



R2

FROM SIL2 TO AI: CELL ROOM SAFETY INNOVATION

**R2 Safety and Condition
Monitoring Solutions for
Green Hydrogen**



R2: GLOBAL LEADER IN ELECTROLYSIS MONITORING AND OPTIMIZATION

With customers in over 25 countries and monitoring over 100,000 cells, R2's expertise lies in developing advanced monitoring and optimization technologies for industrial-scale electrolysis processes.

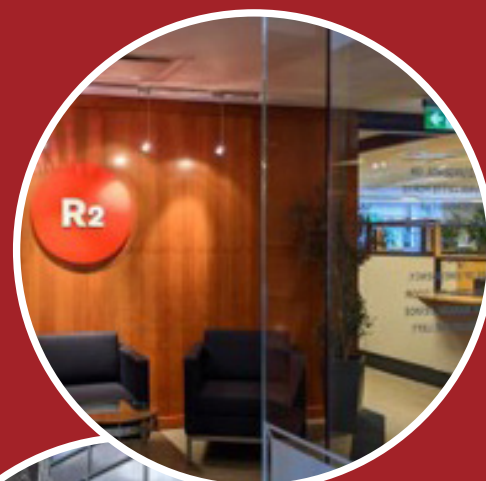


Designed for the critical challenges in the cell room environment, R2's EMOS® SIL2 Safety System has been the reference solution in the chlor-alkali industry for the last thirty years, with leading chemical plants worldwide relying on our EMOS suite of solutions to optimize their efficiency and reliability.

As the only SIL2 certified cell voltage monitoring system on the market, it offers early detection of numerous potential faults and provides recommendations that allow operators to enhance overall electrolyzer safety and productivity.

In addition to rigorous performance analyses, R2's multi-layer protection algorithms and comprehensive diagnostics easily integrate to offer fail-safe and independent operation to ensure continuous protection, even if other systems fail.

R2's EMOS® SIL2 Safety System has been tailored to address water electrolyzer standards in Alkaline Electrolysis (AEL), Proton Exchange Membrane (PEM), and Anion Exchange Membrane (AEM) processes, ensuring hydrogen production is both efficient and secure.





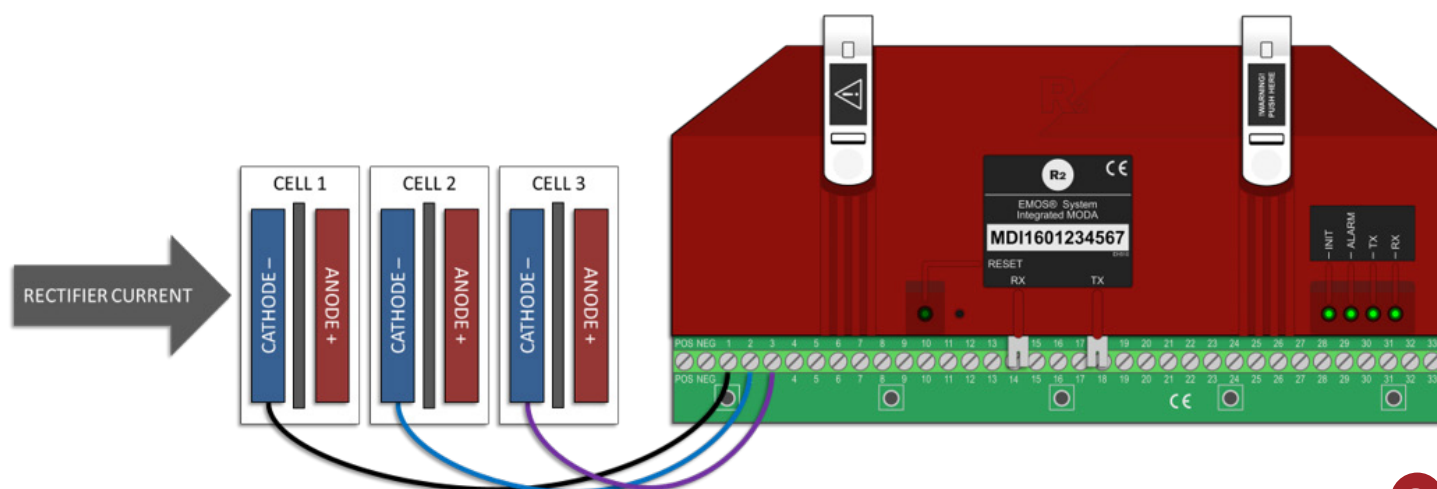
In hydrogen electrolysis, monitoring voltages is vital for assessing process effectiveness and hydrogen production integrity.

