AN OVERVIEW OF INDUSTRIAL AUTOMATION AND ITS IMPLEMENTATION APPROACHES FOR BOOSTING NIGERIAN AND OTHER DEVELOPING ECONOMIES

Supported by tetfund

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Received: October 17, 2020 **Accepted:** February 13, 2021

Abstract: Countries that are heavily applying automation technologies in industrial processes are seen to be the most productive nations globally with higher GDPs and standard of living while developing countries continue to struggle to meet local demands and become globally competitive and significant technologically and economically. It has been found from the paper that, the structure of the Nigerian economy is typical of an underdeveloped nation. The country's industrial sector comprising of manufacturing, mining, and utilities is seen to be hardly constituting more than 6% of her economic activities while the manufacturing sector alone up to 5% of her GDP in any year so far. The level of industrial automation in the country is also found to be generally low. The paper presents consolidated basic educative facts about industrial automation and its implementation approaches with the motive of reawakening application interest and rethinking by all industrial and other production stake holders in developing countries for improving their manufacturing systems to reap the benefits of the technology by boosting their personal and national economic developments and standards of life. Engineers in Nigeria and other developing economies can have great roles and rewards as skilled employees, consultants, entrepreneurs, and apostles in automating industrial and other production systems, machineries, etc in their countries progress to high level of industrialization.

Keywords: Developing economy, industrial contribution, technology, manual process, mechanization, automation

Introduction

Economy is the state of a country or region in terms of the production and consumption of goods and services and the supply of money. An industry is a place where goods or related services are produced within an economy. The fundamental objective of any industry is to make maximum possible profit (Encyclopedia.com, 2019). Industrialization is the period of social and economic change that transforms a human group from an agrarian society into an industrial one, involving the extensive re-organization of an economy for the purpose of manufacturing goods or related services. Industrialization is associated with income growth, urbanization, improvements in health, lifespan, and standard of living for the populace. Industrialization is part of a wider modernization process, where social change and economic development are closely related with technological innovation (*O'Sullivan et al., 2003)*. The dimensions of industrialization are the work or economic activity that people do for a living, the actual goods they produce or economic output, the manner in which economic activity is organized, the energy or power source used, and the systematic methods and innovative practices called technology that is employed to accomplish work (Alan, 1992; Rifkin, 1995; Encyclopedia.com, 2001).

For the last 260 years, the process of industrialization has perhaps had more impact on all the nations of the world than any other complex set of forces. Unfortunately, the process of industrialization has not been uniformly introduced in all countries, nor has it occurred at the same time or at the same rate in all countries. Despite the common features of industrialization, differences in its introduction and adoption have produced inequalities among nations and groups of people on a scale never before experienced.

Countries that are heavily applying automation technologies in industrial processes such as the United States, Japan, Germany, South Korea, United Kingdom, Singapore, Belgium, Denmark, Taiwan, Italy, China, etc are seen to be the most productive nations globally with higher GDPs and standard of living while developing countries continue to struggle to meet local demands and become globally competitive and significant technologically and economically. Much of the discussion on the economic effects of the use of automation has also concentrated on the effects in developed countries (Jobin, 2014; Steve Crowe, 2018).

The structure of the Nigerian economy is typical of an underdeveloped country. Over half of the country's gross domestic product (GDP) is accounted for by the primary sector with agriculture continuing to play the greatest role. The oil and gas sector, in particular, continues to be a major driver of the economy, accounting for over 95 per cent of export earnings and about 85 per cent of government revenue between 2011 and 2012 for example. Although Nigeria is ranked as the 27th-largest economy in the world in terms of nominal GDP and the 22nd-largest in terms of purchasing power parity and the largest economy in Africa, the general standard of life and industrial contribution to the country's economy is low. The country's industrial sector comprising of manufacturing, mining, and utilities is seen to be hardly constituting more than 6% of her economic activities while the manufacturing sector alone hardly up to 5% of her GDP yearly (Ajayi, 2011; Chete *et al.,* 2016). The level of industrial automation and other production systems or processes in Nigeria is also seen to be generally low (Aririguzo *et al.,* 2006). Many products such as shoes, castings, forgings, clothing, etc, rolled parts, machined parts, are made at shop entrepreneurial, firm and industrial levels in Nigeria by what can best be described as various combined levels of manual processing using tools and machineries and/or factory mechanization amidst minimal level of automation. This is seen as a contributing factor to making imported manufactured goods by industrial automation processes to dwarf sales of home grown products in Nigeria and other developing countries due to the imported manufactured goods being better in quality at comparable affordable rates.

