Energy & DER Intelligence

AI-Powered Asset Performance & Field Workforce Intelligence for Modern Utilities

Enabling the Future Grid Through AI-Powered Distributed Energy Resource Management.

www.impresa.ai

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Executive Summary

Intelligent load shedding with Schneider Electric Industrial Power Management

The global energy landscape is undergoing a fundamental transformation. The traditional centralized power generation model is evolving into a distributed energy ecosystem driven by renewable generation, battery storage, electric vehicles, and active consumers. Distributed Energy Resources (DERs) such as rooftop solar PV, Battery Energy Storage Systems (BESS), microgrids, and flexible loads are becoming critical components of modern electricity networks

Protection from power outages

While DER adoption provides significant benefits including renewable energy utilization, carbon reduction, and improved grid resilience, it also introduces new operational challenges. Increasing DER penetration creates uncertainty in generation patterns, bidirectional power flows, voltage fluctuations, power quality concerns, and increased complexity in grid planning and operations.

Impresa Energy & DER Intelligence is an AI-powered platform designed to help utilities monitor, predict, and optimize distributed energy resources. By combining data from GIS, AMI, SCADA, DER systems, IoT devices, and enterprise platforms, the solution enables utilities to transition from reactive grid management toward predictive and autonomous energy operations.

Utilities require advanced intelligence platforms capable of providing real-time DER visibility, predictive analytics, optimization capabilities, and autonomous decision support.

This white paper explores the challenges of DER integration, the role of AI in enabling intelligent grid management, and how utilities can leverage Energy & DER Intelligence to build a resilient, flexible, and future-ready energy ecosystem

The Evolution Toward a Distributed Energy Future

Historically, electricity networks were designed around centralized generation, where large power plants supplied energy through transmission and distribution networks to passive consumers. Power flowed in one direction, and grid planning relied on predictable demand growth and conservative operating assumptions.

The rapid growth of renewable energy, battery storage, and behind-the-meter generation is transforming this model. Consumers are becoming prosumers by generating, storing, and managing their own electricity. Modern feeders now include rooftop solar, battery systems, EV chargers, and flexible loads, creating a more dynamic and bidirectional energy ecosystem.

From One-Way Delivery to a Two-Way Energy Network

Traditional Grid Model

- One-way power flow from generation to consumers
- Centralized generation and dispatch
- Passive customers with predictable demand
- Planning based on peak demand forecasts

Future Distributed Energy Model

- Bidirectional power flow between grid, DERs, and prosumers
- Distributed generation and flexible resources
- Active consumers generating and managing energy
- Scenario-based planning using advanced analytics

Modern distribution networks now include

- Rooftop solar PV systems
- Battery Energy Storage Systems (BESS)
- Smart appliances and flexible loads
- Community and campus microgrids
- EV charging infrastructure

Key Drivers Accelerating DER Adoption

Falling technology costs: Lower costs of solar, inverters, and battery storage are accelerating DER deployment.

Electrification growth: EV adoption and electric heating are increasing demand while creating flexible energy resources.

Policy and market evolution: New tariffs, market participation models, and DER integration policies are enabling new value streams.

Grid resilience needs: Extreme weather events are driving adoption of microgrids and local energy solutions.

Sustainability goals: Corporate and government renewable targets are increasing investment in distributed energy resources

This transition requires utilities to move beyond traditional monitoring systems. Future grid management requires continuous data integration, real-time analytics, renewable forecasting, simulation capabilities, and intelligent decision support.

Challenges of Distributed Energy Resource Integration

DER growth is outpacing the operational tools most utilities use to plan and manage their networks. The challenges below are interconnected and addressing one area in isolation, such as improving forecasting without improving visibility, delivers limited operational value.

Limited DER Visibility

The rapid adoption of distributed energy resources has transformed traditional distribution networks into dynamic energy ecosystems. However, many utilities lack comprehensive visibility into DER assets connected across their networks. Since DERs are distributed across customer locations, maintaining accurate asset information and understanding their grid impact remains challenging

Renewable Generation Uncertainty

Renewable generation is highly dependent on environmental conditions, making its output variable and difficult to predict. Unlike conventional power sources, solar PV generation changes continuously based on external factors, creating challenges for grid balancing and operational planning.

