

# AI and Microgrids: Lessons from Pacific–Australia Links for Resilient, Affordable and Community-Centred Energy Systems

Apéro Scientifique

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Top 2% Scientist (Stanford/Elsevier 2020–2025)



# Acknowledgement

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Charles Darwin University Acknowledges all First Nations People across the Lands on which we live and work and we pay our respects of elders both past and present.

# France, the Pacific and the Northern Territory: a Connected Research Pathway



 A shared focus on resilient, affordable and community-centred energy systems



# Building resilient energy futures

Connecting the Northern Territory and the Pacific through innovation and collaboration



## Stronger together

- Foster long-term partnerships between NT and Pacific communities
- Co-develop solutions that reflect local needs and priorities



## Smarter solutions

- Advance renewable energy, microgrids and storage
- Use AI, digital twins and data to improve decision-making



## Local impact

- Build skills, create jobs and strengthen local capability
- Support affordable, reliable and clean energy systems



## Sustainable future

- Improve energy security and climate resilience
- Deliver lasting benefits for generations to come

# Microgrid Concept

A microgrid is a local energy system that integrates distributed energy resources, storage and loads, coordinated through an energy management system. It can operate either grid-connected or islanded to improve reliability, efficiency and sustainability.



## Integrated resources

Solar, wind, storage and loads working together



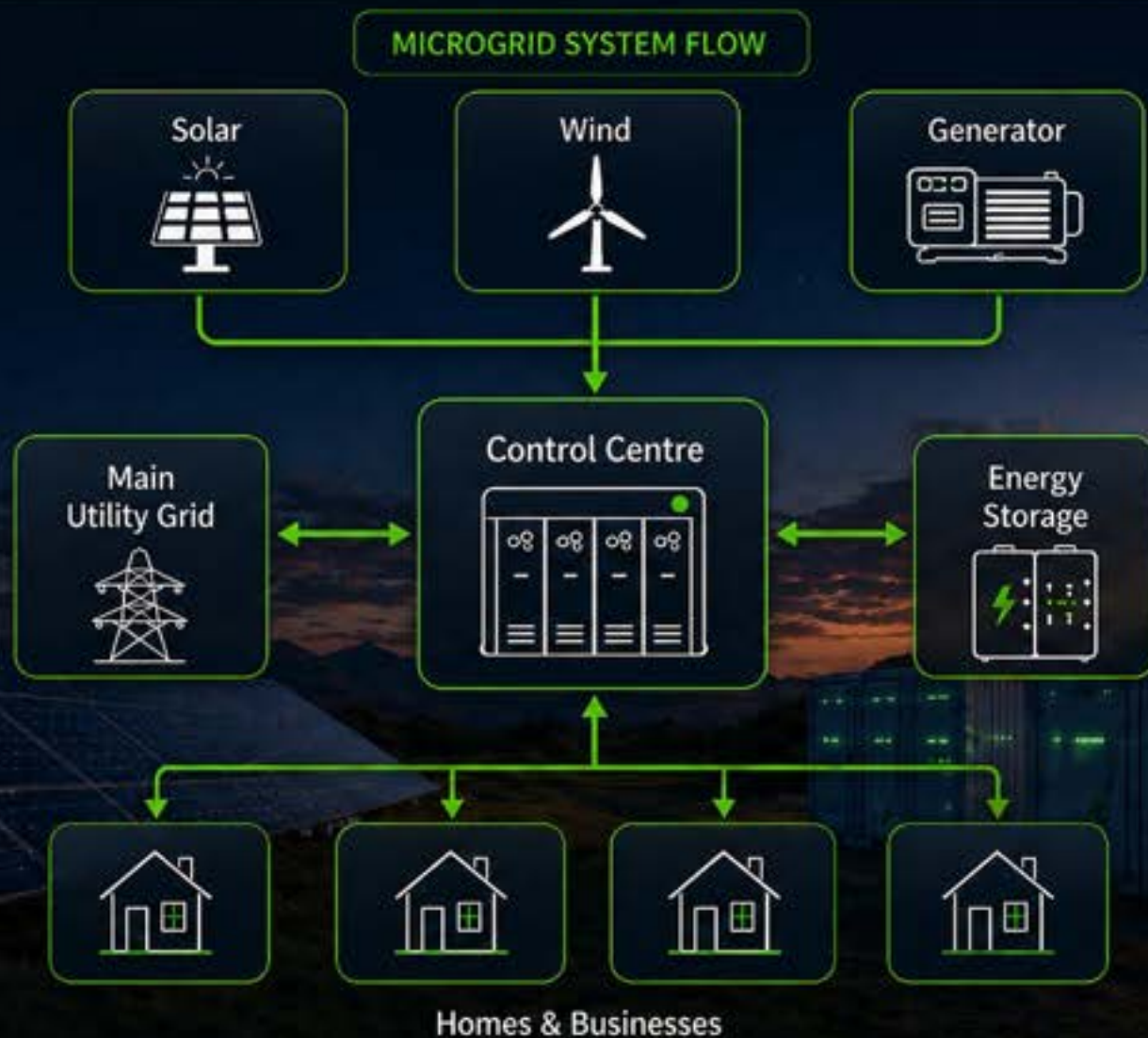
## EMS central role

Optimising operation, ensuring reliability and balancing energy flows



## Grid-connected or islanded

Flexible operation for resilient and sustainable energy systems



# Control Architecture

Hierarchical control for stable and efficient microgrid operation



## PRIMARY CONTROL

- Fast response (ms – s)
- Local control loops
- Voltage and frequency support



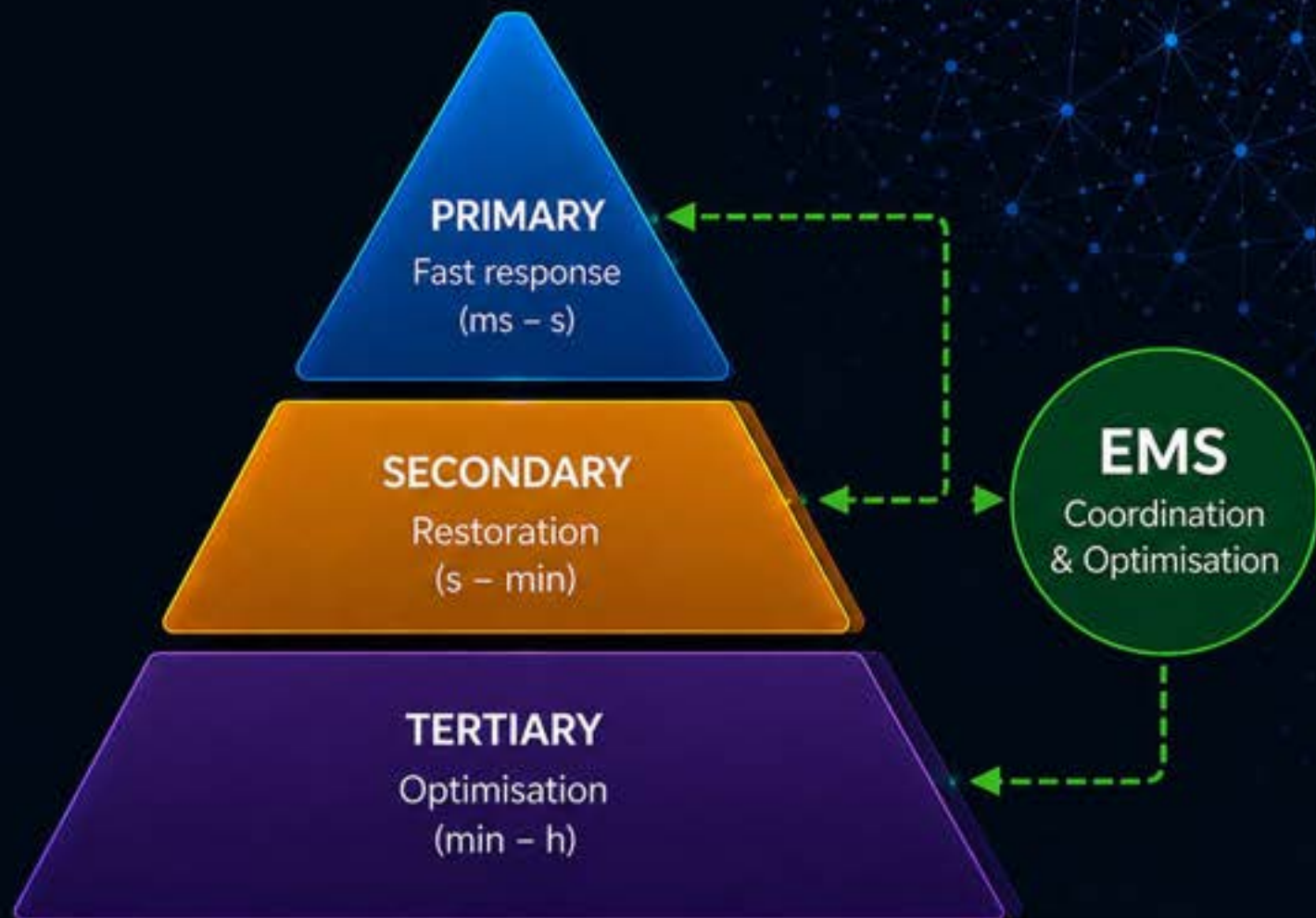
## SECONDARY CONTROL

- Coordination (s – min)
- Restoration of system states
- Power sharing and correction



## TERTIARY CONTROL

- Optimisation (min – h)
- Economic dispatch
- EMS coordination and scheduling



# Why Microgrids Matter Beyond Engineering



## Energy Access

Bringing reliable electricity to remote and underserved communities — from Pacific atolls to NT townships



## Affordability

Reducing dependency on imported diesel, lowering household costs and protecting community livelihoods



## Resilience

Maintaining power during cyclones, droughts and grid outages — keeping schools, clinics and homes running



## Community Benefit & Sovereignty

Enabling capability building, local ownership and energy self-determination for Pacific and Indigenous communities

# Weak Grids in the NT and the Pacific Islands

SCR defines grid strength; X/R influences behaviour in weak-grid applications.

## What matters most in NT remote grids



### Low SCR

High equivalent grid impedance and low short-circuit capacity.



### Voltage & frequency sensitivity

Inverter actions can strongly affect the PCC.



