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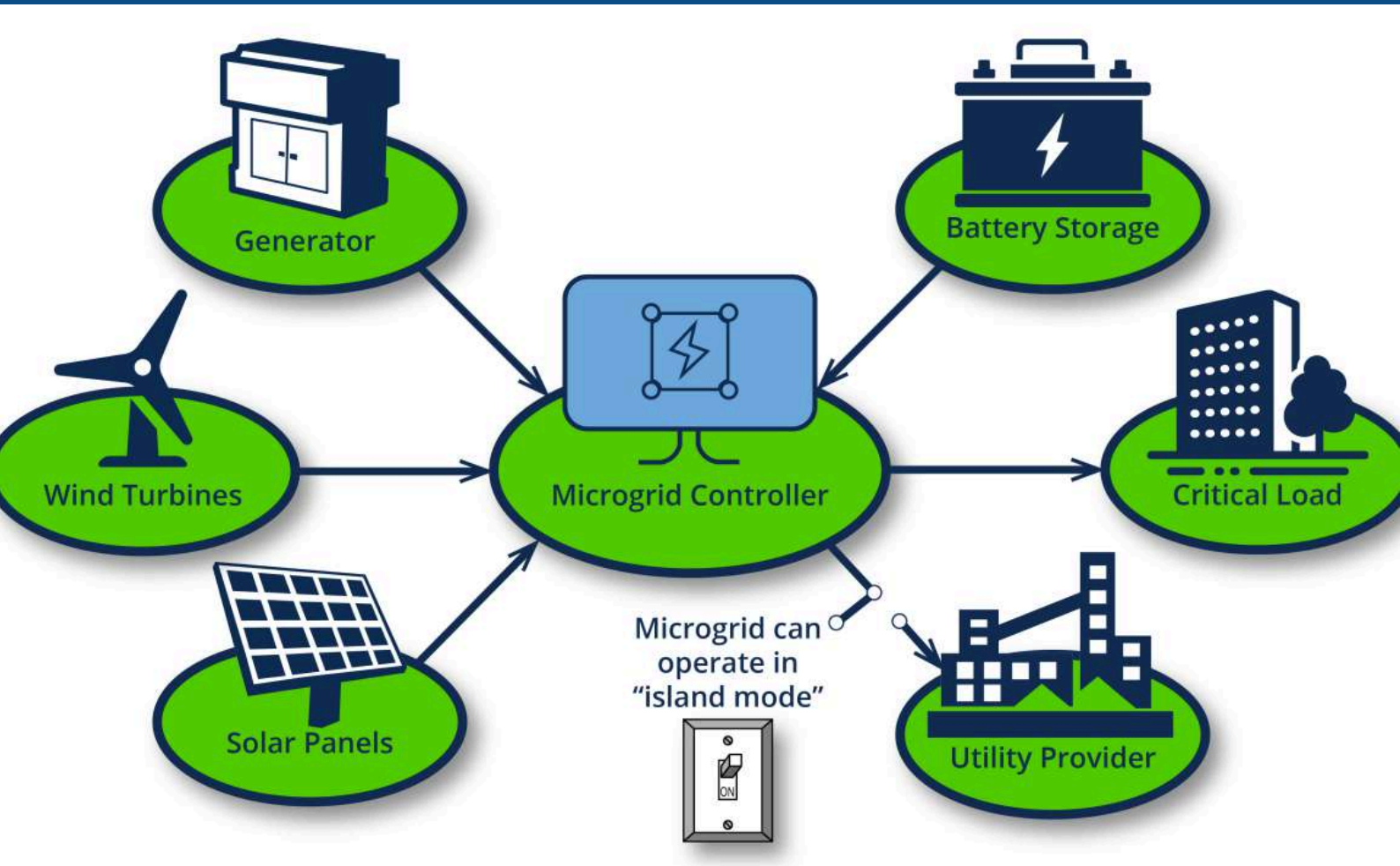
