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A New Approach for Efficient Hydrogen Power Supply

R&D

Dr. Hany Ahmed
R&D Manager

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Climate Action
BREAKTHROUGH TECHNOLOGY CONFERENCE
worldsteel ASSOCIATION
2023

ALL GREEN CONCEPT

OUR New Concept

ALL Green

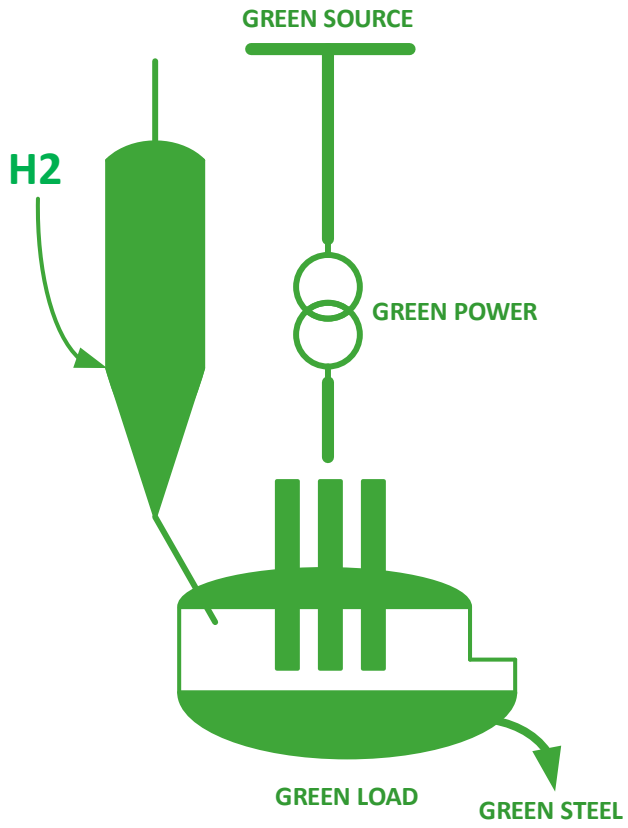
Our new concept for **Green Steel** is extended to:

Green Source, Green Power, Green Load.

Green Source encompasses the utilization of hydrogen and renewable power sources, laying the foundation for a cleaner production process.

Green Power refers to the efficient use of energy through advanced power electronics, ensuring that energy savings and reduced emissions are a priority.

Green Load signifies the end-use where the energy is not only consumed efficiently but also supports the overall sustainability of the system. It is only when these three components align that we can truly achieve and designate the end product as "Green Steel," epitomizing the pinnacle of eco-friendly manufacturing in the steel industry.



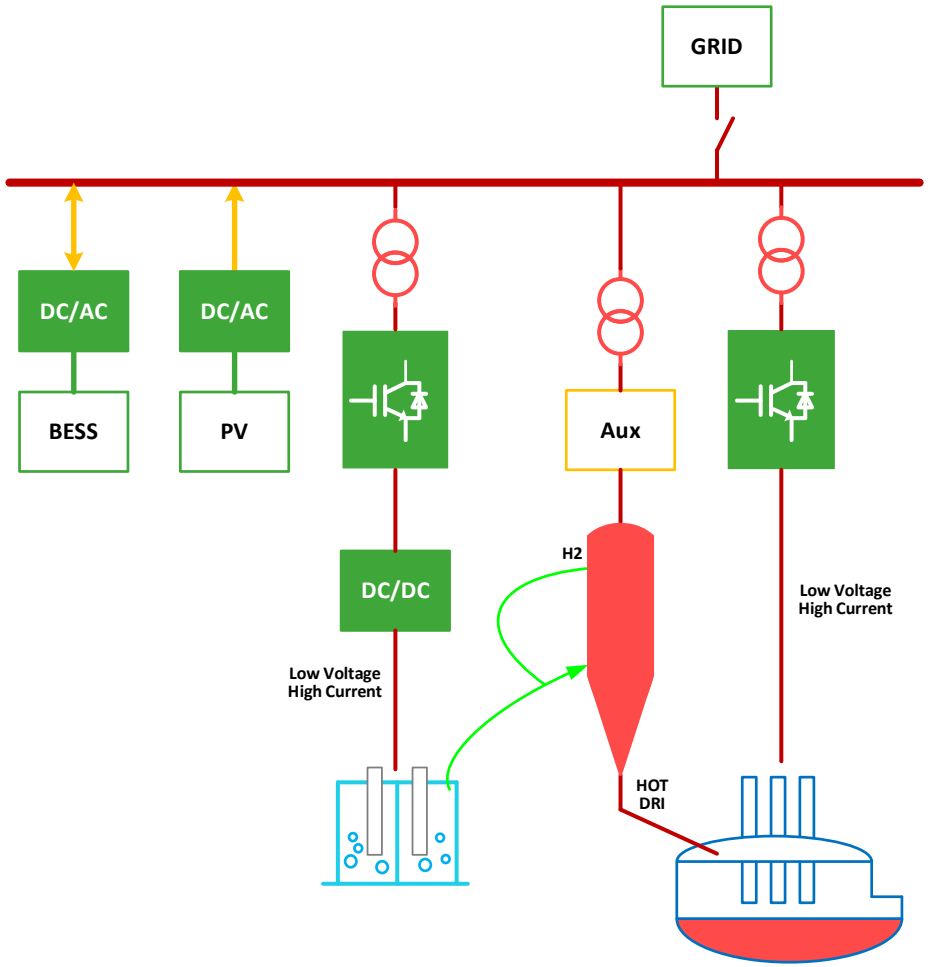
Electrolyzer in Steel Industry

Future Trend

The future trend in steel manufacturing is shifting towards using hydrogen direct reduced iron (H2-DRI) in electric arc furnaces (EAF) powered by power electronics converters. This move away from traditional EAF power sources, which relied on variable power transformers and tap changers, aims to achieve more accurate and sustainable power delivery.

By integrating power electronics, energy efficiency can be enhanced by 10-15% and ensures that the EAF operates as a "Green Load." The same principle can be applied by adding an electrolyzer into the process, which should also result in a "Green Load.“

The concept of "Green DRP/EAF" goes beyond just the hydrogen aspect and encompasses the power source and the load's environmental friendliness. For steel to be classified as "Green Steel," both the power source and the load must be sustainable and environmentally friendly..



Patent: WO2018233833A1, A method for operating an electric-arc furnace, a power electronic converter, and an electric-arc furnace system

SYSTEM REQUIREMENTS

All Green System Design

To extend the **All Green** Concept, the Grid Side, Converter Side, and Electrolyzer side has to be well configured and designed.