Beyond stack monitoring, individual cell performance evaluation is essential for optimal operation and equipment longevity. Identifying underperforming cells allows for effective maintenance strategies prioritizing addressing weak individual cells and detecting potential inefficiencies and mitigating risks. This proactive approach ensures enhanced system performance and reliability.

Traditional methods such as voltage deviation systems, Balance Voltage Monitoring Systems (BVMS), or Stack Monitoring often fall short in detecting critical issues due to their limited precision and susceptibility to noise interference.

The EMOS® SIL2 Safety System introduces a paradigm shift with meticulous measurement and analysis of the voltage-current-time relationship of each individual cell and stack.

With unparalleled precision in individual cell voltage measurement ($\pm 1.5\text{mV}$) and rapid data acquisition, you can ensure a level of sensitivity and accuracy that surpasses industry standards. The rapid response capability of 250ms scan rate and patented fault detection algorithms ensure a superior level of operational safety, adhering to the highest international standards.



UNLOCKING OPERATIONAL BENEFITS WITH R2'S SOLUTIONS

The system is especially designed for the critical challenges in the cell room environment, featuring a high degree of data acquisition precision, a fast-sampling rate, temperature compensated measurements, and noise filtering algorithms.

The **EMOS® SIL2 Safety System** empowers operators with unparalleled insight into the electrolysis process to maintain electrolysis integrity, including the following:



Minimize Power Consumption

Overworked cells become inefficient and can damage the electrolyzer. Proper monitoring, managing, and responding to issues like electrode and membrane degradation keeps operations within a 'safe' zone, avoiding premature aging and ensuring optimal performance.



Protect Against Hazardous Operation

Maintaining stringent operational standards is essential to prevent hazardous incidents, such as explosions due to gas leaks. These leaks are often caused by cell failures due to overheating, cell aging, chemical degradation, or mechanical stress.