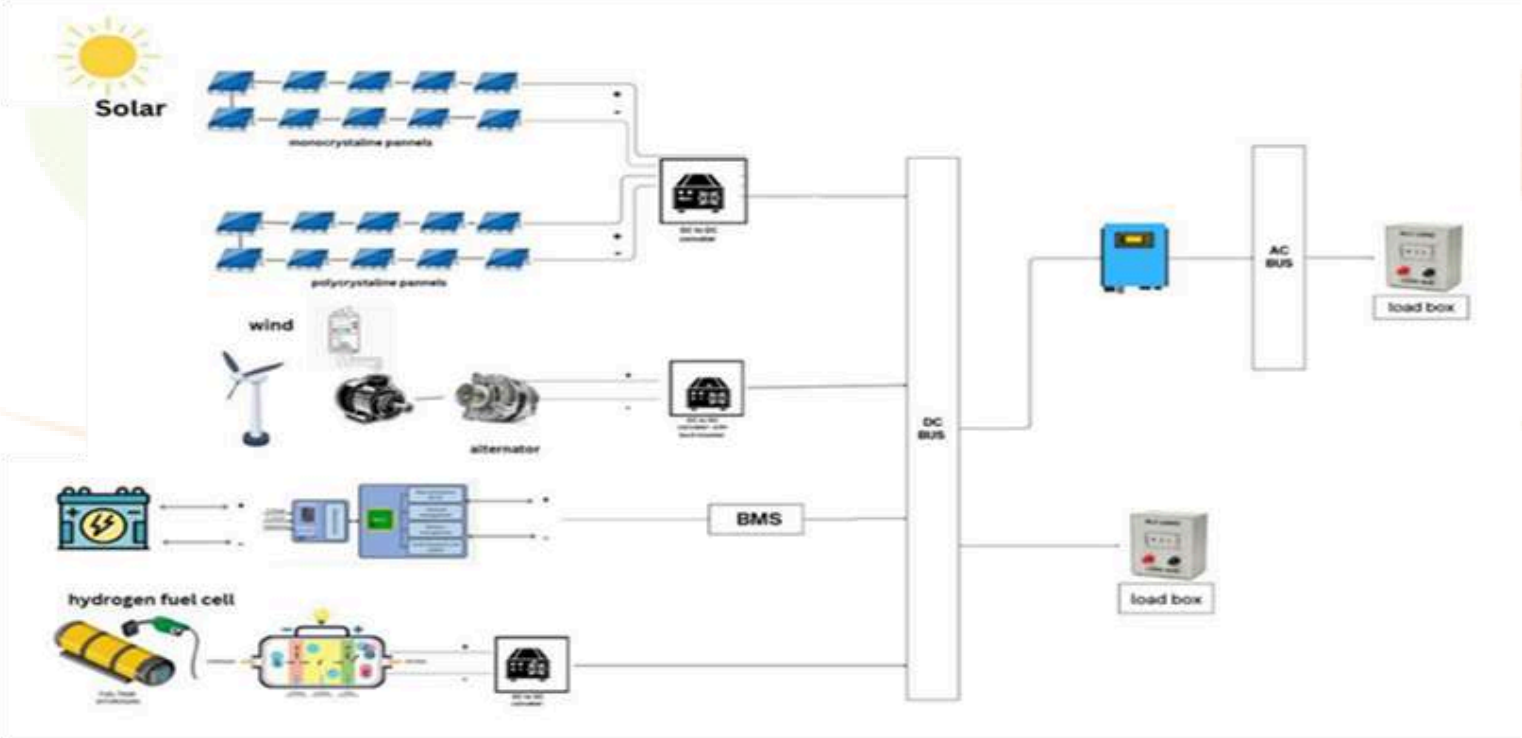
Smart Micro Grid Laboratory