Grid Side

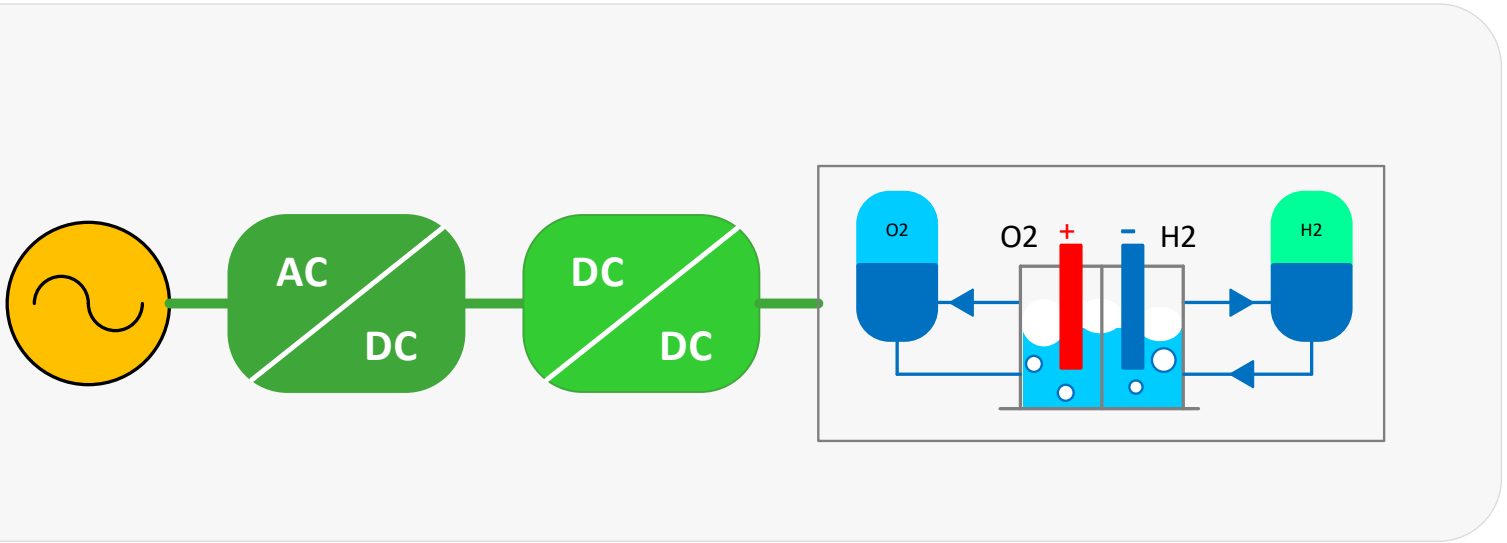
- Voltage Quality (THD, Harmonics)
- Current Quality (Harmonics, THD
- Power Factor

Power Converter

- Scalability
- Fast Power Response
- DC Voltage Stability & Quality
- DC Current Stability & Quality
- Fast Dynamic Response

Electrolyzer

- Maximum Stack DC Voltage
- Cell Voltage operating range (Vdc/Cell
- Cell Current Density (A/cm2)



CONVENTIONAL POWER SUPPLY

Disadvantages

Electrolyzer

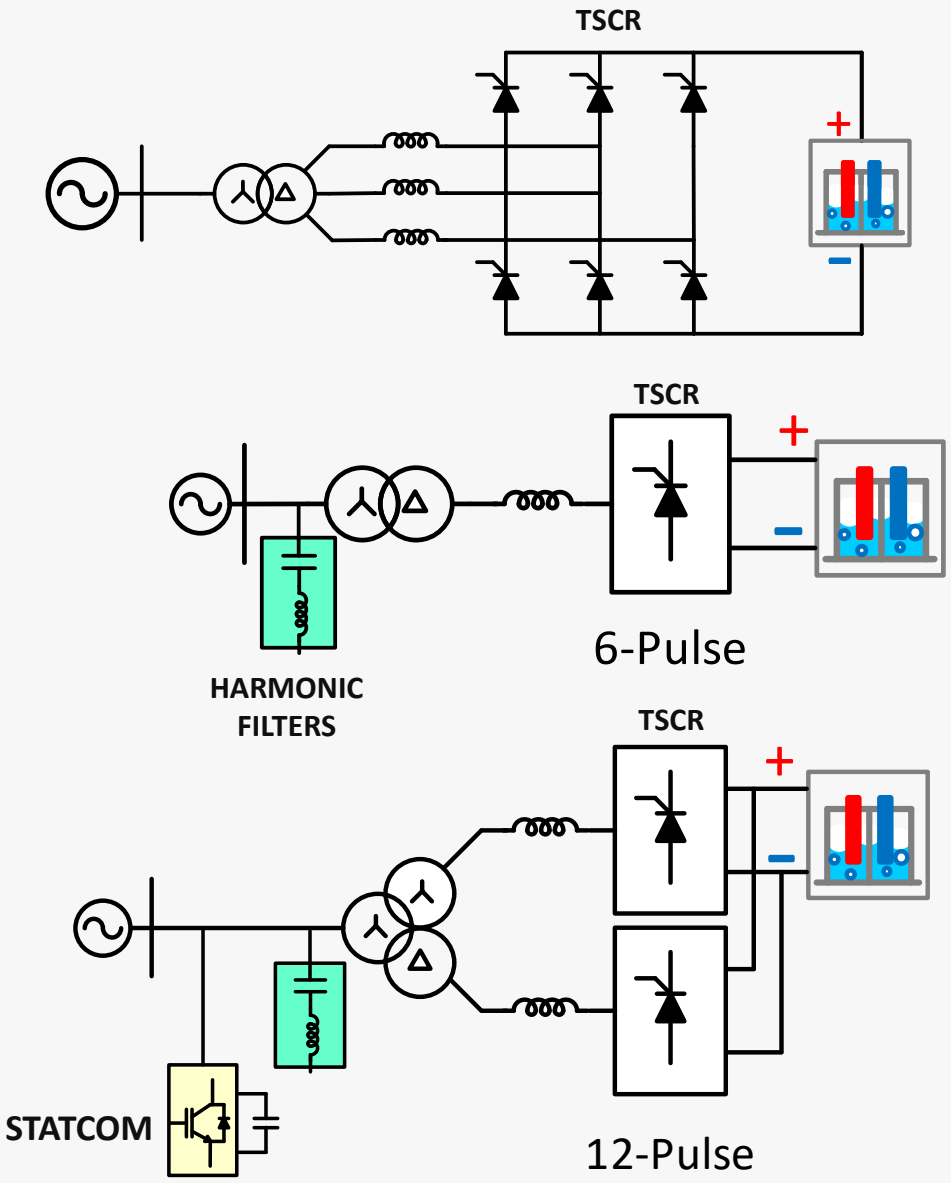
- ✕ DC voltage fluctuation
- ✕ Reduced Electrolyzer Efficiency
- ✕ Potential for Electrolyte Degradation

