Power Convertor for Electrolyzer Applications

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Overview

Timeline and Budget

- Project start date: 03/01/2020
- FY20 planned DOE funding (if applicable): **$550K**
- Total DOE funds received to date: **$550K**

Barriers

- Lack of standardized controls interface for electrolyzer applications in Real-World Operation as per grid codes and interconnection standards, inter-operability standards.
- Coordinated control of multiple electrolyzers, including interaction with other power electronically-interfaced DER technologies.
- Optimized control for Hydrogen and Electricity Co-Production, including Renewable Resources.

Partners

Lead

- National Renewable Energy Laboratory

Industry

- EPC Power Corp, Typhoon HIL, GinerElx, NEL

Relevance

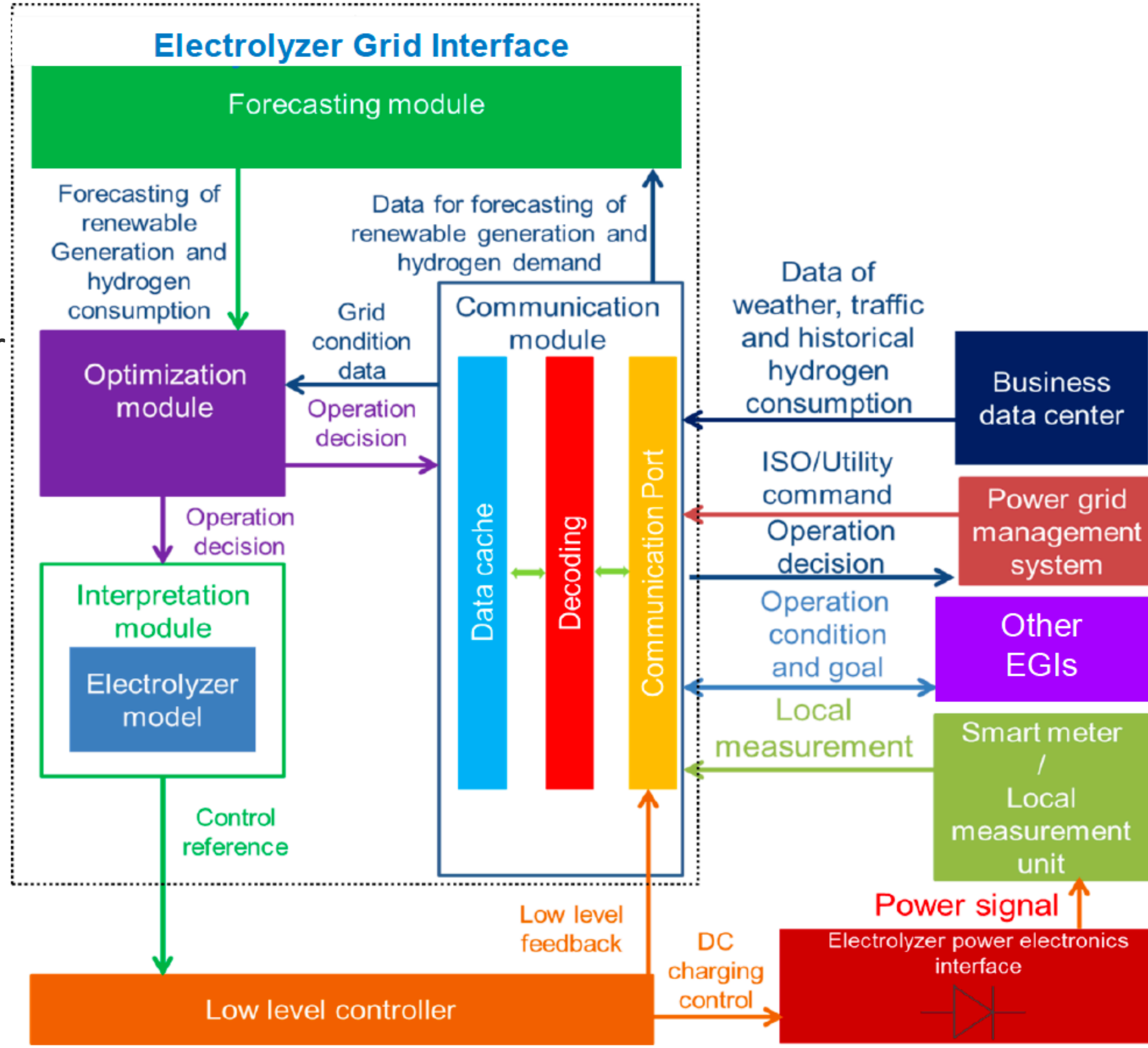
- **Relevance**

This AOP project will develop a standardized electrolyzer control interface for power electronic converter dedicated for low-temperature hydrogen electrolyzer applications to enable grid services.

