# CHAPTER 7 Transmission Network Development Plan

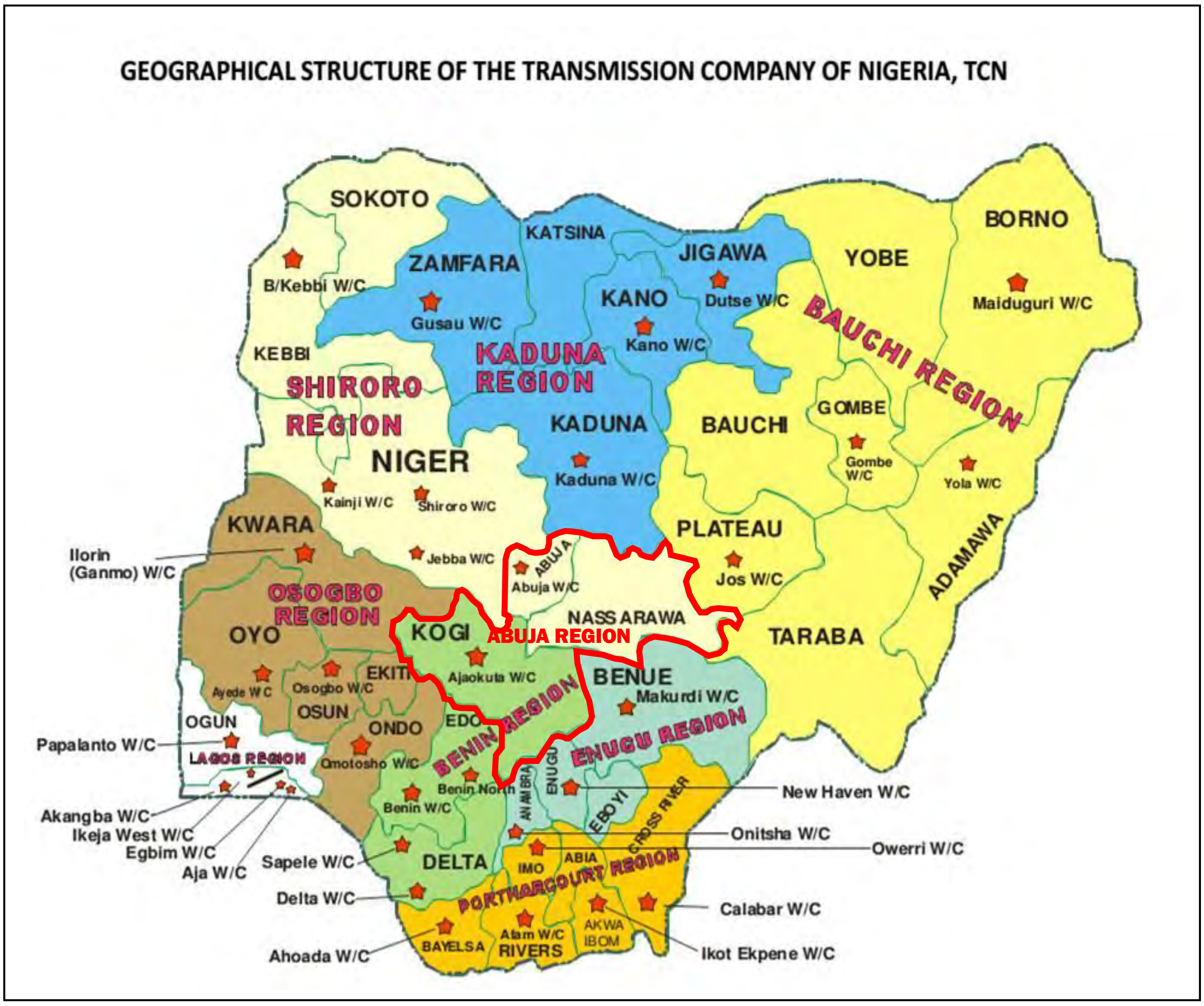
# Chapter 7 Transmission network development plan

## 7-1 Outline of Transmission Network in Nigeria

### 7-1-1 Geographical Structure of the Transmission Company of Nigeria (TCN)

TCN has created eight Transmission Planning Regions for better planning.

The actual regions under the field and maintenance services sector are shown in Figure 7-1.1. Since new regions, Abuja Region (FCT (Abuja), Nasarawa and Kogi states) were settled in July, 2018, there are currently nine Transmission Planning Regions.




Source: TCN

**Figure 7-1.1 Geographical Structure of TCN**

The electricity supply to Nigerian consumers is handled by 11 privatized distribution companies, each with its own area, as shown in Figure 7-1.2.


Source: JICA Study Team

**Figure 7-1.2 Areas of Distribution Companies in Nigeria**

The electricity consumption of the southern DisCos far exceeds their northern equivalents because the former are far more densely populated and most industries are concentrated there.

### 7-1-2 Existing and Planned Power System and Network Configuration

The two latest maps with the existing, ongoing and planned Nigerian 330 and 132 kV transmission network are shown in Annexes 7.1a and 7.1b (respectively dated January and March, 2018).

The latest version of the single-line diagram of the existing network (dated July, 2016), is shown in Annex 7.1c. TCN has advised that there has not been further updated.

Technical data on transmission lines and transformers is shown in Annexes 7.1d and 7.1e respectively.

The present status of reactors and capacitors installed in the TCN network is summarized in Table 7-1.1 and Table 7-1.2. Introducing additional capacitors, as necessary, takes the status of pre-existing units into consideration, as shown in Table 7-1.2, assuming all faulty and repairable capacitors will, if necessary, be repaired and the others will be commissioned as planned.

**Table 7-1.1 Shunt Reactors**

| S/N | Substation | Voltage (kV) | MX (MVar) | Switchable |
|---|---|---|---|---|
| 1 | KANO | 330 | -75.00 | Y |
| 2 | GOMBE | 330 | -50.00 | Y |
| 3 | GOMBE | 330 | -50.00 | Y |
| 4 | YOLA | 330 | -75.00 | Y |
| 5 | KADUNA | 330 | -75.00 | Y |

| S/N | Substation | Voltage (kV) | MX (MVar) | Switchable |
|---|---|---|---|---|
| 6 | JOS | 330 | -75.00 | Y |
| 7 | JEBBA T.S. | 330 | -75.00 | Y |
| 8 | JEBBA T.S. | 330 | -75.00 | Y |
| 9 | OSHOGBO | 330 | -75.00 | N |
| 10 | BENIN | 330 | -75.00 | Y |
| 11 | BENIN | 330 | -75.00 | Y |
| 12 | ALAOJI | 330 | -75.00 | Y |
| 13 | IKEJA WEST | 330 | -75.00 | Y |
| 14 | IKEJA WEST | 330 | -75.00 | Y |
| 15 | KATAMPE | 330 | -75.00 | Y |
| 16 | MAKURDI | 330 | -75.00 | Y |
| 17 | ONITSHA | 330 | -75.00 | Y |
| 18 | OKEARO | 330 | -75.00 | Y |
| 19 | GOMBE | 33 | -30.00 | Y |
| 20 | GOMBE | 33 | -30.00 | Y |
| 21 | YOLA | 33 | -30.00 | Y |
| 22 | YOLA | 33 | -30.00 | Y |

Source: JICA Study Team

**Table 7-1.2 Fixed capacitors**

| S/N | Substation | Voltage (kV) | Capacitor (MVar) | Status | Planned Action |
|---|---|---|---|---|---|
| 1 | Kumbotso | 330 | 50 | In operation | |
| 2 | Kumbotso | 330 | 50 | In operation | |
| 3 | Akangba A | 132 | 72 | Installed but not commissioned yet | To be commissioned |
| 4 | Akangba B | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 5 | Akoka | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 6 | Alausa | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 7 | Alimoso | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 8 | Ejigbo | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 9 | Ijoro | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 10 | Isolo | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 11 | Ogba | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 12 | Otta | 33 | 24 | Installed but not commissioned yet | To be commissioned |
| 13 | Yandev | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 14 | Ikorodu | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 15 | Ikorodu | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 16 | Abeokuta | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 17 | Abeokuta | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 18 | Iseyin | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 19 | Aiyede | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 20 | Aiyede | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 21 | Agbara | 33 | 20 | Commissioned, can be switched on | |
| 22 | Ijebuode | 33 | 20 | Commissioned, can be switched on | |
| 23 | Sagamu | 33 | 20 | Commissioned, can be switched on | |
| 24 | Irua | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 25 | Ilorin | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 26 | Akure | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 27 | Awka | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 28 | Uyo | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 29 | Effurum | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |

| S/N | Substation | Voltage (kV) | Capacitor (MVar) | Status | Planned Action |
|---|---|---|---|---|---|
| 30 | Amkpe | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 31 | Akwanga | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 32 | Akwanga | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 33 | Minna | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 34 | Minna | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 35 | Kontagora | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 36 | Kontagora | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 37 | Zaria | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 38 | Zaria | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 39 | Kaduna Town | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 40 | Kaduna Town | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 41 | Dakata | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 42 | Dakata | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 43 | Apir | 33 | 20 | Faulty, mainly due to CB fault | Can be repaired |
| 44 | Kumbotso | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 45 | Okene | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 46 | Dan-Agundi | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 47 | Katsina | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 48 | Ife | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 49 | Ayede | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 50 | Ijebu-Ode | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 51 | Shagamu | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 52 | Iseyin | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 53 | Ilorin | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 54 | Akure | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 55 | Apo | 33 | 20 | Installed but not commissioned yet | To be commissioned |
| 56 | Apo | 33 | 20 | Installed but not commissioned yet | To be commissioned |

Source: JICA Study Team

### 7-1-3 Operating Frequency and Voltage Limits

In accordance with the Grid Code and to maintain the security and integrity of the transmission system, it is necessary that the System Operator operate and dispatch the transmission system in such a manner as to provide adequate frequency control and achieve operation within applicable frequency limits at all times.

The nominal system frequency shall be 50 Hz. The National Control Center endeavors to control this to within a narrow operating band of +/- 0.5% from 50 Hz (49.75 – 50.25 Hz), but under system stress the frequency on the power system may vary within the limits of 50 Hz +/- 2.5% (48.75 – 51.25 Hz).

The nominal voltage levels of the transmission and distribution system are 330, 132, 66, 33 and 11 kV respectively. Under normal operation, the limits of the 330 and 132 kV systems are 0.85-1.05 and 0.85-1.10 pu respectively. Under contingency conditions the emergency limits for the same are 0.80-1.10 and 0.80-1.15 pu.

### 7-1-4 System Peak Demand and Generation

#### 7-1-4-1 Development of Peak Output and Energy Generated

The installed capacity (less de-commissioned units) in the grid as of December, 2016 was 12,310 MW. In 2016, the plant average MW availability was 7,877 MW, which was 23.07% higher than the 6,401 MW obtained in 2015. The Thermal Station average MW availability contribution was 6,669 MW – exceeding the, 2015 figure of 5,312 MW by 25.53%. The Hydro Station average MW availability was 1208 MW, which exceeded the, 2015 figure of 1,088 MW by 120 MW (11.07%). The maximum daily energy of 109,372 MWh occurred on 2 February, 2016, exceeding the maximum daily energy of 106,825 MWh recorded on 24 November, 2015 by 2,546 MWh (2.38%). The peak generation of 5,074 MW. which was attained on 2 February, 2016 exceeds the peak generation of 4,883 MW recorded on 23 November, 2015 by 190 MW (3.91%).

Peak output of power stations depends on the availability of generation units, water inflow for hydro power plants and gas supply for thermal power plants and not on actual demand. Demand is always much higher than the available generation capacity.

NCC daily operational report on 08.12.2015 shows a Peak Demand Forecast (connected + suppressed load) of 14,630 MW.

The peak generation of 5,074 MW, which was attained on 2 February, 2016 exceeded the peak generation of 4,883 MW recorded on 23 November, 2015 by 190 MW (3.91%)."

In general, only approximately 40% of the estimated demand could be supplied.

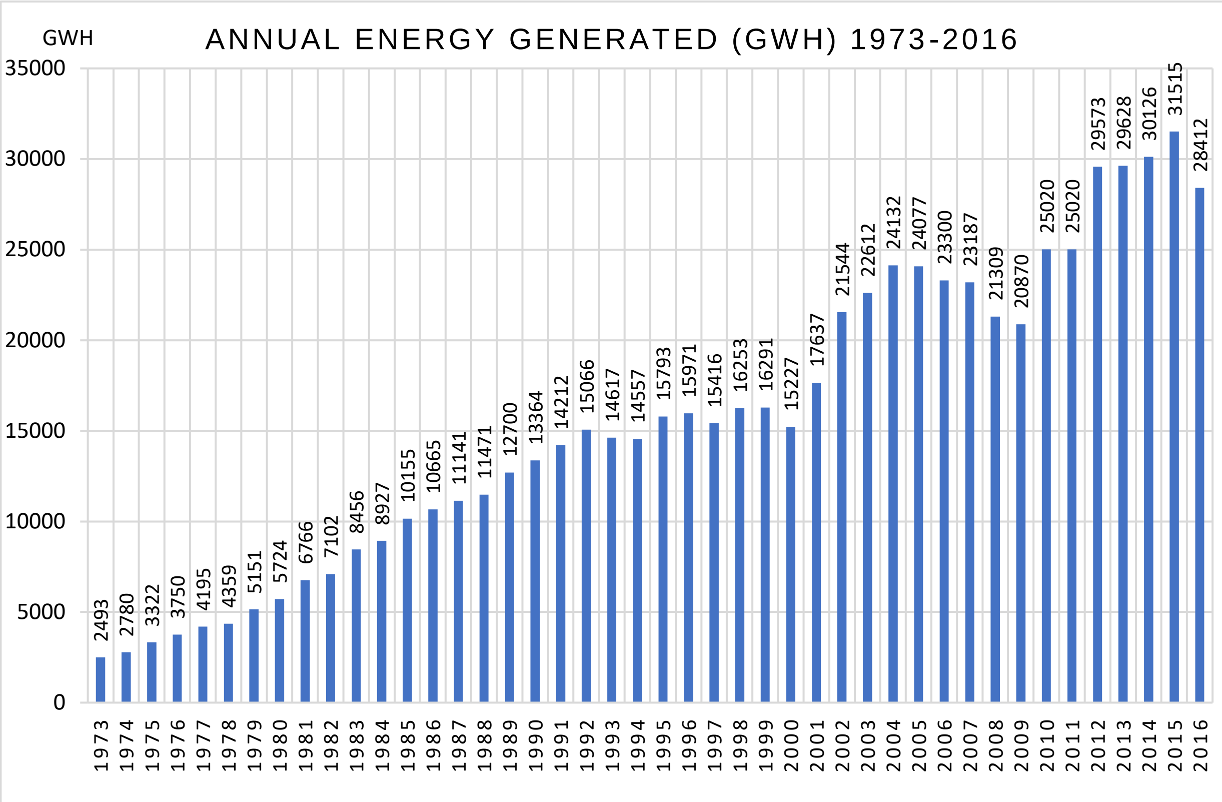
NCC's operational reports show that many generation units are not in operation due to the unavailability of gas. On December 8, 2015 for example, about 1,500 MW of generation capacity were was offline for this reason. The gas supply was interrupted due to sabotage of the pipeline system.

#### 7-1-4-2 Transition of Energy Generation and Peak Demand

Records on annual energy generated and simultaneous national peak demand of electricity show permanent growth with two periods of stagnation/decline.

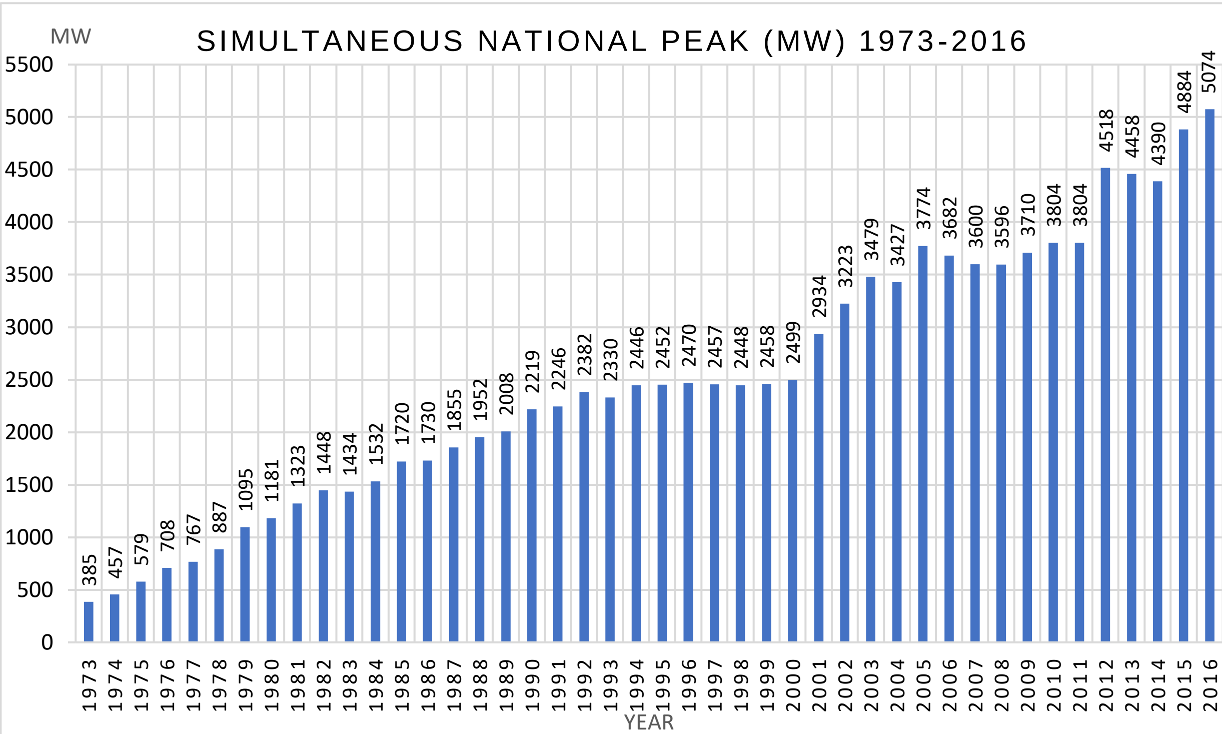
Figure 7-1.3 and Figure 7-1.4 indicate that periods of stagnation/decline of energy generation and peak demand were offset rapidly in the following years.

Between 1973 and 2016, peak generation increased from 385 to 5,074 MW, i.e. with an average growth rate of about 6.2%. During the same period the annual energy generated increased from 2,493 to 28,412 GWh, i.e. with an average growth rate of about 6%.




Source: TCN Annual Report, 2016

**Figure 7-1.3 Annual Energy Generated**




Source: TCN Annual Report, 2016

**Figure 7-1.4 National Peak**

#### 7-1-4-3 Transmission Losses

The overall transmission losses and substation consumptions amounted to 9.92% of the energy sent out in 2016, as shown in Table 7-1.3. The losses in 2016 were lower than the previous year, signifying a steady decline over the past three years.

**Table 7-1.3 Energy balance summary (Dec-Jan, 2016)**

| Energy generated (MWh) | Energy sent out (MWh) | Energy available for sales, incl distr losses (MWh) | Transformer losses and substations consumption (MWh) | Transformer losses and substations consumption (% of energy sent out) | Energy available for sales and distr losses (% of energy) |
|---|---|---|---|---|---|
| 28,532 | 28,033 | 25,251 | 27,821 | 9.92 | 90.08 |

Source: JICA Study Team

#### 7-1-4-4 Existing Generation and Generation Expansion

Based on information provided, the already installed gross power generation capacity is about 13,300 MW, of which some 11,800 MW are noted as net available capacity.

Considering the latest information provided by generating companies, about 9,500 MW (80%) of this capacity should have been available at the end of the year, 2015. However, only 5,900 MW net capacity has been made available, as reflected in the statistics of the National Control Center (NCC).

The reasons for the unavailability include: planned outages for maintenance or forced outages due to technical deficiencies of assets, as well as unplanned unavailability due to fuel supply shortages or sabotage of gas pipelines.

A further analysis of information provided shows that about 20% of the installed generation capacity is based on plants which are 25 or more years old, some of which have efficiency of under 30%.

It is obvious that most of the old thermal power plants are - or will be – subject to more frequent forced outages or long- term planned maintenance outages in the near future. Accordingly, they should be replaced by new and more efficient facilities.

Together with TCN, it was agreed that all existing power plant units not being currently available should be made available by 2020 at the latest, even if currently unavailable for technical reasons.

The Master Plan shows a program for step-by-step modernization of these plants in parallel to implementing new units at existing sites, as well as completely new power plants.

It further shows technical data for all existing and new generation facilities and the respective implementation timetable. Newly proposed power plants are considering diversification of primary energy sources in the form of solar/wind/hydro technology, as well as modern gas- and coal-fired thermal plants.

Installation of new assets will follow the assumed increasing power demand, as well as the need for replacement of existing power generation assets.

#### 7-1-4-5 Daily Load Curve

Electrical power demand in Nigeria peaks in the evening, between 20:00 and 23:00 hours, while power demand is lowest in the early morning between 03:00 and 05:00 hours.

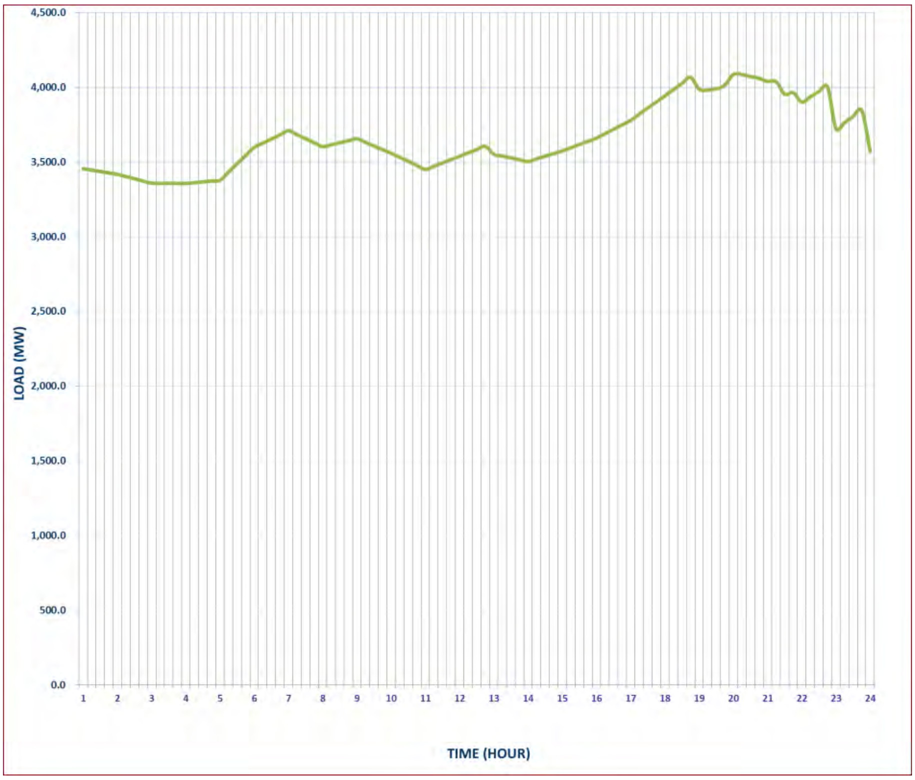



**Figure 7-1.5 Daily Load Curve on 1 October, 2014**

### 7-1-5 Difficulties and Challenges Faced by TCN

#### 7-1-5-1 General

The electric power system of Nigeria has long suffered from a lack of generation capacity which requires permanent load shedding. Furthermore, frequent transmission and distribution system disturbances exacerbate the unreliability of the power system.

The main reasons for power shortages are outages of generation units and a lack of gas to generate power. The gas supply is frequently interrupted due to the pipeline network being sabotaged.

The main concern for the future expansion of generation, however, is the availability of gas for additional generation capacity and the expansion of the gas pipeline network. Currently, most power plants are installed in southern Nigeria close to oil and gas fields. To ensure a reliable and optimally expanded transmission system, there will be a need to install new power plants also elsewhere in Nigeria.

There are some plans for new hydro power plants, while photovoltaic and wind power plants are also under consideration.

However, to provide sufficient base load power in future, large coal-fired power plants may have to be included in the generation expansion program.

In terms of generation and load balance in the eight TCN planning regions, four or five have a significant generation deficit. With the exception of Benin and Port Harcourt regions, demand exceeds available generation power in all others. In the Shiroro region however, the situation will be reversed once new HPP plants (e.g. Zugeru) come into operation.

The reason for this imbalance is due to the generation being mainly concentrated in South (thermal stations in Port Harcourt, Enugu, Benin and Lagos) and Central West (hydro stations of Jebba, Kainji and Shiroro in Shiroro region). The Central, North and North-East in particular are characterized by the total absence of generating stations, while load demand is mainly in the South and South-West.

To supply power in areas with little or no generation such as the North-East, long 330 kV transmission lines are built (radial system), which means voltage regulation problems may occur and the reactive power flowing through them necessitates large reactive power compensation equipment (reactors) at the corresponding substations (Kano, Gombe, Maiduguri).

Additional 330 kV lines running in parallel are expected to exacerbate overvoltage issues, necessitating additional compensation equipment at Yola, Jalingo and other substations.

#### 7-1-5-2 Frequency Control

The Grid Code frequency range is 50 Hz + 0.50%, i.e. 49.75 to 50.25 Hz (Grid Code chapter 4 Section 15.3.1), however due to the low availability of units on free governor control coupled with serious demand/generation imbalance, it was practically difficult to maintain and only Omotosho gas and NIPP and Olorunsogo gas units that were on free governor at one point or the other in recent years.

NCC was therefore constrained on numerous occasions to operate the grid outside the statutory frequency limits.

The frequency fluctuations which are mostly due to load rejection by DisCos and volatile loads from steel mills create harmonics and cause voltage flickering within the system. Most of the UFLS relay schemes installed in some substations to mitigate the impact of system collapses were not functional most of the time, which is why the characteristically strenuous manual frequency control technique, achieved through load shedding, defined year-round operations.

#### 7-1-5-3 Voltage Control

In 2016, the voltage limits specified by the Grid Code were achieved largely on the upper voltage limit. The lower voltage limit meanwhile, formally experienced in the northern axis of the grid and plagued by voltage instability/decay, has been improved by installing capacity banks at Kano T.S. The AVRs of some GenCos are not functional.

#### 7-1-5-4 Transmission Constraints

Transmission is plagued with incessant tripping of transmission lines, improper relay coordination, line limitation, ageing lines and inability to satisfy the N-1 contingency.

Transformers loaded to 100% and above of their rating require very urgent attention. Circumstances where some have to be loaded for hours above 100% reflects the urgent need to reinforce affected transformer banks.

#### 7-1-5-5 Power Pool With Neighboring Countries

The sphere of operations of the Transmission Company of Nigeria transcends the geographical landscape of the country; the Republics of Niger and Benin are interconnected with the Nigerian transmission network.

The energy supplied to Benin Republic in 2016 was 1,275 GWH, signifying a decrease of 16.95% when compared with the 2015 figure of 1,535 GWH. The Republic of Niger was furnished with energy of 666 GWH in 2016, which is lower than the 2015 supply of 692 by 3.77% (ref. Table 7-1.4). These values represent only energy delivered through the 132kV transmission lines only. A fraction of the total supply to that country was through some 33kV distribution feeders.

**Table 7-1.4 Cross-border electricity transactions (MWH)**

| Month | BENIN REPUBLIC | | NIGER REPUBLIC | |
|---|---|---|---|---|
| | 2016 | 2015 | | 2016 |
| JANUARY | 139,232 | 131,851 | JANUARY | 139,232 |
| FEBRUARY | 137,028 | 128,821 | FEBRUARY | 137,028 |
| MARCH | 117,525 | 133,755 | MARCH | 117,525 |
| APRIL | 104,796 | 134,685 | APRIL | 104,796 |
| MAY | 86,139 | 111,132 | MAY | 86,139 |
| JUNE | 63,542 | 125,313 | JUNE | 63,542 |
| JULY | 88,775 | 114,134 | JULY | 88,775 |
| AUGUST | 97,162 | 133,044 | AUGUST | 97,162 |
| SEPTEMBER | 85,785 | 120,276 | SEPTEMBER | 85,785 |
| OCTOBER | 122,435 | 137,372 | OCTOBER | 122,435 |
| NOVEMBER | 116,345 | 137,028 | NOVEMBER | 116,345 |
| DECEMBER | 116,487 | 128,131 | DECEMBER | 116,487 |
| TOTAL | 1,275,251 | 1,535,542 | TOTAL | 1,275,251 |
| AVERAGE | 106,271 | 127,962 | AVERAGE | 106,271 |

Source: JICA Study Team

## 7-2 Ongoing Projects

### 7-2-1 Contents of Projects

In July 2018, the JICA study team received two updated lists of recently completed and ongoing projects from TCN:

- One list with TCN projects and
- One list with NIPP projects.

These are included in Annexes 7.2a and 7.2b respectively.

While executing the Transmission Expansion Plan Study, it was agreed with TCN that as a basis for preparing the plan, we will assume that all ongoing projects will be completed by 2020.

Based on this network configuration, power system studies to identify further transmission system expansions between 2020 and 2040 were carried out.

The challenging nature of implementing transmission projects identified in the Transmission Expansion Plan by 2020 is acknowledged, given that it takes a minimum of three years from now to implement such projects (one year to prepare tender documents and select the implementation contractor and two years for project implementation). Accordingly, projects that may not be completed by 2020 should be prioritized for completion as soon as possible after 2020.

The TCN and NIPP projects that are expected to be implemented by 2020 have been included in the new PSS/E case for 2020. They are listed in Annexes 7.2a and 7.2b and the PSS/E case has also been modified to include the decisions made, following an exchange of dialog between TCN and the JICA study team.

### 7-2-2 Donors Assistance and Prospective Donors

#### 7-2-2-1 Inclusion of TCN, NIPP, JICA and AFD projects

Annexes 7.2c and 7.2d show the 330 kV network configurations in the Lagos region including the projects that will be implemented under JICA financing. Furthermore, the following ongoing projects financed by AFD (Agence Française de Développement) for Abuja area have been considered:

New transmission lines:

- 142km of new 330 kV Double-Circuit line from Lafia 330 kV Substation (new) to New Apo 330/132/33 kV Substation.
- 7km of new 132 kV Double-Circuit line from New Apo 330/132/33 kV substation to Old Apo 132/33 kV substation
- 35km of new 132 kV Double-Circuit line from New Apo 330/132/33 kV substation to the new Kuje132/33 kV substation
- 29km of new 132 kV Double-Circuit line from the proposed Kuje 132/33 kV Substation to West Main (Lugbe) 330/132/33V substation.

New substations:

- 330/132/33 kV substation at New Apo
- 132 kV line bay extension at Old Apo 132 kV SS
- 330/132/33 kV substation at WestMain (Lugbe)
- 132/33 kV substation at Kuje to be equipped with 3 × No. 60MVA
- 132/33 kV Substation at Wumba/Lokogomato
- 132/33 kV GIS substation at Gwarimpa

#### 7-2-2-2 Additional Transmission System Expansions and Rehabilitation Measures Proposed by TCN

In the latest Transmission Expansion Plan submitted to TCN in December 2017, TCN has requested the inclusion of additional transmission system expansions and rehabilitation/reinforcement measures which have been identified by TCN. Six EXCEL lists have been provided with proposed projects, see Annexes 7.2e1 to 7.2e5.

