Ministry of Education (Shiksha Mantralaya)
GLOBAL INITIATIVE OF ACADEMIC NETWORKS

Medium Voltage Multilevel Inverters for High Power Industrial Drives for Manufacturing and Solar Generation Applications

~~(old Dates : 14th to 18th November 2022)~~

(08th – 12th May 2023)

Department of Electrical Engineering, NIT Warangal

Overview

Efficiency is very important at high power applications because a fraction results in large amount of power. For example, for 1 MW application, 0.1% difference in efficiency results in 10kW power loss that results in 240 kWh or 864 MJ of energy loss. At further higher power level, it has increasing im-pact. Higher amount of losses demands for higher thermal dissipating and cooling requirements that adds to cost, space, and weight. Therefore, it is essential to reduce the losses and optimize the efficiency.

One aspect to address this issue is to increase the voltage level. Therefore, several industries such as Siemens, ABB, Rolls-Royce, Rockwell, etc. have moved from low voltage (690 V) to medium volt-age level (4160 V). It reduces the current level by six times (6x) and the conduction losses are significantly reduced. The switching losses in power semiconductor devices are still the same and higher voltage level puts limitation on the availability of the semiconductor devices with higher blocking voltage capability.

To unlock the limitation on power semiconductor devices with low blocking voltage capability, multi-level converters are widely adopted and a major subject of research in industry in terms of circuit topologies, modulation, and power scalability.

To limit the switching losses in power semiconductor devices to reduce the switching loss and optimize the system efficiency, the semiconductor devices of multilevel inverters are modulated at low frequency. It is desired to keep it below 500 Hz. However, low device switching frequency increases the harmonic distortion in output voltage and hence in machine currents too. This adds to harmonic losses as well as increased filtering requirements. Therefore, harmonic distortion should be optimized along with low switching frequency modulation. Therefore, optimal low switching frequency pulse width modulation is critical and a desirable solution to address the objective of limiting both the de-vice switching losses and harmonic distortion.

Major applications of this course include high power industrial drives, manufacturing, marine, solar generation, and other large-scale industrial applications. A study of the several multilevel inverter circuit topologies and optimal low switching frequency modulation techniques will be done through lectures. Merits, demerits, applications, and comparison of the topologies and modulations will be studied. Detailed notes and study material will be provided. Assignments will be given for take home exercises and afternoon tutorials. Numerical problems will be developed to solve them using simulation and mathematical calculations. Such exercise will enhance the understanding and help evaluating the knowledge.

Course participants will learn these topics through lectures and hands-on experiments. Also, case studies and assignments will be shared to stimulate research motivation of participants.

Modules	**Schedule: May 08 - May 12 2023** **Course Objectives:** The primary objectives of this course are to introduce, expose, and train the participants on the following: - Importance, need, and introduction to the Medium Voltage Systems in industry and at higher power applications. Review and requirements of medium voltage applications. - Introduction to the Multilevel Converters: concept and fundamentals - Understanding the operation and comparison of various multilevel converter topologies - Study of Modular Multilevel Converters (MMCs): Generalized approach to develop higher voltage level inverters - Study, impact, and implementation of emerging modulation techniques: Optimal pulse width modulation, synchronous pulse width modulation, model predictive control, and space vector algorithms. - Analysis, design, and control of current-fed multilevel inverters for solar generation - Analysis, design, and control of voltage-fed multilevel inverters for high power industrial drives for manufacturing, solid-state transformer, and marine propulsion system - Analysis, design, and implementation of low frequency control of multilevel inverters - Common mode voltage elimination in open-end winding induction motor drives using dual multilevel inverters - Generalized approach to develop and implement control for multi-voltage level inverters **Number of Participants for the Course will be Limited to Fifty (50).**
You Should Attend If…	▪ You are a Faculty member / Design Engineer/Researcher/Scientist interested in Power Electronics & drives specialization of electrical and electronics engineering, ▪ You are power electronics & drives design engineer/specialist interested to learn Multi Level Inverters for high power Industrial & solar power generation applications in your profession. ▪ You are a UG/PG student or research Scholar from academic institution interested in learning how to do research or want work on Multi Level Inverters for high power Industrial & solar power generation applications.
Fees	**The participation Course fee is as follows:** **Industry/ Research Organizations:** **Rs. 6,000/-** **Faculty from Academic Institutions:** **Rs. 3,000/-** **Students & Research Scholars:** **Without award of Grade: Rs. 1,000/-** **With award of Grade: Rs. 2000/-** **Faculty/Scientists/Industry Participants from abroad: US $400** **The above fee includes all instructional materials, tutorials, assignments, and refreshments during lecture sessions.** **Note: The outstation participants from academic/research institutes and Industry will be provided with boarding and lodging on additional payment basis. Institute accommodation charges will be Rs.500/- per Day per Room on twin sharing basis.** **Account Name: GIAN NITW** **Account No.: 62447453600** **Bank State Bank of India** **Branch REC Warangal (NIT Campus)** **Branch Code: 20149** **IFSC: SBIN0020149** **MICR Code: 506002030** **SWIFT Code: SBININBB** **Last Date for Course Registration with Fee: 20-April-2023** **Refer the GIAN web link to Register for this Course: https://gian.iitkgp.ac.in/GREGN/index**

