

Industrial Automation in Industry 4.0: A Review of PLC–SCADA

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Abstract: Industrial automation is moving from isolated programmable control toward connected, data-driven production systems. This review synthesizes five supplied papers covering Industry 4.0 architectures and supervisory systems, general industrial automation, cyber-physical systems (CPS) for manufacturing, a PLC–SCADA implementation for ratio control and assembly-line operations, and the wider socio-economic implications of automation. The literature indicates that programmable logic controllers (PLCs), human–machine interfaces (HMIs), and supervisory control and data acquisition (SCADA) remain important operational components, while industrial Internet of Things (IIoT), open communication technologies, cloud services, analytics, and CPS extend monitoring and coordination. A reported PLC–SCADA case demonstrates how ratio control, sensor-based sorting, filling, capping, labelling, and storage can be organized as automated process stages. The review also identifies persistent barriers: interoperability with legacy equipment, cybersecurity, implementation cost, skills requirements, architecture complexity, and uneven effects on workers and communities. Rather than treating connectivity as a replacement for conventional automation, the evidence supports a staged integration approach that preserves dependable local control while adding secure data exchange and supervisory analytics. The paper concludes with research directions for measurable performance evaluation, secure legacy integration, human-centred deployment, and more transparent reporting of benefits and trade-offs.

Keywords: Industrial automation; Industry 4.0; PLC; SCADA; HMI; Industrial Internet of Things; cyber-physical systems; interoperability; cybersecurity.

I. INTRODUCTION

Industrial automation uses sensors, actuators, controllers, communication networks, and software to execute or supervise production tasks with reduced manual intervention. The supplied Industry 4.0 review places automation and supervision systems within a wider transformation that connects physical equipment with digital services and data processing [1]. PLCs continue to provide deterministic machine and process control, while SCADA platforms collect data, display process status, manage alarms, and support supervisory decisions. HMI panels provide the operator-facing interface for observing process variables and issuing permitted commands [1], [2].

Industry 4.0 extends this established stack through IIoT connectivity, cyber-physical systems, cloud or edge computing, analytics, and more decentralized architectures. These additions can improve visibility and flexibility, but they also create integration and governance demands. The CPS literature emphasizes that human, cyber, and physical components—and the interfaces between them—must work together for an integrated manufacturing system [3].

This review brings together the supplied papers from a practical electrical-engineering perspective. Its purpose is not to claim a new experimental result; rather, it compares the sources, identifies areas of agreement and difference, and derives a set of implementation and research priorities from the evidence they report.



II. REVIEW METHOD AND SCOPE

The review uses a focused narrative synthesis of the five documents provided for this task. The base paper is Folgado et al.'s 2024 review of Industry 4.0 from the perspective of automation and supervision systems [1]. The supporting documents cover industrial automation concepts and PLC/IIoT/HMI/SCADA [2], a literature review of CPS for manufacturing [3], a PLC–SCADA chemical-process and assembly-line case study [4], and an empirical study of automation exposure and local public goods in the United States [5]. Findings are grouped by technology, implementation, constraints, and wider impacts. No new database search, statistical meta-analysis, or experimental validation was performed for this manuscript; therefore, it should be described as a focused narrative review, not a systematic review.

III. TECHNOLOGY FOUNDATIONS AND INDUSTRY 4.0 ARCHITECTURE

3.1 PLC, HMI, and SCADA

PLCs are industrial controllers designed to read inputs, execute programmed logic, and drive outputs under plant-floor conditions. They are widely used for sequencing, interlocking, motor control, process control, and machine automation. HMI technology presents process variables, equipment states, alarms, and operator controls. SCADA extends supervision across multiple devices or process areas through data acquisition, visualization, alarm handling, trends, and reporting [1], [2]. These roles are complementary: a reliable local control layer can continue to execute essential logic while the supervisory layer provides a broader operational view.

3.2 IIoT and cyber-physical systems

IIoT connects industrial sensors, controllers, and equipment to information platforms so that process data can be exchanged and analyzed. CPS couples computation and communication with physical processes through feedback, linking the physical equipment to models, software, and decision-making. Dafflon et al. reviewed 626 initially identified records and examined 78 prospective studies on CPS for manufacturing published in the 2010–2019 period; their synthesis highlights the human component, cyber component, physical component, and the interfaces between them [3]. This framing is useful because successful integration depends on more than installing sensors: data meaning, control responsibilities, operator interaction, and system boundaries also matter.

3.3 From hierarchical control to connected architectures

The base paper describes an evolution from the traditional automation pyramid toward more decentralized and IoT-oriented architectures [1]. Hierarchical designs can provide clear separation of control and management functions, but highly abstract reference architectures may be difficult to map directly to specific plant equipment. Open communication technologies and middleware can improve data exchange, while legacy devices and conventional control systems usually remain part of the operating environment. Accordingly, modernization is better understood as gradual integration than as wholesale replacement [1].

IV. COMPARATIVE REVIEW OF THE SUPPLIED LITERATURE

Source	Main focus	Evidence/contribution	Caveat for this review
[1] Folgado et al. (2024)	Industry 4.0, automation and supervision architectures	Maps concepts, architectures and trends; stresses continuing PLC/SCADA roles and coexistence with IIoT.	Broad review; cybersecurity is not examined in depth.
[2] Siva Kumar and Chandrashekharan (2025)	Industrial automation, PLC, IIoT, HMI/SCADA and mechatronics	Accessible overview of common components, benefits and limitations.	Short overview paper; reference list and quantitative evaluation are limited.



