Optimization of a Boost-derived Parallel Active Power Decoupler for Microinverter Applications," *IEEE Energy Conversion Congress and Exposition (ECCE), Oct. 2020.*

**C21.** P. McCluskey,, H. Yun, C, Buxbaum, S, Yuruker, R. Mandel, M. Ohadi, Y. Park , **S. Chakraborty**, A. Khaligh, L. Boteler and M. Hinojosa, "Thermo-mechanical reliability design considerations of 3D-integrated SiC power device package," *IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), Jul. 2020.*

**C20.** Y. Park, **S. Chakraborty** and A. Khaligh, "A Bare-die SiC-based Isolated Bidirectional DC-DC Converter for Electric Vehicle On-board Chargers," *IEEE Transportation Electrification Conference and Exposition (ITEC), Jun. 2020.*

**C19.** Y. Park, S. Yuruker, **S. Chakraborty**, A. Khaligh, R. Mandel, P. McCluskey, M. Ohadi, L. Boteler and M. Hinojosa, "Electro-Thermal Co-Design of a Cooling System-Integrated High-Frequency Transformer," *IEEE Transportation Electrification Conference and Exposition (ITEC), Jun. 2020.*

**C18.** S. U. Yuruker, R. K. Mandel, P. McCluskey, M. Ohadi, **S. Chakraborty**, Y. Park, H. Yun, A. Khaligh, L. Boteler and M. Hinojosa, "Advanced Packaging and Thermal Management of High-Power DC-DC Converters," *ASME International Technical Conference and Exhibition on Packaging and Integration of Electronic and Photonic Microsystems (InterPACK), 2019*, Oct. 2019.

**C17.** S. Chaudhuri, **S. Chakraborty**, A. Banjare and S. Chattopadhyay, "A Battery-Integrated High-Frequency Transformer-Coupled Phase-Modulated PV Inverter," *IEEE Energy Conversion Congress and Exposition (ECCE), 2018*, pp. 6364-6371, Sep. 2018.

**C16. S. Chakraborty** and S. Chattopadhyay, "A Dual-active-bridge-based High-frequency Isolated Inverter for Interfacing Multiple PV Modules with Distributed MPPT," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2018*, pp. 3256-3263, Mar. 2018.

**C15. S. Chakraborty** and S. Chattopadhyay, "Approaches for Continuous-Time Dynamic Modeling of the Asymmetric Dual-Active Half-Bridge Converter," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2018*, pp. 952-958, Mar. 2018.

**C14. S. Chakraborty** and S. Chattopadhyay, "Operation of a Triple-active-bridge-based Battery-integrated Isolated PV Microinverter," *Annual Conference of the IEEE Industrial Electronics Society (IECON), 2017*, pp. 2611-2616, Nov. 2017.

**C13. S. Chakraborty** and S. Chattopadhyay, "A Multi-port, Isolated PV Microinverter with Low Decoupling Capacitance and Integrated Battery Charger," *IEEE Energy Conversion Congress and Exposition (ECCE), 2016*, Sep. 2016.

**C12. S. Chakraborty**, S. Tripathy and S. Chattopadhyay, "Minimum RMS Current Operation of the Dual Active Half-Bridge Converter using Three Degree of Freedom Control ," *IEEE Energy Conversion Congress and Exposition (ECCE), 2016*, Sep. 2016.

**C11.** N.K. Kummari, **S. Chakraborty** and S. Chattopadhyay, "Secondary Side Modulation of a Single-stage Isolated High-frequency Link Microinverter with a Regenerative Flyback Snubber," *IEEE Energy Conversion Congress and Exposition (ECCE), 2016*, Sep. 2016.

**C10. S. Chakraborty** and S. Chattopadhyay, "A Novel Single-stage Dual-Active Bridge based Isolated DC-AC Converter," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2016*, pp. 1954-1961, Mar. 2016.

**C9. S. Chakraborty** and S. Chattopadhyay, "An Isolated Buck-Boost Type High-frequency Link Photovoltaic Microinverter," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2016*, pp. 3389-3396, Mar. 2016.

**C8.** P. P. Das, S. Chattopadhyay and **S. Chakraborty**, "A Voltage Independent Islanding Detection Method & Low Voltage Ride Through of a Two-Stage PV Inverter," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2016*, pp. 2652-2659, Mar. 2016.

**C7.** N.K. Kummari, **S. Chakraborty** and S. Chattopadhyay, "A hybrid isolated boost converter with reduced output capacitance and integrated auxiliary circuit for ZVS," *IEEE Energy Conversion Congress and Exposition (ECCE), 2015*, pp. 6320-6327, Sep. 2015.

**C6. S. Chakraborty** and S. Chattopadhyay, "An improved asymmetric half-bridge converter with zero DC offset of magnetizing current," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2015*, pp. 1-8, Mar. 2015.

**C5. S. Chakraborty** and S. Chattopadhyay, "Analysis and comparison of voltage-source and current-source asymmetric dual-active half-bridge converters," *IEEE Energy Conversion Congress and Exposition (ECCE), 2014*, pp. 2072-2079, Sep. 2014.

**C4. S. Chakraborty** and S. Chattopadhyay, "Topology Variations and Design Improvements of a Single-Stage Flyback PV Microinverter," *IEEE Applied Power Electronics Conference and Exposition (APEC), 2014*, pp. 3026-3033, Mar. 2014.