The annexes also show the costs of the individual measures as estimated by TCN.

TCN plans to implement the measures and finance them via development banks as shown in Table 7-2.1.

**Table 7-2.1 Prospective Development Banks Finance**

| Project | Development Bank | Total Cost (million US$) |
|---|---|---|
| Annex 7.2e1 | AFD (French Development Agency - Agence Française de Développement) | 170 |
| Annex 7.2e2 | JICA (Japan International Cooperation Agency) | To be determined |
| Annex 7.2e3 | AfDB (African Development Bank) | 410 |
| Annex 7.2e4 | World Bank | 486 |
| Annex 7.2e5 | AFD (French Development Agency - Agence Française de Développement) | 272 |
| Total | | 1,538 |

Source: JICA Study Team

There are plans to implement all network expansions and rehabilitation/reinforcement measures as soon as possible, but considerable preparatory work (e.g. feasibility studies, tender documents etc.) is required in most cases. At this stage only implementation of system expansions according to Annex 7.2e1 (AFD-Project) is going-on and commissioning by 2020 may be achievable.

For projects financed by other banks (Annexes 7.2e2 to 7.2e5) implementation between 2020 and 2025 can be considered feasible. Usually about two to three years are required for feasibility studies, environmental impact studies, route survey, preparation of technical specifications and tender documents, bidding, tender evaluation and contracting and arrangement financing agreements. Two to three years can also be assumed for constructing and commissioning the projects.

## Table 7-2.2 Main TCN 330 and 132 kV transmission line projects

| Area | Region | Location | Description | Voltage (kV) | in operation by |
|---|---|---|---|---|---|
| ***PROPOSED ABUJA TRANSMISSION RING PROJECT (AFD1)*** | | | | | |
| North-Central | Abuja | New Apo | Construction of about 172km of a new 330 kV Double-Circuit line from Lafia 330 kV Substation (new) to the proposed New Apo 330/132/33 kV Substation. | 330 | 2020 |
| North-Central | Abuja | Old Apo | Construction of about 7km of a new 132 kV Double-Circuit line from New Apo 330/132/33 kV substation to Old Apo 132/33 kV substation: | 132 | 2020 |
| North-Central | Abuja | Old Kuje | Construction of 35km of a new 132 kV Double-Circuit line from New Apo 330/132/33 kV substation to the proposed Kuje 132/33 kV substation. | 132 | 2020 |
| North-Central | Abuja | West Main Lugbe | Construction of 29 km of a new 132 kV Double-Circuit line from the proposed Kuje 132/33 kV Substation to West Main (Lugbe) 330/132/33 V substation. | 132 | 2020 |
| ***LAGOS/OGUN TRANSMISSION PROJECTS (JICA)*** | | | | | |
| South-West | Lagos | New Abeokuta (Kobape) | Ejio (Arigbajo) – New Abeokuta (Kobape) 132 kV D/C Transmission Line (37.8km). | 132 | 2022 |
| South-West | Lagos | Ejio (Arigbajo) | Olorunsogo – Ejio (Arigbajo) 330 kV D/C Transmission Line (12.9km). | 330 | 2022 |
| South-West | Lagos | Ikeja West | Ejio (Arigbajo) – Ikeja West/Osogbo 330 kV D/C Turn-in-out (5.9km). | 330 | 2022 |
| South-West | Lagos | Ejio (Arigbajo) | Likosi (Ogijo) - Aribajo D/C Transmission Line (43.7km). | 330 | 2022 |
| South-West | Lagos | Shagamu | 132 kV Quad Line (2.3km) from Likosi (Ogijo) – Existing Ikorodu/Shagamu 132 kV 2x D/C Transmission Line | 132 | 2022 |
| South-West | Lagos | Abule Oba (Redeem) | 132 kV D/C Transmission Line (10.3km) from Likosi (Ogijo) – Abule Oba (Redeem). | 132 | 2022 |
| South-West | Lagos | Ikeja West | MAKOGI (MFM) – Existing Benin (Omotosho)/Ikeja West 330 kV 2 x D/C Transmission Line (4.2km). | 330 | 2022 |
| South-West | Lagos | Ajegunle (New Agbara) | Ejio (Arigbajo) – Ajegunle (New Agbara) 330 kV D/C Transmission Line (30.6km). | 330 | 2022 |
| South-West | Lagos | Agbara | Ajegunle (New Agbara) – Agbara 132 kV D/C Transmission Line (20.8km). | 132 | 2022 |
| South-West | Lagos | Badagry | Ajegunle (New Agbara) – Badagry 132 kV D/C Transmission Line (34.2km). | 132 | 2022 |
| ***PROPOSAL FOR NORTH-EAST TRANSMISSION INFRASTRUCTURE PROJECT TO BE FINANCED BY AfDB*** | | | | | |
| North-East | Bauchi | Maiduguri - Manguno - Marte - Dikwa - Bama | Construction of a new 321km, 132 kV Double-Circuit Line Between Maiduguri - Manguno - Marte - Dikwa -Bama. | 132 | after 2020 |
| North-East | Bauchi | Maiduguri - Bama - Goza - Gulak | Construction of a new 165km, 132 kV Double-Circuit Line from Maiduguri - Bama - Goza - Gulak. | 132 | after 2020 |
| North-East | Bauchi | Mayo Belwa - Jada - Ganye | Construction of a new 78km, 132 kV Double-Circuit Line from Mayo Belwa - Jada - Ganye. | 132 | after 2020 |
| North-East | Bauchi | Biu - BuniYadi - Damaturu | Construction of a new 134km, 132 kV Double-Circuit Line from Biu - BuniYadi - Damaturu. | 132 | after 2020 |
| North-East | Bauchi | Dambua - Chibok - Uba - Mubi | Construction of a new 130km, 132 kV Double-Circuit Line from Dambua - Chibok - Uba - | 132 | after 2020 |

| Area | Region | Location | Description | Voltage (kV) | in operation by |
|---|---|---|---|---|---|
| | | | Mubi. | | |
| North-East | Bauchi | Mayo Belwa - Jada - Ganye | Construction of a new 78km, 132 kV Double-Circuit Line from Mayo Belwa - Jada - Ganye. | 132 | after 2020 |
| North-East | Bauchi | Biu - BuniYadi - Damaturu | Construction of a new 134km, 132 kV Double-Circuit Line from Biu - BuniYadi - Damaturu. | 132 | after 2020 |
| North-East | Bauchi | Dambua - Chibok - Uba - Mubi | Construction of a new 130km, 132 kV Double-Circuit Line from Dambua - Chibok - Uba - Mubi. | 132 | after 2020 |
| North-West | Kaduna | Construction of Quad 330 kV on Kaduna-Kano 330 kV Single DC Transmission Line | Construction of Double-Circuit 330 kV Quad Conductor Kaduna-Kano Transmission line. | 330 | after 2020 |
| North-West | Kaduna | Zaria | Turn-in Turn-out and Installation of 2x150 MVA 330/132/33 kV Transformer, 6x330 kV bay extension, 2x60MVA 132/33 kV Transformer, associated 132 kV line bays and 6 number 33 kV feeder bays at Zaria. | 330 | after 2020 |
| North-West | Kaduna | Millennium City Kaduna | Turn-in Turn-Out and Installation of 2x150 MVA 330/132/33 kV Transformer, 2 x330 kV bay extension and 2x60MVA 132/33 kV Transformer and 2x3number associated outgoing 33 kV feeders. | 330 | after 2020 |
| North-West | Kaduna | Rigasa town, Kaduna | Turn-in Turn-out and Installation of 2x60 MVA 132/33 kV Transformer and 5 number outgoing 33 kV feeders. | 132 | after 2020 |
| North-West | Kaduna | Jaji, Kaduna | Turn-in Turn-out and Installation of 2x60 MVA 132/33 kV Transformer and 6 number outgoing 33 kV feeders. | 132 | after 2020 |
| South-South | Benin | Reconstruction of Delta to Benin 330 kV Transmission Line | Reconstruction of one of Delta-Benin 330 kV Transmission Line Double-Circuit to Quad Conductor 330 kV Double-Circuit Line. | 330 | after 2020 |
| South-South | Port Harcourt | Reconstruction of Alaoji to Onitsha 330 kV Transmission Line | Double-Circuit Alaoji-Ihiala-Onitsha to Quad conductor 330 kV transmission line. | 330 | after 2020 |
| South-South | Ahoda, Gilili and Sapele | Environmental Impact Assessment and Resettlement Action Plan and Payment of Compensation | Double-Circuit (DC) 132 kV Ahoda-Gilli-Gilli DC Transmission Line and 2x60MVA 132/33 kV Transformer at Gilli plus associated 6 number outgoing 33 kV feeders and DC 132 kV Sapele - Odilli DC Transmission Line and 2x60MVA 132/33 kV Transformer at Gilli plus associated 6 number outgoing 33 kV feeders. | 132 | after 2020 |
| North-East | `Bauchi | Environmental Impact Assessment and Resettlement Action Plan and Payment of Compensation | 132 kV line and associated substations: Maiduguri-Manguno-Marte-Dikwa-Bama, Maiduguri-Bama-Gwoza; Hadeja-Nguru-Gashua-Damaturu; Biu-Miringa-Buni Yadi-Damaturu; Dambua-Chibok-Askira-Uba-Mubi; Mayo Belwa-Jada-Ganye | 132 | after 2020 |
| | | | | | |
| ***PROPOSED NETAP PACKAGE AS OF 03 APRIL, 2017 - $486 MILLION*** | | | | | |
| South-West | Osogbo | Osogbo- Offa -Ganmo - Ilorin | Reconductoring of 150km, 132 kV Line Between Osogbo-Offa/Omuaran to Ganmo and Ilorin T.S. | 132 | 2020 |
| South-West | Osogbo | Ayede - Shagamu | Reconstruction and Conversion of SC to Double-Circuit of Ayede -Ajebo-Ishara-Shagamu 132 kV Line (54km) and Creation of Additional Bays 132 | 132 | 2020 |

| Area | Region | Location | Description | Voltage (kV) | in operation by |
|---|---|---|---|---|---|
| | | | kV Line Bays at Ayede, Ajebo, Ishara and Shagamu. | | |
| South-West | Osogbo | Osogbo- Ife/Ilesha | Reconstruction and Conversion to Double-Circuit of Osogbo-Ife/Ilesha 132 kV Line (39.21 km) and Osogbo-Ilesha 132 kV Line Tie-Off (22.1km) and Creation of Additional 132 kV Line Bays at Osogbo and Ilesha. | 132 | 2020 |
| South-East | Port Harcourt | AFAM - PH Main | Reconstruction of Existing Double 132 kV Line Circuit to 4 x 132 kV Line Circuit Using the Same Right of Way from AFAM to Port Harcourt Main (37.8km) and Creating Additional 3 x 132 kV Line Bays. | 132 | 2020 |
| South-East | Port Harcourt | PH Main - PH Town | Reconductoring of 132 kV Double-Circuit of Port Harcourt Main to Port Harcourt Town 132 kV Line (6km). | 132 | 2020 |
| North-West | Kaduna | Kumbotso - Hadelja | Reconductoring of Kumbotsho- Hadeji 132 kV Line (165 km). | 132 | 2020 |
| North-West | Kaduna | Kumbotso - Kankia | Reconductoring of Kumbotsho- Kankia 132 kV Line (100 km). | 132 | 2020 |
| South-East | Enugu | Onitsha - Oji River | Reconductoring of Onitsha- Orji 132 kV Line (87km) with Turn-In- Turn-Out Tower at Nibo (Agu Awka) in Awka 132 kV Substation. | 132 | 2020 |
| South-East | Enugu | Alaoji to Aba Town | Reconductoring of Alaoji - Aba Town Double-Circuit 132 kV line (8km) Including Rehabilitation of Two Nos. Towers along the Line. | 132 | 2020 |
| South-South | Benin | Irrua - Benin | Reconductoring of Irrua - Benin 132 kV line (81 km). | 132 | 2020 |
| South-South | Benin | Irrua - Okpila | Reconductoring of Irrua- Okpilai 132 kV line (43 km). | 132 | 2020 |
| South-South | Benin | Okpila - Okene | Reconductoring of Okpilai - Okene 132 kV line (65 km). | 132 | 2020 |
| South-South | Benin | Ajakuta-Okene | Reconductoring of Ajakuta- Okene 132 kV line (60 km). | 132 | 2020 |
| North-East | Bauchi | Gombe-Biu-Damboa-Maiduguri | Reconductoring of the Entire Route Length from Gombe -Dadin Kowa- Biu -Damboa - Maiduguri 132 kV line of 356 km Route Length. | 132 | 2020 |
| ***NORTHERN CORRIDOR TRANSMISSION PROJECT 2 (AFD2)*** | | | | | |
| North-West | Shiroro | Kainji - Birnin-Kebbi 330 kV Double-Circuit (DC) Line (310km) | 330 kV DC Transmission Line Kainji-Birnin-Kebbi (following the existing ROW of the SC 330 kV line) and 4x 330 kV bay extension at B/ Kebbi and 2 x 330 kV bay extension at Kainji | 330 | after 2020 |
| North-West | Shiroro | Birnin-Kebbi-Sokoto 330 kV Double-Circuit (DC) Line (130km) | (1) Birnin-Kebbi-Sokoto 330 kV DC Transmission Line on the existing 132 kV Birnin-Kebbi Sokoto ROW and reconducting the existing 132 kV Single-Circuit Birnin-Kebbi Line to double its capacity | 330 | after 2020 |
| North-West | Kaduna | Katsina-Daura-Gwiwa-Minjibir-Kura (234KM) | Construction of length of 330 kV DC Twin line between Katsina-Daura-Gwiwa-Jogana- Kura. | 330 | after 2020 |
| North-Central | Shiroro | Lambata (Mina-Suleja Rd) | Turn-in Turn-out Mina - Suleja 132 kV DC and Construction of 1 x 60 MVA 132/33 kV Complete substation. | 132 | after 2020 |
| North-West | Shiroro | Fakon Sarki-Argungu | Turn-in Turn-Out on Brinin Kebbi-Sokoto 132 kV Line and Construction of 2 x 60MVA 132/33 kV Complete substation. | 132 | after 2020 |

| Area | Region | Location | Description | Voltage (kV) | in operation by |
|---|---|---|---|---|---|
| North-West | Shiroro | Yelwa- Yawuri | Construction of 1 x 60MVA 132/33 kV Complete substation and High-Voltage Switchgears and Associated Equipment. | 132 | after 2020 |
| North-Central | Shiroro | Birnin Gwari | Construction of 1 x 60MVA 132/33 kV Complete substation and High-Voltage Switchgears and Associated Equipment. | 132 | after 2020 |
| North-West | Kaduna | Daura-Katsina State | Installation of 2x150MVA 330/132/33 kV Double-Circuit Substation and with associated 132 kV bay extension and Installation of 2x60MVA 132/33 kV transformers, 6number outgoing 33 kV feeder bays. | 330 | after 2020 |
| North-West | Kaduna | Jogana-Kano | Installation of 2x150MVA 330/132/33 kV Double-Circuit Substation and with associated 132 kV bay extension and Installation of 2x60 MVA 132/33 kV transformers, 6number outgoing 33 kV feeder bays. | 330 | after 2020 |
| North-West | Shiroro | 330 kV Sokoto Transmission Substation | Installation of 2x150 MVA 330/132/33 kV Transformers at Sokoto New 330 Double-Circuit Substation and with associated 132 kV bay extension and Installation of 2 x 60 MVA 132/33 kV transformers, 6 number outgoing 33 kV feeder bays. | 330 | after 2020 |
| North-Central | Shiroro | Shiroro –Kaduna (Mando) 330 kV Lines 1 & 2 SC Transmission Lines (96km) | Reconstruction and upgrading of two Single-Circuit 330 kV Transmission Lines 1 & 2 from Shiroro PS to Mando (Kaduna) to a two Double-Circuit, Quad conductor Shiroro-Mando (Kaduna) Transmission lines 1 and 2. The line bay extension at Mando and Shiroro. | 330 | after 2020 |
| North-East | Bauchi | Bauchi 330 kV Transmission Substation (2km) | Turn-in-out of the existing 330 kV SC Jos-Gombe line at Bauchi and installation of 2x150 MVA 330/132/33 kV Transformers with associated 132 kV bay extension and 2 x 60 MVA 132/33 kV transformers, 6 number outgoing 33 kV feeder bays. | 330 | after 2020 |

Source: JICA Study Team

Some of these projects are critical to operate the system in 2020 and if a load exceeding 9 GW is to be served adequately, these projects will have to be expedited, targeting completion by 2020 or as soon as possible after 2020.

#### 7-2-2-3 Transmission System Expansions Financed by AFD

A financing agreement is in place to improve the transmission system in the Greater Abuja area.

The transmission system expansions included in the ADF-financed project will strengthen the 330/132 kV system supplying power to the capital Abuja. A new 132 kV Double-Circuit transmission line (172 km) between New Apo 330/132/33 kV Substation and the planned Lafia 330 kV Substation will establish a third infeed to the Abuja 132 kV ring allowing power supply from the power plants in the Delta Area and the planned Mambilla Hydro Power Plant.

These network expansions are planned to be commissioned in 2020, see Table 7-2.2.

A detailed list of the transmission system expansions with their cost as estimated by TCN is shown in Annex 7.2e1. The planned transmission lines and substations are shown in Annex 7.1 on a map of Nigeria.

#### 7-2-2-4 Transmission System Expansions to Be Financed by JICA

To improve the transmission system operation and reliability of the transmission network in the Lagos region, there are plans to install new transmission lines and substations financed by JICA, which is currently preparing a feasibility study.

The planned 330 kV substations Likosi (Ogijo) and Ejio (Arigbajo) will reconfigure the transmission system from single- to Double-Circuit configuration improving rehabilitation during line maintenance and outages. The 330-kV Double-Circuit line to Ejio (Arigbajo) - Ajegunle (New Agbara) and Ajegunle (New Agbara) substation will allow power export to Benin bypassing the heavily loaded Ikeja Substation. The new 132/33 kV substations Abule Oba (Redeem), MAKOGI (MFM) and Badagry will provide additional infeed capacity into the distribution system.

Commissioning of these network expansions is scheduled for 2020, see Table 7-2.2.

Annex 7.2d shows the present network configuration in the Lagos area and the future configuration after commissioning new lines and substations.

A detailed list of the transmission system expansions with their cost as estimated by TCN is shown in Annex 7.2e2.

#### 7-2-2-5 Transmission System Expansions to Be Financed by AfDB

The transmission system in the North-East of Nigeria is not well developed. Many north-eastern cities are not yet connected to the transmission system and rely on local generation only.

To improve the electricity supply from the national grid, TCN is planning to install various 132 kV transmission lines and new 132/33 kV substations as follows:

New Transmission Lines

- 321 km, 132 kV Double-Circuit Line Between Maiduguri - Manguno - Marte - Dikwa -Bama
- 165 km, 132 kV Double-Circuit Line from Maiduguri - Bama - Goza - Gulak
- 78 km, 132 kV Double-Circuit Line from Mayo Belwa - Jada - Ganye
- 134 km, 132 kV Double-Circuit Line from Biu - BuniYadi - Damaturu
- 130 km, 132 kV Double-Circuit Line from Dambua - Chibok - Uba - Mubi

132/33 kV Substations

- New 132/33 kV Manguno Substation, 2 x 60 MVA,
- Extension of Old Maiduguri 132 kV switchgear by 2 bays,
- New 132/33 kV Marte Substation, 2 x 60 MVA,

- New 132/33 kV Dikwa Substation, 1 x 60 MVA,
- New 132/33 kV Bama Substation, 2 x 60 MVA,
- Extension of New Maiduguri 132 kV switchgear by 2 bays,
- New 132/33 kV Gwoza Substation, 1 x 60 MVA,
- Extension of Gulak 132 kV switchgear by 2 bays,
- New 132/33 kV Jada Substation, 2 x 60 MVA,
- New 132/33 kV Ganye Substation, 2 x 60 MVA,
- New 132/33 kV Uba Substation, 2 x 60 MVA,
- New 132/33 kV Chibok Substation, 1 x 60 MVA,
- New 132/33 kV Biu Substation, 1 x 60 MVA,
- New 132/33 kV Bunyadi Substation, 1 x 60 MVA,
- Extension of Damaturu 132 kV switchgear by four bays,
- New 132/33 kV Kwaya Kusar Substation, 1 x 60 MVA,
- Extension of Gulak 132 kV switchgear by 2 bays,

In addition to the above, the following lines are planned:

In the North-West planning region of Nigeria there are plans to build a 330-kV Double-Circuit line between Kaduna and Kano, two 330/132 kV substations and two 132/33 kV substations.

In the South planning region, the reconstruction of two 330 kV transmission lines is planned. The 330 kV lines Delta-Benin and Alaoji-Ihiala-Onitsha shall be replaced by Double-Circuit lines with Quad conductors.

Furthermore, environmental impact assessments for various transmission lines are included in the scope.

A detailed list of transmission system expansion measures included in the scope of financing is shown in Annex 7.2e3 with their cost as estimated by TCN**.**

The planned transmission lines and substations are shown in Annex 7.1 on a map of Nigeria.

#### 7-2-2-6 Transmission System Rehabilitations and Reinforcements/Upgrading to Be Financed by the World Bank

Under the Nigeria - Electricity Transmission Project (NETAP) it is proposed to carry out numerous rehabilitations/reinforcements of existing substations and transmission lines, financed by the World Bank.

The reinforcement and upgrading of substations includes the installation of additional 330/132 kV and 132/33 kV transformers, replacement of existing transformers by units with a higher rated capacity and installation of associated switchgear equipment and control and protection equipment. The rehabilitation measures include replacing high-voltage switchgear and associated equipment as well as control and protection equipment.

The rehabilitation/reinforcement of transmission lines includes mostly reconductoring of lines.

A detailed list of system rehabilitations and reinforcements/upgrading with their cost as estimated by TCN is shown in Annex 7.2e4. The annex shows that the substations and transmission lines are located throughout all the TCN planning regions of Nigeria.

#### 7-2-2-7 Transmission System Expansions to Be Financed by AFD

Under a second financing agreement with AFD, there are plans to build new transmission lines and substations and rehabilitate transmission lines and substations in various northern planning areas of TCN, to improve power transmission in the northern transmission corridor. The scope includes also various rehabilitation measures for substations and transmission lines.

A detailed list of transmission system expansion measures included in the scope of financing is shown in Annex 7.4e5 with their cost as estimated by TCN.

## 7-3 Criteria to Formulate a Transmission Network Development Plan

### 7-3-1 Appraisal Criteria for TCN Network Expansions

Each of the main 330 and 132 kV projects has been appraised using ENTSO-E methodology. As such, the benefit of each project is assessed against a number of indicators, ranging from technical and socio-economic issues to their environmental impact.

The analysis has been performed for projects with implementation in the transmission network scheduled for 2025. Applying the ENTSO-E methodology, expected benefits were weighted and individually applied for each project. For this study, the projects were appraised against the following criteria:

**Increase of Network Transfer Capacity,** estimating the incremental power transfer capacity between two points of the transmission system (MW);

**Social and Environmental Impacts,** reflecting the level of certainty with respect to the planned commissioning time of the project and its impacts on the environment;

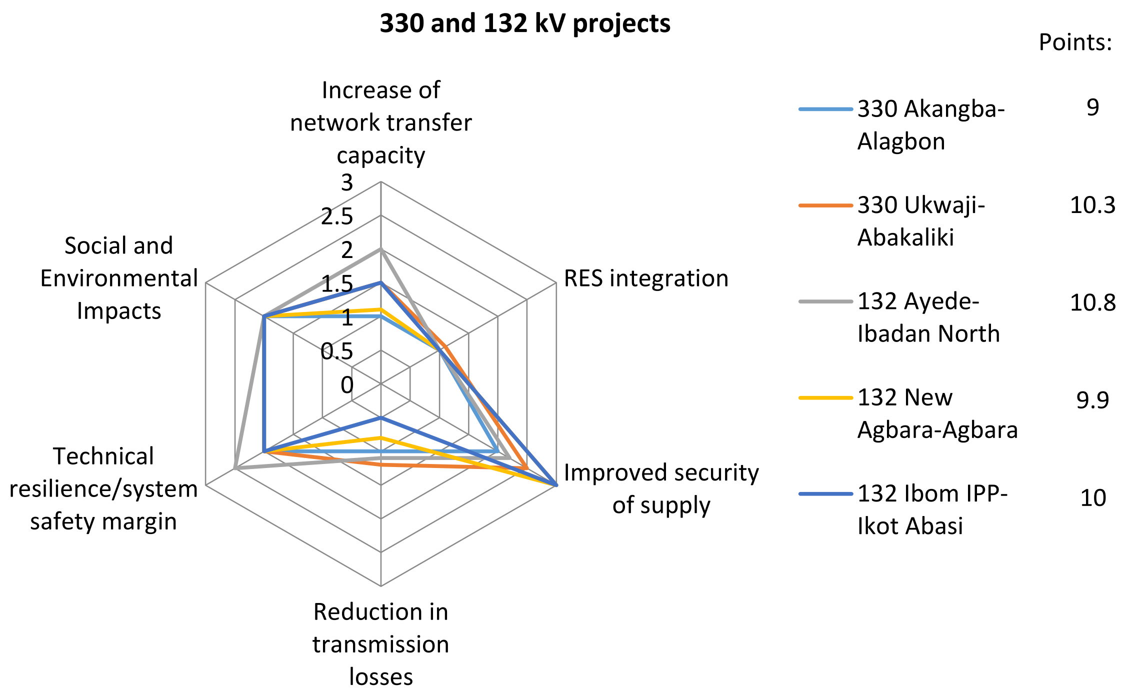
**Security of Power Supply,** evaluating the project impact on the reliability status of connected parts of the network;

**Integration of Renewable Energy Sources (RES)**, Support for RES integration is defined as the ability of the system to allow the connection of new RES plants and unlock existing and future "green" generation;

**Effect on Transmission Losses (Energy Efficiency)**, comparing losses (in MWs) relevant to scenarios with and without projects (or their specific components);

**Technical resilience/system safety margin**, evaluating the project influence on overall system reliability;

The radar format graph of Figure 7-3.1 shows, for example, the points scored by certain projects and hence their priority ranking. When comparing for the five projects, the 132 kV Ayade – Ibadan North project has the highest score and thus the highest priority. Other projects are also calculated and prioritized accordingly.




Source: JICA Study Team

**Figure 7-3.1 Project Appraisal Criteria and Scores**

### 7-3-2 Methodology Overview

The methodology of the power system analysis is summarized as follows:

#### 7-3-2-1 Definition of the Security Reference Level

The goal of the study is to propose the necessary updates and reinforcements to the TCN power system to achieve secure operation for the system for the period 2020 to 2040. First, the present system model is analyzed, taking into account the recently completed and ongoing TCN and NIPP projects scheduled for completion by 2020. It has also been assumed that certain projects in the Lagos area undertaken by JICA will be completed for the period 2020-2025.

**(1) Voltage criteria**

The Grid Code of, 2014, v2, states that the System Operator shall endeavor to control the different busbar voltages to be within the voltage control ranges specified in Table 7-3.1:

**Table 7-3.1 Voltage criteria**

| Voltage Level (kV) | Normal Operation | | Contingency Operation | |
|---|---|---|---|---|
| | Minimum Voltage (kV) (pu) | Maximum Voltage (kV) (pu) | Minimum Voltage (pu) | Maximum Voltage (pu) |
| 330 kV | 280.5 (0.85) | 346.5 (1.05) | 0.80 | 1.10 |
| 132 kV | 112.2 (0.85) | 145.2 (1.10) | 0.80 | 1.15 |
| 66 kV | 62.04 (0.94) | 69.96 (1.06) | 0.89 | 1.11 |
| 33 kV | 31.02 (0.94) | 34.98 (1.06) | 0.89 | 1.11 |
| 11 kV | 10.45 (0.95) | 11.55 (1.05) | 0.90 | 1.10 |

Source: JICA Study Team

Under system stress or following system faults, voltages can be expected to deviate outside the above limits by a further +/-5% (excluding transient and sub-transient disturbances).

#### 7-3-2-2 Thermal Criteria

The maximum permissible thermal overloading for all branches at 330 and 132 kV level is 100% of the nominal rating (Rate A) under normal (N) system conditions and 110% of the nominal rating under contingency (N-1) system conditions.

#### 7-3-2-3 Policy of the Power System Analysis

**(1) Execution of analyses on the 2020 model**

The initial analysis relates to the static security assessment. Using the outcome of this analysis, an initial reinforcement list and recommendations for new lines and transformers are provided.

**(2) Execution of the analysis on the 2025, 2030, 2035 and 2040 models**

Considering the recommendations and reinforcements provided in b) already implemented in the 2020 network model, the same analysis is carried out on the 2025, 2030, 2035 and 2040 scenarios. The reinforcements and recommendations for these years constitute the outcome of this analysis.

The proposed transmission expansion projects from 2020 to 40 are detailed in the following sections.

Five milestone study years have been selected to cover the planning horizon of the Master Plan: 2020, 2025, 2030, 2035 and 2040.

### 7-3-3 Load Demand

The load demand in each of the DisCos areas in Nigeria is summarized in Table 7-3.2

In the 2020 network configuration, the assumed total demand is 9,023 MW, to closely match the validated DisCos load demand, as presented by the 11 DisCos in the workshop of January 2017 in Abuja. Thereafter, the load demand to be served depends on two factors: (a) the rate of increase in forecast demand as presented in Section 5 and, more importantly, (b) the limits of the generation expansion plan.

The maximum load demand that can be realistically supplied will, accordingly, have to follow the development of the generation planning schedule and will be limited by associated financial and time constraints.

The total demand that can be served includes the export requirements to neighboring countries.

