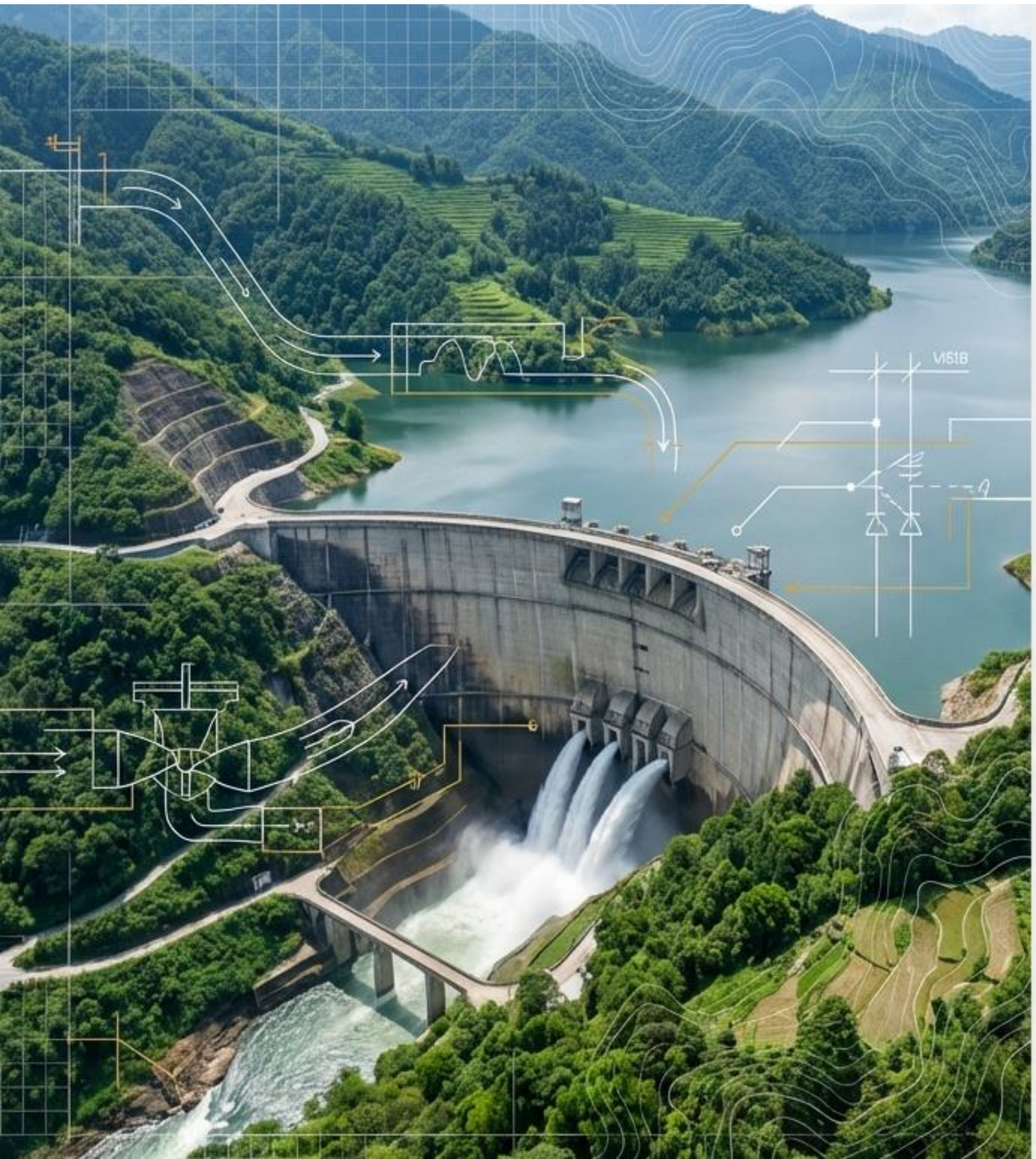


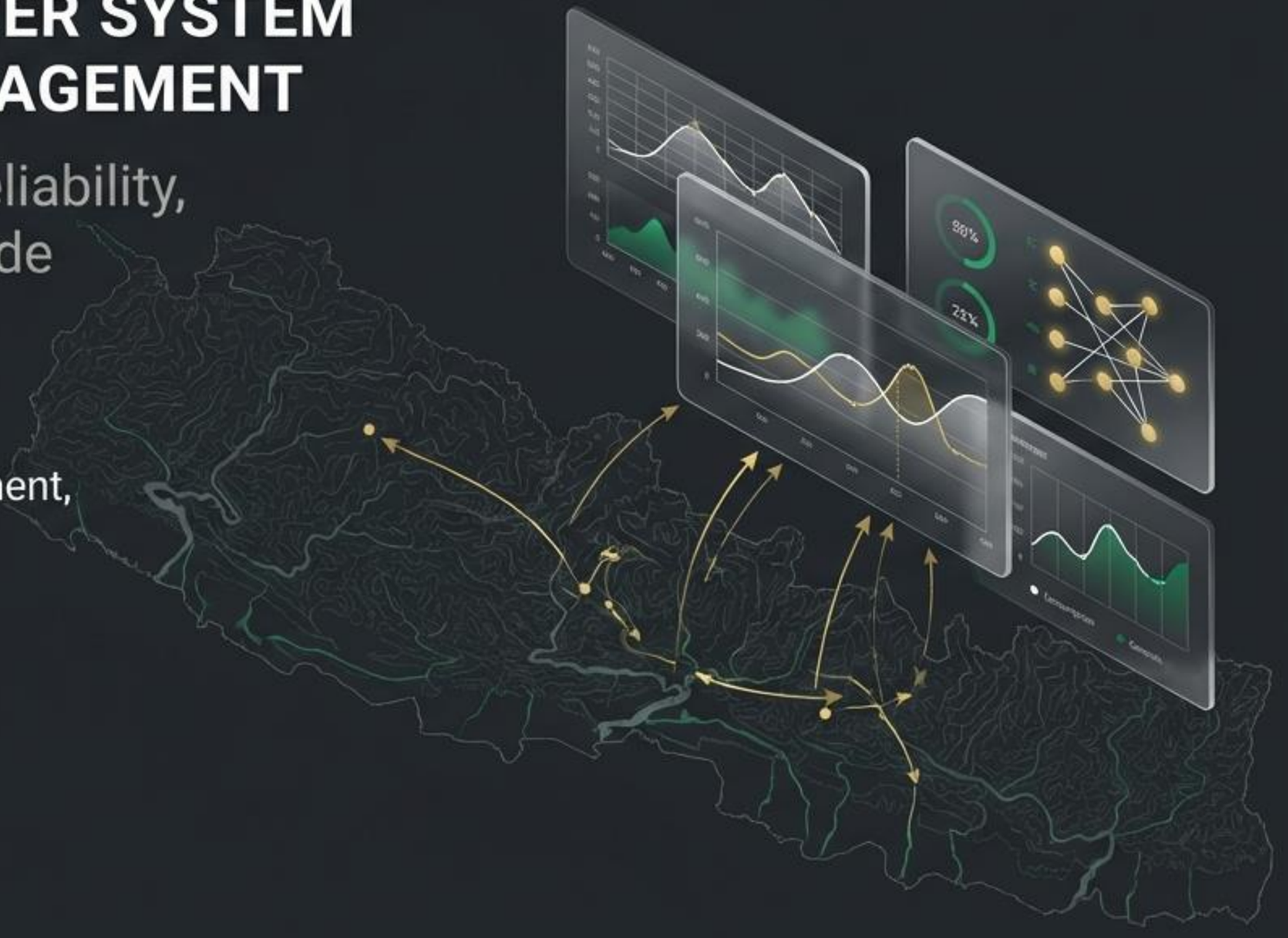
Best Practices in Power System Operation & Grid Management

Modernizing Nepal's Grid for Reliability, Sustainability, and Regional Trade

Presented by:
Chandan Kumar Ghosh
Director, Power System Operation Department
Chief of Load Dispatch Centre
Nepal Electricity Authority
April 2026

