EDF Lab Asia Pacific (EDF-APAC)

AI and Microgrids

International Microgrid Symposium

November 2025

Electricité de France (EDF)

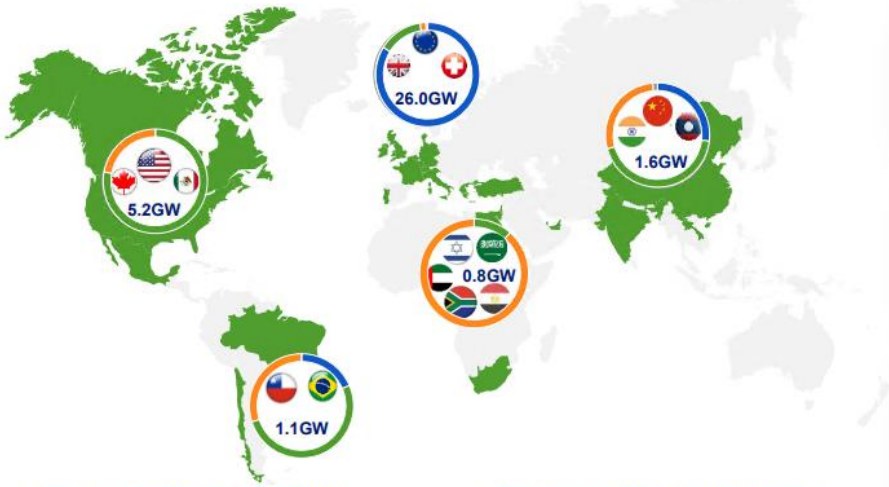
- 190 000 employees
- 140 Bn€ turnover (2023)
- 30 gCO2/kWh carbon intensity for generation

EDF AT THE HEART OF THE FRENCH AND THE EUROPEAN ENERGY TRANSITION AND SECURITY OF SUPPLY

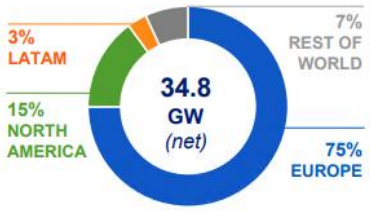
1. LARGEST NUCLEAR FLEET IN EUROPE WITH UNIQUE EXPERTISE TO ACCELERATE NEW NUCLEAR DEPLOYMENT
2. LEADERSHIP POSITION IN THE RENEWABLE INDUSTRY
3. GROWING REGULATED NETWORKS PROVIDING PREDICTABLE RETURNS
4. LEADING ENERGY SUPPLIER WITH INNOVATIVE SERVICES SOLUTIONS

2 EDF: THE EUROPEAN LEADER IN RENEWABLE ENERGY

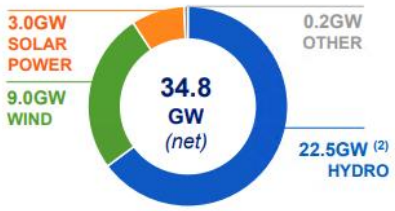
NET INSTALLED CAPACITY: 34.8GW(1)



CAPACITY BY GEOGRAPHY



CAPACITY BY TECHNOLOGY



A DIVERSIFIED MIX WITH 34.8GW IN OPERATION

- **22.5GW of hydropower**
- **12.0GW of wind and solar power**
- **0.2GW others** (biomass, geothermy, …)

HYDROPOWER

- **Leading European producer** of hydropower
- More than **400 production sites** worldwide

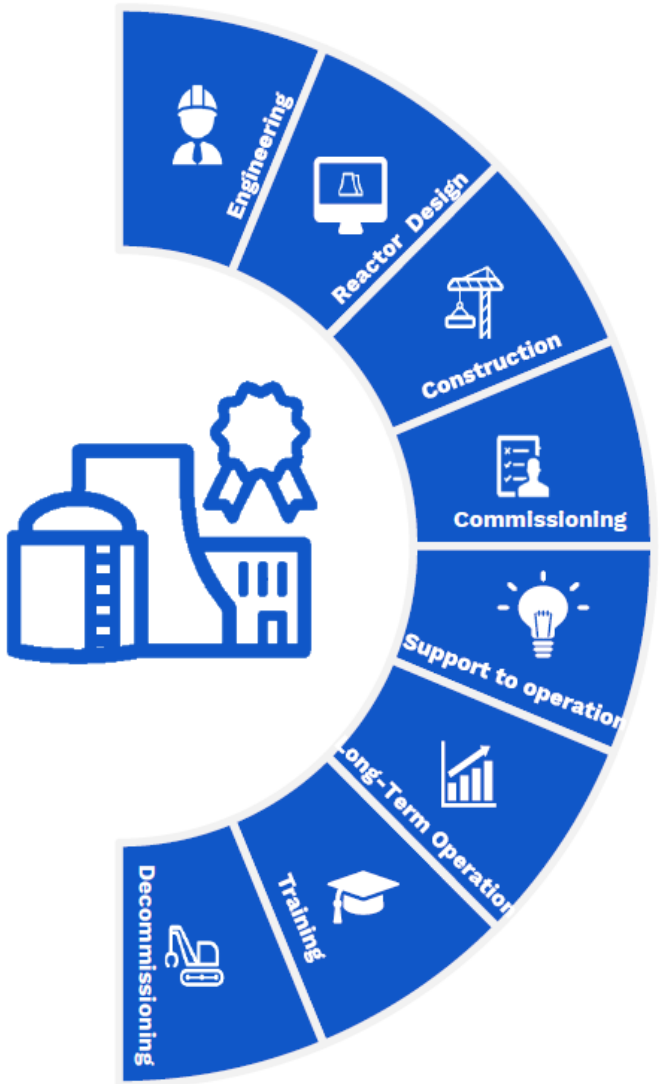
A GLOBAL LEADER IN WIND AND SOLAR ENERGY

- **3.1GW gross** commissioned in 2021
- **7.9GW gross** currently under construction (1.5GW in onshore wind power, 1.9GW in offshore wind power, 4.5GW in solar power)

(1) Installed capacity at end 2021 shown as net, corresponding to the consolidated data based on EDF's participation in Group companies, including investments in affiliates and joint ventures

(2) Including sea energy: 0.24GW

EDF GROUP AND THE FRENCH NUCLEAR INDUSTRY: AN UNRIVALLED EXPERIENCE



- → **66 reactors** operated by EDF (alone) in Europe
- → Nuclear is **the third industrial sector** in France
- → **+220,000 jobs** in France
- → **+3,000 SMEs** involved

