EXECUTIVE SUMMARY

Understanding and Managing the Power Quality Impacts of Large Electrolyzers on the Power Grid

PRIMARY AUDIENCE

The primary audience for this work includes utility engineers, power quality (PQ) engineers, and grid planners who are involved in or would like to prepare for the integration of electrolyzer facilities into the power grid. Additionally, electrolyzer owners, operators, and manufacturers should be aware of this work as well. A key aspect of this work was to increase understanding of the implications of integrating electrolyzers into the power grid, further supporting collaboration and improving the ability of utility engineers and electrolyzer developers to address potential challenges. Finally, regulatory bodies are a target audience as gaps in regulations, codes, and standards are highlighted in this work.

KEY RESEARCH QUESTION

Given the potential scale of future deployment of electrolysis facilities, there is potential for adverse PQ impacts on the grid. Conversely, it is also likely that such facilities will be vulnerable to transient events that occur on the grid. To mitigate adverse impacts to both the grid and electrolysis facilities, a clear need exists to understand vulnerabilities ahead of time. Thus, this project seeks to answer the following research questions:

- How would transient events originating on the electrical grid impact electrolysis systems?
- How would the integration of electrolysis systems affect grid PQ, and how would these impacts vary during different stages of electrolyzer operation?
- How can utilities be best prepared for the integration of electrolysis systems into their grids?
- What tools and techniques need to be developed to help utility planning and PQ engineers better understand the impact of electrolysis systems on the grid?

- How can regulatory bodies and lawmakers support grid reliability as electrolysis facilities are integrated?
- What measurement tools and techniques are necessary to monitor electrolysis facilities after installation?
- What mitigation tools and techniques can be used when electrolysis facilities cause unacceptable PQ excursions?

RESEARCH OVERVIEW

As the push towards reducing emissions intensifies, hydrogen production via electrolysis has emerged as an attractive pathway to decarbonize some hard-to-abate sectors. Thus, electric utilities are gearing up for a future where more electrolyzers and other large loads will be integrated into their systems by understanding the technology and developing tools for planning. As a result, this research focuses on the integration of electrolysis facilities into the power grid, examining the potential PQ impacts and proposing mitigation strategies.

This work builds a foundational understanding of the potential grid impacts, from a PQ perspective, of electrolysis facilities. It does this by identifying best practices to mitigate these impacts and enhance facility energy efficiency, pinpointing vulnerable equipment in electrolysis facilities and proposing methods to harden against adverse PQ events, and reviewing existing standards and identifying gaps in knowledge and standardization.

KEY FINDINGS

- As electrolyzers become integrated into the grid, they are expected to contribute to PQ issues such as:
  - Harmonics emission: Electrolyzer rectifiers emit odd harmonics that can cause disturbances in voltage, leading to heat losses and electromagnetic interference with other equipment connected to the grid.
  - Supraharmonics emission: Active power electronic switching in electrolyzers can cause supraharmonics, leading to the production of visible flicker in lights, interference with landline telephone systems and radio frequencies, and potential malfunction of end use devices.
  - Power factor: Non-linear current drawn by electrolyzer rectifiers can affect power factor, leading to heat losses and inefficiencies.
  - Other PQ phenomena, such as flicker, voltage sags and rapid voltage changes (RVCs) remain potential concerns, depending on the operating parameters of the electrolyzer facility.
- Electrolyzer facilities can be sensitive to grid events like sags and transients, which can cause process disruptions, revenue loss, and equipment damage.
- PQ phenomena can be caused by the electrolyzer and impact the grid and vice versa. PQ impacts of electrolyzer facilities on the grid can be mitigated by employing active filters or static synchronous compensators (STATCOMs) and proper grid planning. PQ impacts of the grid on the electrolyzer

facility can be potentially mitigated by employing STATCOMs, dynamic voltage restorers (DVRs), and uninterruptible power supplies (UPS).