Solar PV output varies due to:

Cloud movement

Rapid changes in solar irradiance can cause sudden fluctuations in generation output.

Weather conditions:

Temperature, humidity, and atmospheric conditions influence renewable generation performance.

Seasonal variations:

Changes in solar position and daylight duration impact energy production patterns.

Time-of-day variations:

Solar generation follows daily cycles, creating differences between peak generation and peak demand periods

Key challenges include

Unknown or unregistered DER installations: Rooftop solar PV, behind-the-meter batteries, and flexible resources may not be fully captured in utility databases.

Incomplete DER asset information: Missing details such as capacity, location, technology type, and operational characteristics limit accurate impact assessment.

Lack of real-time generation monitoring: Limited visibility into DER output, export patterns, and operational status affects grid management

Limited understanding of prosumer behaviour: Changing generation and consumption patterns create uncertainty in forecasting and planning

Without accurate DER visibility, utilities face challenges in network planning, renewable integration, voltage management, and operational risk mitigation. AI-powered DER intelligence integrates data from GIS, AMI, SCADA, IoT, and DER systems to provide unified asset visibility and enable proactive grid management

Grid Stability and Power Quality Issues

High DER penetration introduces technical challenges that were largely absent in traditional one-way distribution networks. These impacts are especially significant in rural and suburban feeders with long conductor runs, where voltage regulation systems were originally designed for conventional load growth rather than dynamic generation patterns and reverse power flows

Voltage Issues

High solar generation during low-demand periods can create voltage management challenges:

- Overvoltage conditions during high solar export
- Rapid voltage fluctuations due to intermittent cloud coverage across PV clusters
- Increased equipment stress on tap changers and voltage regulators

Reverse Power Flow

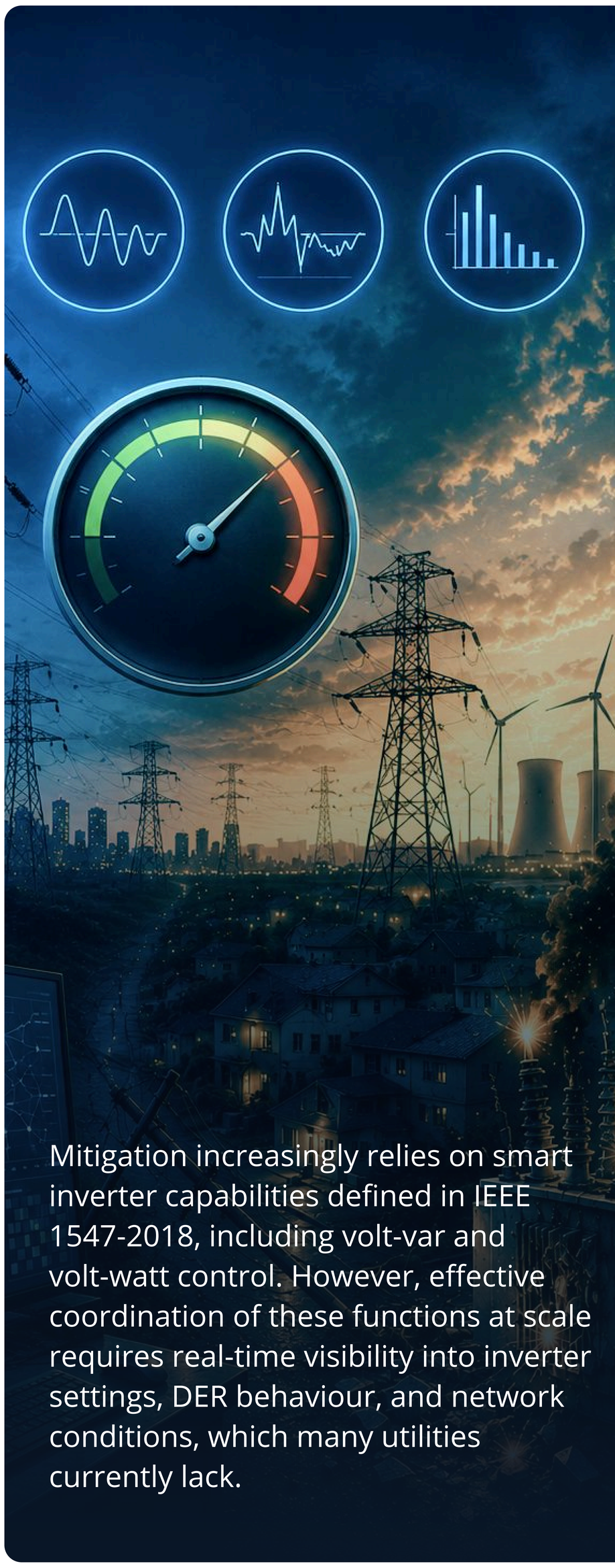
Traditional distribution networks were designed for power flow from substations to consumers. Increasing DER adoption introduces bidirectional power flows, resulting in:

- DER generation pushing excess power back toward substations
- Protection coordination challenges due to changing flow directions
- Metering and monitoring challenges in identifying actual power flow conditions

Power Quality Impact

DER integration can influence power quality due to inverter based generation and variable operating conditions:

- Harmonic distortion (THD) caused by inverter switching
- Voltage imbalance due to uneven DER deployment across phases
- Frequency stability challenges caused by generation variability



Mitigation increasingly relies on smart inverter capabilities defined in IEEE 1547-2018, including volt-var and volt-watt control. However, effective coordination of these functions at scale requires real-time visibility into inverter settings, DER behaviour, and network conditions, which many utilities currently lack.

Battery Storage Management Challenges

Battery Energy Storage Systems (BESS) provide critical flexibility for managing renewable variability, supporting grid reliability, and optimizing energy usage. However, effective battery operation requires intelligent management strategies to balance performance, asset health, and economic value

AI-Powered Energy & DER Intelligence Approach

Artificial Intelligence enables utilities to transform fragmented operational data into a unified intelligence layer for monitoring, prediction, and optimization. Impresa Energy & DER Intelligence integrates with existing systems such as SCADA, ADMS, and GIS to enhance their capabilities without replacing existing investments.

The platform follows a continuous closed-loop model:

Data Sources

Function

Collect operational and enterprise data

Key Components

AMI, GIS, SCADA, DER systems, IoT, weather platforms

AI Analytics Layer

Function

Generate insights, forecasts, and recommendations

Key Components

Machine learning, forecasting, optimization, digital twins

Intelligent Outcomes

Function

Enable smarter grid decisions

Key Components

Predictive insights, recommendations, and grid optimization

This approach enables utilities to progressively move from DER visibility and forecasting toward advanced optimization and autonomous grid management

Key challenges include

Optimal charging and discharging decisions

Determining the right charging and dispatch schedules based on renewable availability, grid conditions, and energy demand patterns.

Battery degradation management

Managing charging cycles, operating conditions, and usage patterns to minimize battery aging and extend asset life.

Maintaining optimal energy levels to ensure battery availability for grid support and future requirements

Revenue optimization

Maximizing economic benefits through applications such as peak demand management, energy arbitrage, and grid flexibility services

AI-powered battery intelligence enables predictive health monitoring, optimized dispatch strategies, and data-driven decision-making to improve battery performance, reliability, and lifecycle value.

Core Capabilities of Impresa.ai Energy & DER Intelligence

DER Situational Awareness

Effective DER management begins with comprehensive visibility into distributed energy assets across the network. Impresa.ai Energy & DER Intelligence creates a unified view of DER deployment, operational status, and grid impact by integrating data from multiple utility systems.

Renewable Forecasting Intelligence

Renewable generation is inherently variable due to changing environmental conditions, making accurate forecasting essential for reliable grid operations. AI-based forecasting enables utilities to predict renewable generation patterns, optimize energy planning, and proactively manage grid flexibility requirements.