The Faculty

Prof. Akshay Kumar Rathore (Fellow, IEEE) received the M.Tech. degree in electrical machines and drives from the Indian Institute of Technology (BHU), Varanasi, India, in 2003, and the Ph.D. degree in power electronics from the University of Victoria, Victoria, BC, Canada, in 2008. He is currently a Professor (engineering) with Singapore Institute of Technology, Singapore. He had two subsequent postdoctoral research appointments with the University of Wuppertal, Wuppertal, Germany, and the University of Illinois at Chicago, Chicago, IL, USA. From November 2010 to February 2016, he served as an Assistant Professor with the Department of Electrical and Computer Engineering, National University of Singapore, Singapore. From March 2016 to December 2021, he served as an Associate Professor with the Department of Electrical and Computer Engineering, Concordia University, Montreal, QC, Canada, where he was listed in the Provost Circle of Distinction in 2021. He has authored/coauthored about 280 research papers in international journals and conferences, including 94 IEEE Transactions. His research interests include current-fed converters and multilevel inverters., Prof. Rathore was the recipient of the Gold Medal for securing the highest academic standing in the master's degree among all electrical engineering specializations. He is a recipient of the 2013 IEEE IAS Andrew W. Smith Outstanding Young Member Achievement Award, 2014 Isao Takahashi Power Electronics Award, 2017 IEEE IES David Irwin Early Career Award, 2020 IEEE IAS Outstanding Area Chair Award, 2020 IEEE Bimal Bose Award for Industrial Electronics Applications in Energy Systems, and 2021 Nagamori Award. He is currently serving as the Awards Department Chair of the IEEE Industry Applications Society and AdCom Member-at-Large of the IEEE Industrial Electronics Society. For More Details Refer: https://www.singaporetech.edu.sg/directory/faculty/akshay-kumar-rathore

Prof. B. L Narasimharaju (Senior Member IEEE) is a Professor of Electrical Engineering, NIT Warangal. India. He received B.E, M.E degree in Electrical Engineering from University Visvesvaraya College of Engineering (UVCE), Bangalore in 1999 and 2002, respectively, and the Ph.D degree from the Indian Institute of Technology Roorkee (IIT Roorkee), Roorkee, India, in 2012. He worked as Project Trainee at ABB Bangalore from March 2001 to August 2001, since then till March 2002 at LRDE, Ministry of Defence, India. He was Teaching Assistant at UVCE, Bangalore from April 2002 to August 2003. Since August 2003 to May 2012, he was Faculty of Electrical Engineering, MIT Manipal University, India. Currently, he is a Professor of Electrical Engineering, NIT Warangal, India. He is a Senior member IEEE, Life member of ISTE Delhi & System Society of India (SSI). His research credential includes, 5 funded research projects to a worth of 2.50 crores, 8 Ph.Ds guidance, 80+ research publications in reputed journals and conference proceedings. In his other academic & research activities, he has conducted more than 19 FDPs through which trained more than 1200+ academic & research community. His research interests include; Power Conversion & Control Techniques; LED Drivers for Lighting Systems; Bidirectional Converter for Energy Storage Integration, Multilevel Inversion; Grid integration of solar energy; Switched Reluctance Motor & Induction Motor drives. For More Details Refer: https://wsdc.nitw.ac.in/facultynew/facultyprofile/id/16242

