DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
M.I.T., MANIPAL
M.Tech. in ELECTRIC VEHICLE TECHNOLOGY

COURSE STRUCTURE:

YEAR	FIRST SEMESTER						SECOND SEMESTER					
	COURSE CODE	**COURSE NAME**	**L**	**T**	**P**	**C**	**COURSE CODE**	**COURSE NAME**	**L**	**T**	**P**	**C**
I	MAT 5130	COMPUTATIONAL METHODS AND APPLIED LINEAR ALGEBRA	4	0	0	4	AAE 5225	VEHICLE DYNAMICS	3	1	0	4
	ELE 5116	ADVANCED CONTROL SYSTEMS	3	1	0	4	ELE 5214	ENERGY STORAGE SYSTEMS FOR ELECTRIC VEHICLES	4	0	0	4
	ELE 5117	ELECTRIC VEHICLES	3	1	0	4	ELE ****	PROGRAM ELECTIVE I	4	0	0	4
	ELE 5118	ENERGY CONVERSION SYSTEMS	3	1	0	4	ELE ****	PROGRAM ELECTIVE II	4	0	0	4
	AAE 5126	AUTOMOTIVE POWER TRAINS	3	1	0	4	ELE ****	PROGRAM ELECTIVE III	4	0	0	4
	HUM 5051	RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION	1	0	3	-	*** ****	OPEN ELECTIVE	3	0	0	3
	ELE 5144	SYSTEM MODELLING AND CONTROL LAB	0	0	6	2	HUM 5051	RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION	1	0	3	2
	AAE 5150	AUTOMOTIVE POWER TRAIN AND SYSTEMS LAB	0	0	3	1	ELE 5245	ELECTRIC VEHICLE DRIVES LAB	0	0	3	1
							ELE 5246	ENERGY STORAGE SYSTEMS LAB	0	0	3	1
	Total		**17**	**4**	**3**	**23**			**24**	**0**	12	**27**
	THIRD AND FOURTH SEMESTER											
II	ELE 6091	PROJECT WORK & INDUSTRIAL TRAINING							**0**	**0**	**0**	**25**

*TAUGHT IN BOTH SEMESTERS AND EVALUATED AND CREDITED IN THE SECOND SEMESTER

PROGRAM ELECTIVES		OPEN ELECTIVES	
ELE 5401	DIGITAL SIGNAL PROCESSING AND APPLICATIONS	ELE 5301	INTELLIGENT CONTROL SYSTEMS
ELE 5402	DISTRIBUTED GENERATION SYSTEMS		
ELE 5404	EMBEDDED SYSTEM DESIGN		
ELE 5407	EV COMMUNICATION SYSTEMS		
ELE 5408	EV DATA ANALYTICS		
ELE 5409	EV GRID INTEGRATION		
ELE 5410	EV POLICIES AND REGULATIONS		
ELE 5411	POWER QUALITY ISSUES AND MITIGATION		
ELE 5412	SMART GRID TECHNOLOGY		
ELE 5413	SOLID STATE LIGHTING AND CONTROLS		
ELE 5414	TIME FREQUENCY ANALYSIS		
ELE 5415	POWER CONVERTERS FOR ELECTRIC VEHICLES		

SEMESTER 1:

MAT 5130: COMPUTATIONAL METHODS & APPLIED LINEAR ALGEBRA [3 1 0 4]

Numerical differentiation and integration, ODE, PDE, Optimization techniques – linear programming, dynamic programming, genetic algorithm, PSO, Linear Algebra - vector space, matrix algebra, simultaneous equations, LU decomposition and matrix inversion, special matrices and Gauss Siedel methods applied in engineering problems, eigen values, characteristic vectors, Cayley-Hamilton theorem, minimal polynomial, polynomial matrices.

References:

1. Steven. C. Chapra and Raymond P. Canale, "*Numerical Methods for Engineers*", Tata McGraw Hill Edition, 2006
2. S. S. Sastry, "*Numerical Analysis for Engineers*" Tata McGraw Hill Edition, 2002
3. Hoffman K and Kunze R, "Linear Algebra", Prentice Hall of India, 2011.

ELE 5116: ADVANCED CONTROL SYSTEMS [3 1 0 4]

Concept of control system and terminology - system modelling using transfer function and state space approach - Mathematical modelling of geared electro-mechanical systems - system stability, time response &frequency response, Design and realization of industrial controllers / compensators, Controller digitization, Controller Tuning, Controllability, Observability, State Feedback Control, Non-linear system, describing function, closed loop limit cycle control, Lyapunov Stability, Sliding Mode Control, Model predictive control.

S**elf-Directed Learning:** Simulation assisted design of Power train control, Motion control, Cruise control.

References:

1. Norman S. Nise, Control Systems Engineering, John Wiley & Sons, Inc, 7th edition, 2014. Ogata K, Modern Control Engineering, Englewood Cliffs, NJ: Prentice Hall, 5th edition 2015.
2. Ogata K, Discrete time Control system, Englewood Cliffs, NJ: Prentice Hall, 2nd edition 2005.
3. Richard C. Dorf, Robert H. Bishop., Modern Control Systems, Pearson, 2011.
4. K.R. Varmah, Modern Control Theory, CBS Publishers & Distributers Pvt. Ltd.,2017
5. William B. Ribbens, Understanding Automotive Electronics: An Engineering Perspective 7th edition, 2015
6. George, V I and Kurian, Ciji Pearl, Digital Control Systems. Cengage Learning India Pvt. Limited, New Delhi,2012.
7. https://www.mathworks.com/learn/training/control-system-design-with-simulink.html
8. NPTEL Material on Advaned Control System (Prof. S. Majhi, IIT Guhavati).