Grid Side

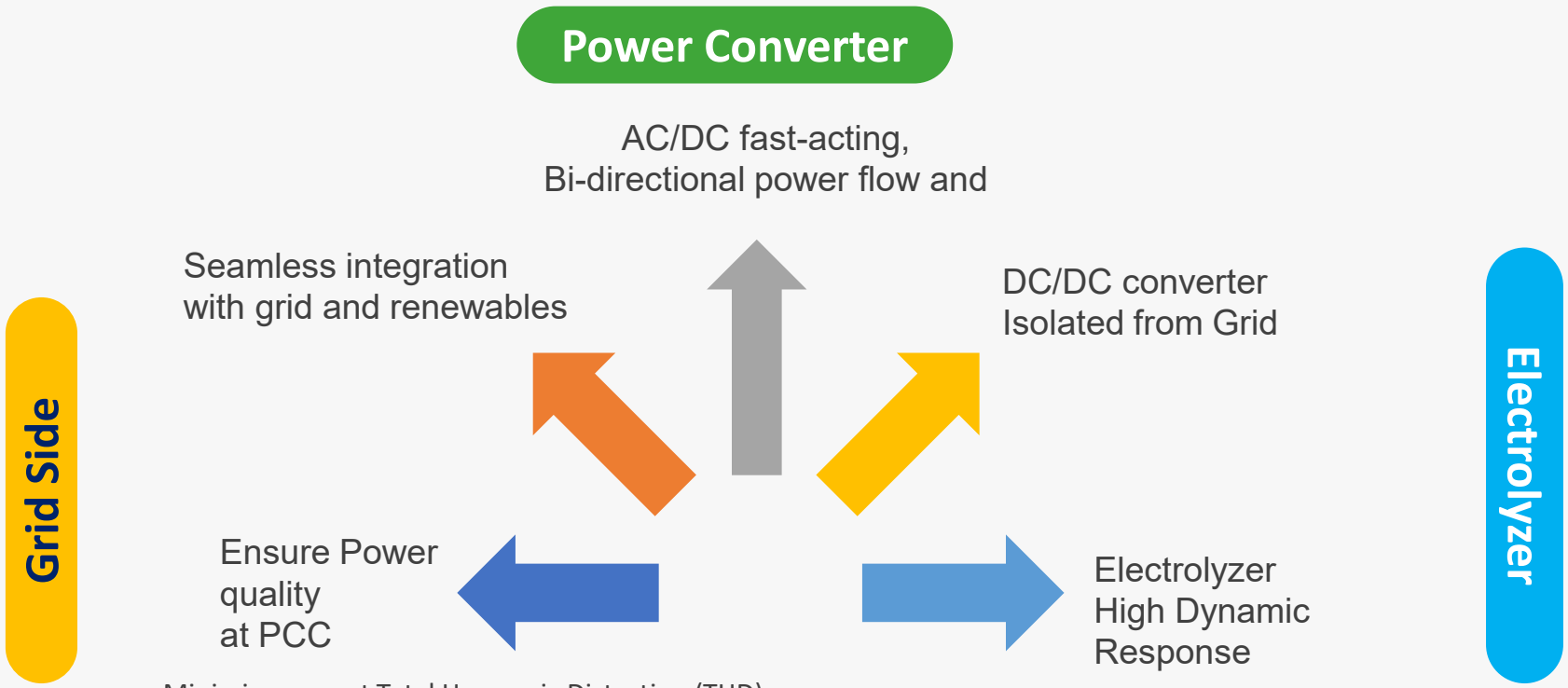
- ✕ Voltage Quality (THD, Harmonics)
- ✕ Current Quality (Harmonics, THD
- ✕ Power Factor

Power Converter

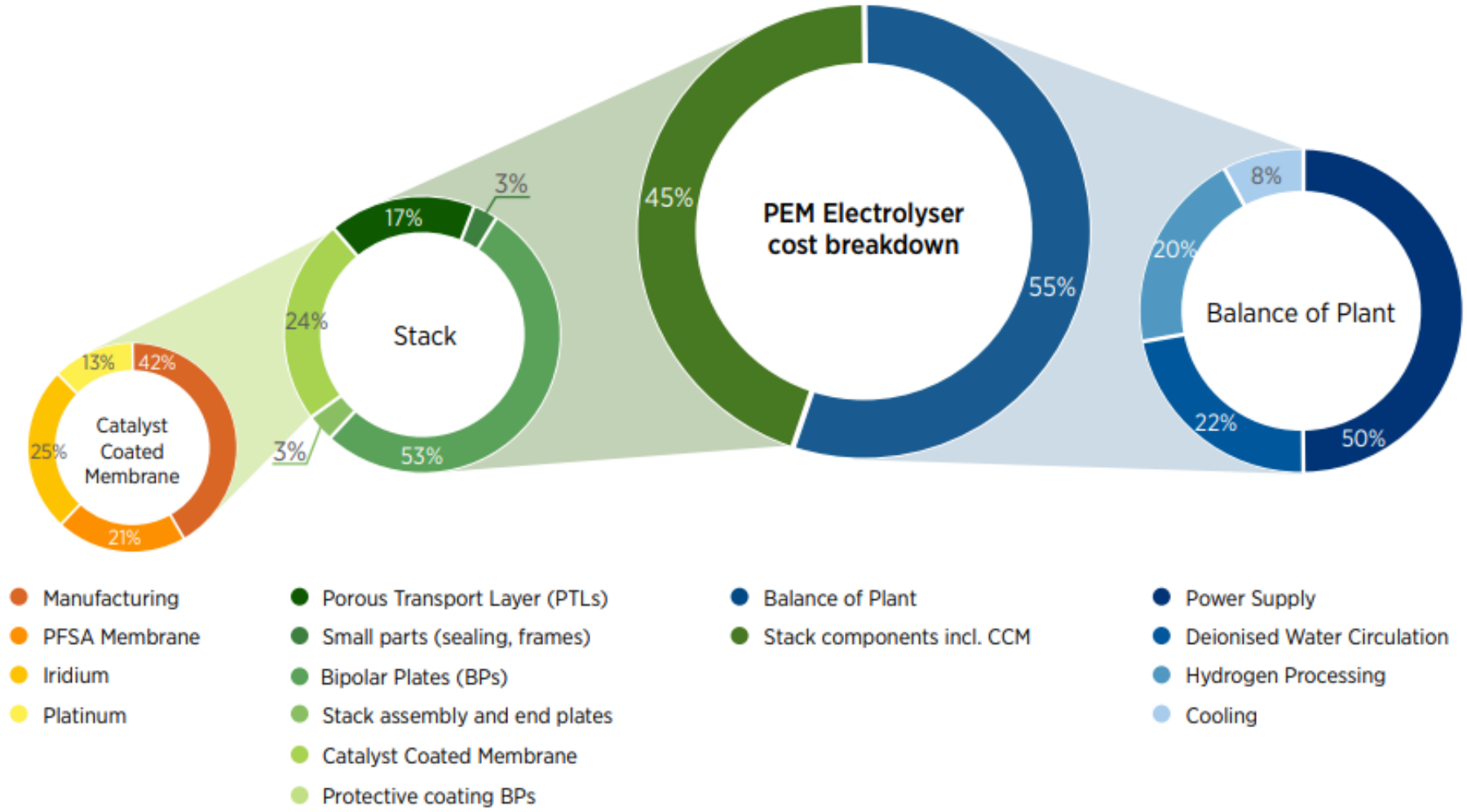
- ✕ Scalability
- ✕ Fast Power Response
- ✕ DC Voltage Stability & Quality
- ✕ DC Current Stability & Quality
- ✕ Fast Dynamic Response



