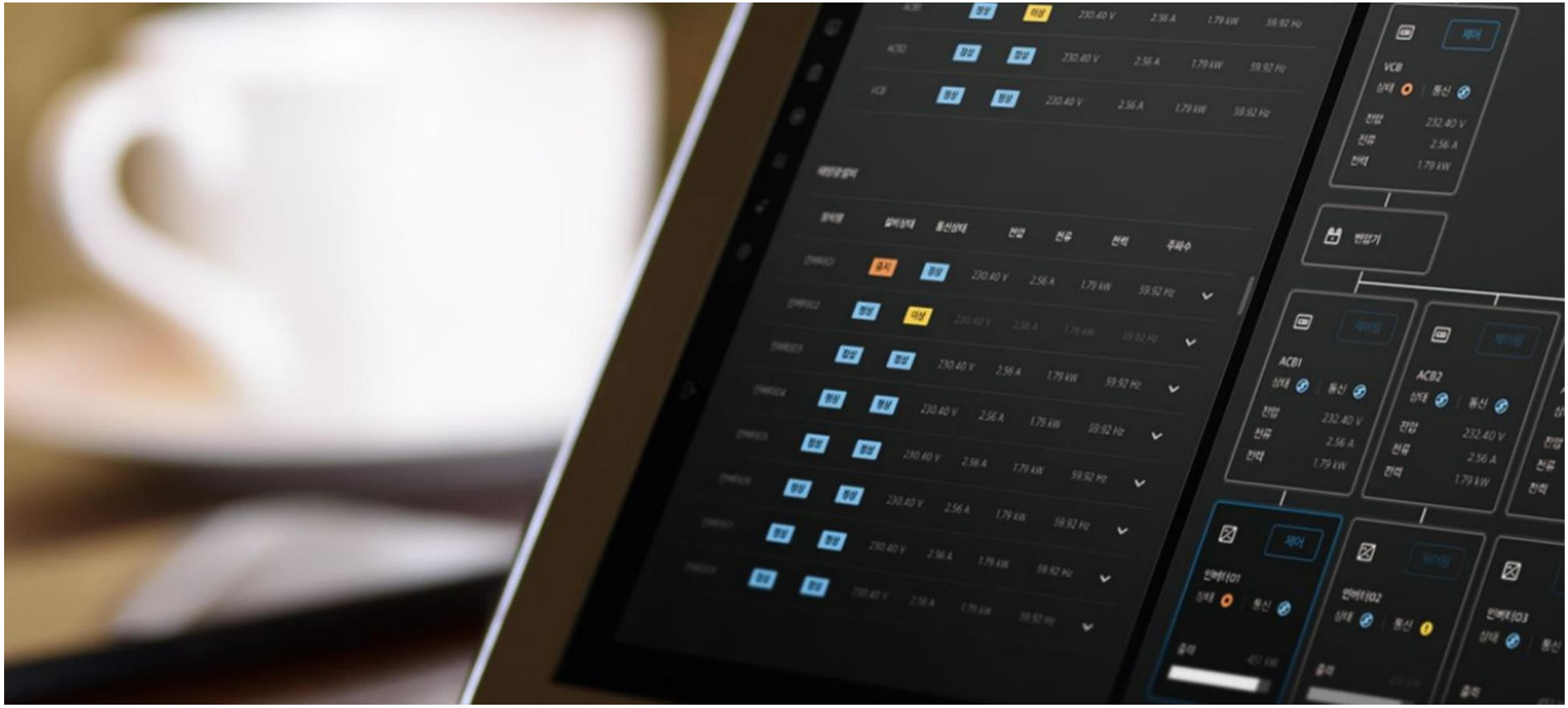


Algorithms and Use Cases for On/Off-Grid Hybrid Microgrids

Symposium on Microgrids, Nov. 9-13, 2025

Hyoseop Lee, Ph.D. / Encored Technologies, Inc.

ENCORED

Company

David had no intention of honoring the practice of one-on-one combat. He placed a smooth stone in his leather catapult pouch and hurled it at Goliath's forehead. The stone struck Goliath, knocking him down and stunned him, and David ran to him, snatched his sword, and slit his throat.

<David and Goliath: The Art of the Underdog to Beat the Strongest (Translated by Malcolm Gladwell, 21st Century Books, 2014)

Company Overview

John Choe
CEO & Founder
Former CEO in LSIS
PhD in Computer Science

Encored is a Silicon Valley-funded IT company specializing in energy, providing various IT solutions in the renewable energy sector based on energy data collection and data management technology and data analysis technology using artificial intelligence. Many customers have already utilized Encored's solutions to achieve additional revenue and increased work efficiency.

CUSTOMERS

KPX 전력거래소 · KOMIPO 한국중부발전 · KOWEPO · KHNP · EWP · 한국남부발전(주) · S-Power · 한화컨버전스 · SK 에코플랜트 · LG 에너지솔루션 · DOOSAN 두산에너빌리티 · LG U+

INVESTORS

STONEBRIDGE · SAMSUNG VENTURE INVESTMENT · L&S VENTURE CAPITAL · formation 8 · SoftBank · HT

Company Overview

Data → Intelligence → Value

Sensor

- The world's first IoT meter
- RTU for renewable power plants with the highest security rating

Product/Services

- Enertalk
- iDERMS RTU

Remark

- Type approval No. KTC-G-19-18
- KC safety certificate R-R-EdT-SGWBWB

Collection

- 1/15 second interval data collection for 50,000 homes
- Build a data pipeline from data collection to analysis

Product/Services

- Enertalk Home Platform
- iDERMS Data Platform

Remark

- Processing approximately 1 TB of real-time data per day
- Providing a data platform to the JV Encored Japan with SoftBank (99.5% SLA support)
- Largest power generation monitoring system in Korea (approx. 3.5GW)

Analysis

- World's first commercialization of NILM for data from tens of milliseconds to hourly intervals
- World's best renewable forecasting technology

Product/Services

- Enertalk Home Platform
- iDERMS Analytics

Remark

- Providing household load analysis (NILM) services to JV Encored Japan with SoftBank
- Solar aggregation resource generation forecast accuracy of 4%

Service

- App-based home energy services
- Largest national DR demonstration in Korea
- Operates the largest VPP service in Korea