57 reactors in operation
+62 GWe

9 reactors in operation
5,9 GWe
2 reactors in construction

2 reactors in operation
EDF minority shareholder

INTRODUCING EDF R&D

INTRODUCING **EDF R&D**

EDF R&D IN THE WORLD

3 centers in France,
6 abroad and an office
in Brussels

EDF R&D **SCIENTIFIC PLAN**

AXIS 1

DECARBONISING OUR CLIENTS' USES THANKS TO ELECTRICITY

AXIS 2

STRENGTHENING THE PERFORMANCE OF GENERATION ASSETS

AXIS 3

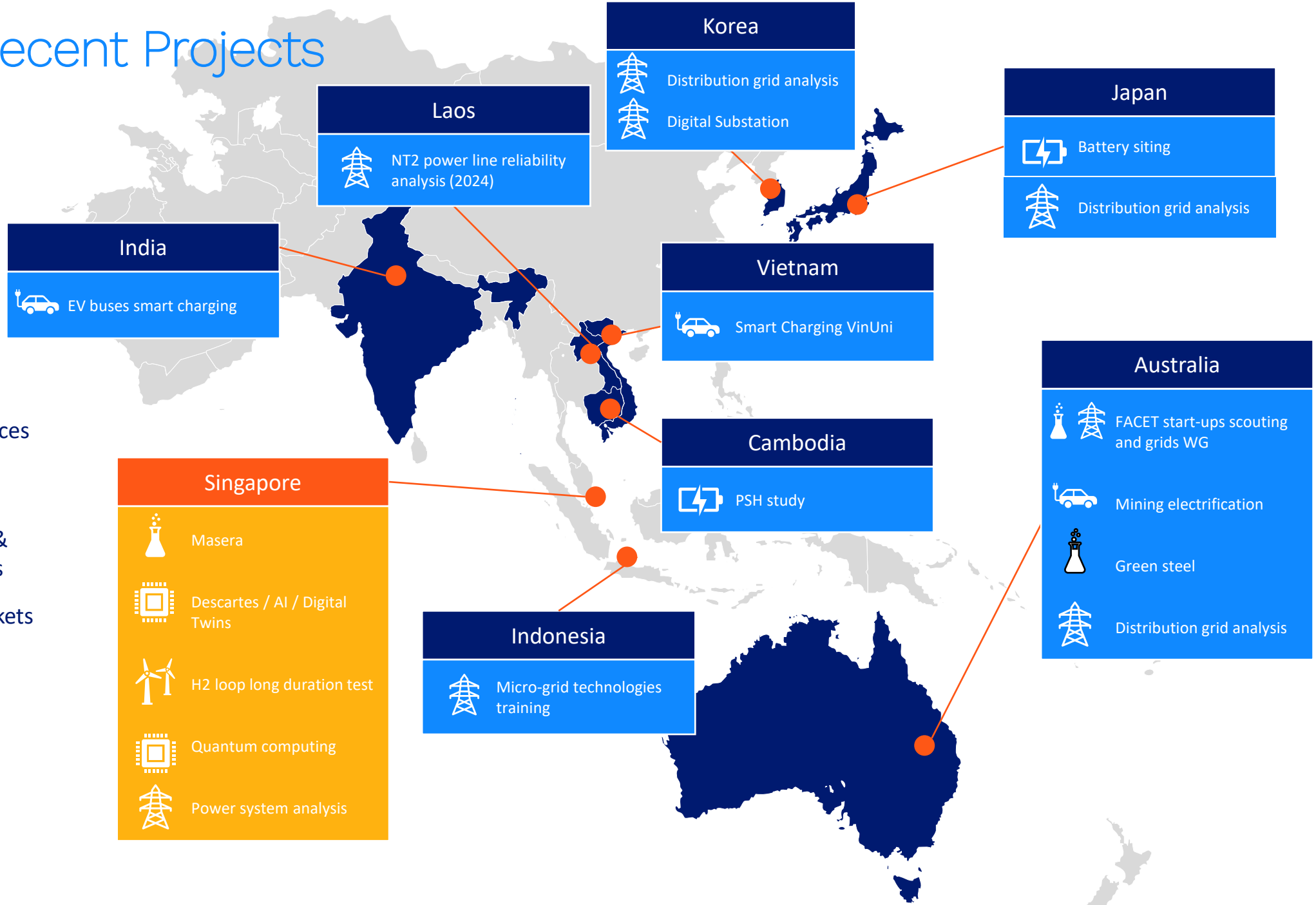
INVENTING TOMORROW'S ENERGY SYSTEMS

AXIS 4

ACCELERATING DIGITAL TRANSFORMATION

SCIENTIFIC PLAN 2021-2024
R&D

APAC: Recent Projects



Korea
- Distribution grid analysis
- Digital Substation

Laos
- NT2 power line reliability analysis (2024)

Japan
- Battery siting
- Distribution grid analysis

India
- EV buses smart charging

Vietnam
- Smart Charging VinUni

Cambodia
- PSH study

Australia
- FACET start-ups scouting and grids WG
- Mining electrification
- Green steel
- Distribution grid analysis

Singapore
- Masera
- Descartes / AI / Digital Twins
- H2 loop long duration test
- Quantum computing
- Power system analysis

Indonesia
- Micro-grid technologies training

- Storage
- Renewable Energy Sources
- Grids
- Innovation & Partnerships
- Energy Markets
- Digital, AI & Quantum
- E-Mobility

EDF

MICROGRIDS BY EDF

R&D EXPERIENCE TO SERVE THE GROUP

Saint Pierre et Miquelon
MicroGrid multi-énergie

France
- Zero Emission generators
- Iles de sein
- Iles de ouessant
- Corrèze Resilient Grid
- …

Singapore
MASERA testbed

Caribbean Islands
Saint Martin et Saint Barthélemy

Guyana
Kaw : one of the first MG

Africa
Solar kits

La Réunion
MAFATE, with H2

MICROGRIDS by EDF

COMPETENCES R&D – Support on the whole value chain for the Groupe

Screening	Prefeasibility	Feasibility	Detailed Design	Procurement, Installation & Commissioning	Operation & Maintenance
Project identification	***Early stage analysis***	***Develop proposals***	***Specifications***	***Deliver expected results***	***Final phase***
• Macro analysis (scale of a region or a country) • Identification of the areas with the highest electrification potential	• Technico-economic prefeasibility tool • Diagnosis of existing network / power system - Customer's requirements / Expected goals	• Technico-economic feasibility tool • Production forecast • Consumption forecast • Market/prices forecast • Grid constraint • Protection system • Reliability • Power Quality • …	• Microgrid technical & economic detailed sizing • Modeling & simulation • Definition of control strategies for DERs • Cyber-security • Lab testing in grid conditions (Concept Grid)	• Assets specifications • Tendering process • RFI/RFC • Pre-construction / Engineering phase • Construction phase • Installation & commissioning	• Optimize cost of energy mix • Operational optimization and forecast • Facilitate DER integration (IEC 61850) • Cybersecurity • Energy Management System (Optimal Use of Resources (DERs)) • Data analysis & performance improvement • Online monitoring • Training

Dedicated tools

Sunyata

LENI

PREMO

odyssee

CONCEPT GRID

Masera multi-energy testbed

Studies at EDF R&D France

Key Themes

- WP1 : Anticipate Electrical system, grid Services and market design of tomorrow
  - Assessment of future BESS revenues / Permitting issues
  - Hybridization with other technologies
- WP2 : Revenue – Asset optimization, Operational performances, Monitoring and Data
  - CAIMAN tool and other tools.
- WP3 : Technical – Asset optimization, Operational performances, Monitoring and Data
  - Ageing model and Knee point.
  - Monitoring algorithms
- WP4 : Power Electronics, Technical Supervision, Control algorithm, dev & deployment
  - Reliability studies and Safety tests.
  - MicroGrid tools.
- WP5 : Technological breakthrough and step forward (recycling, end of life, safety)
  - Cell tests.

Example of monitoring algorithms developped in SSYREN for EDF PS

Studies at EDF R&D France

Key Themes

- WP1 – Network & Protection
  - Develop protection concepts for 100% power-electronic microgrids
  - Define new protection schemes and grid-forming short-circuit strategies
  - Ensure power quality and reliability in high-renewable systems
- WP2 – Storage
  - Design and operational modeling of future battery systems
  - Monitor performance, ageing and safety of Li-ion technologies
  - Evaluate new storage technologies and control modes
- WP3 – Control / EMS
  - Optimize EMS operation and advanced control strategies
  - Improve forecasting and consumption-flexibility algorithms
- WP4 – Thermal Generation
  - Assess biofuel-based generation performance and sizing
  - Track emerging engine technologies and efficiency trends
- WP5 – Methods & Tools
  - Develop simulation and diagnostic tools (Odyssee, Athena)
  - Build analytical dashboards and provide training support

EDF SEI MicroGrids studied in the STORI project

Introduction

Welcome to MASERA Microgrid Testbed!

- Co-developed with Nanyang Technological University (the leading partners of **Renewable Energy Integration Demonstrator Singapore Project REIDS**)
- Commissioned in October 2018 with 4 Microgrid system operators (**EDF**, NTU, Engie and Rolls-Royce)
- Enabled dynamic testing for supporting activities on system optimization, smart grid network management, energy trading, interoperability, and cybersecurity for pre-competitive RD&D in the energy sector.