### Low inertia / low fault level

Protection, stability and commissioning become harder.



### Remote and islanded operation

Common in NT and Pacific Islands.



Typical situations in Northern Territory (NT) and Pacific Islands: microgrids are often connected to weak feeders or operate in standalone mode.



## Grid strength = SCR



$$SCR = \frac{S_{sc}}{S_{rated}}$$



Short-Circuit Ratio is the primary indicator of grid strength at the point of connection.

### Strong grid (high SCR)



- ✓ High short-circuit capacity
- ✓ Low voltage deviation
- ✓ Better disturbance absorption
- ✓ Easier converter synchronisation

### Weak grid (low SCR)



- ⚠ Low short-circuit capacity
- ⚠ Higher voltage sensitivity
- ⚠ Greater control interaction
- ⚠ Harder commissioning and tuning



High SCR → strong grid.  
Low SCR → weak grid.



Fiji electrical system



Northern Territory electrical system



For NT and Pacific applications: prioritise SCR / grid-strength assessment, then include X/R to tune inverter controls, protection and HIL tests.

# Pacific Islands and Northern Territory: Different Geographies, Shared Energy Challenges



## Pacific Island Communities

- Remote island grids
- Diesel dependence > 80%
- Cyclone vulnerability
- Limited O&M capacity
- Energy sovereignty goals



## Shared Challenges

- Weak / isolated grids
- High energy costs
- Intermittency challenges
- Need for robust solutions
- Digital tools & training



## Northern Territory, Australia

- Scattered remote towns
- Diesel & ageing infrastructure
- Extreme heat & storms
- First Nations communities
- Distance from main grid

# From Weak Grids to Smarter Microgrids: The Gap We Need to Close

Weak-grid, inverter-dominated and multi-energy systems require a new paradigm.



Bridging the gap with **grid-forming control, hydrogen-ready architectures, AI-enabled energy management, and community-centred energy sovereignty.**



# Community-centred microgrids: why engagement and energy sovereignty matter


Reliable energy systems work best when communities help shape them, govern them and benefit from them.




**Co-design and trust**  
Engagement helps align the microgrid with real community needs, priorities and daily energy uses.




**Local ownership and sovereignty**  
Energy sovereignty means more local control over decisions, operations, data and future development.



**Capability building**  
Training, participation and local involvement strengthen maintenance, resilience and long-term success.



**Shared benefits**  
Well-designed microgrids can reduce diesel dependence, improve services and keep more value in the community.



The strongest microgrid is not only technically stable — it is **trusted, community-shaped,** and able to deliver **lasting local benefits.**

# Grid-forming inverters: why they matter in weak-grid microgrids

*From stable voltage and frequency support to higher renewable integration*



## 1. Voltage and frequency formation

GFM inverters establish voltage and frequency instead of only following the grid.



## 2. Weak-grid and islanded operation

They improve stability in remote microgrids and low-SCR systems such as the NT and Pacific Islands.



## 3. Renewable integration

They support higher shares of solar, wind and storage with better dynamic behaviour.