ADVANCED POWER SUPPLY



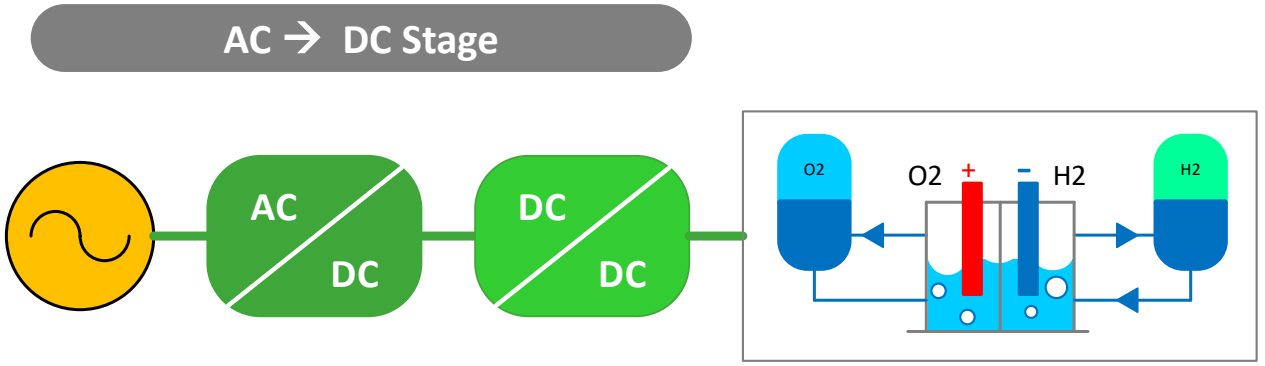
Cost Distribution

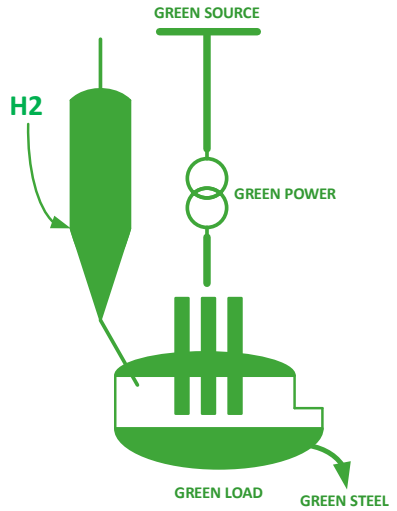


Based on IRENA analysis

Hermann, Chaudhuri and Spagnol, 2005

PROPOSED SYSTEM





Grid Side

- Voltage Quality (THD, Harmonics) ✓
- Current Quality (Harmonics, THD ✓
- Power Factor ✓

FULFILL
GRID
Demands

Power Converter

- Scalability ✓
- Fast Power Response ✓
- DC Voltage Stability & Quality ✓
- DC Current Stability & Quality ✓
- Fast Dynamic Response ✓

MULTILEVEL
NPC
Direct Power Control

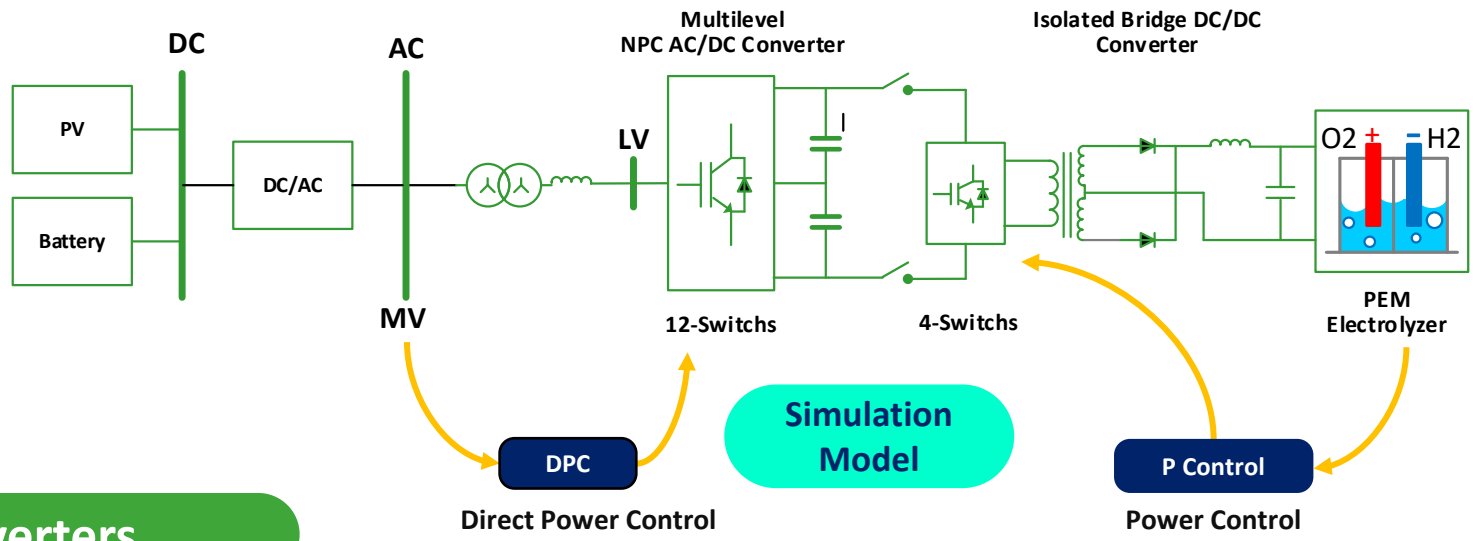
Electrolyzer

- Maximum Stack DC Voltage ✓
- Cell Voltage operating range (Vdc/Cell ✓
- Cell Current Density (A/cm2) ✓

