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PRINCIPLES AND APPLICATIONS OF COMPUTERISED PROCESS INSTRUMENTATION AND CONTROL SYSTEMS TO ADVANCE INDUSTRIAL PROCESS OPERATIONS IN NIGERIA

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ABSTRACT

Nigerian industrial revolution has progressed through stages of development in different periods (eras). The requirement for operator interface in the distributed control system was fulfilled by Supervisory Control and Data Acquisition (SCADA). Operator station enabled information systems automation to enhance enterprise resource Integration which enables better strategization to overcome profit squeeze and liquidation. The Programmable Logic Controller provided solution to sequence automation and fast reaction systems where scan times, sequences and event recording are required. Since 1971, the distributed control system has undergone progressive advancement, some of which include: Integration of Microprocessor, Human-Machine interface, Networked Systems, Modular design, integration with Enterprise Resource Planning along with manufacturing execution systems and Internet of Things (IoTs) which enables adoption of industrial procedures: Data Analytics, Cloud Computing, Edge Computing and Cyber- security Protection. Integration of Digital Twins, Machine Learning and Artificial Intelligence will make Distributed Control Systems smarter, more efficient and adaptable with many benefits. In Nigeria, the integration of advanced technologies such as Artificial Intelligence into the Distributed Control Systems will enhance efficiency, greater productivity and higher product quality resulting in reduced costs and increased profits. The Nigerian Government is therefore encouraged to overcome the challenges and fully implement artificial intelligence in Nigeria.

KEYWORDS: Industrial Revolution; Nigerian Eras; Artificial Intelligence; Distributed Control Systems; Instrumentation and Control.

1.0. INTRODUCTION

In Nigeria, it is observed that manufacturing process has undergone a slow transformative shift from manual labour to machine-driven manufacturing resulting in increased productivity, technological innovations and urban migration.

Nigerian Industrial Revolution Evolved in Eras as follows:

A. The Nigerian Primitive Tools Era (1880-1945) precededby the Stone Age and the Iron Age.

In the Nigerian Primitive tools era, primitive tools were used to enhance survival. Due to growing in - satisfaction and quest for need satisfaction, this era underwent a significant period of industrial revolution which technological changes and novel ways of thinking and living improved the quality of life.

B. The Nigerian Machine and Instruments Era (1946-1970)

In this era, machines and industries were used instead of hand tools. In the Nigerian machine and instruments era, there was increasing demand for goods and services as the population grew. There was therefore the need for industries to increase the rate of production to meet the increasing demand. To achieve this, what should have been done was to employ more workers but there was shortage of skilled manpower to produce these goods and services. This problem was solved by introducing simple machines which would produce these goods and services faster than man. But still, a lot of people were needed to operate every individual machine. In order to reduce the number of operators and make them available for other expanding industries, the machines were made to operate automatically i.e. they operate by themselves once started so that one man can monitor a group of machines as they operate by themselves and only require monitoring. To enhance these machines to operate on their own once they are started and only be monitored; instruments to enhance these were installed.

C. The Nigerian Distributed Control Era (1971 till date)

In the distributed control era, industries grew from machine and instruments to complex bigger process plants that required industrial automation with more efficient process control of complex industrial processes.

The 1970s:

Asamak Industries Ltd. (2025) stated that the need to resolve problems associated with centralized control systems which were beginning to fail resulted in the implementation of the Distributed Control Systems (DCS). The implementation of Distributed Control Systems separated control functions into different controllers and processors. This new architecture made the systems more reliable, flexible and simpler to operate across multiple processors.

Sampson (2014) stated that the Nigerian Government keep setting Millennium Development goals and industrial revolution plans so as to enhance faster industrial growth. Statehouse news (2025, February 17) stated that on the 17th of February 2025, the Nigerian Government unveiled the Nigeria's Industrial Policy with the aim to strengthen production chains including logistics, storage and distribution. It further stated that the Nigerian Industrial Revolution Policy 2025 is a ten year framework designed to transition the Nigerian economy from a consumptive economy to a productive economy targeting 20-25 % manufacturing Gross Domestic Product (G.D.P.) by the year 2035. Templars (2026) stated that the Nigerian Vision 2030 aims at $1 trillion G.D.P. by the year 2030 by driving industrialization, boosting local manufacturing and diversifying the Nigerian economy.

Sampson (2015) stated that industrial process operations must be done using computerized process instrumentation and control systems as it is more efficient than manual control and safes time and effort and with the digital inclusion new technologies that enhance realization of the Nigerian vision are introduced. This will enhance the speedy realization of the Nigerian quest for industrialization. The integration of advanced technologies will enhance efficiency, greater productivity and product quality. This will result in reduced costs and increased profits.

The advances made particularly to the Nigerian computerized instrumentation and control systems by integration of the latest technologies through Progression of Nigerian Eras that are particular to Nigeria has been a research gap. Much research has not yet been done on advances in Artificial Intelligence being a latest technology. Process performance evaluation by help of transfer functions that model instrumentation and control systems dynamics is a limitation of this study. Moreover, a comprehensive comparative study of each of the advanced technologies will not be made.