Nigeria has been in quest to become industrialized amidst hurdles of: inadequate and irregular electric power and portable water supply, acute shortage of qualitative transportation systems, inconsistent policies, high level of crime and corruption, material corrosion, technological backwardness, developing resourceful or skilled manpower in science and engineering technology, etc. (Aayi, 2011; Chete *et al.,* 2016). But even then, industrial development to the pinnacle in the country is not conceivable without reasonable automation level of her entire production systems. Meaningful level of industrialization and automation of critical production processes and services at shop, firm and industrial levels in Nigeria and other developing countries can enable the countries experience quantum leaps in production rates and productivity with: increased GDP and wages for workers, better product quality and more efficient use of materials, improved safety and shortened workweeks for labor, reduced lead times and subjectivity and corruption by promoting transparency in production entrepreneurship, and increment product outputs and qualities that are globally competitive with overall enhancement of their economies and quality of lives of their citizens.

The aim in this paper is to present an overview of consolidated basic information on industrial automation and its implementation approaches with the motive of providing basic awareness on the subject and reawakening rethinking and application interest of much more industrial and other production stake holders in developing countries particularly in Nigeria for improving their manufacturing systems, equipment and factories to reap accruing benefits of industrial automation whilst contributing to boost their national economic progresses and quality of lives of citizenry there in their countries.

Overview of Industrial Automation

Industrial technologies

From the foregoing introduction section of this paper, it is evident that technology is a critical requirement for industrialization. It is also evident that without work and technology, there cannot be industry. The current industrial technologies involve various combined levels of manual processes, mechanization, automation, and robotics inputs (Groover, 2014). It is therefore imperative to know the roles of the different technological processes in order to appreciate the outstanding benefits of automation. A manual technological process involves control or manipulation of production by human operator using hands or physical strength without the help of electricity, computers, etc. The quality and rate of outputs from a manual process depends on how fast and well personnel use their hands or creativity or skill to make or do things. The quality and rate of output from a manual process vary from individual to individual performances. Manual processes are generally tedious, slow, and difficult to predict in performance and reliability (Groover, 2014).

Automation is the technology by which a process or procedure is performed with no or minimal human assistance. Automation achieves performance much superior to what is possible by manual operation in terms of power, precision, and speed of operation. Automation plays an increasingly important role in all aspects of the global economy and in daily expenses (Groover, 2014). The different types of automation according to the application areas of work include: power production automation, mining automation, video surveillance automation, high-way systems automation, waste management automation, home automation, business process automation, laboratory automation, logistics automation, industrial automation, and surgery automation *(Trevathan, 2006).* The current highest achievable level of industrial technology is through automation. Industrial automation eliminates the possibility of human error, reduces costs, saves time, and achieves higher performance. One of the most important application areas of industrial automation technology is in manufacturing. Manufacturing processes basically produce finished product from raw/unfinished material using energy, manpower and equipment and infrastructure. To many people, automation means manufacturing automation (Groover, 2006).

