



**REPUBLIC OF TÜRKİYE
ADANA ALPARSLAN TÜRKER SCIENCE AND TECHNOLOGY
UNIVERSITY**

**GRADUATE SCHOOL
ELECTRICAL AND ELECTRONIC ENGINEERING DEPARTMENT**

**DEVELOPMENT OF REPORTING SYSTEM FOR VARIOUS DCS AND
SCADA SYSTEMS USING OPC IN THERMAL POWER PLANTS**

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M.Sc.



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ÖZET

TERMİK SANTRALLERDE OPC KULLANARAK ÇEŞİTLİ DCS VE SCADA SİSTEMLERİ İÇİN RAPORLAMA SİSTEMİNİN GELİŞTİRİLMESİ

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Raporlar, kurulum aşamasından üretime devam eden, genişlemeye ve hayatta kalmaya kadar her aşamadaki işletmeler için önemlidir. Raporlar, şirketlerin gelişimlerini belgelemelerini ve geçmişe dönük bir denetim izi oluşturmalarını sağlar. İşletmeler, satınalma süreçleri, operasyonel süreçler gibi sebeplerle paydaşlar ve devlet kurumları için zamana bağlı raporlara ihtiyaç duyarlar.

Bu tezde, operasyonel bir termik santral için doğru, güvenilir ve zaman damgalı verilere erişim sağlamak üzere OPC (Open Platform Communications) teknolojisini kullanan otomatik bir raporlama sistemi geliştirilecektir. Çalışma, otomatik raporlamanın, veri kaybına yol açan insan hataları, güvenlik ihlalleri, uyumluluk sorunları ve düşük verimlilik gibi el yazısı ile yazılan veri girişiyle ilişkili ciddi risklere karşı önemli bir çözüm olduğunu vurgulamaktadır. Ayrıca, otomatik bir sistem uygulayarak kuruluşlar daha fazla veri doğruluğu elde edebilir, otomatik hesaplamalar ve biçimlendirme yoluyla hataları en aza indirebilir, zamandan tasarruf edebilir, güvenilir otomatik raporlar oluşturabilir, potansiyel olarak personel ihtiyaçlarını optimize edebilir, düzenleyici gereklilikleri karşılamak ve tüketimi izlemek için personel üretkenliğini artırabilir. Böylece kuruluşlar karar alma süreçlerini iyileştirebilir ve sonuç olarak daha iyi stratejik planlamayı destekleyebilir. Hedeflere ulaşmak için veriler PTC (Kepware) yazılımı ile SCADA ve DCS (Distributed Control Systems) sistemlerinden toplanır. Bu veriler daha sonra bir Microsoft SQL Server veritabanında saklanır. Robosoft Control (Türkiye), çözüm için gerekli diğer yazılım paketlerini sağlar.

Anahtar Kelimeler: DCS, OPC, Otomatik raporlama, SCADA

ABSTRACT

DEVELOPMENT OF AUTOMATED REPORTING SYSTEM FOR VARIOUS DCS AND SCADA SYSTEMS USING OPC IN THERMAL POWER PLANTS

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Reports are important for businesses at every stage, from start-up to production, expansion and survival. Reports allow companies to document their development and create a historical audit trail. Businesses need time-based reports for stakeholders and government agencies for reasons such as procurement processes, operational processes and more.

In this thesis, an automated reporting system will be developed for an operational thermal power plant that uses OPC technology to offer access to accurate, dependable, and time-stamped data. The study emphasizes that automated reporting is a crucial solution to the serious risks associated with manual data entry, such as human errors leading to data loss, security breaches, compliance issues and reduced efficiency. Besides, by implementing an automated system, organizations can achieve greater data accuracy, minimizing errors through automatic calculations and formatting, saving time, establishing reliable automated report, potentially optimizing personnel needs, increasing personnel productivity to meet regulatory requirements and monitor the consumption. Thus, organizations can improve decision-making, and ultimately supporting better strategic planning. To achieve the goals the data is gathered from SCADA and DCS with PTC (Kepware) software. This data is then stored in a Microsoft SQL Server database. Robosoft Control (Turkey) provides the other necessary software packages for the solution.

Keywords: Automated reporting, DCS, OPC, SCADA

Dedication

I dedicate this study entirely to my parents and my family, who have always supported me emotionally, spiritually and morally moreover have been a source of inspiration besides strength when I wanted to give up.

To my classmates, mentors, colleagues and friends who helped me with words and goodwill to finish my studies.

Last but not least, this study is dedicated to Assoc. Prof. Dr Firat EKİNCİ, to whom I am thankful for the skills, confidence, encourage and guidance he has given to me.

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Lastly, I dedicate this dissertation to my parents, who helped me along the way and taught me the importance of education at an early age. I was motivated to set ambitious objectives and put in a lot of effort to reach them by their unshakable faith in my talents.

TABLE OF CONTENTS

CERTIFICATION OF APPROVAL	Error! Bookmark not defined.
ÖZET	i
ABSTRACT	ii
<i>Dedication</i>	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF FIGURES	vii
LIST OF TABLES	viii
LIST OF ABBREVIATIONS	ix
1. INTRODUCTION	1
2. INDUSTRIAL AUTOMATION SYSTEMS	2
2.1. Literature Review	3
2.2. PLC Systems	8
2.3. SCADA Systems	10
2.3.1 SCADA system architecture	11
2.3.2 Functions of SCADA systems	12
2.3.3 Basic components of SCADA	13
2.3.4 The usage areas of SCADA systems	15
2.3.5 Advantages of SCADA systems	15
2.3.6 Disadvantages of SCADA Systems	15
2.4. DCS	16
2.4.1 Architecture of DCS	18
2.4.2 Basic Components of DCS	19
2.4.3 Key Elements of DCS	22
2.4.4 DCS from different vendors	24
2.4.5 The usage areas of DCS	24
2.4.6 Advantages of DCS	25
2.4.7 Disadvantages of DCS	25
2.4.8 Differences between SCADA and DCS	26

2.5.	OPC Unified Architecture (OPC UA)	27
2.5.1	How does OPC communicate with a PLC ?	28
2.5.2	Specifications for OPC UA	29
2.5.2.1	Data Access (DA) Specification	30
2.5.2.2	Alarm & Conditions (AC) Specification	30
2.5.2.3	Historical Access (HA) Specification	31
2.5.2.4	Programs (Prog) Specification	31
2.5.3	Client-Server Architecture of OPC UA	31
2.5.4	OPC UA Information Model	32
2.5.5	OPC UA Address Space Concepts	32
2.5.6	Usage Areas of OPC UA	34
2.5.7	Benefits of OPC UA	34
2.5.8	Future possibilities for OPC UA	35
2.6.	OPC Integration to Control Systems	35
2.6.1	Control Systems Integration Domain	36
2.6.2	Field Level Integration	39
2.6.3	SCADA Level Integration	40
2.6.4	Enterprise Level Integration	43
3.	MATERIALS AND METHODS	46
3.1.	Importance of Reporting in Businesses	46
3.2.	National Load Dispatch Center (NLDC)	48
3.3.	OPC Server and Client Solutions	48
3.3.1.	The functions of an OPC client application	49
3.3.2.	Leading Providers of OPC Server and Client Solutions	50
3.3.3.	Key Considerations When Choosing a Solution	52
3.3.4.	Robosoft Control (Turkey) Solutions	53
3.3.4.1.	KEPServerEX	53
3.3.4.2.	Microsoft SQL Server	54
3.3.4.3.	RBSReport Reporting Software	54
4.	RESULTS AND DISCUSSION	58
5.	CONCLUSIONS	67
	REFERENCES	69

LIST OF FIGURES

Figure 2.1. The automation pyramid	2
Figure 2.2. The Architecture of Programmable Logic Controller (PLC)	8
Figure 2.3. SCADA System Overview	10
Figure 2.4. The SCADA Architecture	11
Figure 2.5. Working principle of a SCADA system	12
Figure 2.6. Human Machine Interface.....	14
Figure 2.7. Enhanced Operational Visibility and Control on SCADA systems.....	16
Figure 2.8. DCS Overview	17
Figure 2.9. DCS Architecture	18
Figure 2.10 Operating stations / process station / distribution controller / local control unit	20
Figure 2.11. DCS Controllers.....	21
Figure 2.12. DCS Communication media	22
Figure 2.13. Emerson DeltaV PredictPro implementation with Function Blocks	23
Figure 2.14. Effective DCS HMI screens	24
Figure 2.15. SCADA system based on OPC server architecture	28
Figure 2.16. OPC UA layers	29
Figure 2.17. Client-Server Architecture of OPC UA	32
Figure 2.18. OPC UA Object Model	33
Figure 2.19. Nodes and References	34
Figure 2.20. Sample OPC System Integration Schematic	36
Figure 2.21. Automation Pyramid with OPC UA vertical and horizontal integration	38
Figure 2.22. Star / Spaghetti integration is a hybrid of horizontal and vertical integration ...	39
Figure 2.23. SCADA Network Architecture	41
Figure 2.24. Sample Network architecture for enterprise level integration	44
Figure 2.25. Activities carried out at various manufacturing levels	45
Figure 3.1. National Load Dispatch Center	48
Figure 3.2. KEPServerEX software sample interface	54
Figure 3.3. RBS Configurator software sample interface	55
Figure 3.4. Some of the RBSReport products	55
Figure 3.5. RBS Excel Trend software sample interface	56
Figure 3.6. RBS Excel Trend software sample results on grid value result seem.....	57
Figure 4.1 RBS Configurator screenshot	59
Figure 4.2 RBS Excel Trend screenshot	60
Figure 4.3 Manual records for the Coal Stock Tracking from older time.....	63

LIST OF TABLES

Table 2.1. Differences between SCADA and DCS [38]	26
Table 4.1. Sample RGVK report output from the automated reporting system for the selected period.....	61
Table 4.2. Sample SFK_10 report output from the automated reporting system for the selected period.....	62
Table 4.3. Sample Coal Stock tracking report output from the automated reporting system for the selected period	64
Table 4.4. Sample Fuel Oil tracking report output from the automated reporting system for the selected period	65

LIST OF ABBREVIATIONS

IIoT	: Industrial Internet of Things
Industry 4.0	: Fourth Industrial Revolution
OPC	: Open Platform Communications
OPC UA	: Open Platform Communications Unified Architecture
HMI	: Human Machine Interface
SCADA	: Supervisory Control and Data Acquisition
DCS	: Distributed (or Decentralized) Control Systems
OEM	: Original Equipment Manufacturer
I/O	: Input / Output
IT	: Information Technology
OT	: Operational Technology
PC	: Personal Computer
PLC	: Programmable Logic Controller
CPU	: Central Processing Unit
MES	: Manufacturing Execution System
ERP	: Enterprise Resource Planning
OP	: Order Processing
CRM	: Customer relationship management
HRM	: Human Resources Management
B2MML	: Business to Manufacturing Markup Language
XML	: Extensible Markup Language
PICA	: Power Industry Computer Applications
RTDs	: Real Time Digital Simulator
RTU	: Remote Telemetry (Terminal) Unit
MTU	: Master Telemetry (Terminal) Unit
NLDC	: National Load Dispatch Center
FPGA	: Field-Programmable Gate Array
HART	: Highway Addressable Remote Transducer
PID	: Proportional-Integral-Derivative
DA	: Data Access

AC	: Alarm & Conditions
HA	: Historical Access
Prog	: Programs
IEC	: The International Electrotechnical Commission
TCP/IP	: Transmission Control Protocol/Internet Protocol used for network and internet communication
UDP /IP	: User Datagram Protocol for time-sensitive services like video UDP/IP
WebSockets	: Real-time server and client communications
AMQP	: Advanced Message Queuing Protocol for client/broker communications
MQTT	: Message Queuing Telemetry Transport, for limited bandwidth messaging
IP	: Internet Protocol
TCP/IP	: Transmission Control Protocol/Internet Protocol
LCD	: Liquid Crystal Display
SNMP	: Simple Network Management Protocol.
DHCP	: Dynamic Host Configuration Protocol
CAN	: Controller Area Network
PAC	: Programmable Automation Controllers
VPN	: Virtual Private Network
SQL	: Structured Query Language
RDBMS	: Relational Database Management System
mA	: Milliampere
V	: Volt
kV	: kilo Volt
DC	: Direct Current
AC	: Alternating Current

1. INTRODUCTION

Reports are vital tools in business. They are critical to a company's start-up, continuous growth, expansion, and even existence. Business reports allow companies to document their development over time. Reports also help to provide a historical audit trail. These documents may be required when approaching financial institutions or looking for investors. To meet with legal requirements, corporations issue time dependent (daily, weekly, monthly, annual etc) reports to their stakeholders and government agencies. Reports can also be useful for decision-making, purchasing, planning an expansion, or deciding to sell the business or the products.

Thousands to millions of input/output (I/O) channels are managed by SCADA and Distributed Control Systems (DCS) in their own network. The market for these systems is expanding due to the adoption of systems with larger I/O capacities day by day. Large facilities benefit from DCS and SCADA systems (OT), which allow for continuous operation along with additional features like monitoring, engineering, controlling multiple loops and even archiving process data. However, these systems are insufficient especially for the reports because they are process-focused or the data is not in the required table format. The best strategy for survival is to use OPC protocol to facilitate data exchange technologies OT and IT network. When the required data is delivered to the IT network, it can be used in any table format.

In this thesis, one sample reporting system with OPC technology will be designed for a thermal power plant to create a customizable reporting system that offers businesses and government agencies efficient access to accurate, reliable, and time-stamped data. The system's goals encompass preventing data loss from handwritten information, minimizing errors via automated calculations and formatting, saving time with streamlined data formatting, establishing dependable report automation, enabling staff to focus on expertise due to automated reports, and potentially optimizing staffing needs. Overall, the system seeks to enhance accuracy, efficiency, and staff productivity by automating report generation and formatting tasks.

2. INDUSTRIAL AUTOMATION SYSTEMS

Business intelligence, or process management, has changed significantly throughout the years. Quality process management companies are always expanding and evolving to keep up with the latest technological advancements. Therefore, from the past to the present, companies have placed a high value on industrial automation, which makes up their infrastructure. Depending on their structure and the environment in which they are utilized, industrial automation systems exhibit a variety of variations. Businesses invest a lot of money on industrial automation systems, and the communication structures they employ are by far the most significant difference between them. To improve process management, businesses want to have the quickest and most cost-effective data transfer from the field. These factors allow us to categorize the emerging industrial automation systems into three groups. These systems include PLC, SCADA and DCS. This section discusses the architecture utilized in industrial automation systems as well as the OPC technology and its integration to the systems for further requirements. Figure 2.1 is summarising the industrial automation systems and their levels

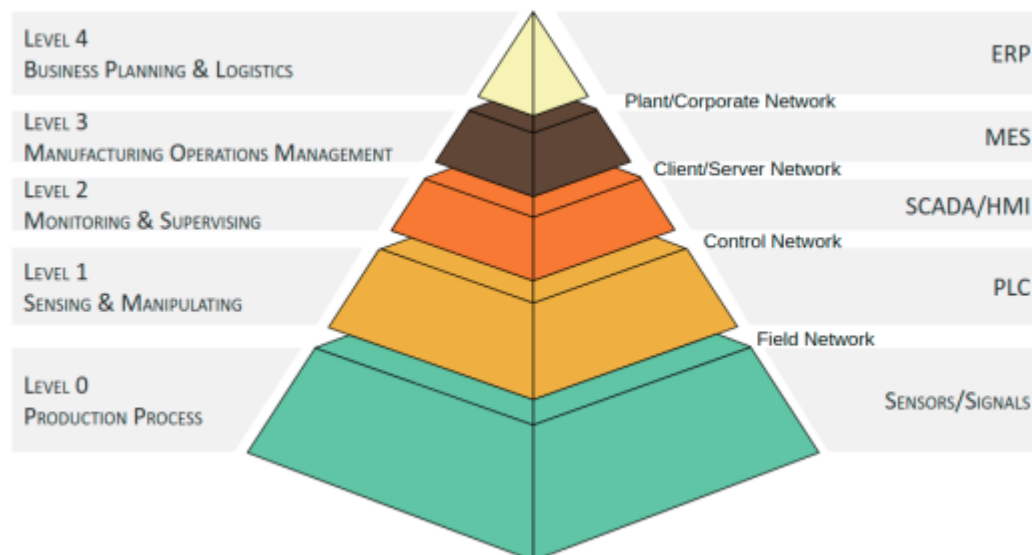


Figure 2.1. The automation pyramid [1]

2.1. Literature Review

In the study, Schleipen (2008) set up an OPC UA server client connection for the purpose of monitoring and controlling a virtual industrial robot [2]. They imitated the connection and monitored data using a UA Sample server and a UA Sample client. The current positions and angles of the robot joints were represented visually using ProVis Visu software, which included a 2D model of a robot arm.

In the study, according to Leitão et al. (2013), the OPC UA protocol will resolve issues with interoperability across vendors and standardize multi-agent communication. They asserted that one of the primary Industry 4.0 standards may be the protocol [3].

Zhong et al. (2013) created a digital twin using an RFID-based system to oversee and control the mass-communication production shop floor of Keda Industrial Group [4].

In the study, researchers have used alternative architecture designs in a variety of applications since the OPC UA standard was released. Two tiers of OPC UA servers comprise the multi-agent architecture that Fernbach et al. (2014) presented as a case study. A wireless area network was used to transmit data from two portable OPC UA servers that were placed in various locations to monitor variables to an aggregating OPC UA cross-domain server in the second layer [5].

In the study, a CNC machine was utilized to evaluate the architecture for a virtual shopfloor that Tao and Zhang (2017) outlined. To forecast malfunctioning behaviors, they suggested creating a digital twin of the CNC machine using a computer-aided design (CAD) model that included additional physical attributes (such as cutting force, torque, and wear) and loads [6].

In the study, two methods were created by Mizuya et al. (2017) to create a digital twin of a Selective Compliance Assembly Robot Arm (SCARA). In the first method, the robot was connected to a Raspberry Pi running a MQTT publisher and an OPC UA client. In the meantime, a Raspberry Pi was linked to a PC running a MQTT subscriber and an OPC UA server. The MQTT subscriber stayed in place but was on a different PC in the second method, which used a PLC to run an OPC UA server rather than a conventional PLC. Although two

clients were linked to the same server in both methods, the second method also employed a PLC to manage other industrial operations in addition to robot control [7].

Data and resources are accessible in the address space, which allows OPC UA to resolve the data accessibility issue between multi-vendor industrial controllers and their interoperability with different embedded devices. All compatible multi-vendor network nodes were successfully connected by Chen et al. (2018), who also improved integration, defect detection, troubleshooting, and automatic correction [8].

In the study, “Development of OPC-UA Based User Interface for a Drilling Rig Automation System” Aksu (2018) explores the use of OPC-UA, a service-oriented communication technology for industrial automation. It focuses on how OPC-UA integrates and shares data between servers and clients, enabling operations like object creation, deletion, modification, and method invocation. The study specifically involves implementing an OPC-UA server in a real-time TwinCAT3 development environment using Structured Text to design and program an object. This object is then published and accessed by a Java client through a graphical interface. The project showcases the practical application of OPC-UA in process control software for drilling rig automation systems [9].

In the study, a new design was given by Haskamp et al. (2018) to use the OPC UA protocol to upgrade conventional PLCs (programmable logic controllers) to Industry 4.0 requirements. DataFEED OPC Suite software functions as an OPC UA server and is connected to four PLCs. A Microsoft Azure cloud service was then used to publish the variables. Then, a specially designed graphical user interface (GUI) could retrieve and show the data that was saved on the cloud [10].

In the study, Langmann and Stiller (2019) suggested an architecture for a server-based mixed mode (SMM) of PLC operations in which runtime activities were conducted on the cloud in order to benefit from server stability and allow for portable device system monitoring. A cloud-based IoT (Internet of Things) or IIoT (industrial IoT) platform is required to rewrite process control algorithms because their architecture eliminated physical controllers, which are utilized by most production lines. They claim that coding and runtime operations on the cloud are more

vulnerable to cyberattacks, and that this could cause delays in the process of moving from the physical controllers to the new system because there is no online debugger to test and accurately simulate the code before operation. They used Node-Red, which offers comparatively less choices for data visualization, secure communication, and connecting to other platforms including tablets and smartphones [11].

In the study, Caiza et al. (2020) presented an architecture that ran on a laptop as an OPC UA client and employed AJAX, an HMI web programming platform, in the context of creating digital twins utilizing an online platform. The first client was linked to a Raspberry Pi-powered OPC UA server. The Siemens S7-1200 was able to read and write tags of interest to and from the server since it was linked to it as the second client [12].

In the study, the viability of building a digital twin on an online application programming interface (API) named DataLink was assessed by Ala-Laurinaho et al. (2020). To operate the overhead crane, they installed an OPC UA server on a Raspberry Pi. A switch was used to connect the Raspberry Pi API gateway—in this case, the GraphQL API—to the crane. They said that while successfully implementing the Raspberry Pi and connecting it to the crane PLC, the crane network's quality was subpar and had a slow response time. As soon as several devices were linked to the gateway or a lot of data was requested at once, the latency dramatically rose [13].