## 4. Resilience and black-start capability

They can help restore and stabilise isolated systems after disturbances.



Key message: in weak grids, the inverter must not only inject power — it must help **form and stabilise the grid.**

# Islanded microgrids can use one or many GFM inverters

At least one source must form voltage and frequency — several GFM units are possible, but only with careful coordination.

## Practical rule



An islanded microgrid needs at least one source that forms voltage and frequency.



This source can be:

- diesel / synchronous generator
- battery inverter in GFM mode
- multiple coordinated GFM inverters
- diesel + GFM combination



A GFL inverter alone cannot stabilise the grid: it follows an existing voltage/frequency reference.

## Possible architectures

### 1 One GFM + many GFL



Simplest to control; practical for small microgrids.

### 2 Multiple GFM + optional GFL



Redundancy, scalability and power sharing — but requires coordination.

### 3 Diesel / synchronous generator + GFL



Simple and robust: the diesel/SG forms the AC bus, while GFL units follow. However, the system remains diesel-dependent and may limit renewable penetration.

### 4 Diesel / synchronous generator + GFM + GFL

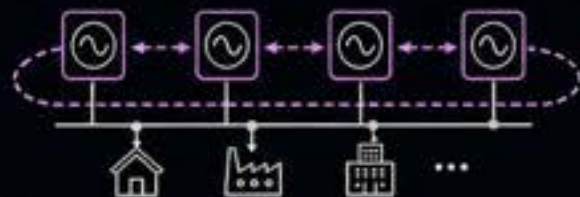


A transition architecture: diesel/SG and GFM support the AC bus together, while GFL units follow. This can improve stability and enable lower-diesel operation.



At least one source must form the grid; the rest may follow or co-form it.

## Why multiple GFM need attention



- GFM units must synchronise rather than compete.
- They must share power and remain dynamically stable.
- Coordination may use droop control, virtual synchronous machine, virtual oscillator control, matching control and hierarchical control.
- Protection settings, tuning, and communication or communication-less sharing are critical.
- This is where collective dynamics become difficult.

“ One GFM can act like the conductor of a small orchestra. With many GFM units, there is no single conductor; stability depends on whether they synchronise rather than compete.

**Key message: The problem is not that multiple GFM inverters are impossible; the problem is that their interactions must be designed, tuned and validated.**

Case 3 is a simple baseline but diesel-dependent; Case 4 better reflects the transition toward high-renewable, lower-diesel islanded microgrids.

# Hydrogen-ready microgrids

Beyond batteries for long-duration resilience



When renewables scale up, hydrogen enters



Electrolysis converts surplus renewable electricity into hydrogen



Hydrogen can provide seasonal or long-duration storage beyond batteries



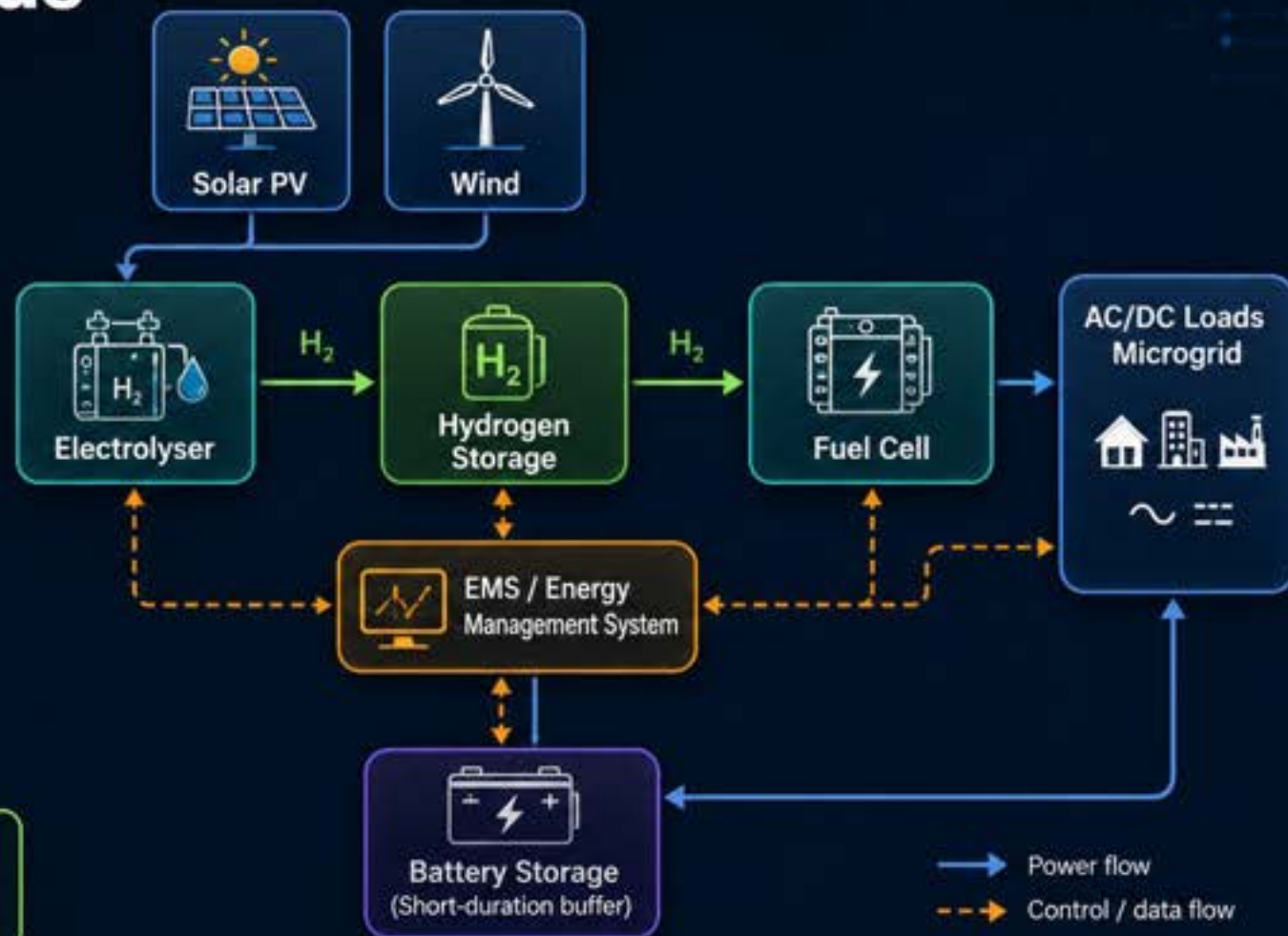
Fuel cells reconvert hydrogen into electricity on demand



Hydrogen-ready microgrids improve resilience, autonomy and fuel security in remote communities