Industrial automation involves use of control systems and devices, such as computer software and robotics, to enable automatic operation of production processes and machinery, boilers, ovens, etc in factories without or with minimal need for human intervention. In order words it involves integrating several operations and ensuring that the different pieces of equipment talk to one another in a synchronized fashion to ensure smooth operation of designed processes to optimally effectuate production. Individual processes, system, equipment, etc can also be automated. Industrial or system or equipment automation eliminates the possibility of human error, reduces costs, saves time, and achieves higher performance in product quality and at the end boost industrial contribution to economy with higher standard of living. Some examples of automated industrial processes are (Aririguzo *et al.*, 2006; Groover, 2006; Electronicshub.org, 2019):

i. Packaging and material handling.
ii. Quality control and inspection.
iii. Metal fabrication such as machining, welding, cutting, cladding, painting, etc.
iv. Food and beverage processing.
v. Planning and decision making.

Automation and mechanization are often confused with each other. In the scope of industrialization, automation is the step beyond mechanization. Mechanization provides human operators with machinery to assist them with the muscular requirement for work without much assistance for mental requirement as well. In other words mechanization mainly displaces physical or manual labor without displacing much human mental requirement whereas automation greatly reduces the need for human sensory and mental requirement as well. Automation replaces human thinking with computers and machines and creates jobs for skilled workers at the cost of unskilled and semi skilled workers. It affects many industries at the same time (Sumtech, 2013). True automation therefore requires reevaluating and changing current processes with smart devices or systems for more complex and advanced control rather than simply mechanizing the processes.

The fields of automation and robotics are also often confused. Robots are programmable machines which are able to carry out a series of actions autonomously, or semi-autonomously. They interact with the physical world via sensors and actuators. Because they are reprogrammable, they are more flexible than single-function machines. Robotics refers to anything involving robots. Robotics is a more advanced form of automation. The differences between the two are revealed through how each works. Robots are able to learn from mistakes, or through constant exposure, while other automated machine slack this ability. The level of movement is also different between automation and robotics, with the level in robotics being faster and more complex (Groover, 2006; Wisegeek, 2016). Generally, automation and robotics differ essentially in terms of (Iasreview, 2012):

i. Set operations and sequence: Automation can only follow one set of operations, and it cannot be changed once programmed. Robots are made to perform several jobs at once, and the sequence of operations can be switched around to make the processes more efficient. The timing of the operations also can be changed in robotics, if needed.
ii. Outside stimuli**:** The automated system per se cannot react to outside stimuli. Even if there is an object blocking the automation, it will continue doing the same operation. However; robots are made to react to outside stimuli so, if something blocks or stops the robot, it will change operations to best fit the situation to continue performing its task.

iii. Artificial intelligence: Automated systems per se are unable to collect knowledge and can't be programmed with any form of intelligence. Robots can be made with intelligence and they are able to learn from mistakes; this allows the robot to fix problems, if it is exposed to them long enough.
iv. Level of movement: The amount of movement and overall velocity of robot and conventional automation are generally very different. Automated machines are made for slower work and are typically programmed with very simple movements compared to robots. For example, an automated arm may be able to pick up a chip, rotate and then place the chip somewhere else. A robot can work faster and is able to accommodate complex movements.

Types of industrial automation

Industrial automation systems are usually categorized into four types. These are (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019):

i) Fixed or rigid or hard automation system.
ii) Programmable automation system.
iii) Flexible or soft automation system.
iv) Integrated automation system.

Fixed or rigid automation

Fixed or rigid automation is a system in which the sequence of processing or assembly operations is fixed by the equipment configuration. The operations in the sequence are usually simple. It is the integration and coordination of many such operations into one piece of equipment that makes the system complex. The typical features of fixed or rigid automation are (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019):

i) High initial investment for custom-engineered equipment.
ii) High production rates.
iii) Relative inflexibility in accommodating product changes.

The economic justification for fixed automation is found in products with very high demand rates and volumes. The high initial cost of the equipment can be spread over a very large number of units, thus making the unit cost attractive compared to alternative methods of production. Examples of fixed automation include mechanized assembly and machining transfer lines (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019).