[3] Dafflon et al. (2021)	CPS for manufacturing	Screens 626 records and synthesizes 78 studies; emphasizes human, cyber and physical components and interfaces.	Literature window covers 2010–2019, so later developments are outside its scope.
[4] Tomar et al. (2023)	PLC–SCADA ratio control and assembly line	Presents a chemical-process and container-handling design using PLCs, sensors, valves, HMI and SCADA.	Specific simulated/prototype design; results should not be generalized to every plant.
[5] Spreen et al. (2025)	Automation exposure and local public finance in the U.S.	Reports associations/estimates linking automation exposure to lower per-capita public revenue and spending, especially education.	Socio-economic U.S. study, not a technical evaluation of control-system performance.

The sources are complementary but not identical in evidence type. References [1] and [3] are reviews; [2] is a short descriptive overview; [4] is an implementation-oriented case study; and [5] is an empirical socio-economic study. Conclusions are therefore compared qualitatively, not treated as directly equivalent measurements.

V. PLC–SCADA INTEGRATION IN PRACTICE

Tomar et al. [4] describe a two-part automation arrangement for a chemical plant: a ratio-control stage and an assembly-line stage. In the ratio-control section, flow rates are measured and a desired ratio is used to generate corrective action through a PLC and control valve. In the assembly-line section, sensors help distinguish container types or sizes, while conveyor and downstream equipment support sorting, filling, capping, labelling, and storage. The system uses PLCs for control and SCADA/HMI software for visualization and operator interaction.

The case illustrates a practical division of responsibilities: sensors supply process feedback, the PLC executes control logic, actuators change the process, and SCADA provides a supervisory view. It also demonstrates that automation quality depends on coordinated sensing, timing, control logic, safety interlocks, and operator information—not on the controller alone. Because the source describes a specific implementation, the reported configuration should be treated as an illustrative design rather than proof that the same architecture is optimal for all chemical plants or assembly lines. For engineering deployment, the case suggests several checks: (i) validate sensor and actuator ranges; (ii) define safe states and interlocks; (iii) verify ratio accuracy and response under disturbances; (iv) test alarm and operator workflows; (v) confirm communication loss does not compromise essential local control; and (vi) document recovery, maintenance, and change-management procedures.

VI. BENEFITS AND PERSISTENT CHALLENGES

6.1 Potential benefits

Across the technical sources, expected benefits include repeatable operation, reduced manual handling, improved process visibility, faster fault detection, traceability, and more efficient use of materials and energy [1], [2], [4]. IIoT and analytics can add remote monitoring and condition-based maintenance, while CPS-based integration can improve coordination between equipment and digital services [1], [3]. These are potential or context-dependent benefits; actual performance depends on system design, process conditions, operator practices, and maintenance quality.

6.2 Technical and organizational challenges

Interoperability remains important because industrial sites combine equipment from different generations, vendors, and communication protocols. Connecting legacy equipment can require gateways, data mapping, and careful testing. Cybersecurity also becomes more consequential as operational technology is connected to broader networks; the base review explicitly does not cover this topic in depth [1]. Other barriers include capital and lifecycle costs, system



complexity, downtime during upgrades, data quality, and the need for personnel who understand control engineering alongside networks, databases, and analytics [1], [2].

Human factors must be considered throughout design and commissioning. Operators need displays that support rapid interpretation, alarms that distinguish urgent conditions from routine events, and training that reflects real procedures. Automation may reduce exposure to hazardous or repetitive tasks, but organizations should also plan for job redesign, skills development, and maintenance of human oversight.

6.3 Wider socio-economic effects

The fifth supplied paper shifts the lens from machine-level performance to local economic outcomes. Spreen et al. [5] estimate that U.S. regions more exposed to industrial automation experienced declines in per-capita state and local revenues and expenditures, with education spending and student outcomes also affected. These results do not establish that every automation project produces these effects, and they are specific to the study's U.S. context and identification strategy. They do, however, caution against evaluating automation only through productivity or equipment-level metrics: workforce transition and regional distribution of benefits may also matter.

VII. RESEARCH GAPS AND FUTURE DIRECTIONS

The reviewed papers support the following research priorities:

- Comparable performance measurement: report cycle time, throughput, product-quality rate, downtime, energy use, material waste, alarm burden, and maintenance cost using clearly defined baselines.
- Secure legacy integration: test practical approaches for segmentation, least-privilege access, authenticated communications, patch management, backup and recovery, and safe remote access without disrupting deterministic control.
- Interoperability and data semantics: evaluate open protocols and middleware against real mixed-vendor systems, including the cost of mapping tags, units, alarms, and asset identities.
- Human-centred automation: assess operator workload, training outcomes, alarm usability, human override, and the impact of changing job tasks.
- Energy- and resource-aware control: connect process optimization to measured energy consumption, waste reduction, and lifecycle impacts rather than relying only on projected benefits.
- Context-sensitive socio-economic assessment: study how training, redeployment, and local policy influence the distribution of automation gains across regions and worker groups.

VIII. CONCLUSION

The supplied literature portrays Industry 4.0 as an integration of established automation with connected devices, CPS, industrial data exchange, and supervisory analytics. PLCs, HMIs, and SCADA remain central: they provide dependable control, operator interaction, and plant-wide visibility, while IIoT and CPS can extend data sharing and coordination. The PLC–SCADA case study shows how these technologies can be assembled into a process-control and material-handling workflow, but it also highlights the need for sound sensor design, safety logic, validation, and operator procedures. The review identifies interoperability, cybersecurity, cost, skills, and human and community impacts as issues that require attention alongside technical performance. Future work should combine measurable engineering evaluation with secure integration and human-centred deployment. This manuscript is a focused narrative synthesis of the supplied papers; further literature searching, reference verification, author-affiliation completion, and target-journal formatting are required before submission.

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