This Technical paper studies among others the Nigerian transition from evolution to the advances made in the Nigerian Computerized Instrumentation and Control Systems by integrating the latest technologies e. g. Artificial Intelligence which could enhance higher efficiency, greater productivity, and higher product quality and hence increased profits.

2.0. MATERIALS AND METHODS

2.1. Materials

The following materials were used for the study: Analog Multiplexer; Digital Filter; Analog/Digital Converter; Amplifier; Process Control Computer; Transducers; Transmitters; Analyzers; Controllers; Distributed Control systems; Programmable Logic Controller to mention but a few of them.

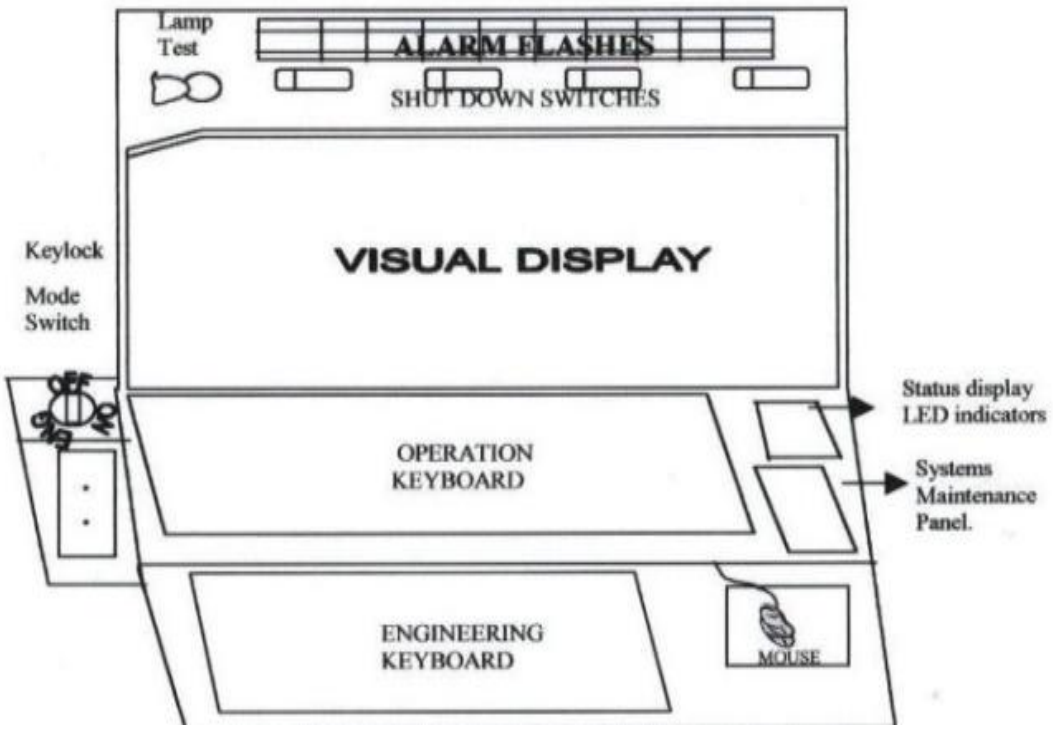


Fig. 1: The Process Control Computer
Source: Yokogawa Engineering Training Center (1994)

2.2. Methods

2.2.1. Integration of Artificial Intelligence in Nigerian Process Industries

High-Value cases and operational pain points were identified after which data infrastructure and readiness was assessed.AI Technology that fit the Process was selected anda test pilot ran. AI work-flows were embedded and the system scaled-up to the designed capacity. System requirements were structured after which integration readiness was determined. Quality, consistency and structure suitability were then determined. Checks were done to ensure compliance to Government regulations.