Product/Services

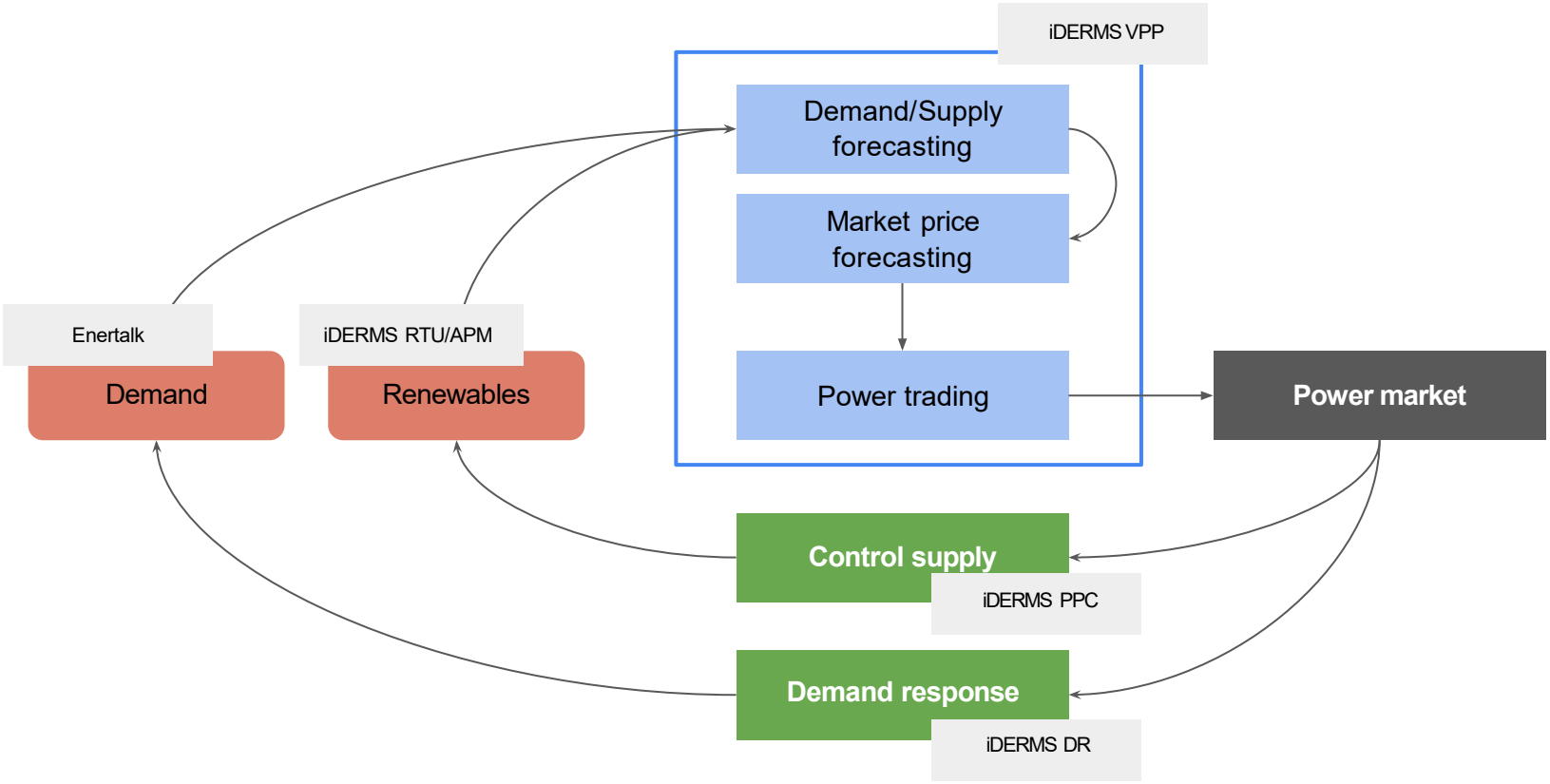
- Enertalk Home App
- iDERMS APM/VPP/PPC

Remark

- Delivering a NILM-based energy app service with US utility data
- Largest national DR demonstration in Korea
- Korea's largest SaaS-based renewable energy brokerage trading system service
- Operating the largest electric vehicle charging station-based DR resource in Korea

Company Overview

The only operator providing an integrated platform for energy consumption, production, and trading



Intelligence for Microgrid

- Challenges in MG Operation
- Forecasting for RE and Load
- ESS Optimal Operation

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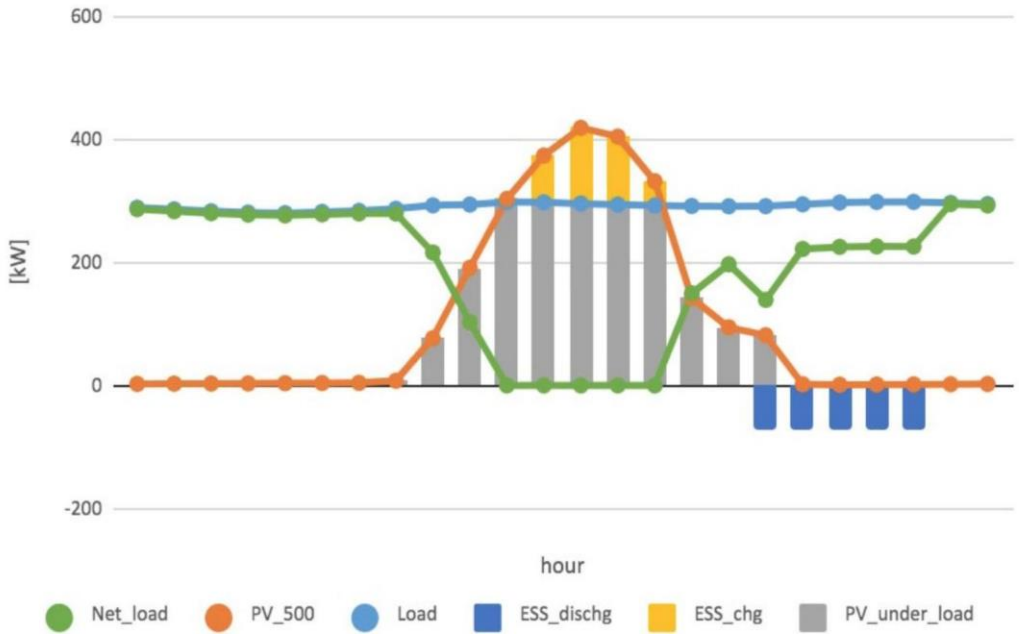
Challenges in Microgrid Operation

The Potential of AI in Enhancing Microgrid Efficiency

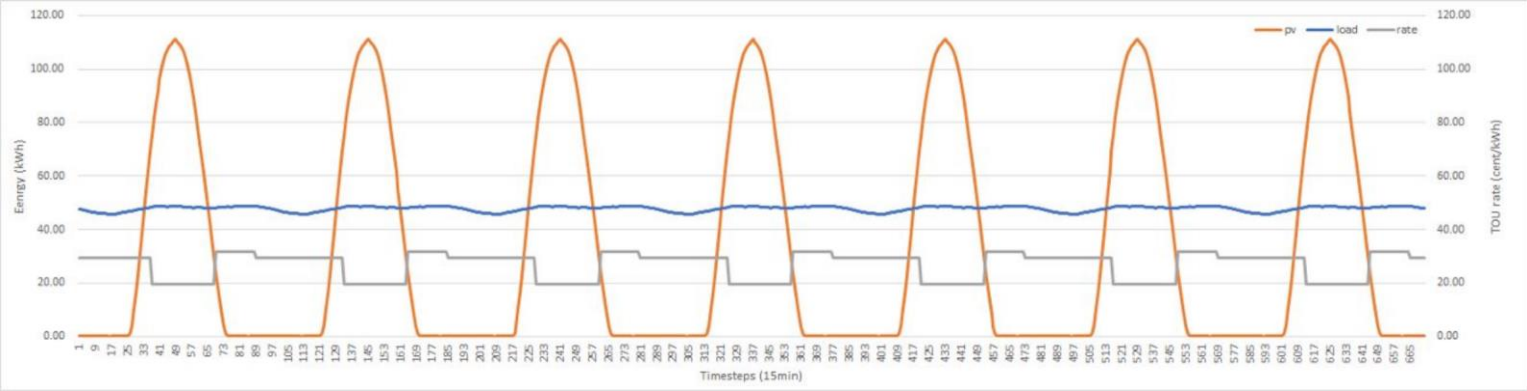


- Improved scheduling leads to greater efficiency in energy bill and reduced ESS wear-out
- To account for the uncertainty of load and renewable energy, schedules must be adjusted continuously
- AI can assist in making better operational decisions, similar to a game