ONLINE KNOWLEDGE SHARING WORKSHOP: BEST PRACTICES IN POWER SYSTEM OPERATION & GRID MANAGEMENT

Modernizing Nepal's Grid for Reliability, Sustainability, and Regional Trade



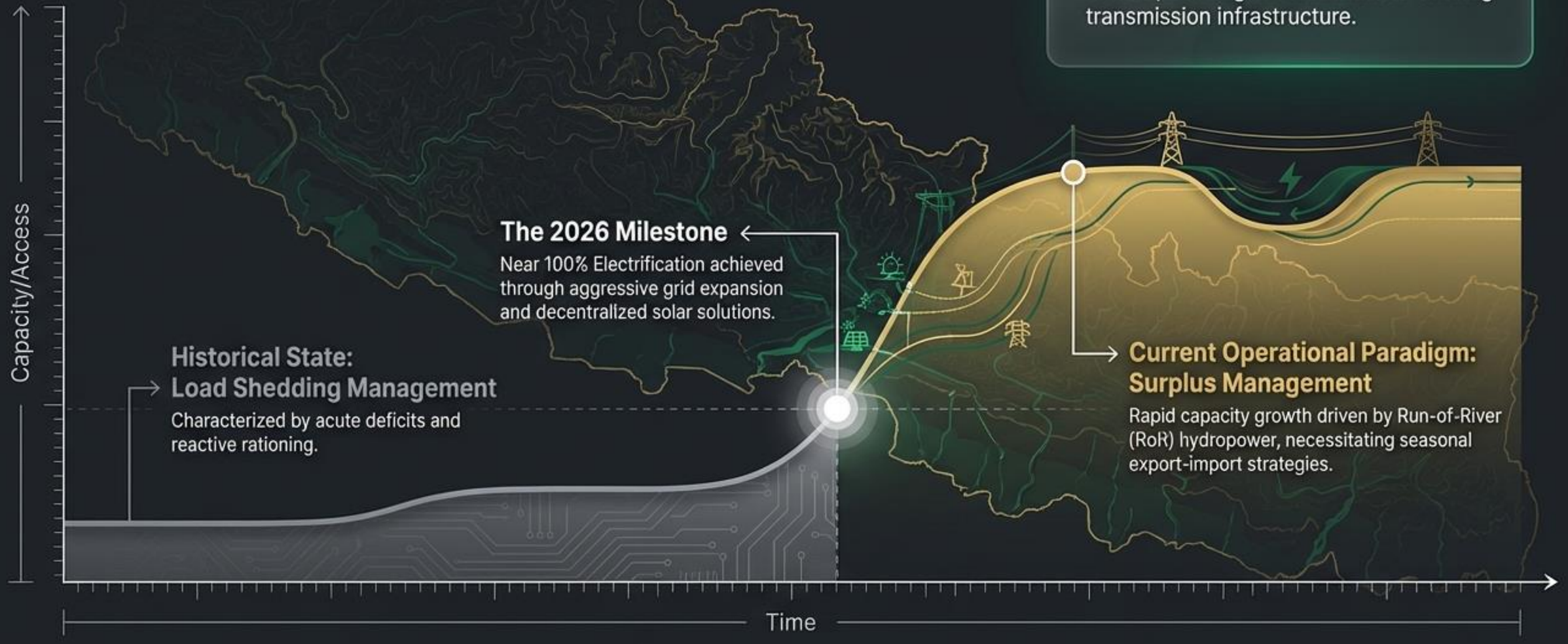
Chandan Kumar Ghosh
Director, Power System Operation Department,
Chief of Load Dispatch Centre
Nepal Electricity Authority (NEA)

April 2026

The Macro Shift: Nepal's Energy Evolution

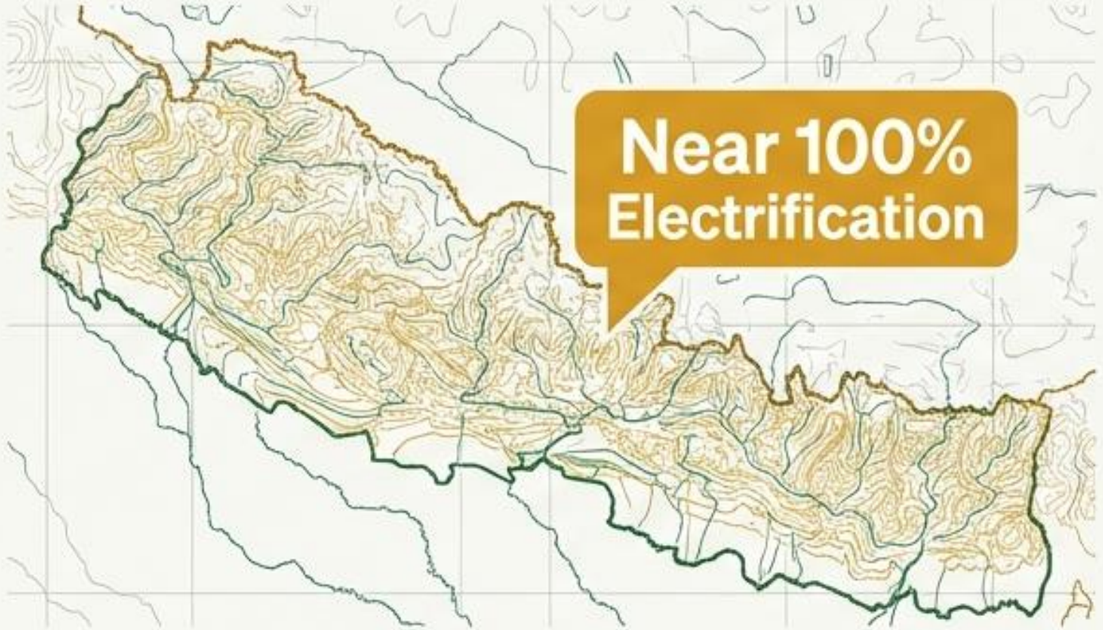
The Core Challenge

Balancing extreme seasonal variations (Monsoon Surplus vs. Winter Deficit) while optimizing the utilization of existing transmission infrastructure.



From Load Shedding Management to Regional Surplus Export

The Milestone



Rapid Capacity Growth: Exponential increase in installed capacity driven by Run-of-River (RoR) hydropower.

Grid Expansion: Achieved near 100% domestic access through robust grid expansion and decentralized solar solutions.

The Operational Shift

Surplus Management: The primary operational focus is now seasonal export-import dynamics.

The Balancing Act: Overcoming the key challenge of monsoon surplus versus winter deficit by optimizing existing transmission infrastructure.

UNIVERSAL ACCESS

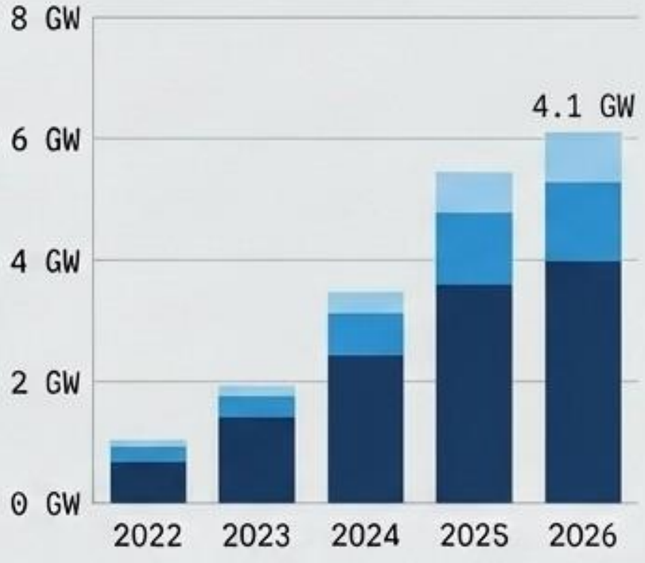
NEAR 100% ELECTRIFION

Achieved via aggressive grid expansion and decentralized solar solutions.

GENERATION MIX

RAPID ROR GROWTH

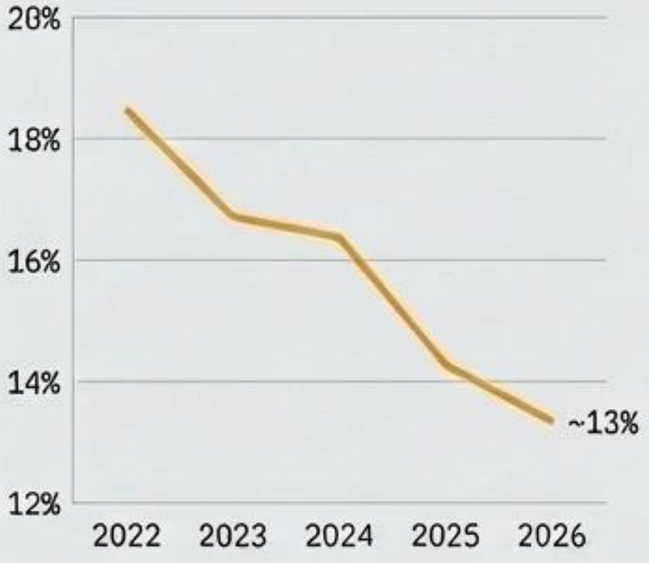
Exponential installed capacity increase driven by Run-of-River hydropower.



SYSTEM EFFICIENCY

~13% SYSTEM LOSS

Aggressive target achieved through high-voltage transmission upgrades.



CORE OPERATIONAL CHALLENGE: Balancing monsoon surplus against winter deficits while optimizing existing transmission.

The Operational Paradigm Shift

LEGACY OPERATIONS	2026 PARADIGM
Primary Goal: Load Shedding Management	**Primary Goal: Surplus Management & Seasonal Export**
Resource Strategy: Supply-Side Focus Only	**Resource Strategy: Integrated DSM, Efficiency & Storage**
Grid Control: Manual / Analog Dispatch	**Grid Control: Master Control Center (MCC) / SCADA Automation**
Borders: Isolated System	**Borders: Trilateral Cross-Border Power Trade**

The Load Dispatch Center Serves as the Central Nervous System

Real-Time Monitoring & Control

Full visibility and command over decentralized grid assets.

Operational Planning

Precision switching instructions and generation scheduling.

LDC: Apex body for real-time integrated operation of the INPS

Disturbance Restoration

Coordinated Black Start protocols to rapidly recover from grid anomalies.

Inter-Utility Coordination

Seamless integration across NEA subsidiaries, IPPs, and Cross-Border entities.

Modernizing the Foundation: Infrastructure & IRP

Pillar 1: Supply (Holistic Planning)

Moving beyond supply-side isolation. Integrating solar PV to complement hydro and reduce seasonal vulnerability.

Prioritizing Pumped Storage Hydro (PSH) and Battery Energy Storage Systems (BESS) for peak management.

Pillar 2: Transmission (Reliability)

Expanding high-voltage capacities and systematically transitioning to underground distribution cabling in dense urban centers like Kathmandu to slash outage rates.