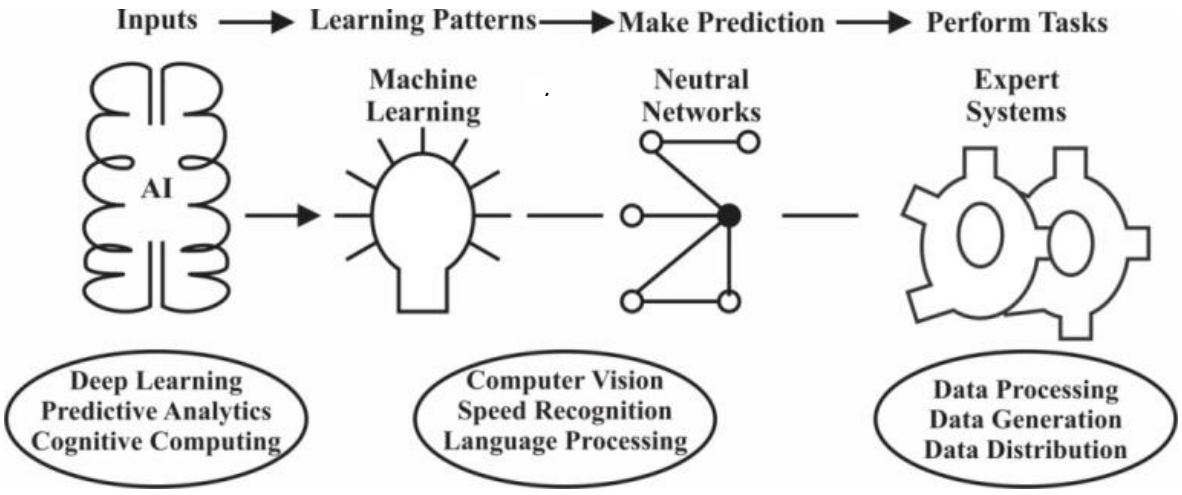


Fig.2: How artificial Intelligence works

2.2.2. Data Acquisition System

A transducer converted physical quantity such as temperature, pressure flow rate, level into electrical signal in the form of voltage. An amplifier brought the range of voltage up to a level capable of operating the rest of the system. A filter removed extraneous signals e.g. noise from the wanted signals. An analog multiplexer allowed one analog to digital converter to operate with several analog channels. The computer controlling data acquisition process selected which of the analog inputs should be coupled to the analog to digital converter. The output of the multiplexer was determined by the computer which also held the signal constant until the analog to digital converter has carried out its conversion of the voltage into digital signals which was read by the microprocessor. The set point or the optimum values of control parameters were fed in digital form to the Analog to Digital Converter which generated the necessary control signals. The computer only understood binary (0 or 1). A string of these binary numbers (bits) represented numerical or word information. In the Arithmetic Logic Unit (ALU) of the intelligence part, the compiler compiled four words typed in four words per bit e.g. 1111, 0111, 0011, etc. The bits were grouped together into discrete units. Units of eight bits were called bytes. The executing unit of the control computer converted binary language to a language which the operator understood and displayed this on the screen.

2.2.3. Control of Process Variables

Instruments enhanced the control of process variables such as temperature, pressure, flow-rate, level and composition by help of transducers and analyzers. A sensing element, a transducer and a transmitter were the component parts of the instruments. Whereas sensing elements were primary detectors which detected changes in process variables by motion or deflection or displacement of elastic components (signals), a transducer converted signal to a form that can be read and interpreted.Transmitters then transmitted the readable and interpreted signals to a display screen in the control room. A Sensing element was a spring, a

diaphragm, a capsule, bellows or a bourdon tube. Bourdon tubes were either C – type, spiral type or helical type. The advantage of the helical or spiral type was that they had more number of turns of coil, compared to the C-type. Therefore there was no need for further magnification or amplification by use of gear mechanisms as it was in the C-type. The absence of gear mechanism eliminated backlash which could have occurred when the gear and pinion mechanism became worn out due to continuous use. Accuracies were higher due to absence of magnifying elements.

The variables under control were:

a. **Manipulated Variable:** The manipulated variables were adjusted such as to bring a change in the value of another variable.

b. **The Controlled Variable:**The controlled variable value needed to be maintained at certain set value by adjusting the value of another variable referred to as "the manipulatedVariable"e.g. to control the temperature of a product by maintaining it a certain set temperature, the flow rate of cooling water or the flow rate of steam could be adjusted. With this, temperature is regarded as the controlled variable whereas flow- rate is regarded as the manipulated variable.

2.2.4. Methods of Effecting Control

a. **Feed-Back Control:** In feed-back control, information about the controlled variable was fed-back into the controller as a basis for control of the process variable. Feedback control can be manual or automatic.

b. **Feed-Forward Control:** In feed-forward control, process disturbances were measured and compensated for without waiting for a change in the controlled variables to indicate that a disturbance had occurred.

c. **CascadeControl:** Cascade control occurred in a situation where one controller referred to as the master supplied set point to another controller referred to as the slave.

2.2.5. Types of Controllers

Controllers compared input signal to the designed value or set point and effected a corrective action.

The following types of controllers were used:

a. Proportional Action (PA) Controller: A proportional action controller was used for a process that responded fast to change.

b. Proportional Integral (PI) Controller: A proportional integral controller was used for a process whose response to change is slow. A PI Controller summed-up the error and eliminated them. It was majorly used for flow, pressure and level control.

c. Proportional Derivative (PD) Controller: A proportional derivative controller was used for any industrial process regardless of its characteristics. It is suitable for all conditions.

d. Proportional Integral Derivative (PID) Controller: A proportional integral derivative controllerwas used for any process which the response to change was extremely slow. This made it more difficult to control. A proportional integral controller generatedoutput that was proportional to the rate of change of the error. It was suitable where the error was a persistent one.

