OPEN ACCESS

Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) | ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Review Article

Artificial Intelligence in Industrial Process Automation System

Shabbir A. Kapasi[1*]

[1]Saudi Aramco Oil Company, Saudi Arabia

DOI: https://doi.org/10.36348/sjet.2025.v10i11.002 | **Received:** 06.09.2025 | **Accepted:** 30.10.2025 | **Published:** 03.11.2025

***Corresponding author:** Shabbir A. Kapasi
Saudi Aramco Oil Company, Saudi Arabia

Abstract

Artificial Intelligence (AI) is revolutionizing industrial process automation by introducing intelligent decision-making and adaptive control to traditionally deterministic systems. In the petrochemical and oil & gas industries where safety, efficiency, and reliability are paramount, AI technologies such as machine learning, deep learning, and digital twins enhance plant operations through predictive maintenance, process optimization, and asset integrity management. Despite challenges in certification, data quality, and cybersecurity, AI continues to evolve as an indispensable enabler of smart and self-optimizing industrial plants. This research examines the integration of AI within programmable logic controllers (PLCs), distributed control systems (DCS) and supervisory control and data acquisition (SCADA) frameworks, the improvements it brings in efficiency, energy management, and maintenance scheduling as well as examines the real-world implementations from major automation vendors such as Honeywell, Emerson, Yokogawa and Siemens.

Key Takeaways:

- Industrial process automation is one domain that is being benefited heavily by AI, offering immense potential for transformation from 'Automation' to 'Autonomous' through AI integration.
- AI driven solutions enhance plant operations, process optimization, and asset integrity management.
- Despite challenges, AI holds substantial potential to address existing gaps in industrial process automation.

INTRODUCTION

Rationale

Artificial Intelligence (AI) is revolutionizing industrial process automation by introducing intelligent decision-making and adaptive control to traditionally deterministic systems. Among the various domains where AI is making its mark, the field of industrial process automation is already benefiting from its integration and offering immense potential for transformation from 'Automation' to 'Autonomous' processes. Industrial process automation has evolved from basic mechanization and manual controls to relay-based systems, then to programmable logic controllers (PLCs), distributed control systems (DCS) and supervisory control and data acquisition (SCADA), enabling greater precision, reliability, and efficiency in monitoring and controlling industrial processes. However, traditional automation systems have limited adaptability as they rely on predefined rules or logic within PLC, DCS or SCADA and cannot easily adapt to changing conditions, product variations and unexpected disturbances without further manual programming. Whereas, industrial process automation with AI utilizes techniques such as machine learning, deep learning, and digital twins which enhance plant operations through predictive maintenance, process optimization, and asset integrity management. Hence, industrial process automation with AI provides predictive capabilities, real-time optimization, and decision support, enabling plants to operate more efficiently and respond proactively to process deviations.

This research seeks to delve into the evolving landscape of AI in industrial process automation and comprehensively explore its potential implications on smoother plant operation, predictive maintenance and improve asset integrity. Examining successful AI implementations and learning from potential pitfalls, this study aims to provide valuable insights to guide organizations in harnessing AI's capabilities to drive superior plant operations. Moreover, anticipating the future trajectory of AI in industrial process automation will empower decision-makers to adapt proactively, capitalizing on emerging AI trends and staying ahead in an ever-evolving business environment.

OBJECTIVES

This study examines the current applications of artificial intelligence in industrial process automation and its future. The objectives that will facilitate the fulfilment of this aim consist of the following:

- To assess the current state of AI adoption in industrial process automation and identify the extent of integration into various industrial process automation processes.
- To analyze the benefits and challenges of implementing AI in industrial process automation and understand its impact on Process plant performance, cost-effectiveness, and resource utilization.
- To investigate the role of industrial process operators and engineers in AI-driven industrial process operations and understand how their responsibilities and skill sets might evolve.
- To anticipate the future trends and developments in AI and assess their implications for industrial process automation.

Significance of the Study

This research aspires to make numerous contributions to the current literature by providing an upto-date assessment of AI adoption in industrial process automation, shedding light on the prevalent AI technologies and their applications. The study comprehensively explains the benefits and challenges of integrating AI in industrial process automation, providing valuable insights to practitioners and decision-makers. Also, it presents insights into the future role of AI in industrial process automation, including its potential to revolutionize industrial process Automation to Industry 4.0 platform towards autonomous process plants *(Chen, H., 2021)*. This research is also essential as it provides recommendations and guidelines for organizations to effectively select AI in their industrial process automation processes and stay competitive in a rapidly evolving technological landscape.