In the study, a case study on a FESTO MPS sorting station and an architecture that conforms with RAMI 4.0 architecture were presented by Melo et al. (2021). A Raspberry Pi was used in place of the conventional Siemens PLC as the physical controller, while TIA Portal with OpenPLC was used for the software. Simulator software and embedded controllers using C or Python are the primary uses for OpenPLC, an open-source development tool that imitates PLC ladder diagrams. They used the Raspberry Pi to run the OpenPLC software and the OPC UA server, and they used Wi-Fi to link four OPC UA clients to the controller. The primary disadvantage of this type of system is the controller's limitations on the flexibility of the applications. Because a unique external UniPi unit—an industrial IO connection board—was utilized for OpenPLC compatibility, the migration procedure was also impacted. Additionally,

as the OpenPLC project did not support Radio Frequency Identification (RFID) devices, a specific API was created from scratch for these [14].

In the study, “Digital Twin Architecture of a SCADA System with Embedded System Connections” was assessed by Abdelsattar, Park, and Marzouk et al. (2022). This paper presents an architecture integrating SCADA systems with digital twin concepts, aligning with Industry 4.0 trends. Using a FESTO MPS processing station as a proof of concept, the authors propose a client-based system using OPC UA and Ignition software to create digital twins of sensors and actuators. The system’s monitoring and control capabilities are enhanced through mobile device connectivity and a Raspberry Pi controller interfaced with traditional microcontrollers. The demonstration confirms the feasibility of this approach for building digital twins within factory automation [15].

In the study, “An Immersive Digital Twin Applied to a Manufacturing Execution System for the Monitoring and Control of Industry 4.0 Processes” by Caiza and Sanz (2024). This research proposes an architecture for industrial process monitoring and control within a Manufacturing Execution System (MES) using an immersive Digital Twin (DT). Integrating Industry 4.0 technologies—such as CPS, IoT, robotics, AR/VR, and OPC UA—the system is implemented in a smart factory lab with Festo equipment, following ISO 23247 standards. Key features include 3D production line visualization, real-time data collection, dynamic digital modeling, and AR/VR user interaction. Results show improved interoperability, real-time issue detection, and enhanced manufacturing efficiency, enabling customization and innovation [16].

In the study, the energy industry's use of AI big models is investigated by Wang, Peng, and Huang (2024), with a focus on Virtual Power Plants (VPPs). Large models improve VPP operations, market strategies, data management, and user interaction, increasing efficiency, security, and service quality, according to the research. Problems including system integration, model openness, and data privacy are also covered. Techniques to deal with these problems are put forth, encouraging the intelligent and sustainable growth of VPPs using AI technologies [17].

In the study, the viability of employing the Open Platform Communication Unified Architecture (OPC UA) protocol for real-time reporting is examined in mobile network-based Virtual Power Plants (VPPs) by Xia (2024). The study assesses OPC UA as a contemporary substitute for antiquated protocols like IEC 60870-5-104, with a focus on the Finnish TSO Fingrid and the power reserve market. The findings of the simulation show that OPC UA improves communication dependability and efficiency, which supports its potential to update VPP operations and make it easier to integrate Distributed Energy Resources (DERs) into the smart grid [18].

In the study, to facilitate distributed solar generation simulation, 3D visualization, and real-time analysis, a modular metaverse architecture for power systems was created by C. Menezes et al. (2024). It demonstrated improved monitoring, operational insights, and decision-making capabilities when tested on a solar power plant at Fluminense Federal University in Brazil. It incorporated SCADA data, fault detection, and weather forecasts [19].

In the study, large language models were used in the development of a generative AI system to automate data extraction, graph updates, and report creation in government organizations by R. Gupta et al. (2025). When tested on *the World Economic Situation and Prospects* report, it improved efficiency, consistency, and analytical insights while achieving error rates of 0.87–17.46%. A review process makes it possible to continuously improve models [20].

In the study, an architecture utilizing OPC UA, IBH Link UA, and the Bluebird platform is suggested for tracking and visualizing automated workplaces by M. Vagaš et al. (2025). Real-time diagnostics, seamless communication, and remote management are made possible by the solution without requiring the replacement of all equipment. Capability Index (CpK) values of 0.58–0.61 and Cp values of 0.58–0.63 were obtained from the evaluation, indicating potential for enhanced process stability. In accordance with Industry 4.0/5.0 standards, the method provides an affordable, interoperable foundation for digitalizing industrial processes [21].

Lastly, to operate aggregated microgrid systems in a safe, scalable, and real-time manner, a three-layer OPC UA-based architecture is suggested by C. Lee et al. (2025). The design supports both real-time BESS control and high-level scheduling by integrating the Distributed Microgrid, Communication Platform, and Microgrid Aggregation layers. By utilizing edge

cloud computing and dynamic information models, it ensures interoperability across diverse devices while reducing network overhead. Up to $17.86\times$ latency reduction is demonstrated via experimental validation, demonstrating compatibility for cloud-integrated microgrids and conformance with Industry 4.0 criteria [22].

As a result, OPC UA-based architectures and reporting systems for a variety of applications have been the subject of multiple independent research; however, none of them particularly address the automated reporting systems of thermal power plants. By combining these technological advancements into a coherent framework, this article aims to close this gap by offering a methodical, efficient, and useful methodology that improves comprehension and real-world application in the context of power plant monitoring and reporting.

2.2. PLC Systems

Programmable logic controllers are microprocessor-based controllers with input-output units and communication interfaces that are appropriate for control circuits, industrial automation solutions, and other applications. In 1969, Modicon manufactured the first commercial PLC to replace regulated circuits. PLCs' internal structure, which includes a processor, memory, and input-output modules. System memory, which houses the system unit, program memory, which houses the user unit, and data memory make up memory. Programme memory is where user-written programmes are stored, and system memory is where the manufacturer's PLC operating system is stored. The general overview of the architecture of a Programmable Logic Controller (PLC) is presented in Figure 2.2.

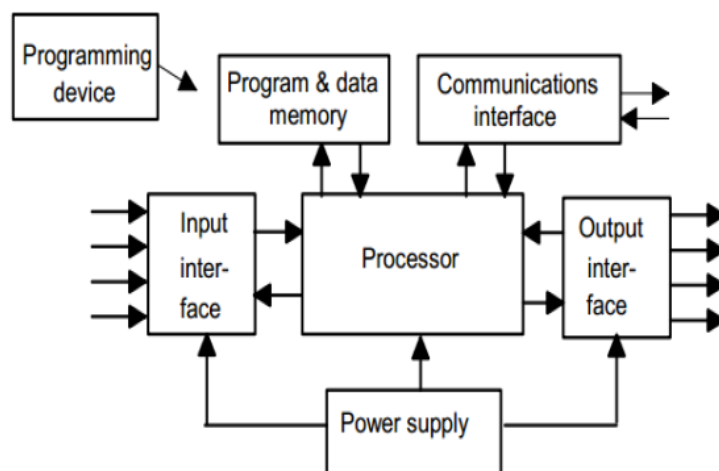


Figure 2.2. The Architecture of Programmable Logic Controller (PLC) [23]

The amount of the input image and the distribution of the output image make up the data unit. The memory location where the signal status at the PLC input points is kept is called the input image memory. The memory location where the program's continuation process and the output points' state are kept is called the output image unit.

The basic components of Programmable Logic Controllers (PLC)s can be shortly described as **Central processing unit (CPU)** maintains an internal program in "non-volatile" memory, meaning that when the power is switched off, the software remains intact. It gives the PLC instructions on how to carry out the duties that running the control commands contained in the user's programs and communicating with other devices, including networks, programming devices, I/O devices, and other PLCs. The other one is **power supply** that supplies the main voltage required for the electronic module of the PLC (I/O logic signals, CPU, memory unit and peripheral devices). Generally PCs and laptops are used for **programming device** to programme the PLCs. It can be shared by several controllers and is detachable from the PLC cabinet.

Input modules link an input device like a panel or sensor to a programmable logic controller (PLC). It serves as a conduit between the CPU and the real-time status of the process variable. Analog input modules receive signals from RTDs and thermocouples that range from 4 to 20 mA and 1 to 5 V. They also receive signals from level transmitters, flow, pressure, ohms, and millivolts. Digital input modules receive 24 V DC, 115 V AC, and 230 V AC signals from switches, pushbuttons, relays, pumps, and valves on off status [24].

Output modules act as link between the CPU and the output devices in the field. Analog output modules supplies output signals in the form of 4 -20 mA or 1-5 V to control valves, speed and vibration devices. Digital output modules supplies output signals in the form of 24 V DC, 115 V AC, 230 V AC to switches, solenoid valves, lamps, actuators, dampers, pumps and valves that are on off control.

Bus system is established with each sensors and actuators that are connected to the I/O modules of the PLCs via point-to-point wire, which is intended to be called by field buses.

2.3. SCADA Systems

The initial letters of the terms Supervisory Control and Data Acquisition were combined to produce the acronym SCADA. It was first used at the 1973 PICA (Power Industry Computer Applications) conference. The development of SCADA systems, which are essential in today's industrial automation environment, keeps pace with advancements in technology. Strip card recorders, signal bulbs, and measuring equipment make up the earliest SCADA systems.

It is a kind of software application program used to control processes. Controllers, network connections, input/output electrical signals, communication devices, and software make up SCADA systems [25]. It monitors, controls and manages industrial processes by combining hardware and software components. It collects data from field devices such as sensors and controllers, processes it and then uses a user-friendly interface, such as a SCADA screen or panel, to provide actionable insights. The general overview of a SCADA System is presented in Figure 2.3.

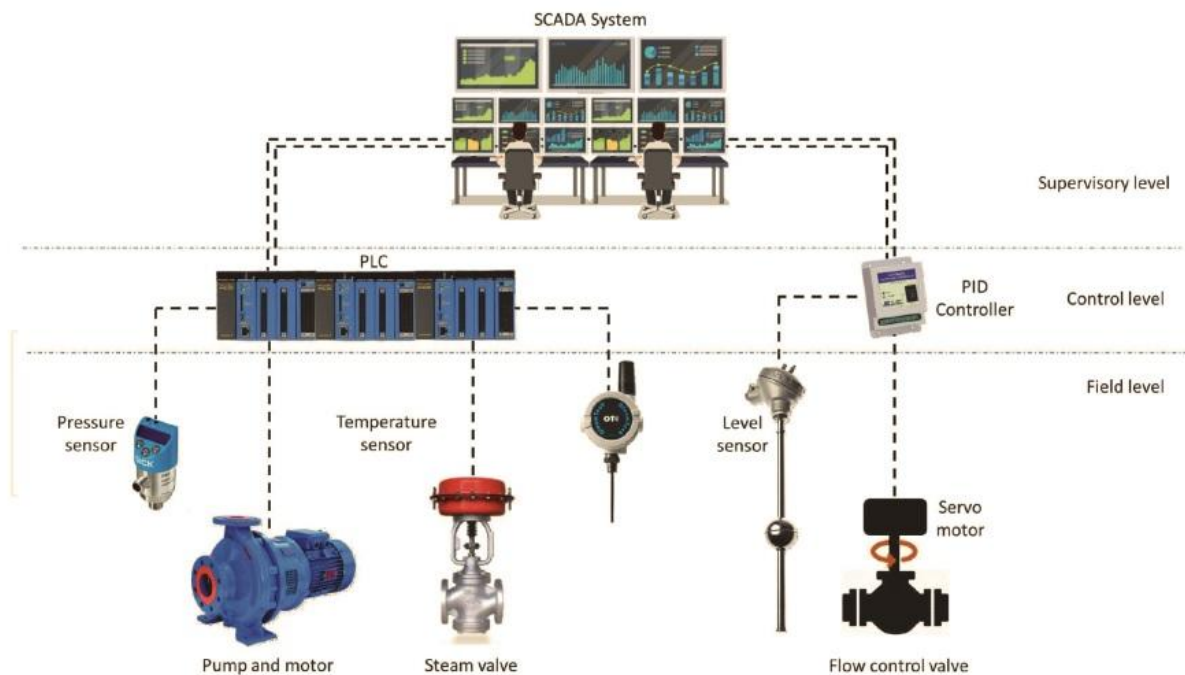


Figure 2.3. SCADA System Overview [26]

2.3.1 SCADA system architecture

The SCADA system is often a centralized system that keeps an eye on and manages the whole region. It sits on top of the hardware and is a pure software package. A supervisory system collects process data and provides the process with directives and control. The SCADA, also referred to as an RTU, is a remote terminal unit. One sample SCADA architecture can be seen in Figure 2.4.

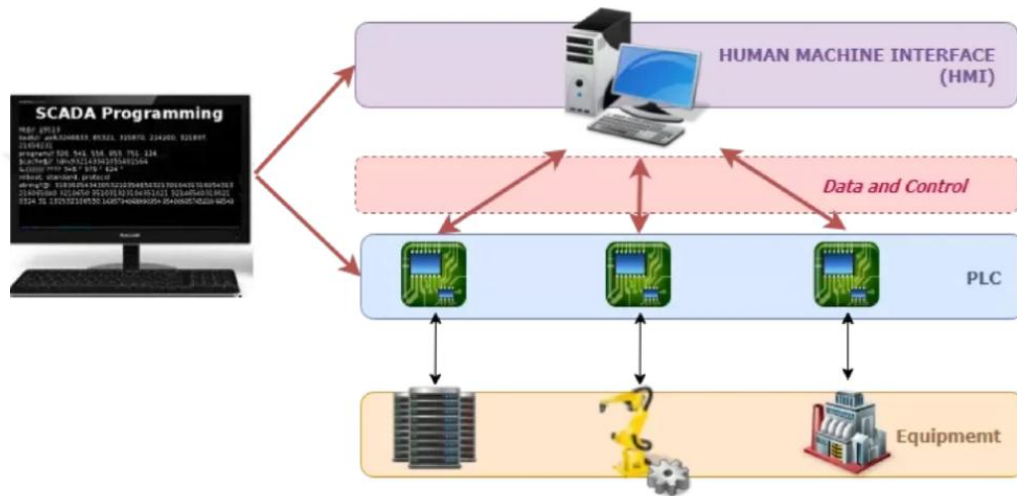


Figure 2.4. The SCADA Architecture [27]

The majority of control actions are carried out automatically by PLCs or RTUs. The programmable logic converter that makes up the RTUs can be adjusted to meet particular needs. For instance, the water flow in a thermal power plant can be adjusted to meet individual needs or set to a fixed value.

In addition to enabling warning conditions in the event of a flow loss or high temperature, the SCADA system enables operators to modify the flow's set point. The situation is shown and recorded. The loop's total performance is tracked by the SCADA system. Client devices can connect via wired and wireless technology thanks to the SCADA system, which is a centralized system. All types of industrial processes can be fully controlled by the SCADA system. For instance, the SCADA system can automatically open a release valve in a gas pipeline if excessive pressure is accumulating [25]. The working principle of a SCADA system is presented in Figure 2.5.

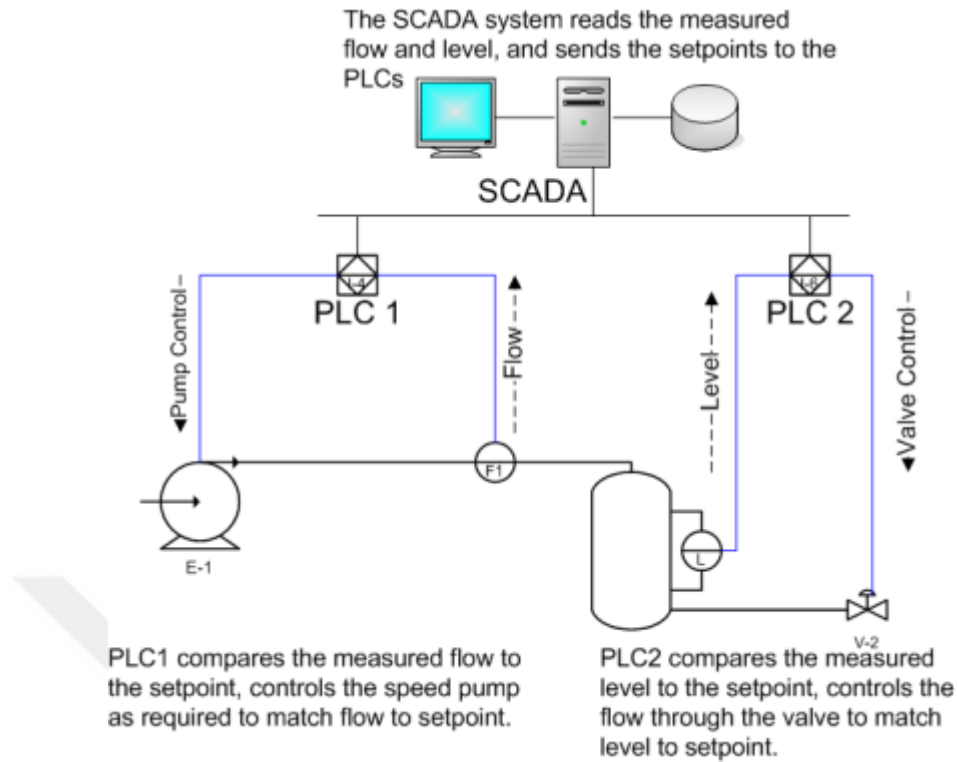


Figure 2.5. Working principle of a SCADA system [25]

2.3.2 Functions of SCADA systems

Data Acquisitions, data communication, information/data presentation and monitoring/control are the basic functions of the SCADA systems.

A communication network, sensors, RTUs, and controllers all carry out these tasks. RTUs are utilized to transmit the vital data to the controller and show the system's current state after the sensors have gathered it. Other system components can be instructed by the user based on the system's current state. The communication network is responsible for this function.

- **Data acquisitions:** Thousands of parts and sensors make up the real-time system. Understanding the condition of specific parts and sensors is crucial. For instance, some sensors track the amount of water that flows from the reservoir to the water tank, and others track the pressure at which the water is released.
- **Data communication:** The SCADA system connects users and devices over a wired network. Numerous sensors and components used in real-time applications need to be operated remotely. Internet communications are used by the SCADA system. Using particular protocols, all data is sent via the internet. RTUs are used to communicate

between sensors and network interfaces since sensors and relays cannot connect with the network protocols.

- **Information / Data presentation:** The real-time SCADA system has thousands of sensors and alarms that cannot be managed at the same time, unlike regular circuit networks, which have a few indicators that are visible and controllable. The SCADA system provides all of the data collected from the different sensors through the human-machine interface (HMI).
- **Monitoring / Control:** To control each device and show the state of the control area, the SCADA system employs various switches. The control station can use these switches to turn on or off any portion of the process. Although SCADA systems are designed to operate automatically without human involvement, human assistance is nevertheless used in emergency situations [25].

2.3.3 Basic components of SCADA

The tasks performed by different types of components can be described shortly as below:

- **Field devices or Sensors** (either digital or analog), actuators and control relays that directly interface with the managed system.
- **Remote Telemetry Units (RTUs)** are small computerized units deployed in the field at specific sites and locations. RTUs serve as local collection points for gathering reports from sensors and delivering commands to control relays.
- **Programmable Logic Controller (PLC)** is a type of programmable computer used mostly in the industrial sector to control electromechanical processes. A PLC's primary purpose as a specialized industrial computer device is frequently referred to as an industrial PC [28].
- **SCADA master units** are larger computer consoles that serve as the central processor for the SCADA system. Master units provide a human interface to the system and automatically regulate the managed system in response to sensor inputs.

- **The communication network** connects the SCADA master unit to the RTUs in the field.
- **Human-machine interface (HMI):** The system and the operator can communicate via all these channels. The user is not only shown pure data, but also information that has been processed at field level. The data is organized and presented in such a way that the operators using the HMI to control the process and can make supervisory decisions. Moreover, alarms are displayed to alert operators whenever potentially unsafe system conditions and events exist (OPC A&E). For instance, the alarm for the tank water level is set at 60% and 70%. An alert will sound if the water level rises above 60%, and a critical warning will sound if the water level rises above 70%. One sample overview of HMI is presented in Figure 2.6.



Figure 2.6. Human Machine Interface

- **Database :** The retention of data from previous processes is crucial. It can be useful for detecting system errors, collecting logistical data and optimizing the process in the future. The database is connected to the HMI to provide the trend data.
- **Advanced control and diagnostic systems:** Most PLC devices are still underpowered to run sophisticated control and diagnostic algorithms. While basic control is done on a PLC, the SCADA level is typically a higher level of control. For example, the PLC uses the PID algorithm, while the SCADA level feedforward algorithm optimizes the PID settings. Sometimes a complex control method cannot be split into two components, so

field-level control is required. In such cases, the use of a dedicated device or a more advanced PLC is required. To meet the requirements of process control, certain PLCs have an integrated signal processor or an FPGA [25].

