JAAST
ONLINE ISSN 2277- 1565
PRINT ISSN 0976 - 4828

International Archive of Applied Sciences and Technology
IAAST; Vol 4 [2] June 2013: 82-86

[ISO9001: 2008 Certified Organization]
www.soeagra.com/iaast/iaast.htm

CODEN: IAASCA ORIGINAL ARTICLE

Nanotechnology: Solution to the Problem of Electricity Generation, Transmission and Distribution in Nigeria

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ABSTRACT
The irregularity and the inconsistency of electricity supply had been a major problem for the populace and industries in some part of the world, especially in developing countries (Nigeria). With the increasing demand of energy by every sector of the economy in the developing countries, there is need to generate more energy for a sustainable and reliable economy in which nanotechnology is the solution. In this study, the use of nanotechnology to generate, transmit and distribute a sustainable, suitable, renewable, free and reliable energy which is one of the most important scientific challenges of the 21st century is discussed.
Key words: *Developing Countries, Economy, Electricity supply, Energy, Nanotechnology*

Received 25.05.2013 Accepted 19.06.2013

INTRODUCTION

Electricity plays a very important role in the socio-economic and technological development of every nation. The shortage of power has been a great barrier for commercial and domestic usage in Nigeria. The country is faced with acute electricity problems, which is hindering its development notwithstanding the availability of vast natural resources in the country [1]. It is widely accepted that there is a strong correlation between socio-economic development and the availability of electricity.

Industries and household have tremendously engaged in using generating set, so as to cover for this short coming in power supply. Incomplete combustion of the fuel in generating set leads to production of carbon monoxide, which is emitted to the atmosphere; these increase the amount of greenhouse gases, which are linked to climate change and global warming.

Nigeria currently has 14 generating plants, which supply electric energy to the national grid. Of the 14 generating plants, 3 are hydro and 11 are thermal (gas/steam). The national grid is made up of 4,889.2km of 330kV line, 6,319.33km of 132kV line, 6,098MVA transformer capacity at 330/132kV and 8,090MVA transformer capacity at 132/33kV [2].

Due to the importance of the sector, late President Umaru Musa Yar'Adua, immediately after he was sworn in on may 29th 2007, recognized the urgency of the emergency on the Sector by specifically addressing the problems of the Sector in an urgent and immediate basis thereby eliminating the usual bureaucratic time wasting procedures of treating issues of the sector, while ensuring that Due Process is not compromised [2].

In August 2010, Nigerian President Goodluck Jonathan approved the construction of a $3.5 billion grid aimed at addressing power transmission problem in Nigeria. The 700-kilovolt "super grid" will be completed within four years. This grid will improve the sustainable energy source. Reduction of power loss per transmitted megawatt and improve power voltage across the country [9].

PROBLEM OF ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION IN NIGERIA

Generation

Electricity generation in Nigeria faces the following challenges: Inadequate generation availability, inadequate and delayed maintenance of facilities, insufficient funding of power stations, obsolete equipment, tools, safety facilities and operational vehicles, inadequate and obsolete communication equipment, lack of exploration to tap all sources of energy from the available resources and low staff morale.

The Total Installed Capacity of the currently generating plants is 7,876 MW, but the Installed available Capacity is less than 4,000MW as at December 2009. Seven of the fourteen generation stations are over 20 years old and the average daily power generation is below 2,700MW, which is far below the peak load forecast of 8,900MW for the currently existing infrastructure. As a result, the nation experiences massive load shedding [11].

Transmission

The transmission system in Nigeria does not cover every part of the country. Currently it has the capacity to transmit a maximum of about 4,000 MW and it is technically weak, therefore very sensitive to major disturbances. The major problems identified are: It is funded solely by the Federal government whose resource allocation cannot adequately meet all the requirements, it is yet to cover many parts of the country, It's current maximum electricity wheeling capacity is 4,000 MW which is awfully below the required national needs, some sections of the grid are outdated with inadequate redundancies as opposed to the required mesh arrangement, the Federal government lack the required fund to regular, update, modernize, maintain and expand the network, there is regular vandalization of the lines, associated with low level of surveillance and security on all electrical infrastructure, the technologies used generally deliver very poor voltage stability and profiles, there is a high prevalence of inadequate working tools and vehicles for operating and maintaining the network, there is a serious lack of required modern technologies for communication and monitoring, the transformers deployed are overloaded in most service areas and inadequate of spare-parts for urgent maintenance [10].