Fig. Aerial View of the Renewable Energy Integration Demonstrator Singapore

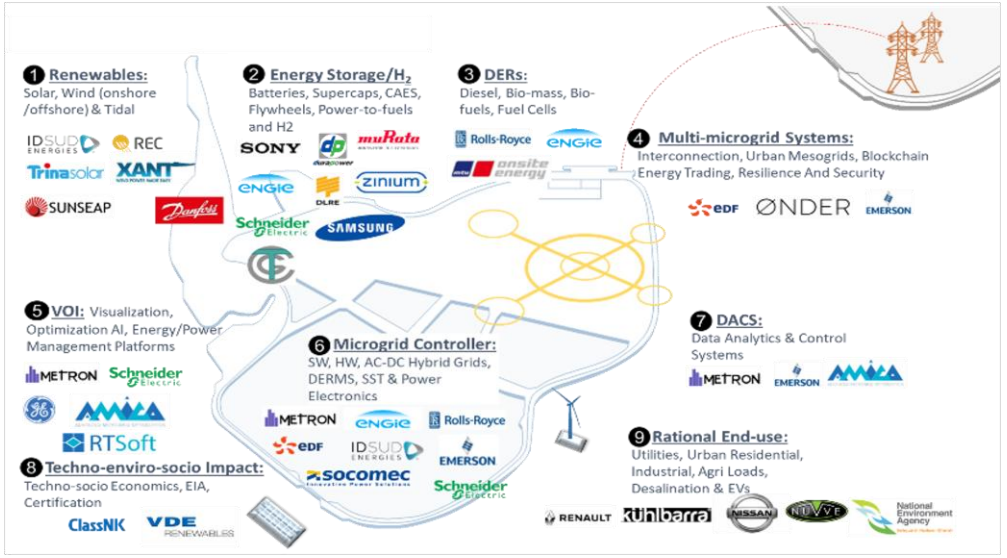


Fig. Collaborators, Equipment Supplier and Microgrid Operators

Single Line Representation of REIDS

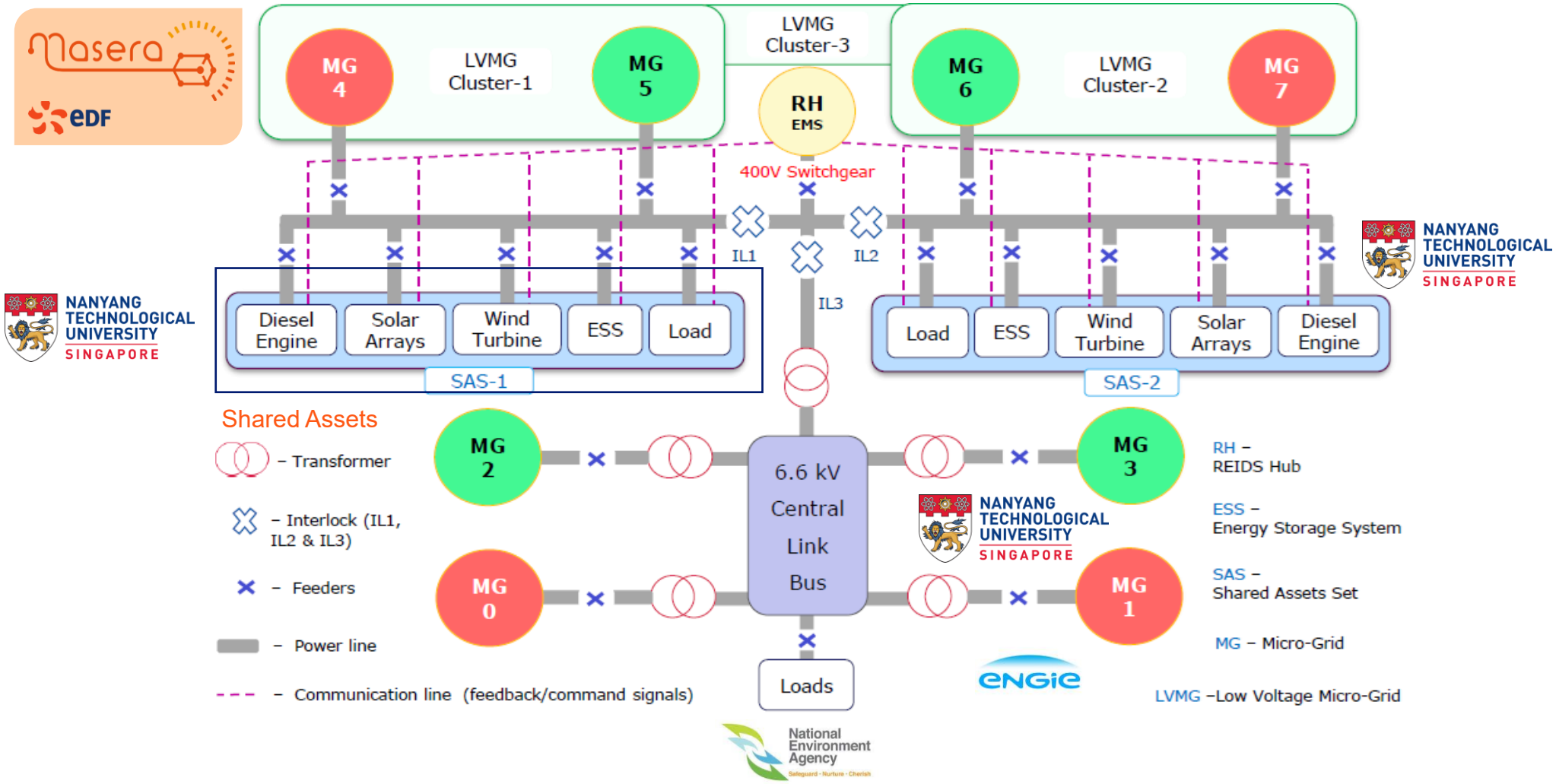


Fig. Single Line Representation of the Renewable Energy Integration Demonstrator Singapore REIDS

MASERA Microgrid Assets

H2 Power-to-Powe Capabilities

- Anion Exchange Membrane (AEM) Enapter Electrolyzer 2units x 2.1kW
- Generate H2 at 35bar and 99.999 % purity
- 8 x 50L (8-hour capacity)
- PEM Fuel Cell Intelligent Energy 2.5kW
- Integrated with MASERA's PV, Lithium-ion Battery, back-up genset, and EMS

MASERA Distributed Energy Resource

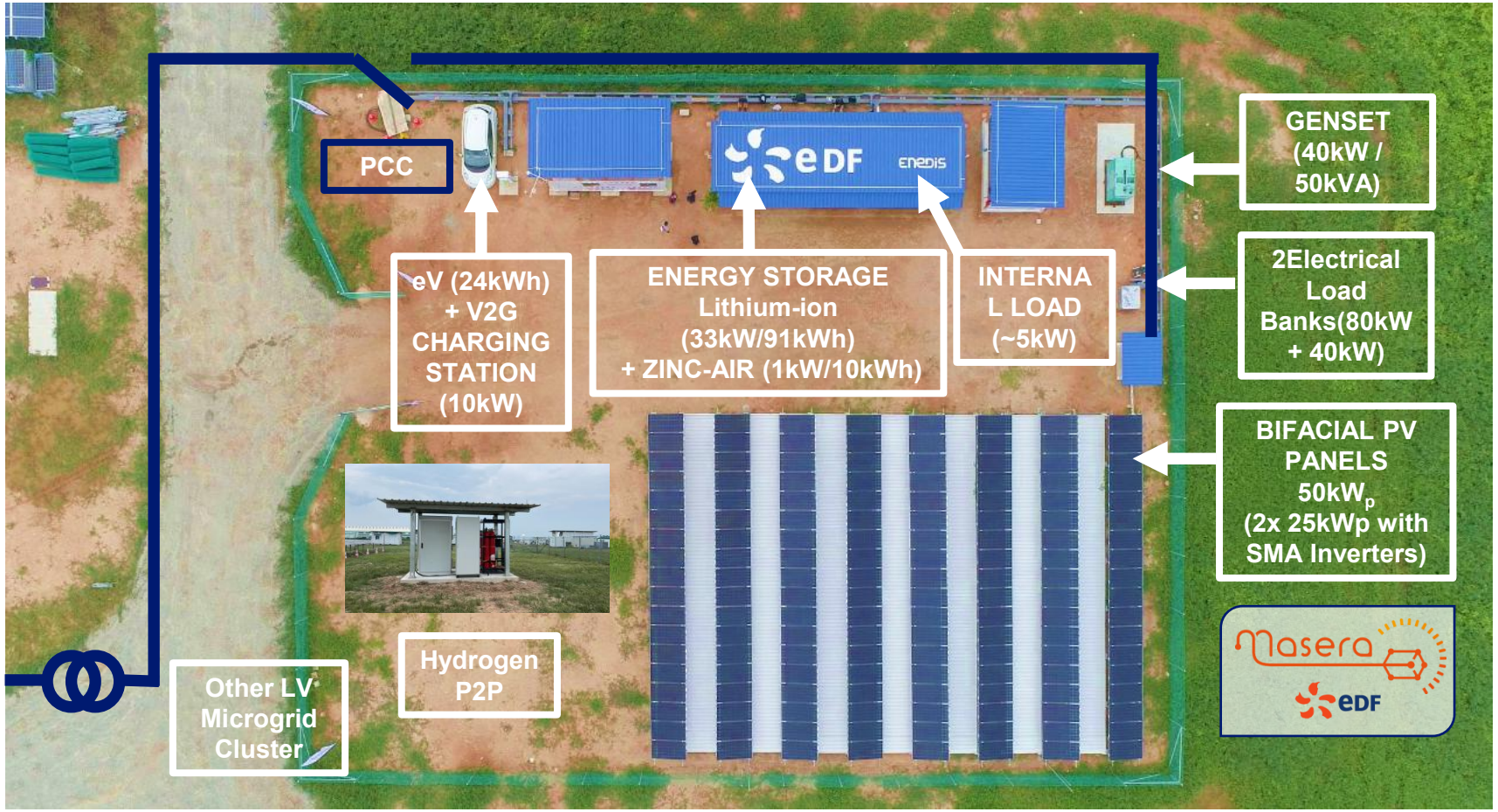


Fig. Description of the MASERA Microgrid Assets

External Collaborations for Technology Demonstration

PXiSE Energy Solution (originally a US-based start up acquired by Yokogawa Electric Corporation in 2021)

- DER management and communication platform (microgrid and renewable power plant controller)
- Memorandum of Understanding between Yokogawa Electric Corporation and EDF Lab APAC February 7, 2024
  - Aim to implement and enhance the Microgrid Controls at MASERA with PXiSE Energy Solution
  - Demonstrate EMS capabilities, improve H2 integration and validate the solutions

Fig. Memorandum of Understanding Signing Ceremony for EMS Integration

Fig. User Interface for Configuration of the PXiSE Energy Solutions

External Collaborations for Technology Demonstration

REDEX and Rekursive Labs (Renewable Energy Certificate Platform from Startups)

- Testing and validation of the RECs creation and retirement platforms
- Proof-of-Concept using Hedera for automated real-time redemption of tokenized Renewable Energy Certificates at EV charging stations via EDF's MASERA Microgrid.