2.3.4 The usage areas of SCADA systems

SCADA systems are used in the areas such as: Generation and Distribution of Power, Public Transport, Water and Sewage Systems, Manufacturing, Industries & Buildings, Communication Networks, Oil & Gas Industries, Power generation, transmission, and distribution, Water distribution and reservoir system, Public buildings like electrical heating and cooling system, Generators and turbines, Traffic light control system, etc [29].

2.3.5 Advantages of SCADA systems

The system can be monitored at any time with savings of time and effort. Enhanced operational visibility and control can be available with data collection and analysis for production. System energy monitoring and conservation can be handled against penalties (Compensation etc.) Getting information about the situation in the field and immediate intervention and recording interventions made to the system. Instantly getting information about the operation of the system (status of switches etc.) has great advantages. Detecting areas with a risk of failure is available with the alarm monitoring and also additional devices can be easily mounted on the structure.

2.3.6 Disadvantages of SCADA Systems

The hardware units and dependent modules make it complicated. To maintain it, analysts, programmers, and knowledgeable operators are required. Installation of a SCADA system requires high costs. It is possible to raise unemployment rates. Both limited software and hardware devices are supported by this system. One sample for enhanced operational visibility and control on SCADA systems is presented in Figure 2.7.

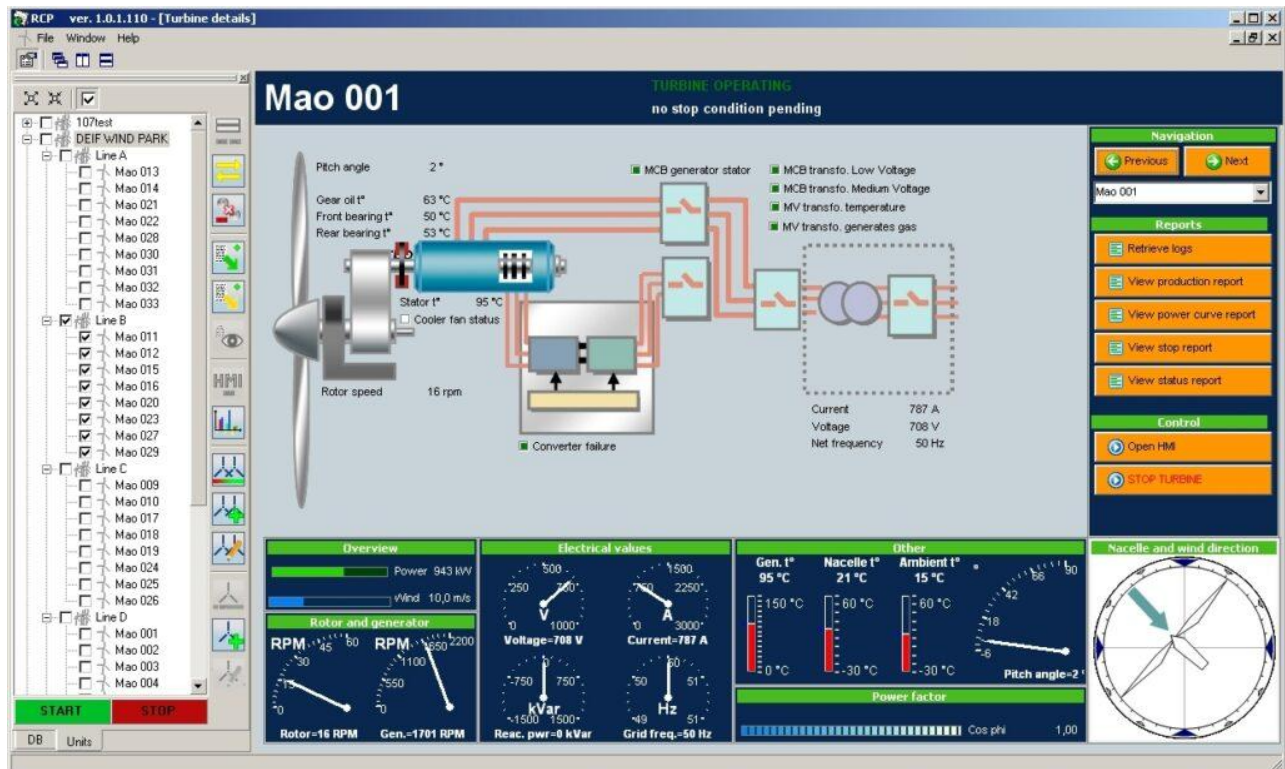


Figure 2.7. Enhanced Operational Visibility and Control on SCADA systems [30]

2.4. DCS

The initial letters of the terms **D**istributed (or **D**ecentralized) **C**ontrol **S**ystems were combined to produce the acronym DCS. It is an automated control system with specialized design that is made up of geographically dispersed control elements around the plant or control region. In contrast to a centralized control system, which has a single controller at a central location, DCS has a dedicated controller for each process element, machine, or group of equipment. DCS is made up of numerous local controllers spread over different plant control areas, all of which are connected by a fast communication network. One sample overview of DCS is presented in Figure 2.8.

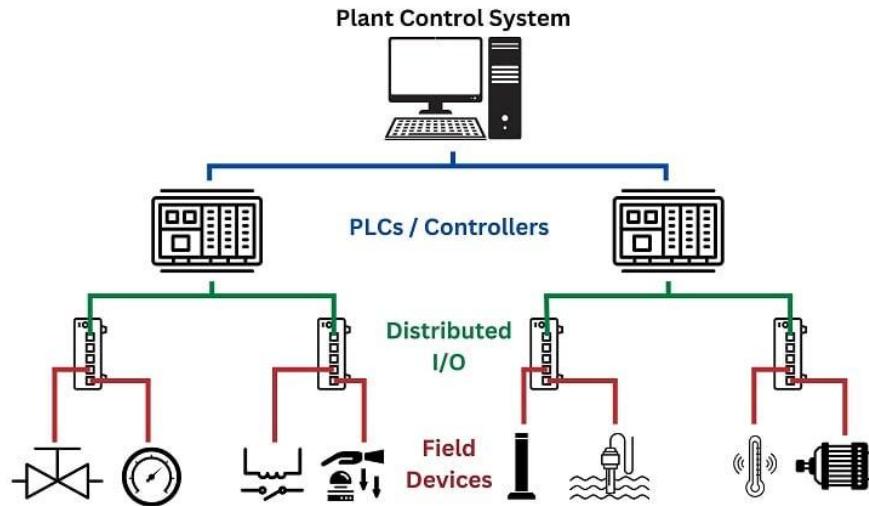


Figure 2.8. DCS Overview [31]

In a DCS, many controllers—microprocessor-based devices dispersed both functionally and geographically throughout the plant and located close to the areas where control or data collection tasks are carried out—are responsible for carrying out data acquisition and control duties. These controllers are able to communicate among themselves and also with other controllers like supervisory terminals, operator terminals, historians, etc.

Field equipment like sensors and actuators are connected to dispersed individual automatic controllers. Through various field buses, these controllers make sure that the collected data is shared with other hierarchical controllers. The controllers communicate with one another using various field buses or common communication protocols. Some of these include Profibus, HART, arc net, Modbus, OPC etc.

Large-scale manufacturing or processing facilities where several continuous control loops need to be monitored and managed are best suited for DCS. Dividing control responsibilities for distributed controllers has the primary benefit of allowing the plant to continue operating even in the event of a DCS failure.

Through the I/O modules, which gather information from the sensors and transmit it to the controllers, the DCS continuously monitors the plant's condition. Using control algorithms, the controllers process this data and produce control signals, which are then transmitted to the actuators via the I/O modules. Based on these control signals, the actuators then modify the plant's operation to guarantee that it runs within the intended parameters.

Additionally, the DCS offers a high degree of redundancy, with each controller able to take over the responsibilities of another in the event of a breakdown. This guarantees that even in the case of a controller failure, the system will continue to function properly. With strong security mechanisms in place to guard against cyber threats, the DCS also offers a high level of security.

2.4.1 Architecture of DCS

A Distributed Control System (DCS) is characterized by three main attributes. Firstly, it segments diverse control functions into small, semi-autonomous subsystems linked by a rapid communication bus, handling tasks like data collection, process control, and information management. Secondly, DCS integrates advanced control techniques to automate manufacturing processes. Lastly, it systematically arranges and unifies these various subsystems through a structured command and information flow, creating a single, comprehensive automation system. The core components of a DCS architecture typically include an engineering workstation, an operational station (HMI), a process control unit (local control unit), smart devices, and a communication system [32]. The architecture of a DCS is presented in Figure 2.9.

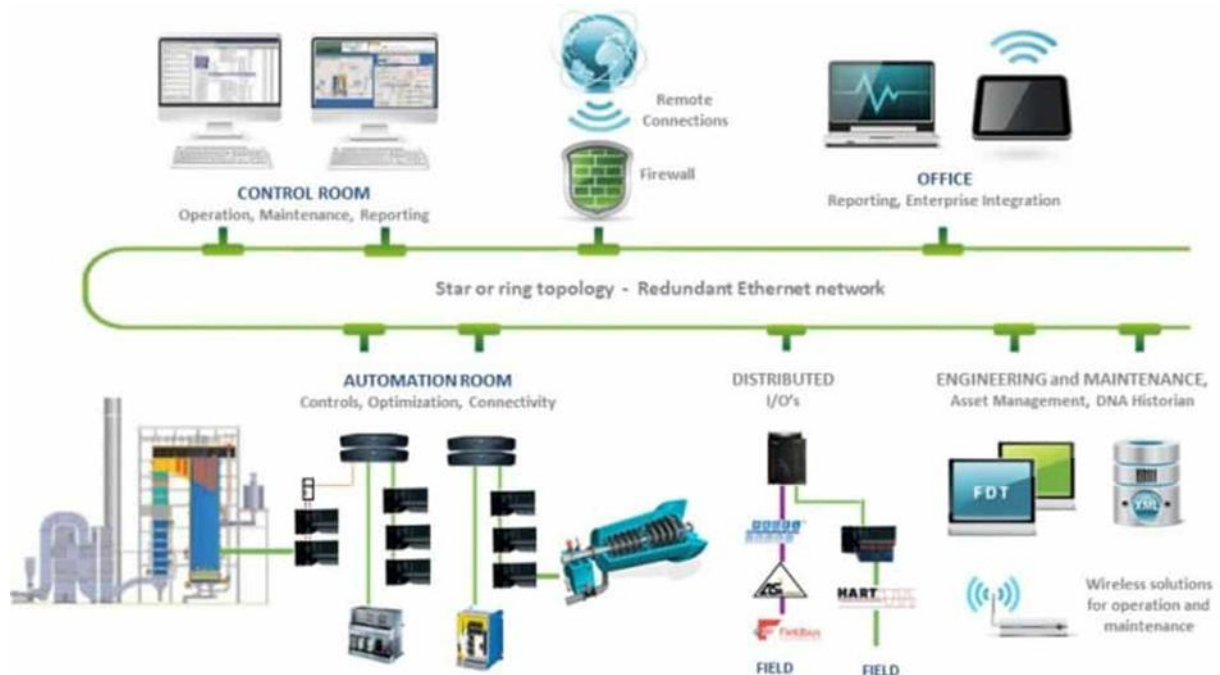


Figure 2.9. DCS Architecture [33]

2.4.2 Basic Components of DCS

The basic components of DCS are described below:

- **Servers** are used for processor-level data collecting. Furthermore, they are used to store historical data that may be used for trends and reports. They oversee the flow of data from the Operator Station to the processors on the plant floor. Operator Station-level communications are often conducted via industrial Ethernet.
- **Engineering workstation** is in charge of overseeing the distributed control system as a whole. It could be a PC or any other computer with engineering-specific software installed. The user can perform engineering tasks like establishing new loops, establishing multiple input and output points, altering sequential and continuous control logic, configuring a variety of distributed devices, creating documentation for each input/output device, and more with the help of this engineering station's robust configuration tools.
- **Operating station or HMI:** Plant parameters are operated, monitored, and controlled via this component. A PC or other monitoring device with a separate software tool that allows the operator to observe process parameter values and conduct appropriate control action can be used. Operating stations can consist of one unit or several units. A single unit can display parameter values, trend information, sound an alarm, and more. Multiple units or PCs can carry out different tasks, such as displaying parameters, archiving trends, logging and acquiring data, etc. Other names for it include process station, distribution controller, and local control unit. One or more process stations that can be expanded with various I/O unit types can make up a distributed control system [32]. A sample schematic for an operating room and the components can be seen in Figure 2.10.



Figure 2.10. Operating stations / process station / distribution controller / local control unit [34]

- Distributed controller or local control unit:** It can be positioned close to field devices, such as sensors and actuators, or at specific points where the communication link connects these field devices. It directly operates field equipment after receiving instructions from the engineering station, such as set point and other settings. Additionally, these controllers are in charge of supplying the servers with the data, which the graphical user interface then uses [25]. Usually, industrial Ethernet is used to connect to the preceding level. When ethernet cabling runs are too long, fiber optics may be utilized. At this stage, a robust CPU module (the processor), a field bus or communication module with extended field bus capacity, and either directly or remotely linked I/Os make up these controllers. The master controllers that keep an eye on the I/O modules and individual processors. The processor follows the logic and takes the necessary actions to maintain process control. Unit's I/O modules are connected to field devices such as sensors and actuators. Smart field devices are those that can be directly connected to a field bus (like Profibus) without the need for an I/O module. Both analog and digital inputs and outputs can be sensed and controlled by analog and digital I/O modules. Depending on the quantity of inputs and outputs, these modules can be expanded. It gathers data from various field devices and transmits it to engineering and operations stations. A sample schematic for DCS and its components can be seen in Figure 2.11.

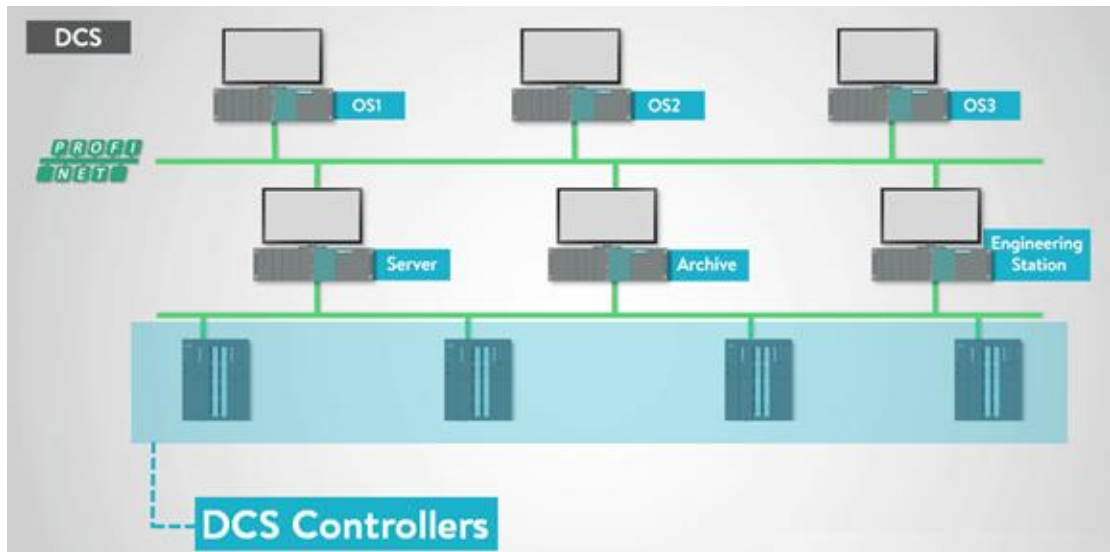


Figure 2.11. DCS Controllers

- Communication media and protocol:** Transmission cables, including coaxial, copper, and fiber optic cables, as well as occasionally wireless ones, are used to carry data over communication media. Depending on how many devices will be connected to this network, different communication methods will be chosen. Devices like transmitters, switches, valves, motors, remote or distributed I/O, etc. would be considered components at this level [35]. Profibus supports 126 devices or nodes, whereas RS232 supports only two. These protocols include the foundation field bus, Ethernet, DeviceNet, Modbus, CAN, OPC and others. DCS uses two or more communication protocols between two or more locations, such as between distributed controllers and supervisory control stations like operational and engineering stations, and between field control devices and distributed controllers [25].

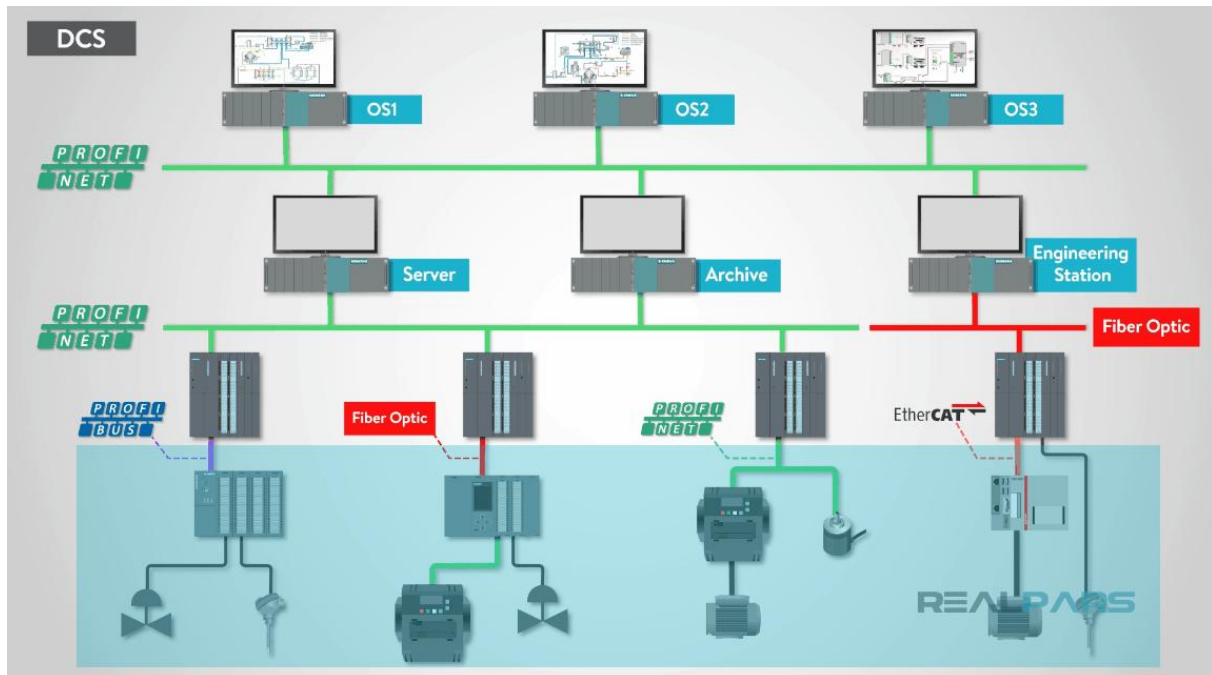


Figure 2.12. DCS Communication media [35]

2.4.3 Key Elements of DCS

- Managing complex procedures:** PLCs, or programming logic controllers, are used in factory automation structures to monitor and regulate process parameters at high speeds. However, PLCs are unable to manage complex architectures because of the limitations of several I/O devices. However, DCSs are able to manage complicated procedures. For complicated control systems with a large number of I/Os and specialized controllers, DCS is therefore recommended. These are employed in manufacturing processes, such as batch process control, where the design of several items is done in several steps.
- Redundancy concept:** DCS provides redundant features at every level to enable system availability when required. Compared to other automation control devices, it is a little better at returning to steady-state performance following any disruptions, whether scheduled or unexpected. By ensuring that the system continues to function normally even in the face of occasional anomalies, redundancy increases system reliability.
- Function blocks variation** is used to handle large, complicated systems, DCS provides a variety of algorithms, more standard application libraries, and pre-tested and pre-

defined functions. Because of this, programming to control different programs is simple and takes less time.

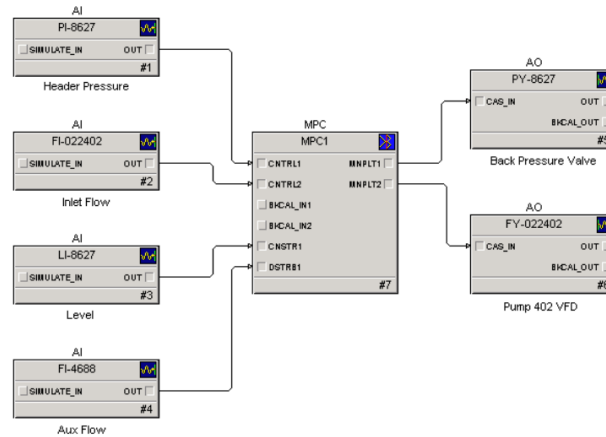


Figure 2.13. Emerson DeltaV PredictPro implementation with Function Blocks [36]

- **Advanced HMI screens** like in the SCADA system, DCS may be monitored and controlled using HMIs (Human Machine Interfaces), which serve as the system's central component and give the operator enough information to charge over a variety of processes. However, DCS covers constrained areas, while this kind of industrial control system covers wide geographical areas. The entire process plant is brought to the control room as a PC window using an effective DCS HMI screens. An efficient user interface is provided via trending, logging, and graphical depiction of the HMIs DCS's robust warning system enables operators to react to plant conditions faster.
- **Security:** Plant safety results from having access to control different processes. For improved industrial automation control, the DCS architecture provides the ideal secure method to manage system functions. Additionally, security is offered at several levels, including operator, entrepreneur, engineer, etc.
- **Scalable platform:** By increasing the number of clients and servers in the communication system as well as the number of I/O modules in distributed controllers,

the DCS structure may be scaled according to the number of I/Os from small to big server systems [25].