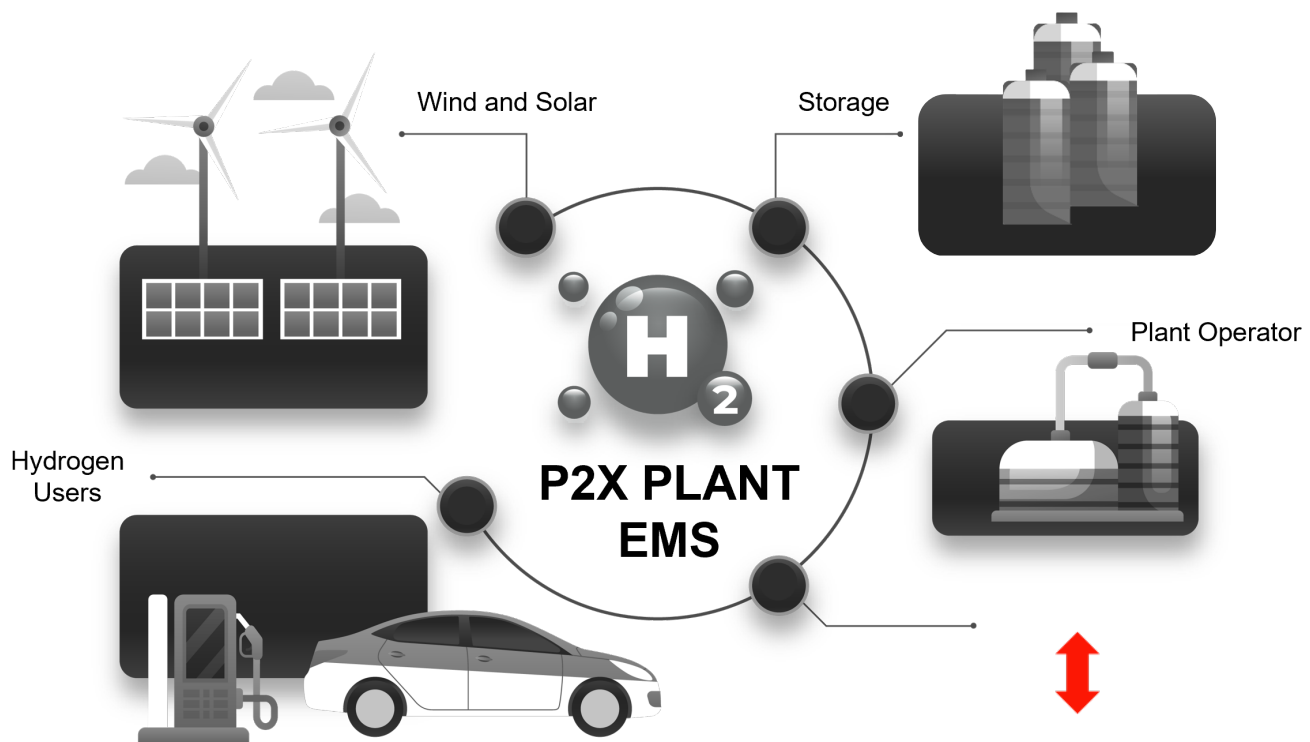
Monitor Membrane Health

The membrane is crucial for ion transport and preventing undesirable crossover. Protecting it ensures efficiency and safety in electrolysis. Shielding it from harsh conditions extends the electrolyzer's life, enhances efficiency, and reduces costs and environmental impact.



Detect Damaged Parts

Damaged parts, such as gaskets, can lead to costly and dangerous hydrogen and oxygen loss. Real-time fault detection uses historical data patterns to warn of potential issues, enabling preemptive maintenance. AI converts raw data into actionable intelligence, offering a comprehensive view of plant health and efficiency.



Our robust technology and software offering is the connection between your electrolyzer and the P2X Plant EMS ecosystem, enabling you to optimize the power consumption of your electrolyzer while handling the power fluctuations caused by energy supply variances.

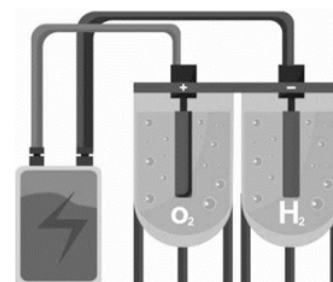
Capable of detecting and mitigating risks like membrane degradation and electrical shorts, our AI-Powered Condition Monitoring analyzes cell behavior in real-time to prevent operational issues and manage frequent starts and stops, thereby preventing accelerated cell degradation.

The power savings enabled through individual cell monitoring not only allows for operational cost savings but provides a rich data source for electrolysis technology R&D teams to analyze performance metrics, identify new optimization strategies, and develop next-generation solutions.



SAFETY AND AI-POWERED CONDITION MONITORING AT CELL LEVEL

HARDWARE	SOFTWARE	SERVICES
		Hazard Operation Protection
		Asset Health Monitoring
		Damage and Fault Detection
		Asset Degradation Prevention

