Annexure-V

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
DEPARTMENT OF HYDRO AND RENEWABLE ENERGY

Program Code : 12 M.Tech. (Renewable and Hydro Energy)
Department : HRE Department of Hydro and Renewable Energy
Year : I

Teaching Scheme					**Contact Hours/Week**			**Exam Duration**		**Relative Weight (%)**				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Semester- I (Autumn)														
1.	HRE-510	Hydropower Planning and Management	PCC	4	3	1	-	3	-	20-35	-	20-30	40-50	-
2.	HRE-513	Renewable Energy Resources Development Technology	PCC	4	3	1	2/2	3	-	15-30	20	15-25	30-40	-
3.		Program Elective Course-I	PEC	4										
4.		Program Elective Course-II	PEC	4										
5.		Program Elective Course-III	PEC	4										
		Total		20										
Semester- II (Spring)														
1.	HRE-583	Grid Integration of Renewable Energy	PCC	4	3	1	2/2	3	-	15-30	20	15-25	30-40	-
2.	HRE-584	Finance, Policy, and Regulations for Renewable Energy	PCC	4	3	1	-	3	-	20-35	-	20-30	40-50	-
3.	HRE-700	Seminar	SEM	2	-	-	-	-	-	-	-	-	100	-
4.	-	Programme Elective Course-IV	PEC	4	-	-	-	-	-	-	-	-	-	-
5.	-	Programme Elective Course-V	PEC	4	-	-	-	-	-	-	-	-	-	-
		Total		**18**										

Program Code : 12 M.Tech. (Renewable and Hydro Energy)
Department : HRE Department of Hydro and Renewable Energy
Year : II

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
Semester- III (Autumn)														
1.	HRE-701A	Thesis Stage–I (to be continued in next semester)	DIS	12	-	-	-	-	-	-	-	-	100	-
		Total		**12**										
Note: Students can take 1 or 2 audit courses as advised by the supervisor, if required.														
Semester-IV (Spring)														
1.	HRE-701B	Thesis Stage–II (contd. From III semester)	DIS	18	-	-	-	-	-	-	-	-	100	-
		Total		**18**										

Summary				
Semester	1	2	3	4
Semester-wise Total Credits	20	18	12	18
Total Credits	68			

1- Programme Elective Courses Courses M.Tech (Renewable and Hydro Energy)

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
1	HRE-514	Hydro Electric Equipment	PEC	4	3	1	2/2	3	-	15-30	20	15-25	30-40	-
2	HRE-515	Design of Hydropower Structures	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
3	HRE-516	Hydro mechanical Equipment	PEC	4	3	1	2/2	3	-	15-30	20	15-25	30-40	-
4	HRE-517 A	Modelling, Simulation & Computer Applications	PEC	4	3	1	2/2	3	-	15-30	20	15-25	30-40	-
5	HRE-518	Environmental Planning and Management	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
6	HRE-522	Wind Energy Application Technology	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
7	HRE-526	Instrumentation for Hydro Power Plants	PEC	4	3	1	2/2	3	-	15-30	20	15-25	30-40	-
8	HRE-528	Rural Electrical Energy System Planning and Design	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
9	HRE-532	Remote Sensing and GIS for Renewable Energy Planning	PEC	4	3	0	2	3	-	10-25	25	15-25	30-40	-
10	HRE-534	Construction Planning and Management	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
11	HRE-536	Biomass Production and Utilisation	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
12	HRE-540	Solar Photo-Voltaic Design and Application	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
13	HRE-542	Energy Conservation and Management	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
14	HRE-580	Climate Change and water Resources	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
15	HRE-581	Energy-water-food nexus	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
16	HRE-582	Electric Vehicular Technology	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
17	HRE-585	Energy Storage Systems	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-
18	HRE-586	Hydrogen Economy	PEC	4	3	1	0	3	-	20-35	-	20-30	40-50	-

HRE-510: HYDROPOWER PLANNING AND MANAGEMENT
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Development and purpose of water resources, electricity act, constitutional provisions, development process, water policy, hydropower policy, electricity regulation, Types of hydro projects, components including civil works and E&M works like turbine, generator, governor and other related equipment, site configurations, hydropower planning on existing structures and new sites, Environmental impact and assessment, cumulative impact assessment, environmental flows, Financing of projects, cost estimation, financial and economic analysis, financial and techno-economic evaluation of hydropower project, tariff computation, Methods for stream gauging, rainfall, runoff and its estimation by different methods, peak flood estimation, demonstration of discharge measuring instruments, Hydrological analysis, flow duration studies, assessment of power potential and determination of installed capacity, Site selection, topographical, geological and power evacuation surveys and investigations, demonstration of surveying instruments, Types of project reports and their relevance, methods of project implementation, project planning, Schedules, Plant and machinery, Operation and maintenance, Management of hydropower plants