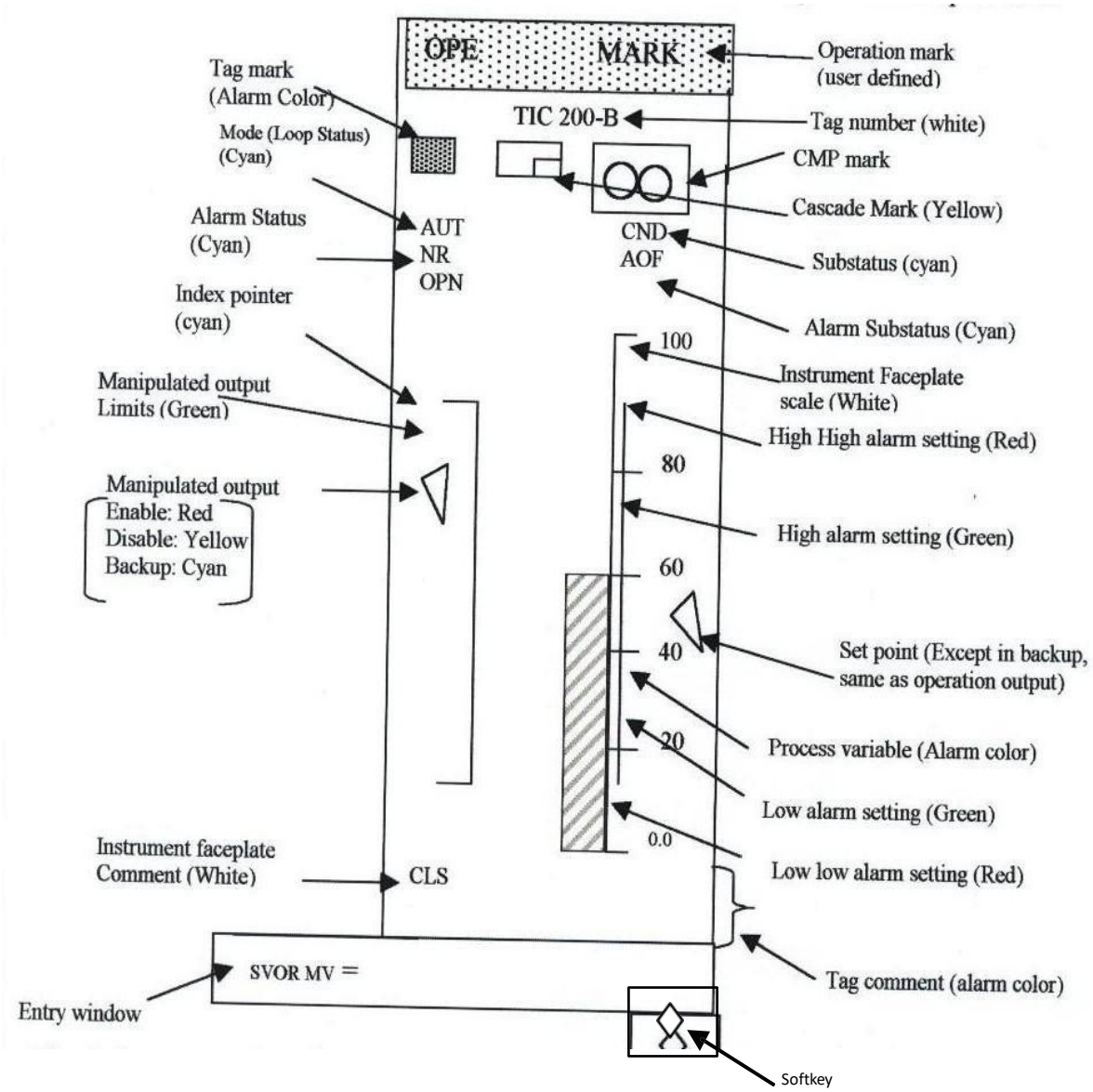


Fig. 3: Instrument faceplate (PID – Controller function block)
Source: Sampson (2015)

Sampson (2015) stated that the controller can be for flow (FIC), Temperature (TIC) or Pressure (PIC). To display single faceplate for a control valve, the value was pointed on the screen. The value status appeared on the screen side. The entry window was opened by touching the soft key below the instrument faceplate. Control keys were then used to adjust the values to the set point. The instrument faceplate was used to display the control state of each tag (function block) assigned to it thereby showing a visual representation of the function block control states.