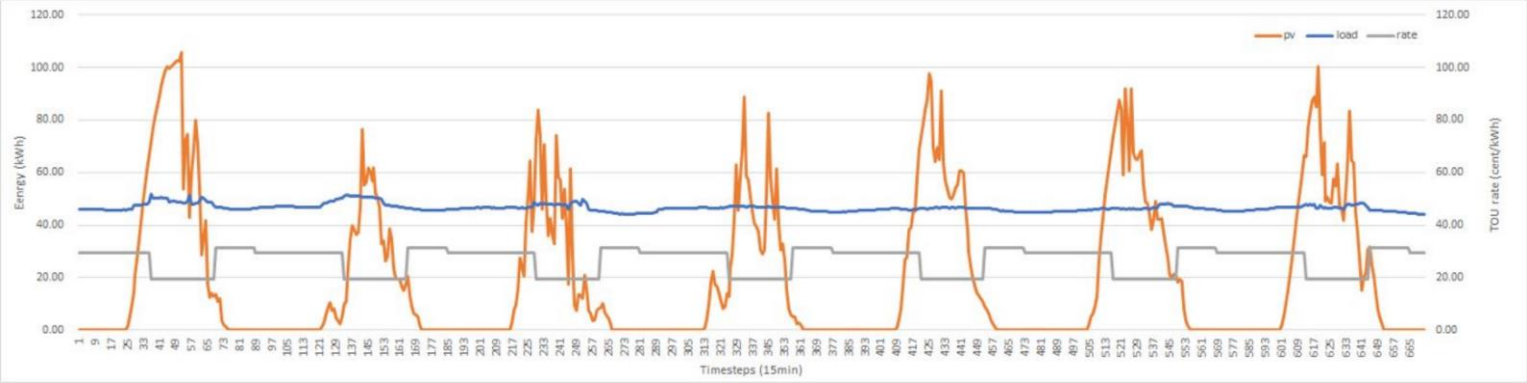
Challenges in Microgrid Operation

Operating ESS for Managing Uncertain Loads and Generation

A Single Rule Applies (Normal Case)

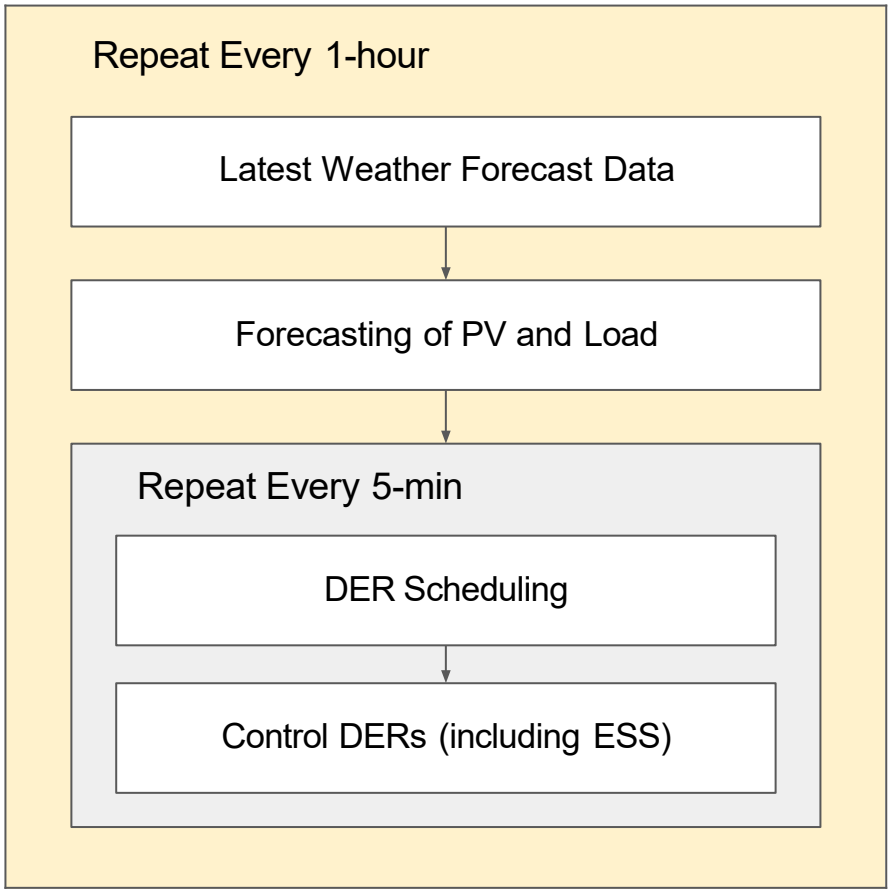


No Single Rule Applies (Harsh Case)



Challenges in Microgrid Operation

Continuous optimization incorporating new data

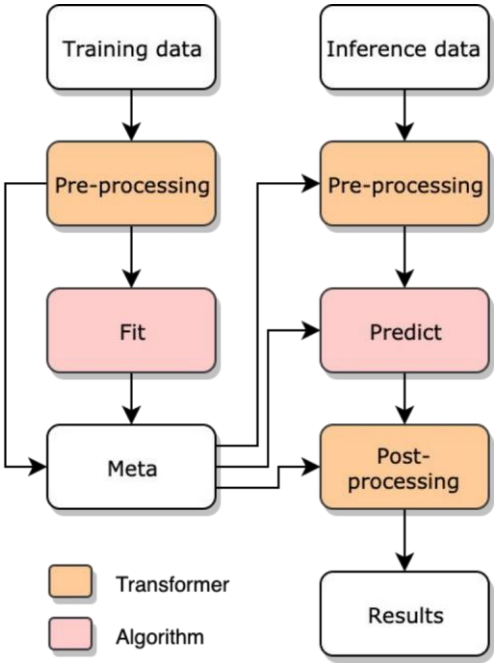


- Hourly forecasting for 24 hours ahead of PV and load based on the latest weather predictions to reduce uncertainty
- Modifying DER Operations Every 5 Minutes Based on Discrepancy Between Actual and Forecasted Values, as well as Recent Forecasts

Forecasting for Renewables and Load

Standardize own training and inference processes by building your own frameworks

Forecasting Framework

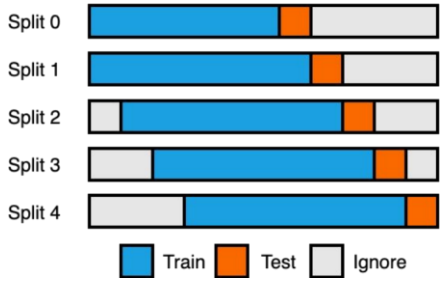


Support for New Models

```
{
  "algorithm":{
    "name":"my_custom_model",
    "params":{
      "hyper_param_01": 0,
      "hyper_param_02": 1
    }
  },
  "transformer":{
    "name":"BasicTransformer",
    "params":{
      "formula":"power ~ weekday + time + temperature"
    }
  }
}
```

- Develop and apply new models for learning and inference
- Python API support for basic functions such as data preprocessing and unified DB queries

