Overview of Course Modules

The curriculum for the Hydropower System Principles Course consists of 8 modules, carefully designed and developed exclusively for the NHA Hydro Academy by more than 50 hydropower subject matter experts (SMEs).

For the course, experienced faculty will teach each module and guide learners through hands-on exercises and assessments.

Click on each module title below to read a module overview, the objectives for that module, expected learner outcomes, and details on key concepts that will be taught in that module.

Module 1: Introduction/Overview/Foundation/Water to Wires

Module 2: Production Planning and Water Management

Module 3: Dam Safety

Module 4: Equipment, Engineering, and Technology

Module 5: Asset Management and Reliability

Module 6: Markets

Module 7: Environment

Module 8: FERC Licensing and Compliance

Module 1: Introduction/Overview/Foundation/Water to Wires

Module Overview:

The introductory module is designed to introduce the participants to one another, review course logistics and agenda, provide a high-level overview of the history of hydroelectric generation in the United States and its role in our nation's energy mix, and briefly introduce the different types of hydroelectric projects and their operations (e.g., conventional hydropower, pumped storage hydropower, peaking and run-of-river operations, seasonal storage, etc.).

By the end of the module, attendees will understand the course components and be equipped with an introductory understanding of the different types of hydroelectric projects from which the other modules will be built.

Module Objectives:

1. Explore the history of hydropower in the United States and its role in the nation's energy mix.
2. Examine the principles of hydropower.
3. Identify different types of hydroelectric projects in the context of the course elements.

Learner Outcomes:

1. Explore the history of hydropower and its role in our nation's energy mix.
    1.1. Learners will review the history of hydropower in the United States.
    1.2. Learners will describe hydroelectric generation's role in our nation's energy mix compared to other generation sources.
2. Examine the principles of hydropower.
    2.1. Learners will describe how flow and head impact hydroelectric generation.
3. Examine the primary types of hydroelectric projects and their operations.
    3.1. Learners will compare the basic characteristics of different types of hydroelectric projects based on key information pieces.
    3.2. By reviewing real-world examples, learners will identify how various types of hydroelectric projects work together from both a water and grid management perspective.

Key Concepts Covered:

1. Introductions, General Logistics, and Agenda Review.
2. History of hydropower in the United States and its role in our nation’s energy mix.
    2.1. Brief history of hydropower in the United States
    2.2. Benefits of hydropower
    2.3. Overview of hydroelectric generation's role in our nation’s energy mix compared to other sources of generation
3. Hydropower Principles
    3.1. Hydrology
    3.2. Head
    3.3. Power and Energy
4. Introduce primary types of hydroelectric projects, their primary components, and mode of operation
    4.1. Conventional Hydropower
    4.2. Pumped Storage Hydropower
    4.3. Hydrokinetic
    4.4. Modes of operation (run-of-river, peaking, storage)

Module 2: Production Planning and Water Management

Module Overview:

The production planning and water management module is designed to educate participants about the role of the water manager in a hydropower environment. Topics covered include runoff forecasting basics, common constraints on power production, developing seasonal/annual water management plans to optimize power production, and adapting seasonal plans to short-term or unplanned events.

By the end of the module, participants will have a broad understanding of the water management process and be able to qualitatively describe how to develop a water management plan.

Module Objectives:

1. Introduce the role of water management in hydropower. The goal of water management is optimization of water resources to maximize power production in a constrained environment. Good water management requires knowledge of watershed hydrology, system limitations, regulatory requirements and water delivery agreements.

2. Introduce concept of runoff forecasting. A manager needs to know how much water will be available and when before s/he decides how to use it.

3. Optimizing water management for hydropower production. Provide an overview of seasonal/annual planning processes and common constraints on production. Constraints covered would include system capacity, regulatory requirements (e.g. minimum instream flows), legally binding agreements (e.g. water delivery minimums to downstream users), and planned maintenance/construction activities.

4. Implementation: adapting seasonal management plans in real time, introduce common sources of disruption such as weather events or damage to infrastructure.

Learner Outcomes:

1. Understand the role of water management in hydropower

    1.1 Learners will understand the goal of water management in a hydropower context.

    1.2 Learners will be able to state the key knowledge areas of a water manager.

2. Understand basic concept of runoff forecasting and typical frequencies of forecasting

   2.1 Learners will understand basic concepts of runoff forecasting and factors that can influence runoff such as geology, vegetation/land cover, and climate.