ELE 5117: ELECTRIC VEHICLES [3 1 0 4]

Introduction to energy scenario in India, importance of various energy storage systems, vehicle dynamics, vehicle load forces, vehicle road-load coefficients from EPA coast-down testing, gradeability, vehicle acceleration; concept of drive cycle, drive cycle for 2-wheeler and 4-wheeler vehicles; well to wheel analysis for conventional, battery, hybrid and fuel-cell electric systems; Electric drivetrains: Basic concepts of electric traction, electric drivetrain topologies, power flow control, control systems, electronic control unit (ECU), fuel economy of a battery electric vehicle (BEV); Introduction to regenerative braking, vehicle auxiliaries, charging infrastructure; role of power quality issues in electric vehicle applications and their mitigation techniques.

Self-Directed Learning: Impact of modern drivetrains on energy supplies, capital and operational costs of EV battery; National Electric Mobility Mission Plan, FAME I and FAME-II.

References:

1. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles – Fundamentals, Theory, and Design*, CRC Press, 2005.
2. James Larminie, John Lowry, *Electric Vehicle Technology Explained*, Wiley, 2012.
3. Iqbal Husain, *Electric and Hybrid Vehicles – Design Fundamentals*, 2 ed., CRC Press, 2016.
4. C. Mi, M.A. Masrur, D.W. Gao, *Hybrid Electric Vehicles*, Wiley, 2011.
5. Allen Fuhs, *Hybrid Vehicles and the Future of Personal Transportation*, CRC Press, 2009.
6. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, *Power Quality: Problems and Mitigation Techniques*, Wiley, 2015.
7. Ashok Jhunjhunwala, Prabhjot Kaur, Kaushal Kumar Jha, L. Kannan, *Fundamentals of Electric vehicles: Technology & Economics*, IIT Madras, 2020: https://nptel.ac.in/courses/108106170

ELE 5118: ENERGY CONVERSION SYSTEMS [4 0 0 4]

Magnetic circuit analysis, generalised electrical machine modelling, general concepts in electric drive systems, DC machines, Induction machines, PMSM, BLDC and Switched Reluctance Machines, AC/DC Converters (Controlled Rectifiers), Choppers, DC/AC Converters, Matrix Converters (AC/AC). Introduction to Electric Motor Drive Systems, Study of DC motor, Induction motor and special machine drives, Field oriented control of induction machines, Comparison of machines used in EV's.

Self-Directed Learning: PMSM and BLDC motor drive and control.

References:

1. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Analysis of Electric Machinery and Drive Systems, Wiley India, 2010.
2. R. Krishnan, Electric Motor Drives Modeling, Analysis, and Control, Pearson, 2015.
3. Bose B. K., Microcomputer Control of Power Electronics and Drives, IEEE Press, 1999. 5. Ajay V Deshmukh, Microcontrollers, TMH, 2007
4. NPTEL course: Modelling and Analysis of Electrical machines, by Dr Krishna Vasudevan, IIT Madras.
5. Latest literature in the field of Electrical Machines, Drives, Power Electronics and Electric Vehicles .

AAE 5126: AUTOMOTIVE POWER TRAINS [3 1 0 4]

Combustion Power plants for Hybrid electric vehicles, techniques used to enhance fuel economy and lower emissions, engine performance. Layouts of automobile power transmission systems: power required for propulsion for different modes of operations, Tractive effort and torque analysis. Power transfer and power dividing units in automobiles. Clutches: torque capacity and design aspects of friction clutches, actuation mechanisms, Gearboxes: necessity, Different types of gearboxes, setting of gear ratios, selector mechanisms. Propeller and drive shafts: Design of propeller shafts, critical speed, Final drives, differentials, live axles, axle design. Hydrodynamic drives: Fluid flywheels, Torque Converters, performance characteristics, efficiency of converters. Advanced transmissions: working principle of Automated manual transmissions, Dual clutch transmissions, CVT systems, actuator mechanisms.

Self-Directed Learning: Primary Sensors used in modern engine management systems, Novel techniques to increase power to weight ratio in automobiles, Torque handling capacity in

friction clutches based on uniform wear and uniform pressure, U-joints used in drivelines, Principle and application of fluid flywheels, Trouble shooting in fluid flywheels, Comparison of different advanced transmission systems, features of hydraulic control systems.

References

1. K. Newton, W.Steeds and T.K.Garret, (2004), "The Motor Vehicle", 13th Edition, Butterworth Heinemann, India
2. N. K. Giri,(2018) , "Automobile Mechanics", Seventh reprint, Khanna Publishers, Delhi
3. Kirpal Singh(2020), "Automobile Engineering"Vol 1 ,Standard publishers., N Delhi
4. Jack Erjavec,(2009), " A systems approach to Automotive Technology", Cengage Learning, YesDee publishing pvt Ltd, Chennai
5. Heinz Heisler, (2002), "Advanced Vehicle Technology", second edition, Butterworth – Heinemann, New York.