POWERING INNOVATION FOR A SMARTER, SUSTAINABLE ENERGY FUTURE

ABOUT THE LAB

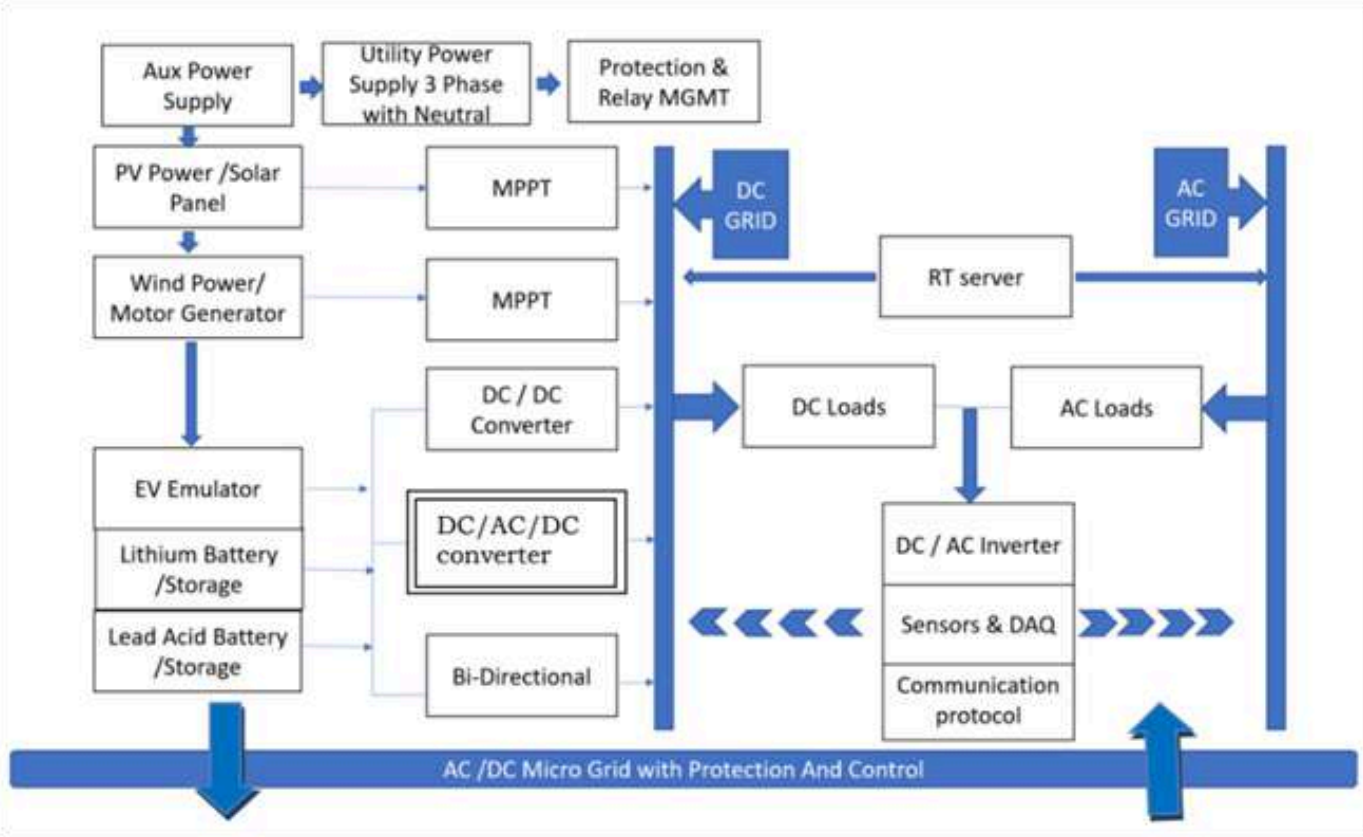
Our Smart Microgrid Lab is a cutting-edge facility designed for hands-on experimentation with localized electrical grids. It integrates advanced control systems and distributed energy resources (solar, wind, and hydrogen fuel) to generate, store, and manage electricity. Supporting both AC and DC architectures, the lab enables flexible testing of multi-source energy integration and modern grid configurations.



SYSTEM ARCHITECTURE :

AC/DC Microgrid System Architecture

A hybrid AC/DC microgrid integrating renewable sources, storage, loads, and intelligent monitoring for reliable operation.



- **Power Sources:** Solar PV, Wind, Auxiliary & Utility supply with MPPT optimization.
- **Energy Storage & Emulation:** Lithium/Lead batteries and EV emulator.
- **Power Conversion:** DC/DC, DC/AC, AC/DC, and Bi-directional converters for flexible power flow.
- **Grid Interface:** Supports AC & DC grids with protection and relay management.
- **Loads:** Supplies both AC and DC loads.
- **Monitoring & Control:** Sensors, DAQ, and communication protocols linked to RT server.
- **Overall:** Provides stable, efficient operation and renewable energy integration.