Course - Coordinator

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Dr. A. V Giridhar (Senior Member, IEEE) is an Associate Professor of National Institute of Technology, Warangal. He received the Doctorate degree from IIT Madras in 2011. He joined the National Institute of Technology, Warangal, India, in 2012, where he is currently an Associate Professor with the Department of Electrical Engineering. He is also working on SPARC Project as a Co PI. Also, he had done consultancy services to state power utility. He has published more than fifteen articles in journals and conferences. His research area includes high-voltage engineering, condition monitoring and diagnosis of high voltage power apparatus, pulsed power technology, and Nano-dielectrics. For More Details Refer: https://wsdc.nitw.ac.in/facultynew/facultyprofile/id/16243

SCHEDULE

Day 1: 08 May 2023

10 AM to 11 AM: Inauguration

11:30 AM to 12:30 PM: Akshay Rathore

Introduction to medium voltage (4130 V), their individual specific requirements, architecture of medium voltage power systems, and comparison with low voltage (690 V) systems.

2:30 PM to 4:30 PM – Akshay Rathore

Introduction to multilevel inverters, their classification, topologies, derivation from two-level, three-level to higher voltage level, comparison of topologies for power semiconductor devices and simplicity/complexity of operation

Day 2: 09 May 2023

10 AM to 12:30 PM: Akshay Rathore

Study of Modular Multilevel Converters (MMCs), their operation, method to scale and develop higher level inverters for higher power applications.

Study and implementation of advanced selected emerging modulation techniques such as optimal pulse width modulation, synchronous pulse width modulation, model predictive control, and space vector algorithms.

2:30 PM to 4:30 PM – Akshay Rathore

Calculations and examples on determination of components' ratings for various multilevel inverter topologies for given specifications including simulation.

Examples on ability of space vector voltage selection with minimum number of device commutations for various modulation techniques for given inverter topology including simulation.

Day 3: 10 May 2023

10 AM to 12:30 PM: Akshay Rathore

Study and analysis of low frequency (50 to 200 Hz device switching frequency) control techniques including fundamental device switching frequency for multilevel inverters, their algorithms, and implementation in real-time and off-line. A generalized modelling and approach to develop and implement such control of higher voltage level inverters.

2:30 PM to 4:30 PM – Akshay Rathore

Examples and simulation on power losses (switching and conduction losses in semiconductor devices), total harmonic distortion (THD), and filter sizing for voltage-fed multilevel inverters.

Day 4: 11 May 2023

10 AM to 12:00 PM: BLN Raju

High gain multilevel inverters for industry applications such as solar PV grid integration, electric vehicles applications, etc.

2:30 PM to 4:30 PM – BLN Raju and AV Giridhar

Examples and Simulation of High gain multilevel inverter circuit topology.

Examples on power losses (switching and conduction losses in semiconductor devices), total harmonic distortion (THD), and filter sizing.

Day 5: 12 May 2023

10 AM to 12:30 PM: Akshay Rathore

Common mode voltage elimination in open-end winding induction motor drives using dual multilevel inverters for industry applications such as marine electrification, manufacturing, oil-rig platform for downhole drill applications, etc.

"Important mathematical parameters and factors in optimization the modulation and control to develop optimal pulse pattern for switching of the semiconductor devices and their implementation for different applications."

2:00 PM to 3:00 PM – Akshay Rathore

Examples and Simulation exercise on determination of common mode voltage, common mode inductance, compromise on THD, increase in device switching frequency or increased harmonic losses, and filter sizing for given modulation and circuit topology.

3:30 to 4:30 PM – Closing ceremony and feedback