HUM 5051: RESEARCH METHODOLOGY & TECHNICAL COMMUNICATION [1 0 3 2]

Research Methodology: Basic concepts: Types of research, Significance of research, Research framework. Sources of data, Methods of data collection. Research formulation: Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Research hypothesis: Criterion for hypothesis construction, Nature of hypothesis, Characteristics and Types of hypothesis, Elements of research design, Introduction to various sampling methods Sources of data, Collection of data, Research reports, references styles, Effective Presentation techniques, Research Ethics.

References:

1. Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*. John Wiley & Sons.
2. Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2013). *Business research methods*. Cengage Learning.
3. Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.
4. Donald R Cooper & Pamela S Schindler, *Business Research Methods*, McGraw Hill International, 2018.

ELE 5144: SYSTEM MODELLING & CONTROL LAB [0 0 6 2]

Module 1: System modelling – time response and frequency response analysis- stability and design of Cascade and feedback controller using MATLAB - Controller digitization - Simulate analog and digital components using Simscape - Automate controller analysis and tuning - Simulate control algorithms to improve power quality- Verify fault-detection, mode logic, and supervisory control across operating conditions**(self-study).**

Module 2: Controller implementation using Microcontroller / OPAMP / FPGA. Practice of HIL/SIL/PIL - Generate control code for real-time testing **(self-study)**

Module 3: Speed Design for Digitally Controlled Power Converters with Simulink Modelling, Control of Automobile Comfort Systems.

Reference:

1. www.mathworks.com,
2. https://in.mathworks.com/solutions/automotive/electric-vehicle.html
3. Norman S. Nise, Control Systems Engineering, John Wiley & Sons, Inc, 2010
4. **Shuvra Das**, Modelling Hybrid electric Vehicles , Morgan & Claypool Publishers, 2021

AAE 5150: AUTOMOTIVE POWER TRAIN AND SYSTEMS LAB [0 0 3 1]

Energy conversion system in engines, basic engine systems, estimation of torque handling in clutches, determination of gear ratios in transmission systems, final drive ratio, vehicle speed

evaluation based on kinematic relation, diagnosis of differentials, Energy consumption evaluation in EV and HEV test rigs.

References:

1. N. K. Giri,(2018) , "Automobile Mechanics", Seventh re print, Khanna Publishers, Delhi
2. Kirpal Singh(2018), "Automobile Engineering" Vol 1 and Vol 2 ,Standard publishers., N Delhi

SEMESTER 2:

AAE 5225: VEHICLE DYNAMICS [3 1 0 4]

Introduction to Vehicle Dynamics, Vehicle Coordinates systems, Forces acting on vehicle for different configurations, level road, gradient, maximum acceleration, car with trailer, car on banked road, Tire construction, function, Tire terminology, axis system, Mechanism of force generation, hysteresis, rolling resistance, Longitudinal slip, cornering properties, camber thrust, slip, camber stiffness, Conicity & Plysteer, Brakes, types, construction, braking force, braking performance, ABS, Brake factor, tire-road friction, brake proportioning. Aerodynamics of a car, pressure distribution on a vehicle, Aerodynamic forces, drag force, lift force, coefficients, aerodynamic aids, Shape optimization of the vehicle, driving stability. Ride quality, car vibrations, Road roughness vibrations. Types of wind tunnel and measurement techniques. Suspension isolation, responses, active control, pitch, bounce motions, Functions of a suspension, Types of suspension, axles, independent suspension, swing axle, Quarter car model.

Self-Directed Learning: Tire contact pressure distribution, Tire mechanics, Aerodynamics, lateral dynamics, Vehicle handling characteristics.

References:

1. Thomas D. Gillespie: Fundamentals of Vehicle Dynamics, 1st Edition, Technology & Engineering publication, 1992
2. Reza N. Jazar, Vehicle Dynamics: Theory and Application by, Springer Science Business Media, LLC, 2008
3. H. B. Pacejka: Tire and Vehicle Dynamics, 1st Edition, Butterworth-Heinemann publication, 2012
4. Georg Rill: Road Vehicle Dynamics: Fundamentals and Modeling, 1st Edition, CRC press publication, 2012
5. Wolf-Heinrich Hucho, Aerodynamics of Road Vehicle, 4th Edition, Society of Automotive Engineers, U.S. 1998.

ELE 5214: ENERGY STORAGE SYSTEMS FOR ELECTRIC VEHICLES [4 0 0 4]

Introduction to various energy storage systems, Battery definitions: C-rate, Specific Energy, State of charge, depth of discharge, and comparison of energy storage technologies and their role in electric vehicles; Battery (Secondary Rechargeable cells) and its working principle, equivalent circuit modelling of a Cell, Cell test, SOC, SOH, and Power Estimation methods. Battery Management System: factors of cell imbalance, cell-balancing strategies, battery pack design, charge controller, thermal management system; Fuel Cells: AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, dynamics, modelling, and Control, design of FC system and FC-based Electric Vehicle. Comparison of battery Vs fuel cell-based vehicles. Hydrogen generation, Hydrogen storage. Super-capacitors: Types, modelling, specific power and energy density, Battery- super-capacitor hybridization, EV Acceleration & Regenerative Braking, aging mechanism. Energy Management Strategies: Importance of energy management strategies and their classification, Regulations, and safety aspects of the battery pack for EV application.