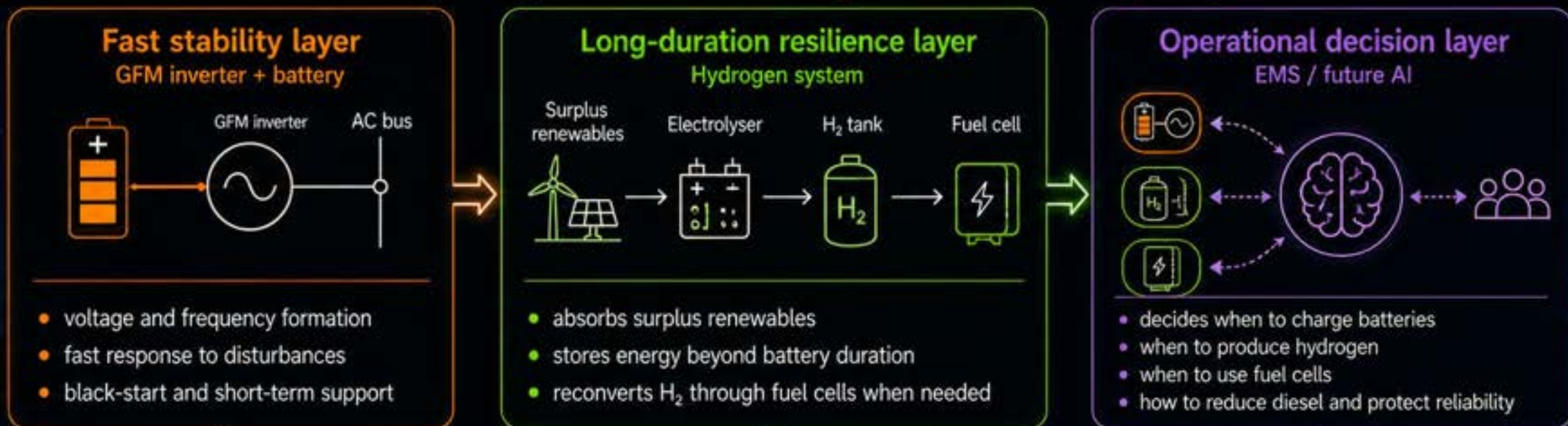


Hydrogen does not replace the microgrid — it becomes one controllable subsystem inside it.



# From Technologies to Operation: Coordinating GFM, Batteries and Hydrogen

*A hydrogen-ready microgrid is not just a set of technologies; it is a coordinated system where stability, energy balance and community needs must be managed together.*



**GFM provides the electrical 'heartbeat'; hydrogen provides long-duration energy flexibility; AI/EMS provides the intelligence to coordinate both.**

*Now the question becomes: who coordinates these layers under uncertainty?  
This is where AI and digital twins become important.*

AI is not an option — it is required to control complex, uncertain and multi-timescale microgrid systems.

## COMPLEXITY

- High-dimensional nonlinear system
- Strongly coupled inverter dynamics
- Multiple energy carriers and constraints
- Multi-timescale dynamics (ms → s → min → h)
- Large combinatorial action space

Classical methods face the curse of dimensionality.

## UNCERTAINTY

- Renewable generation variability
- Stochastic and intermittent loads
- Forecast errors and market uncertainty
- Component faults and degradation
- Partial observability of the system

Future events cannot be perfectly predicted or fully observed.

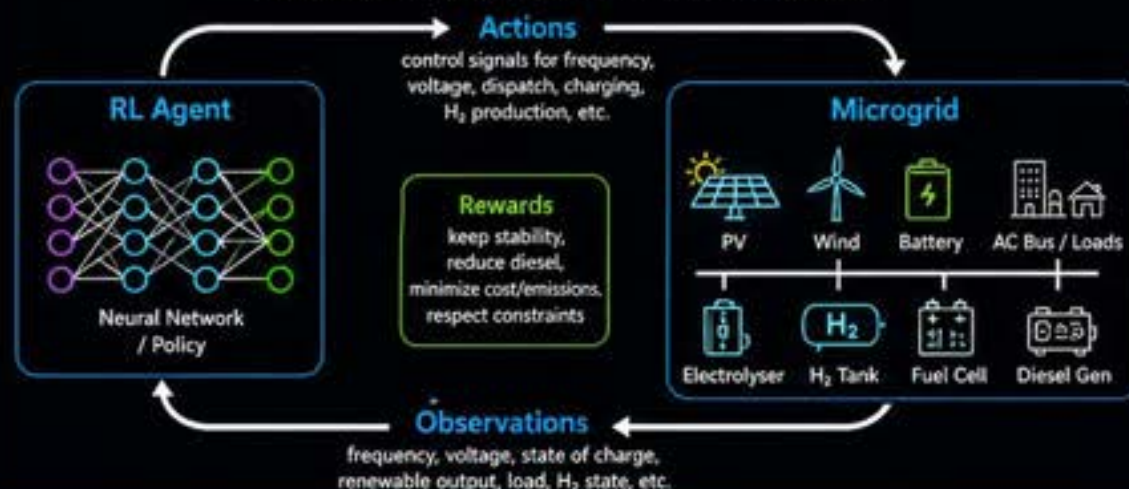
## LIMITS OF CLASSICAL METHODS

- Model-dependent and hard to maintain
- Require simplifications and linearization
- Computationally expensive (e.g. MPC, MILP)
- Poor generalization to unseen conditions
- Limited ability to handle rare events

Do not always scale to real industrial microgrids.

## AI CONTROL FRAMEWORK (DRL)

Closed-loop interaction between agent and microgrid



## WHAT AI BRINGS

- Learning-based control (model-free / data-driven)
- Adaptive policies for changing conditions
- Handles uncertainty and partial observability
- Better exploration of high-dimensional actions
- Improved generalization and robust performance

AI learns control strategies directly from interaction and data.

## MICROGRID ECOSYSTEM

Heterogeneous assets coordinated by the controller



## AI + DRL IN ACTION

- Real-time decisions under uncertainty
- Safe and constraint-aware control
- Scalable to large microgrids
- Integrates forecasting, control and optimization
- Improves resilience, efficiency and autonomy

From reactive control to intelligent autonomy.



A microgrid with many GFM inverters, batteries and hydrogen assets is a coupled energy system. AI is needed to coordinate fast stability, energy balance and long-duration resilience under uncertainty.