Programmable automation

In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded so that the system can read and interpret them. New programs can be prepared and entered into the equipment to produce new products. Some of the features that characterize programmable automation are (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019):

i) High investment in general-purpose equipment.
ii) Low production rates relative to fixed automation,
iii) Flexibility to deal with changes in product configuration
iv) Most suitable for batch production.

Automated production systems that are programmable are used in low and medium volume production. The parts or products are typically made in batches. To produce each new batch of a different product, the system must be reprogrammed with the set of machine instructions that correspond to the new product. The physical setup of the machine must also be changed over. Tools must be loaded, fixtures must be attached to the machine table, and changed machine settings must be entered. This changeover procedure takes time. Consequently, the typical cycle for given product includes a period during which the setup and reprogramming takes place, followed by a period in which the batch is produced. Examples of programmed automation include numerically controlled machine tools and industrial robots (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019).

Flexible or soft automation

Flexible or soft automation is extension of programmable automation. A flexible automated system is capable of producing a variety of products or parts with virtually no time lost for changeovers from one product to the next. There is no production time lost while reprogramming the system and altering the physical setups in tooling, fixtures, and machine setting. Consequently, the system can produce various combinations and schedules of products instead of requiring that they be made in separate batches. The features of flexible automation can be summarized as follows (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019):

i. High investment for a custom-engineered system.
ii. Continuous production of variable mixtures of products.
iii. Medium production rates.
iv. Flexibility to deal with product design variations.

The essential features that distinguish flexible automation from programmable automation are:

i) The capacity to change part programs with no lost production time.
ii) The capability to changeover the physical setup, again with no lost production time.

These features allow the automated production system to continue production without the downtime between batches that is characteristic of programmable automation. Changing the part programs is generally accomplished by preparing the programs off-line on a computer system and electronically transmitting the programs to the automated production system. Therefore, the time required to do the programming for the next job does not interrupt production on the current job. Advances in computer systems technology are largely responsible for this programming capability in flexible automation. Changing the physical setup between parts is accomplished by making the changeover off-line and then moving it into place simultaneously as the next part comes into position for processing. The use of pallet fixtures that hold the parts and transfer into position at the workplace is one way of implementing this approach. For these approaches to be successful; the variety of parts that can be made on a flexible automated production system is usually more limited than a system controlled by programmable automation (Electronicshub.org, 2019; Wisdom.com, 2019).

Integrated automation system

An integrated automation system is a set of independent machines, processes, and data; all working synchronously under the command of a single control system to implement an automation system of a production process. For example, Computer Aided Design, Computer Aided Manufacturing, computer-controlled tools and machines, robots, cranes, and conveyors can all be integrated using complex scheduling and production control (Groover, 2006; Electronicshub.org, 2019; Wisdom.com, 2019).

Advantages of industrial automation

A number of reasons why a company should consider implementing automation into its manufacturing process include the following (Electonicshub.org, 2018; Leecontracting.com, 2018; Britanica.com, 2018):

i. **Increased workplace safety by t**ransferring some dangerous tasks to automated machines. Since the Occupational Safety and Health Act was signed into law in 1970, the safety and health of employees has become a priority. Automation has made the workplace safer for employees.

ii. **Reduced labor cost.** Investing in automation can help to replace manual operations and thus, reduce increasing labor costs.

iii. **Increased labor productivity.** Automation of factory or manufacturing processes increases labor efficiency, productivity, and the total rate of production.

iv. **Reduced manual tasks.** Automation can reduce several operations that are repetitive, tiring or boring for employees.

v. **Accomplishment of impossible manual tasks.** There are certain manufacturing operations and processes that are not possible without the involvement of machines. Examples include rapid prototyping through graphic modeling, making of complex surfaces with Programmable Logic Controllers (PLC) or numerical controlled systems and integrated fabrication of circuits. These processes have special requirements for miniaturization, accuracy and geometry that are impossible to achieve manually.

vi. **Enhanced product quality.** Automation reduces the fraction defect rate and automated operations are performed with greater conformity and uniformity.

vii. **Avoidance of higher costs of not automating.** Automation benefits can lead to higher sales, better quality, improved productivity, a better bottom line due to higher efficiencies and a better company image. Companies that do not implement automation may find themselves lagging behind their competition with those that have chosen to automate.

viii. **Reduced manufacturing lead time.** Automation helps to reduce the elapsed time between the order of the customer and product delivery.

ix. It can significantly improve economy of the industry to have a direct impact on the national GDP and standard of living in a country or community.

