INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-510 **Course Title**: Hydropower Planning and Management
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To give an overview of planning, process of development and management of hydropower systems.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Development and purpose of water resources, electricity act, constitutional provisions, development process, water policy, hydropower policy, electricity regulation	6
2.	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	9
3.	Environmental impact and assessment, cumulative impact assessment, environmental flows	4
4.	Financing of projects, cost estimation, financial and economic analysis, financial and techno-economic evaluation of hydropower project, tariff computation	5
5.	Methods for stream gauging, rainfall, runoff and its estimation by different methods, peak flood estimation, demonstration of discharge measuring instruments	4
6.	Hydrological analysis, flow duration studies, assessment of power potential and determination of installed capacity	5
7.	Site selection, topographical, geological and power evacuation surveys and investigations, demonstration of surveying instruments	4
8.	Types of project reports and their relevance, methods of project implementation, project planning, schedules, plant and machinery, operation and maintenance, management of hydropower plants	5
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Caldwell, J., "Hydropower: Renewable Energy Essentials", Larsen and Keller Education	2019
2.	Breeze, P., Hydropower, 1st Edition, Academic Press	2018
3.	IPCC Special Report on Renewable Energy – Chapter 5 Hydropower, Cambridge university press, New York	2011
4.	Mosonyi, E., "Water Power Development", Vol. I and II, Nem Chand and Brothers	2009
5.	Brown, G., "Hydro-electric Engineering Practice", Vol. I, II & III, CBS Publication	2009
6.	Nigam, P.S., "Handbook of Hydroelectric Engineering", Nem Chand and Bros	2006
7.	Gulliver, J.S. and Arndt, E.A., "Handbook of Hydro Electric Engineering", McGraw Hills	1993
8.	"Civil Engineering Guidelines for Hydroelectric Projects", Vol. (I to V), American Society of Civil Engineers (ASCE)	1989
9.	Fritz, J.J., "Small and Mini Hydro Power Systems: Resource Assessment and Project Feasibility", McGraw Hills	1984

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-515 **Course Title**: Design of Hydropower Structures
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To provide knowledge of design concepts of various civil structures of hydro power schemes.

10. Details of the Course

S.No.	Contents	Contact hours
1.	National and international standards and codes of practice related to designs of civil works for hydropower projects	2
2.	Hydropower layouts, design of diversion works and intake structures, innovative designs	7
3.	Dams and intake works	6
4.	Channel, under drainage works, tunnels	5
5.	Sediment properties and transport, desilting devices, silt disposal	5
6.	Cross drainage works, balancing reservoir, spillway and forebay	6
7.	Penstock, anchor block and saddle, surge shaft, gates, valves and trash racks	6
8.	Power house layout, power house building and machine foundation	5
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Mosonyi, E., "Water Power Development", Vol. I and II, Nem Chand and Brothers	2009
2.	Brown, G., "Hydro-electric Engineering Practice", Vol. I, II & III, CBS Publication	2009
3.	Nigam, P.S., "Hand book of Hydroelectric Engineering", Nem Chand and Brothers	2001
4.	Varshney, R.S., "Hydropower Structures", Nem Chand and Brothers	2001
5.	Gulliver and Arihant, "Hydroelectric Energy", McGraw Hills	1991
6.	"Civil Engineering Guidelines for Hydroelectric Projects", Vol. (I to V), American Society of Civil Engineers (ASCE)	1989

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-532 **Course Title**: Remote Sensing and GIS for Renewable Energy Planning
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To provide knowledge for Remote Sensing and Geographical Information System for planning of Renewable Energy Projects.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Remote sensing: introduction, satellite platforms and sensors, data acquisition, Indian satellite system, application of drone in data acquisition	6
2.	Satellite image: format, resolution, multispectral images, image processing software, geo-referencing, pre-processing and enhancement. information extraction: supervised and unsupervised classification	6
3.	Geographical information system: introduction, components, coordinate system, projection system	3
4.	Data sources and data collection for renewable energy projects: field survey, topographic maps, satellite images, GPS, digitization and layers creation	4
5.	Data types: spatial, non-spatial, vector and raster data, topological relationship	3
6.	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	6
7.	Digital elevation model: characteristics, DEM generation, parameters extraction from DEM	4
8.	Renewable energy projects data analyses: overlay analyses, buffering, neighborhood operation, distance and area measurement, network based analysis	5
9.	RS&GIS based case study for development of renewable energy projects	5
Total		**42**