Figure 2.14. Effective DCS HMI screens [37]

2.4.4 DCS from different vendors

ABB- Freelance 800F and 800 xA , Yokogawa- Centum CS 3000 and 1000, Honeywell-TDC 3000, Emerson- Delta V Digital Automation , Siemens- Simatic PCS 7 / TIA Portal / SPPA T3000 , GE Vernova Mark V1e and Allen- Bradley- NetLinx are some of the products from major vendors [32].

2.4.5 The usage areas of DCS

DCS is mostly utilized in industries including petrochemical and refineries, chemical factories, car manufacturing, power plants, sewage and water treatment facilities, pharmaceutical manufacturing, food processing, and agriculture.

2.4.6 Advantages of DCS

Compared to other kinds of control systems, DCSs offer a number of benefits such as:

- **Enhanced control over the process:** To provide precise and accurate process control, DCSs employ sophisticated control algorithms like PID control.
- **Scalability:** Expanding DCSs to manage bigger and more intricate processes is simple.
- **Accessibility:** A computer or mobile device may be used to remotely access DCSs, enabling process monitoring and control.
- **Safety:** To increase process safety, DCSs may be used to install safety interlocks and alarms.
- **Redundancy:** Replicated controllers and servers are common in DCSs, which increases system dependability and reduces downtime.
- **Improved data collection and analysis:** Large volumes of process data may be gathered and stored by DCSs for analysis and process improvement.
- **Flexibility:** DCSs may be used with a number of input and output devices and are easily programmed to control a wide range of operations.
- **Integration:** PLCs, MES systems, SCADA systems, and other systems may all be readily linked with DCSs to offer a complete control and monitoring solution.
- **Easy Maintenance:** A common feature of DCSs is their modular architecture, which facilitates system maintenance, upgrades, and replacement.
- **Cost-effective:** Compared to conventional hardwired control systems, DCSs are more affordable options for automating and managing intricate and sizable operations.

2.4.7 Disadvantages of DCS

Compared to other kinds of control systems, DCSs has some disadvantages. The cost of buying, installing, and maintaining a DCS can be high. Additionally, because they are intricate systems with several parts, they can be challenging to comprehend and manage. As a result, operating and maintaining it calls for specific training, which can be expensive. Furthermore, DCSs are susceptible to hardware malfunctions and software problems even in networks since they

depend on both hardware and software components. The entire system will not function if the network goes down. Additionally, DCSs are susceptible to cyberattacks, which may result in system failure or shutdown. It may be challenging to examine and comprehend process data when DCSs lack sophisticated data visualization capabilities. It may be challenging to remotely access and manage certain DCSs because to their restricted mobility.

2.4.8 Differences between SCADA and DCS

Despite being monitoring and control systems in industrial settings, DCS and SCADA serve distinct purposes. Although there are some hardware and component similarities between DCS and SCADA, end applications have specific needs that set a reliable and affordable DCS apart from a workable SCADA system. Table 2.1. lists a summary of some of the distinctions between DCS and SCADA.

Table 2.1. Differences between SCADA and DCS [38]

Characteristics	DCS	SCADA
Full Form	Distributed Control System (DCS)	Supervisory Control and Data Acquisition (SCADA)
Control Structure	Centralized	Decentralized
Process Type	Continuous	Batch
Number of Process Variables	Larger	Small to moderate
Control Precision	High	Moderate
Communication Protocols	It supports exclusive protocols.	It supports open protocols.
Processing Time	Processing time of DCS is slow.	Processing time for SCADA is fast compared to DCS.
Industries	Oil and gas, chemicals, and power generation	Water treatment, power generation, and manufacturing
Components	Controllers, sensors, actuators, communication network, and operator stations	RTUs or PLCs, sensors, a communication network, and a central server

2.5. OPC Unified Architecture (OPC UA)

OPC stands for Open Platform Communications or OLE (Object Linking and Embedding) for Process Control. OPC is an interoperability standard that facilitates safe and dependable data sharing in several sectors, including industrial automation. It guarantees the smooth exchange of data across devices from various suppliers. A set of guidelines created by software developers, end users, and industry suppliers makes up the OPC standard. These standards outline how clients and servers communicate with one another, as well as how real-time data access, event and alarm monitoring, historical data access, and other applications are accessed. The OPC Foundation (www.opcfoundation.org) is responsible for the development and maintenance of this standard. OPC Community well over the past 10 years, but as technology moves on so must the interoperability standards.

At first, only the Windows operating system could use the OPC standard. As a result, **OLE (Object Linking and Embedding)** for Process Control gave rise to the abbreviation **OPC**. These requirements, now referred to as **OPC Classic**, have been widely adopted by a variety of industries, including utilities, manufacturing, oil & gas, building automation, and renewable energy.

New security and data modeling concerns arose when service-oriented architectures were implemented in industrial systems. To meet these demands, the OPC Foundation created the OPC UA standards, which also offered an open-platform architecture with a wealth of features that was scalable, extendable, and future-proof. **Open Platform Communications** is now referred to by the abbreviation **OPC**. Many members and other technical groups (collaborations) are using **OPC UA** for their interoperability platform for these and other reasons.

OPC always uses the client/server combination. Data transmitted from the PLC to the hardware is converted into OPC protocol via the OPC server for the purpose of making the data accessible to other applications. The OPC Client is a software module that enables applications to acquire data from an OPC Server or conduct supervisory control using an OPC Server [39]. The basis of this architecture for process control and real-time data management is the creation of objects.

In addition, under certain guidelines process control technology and information technologies must be combined. Figure 2.15. can summarize the OPC-SCADA integration.

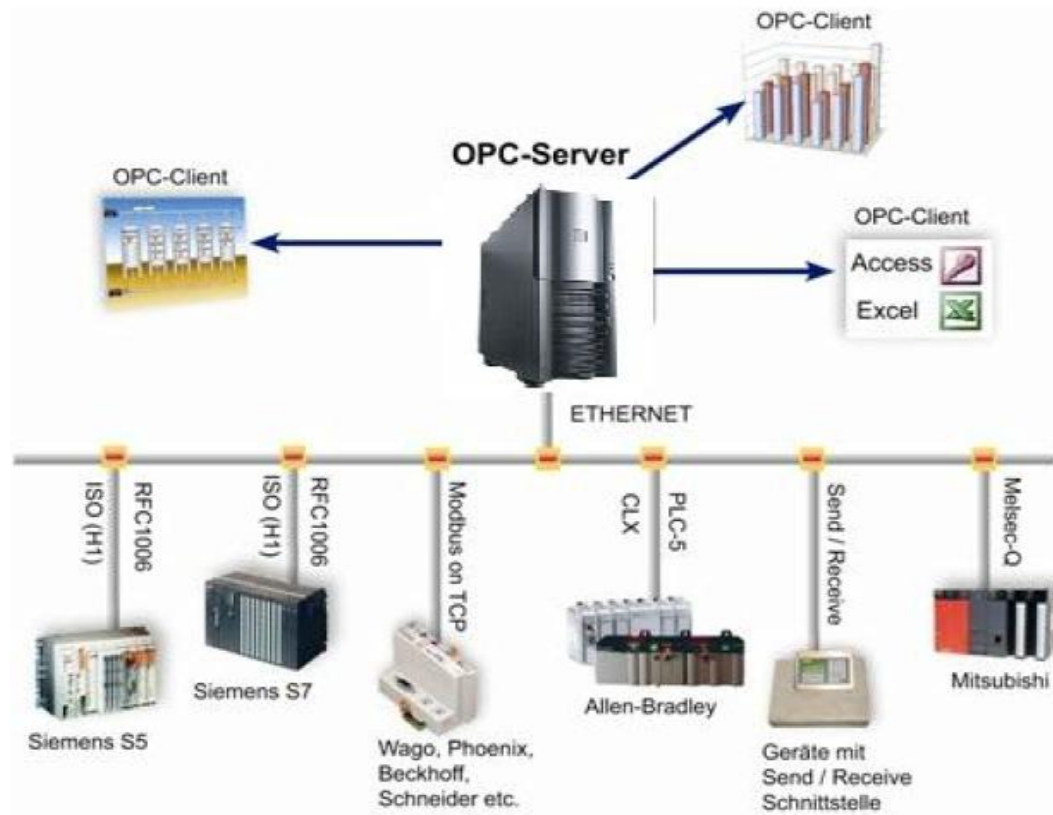


Figure 2.15. SCADA system based on OPC server architecture [40]

The OPC UA server generates the address space with nodes using the OPC UA information model, and then associates the nodes with the variables in the PLC implementation. Finally, the variables and complex structures of the PLC implementation are made available to external OPC UA clients.

2.5.1 How does OPC communicate with a PLC ?

An OPC Client program (such an HMI, Historian, etc.) uses OPC to receive data from an OPC Server. To communicate data with a PLC, however, an OPC Server always use a non-OPC approach.

For instance, suppose a PLC and an OPC server use the Modbus protocol to interact. In this situation, the OPC Server will request specific memory addresses from the PLC that have the information it needs. Modbus is the protocol used for this. Modbus is also used by the PLC to

deliver all of the responses to the OPC Server. This allows the OPC Server to use Modbus to read data from and send data to the PLC. The data is then sent to an OPC Client application after the OPC Server has converted it to OPC "format" from the data it has retrieved from the PLC (using Modbus) [41].

In each case, the OPC Server must know something very specific about the PLC it is connected to. Minimum the protocol or API that the PLC uses must be known. However, most of the time, the integrator must set up the OPC Server for the particular data that the PLC holds, which varies depending on the project. In any instance, any OPC Client application can retrieve data from the OPC Server without needing to know anything about the PLC or its configuration provided the integrator has correctly configured the OPC Server.

2.5.2 Specifications for OPC UA

Parts of the OPC UA requirements are required for IEC standardization. OPC UA is going to be recognized as an IEC 62541 standard. The automation sector has accepted OPC UA requirements as the norm.

OPC UA is made up of distinct model layers with enhanced particulars for some regions. The many levels of information models that OPC UA specifies are shown in Figure 2.16.

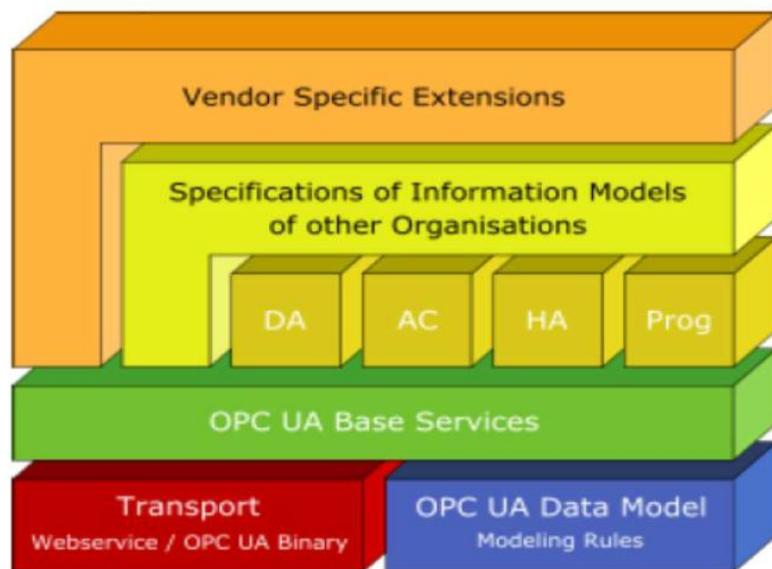


Figure 2.16. OPC UA layers [42]

2.5.2.1 *Data Access (DA) Specification*

OPC UA Data Access is a server-client interface standard that ensures seamless access to devices like HMIs, SCADA systems, ERP/MES systems, and PLCs. It guarantees that an OPC UA client receives data including value, quality, and timestamp in response to requests. A key feature is the real-time data continuity, essential for industrial applications. Key components of OPC UA Data Access include:

- **Discovery:** Allows users to locate OPC UA products on a network or PC.
- **Browsing:** Enables navigation through a server's address space to list available nodes.
- **Reading:** Lets users read multiple nodes in a single call, retrieving value, quality, timestamp, and success/failure status.
- **Writing:** Allows writing to one or more nodes in a single call, with individual success/failure codes for each.
- **Subscription:** Enables servers to notify clients when a node's value changes.

These capabilities apply to devices like I/O cards, controllers, serial-linked I/O modules and PCs.

2.5.2.2 *Alarm & Conditions (AC) Specification*

The OPC UA Alarm and Conditions standard is designed for use in process automation systems to manage alarms and conditions. It enables real-time notifications and displays of system alarms and conditions. Key features of this standard include:

- **Receiving Audit Conditions:** Clients can access audit events, such as user logins, record access, and record modifications.
- **Receiving Alarms:** The server sends alarms to clients, which are then processed and displayed.
- **Responding to Alerts:** Clients can respond to, shelve, acknowledge, and comment on alerts.
- **Event Filtering:** Clients can filter events based on specific criteria.

- **Condition Monitoring:** The OPC UA AC server stores data from sources and evaluates whether specific conditions occur, allowing clients to access these alarms and conditions when requested.

2.5.2.3 *Historical Access (HA) Specification*

OPC UA Historical Access (HA) enables clients to efficiently retrieve historical data for multiple Nodes in a single request. It supports multiplexed parameters, allowing clients to specify start and finish dates for the desired time range and request server-side calculation of statistical aggregates (e.g., Average, Min, Max). Furthermore, OPC UA HA provides functionalities for database data updates, including deleting, updating, and creating historical entries. This contrasts with OPC UA Subscription, which focuses on real-time monitoring and notification of current data changes.

2.5.2.4 *Programs (Prog) Specification*

Within an automation system, programs or procedures may be operated and examined thanks to the OPC UA Programs standard. It uses events to notify clients about the commencement, interception, and outcomes of the program lifecycle. Importantly, the standard makes the program's present status (such as running or interrupted) visible, which is necessary for efficient remote administration and automated process monitoring.

2.5.3 Client-Server Architecture of OPC UA

The OPC UA Server-Client pattern is the fundamental communication mechanism of OPC UA standard that allows software applications to interact consistently. Through their Address Space and Services, OPC UA Servers serve as information providers by making structured data, capabilities, and events available. OPC UA Clients connect to these servers in their capacity as information consumers in order to obtain data, activate services (such as reading and writing data, subscribing to changes, and executing procedures), and carry out certain activities.

A service-oriented design, rich information modeling enabling semantic data description, separation of concerns, and integrated security features are important tenets. Standardization, scalability, flexibility, security, information richness, and platform independence are only a few

advantages that make this pattern a strong choice for smooth integration in industrial automation and other fields. Figure 2.17. summarizes the client-server architecture of OPC UA.

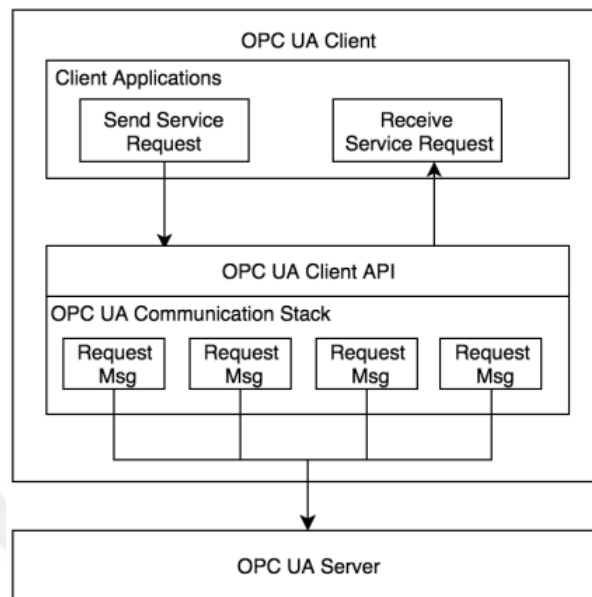


Figure 2.17. Client-Server Architecture of OPC UA [43]

2.5.4 OPC UA Information Model

The OPC UA Information Model provides a structured and standardized way to represent industrial data and functionality within the OPC UA Address Space. This hierarchical structure, composed of Nodes (Objects, Variables, Methods, etc.) with defined attributes and relationships (References), acts as a common language for seamless information exchange between diverse industrial systems. By defining ObjectTypes, VariableTypes, and using Namespaces, the model ensures consistency and avoids naming conflicts. Clients can discover and interact with server data and functions based on this model, enabling interoperability, semantic understanding, scalability, and standardization in industrial automation. Companion Specifications offer industry-specific standard models, while custom models can address unique needs.

2.5.5 OPC UA Address Space Concepts

OPC UA may be thought of as the object-oriented Address Space Model. Typically, clients only represent a selected portion of the entire set of data. There should be public data in those accessible entities to meet this requirement. An OPC UA uses a node model to produce these

addressable entities, and the Address Space is the set of nodes that the OPC UA Server publishes.

The parameters of function blocks in control systems may be thought of as data variables, and the blocks themselves can be thought of as objects.

- **Object Model** identifies “Objects” with regard to Variables and Methods. Besides, it permits connections to other objects to be denoted. Moreover, objects can be written, i.e. OPC UA supplies a way to indicate and display object kinds (classes with associated variables and member techniques) and object models.

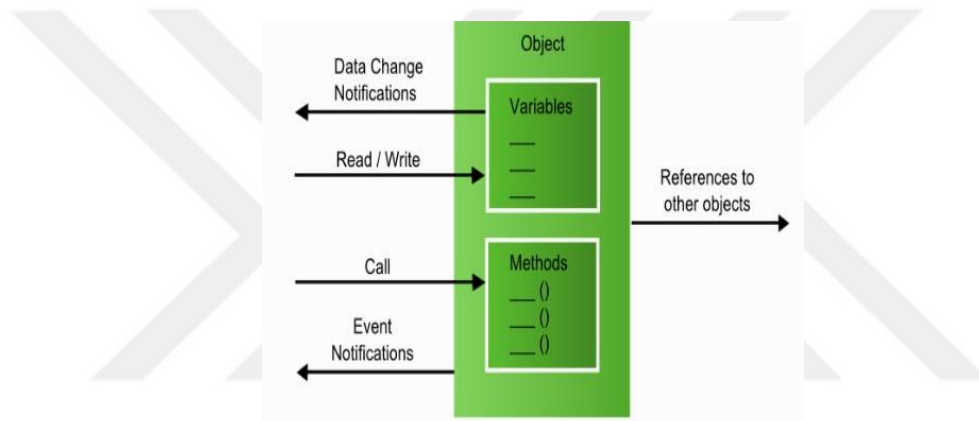


Figure 2.18. OPC UA Object Model [44]

- **Node Model:** The three primary parts of the Node Model are NodeClass, Attributes, and Objects. Their contents are shown in the address space as a group of nodes that are connected by References and identified by Attributes. A set of attributes that are used to identify nodes makes up a node. A lot of references that reflect the semantics of design are also connected to attributes. The most important property, `NodeId`, is utilized to contact the OPC UA node and uniquely identifies a node in an OPC UA server. Clients use the `NodeId` to address Nodes in the Service requirements, and the server generates `NodeIds` while browsing or querying the Address Space. By connecting two Nodes, a Reference may be retrieved by executing a query on a Node.

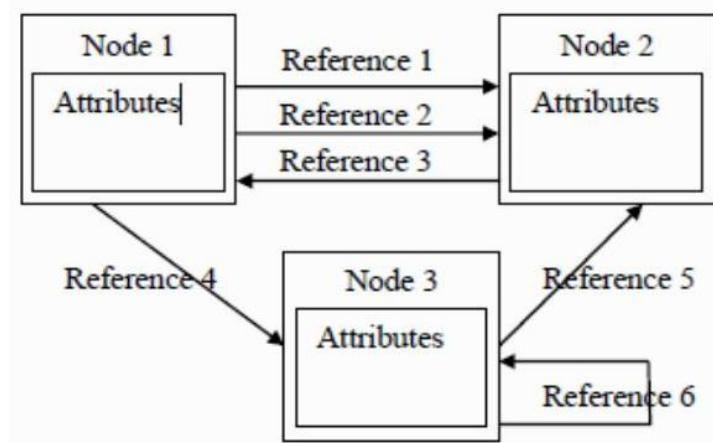


Figure 2.19. Nodes and References [45]

- **Variables:** Clients can read, write, and contribute to changes in the value since variables are used to illustrate values and offer actual data. Variables rely on a data type and are made up of properties and data variables. Properties comprise the server-side specified information of objects. Data variables determine an object's deref.

