

Syllabus for ECE 398GG: Electric Vehicles (EVs)

Topical Outline

Introduction and General Overview: transportation industry's salient characteristics; key drivers of transportation electrification; historical synopsis of EVs in transportation sectors; energy and environmental issues; global EV deployment and e-mobility; course scope and objectives

Vehicle Dynamics and Energy/Power Requirements: basic physics of rolling vehicles; the forces of gravity, aerodynamic drag, hill climbing and descent, rolling resistance, braking; tractive force determination; the impacts of inertia, acceleration and deceleration; energy and power requirements for vehicle rolling motion and their implications in energy storage and transfer; illustrative examples

Key Considerations in EV Design and Operations: EV size and weight; range implications; vehicle parameters and performance metrics, their range and typical values for various vehicle types; definition and role of drive cycles in performance assessment; performance evaluation

EV Architectures and Configurations: the major EV subsystems – motors, drives, inverters, batteries and energy storage, chargers, sensors and controls; architectural structures and configurations; generator sets and hybrid subsystems

Energy Conservation Principle: the energy invariance principle that underlies all of nature's processes; illustrative examples; application to “well to wheels” energy tracking

EV Batteries and Their Management: key portable energy requirements beyond rechargeability; key battery components, their roles and characteristics; electrochemical cell as the building block of battery packs – from cells to modules to packs; battery operations phases – charging, discharging and idle; battery features; major figures of merit – capacity, storage capability, efficiency, health, life, energy density, specific power, state of charge (s.o.c.), depth of discharge, voltage/current characterization, temperature and geometry; today's dominance of Li-ion batteries and their limitations

Basic Principles of, and Design Considerations in, EV Electric Motors and Generators: concepts of electromechanical energy conversion – energy, co-energy, force and torque; review of low-frequency electromagnetics (EM) and EM force calculations of shear stress, machine power density and efficiency; generator application requirements on torque–speed curve, constant power speed range; comparative assessment and equivalent circuits of motor types – induction, surface and internal permanent magnet, switched and synchronous reluctance

Electric Drives for Traction Application in EVs: basic nature and role of electric drives in electro-mechanical energy conversion; fundamentals of electric drives and their operation from an EV perspective; the DC-AC conversion process and approaches to generate controllable AC waveforms; traction inverters and their control with applications to EV acceleration, deceleration and constant speed maintenance

EV Integration into Today's Grids: the impacts of EV loads on distribution grids; EVs as a deferrable load; EVs as distributed storage resources and the vehicle-to-grid (V2G) concept; role of EV aggregations

EV Energy Efficiency Analysis and Evaluation: the wells-to-wheels reference metric used for internal combustion engine vehicles (ICEVs); cumulative impacts of the constituent efficiencies – electricity generation efficiency, grid efficiencies, charging efficiency and battery-to-wheels efficiency; definition and evaluation of efficiency metrics – miles per gallon equivalent and kWh per 100 miles; key assumptions; data sources

EV Environmental Attributes: quantification of GHG emissions of EVs and comparison with the “tailpipe” emissions of ICEVs; evaluation of EV lifecycle emissions; EV battery life extension and disposal

EV Battery Charging Fundamentals: voltage levels and charging types; charging connectors; charging process; protection issues

Power Electronics Applications in EV Battery Charging: AC grid analysis – power system in the sinusoidal steady state, complex power, single and three-phase power, average power and circuit analysis; power electronics topics – the analysis of dc-dc converter operations in the continuous conduction regime and PWM rectifier circuit analysis; power electronics applications in EVSE – EV supply equipment – and in the implementation of EV charging stations – specification of basic and buffer requirements, power converter types for the EV charging levels and DC fast buffer charge; key technology implementations and challenges

The EV Charging Infrastructure (EVCI): the critical role of EVCI to enable massive EV adoption; interdependence and interactions of EVCI with existing infrastructures; principal objectives in the establishment of EVCI; role of renewable and storage resources and their effective integration; location, planning and implementation of EVCI stations; current EV charging providers and their business models; identified gaps and major challenges; policy and regulatory aspects

Policy and Regulatory Issues: the nature and scope of policies to stimulate widespread EV adoption and support EVCI station implementation; policy formulation and implementation at various levels of government; examples of policies and incentives for EV adoption; replacement of the gasoline tax funding source in an increasingly electrified environment

Beyond EVs: further transportation electrification – all electric airplanes, electric buses and freight mobility; battery technology enhancements; wireless charging

Additional Course Information

Team projects and Presentations

Homework assignments not corrected; instead in-class quizzes with similar problems to those in the HWs; one or two Midterm Exams and a comprehensive Final Exam

No textbook will be assigned but relevant papers and reports will be used. Copies of the slides used in the lectures will be downloadable from the course website.

Midterm and Final Exams

Final Exam: Tuesday, May 9, 7 – 10 p.m.; venue TBD.