   2.2 Learners will understand the concept of forecast resolution (time step) and utility of different levels of resolution.

3. Understand the concept of optimization and common constraints in optimizing water management for hydropower production.

4. Understand that water resources often provide multiple beneficial uses and the water manager's role in ensuring these uses are provided/available.

5. Identify potential disruptions to a seasonal management plan.

Key Concepts Covered:

1. Introduction to Production Planning and Water Management
   - 1.1 Goals of water management in a hydropower environment
   - 1.2 Key knowledge areas

2. Runoff Forecasting
   - 2.1 Runoff and the hydrologic cycle
     - -relationship between precipitation and runoff
     - -volume and timing
   - 2.2 The role of the runoff forecast
   - 2.3 Factors influencing runoff
     - -climate (seasonal precipitation patterns, snowpack)
     - -vegetation and land cover
     - -geology
     - -topography (basin shape, slope, etc.)
   - 2.3 Forecasting timestep
     - -monthly/seasonal
     - -daily/subdaily
   - 2.4 Forecasting models and inputs
     - -examples of modeling software/publicly available runoff forecasts
     - -input data

3. Developing a Seasonal Water Management Plan
   - 3.1 Water management goals: optimized use of water resources

-maximizing production
-aligning power production with demand
-respect regulatory/legal constraints

3.2 Inputs to the water management plan
-Runoff forecast
-Power price/demand forecast
-Constraints

3.3 Common constraints in water management
-infrastructure limitations (powerhouse capacity, reservoir capacity, conveyance limits)
-outages
-regulatory/legal
-water delivery/supply
-recreation
-environmental (minimum flows, pulse flows, etc)
-flood control

3.4 Putting the pieces together: steps to creating a management plan
-runoff+pricing
-allocate water to satisfy minimum constraints
-consider water availability vs. system capacity
-generation forecast: allocate available water to highest demand periods
-assess accuracy/opportunities for improvement
-update regularly

4. Adapting the Plan in Real-time

4.1 Weather and rapid changes in runoff
-storm events
-spring snowmelt/reservoir topping off

4.2 Sudden increases in power demand

1.3 Infrastructure damage/forced outages

1.4 Biological/environmental concerns

5. Wrap-up and Review

1.1 Key takeaways

1.2 Assessment (multiple choice quiz; problem-solving exercise)

Module 3: Dam Safety

Module Overview:

The Dam Safety module will give class participants the foundation to understand basic dam safety principles and their implications for a hydroelectric project. This module will provide course participants with an understanding of the various types of dams/water retaining structures and common dam safety issues, types of surveillance and monitoring for dam safety, and touch on federal and state regulatory requirements governing dam safety. Succinct case studies will be presented so that participants can better understand the common dam safety concerns at a hydroelectric project.

By the end of the module, attendees will have a cursory understanding of common dam safety issues and the regulatory requirements governing dam safety at a hydroelectric project.

Module Objectives:

1. Identify water retaining structures and common dam safety issues.
2. Determine the hazard potential classification of a hydroelectric project based on its characteristics and environmental setting.
3. Explore the state and federal regulatory requirements governing safety at dams and hydroelectric projects, and their implications.

Learner Outcomes:

1. Assess water retaining structures and common dam safety issues.
    1.1. Learners will differentiate dam types and general hydropower project features.
    1.2. Learners will recommend appropriate monitoring procedures and instrumentation to assess potential dam safety issues.
2. Determine hazard potential classifications.
    2.1. Learners will evaluate the levels of hazard potential classifications and the analyses used to determine hazard potential classifications.
3. Explain the ins and outs of dam safety regulations.
    3.1. Learners will explore the types of analysis and reporting requirements necessary for state and federally regulated dams.