Pillar 3: Demand (Smart Utilization)

Rolling out Advanced Metering Infrastructure (AMI) to empower Demand-Side Management (DSM), driving per capita electricity consumption, and embedding energy efficiency into network planning.

The Brain of the Grid: LDC & Infrastructure Modernization

SCADA & Automation

Full Master Control Center (MCC) implementation; 39+ grid substations automated for real-time monitoring.

Load Dispatch Center (LDC)

Apex body for real-time integrated operation of the INPS. (Operational planning, switching instructions, inter-utility coordination)

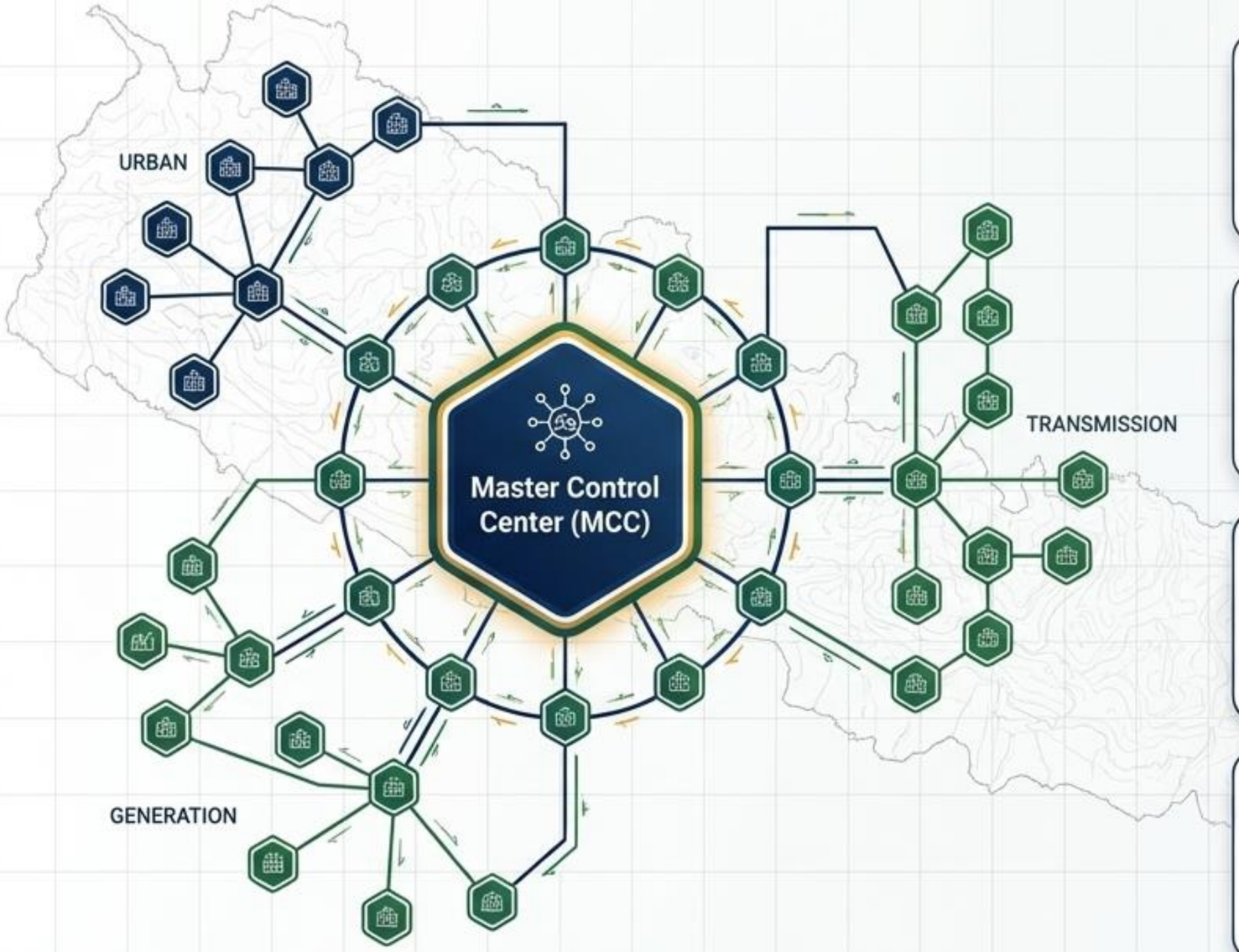
Smart Metering

Accelerated Advanced Metering Infrastructure (AMI) rollout for demand-side intelligence.

Undergrounding

Transition to underground distribution cabling in urban hubs (Kathmandu) for peak reliability.

SCADA and Master Control Centers Provide Total Network Visibility



Core Control

Full implementation of the Master Control Center (MCC) serving as the foundation for EMS and automated contingency analysis.

Substation Automation

39+ grid substations fully automated for remote breaker control, load balancing, and faster fault localization.

Smart Edge Infrastructure

Accelerating the rollout of Advanced Metering Infrastructure (AMI) for precise demand-side management.

Urban Reliability

Extensive transition to underground distribution cabling in Kathmandu, drastically reducing outage duration and improving SAIDI/SAIFI indices.

The SCADA & EMS Value Loop

ACQUISITION (FIELD)

Continuous capture of voltage, current, frequency, power flow, and breaker status.

Integration of PMU data for Wide Area Monitoring Systems (WAMS).

VISIBILITY (MCC)

Real-time dashboard visualization.

Centralized oversight of geographically dispersed generation and transmission assets.

ANALYTICS (EMS)

Facilitating load balancing, fast fault localization, and transition toward AI-driven predictive analytics.

ACTION (CONTROL)

Remote control of circuit breakers/tap changers, automated load shedding schemes, and alarm management.

Proactive Management: EMD & Forecasting

Planning Phase

- Day-ahead & intra-day forecasting.
- Precise renewable forecasting (hydro inflow, solar irradiance).
- 15-minute / hourly scheduling blocks.

Real-Time Phase

- Tight frequency control and tie-line flow monitoring via SCADA/EMS.
- Merit order economic dispatch to minimize system cost/losses.
- Maintenance of drawal limits and cross-border interchange deviation control.