11. **List of Practicals:**

i. Raster data Geo-referencing
ii. Creation of vector layers
iii. DEM generation
iv. Catchment delineation
v. Image classification
vi. GIS query analysis
vii. Union and intersection analysis
viii. GPS surveying

12. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Bhatta, B., "Remote Sensing and GIS", 3rd edition, OUP India	2021
2.	Bhatia, S.C., "Fundamentals of Remote Sensing", Atlantic Publishers	2021
3.	Joseph, G., and Jeganathan, C., "Fundamentals of Remote Sensing", 3rd edition, The Orient Blackswan	2018
4.	Y Chor Pang Lo and Albert K.W. Yeung, "Concepts and Techniques of Geographic Information Systems", 2nd edition, Pearson Education	2017
5.	Jensen, J.R., "Introductory Digital Image Processing and A Remote Sensing Perspective", 4th edition, Pearson Education	2017
6.	Burrough, P. A., McDonnell, R. A., and Lloyd, C.D., "Principles of Geographical Information Systems", 3rd edition, Oxford University Press	2016
7.	Lillesand, T.M. and Kiefer, R.W., "Remote Sensing and Image Interpretation", 7th edition, John Willey and Sons Pte. Ltd.	2015

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-583 **Course Title**: Grid Integration of Renewable Energy
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 2/2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 15-30 **PRS:** 20 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide an overview of grid integration of variable renewable generation over multiple temporal and spatial scales.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	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	4
2.	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	6
3.	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	6
4.	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	6
5.	Overview of VRE forecasting and modelling for resource assessment, production cost simulation studies, and grid reliability assessment in both transmission and distribution systems	8
6.	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	6
7.	Policies 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	6
Total		**42**

11. List of Practicals:

i. Development of generator capacity mix to meet projected load using the Regional Energy Deployment System (ReEDS) software
ii. Unit commitment and economic dispatch of a power system using Flexible Energy Scheduling Tool for Integrating Variable Generation (FESTIV)
iii. Short-term wind and solar forecasting using MATLAB
iv. Transmission system power flow analysis using MATPOWER/PowerWorld
v. Distribution power flow analysis using OpenDSS
vi. Introduction to MATLAB/Simscape as a cross-sectoral modelling tool

12. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Keyhani, A., "Design of Smart Power Grid Renewable Energy Systems (Third Edition), Wiley	2019
2.	Lund, P. D., et al, "Advances in Energy Systems: The Large-Scale Renewable Energy Integration Challenge", Wiley	2019
3.	Apt, J. and Jaramillo, P., "Variable Renewable Energy and the Electricity Grid", Taylor & Francis Ltd	2014
4.	Kersting, W.H., "Distribution System Modeling and Analysis (Third Edition)", CRC Press	2012
5.	Kamaraju, V., "Electric Power Distribution System", Tata McGraw Hill Education Private Limited	2009
6.	Grainger, J.J. and Stevenson, W.D., "Power System Analysis", Tata McGraw Hill Publishing Company Limited	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-584 **Course Title**: Finance, Policy and Regulations for Renewable Energy
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide comprehensive overview of the basic concepts and considerations for finance, policies and regulations for renewable energy growth.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	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	3
2.	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	6
3.	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	4
4.	Organization of wholesale power markets, long term, day ahead, real time market, power market trading, market power mitigation	4
5.	System reliability, financial transmission rights	4
6.	Theories of energy regulation, regulatory mechanism and governance, energy policy, policy interplays and trade-offs	6
7.	Electricity act 2003, functions of central and state electricity regulatory commissions, 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	6
8.	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	5
9.	Financing of renewable energy projects	4
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Raikar, S. and Adamson, S., Renewable Energy Finance – Theory and Practice, 1st Edition, Academic Press	2019
2.	Dubash, N. K. and Kale S. S., (ed.) Mapping Power: The Political Economy of Electricity in India's States, Oxford University Press, New Delhi	2018
3.	Kirschen, D. and Strbac, G., Fundamentals of Power System Economics, 2nd Edition, Wiley	2018
4.	Asquer, A., Regulation of Infrastructure and Utilities: Public Policy and Management Issues, Palgrave Macmillan, London, UK	2018
5.	Curly, M., Finance Policy for Renewable Energy and a Sustainable Environment, CRC Press	2014
6.	Simkins, B. and Simkins, R., Energy Finance and Economics: Analysis and Valuation, Risk Management, and the Future of Energy, John Wiley & Sons	2013
7.	Kumar, A. and Chatterjee, S.K., Electricity Sector in India: Policy and Regulation, OUP, New Delhi	2012
8.	Bhattacharyya, S.C., Energy Economics Concepts, Issues, Markets and Governance, Springer- Verlag., 2011	2011
9.	Gravell, H. and Rees, R., Microeconomics, Prentice Hall, New Jersey, 14th Edition	2004
10.	Brennan, T.J., Palmer, K.L., and Martinez, S.A., Alternating Currents: Electricity Markets and Public Policy (Resources for the Future) Routledge	2002
11.	Griffin, J.M. and Steele, H.B., Energy Economics and Policy, 2nd Edition	1986