Disadvantages of automation

The main disadvantages raised against automation include the following (Electonicshub.org, 2019; Leecontracting.com, 2019; Britanica.com, 2019):

i. Loss of jobs. Since majority of the work is done by machines in automated industries or production systems; the requirement for manual labor is very less. This is what creates fear for industrial automation implementation in some quarters.

ii. All desired tasks cannot be automated using the current technology. For example, products with arbitrary irregular shapes and sizes are best left for manual assembly but the trend seems to be changing with the emerging advanced computers and algorithms.

iii. It may not be feasible to use automation for direct processing of raw materials of certain configurations and sizes or nature to achieve repeatable high-volume of production of desired consistent products.

iv. The initial cost of implementing an automation system can be very high and prohibitive to many manufacturers.

v. Skilled personnel will always be on requirement for maintenance and service of automated system.

Types of industrial automation tools

Factory automation is what is also called industrial automation. Industrial automation means all types of automation done in industry. Industrial automation is the complete automation of the entire process done in an industry to achieve manufacturing of products and managerial functions with least human intervention by using suitable technological tools. The only job a human does in such factory is in monitoring and controlling the whole automation via the technological tools. Factory automation is indoor automation and consists of speed control, packaging, on/off control. It is note-worthy that outdoor automation is applicable to big plant like power grid, chemical process industry, oil refinery, pulp industry, paper industry, cement industry and it is called 'process automation'. An Industrial Automation system consists of various elements in synchronization with each other performing functions like sensing, controlling, supervising and monitoring of industrial processes. The commonly used industrial automation tool types include:

i. Human machine interface (HMI).
ii. Supervisory control and data acquisition (SCADA).
iii. Distributed control systems (DCS).
iv. Programmable logic controller (PLC).
v. Robotics.

In large industrial structures, it is impractical or even impossible to control the individual parts of the system because; in most installations, the parts are often located very far from each other. Thus the need arises to monitor and control them with SCADA and HMI. The main difference between SCADA and HMI is their scope. An HMI is a software application that enables interaction and communication between a human operator through a personal computer (PC) and the machine, or production system for supervisory of the industrial automation control processes. HMI is actually just a part of the larger SCADA system. SCADA systems translate more complex data into accessible information, enabling better control of the production process and its various applications than HMI systems. Without SCADA, the HMI would be pretty much useless. SCADA is a supervisory process control system that is widely used in all types of industrial automation to control and monitor industrial processes. SCADA systems have computers, controllers, actuators, networks, and interfaces that allow automatic process controlling and also acquirement and processing of real-time data through direct interaction with devices, such as sensors and PLCs with records of events into log files. SCADA is important for data analysis, and enables effective decision-making for optimization in industrial processes. It also allows the site operator to monitor and control processes which are placed at remote locations. Mobile Supervisory Control and Data Acquisition which is referred to as Mobile SCADA is the use of SCADA with the mobile phone for supervisory control. A well designed SCADA system eliminates the complexity of monitoring and controlling of plants. It is time saving and cost reducing system thereby eliminating the need for personal attention to visit each site for inspection, data acquisition or make adjustments (Patil *et al.*, 2018; DB, 2019).

The difference between DCS and SCADA is that DCS is a process control system that uses a network to interconnect sensors, controllers, operator terminals and actuators. A DCS typically contains one or more computers for control and mostly use both proprietary interconnections and protocols for communications (DB, 2019).