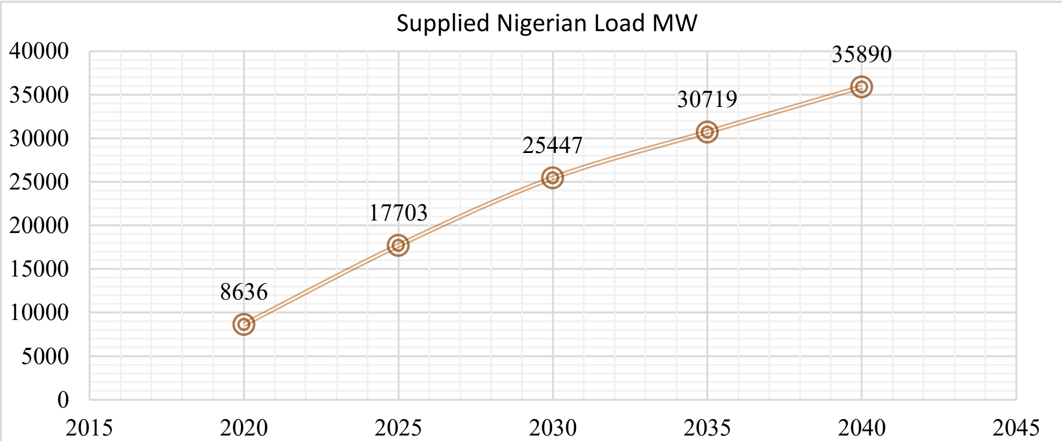
**Table 7-3.2 Load demand per DisCo**

| DisCo | 2020 | incr | 2025 | incr | 2030 | incr | 2035 | incr | 2040 |
|---|---|---|---|---|---|---|---|---|---|
| 1-Ikeja | 1,166 | 76% | 2,058 | 42% | 2,921 | 21% | 3,536 | 22% | 4,300 |
| 2-Ibadan | 1,104 | 107% | 2,285 | 43% | 3,267 | 24% | 4,054 | 25% | 5,055 |
| 3-Abuja | 865 | 169% | 2,329 | 50% | 3,500 | 26% | 4,398 | 21% | 5,336 |
| 4-Benin | 954 | 94% | 1,852 | 34% | 2,489 | 17% | 2,901 | 17% | 3,391 |
| 5-Kaduna | 495 | 136% | 1,169 | 81% | 2,117 | 20% | 2,533 | 20% | 3,045 |

| DisCo | 2020 | incr | 2025 | incr | 2030 | incr | 2035 | incr | 2040 |
|---|---|---|---|---|---|---|---|---|---|
| 6-Jos | 309 | 109% | 646 | 60% | 1,035 | 4% | 1,079 | 5% | 1,131 |
| 7-Enugu | 924 | 81% | 1,668 | 19% | 1,979 | 3% | 2,037 | 4% | 2,112 |
| 8-Port Harcourt | 794 | 122% | 1,762 | 35% | 2,385 | 17% | 2,802 | 18% | 3,305 |
| 9-EKO | 1,087 | 69% | 1,837 | 22% | 2,240 | 6% | 2,382 | 5% | 2,512 |
| 10-Kano | 708 | 121% | 1,565 | 64% | 2,570 | 38% | 3,549 | 13% | 4,023 |
| 11-Yola | 230 | 131% | 532 | 77% | 942 | 54% | 1,448 | 16% | 1,680 |
| Country (MW) | 8,636 | 105% | 17,703 | 44% | 25,447 | 21% | 30,719 | 17% | 35,890 |
| Export (MW) | 387 | | 1,540 | | 1,830 | | 2,000 | | 2,000 |
| Total Load (MW) | 9,023 | 113% | 19,243 | 42% | 27,277 | 20% | 32,719 | 16% | 37,890 |

Source: JICA Study Team

The increase in load that can be supplied by the planned generation for the period 2020-2040 is shown in Figure 7-3.2. The development of the generation system and associated demand can thus be referred to as the 9 GW in 2020, 18 GW in 2025, 26 GW in 2030, 31 GW in 2035 and 36 GW in 2040 respectively.




Source: JICA Study Team

**Figure 7-3.2 Increase in Served Nigerian Load 2020-2040**

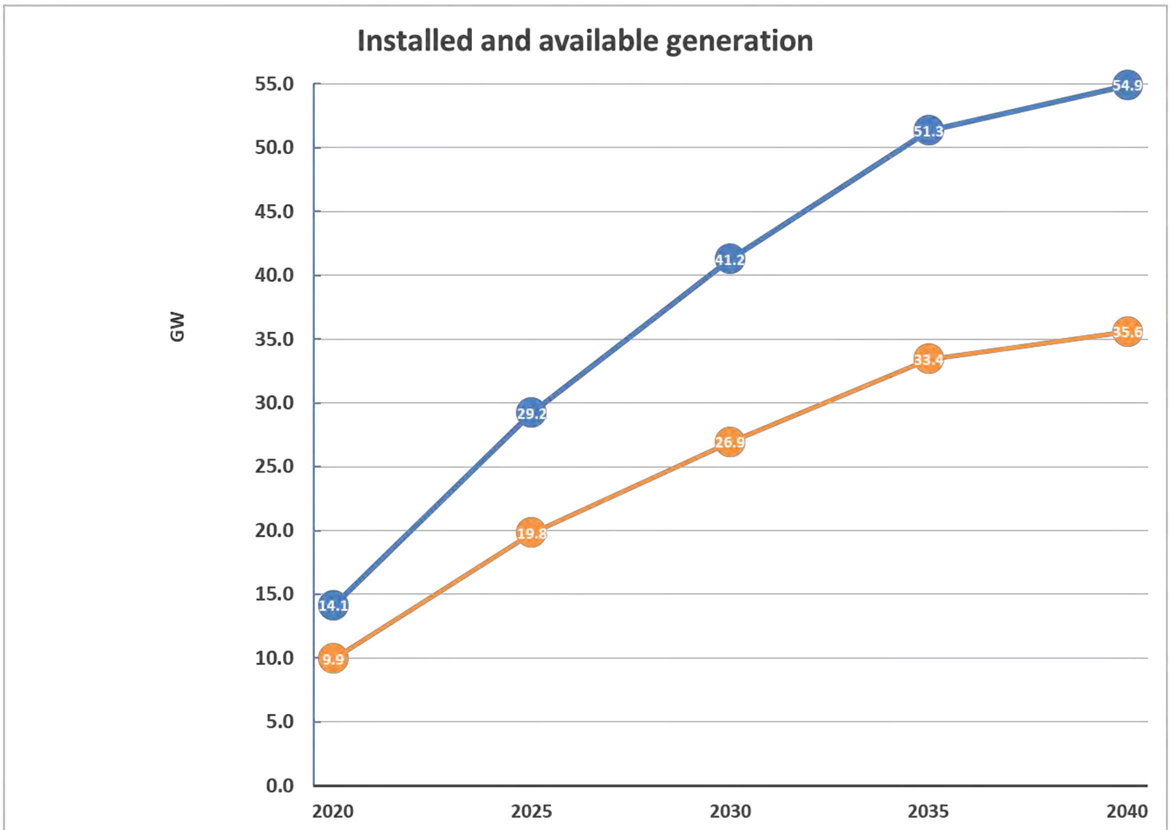
Based on the installed generation, the maximum generation that can be made available to supply the peak demand is calculated as shown in the following Table 7-3.3 and Figure 7-3.3.

The generation expansion assumed for this study, for an average exceeding 2 GW per year for the period 2020-2034, is considered rather optimistic.

**Table 7-3.3 Installed and available generation for 2020, 2025, 2030, 2035 and 2040**

| | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| Installed generation (GW) | 14.1 | 29.2 | 41.2 | 51.3 | 54.9 |
| Proposed candidates (GW) | 0.7 | 9.1 | 18.5 | 28.6 | 32.4 |
| Less PV (not available during peak load) in GW | -1.08 | -1.31 | -2.11 | -2.11 | -2.11 |
| Less a% of proposed candidates (in% and GW) | 0% | 20% | 20% | 20% | 20% |
| | 0.0 | -1.8 | -3.7 | -5.7 | -6.5 |
| Less a min% on planned and unplanned outages (in% and GW) | 20% | 20% | 20% | 20% | 20% |
| | -2.6 | -5.2 | -7.1 | -8.7 | -9.3 |
| Available generation (max./rated) in GW | 10.4 | 20.9 | 28.3 | 34.8 | 37.1 |
| Available generation (running) during peak demand (GW) | 9.9 | 19.8 | 26.9 | 33.4 | 35.6 |
| Available generation (max), as% of the total (installed+planned+proposed). | 74% | 71% | 69% | 68% | 67% |

Source: JICA Study Team




| | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| Installed generation (GW) | 14.1 | 29.2 | 41.2 | 51.3 | 54.9 |
| Available generation (running) during peak demand (GW) | 9.9 | 19.8 | 26.9 | 33.4 | 35.6 |

Year

Source: JICA Study Team

**Figure 7-3.3 Installed and Available Generation for 2020, 2025, 2030, 2035 and 2040**

## 7-4 Expansion Plan for 2020

### 7-4-1 Static Security Analysis, Year 2020

#### 7-4-1-1 Network Configuration

The network configuration for 2020 is shown in the single-line diagrams of Annexes 7.4.2 and 7.4.1. The SLDs include all the ongoing and committed TCN, NIPP and JICA new projects, assuming completion in all cases by 2020.

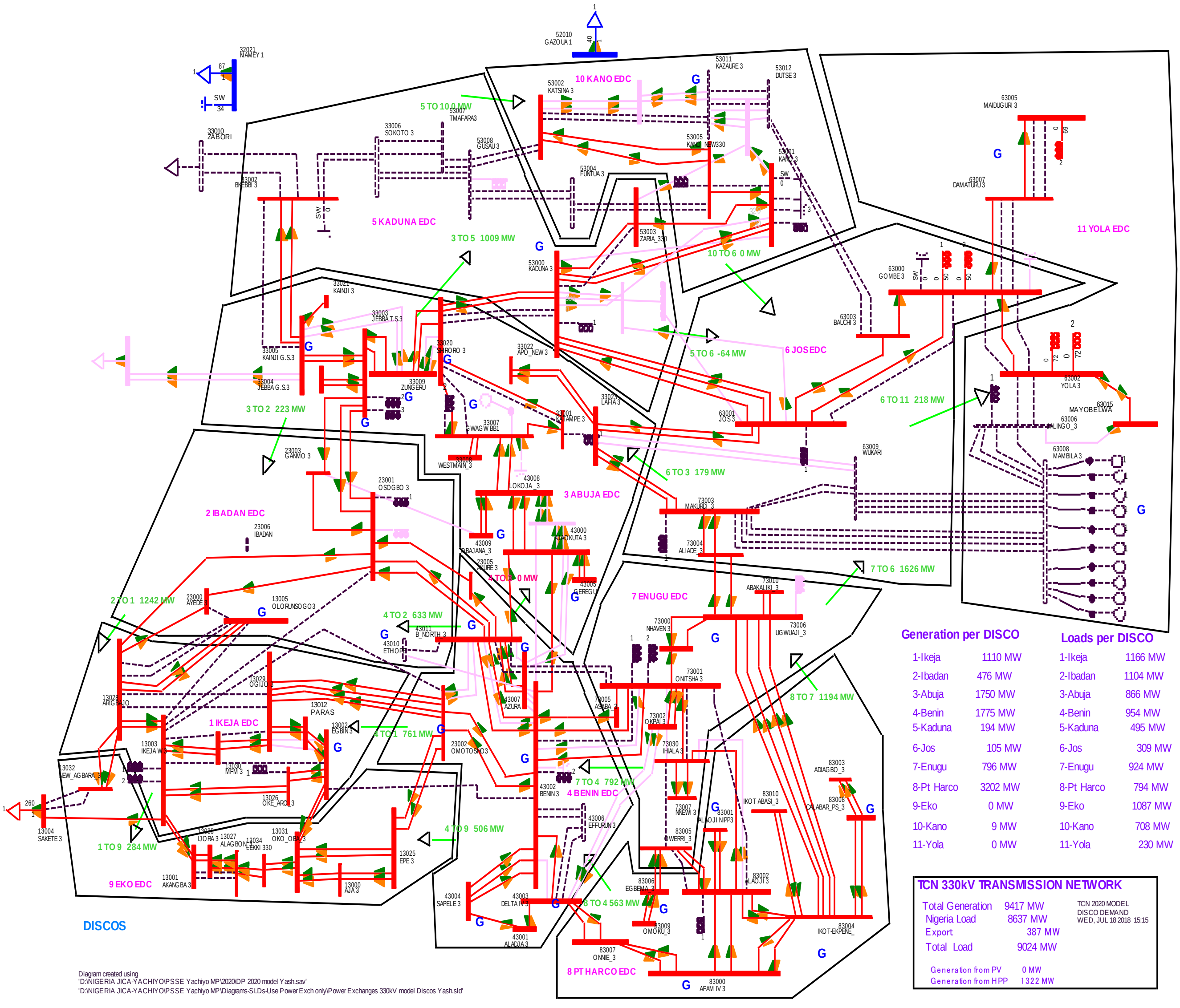
The new transmission expansion projects identified on the basis of the load-flow studies carried out are shown on the map of Annexes 7.4.3 and 7.4.4.

The input data used and the assumptions made with regard to the load demand, generation capacities and expansion, transmission lines and reactive power compensation equipment are detailed in the following sections.

Figure 7-4.1 below shows the 330-kV transmission system in 2020 (red lines), assuming all the ongoing and committed TCN, NIPP and certain JICA new projects will be completed by 2020.

The diagram shows the running generation and load in each DisCo area and the power flows between DisCos.

Dotted lines and lines in magenta denote future projects beyond 2020, which were analyzed in the study of the corresponding year and reported accordingly in this report.




Source: JICA Study Team

**Figure 7-4.1 330 kV Transmission System 2020**

### 7-4-1-2 Load Demand

In the 2020 network configuration the assumed total demand is 9,023 MW, closely matching the validated DisCos load demand, as presented by the 11 DisCos in the workshop of January 2017 in Abuja.

The load in each of the DisCo areas in Nigeria is shown in Figure 7-4.2 and summarized in Table 7-4.1.

The total demand includes the export requirements to neighboring countries as follows:

To Benin (Sakete, 330 kV):
To Niger (Niamey, 132 kV):
To Niger (Gazoua, 132 kV):

The export requirements modeled for 2020, 2025, 2030 and 2035 were based on information provided by TCN and the results of earlier WAPP studies and reports.

In the 2020 load model representation in PSS/E, a pessimistic power factor of around 0.85 has been assumed, despite the new Grid Code requirements calling for a pf of 0.95, as it is believed that most users at distribution level are not in full compliance yet with this requirement. It is noted that the Grid Code requirements (ref. article 15.6 on Demand power factor corrections and 16.7 on provision of voltage control) states that The Off-takers shall maintain a power factor of at least 0.95 at the Connection Point.

Accordingly, the loads in the 2020 models are based on a pf of 0.85, those in the 2025 model on a still-conservative pf of 0.92 and only the 2030 loads have a pf of 0.95.

**Table 7-4.1 Load demand per DisCo**

| SCO | Load (MW) |
|---|---|
| 1-Ikeja | 1,166 |
| 2-Ibadan | 1,104 |
| 3-Abuja | 866 |
| 4-Benin | 954 |
| 5-Kaduna | 495 |
| 6-Jos | 309 |
| 7-Enugu | 924 |
| 8-Port Harcourt | 794 |
| 9-Eko | 1,087 |
| 10-Kano | 708 |
| 11-Yola | 230 |
| Total for Nigeria | 8,637 |
| Export | 387 |
| Total load | 9,024 |

Source: JICA Study Team

The modeled loads of individual substations within each DisCo are detailed in Annex 7.4.5.

The total generation required to meet the load in Nigeria is 9,421 MW and total losses are 397 MW.

### 7-4-1-3 Generation Capacity

The ratings of the conventional generating units in Nigeria for 2020 are shown in Table 7-4.2.

## Table 7-4.2 Ratings of power generating units ($P_{max}$)

| Station Name | Company Name | Primary Energy Resource | Commercial Operation Date | No of Units | Gross Unit Capacity (MW) | Gross Plant Capacity (MW) | Total 2020 |
|---|---|---|---|---|---|---|---|
| ***Existing generation capacity*** | | | | | | | |
| AFAM IV - GT13-18 | AFAM POWER PLC. | GAS | 1982 | 6 | 75 | 450 | 150 |
| AFAM V - GT19-20 | AFAM POWER PLC. | GAS | 2002 | 2 | 138 | 276 | 276 |
| AFAM VI - GT11-13 | SHELL ROT | GAS | 2009 | 3 | 166 | 498 | 450 |
| AFAM VI - ST1 | SHELL ROT | STEAM | 2010 | 1 | 230 | 230 | 200 |
| ALAOJI – NIPP | NIPP | GAS | 2013 | 4 | 120 | 480 | 480 |
| CALABAR / ODUKPANI NIPP | NIPP | GAS | 2015 | 5 | 113 | 565 | 338 |
| DELTA II - GT3-8 | TRANSCORP POWER LTD | GAS | 2002 | 6 | 24 | 143 | 123 |
| DELTA III - GT9-14 | TRANSCORP POWER LTD | GAS | 2005 | 6 | 24 | 143 | 128 |
| DELTA IV - GT15-20 | TRANSCORP POWER LTD | GAS | 1990 | 6 | 99 | 594 | 630 |
| EBUTE BARGE (CYREX) AES | AES / CYREX ENERGY LTD | GAS | 2002 | 9 | 31 | 279 | 0 |
| EGBIN | EGBIN POWER PLC | STEAM | 1985 | 6 | 220 | 1,320 | 1,320 |
| GBARAIN - GT2 NIPP | NIPP | GAS | 2016 | 1 | 113 | 113 | 113 |
| GEREGU FGN 1 | GEREGU GENERATION COMPANY LTD | GAS | 2007 | 3 | 138 | 414 | 414 |
| GEREGU NIPP 1 | NIPP | GAS | 2013 | 3 | 148 | 444 | 220 |
| IBOM 1 | IBOM POWER | GAS | 2009 | 1 | 42 | 42 | 0 |
| IBOM 1 | IBOM POWER | GAS | 2010 | 1 | 114 | 114 | 114 |
| IBOM 1 | IBOM POWER | GAS | 2016 | 1 | 40 | 40 | 0 |
| IHOVBOR (EYAEN) NIPP | NIPP | GAS | 2013 | 4 | 113 | 452 | 339 |
| JEBBA | POWER HOLDING CO OF NIGERIA | HYDRO | 1983 | 6 | 101.15 | 606.9 | 607 |
| KAINJI - G11-12 | POWER HOLDING CO OF NIGERIA | HYDRO | 1976 | 2 | 100 | 200 | 200 |
| KAINJI - G5-6 | POWER HOLDING CO OF NIGERIA | HYDRO | 1968 | 2 | 120 | 240 | 240 |
| KAINJI - G7-10 | POWER HOLDING CO OF NIGERIA | HYDRO | 1978 | 4 | 80 | 320 | 160 |
| OKPAI IPP | NIGERIAN AGIP OIL CO | GAS | 2005 | 2 | 165 | 330 | 300 |
| OKPAI IPP | NIGERIAN AGIP OIL CO | STEAM | 2005 | 1 | 140 | 140 | 140 |
| OLORUNSOGO I | PACIFIC ENERGY | GAS | 2007 | 8 | 42 | 335 | 335 |
| OLORUNSOGO II NIPP | NIPP | GAS | 2011 | 4 | 120 | 480 | 240 |
| OLORUNSOGO II NIPP | NIPP | STEAM | 2012 | 2 | 120 | 240 | 120 |
| OMOKU IPP | FIRST INDEPENDENT POWER | GAS | 2006 | 6 | 25 | 150 | 150 |
| OMOTOSHO I | OMOTOSHO ELECTRIC ENERGY COMPANY | GAS | 2007 | 8 | 42 | 335 | 304 |
| OMOTOSHO II NIPP | NIPP | GAS | 2012 | 4 | 120 | 480 | 240 |
| PARAS ENERGY | PARAS ENERGY & NATURALS RES. DEV. LTD | GAS | 2016 | 9 | 9 | 79 | 170 |
| RIVERS IPP | FIRST INDEPENDENT POWER | GAS | 2012 | 1 | 191 | 191 | 191 |
| SAPELE | SAPELE POWER PLC | STEAM | 1978 | 6 | 88 | 528 | 400 |
| SAPELE OGORODE 1 NIPP | NIPP | GAS | 2011 | 4 | 113 | 454 | 454 |
| SHIRORO | SHIRORO HYDRO ELECTRIC | HYDRO | 1990 | 4 | 150 | 600 | 600 |
| TRANS-AMADI IPP | FIRST INDEPENDENT POWER | GAS | 2010 | 4 | 25 | 100 | 100 |
| | | | | | | Subtotal 1-Existing generation capacity | 10,098 |
| ***Additional generation capacity by 2020*** | | | | | | | |
| AFAM III | | GAS | 2018 | 8 | 30 | 240 | 240 |

| Station Name | Company Name | Primary Energy Resource | Commercial Operation Date | No of Units | Gross Unit Capacity (MW) | Gross Plant Capacity (MW) | Total 2020 |
|---|---|---|---|---|---|---|---|
| AFRINERGIA SOLAR | AFRINIGER SOLAR | PV | 2020 | | | 50 | 50 |
| ANJEED KAFACHAN SOLAR IPP | ANJEED KAFACHAN SOLAR IPP | PV | 2020 | | | 100 | 100 |
| AZURA | | GAS | 2018 | 3 | 150 | 450 | 450 |
| CT COSMOS | CT COSMOS | PV | 2020 | | | 70 | 70 |
| EGBEMA I - NIPP | NIPP | GAS | 2018 | 1 | 113 | 113 | 113 |
| EGBEMA I - NIPP | NIPP | GAS | 2019 | 1 | 113 | 113 | 113 |
| EGBEMA I - NIPP | NIPP | GAS | 2019 | 1 | 113 | 113 | 113 |
| EN Consulting & Projects - Kaduna | | PV | 2020 | | | 100 | 50 |
| GBARAIN / UBIE I | NIPP | GAS | 2017 | 1 | 113 | 113 | 113 |
| GURARA | SALINI NIGERIA LTD | HYDRO | 2017 | 2 | 15 | 30 | 30 |
| IBOM II | | GAS | 2020 | 4 | 138 | 552 | 276 |
| KADUNA IPP | KADUNA IPP | GAS | 2019 | 1 | 215 | 215 | 215 |
| KASHIMBILLA | | HYDRO | 2019 | | 40 | 40 | 40 |
| KVK POWER NIGERIA LTD | KVK POWER NIGERIA LTD | PV | 2020 | | | 55 | 55 |
| LR AARON SOLAR POWER PLANT | LR AARON SOLAR | PV | 2019 | | | 100 | 100 |
| MABON - DADIN KOWA | MABIN LTD. | HYDRO | 2018 | 1 | 39 | 39 | 39 |
| MIDDLE BAND SOLAR | MIDDLE BAND SOLAR | PV | 2020 | | | 100 | 100 |
| MOTIR DUSABLE | MOTIR DUSABLE LTD | PV | 2020 | | | 100 | 100 |
| NIGERIA SOLAR CAPITAL PARTNERS | NIGERIA SOLAR CAPITAL PARTNERS | PV | 2020 | | | 100 | 100 |
| NOVA SCOTIA POWER | Nova Scotia Power Development Ltd | PV | 2018 | | | 80 | 80 |
| NOVA SOLAR | NOVA SOLAR POWER LTD | PV | 2018 | | | 100 | 100 |
| OKPAI IPP II - AGIP (NNPC POWER BUSINESS PLAN) | NIGERIAN AGIP OIL CO | GAS | 2020 | 2 | 150 | 300 | 300 |
| OKPAI IPP II - AGIP (NNPC POWER BUSINESS PLAN) | NIGERIAN AGIP OIL CO | STEAM | 2020 | 1 | 150 | 150 | 150 |
| OMOKU - NIPP | NIPP | GAS | 2018 | 1 | 113 | 113 | 113 |
| OMOKU - NIPP | NIPP | GAS | 2019 | 1 | 113 | 113 | 113 |
| ORIENTAL | | PV | 2020 | | | 50 | 50 |
| PAN AFRICA SOLAR | PAN AFRICA SOLAR LTD | PV | 2019 | | | 75 | 75 |
| QUAINT ENERGY SOLUTIONS | QUAINT ENERGY SOLUTIONS | PV | 2019 | | | 50 | 50 |
| ZUNGERU | | HYDRO | 2019 | 4 | 700 | 700 | 700 |
| Subtotal 2-Additional generation capacity by 2020 | | | | | | | 4,198 |
| Total by 2020 | | | | | | | 14,296 |

Source: JICA Study Team

The PV plants shown in Table 7-4.3, are planned to be installed mainly in northern Nigeria and are most likely to go into operation by 2020.

**Table 7-4.3 PV plants in operation by 2020**

| PN Plant | Location | Installed Capacity (MW) |
|---|---|---|
| Pan Africa Solar | Kankia | 75 |
| Nova Solar | Katsina | 100 |
| LR Aaron Power | Abuja/Gwangwalada | 100 |
| Nova Scotia | Dutse/Jigawa | 80 |

| PN Plant | Location | Installed Capacity (MW) |
|---|---|---|
| KVK Power | Sokoto | 55 |
| Quaint Power/Energy | Kaduna | 50 |
| Anjeed Kafanchan | Kafanchan | 100 |
| Nigeria Solar Capital Partners | Gombe/Bauchi | 100 |
| Motir Dusable | Oji | 100 |
| Afrinergia Solar | Karu-Keffi | 50 |
| CT Cosmos | Jos/Makeri/Pankshin | 70 |
| Oriental | Dutse | 50 |
| EN Consulting-Kaduna | Kaduna-Zaria | 50 |
| Middle Band Solar | Lokoja | 100 |

Source: JICA Study Team

#### 7-4-1-4 Study Cases 2020

Four scenarios, as shown in Table 7-4.4 have been studied for 2020. The focus was on the two cases, (Dry Season Peak and Dry Season Off-Peak), which capture the extreme combinations of generation and load. Other scenarios, such as Wet Season Peak and Wet Season Off-Peak, are less onerous, as it has emerged that their requirements are covered by the extreme case studied:

**Table 7-4.4 2020 study cases**

| Case | | Description | Generation | Load (MW) | |
|---|---|---|---|---|---|
| Dry Season Peak | DP | Dry<br>Night<br>Peak Load | Dry-Reduced HPP generation (1,322 MW)<br>No PV generation<br>Increased requirement from GTs | Peak load (night) | 8637 + export (387) |
| Wet Season Peak | WP | Wet<br>Night<br>Peak Load | Wet-Normal HPP generation (2,100 MW)<br>No PV generation<br>Increased requirement from GTs | Peak load (night) | 8637 + export |
| Dry Season Off-Peak | DOP | Dry<br>Day<br>Off-Peak Load | Dry-Reduced HPP generation (1,100 MW)<br>PV generation (400 MW) | Off-Peak load (day) | 7340+ export (387) |
| Wet Season Off-Peak | WOP | Wet<br>Day<br>Off-Peak Load | Wet-Normal HPP generation (2,100 MW)<br>PV generation (400 MW) | Off-Peak load (day) | 7340 + export (387) |

Source: JICA Study Team

### 7-4-2 2020 Base Case Load-flow Results

The load-flow results are shown in Annexes 7.4.2 and 7.4.6 to 7.4.9

In the base case (N-0) load-flow calculations the following observations are made:

#### 7-4-2-1 Power Flows Between DisCos and Regions

The diagram of Figure 7-4.1 and the SLD in Annex 7.4.1 indicate the power flows between the 11 DisCos areas in Nigeria using green arrows, for general peak load and generation case. The DisCos are:

| | | |
|---|---|---|
| 1-Ikeja | 5-Kaduna | 9-Eko |
| 2-Ibadan | 6-Jos | 10-Kano |
| 3-Abuja | 7-Enugu | 11-Yola |
| 4-Benin | 8-Port Harcourt | |

The Nigeria planning *regions* are:

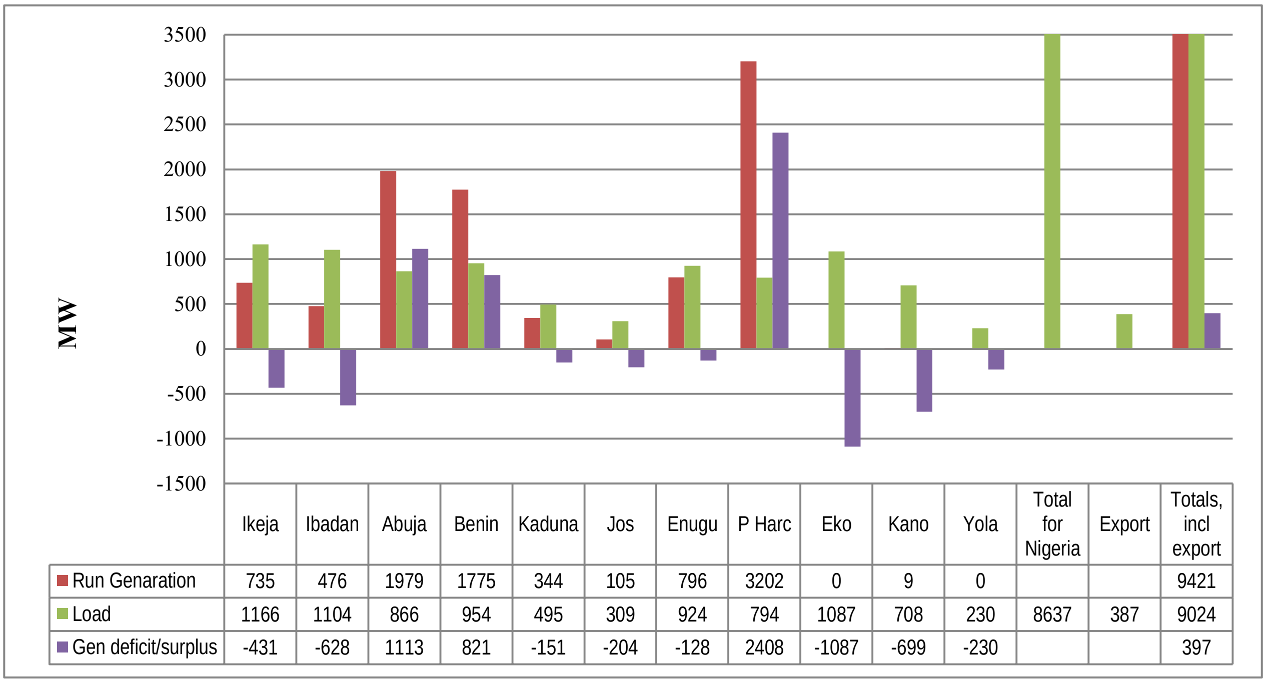
| | | |
|---|---|---|
| 1-Lagos | 5-Kaduna | 9-Abuja (July 2018~) |
| 2-Osogbo | 6-Bauchi | |
| 3-Shiroro | 7-Enugu | |
| 4-Benin | 8-Port Harcourt | |

The generation (installed and running) and the load in each DisCo are summarized in Table 7-4.5 and Figure 7-4.2. The running generation is approximately 74% of the total installed capacity.