2.5.6 Usage Areas of OPC UA

Numerous uses exist for OPC-UA systems, some of which are Automotive, Oil Sector, Natural Gas Services, Public Services, Energy Services, Packaging Sector, Building Automation, Robot / Machine Automation, Sewer Systems, Agriculture Sector, Medical and Pharmaceutical Sector, Electrical Network Systems

2.5.7 Benefits of OPC UA

Some of them can be summarised as below:

- **Interoperable:** With its unified and extensible framework, OPC UA allows different devices and systems to communicate with each other, regardless of the manufacturer or platform. Compatible protocols include TCP/IP (Transmission Control Protocol/Internet Protocol used for network and internet communication), UDP/IP (User Datagram Protocol for time-sensitive services like video), WebSockets (real-time server and client communications), AMQP (Advanced Message Queuing Protocol for client/broker communications), and MQTT (Message Queuing Telemetry Transport, for limited bandwidth messaging).

- **Secure:** OPC UA is highly secure due to its encryption, authentication, checksums, data access, and authorization capabilities. It also provides security key management, including passwords, X.509 certificates, and tokens.
- **Scalable:** OPC UA is highly scalable and runs on anything from small embedded devices to enterprise-level servers.
- **Flexible:** The OPC UA architecture is highly flexible, supporting complex data models and allowing for the integration of new information models.
- **Reliable and fault-tolerant:** OPC UA is designed to ensure maximum “up time” in performance-critical applications.
- **Real-time:** OPC UA supports real-time data exchange, which is critical in industrial automation processes and other time-dependent applications.
- **IIoT and Industry 4.0 Compatible:** Because it facilitates connecting machines and systems to cloud platforms and other enterprise-level applications, OPC UA is compatible with IIoT (Industrial Internet of Things) and Industry 4.0 initiatives [46].

2.5.8 Future possibilities for OPC UA

Future possibilities for OPC UA include achieving universal industrial interoperability, empowering edge computing for real-time processing, being essential for creating and maintaining digital twins, serving as the communication backbone for autonomous systems, offering enhanced cybersecurity, driving IT/OT convergence, expanding into new application domains beyond industrial automation, and featuring simplified development and deployment for broader accessibility.

2.6. OPC Integration to Control Systems

An industrial plant consists of numerous subsystems that work together to ensure that the system as a whole delivers the desired performance. In general, the main goal of control system integration is to combine different hardware, software and technologies into a cohesive whole and ensure that the entire system can provide the desired functions.

2.6.1 Control Systems Integration Domain

In this chapter, the structure of a modern factory is explained, with a particular focus on exploring the potential for integrating data flow using the OPC protocol. The so-called pyramid of automation was used to explain the data flow in the factory. A pyramid can be used to illustrate the amount of parts required and the information that is distributed across the different levels of a system. Sample OPC system integration schematic can be seen in Figure 2.20.

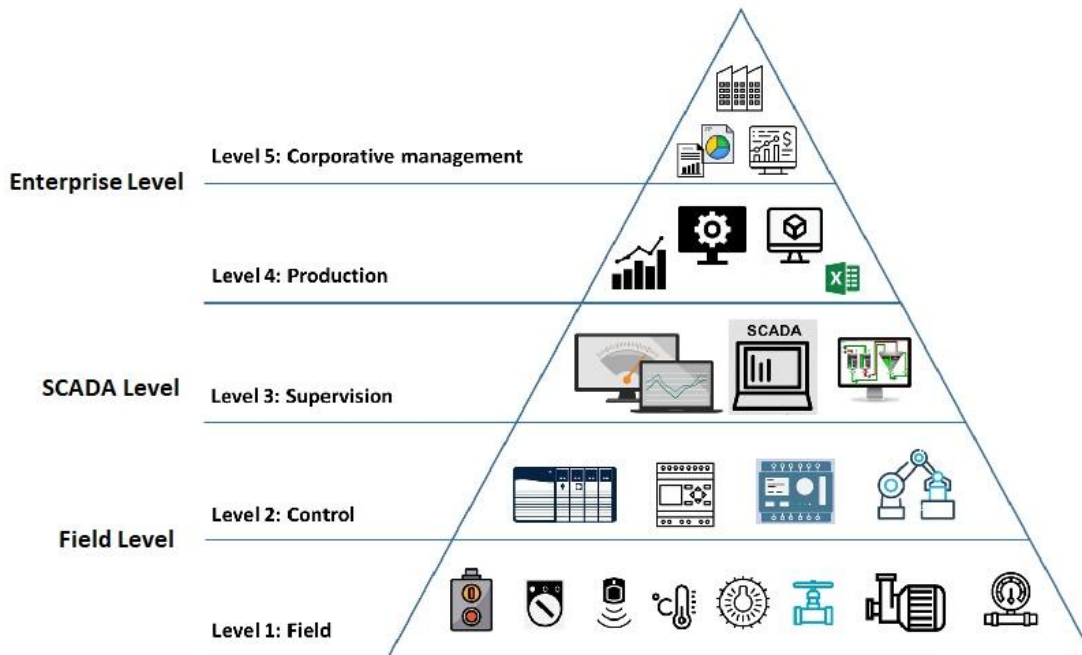


Figure 2.20. Sample OPC System Integration Schematic [47]

As can be seen above, the pyramid is smaller and more information needs to be communicated, but it's also important to remember that there are more devices and that their complexity is lowered at a lower level. There is usually more information at higher levels, although less real-time information is required at lower transmission speeds.

Because of the different data flow requirements, different fieldbuses must be used at the different production levels. It should be possible to communicate via bus systems both within a specific floor and between several production levels. The system integrators are primarily responsible for these connections.

The market for the integration of control systems is growing rapidly today. Due to the significant cost reductions in daily maintenance in manufacturing, the function of system

integration is becoming increasingly important. Both the systems that are being built and the systems that are already in use but still need to be integrated are going through the integration process. The aim is to connect the process control devices with the company's business systems and to achieve integration not only at plant level, but also at true enterprise level [48].

Much has changed since the 1970s, when the trend began to integrate industrial devices into larger installations. Manufacturers and distributors of field devices were initially open to working on sporadic integration projects. As PLCs gained popularity in the 1980s, companies were asked to integrate them on a regular basis and it became clear that uniform standards were needed.

In the late 1980s, software-based human-machine interfaces (HMIs) were developed to enable the monitoring of sensors and control systems as personal computers became more popular and powerful. Since then, integrators have been striving to standardize both software and hardware.

The next phase was the replacement of the earlier generation of long-range analog data acquisition and telemetry systems with PLCs that had an internal fieldbus interface and effective analog-to-digital and digital-to-analog converters. Computers were used for both control and visualization at this time. Soon the outdated architectures of earlier systems were replaced by SCADA (Supervisory Control and Data Acquisition) applications. Rather than choosing one control system vendor and buying all or virtually all the controllers, sensors and the control system itself from them, integrators preferred to use solutions from numerous vendors. A computer-based architecture has proliferated commercial SCADA software. The development of software for industrial use became a new necessity for many software companies. This led to the emergence of the Open Systems movement [49].

The integration of control systems requires a wide range of skills and expertise in many areas. Integrators of industrial systems are usually required to have hardware and software knowledge. This situation requires a broad understanding rather than in-depth information. In addition to interface protocols, software and hardware engineering and general problem solving skills, knowledge of the industrial process is also required. Numerous areas can be integrated. In general, a distinction can be made between vertical and horizontal integration.

Horizontal integration is the process of connecting all the machines on a factory floor. It eliminates separate work areas by combining the entire production process into a single, well-coordinated system. In a factory, for example, all machines on a production line are connected and exchange information about the production flow. By connecting and exchanging data between all information systems at company level, "horizontal integration" also means an improvement in production management and planning.

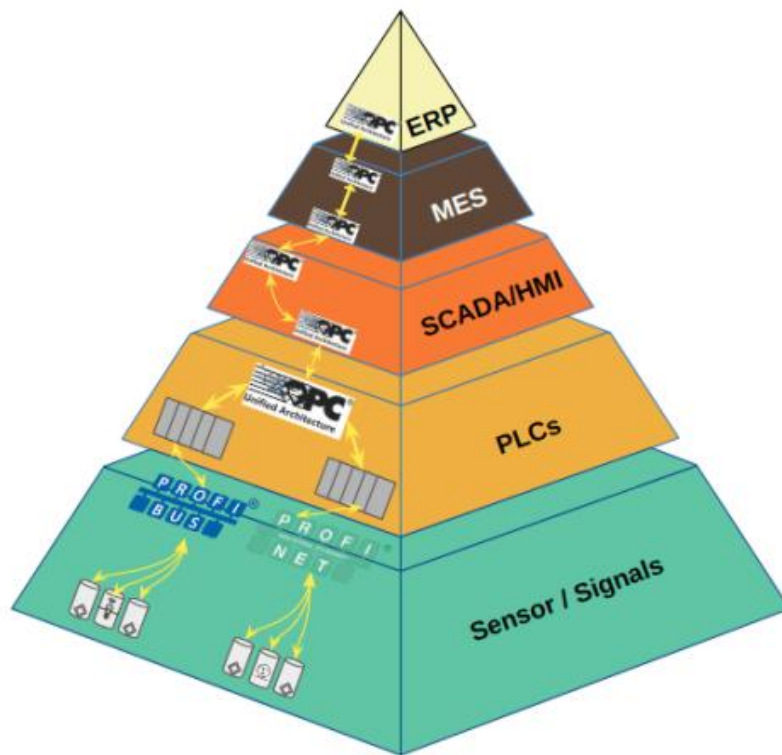


Figure 2.21. Automation Pyramid with OPC UA vertical and horizontal integration [1]

The need to integrate systems set up at different organizational management levels is called vertical integration. In a manufacturing plant, communication between the different factory floors is essential. The simplest sensor on the factory floor can execute work instructions and transmit data to the company intranet in a transparent manner thanks to vertical integration.

The main problem with vertical integration is that it connects multiple factory levels; this often requires the use of a gateway to connect different fieldbuses. To protect the lower levels, a firewall must be used, even if both levels use the same communication layer.

In vertical integration, it is crucial to filter information sufficiently so that only the most important information remains. Supporting management, increasing productivity and reducing downtime are the main goals of vertical integration.

Star integration, sometimes referred to as spaghetti integration, is a hybrid of these two forms of integration. It is a process of system integration in which every system is connected to every other subsystem. This architecture was standard for older systems. It can be deployed quickly for simple systems, but as more subsystems are added, integration time and costs increase. Before the introduction of OPC, system integrators were forced to use this type of integration [48].

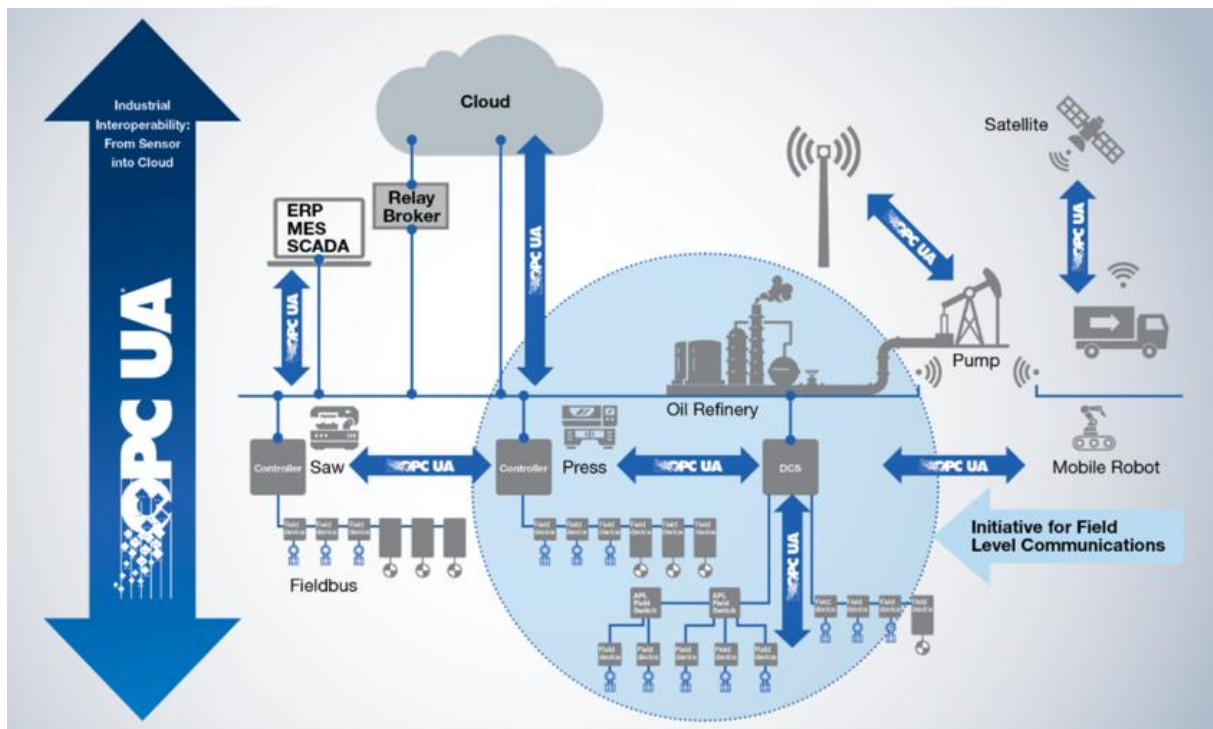


Figure 2.22. Star / Spaghetti integration is a hybrid of horizontal and vertical integration [49]

The specifics of device integration at each level of the system hierarchy are discussed in the next section of this chapter. Particular attention is paid to the OPC integration process.

2.6.2 Field Level Integration

The lowest level in the manufacturing is the field level. All sensors, actuators and measuring devices are located at the field level. Distributed control systems (DCS) are currently the most

widespread trend. The sensors process the measured signals and the devices are becoming increasingly complex. The measuring devices usually contains an LCD panel for interaction with the user. As a result, safety thresholds, measuring units, and data analysis can be configured. To simplify data transfer between dispersed devices, a digital data connection is recommended for all field devices. Standard Ethernet and TCP/IP are primarily used for communication at the higher factory levels. However, as state-of-the-art sensors become more advanced, an industrial version of Ethernet and TCP/IP is becoming increasingly popular at the field level. Please note that Ethernet implementations at field level in devices usually only support the basic functions. They do not provide solutions for security, dynamic IP address configuration (DHCP) or device management (SNMP). Nevertheless, such devices usually have access to OPC servers [48].

Numerous alternative fieldbus standards, including Profibus, ModBus, DeviceNet, CAN and AS-Interface, are accessible at field level. They are still widely used, especially for actuators and measuring devices. They are mostly used for horizontal integration at field level. The main problem with these protocols is that their architecture should be master-slave, which means that information from all other devices can only be read and written by one device. This means that the bus master must not only act as a gateway for data access from and to the actuators and sensors, but also as a process controller. The most popular interface for complicated devices that only record data for diagnostic or visual purposes (e.g. vibration measurements to predict bearing life) is Ethernet. Communication with higher levels of the plant requires the use of a gateway, as fieldbuses other than Ethernet are widely used. To facilitate vertical integration with the SCADA level and other interfaces for communication with lower level devices (sensors, actuators), PLC devices usually have Ethernet interfaces. In the majority of solutions, PLC devices serve both as low-level process control devices and as access points to higher levels of the manufacturing structure. During PLC programming, all data that needs to be sent to SCADA must be provided. Nowadays, almost every PLC device has a dedicated OPC server. These days, almost every PLC device has an OPC server of its own.

2.6.3 SCADA Level Integration

Data acquisition and supervisory control are referred to as SCADA. The term often refers to a group of computer-based programs for process control and monitoring. In many different

industries, they are becoming more and more important as a means for asset owners to keep up productivity, process information for well-informed decision-making, cut expenses, communicate problems to avoid downtime, and adhere to pertinent engineering and health and safety regulations. Key Steps of SCADA systems for OPC can be handed in three stage:

- **Data Acquisition:** Data like temperature, pressure, and flow rates are gathered from the field via sensors and Remote Terminal Units (RTUs).
- **Data Transmission:** Communication networks are used to send this data to the Master Terminal Unit (MTU).
- **Processing and Analysis:** After processing the data, the MTU sends it to SCADA software for real-time analysis and presentation.

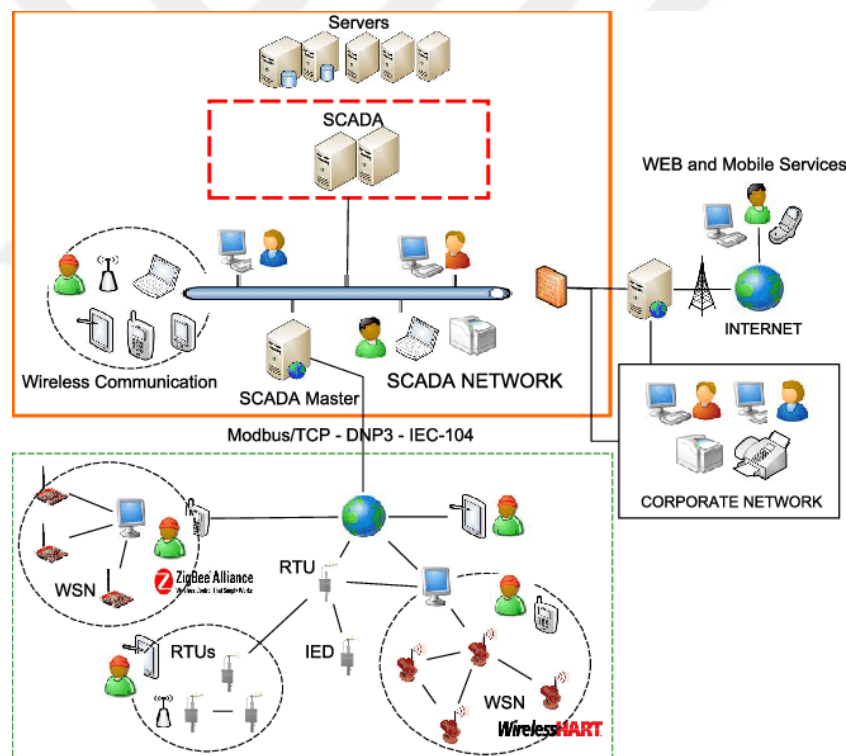


Figure 2.23. SCADA Network Architecture [50]

The market offers a wide variety of SCADA programs which have several features in common. Every significant industrial device supplier aims to offer a comprehensive range of SCADA applications. OPC was primarily created to improve interoperability at SCADA level. Today,

OPC is a widely used industrial communication standard that enables data exchange between different software applications (vertical integration) and between control software and devices from different manufacturers (horizontal integration) without restrictions. For higher production levels, the majority of SCADA systems can currently be configured to act as OPC servers.

The distinction between the SCADA level and the field level devices is no longer as pronounced as it was a few years ago. Due to challenging circumstances in industry in the past, standard PC computers could not be used at the field level. However, much has changed in the modern era. The functionality of today's PLCs is comparable to that of older PCs. The suppliers of automation systems currently refer to a new class of devices as Programmable Automation Controllers (PAC). There are significant differences between the old and modern PLCs. PCs have also descended to the field level. The same components form the basis for industrial personal computers (IPCs), which differ from standard PCs in terms of extended modules, compatibility, reliability and long-term supply.

Despite these problems, it is important to draw clear boundaries between the different levels of the system. Gateways and firewalls should be added to the system to complete the isolation. There are two reasons why this separation is important. First, it filters the data that is sent between the levels, and second, it protects the critical components of the manufacturing infrastructure from cyberattacks. A firewall can be efficiently monitored and protected if all traffic passes through a single connection point. The use of a secure firewall between the corporate network and the Internet is critical beside the separation between the corporate level and the SCADA level. It is advisable to secure the SCADA network control system against intrusions.

Allowing remote access to the company intranet is one of the most crucial tasks for system integrators. When a factory is situated in an area with restricted access this is particularly crucial. SCADA networks can be accessed remotely and securely via a virtual private network (VPN). A VPN is a network that builds on the public Internet but creates a unique, secure channel between the client and the network that permits the exchange of information securely. For the client software, there is no difference between a virtual network and a real network connection,

as this connection is transparent to the client. Since OPC clients would work exactly as if they were on the same network, transparency is essential when configuring OPC connections. Before external users can access SCADA networks, they must authenticate themselves to a VPN server, which is often installed as a standalone computer or as part of the firewall. The initial step in safeguarding SCADA systems is division of the networks. Additionally, it must be guaranteed that only authorized workers will have access to the system. The SCADA software ought to provide role-based access. Another protective approach is using the written policies for cybersecurity as mentioned in standards. Many PLC devices include two Ethernet ports; one may be meant for field-level communication alone, while the other may be intended for vertical SCADA integration. In small and medium control systems, it is the most widely used method of level separation.

2.6.4 Enterprise Level Integration

The effective control of the process is only the "tip of the iceberg" of what goes on within the assembly line. The effectiveness of control is not the only factor that determines the efficiency of production. Monitoring the actions required to keep the factory running used to be the responsibility of various applications. For example, production planning and delivery management were handled by different programs. The lack of integration made it impossible to manage production efficiently and the exchange of information between programs was insufficient that served as a catalyst for the development of Manufacturing Execution Systems (MES).