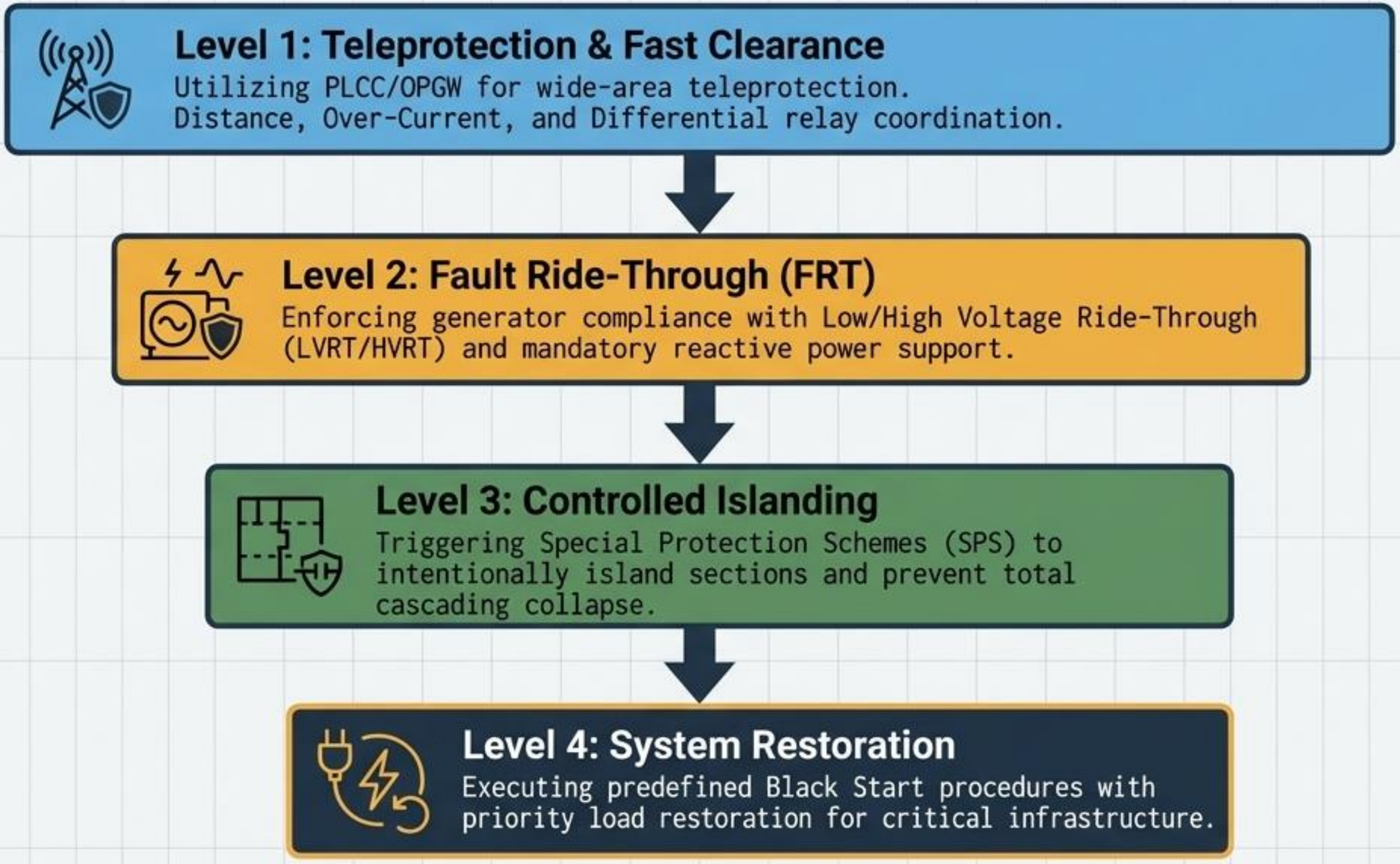
Day-Ahead

Real-Time

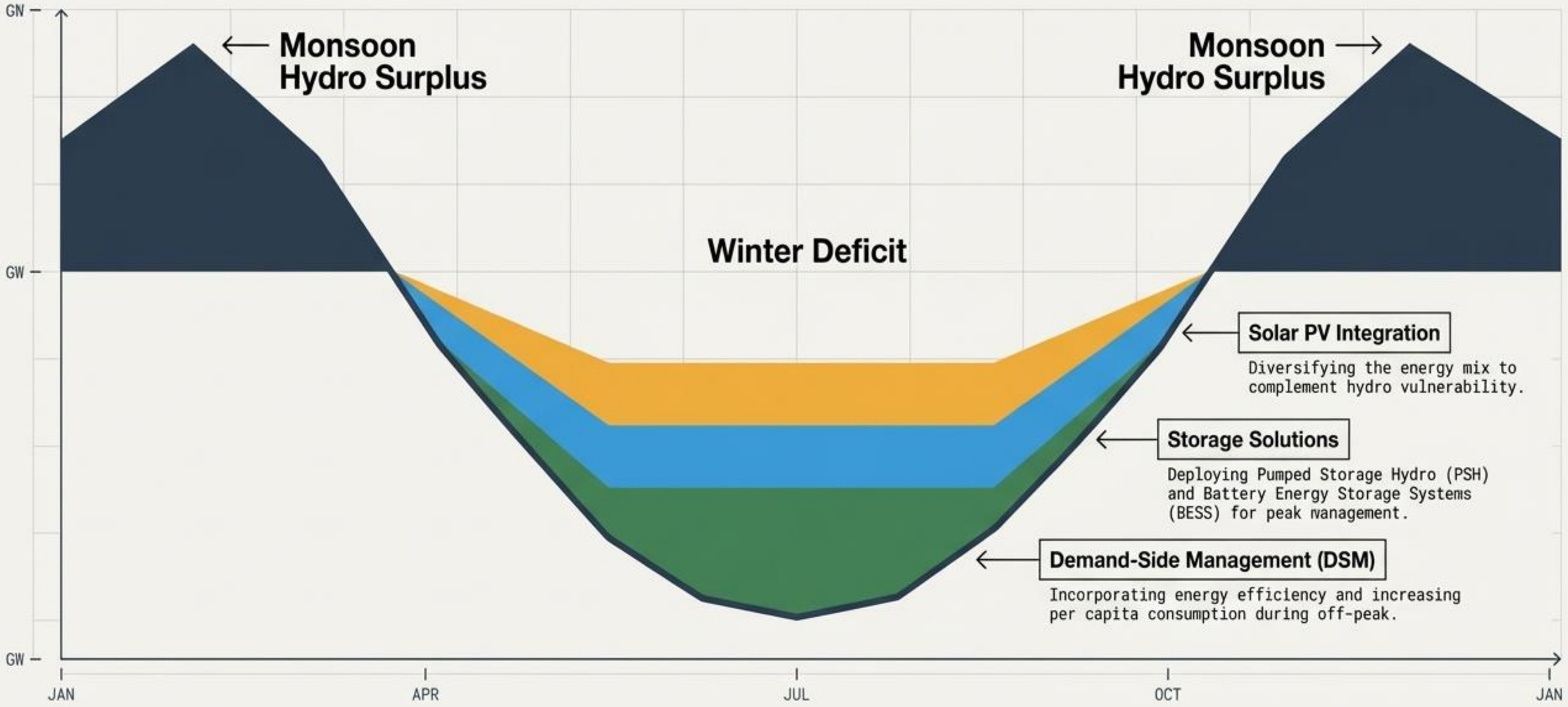
Ancillary Services

Maintaining spinning, non-spinning, and frequency control reserves to buffer unexpected shifts.

Reactive Defense: Disturbance & Protection Management



Integrated Resource Planning (IRP): The Seasonal Balancing Act



Institutional DNA & Resilience Safeguards

Operational Readiness

- 24/7 skilled manpower in the control room.
- Strict adherence to standard operating procedures (SOPs) for switching and emergency handling.

Climate & Environmental Safeguards

- Designing infrastructure to withstand GLOFs (Glacial Lake Outburst Floods) and extreme weather.
- Enforcing Environmental Management Plans (EMP) and community benefit-sharing.

Cyber Security Preparedness

- Securing the digitalized SCADA/EMS grid and WAMS from evolving cyber threats.

The Brain of the Grid: SCADA & Digital Automation

Asset Automation

Full automation of 39+ grid substations enabling remote control of circuit breakers and tap changers.

Master Control Center (MCC)

The apex body for real-time integrated operation of the Integrated Nepalese Power System (INPS).

Advanced Integration

Seamless merging with Energy Management Systems (EMS) and Distribution Management Systems (DMS) for renewable variability management.

Real-Time Visibility

Wide Area Monitoring Systems (WAMS) leveraging PMU data for continuous acquisition of voltage, current, frequency, and power flow.

Future Trajectory

Transitioning toward AI-driven predictive analytics and elevated cybersecurity for data integrity.

The Operational Heartbeat: Energy Management Division

Forecasting & Scheduling

Executing day-ahead and intra-day renewable forecasts (hydro inflow, solar) using precise 15-minute and hourly scheduling blocks.

Economic Dispatch

Utilizing merit order dispatch to minimize system losses and generation costs, supported by strict drawal limits.

Ancillary & Contingency Response

Deploying frequency control reserves (spinning and non-spinning) while running real-time N-1/N-2 contingency assessments to predict and prevent overloads.

Real-Time Monitoring & Coordination

SCADA/EMS tracking of frequency, voltage, and tie-line flows. Managing bilateral/IEX exchanges and tight frequency control.

Structural Resilience: Zero-Downtime Architecture & Redundancy

Unbreakable Failover

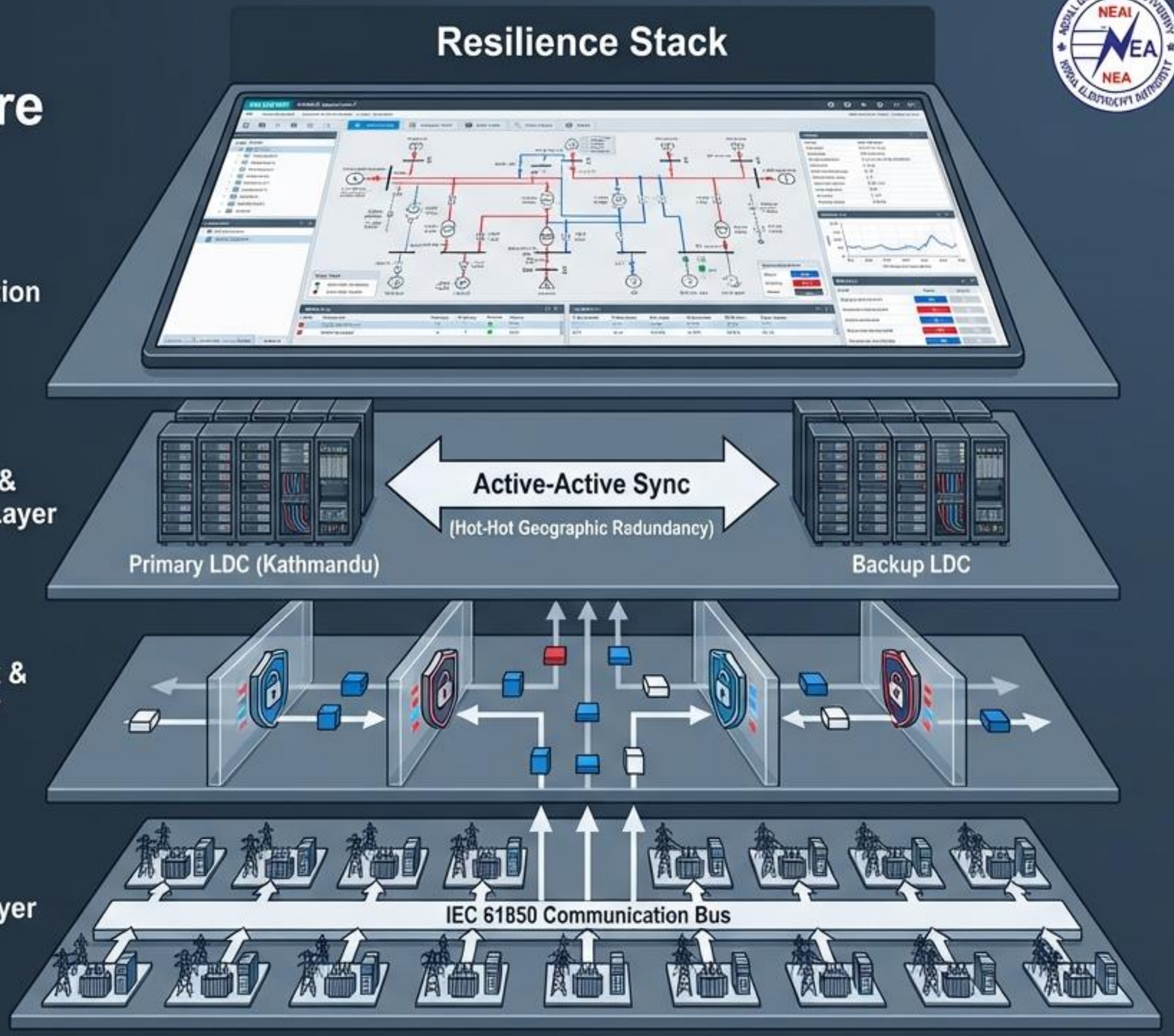
Hot-Hot server synchronization ensures continuous real-time monitoring and control with zero-downtime failover between primary and backup dispatch centers.