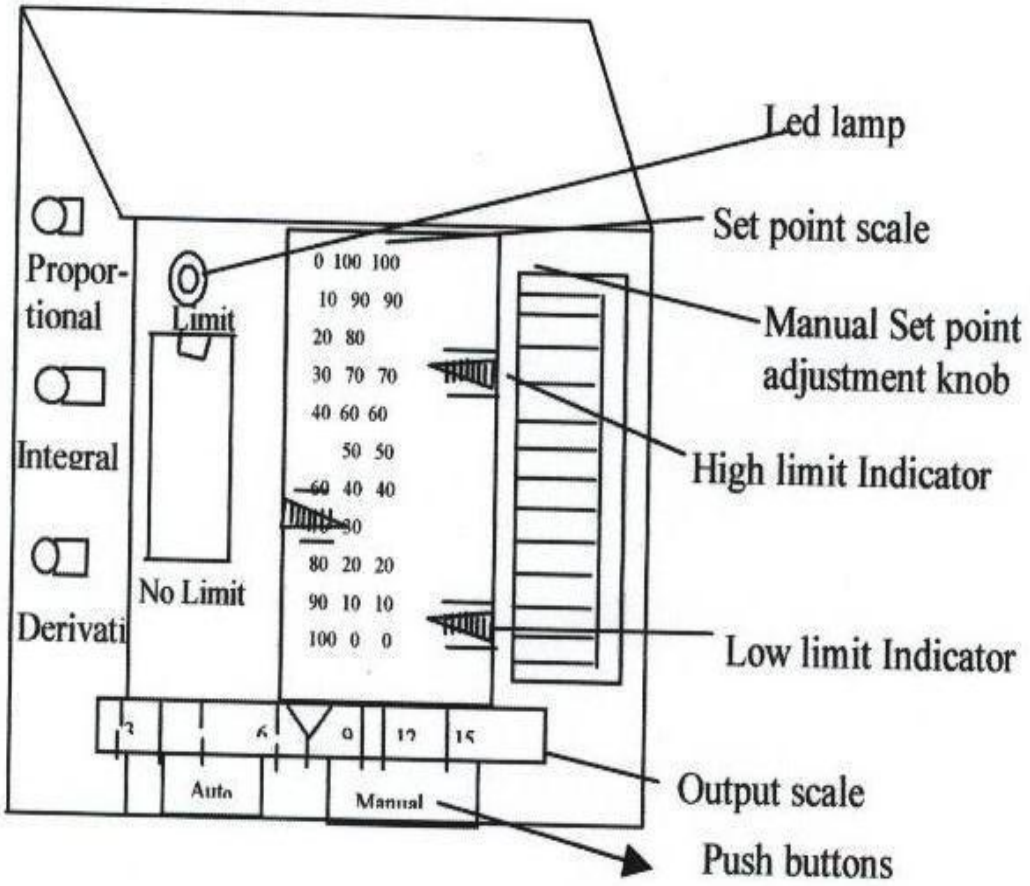


Fig. 4: Analog control computer for PID controllers.

$$Reading = Fraction \times Range + Starting\ Value \qquad (1)$$

Calculation

If a flow controller in the plant has a range 0 – 0.16 m^3hr^{-1} = 1.6 and the pointer is at 50 out of 100.

$$\text{Fraction} = \frac{50}{100} = 0.5$$

$$\boldsymbol{Flow - rate = 0.5 \times 1.6 + 0 = 0.8\ m^3hr^{-1}}$$

2.2.6. Modes Instruments were operated

Instruments were operated:

i. **Pneumatically**: with the help of air e.g. valves.
ii. **Electronically**: with the help of electrons e.g. cathode ray tube.
iii. **Mechanically**: with the help of force e.g. pumps and compressors
iv. **Hydraulically**: with the help of liquid e.g. manometers, gauges with pointers helped indicate the value of process variables which were read directly.

2.2.7. Quantising a Signal

Current to Pneumatic Conversion

Electric Current was converted to pneumatic by a current to pneumatic (I/P) converter. This conformed to a general formula:

$$\left[\frac{\alpha}{I} \times \rho - P\right] + 4 = I - 4 \qquad (2)$$

$$\alpha = I + 4 \quad (3)$$

$$\rho = P + 3 \quad (4)$$

Where α is the succeeding current level
I, the preceding current level
ρ, the succeeding pneumatic level,
P, the preceding pneumatic level

2.2.8. Integrations in Distributed Control

Sampson (2015) &Okehs (2001) stated that the Distributed Control System (DCS), Supervisory Control and Data Acquisition (SCADA) and the Programmable Logic Controller (PLC) were developed and driven by the requirement for total and integrated solution to process plant control. The Programmable Logic Controller provided limited operator interface but helped replace the electromechanical relay logic which was used to provide automatic sequence control. The requirement for operator interface was fulfilled by Supervisory Control and Data Acquisition (SCADA). The PLC provided solution to sequence automation and fast reaction systems where scan times, sequence and event recording were required. SCADA is a real time control system with a man in the loop for both monitoring the status of the process and for controlling the process.

Furthermore, Sampson (2015) & Okehs (2001) stated that Distributed Control Systems (DCS) was developed from the need to replace analog control instrument panels with continuous sequence control with advanced control capability which included such areas as self-tuning; model based predictive control, dead time composition and fuzzy control developed to provide process optimization. Sampson (2015) stated that DCS panel incorporated an operator interface which would allow monitoring and control functions to be executed from single displays incorporating interactive graphics. This spawned an integrated man-machine interface called “Operator Station” thus enabling information systems automation, Automatic Process Control (APC), integration, robotics, telecommunication to enhance Enterprise Resource Integration (ERI) where communications are used to improve resource utilization to obtain better performance and strategization to overcome profit squeeze and liquidation. Sampson (2015) & Bornavita *et al*. (2008) stated that Enterprise Resource Planning (ERP) bridges the gap between transactional and manufacturing levels in areas such as operator support, safety, production and maintenance management. Sampson (2015) & Okehs (2001) cautioned that Enterprise Resource Planning and Supply Chain Management Systems are useful for obtaining cost and production information but if that information is not used to change business practices, poor business practices could be automated. Plant- centric approach to plant information systems provides not only the information necessary to improve plant operation but also improve safety and reliability through asset management capabilities. ERP type systems might not ensure recovery from long term losses due to accidents, hazards and environmental problems but information systems with improved reliability and safety would be more beneficial.

2.2.9. Advances, Innovations, Adoptions of Distributed Control Systems and the Applications, Challenges and Strategies of Implementing Artificial Intelligence in Nigeria

A qualitative research was carried out by analyzing qualitative data obtained from texts sources.

3.0. RESULTS AND DISCUSSION

3.1. Quantising a Signal

For a range of Current: 4 - 20 mA

Pneumatic: 0-15 Psi, the following percent valve opening were obtained as in Table 1.

