inavitas

CASE STUDY

Smart Automation in Renewable Energy: Transforming İzdemir Solar into a Next-Gen Power Plant

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From Compliance to Intelligence: İzdemir's Automation Leap

To meet TEİAŞ's evolving grid compliance requirements, the 165 MW İzdemir Solar Power Plant partnered with inavitas to deploy a full automation system, without modifying core hardware.

The solution integrated high-speed RTU/PLC controllers, a dual-protocol communication framework (Modbus + IEC 104), a centralized SCADA platform, and seamlessly interfaced with the plant's inverter infrastructure, including Huawei 330 KTL string inverter units.

This enabled:

- Real-time control of active/reactive power and frequency
- Full TEİAŞ compliance without manual intervention
- Built-in redundancy for uninterrupted operation
- Scalable architecture for future growth

İzdemir now operates as a smart, fully grid-responsive solar plant, setting a benchmark for compliance, reliability, and automation in utility-scale renewable energy.

İzdemir Solar Now Runs Smarter With Zero Hardware Changes!

A Solar System Meets a Smarter Grid

As utility-scale solar grows across global energy markets, grid operators are raising the bar. Plants must now deliver controllable, stable, and intelligent power on demand.

In Türkiye, these expectations are enforced by TEİAŞ, the national grid operator. Their regulations require dynamic active power curtailment, voltage-reactive compensation, and ultra-fast frequency control, often with sub-second precision.

Most solar plants are not ready for this. Legacy infrastructure and manual operations fall short, leading to energy curtailment, grid code violations, reactive power penalties, and costly inefficiencies that threaten both profits and grid stability.

inavitas solves this by providing a next-generation energy automation platform that upgrades traditional solar plants into fully intelligent, grid-responsive systems.

By integrating real-time monitoring, advanced control algorithms, and standardized communication protocols, inavitas helps operators meet all regulatory demands, improve reliability, and unlock new levels of operational efficiency.

This white paper highlights the İzdemir Solar Power Plant as a proof point. With 165 megawatts of capacity, The plant operates with over 520 inverters, including Huawei 330 KTL string inverter units, forming a highly distributed and flexible generation architecture, İzdemir shows how automation can drive measurable and scalable gains in performance, safety, and compliance. All of this was achieved without replacing existing hardware.

165 MW
520+ inverters
Zero hardware overhaul
100% grid compliance

TEİAŞ is Türkiye's national grid operator, enforcing rules on power, voltage, and frequency to maintain stability and reliability.

Why Manual Systems Couldn't Keep Up

Operating a utility-scale solar facility as İzdemir Solar requires precise, real-time coordination across distributed systems, particularly under evolving regulatory requirements. Before automation was implemented, the plant faced several critical limitations that impacted both operational efficiency and regulatory compliance.

1. Limited Active Power Control During Curtailment

In periods of low grid demand or scheduled curtailment, İzdemir lacked the ability to dynamically adjust active power in real time. This often led to either over-generation, risking grid imbalance, or overly conservative manual reductions that reduced energy output and efficiency.

2. Manual and Static Reactive Power Regulation

Voltage control relied on manual interventions or static settings, which made the plant susceptible to voltage deviations, a key compliance metric monitored by TEİAŞ. Without automated reactive power adjustment or busbar voltage tracking, maintaining consistent voltage regulation was challenging.

3. No Real-Time Frequency Response Capability

Fluctuations in grid frequency require immediate response from generation assets. İzdemir's control infrastructure could not automatically adapt output to match real-time frequency variations. This made it difficult to meet TEİAŞ requirements, especially above the 50.2 Hz threshold where fast curtailment is mandated.

4. Decentralized Control Across Distributed Systems

Reactive power settings and operational controls were manually managed across more than 500 inverters and nearly 60 data loggers. This decentralized structure introduced latency, increased the risk of operational inconsistency, and limited the plant's ability to respond quickly to changing grid conditions or grid events.

The Automation Architecture

To address the operational and regulatory challenges at İzdemir Solar Power Plant, inavitas deployed a targeted automation architecture focused on high-speed control, centralized coordination, and full TEİAŞ compliance. The system combines real-time control algorithms with a resilient communication layer, allowing the plant to dynamically manage active power, reactive power, and frequency behavior in response to live grid conditions.