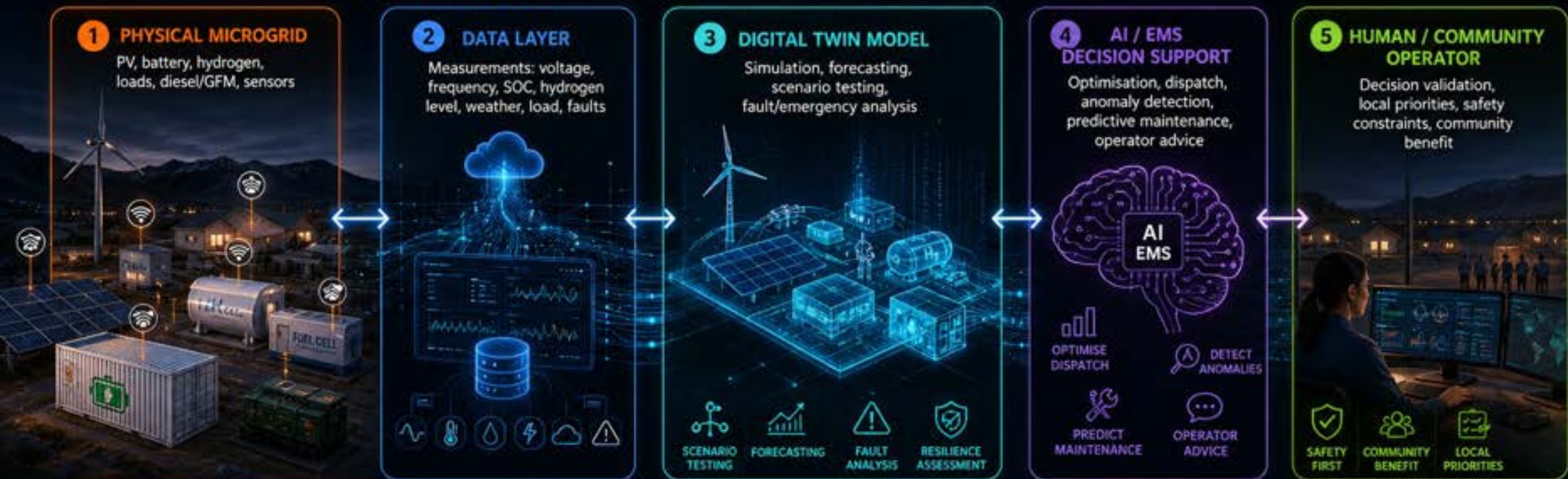


We need AI-powered, scalable frameworks that capture both electrical dynamics and energy management in real time.

# Digital Twins for Trusted Microgrid Operation

Testing AI decisions virtually before acting on real weak-grid systems

A digital twin connects the **physical microgrid**, **real-time data**, **simulation models** and **AI decision support**, allowing operators to test decisions before applying them in the field.



**Digital twins make AI trustworthy: they allow forecasting, validation and operator oversight before real-world action.**

The digital twin is the safe space where AI decisions are tested before they affect the real microgrid.

*This prepares the path from AI algorithms to validated operation — and then to REMHART for real-world testing.*



# REMHART: where digital twins meet real microgrid validation

From AI decisions and simulations to safe testing before community deployment

## REMhart as validation platform

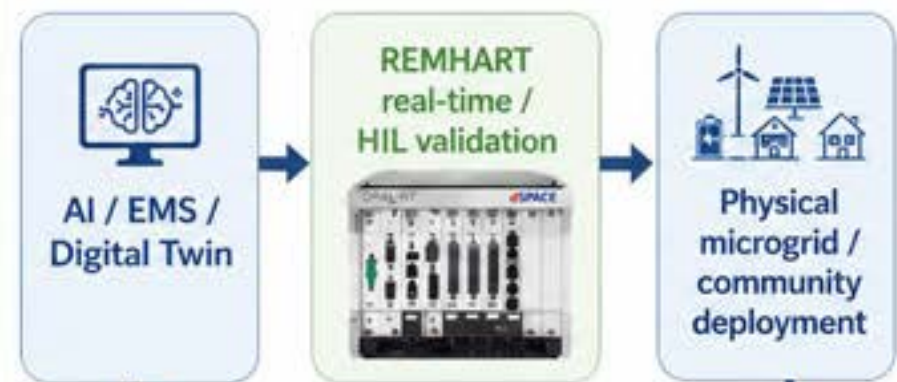


**REMhart**  
Renewable Energy Microgrid Hub for Applied Research and Training

- Research
- Applied testing
- Industry validation
- Training



## Validation flow



Measurements → model update → improved control



## What REMhart validates

- ✓ GFM control stability
- ✓ Hydrogen production, storage and fuel-cell operation
- ✓ Battery and inverter coordination
- ✓ Power quality: voltage, frequency, THD
- ✓ Protection and fault response
- ✓ AI/EMS decisions under realistic disturbances



**REMhart is the safe space where future microgrid solutions are tested before they affect real communities.**

It de-risks deployment by testing technologies, controls and operating strategies under realistic weak-grid conditions.



# Samoa / Uafato: a Pacific community context for resilient microgrids

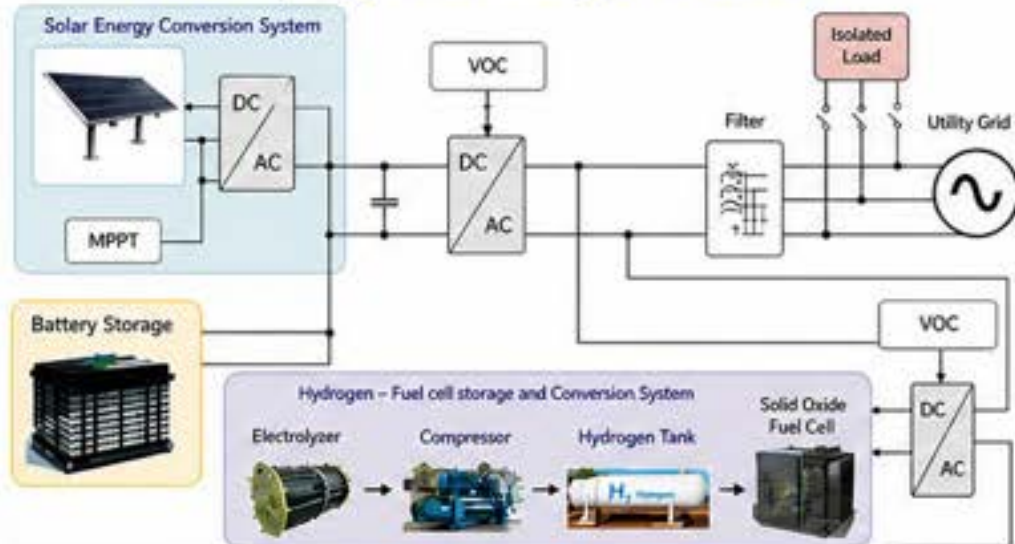
Weak grids, diesel dependence, resilience and community benefit — a deployment context that motivates AI, digital twins and validation work.