Self-Directed Learning: Electric vehicle load forces, extended Kalman filter-based SoC estimation, battery charging protocols, Introduction to thermodynamics, heat dissipation, and design aspects of different cooling systems.

References:

1. Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. (2018). Modern electric, hybrid electric, and fuel cell vehicles. CRC press.
2. M. Barak, Electrochemical Power Sources: Primary and Secondary Batteries, Institution of Engineering and Technology (IET), 1980.
3. Gregory L Plett-"Battery Management Systems," Volume- 1, Battery Modeling, Artech House Publishers, 2015.
4. Gregory L Plett "Battery Management Systems," Volume- II, Equivalent circuit methods, Artech House Publishers, 2015.
5. R. Bove and S. Ubertini "Modeling Solid Oxide Fuel Cells," Springer, 2008.
6. https://www.netl.doe.gov/sites/default/files/netl-file/FCHandbook7.pdf
7. https://nptel.ac.in/noc/courses/noc20/SEM1/noc20-ee18/
8. https://www.coursera.org/learn/battery-state-of-charge
9. https://www.coursera.org/learn/battery-pack-balancing-power-estimation
10. Ibrahim dincer et al., "Thermal Management of Electric Vehicle Battery Systems", Wiley, 2016
11. John G. Hayes and G. Abas Goodarzi, "Electric Powertrain-Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles" John Wiley&Sons Ltd. 2018.

ELE 5243: ELECTRIC VEHICLES DRIVES LAB [0 0 3 1]

Implementation of Induction machine and DC machine model using simulation tool (MATLAB/Simulink) , Analyse the performance of a three-phase Induction machine during starting and load changes, Analysis of power electronic converters such as DC/DC converters and inverters, analysis of converter controlled and chopper controlled DC machine drives (simulation and hardware), analysis of v/f controlled induction machine drives (simulation and hardware), analysis of PMSM drive.

References:

1. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Analysis of Electric Machinery and Drive Systems, Wiley India, 2010.
2. R. Krishnan, Electric Motor Drives Modeling, Analysis, and Control, Pearson, 2015.
3. Bose B. K., Microcomputer Control of Power Electronics and Drives, IEEE Press, 1999. 5. Ajay V Deshmukh, Microcontrollers, TMH, 2007
4. NPTEL course: Modelling and Analysis of Electrical machines, by Dr Krishna Vasudevan, IIT Madras.
5. Latest literature in the field of Electrical Machines, Drives, Power Electronics and Electric Vehicles .

ELE 5244: ENERGY STORAGE SYSTEMS LAB [0 0 3 1]

Simulation analysis of charging and discharging of a battery
Implementation of an equivalent circuit model with 1-RC branch for a lithium-ion battery cell
Implementation of temperature dependant lithium-ion battery model
Implementation of state of charge (SoC) estimation algorithm using Kalman filter for a battery model
Analysis of a passive cell balancing algorithm for a battery/Supercapacitor
Simulation analysis of V-I characteristics of a PEMFC
Analysis of aging effect on the performance of a lithium-ion battery model

Design a battery management system to monitor current and temperature of a battery
Design and implementation of battery pack thermal management system
Design and Implementation of Energy Management Systems (EMS) for a hybrid electric source

SEMESTER 3 & 4:

ELE 6091: PROJECT WORK & INDUSTRIAL TRAINING [0 0 0 25]

Students are required to undertake innovative and research oriented projects, which not only reflect their knowledge gained in the previous two semesters but also reflects additional knowledge gained from their own effort. The project work can be carried out in the institution/ industry/ research laboratory or any other competent institutions. The duration of project work should be a minimum of 36 weeks. There will be a mid-term evaluation of the project work done after about 18 weeks. An interim project report is to be submitted to the department during the mid-term evaluation. Each student has to submit to the department a project report in prescribed format after completing the work. The final evaluation and viva-voice will be after submission of the report. Each student has to make a presentation on the work carried out, before the departmental committee for project evaluation. The mid-term & end semester evaluation will be done by the departmental committee including the guides.

PROGRAMME ELECTIVES:

ELE 5401: DIGITAL SIGNAL PROCESSING AND APPLICATIONS [4 0 0 4]

Overview on frequency analysis of discrete time linear time invariant systems, characteristics of practical frequency selective filters, Phase and Magnitude response of system, Minimum phase, maximum phase, Allpass - FIR, IIR filter design - Multirate signal Processing: Interpolation, Decimation, sampling rate conversion, Filterbank design, applications. - Power spectrum estimation: Spectral analysis of deterministic signals, estimation of power spectrum of stationary random signals. - Adaptive Filter theory: Adaptive algorithms - steepest descent algorithm.

Self-Directed learning: Wiener filters, LMS and RLS adaptive filters, Linear Prediction. - Introduction to multi resolution analysis. Application of DSP in Power Electronics Converters and Drives.

