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Power, Automation and Industrialization: The Nigerian Experience

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***Abstract*-- Electricity provides power that drives automation and industrialization. Most developing countries are experiencing acute power shortages and Nigeria is not an exception. The power situation in Nigeria is so bad that a lot of local industries have been forced to close down. In this work, the state of power generation in Nigeria is surveyed and the current level compared to the level needed to successfully power and industrialize the economy. The results show that for the industrial development of Nigeria, She needs to generate 170MW daily. With sufficient power supply, investment in automation technologies and robotics would boost the productivity and output of local industries thereby creating a buoyant economy.**

***Keywords*-- Automation; Electric power; Industrialization; Nigeria**

I. INTRODUCTION

Before the advent of the industrial revolution, the energy or power used by people to work came almost entirely from their own and animals' muscles. With the advent of industrial revolution, machines changed people's way of life as well as their methods of manufacture. In the beginning of the industrial revolution which began in the later part of the 18th century in about 1760, electricity power was not in use [1]. The first phase of the industrial revolution which lasted till the later part of the 19th century was not driven by electric power. Steam engines actually provided power used to power industries in the first phase of the industrial revolution and the earlier part of the second phase which began in the final third of the 19th century in 1870. With the invention of the electromagnetic rotary devices by Michael Faraday, the foundation of the application and use of electricity in industries and technological development which characterized the second phase of the industrial revolution was laid.

With the development of electric power stations which supplies AC voltage to power homes and industries, electric motors gradually started replacing steam engines as the source of power for machineries used in factories. Electric power replaced steam power in factories because it was cheaper, faster, more flexible and potable.

Electrification is behind the assembly line development and mass production. These aspects of manufacturing constitute the final major developments in manufacturing in the second phase of the industrial revolution. As a matter of fact the National Academy of Engineering described electrification as "the most important engineering achievement of the 20th century".

The third phase of the industrial revolution which began about 1969 is characterized by the use of electronics and information technology to automate production. The third phase of the industrial revolution coincided with the development of electronics, computers and information technology.

The fourth phase of the industrial revolution which is widely regarded as industry 4.0 is characterized by the use of cyber and web technologies to build connected factories and industrial facilities [2, 3]. According to Lee et al. [3], attributes of industry 4.0 factories include self-awareness, self organization, self prediction, self maintenance etc, and these are features of artificial intelligence.

In words of Chete et al. [4], industrialization could be seen as a deliberate and sustained application and combination of suitable technology, management techniques and other resources to move the economy from the traditional low level of production to a more automated and efficient system of mass production of goods and services. The high quality of life enjoyed in modern times is principally due to industrialization hence, according to Adeoye [5], industrialization seems to be central to economic growth and development.

Electricity powers industries which include such industries as manufacturing, service, extractive etc. Industries are engine rooms that drive any economy. Hence, steady electricity power supply is critical to the economic development of any nation. There is a very strong correlation between the economic development of any nation and electricity generation. Highly industrialized economies have very high power density i.e. electricity power generation (GW) per million inhabitants. On the other hand most developing economies have low power density.

Automation and industrialization are powered by electricity. This paper surveys the current state of power generation, transmission and distribution in Nigeria, as well as the current state of industrialization and automation with the view of finding ways of addressing the economic and developmental challenges caused by the perennial power shortages in Nigeria.

II. Industrial Development Of Nigeria

The industrial development of Nigeria can be categorized into two eras namely: pre-independence and post-independence industrial development. Before independence, the level of industrial and technological development of Nigeria is very low. This is because of the attitude and policy of the colonial administration which prefers to tap the raw materials which abound in the country and export them to Europe to feed the industries there. Although the colonial authorities were not very concerned about the industrial and technological development of Nigeria, they still established the department of commerce and industry in 1946. This department according to Kilby [6] had as one of its major assignments the conduct of research on a small scale and the promotion of industrial development, and the activities of the department promoted technological and industrial development of Nigeria in the 1940s. Development of technology and industrialization in Nigeria improved further in the 1950s, and according to Ekundare [7], in September 1952, a World Bank mission came to Nigeria on the invitation of the British government to conduct a survey on the state of technology in Nigeria and ways of improving it. The mission submitted its report in 1954. It observed that research efforts had not been systematic and recommended that an institute of applied technical research be established [7].