PLCs are small complex powerful industrial computers with modular components designed to automate customized control processes by various software designs. PLCs can be used as standalone units in factories and industrial plants to continuously control parameters such as sensors, motors, pumps, lights, fans, circuit breakers and other machinery through interconnections with the parameters by processing and synchronizing input and output electrical signals from them, and using the processed information to carry out preprogrammed feedback commands to reliably meet various customized industrial automation design needs without the chances of human error (Nandgave *et al.,* 2014).

Robots are designed with software and mechanically powered to perform movement and execute one or more tasks automatically with speed and precision. Robot is, essentially, a cognitive technology that features human-like capabilities. Robots (Aririguzo *et al.,* 2006; Cook, 2014; Karabegović, 2016):

i. Can efficiently perform tasks in complicated or dangerous situations, improve production flow and quality, and increase safety for employees. Additionally, robots can make daily life much more comfortable or convenient
ii. Perform tasks in unsafe environments, such as cleaning up hazardous waste. They reduce the risk of injury in the manufacturing industry, such as welding car bodies.
iii. Are able to repeat their actions accurately.
iv. Never become tired and can complete jobs requiring extreme precision.
v. Robots will always perform their task in exactly the same way, such as drilling a hole in the same position.
vi. Are able to complete tasks in locations difficult for people to access.
vii. Are used to manufacture integrated circuits. The tiny components on a silicon chip require very precise placement that is difficult for humans
viii. Are able to work 24 hours a day, without lunch breaks, sick leave or holidays.
ix. Are expensive to design and install but when operational reduce labour costs.
x. Are used to perform physical tasks such as welding, painting or part fitting in workstations of assembly lines that produce products.
xi. Carry out maintenance works such as fixing equipment in many industries like nuclear power plant, aircraft servicing and underwater facilities.
xii. Are chosen for industrial works because of their precision or because the environment is dangerous and/or inaccessible by humans.

Hierarchical levels of industrial automation

An Industrial Automation system consists of various elements that work in synchronization with each other to achieve production and management by performing functions like sensing, controlling, supervision and monitoring of industrial processes. Fig. 1 shows various hierarchical levels of functional elements of industrial automation system (Mesta, 2018).

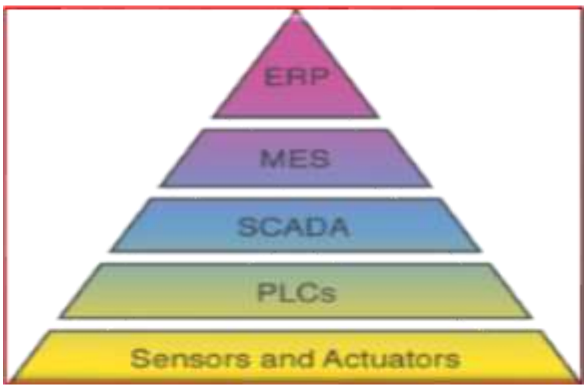

Fig. 1: Various hierarchical levels of functional elements of industrial automation system (Mesta, 2018)

The lowest hierarchical level of functional elements in industrial automation system is called Field Level. Field level is where sensors and actuators are installed. Sensors are used to collect physical process signals and measurements such as flow, pressure, temperature etc. and convert them into electrical or pneumatic form. The signals from these sensors such as LDR, thermocouple, strain gauge etc. are used for processing, analyzing and decision making to produce the control output. Control systems like PLCs, Remote Terminal Units (RTUs), etc are connected to these sensors to produce the required output by processing the signals in accordance with the program and set values. The controllers produce the computed output and are applied as electrical or pneumatic signal inputs to the actuating elements. Actuators convert the electrical or pneumatic signals into the physical process variables such as controlling valves, relays, pneumatic actuators, DC motors etc (Mesta, 2018).