N-1 Contingency Ready

Distributed architecture prevents cascading outages, ensuring the INPS withstands the failure of any single major component.

Cyber-Hardened

Strict IT/OT layer segmentation isolates the core SCADA servers from the field layer, securing the digitalized grid from external threats.

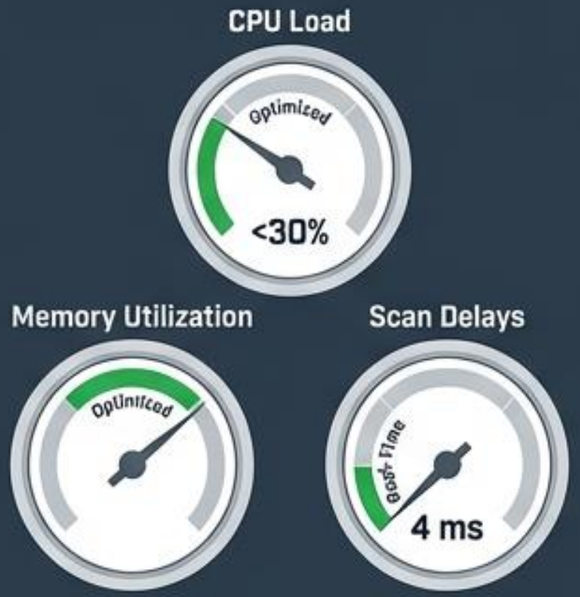


Operational Vigilance: Health Monitoring & Maintenance Regimens

नेपाल विद्युत प्राधिकरण
NEPAL ELECTRICITY AUTHORITY

Control Panel

Real-Time Telemetry



Continuous acquisition of field data and system health for rapid operator decision-making.

Control Panel

Automated Backup Rhythm

Automated historical archiving ensures rapid system restoration and safeguards against data corruption.

Control Panel

Documentation & SOPs

Empowering 24/7 skilled manpower with data-driven insights to refine Standard Operating Procedures.

Technology paired with rigorous operational policy ensures total grid stability for Nepal's transition to surplus management and regional trade.

AI-Driven Dynamic Line Rating Unlocks Hidden Transmission Capacity

DLR Intelligence Stack

Step 1: SCADA Input

Fetch real-time current data at 2-second intervals.

Step 2: Weather Data

Ingest ambient temp, wind speed, solar radiation via API.

Step 3: Physics Engine

Apply IEEE 738 heat balance models.

Step 4: ML Calibration

Random Forest algorithms learn site-specific thermal behavior to correct standard physics model errors.

Step 5: Predictive Forecasting

XGBoost models predict 24-hour DLR utillzing historical patterns for Open Access scheduling.

Step 6: Output & Action

Calculate accurate sag/clearance and publish available capacity.

Economic & Technical Impact

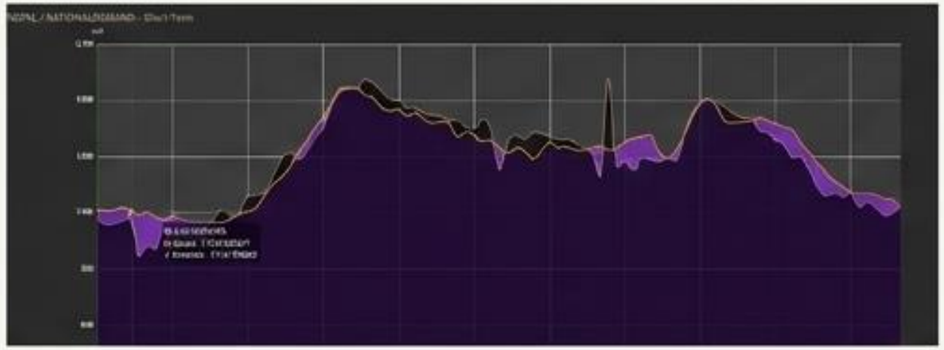
Accuracy: 10-15% improvement in line rating calculations.

Capacity: ~+230 MVA unlocked.

Economic Impact: Rs 80Cr/year potential revenue increase.

15-Minute Scheduling Blocks Drive Precision Economic Dispatch

Predictive Forecasting



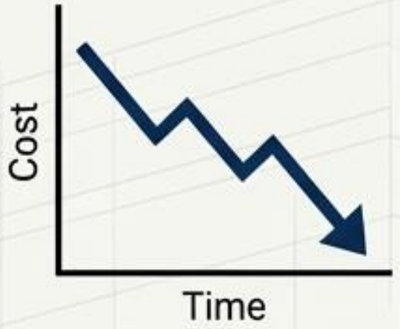
Execution of Day-ahead, Intra-day, and localized renewable forecasting (inflow/solar).

High-Resolution Scheduling

S.No	Date	Time Stamp	Projected Load	Scheduled Load	Load (MW)	Load %ti Met (160)	Remarks
1	29|2.12.24	0000 - 00.15					
2	29|2.12.24	00.15 - 00.30					
3	29|2.12.24	00.30 - 00.45					
4	29|2.12.24	00.45 - 01.00					
5	29|2.12.24	01.00 - 01.15					
6	29|2.12.24	01.15 - 01.30					
7	29|2.12.24	01.45 - 02.00					

Migration to 15-minute and hourly scheduling blocks to handle variable renewable generation precisely.

Economic Dispatch

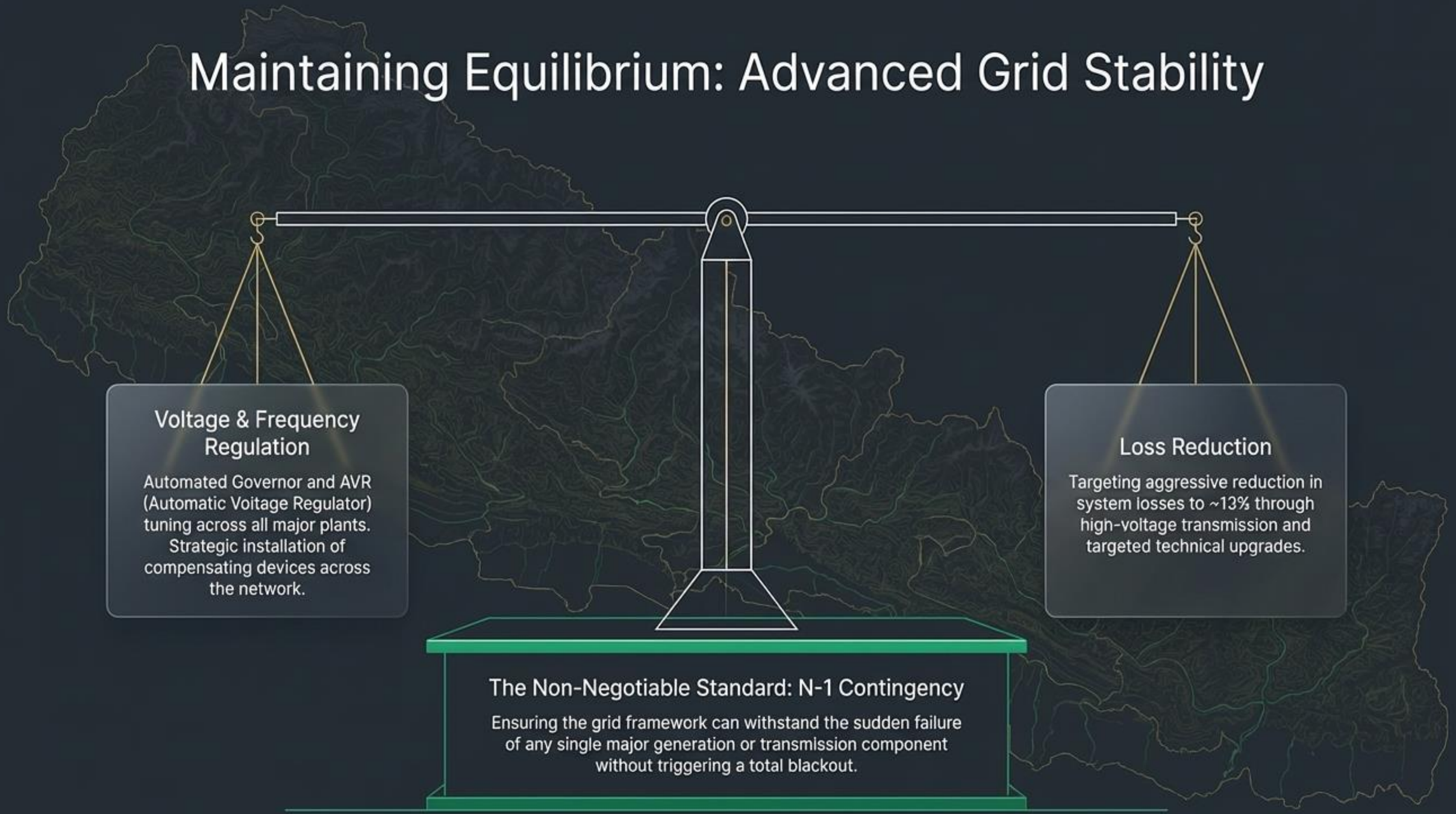


Strict adherence to **Merit Order Dispatch** to minimize system costs, supported by real-time loss reduction metrics.