Following this recommendation, the British colonial authorities provided the sum of £260,000 which was used to establish the Institute of Applied Technical Research in 1956. This Institute, which later became the Federal Institute of Industrial Research, was responsible for coordinating research into new methods of production throughout Nigeria from when it was established. The institute continued carrying out the same function after independence in 1960. Some important industrial researches carried out by the institute include the use of wide fibres for the making of sack, the use of local dye stuff for textile manufacture and mechanization of the production of gari (a local staple food) [6].

It is noteworthy through the efforts of the department of commerce and industry and the World Bank that the industrial production of some goods in Nigeria, especially those items in which raw materials were available, resulted in the establishment of many new factories in the 1950s.

According to Ekundare [7], modest achievements recorded by the Institute of Applied Technical Research, and the few breakthroughs made before its establishment, which included the results of the research efforts of the West Africa Institute of Oil-Palm Research, constituted the level of technological development of Nigeria at independence in Nigeria. The colonial government transfer of industrial development to regional governments in Nigeria in 1954 helped boost further industrial development with the development of specialized financial institutions designed to boost investment in industries and industrialization prior to independence.

The various regions of Nigeria and the central government after independence in 1960 continued their giant strides towards industrial development driven largely by the need for import substitution. The various regional governments of Nigeria established industries/factories such as cement factory, Brewery, soap factory, Textile industry, shoe factories, vegetable oil refinery etc. thus according to Onyemelukwe [7], at independence in 1960, Nigeria had a total of 389 industrial establishments. Industries in Nigeria continued growing post independence and in 1964, Nigeria had about 687 manufacturing establishments which increased to 776 in 1965. The number fell to 625 in 1968 due to the Nigerian Civil War, however after the war in 1970, the number rose to 703 and jumped to 1,054 in 1972 [9].

Steady progress in industrialization occurred between 1970 and 1975 as the price of oil, Nigeria's main export earner, rose steadily in the international market. The total number of manufacturing establishments rose from 1,054 in 1972 to 1,290 in 1975 [9].

The growth and industrial development continued in Nigeria in the 70s until the turn of the decade when industrialization started slowing down with the slide in oil price. The economic recession in the 80s occasioned by the end of the oil boom of the 70s led to decline in industrial development in the 80s. Even the structural adjustment programme introduced in 1985 to help reduce Nigeria's overdependence on imported goods and boost local industries and industrialization met with limited success.

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In the nineties the political crises brought about by the annulment of democratic elections held on June 12 1993, and the attendant economic sanctions imposed on the military government in Nigeria helped to stagnate industrial development. At the turn of the decade, a new civilian administration which replaced the military government in Nigeria started putting in place measures to restore moribund industries and stimulate industrial development.

Part of the strategies adopted by the civilian government was to launch massive investment in power generation transmission and distribution. But with bribery and corruption associated with the award of contracts for these new investments, most the proposed new investments power infrastructure failed with result that the new civilian administration recorded little success in improving industrial development.

Table 1:
Percentage contribution of manufacturing to Nigeria's GDP (1960-2015)

Period	1960-1970	1971-1980	1981-1990	1991-2000	2001-2010	2011-2015
Percentage	6.6	7.3	6.1	4.9	3.9	4.8

Source: National Bureau of Statistics.

Table 1 shows the percentage contribution of manufacturing to Nigeria's GDP from 1960 to 2015. As shown in Table 1, the period of the oil boom from 1971 to 1980 was the period manufacturing contributed highest to Nigeria's GDP. The contributions started declining during the economic recession of the 80s and have not recovered since to the levels of the oil boom era of the 70s.

III. Electricity Power Generation In Nigeria

Electricity generation in Nigeria began in 1896 with two 30kw diesel generators in Lagos. This occurred just fifteen years after power was first generated in England. In the early stages of Nigeria development as a nation, power generation was done by individual power generating units scattered in cities and towns across the country.

With the formation of Electricity Company of Nigeria (ECN) in 1950, the national grid for supply of electricity was borne. The ECN greatly improved the electric power supply in the country through grid connection of generation, transmission and distribution of electricity [10]. With the creation of ECN and increase in demand for electricity, the Nigerian government started constructing new power stations, as well as increasing the capacity of existing ones. Further efforts towards improving power generation led to the formation of Niger Dams Authority (NDA) in 1962. NDA was charged with developing the vast hydropower potential of River Niger. NDA started the construction of a large hydropower station at Kainji in 1962 and completed it in 1968. The hydropower station had an initial capacity of 4x80MW. The ECN and NDA were merged in 1972 to create the National Electric Power Authority of Nigeria (NEPA).