INTRODUCTION

Selected Approach

The research will involve collecting secondary data from various reputable and scholarly sources. Secondary data refers to existing data previously collected and published by other researchers, organizations, or authorities. This data can include academic papers, reports, case studies, industry publications, and online resources relevant to the research objectives. The first step in the methodology will be conducting an extensive literature review to gather a comprehensive collection of secondary data related to AI in industrial process automation. This review will involve searching academic databases such as Google Scholar, IEEE Xplore, ACM Digital Library, and other relevant repositories for peer-reviewed articles, conference papers, and journal publications. Keywords such as "Artificial Intelligence in industrial process automation," "AI in plant operations," "AI in process automation," and "Future of AI in plant automation" will help to identify relevant literature.

Eligibility Criteria

The researcher considered multiple factors before selecting papers for inclusion in the study. Firstly, the pieces had to be published between 2015 and 2025 to qualify for inclusion, as older documents were more likely to contain misleading information. Secondly, to streamline the research process, only articles in English were included, avoiding the need for translation.

RESULTS

The search on the relevant databases led to identifying twenty-seven relevant articles. Six of the included sources addressed the topic of the evolution of AI in industrial process automation. Six reports also evaluated the various successful instances of AI integration into industrial process automation, while seven others examined the shortcomings organizations face when using AI for industrial process automation. The rest of the eight papers highlight the potential for AI to deal with the current gaps in industrial process automation activities.

DISCUSSIONS

Existing Problems

Although, traditional industrial process automation systems have been doing the required job so far, they face several limitations such as Limited Adaptability, Lack of Predictive Capabilities, Data Underutilization, High Dependency on Human Expertise, Inefficient Maintenance, Suboptimal process efficiency, Limited interconnectivity and Scability, Poor Decision Support.

Traditional industrial process automation systems face several limitations:

- They rely on predefined rules and fixed logic, which restricts adaptability to changing conditions or unexpected disturbances (M. Bernabei *et al.*, 2024).
- These systems operate reactively, lacking predictive capabilities for equipment failures or quality deviations, and underutilize the large volumes of process data generated (F. Balaha *et al.*, 2025)
- Maintenance is often time-based rather than condition-based, leading to inefficiencies and unplanned downtime (M. Achouch…M. Adda, 2022)
- Decision-making and process optimization remain heavily dependent on human expertise, limiting scalability and responsiveness (A. Sama *et al.*, 2023)

- Additionally, legacy systems often struggle with interoperability, making integration with modern technologies challenging (A. Alqoud *et al.*, 2022)

Overall, these limitations result in suboptimal process efficiency, higher operational costs, and reduced ability to respond dynamically to evolving industrial demands.

Evidence of Solutions

Evolution of AI in Industrial Process Automation to tackle the existing problems:

The evolution of AI in industrial process automation has been a remarkable journey marked by significant advancements and transformative impacts on how plants operate through predictive maintenance, process optimization, and asset integrity management. Over the years, AI technologies have progressively integrated into industrial process automation practices, revolutionizing traditional automation systems into Industry 4.0 platform, and enhancing safety and availability of the process operations. AI is a vehicle for Industry 4.0 revolution, the way companies make, improve, and distribute their products. It has radically transformed the industrial and manufacturing world by enabling intercommunication between equipment through the Internet of Things, Big Data, computer intelligence, and decision-making systems. (M. Achouch…M. Adda, 2022) People primarily associated AI with academic research and theoretical concepts in the early stages. However, as computing power increased and data became more accessible, AI applications began to emerge in various industries, including industrial process automation. Reviewing actions taken by major automation system manufacturers, significant contributions of AI in industrial process automation systems can be gauged.