**Table 7-4.5 Running generation and load in different areas (DisCos)**

| Region | Running Generation (MW) | Load (MW) | Generation deficit/surplus (MW) | Remarks |
|---|---|---|---|---|
| **1-Ikeja** | 735 | 1,166 | -431 | Generation deficit |
| **2-Ibadan** | 476 | 1,104 | -628 | Generation deficit |
| **3-Abuja** | 1,979 | 866 | 1,113 | Generation surplus |
| **4-Benin** | 1,775 | 954 | 821 | Generation surplus |
| **5-Kaduna** | 344 | 495 | -151 | Generation deficit |
| **6-Jos** | 105 | 309 | -204 | Generation deficit |
| **7-Enugu** | 796 | 924 | -128 | Generation deficit |
| **8-Port Harcourt** | 3,202 | 794 | 2,408 | Generation surplus |
| **9-Eko** | 0 | 1,087 | -1,087 | Generation deficit |
| **10-Kano** | 9 | 708 | -699 | Generation deficit |
| **11-Yola** | 0 | 230 | -230 | Generation deficit |
| **Total for Nigeria** | - | 8,637 | - | |
| **Export** | - | 387 | - | |
| **Totals** | 9,421 | 9,024 | 397 (losses) | |

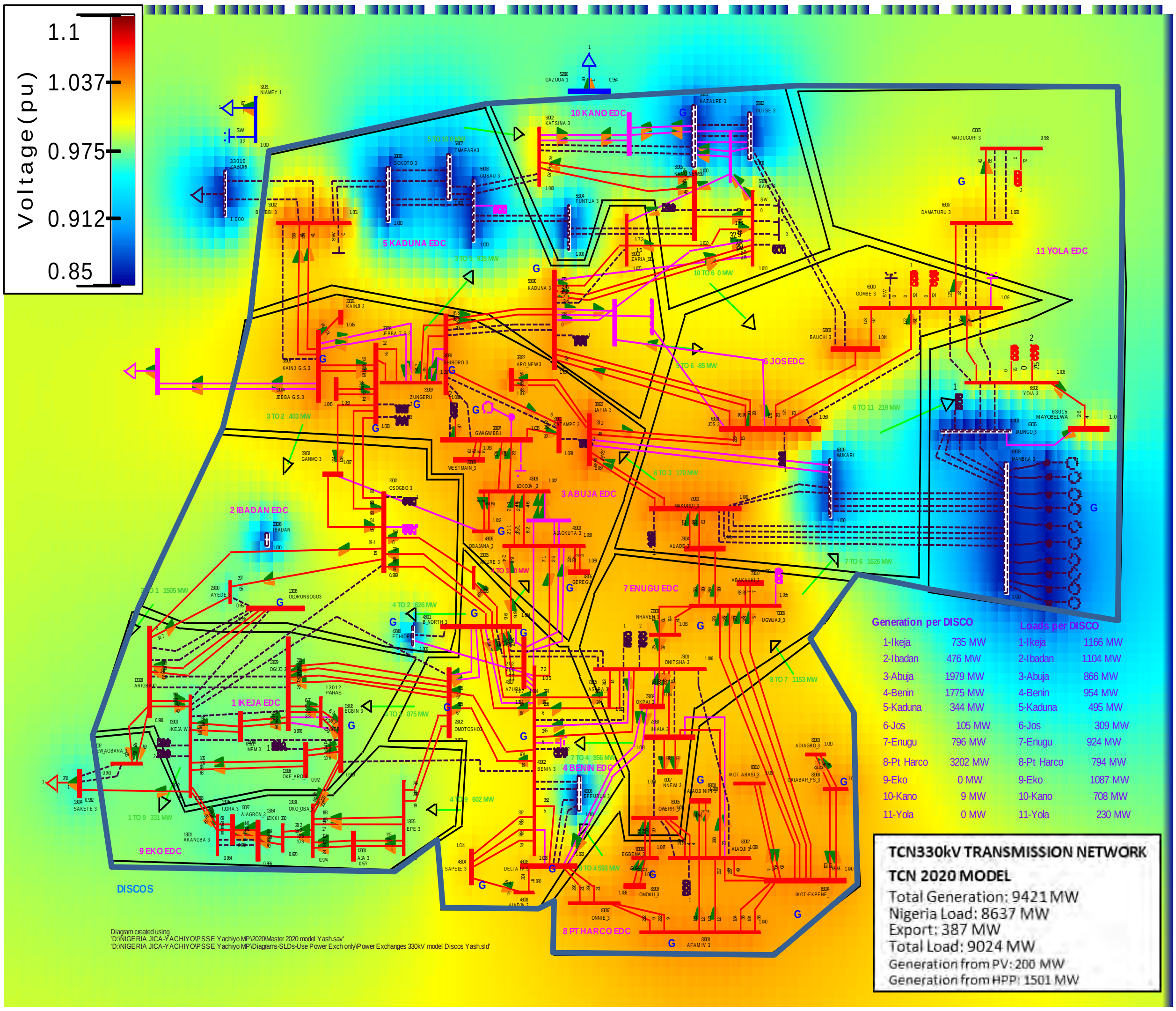
Source: JICA Study Team




Source: JICA Study Team

**Figure 7-4.2 Generation and Load per DisCo**

The general voltage profile is shown in Figure 7-4.3, with blue and red indicating relatively low and high voltages respectively. Lagos, Osogbo and Kaduna are clearly areas with low voltages encountered due to high demand, insufficient local generation, voltage drop in radial feeders and overloaded 132 kV lines and 132/33 kV transformers, even in some areas with high generation.




Source: JICA Study Team

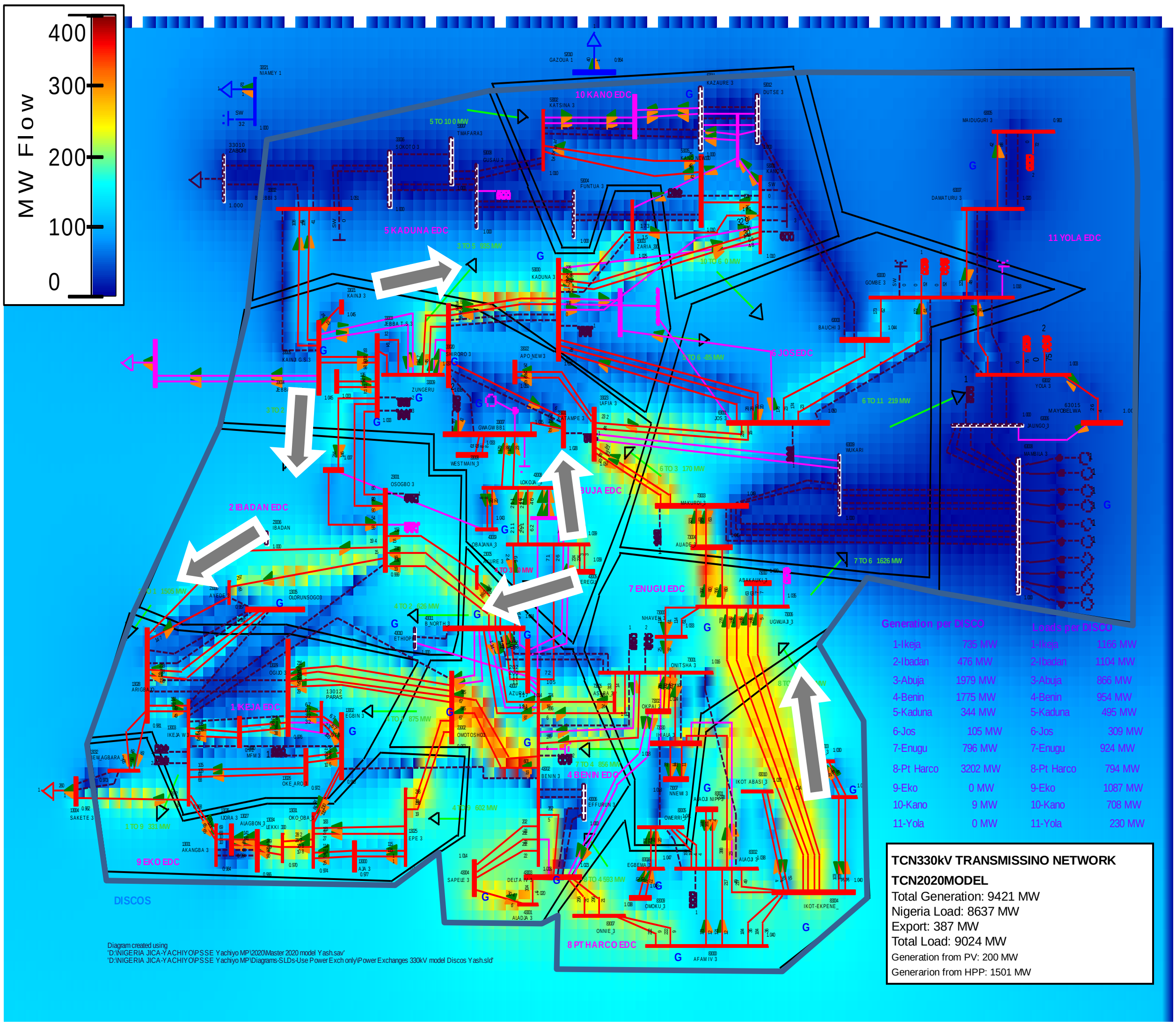
**Figure 7-4.3 Voltage Profile of 330, 132 and 33 kV Systems**

It can be seen that:

- The generation is mainly concentrated in the South (thermal stations in Port Harcourt, Enugu, Benin and Lagos) and Central West (hydro stations of Jebba, Kainji and Shiroro in the Shiroro region). The Central, North and North-East regions in particular are characterized by the total absence of generating stations.
- Load demand centers in the South and South-West. Table 7-4.5 shows that with the exception of Benin, Abuja and Port Harcourt areas, where there is a significant generation surplus, demand exceeds available supply in all other regions of Nigeria.

- To supply load to areas with little or no generation such as the North-East, long 330 kV transmission lines are built (radial system), which are then prone to voltage regulation problems. Moreover, the excessive reactive power flowing through these lines necessitates large reactive power compensation equipment (reactors) at the corresponding substations (Kano, Gombe, Maiduguri).
- Any addition of more 330 kV lines running in parallel, as planned, may require additional compensation equipment, as of Yola and Jalingo and possibly elsewhere to limit the overvoltages due to line charging currents.

The general profile of power flows in the TCN system is shown graphically in Figure 7-4.4




Source: JICA Study Team

**Figure 7-4.4 Power flows in the TCN system**

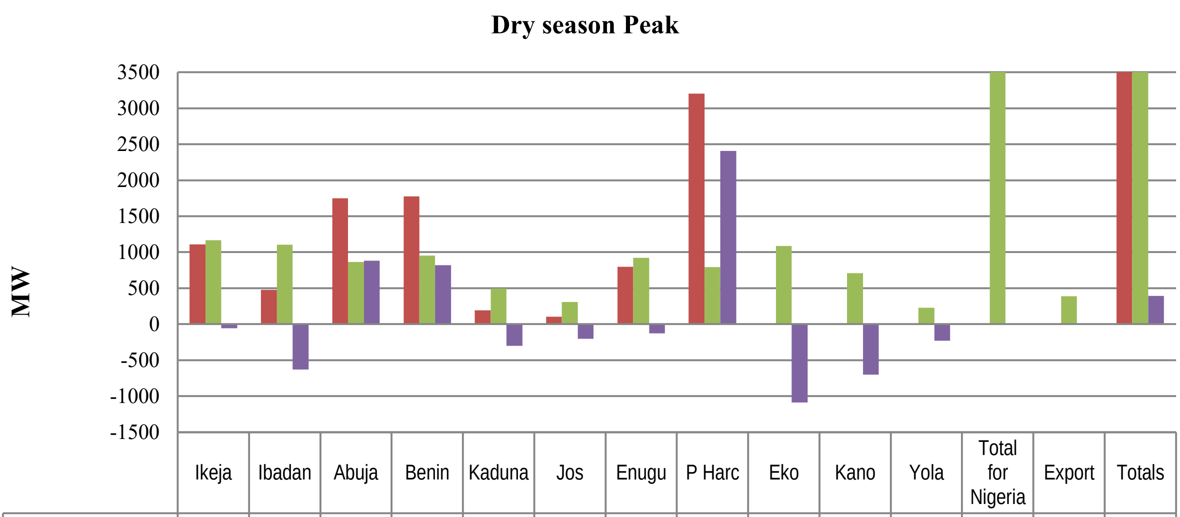
### 7-4-2-2 Dry Season Peak Case

#### (1) Prerequisites for analysis

(a) Generation from PVs = 0 MW and

(b) Reduced generation from HPP plants of 1,322 MW)

The running generation and load for each DisCo are shown in Figure 7-4.5 and Table 7-4.6. The total running generation to meet the load and losses is 9,417 MW.




| | Ikeja | Ibadan | Abuja | Benin | Kaduna | Jos | Enugu | P Harc | Eko | Kano | Yola | Total for Nigeria | Export | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run Genaration | 1110 | 476 | 1750 | 1775 | 194 | 105 | 796 | 3202 | 0 | 9 | 0 | | | 9417 |
| Load | 1166 | 1104 | 866 | 954 | 495 | 309 | 924 | 794 | 1087 | 708 | 230 | 8637 | 387 | 9024 |
| Gen deficit/surplus | -56 | -628 | 884 | 821 | -301 | -204 | -128 | 2408 | -1087 | -699 | -230 | | | 393 |

Source: JICA Study Team

**Figure 7-4.5 Dry Season Peak Generation and Load Per DisCo**

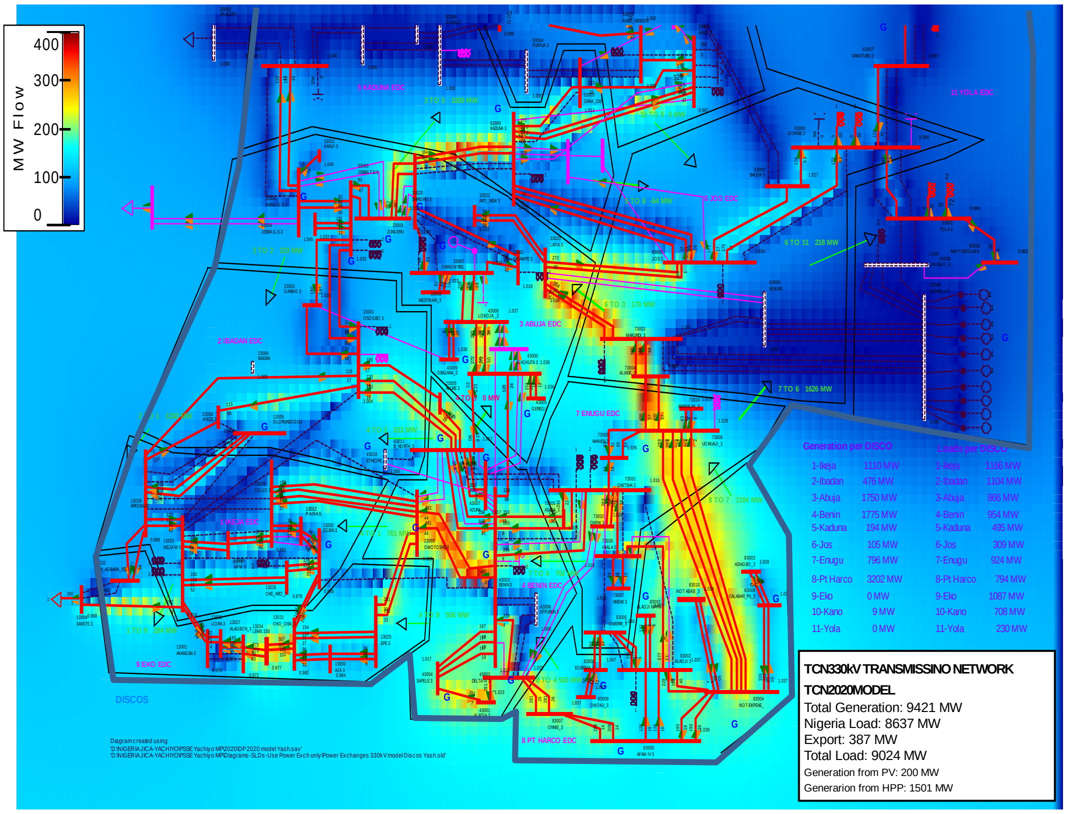
**Table 7-4.6 2020 Dry Season Peak - Running Generation**

| Bus Name | $P_{Gen}$ (MW) | Bus Name | $P_{Gen}$ (MW) | Bus Name | $P_{Gen}$ (MW) |
|---|---|---|---|---|---|
| AARON PV 15.000 | 0 | EGBIN ST 2 16.000 | 171.4 | NOVA SOLA PV33.000 | 0 |
| AES BERG202 11.000 | 0 | EGBIN ST 3 16.000 | 171.4 | NSCP PV 15.000 | 0 |
| AES BERG203 11.000 | 0 | EGBIN ST 4 16.000 | 171.4 | O REN SOL PV15.000 | 0 |
| AES BERG204 11.000 | 0 | EGBIN ST 5 16.000 | 171.4 | OBAJANA 15.000 | 0 |
| AES BERG205 11.000 | 0 | EGBIN ST 6 16.000 | 171.4 | OKPAI GT11 11.500 | 135 |
| AES BERG207 11.000 | 0 | ELEME 15.000 | 0 | OKPAI GT12 11.500 | 135 |
| AES BERG208 11.000 | 0 | EN ARFICA PV15.000 | 0 | OKPAI ST18 11.500 | 126 |
| AES BERG209 11.000 | 0 | ETHIOPE 15.000 | 0 | OKPAI_IPPII 11.500 | 400 |
| AES BERG210 11.000 | 0 | GBARAIN_GTB115.000 | 102 | OLOR NIPPST110.500 | 108 |
| AES BERG211 11.000 | 0 | GBARAIN_GTB215.000 | 102 | OLOR NIPPST210.500 | 0 |
| AFAM VI GT1111.500 | 150 | GEN DANGOTE 15.000 | 0 | OLORNIPPGT1110.500 | 0 |
| AFAM VI GT1211.500 | 150 | GEN_AMADI 15.000 | 90 | OLORNIPPGT1210.500 | 0 |
| AFAM VI GT1311.500 | 105 | GEN_KADUNA 15.000 | 194 | OLORNIPPGT2110.500 | 108 |
| AFAM VI ST1011.500 | 180 | GEOMETRIC_AB15.000 | 0 | OLORNIPPGT2210.500 | 108 |
| AFAM1GT1-2 11.500 | 0 | GER NIPPGT2110.500 | 100 | OLORUNSO GT110.500 | 22 |
| AFAM1GT3-4 11.500 | 0 | GER NIPPGT2210.500 | 0 | OLORUNSO GT210.500 | 22 |

| Bus Name | $P_{Gen}$ (MW) | Bus Name | $P_{Gen}$ (MW) | Bus Name | $P_{Gen}$ (MW) |
|---|---|---|---|---|---|
| AFAM2 GT5-6 11.500 | 54 | GER NIPPGT2310.500 | 100 | OLORUNSO GT310.500 | 20 |
| AFAM2GT 7-8 11.500 | 54 | GEREGU GT11 10.500 | 83 | OLORUNSO GT410.500 | 0 |
| AFAM3 GT9-1011.500 | 54 | GEREGU GT12 10.500 | 83 | OLORUNSO GT510.500 | 22 |
| AFAM3GT11-1211.500 | 54 | GEREGU GT13 10.500 | 83 | OLORUNSO GT610.500 | 22 |
| AFAM4GT13-1411.500 | 67 | GR COWRI PV 33.000 | 0 | OLORUNSO GT710.500 | 22 |
| AFAM4GT15-1611.500 | 0 | GURARA GBUS 11.500 | 0 | OLORUNSO GT810.500 | 22 |
| AFAM4GT17-1811.500 | 0 | IBOM GT1 11.500 | 34 | OMOKU1 GT1 15.000 | 68 |
| AFAMV GT 19 11.500 | 125 | IBOM GT2 11.500 | 34 | OMOKU1 GT2 15.000 | 50 |
| AFAMV GT 20 11.500 | 125 | IBOM GT3 11.500 | 34 | OMOKU2 GT1 15.000 | 102 |
| AFRINEGIA PV15.000 | 0 | IBOM II 11.500 | 260 | OMOKU2 GT2 15.000 | 102 |
| ALAOJI_GTB1 15.000 | 81 | IHOVBOR_GTB115.000 | 110 | OMOTNIPP GT110.500 | 108 |
| ALAOJI_GTB2 15.000 | 81 | IHOVBOR_GTB215.000 | 110 | OMOTNIPP GT210.500 | 108 |
| ALAOJI_GTB3 15.000 | 81 | IHOVBOR_GTB315.000 | 110 | OMOTNIPP GT310.500 | 0 |
| ALAOJI_GTB4 15.000 | 81 | IHOVBOR_GTB415.000 | 0 | OMOTNIPP GT410.500 | 0 |
| ALAOJI_STB1 17.000 | 0 | IJORA GT 4-611.000 | 0 | OMOTOSO GT1 10.500 | 70 |
| ALAOJI_STB1 17.000 | 0 | JBS WIND 15.000 | 70 | OMOTOSO GT3 10.500 | 66 |
| ALSCON GT1 11.500 | 0 | JEBBA 2G1 16.000 | 90 | OMOTOSO GT5 10.500 | 0 |
| ALSCON GT2 11.500 | 0 | JEBBA 2G2 16.000 | 90 | OMOTOSO GT7 10.500 | 0 |
| ANJEED PV 15.000 | 0 | JEBBA 2G3 16.000 | 0 | PAN AFRIC PV15.000 | 0 |
| ASCO G1 11.000 | 0 | JEBBA 2G4 16.000 | 0 | PARAS 11.500 | 0 |
| ASCO G2 11.000 | 0 | JEBBA 2G5 16.000 | 0 | PARASGT1-9 11.000 | 81 |
| AZURA GT 15.000 | 280 | JEBBA 2G6 16.000 | 90 | QUAINT PV 15.000 | 0 |
| AZURA ST 15.000 | 125 | KAINJ 1G11 16.000 | 90 | RIVERS _GT1 10.500 | 172 |
| BRESSON GTS 11.000 | 0 | KAINJ 1G12 16.000 | 90 | RIVERS_GT2 10.500 | 0 |
| CALABAR_GTB115.000 | 100 | KAINJ 1G5 16.000 | 45 | SAP_NIPP_GT115.800 | 77 |
| CALABAR_GTB215.000 | 102 | KAINJ 1G6 16.000 | 45 | SAP_NIPP_GT215.800 | 77 |
| CALABAR_GTB315.000 | 102 | KAINJ 1G7-8 16.000 | 160 | SAP_NIPP_GT315.800 | 76 |
| CALABAR_GTB415.000 | 0 | KAINJ 1G9-1016.000 | 0 | SAP_NIPP_GT415.800 | 76 |
| CALABAR_GTB515.000 | 0 | KASHIMB HP2 15.000 | 0 | SAPELE GT1-215.800 | 0 |
| CT COSMO PV 15.000 | 0 | KASHIMB HP3 15.000 | 0 | SAPELE GT3-415.800 | 0 |
| DELT3 GT9-1111.500 | 38 | KASHIMB HP4 15.000 | 0 | SAPELE ROT 15.800 | 0 |
| DELT3GT12-1411.500 | 0 | KASHIMB HPP 15.000 | 21 | SAPELE ST1 15.800 | 0 |
| DELTA GT 15 11.500 | 96 | KAZAURE PV1 11.000 | 0 | SAPELE ST2 15.800 | 0 |
| DELTA GT16 11.500 | 96 | KAZAURE PV1011.000 | 0 | SAPELE ST3 15.800 | 0 |
| DELTA GT17 11.500 | 97 | KAZAURE PV2 11.000 | 0 | SAPELE ST4 15.800 | 0 |
| DELTA GT18 11.500 | 0 | KAZAURE PV3 11.000 | 0 | SAPELE ST5 15.800 | 0 |
| DELTA GT19 11.500 | 0 | KAZAURE PV4 11.000 | 0 | SAPELE ST6 15.800 | 0 |
| DELTA GT20 11.500 | 0 | KAZAURE PV5 11.000 | 0 | SHIROR 411G116.000 | 140 |
| DELTA1 GT1 11.500 | 0 | KAZAURE PV6 11.000 | 0 | SHIROR 411G216.000 | 140 |
| DELTA1 GT2 11.500 | 0 | KAZAURE PV7 11.000 | 0 | SHIROR 411G316.000 | 0 |
| DELTA2 GT3-511.500 | 45 | KAZAURE PV8 11.000 | 0 | SHIROR 411G416.000 | 0 |
| DELTA2 GT6-811.500 | 10 | KAZAURE PV9 11.000 | 0 | SINOSUN PV 15.000 | 0 |
| DKOWA G1 11.000 | 14 | KT WF 33 33.000 | 9 | SYNER GEN PV15.000 | 0 |
| DUSABLE PV 15.000 | 0 | KVKPOWER PV 15.000 | 0 | ZUNGE_G1 16.000 | 107 |
| EGBEMA_GTB1 15.000 | 102 | LAFARAGE 1 11.000 | 0 | ZUNGE_G2 16.000 | 107 |
| EGBEMA_GTB2 15.000 | 102 | MIDBAND PV 15.000 | 0 | ZUNGE_G3 16.000 | 0 |
| EGBEMA_GTB3 15.000 | 102 | NOVA SCOT PV132.00 | 0 | ZUNGE_G4 16.000 | 107 |
| EGBIN ST 1 16.000 | 171.4 | NOVA SOLA PV15.000 | 0 | | |

Source: JICA Study Team

The power flows are shown in Figure 7-4.6.




Source: JICA Study Team

**Figure 7-4.6 2020 Dry Season Peak Power Flows in 330 kV System**

## (2) Overloads of lines and transformers

The base case (N-0) overloaded 132 kV lines as well as the 330/132 kV and 132/33 kV transformers are listed in Table 7-4.7, Table 7-4.8 and Table 7-4.9.

It should be noted that introducing the 330kV substation at Ijora eliminates the overloads of the 132kV line Alagbon - Ijora and the need to have this line reinforced. It will become even more crucial in subsequent years, so it should be integrated into the system as soon as possible.

**Table 7-4.7 2020 Dry Season Peak - Overloaded Lines (base case)**

| Bus Number | Bus name | Bus Number | Bus name | CKT | Contingency label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 82024 | IBOM IPP 1 132.00 | 82031 | IKOT_ABASI 132.00 | 1 | BASE CASE | 125.7 | 182.1 | 144.8 |

Source: JICA Study Team

**Table 7-4.8 2020 Dry Season Peak - Overloaded 330/132 kV transformers (base case)**

| Bus Number | Bus Name | Voltage (kV) | Area | Bus Number | Bus Name | Wind Number | CKT | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 330/132 kV 3-W and A/T | | | | | | | | | | |
| 23003 | GANMO 3 | 330 | 2 | 3WNDTR | GANMO TR2A | 1 | 1 | 157.4 | 150 | 104.9 |
| 33002 | BKEBBI 3 | 330 | 3 | 3WNDTR | B_KEBBI T1 | 1 | 1 | 176.9 | 150 | 118 |
| 43002 | BENIN 3 | 330 | 4 | 3WNDTR | BENIN TR1 | 1 | 1 | 156 | 150 | 104 |
| 43002 | BENIN 3 | 330 | 4 | 3WNDTR | BENIN TR2 | 1 | 1 | 156 | 150 | 104 |
| 43002 | BENIN 3 | 330 | 4 | 3WNDTR | BENIN TR3 | 1 | 1 | 156 | 150 | 145.6 |
| 43011 | B.NORTH_3 | 330 | 4 | 3WNDTR | BENIN 9T1 | 2 | 1 | 88 | 67.5 | 131.6 |

Source: JICA Study Team

**Table 7-4.9 2020 Dry Season Peak - Overloaded 2-winding transformers (base case)**

| Bus Number | Bus Name | Voltage (kV) | Area | Bus Number | Bus Name | Voltage (kV) | cct | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 132/33 and 132/11 kV 2-W transformers | | | | | | | | | | |
| 32017 | SULEJA 1 | 132 | 3 | 36016 | SULEJA 11 | 11 | 1 | 18.6 | 7.5 | 247.6 |
| 42004 | BENIN 1 | 132 | 4 | 45029 | BENIN T22 33 | 33 | 1 | 85.9 | 60 | 143.1 |
| 52001 | KANO 1 | 132 | 5 | 55058 | KUMB T3 MOB | 33 | 3 | 41.9 | 30 | 139.6 |
| 42004 | BENIN 1 | 132 | 4 | 45031 | BENIN T24 33 | 33 | 1 | 82.9 | 60 | 138.1 |
| 42004 | BENIN 1 | 132 | 4 | 45030 | BENIN T23 33 | 33 | 1 | 80.9 | 60 | 134.8 |
| 52016 | FUNTUA 1 | 132 | 5 | 56000 | FUNTUA 11 | 11 | 1 | 9.6 | 7.5 | 127.6 |
| 42005 | B_N0RTH 1 | 132 | 4 | 45015 | B_NORTH_33 | 33 | 1 | 73.9 | 60 | 123.2 |
| 22015 | OMUARAN 1 | 132 | 2 | 25016 | OMUARAN 33 | 33 | 1 | 33.4 | 30 | 111.4 |
| 52016 | FUNTUA 1 | 132 | 5 | 55003 | FUNTUA 33 | 33 | 1 | 33 | 30 | 109.9 |
| 52016 | FUNTUA 1 | 132 | 5 | 56005 | FUNTUA T2 | 11 | 2 | 7.9 | 7.5 | 105.9 |
| 22013 | OFFA 1 | 132 | 2 | 25015 | OFFA 33 | 33 | 1 | 31.8 | 30 | 105.8 |
| 12029 | OJO 1 | 132 | 1 | 15030 | OJO 33 | 33 | 1 | 30.4 | 30 | 101.4 |

Source: JICA Study Team

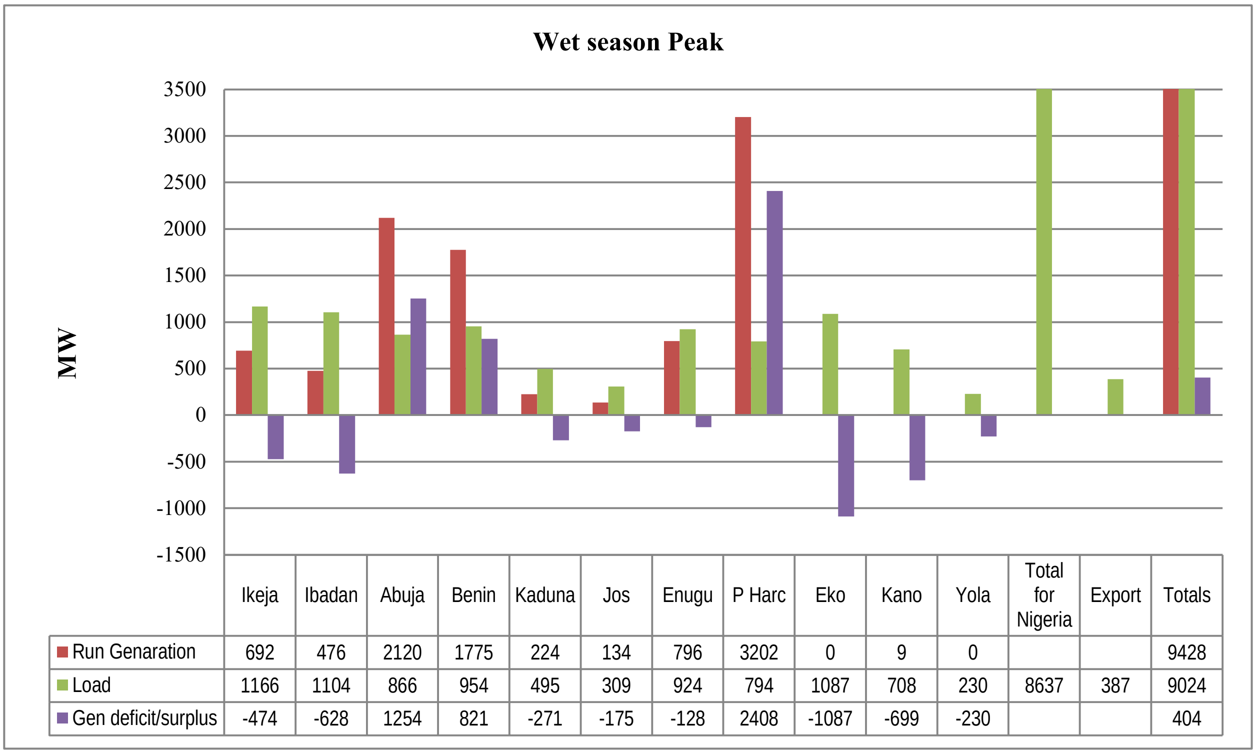
### 7-4-2-3 Wet Season Peak Case

#### (1) Prerequisites for analysis

(a) Generation from PVs = 0 MW and

(b) Normal generation from HPP plants of 2,100 MW,

The running generation and load for each DisCo are shown in Figure 7-4.7.