Automation runs directly on RTU/PLC controllers and integrates seamlessly with the plant's network of over 500 inverters, including Huawei 330 KTL string inverter units, and dozens of data loggers. This creates a unified, high-resolution control environment capable of fast, site-wide synchronization, critical for real-time compliance and grid stability.

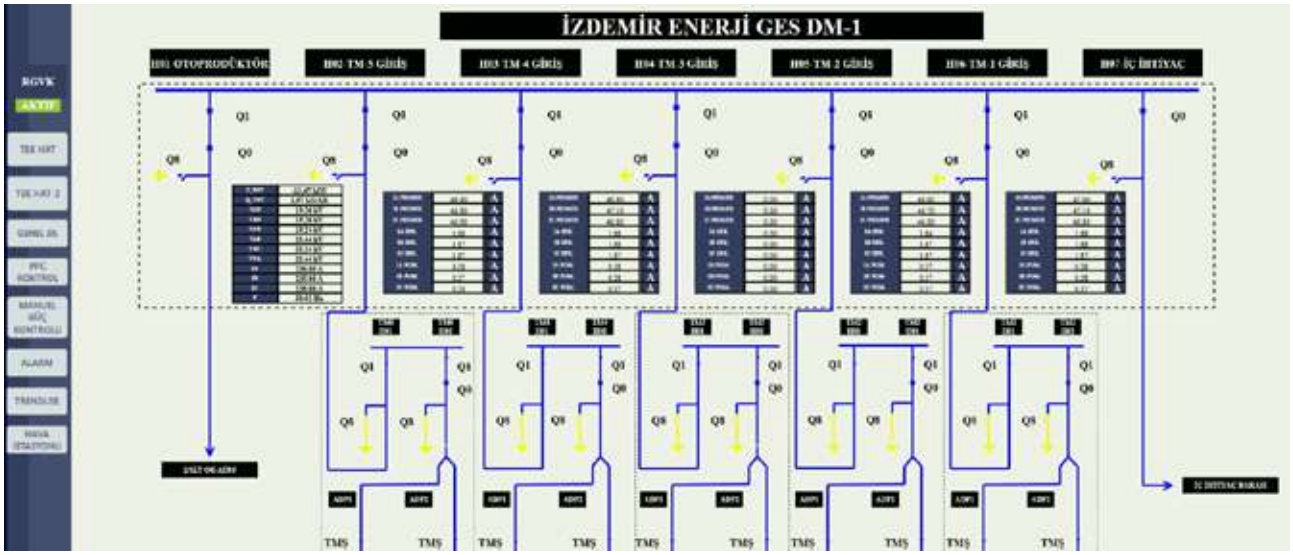
1. Dynamic Active Power Limitation

The Dynamic Active Power Limit Algorithm operates in a closed-loop cycle, recalculating power setpoints every 100 milliseconds. It processes real-time data from inverters, grid reference signals, and plant conditions to optimize output within regulatory limits. This function ensures that the plant stays compliant with TEİAŞ's active power curtailment rules while maintaining operational efficiency.

This high-frequency execution allows the system to:

- Rapidly respond to irradiance changes
- Instantly act on curtailment commands
- Keep all inverters synchronized under changing grid conditions

The result is reliable, compliant power output, even during grid instability or demand fluctuations.



System topology view of İzdemir GES DM-1: Real-time control across distributed inverters and transformers.

2. Reactive Power Control Modes

At İzdemir, reactive power compensation is automated through two real-time control modes, selected dynamically based on grid conditions and regulatory voltage setpoints.

a) Fixed Reactive Power Control

In stable grid conditions, the system uses a fixed setpoint for reactive power output, aligned with the plant's immediate support requirements. This value is distributed across all dataloggers to ensure consistent behavior from all inverters.

b) Q(V) Voltage-Responsive Mode

When voltage regulation is required, the system switches to dynamic Q(V) control. It continuously monitors busbar voltage and compares it to the TEİAŞ-defined target.