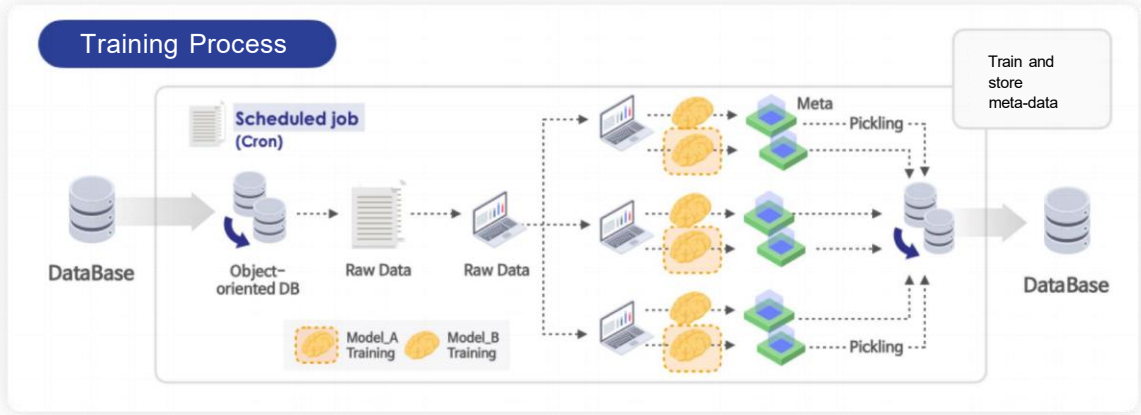
Evaluation of Models



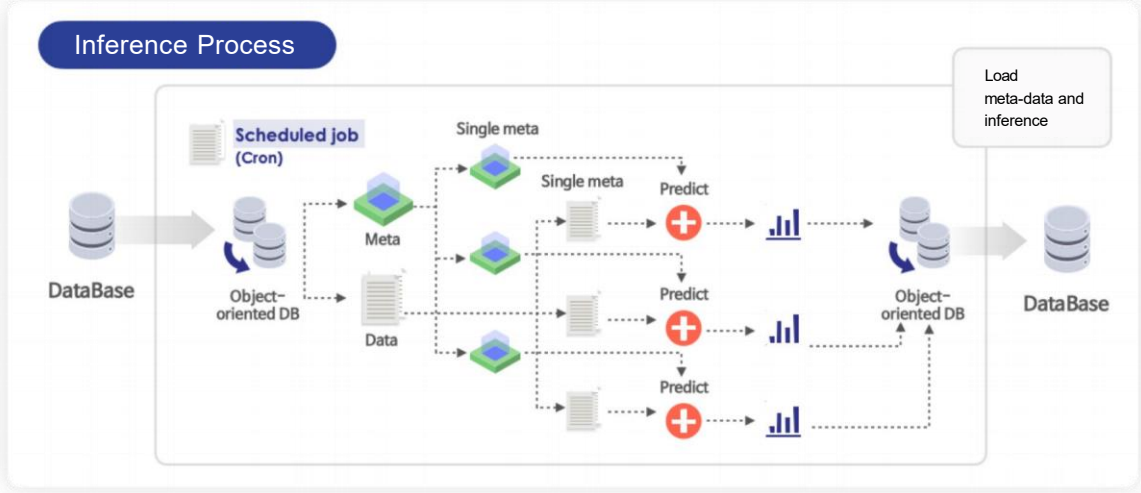
- Cross-validation tailored for time-series data, enabling scientifically rigorous forecast evaluation
- Supports multiple accuracy metrics, enabling fair comparison across models using consistent evaluation formulas

Forecasting for Renewables and Load

Training and Inference Processes for Forecasting



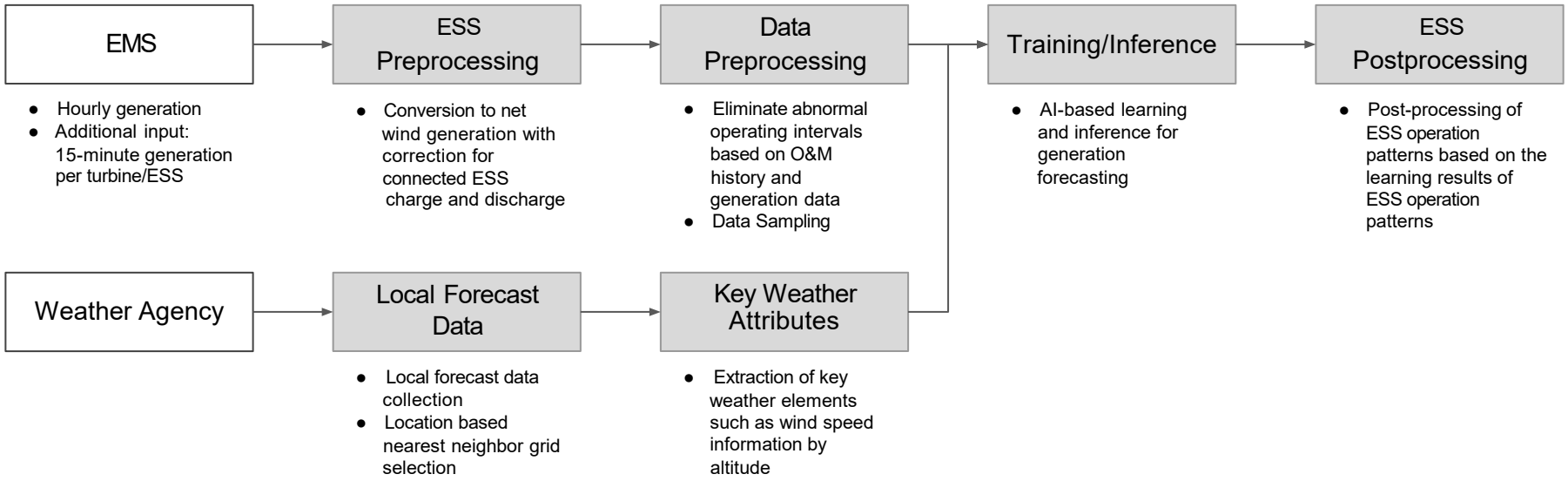
- Periodic training through scheduled operations to incorporate recent data
- Improved solar forecasting by selecting specific weather data
- Enhanced forecasting performance through integration of advanced models



- Immediate inference generation through pre-trained parameters integration
- Continuous operations for integration of the latest weather forecasting data

Forecasting for Renewables and Load

Power generation forecasts based on public and our in-house weather models

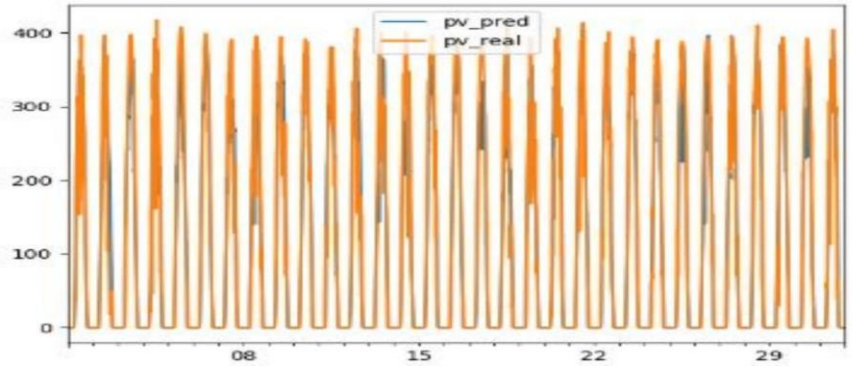


- Utilizing high-resolution forecast data to obtain spatially resolved data
- Select meteorological factors critical to wind power generation forecasting and use them for AI models
- Improve learning performance by correcting data through anomaly data extraction, data sampling, etc.
- Improved accuracy by utilizing additional data such as maintenance history of turbines

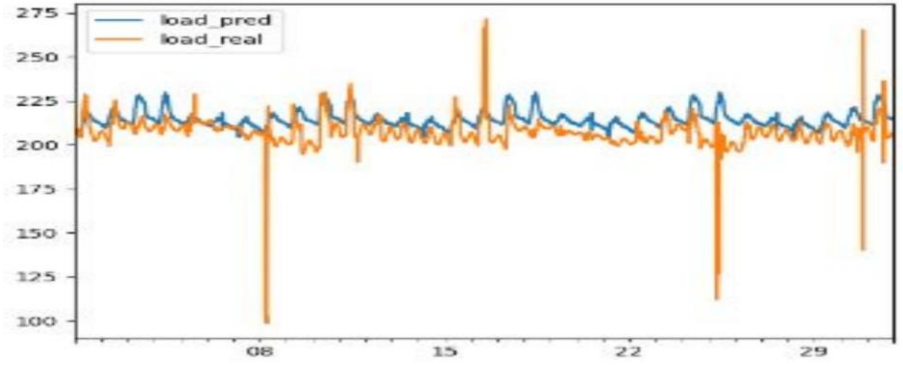
Forecasting for Renewables and Load

Forecasting Results

ITEM	PV at NELHA	Load at NELHA
Period	2022. 8. 1 ~ 2022. 8. 31	2022. 8. 1 ~ 2022. 8. 31
Error	3.725% (NAME10)	3.99% (MAPE)