References:

1. John G. Proakis, Dimitris G Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications*, (4e), Pearson, 2007
2. Sanjit K. Mitra, *Digital Signal Processing: A Computer-Based Approach*, (4e), McGraw-Hill, 2011
3. Oppenheim A. V. and R. W. Schafer, Discrete time signal processing, (3e), Pearson, 2014
4. Sozański K. Digital signal processing in power electronics control circuits, (2e), Springer, 2017
5. Vaidyanathan, Parishwad P - Multirate systems and filter banks, Pearson Education India, 2006.
6. Vaidyanathan Palghat P- The theory of linear prediction, Springer, 2008
7. NPTEL Course on Introduction to Adaptive Filters, https://nptel.ac.in/courses/117105075

ELE 5402: DISTRIBUTED GENERATION SYSTEMS [4 0 0 4]

Introduction to Distributed Generation Systems- Principle and Structure of DGS- Features of DGS, Distributed Generation Technologies-Overview, Integrating Distributed Energy Resources with the Grid, Planned/non-planned DG,. DG Technologies DG Technologies:

Wind Energy Conversion System, Photovoltaic Systems-PV grid tied systems and different configurations. Micro turbine Generation, Small Hydro Generation Systems, Fuel Cells.Energy Storage Technologies-Different Energy storage technologies-Overview, Design Issues and control of Distributed Generation Systems-General model of DGS, Technical Regulation of DG integration, DG Optimization and Energy Management. Concept of smart grid technology.
Self-Directed Learning: Introduction to microgrids, components, micro-sources, loads, power electronic interface, Overview of protection scheme in microgrid and challenges associated with it.

References:

1. G.B. Gharehpetian and S. Mohammad MousaviAgah, Distributed Generation Systems. Design, Operation and Grid Integration, Butterworth-Heinemann, 2017.
2. Magdi S. Mahmoud, Fouad M. AL-Sunni, Control and Optimization of Distributed Generation Systems, Springer International Publishing, 2015.
3. Bo Zhao, Caisheng Wang, Xuesong Zhang, Grid integrated and standalone photovoltaic distributed generation systems analysis, design and control, Wiley, 2017.

ELE 5404: EMBEDDED SYSTEM DESIGN [4 0 0 4]

Embedded Systems-Introduction, Embedded hardware, Processor for embedded systems, Processing power and benchmark. PIC16F877 microcontroller, architecture, on chip peripherals, programming. ARM processors, ARM7TDMI processor architecture, processor modes, register bank, instruction set, programming, stack and subroutines, exceptions, 3-stage pipeline. Embedded C programming, ARM CORTEX microcontroller, architecture, programming. Memory for embedded systems, Cache memory. Input and output device interfacing, Parallel and serial communication protocols, Wireless communication protocols. Data converters and timers for embedded systems, interrupts. Current trends in embedded system design. Introduction to Real time systems, task types, task scheduling, Real Time Operating Systems.
Self-Directed Learning: PCI express, Advanced Microcontroller Bus Architecture-AHB and APB, Watchdog timers, Embedded system design- design metrics, issues and challenges, stages, development tools.

References:

1. Frank Vahid and Tony Givargis, Embedded system design, Wiley India, 2012.
2. Ajay V Deshmukh, Microcontrollers, TMH, 2007.
3. Steve Furber, ARM System on chip architecture, Pearson, 2012
4. William Hohl, Christopher Hinds, ARM Assembly Language Fundamentals and Techniques, CRC Press, 2014
5. Jane W.S. Liu, Real time systems, Pearson Education, 2013.
6. https://developer.arm.com/Architectures/AMBA

ELE 5407: EV COMMUNICATION SYSTEMS [4 0 0 4]

Vehicular Communication and networking - layers of OSI reference model, classification of bus systems. Networks and communication Protocols – Ethernet, TCP, UDP, IP, ARP, RARP. LIN standard, specification, frame transfer, frame types, schedule tables, Task behaviour model, Network management, status management, CAN, message transfer, frame types, error handling, fault confinement, Bit time requirements. Higher Layer Protocol –CAN open, TTCAN, Device net, SAE J1939, Logical device model, protocol basics, MOST protocol- data channels, control channel, synchronous channel, asynchronous channel, , Network section, data transport, blocks, frames, preamble, boundary descriptor. FlexRay Protocol –network topology, ECUs and bus interfaces, controller host interface and protocol operation controls, media access control, frame and symbol processing, coding/decoding unit, FlexRay

scheduling. Vehicular communications – Intelligent transportation systems, IEEE 802.11p-ITS-IVC, Inter-Vehicle communications-mobile wireless communications and networks, Architecture, layers, communication regime, V2V communication

Self-Directed Learning: Internet of vehicles, Open communication protocols and standards for electric vehicle charging, V2V-applications and case studies, Simulation of CAN transmission and reception.