Core Components

- **Bidirectional Inverters/Chargers:** Enable smooth AC/DC conversion and interaction with the grid.
- **Renewable Source Controllers:** DC-DC modules connect solar and wind sources to the central 48 V bus.
- **Fuel Cell Integration Converter:** Boosts hydrogen fuel cell output to the system bus.
- **DC Distribution & Protection:** Safeguards circuits with fuses and intelligent branch management.
- **Control & Data Logging System:** Provides real-time monitoring, automated control, and remote accessibility.

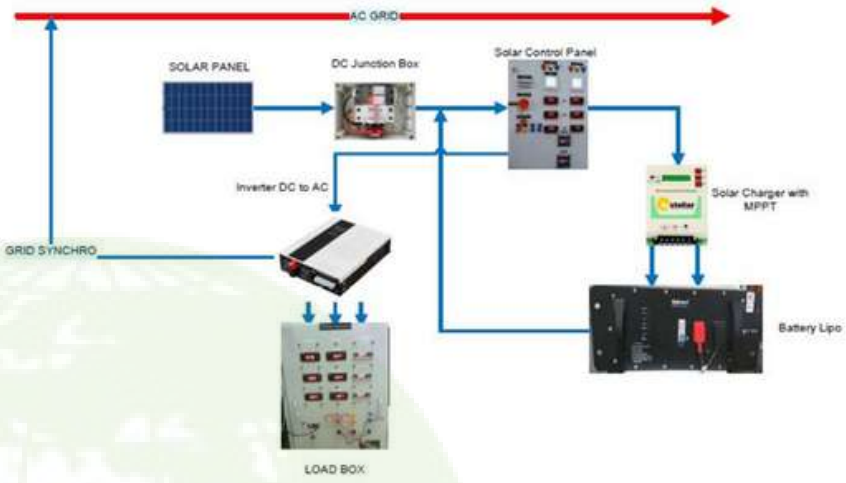
OUR OFFERED SOLUTION:

01 Solar OFF grid and ON grid system

Solar Off-Grid System: Works independently with solar panels and batteries, ideal for remote areas without grid access.

Solar On-Grid System: Connected to the utility grid, feeds excess power back and draws electricity when needed, ensuring cost efficiency.

- **Solar Panel -** Converts sunlight into DC electricity.
- **DC Junction Box -** Collects DC power from solar panels.
- **Inverter -** Converts DC to AC Power
- **Load Box -** Represents the electrical loads
- **Solar Charger with MPPT** (Maximum Power Point Tracking)
- **Battery -** Provides backup power during grid failure (OFF-Grid Mode)



- **AC Grid (ON-Grid) -** If solar power is insufficient, loads draw power from the grid. Extra solar power can be fed back to the grid.

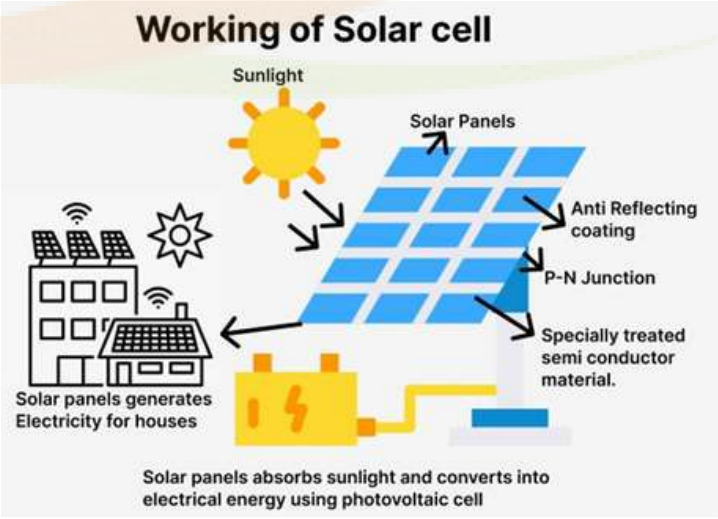
Applications:

- Residential & Educational Institution rooftops
- Commercial and industrial buildings
- Rural electrification and remote villages
- Street lighting and water pumping
- Disaster relief and emergency backup power

02 Solar PV Integration

A PV cell converts sunlight into electricity using the photovoltaic effect, serving as the core component of solar panels for clean, renewable energy generation.