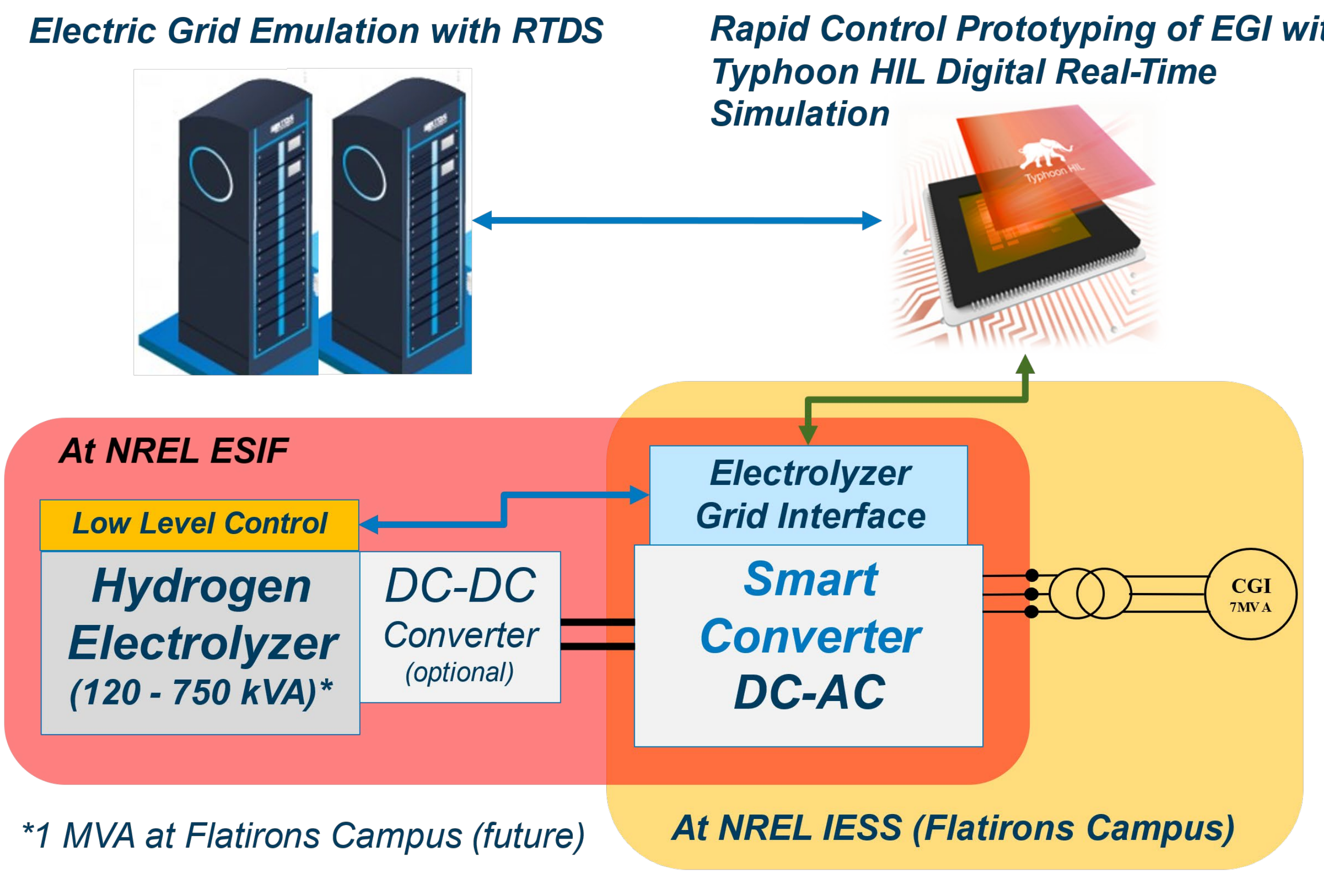
- **Objectives**:
  - Survey off-the-shelf power electronic converters suitable for electrolyzer operation and control.
  - Identify the high-level design for smart power electronics converter.
  - Develop control architecture for bulk (transmission) and distribution grid interconnection codes and standards.
  - Identify a power electronics vendor and jointly develop power converter controllers.
  - Implement and test power converter at NREL with electrolyzer stack (*120 kVA to 750 kVA at NREL ESIF, 1 MVA at NREL IESS at Flatirons Campus in future*) under various dynamic conditions.

