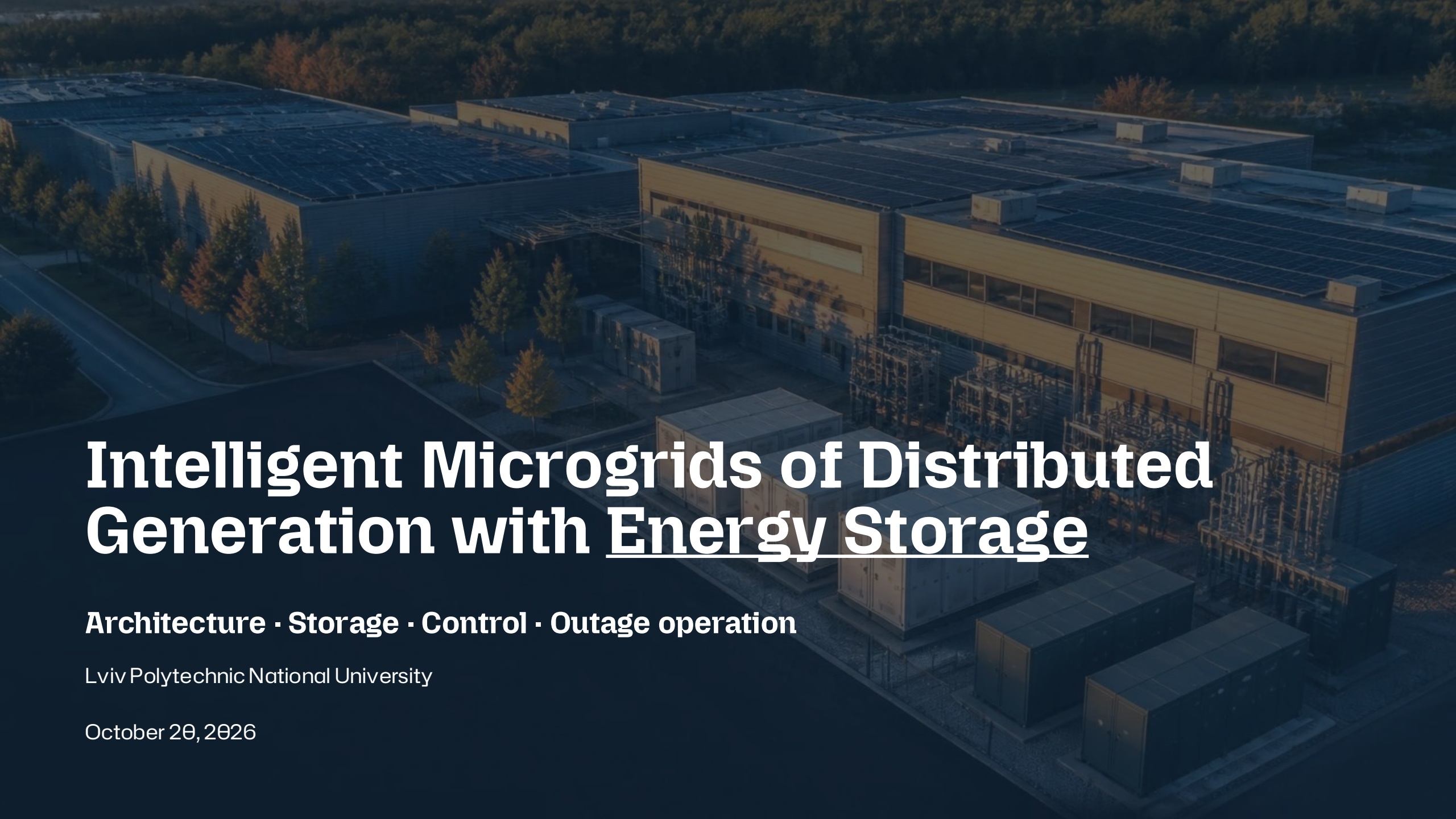


Intelligent Microgrids of Distributed Generation with Energy Storage

Architecture · Storage · Control · Outage operation

Lviv Polytechnic National University

October 20, 2026

LECTURER PROFILE

About the Lecturer



Rostyslav Kuzyk

PhD, assistant

Department of Electromechanical and Electrotechnical Systems, Institute of Power Engineering and Control Systems, Lviv Polytechnic National University, Ukraine

- Research: electric drives and EV control, photovoltaic and wind generation, hybrid energy storage, mathematical modeling of multiphysics energy-based systems, and energy-based control synthesis