If voltage deviates by more than 10% from the reference, the algorithm automatically adjusts reactive output, delivering either inductive or capacitive support depending on the deviation. Commands are sent to all dataloggers every 100 milliseconds, ensuring fast, plant-wide voltage stabilization.
The plant meets compliance thresholds while minimizing manual intervention, even during volatile grid scenarios.

3. Automated Frequency Support

To comply with TEİAŞ's frequency control rules, İzdemir must reduce active power output when frequency exceeds 50.2 Hz. inavitas developed a fully automated frequency response algorithm that dynamically adjusts output in real time.

Key capabilities of the frequency control function:

- Begins curtailment as frequency exceeds 50.2 Hz
- Follows TEİAŞ-specified reduction ratios for progressive curtailment
- Shuts generation down entirely at 51.5 Hz
- Executes all control actions autonomously using real-time frequency data

İzdemir supports grid stability without operator input, even during critical frequency events.

Data as the New Power Line: Building a Real-Time System

A high-performing solar plant depends on fast, reliable data flow across every layer of operation. At İzdemir, inavitas implemented a scalable communication infrastructure that enables real-time coordination between field devices, controllers, and the SCADA system, all while ensuring compliance with grid-level requirements. By combining standardized protocols and robust architecture, the system supports secure and synchronized data exchange from inverter-level telemetry to national grid communication.

1. Local Communication: Modbus Protocol

Within the plant, Modbus is the core protocol used for internal data and control communication. It connects inverters, RTU/PLC controllers, and dataloggers across the site through a two-way messaging system.

- Each device operates as both a client and a server, enabling:
- Continuous real-time data acquisition
- Fast and consistent command distribution
- Individual device status tracking
- Seamless compatibility with third-party hardware

This standardized approach ensures interoperability across diverse hardware components, minimizes integration complexity, and maintains high reliability for site-wide data responsiveness.maintaining high data reliability and responsiveness.

The dashboard shows İzdemir's PPC in action, aggregating data across systems, monitoring power trends, and enabling centralized operator oversight through a single interface.

2. Grid-Level Communication: IEC 60870-5-104 Protocol (IEC 104)

To meet national grid requirements, İzdemir Solar communicates directly with TEİAŞ using the IEC 104 protocol. This enables secure, standardized data exchange with the national grid control center, essential for regulatory compliance and real-time grid coordination. IEC 104 transmits all key operational signals, including:

- Active and reactive power measurements
- Voltage and frequency data
- Alarm notifications and fault signals
- Remote control commands and acknowledgements

To meet national grid requirements, SCADA/PPC system communicates directly with TEİAŞ RTU on the site using the IEC 104 protocol. TEİAŞ RTU communicates with TEİAŞ via IEC 101 protocol. This enables secure, standardized data exchange with TEİAŞ RTU on the plant, essential for regulatory compliance and real-time grid coordination.

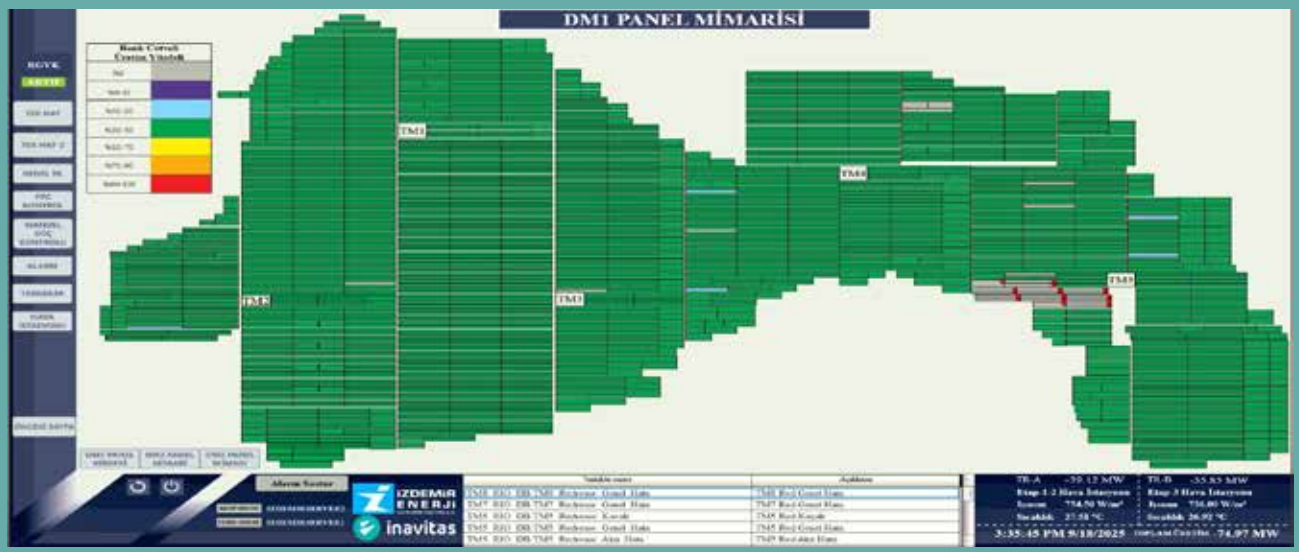
3. Unified Infrastructure for Local and Remote Control