## Why this context matters

-  Remote island energy systems
-  Diesel dependence and fuel logistics
-  Climate resilience and reliability
-  Community-centred operation and local capacity

## RES + hydrogen-chain microgrid architecture



### Reference technical data

- Solar PV system: 45 kWp DC
- Inverter / charger cluster: 45 kVA
- Battery bank: 4800 Ah, 48 V (in figure)
- Battery specification in table: 4000 Ah @ 48 V = 192 kWh
- Charge controller: MPPT, ≥98% efficiency
- Modes: grid-connected and islanded microgrid operation
- Monitoring: IoT remote monitoring + Starlink connectivity



**PROJECT OBJECTIVE:** Realization of a real-scale MG of about 25 kW to power a small village of about 35 households and composed of RES and hydrogen chain.

**FEASIBILITY STUDY:** The feasibility study has been completed and is ready for review.



Samoa/Uafato shows the type of real Pacific setting where resilient, community-centred microgrid solutions become relevant.

## TURNKEY AI-DRIVEN CONTROL AND DIGITAL TWIN PLATFORM FOR $\geq 100$ kW MICROGRIDS



**Adaptive EMS + Digital Twin**  
for off-grid, islanded and weak-grid operation.



**REMHART HIL validation**  
to test controllers, inverter modes, disturbances and commissioning readiness.



**Grid-edge services**  
synthetic inertia, voltage support, harmonic mitigation and faster compliance.



Australian off-grid energy solutions provider



Specialists in solar, storage and hybrid microgrids



Delivering reliable, sustainable energy for remote communities and industries

### CONSORTIUM PARTNERS



**Murdoch University**



**PowerCore**



**SWINBURNE UNIVERSITY OF TECHNOLOGY**

### MICROGRID OPERATION MODES

#### GRID-CONNECTED (WEAK GRID)



Operates with weak or unstable utility grid. Provides support services (voltage, frequency, synthetic inertia) while ensuring local reliability.

#### ISLANDED MODE



Fully autonomous operation when disconnected from the main grid. Ensures continuous power supply for critical loads.

#### OFF-GRID / STAND-ALONE



Designed for remote locations with no grid access. Solar + storage + generators provide resilient and cost-effective energy.

### KEY OUTCOMES



Faster deployment and commissioning



Higher renewable hosting capacity



More resilient remote microgrid operation



Lower emissions and sustainable solutions



Empowering remote communities with reliable energy



**BUILT FOR REMOTE & WEAK-GRID COMMUNITIES**  
NT & WA | Pacific | Global



**RESEARCH, TRAINING & INNOVATION HUB**  
From prototype to real-world impact



**CLEAN, RESILIENT & SUSTAINABLE**  
Powered by AI, renewables & hydrogen



# COPILLOT MICRO – ISIF Asia

AI-driven control and Digital Twin platform for resilient, efficient and sustainable remote microgrids

Funded by

Innovation for a Sustainable Indo-Pacific

**ISIF ASIA Grant**  
Driving innovation for resilient, low-carbon and inclusive energy futures across the Indo-Pacific region.

- AI & DRL**  
Intelligent decision making
- Digital Twin**  
Real-time monitoring & simulation
- HIL & Real-world Validation**  
REMhart tested
- Grid-edge Services**  
Support weak & islanded grids
- Sustainable Energy**  
Lower emissions and cost

## PROJECT OVERVIEW

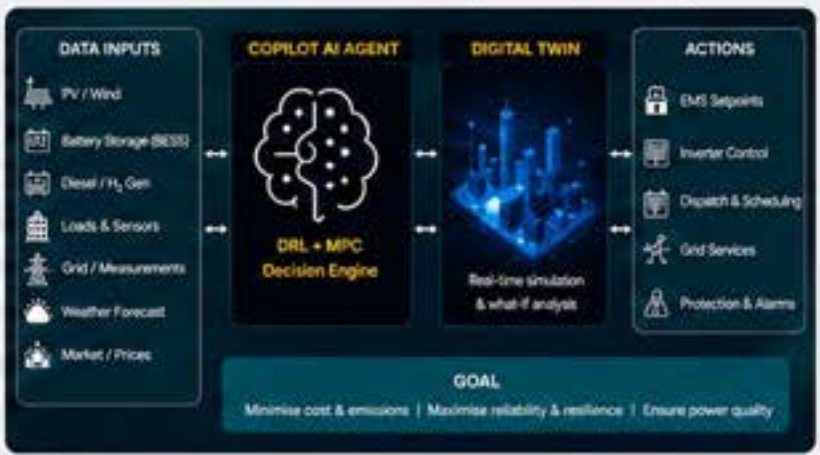
COPILLOT MICRO – ISIF Asia develops and validates an AI-powered control and Digital Twin platform for off-grid, weak-grid and islanded microgrids in remote communities and island nations.

- AI & DRL CONTROL**  
Intelligent, adaptive and predictive control using Deep Reinforcement Learning and Model Predictive Control.
- DIGITAL TWIN**  
Real-time simulation, monitoring and what-if analysis for operational optimisation.
- HIL & REAL-WORLD VALIDATION**  
Hardware-in-the-Loop (HIL) and field testing at REMhart microgrid testbed (CDU).
- GRID-EDGE SERVICES**  
Voltage support, frequency regulation, synthetic inertia and black start capability.
- SUSTAINABLE & RESILIENT**  
Lower emissions, higher renewable hosting capacity and energy security.

## MICROGRID OPERATION CONTEXT

WEAK GRID CONNECTION	ISLANDED OPERATION	OFF-GRID / STAND-ALONE
Low short-circuit ratio, voltage fluctuations and unreliable supply.	Disconnected from the main-grid. Autonomous operation with local resources.	Remote locations with on-grid access. Solar + storage + generators / H <sub>2</sub> systems provide resilient and cost-effective energy.

## COPILLOT MICRO ARCHITECTURE (AI AGENT + DIGITAL TWIN)



## KEY OUTCOMES & IMPACT

- 15–25% improvement in system efficiency through AI-optimised control
- Higher renewable hosting capacity with stable grid operation
- Improved resilience for remote and climate-vulnerable communities
- Lower emissions and reduced fuel consumption
- Scalable and replicable solution for Indo-Pacific deployment
- Enables local capacity building, training and skills development

## VALIDATED IN REMHART – CDU MICROGRID TESTBED

REMhart enables confidence in performance, safety and reliability before field deployment.

HIL VALIDATION	REAL-WORLD DISTURBANCES	COMMISSIONING READINESS
Hardware-in-the-Loop (HIL) testing of controllers and inverter modes.	Testing under real-world disturbances and weak-grid scenarios.	Commissioning readiness and performance validation.