PV at Research Campus

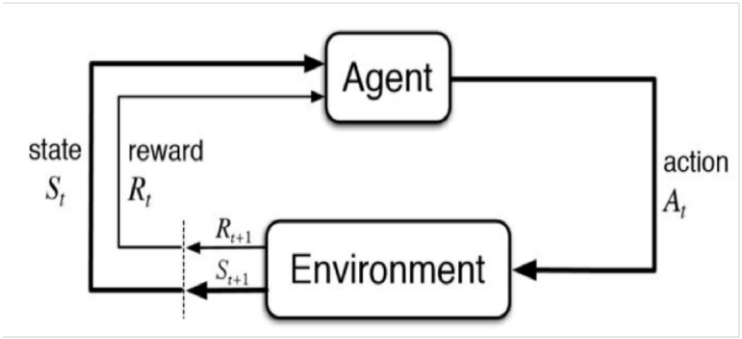


Load at Pump station

ESS Optimal Operation

Our Approach: Reinforcement Learning

- Reinforcement Learning
  - Based on the state information received from the environment, the agent takes an action that returns to the environment with a reward and the next state
  - The agent aims to maximize its expected cumulative reward through continuous interaction with the environment.
- In this problem:
  - Environment: NELHA MG site
  - Agent: MG (ESS) operator
  - State: Measured/predicted of PV and Load, ESS SOC measured, TOU rate
  - Action: Determining the charging/discharging power of ESS
  - Reward: Value function based on energy cost



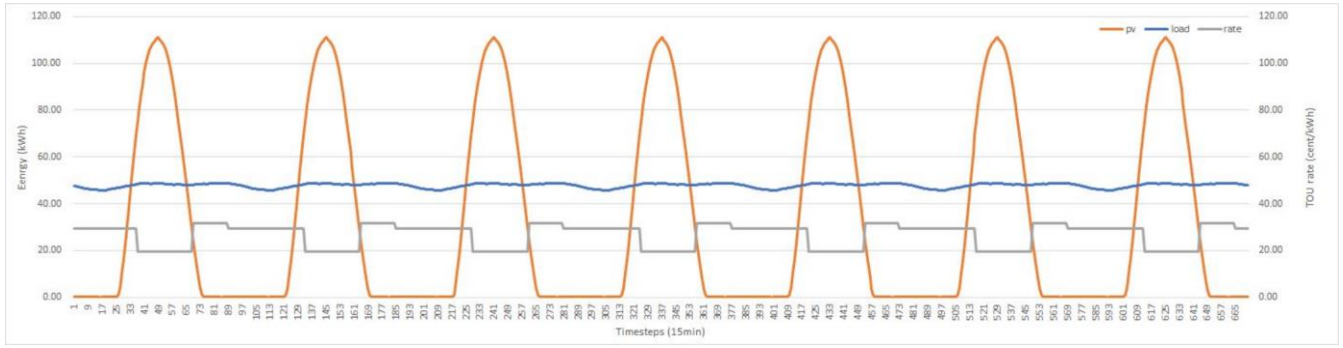
ESS Optimal Operation

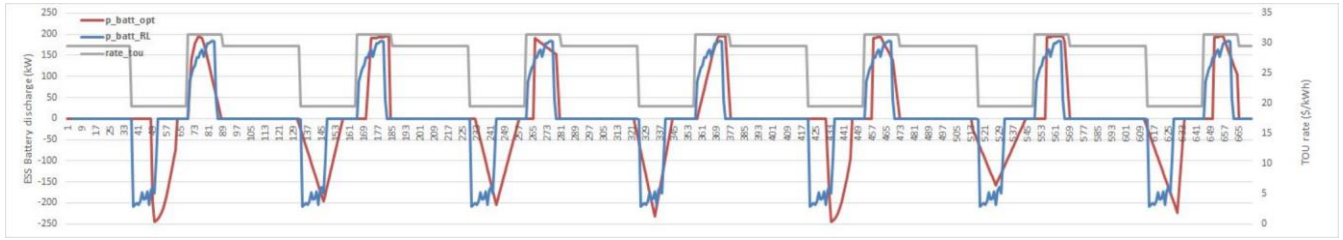
Our Approach: Reinforcement Learning

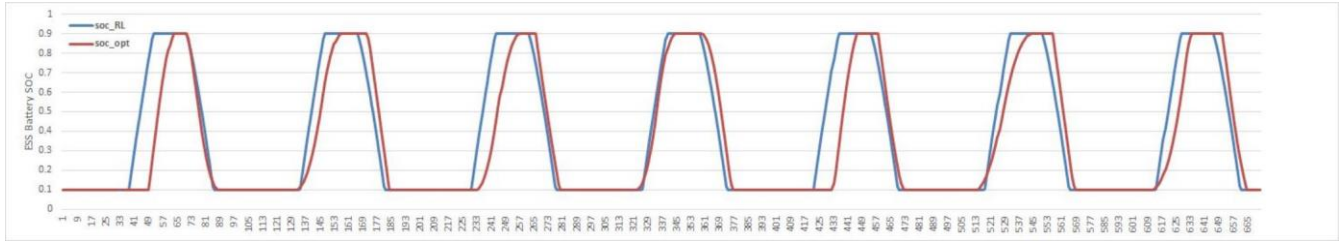
- All reinforcement learning must be defined mathematically in terms of State, Action, and Reward
- Definition in this problem:
  - State: [① Time of day, ② Past measurement data, ③ Present/future prediction data, ④ ESS SOC, ⑤ TOU rate]
  - Action: [ESS discharge request] (clipped to [-1, 1])
  - Reward: [Base Reward - (α * Cost Penalty + β * SOC Penalty + γ * Curtailment Penalty)]
    - Base Reward = 1
    - Cost Penalty = (Cost_t / Max_Cost) where Max_Cost is calculated based on Peak Load constraint
    - SOC Penalty = If the charging/discharging action violates the SOC or backflow constraints, the SOC is penalized for the amount of violation
    - Curtailment Penalty = (PV_Curtailment_t / PV_Size), assigned to minimize PV Curtailment
    - If the Peak Load constraint is violated, a reward of -1 is assigned and the episode terminates.

