# AI-POWERED MICROGRIDS FOR AUTONOMOUS ENERGY MANAGEMENT -A FRAMEWORK

Thematic Track 1 on Improving Access to Clean Energy Solutions

Asia Clean Energy Forum 2025

Developed under the ADB TA 57003-001 SRI
Artificial Intelligence Powered Microgrids to Enable Futuristic and Reliable Distributed Renewable Energy System

# GLOBAL CHALLENGE TO MOTIVATION

- **Energy inequality** remains a major barrier to global development. **Traditional grid expansion** is slow, expensive, and often impractical in remote or disaster-prone regions.

- Microgrids offer a decentralized solution but current systems heavily realies on manual control. Lack adaptability to the unique characteristics of a grid and do not ensure fair and inclusive energy distribution

- **Motivation:**
  - There is a critical need for an autonomous, intelligent, and fair energy management system that can learn, adapt, and coordinate energy use in real time across diverse regions.

- **Objective:**
  - Design a system that enables dynamic, AI-driven microgrids capable of self-management, social equity, and secure operation scalable to any part of the world.

# VISION – AI-EMS FRAMEWORK

AI-EMS is a conceptual blueprint for building intelligent microgrids with autonomous agents managing grid dynamics.

The system is designed to operate in islanded or grid-tied modes, adapting in real-time to physical and economic conditions while ensuring equitable energy access.

**Key Features:**

- Agent-based decentralized control
- Learning-based optimization
- Fair usage and pricing models
- Adaptable for different regions and regulations

# LAYERED SYSTEM ARCHITECTURE

The AI-EMS system is built on a modular 7-layer architecture:

- Physical Layer – Grid Core and Attachment
- Communication Layer – Protocols for data exchange
- Information Layer – Data aggregation and management
- Intelligence Layer – AI agents and decision logic
- Control Layer – Executes system-level control actions
- Application Layer – Interfaces for users and operators
- Business Layer – Economic policies and compliance

This layered structure ensures transparency, modular deployment, and scalability.

# INTELLIGENCE LAYER – HIERARCHY OF MULTI AGENT SYSTEM

AI-EMS introduces a multi-agent system where each SEM acts as an intelligent agent and abstract the Grid core and Attachment for Generalized control.

Agent Types:

Core Agent: Oversees grid-wide coordination

Coordinator Agent: Manages import/export regulation

Consumer/Prosumer Agents: Optimize energy flows

ESS Agent: Ensures health and efficient energy storage system

Lifeline Market Agent: Manages critical access and pricing

Agents operate independently but align through **negotiation** to achieve system goals.

# MULTI-AGENT NEGOTIATION AND INFORMATION EXCHANGE

Mechanism:

- Agents in the AI-EMS framework operate autonomously but achieve system-wide optimization through structured negotiation and real-time data exchange.
- The Coordinator Agent evaluates information to select and activate appropriate agents based on grid conditions and core agents' goals.

- Basic Negotiation Strategy:
  - Modeled as a search and selection process guided through goal functions.

Outcome:

- Enables real-time, distributed decision-making.
- Reduces centralized bottlenecks.
- Increases flexibility, fairness across all microgrid components.

# REAL-TIME GRID CONTROL

- The AI-EMS uses data from the **grid-connected data loggers** to continuously monitor real-time data which enables AI agents to autonomously manage and stabilize the grid.

- Controls:
    1. Load Balancing
    2. Voltage & Frequency Regulation
    3. Phase Disconnection for Lifeline Power
    4. BESS Charge/Discharge Control
    5. Fault Detection and Isolation
    6. Renewable Generation Moderation
    7. Islanded Mode Switching

# USER-CENTRIC DESIGN & TRANSPARENCY

The platform empowers both administrators and users

- **Admin Portal:** Registers SEMs, enforces compliance, initiates grid setups , Control Agents
- **User Access:** View energy use, pricing, and participation status

**Features:**

- Virtual Net Metering
- Energy Credits
- Renewable Integration Transparency.
- Scalable ESS
- QR-based SEM enrollment

# MARKET & SOCIAL EQUITY & PRICING

The business layer governs pricing, compliance, and strategic planning.

**System Stress Factor (SSF) based Energy Market pricing**

- Quantifies inverter and BESS load stress.
- Reflects user consumption urgency and behavioral history
- Scales pricing through non-linear multipliers in the scale from 0.1 to 50

AI-EMS ensures fair access to energy during constrained supply through a lifeline market mechanism.

**Fair Usage Policy (FUP):**

- Prioritizes essential users (e.g., students, medical devices)
- Monitors and penalizes misuse over time
- Block-based bidding distributes surplus fairly, while maintaining lifeline priorities.
- Unused reserved power is converted into energy credits for later use or trading.

# CYBERSECURITY & RELIABILITY FEATURES

Cybersecurity is integrated across layers with AI and protocol-based defenses. Each layer have its own security.

Layer wise Security,

- **Intelligence Layer :** AI Agent based Anomaly Detection
  - Identifies irregular patterns and Adversarial attacks
  - Agents won't have the access to use raw data.
- **Information Layer :** Data Validation , Block chain integrity.
- **Communication Layer :** IP tunnels, firewalls, authentication protocols
- **Physical Layer :** Encrypted QR code for physical access to device software.

Admin can override AI control decisions via the Admin Portal for safety or regulatory compliance.

# CONCLUSION

**AI-EMS is not just a concept—it is a transformational blueprint** for how the world can achieve equitable, intelligent, and resilient energy systems.

**Autonomous** – Agents learn, adapt, and manage grid operations in real time without human dependency.

**Equitable** – Fair pricing and usage policies prioritize critical needs and protect vulnerable communities.

**Scalable** – Seamlessly deployable across urban, rural, islanded, or disaster-prone regions with minimal infrastructure.

**Secure** – AI-driven decisions are auditable, overridable, and safeguarded through layered cybersecurity.

**Intelligent** – Combines temporal deep learning with decentralized agent coordination to optimize energy flow.

# ANY QUESTIONS ?

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This project, supported under the **Asian Development Bank's Technical Assistance Program (TA 57003-001 SRI)**, aims to design and pilot a transformative **AI-powered microgrid energy management system (AI-EMS)** tailored for decentralized, renewable, and equitable energy access in Sri Lanka and beyond. Implemented by **Lanka Electricity Company (LECO). With the collaboration of state universities**

University of Jaffna – Core technical partner for designing and building the AI and the digital platform
University of Moratuwa – Project coordination, Microgrid Design Simulation.
University of Peradeniya – BESS, Grid Controller and EMS Selection and Simulation
University of Ruhuna – Deployment of Smart Energy Meters Program

# Thank you,

Speaker: Eng. Y. Pirunthapan BSc.Eng (Hons)
Lecturer, Department of Computer Engineering,
Faculty of Engineering
University of Jaffna, Sri Lanka