Source: JICA Study Team

**Figure 7-4.7 Wet Season Peak Generation and Load Per DisCo**

### (2) Overloads of lines and transformers

The base case (N-0) overloaded 132 kV lines are listed in Table 7-4.10.

**Table 7-4.10 2020 Wet Season Peak - Overloaded Lines (base case)**

| Bus Number | Bus name | Bus Number | Bus name | CKT | Contingency label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 82024 | IBOM IPP 1 132.00 | 82031 | IKOT_ABASI 132.00 | 1 | BASE CASE | 125.7 | 182.6 | 145.2 |

Source: JICA Study Team

No new overloaded lines are reported, in addition to those overloaded in the Dry Season Peak case. The same applies for the overloaded transformer.

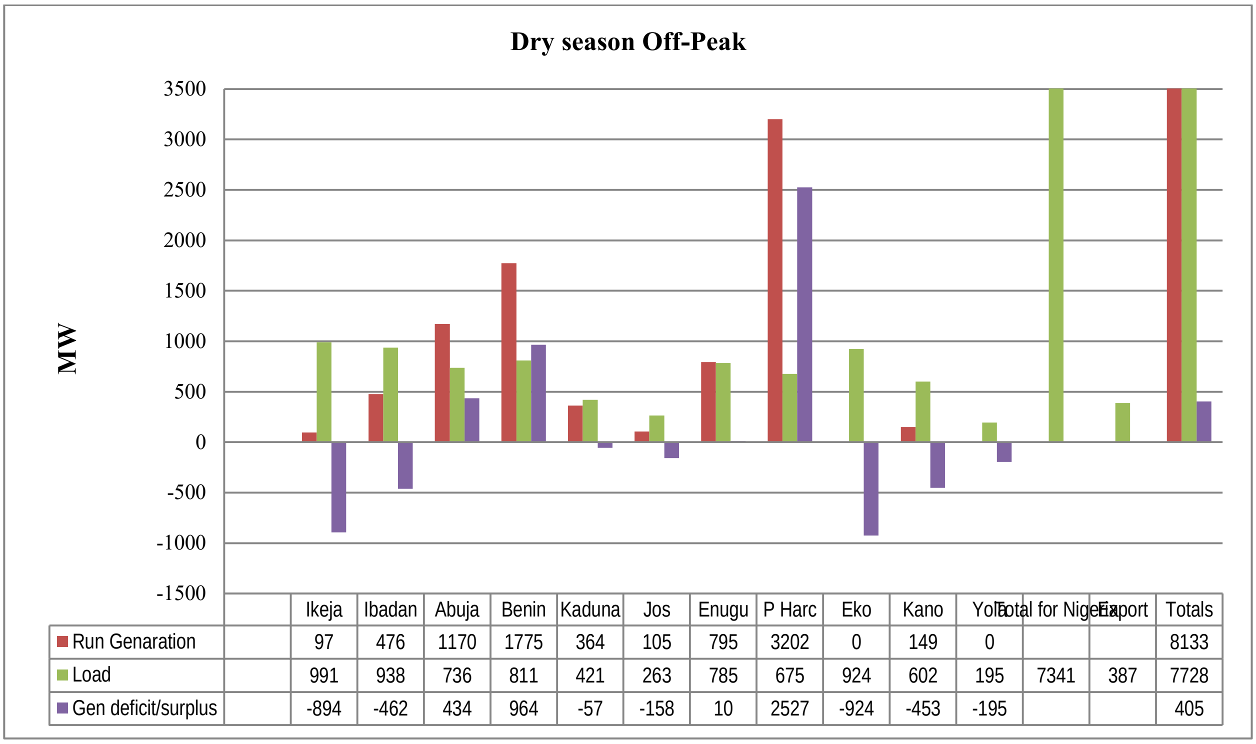
## 7-4-2-4 Dry Season Off- Peak Case

### (1) Prerequisites for analysis

(a) Generation from PVs = 400 MW and

(b) Reduced generation from HPP plants of 1,100 MW,

The running generation and load for each DisCo are shown in Figure 7-4.8.




Source: JICA Study Team

**Figure 7-4.8 Dry Season Off-Peak Generation and Load per DisCo**

### (2) Overloads of lines and transformers

The base case (N-0) overloaded 132 kV lines are listed in Table 7-4.11.

**Table 7-4.11 2020 Dry Season Off-Peak - Overloaded Lines (base case)**

| Bus Number | Bus name | Bus Number | Bus name | CKT | Contingency label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 82024 | IBOM IPP 1 132.00 | 82031 | IKOT_ABASI 132.00 | 1 | BASE CASE | 125.7 | 189.6 | 150.9 |

Source: JICA Study Team

The overloaded line(s) are the same as in the Dry Season Peak case.

The overloaded transformers are fewer than the Dry Season Peak case, as shown in the following tables, Table 7-4.12 and Table 7-4.13.

**Table 7-4.12 2020 Dry Season Off-Peak - Overloaded 330/132 kV transformers (base case)**

| Bus Number | Bus Name | Voltage (kV) | Area | Bus Number | Bus Name | Wind | CKT | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 43011 | B.NORTH_3 | 330 | 4 | 3WNDTR | BENIN 9T1 | 2 | 1 | 74.3 | 67.5 | 110 |

Source: JICA Study Team

**Table 7-4.13 2020 Dry Season Off-Peak - Overloaded 2-winding transformers (base case)**

| Bus Number | Bus Name | Voltage (kV) | Area | Bus Number | Bus Name | Voltage (kV) | cct | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 132/33 and 132/11 kV 2-W transformers | | | | | | | | | | |
| 32017 | SULEJA 1 | 132 | 3 | 36016 | SULEJA 11 | 11 | 1 | 15.5 | 7.5 | 206 |
| 42004 | BENIN 1 | 132 | 4 | 45029 | BENIN T22 33 | 33 | 1 | 72.4 | 60 | 120.6 |
| 52001 | KANO 1 | 132 | 5 | 55058 | KUMB T3 | 33 | 3 | 34.9 | 30 | 116.3 |

| Bus Number | Bus Name | Voltage (kV) | Area | Bus Number | Bus Name | Voltage (kV) | cct | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MOB | | | | | |
| 42004 | BENIN 1 | 132 | 4 | 45031 | BENIN T24 33 | 33 | 1 | 69.9 | 60 | 116.4 |
| 42004 | BENIN 1 | 132 | 4 | 45030 | BENIN T23 33 | 33 | 1 | 68.2 | 60 | 113.7 |
| 52016 | FUNTUA 1 | 132 | 5 | 56000 | FUNTUA 11 | 11 | 1 | 9.6 | 7.5 | 127.6 |
| 42005 | B_NORTH 1 | 132 | 4 | 45015 | B_NORTH_33 | 33 | 1 | 62.4 | 60 | 104 |

Source: JICA Study Team

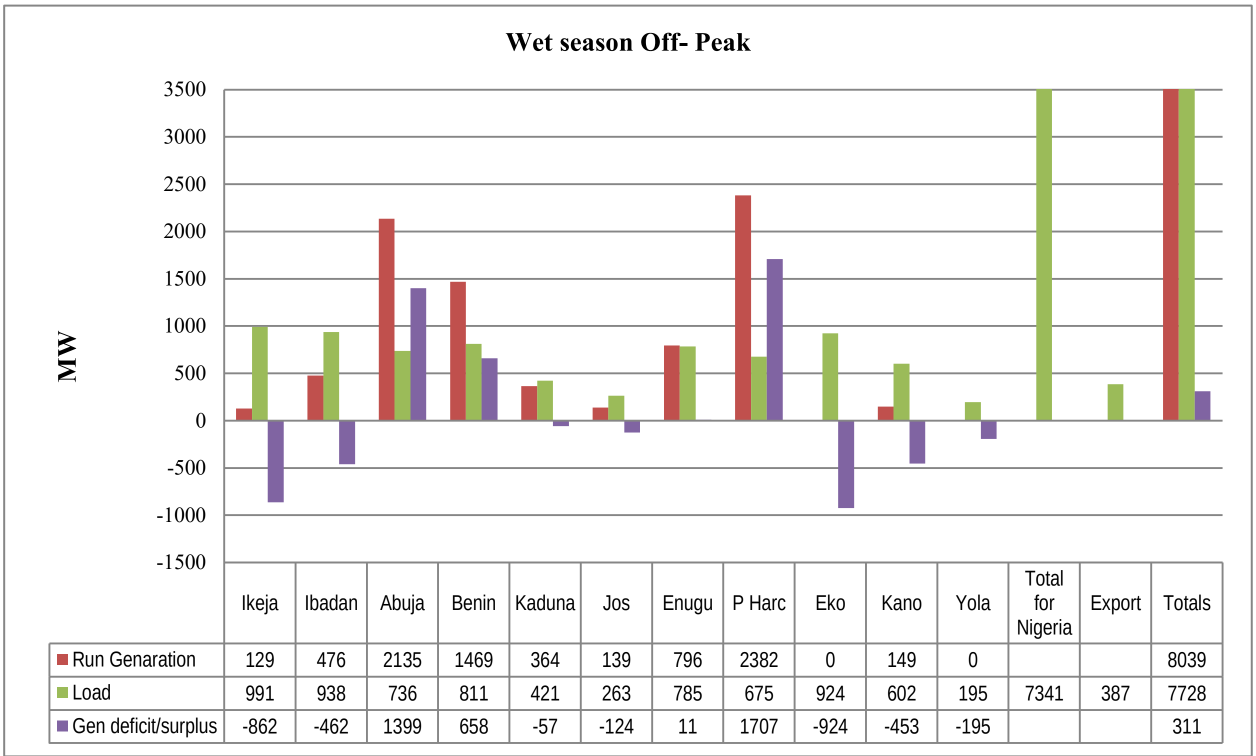
### 7-4-2-5 Wet Season Off-Peak Case

#### (1) Prerequisites for analysis

(a) Generation from PVs = 400 MW and

(b) Normal generation from HPP plants of 2,100 MW,

The running generation and load for each DisCo are shown in Figure 7-4.9.




Source: JICA Study Team

**Figure 7-4.9 Wet Season Off-Peak Generation and Load Per DisCo**

#### (2) Overloads of lines and transformers

The base case (N-0) overloaded 132 kV lines are listed in Table 7-4.14.

**Table 7-4.14 2020 Wet Season Off-peak - Overloaded Lines (base case)**

| Bus Number | Bus name | Bus Number | Bus name | CKT | Contingency label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 82024 | IBOM IPP 1 132.00 | 82031 | IKOT_ABASI 132.00 | 1 | BASE CASE | 125.7 | 189.4 | 150.7 |

Source: JICA Study Team

No new overloaded lines are reported, in addition to those overloaded in the Dry Season Peak case.

The same applies for the overloaded transformer.

### 7-4-3 2020 Contingency Analysis Load-flow Results

An N-1 contingency analysis using ACCC in PSS/E has been carried out for the 330 and 132 kV transmission lines, using their RATE B as short-term overload ratings.

The N-1 criterion is not applicable for transformer circuits. The results are summarized in tables fromTable 7-4.15 to Table 7-4.19.

**Table 7-4.15 Non-converged cases**

| Contingency | LINE | Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus name | CKT |
|---|---|---|---|---|---|---|---|
| SINGLE 53001-53005(2) | OPEN LINE | 53001 | KANO 3 | 330 | 53005 | KANO_NEW330 | 2 |
| SINGLE 63000-63002(1) | OPEN LINE | 63000 | GOMBE 3 | 330 | 63002 | YOLA 3 | 1 |
| SINGLE 63000-63007(1) | OPEN LINE | 63000 | GOMBE 3 | 330 | 63007 | DAMATURU 3 | 1 |
| SINGLE 32003-32041(3) | OPEN LINE | 32003 | BKEBBI 1 | 132 | 32041 | KVKPOWER PV | 3 |
| SINGLE 32016-32041(3) | OPEN LINE | 32016 | SOKOTO 1 | 132 | 32041 | KVKPOWER PV | 3 |
| SINGLE 52015-52016(1) | OPEN LINE | 52015 | ZARIA 1 | 132 | 52016 | FUNTUA 1 | 1 |

Source: JICA Study Team

In the above contingency cases of the loss of 330 kV lines from Gombe to Yola and Damaturu, the load-flow case did not converge as expected, due to the absence of a second parallel circuit and insufficient support from alternative routes.

Converting to a Double-Circuit will resolve these issues.

The overloads reported for the 132 kV circuits will have to be resolved by either reinforcing these lines or providing new alternative routes for the power flow.

In all N-1 contingencies, a number of 132 kV voltages are lower than the minimum permissible level of 0.8p.u. However, this is due to overloads of the associated 132 kV lines and transformers and the remedial actions for the U/V are linked to the solutions initially required for overloads of these circuits.

#### 7-4-3-1 2020 Dry Season Peak Case-ACCC

The base case and N-1 contingency analysis results are shown in Table 7-4.16.

It can be seen that the loadings of all the 330 kV lines are within their thermal rating limits with the exception of the Double-Circuit 330 kV lines from Benin to Omotosho and from Shiroro to Kaduna.

Table 7-4.16 shows the overloaded 132 kV lines.

**Table 7-4.16 2020 Dry Season Peak - Overloaded Lines (base case and under N-1)**

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 330 kV System | | | | | | | | |
| None | | | | | | | | |
| 132 kV System | | | | | | | | |
| 82024 | IBOM IPP 1 | 82031 | IKOT_ABASI | 1 | BASE CASE | 125.7 | 182.1 | 144.8 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82019-82036(1) | 138.3 | 219 | 158.3 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82019-82036(2) | 138.3 | 219 | 158.3 |
| 42000 | AJAOKUTA 1 | 42009 | OKENE 1 | 1 | SINGLE 42004-42008(1) | 138.3 | 211.5 | 152.9 |
| 42004 | BENIN 1 | 42008 | IRRUA 1 | 1 | SINGLE 42000-42009(1) | 138.3 | 203.5 | 147.1 |
| 22002 | OSOGBO 4T2 | 22008 | IWO 1 | 1 | SINGLE 22000-22006(1) | 138.3 | 201.9 | 146 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 2 | SINGLE 82017-82022(1) | 138.3 | 191.2 | 138.2 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 1 | SINGLE 82017-82022(2) | 138.3 | 191.2 | 138.2 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 2 | SINGLE 12003-12019(1) | 138.3 | 176.8 | 127.9 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 1 | SINGLE 12003-12019(2) | 138.3 | 176.8 | 127.9 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 2 | SINGLE 52033-52035(1) | 138.3 | 172.5 | 124.8 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 1 | SINGLE 52033-52035(2) | 138.3 | 172.5 | 124.8 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | SINGLE 22002-22008(1) | 138.3 | 172 | 124.4 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 2 | SINGLE 82017-82018(1) | 138.3 | 171.4 | 123.9 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 1 | SINGLE 82017-82018(2) | 138.3 | 171.4 | 123.9 |
| 62009 | BIU 1 | 62026 | DADINKOWA 1 | 1 | SINGLE 63005-63007(1) | 76.7 | 94.7 | 123.5 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82024-82031(1) | 150.4 | 184.2 | 122.4 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82024-82031(1) | 150.4 | 184.2 | 122.4 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82007-82036(1) | 138.3 | 166 | 120 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82007-82036(2) | 138.3 | 166 | 120 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 2 | SINGLE 82000-82002(1) | 138.3 | 160.2 | 115.8 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 1 | SINGLE 82000-82002(2) | 138.3 | 160.2 | 115.8 |
| 52015 | ZARIA 1 | 52016 | FUNTUA 1 | 1 | SINGLE 32016-52004(1) | 99.3 | 110.4 | 111.2 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82005-82024(1) | 150.4 | 166.5 | 110.7 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82005-82024(2) | 150.4 | 166.5 | 110.7 |

Source: JICA Study Team

### 7-4-3-2 2020 Wet Season Peak case-ACCC

The base case and N-1 contingency analysis results are shown in Table 7-4.17.

**Table 7-4.17 2020 Wet Season Peak - Overloaded Lines (base case and under N-1)**

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 330 kV System | | | | | | | | |
| None | | | | | | | | |
| 132 kV System | | | | | | | | |
| 82024 | IBOM IPP 1 | 82031 | IKOT_ABASI | 1 | BASE CASE | 125.7 | 182.6 | 145.2 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82019-82036(2) | 138.3 | 220 | 159.1 |
| 42000 | AJAOKUTA 1 | 42009 | OKENE 1 | 1 | SINGLE 42004-42008(1) | 138.3 | 208.8 | 151 |
| 42004 | BENIN 1 | 42008 | IRRUA 1 | 1 | SINGLE 42000-42009(1) | 138.3 | 201.9 | 146 |
| 22002 | OSOGBO 4T2 | 22008 | IWO 1 | 1 | SINGLE 22000-22006(1) | 138.3 | 200.8 | 145.2 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 2 | SINGLE 52033-52035(1) | 138.3 | 200.2 | 144.8 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 1 | SINGLE 52033-52035(2) | 138.3 | 200.2 | 144.8 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 2 | SINGLE 82017-82022(1) | 138.3 | 191.2 | 138.3 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 1 | SINGLE 82017-82022(2) | 138.3 | 191.2 | 138.3 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 2 | SINGLE 12003-12019(1) | 138.3 | 180 | 130.1 |

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 1 | SINGLE 12003-12019(2) | 138.3 | 180 | 130.1 |
| 62009 | BIU 1 | 62026 | DADINKOWA 1 | 1 | SINGLE 63005-63007(1) | 76.7 | 98.1 | 128 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | SINGLE 22002-22008(1) | 138.3 | 172.9 | 125 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 2 | SINGLE 82017-82018(1) | 138.3 | 171.5 | 124 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 1 | SINGLE 82017-82018(2) | 138.3 | 171.5 | 124 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82024-82031(1) | 150.4 | 184.5 | 122.7 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82024-82031(1) | 150.4 | 184.5 | 122.7 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82007-82036(1) | 138.3 | 167.1 | 120.8 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82007-82036(2) | 138.3 | 167.1 | 120.8 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 2 | SINGLE 82000-82002(1) | 138.3 | 160.2 | 115.8 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 1 | SINGLE 82000-82002(2) | 138.3 | 160.2 | 115.8 |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 | 2 | SINGLE 23002-43002(1) | 855.1 | 948.8 | 111 |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 | 1 | SINGLE 23002-43002(2) | 855.1 | 948.8 | 111 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82005-82024(1) | 150.4 | 166.4 | 110.6 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82005-82024(2) | 150.4 | 166.4 | 110.6 |
| 52015 | ZARIA 1 | 52016 | FUNTUA 1 | 1 | SINGLE 32016-52004(1) | 99.3 | 106.3 | 107 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 2 | SINGLE 82013-82040(1) | 138.3 | 139.6 | 100.9 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 1 | SINGLE 82013-82040(2) | 138.3 | 139.6 | 100.9 |

Source: JICA Study Team

### 7-4-3-3 2020 Dry Season Off-Peak Case-ACCC

The base case and N-1 contingency analysis results are shown in Table 7-4.18. The 330 kV lines overloaded under N-1 are shown in red fonts.

**Table 7-4.18 2020 Dry Season Off-Peak - Overloaded Lines (base case and under N-1)**

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 330 kV | | | | | | | | |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 | 2 | SINGLE 23002-43002(1) | 855.1 | 1,081.6 | 126.5 |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 | 1 | SINGLE 23002-43002(2) | 855.1 | 1,081.6 | 126.5 |
| 132 kV | | | | | | | | |
| 82024 | IBOM IPP 1 | 82031 | IKOT_ABASI | 1 | BASE CASE | 125.7 | 189.6 | 150.9 |
| 62000 | GOMBE 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 151.3 | 197.2 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82019-82036(1) | 138.3 | 213.6 | 154.5 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82019-82036(2) | 138.3 | 213.6 | 154.5 |
| 62003 | YOLA 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 114.4 | 149.2 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 2 | SINGLE 52033-52035(1) | 138.3 | 202.6 | 146.5 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 1 | SINGLE 52033-52035(2) | 138.3 | 202.6 | 146.5 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 2 | SINGLE 82017-82022(1) | 138.3 | 191.5 | 138.5 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 1 | SINGLE 82017-82022(2) | 138.3 | 191.5 | 138.5 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 2 | SINGLE 82000-82002(1) | 138.3 | 181.4 | 131.1 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 1 | SINGLE 82000-82002(2) | 138.3 | 181.4 | 131.1 |
| 22002 | OSOGBO 4T2 | 22008 | IWO 1 | 1 | SINGLE 22000-22006(1) | 138.3 | 175.5 | 126.9 |
| 62009 | BIU 1 | 62026 | DADINKOWA 1 | 1 | SINGLE 63005-63007(1) | 76.7 | 97.0 | 126.5 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 2 | SINGLE 82017-82018(1) | 138.3 | 174.5 | 126.2 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 1 | SINGLE 82017-82018(2) | 138.3 | 174.5 | 126.2 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82024-82031(1) | 150.4 | 185.3 | 123.2 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82024-82031(1) | 150.4 | 185.3 | 123.2 |
| 42000 | AJAOKUTA 1 | 42009 | OKENE 1 | 1 | SINGLE 42004-42008(1) | 138.3 | 169.9 | 122.9 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82007-82036(1) | 138.3 | 169.5 | 122.5 |

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82007-82036(2) | 138.3 | 169.5 | 122.5 |
| 42004 | BENIN 1 | 42008 | IRRUA 1 | 1 | SINGLE 42000-42009(1) | 138.3 | 169.1 | 122.3 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 2 | SINGLE 82013-82040(1) | 138.3 | 157.5 | 113.9 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 1 | SINGLE 82013-82040(2) | 138.3 | 157.5 | 113.9 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 2 | SINGLE 12003-12019(1) | 138.3 | 153.1 | 110.7 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 1 | SINGLE 12003-12019(2) | 138.3 | 153.1 | 110.7 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82005-82024(1) | 150.4 | 155 | 103.1 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82005-82024(2) | 150.4 | 155 | 103.1 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | SINGLE 22002-22008(1) | 138.3 | 142.4 | 103 |

Source: JICA Study Team

#### 7-4-3-4 2020 Wet Season Off-Peak case-ACCC

The base case and N-1 contingency analysis results are shown in Table 7-4.19. The 330 kV lines overloaded under N-1 are shown in red fonts.

**Table 7-4.19 2020 Wet Season Off- peak - Overloaded Lines (base case and under N-1)**

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 330 kV System | | | | | | | | |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 | 2 | SINGLE 23002-43002(1) | 855.1 | 944.4 | 110.4 |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 | 1 | SINGLE 23002-43002(2) | 855.1 | 944.4 | 110.4 |
| 132 kV System | | | | | | | | |
| 82024 | IBOM IPP 1 | 82031 | IKOT_ABASI | 1 | BASE CASE | 125.7 | 189.4 | 150.7 |
| 62000 | GOMBE 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 153.2 | 199.7 |
| 62003 | YOLA 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 116.3 | 151.6 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 2 | SINGLE 52033-52035(1) | 138.3 | 202.5 | 146.4 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 1 | SINGLE 52033-52035(2) | 138.3 | 202.5 | 146.4 |
| 62009 | BIU 1 | 62026 | DADINKOWA 1 | 1 | SINGLE 63005-63007(1) | 76.7 | 98.2 | 128.1 |
| 22002 | OSOGBO 4T2 | 22008 | IWO 1 | 1 | SINGLE 22000-22006(1) | 138.3 | 175.5 | 126.9 |
| 42004 | BENIN 1 | 42008 | IRRUA 1 | 1 | SINGLE 42000-42009(1) | 138.3 | 171.2 | 123.8 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82024-82031(1) | 150.4 | 184.6 | 122.7 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82024-82031(1) | 150.4 | 184.6 | 122.7 |
| 42000 | AJAOKUTA 1 | 42009 | OKENE 1 | 1 | SINGLE 42004-42008(1) | 138.3 | 169.4 | 122.5 |
| 82007 | PHCT MAIN1 | 82014 | RIVERS_IPP | 2 | SINGLE 82007-82014(1) | 138.3 | 155.2 | 112.2 |
| 82007 | PHCT MAIN1 | 82014 | RIVERS_IPP | 1 | SINGLE 82007-82014(2) | 138.3 | 155.2 | 112.2 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 2 | SINGLE 12003-12019(1) | 138.3 | 153.8 | 111.2 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 1 | SINGLE 12003-12019(2) | 138.3 | 153.8 | 111.2 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82005-82024(1) | 150.4 | 156.7 | 104.2 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82005-82024(2) | 150.4 | 156.7 | 104.2 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | SINGLE 22002-22008(1) | 138.3 | 142.4 | 103.0 |

Source: JICA Study Team

### 7-4-4 Summary of Results of Load-flow Analysis for 2020

The results of the static security analysis for 2020 are summarized as follows:

#### 7-4-4-1 Overloaded 330 and 132 kV Transmission Lines

There are no overloads in 330 kV lines under normal operation. However, when tripping the 330 kV lines from Gombe to Yola and Damaturu, the load-flow case did not converge, as expected, due to the absence of a second parallel circuit and insufficient support from alternative routes. Converting to a Double-Circuit will resolve these issues.

Under N-1, if any of the following 132 kV lines are tripped, the case will also not converge:

From BKebbi to KVK Power PV
From Zaria to Funtua

These 132 kV N-1 cases will have to be resolved by providing new alternative routes for the power flow.

Priority is to resolve the overloads occurring under normal (N-0) operation of the 132 kV lines shown in Table 7-4.20.

**Table 7-4.20 Reinforcements of 132 kV lines overloaded under N-0**

| Bus Name | Bus Name | Proposed Solution |
|---|---|---|
| Ibom IPP | Ikot Abasi | convert to DC |

Source: JICA Study Team

As a next priority, the overloaded 330 and 132 kV lines under N-1 contingencies must be reinforced. This entails either reconductoring to higher rating conductors or, in the case of SC, converting to DC by installing a second parallel circuit.

The lines in Table 7-4.21 are ranked according to their percentage overload. The table lists the worst scenarios in terms of overloads, out of the four study cases (DP, DoP, WP, WoP). The shaded lines are DC lines for which reconductoring is recommended. The 330 kV lines overloaded under N-1 are shown in red fonts.

**Table 7-4.21 Reinforcements of 330 and 132 kV lines overloaded under N-1**

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 330 kV | | | | | | | | |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 cct1 | | SINGLE 23002-43002(1) | 855.1 | 1,081.6 | 126.5 |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 cct2 | | SINGLE 23002-43002(2) | 855.1 | 1,081.6 | 126.5 |
| 132 kV | | | | | | | | |
| 82024 | IBOM IPP 1 | 82031 | IKOT_ABASI | 1 | BASE CASE | 125.7 | 189.6 | 150.9 |
| 62000 | GOMBE 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 151.3 | 197.2 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82019-82036(2) | 138.3 | 220 | 159.1 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82019-82036(1) | 138.3 | 213.6 | 154.5 |
| 42000 | AJAOKUTA 1 | 42009 | OKENE 1 | 1 | SINGLE 42004-42008(1) | 138.3 | 211.5 | 152.9 |
| 62003 | YOLA 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 116.3 | 151.6 |
| 42004 | BENIN 1 | 42008 | IRRUA 1 | 1 | SINGLE 42000-42009(1) | 138.3 | 203.5 | 147.1 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 2 | SINGLE 52033-52035(1) | 138.3 | 202.6 | 146.5 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 1 | SINGLE 52033-52035(2) | 138.3 | 202.6 | 146.5 |
| 22002 | OSOGBO 4T2 | 22008 | IWO 1 | 1 | SINGLE 22000-22006(1) | 138.3 | 201.9 | 146 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 2 | SINGLE 82017-82022(1) | 138.3 | 191.5 | 138.5 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 1 | SINGLE 82017-82022(2) | 138.3 | 191.5 | 138.5 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 2 | SINGLE 82000-82002(1) | 138.3 | 181.4 | 131.1 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 1 | SINGLE 82000-82002(2) | 138.3 | 181.4 | 131.1 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 2 | SINGLE 12003-12019(1) | 138.3 | 180 | 130.1 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 1 | SINGLE 12003-12019(2) | 138.3 | 180 | 130.1 |

| Bus Number | Bus Name | Bus Number | Bus Name | cct | Contingency Label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 62009 | BIU 1 | 62026 | DADINKOWA 1 | 1 | SINGLE 63005-63007(1) | 76.7 | 98.2 | 128.1 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 2 | SINGLE 82017-82018(1) | 138.3 | 174.5 | 126.2 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 1 | SINGLE 82017-82018(2) | 138.3 | 174.5 | 126.2 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | SINGLE 22002-22008(1) | 138.3 | 172.9 | 125 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82024-82031(1) | 150.4 | 184.5 | 122.7 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82024-82031(1) | 150.4 | 184.5 | 122.7 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82007-82036(1) | 138.3 | 169.5 | 122.5 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82007-82036(2) | 138.3 | 169.5 | 122.5 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 2 | SINGLE 82013-82040(1) | 138.3 | 157.5 | 113.9 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 1 | SINGLE 82013-82040(2) | 138.3 | 157.5 | 113.9 |
| 82007 | PHCT MAIN1 | 82014 | RIVERS_IPP | 2 | SINGLE 82007-82014(1) | 138.3 | 155.2 | 112.2 |
| 82007 | PHCT MAIN1 | 82014 | RIVERS_IPP | 1 | SINGLE 82007-82014(2) | 138.3 | 155.2 | 112.2 |
| 52015 | ZARIA 1 | 52016 | FUNTUA 1 | 1 | SINGLE 32016-52004(1) | 99.3 | 110.4 | 111.2 |

Source: JICA Study Team

Note: It should be noted that with regard to the overloaded 330 kV lines in 2020 (Benin-Omotosho), remedial actions are already planned and these lines will not be overloaded in 2025, as shown in Section 7.5.