References:

1. J. Gabrielleen, "Automotive In-Vehicle Networks", John Wiley & Sons, Limited, 2008.
2. Indra Widjaja, Alberto Leon-Garcia, "Communication Networks: Fundamental Concepts and Key Architectures", McGraw-Hill College; 1st edition, 2000
3. Robert Bosch, "Bosch Automotive Networking", Bentley publishers, 2007
4. Konrad Etschberger, "Controller Area Network, IXXAT Automation", 2001
5. OlafPfeiffer, Andrew Ayre, Christian Keydel, "Embedded Networking with CAN and CANopen", Annabooks / Rtc Books, 2003

ELE 5408: EV DATA ANALYTICS [4 0 0 4]

Data Ecosystem, Analysis Process, Parts of Data Analytics, Data Structure Types, File formats, Extract, Transform, Load Process, Statistical Tools & Techniques, Python Programming, Python Libraries, Data Visualization. Data Sourcing & Cleaning, Feature Selection, Feature Engineering. Univariate / Bivariate Analysis and Derived Metrics, Segmented Univariate & Bivariate Analysis, Random Variables, Gaussian Distribution, Central Limit Theorem, Chebyshev's Inequality, Inferential Statistics, Probability, Bayes' Theorem, Hypothesis Testing. Regression & Classification, SVM, Tree Models, KNN, Occam's Razor, Model Evaluation, Clustering & Association. Deep Learning Neural Network, Vanishing & Exploding Gradient, Dropout & Regularization, Parameters & Hyperparameters Tuning, Convex & Non-Convex Optimization, Cross Validation. Data Analytics on Vehicle Telematics – Big Data, Driving Telematics Sensor Data, Reaction Time, Fuel Consumption, Health & Failure Prediction, Autonomous Vehicular Systems.

Self-Directed Learning: EV Data Mobility, Battery Consumption, Optimized Charging, Travel/Parking/Availability, Decision Support Metering, Python Based Implementation of ML Models, ANN based DL Model, ARIMA, SARIMA, AR, MA Models, LSTM Based ANN Model.

References

1. EMC Education Services, "Data Science & Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data", John Wiley & Sons, 2015.
2. Glenn J. Myatt, Wayne P. Johnson, "Making Sense of Data I: A Practical Guide to Exploratory Data Analysis and Data Mining", 2nd Edition, John Wiley & Sons, 2014.
3. Douglas C M, George C R, "Applied Statistics and Probability for Engineers," 5th Edition, John Wiley & Sons, 2011.
4. Coursera Course, "Introduction to Self-Driving Autonomous Vehicles", University of Toronto, Part of Self-Driving Car Specialization, Modules: 1 to 4. *(Self Directed Learning)*

ELE 5409: EV GRID INTEGRATION [4 0 0 4]

History, Definition, and Status of Vehicle-to-Grid (V2G), Benefits, Technical Challenges, Realizing and Problematizing a V2G Future. Influences of EVs on Power System, the Response of EV Charging Load to the Grid Voltage, Analysis on Typical Schemes of the Integration, EV Charging Facility Planning. Grid integration and management, Dispatch of vehicle-to-grid battery storage, renewable energy integrations, Optimal location and charging of electric vehicle, Optimal coordination of vehicle-to-grid batteries and renewable generators. Smart Grid using PEVs, Impact of EV and V2G on the Smart Grid and Renewable Energy Systems,

Power Conversion Technology, Power Control and Monitoring, PEV Charging Technologies and V2G on Distributed Systems and Utility Interfaces, Dynamic Programming and Potential Game Approach, Evolutionary Game Theory Approach.

Self-Directed Learning: EV Grid Integration worldwide, EV Charging Facility, Impact of EV and V2G on the Smart Grid and Renewable Energy Systems, Game Theory on Grid Optimal Integration of Electric Vehicles.

References:

1. Lance Noel, Gerardo Zarazua de Rubens, Johannes Kester, Benjamin K. Sovacool, "Vehicle-to-Grid A Sociotechnical Transition Beyond Electric Mobility", Energy, Climate and the Environment, Springer Nature, 2019.
2. Canbing Li, Yijia Cao, Yonghong Kuang, Bin Zhou, "Influences of Electric Vehicles on Power System and Key Technologies of Vehicle-to-Grid," Power Systems, Science Press & Beijing Springer Nature, 2016.
3. Nand Kishor and Jesús Fraile-Ardanuy, "ICT for Electric Vehicle Integration with the Smart Grid" The Institution of Engineering and Technology, 2019.
4. Junwei Lu and Jahangir Hossain, "Vehicle-to-Grid: Linking Electric Vehicles to the Smart Grid", The Institution of Engineering and Technology, London, United Kingdom 2015.
5. Andrés Ovalle, Ahmad Hably, Seddik Bacha, "Grid Optimal Integration of Electric Vehicles: Examples with Matlab Implementation", Studies in Systems, Decision and Control, Springer Nature, 2018.

ELE 5410: EV POLICIES AND REGULATIONS [4 0 0 4]

EV Prospects, Policy Framework, Policies & Schemes – FAME 1 & FAME 2, NEMMP, PLI, National & State Policies, Regulations, Incentives & Subsidies. GHG Emissions, Transport Energy Mix Diversification, CO_2 Regulations, ZEV & NEV Mandate, Incentives, Fuel Economy & Emission Standards. EV Charging Ecosystem: Regulations & Incentives on EVSE, Interconnected Charging Network, Charge Point Operators & E-Mobility Service Providers, Public EV Charging Demand, Location & Site Planning, Role of DISCOMs, Implementation & Business Models, Public Charging Infrastructures, Batteries Regulations & Directives, Alliance, Use & Recycling Solutions, Second Life Commercialization, Recycle Management, Energy Economics, Infrastructure Upgrades, EV Clustering, Tracking & Billing, Third Party Charging Station, Utility Ownership of EVSE, Sub-Metering, Payment & Billing Models. Barriers in EV, EV Deployment across Public, Commercial & Corporate Fleets, Public Awareness, Education & Skills Training, Industry Incentives, Cost Estimates & Revenue Model.