**C3.** U. Kundu, **S. Chakraborty** and P. Sensarma, "Analog Controller for MPPT and Self-tuning of Resonant Frequency in Parallel LLC Boost Dc-Dc Converter for PV Microinverter," *National Power Electronics Conference (NPEC), 2013*, IIT Kanpur, India, Dec. 2013.

**C2. S. Chakraborty**, N. Gupta and S. Chattopadhyay, "A Digital Charge-Mode Control Algorithm for Power Decoupling in a Flyback Microinverter," *IEEE Energy Conversion Congress and Exposition (ECCE), 2013*, pp. 4785-4792, Sep. 2013.

**C1. S. Chakraborty** and P. Sensarma, "High gain high efficiency front end resonant dc-dc boost converter for PV microinverter," *IEEE Energy Conversion Congress and Exposition (ECCE), 2012*, pp. 180-187, Sep. 2012.

**Under preparation** M. D'Antonio, **S. Chakraborty**, A. Hasnain, Y. Shen and A. Khaligh, "Multi-Objective Design Optimization of a DAB-Based Single-Stage PV Microinverter," preparing for submission to *IEEE Journ. of Emerg. and Sel. topics in Power Electron.*

## PATENTS/ INVENTION DISCLOSURES

**[4]** M. D'Antonio, A. Khaligh and **S. Chakraborty**, "Family of Active Power Decoupling Integrated Inverters and Rectifiers, and Associated Control Schemes," Invention Disclosure filed, University of Maryland.

**[3] S. Chakraborty**, Y. Park and A. Khaligh, "Ultra-low-inductance SiC-based Half-bridge Die with Integrated On-chip Decoupling Capacitor and Gate Resistors," Invention Disclosure filed, University of Maryland.

**[2]** Y. Park, **S. Chakraborty** and A. Khaligh, ""Methods for manufacturing, layout and thermal management of wire-bondless switch modules in power electronic converters," Invention Disclosure filed, University of Maryland.

**[1]** R. Mandel, A. Khaligh, P. McCluskey, Y. Park, A. Mallik, **S. Chakraborty**, S. Yuruker, C. Buxbaum, "Wire-Bondless, Electro-Thermally-Integrated Switch Module," Provisional Patent filed, University of Maryland.

## PROPOSAL WRITING EXPERIENCE

At IIT Kharagpur, worked with Ph.D. advisor to draft the following proposals.

- "A 1 kW rooftop solar installation system with module-level MPPT";
  *Funding agency* : Department of Science and Technology, Govt. of India.
- "Development of high-frequency planar magnetics";
  *Funding agency* : National Mission on Power Electronics Technology (NaMPET) Phase III, Ministry of Electronics and Information Technology, Govt. of India.
- "A combined ac and dc charging infrastructure for electric vehicles employing a PV array, a DG set and a supercapacitor for fast charging";
  *Funding agency* : Mission Innovation India (jointly with IIT Kanpur, IIT BHU).
- "Development of a current-fed DAHB-based low-device count, modular 5 kW, 70 V to 350 V dc-dc converter for spacecraft thruster application";
  *Funding agency* : Indian Space Research Organisation.
- "Development of a Single-Stage, Isolated PV inverter with MPPT, Battery Charging Capability and Low Decoupling Capacitance";
  *Funding agency* : Department of Science and Technology, Govt. of India.

At the University of Maryland, worked with Post-doc. advisor to draft the following proposals.

- "Innovative Virtual Learning Platform for Teaching Renewable Energy";
  *Funding agency* : University of Maryland.
- "Design of a high-voltage flyback dc-dc converter with integrated, wire-bond-less switch module for pulsed-power applications" (white paper submitted);
  *Proposed Funding agency* : U.S Army Research Laboratory.
- "Development of a 100 kW/l high-power-density multi-level traction inverter" (in collaboration with Princeton University, Cascadia Motion and USCi);
  *Proposed Funding agency* : U.S Department of Energy.
- "Development of a 100 kW/l traction inverter for next-gen EVs with wire-bondless SiC switches" (in collaboration with John Deere, TDK and Infineon);
  *Proposed Funding agency* : U.S ARPA-E.
- "Investigations on reliability, manufacturing and EMI enhancements in electro-thermally integrated, wire-bondless switch module";
  *Proposed Funding agency* : U.S National Science Foundation (NSF).

## CONFERENCES ATTENDED

| Year | Name | Number of papers presented |
|---|---|---|
| 2018 | IEEE APEC, San Antonio, Texas, U.S.A | 2 (1 oral, 1 poster) |
| 2017 | IEEE IECON, Beijing, China | 1 (oral) |
| 2016 | IEEE ECCE, Milwaukee, Wisconsin, U.S.A | 3 (1 oral, 2 poster) |
| 2016 | IEEE APEC, Long Beach, California, U.S.A | 1 (oral) |
| 2013 | NPEC, I.I.T Kanpur | 1 (oral) |

## SERVICE, MEMBERSHIP

- Reviewer since 2014 for *IEEE Trans. on Power Electron., IEEE Trans. on Ind. Electron., IEEE Journ. of Emerg. and Sel. topics in Power Electron., IEEE Trans. on Ind. Appl., IEEE Trans. on Circuits Syst., APEC, ECCE, IECON.*
- Member-IEEE, IEEE Power Electronics Society, Industrial Electronics Society, Industry Applications Society.