### 7-4-4-2 Overloaded Transformers

#### (1) Overloads above 100% of transformer ratings

The 330/132 kV 3-W and A/T transformers overloaded above their 100% rating MVA under normal (base case) operation, listed in Table 7-4.22, must be upgraded:

**Table 7-4.22 Upgrading requirements of 330/132 kV 3-winding transformers overloaded under N-0**

| Bus Number | Bus Name | Voltage (kV) | Bus Name | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|
| 330/132 kV 3-W transformers | | | | | | |
| 43002 | BENIN 3 | 330 | BENIN TR3 | 156 | 150 | 145.6 |
| 43011 | B.NORTH_3 | 330 | BENIN 9T1 | 88 | 67.5 | 131.6 |
| 33002 | BKEBBI 3 | 330 | B_KEBBI T1 | 176.9 | 150 | 118 |
| 23003 | GANMO 3 | 330 | GANMO TR2A | 157.4 | 150 | 104.9 |
| 43002 | BENIN 3 | 330 | BENIN TR1 | 156 | 150 | 104 |
| 43002 | BENIN 3 | 330 | BENIN TR2 | 156 | 150 | 104 |

Source: JICA Study Team

The 132/33 kV and 132/11 kV transformers overloaded above their 100% rating MVA under normal (base case) operation, listed in Table 7-4.23, must be upgraded:

**Table 7-4.23 Upgrading requirements of 132/33 kV and 132/11 kV 2W transformers overloaded under N-0**

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 132/33 and 132/11 kV 2-W transformers | | | | | | | | |
| 32017 | SULEJA 1 | 132 | 36016 | SULEJA 11 | 11 | 18.6 | 7.5 | 247.6 |
| 42004 | BENIN 1 | 132 | 45029 | BENIN T22 33 | 33 | 85.9 | 60 | 143.1 |
| 52001 | KANO 1 | 132 | 55058 | KUMB T3 MOB | 33 | 41.9 | 30 | 139.6 |
| 42004 | BENIN 1 | 132 | 45031 | BENIN T24 33 | 33 | 82.9 | 60 | 138.1 |
| 42004 | BENIN 1 | 132 | 45030 | BENIN T23 33 | 33 | 80.9 | 60 | 134.8 |
| 52016 | FUNTUA 1 | 132 | 56000 | FUNTUA 11 | 11 | 9.6 | 7.5 | 127.6 |
| 42005 | B_N0RTH 1 | 132 | 45015 | B_NORTH_33 | 33 | 73.9 | 60 | 123.2 |

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | Loading (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| 22015 | OMUARAN 1 | 132 | 25016 | OMUARAN 33 | 33 | 33.4 | 30 | 111.4 |
| 52016 | FUNTUA 1 | 132 | 55003 | FUNTUA 33 | 33 | 33 | 30 | 109.9 |
| 52016 | FUNTUA 1 | 132 | 56005 | FUNTUA T2 | 11 | 7.9 | 7.5 | 105.9 |
| 22013 | OFFA 1 | 132 | 25015 | OFFA 33 | 33 | 31.8 | 30 | 105.8 |
| 12029 | OJO 1 | 132 | 15030 | OJO 33 | 33 | 30.4 | 30 | 101.4 |

Source: JICA Study Team

### (2) Overloads above 85% of transformer ratings

Table 7-4.24 shows 330/132 kV, 132/33 kV and 132/11 kV transformers which are overloaded above their 85% rating MVA under normal (base case) operation and shall be considered for upgrading.

**Table 7-4.24 Upgrading requirements of 330/132 kV, 132/33 kV and 132/11 kV transformers overloaded over 85% under N-0**

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | cct | Load (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|
| 330/132 kV Transformers 3-W | | | | | | | | | |
| 52001 | KANO 1 | 132 | 3WNDTR | KANO T3A | WND 2 | 1 | 112.3 | 120 | 93.6 |
| 42005 | B_N0RTH 1 | 132 | 3WNDTR | BENIN 9T1 | WND 1 | 1 | 82.8 | 90 | 92 |
| 132/33 kV and 132/11 kV Transformers | | | | | | | | | |
| 82005 | EKET 1 | 132 | 85002 | EKET T1B | 33 | 1 | 43.7 | 45 | 97.2 |
| 12055 | ODOGUNYAN 1 | 132 | 15063 | ODOGUNYA 33 | 33 | 1 | 57.9 | 60 | 96.5 |
| 12055 | ODOGUNYAN 1 | 132 | 15063 | ODOGUNYA 33 | 33 | 2 | 57.9 | 60 | 96.5 |
| 22022 | GANM0 T1 BB | 132 | 25032 | GANMO T1 | 33 | 1 | 57.1 | 60 | 95.2 |
| 12023 | EJIGBO 1 | 132 | 15128 | EJIGBO 33 | 33 | 1 | 28.4 | 30 | 94.5 |
| 12023 | EJIGBO 1 | 132 | 15128 | EJIGBO 33 | 33 | 2 | 28.4 | 30 | 94.5 |
| 12029 | OJO 1 | 132 | 15047 | OJO T3_T4 | 33 | 5 | 55.8 | 60 | 92.9 |
| 12019 | ALIMOSHO 1 | 132 | 15072 | ALIMOSHO T1 | 33 | 3 | 27.5 | 30 | 91.8 |
| 42002 | UGHELLI 1 | 132 | 45001 | UGHELLI 33 | 33 | 1 | 53.6 | 60 | 89.3 |
| 12037 | PARAS_1 | 132 | 15116 | AFR FOUNDRY | 33 | 1 | 35.6 | 40 | 89 |
| 22027 | SHAGAMU 1 | 132 | 25035 | SHAGAMU 33 | 33 | 1 | 26.5 | 30 | 88.3 |
| 82000 | AFAM 1-2-3 | 132 | 86000 | AFAM 11 | 11 | 1 | 55.1 | 64 | 86.1 |
| 22008 | IWO 1 | 132 | 25002 | IWO 33 | 33 | 1 | 12.9 | 15 | 85.9 |
| 22008 | IWO 1 | 132 | 25002 | IWO 33 | 33 | 2 | 34.3 | 40 | 85.9 |
| 82005 | EKET 1 | 132 | 85002 | EKET T1B | 33 | 1 | 43.7 | 45 | 97.2 |

Source: JICA Study Team

### 7-4-4-3 Undervoltages Under N-1 Conditions

In all N-1 contingencies, a number of 132 kV voltages are lower than the minimum permissible level of 0.8p.u. However, this is due to overloads of the associated 132 kV lines and transformers and the remedial actions for the undervoltages (U/V) is linked with the solutions required first for overloads of these circuits, as well as with the implementation of reactive power compensation equipment.

The reactive power requirements, i.e. the need to have existing reactors and capacitors in operation and/or install new ones by 2020, including the need for new SVCs, are summarized in the following sections:

### (1) SVC requirements

No SVC at Gombe is necessary by 2020.

### (2) Reactors

The status of reactors required in the Dry Season Peak case is shown in Table 7-4.25. It can be seen that only reactors at Gombe, Yola and Maiduguri are required. The new equipment required is shown in bold:

**Table 7-4.25 Reactor requirements for 2020 Dry Season Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | B-Shunt (MVar) |
|---|---|---|---|---|---|
| 63005 | MAIDUGURI 3 330.00 | 330 | 2 | 1 | -75.00 |
| 63002 | YOLA 3 330.00 | 330 | 1 | 1 | -75.00 |
| 63002 | YOLA 3 330.00 | 330 | 2 | 1 | -75.00 |
| 63000 | GOMBE 3 330.00 | 330 | 1 | 1 | -50.00 |
| 63000 | GOMBE 3 330.00 | 330 | 2 | 1 | -50.00 |
| 65001 | YOLA T1 33 33.000 | 33 | 1 | 1 | -30.00 |
| 65014 | GOMBE T4A 33.000 | 33 | 1 | 1 | -30.00 |

Source: JICA Study Team

The status of reactors required in Dry Season Off-Peak and in Wet Season Off-Peak cases is shown in Table 7-4.26. The new equipment required is shown in bold:

**Table 7-4.26 Reactor requirements for 2020 dry and wet season off-peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | B-Shunt (MVar) |
|---|---|---|---|---|---|
| 53001 | KANO 3 | 330 | 1 | 1 | -75 |
| 63001 | JOS 3 | 330 | 1 | 1 | -75 |
| 63002 | YOLA 3 | 330 | 1 | 1 | -75 |
| 63002 | YOLA 3 | 330 | 2 | 1 | -75 |
| 63005 | MAIDUGURI 3 | 330 | 2 | 1 | -75 |
| 63000 | GOMBE 3 | 330 | 1 | 1 | -50 |
| 63000 | GOMBE 3 | 330 | 2 | 1 | -50 |
| 65001 | YOLA T1 33 | 33 | 1 | 1 | -30 |
| 65014 | GOMBE T4A | 33 | 1 | 1 | -30 |

Source: JICA Study Team

### (3) Capacitors

The status of capacitors required in the Dry Season Peak case is shown in Table 7-4.27. The new equipment required is shown in bold:

**Table 7-4.27 Capacitor requirements for 2020 Dry Season Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 62021 | MAIDUGURI 1 | 132 | 1 | 1 | 10.8 |
| 52022 | HADEJIA 1 | 132 | 1 | 1 | 20 |
| 22017 | ONDO2 1 | 132 | 1 | 1 | 24 |
| 42008 | IRRUA 1 | 132 | 1 | 1 | 24 |
| 52011 | GUSAU 1 | 132 | 1 | 1 | 50 |
| 12004 | AKANGBA BBII | 132 | 1 | 1 | 72 |

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 15002 | AGBARA 33 | 33 | 1 | 1 | 20 |
| 15022 | IKORODU 33 | 33 | 2 | 1 | 20 |
| 15027 | ILUPEJU 33 | 33 | 1 | 1 | 20 |
| 25018 | AKURE T3A 33 | 33 | 1 | 1 | 20 |
| 45003 | OKENE 33 | 33 | 1 | 1 | 20 |
| 55001 | DAN AGUNDI 3 | 33 | 2 | 1 | 20 |
| 55010 | KATSINA 33 | 33 | 1 | 1 | 20 |
| 15037 | NEW ABEOK 33 | 33 | 1 | 1 | 20 |
| 25004 | AYEDE 33 | 33 | 1 | 1 | 20 |
| 25012 | ISEYIN 33 | 33 | 1 | 1 | 20 |
| 25035 | SHAGAMU 33 | 33 | 1 | 1 | 20 |
| 25038 | IJEBU-ODE 33 | 33 | 1 | 1 | 20 |
| 15006 | AKANGBA 33 | 33 | 1 | 1 | 24 |
| 15007 | AKOKA T1 33 | 33 | 1 | 1 | 24 |
| 15009 | ALAUSA 33 | 33 | 1 | 1 | 24 |
| 15010 | ALIMOSHO 33 | 33 | 1 | 1 | 24 |
| 15014 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 15015 | IJORA 33 | 33 | 1 | 1 | 24 |
| 15018 | OGBA 33 | 33 | 1 | 1 | 24 |
| 15028 | ISOLO 33 | 33 | 1 | 1 | 24 |
| 15128 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 15079 | OTTA T2 | 33 | 1 | 1 | 24 |
| 15080 | OLD ABEOK T2 | 33 | 3 | 1 | 24 |
| 25011 | ILORIN 33 | 33 | 1 | 1 | 24 |

Source: JICA Study Team

The status of capacitors required in Dry Season Off-Peak case is shown in Table 7-4.28.

**Table 7-4.28 Capacitor requirements for 2020 Dry Season Off-Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 62021 | MAIDUGURI 1 | 132 | 1 | 1 | 10.8 |
| 52022 | HADEJIA 1 | 132 | 1 | 1 | 20 |
| 22017 | ONDO2 1 | 132 | 1 | 1 | 24 |
| 42008 | IRRUA 1 | 132 | 1 | 1 | 24 |
| 52011 | GUSAU 1 | 132 | 1 | 1 | 50 |
| 12004 | AKANGBA BBII | 132 | 1 | 1 | 72 |
| 15002 | AGBARA 33 | 33 | 1 | 1 | 20 |
| 15022 | IKORODU 33 | 33 | 2 | 1 | 20 |
| 15027 | ILUPEJU 33 | 33 | 1 | 1 | 20 |
| 15037 | NEW ABEOK 33 | 33 | 1 | 1 | 20 |
| 25004 | AYEDE 33 | 33 | 1 | 1 | 20 |
| 25012 | ISEYIN 33 | 33 | 1 | 1 | 20 |
| 25018 | AKURE T3A 33 | 33 | 1 | 1 | 20 |
| 25035 | SHAGAMU 33 | 33 | 1 | 1 | 20 |
| 25038 | IJEBU-ODE 33 | 33 | 1 | 1 | 20 |
| 45003 | OKENE 33 | 33 | 1 | 1 | 20 |
| 55001 | DAN AGUNDI 3 | 33 | 2 | 1 | 20 |
| 55010 | KATSINA 33 | 33 | 1 | 1 | 20 |
| 15006 | AKANGBA 33 | 33 | 1 | 1 | 24 |

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 15007 | AKOKA T1 33 | 33 | 1 | 1 | 24 |
| 15009 | ALAUSA 33 | 33 | 1 | 1 | 24 |
| 15010 | ALIMOSHO 33 | 33 | 1 | 1 | 24 |
| 15014 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 15015 | IJORA 33 | 33 | 1 | 1 | 24 |
| 15018 | OGBA 33 | 33 | 1 | 1 | 24 |
| 15028 | ISOLO 33 | 33 | 1 | 1 | 24 |
| 15079 | OTTA T2 | 33 | 1 | 1 | 24 |
| 15080 | OLD ABEOK T2 | 33 | 3 | 1 | 24 |
| 15128 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 25011 | ILORIN 33 | 33 | 1 | 1 | 24 |

Source: JICA Study Team

#### 7-4-4-4 Power Factor Correction at DisCo's Level

With reference to the Grid Code requirements (ref. article 15.6 on Demand power factor corrections and 16.7 on the provision of voltage control stating that The Off-takers shall maintain a power factor not less than 0.95 at the Connection Point), since the resulting power factor of loads connected at 33 kV level and below is less than the 0.95 required, all DisCos shall be required to undertake a program of having capacitors installed at distribution level to ensure the power factor at all 33 kV S/S is not less than 0.9 by 2020 and 0.95 by 2025, in line with the Grid Code requirements. (Note: the loads in the 2025 model however have been based on a conservative power factor of 0.92 and only the 2030 loads have a pf of 0.95)

### 7-4-5 Expansion Plan for 2020

#### 7-4-5-1 Transmission Lines

As shown in the SLDs of Annexes 7.4.1 and 7.4.2, the transmission lines shown in Table 7-4.29 must be implemented by 2020 or as soon as possible thereafter. Line Nos. 1 to 5 in Table 7-4.29 require reconductoring only. A priority ranking from 1 to 3 has been included in this table, with 1 denoting the highest priority.

### Table 7-4.29 New transmission lines required by 2020

| No | | From | To | | kV | km | Remarks | Priority/ Ranking |
|---|---|---|---|---|---|---|---|---|
| 1 | Part of North-East Ring | Damaturu | Maiduguri | DC | 330 | 260 | An SC already exists. | 1 |
| 2 | | Gombe | Damaturu | DC | 330 | 180 | An SC already exists. | 1 |
| 3 | | Gombe | Yola | DC | 330 | 240 | An SC already exists. | 1 |
| 4 | | Yola | Jalingo | DC | 330 | 160 | Can be delayed beyond 2020 but ASAP thereafter. One circuit via Mayo Belwa. | 3 |
| 5 | | Jos | Gombe | DC | 330 | 270 | Via Bauchi.<br>Should be completed by 2020 or ASAP thereafter.<br>A SC already exists. | 1 |
| 6 | Part of North-West ring | Kainji | Birnin-Kebbi | DC | 330 | 310 | An SC already exists. Needs to be expedited by 2020 if possible or ASAP thereafter. | 3 |
| 7 | | Kaduna | Kano | DC | 330 | 230 | Undertaken by TCN as part of the NTEP to be financed by IDB. Needs to be expedited by 2020 if possible or ASAP thereafter. | 2 |
| 8 | | Akangba | Ijora | DC | 330 | 14 | A 330kV substation at Ijora and associated 330kV lines are necessary after 2020, but since they remove in 2020 the overloads at 132kV Ijora-Alagbon line and improve voltage profile in the area, it is recommended to implement as soon as possible after 2020. | 2 |
| 9 | | Ijora | Alagbon | DC | 330 | 8 | | 2 |
| 10 | | Arigbajo | New Agbara | DC | 330 | 40 | If not undertaken by JICA.<br>Not considered necessary for 2020, as it is lightly loaded. However, it is necessary for meeting the N-1 criterion for the export lines to Sakete. | 2 |
| 11 | | Ugwaji | Abakaliki | DC | 330 | 85 | | 1 |
| 12 | | Osogbo | Arigbajo | DC | 330 | 183 | If not undertaken by JICA. | 1 |
| 13 | | Ayede | Ibadan North | DC | 132 | 15 | An SC exists. A second circuit in parallel is needed. | 1 |
| 14 | | New Agbara | Agbara | DC | 132 | 18 | | 2 |
| 15 | | Ogijo | Redeem | DC | 132 | 14 | If not undertaken by JICA. | 2 |
| 16 | | Birmin Kebbi | Dosso | DC | 132 | 128 | An SC already exists. | 2 |

Source: JICA Study Team

Notes:

- The lines recommended for the North-East ring above must comply with the N-1 static security criterion, as well as improving the voltage stability of the area. It is recognized however that in implementation terms it will be challenging to complete it all by 2020. However, if it is not possible to implement by 2020, they should be implemented as soon as possible thereafter within the period 2020-2025, based on which the investment plan detailed in Section 9 has been drawn up.
- The JICA project of new 330 kV lines (DC) from Ogijo to Arigbajo is not considered necessary in 2020, as it is lightly loaded under all scenarios (it will be required, though, in 2025).
- The JICA project of new 330 kV lines (DC) from Arigbajo to New Agbara is not considered necessary for 2020, as it is lightly loaded. It is necessary only for meeting the N-1 criterion for the export lines to Sakete.

As shown in Section 8, the first priority is to resolve the overloads occurring under normal (N-0) operation of the following 132 kV lines shown in Table 7-4.30:

**Table 7-4.30 Reinforcements of 132 kV lines overloaded under N-0**

| From | To | Proposed solution |
|---|---|---|
| Ibom IPP | Ikot Abasi | Convert to DC |

Source: JICA Study Team

As a next priority, the overloaded 330 and 132 kV lines under N-1 contingencies must be reinforced. This entails either reconductoring to higher rating conductors or, in case of SC, conversion to DC by installing a second parallel circuit.

The lines in Table 7-4.31 are ranked according to their percentage overload. The shaded lines are DC lines for which reconductoring is recommended.

**Table 7-4.31 Reinforcements of 132 kV lines overloaded under N-1**

| FROM Bus No. | Bus name | TO Bus No. | Bus name | cct | Contingency label | Rating (MVA) | Flow (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|
| ***330 kV*** | | | | | | | | |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 cct1 | | SINGLE 23002-43002(1) | 855.1 | 1081.6 | 126.5 |
| 23002 | OMOTOSHO3 | 43002 | BENIN 3 cct2 | | SINGLE 23002-43002(2) | 855.1 | 1081.6 | 126.5 |
| ***132 kV*** | | | | | | | | |
| 82024 | IBOM IPP 1 | 82031 | IKOT_ABASI | 1 | BASE CASE | 125.7 | 189.6 | 150.9 |
| 62000 | GOMBE 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 151.3 | 197.2 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82019-82036(2) | 138.3 | 220 | 159.1 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82019-82036(1) | 138.3 | 213.6 | 154.5 |
| 42000 | AJAOKUTA 1 | 42009 | OKENE 1 | 1 | SINGLE 42004-42008(1) | 138.3 | 211.5 | 152.9 |
| 62003 | YOLA 1 | 62013 | T_JUNCTION 1 | 1 | SINGLE 63000-63002(1) | 76.7 | 116.3 | 151.6 |
| 42004 | BENIN 1 | 42008 | IRRUA 1 | 1 | SINGLE 42000-42009(1) | 138.3 | 203.5 | 147.1 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 2 | SINGLE 52033-52035(1) | 138.3 | 202.6 | 146.5 |
| 52033 | MANDO T4A BB | 52035 | KUDENDA 1 | 1 | SINGLE 52033-52035(2) | 138.3 | 202.6 | 146.5 |
| 22002 | OSOGBO 4T2 | 22008 | IWO 1 | 1 | SINGLE 22000-22006(1) | 138.3 | 201.9 | 146 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 2 | SINGLE 82017-82022(1) | 138.3 | 191.5 | 138.5 |
| 82017 | YENAGOA 1 | 82022 | GBARAIN UBIE | 1 | SINGLE 82017-82022(2) | 138.3 | 191.5 | 138.5 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 2 | SINGLE 82000-82002(1) | 138.3 | 181.4 | 131.1 |
| 82000 | AFAM 1-2-3 | 82002 | AFAM IV | 1 | SINGLE 82000-82002(2) | 138.3 | 181.4 | 131.1 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 2 | SINGLE 12003-12019(1) | 138.3 | 180 | 130.1 |
| 12003 | IKEJA W 1BB1 | 12019 | ALIMOSHO 1 | 1 | SINGLE 12003-12019(2) | 138.3 | 180 | 130.1 |
| 62009 | BIU 1 | 62026 | DADINKOWA 1 | 1 | SINGLE 63005-63007(1) | 76.7 | 98.2 | 128.1 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 2 | SINGLE 82017-82018(1) | 138.3 | 174.5 | 126.2 |
| 82017 | YENAGOA 1 | 82018 | AHOADA 1 | 1 | SINGLE 82017-82018(2) | 138.3 | 174.5 | 126.2 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | SINGLE 22002-22008(1) | 138.3 | 172.9 | 125 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | SINGLE 82024-82031(1) | 150.4 | 184.5 | 122.7 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | SINGLE 82024-82031(1) | 150.4 | 184.5 | 122.7 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 2 | SINGLE 82007-82036(1) | 138.3 | 169.5 | 122.5 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 1 | SINGLE 82007-82036(2) | 138.3 | 169.5 | 122.5 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 2 | SINGLE 82013-82040(1) | 138.3 | 157.5 | 113.9 |
| 82013 | ONNE 1 | 82040 | TRAMADI | 1 | SINGLE 82013-82040(2) | 138.3 | 157.5 | 113.9 |
| 82007 | PHCT MAIN1 | 82014 | RIVERS_IPP | 2 | SINGLE 82007-82014(1) | 138.3 | 155.2 | 112.2 |
| 82007 | PHCT MAIN1 | 82014 | RIVERS_IPP | 1 | SINGLE 82007-82014(2) | 138.3 | 155.2 | 112.2 |
| 52015 | ZARIA 1 | 52016 | FUNTUA 1 | 1 | SINGLE 32016-52004(1) | 99.3 | 110.4 | 111.2 |

Source: JICA Study Team

Note: It should be noted that with regard to the overloaded 330 kV lines in 2020 (Benin-Omotosho), remedial actions are already planned and these lines will not be overloaded in 2025.

### 7-4-5-2 Transformers

- The upgrading of 6 x 330/132 kV 3-W and A/T transformers which are overloaded above their 100% rating MVA under normal (base case) operation, is required, as listed in Table 7-4.22.
- The upgrading of 12 x 132/33 kV and 132/11 kV transformers which are overloaded above their 100% rating MVA under normal (base case) operation, is required, as listed in Table 7-4.23.
- The upgrading of the following types of transformers overloaded above their 85% rating MVA under normal (base case) operation shall be upgraded, as listed in Table 7-4.24:
  a) 2 x 330/132 kV 3-w and A/T,
  b) 15 x 132/33 kV and 132/11 kV transformers

#### 7-4-5-3 Reactive Power Compensation

**(1) SVC requirements**

No SVC at Gombe is necessary by 2020.

**(2) Reactors**

The new reactors required in the Dry Season Peak and Dry Season Off-Peak cases are shown in Table 7-4.32. Only reactors at Gombe, Yola and Maiduguri must be in operation. The new reactor at Maiduguri is shown in bold:

**Table 7-4.32 Reactor requirements for 2020**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | B-Shunt (MVar) |
|---|---|---|---|---|---|
| 63005 | MAIDUGURI 3 330.00 | 330 | 2 | 1 | -75.00 |

Source: JICA Study Team

**(3) Capacitors**

The new capacitors required in the Dry Season Peak, *Dry Season Off-Peak* and *Wet Season Off-Peak* cases are shown in Table 7-4.33:

**Table 7-4.33 Capacitor requirements for 2020**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | B-Shunt (MVar) |
|---|---|---|---|---|---|
| 22017 | ONDO2 1 | 132 | 1 | 1 | 24 |
| 42008 | IRRUA 1 | 132 | 1 | 1 | 24 |
| 52011 | GUSAU 1 | 132 | 1 | 1 | 50 |

Source: JICA Study Team

### 7-4-6 Fault Analysis

Short-circuit calculations were carried out for three-phase faults under all load scenarios. As a result of the calculations, design parameters for new substations and lines, short-circuit levels on existing substations and the impact of the expansion measures are shown. It is important to calculate the short-circuit currents since they are a measure to indicate the strength of both systems which will be interconnected.

The short-circuit calculations were performed according to the IEC 60909 standard and the following values were determined at all 330 and 132 kV substations in the TCN network:

- 3-phase symmetrical short-circuit power $S_{k3}$ (MVA)
- $I_{k3"}$ total symmetrical short-circuit current for three-phase solid faults

The calculations are based on the operational condition available in the corresponding load-flow scenarios.

The results of the preliminary fault analysis are summarized in Annex 7.4.10 (Table 1) for all 330 and 132 kV substations. The generators sub-transient reactance are used.

The most critical 330 and 132 kV substations are shown in Table 7-4.34.

**Table 7-4.34 Fault analysis results 2020**

| Bus Number | Bus Name | Voltage (kV) | I (A) | Bus Number | Bus Name | Voltage (kV) | I (A) |
|---|---|---|---|---|---|---|---|
| 43002 | BENIN 3 | 330 | 30,340 | 82000 | AFAM 1-2-3 | 132 | 29,882 |
| 83000 | AFAM IV 3 | 330 | 29,491 | 82002 | AFAM IV | 132 | 29,767 |
| 83002 | ALAOJI 3 | 330 | 28,225 | 12003 | IKEJA W 1BB1 | 132 | 28,156 |
| 83001 | ALAOJI NIPP3 | 330 | 27,810 | 82019 | OMOKU 1 | 132 | 26,663 |
| 43011 | B_NORTH_3 | 330 | 27,132 | 12042 | OKE_ARO_1 | 132 | 25,624 |

Source: JICA Study Team

The most critical 330 kV substations are BENIN, AFAM IV, ALAOJI and BENIN NORTH, with fault levels ranging from 30.3 kA to 27.1 kA for a 3ph busbar fault.

The most relatively critical 132 kV substation is AFAM and IKEJA WEST, with fault levels of 29.8 and 28.1 kA. It is clear from this analysis that the TCN standard switchgear ratings of 31.5 kA will be inadequate in future when new power plants are commissioned in later years.

a) Install switchgear with higher capacity breakers (63 kA).

b) Study different topological configurations of the elements connected to the different bus sections.

c) Install Current Limiting Reactors (CLR) aiming to reduce the short-circuit current contributions from adjacent bus sections.

## 7-5 Expansion Plan for 2025

### 7-5-1 Static Security Analysis, Year 2025

#### 7-5-1-1 Transmission lines

The network configuration for 2025 is shown in the PSS/E SLD of Annex 7.5.1

#### 7-5-1-2 Evacuation from Mambilla HPP

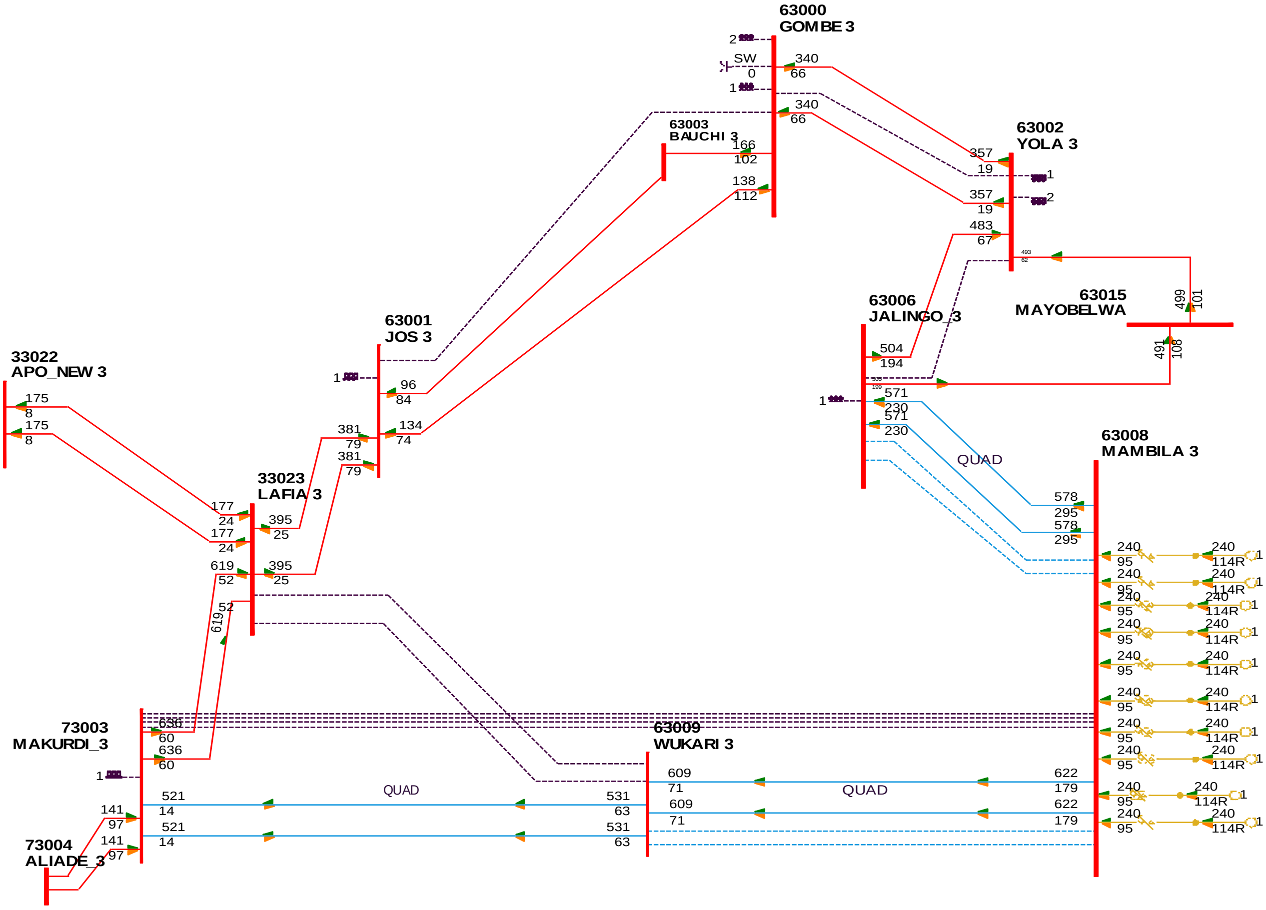
**(1) New transmission lines**

A major development for 2025 is the operation of the first units of the Mambilla HPP. The new transmission lines required to evacuate the power from Mambilla will have to be designed to evacuate full power, assuming power of 2,400 MW is to be evacuated from the Mambilla Hydro Power Plant:

1. If the N-1 criterion is to be maintained, as per the current Grid Code, the following is proposed:
    a) 330/132/33 kV substation at Wukari
    b) Double-Circuit with Quad Bison conductors from Mambilla to Wukari
    c) Double-Circuit with Quad Bison conductors from Wukari to Makurdi
    d) Double-Circuit with Quad Bison conductors from Mambilla to Jailingo (to close the 330-kV loop)
2. Due to the importance of the power station and in line with international practice by other utilities, it is proposed to apply the N-2 criteria only for the transmission lines leaving the power plant. If this is adopted, it would be necessary to have:
    a) Two Double Circuits with Quad Bison conductors from Mambila to Wukari
    b) Two Double Circuits with Quad Bison conductors from Mambila to Jailingo

Each Quad Bison circuit will be rated 1,550MVA approx. The scheme is shown on the Single-Line Diagram of Figure 7-5.1.

In both cases, two evacuation routes must be maintained (one towards Makurdi and another towards Jalingo) at all times, since 2,400MW will not be able to be evacuated through one route only, given that bottlenecks will occur downstream, beyond Makurdi and Jalingo respectively.