The İzdemir Solar Plant uses a dual-protocol control strategy:

- Modbus handles internal communication between field devices, inverters, and controllers
- IEC 104 manages communication with the TSO RTU

This architecture delivers a seamless control environment that connects local automation with remote supervisory systems. Key benefits of this unified setup:

- Full operational visibility, from inverter-level data to grid-level control
- Synchronized decision-making between plant systems and TEİAŞ operators
- High system reliability with protocol redundancy and fault tolerance
- Future-ready design for hybrid integration, system scaling, or DER participation



DMI panel architecture visualizing real-time system communication and status across İzdemir's distributed infrastructure.

SCADA at the Core: Real-Time Intelligence Across the Grid

The İzdemir Solar Power Plant uses a centralized SCADA system to monitor, control, and optimize performance across all operational layers, from inverters to the national grid. This platform serves as the plant's single point of visibility and control, enabling operators to manage power output, respond to events, and maintain regulatory compliance in real time.

Integrated with both internal (Modbus) and external (IEC 104) communication protocols, the SCADA system ensures seamless interaction between local field devices and TEİAŞ grid systems. This dual-protocol integration supports synchronized operation across plant and grid-level control environments.

SCADA System Capabilities

Real-Time Monitoring

- Displays active and reactive power output across the site
- Continuously tracks inverter performance and grid signals
- Provides a unified, real-time operational view for faster decision-making

Alarm and Event Management

- Automatically detects, classifies, and prioritizes system faults
- Issues real-time alerts for faster operator response
- Minimizes unplanned downtime and improves plant availability

Historical Data and Compliance Reporting

- Logs operational performance data for diagnostics and audits
- Supports TEİAŞ compliance documentation
- Enables long-term analysis for preventive maintenance and optimization

Control and Command Interface

- Allows manual or automated command execution
- Features an intuitive and secure Human-Machine Interface (HMI)
- Supports both local and remote operations with full control flexibility

By consolidating all monitoring, control, and compliance functions under a single SCADA interface, İzdemir achieves a fully transparent and highly coordinated plant environment. This architecture not only improves operational resilience but also future-proofs the plant for grid evolution and hybrid system integration.

Engineering for Zero Downtime

To maintain uninterrupted operation and ensure compliance under all conditions, the İzdemir Solar Power Plant is designed with built-in redundancy across all mission-critical systems. This architecture eliminates single points of failure and provides seamless failover in the event of hardware malfunctions or communication disruptions.

Redundant System Components

Controller Redundancy (RTUs / PLCs):

All plant controllers operate in an active–standby configuration. If the active unit encounters a fault, the standby controller takes over instantly with no loss in functionality. This ensures uninterrupted execution of control algorithms and continuous adherence to grid compliance requirements.

Redundant Communication Infrastructure

The plant's communication network features redundant data paths and switching mechanisms between field devices, the SCADA platform, and the control center. In the event of a partial network failure, critical data and control commands continue to flow without interruption, preserving data integrity, situational awareness, and system responsiveness.

Outcome: Resilient, Always-On Operations

By embedding redundancy at both the control and communication levels, İzdemir achieves a high-availability automation environment. This allows operators to maintain monitoring, control, and compliance, even during unexpected faults or adverse grid conditions.