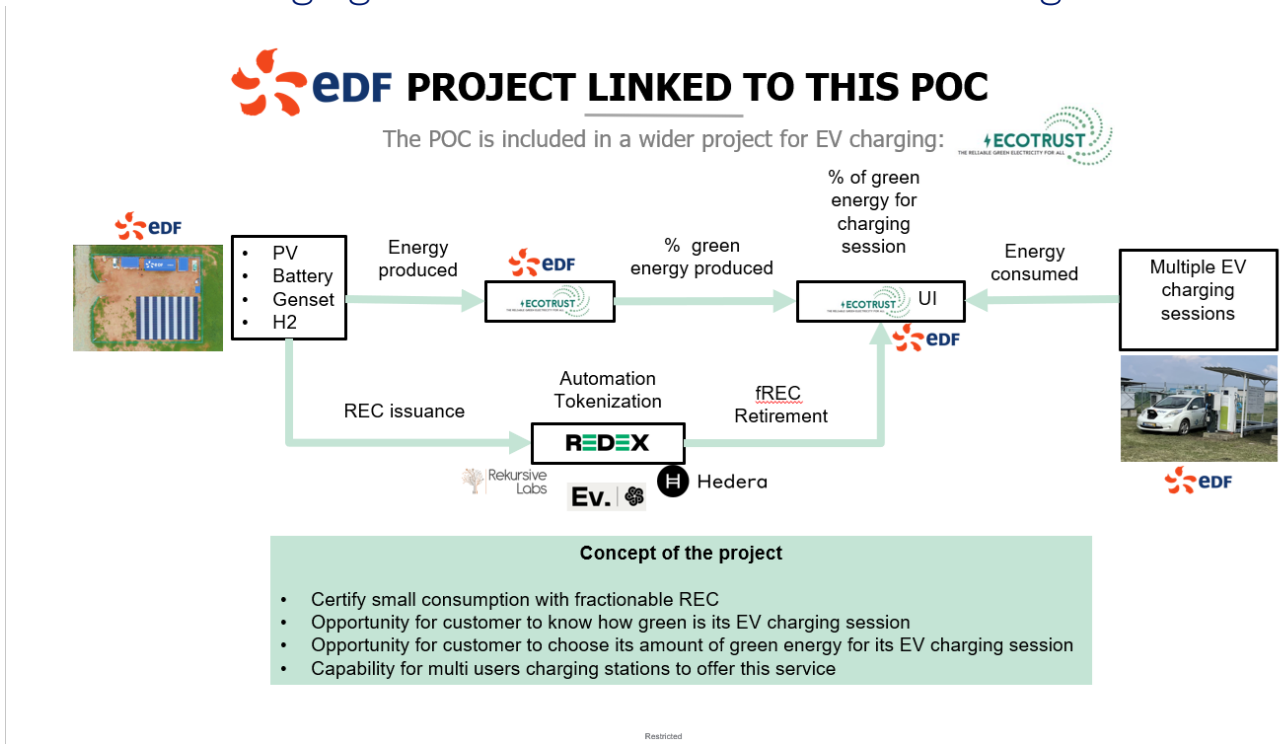


Fig. System Level Representation of REC Creation and Retirement Platform

External Collaborations for Technology Demonstration

Canopy Energy – Founded in 2016 (Installed and Tested on MASERA)

- Real-Time Monitoring of microgrid performance via edge devices and cloud portal
- Scalable and Remote Access for off-grid and hybrid energy systems

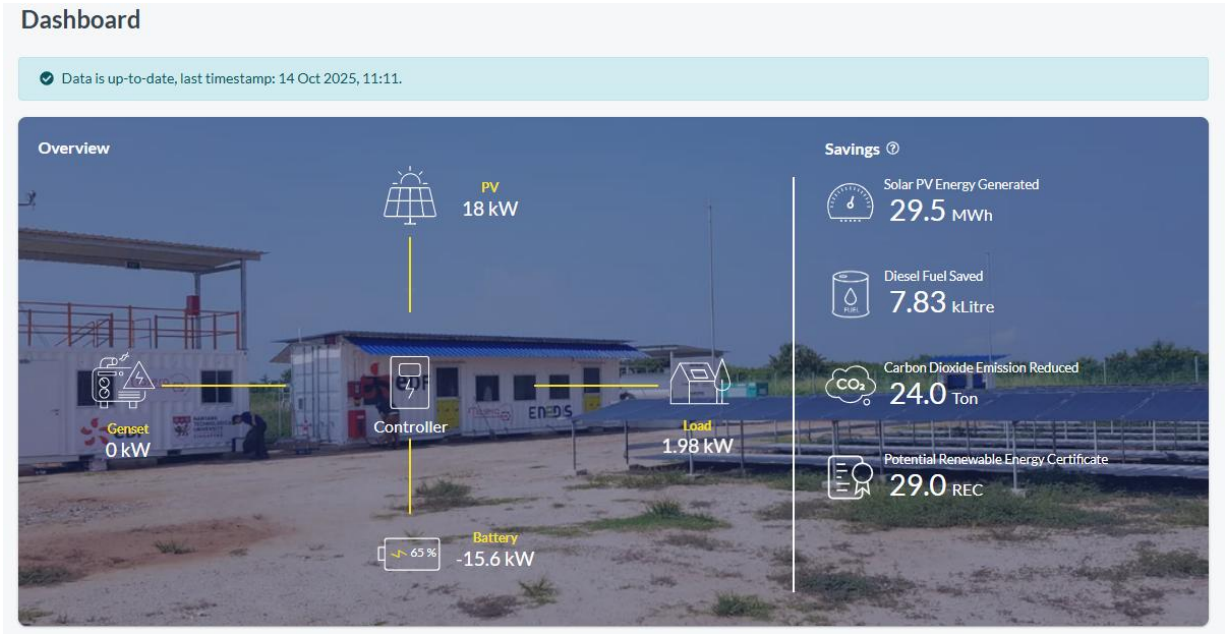


Fig. CANOPY Power User Dashboard

CANOPY POWER

Internal Collaborations for Technology Demonstration

Store and Forecast (originally a EDF start up and integrated into EDF Agregio Solutions - a wholly-owned subsidiary of the EDF corporation)

- Developed and marketed software to forecast solar and wind energy production and consumption.
- Provided energy optimization software, energy management systems (EMS), and services related to battery energy storage and renewable energy aggregation.
- Tested the various forecasting algorithms on MASERA at the start of the REIDS project in 2019 especially on the solar PV

