GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-IV

Course Title: Electric Vehicles
(Course Code: 4342403)

Diploma programmer in which this course is offered	Semester in which offered
Power Electronics	4th semester

1. RATIONALE

Transport is a fundamental requirement of modern life, but the traditional combustion engine is quickly becoming outdated. Petrol or diesel vehicles are highly polluting and are being quickly replaced by fully electric vehicles. Electric vehicles use electricity to charge their batteries instead of using fossil fuels like petrol or diesel. Fully electric vehicles (EV) have zero tailpipe emissions and are much better for the environment. The objective of this course is to provide good depth knowledge of EVs, their control for various drive mechanism.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain Electric Vehicles.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

CO 1) Identify various parts used in EVs and HEVs.
CO 2) Select appropriate source of energy for the electric vehicle based on driving cycle.
CO 3) Operate AC and DC drives used for EVs.
CO 4) Maintain transmission and braking system for EVs.
CO 5) Test chargers used for EVs.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	-	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**– Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** – Practical; **C** – Credit, **CA** – Continuous Assessment; **ESE** – End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

*Following practical outcomes (PrOs) that are the sub-components of the Course Outcomes (Cos). Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1.	Construct the concept of power train system of a vehicle with neat sketch also to derive the expression for vehicle speed	I	2*
2.	Test the performance battery using battery management system	II	4*
3.	Test the performance of fuel cell and ultra capacitor.	II	4
4.	Identify and test various parts of DC motors used for EVs.	III	4*
5.	Identify and test various parts of AC motors used for EVs.	III	4*
6.	Test the performance of PMDC motor drive	III	2*
7.	Test the performance of 6 step 3-phase inverter drive.	III	2*
8.	Test the performance of 3-phase sinusoidal PWM inverter drive.	III	2*
9.	Test the performance of SRM drive.	III	2*
10.	Test the performance of various parts of EMB.	IV	2
11.	Test the performance of Conventional Boost PFC Converter	V	2*
12.	Test the performance of Bridgeless Boost PFC Converter.	V	2*
13.	Test the performance of Zero Voltage Switching Full-Bridge Phase-Shifted Converter.	V	2*
14.	Test the performance of Full-Bridge LLC Resonant DC–DC Converter	V	2*
15.	Perform modeling of Electric Vehicle in MATLAB	--	4
16.	Electric Vehicle battery modeling in MATLAB including self-discharge	II	4
17.	Study the N-T (Speed -Torque) characteristic of BLDC Motor and running, reversing & braking of BLDC motor.	III	4
18.	Study of working of BLDC motor and Hall sensor with real time waveform analysis.	III	2
19.	Study of speed control of BLDC motor using PWM method	III	2
	Minimum 14 Practical Exercises		**28* Hrs.**