For several years, NEPA continued to exist as a government owned/public utility and when inefficiency and poor performance which characterized several government enterprises crept into the organization, the government started thinking of how to privatize the utility company.

As a first step towards the complete privatization of NEPA, the government created a company called the Power Holding Company of Nigeria (PHCN) to help wind down NEPA and remove the control of generation, transmission and distribution of electricity from government hands. The PHCN was later unbundled in 2013 into 18 successor companies which include six generation, one transmission and 11 distribution companies.

Despite these efforts to improve electricity generation, transmission and distribution in Nigeria, the power supply is grossly in adequate. As of December 2013, the total installed capacity of the power plants was 6,953MW. Available capacity was 4,598MW while actual average generation was 3,800MW [11]. As of December 2014, the total installed capacity of all power plants was 7,445MW, available capacity was 4, 949MW, while actual average generation was less than 3,900MW [12]. As at April 2016, the total installed capacity has risen to 12,000MW, available capacity was about 8,000MW, while actual average generation was about 3,900MW.

From the statistics reeled out above the total installed capacity and available capacity are increasing substantially but the average generation has barely increased.

On the assumption that roughly 1000MW is required per 1,000,000 (1million) residents for an industrialized economy, Nigeria with an estimated population of 170 million will require 170,000MW or 170GW average generation of electricity to become fully industrialized.

IV. The State Of Automation In Nigeria

With the exception of industries operated by Multinational Companies Like Nigerian Breweries (Owned By Heineken BV), British American Tobacco, Procter and Gamble, Patterson Zochonis (PZ), Lever Brothers etc which uses modern sophisticated automation and robotics technologies for production operations, most industries in Nigeria lack basic technology for automation.

The poor electricity power infrastructure is principally to be blamed for this. This is because industries in Nigeria are powered about ninety percent (70%) of the time by power generated by generators acquired by these industries [13]. According to Yakubu et al. [13], the proportion of electricity cost in manufacturing production cost in Nigeria is 30% to 35% as compared to some other developed and developing countries which is 5% to 10%. Marchat et al. [14] carried out a survey of Nigerian firms and discovered that 93.9% of the firms regarded electricity as their major problem, while 97.4% of the firms have their private generators. This makes the cost of production of goods very expensive. In fact economists have projected that the average cost of goods manufactured in Nigeria would be reduced by as much as fifty percent (50%), for certain products, if twenty four hour public power is supplied to local industries.

The extra investment needed in power generation by investors in manufacturing plants and factories, and low margins occasioned by high operational costs caused by operation and maintenance of power generators means that most existing factories and manufacturing plants are barely managing to stay in business.

As a matter of fact many factories and plants have closed shop in Nigeria due to poor public power supply. A classical example is Michelin Nigeria Limited which stopped operations in Nigeria in 2007 when it found it far more profitable to import tyres from overseas rather than make them in Nigeria. Michelin realized that their tyre production operation in Nigeria was no longer profitable because of poor electricity supply hence, they closed shop. According to Yakubu et al. [13], the high cost of operating on generators caused as much as about 800 firms to shut down in Nigeria between 2009 and 2011.

It is pertinent to note that investment in Robotics and automation technologies requires large capital outlay. Coupled with extra investment in power generation and low and risky operating margins, most investors considering investment in Automation technologies are weary of risky investments and long payback periods.

This is the primary reason why commercial banks in Nigeria rarely give loans and credit facilities for investment in the real sector of the economy.

V. Discussion

If we compare the per capita power generation of Nigeria with that of a highly developed economy like the United States shown in Table 2, it is obvious that the US is very far ahead of Nigeria in terms of energy supply required for an economy to be developed. A developing country like India with a population of 1.2 billion has ten times per capita consumption more than that of Nigeria.

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Table 2:
Per capita energy consumption of some selected countries

Country	Approximate Population (Million)	Approximate Generation (GW)	Per Capita Consumption (GW/Million)	Status
USA	300	813	2.7100	Developed
Nigeria	170	4	0.0235	Developing
India	1200	235	0.1958	Developing
South Africa	50	40	0.8000	Developing
Egypt	82	30	0.3659	Developing
Germany	80	120	1.5000	Developed
Ghana	25	2	0.0800	Developing
Kenya	44.5	1.8	0.0404	Developing
Singapore	5.5	10	1.8182	Developed
Indonesia	250	45	0.1800	Developing
UAE	9.5	18	1.8947	Developing
Brazil	200	100	0.5000	Developing
Malaysia	29.72	19.023	0.6403	Developing

Table 3 shows countries and the percentage contribution of manufacturing to GDP. Looking at Table 3, it is obvious that at 5% Nigeria has the lowest contribution of manufacturing to GDP.