Approach

- Hardware and Software Architecture for Electrolyzer Grid Interface (EGI) is shown.
- Focus is on interfacing EGI on Smart Power Converter with the low-level controller (electrolyzer embedded), including BOP.
- As part of the project, the optimization and control will reside on the EGI, and will be programmed at digital microprocessor, ASIC or FPGA on converters for real-time communication.



Approach



- Development of power converter hardware prototype for demonstrating advanced control functionalities as per grid codes, standards (IEEE 1547-2018).
- At-scale testing protocols for electrolyzer specific applications, including CHIL validation with other ongoing FCTO-funded projects (e.g. GMLC FlexPower).

Accomplishments and Progress

- The project was kicked-off on March 2020.
  - In conversation to develop high-level planning with industry partner vendors for power converter, controls interfacing, and electrolyzer systems.
  - Technical progress and milestones will be reported in future AMRs.

Accomplishments and Progress: Responses to Previous Year Reviewers' Comments

- The project was not reviewed last year.

Collaboration and Coordination

- Project collaborators
  - Typhoon HIL (Rapid Control Prototyping, Power Electronics Interfacing, and Standardization as per IEEE 1547-2018)
  - EPC Power Corp. (Power Converter hardware, Modular Hardware Implementation for Electrolyzer Control Interface).
  - Coordination with GMLC FlexPower (CHIL validation of EGI).
- Working directly with the power converter manufacturer for advanced grid applications at multi-MW levels through modular implementation.
- Technology transfer to industry and standards community for electrolyzers as DERs.

nel

Typhoon HIL

GINERELX

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excellence in power conversion

Remaining Challenges and Barriers

- Current work will develop and test EGI for a modular approach from 120 kVA to 225 kVA. To prove MW-level scalability of modular approach, the future work will include 1 MVA electrolyzer using the same EGI control configuration.

Proposed Future Work

Future control functionalities to be developed in EGI for Electrolyzer dedicated applications are listed below.

- Sparse communication-based approach for coordinated control between various distributed nodes with various controllable DERs to provide a cohesive autonomous or guided response.
- Establish and maintain a real-time communication and control mechanism at individual DER converters that will appear as a single controllable entity to the bulk electric grid for hybrid applications.
- Enable and serve as a platform for cybersecurity implementation based on typical and upcoming grid communication protocols.

Any proposed future work is subject to change based on funding levels.

Technology Transfer Activities

- The development of controls and interface will be in open-source as per grid codes and standards such as IEEE 1547-2018.
- Working directly with the power converter manufacturer for modular implementation of advanced grid applications at multi-MW levels.
- Technology transfer to industry and standards community for electrolyzers as DERs.

Summary

- Project Summary
  - **Electrolyzer dedicated Smart Power Converter** hardware prototype for demonstrating advanced control functionalities for **grid services** such as voltage and frequency support, ride-through controls, virtual inertial response, etc.
  - **Rapid control prototyping**-based approach for actual power converter and electrolyzer hardware (120 kVA – 225 kVA, and **1 MVA in future**).
  - **Standardization of control** functionalities and at-scale testing protocols for electrolyzer dedicated applications as per grid codes and standards such as IEEE 1547.
  - Controller Hardware-In-the-Loop (CHIL) validation using digital twin in a **real-world at-scale** environment to **reduce risk of field deployment**.
  - **Coordination** with ongoing FCTO funded project for CHIL validation (GMLC FlexPower)
  - **Technology transfer** to industry and standards community for electrolyzers as DERs.

Thank You

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Smart Converter for Dedicated Electrolyzer Applications to Enable Grid Services

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H2 Electrolyzer Power Converter development environment

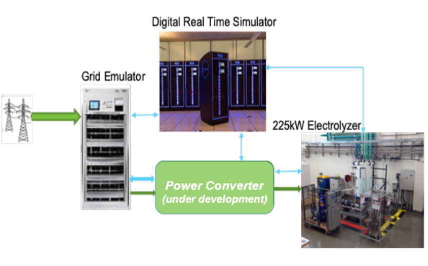

Figure 1: Hydrogen Refueling Station Power Converter Development Environment

PHIL testing

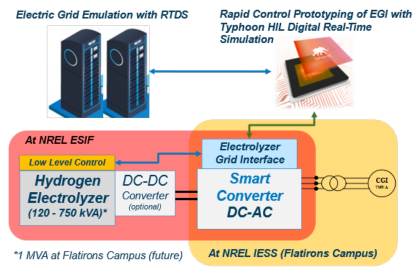

Figure 2: PHIL testing of Smart Converter with DRTS, Electrolyzer for rapid prototyping of advanced control functionalities.

