The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6205 POWER ELECTRONICS CONVERTERS

Credits: 15

Course Description including Aims

This unit introduces power conversion principles, defines the terminology and analyses operational principles, modulation methods and control of selected power converters topologies for industrial applications. The aims of the module are to understand:

1. Main operational principles of power electronic converters
2. Current-source and voltage-source converter requirements and restrictions
3. Multi-level modulation and control strategies for standard multilevel converters
4. Operation of load resonant, resonant-switch and resonant dc-link converters
5. Challenges in control of matrix converters

Outline Syllabus

Introduction to power conversion: Structure of power converters, main characteristics and requirements, elementary commutation cells, overview of switching power devices, overview of thermal management and packaging. **Two-level voltage source and current source converters**: Requirements on the switches, standard modulation strategies, implementation in a digital controller and analysis of output voltage harmonics, power factor control and active damping control of current source rectifiers. **Multilevel voltage source converters**: Multilevel modulation strategies and capacitor voltage balancing approaches for the cascaded symmetrical and asymmetrical H-bridge multilevel converter, diode clamped multilevel converter and flying capacitor multilevel converter, control of multilevel converters for power quality improvements. **Matrix converters**: Main requirements and restrictions on the switches, input filter and converter operation, overview of direct and indirect modulation and control methods. **Resonant converters**: Basic resonant circuit concept and main classification of resonant converters, analysis of load-resonant, resonant-switch and resonant dc-link converters.

Time Allocation

32 lectures including problem-based classes, 4 hours of Matlab-based simulation exercises plus 12 hours of support material.

Recommended Previous Courses

Background knowledge equivalent to EEE202 “Electromechanical Energy Conversion”, EEE342 “Feedback Systems Design”, and EEE307 “Power Electronics”

Assessment

3-hour examination, answer 4 questions from 6 contributes to 80% of the total mark

2 coursework assignments contributes to 20% of the total mark

Recommended Literature

Williams B.W.	*Power Electronics - Devices, Drivers & Applications*	Macmillan
Mohan, N., Undeland, T.M. & Robbins, W.P.	*Power Electronics: Converters, Applications and Design*	John Wiley&Sons
D.Grahame Holmes, Thomas A.Lipo	*Pulse width modulation for power converters: Principles and Practice*	John Wiley&Sons
Gonzalez .A., Verne S.A. & Valla M.I.	*Multilevel Converters for Industrial Applications*	CRC Press Taylor& Frances Group
Bin Wu	*High-Power Converters and AC Drives*	IEEE Press
M.Kazimierczuk& D.Czarkowski	*Resonant power converters*	John Wiley &Sons,Inc.
J.Rodriguez, M.Rivera, J.W.Kolar& P.W.Wheeler	*A Review of Control and Modulation Methods for Matrix Converters*	IEEE Transactions on Industrial Electronics Vol. 59, No. 1, pp. 58-70, January 2012.

Objectives

By the end of this module successful students will be able to

1. master standard modulation and control techniques for two-level current/voltage source converters
2. demonstrate detail understanding of multilevel modulation strategies and capacitor voltage balance issues for standard multilevel power converter topologies
3. design controllers for multilevel power converters for power quality improvements
4. understand matrix converters operation principles, major restrictions and requirements
5. display in-depth knowledge of resonant power electronics converters

Detailed Syllabus

1 Power converters: definitions, classification, converter topologies, and applications

2 Silicon power electronic devices, wide band-gap power electronics, overview of thermal management and packaging

3, 4 Elementary commutation cells in power converter examples - chopper, single-phase voltage/current source inverter, three-phase voltage/current source inverter, zero voltage/current switching principle, switching losses

5, 6 Review of Two-Level Voltage Source Inverter – Sinusoidal PWM (modulation scheme, harmonic content, over-modulation, third harmonic injection PWM), Space Vector Modulation (switching states, space vectors, dwell time calculation, modulation index, switching sequence, spectrum analysis, even order harmonic elimination); Harmonic analysis based on Double Fourier Series Expansion

7, 8 PWM Current Source Inverters - requirements on the switches, trapezoidal modulation, selective harmonic elimination, space vector modulation, VSI modulator mapping