FULFILL
Electrolyzer
Demands

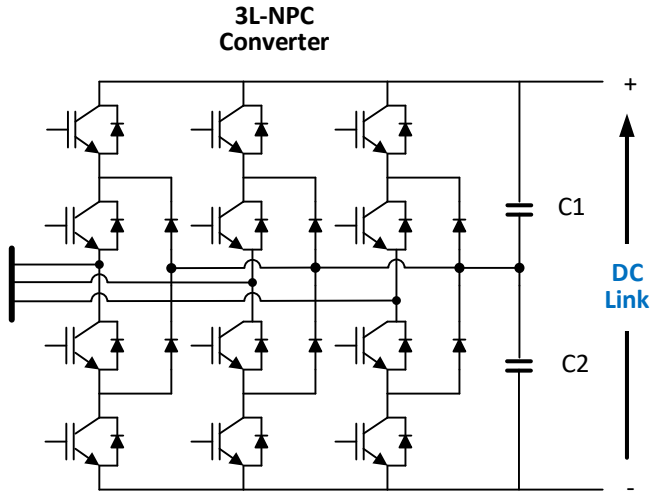
PROPOSED POWER SUPPLY SYSTEM

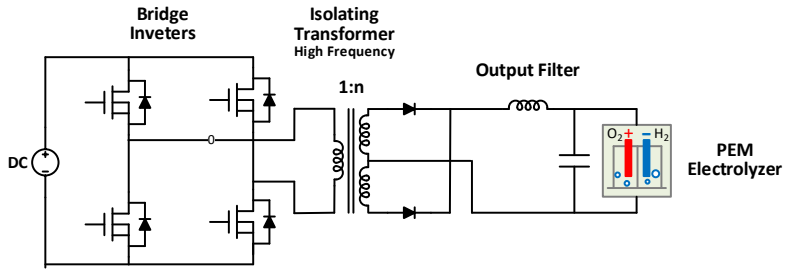
AC → DC Stage



Power Converters

- Scalability (**NPC Converter**)
- Fast Power Response **(Direct Power Control DPC)**
- DC Voltage Stability & Quality (**ISOLATED Bridge DC/DC converter**)
- DC Current Stability & Quality (**High-Switching Bridge**)
- Fast Dynamic Response (**High Stabilized dc-Link**)



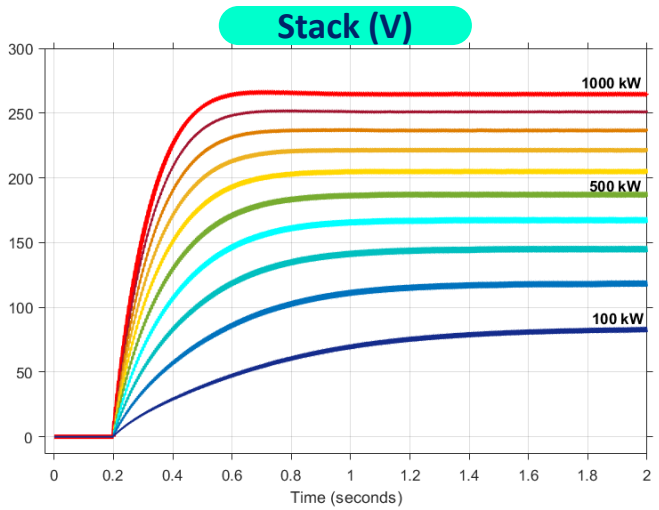


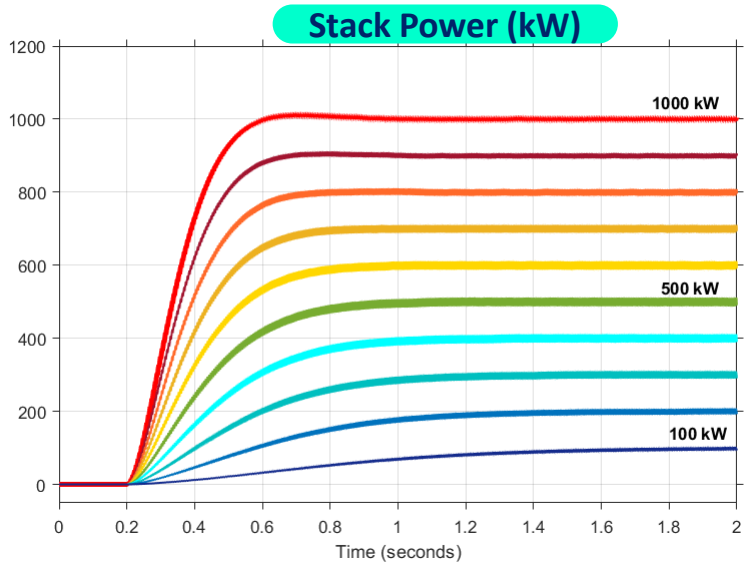
Electrolyzer RESPONSE

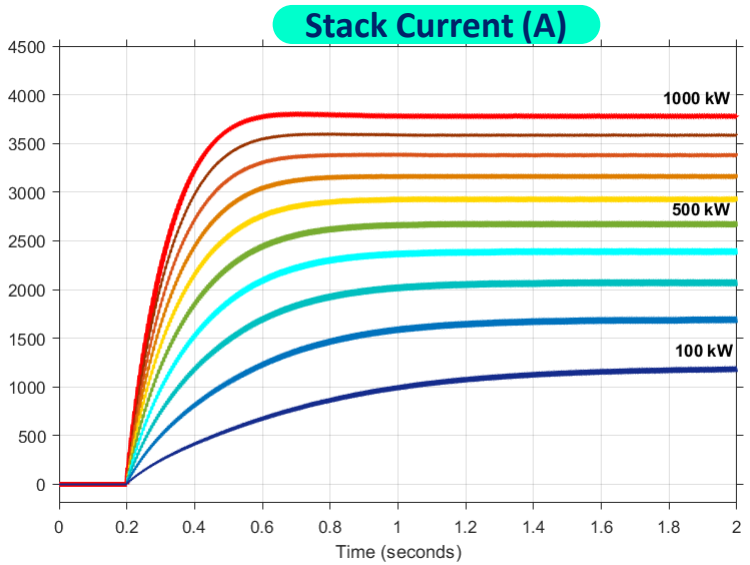
Result

- Fast Power Response at higher demands
- Adaptive tuning required based on power reference
- Stable current, voltage response over full range