HONEYWELL:

Honeywell integrates AI into its core industrial platforms to enhance automation, decision support, and operational efficiency. October 2024, Honeywell introduced new AI enabled solutions designed to help employees work smarter, make systems more efficient and allow plant operations to accelerate the path to autonomy. By combining decades of industry knowledge and deep domain data with the latest AI technologies, including Honeywell Forge, Honeywell is infusing AI into both new and existing solutions. This provides companies with an end-to-end AI experience for the worker in the field, the process operator in the control room and executives at an enterprise level. Today's energy industry faces several challenges, including a widespread shortage of skilled talent to run facilities and a need to enhance efficiency while maintaining accuracy and quality. To address these challenges, Honeywell's AI solutions can help enhance decision-making speed, operational efficiency and workforce productivity while also upskilling the workforce through enhanced training. To further expand the solutions available for the energy sector, Honeywell also announced a partnership with Chevron to develop additional advanced AI-enabled solutions focused on enhancing refining operations. Honeywell's new AI capabilities include the Experion Operations Assistant, which integrates explainable AI into the industrial process to help operators identify production issues and offer step-by-step guidance to address the issue. With an Experion Operations Assistant running alongside plant operators, companies can optimize operations and less experienced operators can build new expertise more quickly by gaining access to the decades of industry knowledge within their company.

EMERSON:

Emerson, an industrial technology company delivering advanced automation solutions, is empowering manufacturers across every industry to drive toward optimized autonomous operations with the most advanced industrial AI and data solutions for online, mission-critical applications. DeltaV™ Revamp uses AI to accelerate a low-risk transition of legacy control and safety system configuration to a modern DeltaV system, informed by data gathered from thousands of modernization projects across every industry. The AI tools in Emerson's DeltaV Revamp analyze information learned from each control system update to further improve the core database for increased speed, accuracy and agility with each modernization. AspenTech Strategic Planning for Sustainability Pathways™ leverages GenAI technology to navigate complex options and pathways to help companies more easily develop long-term strategies for decarbonization. In addition, Aspen Virtual Advisor (AVA), an AI-driven advisor built into Emerson technologies, provides expert operational guidance to users across a wide range of experience levels as they navigate sophisticated tools used for design, planning, scheduling and automation of operations. Today, AVA leverages deep knowledge of Aspen PIMS™ planning software and Aspen DMC3™ adaptive process control software, allowing users to ask natural language questions to identify process bottlenecks or find ways to achieve specific goals. Other virtual advisors, like those built into Emerson's Ovation™ 4.0 Automation Platform and Guardian™ Digital Platform, provide the tools users need to visually translate and simplify complex issues to easily understand what is happening in their control system.

Yokogawa:

Yokogawa Electric Corporation emphasises its "Industrial AI" vision of perceive the present, predict the future and optimise operations, underlining its commitment to leveraging data and advanced analytics across industrial environments. Its flagship OpreX™ brand, which spans digital and automation offerings, provides a flexible foundation for AI, cloud/edge computing, robotics and autonomous applications. Among its key technologies is the e-RT3 Plus Industrial AI Platform — an edge/OT controller supporting Python libraries and machine-learning modules, connecting real-time equipment I/O to cloud and edge ecosystems to enable smart manufacturing and digital transformation solutions. The company further expands these capabilities via strategic partnerships: for example, its collaboration with UptimeAI integrates generative/LLM-based agents into the "OpreX Asset Health Insights" asset-management solution, while joint work with Shell Global Solutions International B.V. applies machine vision and AI analytics to robotics for autonomous operator rounds and plant-monitoring tasks. These efforts span autonomous control (via an FKDPP-based algorithm for advanced edge controllers), anomaly detection and predictive asset-health management, and IT/OT convergence platforms to bridge legacy systems and next-gen digital operations.

Siemens:

Siemens applies industrial-grade AI across key systems such as its Industrial AI Suite, which runs AI/ML workloads on industrial PCs with NVIDIA GPUs, and its Industrial Copilot (developed with Microsoft) that uses generative-AI to assist engineering and operations. These platforms enable applications including high-speed computer-vision inspection in manufacturing, AI-enhanced advanced process control, edge-deployed inference for real-time responsiveness, and automated engineering support through AI copilots that generate code, documentation, and optimisation insights — ultimately making automation systems more agile, productive, and data-driven.