Interchange Coordination

Active management of Bilateral/IEX exchanges while strictly maintaining drawal limits and deviation control.

Maintaining Equilibrium: Advanced Grid Stability



Voltage & Frequency Regulation

Automated Governor and AVR (Automatic Voltage Regulator) tuning across all major plants. Strategic installation of compensating devices across the network.

Loss Reduction

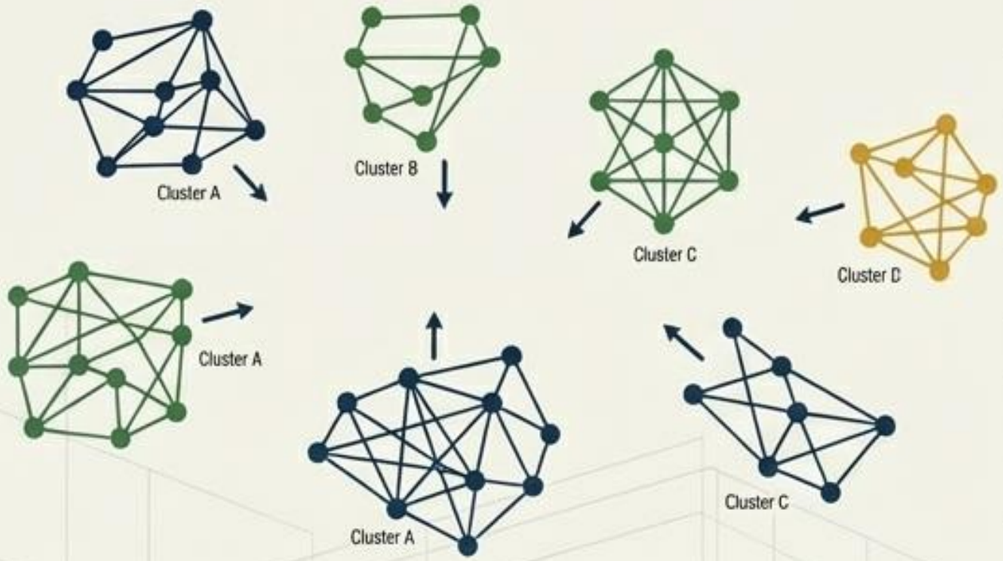
Targeting aggressive reduction in system losses to ~13% through high-voltage transmission and targeted technical upgrades.

The Non-Negotiable Standard: N-1 Contingency

Ensuring the grid framework can withstand the sudden failure of any single major generation or transmission component without triggering a total blackout.

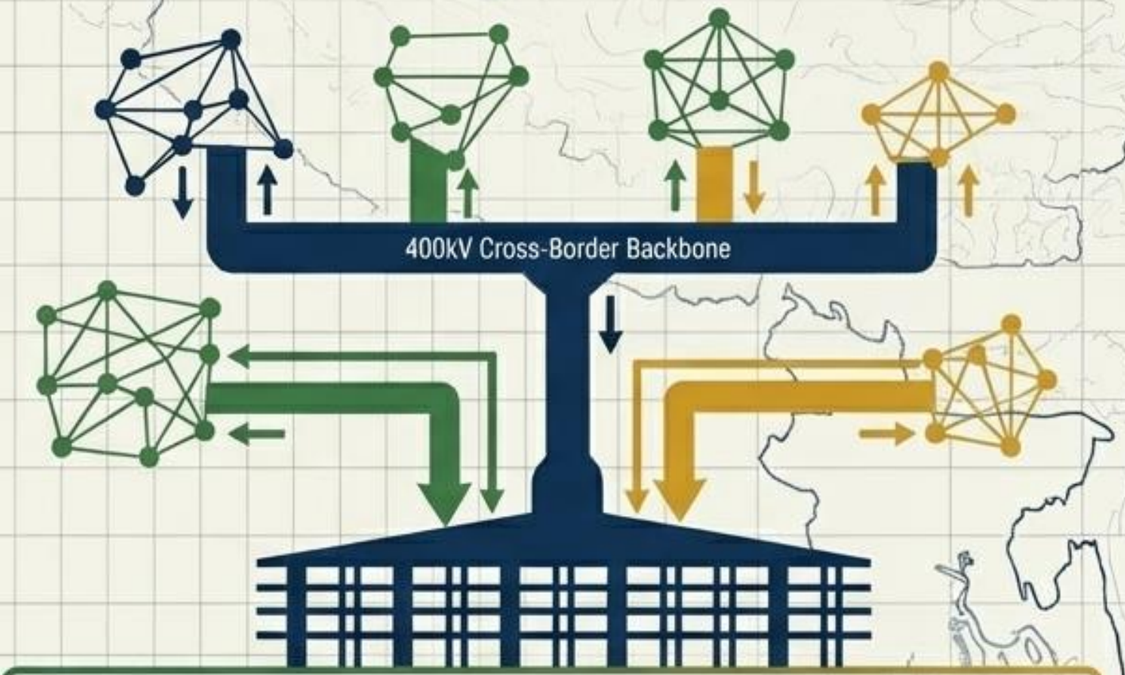
Synchronizing Isolated Networks into a Unified Regional Exporter

The Present State



Operating with high efficiency and minimal interruptions, despite currently managing 5 to 6 distinct, isolated systems within the domestic grid. Transitioning rapidly from manual control to high-degree automation.

The Regional Vision



Standardizing the 400kV cross-border backbone to achieve full interconnection with the gigantic Indian grid. Mastering multiple import-export points and diverse modalities to cement Nepal's position as the keystone of South Asian clean energy.

Concentric Defense Mechanisms: System Protection

Outer Ring: Prevention & Coordination

Proper relay coordination (distance, O/C, differential) with backup protection for critical elements. Teleprotection utilizing PLCC/OPGW infrastructure.

Middle Ring: Containment & Stability

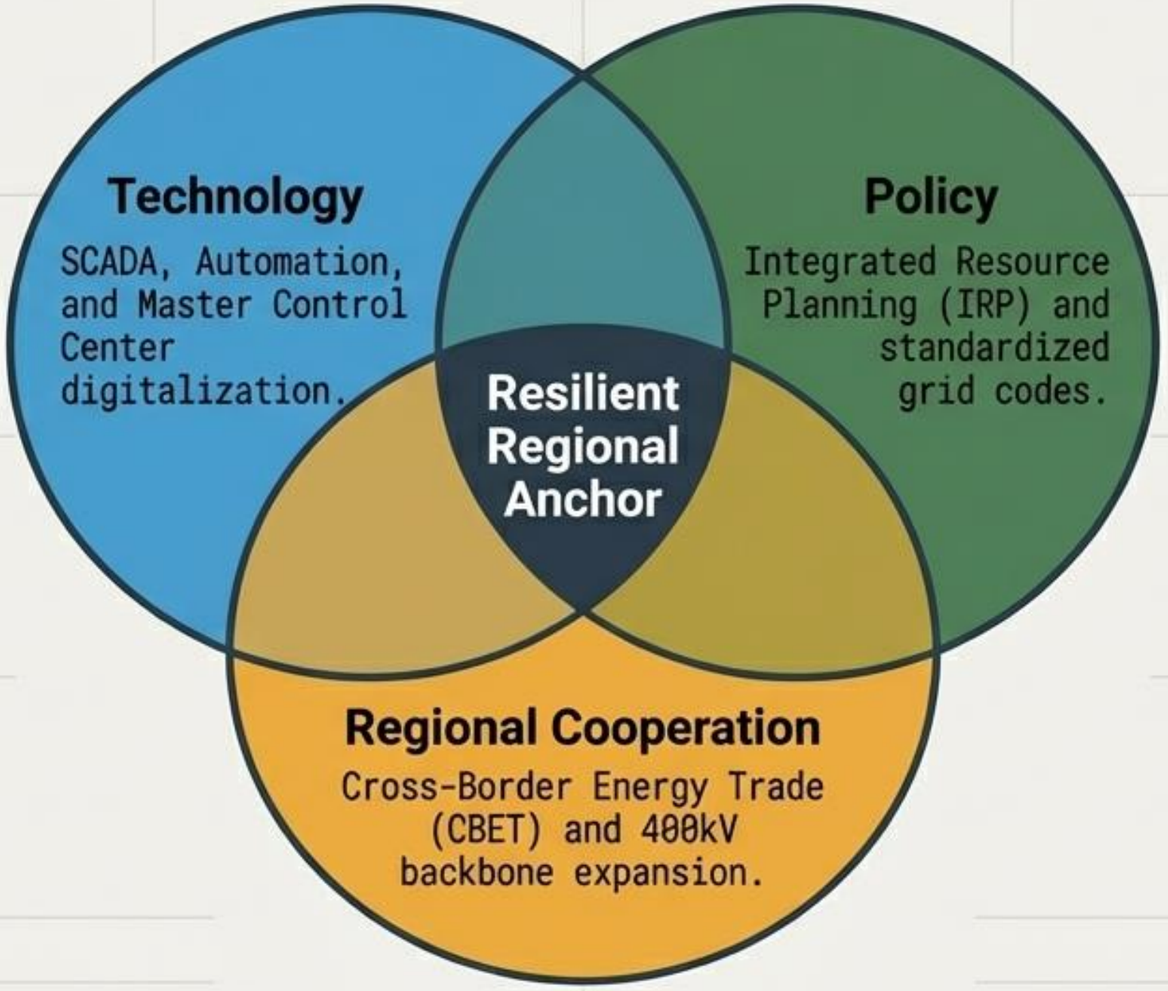
Generator compliance with Fault Ride-Through (LVRT/HVRT) and reactive power support. Fast fault clearance protocols and Special Protection Schemes (SPS) to avoid cascading outages.

