NEW INITIATIVES ON ELECTRIC POWER TRANSMISSION AND DISTRIBUTION IN NIGERIA

Being a Presentation by

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1.0 Background to Nigeria’s Present Transmission and Transmission Projects’ Initiative

• The problem of electricity in Nigeria was initially diagnosed as inadequate generation capacity.
• The national Integrated Power Project (NIPP) was conceived in 2004 to solve the problem by initially building 7 medium sized power plants.
• However, this led to a need for Transmission projects for power evacuation and grid strengthening.
• Also, the need for improved Distribution Network was realized.
• The NIPP has now grown into a programme of 10 No Power Stations, 116, Transmission Stations with associated Trx Lines and Telecomms/Teleprotection, 1230 Distribution Projects (298 Distribution Injection Substations and 932 Distribution Lines) 12 Gas Transmission Lines with associated Gas Metering Stations
2.0 Management of NIPP Projects

• A successful relationship has been developed and sustained over the past 7 years between Lahmeyer International (LI) of Germany and O.T. Otis Engineering (Otis) of Nigeria, for the Management of the NIPP in Nigeria, with desirable transfer of knowledge and technology.

• The consortium – LI/Otis is the Design and Project Management Consultant (D.C) for the NIPP
  – Started in 2005 with LI bringing 9 experts and Otis bringing 4 experts
  – When Basic Engineering for Generation and Transmission Started, LI’s participation increased to 23 experts, while Otis brought 16 experts
  – Under Addendum 1 and Addendum 2 to the base contract, LI had 23 experts, while Otis participation increased to 34 experts
  – Under Addendum 3 and Addendum 4, LI has 13 experts, while Otis has 70.

• Project Consultants have been selected to manage various projects, grouped into work packages:
  – 10 No Power stations are structured into 6 Project Consultancy Lots (with 6 different Project Consultants)
  – 115 Transmission Projects are Structured into 17 Project Consultancy Lots
  – 1230 Distribution Projects are structured into 9 Project Consultancy Lots

• The DC supervises and controls all the Project Consultants, under the Design and Project Management Consultancy segment.

• For services that are common to all projects, for example, GE OEM and Distribution OEM; and Telecommunication/Teleprotection, the DC carries out Project Consultancy Services
2.1 Role of LI/Otis

- The DC supports the client by rendering Project Management Services (PMS), Contract Management Services (CMS), Technical Advisory Services (TAS) and Administrative Management Services (AMS)
  - Assist and Advise the Client in all managerial, technical and financial aspects of the project
  - Support the client in a daily business and strategic decision making;
  - Monitor project planning, organization and implementation schedules;
  - Support the client to establish an integrated project management organization for effective and coordinated management of the entire project
  - Supervise the project implementation with emphasis on time and budget;
  - Supervise the project quality management system;
  - Assist and advise client in the justification of critical and disputed requests for (PC's, EPC contractors) contract variation and claims;
  - Evaluate and monitor risks and advise in mitigation strategies;
  - Organize project meetings to coordinate the parties;
  - Monitor the overall project progress and advice on deficiencies;
  - Plan and conduct the assessment of current overall project status;
  - Support the Client in coordination of activities during the defect liability period (DLP)
3.0 Concept of the Transmission Projects

- The National Grid in Nigeria has been radial.
  - When one link is out, large areas are thrown into darkness.
- Under the new initiative, projects were embarked upon to stabilize the grid by closing the loop.
- A grid study was commissioned in 2006 to assess the state of the grid.

- A Grid Study was carried out in 2006 with the following objectives:
  - To investigate the capacity of the existing PHCN grid network under the NIPP scheme & how it can be integrated to conform with additional generation infrastructures.
  - To ascertain the network capability for the evacuation of NIPP power Generation.
  - To simulate the power flow system using the existing structure of NIPP projects to evaluate the contingencies of N-1 criteria within the network. (N = Total Network; N-1 = Loss of one major part)
  - To plan for load forecast in three different dimensions namely short term, medium term & long term of power demand in the country.
  - To ascertain equitable load distribution within Nigeria’s network (demand & supply).