The second level in industrial automation system control is called Supervisory Control. This level is where the smaller subsystems are controlled. It consists mainly of process computers and HMIs. These personal computers perform elevated level control operations like set point computations, performance monitoring, diagnostics, start-up, shut down and other emergency operations. Most of the system contains DCS or SCADA and HMI in this level (Mesta, 2018).

The third stage in industrial automation system control is the manufacturing execution system (MES). MES is an information system that connects, monitors, and controls complex manufacturing systems and data flows on the factory floor. The main goal of an MES is to ensure effective execution of the manufacturing operations and improve production output.

The fourth and top level of industrial automation control is the Enterprise Resource Planning (ERP). ERP manages the whole automation system. The level handles production planning, customer and market analysis, and orders and sales. ERP deals more with commercial activities and less with technical aspects (Mesta, 2018).

All the four automation levels must be well linked. Industrial communication networks are used to tie all these levels together, sending data from one level to the other. These communication networks can be different from level to level. With this hierarchy in place, there is a continuous flow of information from high level to low level and vice-versa. As data goes up, information gets aggregated; and as data goes down, it provides detailed information about the process.

Industrial automation implementation approaches

The steps required for implementing industrial automation include:

i. Identification of opportunities to automate. It is essential that process adaptability to automation be determined before automation implementation. This is because each individual process is more viable to automation or not based on various factors such as process size, industry, and current process type (Aririguzo *et al.,* 2006; Ram Mohan Natarajan, 2015).
ii. Validation of the opportunity. Before automation, it is necessary to check how adaptable the industrial process is to being automated. A look at most processes can show that they typically comprise both transaction and designing parts. Automation can be designed to achieve some quick wins on the transactional part which is the more time-consuming repetitive task (Aririguzo *et al.,* 2006; Ram Mohan Natarajan, 2015).
iii. Selection of a design model. The best automation model for given requirement should be selected. There can also be need to redesign the process to maximize the scope for automation. In some cases, this will yield

additional benefits. The automation plan that suits the business structure should be designed, and the automation model customized to suit the process needs (Aririguzo *et al.,* 2006; Ram Mohan Natarajan, 2015).

iv. Development of the automation plan. A thorough study of the process to be automated must be conducted to understand all the exception scenarios. It is needful to automate time-consuming repetitive tasks in processes that include these. The automation implementation plan should be developed in phases, considering all of the level three scenarios in the hierarchical levels of automation. That is instead of automating all the scenarios, about 75% can be automated and experts can continue to be involved in handling the rest of the scenarios. Plan performance must be evaluated at every phase before moving on to the next phase (Aririguzo *et al.,* 2006; Ram Mohan Natarajan, 2015).

v. Deployment of the pilot phase. When automation plan is developed and ready to be implemented, it is needful to first run a pilot project to observe effectiveness and the overall performance of the automation plan with the actual process in real-time. Results of the pilot project can then be taken to make improvements accordingly. The results of the pilot can also be looked at to include those scenarios that need to be automated and those that can remain an exception (Aririguzo *et al*, 2006; Ram Mohan Natarajan, 2015).

vi. Roll out the plan. Besides development of automation plan, it is important to build a plan needs for training and handling contingency depending on the criticality of the process. It is good to ensure that while people are trained on the revised process there is also documentation on the process before automation to handle any contingency due to a change in applications or systems (Aririguzo *et al.,* 2006; Ram Mohan Natarajan, 2015).

vii. Maintenance of automation activity. Automation is not usually a one-time activity, and it is not something to be executed and then forgotten. There is always need for changes in the process and systems, and there can also be need for good change in the management process to handle any changes. It is therefore important to estimate the impact of change in systems or process and have a plan ready for this. Where change is necessary, a change in management plan should be prepared (Aririguzo *et al.,* 2006; Ram Mohan Natarajan, 2015).

viii. Consultation of reputable automation company. Reputable global automation companies such as ABB, Siemens AG, Emerson Electric Co, Schneider Electric, KUKA Robotics, Bosch RexRoth can be engaged at any or all stages of automating process if there is need to help identify the specific technical details and alternative available needs to: operate and control the requisite factory or equipment remotely, implement preparation of visualization PLC and/or HMI/SCADA panels, and preparation of technical documentation in accordance with the applicable legal requirements. A couple of organizations in other industries if any that have done something similar to benchmark with and gain advice from should be studied. Their experiences will help in making a great choice when selecting the consulting partner.