Key Concepts Covered:

1. Water Retaining Structures
    1.1. Types of dams

1.2. Additional water-retaining structures

2. Common Dam Safety Issues
    2.1. Examples of dam failures, why dam safety programs exist
    2.2. Overview of common dam safety issues
3. Instrumentation to Monitor Dam Safety
    3.1. Overview of common instrumentation used to monitor dam safety
4. Hazard Potential Classifications of Dams
    4.1. Overview of the hazard potential classifications – low, significant, and high
    4.2. Implications of each hazard potential classification
5. Dam Safety Requirements
    5.1. Overview of federal and state regulatory agencies
    5.2. Examples of state requirements
    5.3. What makes a dam subject to CFR Part 12D?
    5.4. Annual and Periodic FERC requirements
6. Module Practicum and Wrap-Up
    6.1. Class Activity: Identify potential dam safety issues, potential instrumentation that could be used to monitor or prevent future dam safety issues, and the hazard potential classification of a hypothetical hydroelectric project
    6.2. Key takeaways from the module

Module 4: Equipment, Engineering, and Technology

Module Overview:

The intent of this module is to briefly introduce the equipment installed at hydropower facilities across North America. The entire course content will consist of outlining the major equipment that is used in a typical hydropower facility to turn water power into electrical power, along with the associated auxiliary equipment / assets.

This module will provide a high-level overview of the components to ensure that participants can develop the industry language for various equipment installed at a hydropower facility.

Module Objectives:

The goal of this module is to provide the language required for participants to understand the equipment used in a hydropower facility, along with the proper names and general locations of this equipment.

The module will:

1. Communicate the proper names of the turbine generator components.
2. Review the major equipment located in a hydropower facility.
3. Walk through the big picture of how various equipment interacts with each other.

Learner Outcomes:

1. Able to name the major equipment in a hydropower facility.
2. Understand the high-level purpose of the major equipment as part of the overall hydrogeneration system.

Key Concepts Covered:

1. Introduction to equipment at a hydropower facility
    1.1. Module Overview
    1.2. How engineering relates to selection and design of equipment.

2. Understanding the machine – Turbine / Generator (T/G): This section is intended to outline how a T/G pair works and provides the names of the major associated equipment

3. Gates / Spillways / Water Facilities: This section is to outline the equipment related to control the associated water at the hydropower facility

3.1. Dams
3.2. Dikes
3.3. Station / Spillway interaction
3.4. Gates
    3.4.1. Gate Hoists
    3.4.2. Gate Controls
3.5. Trash Rack/Trash Rake
3.6. Fish Passage Facilities

4. Overview of water power to electrical power (with learner interactions)
    4.1. Water to Mechanical Power
        4.1.1. Power Equation/Potential Energy
        4.1.2. Penstocks
            4.1.2.1. Penstock Shutoff Valve
            4.1.2.2. Intake Gates
        4.1.3. Intake / Turbine Inlet
            4.1.3.1. TSVs
        4.1.4. Wicket Gates / Guide Vanes
        4.1.5. Governor
        4.1.6. Turbine / Runner
            4.1.6.1. Impulse (Pelton, Cross-flow)
            4.1.6.2. Reaction (Francis, Propeller Type)
        4.1.7. Turbine Bearings
            4.1.7.1. Thrust
            4.1.7.2. Guide
            4.1.7.3. Journal
        4.1.8. Tailrace/Tailrace gates
        4.1.9. Bypass Systems
        4.1.10. Surge Facilities
    4.2. Electrical Power
        4.2.1. Generator
        4.2.2. Exciter
        4.2.3. Generator Breaker
        4.2.4. Generator Step Up (GSU) Transformer

5. Auxiliary Systems: This section is intended to outline the support systems for the machine

    5.2. Cooling Water Systems
    5.3. Lubrication Systems

6. Operating Systems: This section is meant to outline the equipment that lets us control the station
    - 6.1. Protections
    - 6.2. Unit and Plant Controls
        - 6.2.1. Governors
    - 6.3. RTU / SCADA Systems
    - 6.4. Control Room

7. Maintenance Systems: This is an overview of the large equipment needed in order to perform maintenance
    - 7.1. The “Powerhouse”
    - 7.2. Stoplogs
    - 7.3. Powerhouse Cranes
    - 7.4. Service Bays

8. Balance of Plant Systems: This is an overview of the other typical associated systems
    - 8.1. AC Station Service
    - 8.2. DC Station Service
    - 8.3. Station Dewatering Systems
    - 8.4. HVAC Systems
    - 8.5. Fire Protection Systems
    - 8.6. Station Security
    - 8.7. Lighting and service power