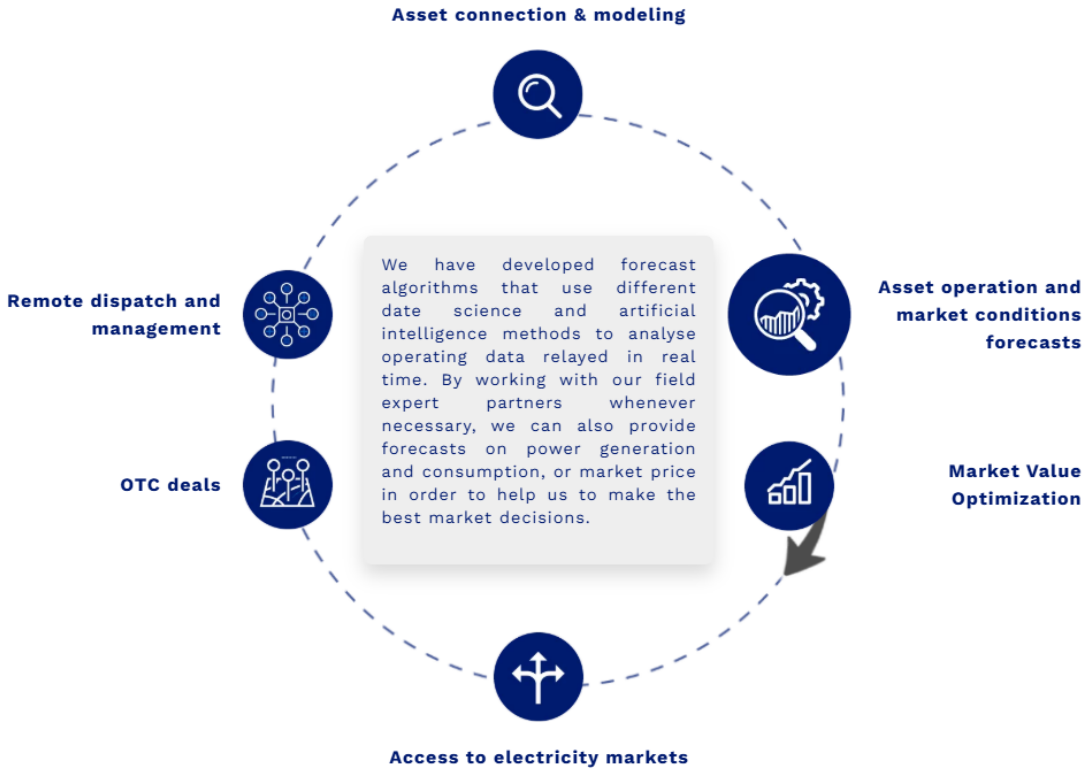


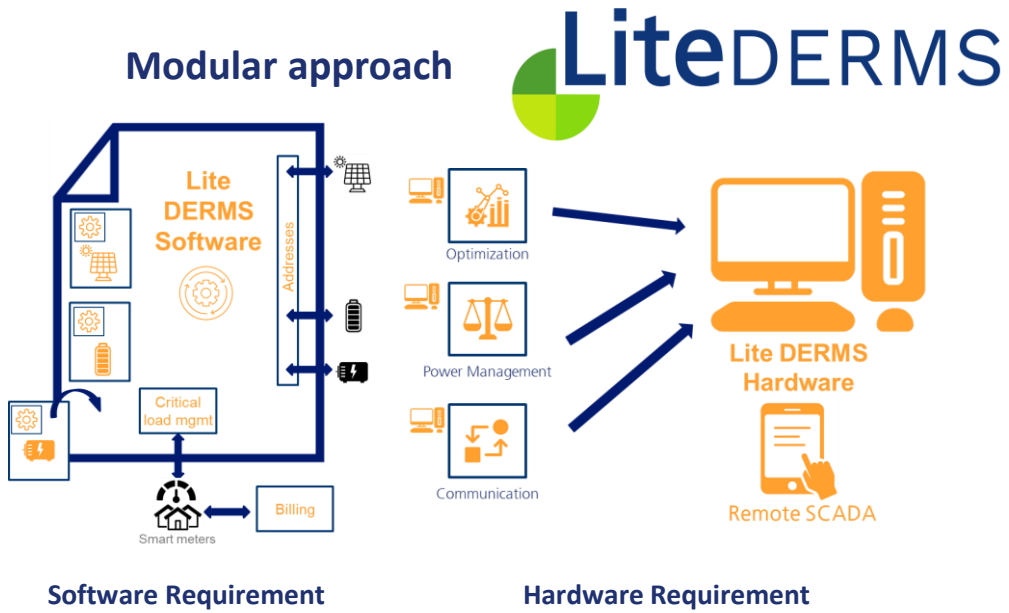
Fig. Memorandum of Understanding Signing Ceremony for EMS Integration

store & forecast
EDF GROUP

Internal Technology Demonstration

LiteDERMs – EDF's Solution on Energy Management

- All-in-one solution for a compact and simple Lite DERMS.
- Not linked to a dedicated hardware (technology agnostic)
- Deployment by one technician in one day with clear operating mode.
- Local and remote SCADA on laptops or tablets, easy to operate (HMI) and configure.
- Data storage and data historian (simple, temporary, or just samples).
- Communication protocols: Modbus RTU/TCP, and IEC 61850



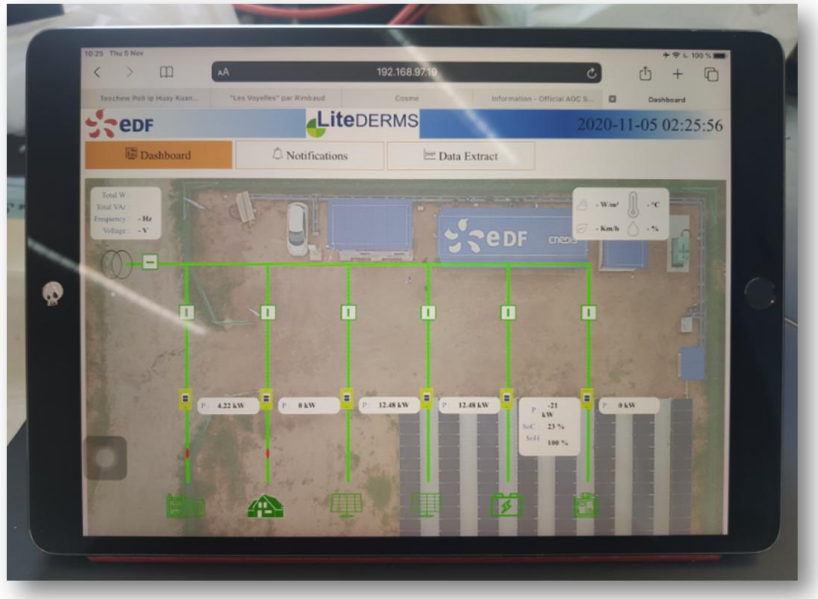


Fig. User Interface for Energy Management Solution LiteDERMS

Internal Technology Demonstration

Zinium (EDF Spin-off) – An affordable and eco-friendly Zinc-Air battery

- Zinc-air Batteries, created in July 2016 with target audience with the storage size of <200kWh
- Spin-off company of EDF Labs (Shareholder : EDF 100%, through EDF Nouveaux Business Holding)

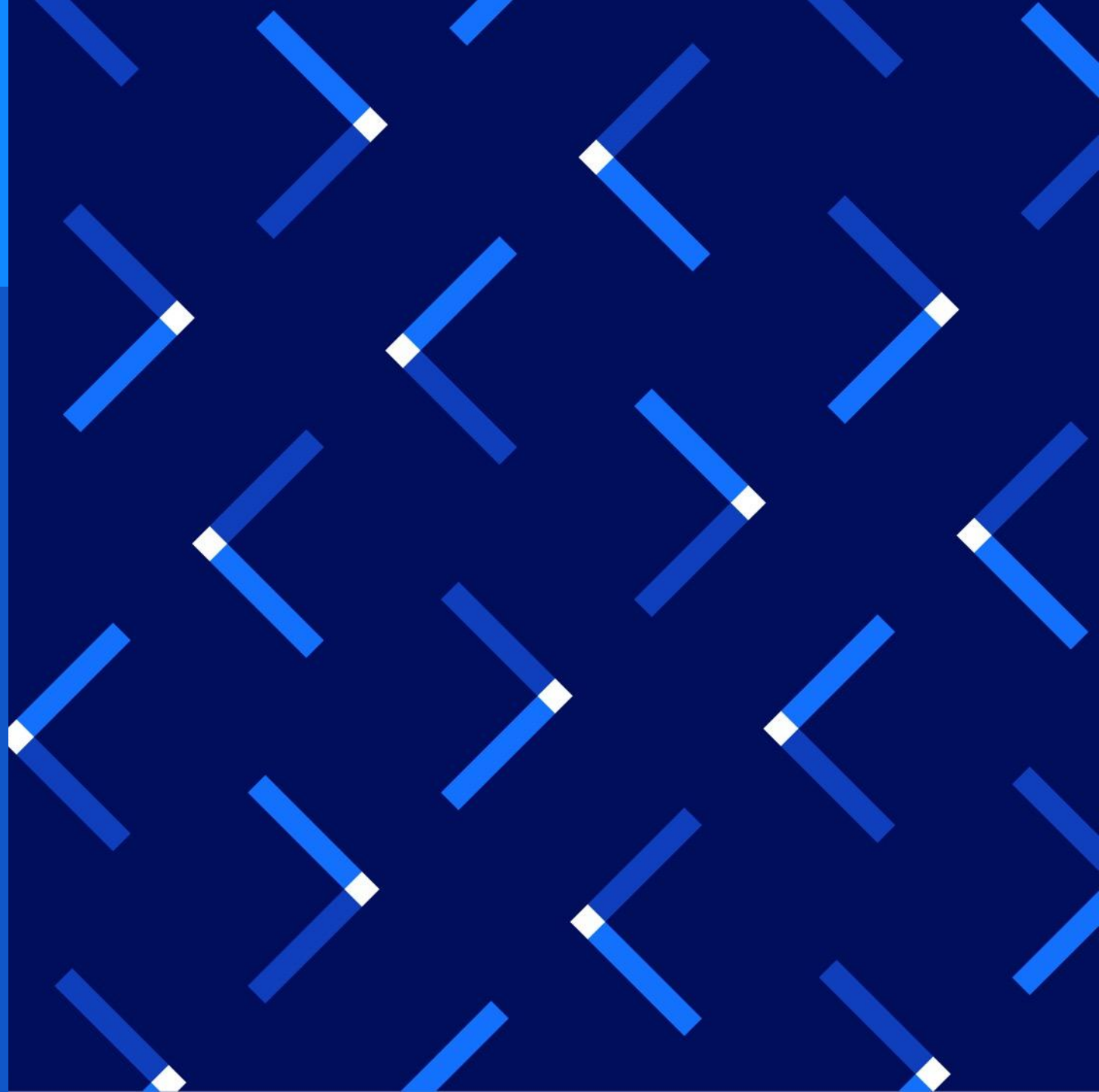
NUVVE – Intelligently Electrifying the Planet Through Cutting-Edge Vehicle-To-Grid (V2G) Innovation