The solution analyses

Historical generation patterns

Identifies past renewable output trends, seasonal variations, and generation behaviour.

Weather conditions:

Incorporates weather forecasts, cloud movement, temperature, and environmental factors affecting renewable production

Solar radiation data:

Evaluates solar irradiance patterns to improve PV generation prediction accuracy

Asset performance trends:

Monitors DER performance characteristics to identify deviations and improve forecast reliability

AI-powered renewable forecasting allows utilities to transition from reactive grid management toward predictive and flexible energy operations

Capabilities include

GIS-based DER mapping:

Visualize DER assets across feeders, transformers, and network locations.

Solar PV identification:

Detect and track rooftop solar installations and generation capacity

DER asset inventory:

Maintain accurate information on DER type, capacity, location, and operational characteristics.

Prosumer profiling:

Analyse customer generation and consumption behaviour to understand energy patterns

DER performance monitoring

Continuously evaluate DER performance and its impact on network operations.

Utilities gain complete awareness of DER penetration levels, asset behaviour, and potential operational risks, enabling data-driven planning and proactive grid management

DER Hosting Capacity Analysis

DER Hosting Capacity Analysis determines the maximum amount of additional distributed energy generation that can be safely integrated into the distribution network while maintaining grid reliability, power quality, and operational limits. It enables utilities to evaluate the impact of new DER connections before deployment and make data-driven decisions for renewable integration.

Microgrid Intelligence

Microgrids are becoming critical solutions for enhancing energy resilience, integrating renewable resources, and enabling localized energy management. Impresa.ai Energy & DER Intelligence provides advanced analytics to monitor, simulate, and optimize microgrid operations

Capabilities include

- Grid-connected operation monitoring
- Islanding scenario analysis
- Renewable generation and storage
- coordination
- Energy optimization and operational
- recommendations

Applications include

- Industrial microgrids
- Campus microgrids
- Community energy systems

The platform helps utilities optimize distributed resources, improve resilience, and enable future autonomous energy networks

The analytics evaluate

Voltage constraints and voltage rise risks: Assess the impact of additional DER generation on feeder voltage profiles and identify potential voltage violations

Feeder and transformer thermal loading: Analyse equipment loading conditions to ensure network assets operate within safe capacity limits.

Reverse power flow conditions: Evaluate the impact of excess DER generation flowing back toward substations and upstream networks

Protection system limitations: Identify potential challenges related to protection coordination and fault current variations.

Network capacity constraints: Determine available grid capacity and identify infrastructure requirements for future DER growth

By combining grid analytics, DER visibility, and simulation capabilities, utilities can accelerate DER connection assessments, optimize infrastructure investments, reduce integration risks, and enable higher renewable adoption while maintaining grid stability and power quality

Battery Energy Storage Intelligence

Battery Energy Storage Systems (BESS) play a key role in managing renewable variability, improving grid flexibility, and supporting energy optimization. Impresa.ai Energy & DER Intelligence provides AI-driven battery analytics to optimize performance and lifecycle value.

Capabilities include

- Battery performance monitoring
- State-of-charge (SoC) analytics
- Battery health and degradation prediction
- Charging optimization
- Intelligent dispatch recommendations

AI models continuously analyse battery behavior to improve operational efficiency, extend asset life, and maximize storage utilization.

Digital Twin and Simulation-Based Grid Optimization

Digital twins provide continuously updated virtual representations of physical energy networks by combining network topology, asset characteristics, live telemetry, and power-flow simulation capabilities. Unlike traditional planning studies that rely on periodic analysis and static assumptions, the Impresa.ai digital twin continuously reflects network conditions, enabling utilities to move from reactive problem-solving to proactive, scenario-based grid planning.