Source: JICA Study Team

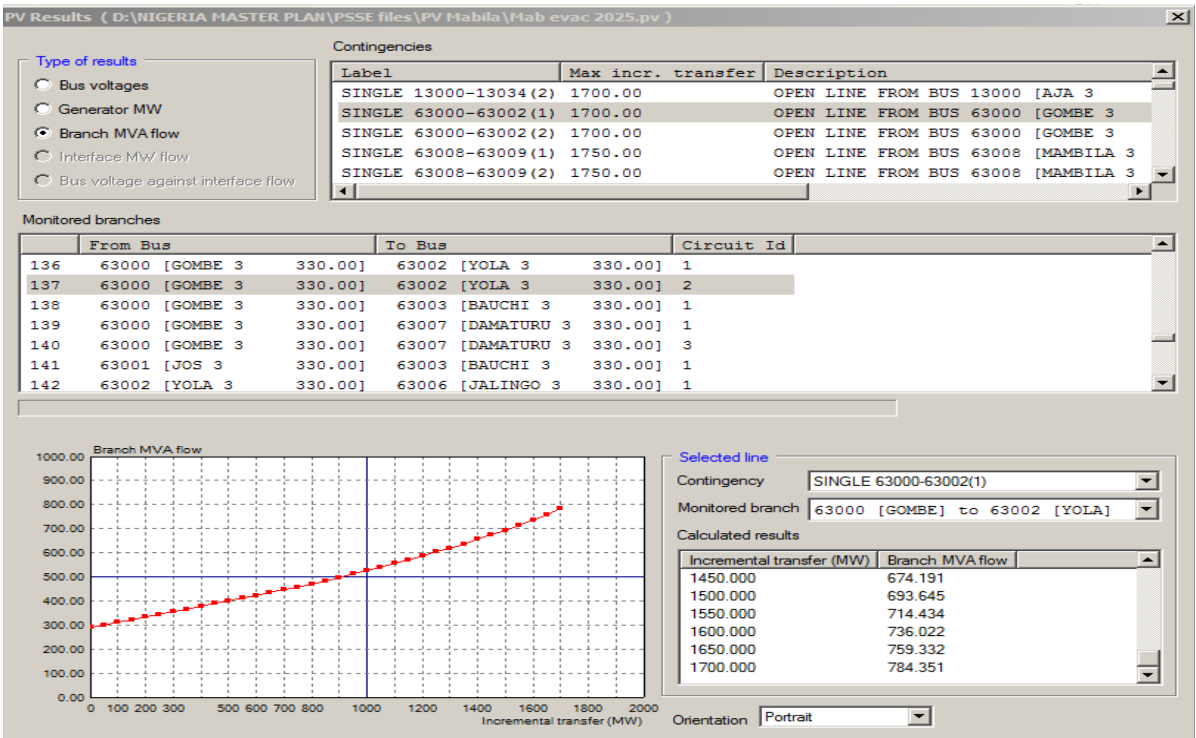
**Figure 7-5.1 Evacuation from Mambilla HPP**

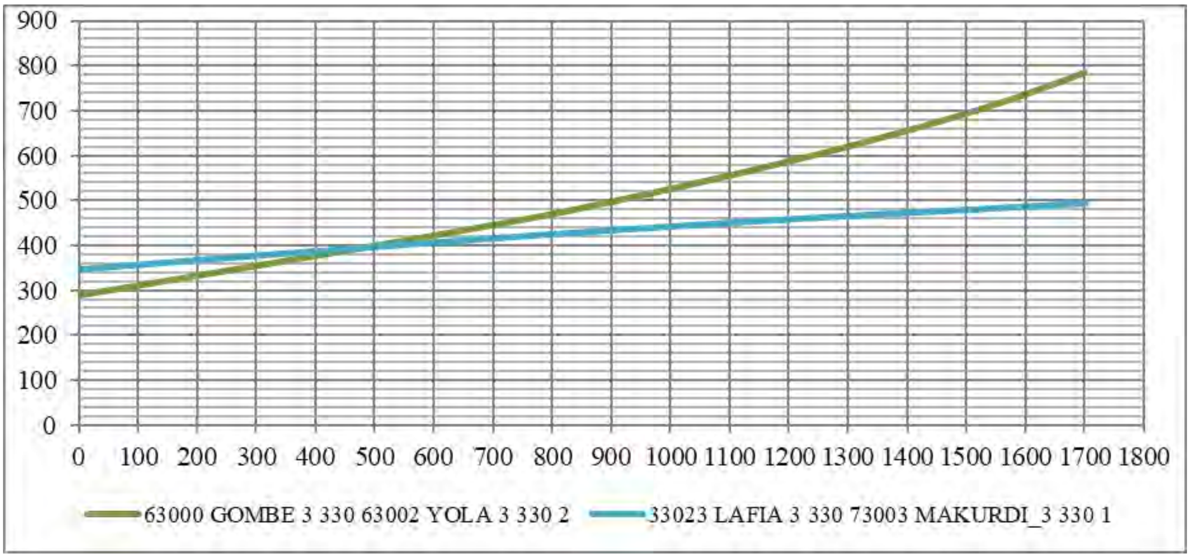
### (2) PV analysis

A PV analysis was carried out to determine the maximum power that can be evacuated from Mambilla HPP (MHPP).

The starting scenario was set up with an initial generation of 1,000 MW at MHPP and both base case and contingency (N-1) conditions were analyzed. It was determined that:

- Under base case (normal) conditions, an additional 2,000 MW can be evacuated, i.e. a total of 3,000 MW, before a 330-kV line in the TCN system reaches its limit.
- Under contingency conditions, an additional 1,700 MW can be evacuated, i.e. total 2,700 MW, before a line in the TCN system reaches its thermal limit (777 MVA), in this case the Gombe-Yola 330 kV line (cct1) when the other Gombe-Yola line (cct 2) is tripped. This is shown in the graphs of Figure 7-5.2.




Source: JICA Study Team

**Figure 7-5.2 PV Analysis for Mambilla Evacuation**

Considering that the Mambilla plant is rated 3,000 MW and is highly unlikely to reach production exceeding 2,400 MW, it is concluded that all power can be evacuated without any additional reinforcements in the transmission system required.

### (3) Specifications of transmission lines

The following data is used: the 330-kV conductor is 4-bundle ACSR350 per phase, spaced at 400 mm. The conductor types (aluminum conductor steel reinforced):

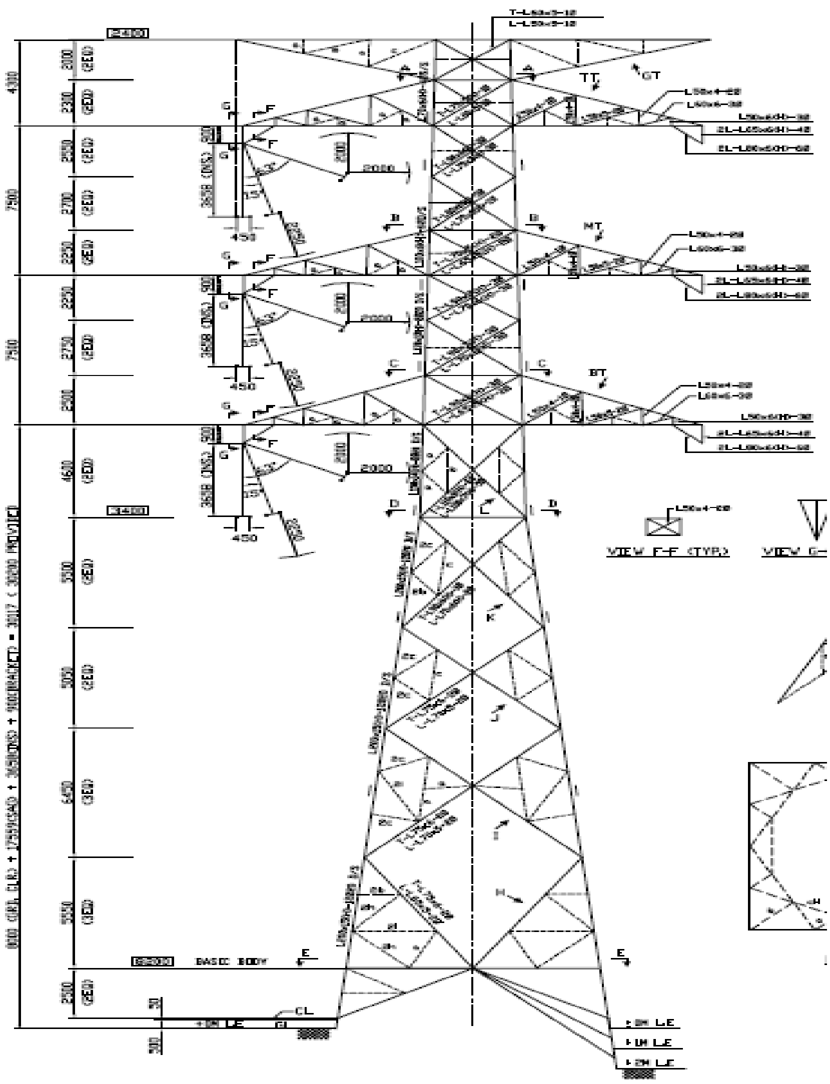
ACSR 350 'Bison' (381-AL1/49-ST1A; 54 Al wires diameter 3.0 mm; seven Fe wires diameter 3.0 mm, i.e. 54/7), Outside diameter 27 mm. The Basic Conductor Characteristics are in Table 7-5.1

**Table 7-5.1 Basic Conductor Characteristics for 330 kV OHL**

| Description | Value |
|---|---|
| Cross-section | |
| Aluminum (mm²) | 381.6 |
| Steel (mm²) | 49.4 |
| Total (mm²) | 431 |
| Stranding and wire diameter | |
| Aluminum (mm) | 54 / 3.0 |
| Steel (mm) | 7 / 3.0 |
| Overall diameter (mm) | 27 |

### (4) 330 kV Transmission Line R, X and B

The tower design is shown in Figure 7-5.3 and the conductors' arrangements in Figure 7-5.4.

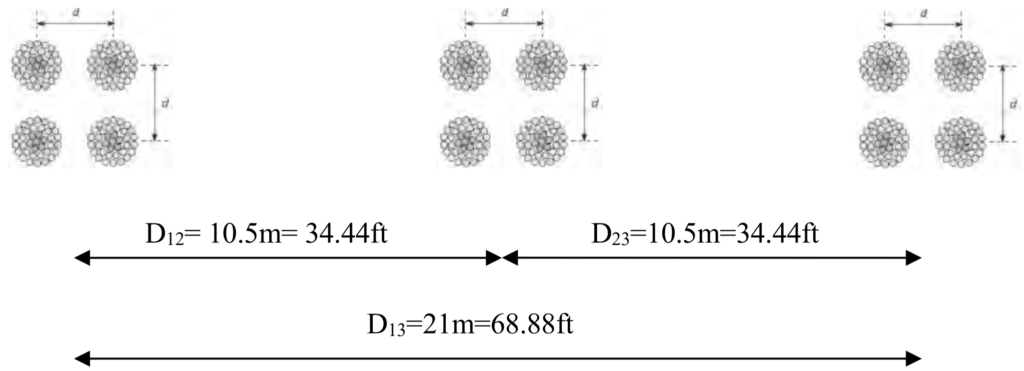



Source: JICA Study Team

**Figure 7-5.3 Tower Design**

Based on the above, with d=400mm (1.32 ft):

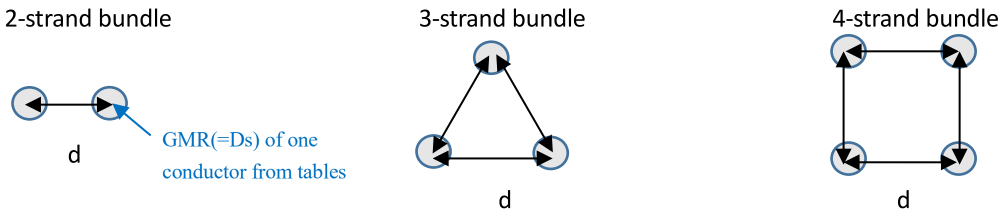
d=400mm=1.32ft




Source: JICA Study Team

**Figure 7-5.4 Conductors Spacing 330 kV Line**

In general:




The Geometric Mean Radius (GMR) of bundled conductors:

$$D_s^b = \sqrt{D_s.d} \qquad D_s^b = \sqrt[3]{D_s.d^2} \qquad D_s^b = 1.09\sqrt[4]{D_s.d^3}$$

where Ds is the GMR of <u>one</u> stranded conductor.

For Bison conductors, the GMR (=Ds) of one conductor, as taken from tables, is:

GMR=Ds=0.0363 ft

For bundled conductors the equivalent GMR is

$$D_s^b = \sqrt{D_s.d} \quad \text{for 2-bundle conductors} \quad (1)$$

$$D_s^b = \sqrt[3]{D_s.d^2} \quad \text{for 3-bundle conductors} \quad (2)$$

$$D_s^b = 1.09\sqrt[4]{D_s.d^3} \quad \text{for 4-bundle conductors} \quad (3)$$

In this case, for 4-b (Quad):

$$D_s^b = 1.09\sqrt[4]{D_s.d^3} = 1.09\sqrt[4]{0.0363 \times 1.32^3} = 0.586\ ft$$

The equivalent spacing between phases is:

$$D_{eq} = D_m = \sqrt[3]{D_{12}.D_{23}.D_{31}} = \sqrt[3]{34.44 \times 34.44 \times 68.88} = 43.4\ ft$$

**Inductive Reactance:**

$$X_L = 4.657 . 10^{-3} . f . \log\frac{D_m}{D_s^b} = 0.4353 \text{ ohms/mile} = 0.27 \text{ ohms/km (for SC)}$$

$$= 0.25 \text{ ohms/km (for DC)}$$

**Capacitance:**

$$C_n = \frac{0.0388}{\log\frac{D_{eq}}{D_{s\,c}^b}} \quad \mu F/mile$$

where $D_{s\,c}^b$ is the equivalent GMR for capacitance calculations and derived from eqs. (1), (2) and (3) used for inductance calculations, except that the $D_s$ is replaced by the radius r of the conductor in ft, i.e.

$r = \frac{D_{out}}{2 \times 12}$ ft, where $D_{out}$ is the conductor outside diameter in inches

Accordingly, for capacitance:

$D_{s\,c}^b = \sqrt{r.d}$ for 2-bundle conductors (4)

$D_{s\,c}^b = \sqrt[3]{r.d^2}$ for 3-bundle conductors (5)

$D_{s\,c}^b = 1.09\sqrt[4]{r.d^3}$ for 4-bundle conductors (6)

For Bison conductors: $r = \frac{D_{out}}{2 \times 12} = \frac{1.062}{2 \times 12} = 0.04425$ ft

$$D_{s\,c}^b = 1.09\sqrt[4]{r.d^3} = 1.09\sqrt[4]{0.04425 \times .1.32^3} = 0.6156\ ft$$

$$C_n = \frac{0.0388}{\log\frac{D_{eq}}{D_{s\,c}^b}} = \frac{0.0388}{\log\frac{43.4}{0.6156}} = 0.021\ \mu F/mile = 0.013\ \mu F/km \text{ (for SC)}$$

$$= 0.014\ \mu F/km \text{ (for DC)}$$

Susceptance B=ωC=314 x 0.013 = 4.08 μmho/km = 4.08 μS/km), for SC

= 4.39 μS/km), for DC

Resistance: R=0.0762 ohms/km (R=0.019 ohms/km for four bundle conductors)

The electrical parameters in PSS/E of the DC 330 kV line Mambila-Wukari and Mambila-Jalingo are summarized in Table 7-5.2.

**Table 7-5.2 Double-Circuit 330 kV line characteristics**

| Substation Name | Substation Name | L (km) | R (Ω/km) | L (mH/km) | X (Ω/km) | C (μF/km) | PSS/E input data R (ohms) | PSS/E input data X (ohms) | PSS/E input data C (μF) |
|---|---|---|---|---|---|---|---|---|---|
| Mabila | Wukari | 159 | 0.019 | 0.7962 | 0.25 | 0.014 | 3.021 | 39.750 | 2.2260 |
| Mabila | Jalinko | 95 | 0.019 | 0.7962 | 0.25 | 0.014 | 1.805 | 23.750 | 1.3300 |

Source: JICA Study Team

## (5) Line surge impedance and thermal rating

### 1) Surge Impedance Loading Limits - Natural Line Rating

As power flows along a transmission line, there is an electrical phase shift, which increases with distance and power flow. As this phase shift increases, the system in which the line is embedded can become increasingly unstable during electrical disturbances.

Typically, for very long lines, the power flow must be limited to what is commonly called the Surge Impedance Loading (SIL) of the line.

Surge Impedance Loading is equal to the product of the end bus voltages divided by the surge (characteristic) impedance of the line. Since the characteristic impedance of various HV and EHV lines is relatively similar, the SIL depends approximately on the square of the system voltage:

$$SIL = \frac{kV^2}{Zs}$$

where Zs is the surge impedance of the line: $Zs = \sqrt{\frac{L}{C}} = \sqrt{\frac{0.7962x1000}{0.014}}$ = 238.5 ohms

$$\boldsymbol{SIL = \frac{330^2}{238.5} = 456\ \mathrm{MW}}$$

Typically, stability limits may determine the maximum allowable power flow on lines that are more than approx. up to 250 km in length.

### 2) Thermal Limits

Thermal power flow limits on overhead lines are intended to limit the temperature attained by the energized conductors and the resulting sag and loss of tensile strength. In most cases, the maximum conductor temperature applied to modern transmission lines reflect ground clearance concerns rather than annealing of aluminum.

Thermal limits are not a function of line length. Thus for a given line design, lines of 1 km and 500 km long typically have the same thermal limit.

The thermal transmission capacities of the 330 kV OHL have been calculated as follows:

Voltage 330 kV

| | |
|---|---|
| Conductor Type | 3 x AC 381/49 |
| Wind Speed | 0.6 m/s |
| Air temperature | 40 °C |
| Maximum conductor temperature | 75 °C |

<u>Thermal Ratings:</u>

| | |
|---|---|
| Capacity | 1,555 MVA |
| Capacity | 1,400 MW |

#### 7-5-1-3 2025 Load demand

Table 7-5.3 shows that the increase in load demand follows an approximately equivalent increase (in percentage terms) in the load forecast.

**Table 7-5.3 Load demand per DisCo**

| DisCo | Load demand 2020 (MVA) | Increase 2020-2025 | Load demand 2025 (MVA) |
|---|---|---|---|
| 1-Ikeja | 1,166 | 76% | 2,058 |
| 2-Ibadan | 1,104 | 107% | 2,285 |
| 3-Abuja | 865 | 169% | 2,329 |
| 4-Benin | 954 | 94% | 1,852 |
| 5-Kaduna | 495 | 136% | 1,169 |
| 6-Jos | 309 | 109% | 646 |
| 7-Enugu | 924 | 81% | 1,668 |
| 8-Port Harcourt | 794 | 122% | 1,762 |
| 9-EKO | 1,087 | 69% | 1,837 |
| 10-Kano | 708 | 121% | 1,565 |
| 11-Yola | 230 | 131% | 532 |
| Country MW | 8,636 | 105% | 17,703 |
| Export* MW | 387 | - | 1,540 |
| Tota Load MW | 9,023 | 113% | 19,243 |

Source: JICA Study Team

Ref: 330 kV export lines: To Sakete 360MW, To Faraku 400MW, To Zabori 631MW

#### 7-5-1-4 Study cases 2025

Table 7-5.4 shows the two scenarios studied for 2025, to capture the extreme combinations of generation and load.

**Table 7-5.4 2025 study cases**

| Case | | Description | Generation | Load (MW) | |
|---|---|---|---|---|---|
| Dry Season Peak | DP | Dry<br>Night<br>Peak Load | Reduced HPP generation (2228 MW)<br>No PV generation<br>Increased requirement from GTs | Peak load (night) | 17703 + export (1540) |
| Dry Season Off-Peak | DOP | Dry<br>Day<br>Off-Peak Load | Reduced HPP generation<br>PV generation<br>Increased requirement from GTs | Off-Peak load (day) | 15000 + export (1540) |

Source: JICA Study Team

### 7-5-2 2025 Base Case Load-flow Results

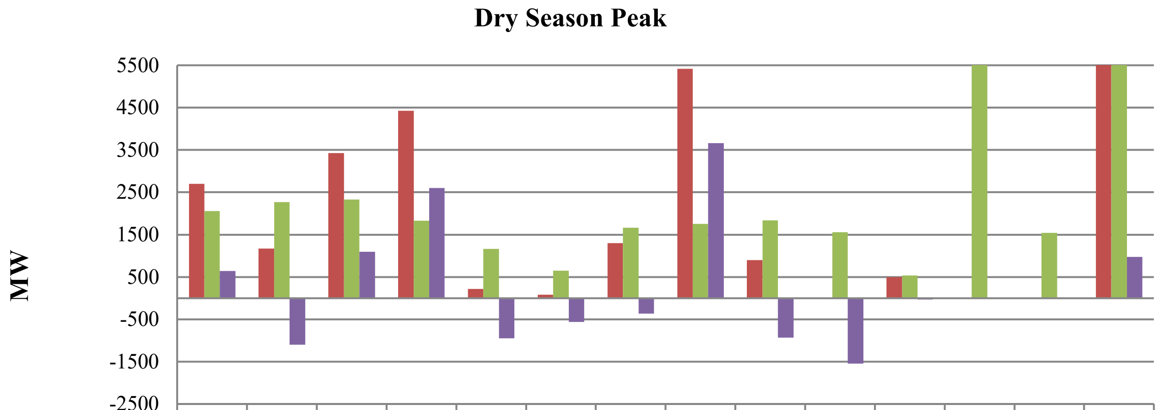
#### 7-5-2-1 Dry Season Peak-2025

**(1) Prerequisites for analysis**

(a) Generation from PVs = 0 and

(b) Reduced generation from HPP plants of 2,228 MW,

The running generation and load for each DisCo is as shown in **Figure 7-5.5**.




| | Ikeja | Ibadan | Abuja | Benin | Kaduna | Jos | Enugu | P Harc | Eko | Kano | Yola | Total for Nigeria | Export | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run Genaration | 2699 | 1168 | 3426 | 4430 | 218 | 84 | 1301 | 5415 | 900 | 9 | 500 | | | 20150 |
| Load | 2058 | 2268 | 2330 | 1827 | 1165 | 648 | 1666 | 1753 | 1837 | 1555 | 532 | 17639 | 1540 | 19179 |
| Gen deficit/surplus | 641 | -1100 | 1096 | 2603 | -947 | -564 | -365 | 3662 | -937 | -1546 | -32 | | | 971 |

Source: JICA Study Team

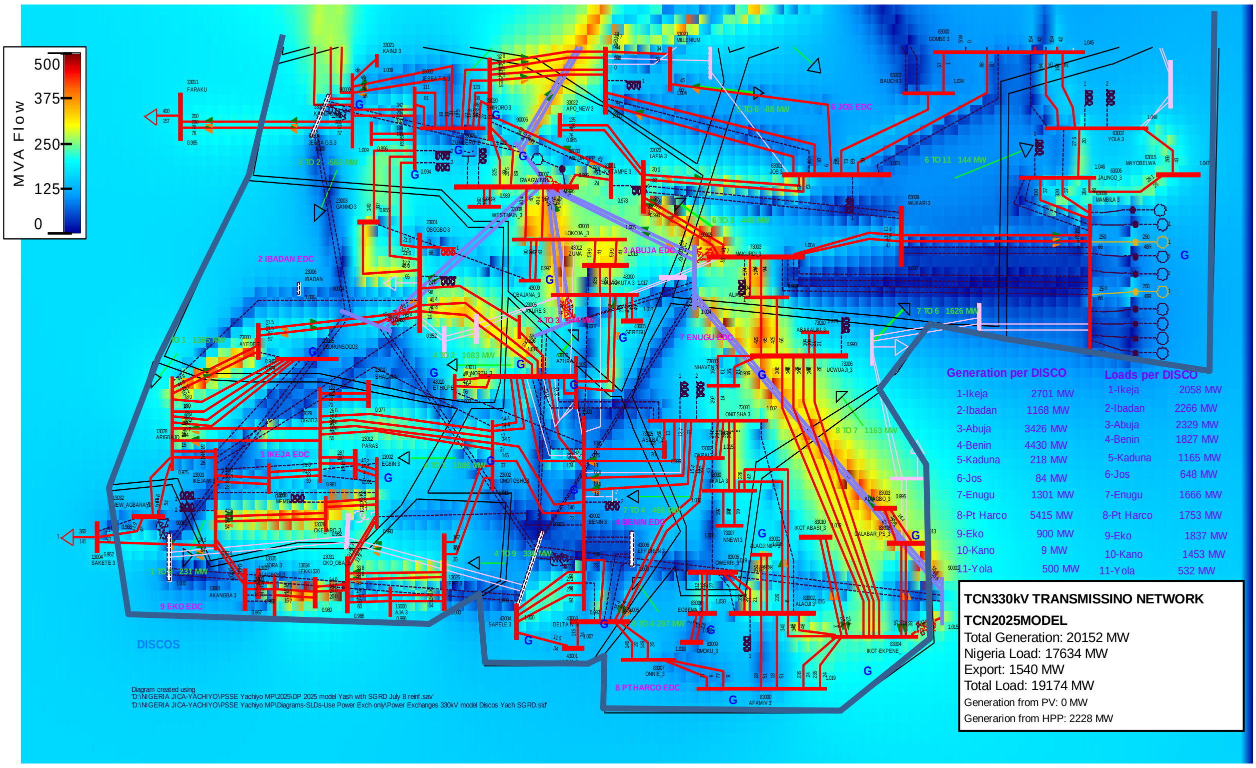
**Figure 7-5.5 Dry Season Peak Generation and Load per DisCo**

**Table 7-5.5 Dry Season Peak Generation and Load per DisCo**

| Bus Number | Bus Name | $P_{Gen}$ (MW) | Bus Number | Bus Name | $P_{Gen}$ (MW) | Bus Number | Bus Name | $P_{Gen}$ (MW) |
|---|---|---|---|---|---|---|---|---|
| 16040 | AES BERG202 | 31 | 16004 | EGBIN ST 5 | 274.8 | 76022 | OKPAI STPH2 | 135 |
| 16041 | AES BERG203 | 31 | 16005 | EGBIN ST 6 | 274.8 | 16064 | OLOR NIPPST1 | 108 |
| 16042 | AES BERG204 | 31 | 16006 | EGBIN ST_123 | 600 | 16065 | OLOR NIPPST2 | 108 |
| 16043 | AES BERG205 | 31 | 86050 | ELEME | 68 | 16060 | OLORNIPPGT11 | 132 |
| 16045 | AES BERG207 | 31 | 96012 | ETHIOPE | 450 | 16061 | OLORNIPPGT12 | 100 |
| 16046 | AES BERG208 | 31 | 46037 | ETHIOPE GTS | 344 | 16062 | OLORNIPPGT21 | 100 |
| 16047 | AES BERG209 | 31 | 46038 | ETHIOPE ST | 156 | 16063 | OLORNIPPGT22 | 100 |
| 16048 | AES BERG210 | 31 | 86068 | GBARAIN_GTB1 | 112.5 | 16050 | OLORUNSO GT1 | 30 |
| 16049 | AES BERG211 | 31 | 86069 | GBARAIN_GTB2 | 112.5 | 16051 | OLORUNSO GT2 | 30 |
| 86012 | AFAM VI GT11 | 150 | 86055 | GEN_AMADI | 100 | 16054 | OLORUNSO GT5 | 30 |
| 86013 | AFAM VI GT12 | 150 | 56010 | GEN_KADUNA | 200 | 16055 | OLORUNSO GT6 | 30 |
| 86014 | AFAM VI GT13 | 150 | 46023 | GER NIPPGT21 | 140 | 16056 | OLORUNSO GT7 | 30 |
| 86015 | AFAM VI ST10 | 180 | 46024 | GER NIPPGT22 | 140 | 86047 | OMA_GT | 225 |
| 86003 | AFAM2 GT5-6 | 48 | 46025 | GER NIPPGT23 | 140 | 86023 | OMOKU1 GT1 | 75 |
| 86004 | AFAM2GT 7-8 | 48 | 46020 | GEREGU GT11 | 124 | 86024 | OMOKU1 GT2 | 75 |
| 86005 | AFAM3 GT9-10 | 50 | 56003 | GURARA GBUS | 18 | 86021 | OMOKU2 GT1 | 113 |
| 86006 | AFAM3GT11-12 | 50 | 86025 | IBOM GT1 | 32 | 86022 | OMOKU2 GT2 | 113 |
| 86080 | AKWA-IBOM NU | 600 | 86026 | IBOM GT2 | 32 | 26026 | OMOTNIPP GT1 | 110 |
| 86039 | ALAOJI_GTB1 | 112.5 | 86027 | IBOM GT3 | 32 | 26027 | OMOTNIPP GT2 | 110 |
| 86040 | ALAOJI_GTB2 | 112.5 | 86028 | IBOM II | 260 | 26028 | OMOTNIPP GT3 | 110 |
| 86041 | ALAOJI_GTB3 | 112.5 | 46031 | IHOVBOR_GTB1 | 110 | 26029 | OMOTNIPP GT4 | 110 |
| 86042 | ALAOJI_GTB4 | 112.5 | 46032 | IHOVBOR_GTB2 | 110 | 26020 | OMOTOSO GT1 | 70 |
| 86043 | ALAOJI2_STB1 | 257 | 46033 | IHOVBOR_GTB3 | 110 | 26022 | OMOTOSO GT3 | 70 |
| 86031 | ALSCON GT1 | 90 | 46034 | IHOVBOR_GTB4 | 110 | 26024 | OMOTOSO GT5 | 62 |
| 46027 | ASCO G1 | 55 | 66033 | JBS WIND | 70 | 26025 | OMOTOSO GT7 | 62 |
| 46028 | ASCO G2 | 55 | 36006 | JEBBA 2G1 | 90 | 96008 | ONDO IPP | 405 |
| 46035 | AZURA GT | 280 | 36007 | JEBBA 2G2 | 90 | 16012 | PARAS | 270 |
| 46036 | AZURA ST | 140 | 36008 | JEBBA 2G3 | 90 | 16011 | PARASGT1-9 | 93 |
| 16008 | BRESSON GTS | 80 | 36009 | JEBBA 2G4 | 40 | 46070 | PROTON | 135 |
| 96009 | CABLE INLAND | 900 | 36011 | JEBBA 2G6 | 90 | 86070 | QUA IBOE PP | 480 |
| 86062 | CALABAR_GTB1 | 100 | 36004 | KAINJ 1G11 | 80 | 86035 | RIVERS _GT1 | 190 |
| 86061 | CALABAR_GTB2 | 100 | 36005 | KAINJ 1G12 | 80 | 46050 | SAP_NIPP_GT1 | 100 |
| 86060 | CALABAR_GTB3 | 100 | 36000 | KAINJ 1G5 | 80 | 46051 | SAP_NIPP_GT2 | 100 |
| 86063 | CALABAR_GTB4 | 100 | 36001 | KAINJ 1G6 | 80 | 46052 | SAP_NIPP_GT3 | 100 |
| 76011 | CENTURY IPP | 480 | 36002 | KAINJ 1G7-8 | 160 | 46012 | SAPELE GT1-2 | 175 |
| 86030 | CUMMINS | 135 | 36003 | KAINJ 1G9-10 | 160 | 46013 | SAPELE GT3-4 | 95 |
| 46010 | DELTAIV GT19 | 133 | 46080 | KOJI NUCLEAR | 600 | 36012 | SHIROR 411G1 | 140 |
| 46011 | DELTAIV GT20 | 133 | 55075 | KT WF 33 | 9 | 36013 | SHIROR 411G2 | 140 |
| 66005 | DKOWA G1 | 14 | 16010 | LAFARAGE 2 | 100 | 36014 | SHIROR 411G3 | 80 |
| 86065 | EGBEMA_GTB1 | 100 | 66007 | MAMBILA GT1 | 250 | 96016 | TURBINE DR | 300 |
| 86066 | EGBEMA_GTB2 | 100 | 66008 | MAMBILA GT2 | 250 | 96017 | YELLOW STONE | 162 |
| 86067 | EGBEMA_GTB3 | 100 | 76000 | OKPAI GT11 | 145 | 46029 | ZUMA | 540 |
| 16000 | EGBIN GT 1 | 274.8 | 76001 | OKPAI GT12 | 145 | 86071 | ZUMA (GAS) | 337 |
| 16001 | EGBIN GT 2 | 274.8 | 76020 | OKPAI GT4PH2 | 135 | 36024 | ZUNGE_G1 | 150 |
| 16002 | EGBIN GT 3 | 274.8 | 76021 | OKPAI GT5PH2 | 135 | 36025 | ZUNGE_G2 | 150 |
| 16003 | EGBIN GT 4 | 274.8 | 76002 | OKPAI ST18 | 126 | 36027 | ZUNGE_G4 | 10 |

Source: JICA Study Team

The power flows are shown in Figure 7-5.6.