Inner Ring: Survival & Restoration

Controlled islanding schemes to prevent total collapse. Predefined Black Start procedures prioritizing critical infrastructure load restoration.

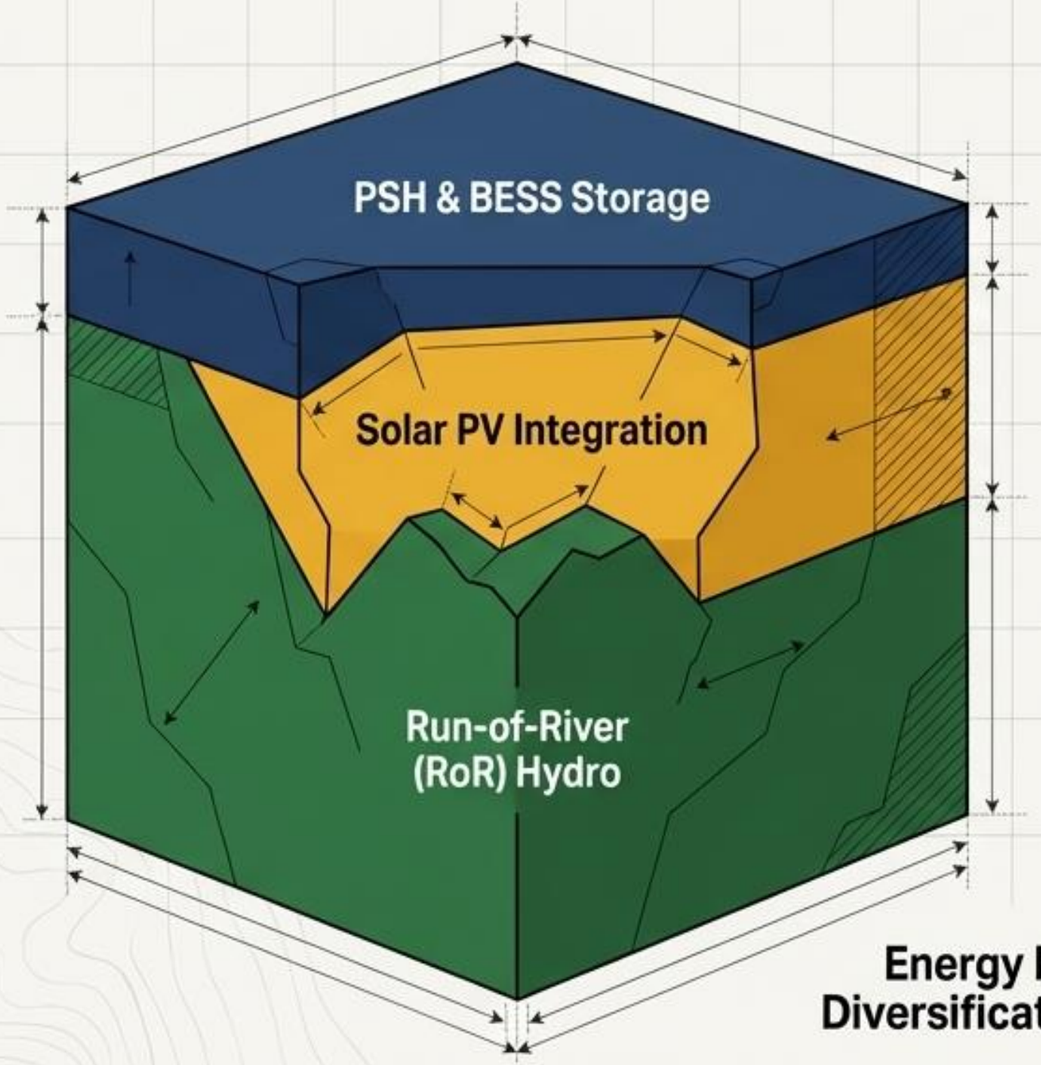
Continuous Foundation: Rigorous periodic testing, relay calibration, and comprehensive protection audits.

The Way Forward: Nepal as a Regional Energy Anchor



Successful grid management is not merely an equipment upgrade; it is the synthesis of smart technology, holistic policy, and unified regional integration.

Diversifying the Energy Mix Mitigates Seasonal Hydro Vulnerability



Energy Mix Diversification

The Baseline (Run-of-River Hydro)

Drives total capacity but remains highly vulnerable to winter low-flow and extreme weather (GLOFs).

The Complement (Solar PV)

Strategically integrated into the Integrated Resource Plan (IRP) to offset seasonal hydro deficits.

The Peak Managers (PSH & BESS)

Prioritization of Pumped Storage Hydro and Battery Energy Storage Systems to ensure rapid-response grid stability during peak demand periods.

Demand-Side Integration

Evolving beyond supply-side limitations to actively shape consumption patterns and enforce energy efficiency.

The Trilateral Trade Corridor

Market Harmonization

Emphasizing the need for standardized competitive bidding and transparent energy trading to scale the quantum of trilateral export.

The Regional Artery: Cross-Border Energy Trade (CBET)

Trilateral Trade Corridor

Leveraging the interconnected India-Nepal-Bangladesh corridor to export the massive monsoon hydro surplus.

Market Harmonization

Standardizing grid codes and enabling transparent, competitive bidding for cross-border energy trading.

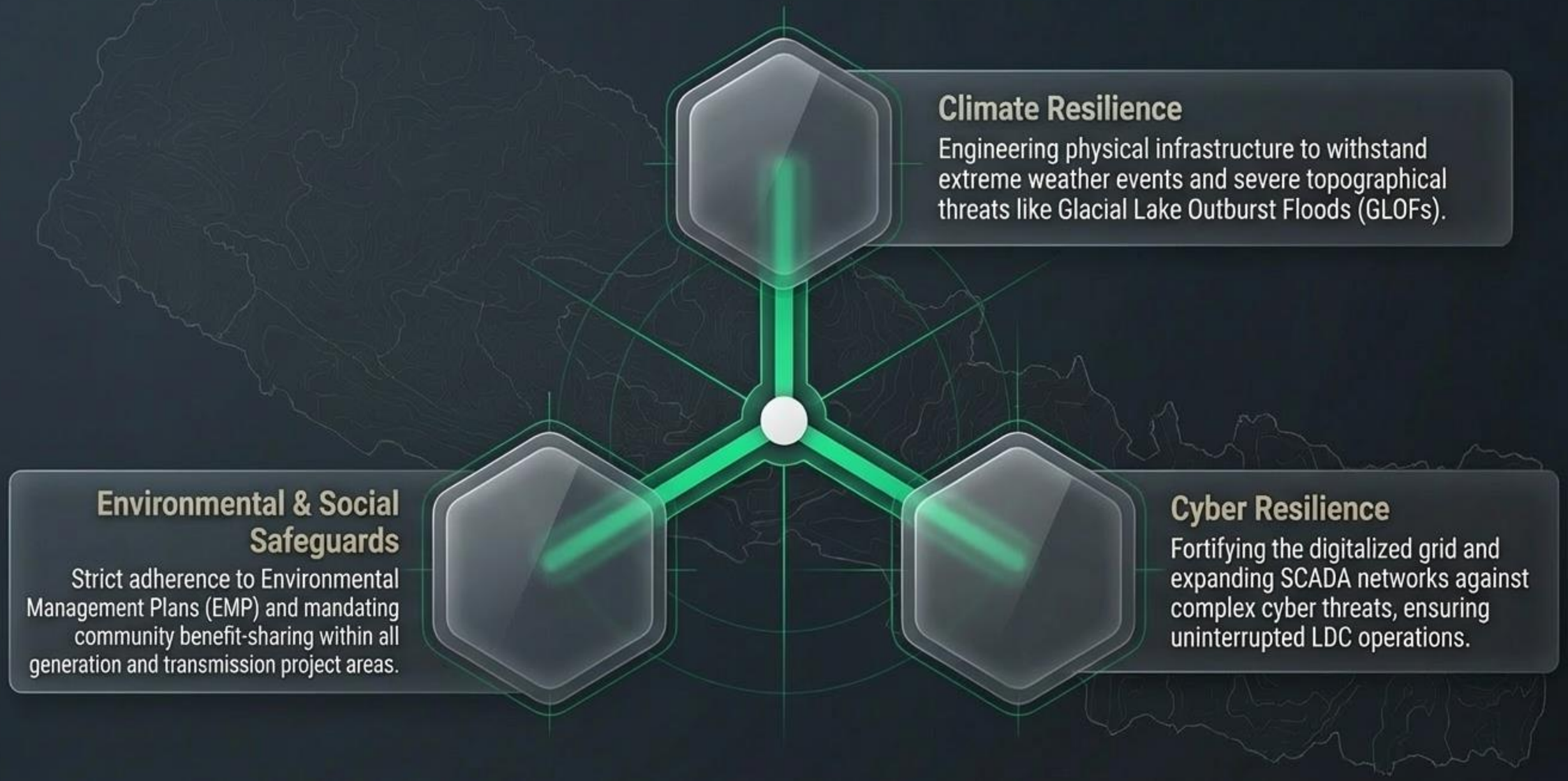
Strategic Export

Expanding the quantum of export to Bangladesh routed through the Indian grid network.