ESS Optimal Operation

RL Outcomes: Analyzing the Results





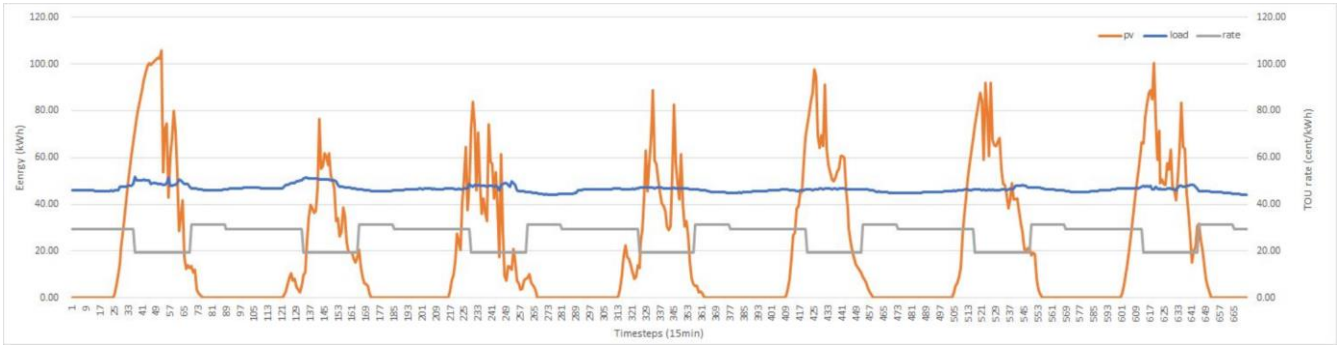


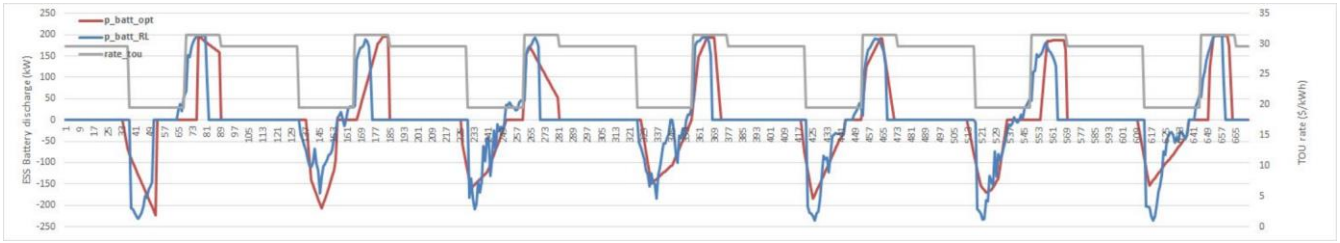
Normal Case

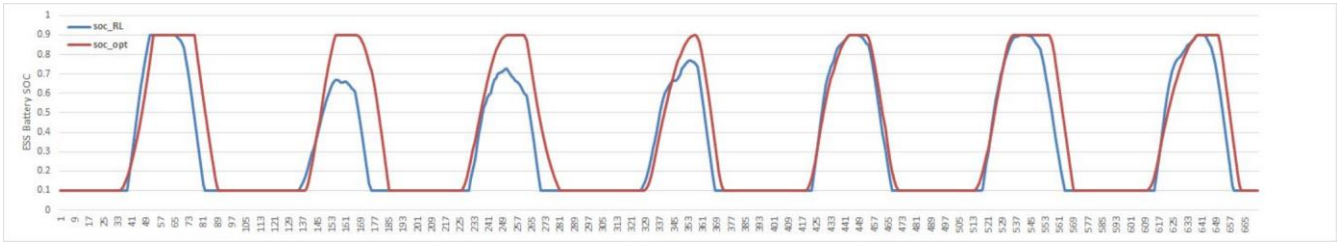
- Formation of charging/discharging patterns based on TOU rates
- Differences can occur if PV used for loads instead of being curtailed

ESS Optimal Operation

RL Outcomes: Analyzing the Results







Harsh Case

- Due to the instability of PV generation, the SOC cannot be fully utilized
- The decision to prioritize safe operation with cost equal to or less than the optimal cost is believed to have been made

Microgrid EMS

Putting all intelligence into the EMS

Cost-Optimized Hybrid Operation (Diesel / PV / ESS)

- Integrates Diesel, PV, and ESS for coordinated energy management
- Performs cost-optimized dispatch based on load and generation forecasts
- Automatically manages diesel generator output and ESS charge/discharge cycles within the allowable operational constraints

Load Monitoring and Predictive Control

- Monitors real-time load data with high granularity
- Forecasts future load profiles using historical and real-time data
- Supports circuit-level control by enabling selective load disconnection through wiring separation

Automated Black Start Logic

- Provides fully automated control logic for black start scenarios
- Restores system operation without manual intervention after full outages
- Enhances system resilience and operational autonomy

Remote Monitoring and Manual Control

- Enables remote system monitoring via web-based or mobile interfaces
- Allows manual override and control of devices when needed
- Provides real-time alarms, status views, and command execution remotely

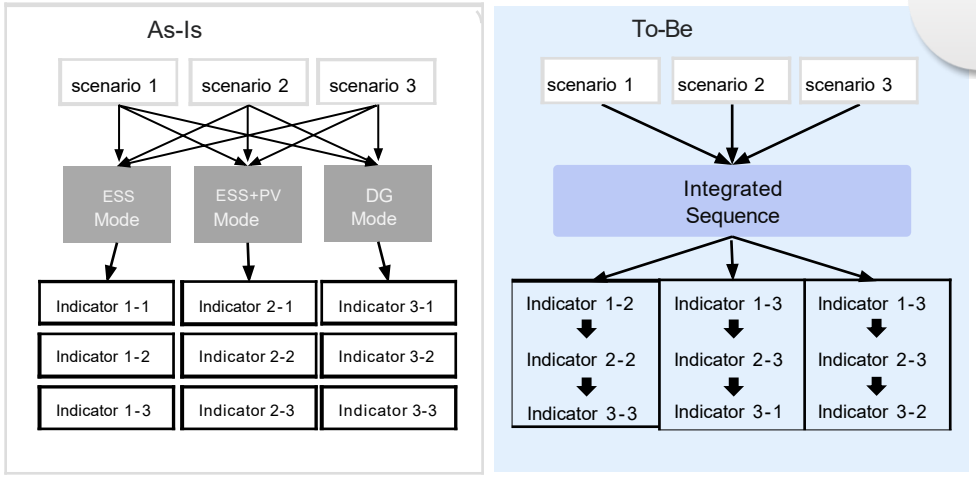
Microgrid EMS

UI/UX for Operation by Non-Experts

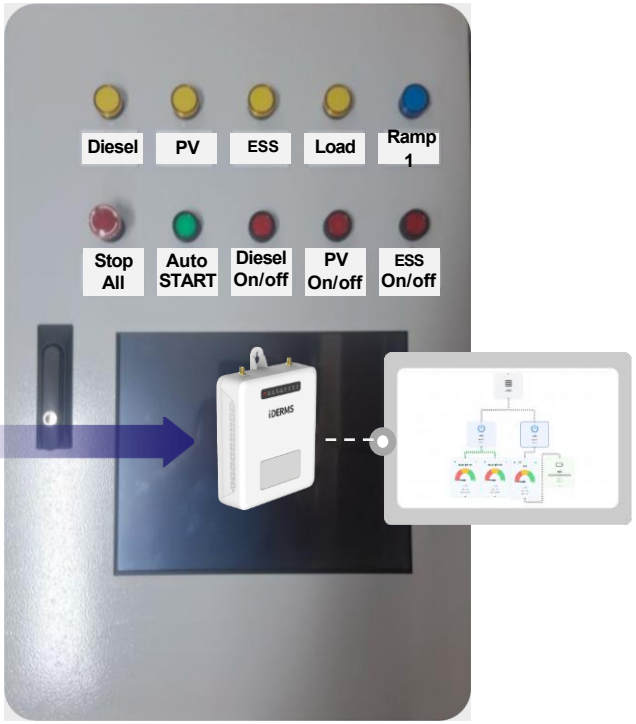
- **Gen/Load Forecasting and Optimization**

- Model the fuel efficiency of a diesel generator and the minimum output constraint, combining these with demand and generation forecasts to calculate the optimal ESS schedule.

- **Automated Black Start Logic**



- **EMS Controller**



- Built-in RTU and modem for seamless data acquisition and communication
- No need for external communication modules
- One-touch black start activation for system recovery
- One-touch full system shutdown for safe and quick power-off operation

Microgrid EMS

EMS System Specification

- **MICROGRID EMS Specification**

TYPE		Description
Electrical	Input voltage	AC 100 ~240V, 50/60 Hz
	Power consumption	~ 300W
Communication	Interface	• Serial : RS485 x4, USB2.0 x1, Digital Input x1 • Ethernet : RJ45 x2 • LTE (Optional)
	Protocols	Modbus RTU/TCP, HTTP(S), MQTT, DLMS/COSEM, DNP3
Control Unit	Model	iDERMS RTU2
	Processor	AM6254A(TI)
	Memory	4GB(RAM) / eMMC(32GB)
	OS	Linux (Encored proprietary build)
	Firmware Update	FOTA
User Interface Unit	Model	Mini PC (Intel N100, 8GB Ram, 256G SSD)
	Screen	LED / LCD with touch function
	OS	Windows

Case Study

- NELHA
- Bakalan Island

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Case Study #1: NELHA

System Requirements

NELHA (Natural Energy Laboratory of Hawaii Authority)