9, 10 PWM Current Source Rectifiers – power factor control, active damping control: series and parallel resonant modes, LC resonance suppression, harmonic reduction, selection of active damping resistance

11, 12, 13 Multilevel topologies - generalised topology with a common dc bus, basic cell characteristics, converters derived from the generalised topology, cascaded H-bridge multi-level converter with equal/unequal DC voltages: unipolar/bipolar PWM for H-bridge inverter, phase/level-shifted multi-carrier PWM, staircase modulation, comparison of different modulation techniques

14, 15 Diode Clamped Multilevel Converter – three-level inverter (converter configuration, switching states, commutation), space vector modulation, neutral point voltage control (cause of neutral point voltage deviation, effect of motoring and regenerative mode, feedback control of neutral-point voltage), four and five level diode clamped inverters, carrier-based PWM

16, 17 Flying capacitor multilevel converter: modulation strategies, charge balance using PSCPWM, dynamic voltage balance (dynamic model, tuned balancing network: root locus analysis)

18, 19, 20 Applications of multilevel converters– power quality improvements: shunt/series and combined shunt and series connection, compensation principles, reactive power and harmonic compensation

21, 22, 23 Direct Matrix Converter - requirements on the switches, restrictions on the converter operation, switching function requirements, input filter requirements, modulation and control methods (Venturini, Roy's method, carrier-based modulation method, space vector method, predictive control)

24, 25 Indirect virtual dc-link matrix converter - power flow direction, space vector modulation: rectification stage, inverter stage, synchronisation between these two stages, protection issues, comparison with the DMC

26, 27, 28 Basic resonant circuit concept - series/parallel resonant circuits (un-damped circuit, frequency characteristics), classification of resonant converters, series/parallel-loaded resonant dc-dc converters (continuous and discontinuous conduction mode, operating characteristics and control)

29 Current-source parallel-resonant dc-to-ac inverters (application: induction heating)

30, 31 Zero current/voltage resonant-switch dc-dc converters operating principals

32, 33, 34 Parallel resonant dc voltage link power converter, active voltage clamp, series resonant dc current link power converter, RC damping for reducing motor resonance conditions, active current clamp, sigma delta modulation strategies for resonant dc link converters, equivalent circuit of the converter during each resonant pulse

35, 36 Practical issues in application. Contingency and reading week

UK-SPEC/IET Learning Outcomes

Outcome Code	**Supporting Statement**
SM4m	An overview of developing technologies related to power electronic devices is provided and their main challenges and applications discussed. Advances in thermal management and packaging are also addressed.
SM2p	Mathematical methods and tools to obtain frequency spectra of pulse-width modulated power converter output waveforms are addressed and their application is demonstrated on selected examples.
SM2m	The importance of simulation in assessing the design of controllers for power electronics converters is high-lighted and Matlab/Simulink is employed for the development of models for power electronics converters.
SM5m	Analytical equations describing the harmonic spectra and total harmonic distortion of the power converter output are derived.
SM6m	Critical evaluation of different power converter topologies and modulation strategies with respect to specific application requirements through short-term projects-based exercises.
SM1fl	The effects of non-linear phenomena of power conversion by means of power electronics converters are quantified and equivalent models of non-ideal converters are derived and compared with the models that describe only ideal behaviour of the converters

SM1fl	The principles of neutral point voltage control of diode clamped voltage source inverters are explained and causes of neutral point voltage deviation in motoring and regenerative modes have been investigated.
SM2fl	The critical analyses of the current balancing control techniques for multilevel power converters, in particular for the five-level diode clamped inverter.
SM1fl	Comprehensive understanding of the inherent balancing phenomena of phase shifted carrier Pulse Width Modulation strategies for multilevel converters, in particular, the strategy for the flying capacitor multilevel power converter.
SM3fl	Critical evaluation of different power converter topologies and modulation strategies with respect to specific application requirements through short-term projects-based exercises.
EA5m	Analysis of emerging power converter technologies and their current challenges, in particular, analysis of matrix converter and multilevel converter challenges
EA1fl	Application of numerical and complex analytical methods to obtain harmonic spectra of output voltage of different power converter topologies and assessment of their limitations.
EA2fl	Analysis of emerging power converter technologies and their current challenges, in particular, analysis of matrix converter and multilevel converter challenges