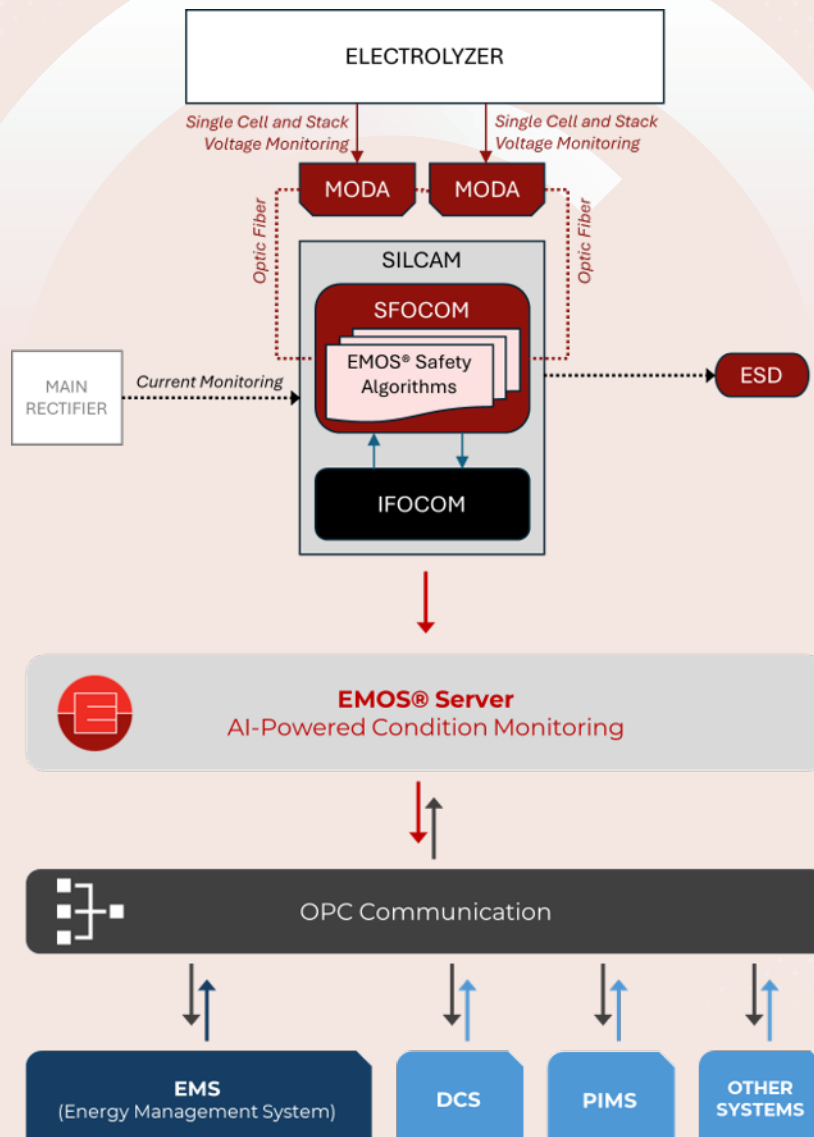


ENSURING SAFETY AND EFFICIENCY WITH R2'S INTEGRATED SOLUTIONS

R2's innovative **EMOS® SIL2 Safety System** is composed of our MODA, an intelligent data acquisition sensor, along with the SILCAM, the logic solver, which has the SFOCOM that contains our patented algorithms provide a safe zone of operation, and the IFOCOM to reliably communicate with the EMOS® Server.

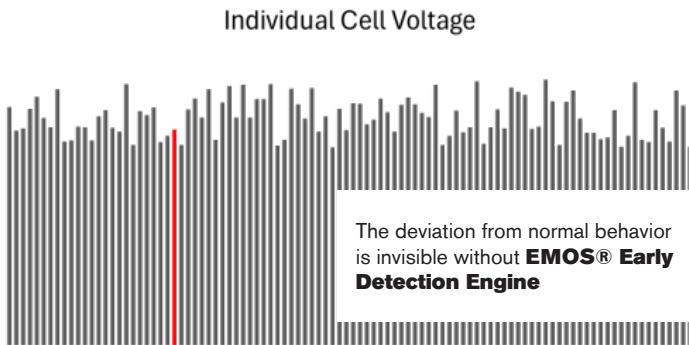
Engineered with safety at its core, the system features IPX7-rated chemical protection and optional Explosion Proof certification for high-risk environments. Equipped with advanced fiber optic communications our system ensures a superior level of operational performance, adhering to the highest international standards.

The system is designed to easily integrate with various supervisory and management systems such as Energy Management Systems (EMS) and Distributed Control Systems (DCS). Facilitated through the SFOCOM and IFOCOM, inside the SILCAM Logic Solver, and the EMOS Server, the overall integration is enhanced by the ability to communicate with other systems via standard and proprietary protocols and OPC communication, ensuring that all components of the system maintain operational safety and efficiency.



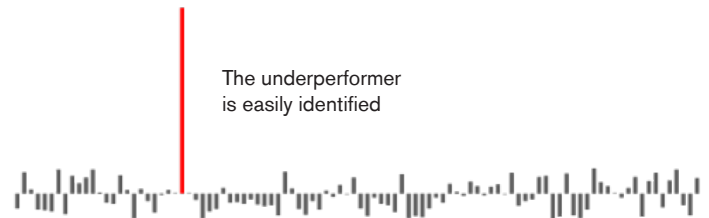
ADVANCED REAL-TIME ANALYTICS FOR EARLY FAULT DETECTION

Adding another layer to the cell and stack voltage monitoring, the EMOS® Early Detection Engine (EDE) employs cutting-edge machine learning predictive analytics to anticipate failures before they manifest.



The EDE system's ability to compare real-time cell voltage with its modeled normal behavior enables prompt corrective actions, not only reducing reliance on operator expertise but also minimizing the time required to resolve incidents, thereby enhancing overall plant safety and productivity.