- **DC-Coupled Solar PV (3 kW):** Connected to the 48 V DC bus via a high-voltage DC-DC charge controller for efficient energy management.
- **AC-Coupled Solar PV (3 kW, 5 kVA):** Grid-tied inverter enables seamless integration with the utility grid and system bus for renewable support and hybrid energy experiments.



Applications:

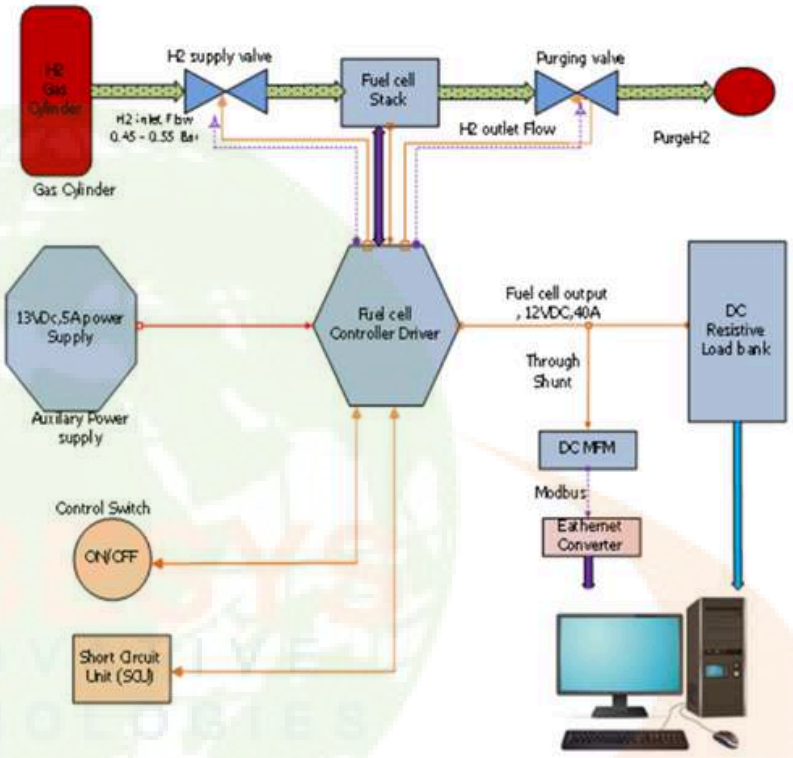
- **Residential & Commercial Power:** Rooftop and building-integrated solar energy.
- **Grid-Connected Systems:** Feeding electricity into the utility grid.
- **Remote & Off-Grid Areas:** Powering homes, telecom towers, and rural communities.

03 Hydrogen Fuel Cell(12 V, 500 W) -DC-DC boost converter, 12 V input to 48 V DC bus.

A hydrogen fuel cell is an electrochemical device that converts hydrogen and oxygen directly into electricity, with water and heat as the only by-products. Hydrogen fuel cells enhance smart microgrids by providing flexible energy storage and reliable backup power, improving stability and resilience. Excess renewable energy is stored as hydrogen through electrolysis and later converted back to electricity by fuel cells, ensuring steady power supply, outage support, and a sustainable low-emission energy ecosystem.

Applications:

- **Transportation:** Cars, buses, trucks, trains, ships, and drones with zero emissions.
- **Stationary Power:** Backup power, microgrids, and combined heat & power for homes and industries.
- **Industrial Use:** Forklifts, material handling, and renewable energy storage.
- **Grid Support:** Energy storage, peak shaving, and renewable integration.
- **Military:** Reliable power for remote operations and vehicles.