Note

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

*ii. The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare of experimental setup	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipments with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical's in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	MATLAB software student version	15,16
2	Microcontroller Based Chopper FED PMDC Motor Drive The kit comprises of a 0.5HP, 180V, 1500RPM Permanent Magnet DC motor, control module consist of IGBT based H-Bridge to drive the DC motor with proximity sensor as speed sensor and microprocessor based digital controller. ϖMicrocontroller based control circuit with LCD and keyboard interface is provided for selecting different operating modes. Observation of intermediate stage waveforms of gate pulse generation. Single phase rectifier with capacitive filter as input DC source. Open loop and closed loop speed control of PMDC motor. MATLAB utility for viewing and controlling speed of the motor from personal computer. The kit works directly with 230 V, 50 Hz, AC supply. Proper isolation between control and power circuit is provided. Motor Controller: SST89E516RD 8-bit MCU clocked @18.432MHz5 Rating: 300V, 5A 1200V, 30A IGBTs - STGW30NC120HD	6
3	BLDC (Brushless DC) Motor Training System: Mains Supply : Single Phase, 230V ±10%, 50Hz Machine Type : BLDC Rating : 200W Voltage Rating : 24V Current : 8 Amp. Speed : 2500 rpm ±10% Loading arrangement : Mechanical Brake Drum/Pulley : Aluminum casted Instrumentation power supply : 24V, 10Amp. Digital Meters used DC Voltmeter : 300V DC Ammeter : 10A Digital Tachometer : 20,000 rpm	4
4	Battery Management Training System: Mains Supply : Single Phase, 230V ±10%, 50Hz Battery pack Type : Li-ion No of Cell : 6 nos Power rating : 3000 mAh Configuration : Series type Machine (for charging & discharging battery pack) Type : BLDC Rating : 100 Watt approx. Voltage Rating : 24V Current : 3 Amp. approx. (at no load) Speed : 2800 rpm ±10% Instrumentation power supply : 24V, 10Amp. Graphical LCD : For Voltage, Current and Temperature measurements Digital Meters used DC Voltmeter : 300V DC Ammeter : 10A Digital Tachometer : 20,000 rpm	2
5	Electric Vehicle Training System BLDC Motor Type of Motor : Hub motor Rated Voltage : 36V Power : 250W RPM : 200 RPM approx. (on full load) Battery Type of battery : Li-ion battery Capacity : 10 AH Voltage : 36V Meters • AC Voltmeter • AC Ammeter • DC Voltmeter • DC Ammeter • RPM meter Package contains Key switch, Head light, Tail light, Brake, Horn and Battery level indicator	17,18,19
6	Microcontroller Based Three Phase Induction Motor Drive The kit comprise of single phase uncontrolled rectifier, three phase inverter, 1 HP, 415 V, 50 Hz, 1440 RPM three phase induction motor with proximity as speed sensor and 32-bit Cortex M4 ARM Microcontroller based control circuit. Microcontroller based control circuit with LCD and keyboard interface is provided for selecting different operating modes. Observation of intermediate stage waveforms of gate pulse generation. ϖBoth Digital and Analog mode of control is possible. External circuit interfacing through analog mode of control. MATLAB utility for viewing and controlling speed of the motor from personal computer. The kit works directly with 230 V, 50 Hz, AC supply. Proper isolation between control and power circuit is provided. Observation of stator current	7,8

S. No.	Equipment Name with Broad Specifications	PrO. No.
	through current transformers.	
7	Switched Reluctance Motor Drive The kit comprises of power module, 0.5 HP, 3000rpm SRM motor, 500ppr encoder and 32-bit ARM Microcontroller based digital control circuit. Microcontroller based control circuit with LCD and keyboard interface Open loop and closed loop speed control of motor. 230 V, 50 Hz, AC supply. Proper isolation between control and power circuit is provided. Motor Controller: STM32F407VGT6 ARM Cortex LCD interface, 5 keys interface. 3 high speed digital outputs and 2 High speed digital input lines. 6 PWM outputs.	9

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above mentioned COs and PrOs. More could be added to fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow error free measurement rules during measurement.
c) Practice environmentally friendly methods and processes.(Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Introduction to Electric and Hybrid Vehicles	1.a Explain the basics of Electric and Hybrid electric vehicles. 1.b Describe the history and recent development in EV and HEV 1.c Explain Law of motion and forces acting on vehicles.	1.1 Electric and Hybrid electric vehicles: Features and components, comparisons with ICEV 1.2 EV and HEV: History, Recent development. 1.3 Law of motion, forces acting on vehicles.
	1.d Explain architecture of BEV and HEV. 1.e Explain EV power train component sizing. 1.f Explain basics of electric	1.4 Architecture: BEV, series HEV, Parallel HEV, series-parallel HEV, PHEV. 1.5 EV power train sizing: Initial Acceleration Rated Vehicle Velocity, Maximum Velocity Maximum Gradability. 1.6 Functional block diagram of electric

