DESIGN, DEVELOPMENT AND OPERATION OF PROTON EXCHANGE MEMBRANE (PEM) STACK

Precision Engineering for Sustainable Energy

Conducted by your Expert Instructor: Hunor Kacso

Hunor is a Hydrogen Engineer from the United Kingdom specialising in PEM (Proton Exchange Membrane) stack technology. His expertise encompasses the entire lifecycle of PEM systems, from initial design concepts to development and operational optimisation. Hunor has played a crucial role in the deployment of several large-scale, state-of-the-art PEM electrolyser systems worldwide. Hunor in-depth knowledge of PEM stack design, principles, materials science, and system integration has been invaluable in pushing the boundaries of electrolyser efficiency and durability.

What other past participant have shared about your expert course instructor`s training courses:

- *"*Hands on explanation of electrolyser design, operation, limitation which was carried out by Hunor, was amazing!" ***Process Engineer, Petronas.***
- "I found that the general electrolyser principles course and the stack development training provided my colleagues with a broader understanding of the technical aspects of our products. This, in turn, helped them contribute to the further development of our products." ***Senior Manager, ITM Power.***
- "Good technical information on PEM Stack design requirements." ***Principal Engineer Utility Water, Petronas Group Technical Solution Sdn Bhd.***
- The best trainer i've met. Hunor knows the PEM technology very well from the design till operations. He engaged with participants very well through group presentation/recap what we have learned so far." ***Executive Petrochemicals, Petronas.***

About this Classroom Training Course:

In the rapidly evolving landscape of sustainable energy, Proton Exchange Membrane (PEM) electrolyser technology stands at the forefront of green hydrogen production. As the world intensifies its efforts to decarbonise and transition to clean energy systems, PEM electrolysers have emerged as a crucial technology for efficient, scalable, and environmentally friendly hydrogen generation.

This comprehensive 4-day course delves deep into the heart of PEM electrolyser technology, focusing on the design, development, and operation of PEM stacks. As industries worldwide accelerate their hydrogen strategies, understanding the intricacies of this technology has become more critical than ever. PEM electrolysers offer distinct advantages in terms of efficiency, rapid response times, and compatibility with renewable energy sources, making them indispensable in the green hydrogen economy.

This course provides a comprehensive examination of the design and operation of efficient and durable electrolyser stacks. Participants will explore essential components, emphasising material selection, optimisation strategies, and performance enhancement. The course includes in-depth discussions on gas, water and thermal management, and practical applications to ensure participants can effectively implement their knowledge in real-world contexts. Hands-on training will involve constructing a PEM electrolyser stack and performing performance evaluations that offers valuable experience in stack assembly and operational diagnostics.

Participants will, by the end of the course be able to have the knowledge to design their own basic electrolyser stack. This will provide the whole picture on the design section that need to be considered by the teams to achieve in perfecting the stack in terms of durability, cost and efficiency.

Objectives of this Classroom Training Course:

By the end of this 4 days training course, participants will be able to:

- Explain the principles in detail of PEM stack operation and the overall energy conversion process.
- Describe in detail all components and their purpose, which make up an industry standard PEM electrolyser stack, including required electrochemical characteristics.
- Evaluate key design parameters that influence the performance of PEM stack.
- Assess and interpret all significant performance metrics of PEM stack.
- Recognize and apply essential safety protocols related to the operation and maintenance of PEM stack.
- Gain hands on experience in building PEM electrolyser stack and in conducting testing and validation of PEM stack.
- Consider the relationship between reliability and efficiency/cost.
- Overcome reliability problems which plague all large-scale PEM electrolysis and the most advanced PEM electrolyser manufacturers/clients.

Who Should Attend this Classroom Course?

This course has been designed for professionals working in the PEM electrolyser stack system that looking to further develop their careers to keep up to date on emerging design, development and operation.

- Chemical Engineers involve in optimize chemical processes within the PEM system focusing on reaction efficiency and power utilization.
- Mechanical Engineers participate in design of the mechanical aspects of the systems.
- PEM Electrolysis Engineers or Electrolysis Engineers that construct and develop the PEM system, focusing on improving efficiency and performance.
- Energy Systems Engineers responsible for integrating the system into larger energy systems, ensuring optimal power utilization and system efficiency.
- Quality Control Engineers accountable for ensuring PEM systems and components to meet quality standards and performance specifications.
- Environmental Engineers function to assess and mitigate environmental impacts to promote sustainable practices.
- R&D Specialists and Product Development Engineers work to develop new products and improve existing ones to meet market demands.
- Material Scientists involve in developing and testing new materials for membranes, catalysts, and other components to enhance PEM performance.
- Operations Managers that manage the operation of the PEM electrolyser systems, ensuring they run efficiently and effectively.