Table 1: Current to Pneumatic (I/P) Conversion

CURRENT (I)	PNEUMATIC (P)	% VALVE OPENING
4 mA	3 Psi	0%
8 mA	6 Psi	25%
12 mA	9 Psi	50%
16 mA	12 Psi	75%
20 mA	15 Psi	100%

Signals in the form of electric current are converted to pneumatic for opening of valves. The percent valve opening depended on the amount of current.

3.2. Advances in Distributed Control Systems

The distributed Control System experienced the following advancements as in Table 2.

Table 2: Advances in Distributed Control Systems (DCS)

Period	Advancement	Advantages
The 1970s	The implementation of DCS separated control functions into different Controllers and processors.	This Architecture, made the systems more reliable, flexible and simpler to operate across multiple processors
The 1980-1990s:	a. Integration of microprocessors	i. Firm and sophisticated control algorithm can be executed with reduced response duration. ii. Improved Reliability, accuracy and overall performance. iii. Adoption of standardized communication protocols was improved; hence devices from various process units could communicate flawlessly. iv. Improved flexibility and scalability.
	b. Enhanced Human-Machine Interfaces (HMIs)	i. Text-based displays transitioned to graphical user interfaces which make it easier for the operator to monitor and interact with real time operations with improved visualizations. ii. Faster response to faults and reduced human error.
	c. Expanded Industry Application	i. Better reliability ii. Easier usage iii. Enhanced connection possibilities.
The 2000s – 2010s	a. Networked Systems	i. Real-time and uninterrupted connection between Human-machine interfaces, the controllers and field devices. ii. Enabled distant monitoring.
	b. Modular Design	i. Sped-up data exchange. ii. Simplified maintenance procedures.

	iii. Enabled scalability iv. Improved capacity of the system to accept process requirement changes.
c. Enterprise Resource Integration (ERI)	i. Combines operational visibility between the production process and the business management department. ii. Better access to real-time resource planning systems, decision making tools and performance tracking capabilities. iii. Control accuracy, data monitoring. iv. Co-ordination of production work-flow with business objectives. v. Data-centric capabilities .
d. Internet of Things (IoTs)	i. Real-Time Analytics ii. Predictive maintenance iii. Cloud Computing iv. Edge Computing v. Cyber - Security Protection

Each advancement resulted in improved technology and system efficiency for enhanced profitability.

3.3. Future Trend and Innovations on Distributed Control Systems

The DCS will become smarter, more adaptable and efficient as the innovations on Table 3 are integrated.

Table 3: Innovations on DCS, Procedures and Advantages

Innovation	Procedure	Advantages
Digital Twins and Virtual Simulation	Simulation and testing are done within virtual replicas called Digital Twins	i. Help in conduction of modeling and simulation without any effect on current operations. ii. Operators to achieve better optimization by testing alterations while monitoring anticipated results before the actual implementation within the physical domain.
Machine Learning (ML)	With the aid of a mechanism, ML enables systems to gain knowledge by reviewing the data throughout the operation in a system governed by rules.	i. Helps DCS to recognize hidden patterns, irregularities and emerging trends. ii. Adjustment to control strategies become possible as historical data enhances smarter control and fast response. iii. Pro-active measures that advance operational improvement are taken through data learning capabilities supported by predictive analytics tools.
Artificial Intelligence (AI)	AI) enables the DCS to make decisions by implementing AI algorithms for analysis of tremendous sensor and	i. The fault detection systems of AI have improved capabilities to foresee equipment failures thus

	process data streams.	helping maintenance planning and minimization of operational interruption. ii. Deliver more self-operating optimized data choices. iii. Minimize human mistake and optimize system performance. iv. Globally, AI is re-shaping manufacturing by making processes smarter, faster and more efficient. v. From predictive maintenance to real-time quality control, AI systems reduce down time, cut costs and improve product quality. vi. AI also creates opportunities for investors and entrepreneurs seeking to tap into emerging business models and manufacturing innovations.

Mato consulting (2025) stated that the manufacturing industry is undergoing a revolutionary transformation known as industry 4.0. which integrates advanced technologies, such as Internet of Things (IoTs), robotics, big data analytics and most importantly Artificial Intelligence (AI), Digital Twins and Machine Learning.

3.4. Adopting Artificial Intelligence in Nigeria

As Nigeria positions itself to join this industrial revolution, anyone interested in advancing Nigeria's manufacturing sector or launching ventures within Nigeria needs to understand AI's transformative potential. Reasons AI should be adopted in Nigeria are as in Table 4.

Table 4: Need for Adoption of AI in Nigeria

Necessity	Need	Advantages
Rising competitiveness	i. Faster decision-making ii. better product quality iii. flexible manufacturing processes	i. Meeting international standards ii. Fast respond to market demands iii. Capturing greater market share. iv. Attraction of foreign investment.
Efficiency Gains	i. Predictive Maintenance ii. Automated Quality Control iii. Supply Chain optimization. iv. Visual Automated Inspections. v. Optimized Inventory Management.	i. Prediction of equipment failures before they occur. Reduction of costly down-time. ii. Consistentproduct quality. iii. Minimizing wastes andre-works. iv. Reduction of carrying costs and excess stock. v. Potential cost savings. vi. High profitability.
Modernization	i. Aligning with the Nigerian Industrial Revolution Plan. ii. Upgrading manufacturing infrastructure and skills. iii. Diversify the Nigerian economy to reduce dependence on Petroleum Oil revenues.	i. Boosting productivity ii. Creating employment iii. Fostering innovation iv. Enhancing technology transfer. v. Sustainable economic and industrial growth. vi. Improvement of Nigeria's position

in the global value chain.