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	propulsion system.	propulsion system, classification of motor used for EV and HEV.
Unit– II Energy Storage system.	2.a Classify rechargeable batteries. 2.b List battery specification of different EV segments 2.c Explain battery parameters.	2.1 Rechargeable batteries: basic cell structure, Classification and features. 2.2 Battery specification of different EV segments. 2.3 Battery parameter: Battery capacity, Open circuit voltage, terminal voltage, practical capacity, discharge rate, battery energies and powers.
	2.d Explain traction batteries.	2.4 Batteries: Lead acid battery, nickel-cadmium battery, nickel-metal-hydride (NI-MH) battery, LI-ion battery, LI-polymer battery, zinc-air battery, sodium-sulfur battery, sodium-metal-chloride battery, battery management system.
	2.e Explain Fuel cell. 2.f Explain basics of ultra capacitor.	2.5 Fuel cell: Basic structure, types. 2.6 Ultra capacitor: basic, features and types.
Unit – III Electric Motor Drives	3.a Classify Electric motors used in EV.	3.1 Electric vehicle motor: classification, advantages, disadvantages, Vehicle used in.
	3.b Explain two quadrant chopper DC drive for Electric vehicle.	3.2 Two quadrant operation of DC drive, Open loop drive, acceleration and breaking operation, regenerative power, Operating point analysis.
	3.c Explain 3-phase AC drives for electric vehicle.	3.3 Six step voltage source inverter, sinusoidal PWM control.
	3.d Explain SRM drives for electric vehicle.	3.4 Switched Reluctance motor: Construction, Principle, Operation, control.
Unit – IV Power transmission and Braking System	4.b Explain power transmission components in electric vehicle.	4.1 Power transmission components: Electric vehicle power train, Gears, Gear ratio, Torque speed characteristics.
	4.c Explain Electromechanical brake system	4.2 EMB system in a vehicle: Block diagram, four quadrant operation of electric motor used in EMB, EMB system with actuator, advantages.
Unit– V Fundamentals of Chargers.	5.a Classify Charger. 5.b Explain Indian Standards for Charging.	5.1 Classification: AC Charging Systems, DC Charging Systems, requirements. 5.2 Indian Standard for AC and DC charging.
	5.c Explain topology selection for level 1 and 2 ac chargers.	5.3 Topologies: • Front-end AC–DC converter topologies: Conventional Boost PFC Converter, Bridgeless Boost PFC Converter. • Isolated DC–DC converter topologies:

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
		Zero Voltage Switching Full-Bridge Phase-Shifted Converter, Zero Voltage Switching Full Bridge with Capacitive Output Filter Converter, Full-Bridge LLC Resonant DC–DC Converter.

***Note**: The UOs need to be formulated at an 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I.	Introduction to Electric and Hybrid Vehicles.	08	10	8	0	18
II.	Energy Storage system.	09	8	8	0	16
III.	Electric Motor Drives.	10	3	6	8	17
IV.	Power transmission and Braking System.	05	3	3	3	09
V.	Fundamentals of Chargers.	10	0	4	6	10
Total		42	24	29	17	70

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) **List the type of EV system.**
b) **Take a survey for latest EVs with their Powertrain system.**
c) **Visit EV showroom and charging station and make a report of technical specifications and standards.**
d) **Take a survey for EV Tariffs (Energy charge and Demand Charge) In Different States of India.**

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.

b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students for selecting a proper electric motor for electric vehicle.
g) Guide students for selecting a proper controller for specific electric motor vehicle.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should **not exceed three**.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14-16 (fourteen to sixteen) student engagement hours** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Make a presentation of comparison of various EVs and HEVs.
b) Design a basic drive circuit for DC motor used in EV.
c) Design a basic charger circuit used for EVs.

13. SUGGESTED LEARNING RESOURCES:

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Electric and Hybrid Vehicles Design Fundamentals	Iqbal Husain	CRC Press ISBN: 978-1-138-59058-8
2	Advance Electric Drive Vehicles	Ali Emadi	CRC Press ISBN: 978-1-4665-9770-9
3	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles	Mehrdad Ehsani Yimin Gao Stefano Longo Kambiz Ebrahimi	CRC Press ISBN: 978-1-4987-6177-2
4	Handbook of Electric vehicle Charging Infrastructure Implementation	--	NITI Ayog

14. SOFTWARE/LEARNING WEBSITES

a) https://www.vlab.co.in
b) https://nptel.ac.in
c) https://www.classcentral.com

d) https://swayam.gov.in/
e) https://shodhganga.inflibnet.ac.in/
f) https://onlinecourses.nptel.ac.in/

15. PO-COMPETENCY-CO MAPPING

Semester IV	Electric Vehicles(4342403)						
	POs and PSOs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	Maintain Electric Vehicles						
CO 1)Introduction to Electric and Hybrid Vehicles.	1	-	1	-	1	1	1
CO 2)Energy Storage system.	1	2	2	2	2	2	3
CO 3)Electric Motor Drives.	3	2	3	3	2	2	3
CO 4)Power transmission and Braking System.	1	2	-	1	2	2	2
CO 5)Fundamentals of Chargers.	3	2	2	2	2	2	3

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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