Recommendations

For greater industrial automation in Nigerian and other developing economies, the following recommendations are made from the paper:

i. All production entrepreneurs in developing countries whether at industrial level, firm, unit, and shop level can evaluate their production systems or equipments in line with the automation approaches outlined in this paper and where suitable embark on automating the systems or replacing them with automated equipments. If the cost of automation is not immediately affordable by them automation should be implemented as soon their production returns warrants it.

ii. Different industries or manufacturers dealing in related services in producing a product or system can get clustered in units at some suitable locations and automate their entire units at a cheaper cost for their greater benefits.

iii. It should be easy to acquire automation tools, hardware or automated production machines or systems in developing countries by policies.

iv. A reasonable number of engineers in developing countries should be trained to acquire expertise in various areas of industrial automation technology. Governments of industrially backward countries should also set up industrial automation institutes or research centers, and university departments that have committed well-paid world-class staff for advancing automation know-how in their countries.

v. Governments and engineers in developing countries should serve as apostles of industrial automation or better production systems in their countries.

vi. World-reputable industrial automation companies should be encouraged to invest in developing countries and have many indigenous engineers on their payrolls to enable indigenous engineers who have not been able to train abroad have better understanding of what is involved in the technology and its acquisition.

Concluding Remarks

i. Industrialization is capable of increasing the pace of growth and ensuring swift structural transformation of economies. Most developing countries have however failed to achieve industrial development despite their several industrial policies and reforms.

ii. In Nigeria, the drive to transform the country's economy from non-industrialized state to an industrialized one has been the pre-occupation of successive administrations that have piloted the affairs of the nation since its independence till date. Unfortunately, despite the abundant natural endowment of the country in both human and non-human resources, efforts at creating a vibrant and sustainable industrial sector growth and development have proved abortive. Worst of all, over the years there has been a steady decline in the contribution of the industrial sector to national productivity and hence economic development has been disappointingly low while poverty level has increased tremendously.

iii. Generally, the benefits of greater implementation of industrial automation in Nigeria and other developing countries will outweigh the challenges, especially when industrial automation can increase production efficiency, output, and safety with better product quality and heavy returns. It is realistic to see appreciable increase in production by using automation in any manufacturing process.

iv. If appropriately and effectively pursued, industrial automation technology can yield substantial opportunities for boosting developing economies.

v. One important fear for implementing industrial automation in many countries is loss of jobs by employees, but this fear is far from being true as automation opens the door for employees to advance to new opportunities with the creation of new positions.
vi. In this paper an overview of basic facts on industrial automation and its implementation approaches with the motive of reawakening application interest and rethinking by all industrial and other production stake holders in developing countries particularly in Nigeria for improving their manufacturing systems, equipment and factories to reap accruing benefits of industrial automation whilst boosting their national economic progresses has been presented for consideration.

Engineers in Nigeria and other developing countries can find jobs in industrial automation in their countries as; control system programmer in which they have tasks to program a control system, service engineers who by understanding customer requirements in the plants can implement any necessary changes in software such as those of PLC and DCS, maintenance engineers to ensure the continued designed plant safety and its efficient operation, and HMI/SCADA graphics developers in which they have the tasks to design HMI screens with the help of HMI software. They can also act as industrial automation feasibility consultants or entrepreneurs in various capacities with great rewards.

Conflict of Interest

The author has declared that there is no conflict of interest reported in this paper

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