- Simulation models that used data from an actual electrolyzer design were employed in this study. Results revealed:
  - Voltage sags and oscillatory transients can cause nuisance breaker tripping and disrupt the electrolysis process.
  - Steady-state phenomena like harmonics and unbalance affect both AC and DC power quality, leading to efficiency reductions and excess heat production in the electrolyzer.
  - Potential voltage harmonics limits violations may occur in a deployment where the system may not be sufficiently strong.
  - Utilities must be mindful of harmonic limits violations when integrating electrolyzers, especially in weak grids.
  - The grid impact of supraharmonics emission depends on the frequency response of the step-up transformer.
  - Transients can disrupt the electrolysis process, causing damage to the thyristor rectifier and other issues.
- Current gaps in standards and modelling were addressed. It was suggested that IEEE 519 be updated to address the risk of harmonics violations of large converter-interfaced loads, such as electrolyzers. It was also suggested that IEEE 1159 be updated to address supraharmonics and how to monitor them. Methods to overcome the inaccuracy and limited bandwidth of voltage and current sensors should also be explored. Finally, models should be updated to be able to accurately simulate the dynamic response of the electrolyzer to grid events.

WHY THIS MATTERS

The energy sector will have to carefully plan for the significant power consumption that is expected from electrolyzer facilities. Proper integration ensures grid stability and prevents PQ issues that can affect both the grid and those facilities. Mitigating PQ issues and avoiding process disruptions can save costs and improve the reliability of hydrogen production. Bringing electrolyzer companies, grid planners, power quality engineers, and regulatory bodies together is crucial to understand the implications of integrating electrolyzers into the power grid, address potential challenges, and develop effective solutions for a stable and efficient energy system. Furthermore, staying informed about the latest developments and best practices in electrolyzer technology can assist in informed decision making. By addressing these aspects, stakeholders can be prepared as more and increasingly large electrolyzer facilities are integrated on the grid.

HOW TO APPLY RESULTS

These results should encourage the implementation of the mitigation strategies suggested throughout the report. Careful planning and analysis of the grid's strength by utility engineers and grid planners are crucial steps to mitigate negative PQ impacts. Integration of the electrolyzer into weak parts of the grid should be avoided. Large electrolyzer facility planners must consider mitigating solutions such as filters and STATCOMs during the planning process to address harmonics and power factor issues. Electrical standards and best practices must guide utility engineers to prevent PQ problems and ensure smooth integration of electrolyzers, but regulations and standards should also be updated to address current gaps. Such efforts must be supported by research to create better simulation models for electrolysis processes. Models should be updated to be able to simulate the nonlinear characteristics of the electrolyzer stack, the control algorithms of the electrolyzer rectifier, and the input power characteristics of major electrolyzer components. Facilitate collaboration amongst all of the stakeholder entities (i.e., electrolyzer companies, grid planners, power quality engineers, regulators, modelers, and researchers) to better address these challenges and develop effective solutions. Finally, since the electrolyzer industry is evolving quickly, continuous updates to research and standards are necessary to keep pace with technological advancements.

THE LOW-CARBON RESOURCES INITIATIVE

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

LCRI CONTACT

Krystal York, PhD
Senior Engineer, Low-Carbon Resources
269.391.4580
kyork@epri.com

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

GTI Energy is a leading research and training organization. Our trusted team works to scale impactful solutions that shape energy transitions by leveraging gases, liquids, infrastructure, and efficiency. We embrace systems thinking, open learning, and collaboration to develop, scale, and deploy the technologies needed for low-carbon, low-cost energy systems. www.gti.energy

For more information, contact:

EPRI Customer Assistance Center
800.313.3774 • askepri@epri.com

3002030829 **October 2024**

EPRI
3420 Hillview Avenue, Palo Alto, California 94304-1338 USA • 650.855.2121 • www.epri.com

© 2024 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ENERGY are registered marks of the Electric Power Research Institute, Inc. in the U.S. and worldwide.