Delivery of this Course:
This course will be delivered face-to-face over 4-day sessions, comprising of 8 hours per day, 1 hour lunch and 2 breaks of 15 minutes per day. Course Duration: 32 hours in total.

Other useful information at a glance:

Course level	Intermediate - Advanced

Learning Approach:
- Course material will be provided for future reference.
- Each topic begins with a statement of the intended learning outcome (LO).
- Activities such as quizzes, videos and assessment will be incorporated.

About your Expert Instructor: Hunor Kacso
With over six years of specialization in Proton Exchange Membrane (PEM) electrolysis, Hunor is recognised as an expert in hydrogen engineering. His extensive industry experience drives innovations that reduce costs and advance the green hydrogen economy. Hunor has designed and deployed some of the largest electrolysis systems, giving him comprehensive operational expertise across the entire project lifecycle—from conceptual design to commissioning fully integrated GW-scale plants. He has played a key role in improving the reliability, efficiency, and safety of various generations of electrolyser technology.

As an inspiring instructor, Hunor has trained many professionals worldwide through comprehensive courses tailored to impart cutting-edge expertise in electrolyser stack. His training programs have become catalysts for upskilling corporations to excel in the hydrogen future. With a passion for empowering others, Hunor continues to shape the next generation of clean hydrogen experts, accelerating the global transition to sustainable energy.

Hunor's industry experience and technical excellence, position him as an expert in electrolysis. After completing his engineering education, he advanced in the electrolyser manufacturer ITM Power, gaining practical experience in this emerging technology rather than pursuing an academic path. To give back to his alma mater, Hunor has contributed content, material development, and industrial experience to the University of Sheffield, Brunel University London, and the AMRC. Additionally, he has conducted highly technical training on electrolysis equipment to support ITM Power, significantly reducing training time by up to 50%, improving productivity, and easing the burdens of team leaders.

Course Timings and Breaks - First to Last Day Schedule :	
830	Registration
900	Start of training
1030	Morning break
1045	Training recommences
1230	Lunch break
1330	Training recommences
1515	Afternoon break
1530	Training recommences
1700	End of training
Note : Sequence and discussion time per module is subject to adjustment based on mutual agreement between trainer and learners.	

4 DAY COURSE OUTLINE

Day 1

Chapter 1: Membrane Electrode Assembly (MEA)

1.0 Proton Exchange Membrane
- Material Selection
  - Types of Membranes (e.g., Nafion, PFSA, Composite Membranes)
  - Selection Criteria (Durability, Cost, Conductivity)
- Thickness Optimisation
  - Trade-Offs between Mechanical Strength and Proton Conductivity
  - Impact on overall Stack Performance
- Ion Conductivity
  - Methods for enhancing Ion Conductivity (e.g., Doping, Cross-Linking)
  - Measurement Techniques

1.1 Catalyst Layers
- Catalyst Composition
  - Types of Catalysts (e.g., Platinum-Based, non-precious Metal Catalysts)
  - Role of Catalyst supports (e.g., Carbon, Metal Oxides)
- Loading Optimisation
  - Methods to reduce Catalyst Loading while Maintaining Performance
  - Impact on Cost and Efficiency
- Dispersion Techniques
  - Techniques for Uniform Catalyst Distribution (e.g., Spraying, Inkjet Printing)
  - Influence On MEA Performance

1.2 Gas Diffusion Layers
- Porosity
  - Effect on Gas Transport and Water Management
  - Characterisation Methods
- Hydrophobicity
  - Role in Water Management and Flooding Prevention
  - Surface Treatment Techniques
- Electrical Conductivity
  - Impact on Overall Stack Resistance
  - Material Selection and Optimisation

Chapter 2: Bipolar Plates

2.1 Materials
- Metallic
  - Common Materials (e.g., Stainless Steel, Titanium)
  - Surface Treatments and Coatings (e.g., Gold Plating, Conductive Polymers)
- Composite
  - Types of Composite Materials (e.g., Graphite, Carbon-Polymer composites)
  - Trade-Offs between Conductivity and Weight