DISTRIBUTION AND MARKETING

In most locations in Nigeria, the distribution network is poor, the voltage profile is bad and the billing is inaccurate. As the department, which inter-faces with the public, the need to ensure adequate network coverage and provision of quality power supply in addition to efficient marketing and customer service delivery cannot be over emphasize. Some of the major problems identified are: Weak and Inadequate Network Coverage, overloaded Transformers and bad Feeder Pillars, substandard distribution lines, poor billing system, Unwholesome practices by staff and very poor Customer relations, inadequate logistic facilities such as tools and working vehicles, poor and obsolete communication equipment, low staff morale, lack of regular training and insufficient funds for maintenance activities [10].

Nanotech Solar cell for electricity generation

Before introducing new solar products which use nanotechnology, it is necessary to explain the basic process that a normal solar cell uses. Conventional solar cells are called photovoltaic cells. These cells are made out of semiconducting material, usually silicon. When light hits the cells, they absorb energy though photons. This absorbed energy knocks out electrons in the silicon, allowing them to flow [6]. By adding different impurities to the silicon such as phosphorus or boron, an electric field can be established. This electric field acts as a diode, because it only allows electrons to flow in one direction [5].

Consequently, the end result is a current of electrons, better known to us as electricity. Conventional solar cells have two main drawbacks: they can only achieve efficiencies around ten percent and they are expensive to manufacture [7]. The first drawback / inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy then it will pass through. But if it has more energy than the band gap, then that extra energy will be wasted as heat.

Nanotech solar cell is unique both for its energy efficiency and cost effectiveness. It is used in a printing process to deposit a thin-film, copper indium gallium dieseline CIGS-based PV semiconductor to create an efficient, durable solar cell [3]. This semiconductor was 100 times thinner than a silicon wafer and the printing process was 10 times faster than the conventional thin-film process of high-vacuum deposition. It brought the economics of printing to semiconductor manufacturing, copper indium gallium diselenide CIGS semiconductor on low-cost conductive aluminium foil. The solar cells were lightweight, pliable, easily interconnected, adjustable, and capable of supporting up to 25 amps of current per cell (up to 25 times more than was possible with other thin-film technology available at the time) and its standard size is $165 \times 135mm$ [8].

Due to its flexibility, Nanotech solar cell created solar cell units independently of solar panel units. The process of creating a solar panel unit included assembling the cells into circuits and then laminating them into panels (encapsulating the solar cells between two panes of tempered glass). A panel of Nanotech solar cells included 84 cells on a panel measuring 2 square meters and weighing 8.6Kg [11].

Electricity Conversion Efficiency

The uses of copper indium gallium diselenide-based PV thin-films had reached sunlight-to-electricity conversion efficiencies of about 19.9 percent in laboratory tests. This is far superior to other thin-film technologies and even better than most crystalline silicon technologies, using mono-crystalline silicon, is able to convert the most sunlight into electricity, about 20 percent per panel, but the cost of the silicon was much greater than that of thin-film cells [4].

Nanotech solar cell CIGS roll-printing technology resulted in efficiencies for electricity generation ,cheap in production, longevity and easy to install due to flexibility and light weight as confirmed by the National Renewable Energy Laboratory (NREL), of 17.1 percent active-area on foil in 2011. This is a world record for any printable solar cell [8].

Nanotech transmission

Nanotechnology will help to improve the efficiency of electricity transmission wires. There are numerous nano-materials and other nano-related applications relevant to electricity transmission.

Aluminium conductor steel reinforced (ACSR) wire is the standard overhead conductor against which alternatives are compared. In 2010, the development of new overhead conductors increased the capacity of existing Right (s) of Ways (ROWs) by five times that of ACSR wire at current costs and developed nano-material based metal-matrix overhead conductor known as the aluminium conductor composite reinforced (ACCR) wire, which is designed to resist heat sag and provide more than twice the transmission capacity of conventional conductors of similar size [6]. The difference is that ACCR wire is based on the use of aluminium processed in new ways to create high-performance and reliable overhead conductors that retain strength at high temperatures and are not adversely affected by environmental conditions." The ACCR wire's strength and durability derive from its nano-crystalline aluminium oxide fibers, which are embedded in the high-purity 3M aluminium matrix core wires using a patented process [2].

The constituent materials are chemically inert with respect to each other and can withstand extreme temperatures without chemical reactions or any appreciable loss in strength. The material used in the core of the cable replaces the steel used in conventional cables [10].

Another example is the use of armchair Carbon Nano Tubes (CNTs) – which is a special kind of single-walled CNT that exhibits extremely high electrical conductivity (more than 10 times greater than copper). Also possessing flexibility, elasticity, and tremendous tensile strength, CNTs have the potential, when woven into wires and cables, to provide electricity transmission lines with substantially improved performance over current power lines [11].

Also, the current wires can be replaced with nano-scale transmission wires, called quantum wires (QWs) or armchair QWs, which revolutionize the electrical grid. The electrical conductivity of QW is higher than that of copper at one-sixth the weight and QW is twice as strong as steel. A grid made up of such transmission wires would have no line losses or resistance, because the electrons would be forced lengthwise through the tube and could not escape out at other angles. Grid properties would be resistant to temperature changes and would have minimal or no sag [11]. (Reduced sag would allow towers to be placed farther apart, reducing footprint and attendant construction and maintenance impacts.