HRE-513: RENEWABLE ENERGY RESOURCES DEVELOPMENT TECHNOLOGY
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Introduction to energy sources, reserves and estimates, global energy scenario, renewable energy vis-à-vis environment implications, global warming and climate change, Solar energy and its application, availability of solar radiation energy, collection and solar thermal storage, photovoltaic and thermal power generation, Wind energy and its application, types of wind mills and their characteristics, elementary design principles, Biomass and its sources, energy plantation, production of fuel wood, Bio-conversion processes, bio-gas, bio-diesel and ethanol production and utilization, Thermo-chemical processes, biomass gasification, process, types of reactors, utilization of producer gas for thermal and electricity generation, New energy technology, ocean and geothermal energy, hydrogen energy, alternate fuels for surface transportation.

HRE-583: GRID INTEGRATION OF RENEWABLE ENERGY
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Introduction, current state of variable renewable energy (VRE) generation globally and in India; definition of VRE generation; variability and uncertainty associated with VREs; examples related to the impact of VREs on power systems operations; differences in grid integration with conventional and VRE generation. Various aspects of VRE such as sensing and measurement, forecasting, power electronics in grid integration, energy storage, conventional and upcoming analysis approaches and policies and regulations, Impact of VRE uncertainty and variability in power systems operations; impact of energy storage on grid integration; reliability concerns including system protection, inertia and ramping; must-run vs. at-par treatment with conventional generation resources; role of transmission expansion in VRE integration; improving grid reliability and resilience, Impact of increasing levels of electric vehicles; visibility and control concerns of distributed VRE generation; use of distributed VRE generation for providing grid services at multiple temporal and spatial scales, Overview of VRE forecasting and modelling for resource assessment, production cost simulation studies, and grid reliability assessment in both transmission and distribution systems, Latest advances in grid integration of VREs including use of artificial intelligence for forecasting in transmission and distribution systems; inter-sectoral modelling (e.g., transportation and-electricity sector modelling); cyber-physical systems modelling, Polices and regulations to support bulk-connected and distributed VRE generation from India and those found in countries with high VRE levels; different types of tariffs for renewable energy; case studies,

HRE-584: FINANCE, POLICY AND REGULATIONS FOR RENEWABLE ENERGY
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Introduction and scope of energy economics; basic concepts; energy statistics and energy balances; renewable sources of energy; impact of energy and energy use on the economy, Determinants of energy demand and supply; variability and uncertainty of renewable energy sources; elasticity of energy demand and supply; consumer and producer demand; transition from consumer to prosumer; sectoral composition of demand; alternative approaches to energy demand estimation; complementarity/substitution issues; forecasting energy demand: approaches, tools and techniques, Economic basics for power markets, vertically integrated utilities vs re-structured power markets, demand side aspects, different power generation technologies, costs constraints, market principles and the theory of firm, strategic power supplier behavior (game theory), power purchase agreements and market risks,Organization of wholesale power markets, long term, day ahead, real time market, power market trading, market power mitigation, System reliability, financial transmission rights, Theories of energy regulation; regulatory mechanism and governance, energy policy, policy interplays and trade-offs, Electricity act 2003, the central and state electricity regulatory commissions: objectives and functions; electricity tariff, availability based tariff (ABT), tariff models: open access, renewable purchase obligations (RPO), licensing, trading; central electricity authority, ministry of power, appellate authority, case studies, Models of renewable energy power purchase agreements (RPPAS) at bulk power system and in distribution systems; design considerations for RPPAS; impact of policies and regulations on RPPA design; case studies from India and abroad, Financing of renewable energy projects

HRE-514: HYDRO ELECTRIC EQUIPMENT
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Types, characteristics and testing of ac generators, Sizing and specification of single and three phase generators, Power factor and its correction methodologies, excitation systems, Electro-mechanical and digital governor, electronic load controller, Types of relays, contactors and control schemes for SHP stations, Supervisory control and data acquisition (SCADA), integrated computer control system for SHP station, Switchyard equipments, power and instrument transformers, circuit breakers, bus-bar, Protection schemes for generator, transformer and bus-bar, design of circuit diagram for auxiliary and grounding systems