MES's primary function is to facilitate an automated information flow inside a factory. That enables us to use real-time data to perform maintenance tasks. For instance, when a manufacturing floor alarm is set off, a work order for maintenance is instantly generated. MES assists those in charge of capacity planning, production, maintenance, supply chain management, and other duties. It computes information and produces reports that are necessary for making decisions. Based on all relevant information, including actual orders, stock levels of materials, and many other factors, managers can optimize the scheduling of short-term production. While MES focuses primarily on automating human tasks, control systems are in charge of automating a manufacturing line.

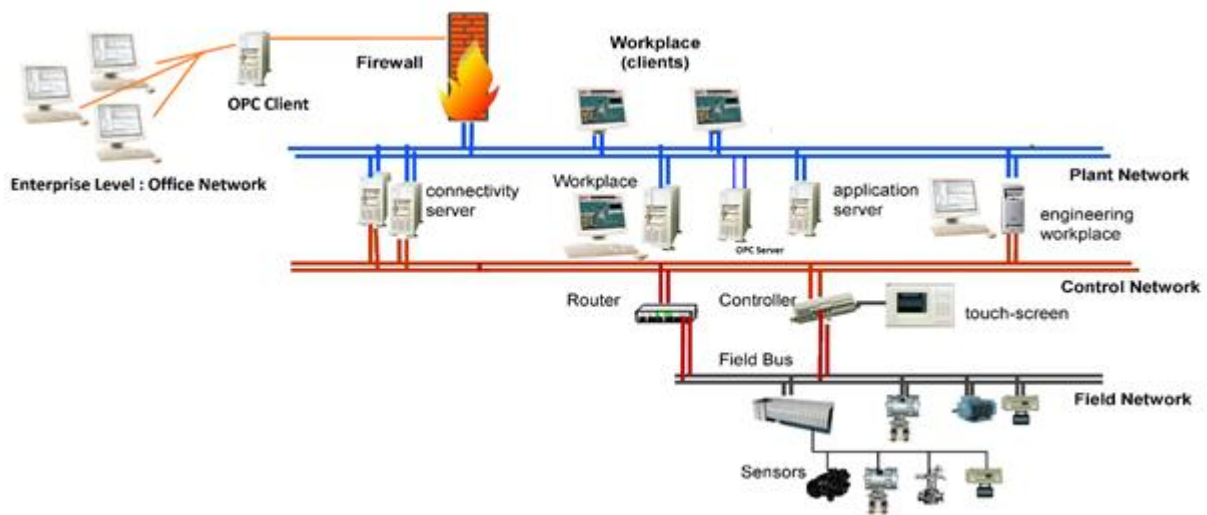


Figure 2.24. Sample Network architecture for enterprise level integration [51]

A standard system that included features not directly related to manufacturing, such as order processing (OP), customer relationship management (CRM), human resources management (HRM), and many more, was required by businesses. ERP (Enterprise Resource Planning) was the name of the solution. Initially, Material Requirements Planning (MRP) served as the foundation for ERP. An ERP system is a powerful tool that automates and unifies key business processes, providing organizations with a unified view of data and enabling more efficient operations, more informed decision-making, and the achievement of strategic goals. A collection of techniques called MRP aids in production management. It was in use long before the widespread usage of computers. Lack of interaction with a production floor was the main issue with those tools. ERP systems began using MES-type solutions as an information source when they were widely used. MES is now incorporated into a lot of ERP packages.

In order to facilitate straightforward horizontal integration, an ERP system is built around a shared database. OPC is used to integrate vertically with SCADA levels. ERP systems only create very little additional OPC traffic, and thus has little effect on the overall performance of

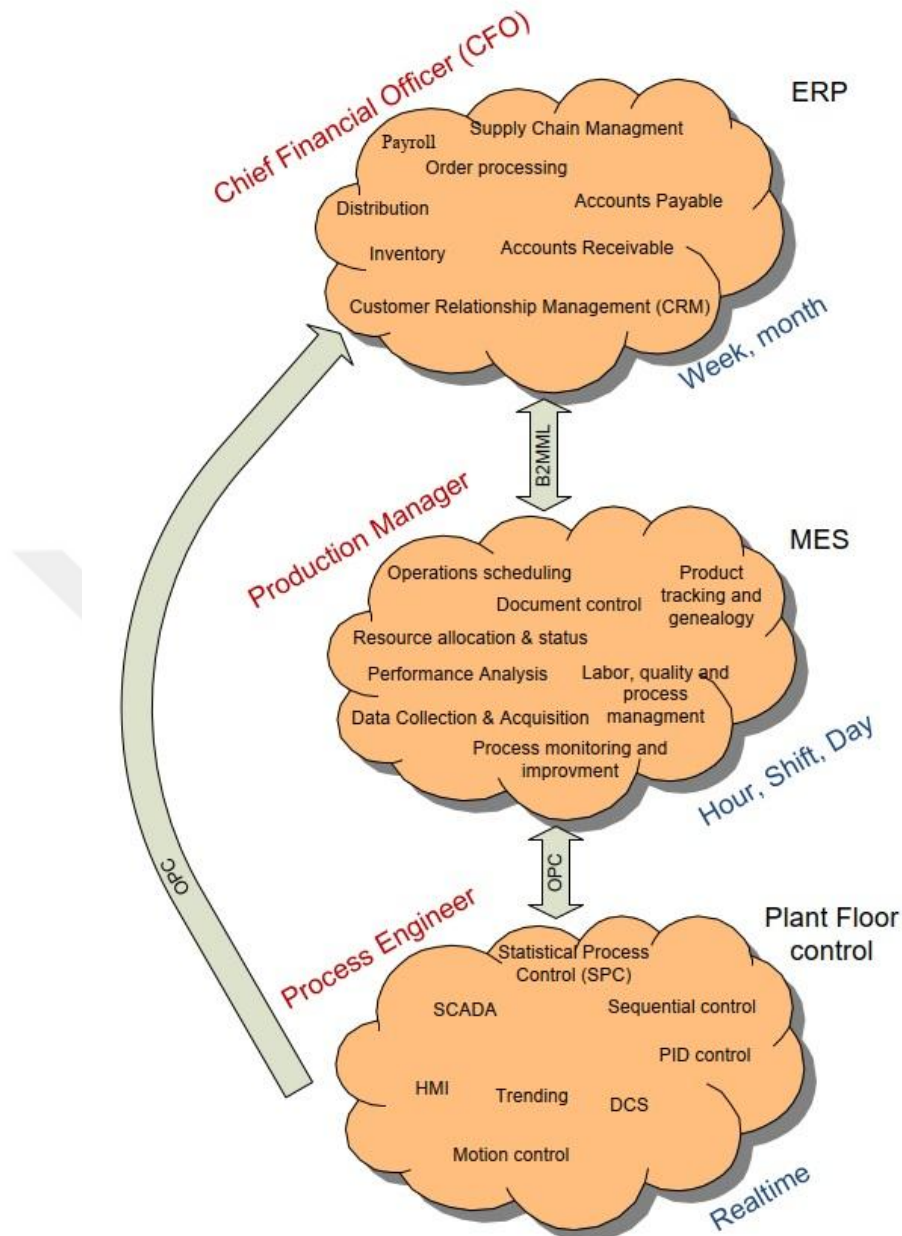


Figure 2.25. Activities carried out at various manufacturing levels

the system. When software developed by many suppliers has to link, OPC is occasionally also utilized for enterprise-level horizontal integration. The Business to Manufacturing Markup Language, or B2MML, approach is more often used when integrating software at the corporate level. In order to connect ERP and MES, a common data specification is intended to be provided by the B2MML set of XML schemes [48].

3. MATERIALS AND METHODS

3.1. Importance of Reporting in Businesses

Effective reporting is crucial for all business and the reasons can be categorized as follows:

Information-based decision-making is fundamental for businesses seeking to thrive in today's dynamic environment. By transforming raw data into an understandable format, reports offer invaluable **insights**. They reveal crucial trends, patterns, and **Key Performance Indicators** (KPIs), empowering leaders and managers to grasp the current state of affairs and make well-informed operational and strategic choices. Furthermore, these reports actively **support strategic planning**. Historical performance data and contemporary patterns provide a robust foundation for establishing achievable objectives, forecasting future performance, and developing successful long-term plans. Finally, data-driven reports are essential for **justifying choices**. They provide the necessary evidence and rationale, making decisions more defensible and significantly boosting stakeholder confidence.

Effective **monitoring and performance assessment** are crucial for business success. They enable organizations to **track progress** by regularly reporting on performance against predetermined targets and benchmarks, helping businesses determine if they're on track or falling behind. This continuous evaluation also aids in **identifying advantages and disadvantages**, highlighting areas where the company excels and where improvements are needed. This focused insight allows for targeted interventions and efficient resource allocation. Furthermore, regular reporting **evaluates productivity and effectiveness**, with operational reports pinpointing how well a business uses its resources and identifying potential bottlenecks or areas for improvement. Lastly, reports are vital for **evaluating the effectiveness of strategies**, as they allow businesses to monitor the results of implemented plans and identify areas for refinement.

Improved communication and transparency are crucial for any organization. Effective reports play a vital role in notifying interested parties, such as staff members, investors, and regulatory agencies, about the company's performance, financial situation, and significant operations. By sharing these reports among teams, organizations foster collaboration and a

unified sense of purpose, ensuring that everyone remains informed about the company's objectives and developments. Additionally, regular and transparent reporting enhances stakeholder understanding of the business's performance and operations, ultimately increasing credibility and trust.

Effective reporting is crucial for **maintaining accountability and ensuring compliance** within any organization. By establishing a clear **audit trail**, reports provide a historical record of decisions, actions, and outcomes. This comprehensive documentation is invaluable for future reference, analysis, and understanding the progression of company operations. Furthermore, accurate and timely reporting is essential for guaranteeing **compliance with regulations**. Many industries are subject to stringent legal and regulatory frameworks that mandate specific reporting requirements. Adhering to these requirements through precise reporting helps organizations avoid costly fines and legal repercussions. Ultimately, reports serve as a powerful tool to **encourage responsibility** by documenting the contributions and performance of individuals and teams, thereby holding them accountable for their actions and results.

Effective reporting is a critical tool for **discovering risks and opportunities** within an organization. By analyzing data over time, reports can **highlight trends and patterns** that might otherwise go unnoticed. This in-depth analysis can reveal emerging market demands, shifts in customer behavior, or operational efficiencies, thereby uncovering potential areas for development or expansion. Furthermore, regular reporting facilitates **early problem identification**. By closely monitoring key performance indicators, organizations can quickly spot potential issues or declining performance, enabling prompt action and effective risk mitigation before minor problems escalate into significant challenges.

Business reporting essentially serves as an essential compass, directing firms toward their goals by offering the data required for risk mitigation, performance management (decision-making) and efficient communication. It is an ongoing procedure that changes to meet the demands of the company and its stakeholders.

3.2. National Load Dispatch Center (NLDC)

The primary role of the National Load Dispatch Center is to ensure the real-time generation-consumption balance by operating the 400 kV transmission system in Turkey, which serves as the network's main backbone, maintaining the security and supply quality of the national energy generation and transmission system, and running the balancing power market and real-time ancillary services market. Regional load dispatch centers are primarily responsible for the operation, maneuvering, data gathering, and evaluation of 154 kV transmission systems. Load dispatch operations include real-time electricity supply and demand balancing, the operation of the Balancing Power Market and Ancillary Services Market, operational planning, international interconnection lines, emergency situations and planned work maneuvers, short-term energy planning, daily operation programs, load frequency control, and N-1 analyses to ensure system security.

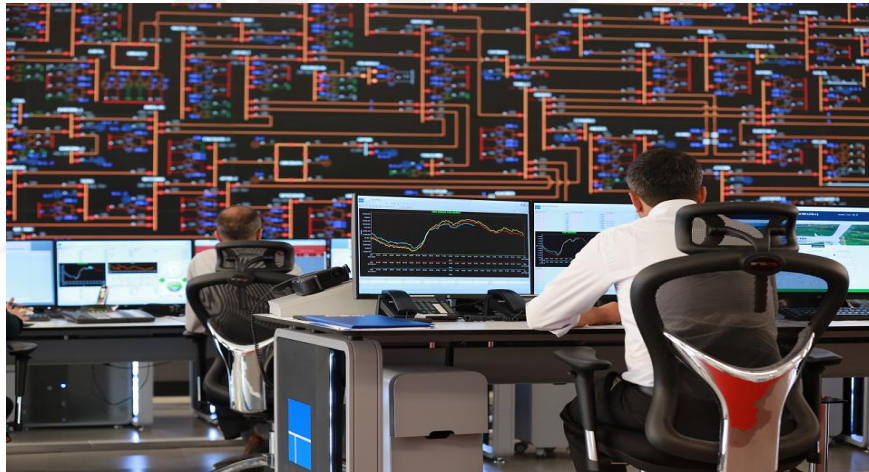


Figure 3.1. National Load Dispatch Center [52]

3.3. OPC Server and Client Solutions

An OPC client application is a software program that connects to an OPC server to read and write real-time data from industrial automation devices and systems. Think of it as an interface that allows various software applications (like HMIs, SCADA systems, historians, and reporting tools) to communicate with different types of industrial hardware through a standardized protocol [53].

3.3.1. The functions of an OPC client application

In essence, an OPC client application acts as the consumer of data provided by OPC servers, enabling different software systems to smoothly interact with the diverse world of industrial automation. The general functions of an OPC client application can be listed as below:

- **Connecting to OPC Servers:** It connects to one or more OPC servers to establish a communication channel. These servers function as go-betweens, converting various devices' proprietary communication protocols into the OPC standard.
- **Browsing OPC Server Data:** After connecting, the client can explore the OPC server to find the data points (sometimes called "tags" or "items") that are available. Real-time values from the linked devices are represented by these data points (e.g., temperature measurements, pressure levels, motor speeds, status indications).
- **Reading Data:** Reading the current values of the data points that the OPC server has made available is the main purpose of an OPC client. This enables real-time process information to be displayed and used by the client application.
- **Writing Data (if supported):** In order to control the linked industrial equipment, certain OPC clients can also write data back to the OPC server (e.g., setting a target temperature, starting or halting a motor).
- **Subscribing to Data Changes:** OPC clients can subscribe to particular data points in order to effectively monitor real-time data. As a result, the client won't need to continuously request updates because the OPC server will automatically alert them anytime the value of a subscribed data point changes.
- **Handling Data Quality and Timestamps:** Reliable process monitoring and analysis depend on OPC's reporting of data quality (e.g., good, bad, unsure) and the timestamp of the value's most recent change [54].

3.3.2. Leading Providers of OPC Server and Client Solutions

There are various types of OPC server and client solutions available from numerous software providers, ranging from simple diagnostic tools to complex HMI/SCADA systems. Some are commercial products, while others are free or open-source. The specific features and capabilities vary depending on the application's purpose. The leading providers of OPC Server and Client Solutions can be listed as below:

- **PTC (Kepware):** A well-established provider of industrial connectivity software. The **KEPServerEX** platform is a leading multi-protocol OPC DA and OPC UA server, supporting a vast array of industrial devices and protocols. Additionally, tools and client drivers are provided for connecting to other OPC servers.
- **MatrikonOPC (Honeywell):** OPC UA and OPC-based data interoperability tools are the focus of this vendor-neutral supplier. They provide OPC client tools such as **MatrikonOPC Explorer** (a free testing client) and a large selection of OPC servers for different industrial systems (PLC, DCS, Building Automation, etc.). Additionally, they provide OPC UA Tunneller and Data Manager, which in certain situations can function as both client and server.
- **Software Toolbox:** A range of OPC client and server solutions are available from them, such as their flagship **TOP Server**, which serves as both an OPC server and a client with the ability to connect to other OPC servers (bridge or gateway). They also provide client tools and components for developers.
- **Iconics (Mitsubishi Electric):** Iconics is a charter member of the OPC Foundation and provides OPC server and client software as part of their automation software suites, including **GENESIS64**. They have a crucial product called **DeviceXPlorer OPC Server**, and their entire program frequently serves as an OPC client to several data sources.

- **Advantech:** They provide OPC servers for their ADAM and Modbus devices, enabling these to communicate with OPC clients. While their focus is strong on the server side for their hardware, their broader industrial automation software may include client functionalities.
- **Endress+Hauser:** The company is mostly recognized for their process measurement equipment, but they also provide OPC server software for system integration. Providing the server component for their products is their primary focus.
- **Siemens:** Siemens, a leading manufacturer of industrial automation products, provides OPC servers for its SIMATIC controllers. WinCC and other SCADA/HMI systems frequently serve as OPC clients.
- **OPC Labs:** They provide end-user tools and solutions like **OPC Studio**, which incorporates OPC UA client and server development capabilities, and they specialize in OPC development tools.
- **Takebishi (DeviceXPlorer):** A company with extensive OPC experience and close relationships to Japanese manufacturers. In addition to supporting a large variety of devices, its **DeviceXPlorer OPC Server** has client connectivity functions as part of their larger software portfolio.
- **Moxa:** Moxa is mostly recognized for its industrial networking devices, but they also provide OPC server solutions, like their **EDS-SNMP OPC Server Pro**, which enables OPC communication between SNMP devices. OPC client functionalities may also be incorporated into their industrial computers and software.
- **CimQuest INGEAR:** OPC servers are offered for particular controllers such as Modbus and Omron. Their specialty is building reliable server-side communication.
- **OPCTechs:** Provides a selection of OPC servers for different devices and protocols, and it might also offer client features or tools.

3.3.3. Key Considerations When Choosing a Solution

Many vendors offer trial versions or free OPC client tools that can be helpful for testing connectivity and evaluating their solutions. Before selecting an OPC client solution, it is advised that a comprehensive evaluation of particular requirements be carried out. The key points can be listed as below:

- **Compatibility:** Make sure the client can connect to the specific OPC server (DA, UA) and that the server supports the connection protocols of selected industrial devices (e.g., Modbus, PROFINET, Ethernet/IP).
- **OPC Standard:** Take into account aspects like security, platform independence, and information modeling when determining if it is required that OPC Classic (DA, HDA, A&E) or the more recent OPC UA.
- **Ease of Use and Configuration:** To make setup and maintenance easier, look for solutions with user-friendly interfaces and comprehensive documentation.
- **Scalability and Performance:** It should be ensured that the needs can be met by the solution by taking into account the quantity of data points and the required data.
- **Security Features (especially for OPC UA):** Consider security features like authorization, authentication, and encryption.
- **Support and Reliability:** Select suppliers who are known for their product stability and technical assistance.
- **Cost:** To choose a solution that suits the planned budget, compare pricing structures and license methods.

3.3.4. Robosoft Control (Turkey) Solutions

This company focuses on industrial automation solutions.

- A key offering is OPC server software, particularly KEPCON OPC Server.
- Provide services for:
 - Data acquisition from industrial systems.
 - Cloud-based monitoring and reporting.
 - Development of SCADA and MES applications.
- Provide services to industries like:
 - Energy (hydro, wind, solar).
 - Manufacturing.
 - Process automation.
- They integrate with ERP systems like SAP and Oracle.
- Robosoft is a local OEM (Original Equipment Manufacturer) partner of KEPCON.
- The company is a Microsoft Solutions Partner and use Microsoft products in their projects.
- They offer industrial reporting software (RBSReport) which is an OPC Client application that connects to any OPC Server and records tag values to MS SQL Server.

3.3.4.1. *KEPServerEX*

KEPServerEX is the industry's leading connectivity platform that provides a single source of industrial automation data to many other applications. Users can connect, manage, monitor, and control diverse automation devices and software applications through one intuitive user interface. KEPServerEX leverages OPC [55] and IT-centric communication protocols (such as SNMP, ODBC, and web services) to provide users with a single source for industrial data. This application is used for reaching the raw data on OPC server [56]. KEPServerEX software sample interface is shown in Figure 3.2.