Self-Directed Learning: Financial, Regulatory & Fleet Management Authorities, CEA, CERC, SERCs, NITI Aayog, MoP, PGCIL, DST, BEE, MoUHA, MoEFCC, MoRTH, DHI, WRI India, ISGF etc.

References

1. Guidelines & Standards for Electric Vehicle Charging Infrastructure, MoUHA, GOI, Feb 2019 & MoP, GOI, Oct 2019.
2. Electric Vehicle Charging Stations Business Models for India, ISGF white Paper, Version-1, Sep 2018.
3. Handbook of Electric Vehicle Charging Infrastructure Implementation, Version1, NITI Aayog, MoP, DST, WRI India – Ross Center.
4. Electric Vehicle Guidebook for Indian States, International Council on Clean Transportation (ICCT), 2019.
5. State Electric Vehicle Policy and State Electric Vehicle Policy Documents. *(Self Directed Learning)*

ELE 5411: POWER QUALITY ISSUES & MITIGATION [4 0 0 4]

Power quality issues: modern power systems, classifications and causes of power quality problems, PQ terminology, effects of power quality problems on customers, PQ standards, PQ Monitoring, mitigation techniques, passive shunt and series compensators: analysis and design of 1-ph shunt compensators for pf correction and zero voltage regulation, analysis and design of 3ph 3-wire compensators for pf correction, load balancing and zero voltage regulation, 3ph 4-wire compensators for pf correction, load balancing and neutral current mitigation, custom power devices: types, classification of DSTATCOMs and DVRs, operation and applications of 2-wire, 3ph 3-wire and 3ph 4-wire DSTACOMs, control methods of DSTATCOMs: UPF mode of operation and ZVR operation, design of DSTATCOM, capacitor supported DVR operation for the compensation of voltage sag, swell and unbalance, battery supported DVR operation, control techniques for DVRs, design and analysis of unified power quality conditioner (UPQC), rating based classification of UPQC, UPQC-Q, UPQC-P, UPQC-S, control of UPQCs;

Self-Directed Learning: active power filters, design and control algorithm to eliminate voltage and current harmonics, design and performance analysis of simple systems through modelling and simulation studies, PQ improvement in electrical system.

References:

1. Bhim Singh, Ambrish Chandra and Kamal Al Haddad, Power Quality: Problems and Mitigation Techniques, John Wiley & Sons Ltd., U. K, 2015
2. C. Shankaran, Power Quality, CRC Press, 2013.
3. Math H J Bollen, Understanding Power Quality Problems; Voltage Sags and Interruptions, Wiley India, 2011.
4. Roger C Dugan, et.al, Electrical Power Systems Quality, 3rd Edition, TMH, 2012.
5. Arindam Ghosh et.al, Power Quality Enhancement Using Custom Power Devices, Kluwer Academic Publishers, 2002

ELE 5412: SMART GRID TECHNOLOGY [4 0 0 4]

History, Definition, Characteristics and benefits, Basic components of Smart Grid and its technical infrastructure, Impact of EV and V2G on the Smart Grid and Renewable Energy Systems, Power Conversion Technology, Power Control and Monitoring, PEV Charging Technologies and V2G on Distributed Systems and Utility Interfaces. Application of Smart Grid to distribution networks, energy storage systems, Power system protection, Sizing High Speed Micro Generators, Intelligent Multi-agent System, Synchronized Phasor Measurement, Modelling and Control of Fuel Cells, Cyber interoperability standards, Cyber Security, Smart Grid Communications and Measurement Technology, Performance Analysis, Stability Analysis, Smart Grid Design.

Self-Directing Learning: Smart Grids worldwide, Smart Grid with EVs, Smart Grid application; Smart Grid standards, Cyber Security, Challenges in Smart Grid Implementation; Design and Analysis of SMART GRID.

References:

1. S.K. Salman - Introduction to the Smart Grid_ Concepts, Technologies and Evolution-The Institution of Engineering and Technology (2017).
2. Hossain, Jahangir_ Lu, Junwei - Vehicle-to-grid_ linking electric vehicles to the smart grid-Institution of Engineering and Technology (2015).
3. James Momoh - Smart Grid_ Fundamentals of Design and Analysis-Wiley-IEEE Press (2012).
4. Ali Keyhani, Muhammad Marwali, Smart Power Grids, Springer-Verlag Berlin Heidelberg (2011).

5. Takuro Sato, Daniel M. Kammen, Bin Duan, et al. - Smart Grid Standards_ Specifications, Requirements, and Technologies-Wiley (2015)
6. https://archive.nptel.ac.in/courses/108/107/108107113/

ELE 5413: SOLID STATE LIGHTING & CONTROLS [4 0 0 4]

Fundamentals of illumination technology, Introduction to solid state lighting, principle of light generation. Types of LEDs and their photometric and colorimetric characteristics. Colour tunability and white light generation. LED driver considerations and power supply design. LED dimming and control strategies. Thermal management in LED luminaires. Testing standards, Reliability, and performance analysis of LED luminaires. Applications of solid-state lighting.