Other Electrical Transmission Infrastructure

Nanotechnology applications will help to improve other components of the electric transmission infrastructure, thereby potentially reducing environmental impacts. The examples below pertain to transformers, substations and sensors.

(a) Transformers. Fluids containing nano-materials could provide more efficient coolants in transformers, possibly reducing the footprints, or even the number of transformers. Nano-particles increase heat transfer and solid nano-particles conduct heat better than liquid. Nano-particles stay suspended in liquids longer than larger particles and they have a much greater surface area, where heat transfer takes place. Using nano-particles in the development of High Temperature Superconductors (HTS) transformers could result in compact units with no flammable liquids, which could help increase it flexibility (10).

(b) Substations. Substation batteries are important for load-levelling peak shaving, providing uninterruptible supplies of electricity to power substation switchgear and for starting backup power systems. Smaller and more efficient batteries, which will reduce the footprints of substations and possibly the number of substations within a ROW [11].

(c) Sensors. Nano-electronics have the potential to revolutionize sensors and power-control devices. Nanotechnology-enabled sensors would be self-calibrating and self-diagnosing. They could place trouble calls to technicians whenever problems were predicted or encountered. Such sensors could also allow for the remote monitoring of infrastructure on a real-time basis [11].

Miniature sensors deployed throughout an entire transmission network could provide access to data and information previously unavailable. The real-time energized status of distribution feeders will speed outage restoration; phase balancing and line loss would be easier to manage. Also help to improve the overall operation of the distribution feeder network.

Energy Storage

The ability to store energy locally can reduce the amount of electricity that needs to be transmitted over power lines to meet peak demands. Energy storage allow downsizing of base load capacity and is a prerequisite for increasing the penetration of renewable and distributed generation technologies such as wind turbines at reasonable economic and environmental costs. Suitable energy storage is critical to the increased use of renewable energies, particularly solar and wind. Nanotechnology plays a role in distributed generation through the development of cost-effective energy storage in batteries, capacitors and fuel cells [2].

a. Batteries. Carbon Nano Tubes (CNTs) have extraordinarily high surface areas, good electrical conductivity and has a linear geometry that makes their surface areas highly accessible to a battery's electrolyte.

These properties enable CNT-based electrodes in batteries to generate an increased electricity output as compared to traditional electrodes. This ability to increase the energy output from a given amount of material means not only that batteries could become more powerful, but also that smaller and lighter batteries could be developed for a wider range of applications.

The battery technology utilizes 25-nm nano-structured lithium titan ate spinet (a hard, glassy mineral) as the electrode material in the anode of a rechargeable lithium-ion battery, replacing the graphite electrode typically used in such batteries and contributing to performance and safety issues. The new battery offers vastly faster discharge and charge rates, meaning that the time to recharge the battery can be measured in minutes rather than in hours. The nano-structured materials also increase the useful lifetime of the battery by 10 to 20 times over current lithium batteries and provide battery performance over a broader range of temperatures than currently achievable, over 75% of normal power would be available at temperatures between −40°C and +67°C [11].

b. Capacitors. While batteries, which derive electrical energy from chemical reactions, are effective in storing large amounts of energy, they must be discarded after many charges and discharges. Capacitors, however, store electricity between a pair of metal electrodes. They charge faster and longer than normal batteries, but because their storage capacity is proportional to the surface area of their electrodes, even today's most powerful capacitors hold 25 times less energy than similarly sized chemical batteries. Presently, capacitor electrodes have been covered with millions of nano-tubes to increase electrode surface area and thus the amount of energy that they can hold [11]. This new technology "combines the strength of today's batteries with the longevity and speed of capacitors and has broad practical possibilities, affecting any device that requires a battery".

CONCLUSION

Based on the information discussed in this paper, it is worthy of note that in order to tap into the nanotechnology solution to electricity generation, transmission, storage and distribution in Nigeria, the three tiers of government in Nigeria (Federal, State and Local government) should provide funds for research on nanotechnology and provide a conducive atmosphere for adaptation of the technology in Nigeria. The people should also be informed about the technology and possible adaptation to electricity generation. Also, the researchers should work more on this new profitable technology that is useful in many facet of the economy.

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Citation of Article: Ogunji, B. Abdulrahaman. Atilade, A. Oluwafemi and Coker, J. Olakunle. Nanotechnology: Solution to the Problem of Electricity Generation, Transmission and Distribution in Nigeria. Int. Arch. App. Sci. Technol., Vol 4 [2] June 2013: 82- 86