What Utilities Can Simulate

Scenario Inputs

- Proposed DER deployments including solar PV and battery storage at different locations and capacities
- Weather and load condition scenarios to evaluate grid behaviour under varying conditions
- Microgrid formation, islanding, and operational scenarios
- Future network expansion and planning scenarios

Simulation Outputs

- Voltage impact across the affected feeder segment
- Transformer and conductor loading under peak conditions
- Thermal, protection, and reverse power flow constraints
- Required mitigation actions, ranked by cost and effectiveness

This capability enables proactive grid planning instead of reactive problem solving. Engineers can evaluate the network impact of proposed DER interconnections, storage deployments, or microgrid designs before implementation, reducing the risk of constraint violations after deployment.

Illustrative Scenario: Evaluating a New Rooftop Solar Cluster

Consider a utility planning team evaluating interconnection requests for multiple rooftop solar installations on a residential feeder. Using the digital twin, engineers can simulate DER impacts through a structured evaluation process:

Generative AI for Utility Energy Operations

Generative AI introduces a new interaction model between utilities and grid intelligence platforms — allowing operators, planners, and engineers to query complex operational data using natural language rather than navigating multiple dashboards or writing custom queries.

Impresa LM

Impresa LM is a domain-grounded conversational assistant purpose-built for energy and DER operations. Rather than relying on general-purpose knowledge, it retrieves and reasons over the utility's own live network, asset, and forecast data, and every response is traceable back to the underlying data sources it drew from Operators can ask direct operational questions, for example:

"Which feeders have high solar export risk today?"

The AI assistant provides a structured, decision-ready response:

- Impacted locations, identified down to the feeder and transformer level
- Risk severity, ranked and prioritized against defined operating thresholds
- Historical trends, showing whether the condition is new, recurring, or worsening
- Recommended actions, drawn from the same optimisation engine used in digital twin simulations

Capabilities include

Baseline Assessment

The digital twin integrates feeder topology, existing DER assets, and historical load and generation data to establish the current network condition

Scenario Simulation

Proposed PV capacity is added to the model and evaluated under different operating conditions, including high-generation and low-load scenarios

Constraint Analysis

The platform assesses voltage profiles, transformer loading, and reverse power flow risks to identify potential network limitations

Mitigation Recommendations

AI-driven analytics recommend and prioritise solutions such as smart inverter settings, phase balancing, or infrastructure upgrades based on cost and effectiveness

Decision Support

Engineers use these insights to make informed interconnection decisions, while the digital twin continuously updates with new information for future planning studies

The result is a repeatable and auditable planning approach that replaces manual analysis with scalable simulation-based decision support, enabling utilities to manage DER growth across large distribution networks.

Additional Example Queries

Operator Question	*What Impresa LM Returns*
"Show me batteries below 90% state of health	Ranked list of assets, degradation trend, and recommended maintenance or replacement priority
Summarize today's curtailment events	Feeder-level curtailment volumes, root cause, and comparison to the prior week
What happens if we add 2 MW of solar at substation 14?"	A digital-twin scenario run with voltage, loading, and mitigation results
Draft an operations report for this week's DER performance."	An automatically generated summary report ready for supervisor re

Business Benefits for Utilities

Improved Grid Visibility

- Complete DER awareness
- Better asset understanding
- Improved planning decisions