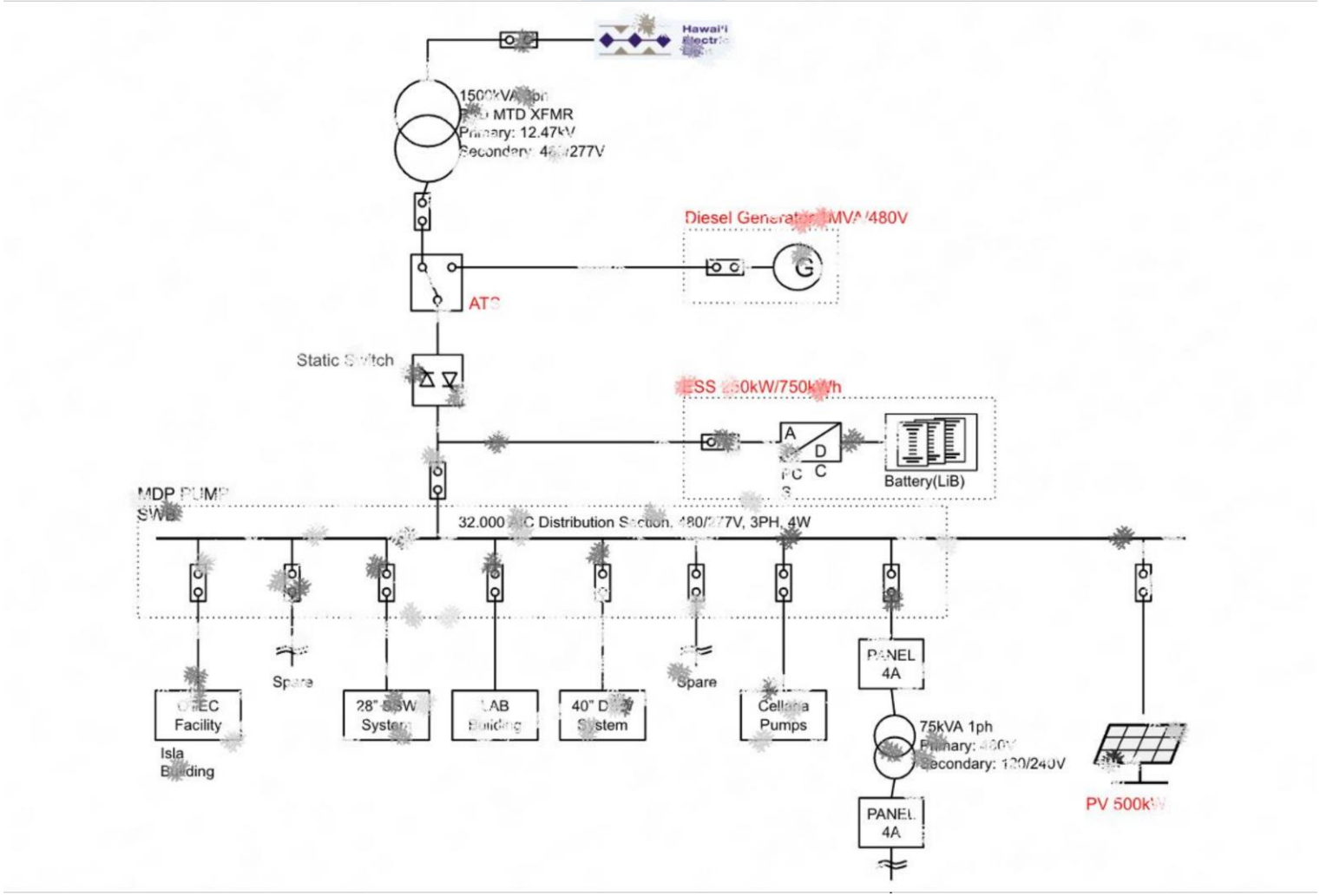
- Hawaii government entity for renewable energy research
- About 4,000 acre
- More than 40 companies operate business/pilot sites
- Owns research institute and seawater pump facility

Requirement

- Reducing utility bill through the installation of renewable
- Maximize operation time during outage
- Stable operation of system with various generation resources

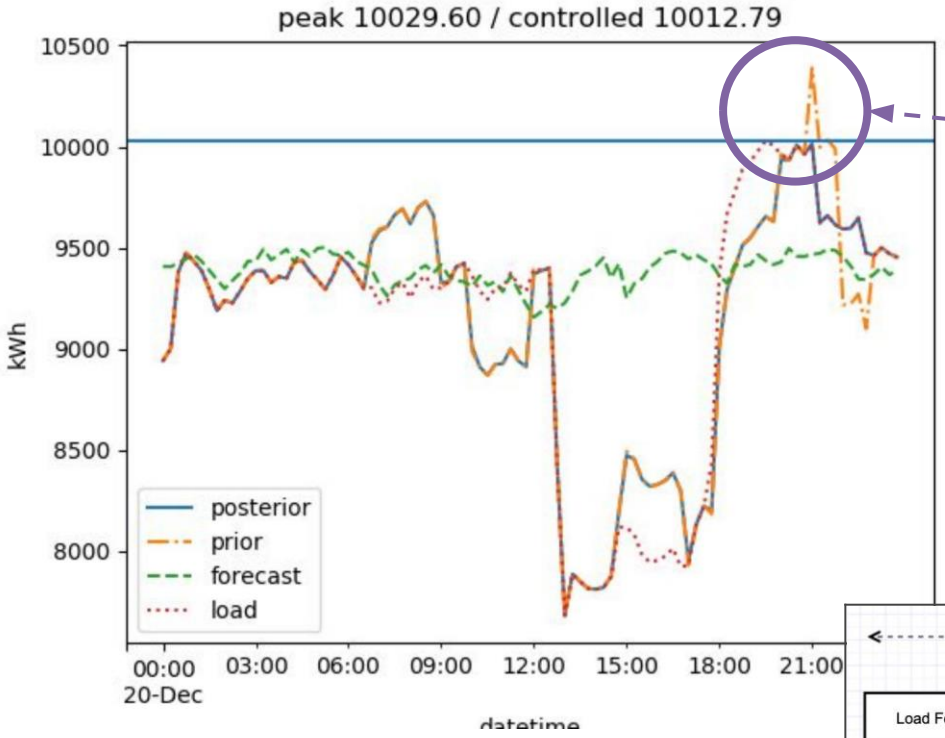
Case Study #1: NELHA

System Overview



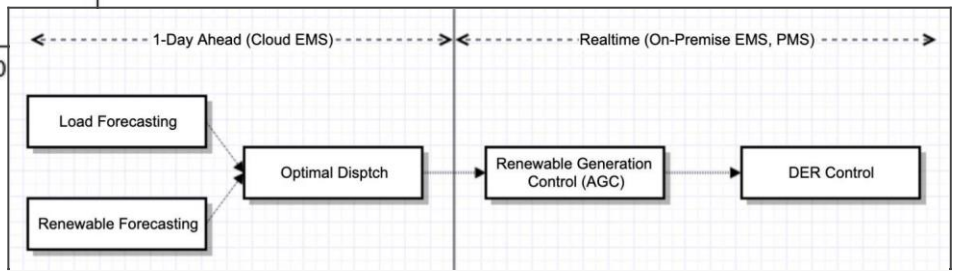
Case Study #1: NELHA

Cost Minimization for on-grid Operation



1. When forecasting fails, the peak demand exceeds expectations.
2. The EMS makes a discharge decision to prevent a peak.
3. Updated into an optimized schedule after peak control adjustment.