1.2.1 Conclusions From the Grid Study:
- The PHCN existing network results indicated that the installed breakers were rated high enough to face the present fault levels.
- For existing network, the installed breakers were adjudged adequate, but for long term fault levels, a need to order breakers with ratings above 40 kA for several substations was recommended.
- The study identified congestion on Benin-Lagos axis, with bottleneck at Benin. This was resolved with a recommendation for network splitting.
- The Grid Study enabled adequate planning to be made for the transmission projects.
3.1 Configuration of NIPP Transmission Projects

A total of 116 Trx. Projects:

- 50 Trx Lines Projects
- 29 No new Trx substation projects
- 36 No Trx SS Extension/Rehabilitation Projects
- 1 No Telecoms/Teleprotection Project at 69 Trx SS, 13 Power Stations 1 No Optical Ground Wire (OPGW) TL
- About 2,950km of 330kV and 1,390km of 132kV transmission lines, with a total capacity of 7610MVA

The Following Projects Have Been Completed

- 330kV Sapele Substation (Rehab & Ext.) + Benin Main SS (Rehab.)
- 330/132kV Ganmo (Ilorin) Substation
- 330/132kV Ayede (Ibadan) Substation (Rehab & Ext)
- 330kV SC Transmission Line Ganmo to Jebba – Oshogbo (Turn-in/Turn Out)
- 132kV SC Transmission Line Ganmo to Ilorin – Oshogbo (Turn in/Turn out)
- 330kV DC Transmission Line Omotosho to Ikeja West - Benin Main (Turn –in/Turn out)
- 330/132kV Mando (Kaduna) Substation (Ext)
- 132/33kV Kumbotso (Kano) Substation (Ext)
- 330/132kV Katampe (Abuja) Substation (Ext)
- 132/33kV Central Area (Abuja) Substation (Ext)
- 132/33kV Oworonshoki (Lagos) Substation (Ext)
- 132/33kV Agbara (Lagos) Substation (Ext)
- 132/33kV Ojo (Lagos) Substation (Ext)
Post NIPP National Transmission Grid
3.2 Challenges

- Major challenges faced are way leave issues.
  - All over the world, transmission line projects have always been resisted by the host communities.
  - While elsewhere, resistance is due to fear of electromagnetic radiation and degradation of property value, in Nigeria resistance is fuelled by demand for payment of compensation for traversing ancestral lands.
- The weather has a significant influence on the pace of work. During the periods of heavy rainfall, not much work can be accomplished.
- Again, since the transmission projects cut across forests the work is generally slowed down by the lack of access roads, this is made worse during the rainy season.
- Bad roads also affect the transportation and handling of heavy equipment like transformers. A case in point is an incident where two power transformers fell and were damaged when being transported to the site.
3.3 Proposed New Transmission Lines and Associated Sub-Stations Projects

The Federal Ministry of Power has initiated tender processes to select Project Consultants for the following projects:

Lot 1: Kaduna – Kano – 330kv D/C 235km with associated substations
Lot 2: Delta – Port Harcourt (Onne) -330KV D/C 150km with associated Substations
Lot 3: Abakiliki – Amasiri -132 KV D/C (70km) with associated substations
Lot 4: Keffi - Kwoi – Kachia -132KV D/C (135 km) with associated substations
Lot 5: Ugwuaji – Nenwe -Mpu 132kV D/C (86km) with associated substations
Lot 6: Omuaran – Egbe 132KV D/C (50km) with associated substations
Lot 7: Yola – Song – Little Gombi – 132kV D/C (125km) with associated substations
Lot 8: Little Gombi – Mubi – Gulak – 132kV D/C (225km) with associated substations

New Super Grid Projects are also planned to:

- Deliver Bulk Power in excess of 5000MW to all the Load Centers.
- Minimize transmission Load losses
- Avoid instability and Grid Collapses
- To accommodate future sub – super grid networks

Also under the Federal Ministry of Power, Tendering is currently going on to select consultants for the following super grid projects:

Transmission Lines – 765kV Capacity:

- Mambilla – Jalingo – Gombe (1000km)
- Mambilla – Markurdi – Ajaokuta – Benin North (1000km)
- Ajaokuta – Abuja – Kano (800km)
- Egbema – Benin North (250km)
- Benin North – Oshogbo – Olorunsogo (350km)
3.3.1 Associated Sub-Stations – 765/330kV

- 12 X 333MVA (1 – phase) Mambilla
- 4 X 333MVA (1 - phase) Markurdi
- 4 X 333MVA (1 - phase) Gombe
- 4 X 333MVA (1 - phase) Jalingo
- 4 X 333MVA (1 – phase) Abuja
- 4 X 333MVA (1 - phase) Kano
- 12 X 333MVA (1 - phase) Ajaokuta
- 12 X 333MVA (1 – phase) Benin North
- 12 X 333MVA (1 - phase) Egbema
- 4 X 333MVA (1 - phase) Oshogbo
- 8 X 333MVA (1 - phase) Olorunsogo (Lagos)
4.0 NIPP Distribution Projects

• Distribution Infrastructure comprising Medium Voltage (33kV) transmission lines, 33/11kV Injection Substations and Distribution networks were part of the new initiative for the evacuation of power from the original Seven (7) medium-sized power plants in Nigeria’s NIPP