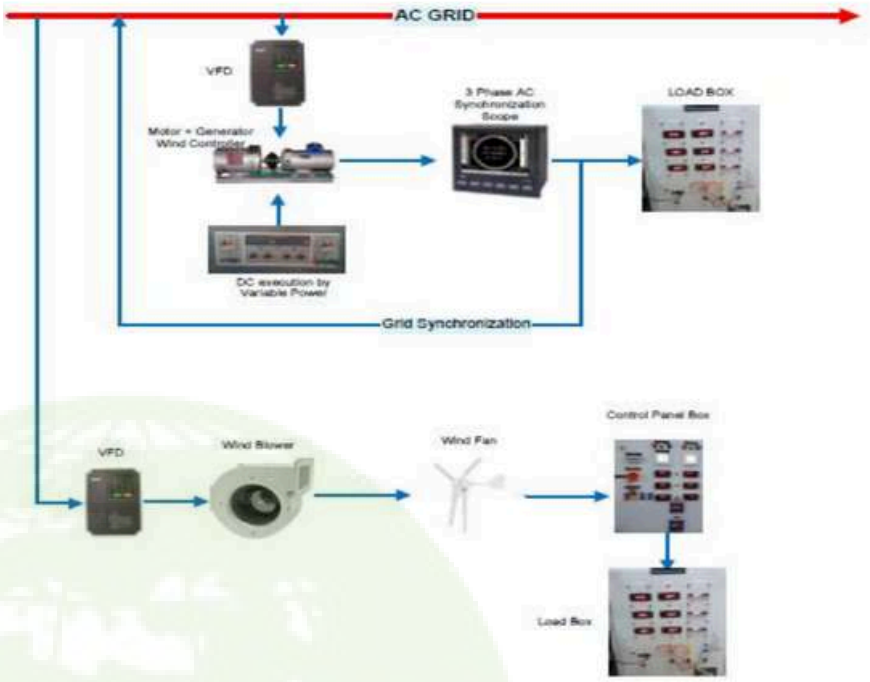
04 Wind Emulator(2 kW, 220 V DC)

Wind Emulator allows for the evaluation of energy management power converters without the complexity and expense of using a real wind turbine, which is essential for integrating and stabilizing renewable energy sources in micro grids.

The Wind Emulator System features a Variable Frequency Drive (VFD) to control motor speed, coupled with a Motor-Generator Wind Controller for precise turbine simulation. A 3-Phase AC Synchronization Scope monitors phase, voltage, and frequency for grid integration. The system includes an AC grid interface for synchronization and a wind blower with fan, which generates airflow to drive the generator, enabling realistic wind turbine testing and performance evaluation.

Applications:

- Test wind turbine performance and efficiency
- Optimize turbine control algorithms
- Study hybrid renewable energy systems
- Simulate real-world wind conditions for research
- Analyse turbine response to gusts and faults



05 Motor-Generator Set with Closed-Loop VFD Drive

- **VFD:** Closed-loop vector-controlled drive with encoder feedback
- **Encoder Integration:** Incremental/absolute encoder for precise control
- **Connections:** Three-phase AC input to VFD and output to motor
- **Wiring Provision:** Terminal blocks and entry glands for encoder and motor connections

Applications:

- Load testing and performance evaluation of motors and generators
- Speed control and variable frequency experiments
- Renewable energy system simulation and grid emulation
- Power quality and stability testing
- Educational and research experiments in electrical machines

06 Modular Data Acquisition System

cDAQ

It isused for real-time monitoring and data acquisition of voltage, current, power, and environmental parameters. Supports distributed measurements, fault detection, energy management, and performance analysis of renewable energy sources, storage systems, and microgrid operations.