Adopting AI in Nigeria has numerous advantages arising from the need and necessity for the adoption. Considering the rising competitiveness, efficiency gains and modernization, adoption of AI could enhance speedy realization of the Nigerian quest for advanced industrialization.

3.5. Integration of Artificial Intelligence in Nigerian Process Industries

The results of integration of Artificial intelligence in Nigerian process industries are discussed on Table 5.

Table 5: Integration of Artificial Intelligence in Nigerian Process Industries

Result	Discussion
Pilot -Test	Allows organization to test model with real data, identify technical integration gaps, measure the feasibility, functionality and business impact before scale-up.
Work-flows	Machine language algorithms are used to analyze data, recognize patterns and save time on repetitive tasks.
Scale-up	Enhance system capability to handle greater work load by adding more resources such as faster processors, more memory or increased storage capacity to an existing system.
Structured Systems	Enables understanding of the hardware that are needed e.g. the Central Processing Unit (CPU), Graphics Processing Unit (GPU) and Random Access Memory (RAM).
Integration Readiness	Emerging technologies like cloud platforms automation, generative AI and no code solutions such as Knack are used to accelerate readiness such as to enable Scalable AI integration.
Structural Suitability	Checks ensured system met specific needs, risks and operability realities following standards such as International Standard Organization (ISO).
Compliance to Government Regulations	Checks ensured that Data governance aligned with data protection laws, transparency obligations for AI generated content, accountability framework for AI developers and deployers, safety requirement for risky AI systems.

The integration of Artificial Intelligence has advanced industrial operations in Nigeria making operations easier, smarter, faster and more efficient resulting in reduced cost, high yields, high product quality and profits.

3.6. Applications of Artificial Intelligence in the Nigerian Manufacturing Sector

The application of artificial intelligence in the Nigerian manufacturing sector is as illustrated on Table 6.

Table 6: Applications of Artificial Intelligence in the Nigerian Manufacturing Sector

Application	Use	Advantages
Predictive Maintenance	Analysis of sensor data from machines and process equipment such as to predict when the equipment might eventually fail	i. Maintenance scheduling before equipment breakdown. ii. Reduction of down-time and repair costs
Quality Control and Visual Inspection	Inspection of products for defects or inconsistencies	i. High quality product ii. Wastes reduction
Supply chain optimization	i. Forecasts demand ii. Manage inventory iii. Optimize Procurement iv. Enhance logistics	i. Learner inventories ii. Lower costs iii. Improved delivery times
Robotics and Automation	i. Material handling ii. Assembly welding iii. Packaging	i. High flexibility. ii. High precision.
Digital Twins and Simulation	Virtual replicas of physical assets or processes can be simulated and analyzed.	i. Scenario testing. ii. Troubleshooting. iii. Performance optimization.
Generative Design	i. Generate multiple design alternatives based on specific constraints.	i. Improve design efficiency. ii. Accelerated product innovation.
Augmented Reality (AR)	i. Immersive training. ii. Troubleshooting support. iii. Instructions for workers.	i. Minimization of errors. ii. Enhancing skills acquisition.
Energy Management	Monitoring and optimizing energy consumption.	Reduction of environmental impact and costs.
Process Optimization and Product Scheduling	i. Minimizing bottlenecks ii. Balancing work-flows	i. Improves throughput ii. Work-flows

3.7. Challenges of Implementing Artificial Intelligence in Nigeria

The challenges of implementing artificial intelligence in Nigeria and how to overcome them are as in Table 7.

Table 7: Challenges of Implementing Artificial Intelligence in Nigeria

Challenge	Constraints	Strategies
Infrastructural Deficits	i. Limited internet connectivity ii. Epileptic power supply iii. High implementation costs iv. Scarcity of skilled personnel	i. Making-up for the Nigerian energy deficit. ii. Provision of training for personnel.
Organizational Dynamics and Human Factor	i. Integration with workforce ii. Balancing worker acceptance with Automation iii. Training and incentives	Aligning with positive organization change management and culture
Data Readiness and Quality	Lack of clean, structured and contextualized data	i. Adoption of hybrid edge-to-cloud models. ii. Implementation of data lake houses. iii. Centralizing and standardizing data through investment in data infrastructure.
High Implementation Costs	i. Initial investment required for AI implementation may be prohibitive. ii. Implementation expenses may be indeterminate. iii. Hidden cost: cost of data preparation, training and systems integration.	i. Seeking financial aids, incentives and subsidies from the Government. ii. Public-Private Partnership to offset costs. iii. phased implementation by starting with a pilot project to demonstrate the rate of return on the investment
Skill Shortages	i. Shortage of skilled personnel trained in AI ii. Digital technologies iii. Data science	i. Collaboration with educational institutions for manpower development and training programs. ii. Implementation of continuous learning initiatives for knowledge transfer from experienced professionals to graduate trainees
Integration with Legacy systems	i. Outdated infrastructure ii. Incompatible systems	i. Modular approach to integration. ii. Incremental upgrades to bridge the gap between new AI applications and legacy systems could ensure smooth interoperability
Ethical and Governance Concerns	i. Data privacy. ii. Algorithmic bias iii. Improper governmental frameworks. iv. Mistrust v. Litigations among stakeholders	i. Clear ethical guidelines. ii. Governmental principles that promote accountability, fairness and transparency. iii. Deliberations and discussions among stakeholders such that could align AI initiatives with societal values and expectations.