• Present Configuration of NIPP Distribution Projects:
  – NIPP Distribution projects in all 11 Electricity Distribution Zones.
  – 22,598 No (25kV and 50kV) Distribution Transformers.
  – 388 Power Transformers
  – 190 No of 11 kV Switch-Gears
  – 1,230 No of 33kV Outdoor Switch-Gears
  – 18 Sets (of 9 Panels Each) of 33kV Outdoor Switch-Gears
  – 3,540MVA additional injection capacity.
  – 2,666 KM of 11KV lines.
  – 1,701 KM of 33KV lines.
• **Design Philosophy**
  – Designed to improve on Existing Public Utility Distribution Network in terms of:
    • Robustness
    • Security of supply
    • Reduction of Losses
    • Modernization

• **Robustness**
  • The present Power Holding Company of Nigeria (PHCN) distribution network nationwide is fragile and characterized by:
    – Poor ventilation
    – Poor outdoor equipment spacing
    – Poor cabling arrangement
    – Insufficient number of outgoing feeders
    – Poor protection coordination/Automation
  • With the new initiative, each new Injection Substation under the NIPP is to sit on 40m x 60m parcel of land. This allows for bigger Control Building, outdoor equipment spacing to IEC standards, and addresses the inadequacies of PHCN networks
• **Security of Supply**

Existing PHCN distribution network is built with supposedly treated Wooden Cross-arms at both 33kV and 11kV sub-transmission voltages.

  - Fail with time because they are affected by weather changes. This frequently leads to loss of supply

• The NIPP design has introduced the use of Fibre Glass Cross-Arm which is weather resistant.

• Under the new Initiative, the NIPP design is based on High Voltage Distribution System (HVDS).

  - Uses Completely Self-Protected (CSP) transformers of 25 and 50 kVA ratings
  - Located as close as possible to the customers.
  - Fewer customers are connected to each of these transformers.
  - The service cables are for very short distances, thereby guaranteeing good voltage profile to the consumer.
  - Consequently, outage periods are reduced, making the power supply more reliable.
Modernization of Substation

Under the new initiative, 33/11kV Injection Substations have bigger Control Building that contains Cash Office, Maintenance workshop, System Operation office, and the Manager’s Office.

Adequate space in the equipment room to allow for the minimum 3No Outgoing Feeder breakers with enough for extensions.

Injection Substations are now designed to include Bore-hole and ancillary facilities for water supply, 27 kVA Standby generator for emergency power supply to the Injection Substation to enable the operator carry out necessary switching in case of general power failure.

2.4.1 Amorphous Core Vs Cold –Rolled Grain – Oriented (CRGO) Silicon Steel Core

HVDS were introduced under the new initiative

- The CSP (Completely Self-protected) transformers have minimum core (iron) losses whereas line (technical) losses are negligible because of short service cables.
- In order to further improve on the loss reduction, Amorphous Core CSP transformers have also been introduced in the new NIPP distribution networks.
- The amorphous metal has the property of very low core losses when compared with the conventional CRGO.

The choice of the Amorphous Core over the CRGO Core was also informed by:

- Capitalization of losses (Cost of Transformer + Operating Cost [i.e., Cost of Losses]) which saw the Amorphous Core emerging as the cheaper option in the long run than the CRGO Core, and
- Favourable Experiences and References from some Companies that are using Amorphous Core transformers, especially in India.

However, maintenance will involve the replacement of the entire core if and when damaged.

A total of 22,598 Amorphous Core CSP transformers are needed for the NIPP Distribution projects.
4.1 Distribution Major Equipment

- The Distribution projects were split between Engineering, Procurement and Construction (EPC) Contracts and Original Equipment Manufacturers (OEM) contracts.
- Major 33/11kV Injection Substation equipment procured directly from the Original Equipment Manufacturers:
- Decision was informed by the need to standardize such equipment for operational flexibility/maintainability.
- A major advantage of procuring the Distribution Major Equipment (DME) directly from the manufacturers is the significant cost savings made.