SCADA interface view showing real-time performance continuity and system redundancy status across İzdemir's control architecture

Operational Intelligence in Action: Tangible Gains from Automation

The automation system implemented at the İzdemir Solar Power Plant delivers proven operational, regulatory, and strategic advantages. Designed to meet TEİAŞ's most demanding requirements, the platform ensures real-time compliance and uninterrupted performance, without reliance on manual intervention.

1. Real-Time Grid Compliance

The system automatically manages:

- Active power curtailment
- Reactive power regulation
- Frequency response

These functions operate continuously in the background, ensuring that İzdemir remains fully compliant with TEİAŞ grid codes at all times.

2. Continuous, Fault-Tolerant Operation

Redundancy is built in at every level:

- Active–standby RTUs/PLCs ensure seamless controller failover
- Dual-path communication networks prevent data loss during outages
- SCADA integration provides full visibility, fast fault detection, and secure remote/manual control

Together, these features guarantee high availability, even during hardware or communication failures.

3. Full Visibility and Data Transparency

With SCADA and real-time telemetry, operators gain:

- Live system insights across all devices and grid signals
- Alarm and event tracking with automated alerts
- Continuous data logging for diagnostics, reporting, and predictive maintenance

This transparency supports regulatory reporting, performance optimization, and early issue detection.

4. Scalable, Future-Ready Architecture

The system's modular design enables:

- Easy expansion for future capacity or hybrid integration
- Support for additional protocols and evolving standards
- Safe, flexible operations under changing energy conditions

Advanced logic functions, such as automated alarms and protective controls, further enhance plant safety, reduce risk for personnel, and extend equipment life.

Overall, İzdemir Solar is now a smart, resilient, and grid-responsive asset, optimized for high performance, low risk, and long-term adaptability.

A Smarter, Safer, and Fully Compliant Plant

The İzdemir Solar Power Plant has been fully transformed into a smart, resilient, and grid-compliant facility through the deployment of inavitas' automation system. By combining real-time control, SCADA-driven oversight, and redundant infrastructure, the plant now operates with precision, continuity, and full TEİAŞ compliance, without manual intervention.

System Highlights

- **Redundant RTUs/PLCs** ensure uninterrupted control execution
- **Real-time SCADA** interface provides full observability and rapid response
- **Dual-protocol communication** with Modbus (local) and IEC 104 (grid)
- **Advanced control algorithms** manage power limitation, reactive support, and frequency stabilization

Performance Outcomes

- **100% compliance** with TEİAŞ regulations across active power, reactive power, and frequency domains
- **Dynamic active power control has increased energy output** by minimizing over-curtailment during grid events.
- **Millisecond-level responsiveness** to grid and environmental changes (100 ms control cycles)
- **High fault resilience** via controller and communication redundancy
- **Scalable architecture** supports future growth, hybrid integration, and evolving grid demands
- **The plant has achieved 100% operational availability** since commissioning, demonstrating the reliability of its automated control and communication architecture.

This automation platform allows İzdemir to consistently deliver stable, optimized output, even under fluctuating grid conditions.

It has reduced operational risk, eliminated manual processes, and positioned the facility as a model for utility-scale renewable automation in Türkiye. İzdemir is now a benchmark for future-ready solar operations, demonstrating how inavitas enables fast, flexible, and compliant energy infrastructure at scale.

What İzdemir Teaches Us?

As solar power scales globally, grid operators are demanding more than clean energy, they need smart, compliant, and highly responsive energy assets. The İzdemir Solar Power Plant proves that advanced automation is not only possible, but essential.

By deploying inavitas' automation platform, İzdemir transformed from a traditionally operated plant into a fully digitized energy asset, capable of real-time control, TEİAŞ-aligned compliance, and uninterrupted performance under any condition.

- This transformation was made possible through:
- High-frequency, real-time automation
- Redundant infrastructure for fault-tolerant operations
- Standardized Modbus and IEC 104 communication protocols
- Unified SCADA-based monitoring and control

İzdemir is now a benchmark for what modern solar operations can look like, scalable, secure, and grid-synchronized from end to end.

Ready to bring this level of control and compliance to your energy project?
Contact us to schedule a consultation or technical demonstration.