9. Considerations: This section covers some of the big picture concepts
    - 9.1. The Grid / Water / TG interaction
    - 9.2. Impacts on the region
    - 9.3. The Environment (how the region affects equipment)
    - 9.4. Public Safety Equipment

10. Module Wrap Up, Review, and Assessment

Module Overview:

The Asset Management and Reliability module is designed to provide a preliminary foundation for engineers, planners, asset managers, and new employees joining the industry as well as all stakeholders interacting with planning and asset management functions on the fundamentals of Asset Management (AM). This module will focus on three key areas, including establishing a baseline understanding of asset management industry standards (e.g. ISO 55000) that serve to provide a foundation for organizations to begin developing their asset management practices, processes, analytics, reliability analyses and planning outputs.

Participants will gain hands-on learning of fundamental asset management decision-making frameworks and processes, and how these frameworks and processes can be leveraged to deliver long-term, short-term and maintenance planning outputs.

By the end of the module, attendees will be equipped with the preliminary skills and knowledge necessary to be able to assess their own organization from an AM perspective, develop the necessary decision-making processes, and ensure that the produced outputs are data-driven, prudent and defendable.

Module Objectives:

1. Provide insights into the major philosophies and accepted industry standards for asset management and reliability analyses, as well as relevant and necessary foundational resources and requirements for a successful AM practice implementation.

2. Provide relevant guidance on how existing data - of any data quality and maturity level - can be leveraged to develop objective, data-driven and justified AM decisions and outputs, and how this data can evolve to enhance AM outputs over time.

3. Walkthrough and develop sample AM applications, including decision-making analytics and investment plans, leveraging applicable real-world case studies, that meet the objectivity, prudence and data-driven requirements.

4. Discuss the methods available to continually evolve and improve upon the AM practice, leveraging easy-to-implement measures and metrics.

5. Evaluate the potential challenges that every AM practice faces from a change management perspective, and explore options to mitigate these challenges and maximize buy-in.

Learner Outcomes:

1. Establishing Foundational Asset Management Resources
    1.1. Participants will have gained an understanding of the AM definitions and key benefits
    1.2. By the end of this module, participants will be able to identify and explain the fundamental principles of accepted industry-wide AM standards such as ISO 55000, as well as recommended forms of analytics as derived from these standards (e.g. criticality and risk-based analytics)
    1.3. Participants will have developed knowledge of the foundational requirements and components necessary for a successful AM practice, including AM Policy, SAMP and AMPs.
2. Building the Asset Management Intelligence
    2.1. Participants will also be able to recognize how improved data quality and maturity levels of AM inputs (i.e. availability, accessibility and quality of data within their organizations) can result in enhanced AM outputs and decision-making.
    2.2. By the end of this module, participants will possess introductory knowledge of practical analytics to support capital investments and perform reliability analyses.
    2.3. By the end of this module, participants will possess introductory knowledge of practical analytics to support maintenance investments and perform reliability analyses.
3. Delivering Asset Management Outputs
    3.1. By the end of this module, participants will understand how their AM practice can lead to the development of capital and maintenance plans.
    3.2. By the end of this module, participants will understand how to establish Reliability Reporting Frameworks.
    3.3. By the end of this module, participants will understand how to develop business cases and justification.
    3.4. Participants will gain knowledge from a practical case study showing the adoption of an AM practice within the organization, including key successes and challenges.

Key Concepts Covered:

1. Establishing Foundational Asset Management (AM) Resources
    1.1. Definition and Key Benefits of Asset Management
    1.2. AM Standards and Best Practices (e.g. ISO 55000, IAM AM Anatomy & Competences Framework, Risk-Based Analytics)