HRE-515: DESIGN OF HYDROPOWER STRUCTURES
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

National and international standards and codes of practice related to designs of civil works for hydropower projects, Hydropower layouts, design of diversion works and intake structures, innovative designs, Dams and intake works, Channel, under drainage works, tunnels, Sediment properties and transport, desilting devices, silt disposal, Cross drainage works, balancing reservoir, spillway and forebay, Penstock, anchor block and saddle, surge shaft, gates, valves and trash racks, Power House Layout, Power house building and machine foundation

HRE-516: HYDRO MECHANICAL EQUIPMENT
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Classification and working principles of hydro turbines, different components of impulse and reaction turbines, Design concepts of hydro turbines, pump-as-turbine and other non conventional hydro turbines, Characteristics of hydro turbines, geometric similarity, main characteristic and operating characteristic curves, hill curves, Governing of hydro turbines, mechanical and electro-mechanical governors, electronic load controller, mechanical drives, gear box, pulleys, Selection of hydro turbines based on specific speed and their optimal selection, Classification, components and selection of gates and valves, Model testing of hydro turbines, performance testing of turbines at site, Causes and impact of cavitation, silt erosion and their combined effect on operation of hydro turbines, Erection, commissioning, operation and maintenance of turbines.

HRE-517 A: MODELLING, SIMULATION AND COMPUTER APPLICATIONS
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Review of C++, Principles of modeling, physical, mathematical, static and dynamic models, Model development, parameter estimation, validation of model, Nature of simulation, techniques of simulation, discrete and continuous system simulation, parallel and distributed simulation, simulation of queuing and inventory system, Methods of random number generation, Monto-Carlo simulation, spread sheet simulation, numerical computation techniques for continuous and discrete models, Modeling of intake, channel, desilting tank, forebay tank, penstock, Modeling of electro mechanical equipment, Introduction of simulation language and package

HRE-518: ENVIRONMENTAL PLANNING AND MANAGEMENT
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Basic ecological principles, concept and components of ecosystem, energy flow, nutrient cycling, cybernetics, ecological regulation, ecological diversity; Interaction of various components of environment, ecological disorders; Environmental impact assessment (EIA) of water resources projects with emphasis on renewable energy projects e.g. SHP, biomass, solar energy; Conservation of resources, environmental policies, laws and acts; Significance of EIA of renewable energy projects, case studies of large and small hydro projects; Environmental compatible growth.

HRE-522: WIND ENERGY APPLICATION TECHNOLOGY
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Wind energy scenario in India, properties of wind, wind velocity and wind rose diagram, estimation of power in wind; Types of wind turbines, characteristics, construction of wind mills; Aerodynamic considerations of wind mill design, wind stream profile, rotor blade profile and cross section; Drive system-gears, wind electric generators, regulating and control systems for wind mills; Performance evaluation and recent technologies of wind energy conversion system; Wind energy potential estimation and site selection; wind farms, cost estimation of the energy from wind energy conversion system.

HRE-526: INSTRUMENTATION FOR SMALL POWER STATION
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Industrial instrumentation, transducers and their applications; Instrumentation for power system, analog and digital instruments, principles of measurement of voltage, current and power; Electronic voltmeters for non-sinusoidal voltages, dc voltmeter, mechanical and electrical tachometer, altimeter; Current transformers and potential transformers, AC/DC current probs; Digital instrumentation, technology of regulators, sensors and actuators, recorders, signal processing circuits, data acquisition system; Types of A.C. bridges, equation for bridge balance, measurement of self inductance, capacitance, mutual inductance and frequency; Case study of the instrumentation scheme used in small hydro power development.

HRE-528: RURAL ELECTRICAL ENERGY SYSTEM PLANNING AND DESIGN
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Electrical load survey and forecasting, rural load management; Route survey and profiling of transmission and distribution lines; Mechanical design of low-tension distribution lines, selection of poles/supports etc; Electrical design of low-tension distribution lines: selection of conductors and insulators etc; Planning, selection and design of substations for rural electrical system; Load flow methods for transmission and distribution system; fault analysis: different types of faults and their calculation procedures; Co-ordination between power and tele-communication lines; Maintenance of transmission and distribution lines; Case study of a typical system.