WHY MICROGRIDS

Resilience depends on coordinating resources, not only on capacity

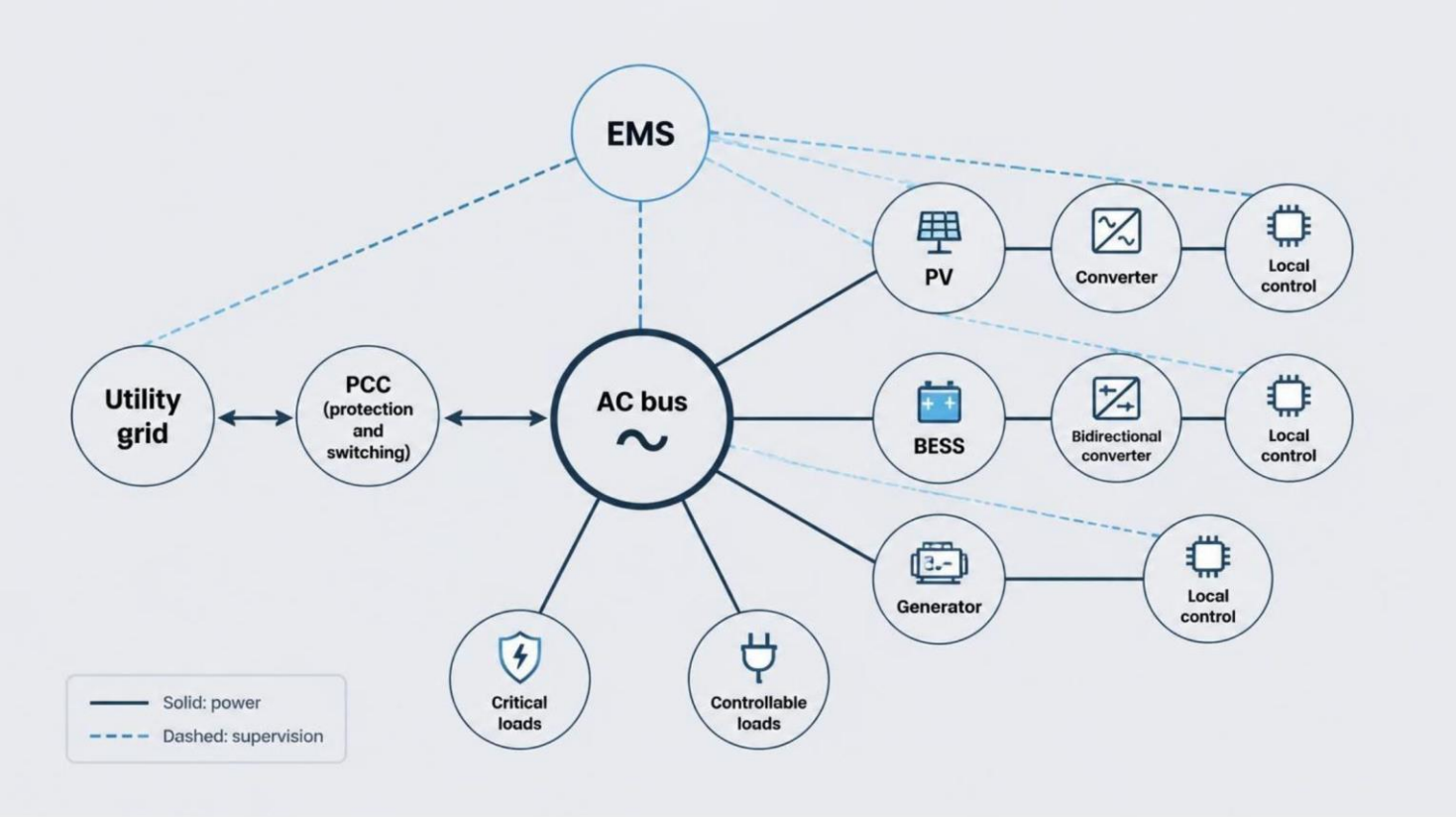
Variable renewables.
Disturbed grids.
Critical loads.

Passive backup becomes an actively managed local energy system.



ARCHITECTURE

The PCC is the grid interface; the controller coordinates everything inside



DER and storage connect electrically; EMS supervision does not replace local control or protection.



BESS

Storage does far more than hold surplus energy

Power

kW · MW

How fast energy flows

Energy

kWh · MWh

How long it lasts

Charge BESS Discharge

Shift energy, shave peaks and limit ramps. Support voltage and frequency where converter controls allow.

Hold critical-load reserve; support black start if designed for it.

INTELLIGENCE

Intelligence means coordinated decisions, not remote monitoring

Measure

Voltage, current, frequency and power

Anticipate

Forecast generation and demand

Dispatch

Optimize storage and generators within constraints

Close the loop: communication between EMS, local controllers and protection; fault detection, alarms and event logging.

CONTROL HIERARCHY

Three control levels work at different timescales



Exact allocation depends on the design.