1.3. Foundational AM Documentation (AM Policy, SAMP, AMPs)

2. Building the Asset Management Intelligence
    2.1. Walkthrough on typical data inputs and maturity levels, and on how improved data quality, accessibility and availability can result in enhanced reliability analyses, capital and maintenance investment decision-making
    2.2. Developing Asset and Reliability Analytics to Support Capital Investment Decision-Making (age, condition, criticality and risk, life-cycle costing models, reliability reporting and forecasting)
    2.3. Developing Asset and Reliability Analytics to support Maintenance Investment Decision-Making (maintenance planning strategies (time-based, age-based, condition-based, RCM, risk-based, etc.), maintenance frequencies, root cause analyses, computerized maintenance management systems (CMMS), failure mode and effect analyses (FMEA), etc.)
3. Delivering Asset Management Outputs
    3.1. Developing Capital and Maintenance Investment Plans
    3.2. Developing Reliability Reporting Frameworks
    3.3. Developing Business Case Justification
    3.4. Adoption of AM in an Organization: Successes and Challenges

Module 6: Markets

Module Overview:

This module introduces the North American energy markets, specifically focusing on hydro generation. It aims to familiarize participants with the U.S. energy markets' histories, regulatory compliance, and daily operations.

The module is designed for individuals with minimal prior market experience.

Module Objectives:

4. Explore the historical development of North American energy markets.
5. Determine the regulatory and compliance requirements for hydro generation.
6. Characterize hydro generation's daily operations and market dynamics within the U.S.
7. Evaluate key challenges and opportunities within the energy markets for hydro generation.

Learner Outcomes:

4. Explore the historical development of energy markets.
    4.1. Review the history and evolution of North American energy markets.
5. Characterize daily operations and market dynamics.
    5.1. Outline the daily operational processes in U.S. energy markets.
6. Evaluate key challenges and opportunities within the energy markets.
    6.1. Apply knowledge of market dynamics to optimize hydro generation operations.

Key Concepts Covered:

1. Introduction to North American Energy Markets
    1.1. Overview of energy markets
    1.2. Key regulatory bodies and their roles
    1.3. Historical context and evolution
2. Market Operations and Dynamics
    2.1. Overview of market operations
        2.1.1. Day Ahead and Real-Time

        2.1.2. Energy and Capacity Products
    2.2. Role of hydro generation in the energy mix
    2.3. Market mechanisms and price formation
    2.4. Case study: Typical day in the life of a market participant with hydro
3. Challenges and Opportunities in Hydro Generation
    3.1. Key challenges (e.g., environmental regulations, water rights)
    3.2. Opportunities for optimization and innovation
    3.3. Future trends and market developments
4. Q&A and Wrap-up
    4.1. Summary of key points
    4.2. Questions

Module 7: Environment

Module Overview:

The Environment Module is designed to educate course attendees on the environmental review process and potential environmental impacts associated with the operation of various hydroelectric projects. This comprehensive module will cover the broad range of environmental resource categories evaluated during a National Environmental Policy Act (NEPA) review. Such categories include geology and soils, water use and quality, fish and aquatics, terrestrial and wetlands, rare, threatened, and endangered species, recreation and land use, aesthetics, socioeconomics, environmental justice, and cultural and tribal resources.

In addition, course attendees will develop a cursory understanding of common mitigation measures implemented at hydroelectric projects to address environmental impacts.

By the end of the module, attendees will be equipped with the skills needed to identify the potential environmental impacts and benefits of a hydroelectric project based on its characteristics and environmental setting, as well as possible mitigation measures that may be required.

Module Objectives:

1. Explore NEPA and its implications for a hydroelectric project.
2. Determine various resource elements in a NEPA review and how they are addressed.
3. Evaluate a hydroelectric project's potential environmental impacts and benefits based on its characteristics and environmental setting.
4. Examine common mitigation measures that are often implemented at hydroelectric projects.

Learner Outcomes:

1. Describe NEPA.
    1.1. Learners will explain what NEPA is, who is responsible for implementing it, and its implications for a hydroelectric project.
2. Explain various NEPA environmental resource categories.
    2.1. Learners will identify the environmental resource areas associated with an NEPA review and the project’s potential impacts to those resources.
3. Assess potential environmental impacts and benefits of a hydroelectric project.

3.1. Learners will evaluate potential environmental resource impacts and benefits at a hydroelectric project based on its characteristics and environmental setting.

4. Compare common mitigation measures.
    4.1. Learners will explore common mitigation measures applied at hydroelectric projects to address various resource impacts.
    4.2. Learners will select potential mitigation measures for potential project impacts.