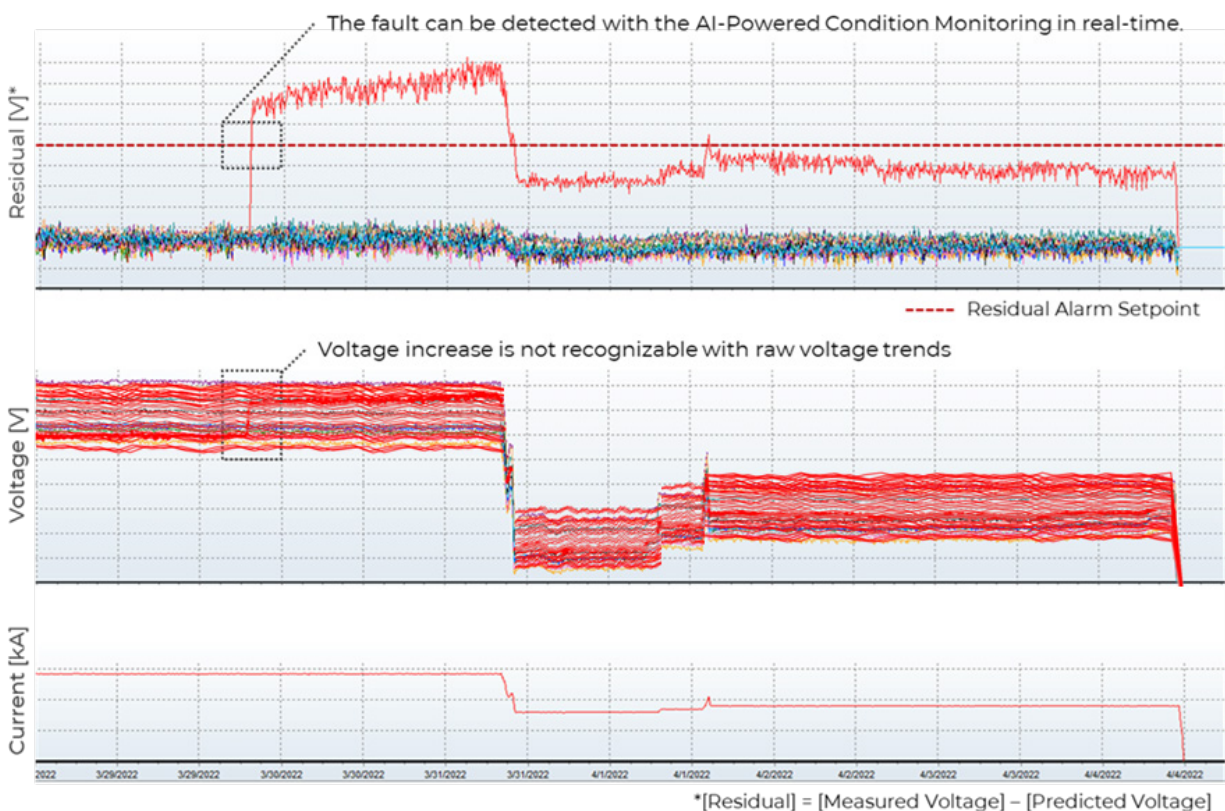
EDE Residual - Voltage deviation between the predicted and the measured values.



The impact of the **EMOS® Early Detection Engine** on monitoring electrolytic cell performance is significant. It clearly identifies abnormal behavior through significant deviations that mask underlying issues, potentially leading to unplanned shutdowns or irreversible damage.



EMOS® Early Detection Engine
The Residual* is the KPI the process needs.



THE POWER OF EMOS® ADVISORY AI

Building upon the foundation of EDE, **EMOS® Advisory AI** represents an evolution in fault detection and resolution capabilities. Developed from over 30 years of HAZOP and Root Cause Analysis, **EMOS® Advisory AI** identifies the specific problems and their locations and recommends corrective actions through the **EMOS® View** user interface.

By continuously monitoring process parameters such as temperatures, pressures, flow rates and their interrelationships from both historical and real-time performance metrics, it goes beyond traditional alarm systems by offering detailed root cause analysis and suggesting actionable recommendations to operators, avoiding extensive HAZOP sections.

Additionally, the intelligent monitoring capabilities of **EMOS® Advisory AI** streamline alarm resolution, reduce training times, and minimize dependence on operator skills or the need for higher management intervention.

This advanced system offers customizable recommendations tailored to incorporate your specific Plant Standard Operating Procedures, providing operators with precise, actionable insights for immediate corrective actions.

ACHIEVING PEAK PERFORMANCE WITH AI-POWERED CONDITION MONITORING

Safety is paramount, but so is optimizing performance and extending the equipment's lifespan. Achieving these goals requires real-time insights and actionable data for informed decision-making by the operation and maintenance teams.

The AI-Powered Condition Monitoring system from R2 offers a complete solution for the electrolysis process, integrating high precision SIL2 Hardware and Software Voltage Monitoring System. Integrating seamlessly with existing infrastructure, including Energy Management System (EMS), we provide unparalleled customization.

Our software allows operators and maintenance teams to take informed decisions and swiftly correct faults, leading to reduced downtime and ensures production targets are met.