Self-Directed Learning: Characteristics of different coloured LEDs and colour mixing of LEDs, Junction temperature measurement, Effect of drive current and temperature on performance of LEDs.

References:

1. E. Fred Schubert, "Light-Emitting Diodes (3rd Edition)", Cambridge University Press, 2018
2. W.D. van Driel, Xuejun Fan., "Solid State Lighting Reliability: Components to Systems", Solid State Lighting Technology and Application Series, Springer Publications, 2013. (DOI: 10.1007/978-1-4614-3067-4.)
3. Robert Karlicek, Ching-Cherng Sun, Georges Zissis, Ruiqing Ma., "Handbook of Advanced Lighting Technology", Springer International Publishing, 2017. (DOI: https://doi.org/10.1007/978-3-319-00176-0)
4. Clemens J.M. Lasance, András Poppe., "Thermal Management for LED Applications", Solid State Lighting Technology and Application Series, Springer Publications, 2014. (DOI: 10.1007/978-1-4614-5091-7.)
5. NPTEL: Introduction to DC-DC converter. https://nptel.ac.in/courses/108108036

ELE 5414: TIME FREQUENCY ANALYSIS [4 0 0 4]

The time and frequency description of signals, bandwidth equation, AM and FM contributions to the bandwidth, Fourier transform of the time and frequency densities, non-additivity of spectral properties, uncertainty principle. Instantaneous frequency and the complex signal, analytic signal, quadrature approximation, instantaneous frequency, density of instantaneous frequency, one dimensional densities, two dimensional densities, local quantities, negative densities, Time-Frequency Distributions - global averages, local average, time and frequency shift invariance, linear scaling, weak and strong finite support, uncertainty principle and joint distributions, short-time Fourier transform and spectrogram, global quantities, local averages, optimal window. Wavelet bases for discrete and continuous variables, The Haar basis, Differentiable wavelet bases, Compact wavelet bases, Multiresolution analysis.

Self-Directed learning: Heisenberg uncertainty principle. Applications of short-time Fourier transform. Spectrogram and its use in signal processing. Applications of wavelet transforms.

References:

1. L. Cohen, Time-Frequency Analysis. Prentice Hall, 1995.
2. S. Mallat, A Wavelet Tour of Signal Processing - The Sparse Way. Elsevier, Third Edition, 2009.
3. M. Vetterli, J. Kovacevic, and V. K. Goyal, Fourier and Wavelet Signal Processing. Book site: http://fourierandwavelets.org/terms.php

ELE 5415: POWER CONVERTERS FOR ELECTRIC VEHICLES [4 0 0 4]

Overview of power semiconductor switching devices and their control, introducing various power electronic circuits for the realization of line commutated converters, the principles of

operations, analysis, power factor improvement methods, pulse width modulated converters, and design of converter circuits. DC-DC Converters: classifications, analysis, and design of non-isolated and isolated converters. DC-AC converter: The principle of operation, and analysis, pulse-width modulation, pulse frequency control of power electronic converters, design problems, and Multilevel inverters. AC-AC Converters: AC Voltage Controllers, Cyclo-converters, matrix converters. Power supply applications.

Self-directed learning: Simulation exercise on AC-DC converter. Current fed and Power factor correction of DC-DC converter. Matrix converters and their applications. Harmonic minimization in inverters and cyclo-converters.

References:

1. Robert W. Erickson, Dragan Maksimovic; Fundamentals of Power Electronics, (2 ed), Springer, 2005.
2. Mohan, Undeland & Robbins; Power Electronics, Converters, Applications and Design, Wiley-2001.
3. Daniel.W. Hart, Introduction to Power Electronics by, PHI-1997 edition.
4. http://nptel.ac.in/courses/108108036/

OPEN ELECTIVE:

ELE 5301: INTELLIGENT CONTROL SYSTEMS [3 0 0 3]

Fundamentals of Artificial Neural Networks - Feed forward and feedback networks, learning rules, Single layer feed forward networks, Multilayer feed forward networks, Linearly non-separable pattern classification, generalized delta learning rule, error back propagation training algorithms, Single layer feedback network - Energy function, Application of neural networks, Introduction to Fuzzy control, Inference rules, Fuzzy knowledge based controllers, Fuzzification, membership function evaluation, Defuzzification methods, Application of fuzzy logic to control systems, fuzzy-neural systems, Introduction to Genetic Algorithms.

References:

1. J. S. T Jang, C.T Sun and E. Mitzutani, *Neuro-Fuzzy and Soft Computing*, Prentice Hall International, Inc, 2011.
2. Chin-Teng Lin, C.S.George Lee, *Neural Fuzzy Systems*, Prentice – Hall International, Inc.1996.
3. S. Haykin, *Neural Networks - A Comprehensive Foundation - 2nd Edition*, Prentice Hall, 2005.
4. T. J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw-Hill, Inc., 2014
5. Jacek M. Zurada, *Introduction to Artificial Neural Networks*, Jaico, 2016