Stack Simulation







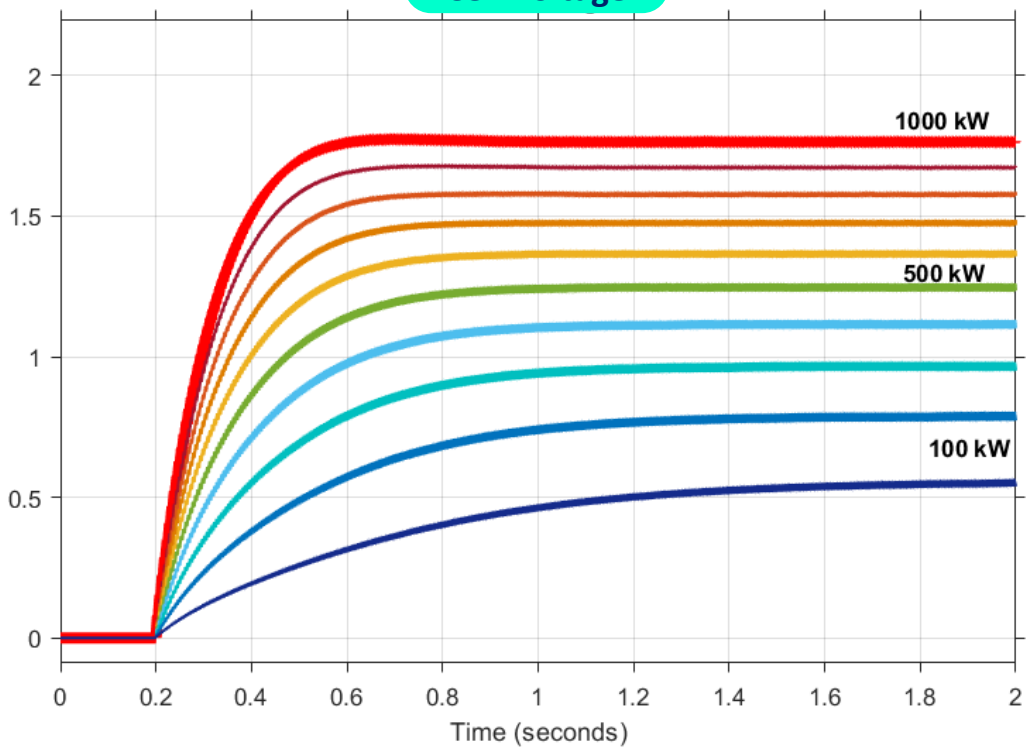
STACK & CELLS RESPONSE

Result

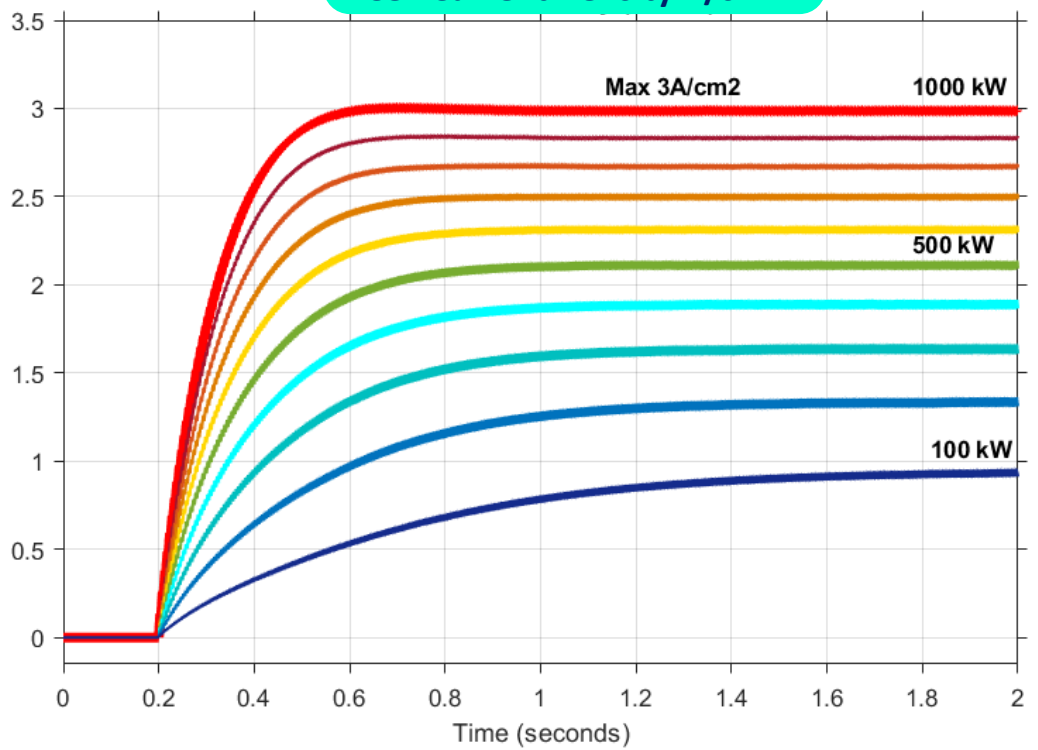
- Cell Voltage is less than 2 V at full power ensures lower losses and increases the lifetime of stack.
- Cell Current Density maintain below 3A/cm2

Cell Simulation

Cell Voltage



Cell Current Density A/cm2



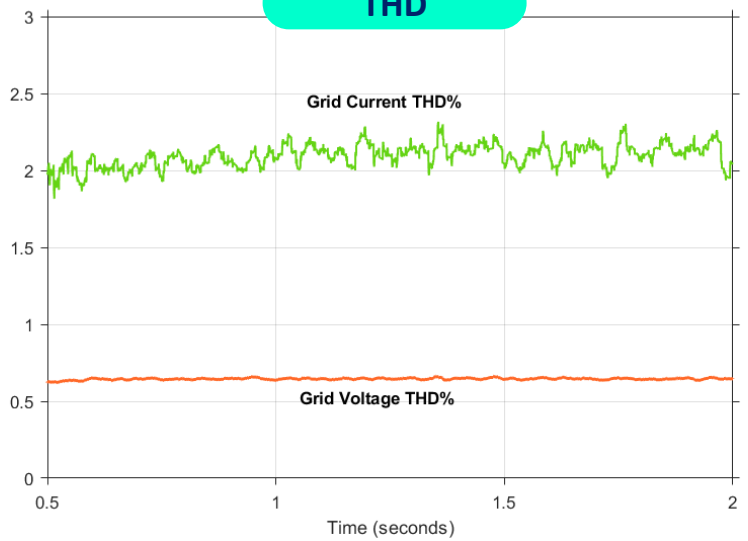
SYSTEM DYNAMICS

Result

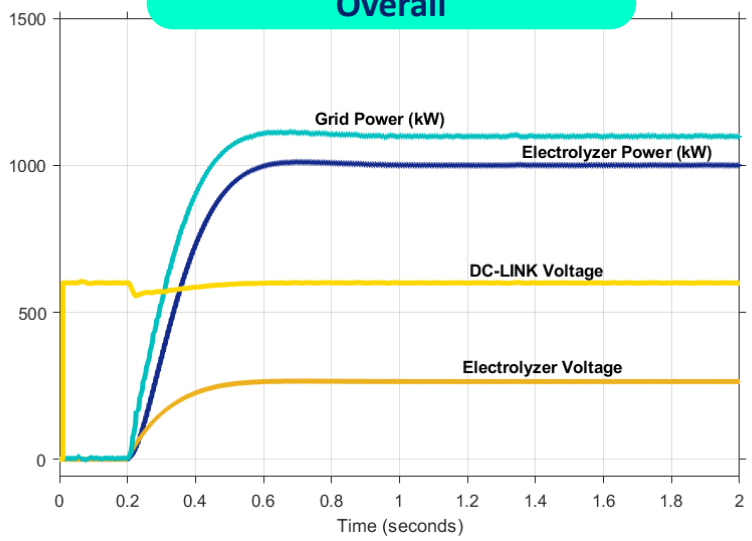
- Unity power factor at all operating range.
- Very low THD
- Fact dc-link response to full load
- Power Electronics efficiency is above 95% however system efficiency is between 90% and 92%.