BATTERY STATE OF CHARGE

Usable battery energy is less than nominal

Of 200 kWh nominal, about 160 kWh is usable after reserve and operating limits.

- Power: inverter and cell C-rate limits
- Temperature: derate when cells run hot or cold
- Ramp rate: limits how fast output can change

Illustrative values from the worked example.

Headroom · 90–100%

Absorbs surplus; avoids overcharge stress

Working window · 10–90%

About 160 kWh for tariff dispatch and peak shaving

Outage reserve · 0–10%

Held for critical loads during islanding

OPERATING MODES

Grid-connected and islanded modes are fundamentally different

Grid-connected

Utility PCC closed Microgrid

The grid supports voltage and frequency.

Import/export within limits.

Peak shaving and arbitrage.

Islanded

Utility | PCC open | Microgrid

Local resources balance generation and demand.

Grid-forming control and reserve management.

Load shedding when necessary.

A grid-following inverter alone does not establish a stable islanded AC grid.

OUTAGE RESPONSE

A grid failure triggers a six-step sequence



Protection must fit both modes. Black start needs equipment and a defined sequence. Seamless transition requires a supporting design.



ILLUSTRATIVE CASE

Case study: an industrial microgrid loses the grid at midday

300 kWp

PV

100 kW / 200 kWh

Inverter / battery

60 kW

Critical load

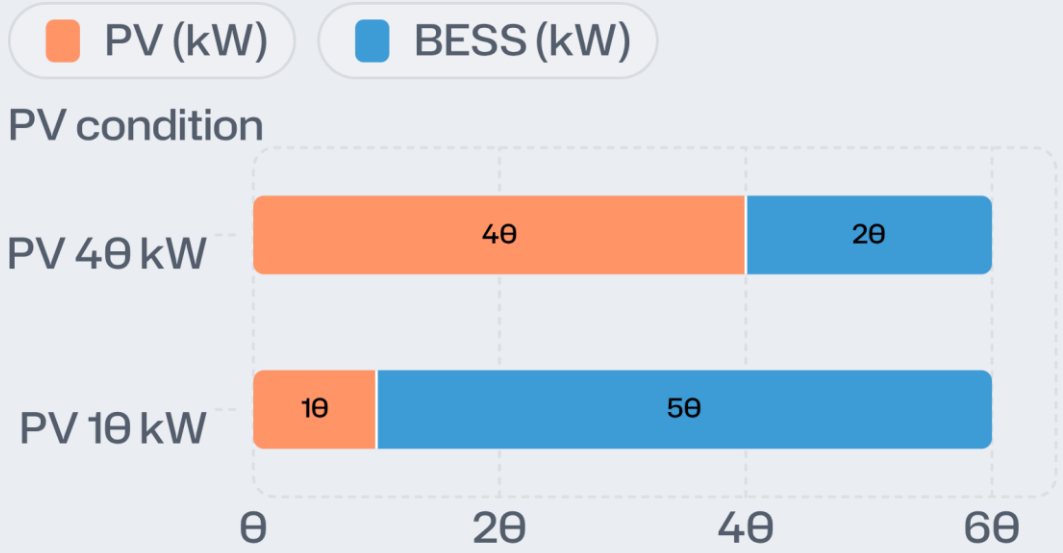
Isolate → supply critical loads → use PV directly → BESS covers the deficit.

Optional standby generator. Is the battery large enough? Illustrative values, not an equipment design.

WORKED CALCULATION · CONSTANT CONDITIONS

Autonomy depends on the power deficit, not nominal capacity

Supply to a 60 kW critical load



Usable energy: 160 kWh of 200 kWh nominal.

$$P_{\text{BESS}} = 60 - 40 = 20\ \text{kW}$$

$$T \approx \frac{160\ \text{kWh}}{20\ \text{kW}} \approx 8\ \text{h}$$

$$P_{\text{BESS}} = 60 - 10 = 50\ \text{kW}$$

$$T \approx \frac{160\ \text{kWh}}{50\ \text{kW}} \approx 3.2\ \text{h}$$

Check inverter capability at 50 kW, losses, the SoC window and equipment power limits.

IMPLEMENTATION

An intelligent microgrid is a cyber-physical system

Electrical performance depends on trustworthy information and coordinated action.



Cybersecurity and communications

Failures must not compromise safe local operation.



Interoperability

Coordinate equipment across manufacturers.



Asset life and protection

Battery degradation, replacement cost and protection in both modes.



Economy versus reserve

Plan for emergencies under uncertain forecasts.

CONCLUSIONS AND DISCUSSION

Design resilience around critical loads and credible outages

Generation

Local power, with variability

Storage

Flexibility, reserve and fast support

Control

Technical and economic goals

Islanding needs suitable converters, switching, protection and control.

Thanks for your attention