- forecast : Forecasting
- load : Real demand
- prior : ESS + demand
- posterior : EMS (after the control) + demand

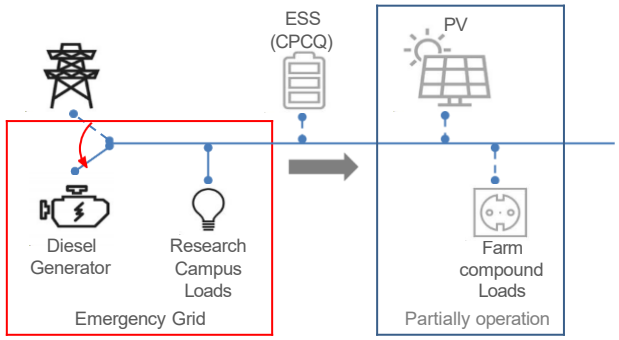


Case Study #1: NELHA

Extend Operation Time by the Coordinated Control

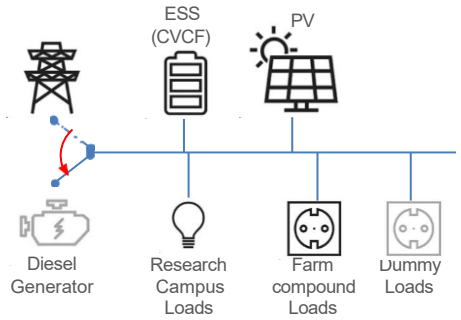
Typical Operation in case of emergency

Case 1) Emergency Diesel Generation



- Low reliability to supply premium loads (short operation time)

Case 2) CVCF Control by ESS

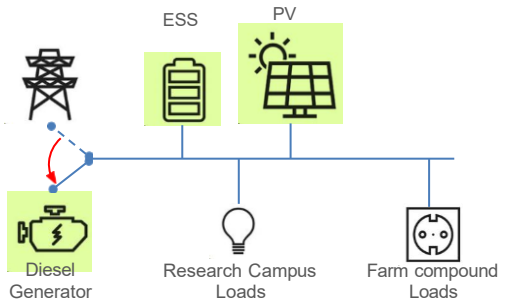


- Maintain SOC with a diesel generator and dummy loads control
- Require large capacity of ESS for full load support

①

②

Coordinated Control for off-grid operation



- Coordinated control for 3-resource
- Extend operation time with a limited ESS capacity
- Change of a main source between ESS and a diesel

Case Study #2: Bakalan Island

Provide Wider Energy Access

- Encored is selected as one of 9 proponents in GGGI's 4th BKCF Grant program
- Provide wider energy access for community development through PV/ESS

GGGI

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4th BKCF Result Announcement

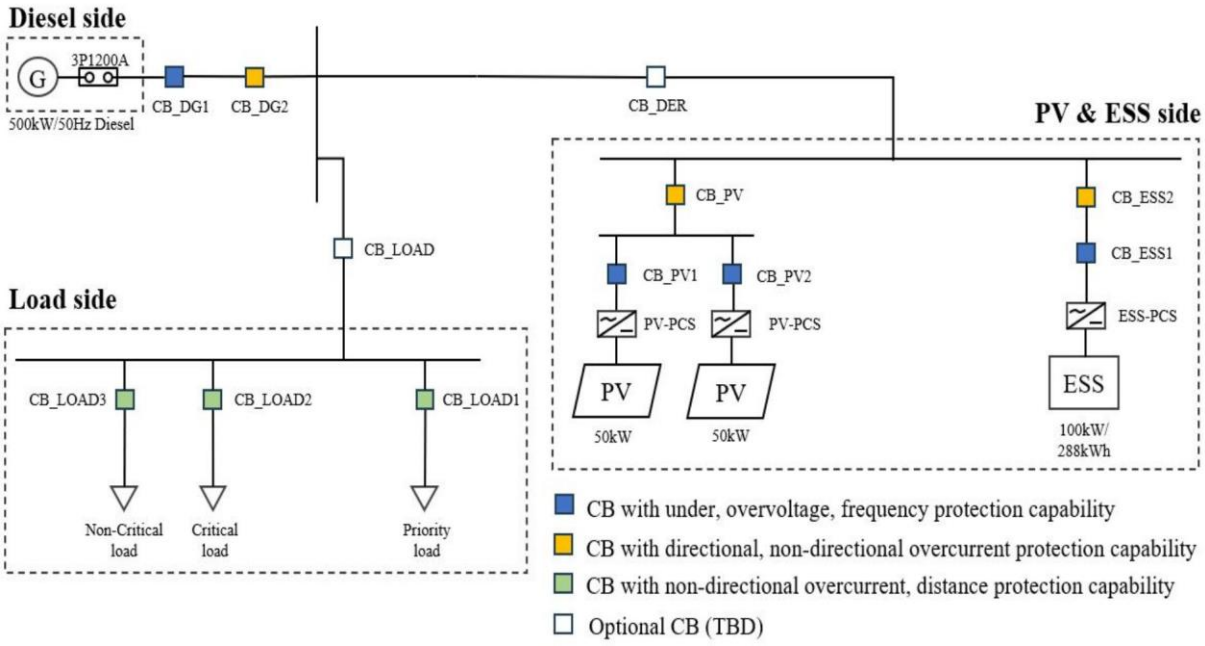
During the 4th BKCF Call for Proposals, a total of 213 project proposals have been submitted.

Under the agreement of the BIMP-EAGA and ROK during the Senior Officials Meeting, the following nine project proposals have been selected for the 4th BKCF.

#	Country	Project Title	Proponent	Project Sector
1	Philippines	Development of Virtual Power System to Increase Energy Flexibility in Philippines	Korea Institute of Energy Research, RES Consortium	Environment
2	Indonesia	From Floating Farm to Table: Enhancing Food Security and Climate Adaptation in Indigenous Communities of South Papua Province	World Vision Korea	Environment, Agriculture & Fisheries
3	Indonesia	Construction of AI-based Microgrid System in Bangkalan Island, Indonesia	Encored Technologies, Inc.	Environment
4	Philippines	Assessment of Microplastic Pollution in the Kabacan Marine Ecosystem: A Path Towards Mitigation Strategies and Policy Formulations for Sustainable Fisheries in the Philippines EAGA Region	Mindanao State University at Naawan	Environment, Agriculture & Fisheries
5	Indonesia	Preserving Soil Organic Carbon in Oil Palm Plantations with Oil Palm Waste Biochar	University of Lampung (UNILA)	Environment, Agriculture & Fisheries
6	Malaysia	Securing Futures: Enhancing Community Resilience and Sustainability of Sungai Rambai, Melaka through Implementation of Smart Crab Culture Systems	Universiti Putra Malaysia	Agriculture & Fisheries
7	Philippines	FISH-CAP (Fisheries Capacity Advancement Project)	Good Neighbors International Philippines, Inc	Agriculture & Fisheries
8	Brunei Darussalam	Cultivating Harmony: Progressive Approaches to Soil Management for Sustainable Agriculture and Ecosystem Resilience (CHaPA)	Universiti Brunei Darussalam	Agriculture & Fisheries
9	Malaysia	Induced Systemic Technology Transfer to Intensify Papaya Industry in East Malaysia	Malaysian Agriculture Research and Development Institute (MARDI)	Agriculture & Fisheries

Case Study #2: Bakalan Island

System overview and considerations



- Add 100kW PV and 300kWh ESS
- Coordinated Control with diesel, PV, and ESS
  - provide more energy with the limited fuel
- Black start and off-grid operation solely with PV or ESS
  - To ensure reliable off-grid recovery, simplified black start procedures are implemented for PV- or ESS-only operation.

Summary

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- Microgrid
  - A microgrid provides a foundation for effective utilization of renewable energy.
  - However, its efficiency depends heavily on the applied algorithms.
- Algorithms for Microgrid
  - Algorithms should accurately forecast the variability of renewables and load, optimize based on the tariff structure and co-operated assets,
  - Algorithms and operations should be designed for intuitive use by non-experts.

Encored Technologies, Inc.
13th fl, Gungdo B/D, 327 Bongeunsaro, Gangnamgu, Seoul
+82-2-3443-5800

http://www.encoredtech.com
esolution@encoredtech.com