Table 3:
Percentage contribution of manufacturing to GDP of some countries

Country	Contribution of Manufacturing to GDP (%)
Nigeria	5
Malaysia	26
Germany	25.8
India	17.18
South Africa	14
Indonesia	27
Kenya	6

Even Kenya at 6% contribution of manufacturing to GDP performed slightly better than Nigeria even though the economy of Nigeria is far bigger than that of Kenya.

Developing countries like India and Malaysia where the manufacturing sectors performing very well have values of 17.18% and 26% respectively, which are respectively 3 and 4 times greater than that of Nigeria's manufacturing sector contribution to GDP.

Comparing Table 3 with the per capita power consumption shown in Table 2, it is obvious that India, Malaysia and Kenya have better per capita power consumption than Nigeria. No wonder these countries have higher contributions of manufacturing to GDP as shown in Table 3. This is further evidence that increasing power generation would increase industrialization and automation.

It is pertinent to note that the power situation in the country was so bad that in 2007, the late Nigerian President, Umaru YarAdua, declared a state of emergency in the Nigeria power sector [15, 16, 17]. The privatization of power infrastructures which was done as part of the emergency measures to improve electricity generation, transmission and distribution has not achieved much to reduce acute power shortages. In the area of power distribution, the chairman of National Electricity Regulatory Commission of Nigeria (NERC) stated recently that 44% of registered electricity consumers in Nigeria are without meters. Thus one of the objectives of privatization of power distribution, 100% metering of consumers, has not been achieved three years after privatization in 2013. The power distribution companies rely on estimated billing system to bill the unmetered consumers. This practice, which is fraught with fraud and irregularities, is preferred by the distribution companies as consumers are forced to pay even when power was not supplied.

The privatization of power distribution has not achieved its desired objectives because the power distribution facilities were sold to incompetent investors without adequate knowledge of the electricity industry. The investors have not done much to meter the consumers because they prefer estimated billing which gives them more money, while the distribution infrastructures are left to rot.

VI. Recommendations And Conclusions

6.1 Recommendations

In order to improve electric power generation and boost industrialization and automation of production processes, Nigeria needs to put certain measures in place. First and foremost devolution of power to state governments is recommended as this would give state governments more money and power to make decisions on investments in power infrastructures. In India where the state governments are autonomous, the government of Gujarat under the chief Minister, Narendra Modi, made massive investments in power infrastructures which attracted many investors to come to the state to build industries.

This made the economy of the state to grow very rapidly during the tenure of Modi as Chief Minister, and contributed primarily to his being elected the prime minister of India.

With autonomy and devolution of powers, Nigerian states like, Lagos, Rivers, Akwa Ibom, Delta, Anambra and Kano, with good government could develop their power infrastructures such that the per capita power consumption could reach 0.5 which is more than that of India which is 0.1958. With a modest per capita power consumption of 0.5 such states would make very modest gains in industrialization and automation.

Nigeria is a tropical country with abundant sunshine. As matter of fact there is sunshine all year round in Nigeria. This type of climate is very attractive to renewable energy development. The drastic fall in the cost of solar panels in recent times makes investments in solar power very attractive. This could be used to power homes and offices freeing power resources from conventional electric power sources, like gas and hydro turbines, to be used to power factories.

Grey areas in the privatization of power utilities should be revisited as a matter of urgency. The distribution companies have not added any value to the state of power distribution from what it was prior to privatization. The efficiency of distribution has not been improved nor the distribution facilities improved in terms of acquisition of new equipment and effective maintenance of existing ones. It is my opinion that power distribution were sold to incompetent companies which were fronts for politicians and government officials hence, instead of investing in power distribution infrastructures they are in fact extorting money from the public to enrich themselves.

6.2 Conclusions

In this study we have seen that for any country to be industrialized and grow economically there must be substantial electric power generation to drive economic growth. In order to maximize the productivity of industries, automation is absolutely necessary. As a matter of fact automation of production processes is the main feature of the third phase of the industrial revolution. The third phase was preceded by the second phase which was driven by electrification. Nigeria needs massive investment in power generation, transmission and distribution infrastructures in order to join in the third phase of the industrial revolution which is gradually giving way to the fourth phase where the developed world are in today.

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