The challenges of implementing Artificial intelligence in Nigeria can be overcome by applying strategies that could help eliminate or minimize the constraints without negative effects on industrial process operations.

3.8. Strategies for Engaging Artificial Intelligence in Nigerian Industries

The strategies for implementing artificial intelligence in Nigerian industries are as in Table 8.

Table 8: Strategies for Engaging Artificial Intelligence in Nigerian Industries.

Strategy	Implementation	Benefits
Pilot Programs	AI technologies such as predictive maintenance or digital twins should be tested first on a small scale in a critical high impact area of the process plant. From the results obtained, approaches should be refined before full scale implementation	This helps build confidence and also minimizes risk.
Infrastructural Investment	Nigerian industries should invest in reliable power supplies, Internet of Things (IoTs) Sensors and high speed internet.	Internet of Things (IoTs) sensors will enhance data flow that enables accurate analytics and timely decision making.
Training and Partnerships	Collaboration with Technical Schools, Universities and Technology Consultants could help in training workforce capable of designing installation, operation, maintenance and innovation.	Training programs prepare workers for evolving technologies.
Supportive Policies and Incentives	Industries should partner with government agencies to formulate and implement policies that enhance AI adoption. Incentive could be in the form of grants and subsidies.	Technology diffusion and innovation can be accelerated through public-private partnership.

The implementation of artificial intelligence in Nigerian industries could be highly beneficial. The benefits of artificial intelligence implementation are stated on Table 8.
Besides these industrial benefits the benefits of AI implementation in Nigeria include the following:

i. Enhancement of global competitiveness.
ii. Support for economic modernization.
iii. Optimization of resource use by enabling smarter production processes.
iv. Acceleration of product development.
v. Enhancement of Sustainable Industrial growth.
vi. Enhancement of Economic Diversification.

4.0. CONCLUSION

The principles and applications of computerized process instrumentation and control systems have been studied. In this study, a transformative shift in the Nigerian industrial revolution from manual labour to machine-driven manufacturing has been detected through progression in different periods and eras. The importance of integration of technologies such as artificial intelligence etc., into the Nigerian instrumentation and control system has been elucidated. Integration of artificial intelligence into the Nigerian manufacturing sector will enhance efficiency, reduce costs, enhance productivity and product quality, energy management, process optimization, economic diversification, environmental conservation, industrial growth and modernization, process design, process control, plant maintenance, etc. to mention but a few.The Nigerian industries and the Nigerian Government will stand to take the advantage if bold steps are taken to overcome the challenges and adopt artificial intelligence to advance industrial process operation in Nigeria.

5.0. RECOMMENDATIONS TO THE NIGERIAN GOVERNMENT

The following recommendations are made:

i. Equivalent Restitutions

The Nigerian Government should promulgate a legislative act that makes provision for schemes and regulations stipulating that employees that cause losses and damages make equivalent restitutions for the losses and damages they caused. This will enable the workers to be more safety and loss prevention conscious in Doing Right Things Right, First Time, On Time and All the Time. This will serve as a deterrent to others and minimize losses and damages due to mal-operations. The law of equivalent restitutions can equally be enforced on production and distribution of off-specification and inferior goods. This will enhance production and distribution of high quality products that are durable.

ii. Enforcement of Industrial Regulations on Process Design, Operations, Instrumentation and Control.

Enormous losses would have been avoided if not for underutilization of process instrumentation and control systems. Examples: As in Sampson (2015) the hardening of polymer in a reactor because one of the ingredients of polymerization reaction did not go in despite a large valve opening should have been avoided if the system had a visual display unit for observation of movement of the reactants. The tripping of a compressor due to low cooling water flow- rate should have been avoided if the cooling water flow- rate were cascaded to the temperature in the receiving condenser. The explosion of a furnace due to improper purging before light up should have been avoided if a gas analyzer was installed and the readings directly monitored at the main control panel, just to mention but a few of them. Promulgation and Enforcement of Government laws on industrial process design, operation, instrumentation and control will make industrial professionals work professionally such as to avoid penalties, avoid mal-operations, accidents and losses.

iii. Governance Frameworks

It is crucial to establish governance frameworks that could promote equity, support workforce transitions and ensure the ethical use of data and automation.

Policy makers and industry leaders must work together to create inclusive policies that safeguard privacy, manage automations, impact jobs and foster responsible artificial intelligence deployment.

iv. Industrial compliance

Industries should be Artificial Intelligence compliant before being allowed to operate in Nigeria. Nigerian industries should have instrumentation and control system that could allow integration of artificial intelligence and other technologies before being allowed to operate in Nigeria. Nigerian companies should be able to train their staff, develop knowledge and skills needed for instrumentation and controls and rethink their systems.

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