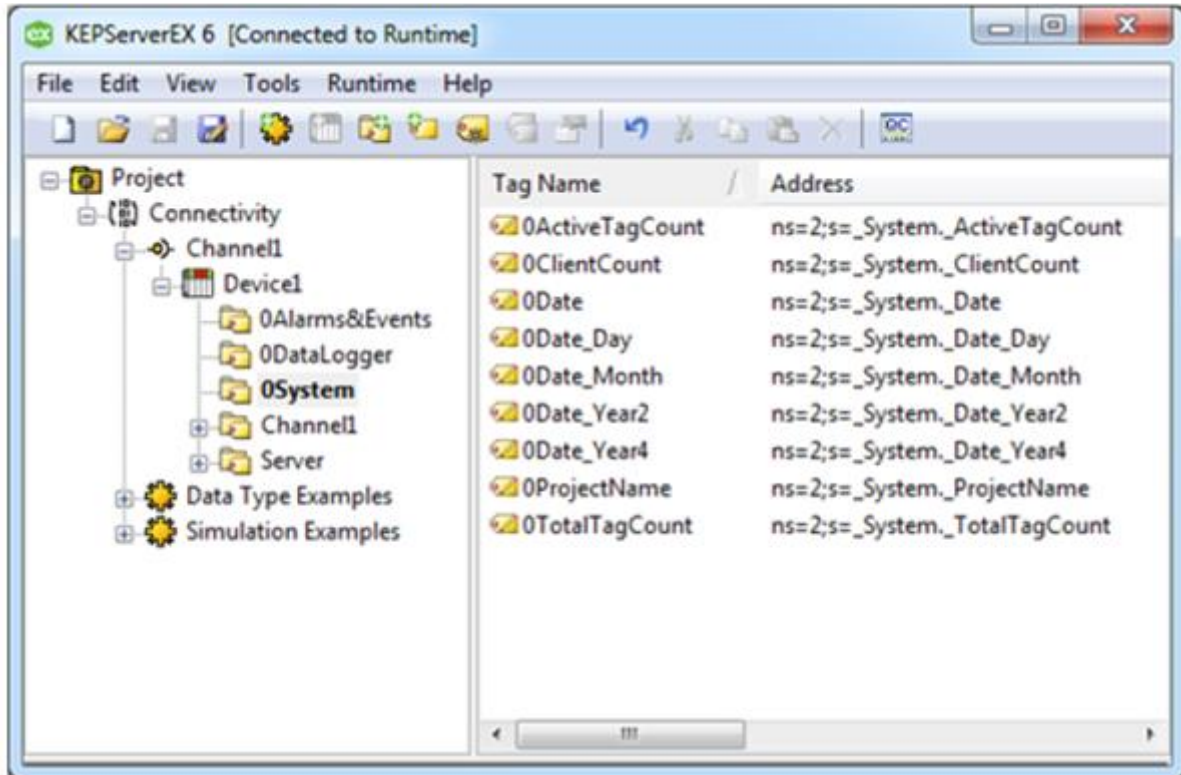


Figure 3.2. KEPServerEX software sample interface [57]

3.3.4.2. *Microsoft SQL Server*

It is a relational database management system (RDBMS) developed by Microsoft. It is used to store and retrieve data organized in tables with relationships. The main attributes, including cloud capabilities, business intelligence tools, in-memory technology, scalability, security, high availability, and integration covered with the Microsoft ecosystem. The database, raw data taken from OPC server, for the reports is kept here [58].

3.3.4.3. *RBSReport Reporting Software*

The basic software from the “RBSReport Reporting Software” used for this study can be summarised in 3 products as described below although there is some more products in the software:

- **RBS Configurator** is the main configuration tool for the reporting system. All the parameters such as the OPC server-client connection parameters, user, tables, database rules, table templates, etc. are configured with the help of this application.

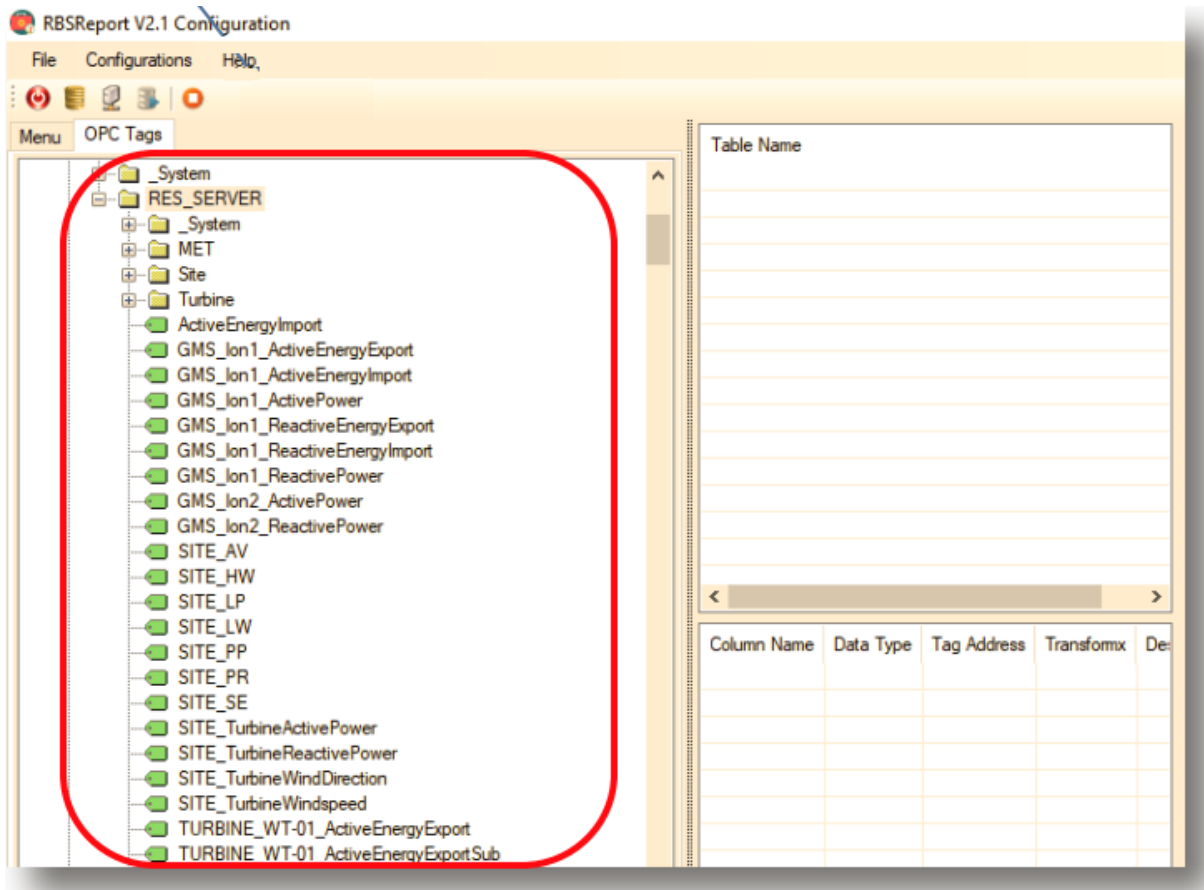


Figure 3.3. RBS Configurator software sample interface [59]

- **RBS Data Logger** allows data record via read from OPC Servers on time and event basis to tables created with RBS Report on MS SQL Server. The only requirement for this package is an OPC Server software, so it can be stored any type of data on MS SQL Server.



Figure 3.4. Some of the RBSReport products [60]

- **RBS Excel Trend:** Utilizing previously set Excel file templates that may be exported as Excel files, the OPC Excel Trend package enables users to perform column and date queries and create reports from the data entered into an MS SQL Server database. Also trend reports can be produced based on preset intervals of data records.

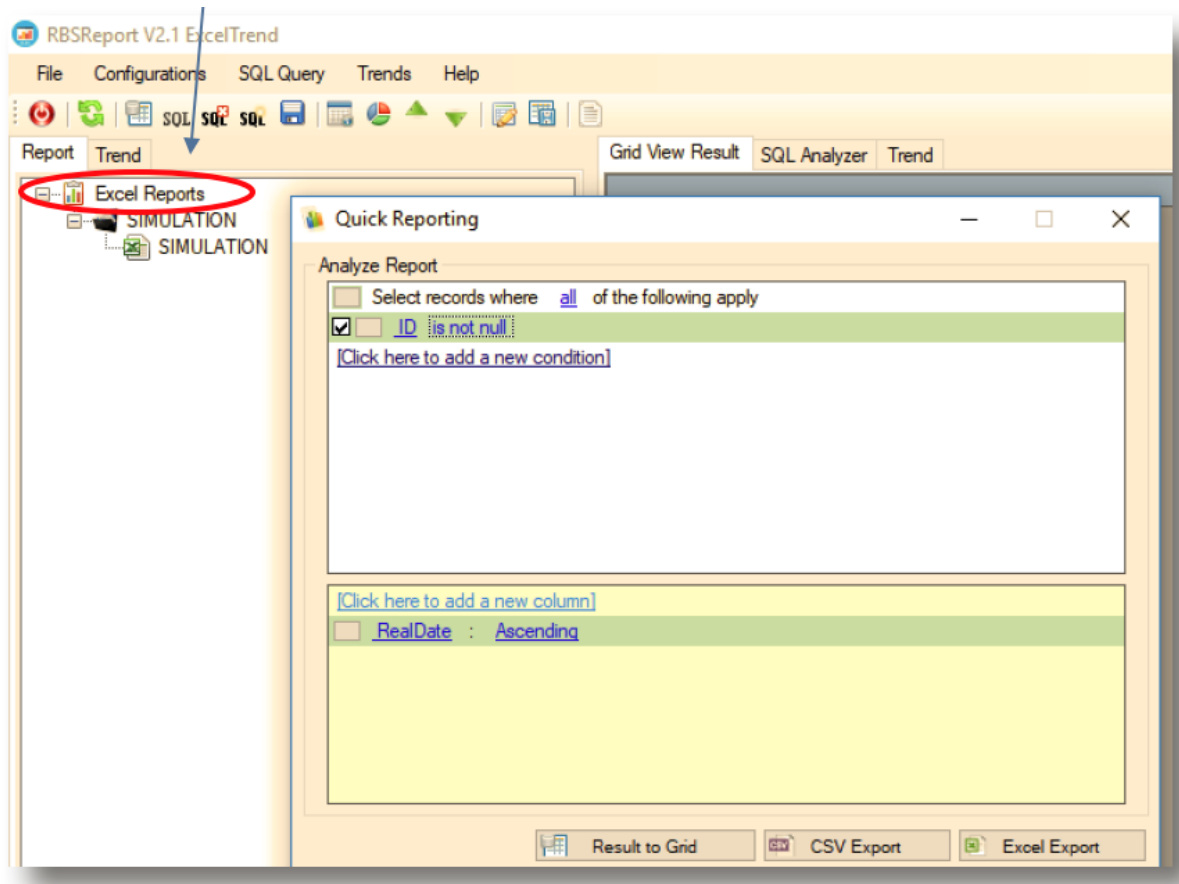


Figure 3.5. RBS Excel Trend software sample interface [59]

Whenever the saved template is selected and the date intervals are called the table appears as in the following figure dashboard or it can also be saved in csv or Excel format.

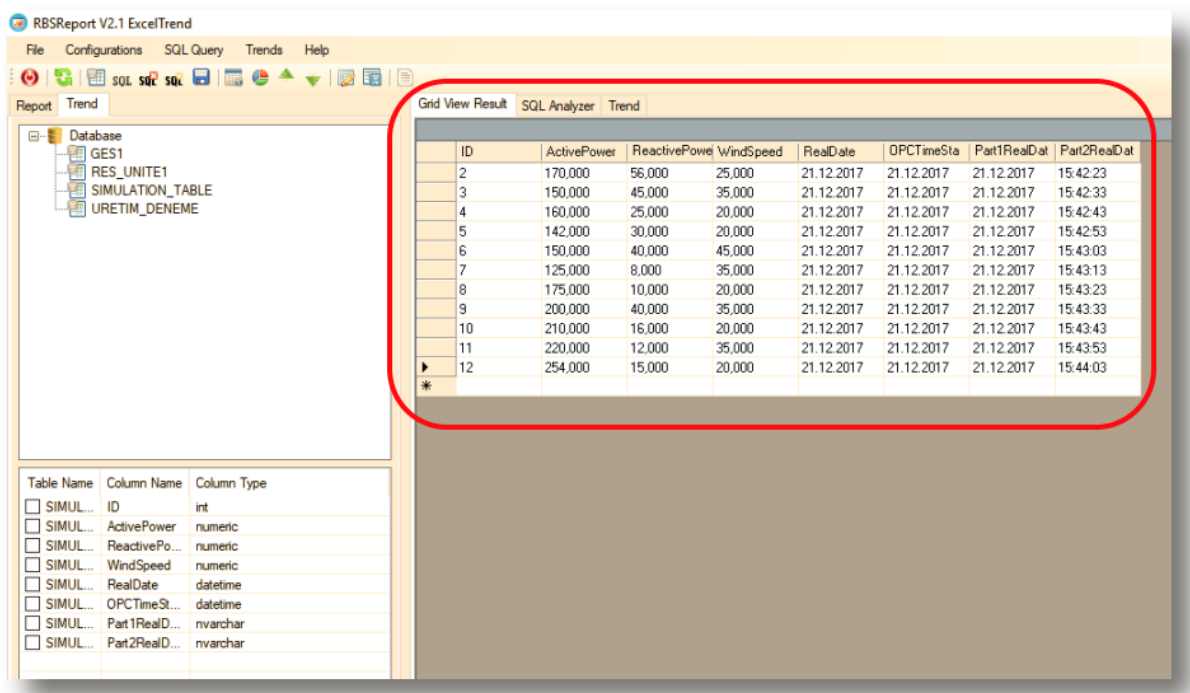


Figure 3.6. RBS Excel Trend software sample results on grid value result seem [59]

4. RESULTS AND DISCUSSION

The power plants require the reporting systems for the majority of the objectives stated in part 3.1. This study examines how OPC technology may be used to automatically create reports for the "National Load Dispatch Center (NLDC)" in order to comply with legal and regulatory requirements; besides "Coal and Fuel Consumptions" data can be handled to provide information for monitoring coal usage, stock levels, and supply chain management from the related scada system.

All the studies are done in an operating thermal power plant to achieve the goals. An automated reporting system is developed by using OPC technology to offer access to accurate, dependable, and time-stamped data. Thereby, crucial solution to the serious risks associated with manual data entry, such as human errors leading to data loss, security breaches, compliance issues and reduced efficiency. Besides, by implementing an automated system, the plant achieved greater data accuracy, minimizing errors through automatic calculations and formatting, saving time, establishing reliable automated report, potentially optimizing personnel needs, increasing personnel productivity to meet regulatory requirements and monitor the consumption. After all, decision-making became easier and ultimately better strategic planning ability obtained.

The software utilized to meet the requirement of this study is briefly explained below.

OPC Server and Client Solutions are used in this study to establish a reporting system utilizing OPC communication technology and its architecture. An OPC client application is a software program that connects to an OPC server to read and write real-time data from industrial automation devices and systems. Regarding this, **PTC (Kepware)** software is used for establishing the communication with various DCS and SCADA systems.

Microsoft SQL Server is used to store and retrieve data organized in tables with relationships. The database, raw data taken from OPC server, of the reports is kept in here.

The products of the company **Robosoft Control (Turkey) solutions** is used since it supplies the other necessary software packages such as:

- **RBS Configurator** is used for configuration tool of the reporting system. All the parameters such as the, user tables, database rules, table templates,etc. are configured with the help of this application.

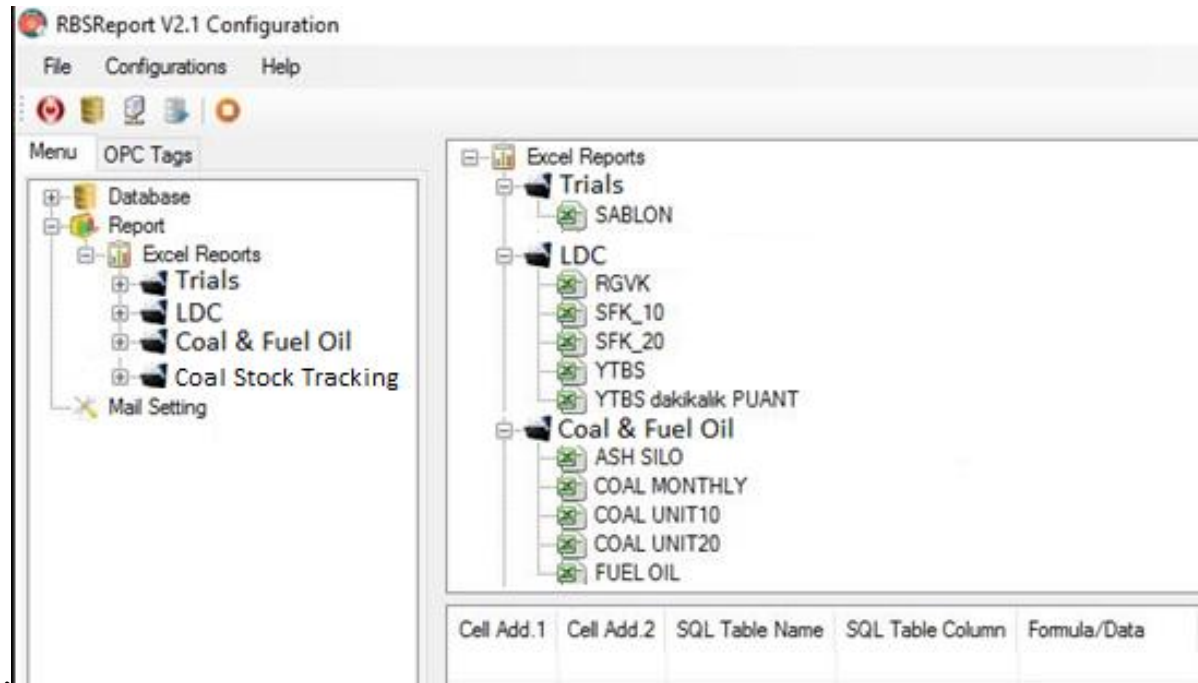


Figure 4.1. RBS Configurator screenshot

- **RBS Data Logger** is used to record data read from OPC Servers on time and event basis to tables created with RBS Report on MS SQL Server
- **RBS Excel Trend** is used to serve the tables with the configured data for the desired time period from the data stored into the MS SQL Server database. The tables can be observed in its dashboard or they can also be saved in csv or excel format.

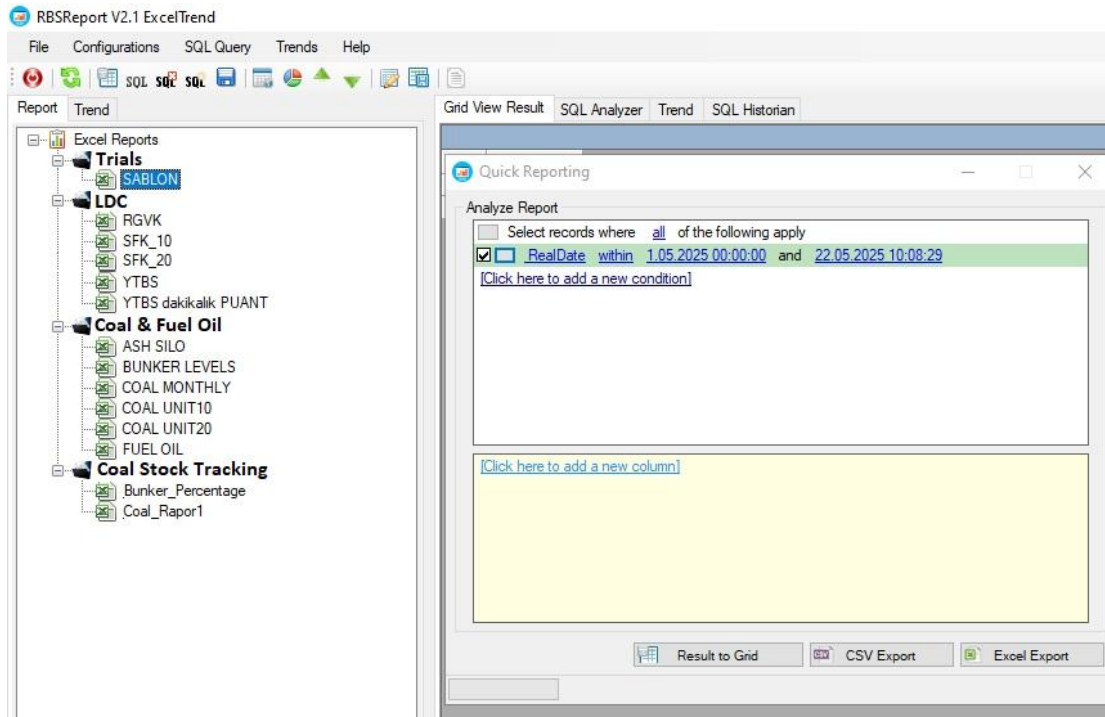


Figure 4.2. RBS Excel Trend screenshot

All pertinent data is stored in a SQL database after the configurations are complete. It is always accessible, as demonstrated below by the sample outputs from the automated reporting system that was created.

The power generation values are needed for NLDC. After implementation of the related signals taking from the DCS to the reporting system, it became more easy to serve it clearly as seen on the Table 4.1. The report summarizes each unit's nominal active power and minimum stable generation level. It also details the mandatory reactive power limits for over- and under-excitation.

Table 4.2. report summarizes the performance of a power unit participating in frequency control, with reference values. It covers the unit's nominal power, droop settings, response time to a 200 mHz frequency change, loading/unloading speeds, and speed regulator dead-band. This data helps evaluate and optimize the unit's contribution to grid frequency stability.