I/O Modules

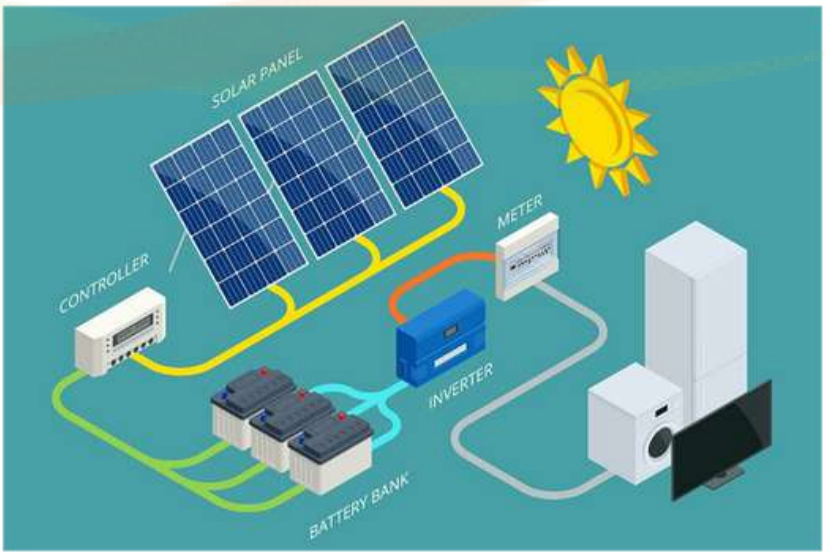
I/O Modules Enable real-time measurement and monitoring of voltage, current, power, and environmental signals. Support data acquisition from renewable sources, storage systems, and loads for energy management, fault detection, and grid performance analysis.

07 Battery Energy Storage System (BESS):

Stores electrical energy for later use, providing load balancing, peak shaving, and backup power.The system features a Smart Battery Management System (BMS) with analytics for State of Charge (SoC) and State of Health (SoH), providing valuable insights into battery performance and lifecycle.

Applications:

- Grid stabilization and renewable energy integration
- Peak load management and demand response
- Backup power for critical facilities
- Electric vehicle charging support and microgrid operation



08 EV Charging Interface:

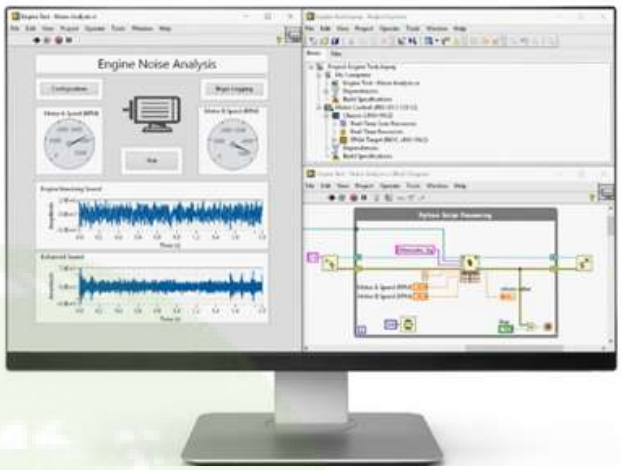
Provides a dedicated station for testing and analysing electric vehicle charging.

Applications:

- Study EV charging patterns and energy demand
- Evaluate grid impact and integration with renewable sources
- Support experiments on smart charging and green mobility solutions

09 Data Control and Simulation:

- **System Gateway:** Central hub coordinating inverters, charge controllers, and protection devices.
- **Communication Protocols:** RS485, CAN bus, and proprietary links for seamless integration.
- **Supervisory Interface:** Modbus-TCP API for LabVIEW-based monitoring and control.



10 Power Panel & Protection:

- **Protection Devices:** Complete AC/DC safeguards with fuses, breakers, relays, and surge protection.
- **Enclosure:** Industrial-grade, ventilated, and temperature-controlled cabinet for safe operation.

LIST OF EXPERIMENTS TO BE PERFORMED:

- Effect of irradiance and temperature on PV output
- Maximum Power Point Tracking (MPPT)
- Grid-tied inverter performance
- Power injection and synchronization with grid
- Grid fault response and protection analysis
- Standalone PV system with battery storage
- Load management and peak shaving in off-grid PV
- Wind turbine performance under variable wind speeds
- Turbine control algorithm testing
- Hybrid system integration (PV + Wind + Battery)
- Fuel cell integration with DC bus
- Load response and hybrid system testing
- Real-time monitoring with cDAQ/I/O modules
- Variable speed operation with Motor-Generator set
- Simulation of microgrid and renewable integration
- Multi-source energy management and load sharing

CONCLUSION:

The Smart Grid Laboratory offers a hands-on platform to study and optimize renewable energy, storage, and grid integration, fostering innovation for a sustainable and resilient energy future.

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