## FOCUS: REMOTE COMMUNITIES & INDUSTRIES

Remote Communities	Islands & Atolls	Resource Industries	Critical Facilities
<ul style="list-style-type: none"> <li>Delivering reliable, clean and affordable energy solutions</li> <li>Tailored for local needs, climates and resources</li> <li>Supporting energy independence and economic development</li> </ul>			

## ALASKA CENTER FOR ENERGY & POWER (UAF)

Advancing energy and power solutions for Alaska and the Arctic through research, education and partnerships.

- Grid integration & resilience
- Renewable energy & storage
- Microgrid & energy systems
- Community & industry support

## STRONG PARTNERSHIP

 Project Lead Energy & Resources Institute (ERI)	 AI Control & Optimization Research Partner	 Pacific Islands Engagement & Deployment Partner	 AI Digital Twin & Systems Engineering Partner	 Alaska Center for Energy & Power Cold Climate & Remote Microgrid Research Partner	 Industry Partner Microgrid Solutions Provider
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**COPILLOT MICRO – ISIF Asia**

A collaborative ISIF-funded initiative delivering AI-powered microgrid solutions for a sustainable, resilient and inclusive Indo-Pacific future.

### COLLABORATION FOCUS

Joint research and development to advance water electrolysis performance, durability and integration with renewable energy systems for northern Australia and Indo-Pacific applications.



#### Technology Development

Improve electrolyser efficiency, durability and operational flexibility.



#### System Integration

Integration with renewable energy, storage and microgrids.



#### Real-world Validation

Testing and demonstration in relevant tropical and remote conditions.

### HyWATTS ELECTROLYSER TECHNOLOGY

- ✔ **HIGH EFFICIENCY**  
> 4.3 kWh/Nm<sup>3</sup> H<sub>2</sub>
- ✔ **MODULAR DESIGN**  
Scalable from 100 kW to multi-MW
- ✔ **HIGH PURITY**  
99.999% Hydrogen
- ✔ **DESIGNED & BUILT**  
in the USA



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### ADVANCED ELECTROLYSIS SOLUTIONS



**Advanced Electrolysis**  
High-efficiency alkaline electrolysers with long life and low operating costs.



**Renewable Integration**  
Optimised for integration with solar, wind and energy storage systems.



**Sustainable Hydrogen**  
Enabling clean hydrogen production to support decarbonisation and energy security.



**Remote & Tropical Focus**  
Designed for harsh, remote and islanded environments.



**System Modelling**  
Advanced modelling and optimisation for hydrogen systems and microgrids.

### SHIFT Hyder – CDU PROJECT

Field validation of advanced water electrolysis in a remote, renewable energy microgrid.

The SHIFT Hyder project will demonstrate and validate HyWATTS alkaline electrolyser performance and integration within CDU's renewable microgrid testbed.

#### Project Objectives

- ✔ Validate performance and durability in tropical conditions
- ✔ Assess integration with renewable generation and storage
- ✔ Demonstrate reliable operation for remote and islanded communities
- ✔ Generate data to accelerate commercial deployment



### APPLICATIONS



**REMOTE COMMUNITIES**  
Clean hydrogen for power, heating and essential services in remote areas.



**INDUSTRY & RESOURCES**  
Decarbonising industrial processes and supporting resource projects.



**MICROGRIDS & ISLANDS**  
Resilient, low-carbon energy for isolated and islanded grids.

### ABOUT HyWATTS

HyWATTS designs and manufactures advanced alkaline electrolysers for clean hydrogen production. Our systems are built for reliability, efficiency and scalability – enabling industry and communities to transition to a sustainable energy future.

[www.hywatts.com](http://www.hywatts.com)



### DELIVERING IMPACT



Enables clean hydrogen for a low-carbon future



Reduces emissions and supports decarbonisation



Strengthens energy security in remote and regional areas



Creates local jobs and builds skills and capability



Supports a sustainable Indo-Pacific energy transition

### STRONG COLLABORATION

Bringing together HyWATTS' leading electrolysis technology and CDU ERI's expertise in renewable energy and remote microgrids to deliver real-world solutions for northern Australia and the Indo-Pacific.

# NGARDARA PROJECT

AI Digital Twin for Teaching and Research

ERI's role in advancing remote microgrid education and innovation



BORROLOOLA, NORTHERN TERRITORY

The Ngardara Community Microgrid Project is the first utility-scale First Nations-led microgrid.

Proudly funded by

**ARENA**

Australian Renewable Energy Agency



Borroloola, Northern Territory

The Ngardara Community Microgrid Project is the first utility-scale First Nations-led microgrid project, designed to reduce diesel use, lower CO<sub>2</sub> emissions and build community resilience.

## PROJECT OVERVIEW



Solar PV  
**2.1 MW DC**  
Single-axis tracking array



Battery Storage  
**1.8 MW / 6.2 MWh**  
BESS



Grid-connected to existing Borroloola network



Diesel dependence today  
**~87%**  
of electricity



Community-led First Nations-led co-operative majority owner



Supported by **ARENA** with Original Power as lead manager

## ERI'S ROLE: AI DIGITAL TWIN FOR TEACHING AND RESEARCH



**1** Real-time Data  
Live operational data from the Ngardara microgrid



**2** AI Digital Twin Development  
Build a high-fidelity virtual model of the microgrid



**3** Scenario Testing  
Test operational scenarios, faults and optimisation strategies



**4** Teaching & Learning Applications  
Interactive platform for courses, labs & student projects.



**5** Research & Innovation  
Enable research in energy systems, AI, optimisation and remote operations

## PROJECT SIGNIFICANCE



**Reduces barriers to energy justice**  
Support fair access to reliable, affordable clean energy.



**Delivers local clean-energy benefits and resilience**  
Lower diesel use and CO<sub>2</sub> emissions; stronger, more resilient community.



**Designed for knowledge sharing and replicability**  
Built to share learnings and support replication across remote communities.

## COMMUNITY LEADERSHIP AND KNOWLEDGE SHARING



**First Nations-led co-operative model**  
Majority owned by Ngardara Co-operative.



**Community Benefit Plan**  
Developed with residents to deliver local benefits.



**Knowledge sharing and replicability**  
Sharing learnings to support other remote communities.



# Pacific Partnership Projects: PaSCap-AFRAN & PacDigiTwin

Capacity Building, Digital Innovation and Clean Energy in the Pacific



## PaSCap-AFRAN

Pacific Sciences de la Durabilité Capacity Building



### Partners

- AFRAN
- Charles Darwin University (CDU / ERI)
- Université de la Nouvelle-Calédonie (UNC)
- University of the South Pacific (USP)



ERI



### Objectives

- Build capacity in sustainability sciences across the Pacific.
- Strengthen Australia–France–Pacific collaboration.
- Deliver hybrid workshops, public engagement, and an intensive course.
- Support the Master in “Sciences de la Durabilité” at UNC.