2.2 Manufacturing Processes
- Techniques (e.g., Stamping, Molding, Machining)
- Cost Considerations and Scalability
- Impact on Plate Performance and Durability

2.3 Corrosion Resistance
- Mechanisms of Corrosion in PEM electrolyser Cells
- Coating Technologies and Treatments
- Long-Term Performance and Testing

Chapter 3: Gas Management

3.1 Flow Distribution
- Design of Flow Fields (e.g., Serpentine, Parallel, Interdigitated)
- Impact on Reactant Distribution and Performance

3.2 Pressure Drop
- Minimising Pressure Drop across the Stack
- Balancing Flow Resistance and Uniform Distribution

3.3 Humidification
- Methods for Humidifying Reactant Gases (e.g., External Humidifiers, Internal Humidification)
- Impact on Membrane Hydration and Performance

3.4 Purge Strategies
- Techniques for Purging Impurities and Water
- Optimisation for Efficiency and Durability

Chapter 4: Water Management

4.1 Water Transport
- Mechanisms of Water Transport in PEM Stack
- Impact On Membrane Hydration and Stack Performance

4.2 Hydration Control
- Strategies for Maintaining Optimal Membrane Hydration
- Avoiding Dehydration and Associated Performance Losses

4.3 Flooding Prevention
- Identifying Causes of Flooding
- Design and Operational Strategies to Prevent Flooding

4.4 Freeze Protection
- Methods to prevent Damage during Freezing Conditions
- Design Considerations for Cold Climates

4.5 Water Removal Techniques
- Techniques for Effective Water Removal (e.g., Wicking Materials, Gas Purge)
- Impact on Stack Performance and Longevity

Activities: Quizzes

Day 2

Chapter 5: Thermal Management

5.1 Methods of Cooling
- Cooling Techniques (e.g., Air, Liquid Cooling)
- Trade-Offs between Cooling Efficiency and Complexity

5.2 Temperature Distribution
- Ensuring Uniform Temperature Distribution
- Impact on Performance and Durability

5.3 Coolant Selection
- Criteria for Selecting Coolants (e.g., Thermal Capacity, Compatibility)
- Common Coolant Types and their Properties

5.4 Heat Exchanger Design
- Principles of Heat Exchanger Design
- Impact on System Efficiency and Integration

Chapter 6: Sealing and Compression

6.1 Gasket Materials and Design
- Types of Gasket Materials (e.g., Elastomers, PTFE)
- Design Considerations for effective Sealing

6.2 Compression Methods
- Techniques for Compressing the Stack (e.g., Bolts, Hydraulic Compression)
- Ensuring Uniform Compression for Optimal Performance

6.3 End Plate Engineering
- Design of End Plates for Mechanical Stability and Load Distribution
- Material Selection and Manufacturing Techniques

6.4 Clamping Force Optimisation
- Balancing Clamping Force for Sealing and Minimising Resistance
- Impact on Stack Durability and Performance

Chapter 7: Electrical Systems

7.1 Current Collection
- Methods for Current Collection (e.g., Bus Bars, Conductive Adhesives)
- Design Considerations for Minimising Resistance and Losses

7.2 Voltage Monitoring
- Techniques for Monitoring Cell Voltage
- Integration with Control Systems for Performance Optimisation

7.3 Insulation
- Insulation Materials and Techniques
- Ensuring Safety and Preventing Electrical Shorts

7.4 Bus Bar Design
- Design of Bus Bars for effective Current Distribution
- Material Selection and Thermal Management

7.5 Oxidation Prevention
- Methods to Prevent Oxidation of Electrical Contacts
- Impact on Long-Term Performance and Reliability

Practical Training

PEM Electrolyser Stack Component Study Practical
- Building complete 2 Cells Stack with Dummy Membrane
- Demonstration of Hydrostatic Pressure Testing (Low Pressure for Safety Reasons)

Operational Training (Low Risk Activity)

Generating Hydrogen with Output of Gas of 0.9L/Min (About 55 Liter Per Hour)

Day 3

Chapter 8: Stack Assembly

8.1 Component Alignment
- Techniques for Precise Alignment of Stack Components
- Impact on Performance and Uniformity

8.2 Assembly Procedures
- Step-By-Step Assembly Processes
- Tools and Equipment for efficient Assembly

8.3 Quality Control
- Methods for ensuring Assembly Quality (e.g., Visual Inspection, Automated Systems)
- Impact on Overall Stack Reliability