2.4.1 Distribution Major Equipment – Procured Directly:

- 2.5 MVA 33/11kV Injection transformers - 19 Nos
- 7.5 MVA 33/11kVA Injection transformers - 209 Nos
- 15 MVA 33/11kVA Injection transformers - 155 Nos
- 11kV Indoor Switchgear - 190 Nos
- 33kV Outdoor Circuit Breakers - 1220 Nos
- 33kV Indoor Switchgears - 18 Nos
- 33kV Voltage Transformers - 1730 Nos
- 33kV Current Transformers - 3593 Nos
- 33kV Control/Relay Panels - 295 Nos
NIPP Distribution Targets

- 22,598 25kV and 50kV distribution transformers
- 3,540 MVA additional injection capacity
- 2,666km of 11 kV lines
- 1,701 km of 33 kV lines
4.2 CHALLENGES

• The EPC Contractors could not move at the same speed as the OEM contractors
  – Some of the EPC Contractors did not get their advance payment as planned and therefore could not commence as programmed.
• Community issues: many of the sites were unavailable and so some of the EPC Contractors had no sites to work on.
• Most of the DME suppliers completed their contracts well ahead of the scheduled six months.
• Storage of DME equipment was not originally planned. Due to the different speeds of OEMCs and EPCCs, Storage became a major issue.
• Difficulties in clearing of imported items: some incurred demurrage due to delays in clearing.
• Logistics challenges: quite a few of these major equipment items were damaged in transit.
5.0 Grid Integration Issues in the Light of On-going Renewable Energy Projects

- On going Renewable Energy (RE) Projects In Nigeria:
  - 10 MW Wind farm Project ongoing in Katsina, Nigeria,
  - Various Solar Plants Projects Across Nigeria
  - Small Hydro Plants Planned
  - Waste to Energy Plant ongoing (Ondo State – Nigeria)
5.1 Illustration of Various Levels of Grid Connection

Power Grid: An interconnected network of generators, transmission system and distribution system.
5.2 Grid Integration Issues in the Light of On-going Renewable Energy Projects

- Conversion efficiencies of Various Power Plant Generators

- Power availability: Firm/ infirm

- Operational flexibility

- Scheduling of wind power generation (10 MW & above and connected at 33 kV & above) often deviates more than +/- 30%. Revision of schedules possible 8 times a day for each 3 hour slot
5.3 **Grid Connection Issues for RE Projects**

- Voltage Issues
- Network Power Quality Management
- Frequency Requirements
- SCADA & communication facilities
- Protection & Controls
- Tolerance
- Active Power Control
- Reactive Power Control

5.4 **Applicable standards & regulations**

- Equipment standards
  - Must conform to IEEE or IET
- Technical specifications
  - Nigeria’s Wind Farm applies Pitch Control System
  - Grid Code/ Distribution Code
    - Published by the Nigerian Electricity regulatory Commission (NERC)
    - Provide Guidelines for Grid Connection and Distribution in Nigeria
5.5 Flexibility in Grid Operation

Major concern:
Difficulties in forecasting availability of power for scheduling & dispatch

Illustrative example: CUF & wind speeds in a wind farm

Capacity utilization factor (CUF)(Jan-Dec)  Hourly wind speeds
5.6 System Planning Philosophy

RE Source Embedded in Distribution Network

- No longer radial network
- Direction and quantum of power flow changes
- So also short circuit levels & protection requirements
5.7 Focal Areas for Action

- Guidelines & planning criteria for interconnection studies
- Design of RE machines & co-ordination of protection equipment keeping in view grid requirements as well.
- Use of better prediction tools to improve for forecasting
- Integrated operation of infirm RE generation with dispatchable power plants
- Operation as part of “Smart Grids”
- Inclusion of RE in Grid Code/ Connection Code
- Regulations relating to implementation and cost sharing of transmission facilities, metering, etc
6.0 Proposed West African Sahelian Integrated Development Project

• Conceived originally by Dr. Newton Jibunoh, Environmentalist and Desert Explorer.
• In furtherance of integration and coordinated development across the West African Sub Region, the West African Integrated Development Project has been proposed.
• Will include a 3000 km. West African Trans Sahelian Highway, to traverse Nigeria, Niger, Benin Republic, Togo, Ghana, Burkina faso, Cote D’Voire, Guinea, Mali and Senegal.

• The Trans – Sahelian Highway will have tree Corridors, which will be sustained by sea water to be piped from the ocean at chosen locations.

• Desalination Plants and pumping stations will be built along the routes of the piped sea water.
  – Treated sea water will sustain the vegetative cover
  – Provide Domestic Water Supply for the localities along the affected regions

- Dr. Jibunoh Expressed interest in handing over the project to the Nigerian Society of Engineers in December 2011. The NSE proposes to reconfigure the project to incorporate energy elements in addition to the original concept.
- Abundance of Sunlight within the Sahelian Corridor - Solar Power Plants will be built to generate power.
- Abundance of Wind – Clusters of Wind farms will be built.
- A super-grid will be needed to transmit the power, since it will traverse 10 countries, and a length of almost 3,000 km.
- Similar to the DESERTEC proposal for generation of Electricity in Northern Africa.
Proposed West Africa Trans Sahelian Highway indicated in black dashed lines

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