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-585 **Course Title**: Energy Storage Systems
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To impart knowledge on fundamentals, design and sizing of energy storage systems for renewable energy, smart grid and electric transportation systems.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Overview of energy storage technologies: thermal, mechanical, chemical, electrochemical, electrical, comparison and applications of ESS, national and international experience	4
2.	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	4
3.	Pumped hydro storage, national and international status, fixed and variable technology, innovative options for PSP development	7
4.	Pumped hydro potential assessment, investigations, and clearances, financial, regulations and policy for pumped storage and battery storage	8
5.	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	6
6.	ESS design and sizing, hybrid energy storage systems, integration with renewables, case studies	5
7.	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	8
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Kabo-Bah, A., Diawuo, F. and Antwi, E., "Pumped Hydro Energy Storage for Hybrid Systems", Academic Press	2021
2.	Hussain, I., Electric and Hybrid Vehicles: Design Fundamentals, 3rd Edition, CRC Press	2021
3.	Ter-Gazarian, A.G., Energy Storage for Power Systems, 3rd Edition, The Institution of Engineering and Technology Press	2020
4.	Lombardi, P., Komarnicki, P., and Styczynski, Z.A., Electric Energy Storage Systems: Flexibility Options for Smart Grids, Springer	2017
5.	D´ıaz-Gonz´alez, Andreas F., Sumper, A., and Gomis-Bellmunt, O., Energy storage in Power Systems, John Wiley & Sons Ltd.	2016
6.	Guyer J.P., An Introduction to Pumped Storage Hydroelectric Power Plant Projects (Dams and Hydroelectric Power Plants), The Clubhouse Press	2016
7.	Mosonyi, E., "Water Power Development", Vol. I and II, Nem Chand and Brothers	2009
8.	Brown, G., "Hydro-electric Engineering Practice", Vol. I, II & III, CBS Publication	2009
9.	Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments, Vol. 5: Pumped Storage and Tidal Power	1989

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Hydro and Renewable Energy

1. **Subject Code:** AHN-586 **Course Title**: Hydrogen Economy
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To provide knowledge on various features on hydrogen economy including fuel cells, use in transportation and power generation and scale up issues.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	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	8
2.	Hydrogen economy and financial market opportunities	3
3.	Fuel cells, characterization, life cycle sustainability assessment (LCSA), recycling and eco-design	8
4.	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	5
5.	Hydrogen and fuel cells for mobility applications & vehicles, distribution & grid infrastructure	6
6.	Storage and carbon capture, safety	5
7.	Government policies, hydrogen as part of a climate neutral strategy, national hydrogen mission, case studies	7
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Hall, W., Spencer, T., Renjith, G., and Dayal, S., The Potential Role of Hydrogen in India: A pathway for scaling-up low carbon hydrogen across the economy. New Delhi: The Energy and Resources Institute (TERI)	2020
2.	Scipioni, A., Manzardo, A., and Ren, J., "Hydrogen Economy Supply Chain, Life Cycle Analysis and Energy Transition for Sustainability", Elsevier	2017
3.	O'Hayre, R., Cha, Suk-Won, Colella, W., and Prinz, F. B., "Fuel Cell Fundamentals", (3rd edition), Wiley	2016
4.	Stolten, D., Samsun, R.C., and Garland, N., "Fuel Cells: Data, Facts, and Figures", 1st Edition, Wiley	2016
5.	Pahwa, P.K. and Pahwa, G.K., Hydrogen Economy, TERI Press	2014
6.	Sherif, S.A., Goswami, D. Yogi, Stefanakos, Elias K., Steinfeld, Aldo, "Handbook of Hydrogen Energy", 1st Edition, CRC press	2014
7.	Ball, M. and Wietschel. M., The Hydrogen Economy: Opportunities and Challenges, Cambridge University Press	2009
8.	Gupta, Ram B., "Hydrogen Fuel: Production, Transport, and Storage", 1st Edition, CRC Press	2008
9.	Rifkin, J., The Hydrogen Economy, Tarcher Perigee, USA	2002