- Bi-Directional Charging: EVs can send power back to the grid
- Grid Services: Supports energy balancing and peak shaving

Linky (ENEDIS) – Smart Meter Integration

- Remote Monitoring & Control
- Real-Time Consumption Insights
- Supports Smart Grid Integration –Facilitates dynamic pricing and renewable energy adoption

AI and Microgrids: Hybrid AI in EMS Digital Twin



Digital Twin Definitions

A DT is **a set of adaptive models** that emulate the behaviour of a physical system in a virtual system getting **real time data to update itself along its life cycle**. The digital twin replicates the physical system to predict failures and opportunities for changing, to prescribe real time actions for optimizing and/or mitigating unexpected events observing and evaluating the operating profile system

Semeraro C., Lezoche M., Panetto H., Dassisti M. "Digital twin paradigm: A systematic literature review" Comput. Ind., 130 (2021), Article 103469, 10.1016/j.compind.2021.103469

A DT is **more than a simple model** or simulation. A DT is a living, intelligent and **evolving model**, being the virtual counterpart of a physical entity. It **follows the lifecycle of its physical twin** to monitor, control, and optimize its processes and functions. It continuously predicts future statuses (e.g., defects, damages, failures), and allows simulating and testing novel configurations, in order to preventively apply maintenance operations…

B. R. Barricelli, E. Casiraghi and D. Fogli, "A Survey on Digital Twin: Definitions, Characteristics, Applications, and Design Implications," in IEEE Access, vol. 7, pp. 167653-167671, 2019, doi: 10.1109/ACCESS.2019.2953499

Energy Management System Digital Twin

The LdPMS acts as the brain of the system, allowing the grid to take decision regarding the energy

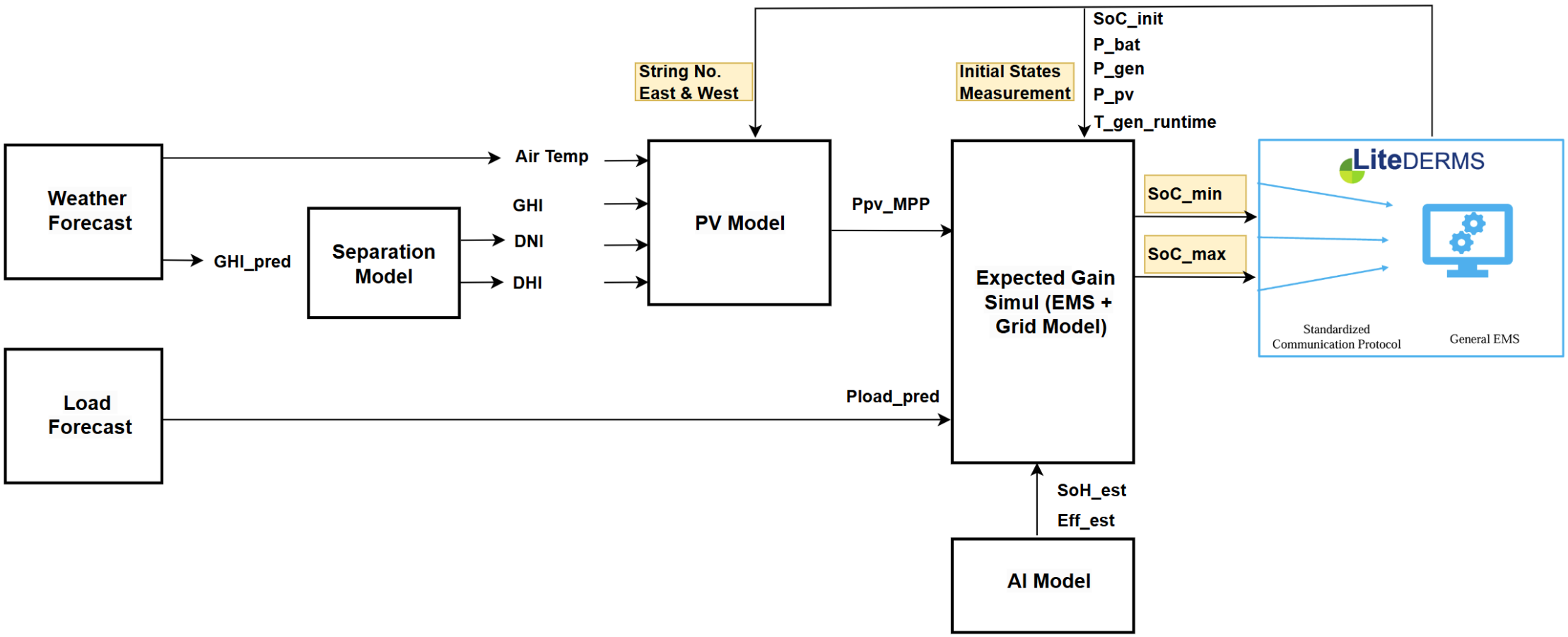
Function in auto modes :