HRE-532: REMOTE SENSING AND GIS FOR RENEWABLE ENERGY PLANNING
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 0, Practical: 2

Remote sensing: introduction, satellite platforms and sensors, data acquisition, Indian satellite system, Application of Drone in data acquisition, Satellite image: format, resolution, multispectral images, image processing software, geo-referencing, pre-processing and enhancement. information extraction: supervised and unsupervised classification, Geographical information system: introduction, components, coordinate system, projection system, Data sources and data collection for renewable energy projects: field survey, topographic maps, satellite images, GPS, digitization and layers creation, Data types – spatial, non-spatial, vector and raster data, topological relationship, Data base development for renewable energy projects: database structure, editing, data retrieval and query, managing data errors: rubber sheeting, edge matching and removal of sliver polygon, Digital elevation model: characteristics, DEM generation, parameters extraction from DEM, Renewable energy projects data analyses – overlay analyses, buffering, neighborhood operation, and distance and area measurement, network based analysis, RS&GIS based case study for development of renewable energy projects

HRE-534: CONSTRUCTION PLANNING AND MANAGEMENT
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Planning for construction of projects, advantages, stages and limitations of planning; Project objectives and activities, tender documents, types of tenders and procedures, cost estimates; Construction schedules, network techniques, interrelationship of activities, advantages of network diagrams; Construction methods, direct and indirect costs, construction plants and machinery, resource mobilisation; Importance of safety, safety measures and benefits; Quality control and management, coordination between different organizations and monitoring; Construction planning for river diversion, foundation construction and treatment.

HRE-536: BIOMASS PRODUCTION AND UTILISATION
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Energy crisis, rural and urban energy loads, biomass as a source of energy, energy plantation, forest and agro residues, aquatic biomass, animal waste; Classification, shape, size, ash content and volatile matter in biomass; Biomass characteristics, procedures, proximate and ultimate analysis, ash deformation and fusion characteristics, calorific value, bulk density, devolatilisation; Biomass production through energy plantation, agroforestry, short rotation intensive culture, biomass harvesting, handling and pre-conversion processes; Physical, biological and thermo-chemical conversion processes, combustion, pyrolysis, gasification, bio-diesel, biogas production, biogas plants, briquetting/size reduction; Synthetic fuel production, bagasse based co-generation for power, utilization of biomass for the generation of solid, liquid/gaseous fuels for meeting heat and power needs; Environmental aspects of biomass production and utilisation and waste minimization system.

HRE-540: SOLAR PHOTO-VOLTAIC DESIGN AND APPLICATION
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Solar energy data, estimation of solar energy on different planes; Principle, characteristics and types of solar photo-voltaic (PV) cell; Manufacturing and performance testing of solar PV modules; PV modules, array, batteries, battery chargers, block diodes, inverters, load distribution unit, monitoring equipment, circuit breakers; Load estimation, sizing of array and battery; Types of PV system, isolated and grid connected PV power plants; Installation and maintenance, grid interfacing, field monitoring; economic analysis, cost effective hybrid designs.

HRE-542: ENERGY CONSERVATION AND MANAGEMENT
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Definition, organization of an energy conservation programme, definition of energy conservation, energy management, energy conservation opportunities, general principles, types, procedures and instruments for energy auditing; Assessments of technical merits of energy conservation methods and techniques in specific applications, energy saving methods, energy strategy, industrial energy applications; Methods of cost estimation for potential savings of fuel and electricity; Supply and demand side management of energy in residential, commercial, transport and industrial sectors, electricity utilities; Energy conservation in steam boilers, engines; principles, types and applications of different heat recovery systems; Energy conservation in electrical motors, transformers and conductors; Energy conservation in illumination in building shells; Material conservation and recycling, buildings heat losses, effect of fabrics, solar gains, ventilation, cooling, thermal storage and heat pumps; Topping and bottoming cogeneration cycles, total energy systems.