Hardware and Software Architecture for EGI

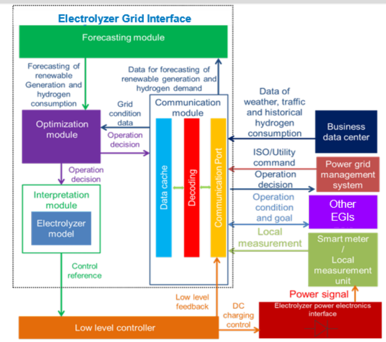

Figure 3: Hardware and Software Architecture for EGI

Development and testing environment at NREL ESIF and NREL IESS at Flatirons Campus

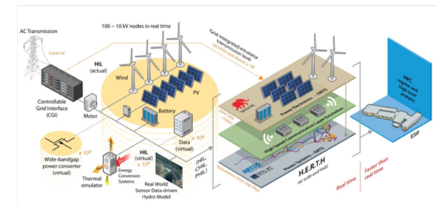

Figure 4: Development and testing environment at NREL ESIF and NREL Flatirons Campus

Provision of Grid Support Services from Hydrogen Electrolyzers

- Electrolyzers have emerged as a promising technology for supporting grid frequency and voltage support for bulk grid.
- The provision of flexibility in electric grid from electrolyzers has been proven in a real -time grid simulation environment.
- Fast-autonomous response of electrolyzers/hydrogen refueling stations (HRS) through load curtailment and planned operation for hydrogen production has been tested in a laboratory environment using actual utility data, including the PG&E grid.

However, for actual grid implementations and adoption by utilities, there exist research gaps:

1. Controls development as per grid codes/interconnection standards (IEEE 1547 - 2018), inter-operability standards.
2. Coordinated control of multiple HRS, including interaction with other power electronically - interfaced DER technologies including solar, wind, electric vehicles, electrical energy storage, and conventional power plants in the electric grid.

Functionalities of Electrolyzer Grid Interface (EGI)

This AOP project proposes **electrolyzer grid interface (EGI)** with the following functionalities:

Functionalities

1. Integrated controller at lower level of off -the-shelf power electronics for energy and hydrogen generation.
2. Optimization- based control to enable optimal participation in hydrogen production/sale and electricity market.
3. Support advanced functionalities such as voltage and frequency ride- through controls, virtual inertial response, etc .

Partners and Vendors

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Development and Hardware Implementation of EGI

- As part of the project, the optimization and control will reside on the EGI, and will be programmed at microprocessor, FPGA or ASIC on converters for real -time communication.
- Coordinated control of cluster of DERs with electrolyzers / HRS, as well as communication capabilities with power system operator.

Project Tasks (FY 2020)

1. Survey off-the-shelf power electronic converters suitable for electrolyzer operation and control.
2. Identify the high -level design for smart power electronics converter.
3. Develop control architecture for bulk (transmission) and distribution grid interconnection codes and standards.
4. Identify a power electronics vendor and jointly develop power converter controllers.
5. Implement and test power converter at NREL with electrolyzer stack (120 kVA to 750 kVA at ESIF, 1 MVA at Flatirons in future) under various dynamic conditions.

Project Outcomes

1. Power converter hardware prototype for demonstrating advanced control functionalities for grid services.
2. Standardization of control functionalities as per grid codes and standards such as IEEE 1547.
3. At-scale testing protocols for electrolyzer specific applications.
4. CHIL validation with ongoing projects (*e.g. GMLC FlexPower*)
5. Technology transfer to industry and standards community for electrolyzers as DERs.

Future functionalities

1. Sparse communication -based approach for coordinated control between various distributed nodes with various controllable DERs to provide a cohesive autonomous or guided response.
2. Establish and maintain a real- time communication and control mechanism at individual DER converters that will appear as a single controllable entity to the bulk electric grid for hybrid applications.
3. Enable and serve as a platform for cybersecurity implementation based on typical and upcoming grid communication protocols .