- *battery grid forming/grid following*
- *genset grid forming/grid following*

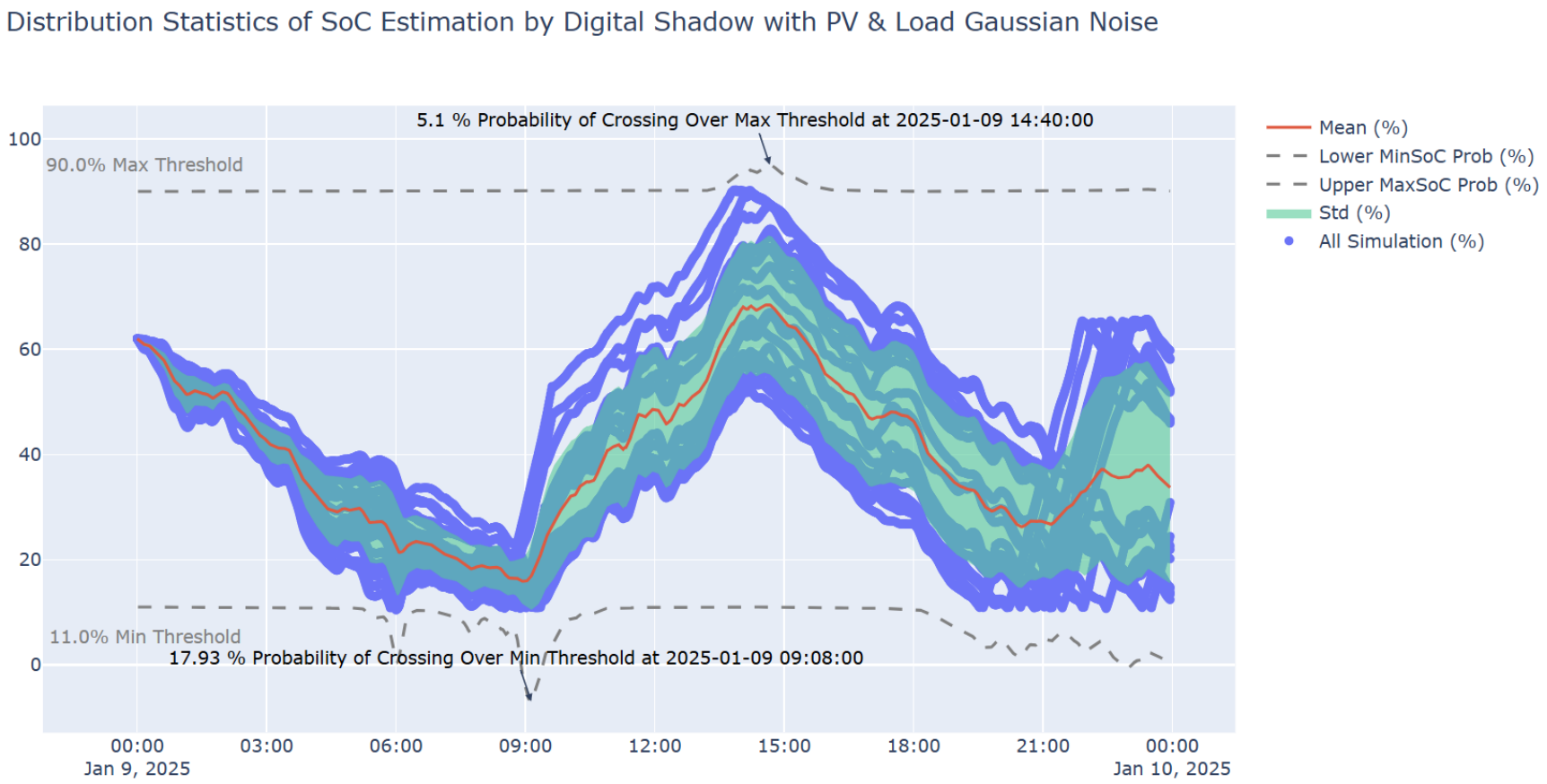
Prioritize the seamless use of RES

- Hybrid AI for Energy Management System
  - Hybrid AI = AI systems that interact with the physical world, combining digital intelligence with real-world (physical) systems.
- AI models of PVs and batteries for PV production forecast and battery state of health and state of charge forecast
  - AI improved physical models
  - AI models
  - Machine Learning / Deep Learning …
- First stage: minimize diesel use

Digital Twin Data Communication with LiteDERMS



Probability for Expected Gain of Threshold Expansion



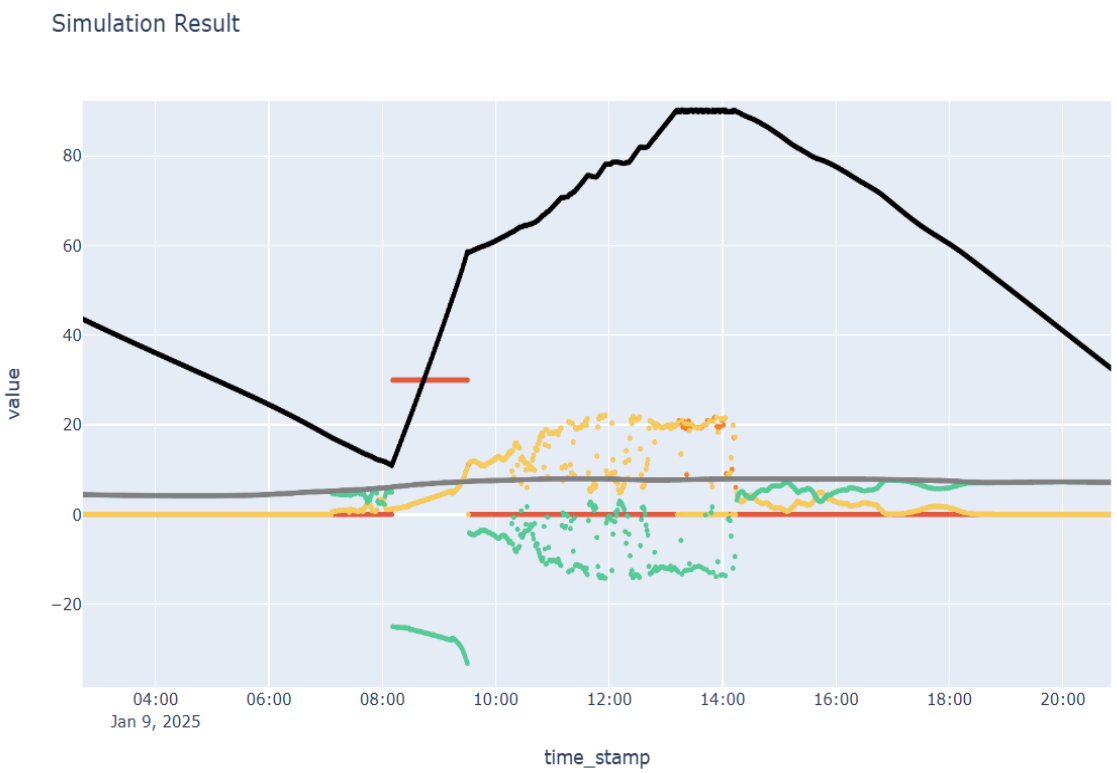
- By simulating predicted Load and PV production with Gaussian Process Noise, the **probability** of crossing over Min and Max thresholds can be calculated.

- It applies **Cumulative Distribution Function** for normal distribution.

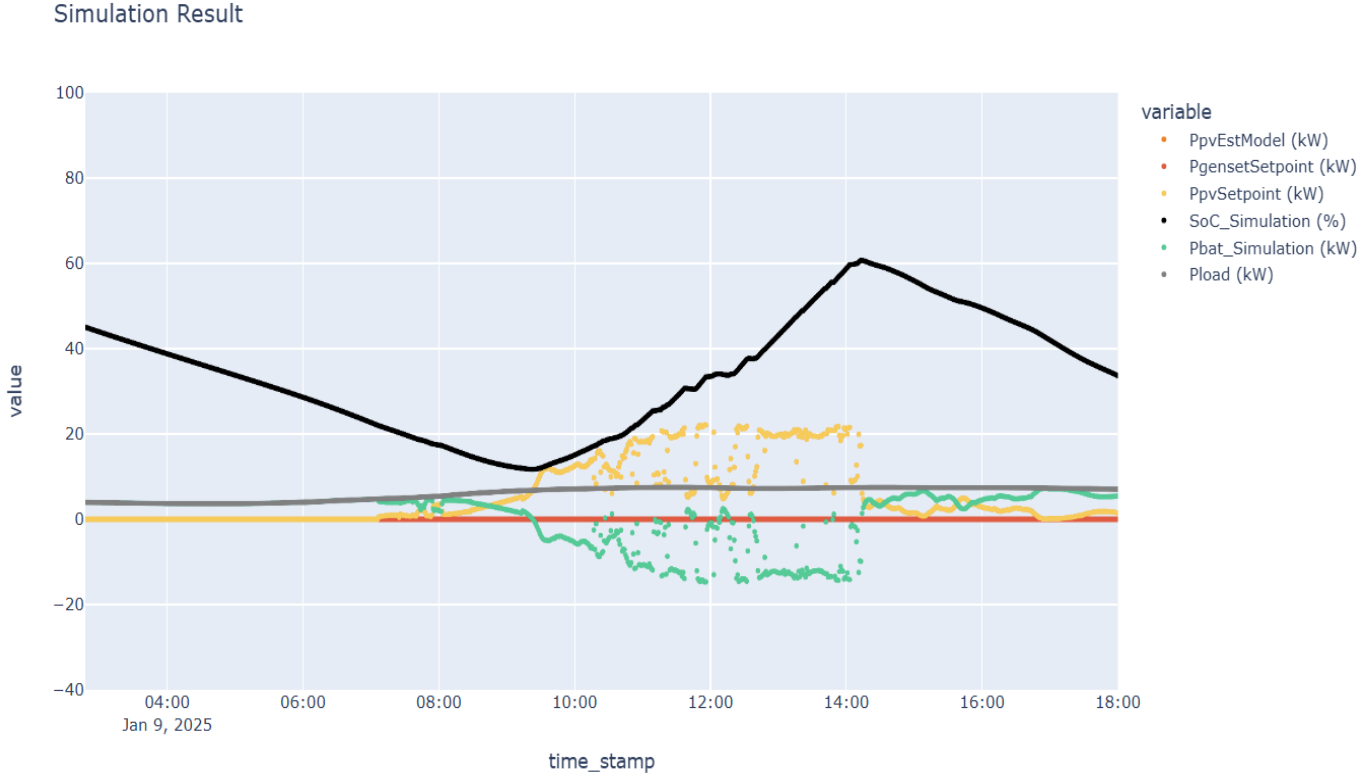
(The Variance for Gaussian Process Noise is 10% Max Nominal Power for PV and 10% Max Power for Load)

Simulation with SOCmin modification

Min SoC Threshold of 11%



Min SoC Threshold of 6%



- Expected Gain Probability gives estimation of how much benefit is gained for expanding current Thresholds.
- By lowering the minimal SoC threshold to 6%, it's expected to save up to 1h20' of early Genset usage, equivalent to 39kWh.