HRE-580: CLIMATE CHANGE AND WATER RESOURCES
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 2/2

Natural eco-systems, autotrophs, heterotrophs, energy flows, pre-industrial humanity; efficiency of photosynthesis and ecosystems like forests, crops, respiration, combustion and other oxidation processes, biomethanation; History of climate change, greenhouse gas effect, anthropogenic climate change, role of different gases, global climatic problems, integrated assessment model, impacts and adaptation, uncertainties, precautionary principle; Biological and physico-chemical methods for carbon sequestration, CO_2 capture from large point sources, pre-, post- and oxy-combustion technology, transport, storage and monitoring, feasibility, economics and public perceptions; Water resources and green house gas emissions, mitigation measures and adaptation to climate change; Kyoto protocol, UNFCCC, IPCC, geopolitics of GHG control, CDM and other emission trading mechanisms, non-CO2 GHGs, relevance for India, procedure for registration for CDM projects and its benefit; Case studies.

HRE-581: ENERGY-WATER-FOOD-NEXUS
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Energy, water, food (E-W-F) and Sustainable Development Goals (SDGs); Global and Indian energy, water, and food scenario; Transdisciplinary approach towards nexus; Need to understand the interdependencies and interrelationships between the three resources, Energy market; Energy sources and applications; Energy policies; Energy-Water interactions; Energy-Food interactions; Role of Renewables; Challenges and opportunities, Water sources and applications; Virtual water, and water footprint; Water-Food interactions; Water security and policies; Challenges and opportunities, Food dependence on water and energy; Industrialization of the agri-food system; Challenges and opportunities in context of water and energy sectors; Case studies in food production and processing industry, Methods and models for E-W-F nexus; Multi-criteria decision making and Sustainability analysis methods; Complexity and Uncertainty; Resource management; E-W-F nexus at local and regional levels; Sustainable practices for water and energy consumption, Practical methodological implications of nexus; Role of technology in the nexus; Impact of nexus on economy, environment, policies, and community engagement, Interdisciplinary case studies – Formulation and analysis (Exercise/Project activity); Climate change and nexus; Agriculture and nexus; Opportunities for business and innovation

HRE-582: ELECTRIC VEHICULAR TECHNOLOGY
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

To impart knowledge on the fundamentals, design, current status, and future industry trends of electrified vehicular systems, Vehicle architectures, powertrain components, electric traction motor sizing and performance, Traction motors, practical electric vehicle design considerations (with examples) standard drive cycles, Power electronic switches, DC/DC converters, DC/AC converters, modulation schemes and traction motor control, Batteries, cell balancing circuits, and battery pack management, Hybrid energy storage systems and alternative vehicle architectures, Battery charging infrastructure, charging requirements, types of charging, AC/DC converters, Types of battery chargers, on-board chargers, off-board chargers, wireless charging electric vehicle charging and renewable based electric charging, Standards, polices and regulations

HRE-585: ENERGY STORAGE SYSTEMS
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Overview of energy storage technologies: thermal, mechanical, chemical, electrochemical, electrical, comparison and applications of ESS, national and international experience, Types and working principle of mechanical and thermal energy storage systems, applications of thermal energy storages, advances in thermal energy storages: sensible heat, latent heat and thermo-chemical energy storage systems, demand management for storage, Pumped hydro storage, national and international status, technology: fixed and variable, and innovative options for PSP development, Pumped hydro Potential assessment, investigations, and clearances, Financial, regulations and policy for pumped storage and battery storage, Electrochemical ESS (batteries): theory, types, characteristics, modeling, design and sizing, batteries safety, cell balancing circuits, charging techniques, state of charge and health estimation techniques, thermal management, battery pack design and management, ESS design and sizing, hybrid energy storage systems, integration with renewables, case studies, ESS installation and role in an isolated and grid connected power system with renewable energy sources, short-term and long-term applications of ESS; case studies, environmental impacts and mitigations for energy storage projects

HRE-586: HYDROGEN ECONOMY
Credit: 4
Contact Hours: Lecture: 3, Tutorial: 1, Practical: 0

Hydrogen technology, production and conversion, Thermal- steam reformation, thermo- chemical, water splitting, nuclear thermos catalytic and partial oxidation methods, Electrochemical- Electrolysis, photo-electrochemical, Biological- anaerobic digestion, Hydrogen economy and financial market opportunities, Fuel cells, characterization, life cycle sustainability assessment (LCSA), recycling and eco-design, Thermodynamics of fuel cells: thermodynamic potential, reversible cell potential, effect of operating conditions on reversible cell potential (Nernst potential), energy conversion efficiency, losses in energy conversion, Hydrogen and fuel cells for mobility applications & vehicles, distribution & grid infrastructure, Storage and carbon capture, safety, Government policies- worldwide, hydrogen as part of a climate neutral strategy, national hydrogen mission, case studies