Table 4.1. Sample RGVK report output from the automated reporting system for the selected period

	SAAT	SIRA_NO	BARA_GEN_ _kv	BARA_GEN_ _SET DEG _kv	BRM_DON EN ASRIK AZ_ZOR_M VAR	BRM_DON EN DUSUK IKAZ_ZOR_ MVAR	BRM_GEN_ TER_TOPL AM_INVAR	UNI_1_GEN_ TER_AKT_ CHK_GUCU_ _MW	UNI_1_GEN_ TER_REA_ _GUCU_MV_ _Ar	UNI_1_GEN_ TER_GEN_ _kv	UNI_1_GEN_ _MOD	UNI_2_GEN_ TER_AKT_ CHK_GUCU_ _MW	UNI_2_GEN_ TER_REA_ _GUCU_MV_ _ar	UNI_2_GEN_ TER_GEN_ _kv	UNI_2_GEN_ _MOD
15.03.2025	00:00:00	1	406,556	408,000	633,500	-429,920	161,600	680,898	65,300	21,692	1	681,035	95,100	21,685	1
15.03.2025	00:01:00	2	406,723	404,000	633,500	-429,920	181,600	679,535	76,700	21,692	1	682,697	105,800	21,712	1
15.03.2025	00:02:00	3	406,250	404,000	633,500	-429,920	195,600	679,290	84,300	21,692	1	678,081	110,900	21,695	1
15.03.2025	00:03:00	4	405,498	404,000	633,500	-429,920	205,500	680,473	88,600	21,692	1	678,047	113,200	21,695	1
15.03.2025	00:04:00	5	405,289	404,000	633,500	-429,920	210,200	680,414	92,400	21,692	1	676,903	118,900	21,695	1
15.03.2025	00:05:00	6	404,927	404,000	633,500	-429,920	218,000	677,821	96,100	21,692	1	676,652	123,600	21,695	1
15.03.2025	00:06:00	7	404,705	404,000	633,500	-429,920	221,200	680,881	97,800	21,692	1	677,524	124,500	21,695	1
15.03.2025	00:07:00	8	404,413	404,000	633,500	-429,920	222,600	680,634	98,400	21,692	1	678,545	124,500	21,680	1
15.03.2025	00:08:00	9	404,232	404,000	633,500	-429,920	220,800	679,357	97,400	21,692	1	675,028	124,500	21,697	1
15.03.2025	00:09:00	10	404,357	404,000	633,500	-429,920	227,500	678,933	99,200	21,692	1	678,838	127,200	21,697	1
15.03.2025	00:10:00	11	404,635	404,000	633,500	-429,920	226,800	679,790	99,600	21,692	1	680,447	127,200	21,697	1
15.03.2025	00:11:00	12	404,273	404,000	633,500	-429,920	222,200	678,695	97,600	21,692	1	678,736	125,500	21,697	1
15.03.2025	00:12:00	13	403,926	404,000	633,500	-429,920	229,700	677,737	101,200	21,692	1	678,962	125,500	21,697	1
15.03.2025	00:13:00	14	404,287	404,000	633,500	-429,920	229,300	680,132	101,500	21,692	1	679,923	128,000	21,697	1
15.03.2025	00:14:00	15	404,385	404,000	633,500	-429,920	227,400	681,130	101,400	21,692	1	678,461	128,000	21,697	1
15.03.2025	00:15:00	16	404,190	404,000	633,500	-429,920	231,700	679,670	101,400	21,692	1	681,446	128,000	21,697	1
15.03.2025	00:16:00	17	404,009	404,000	633,500	-429,920	233,600	679,276	103,800	21,692	1	684,704	128,000	21,697	1
15.03.2025	00:17:00	18	403,995	404,000	633,500	-429,920	239,200	681,326	105,800	21,692	1	683,228	131,500	21,707	1
15.03.2025	00:18:00	19	404,079	404,000	633,500	-429,920	236,300	681,198	103,800	21,692	1	683,767	131,500	21,687	1
15.03.2025	00:19:00	20	404,301	404,000	633,500	-429,920	236,300	681,341	103,300	21,692	1	686,143	131,500	21,700	1
15.03.2025	00:20:00	21	403,689	404,000	633,500	-429,920	236,600	681,126	103,300	21,692	1	686,161	131,500	21,715	1
15.03.2025	00:21:00	22	403,856	404,000	633,500	-429,920	235,600	679,350	103,300	21,692	1	683,821	131,500	21,707	1
15.03.2025	00:22:00	23	403,926	404,000	633,500	-429,920	236,800	681,423	104,300	21,692	1	685,297	131,500	21,700	1
15.03.2025	00:23:00	24	403,842	404,000	633,500	-429,920	236,800	682,466	104,300	21,692	1	684,586	131,500	21,700	1
15.03.2025	00:24:00	25	403,717	404,000	633,500	-429,920	236,800	679,898	104,900	21,692	1	680,709	132,900	21,700	1
15.03.2025	00:25:00	26	403,912	404,000	633,500	-429,920	238,900	678,437	104,900	21,692	1	679,445	132,900	21,700	1
15.03.2025	00:26:00	27	403,689	404,000	633,500	-429,920	237,900	679,461	105,900	21,692	1	679,417	130,900	21,682	1
15.03.2025	00:27:00	28	403,550	404,000	633,500	-429,920	234,600	680,572	105,600	21,692	1	678,405	134,000	21,712	1
15.03.2025	00:28:00	29	403,355	404,000	633,500	-429,920	238,500	681,240	105,500	21,692	1	680,644	130,100	21,695	1
15.03.2025	00:29:00	30	403,926	404,000	633,500	-429,920	240,200	678,820	107,500	21,692	1	680,619	132,300	21,695	1
15.03.2025	00:30:00	31	403,856	404,000	633,500	-429,920	238,900	679,738	106,800	21,692	1	683,147	132,300	21,695	1
15.03.2025	00:31:00	32	403,981	404,000	633,500	-429,920	242,200	679,628	107,300	21,692	1	683,499	135,300	21,720	1
15.03.2025	00:32:00	33	403,605	404,000	633,500	-429,920	238,200	680,374	105,200	21,692	1	679,845	132,000	21,705	1
15.03.2025	00:33:00	34	403,759	404,000	633,500	-429,920	241,800	679,047	107,300	21,692	1	678,756	133,300	21,717	1
15.03.2025	00:34:00	35	404,273	404,000	633,500	-429,920	240,000	681,222	107,600	21,692	1	680,327	133,300	21,685	1
15.03.2025	00:35:00	36	403,605	404,000	633,500	-429,920	240,900	679,397	107,200	21,692	1	678,010	133,300	21,705	1
15.03.2025	00:36:00	37	403,605	404,000	633,500	-429,920	237,300	680,569	105,000	21,692	1	678,554	133,300	21,692	1
15.03.2025	00:37:00	38	403,689	404,000	633,500	-429,920	244,800	681,675	107,000	21,692	1	677,181	133,300	21,692	1
15.03.2025	00:38:00	39	403,522	404,000	633,500	-429,920	242,300	681,108	109,200	21,692	1	677,727	133,300	21,697	1
15.03.2025	00:39:00	40	403,828	404,000	633,500	-429,920	244,100	679,842	108,300	21,692	1	679,773	133,300	21,697	1
15.03.2025	00:40:00	41	403,898	404,000	633,500	-429,920	244,800	681,128	108,400	21,692	1	680,747	133,300	21,697	1

Table 4.2. Sample SFK_10 report output from the automated reporting system for the selected period

TARIH	SAAT	SIRA_NO	FRE_HZ	BRM_GUC_ REF_DEG_ MW	BRM_AKT_ CIK_GUC_ BRUTMW	BRM_AKT_ CIK_GUC_ NETMW	BRM_PFK_ TPLM_NOM _GUCMW	BRM_SEK_ MAK_MW	BRM_SEK_ MIN_MW	BRM_PRI_ MAKC_MW	BRM_PRI_ MINC_MW	BRM_GNCL _KPR_MW/ _HZ	BRM_SFK_ REZ_MIK_M _W	BRM_PFK_ REZ_MIK_M _W
15.03.2025	09:00:00	32401	50,013	577,998	576,579	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:01	32402	50,005	577,998	579,001	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:02	32403	49,997	577,998	579,001	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:03	32404	49,997	577,998	579,001	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:04	32405	50,001	577,998	579,001	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:05	32406	50,005	577,998	579,001	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:06	32407	49,997	577,998	579,001	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:07	32408	49,989	577,998	582,396	541,218	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:08	32409	49,989	577,998	579,347	542,288	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:09	32410	49,992	577,998	579,347	542,288	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:10	32411	49,992	577,998	581,603	542,288	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:11	32412	49,992	577,998	581,603	542,288	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:12	32413	49,989	577,998	581,603	542,288	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:13	32414	49,985	578,981	581,603	542,288	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:14	32415	49,985	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:15	32416	49,981	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:16	32417	49,977	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:17	32418	49,985	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:18	32419	49,989	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:19	32420	49,985	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:20	32421	49,977	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:21	32422	49,973	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:22	32423	49,977	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:23	32424	49,977	578,981	583,505	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:24	32425	49,973	578,981	584,629	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:25	32426	49,969	578,981	584,629	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:26	32427	49,972	578,981	585,691	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:27	32428	49,972	578,981	585,691	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:28	32429	49,974	578,981	585,691	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:29	32430	49,974	578,981	585,691	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:30	32431	49,973	578,981	585,691	543,125	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:31	32432	49,985	578,981	585,691	543,181	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:32	32433	49,985	578,981	585,691	543,181	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:33	32434	49,977	578,981	585,691	543,181	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:34	32435	49,973	578,981	585,691	543,181	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:35	32436	49,976	578,981	585,691	543,181	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:36	32437	49,980	578,981	585,691	543,181	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:37	32438	49,984	578,981	585,691	544,590	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:38	32439	49,984	578,981	585,691	544,590	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:39	32440	49,980	578,981	585,691	544,590	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000
15.03.2025	09:00:40	32441	49,972	578,981	585,691	544,590	654,000	630,000	530,000	680,000	480,000	250,000	50,000	50,000

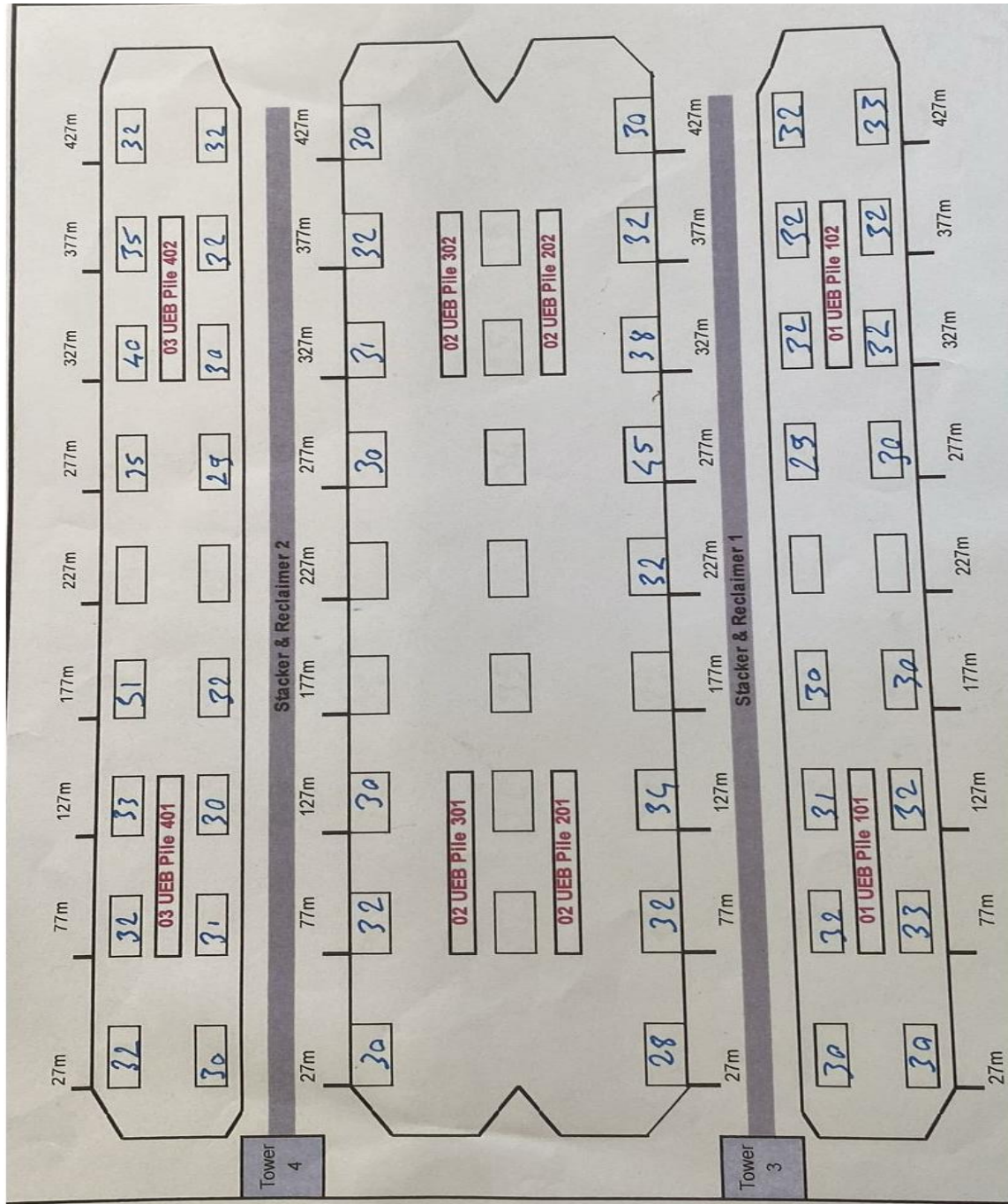


Figure 4.3. Manual records for the Coal Stock Tracking from older time

The coal stock tracking was done by the handwritten paper notes which was having uncertainty and time dependency was not existed as seen Figure 4.3. However, after the automated reporting system, the values became more accurate, time dependant and the reports also any recorded values can be available at anytime as seen on the Table 4.3.

Not only the coal but also the fuel oil consumption, stock values and other so much measurement had already implemented to the reporting system.

Table 4.4. Sample Fuel Oil tracking report output from the automated reporting system for the selected period

TARIH	SAAT	00EGB11CL 002 XQ11	00EGB11CL 002 ZQ11	00QHH01CL 001 XQ11	00QHH01CL 001 ZQ11	00QLB30CF 901Q ZQ24	00QHH00GH 001Q ZQ24	00QHH00GH 001Q ZQ03	00QHH01FL 001 XQ11	00QHH10CF 901Q ZQ24	00QHH20CF 901Q ZQ24
01.02.2025	01:05:00	0,000	0,000	92,230	23,565	0,000	0,000	0,000	22,608	0,263	0,000
02.02.2025	01:05:00	0,000	0,000	92,240	23,565	0,000	0,000	0,000	22,611	0,280	0,000
03.02.2025	01:05:00	0,000	0,000	92,240	23,576	0,000	0,000	0,000	22,614	0,238	0,000
04.02.2025	01:05:00	0,000	0,000	92,300	23,581	0,000	0,000	0,000	22,618	0,149	0,000
05.02.2025	01:05:00	0,000	0,000	92,380	23,599	0,000	0,000	0,000	22,628	0,205	0,000
06.02.2025	01:05:00	0,000	0,000	92,220	23,560	0,000	0,000	0,000	22,608	0,010	0,000
07.02.2025	01:05:00	0,000	0,000	92,150	23,540	0,000	0,000	0,000	22,597	0,010	0,000
08.02.2025	01:05:00	0,000	0,000	92,020	23,509	0,000	0,000	0,000	22,580	0,003	0,000
09.02.2025	01:05:00	0,000	0,000	92,030	23,514	0,000	0,000	0,000	22,583	0,032	0,000
10.02.2025	01:05:00	0,000	0,000	92,090	23,530	0,000	0,000	0,000	22,590	0,016	0,000
11.02.2025	01:05:00	0,000	0,000	92,140	23,540	0,000	0,000	0,000	22,598	0,002	0,000
12.02.2025	01:05:00	0,000	0,000	92,140	23,540	0,000	0,000	0,000	22,597	0,005	0,000
13.02.2025	01:05:00	0,000	0,000	92,130	23,537	0,000	0,000	0,000	22,595	0,008	0,000
14.02.2025	01:05:00	0,000	0,000	92,040	23,514	0,000	0,000	0,000	22,583	0,001	0,000
15.02.2025	01:05:00	0,000	0,000	92,030	23,512	0,000	0,000	0,000	22,581	0,020	0,000
16.02.2025	01:05:00	0,000	0,000	92,160	23,545	0,000	0,000	0,000	22,599	0,046	0,000
17.02.2025	01:05:00	0,000	0,000	92,300	23,583	0,000	0,000	0,000	22,623	0,074	0,000
18.02.2025	01:05:00	0,000	0,000	92,440	23,614	0,000	0,000	0,000	22,645	0,064	0,000
19.02.2025	01:05:00	0,000	0,000	92,580	23,650	0,000	0,000	0,000	22,706	0,211	0,000
20.02.2025	01:05:00	0,000	0,000	92,690	23,680	0,000	0,000	0,000	22,744	0,088	0,000

There are serious hazards associated with manual data entry that endanger reporting accuracy, security, compliance, data integrity, and business reputation. Human mistake is the main cause of these dangers, which can result in:

- **Data Loss:** Because of mistakes like misspellings, duplicates, or omissions, data integrity is compromised, and decision-making is affected.
- **Security Breaches:** Lack of strict verification increases the risk of identity theft and unauthorized access.
- **Compliance Issues:** Without adequate supervision and training, there could be legal issues and regulatory offenses.
- **Inaccurate Reporting:** Mistakes that result in differences, which compromise credibility and impair the correctness of decisions.
- **Reputation Damage:** Loss of stakeholder trust is a result of mistakes, excessive falsehoods, and noncompliance with regulations.
- **Reduced Efficiency:** Time-consuming processes and increased vulnerability to human error impacting overall operational productivity.

To mitigate these risks, organizations should prioritize automated reporting systems with robust validation mechanisms. This minimizes manual intervention, improves data accuracy, enhances security, ensures compliance, and ultimately leads to smoother operations and better decision-making capabilities.

Automated reporting system significantly boosts the accuracy and reliability of the business reports. By removing the need for manual data entry and copying, it ensures data is entered just once and then automatically pulled from all relevant sources. This greatly reduces errors, giving greater confidence in the data, which leads to better decision-making and deeper insights into the business operations and legal. Moreover, the people who are responsible for preparation of the reports can have much more time for the other tasks and can provide much more benefit to their company. Additionally, automated reporting system supports strategic planning since projecting future performance, and creating successful long-term plans.

5. CONCLUSIONS

An automated reporting system offer access to accurate, dependable, and time-stamped data. There are numerous risks associated with manual data entry, which can cause a number of issues for an organization. Data loss and security breaches are among these problems, which raise the possibility of identity theft and illegal access. Businesses may also encounter legal and regulatory challenges in the absence of adequate supervision. Additionally, manual errors may lead to poor decision-making and incorrect reporting, which could damage reliability. This can therefore lead to a loss of stakeholder trust and harm to one's reputation. In the end, manual methods' lengthy and prone to mistakes result in decreased efficiency. Organizations should give top priority to automated reporting systems with strong validation procedures in order to reduce these risks. The reduction of manual involvement, the improvement of data correctness, the reinforcement of security, and the provision of compliance all contribute to more effective operations and better decision-making abilities. Furthermore, the individuals in charge of creating the reports can devote a lot more time to other activities and assist their organization more. Lastly, strategic planning is supported by automated reporting systems since they can forecast future performance and develop long-term goals of the organization.

The main objective of this thesis is to develop a reporting system for power plants with multiple DCS and SCADA systems using OPC communication technology and its architecture. Since they handle dozens or millions of signals, SCADA and DCS are essential for continuous operation, engineering, monitoring, multi-loop control, and operational data archiving are all made possible by these systems. They are insufficient for reporting, nevertheless, because they are transaction-oriented and do not offer data in the necessary tabular formats. The only way to get around this restriction is to use an OPC-based solution, which also makes it possible to gather all of the disparate system data into a single database for reporting purpose.

During the study; PLC, SCADA, DCS, OPC communication technology and their architecture is explained. The major vendors and their softwares are briefly explained. After all, selection between them according to the requirements is handled. At the end the reporting system is designed which gathers data from 4 seperated DCS and SCADA and stores it in its own database to serve data at any time in the designed style. After this improvement, uninterrupted data recording is now possible regularly, handwriting or misreading problems in data are no longer

an issue and reporting takes place more quickly. Besides, the number of the staff responsible for reporting and also the time consuming on preparation of the reports are decreased.

The study recommends adopting OPC-based automated reporting systems in power plants to centralize and standardize data by integrating with existing DCS and SCADA platforms. It emphasizes investing in staff training, implementing strong cybersecurity measures, and ensuring systems are scalable for future expansion and advanced analytics. Reporting should align with regulatory and stakeholder requirements to improve transparency. Future research should explore cloud integration and machine learning to enhance forecasting, fault detection, and overall operational efficiency.



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