Improved Reliability

- Early risk identification
- Predictive grid management
- Faster response

Enhanced Renewable Utilization

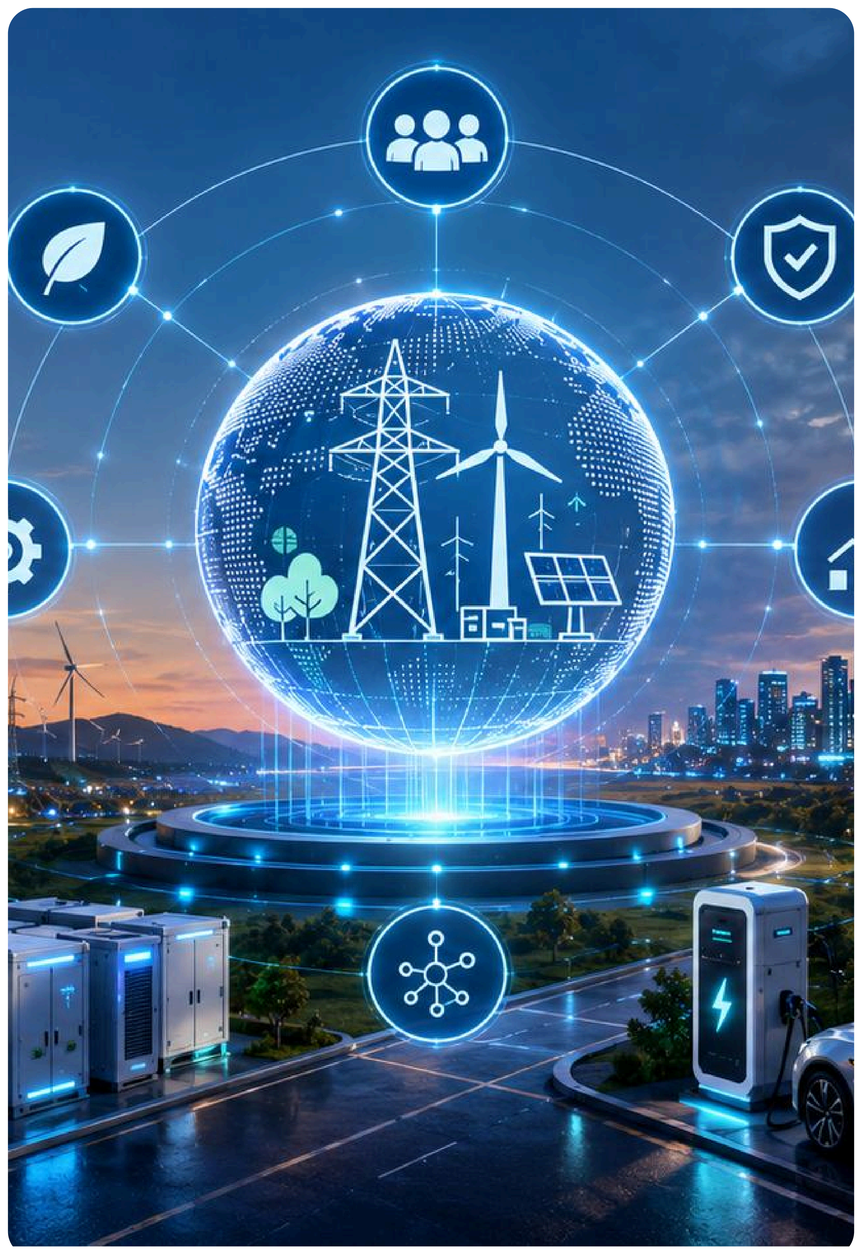
- Reduced curtailment
- Better renewable forecasting
- Increased clean energy adoption

Operational Efficiency

- Automated analytics
- Reduced manual analysis
- Faster decision-making

Conclusion

The transition toward renewable and distributed energy requires utilities to transform traditional grid management approaches and adopt more intelligent, flexible, and data-driven operating models. The increasing adoption of DERs creates significant opportunities for clean energy integration while introducing new challenges related to visibility, variability, grid stability, and operational complexity.



Utilities that leverage DER intelligence can improve renewable utilization, enhance grid reliability, optimize asset performance, and enable more effective planning and decision-making.

Impresa Energy & DER Intelligence provides the foundation for the future autonomous grid by combining artificial intelligence, advanced analytics, forecasting, digital twin simulation, and optimization capabilities into a unified intelligence platform.

By transitioning from reactive operations to predictive and proactive energy management, utilities can build a cleaner, smarter, and more resilient energy ecosystem capable of supporting the evolving needs of the future grid.

About Impresa AI

Impresa AI delivers **AI-powered** intelligence platforms for modern utilities, enabling smarter operations across grid intelligence, asset management, customer analytics, energy optimisation, and distributed energy management.

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Smart.Simple.Innovative

Learn More
To schedule a live demo or find out more information, visit **www.Impresa.ai** or call **+1-281-794-5700**