Challenges Faced by Organizations

Implementing AI in the industrial process automation system presents several challenges for organizations. These challenges can hinder the successful adoption and utilization of AI-driven solutions. For example, Industrial environments often have fragmented, heterogeneous data sources, legacy systems, and inconsistent data structures. Without high-quality, well-curated data, AI models struggle to deliver reliable results (*Xuejiao et al, 2024*) Additionally, many plants operate with older automation systems that aren't built for AI or modern analytics. Integrating AI into these systems can require substantial architecture overhaul, which is costly and risky for continuous operations (*Alexander et al, 2024*). Also, deploying AI systems often involves upfront costs: sensors, data infrastructure, compute resources, re-engineering. For industrial operators with tight margins or risk-averse culture this is a major impediment. (*Sahil et al. 2025*). In addition, industrial automation has traditionally been about control logic, PLCs, deterministic systems. Transitioning to AI demands new skills (data science, ML ops, interpretability), and some workforce may resist change or lack training. In industries like chemicals, energy, heavy manufacturing, safety and uptime are critical. AI systems often behave as "black boxes", and companies may be reluctant to trust them for critical operations without proven reliability. *(Constantine, 2025).* Without a clear roadmap, measurable KPIs, and business case for AI, companies may hesitate to proceed. AI tends to require scale for benefits to show, but many implementations remain pilot-only *(Kara, 2025).*

The Potential for AI to Address Existing Gaps

Artificial Intelligence (AI) holds significant potential to address existing gaps in industrial process automation systems, driving transformative improvements and optimizing operational performance. One of the central challenges in automation is making accurate, real-time decisions using vast streams of data from sensors and industrial control systems. AI's capability to process and interpret complex datasets enables data-driven operational decision-making, equipping engineers and operators with valuable insights for more precise and timely interventions (Kusiak, 2018). Additionally, traditional fault detection and maintenance practices often rely on periodic inspections and reactive responses. AI-powered predictive analytics can detect anomalies and anticipate equipment failures early, allowing proactive maintenance strategies that reduce downtime and operational disruptions (Lee *et al.*, 2020). AI systems can also optimize resource utilization by analyzing production requirements, energy consumption, and equipment capabilities. Intelligent optimization ensures efficient assignment of machinery and raw materials, minimizing waste and improving throughput across processes (Vogl *et al.*, 2019). From a related standpoint, real-time process monitoring stands as a significant advantage. AI-enabled automation platforms offer continuous monitoring, diagnostics, and reporting functionalities, providing stakeholders with up-to-date performance indicators and deviations. This enhanced visibility supports rapid corrective actions and consistent quality control (Rojas *et al.*, 2021). Furthermore, AI can improve production planning by learning from historical manufacturing data, identifying operational patterns, and generating more reliable forecasts for cycle times and process performance (Reinartz & Bender, 2019). As a result, production schedules become more realistic and adaptive to demand fluctuations. According to Pereira and Romero (2022), AI-driven control algorithms can automate complex decision-making at the shop-floor level, dynamically adjusting workflows and optimizing system responsiveness. This improves operational continuity and ensures alignment with key performance objectives. Finally, AI's adaptability makes it a key enabler of Industry 4.0 and smart factory environments. AI analytics support increased flexibility, continuous improvement, and rapid response to variability in production conditions, enhancing overall system agility (Javaid *et al.*, 2021). Leveraging AI to close these critical automation gaps allows industrial organizations to significantly enhance their productivity, reliability, and competitiveness. However, successful integration requires clear strategic objectives, robust cybersecurity measures, and a long-term commitment to workforce upskilling and innovation.

LIMITATIONS

One of the primary drawbacks of this study is its reliance solely on English-language sources. This limitation potentially hinders the quality of the findings, as the researcher may have overlooked relevant data published in other languages. Consequently, the trustworthiness of the conclusions becomes uncertain. Another limitation is the study's use of sources from 2015 to 2025. This timeframe might have resulted in the exclusion of pertinent articles published before 2015, potentially compromising the accuracy of the current information. Lastly, the adoption of a cross-sectional design poses a further disadvantage. This choice means the information gathered may become outdated in the coming years.

Practical and Research Implications

The practical implications of AI in industrial process automation encompass improved efficiency, decision making, and resource allocation. In contrast, research implications involve developing frameworks, addressing ethical concerns, and understanding AI integration's long-term impact and opportunities. Advancing knowledge in these areas can lead to more effective AI adoption and transformational change in industry practices.