Next steps in EMS Digital Twin

- Long duration tests on existing solution and improvement measurement
- Improvement of existing solution by modifying the AI based decision
- Implementation of new rules
  - Prices
  - Flexibility
  - …
- Implementation of new assets
- …

AI and Microgrids: AI Models of Electrolysers

Electrolyzer Long Duration Test in Masera

Context/Objective

- This study advances the **operational understanding of AEM electrolyzers** through over 2000 hours of long-duration testing across two units. It enables **robust performance evaluation and model validation**, supported by innovations such as a web-based automation system for data acquisition and renewable energy simulation, and a degradation-aware algorithm to improve green hydrogen production. Predictive modeling of key parameters further supports scalable, autonomous operation.

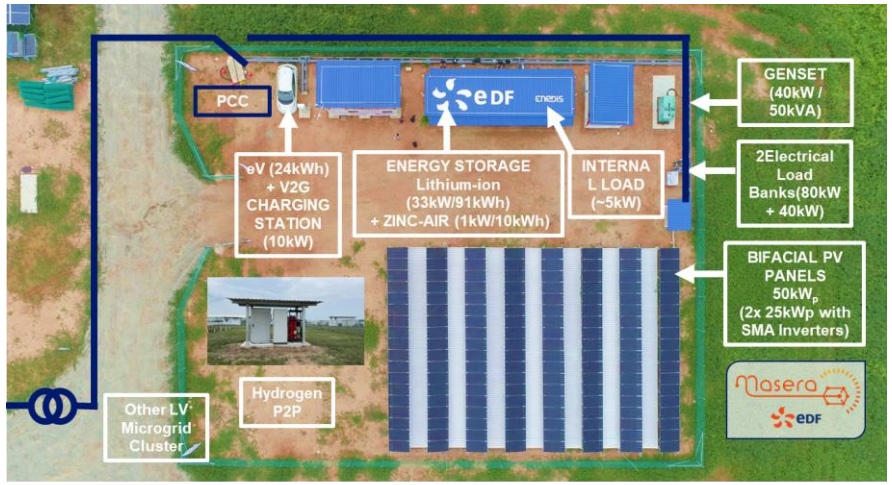


Fig. Description of the MASERA Microgrid Assets

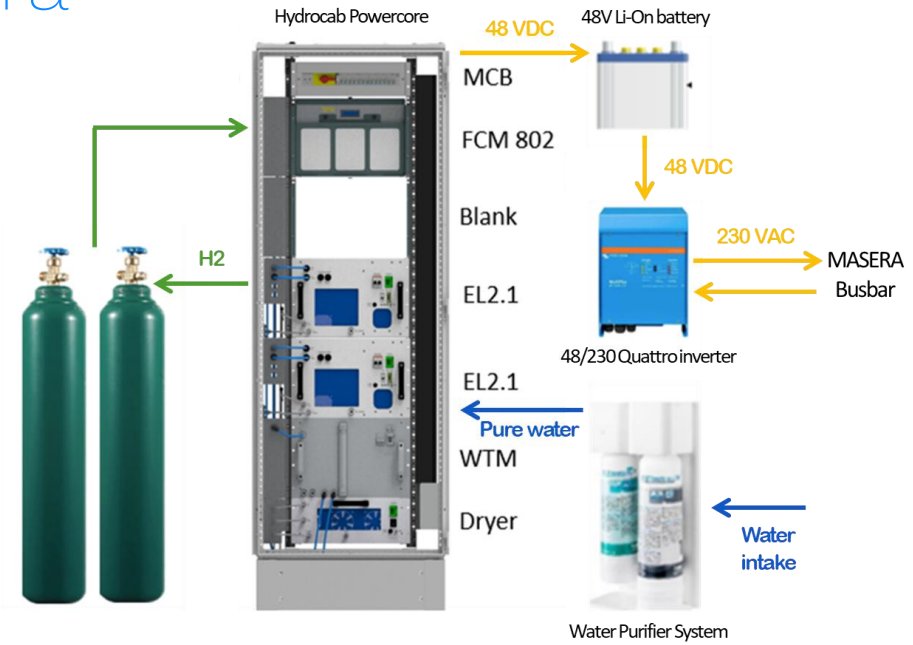
Key Achievements

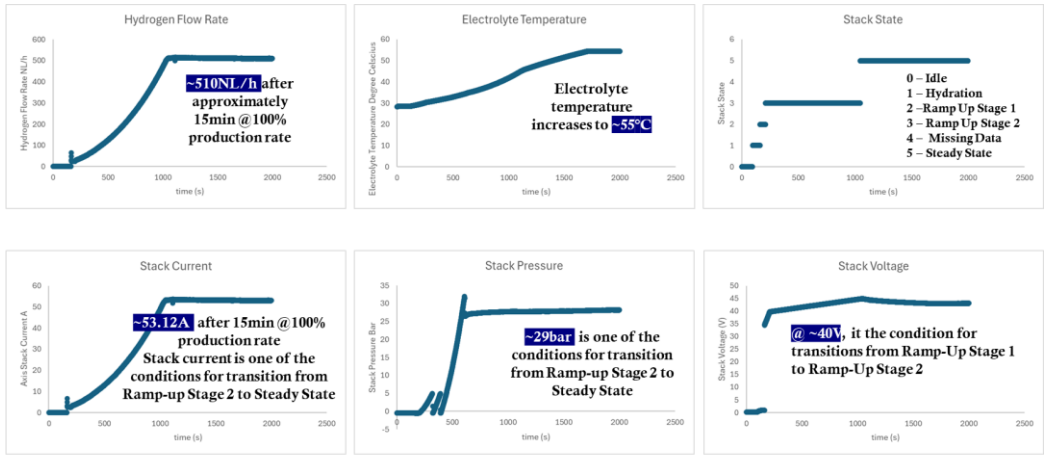
- **Achieved over 1500 hours of combined electrolyzer operation** to date, providing robust data for long-term performance analysis and model validation.
- **Developed a degradation-aware management algorithm based on AI** for green hydrogen plants, enhancing operational efficiency and reliability under dynamic conditions, energy storage integration and grid-connections.
- **Developed a web-based automation system** for electrolyzer data acquisition and control, enabling long-duration testing and renewable energy simulation.
- **Established an AI data-driven operational model for AEM electrolyzers** through long-term testing, overcoming limited commercial data by predicting dynamic parameters such as hydrogen output, voltage, and pressure—reducing reliance on manual tuning.

Electrolyzer Long Duration Test in Masera

H2 Loop Long Duration Testing

- Web-based automation system for simulation of renewable energy profile and data acquisition and management
- Data-driven Operational Model for Key Performance Criteria (Hydrogen flow rate, stack current, stack voltage, stack pressure, and electrolyte temperature)
  - Benchmark with 9 unique data-driven algorithms
  - Identification and modeling of key importance features
  - Establish state transition diagram/state-flow diagrams
- Development of Long-time horizon simulation model (25 years) with performance tracking, degradation monitoring and preventive-regular maintenance schedule
- Electrolyser degradation analysis through AI





Note: Test Performed on the 2025-02-04 02:18:19 – Starting from 29°C and Production Rate from 0% to 100%

Electrolyzer Long Duration Test in Masera

What is Next for 2026?

- Demonstrate modeling and simulation capabilities in EDF Lab APAC (shows capabilities to be part of larger eco-system in EDF R&D France Projects)
- Proposed tool (Electrolyzer Manufacturing Plant Management) can be further developed into a product (e.g., demonstrate with hard-ware-in-the-loop, communication)
- Real-time assessment of electrolyzers health using Operational Model
- Expand the simulation tool for other technologies
  - Degradation-aware Market Participate for Large-scale Batteries or Hydro Power/Storage Stations
  - Adapt to other technologies that EDF Power Solutions is exploring (e.g., Concentrated Solar Power, Wind and Electro-Thermal Coupling in Waste-heat Recovery Projects)

Contact Point

Morgan Philippon

Morgan.philippon@edf.sg

MASERA Site Operations Manager

Thank you!