Power Supply Simulation

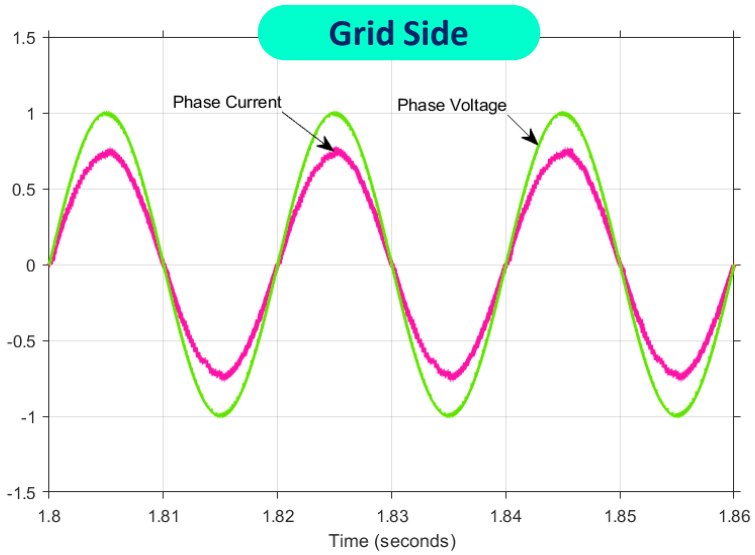
THD



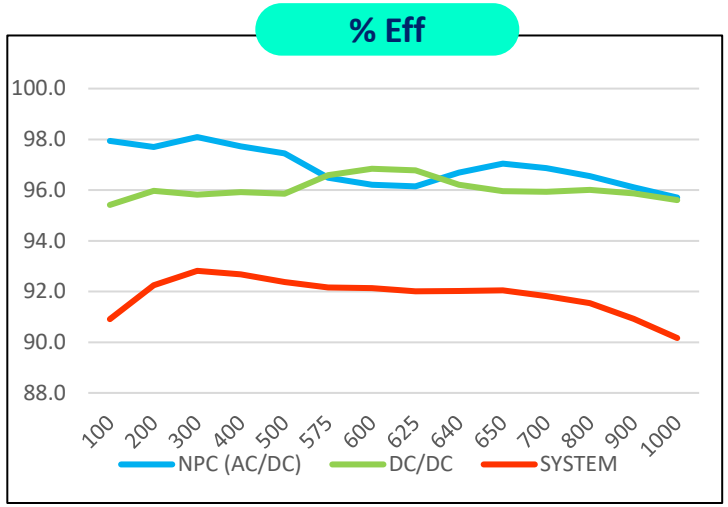
Overall



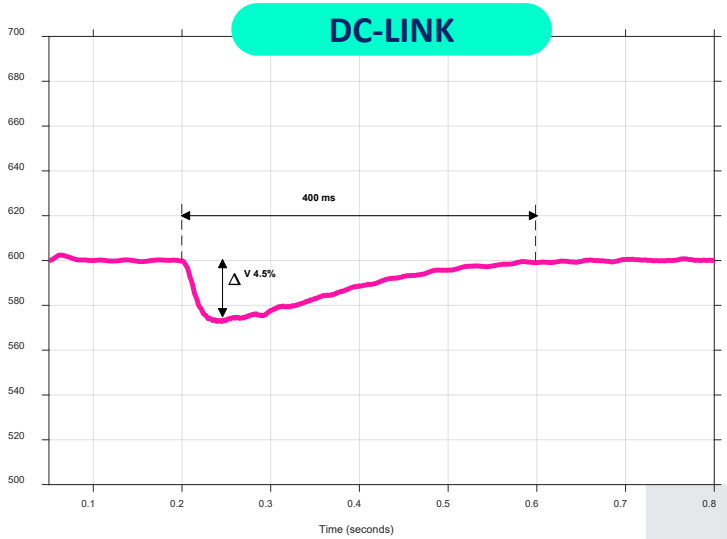
Grid Side



% Eff



DC-LINK

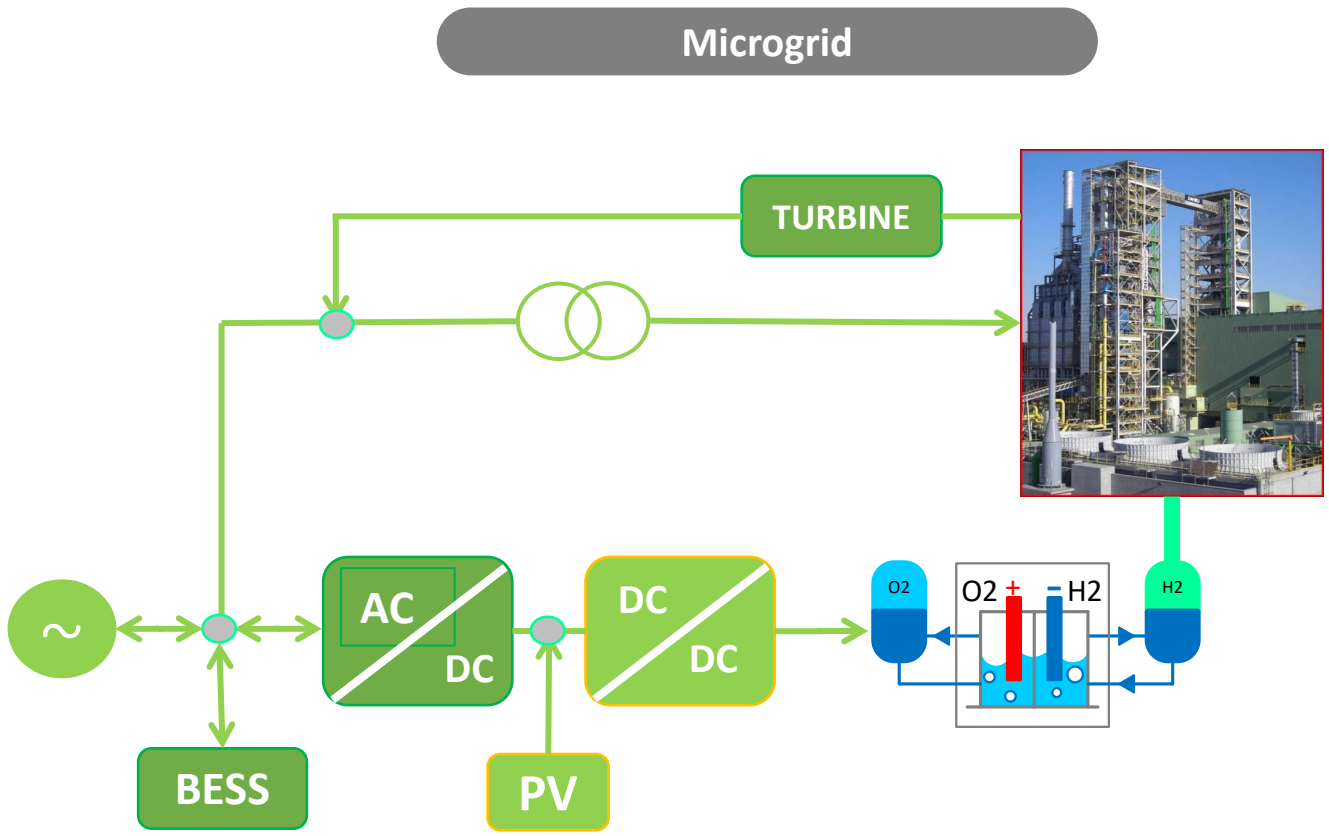


INTEGRATED SYSTEM

Final Proposed Concept

The proposed concept involves a microgrid system that provides power to a Direct Reduced Iron (DRP) plant. The system achieves power flexibility through local generation, which can come from Renewable Energy Sources (RES) or Waste-to-Heat energy. An Electrolyzer, which is essential for hydrogen production in the DRP process, will draw power from advanced power electronics converters governed by sophisticated control algorithms.

A Smart Energy Management System is integral to this configuration, ensuring the system operates at its optimum. The holistic approach aims to fulfill multiple objectives: minimizing energy losses, reducing the carbon footprint, and enhancing the efficient distribution of energy across various sources.

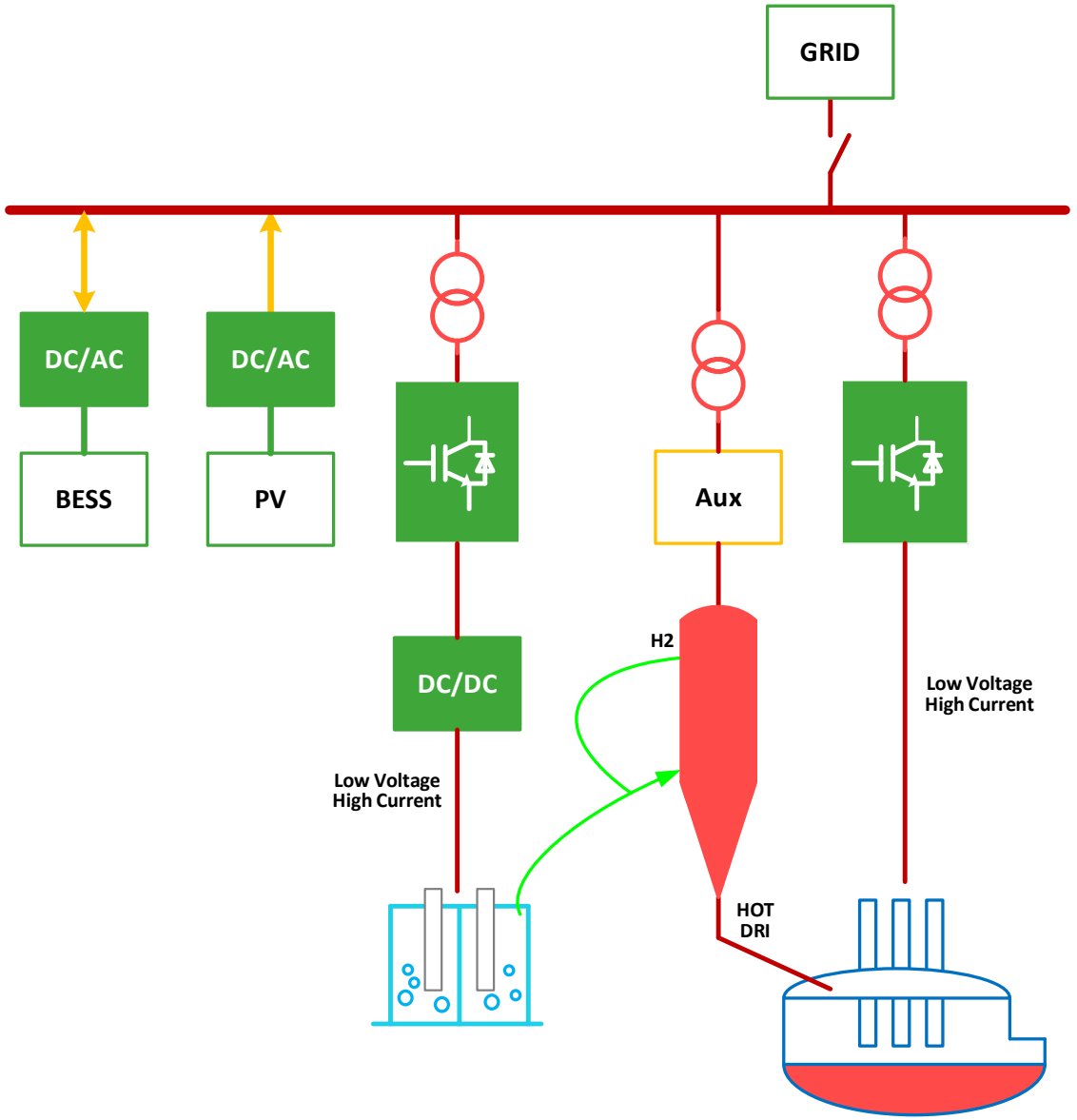


Executive Summary

To conclude, the "**All Green Concept**" proposes a transformative approach to steel manufacturing that focuses on sustainability at every stage of the production process. Through the use of hydrogen as a **Green Source**, advanced **Green Power** technologies to optimize energy use, and **Green Load** practices to ensure efficient energy consumption, we're setting a new standard for the industry.

This method not only addresses the environmental impact of steel production but also enhances operational efficiency and cost-effectiveness. By integrating Smart Energy Management Systems and state-of-the-art power converters, we demonstrate our commitment to innovation and continuous improvement.

As we move towards this future trend, the steel industry is poised to significantly reduce its carbon footprint, ensuring a more sustainable and responsible approach to one of the world's most critical construction and manufacturing materials. This creates a compelling vision of the future where industry needs and environmental stewardship go hand in hand, marking a significant step towards the industrial symbiosis of technology and ecology.



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