CONCLUSIONS

The evolution of AI in industrial process automation has seen remarkable advancements and transformative impacts. Once limited primarily to academic experimentation, AI has progressively become embedded within industrial environments, enhancing automation capabilities across manufacturing and production systems. Successful AI deployments in industrial automation have been true game-changers, improving operational efficiency and system reliability. However, implementing AI in automation environments is not without challenges. Issues such as data quality, system interoperability, cybersecurity vulnerabilities, and uncertainties around initial investment can complicate adoption efforts. Despite these obstacles, AI demonstrates strong potential in overcoming existing limitations within industrial automation practices. It enables data-driven operational decisions, strengthens predictive maintenance and fault detection, optimizes resource utilization, and supports real-time monitoring and control. Future research within the field can focus on developing AI-integration frameworks, addressing ethical and workforce implications, and assessing long-term impacts on productivity and sustainability. Advancing knowledge in these areas can foster more widespread and effective AI adoption, leading the way toward smarter, more adaptive, and highly resilient industrial automation systems.

REFERENCES

- Chen, H. (2021). *From Automation System to Autonomous System.* MDPI.
- M. Achouch, M. Dimitrova, K. Ziane, S. Sattarpanah Karganroudi, R. Dhouib, H. Ibrahim, & M. Adda (2022) On Predictive Maintenance in Industry 4.0: Overview, Models, and Challenges by — *Applied Sciences*, 12(16): 8081. DOI: 10.3390/app12168081.
- F. Balaha et al. (2025). An analytical review of data integration for decision support by — *Engineering Applications of Artificial Intelligence* (forthcoming).
- A. Sama et al. (2023). Acquiring Automation and Control Data in the Context of Digital Transformation.
- A. Alqoud *et al.*, 2022. Industry 4.0: a systematic review of legacy manufacturing systems.
- M. Bernabei *et al.*, 2024. Adaptive automation: Status of research and future directions.
- Honeywell To Power Energy Sector with New Artificial Intelligence Solutions
- https://www.prnewswire.com/news-releases/emersons-expanded-ai-portfolio-paves-the-way- for-more-optimized-autonomous-operations-302459361.html
- https://www.yokogawa.com/special/artificial-intelligence
- https://aimagazine.com/articles/siemens-unveils-industrial-ai-tools-at-ces-with-nvidia-sony
- ABB Review article: "Autonomous systems – five years on" (ABB Review 02/2024).
- Siemens press release: "Industrial AI Agents: Automating the Future of Manufacturing" (May 12, 2025).
- Xuejiao Li, Cheng Yang, Charles Møller, Jay Lee, June 2024. Data Issues in Industrial AI System: A Meta-Review and Research Strategy.
- Alexander Windmann, Philipp Wittenberg, Marvin Schieseck, Oliver Niggemann, May 2024. Artificial Intelligence in Industry 4.0: A Review of Integration Challenges for Industrial Systems.
- Dhawan, A. (2022). Challenges in Automation – A review. Proceedings of the IEOM Society.
- Constantine Lau, June 2025. Lessons from the frontline: This is what AI does in the industrial world
- SahilBansal and Dinesh Dakshinamoorthy, SCB Contributors, Jan 2025. Overcoming Barriers to AI Adoption in Manufacturing: A Roadmap for Transformation
- Harshada G, March 2025. AI in Industrial Automation: How smart solutions are powering the future of Industry.
- Article:Top 5 Challenges of AI Adoption in Manufacturing — and How to Overcome Them
- Kara Martin, 2025. 10 Common Challenges to AI Adoption and How to Avoid Them
- Kusiak (2018). Focuses on AI applications in smart manufacturing and intelligent industrial systems.
- Lee et al. (2020). Explores AI-based predictive maintenance and failure detection in industrial environments.

- Vogl et al. (2019). Discusses AI-enabled resource optimization such as energy efficiency and production throughput.
- Rojas et al. (2021). Addresses real-time monitoring, diagnostics, and AI-enhanced automated reporting for industrial systems.
- Reinartz & Bender (2019). Examines AI's role in production planning, forecasting, and data-driven process performance improvement.
- Pereira & Romero (2022). Investigates AI-driven automation and decision-making for smart factories under Industry 4.0 initiatives.
- Javaid et al. (2021). Highlights AI's role in increasing flexibility and agility in industrial process automation and smart manufacturing.