Key Concepts Covered:

1. Overview of NEPA
    1.1. What is NEPA
    1.2. Who is responsible for satisfying its requirements
    1.3. How does it apply to a hydroelectric project
2. NEPA Environmental Resource Categories
    2.1. Geology and Soils
    2.2. Water Use and Quality
    2.3. Fish and Aquatics
    2.4. Terrestrial and Wetlands
    2.5. Rare, Threatened, and Endangered Species
    2.6. Recreation and Land Use
    2.7. Aesthetics
    2.8. Socioeconomics and Environmental Justice
    2.9. Cultural and Tribal Resources
    2.10. Climate Change
3. Overview of Common Mitigation Measures
    3.1. Downstream flow requirements
    3.2. Water level operational restrictions
    3.3. Fish passage
    3.4. Water quality enhancement
    3.5. Recreation enhancements
    3.6. Management plans
4. Module Practicum and Wrap-Up

4.1. Case Study/Class Exercise: Identify potential environmental resource issues at a hypothetical project(s) and possible mitigation measures to address such issues

4.2. Key takeaways from the module

Module 8: FERC Licensing and Compliance

Module Overview:

Most non-federal hydroelectric projects in the United States fall under the jurisdiction of the Federal Energy Regulatory Commission (FERC), requiring authorization for construction and operation in the form of a long-term FERC license or license exemption. Hydroelectric projects and associated facilities are also subject to other federal and state environmental statutes and regulations.

The FERC Licensing and Compliance Module is designed to provide attendees with an understanding of the various regulatory processes associated with the licensing of hydroelectric projects and major aspects of license compliance. This comprehensive module will cover a broad spectrum of regulatory topics, including FERC licensing and other authorizations of non-federal hydropower projects, pertinent statutes and associated consultation requirements, license amendments, transfers, and surrenders.

Participants will engage in hands-on training and simulations to understand the complexities of these regulatory processes.

By the end of the module, attendees will be equipped with a cursory knowledge of a broad range of regulatory requirements and a firm understanding of the key players involved in these regulatory proceedings.

Module Objectives:

1. Examine the various FERC authorizations for hydropower projects.
2. Assess the key players and their associated statutory authority as it pertains to FERC licensing.
3. Evaluate other regulatory considerations pertaining to license compliance.

Learner Outcomes:

1. Assess the pertinent laws and regulations associated with FERC licensing.
    - 1.1. Learners will examine the various laws and regulations that are pertinent to FERC licensing as well as their implications
    - 1.2. Learners will identify regulatory jurisdictions and conditioning authority for the key players likely to participate in FERC licensing
    - 1.3. Learners will explain the consultation requirements and potential implications associated with key players' regulatory authority
    - 1.4. Based on the resource issues present at a given hydroelectric project, learners will evaluate which key players would likely participate in a FERC licensing proceeding and which laws and regulations they would have authority under.

2. Examine the FERC licensing process.
    2.1. Learners will identify the difference between a license and an exemption
    2.2. Learners will compare the three primary FERC licensing processes
3. Evaluate license compliance regulatory considerations.
    3.1. Learners will explain license amendments, surrenders, and transfers as well as other standard compliance requirements

Key Concepts Covered:

1. Hydropower Authorizations
    1.1. Preliminary Permits
    1.2. Licenses
    1.3. Exemptions
2. Hydropower Jurisdictions and Statutory and Regulatory Requirements
    2.1. Federal Energy Regulatory Commission (FERC)
    2.2. Federal Power Act
    2.3. National Environmental Policy Act (NEPA)
    2.4. Clean Water Act
    2.5. Endangered Species Act
    2.6. National Historic Preservation Act
    2.7. Other miscellaneous laws and regulations pertinent to licensing
3. Overview of FERC Licensing
    3.1. Overview of FERC Licensing
    3.2. Licensing Processes (TLP, ILP, ALP, Expedited Licensing Process)
    3.3. Class Activity: Identify key regulatory players and the applicable laws and regulations they have authority under based on a hypothetical example.
4. License Compliance
    4.1. Amendments
    4.2. Surrenders
    4.3. Transfers
    4.4. Non-FERC Permitting
    4.5. Tools and Resources
5. Module Wrap-Up
    5.1. Key takeaways from the module