### CDU/ERI Role

- Lead coordinator.
- Provide technical leadership on microgrids and sustainable energy systems.
- Organise hybrid workshops and training activities.



## PacDigiTwin

Pacific Digital Twin for Hydrogen-Powered Microgrid Resilience and Clean Energy



### Partners

- University of the South Pacific (USP, lead)
- Charles Darwin University (CDU / ERI)
- Université de la Polynésie Française (UPF)



ERI



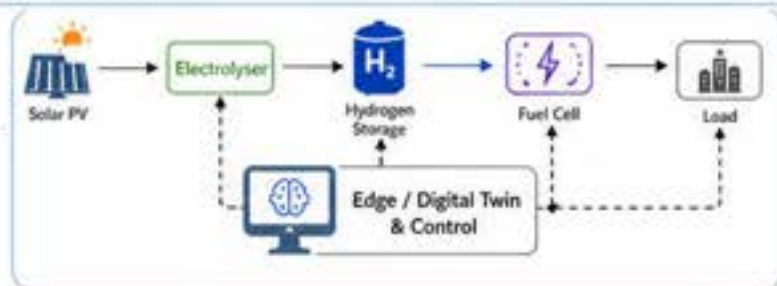
### Objectives

- Develop a modular digital twin platform for Pacific island microgrids.
- Pilot the system on the Tarawa hybrid solar–diesel–hydrogen microgrid.
- Integrate AI for predictive maintenance, diagnostics, and energy scheduling.
- Reduce diesel dependence and improve resilience, sustainability, and local capacity.



### CDU/ERI Role

- Technical partner.
- Support digital twin prototyping, AI deployment, and system integration.
- Use REMHART expertise for edge–device development and testing.



From capacity building to digital twins, these Pacific partnerships strengthen regional skills, clean energy innovation, and resilient microgrid deployment.



Stronger Regional Skills



Clean Energy Innovation



Resilient Communities

# Cybersecurity for NT Weak-Grid Microgrids

Survey Research and PhD Thesis Development



## Published Survey

- Survey article on cyber-attack detection in smart grids
- Focus: methods, challenges, datasets, and future directions
- Covers FDIA, DDoS, adversarial attacks, APTs, and multi-layer threats
- Provides benchmark-dataset analysis and evaluation metrics

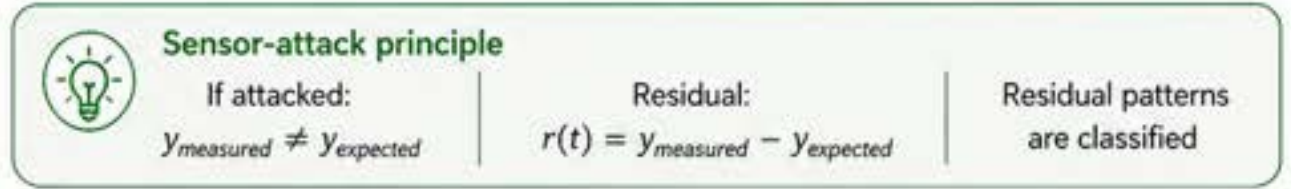
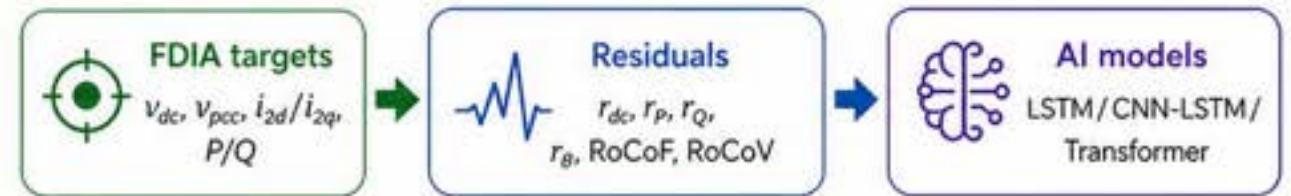


P. Vigneshwaran • B. Shanmugam



## Ongoing PhD Thesis

- PhD by Vigneshwaran on cyber-attack detection in microgrids
- Focus on NT remote and weak-grid microgrids
- RO1: sensing-layer FDIA detection
- RO2: hybrid-layer attack recognition
- RO3: optimized and robust detection frameworks
- Physics-informed detection for GFM weak-grid microgrids (SCR = 1, 2, 3)



From survey to thesis: building cyber-resilient microgrids for remote NT communities



# Policy pathways for resilient community microgrids

From pilot projects to scalable, community-centred energy systems



## 1 From projects to services

Treat microgrids as long-term community energy services, not one-off infrastructure installations.



## 2 Community benefit and ownership

Support governance models that strengthen local participation, employment, benefit-sharing and energy sovereignty.



## 3 Validated deployment

Require feasibility studies, load assessment, system sizing, protection design, digital simulation and experimental validation before deployment.



## 4 Weak-grid readiness

Develop clear requirements for grid-forming inverters, islanded operation, interoperability, protection, resilience and cybersecurity.



## 5 Local capability building

Fund workforce pathways for local technicians, operators, Indigenous rangers and community energy champions.



## 6 Energy for livelihoods

Design systems around real needs: lower costs, refrigeration, water, schools, health, communications, emergency response and small enterprise.



Microgrid policy should connect **technology, community benefit, local skills and long-term resilience.**

Microgrids support these SDGs



# Conclusion & Acknowledgements

From technical innovation to community-centred resilient energy futures



## Key messages

- ✓ Remote and weak-grid regions in the Pacific and Northern Australia face common pressures: diesel dependence, scattered loads, low inertia and renewable variability.
- ✓ Microgrids are not only an engineering solution, but a pathway to resilience, affordability and stronger local energy decisions.
- ✓ The next frontier is smarter systems: AI-enhanced management, digital twins and experimental validation.
- ✓ REMHART provides a bridge from modelling to real-world testing, training and deployment support.



## Community-centred pathways

- Support livelihoods and essential services through more reliable, affordable electricity.
- Build local capability, workforce skills and long-term operational confidence.
- Advance renewable and hydrogen microgrids with better sizing, control and validation.
- Strengthen France–Australia–Pacific collaboration around modelling, control, AI and demonstration.



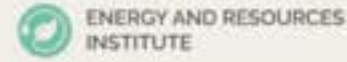
## Acknowledgements

Thank you to AFRAN, CDU leadership, ERI colleagues, project partners, and community collaborators across the Pacific and Australia.



## Questions?





# Thank you for attending!

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