

AUTOMATED CONTROL SYSTEMS FOR ENERGY EFFICIENCY IN INDUSTRIAL ENTERPRISES: INTEGRATING IOT, EDGE, AND AI

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Abstract This article explores the implementation of automated control systems to achieve energy efficiency in industrial enterprises. It highlights the integration of IoT sensors, Edge computing, and artificial intelligence for real-time monitoring, predictive maintenance, and energy optimization. Drawing on recent global and Uzbekistan-based projects, the paper proposes a novel Hybrid IoT-Edge-AI platform to reduce energy consumption by up to 25% and operational costs by 20%. Key challenges such as cybersecurity, investment costs, and infrastructure limitations are also discussed.

Keywords : Energy efficiency, industrial automation, IoT, Edge computing, artificial intelligence, predictive maintenance

Аннотация В статье рассматривается внедрение автоматизированных систем управления для достижения энергоэффективности на промышленных предприятиях. Описана интеграция IoT-сенсоров, Edge computing и искусственного интеллекта для мониторинга в реальном времени, прогнозного обслуживания и оптимизации энергопотребления. На основе мирового и узбекского опыта предлагается гибридная платформа IoT-Edge-AI, способная снизить потребление энергии до 25 % и операционные расходы до 20 %.

Ключевые слова : Энергоэффективность, промышленная автоматизация, IoT, Edge computing, искусственный интеллект, прогнозное обслуживание.

Annotatsiya Ushbu maqola sanoat korxonalarida energiya tejamkorligiga erishish uchun avtomatlashtirilgan boshqaruv tizimlarini joriy etish masalasini

yoritadi. IoT sensorlari, Edge computing va sun'iy intellekt integratsiyasi orqali real vaqt monitoringi, prognozli texnik xizmat ko'rsatish va energiyani optimallashtirish imkoniyatlari tahlil qilinadi. Maqolada global va O'zbekiston tajribasi asosida energiya sarfini 25 foizgacha, operatsion xarajatlarni 20 foizgacha kamaytirishga xizmat qiluvchi gibril IoT-Edge-AI platformasi taklif etiladi.

Kalit so'zlar :*Energiya tejamkorligi, sanoat avtomatlashtirish, IoT, Edge computing, sun'iy intellekt, prognozli xizmat.*

Introduction

Global climate change, limited energy resources, and rising costs pose serious challenges to modern industry. Many countries, including Uzbekistan, are pursuing “green economy” strategies and carbon-neutrality targets. Industrial enterprises are therefore implementing technological solutions aimed at increasing energy efficiency and reducing emissions.

Recent years have seen the widespread adoption of automated control systems (PLC, SCADA, DCS), IoT sensors, Edge computing, and AI-driven predictive control to optimize industrial production processes. IoT Analytics reports that global investments in industrial automation projects continue to grow, with leading companies such as Siemens, ABB, and Schneider Electric launching projects to optimize energy management and production distribution.

In Uzbekistan, Honeywell has implemented automation projects in the energy, oil and gas, and metallurgy sectors using real-time data to optimize processes. Moreover, the country is planning the deployment of smart grids, IoT-based energy distribution, and monitoring technologies.

The aim of this paper is to demonstrate how integrating automated control systems with IoT, Edge computing, and AI can significantly enhance energy efficiency, based on new projects and proposals.

Technical Foundation and Terminology

Automated control systems involve sensors, actuators, and controllers to optimize production. IoT enables real-time data collection, Edge computing processes data locally to reduce latency, and AI enables predictive maintenance and energy optimization.

Case Studies and New Project Proposal

This article reviews global and Uzbekistan-based projects, such as IoT-enabled smart manufacturing frameworks and Honeywell's real-time optimization systems. A novel Hybrid IoT-Edge-AI Control Platform is proposed, incorporating smart sensors, edge analytics, and AI/ML modules for predictive analysis and optimal energy usage. Expected results include:

15–25 % energy savings

10–20 % reduction in operational costs

20–30 % decrease in machine downtime

Challenges

Investment costs, cybersecurity risks, technical infrastructure limitations, and organizational resistance are key challenges to implementing these technologies. Addressing these issues requires government incentives, staff training, and phased implementation strategies.

Broader Industrial Context

Across global heavy industries—such as steelmaking, cement production, and large-scale chemical processing—energy use accounts for more than 30 % of total operational cost. Recent reports from the International Energy Agency (IEA, 2025) estimate that Digital Twin technology combined with AI-driven predictive control can cut energy losses by 20–35 % when implemented comprehensively. Early adopters in Europe and East Asia have already documented significant carbon-footprint reductions, which directly supports corporate sustainability targets and net-zero commitments.

Integration with Renewable Energy Sources

An important next step is coupling Digital Twin models with on-site renewable generation (solar arrays, wind turbines) and battery energy storage systems. Real-time simulation allows the control software to decide when to draw power from renewables, when to store excess, and when to switch to grid supply. This not only reduces energy cost but also stabilizes plant operation during grid disturbances.

Workforce and Skills Development

While technology is central, human capital remains critical. Engineers and technicians need training in data analytics, virtual modeling, and cybersecurity. Several universities in Europe and Central Asia now offer joint certification programs in “Industrial Digital Twin Engineering,” and similar initiatives could be replicated in Uzbekistan’s technical institutes.

Lifecycle Energy Management

A full-scale Digital Twin is not limited to day-to-day operations. It supports the entire lifecycle of an industrial asset—from design and commissioning to decommissioning. During the design phase, engineers can simulate different plant layouts to identify the most energy-efficient configuration before construction begins. During operation, the twin continuously compares expected performance with real sensor data, automatically flagging deviations. When the asset approaches end-of-life, data collected over years informs recycling or refurbishment decisions, further reducing energy and material waste.

Interoperability and Standards

Adoption success depends on open standards such as OPC UA and ISO 23247 for digital-twin architecture. Using common data models enables multi-vendor equipment to “speak the same language,” making it easier for Uzbek industrial plants to integrate new equipment without locking themselves into a single supplier.

Practical Implementation Roadmap

1. Pilot Study – Select a single production line with measurable energy KPIs.

2. Data Acquisition – Install IoT sensors for temperature, vibration, and electricity use.

3. Twin Creation – Build a physics-based model using CAD and historical data.

4. AI Training – Feed the model with at least 6–12 months of operational data

5. Scale Up – Extend to entire facility after validating 10–15 % savings in pilot

Conclusion

Automated control systems integrated with IoT, Edge computing, and AI provide one of the most effective paths toward energy efficiency in industrial enterprises. These technologies not only reduce energy consumption but also enhance operational efficiency and environmental sustainability, making them particularly valuable for Uzbekistan's industrial sector.

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