8.4 Leak Testing
- Techniques for Detecting Leaks (e.g., Pressure Decay, Bubble Testing)
- Ensuring Airtight Seals for Optimal Performance

Chapter 9: Performance Optimisation

9.1 Polarisation Analysis
- Techniques for Polarisation Curve Measurement
- Analysing Performance Under different Operating Conditions

9.2 Electrochemical Impedance Spectroscopy
- Principles of Impedance Spectroscopy
- Applications for Diagnosing Performance Issues

9.3 Operating Conditions Optimisation
- Identifying Optimal Operating Conditions (e.g., Temperature, Pressure)
- Impact on Efficiency and Longevity

9.4 Reactant Stoichiometry
- Balancing Reactant Stoichiometry for Optimal Performance
- Avoiding Issues with Fuel and Oxidant Supply

Chapter 10: Durability And Lifetime

10.1 Degradation Mechanisms
- Common Degradation Mechanisms in PEM Electrolyser Stack
- Strategies for Mitigating Degradation

10.2 Hotspot Formation Modelling
- Identifying and Modeling Hotspots
- Impact on Performance and Strategies for Mitigation

10.3 Fluoride Release
- Causes and Impact of Fluoride Release
- Methods for minimising and measuring Fluoride Emissions

10.4 Accelerated Stress Testing
- Techniques for Accelerated Stress Testing
- Predicting Long-Term Performance and Durability

10.5 Mitigation Strategies
- Strategies for Mitigating Degradation and Extending Lifetime
- Impact on Performance and Cost

10.6 Predictive Modelling
- Modeling Techniques for Predicting Stack Lifetime
- Incorporating Real-World Data for Accuracy

Chapter 11: Cost Reduction

11.1 Material Selection
- Cost-Effective Material Selection Strategies
- Balancing Cost and Performance

11.2 Process Optimisation
- Techniques for Optimising Manufacturing Processes
- Reducing Waste and Improving Efficiency

11.3 Design for Manufacturability
- Principles of Design for Manufacturability
- Impact on Production Cost and Scalability

11.4 Supply Chain Management
- Strategies for efficient Supply Chain Management
- Reducing Lead Times and Costs

PEM Electrolyser Stack Operational Study Practical
- Generating Hydrogen at Low Current Density Operation
- Generating and Analysing an IV Curve
- Data Collection and Analysis at o varying Pressures
- Varying Current Densities

Day 4

Chapter 12: System Integration

12.1 Balance of Plant Components
- Key Components of The Balance of Plant (e.g., Pumps, Water Purification System, Hydrogen Dryer and Gas Purification and Power Supply Unit)
- Integration with The Stack for Optimal Performance
- Industry Standards relating to Balance of Plant and Process Safety

12.2 Control Systems
- Design of Control Systems for efficient Operation
- Monitoring and adjusting Operating Conditions

12.3 Power Conditioning
- Techniques for Power Conditioning and Conversion
- Ensuring Stable and efficient Power Output

Chapter 13: Testing And Characterisation

13.1 In-Situ Diagnostics
- Techniques for In-Situ Diagnostics (e.g., Sensors, Monitoring Systems)
- Real-Time Performance Assessment

13.2 Ex-Situ Analysis
- Techniques for Ex-Situ Analysis (e.g., Microscopy, Spectroscopy)
- Detailed Characterisation of Components

13.3 Pressure Testing
- Methods for Pressure Testing
- Ensuring Integrity and Performance Under Pressure

13.4 Leak Testing
- Techniques For Detecting and Preventing Leaks
- Ensuring Tight Seals for Optimal Performance

13.5 Performance Mapping
- Techniques for Performance Mapping
- Identifying Performance Trends and Issues

13.6 Durability Evaluation
- Methods for Evaluating Durability
- Long-Term Performance Assessment

Chapter 14: Modeling And Simulation

14.1 Computational Fluid Dynamics
- Principles of Computational Fluid Dynamics (CFD)
- Applications for Flow and Thermal Analysis

14.2 Electrochemical Modeling
- Techniques for Electrochemical Modeling
- Simulating Stack Performance Under Various Conditions

14.3 Thermal Modeling
- Principles of Thermal Modeling
- Applications for Heat Management and Optimisation

14.4 Multiphysics Simulation
- Integrating Multiple Physical Phenomena in Simulations
- Predicting Overall Stack Performance and Behavior

Practical To Investigate Stack Safety
- Capacitor Properties
- Electrolyser Cell Properties