Transmission Backbone

Accelerating the deployment and optimization of the 400kV cross-border transmission backbone to handle massive bilateral exchanges.

The Immune System: Resilience & Sustainability



Climate Resilience

Engineering physical infrastructure to withstand extreme weather events and severe topographical threats like Glacial Lake Outburst Floods (GLOFs).

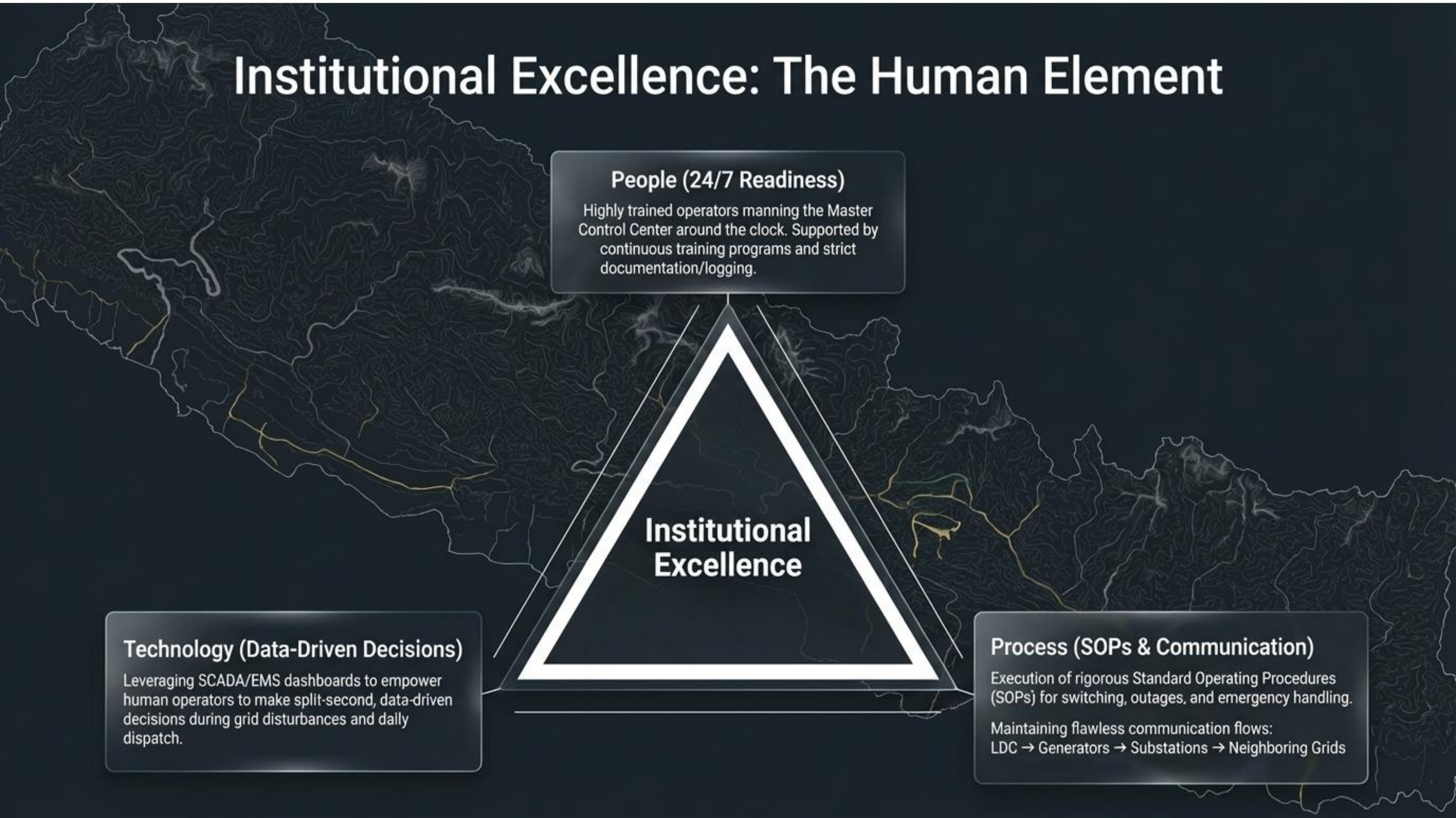
Environmental & Social Safeguards

Strict adherence to Environmental Management Plans (EMP) and mandating community benefit-sharing within all generation and transmission project areas.

Cyber Resilience

Fortifying the digitalized grid and expanding SCADA networks against complex cyber threats, ensuring uninterrupted LDC operations.

Institutional Excellence: The Human Element



People (24/7 Readiness)

Highly trained operators manning the Master Control Center around the clock. Supported by continuous training programs and strict documentation/logging.

Technology (Data-Driven Decisions)

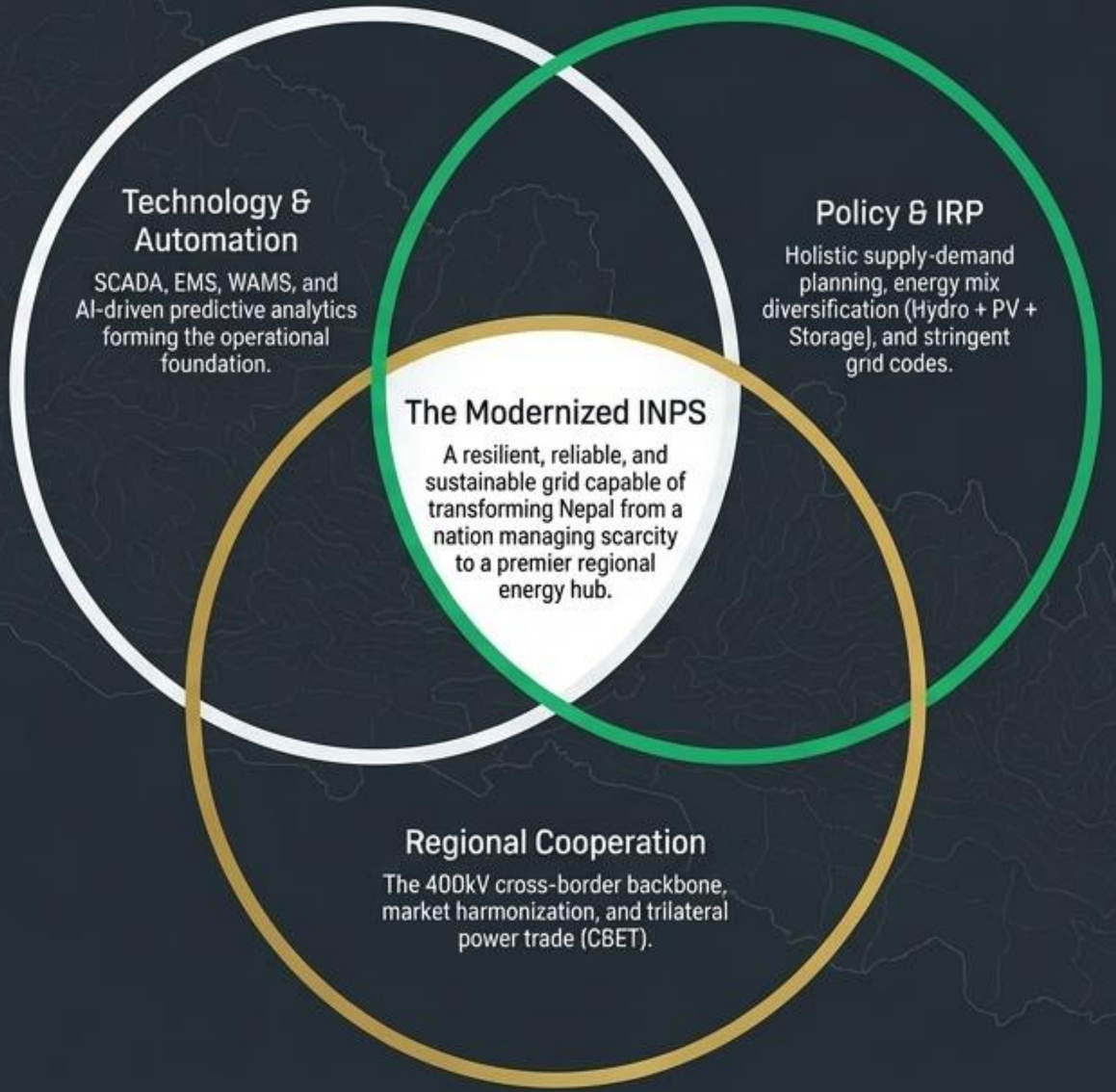
Leveraging SCADA/EMS dashboards to empower human operators to make split-second, data-driven decisions during grid disturbances and dally dispatch.

Process (SOPs & Communication)

Execution of rigorous Standard Operating Procedures (SOPs) for switching, outages, and emergency handling.

Maintaining flawless communication flows:
LDC → Generators → Substations → Neighboring Grids

Synthesis: The Golden Triangle of Grid Strategy



Forging the Future of South Asian Grid Integration

Technology, robust policy, and regional cooperation are the **pillars of our shared energy security.**

Chandan Kumar Ghosh
Director, Power System Operation Department
Chief of Load Dispatch Centre
Nepal Electricity Authority (NEA)

Thank You!

Questions & Discussion

We welcome any questions, comments,
or insights from the viewers.

Chandan Kumar Ghosh
Director, Power System Operation Department (Load Dispatch Center)
Nepal Electricity Authority