Source: JICA Study Team

**Figure 7-5.6 2025 Dry Season Peak Power Flows in 330 kV System**

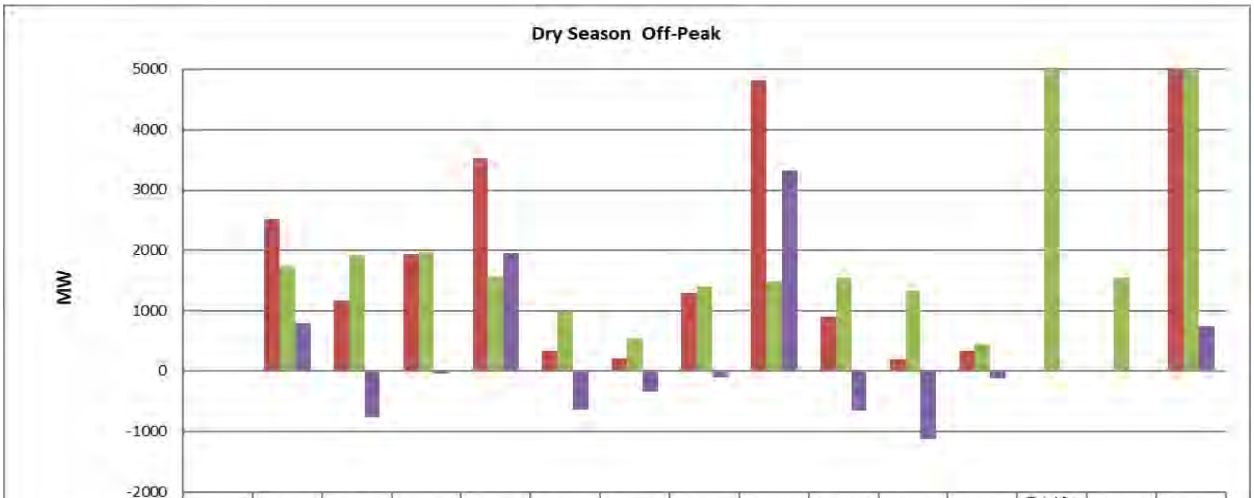
### 7-5-2-2 Dry Season Off-Peak-2025

#### (1) Prerequisites for analysis

(a) Generation from PVs = 750MW and

(b) Reduced generation from HPP plants of 1,390 MW,

The running generation and load for each DisCo are shown in Figure 7-5.7.

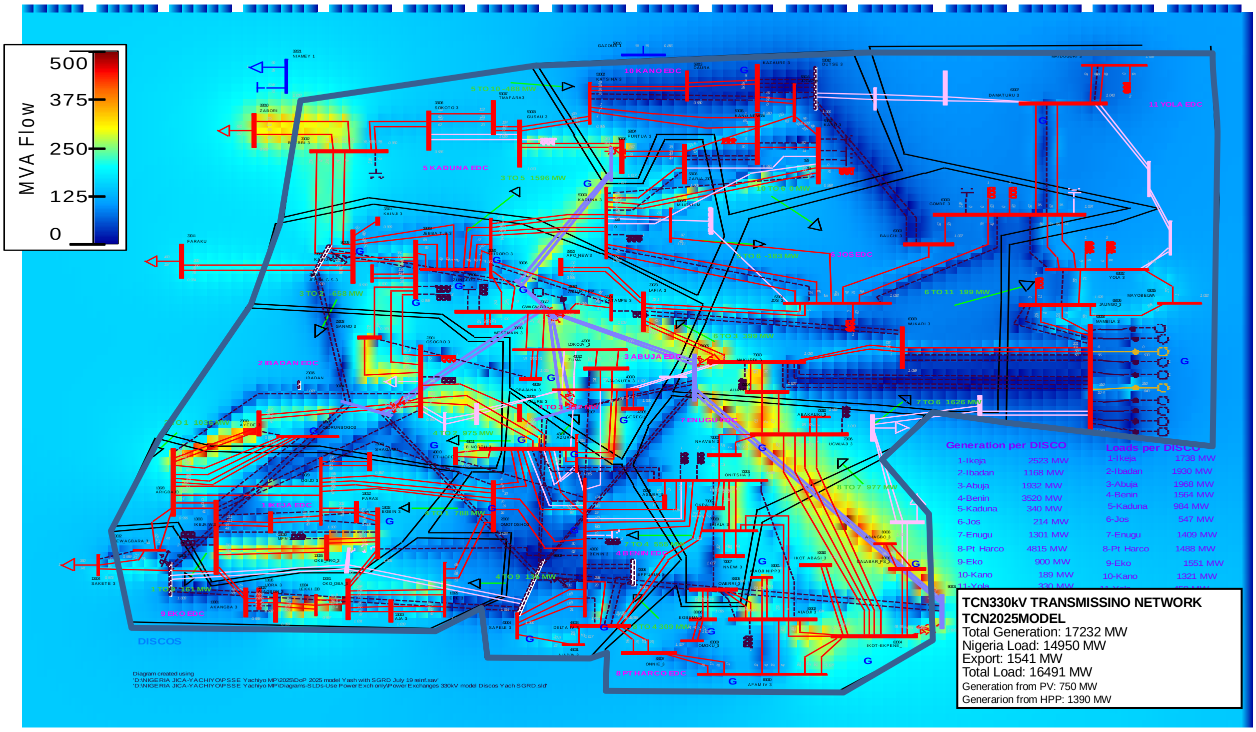



| | Ikeja | Ibadan | Abuja | Benin | Kaduna | Jos | Enugu | P Harc | Eko | Kano | Yola | Total for Nigeria | Export | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run Genaration | 2523 | 1168 | 1932 | 3520 | 340 | 214 | 1301 | 4815 | 900 | 189 | 330 | | | 17232 |
| Load | 1738 | 1930 | 1968 | 1564 | 984 | 547 | 1409 | 1488 | 1551 | 1321 | 450 | 14950 | 1541 | 16491 |
| Gen deficit/surplus | 785 | -762 | -36 | 1956 | -644 | -333 | -108 | 3327 | -651 | -1132 | -120 | | | 741 |

Source: JICA Study Team

**Figure 7-5.7 Dry Season Off-Peak Generation and Load per DisCo**

The power flows are shown in Figure 7-5.8.




Source: JICA Study Team

**Figure 7-5.8 2025 Dry Season Off- Peak Power Flows in 330 kV System**

### 7-5-3 Contingency (N-1) Analysis for 330 kV Circuits

The contingency N-1 analysis carried out for the 330 kV lines has shown that the following 330 kV DC lines are overloaded and require reinforcement by converting to Quad conductors.

**Table 7-5.6 Overloaded 330 kV lines under N-1**

| Substation Name | Substation Name | Rating (MVA) | Flow (MVA) | Loading (%) | Length (km) |
|---|---|---|---|---|---|
| AJA | LEKKI | 856 | 1,372 | 160.4 | 7 |
| ALAGBON | LEKKI | 856 | 1,184 | 138.5 | 14 |
| LOKOJA | ZUMA | 856 | 1,117 | 130.7 | 24 |

Source: JICA Study Team

Reconductoring to Quad-bundle conductors has already been implemented by TCN. This is also assumed to be possible for these lines, but must be verified to ensure the structures are suitable. If not, the DC lines will need to be replaced.

### 7-5-4 2025 Base Case Load-flow Results

#### 7-5-4-1 Overloads of 330 kV or 132 kV Lines

There are no overloaded 330 kV or 132 kV lines which are overloaded under normal operation (base case).

#### 7-5-4-2 Overloads of Transformers

The 330/132 kV 3-W and A/T transformers overloaded above their 100% rating MVA under normal (base case) operation, in addition to those reported for the 2020 case, are listed in Table 7-5.7 and must be upgraded.

**Table 7-5.7 Overloaded 330/132 kV transformers**

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | cct | Load (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|
| 83003 | ADIAGBO_3 | 330 | 3WNDTR | ADIAGB T1A | WND 1 | 1 | 188.2 | 150 | 125.5 |
| 83003 | ADIAGBO_3 | 330 | 3WNDTR | ADIAGB T1B | WND 1 | 2 | 188.2 | 150 | 125.5 |
| 12000 | AJA 132 | 132 | 3WNDTR | AJA T4 | WND 1 | 1 | 68.9 | 45 | 153.2 |
| 13000 | AJA 3 | 330 | 3WNDTR | AJA T2A | WND 1 | 3 | 194.6 | 150 | 129.8 |
| 42000 | AJAOKUTA 1 | 132 | 3WNDTR | AJAOK T1A | WND 2 | 1 | 86 | 80 | 107.5 |
| 42000 | AJAOKUTA 1 | 132 | 3WNDTR | AJAOK T2A | WND 2 | 1 | 86 | 80 | 107.5 |
| 42000 | AJAOKUTA 1 | 132 | 3WNDTR | AJAOK T3A | WND 2 | 1 | 86 | 80 | 107.5 |
| 13001 | AKANGBA 3 | 330 | 3WNDTR | AKANGBA5T4A | WND 1 | 1 | 152.4 | 150 | 101.6 |
| 13001 | AKANGBA 3 | 330 | 3WNDTR | AKANGBA5T4B | WND 1 | 1 | 152.4 | 150 | 101.6 |
| 12016 | AKOKA 1 | 132 | 3WNDTR | AKOKA T1 | WND 1 | 1 | 53.8 | 45 | 119.6 |
| 23005 | AKURE 3 | 330 | 3WNDTR | AKURE T1A | WND 1 | 1 | 182.2 | 150 | 121.5 |
| 23005 | AKURE 3 | 330 | 3WNDTR | AKURE T1B | WND 1 | 2 | 182.2 | 150 | 121.5 |
| 12022 | APAPA RD 1 | 132 | 3WNDTR | APAPA RD T1 | WND 1 | 1 | 46.4 | 45 | 103.2 |
| 23000 | AYEDE 3 | 330 | 3WNDTR | AYEDE TR1 | WND 1 | 1 | 198.9 | 150 | 132.6 |
| 23000 | AYEDE 3 | 330 | 3WNDTR | AYEDE TR2 | WND 1 | 1 | 197.1 | 150 | 131.4 |
| 23000 | AYEDE 3 | 330 | 3WNDTR | AYEDE TR3 | WND 1 | 1 | 197.1 | 150 | 131.4 |
| 42003 | DELTA 1 | 132 | 43003 | DELTA IV 3 | 330 | 1 | 270.1 | 150 | 180.1 |
| 42003 | DELTA 1 | 132 | 43003 | DELTA IV 3 | 330 | 2 | 270.1 | 150 | 180.1 |
| 23003 | GANMO 3 | 330 | 3WNDTR | GANMO TR1A | WND 1 | 1 | 212.4 | 150 | 141.6 |
| 72036 | IHIALA 1 | 132 | 3WNDTR | IHIALA TR | WND 2 | 1 | 124.2 | 120 | 103.5 |

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | cct | Load (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|
| 13003 | IKEJA W 3 | 330 | 3WNDTR | IKW T2B | WND 1 | 3 | 163.1 | 150 | 108.7 |
| 12027 | ISOLO 1 | 132 | 3WNDTR | ISOLO TR3 | WND 1 | 1 | 53.3 | 45 | 118.3 |
| 22012 | JERICHO 1 | 132 | 3WNDTR | JERICO TR1 | WND 1 | 1 | 73.7 | 45 | 163.8 |
| 53001 | KANO 3 | 330 | 3WNDTR | KANO OLD T5A | WND 1 | 2 | 169.6 | 150 | 113 |
| 53001 | KANO 3 | 330 | 3WNDTR | KANO T3A | WND 1 | 1 | 169.6 | 150 | 113 |
| 52030 | KUMB T1A BB | 132 | 3WNDTR | KANO T1A | WND 2 | 1 | 242.5 | 225 | 107.8 |
| 73007 | NNEWI 3 | 330 | 3WNDTR | NNEWI T2A | WND 2 | 1 | 91.8 | 67.5 | 136 |
| 22014 | OMOTOSHO 1 | 132 | 3WNDTR | OMOTOSHO TR1 | WND 2 | 1 | 134.3 | 120 | 111.9 |
| 22024 | OMOTOSHO 2 | 132 | 3WNDTR | OMOTOSHO TR2 | WND 2 | 1 | 137.7 | 120 | 114.8 |
| 73001 | ONITSHA 3 | 330 | 3WNDTR | ONITSH T3A | WND 1 | 1 | 152.4 | 150 | 101.6 |
| 73001 | ONITSHA 3 | 330 | 3WNDTR | ONITSHA T4 | WND 1 | 1 | 157.6 | 150 | 105.1 |
| 22001 | OSOGBO 1 | 132 | 3WNDTR | OSOGBO 4T1 | WND 2 | 1 | 134.9 | 120 | 112.5 |
| 22001 | OSOGBO 1 | 132 | 3WNDTR | OSOGBO 4T6 | WND 2 | 1 | 134.9 | 120 | 112.5 |
| 22001 | OSOGBO 1 | 132 | 3WNDTR | OSOGBO N T5 | WND 2 | 5 | 134.9 | 120 | 112.5 |
| 82028 | OWERRI 1 | 132 | 3WNDTR | OWERRI TR1 | WND 1 | 1 | 70.1 | 60 | 116.8 |
| 83005 | OWERRI_3 | 330 | 3WNDTR | OWERRI T1A | WND 1 | 1 | 160.6 | 150 | 107.1 |
| 32027 | WESTMAIN_1 | 132 | 3WNDTR | EASTMAIN TR1 | WND 2 | 1 | 135.3 | 120 | 112.7 |
| 32027 | WESTMAIN_1 | 132 | 3WNDTR | EASTMAIN2 | WND 2 | 2 | 135.3 | 120 | 112.7 |

Source: JICA Study Team

The 132/33 kV and 132/11 kV transformers overloaded above their 100% MVA rating under normal (base case) operation, listed in Table 7-5.8, are in addition to those overloaded in 2020 and must be upgraded. Some of these transformers, shown in bold, have already been reported in the 2020 case as being overloaded above their 85% rating:

**Table 7-5.8 Overloaded 132/33 kV transformers**

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | cct | Load (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|
| 82026 | ABA 1 | 132 | 86020 | ABA T1A 6.6 | 6.6 | 1 | 8.6 | 7.5 | 114 |
| 82026 | ABA 1 | 132 | 85023 | ABA T4A(MOB) | 33 | 1 | 17.5 | 15 | 116.4 |
| 72016 | ABAKALIKI 1 | 132 | 75001 | ABAKALIKI 33 | 33 | 1 | 72.1 | 60 | 120.2 |
| **82000** | **AFAM 1-2-3** | **132** | **86000** | **AFAM 11** | **11** | **1** | **119.3** | **64** | **186.4** |
| 82018 | AHOADA 1 | 132 | 85038 | AHOADA T2 | 33 | 2 | 42.9 | 40 | 107.4 |
| 12000 | AJA 132 | 132 | 15003 | AJA 33 | 33 | 1 | 107.2 | 60 | 178.6 |
| 42000 | AJAOKUTA 1 | 132 | 45033 | AJAOKUTA T2 | 33 | 1 | 64.8 | 60 | 107.9 |
| 12004 | AKANGBA BBII | 132 | 15053 | AKANGBA 33 | 33 | 1 | 67.8 | 60 | 113 |
| 12016 | AKOKA 1 | 132 | 15067 | AKOKA T2 | 33 | 1 | 47.6 | 40 | 119 |
| 22005 | AKURE 1 | 132 | 25003 | AKURE 33 | 33 | 1 | 40.9 | 30 | 136.4 |
| 22005 | AKURE 1 | 132 | 25028 | AKURE T2A | 33 | 2 | 46.7 | 30 | 155.6 |
| 22005 | AKURE 1 | 132 | 25018 | AKURE T3A 33 | 33 | 1 | 82.6 | 60 | 137.7 |
| 12017 | ALAGBON 1 | 132 | 15008 | ALAGBON 33 | 33 | 1 | 70.9 | 66 | 107.4 |
| 12017 | ALAGBON 1 | 132 | 15008 | ALAGBON 33 | 33 | 2 | 70.9 | 66 | 107.4 |
| 12019 | ALIMOSHO 1 | 132 | 15010 | ALIMOSHO 33 | 33 | 1 | 37.8 | 30 | 125.9 |
| **12019** | **ALIMOSHO 1** | **132** | **15072** | **ALIMOSHO T1** | **33** | **3** | **48.5** | **30** | **161.6** |
| 42015 | AMUKPE 1 | 132 | 45026 | AMUKPE BB 33 | 33 | 1 | 68.3 | 60 | 113.9 |
| 12054 | ARIGBAJO 1 | 132 | 15062 | ARIGBAJO 33 | 33 | 1 | 61.1 | 60 | 101.9 |
| 12054 | ARIGBAJO 1 | 132 | 15062 | ARIGBAJO 33 | 33 | 2 | 61.1 | 60 | 101.9 |
| 22000 | AYEDE 1 | 132 | 25004 | AYEDE 33 | 33 | 1 | 107.1 | 100 | 107.1 |
| 22000 | AYEDE 1 | 132 | 25045 | AYEDE 33 | 33 | 3 | 81.3 | 60 | 135.5 |
| 42004 | BENIN 1 | 132 | 45000 | BENIN 33 | 33 | 1 | 67.8 | 60 | 112.9 |
| 42004 | BENIN 1 | 132 | 45000 | BENIN 33 | 33 | 9 | 67.8 | 60 | 112.9 |

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | cct | Load (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|
| 52007 | DAN AGUNDI 1 | 132 | 55001 | DAN AGUNDI 3 | 33 | 1 | 73.2 | 60 | 122 |
| 12002 | EGBIN 1 | 132 | 15033 | EGBIN 33 | 33 | 1 | 46.9 | 40 | 117.2 |
| 12023 | EJIGBO 1 | 132 | 15014 | EJIGBO 33 | 33 | 1 | 46.2 | 30 | 153.9 |
| 12023 | EJIGBO 1 | 132 | 15014 | EJIGBO 33 | 33 | 2 | 46.2 | 30 | 153.9 |
| **12023** | **EJIGBO 1** | **132** | **15128** | **EJIGBO 33** | **33** | **1** | **46.2** | **30** | **153.9** |
| **12023** | **EJIGBO 1** | **132** | **15128** | **EJIGBO 33** | **33** | **2** | **46.2** | **30** | **153.9** |
| 12023 | EJIGBO 1 | 132 | 15016 | EJIGBO BBI 3 | 33 | 1 | 104.6 | 100 | 104.6 |
| 82005 | EKET 1 | 132 | 85003 | EKET 33 | 33 | 2 | 80.2 | 60 | 133.6 |
| **82005** | **EKET 1** | **132** | **85002** | **EKET T1B** | **33** | **1** | **96.3** | **45** | **213.9** |
| 82035 | ELELENWO 1 | 132 | 85036 | ELENLEWO 33 | 33 | 1 | 42.1 | 40 | 105.3 |
| 82035 | ELELENWO 1 | 132 | 85036 | ELENLEWO 33 | 33 | 2 | 42.1 | 40 | 105.3 |
| **22022** | **GANM0 T1 BB** | **132** | **25032** | **GANMO T1** | **33** | **1** | **118.5** | **60** | **197.5** |
| 62029 | GASHUWA 1 | 132 | 65062 | GASHUWA T2A | 33 | 2 | 54.9 | 45 | 122 |
| 62029 | GASHUWA 1 | 132 | 65061 | GASHUWAT1A | 33 | 1 | 54.9 | 45 | 122 |
| 52011 | GUSAU 1 | 132 | 55004 | GUSAU 33 | 33 | 1 | 40.6 | 30 | 135.4 |
| 52011 | GUSAU 1 | 132 | 55046 | GUSAU T1 | 33 | 2 | 35.6 | 30 | 118.5 |
| 22006 | IBADAN NORTH | 132 | 25007 | IBADAN NORTH | 33 | 1 | 88.3 | 60 | 147.2 |
| 22006 | IBADAN NORTH | 132 | 25042 | IBADAN T2 BB | 33 | 2 | 79.3 | 60 | 132.2 |
| 22028 | IJEBU-ODE 1 | 132 | 25041 | IJEBU T1 BB | 33 | 1 | 60.6 | 60 | 101 |
| 12024 | IJORA 1 | 132 | 15045 | IJORA T1A&B | 33 | 2 | 33.2 | 30 | 110.8 |
| 12024 | IJORA 1 | 132 | 15046 | IJORA T2B | 33 | 2 | 36.1 | 30 | 120.4 |
| 12025 | IKORODU | 132 | 15050 | IKORODU T3 | 33 | 3 | 102.5 | 100 | 102.5 |
| 82031 | IKOT_ABASI | 132 | 85092 | IKOT ABAS 33 | 33 | 1 | 52.3 | 40 | 130.9 |
| 82031 | IKOT_ABASI | 132 | 85092 | IKOT ABAS 33 | 33 | 2 | 52.3 | 40 | 130.9 |
| 22009 | ILESHA 1 | 132 | 25010 | ILESHA 33 | 33 | 1 | 40.1 | 40 | 100.3 |
| 22009 | ILESHA 1 | 132 | 25031 | ILESHA T1 | 33 | 2 | 40.1 | 40 | 100.3 |
| 12026 | ILLUPEJU 1 | 132 | 16033 | ILLUPEJU T2 | 11 | 3 | 31 | 30 | 103.2 |
| 12026 | ILLUPEJU 1 | 132 | 16025 | ILUPEJU 11 | 11 | 2 | 15.1 | 15 | 100.8 |
| 12026 | ILLUPEJU 1 | 132 | 15027 | ILUPEJU 33 | 33 | 1 | 32 | 30 | 106.7 |
| 42008 | IRRUA 1 | 132 | 45002 | IRRUA 33 | 33 | 1 | 79.1 | 60 | 131.9 |
| 22011 | ISEYIN 1 | 132 | 25012 | ISEYIN 33 | 33 | 1 | 46.8 | 45 | 104 |
| 22011 | ISEYIN 1 | 132 | 25049 | ISEYIN T2 33 | 33 | 1 | 40.8 | 30 | 136.1 |
| 12027 | ISOLO 1 | 132 | 15028 | ISOLO 33 | 33 | 1 | 77.6 | 60 | 129.4 |
| 12020 | ITIRE 1 | 132 | 16034 | ITERE T3 | 11 | 2 | 44.9 | 40 | 112.1 |
| 12020 | ITIRE 1 | 132 | 16032 | ITIRE 11 | 11 | 1 | 33.4 | 30 | 111.2 |
| **22008** | **IWO 1** | **132** | **25002** | **IWO 33** | **33** | **1** | **45.8** | **40** | **114.5** |
| **22008** | **IWO 1** | **132** | **25002** | **IWO 33** | **33** | **2** | **45.8** | **40** | **114.5** |
| 62020 | JALINGO 1 | 132 | 65015 | JALINGO 33B | 33 | 1 | 32.4 | 30 | 108 |
| 22012 | JERICHO 1 | 132 | 25013 | JERICHO2 33 | 33 | 1 | 66.4 | 40 | 166.1 |
| 62001 | JOS 1 | 132 | 65005 | JOS T4 60MVA | 33 | 2 | 99.7 | 60 | 166.2 |
| 52003 | KADUNA TOWN | 132 | 55006 | KADUNA TOWN | 33 | 1 | 33.6 | 30 | 111.9 |
| 52003 | KADUNA TOWN | 132 | 55061 | KD TWN T1 | 33 | 2 | 33.6 | 30 | 111.9 |
| 62025 | KAFANCHAN 1 | 132 | 65037 | KAFANC M TR1 | 33 | 3 | 55.2 | 40 | 138.1 |
| 52001 | KANO 1 | 132 | 55057 | KUMB T2 | 33 | 1 | 53 | 40 | 132.5 |
| 52001 | KANO 1 | 132 | 55059 | KUMB T4 | 33 | 4 | 68.8 | 60 | 114.7 |
| 52029 | KANO_NEW132 | 132 | 55070 | KANOII 33 | 33 | 1 | 72.7 | 60 | 121.2 |
| 52029 | KANO_NEW132 | 132 | 55070 | KANOII 33 | 33 | 2 | 72.7 | 60 | 121.2 |
| 52012 | KATSINA 1 | 132 | 55056 | KATSINA T3 | 33 | 3 | 41.7 | 30 | 139.1 |
| 52042 | KAZAURE 1 | 132 | 55092 | KAZAURE 33 | 33 | 1 | 32.4 | 30 | 108 |
| 52042 | KAZAURE 1 | 132 | 55092 | KAZAURE 33 | 33 | 2 | 32.4 | 30 | 108 |
| 62024 | MAKERI 1 | 132 | 65033 | MAKERI 33 | 33 | 1 | 30.3 | 30 | 101.1 |

| Bus Number | Bus Name | Voltage (kV) | Bus Number | Bus Name | Voltage (kV) | cct | Load (MVA) | Rating (MVA) | Loading (%) |
|---|---|---|---|---|---|---|---|---|---|
| 72002 | NHAVEN 1 | 132 | 75039 | NHAV TR2 | 33 | 2 | 32 | 30 | 106.6 |
| 72002 | NHAVEN 1 | 132 | 75041 | NHAV TR4 | 33 | 4 | 68 | 60 | 113.4 |
| 72011 | NKALAGU 1 | 132 | 75044 | NKALGU T1A | 33 | 2 | 31.9 | 30 | 106.3 |
| **12055** | **ODOGUNYAN 1** | **132** | **15063** | **ODOGUNYA 33** | **33** | **1** | **84.4** | **60** | **140.6** |
| **12055** | **ODOGUNYAN 1** | **132** | **15063** | **ODOGUNYA 33** | **33** | **2** | **84.4** | **60** | **140.6** |
| 12032 | OGBA 1 | 132 | 16027 | OGBA 11 | 11 | 1 | 20.4 | 20 | 102 |
| 12029 | OJO 1 | 132 | 15030 | OJO 33 | 33 | 2 | 33.5 | 30 | 111.6 |
| **12029** | **OJO 1** | **132** | **15047** | **OJO T3_T4** | **33** | **5** | **85.2** | **60** | **142** |
| 22017 | ONDO2 1 | 132 | 25017 | ONDO1 33 | 33 | 1 | 63.7 | 60 | 106.2 |
| 72001 | ONITSHA 1 | 132 | 75037 | ONITSH TR14 | 33 | 5 | 42.9 | 40 | 107.2 |
| 72001 | ONITSHA 1 | 132 | 75038 | ONITSHA TR11 | 33 | 4 | 65.1 | 60 | 108.4 |
| 22001 | OSOGBO 1 | 132 | 25026 | OSOGBO 33 | 33 | 3 | 64.8 | 60 | 108 |
| 22001 | OSOGBO 1 | 132 | 25029 | OSOGBO T1 | 33 | 1 | 41.3 | 30 | 137.7 |
| 22001 | OSOGBO 1 | 132 | 25030 | OSOGBO T2 | 33 | 2 | 34.9 | 30 | 116.3 |
| 12033 | OTTA 1 | 132 | 15079 | OTTA T2 | 33 | 2 | 76.8 | 60 | 127.9 |
| 82028 | OWERRI 1 | 132 | 85020 | OWERR T1MOB | 33 | 1 | 40.2 | 40 | 100.6 |
| 12034 | OWOROSOKI 1 | 132 | 15020 | OWOROSOKI 33 | 33 | 1 | 64.7 | 60 | 107.8 |
| **12037** | **PARAS_1** | **132** | **15116** | **AFR FOUNDRY** | **33** | **1** | **62.9** | **40** | **157.2** |
| 12037 | PARAS_1 | 132 | 15115 | PARAS IPP | 33 | 1 | 43.8 | 40 | 109.6 |
| 12037 | PARAS_1 | 132 | 15115 | PARAS IPP | 33 | 2 | 65.8 | 60 | 109.6 |
| 82008 | PHCT TOWN1 1 | 132 | 85027 | PHCT T1A | 33 | 2 | 63.4 | 60 | 105.6 |
| 82009 | PHCT TOWN2 1 | 132 | 86018 | PHCT TOWN 11 | 11 | 1 | 65.6 | 60 | 109.3 |
| 82036 | RUMUSOI 1 | 132 | 85060 | RUMUSOI T133 | 33 | 1 | 70 | 60 | 116.7 |
| 82036 | RUMUSOI 1 | 132 | 85061 | RUMUSOI T233 | 33 | 1 | 70 | 60 | 116.7 |
| 62012 | SAVANNAH 1 | 132 | 65010 | SAVANNAH 33 | 33 | 1 | 18.4 | 15 | 122.5 |
| 22027 | SHAGAMU 1 | 132 | 25040 | SHAGAM T2 BB | 33 | 2 | 38 | 30 | 126.6 |
| **22027** | **SHAGAMU 1** | **132** | **25035** | **SHAGAMU 33** | **33** | **1** | **59.1** | **30** | **197.1** |
| 12036 | SHAGAMU CEME | 132 | 16007 | SHAG CEM 11 | 11 | 1 | 16.1 | 15 | 107.4 |
| 12036 | SHAGAMU CEME | 132 | 16038 | SHAG CEM 11 | 11 | 2 | 16.1 | 15 | 107.4 |
| **32001** | **SHIRORO 1** | **132** | **35013** | **SHIRORO 33** | **33** | **1** | **51.3** | **30** | **171** |
| 32016 | SOKOTO 1 | 132 | 35050 | SOKOTO T3 | 33 | 3 | 41.8 | 30 | 139.5 |
| 32017 | SULEJA 1 | 132 | 35047 | SULEJA T3 | 33 | 2 | 41.4 | 30 | 138.1 |
| 32014 | TEGINA 1 | 132 | 35015 | TEGINA 33 | 33 | 1 | 42.6 | 30 | 142.1 |
| **42002** | **UGHELLI 1** | **132** | **45001** | **UGHELLI 33** | **33** | **1** | **92.6** | **60** | **154.3** |
| 82027 | UMUAHIA 1 | 132 | 85024 | UMUAHIA 33 | 33 | 1 | 44.5 | 40 | 111.2 |
| 82027 | UMUAHIA 1 | 132 | 85024 | UMUAHIA 33 | 33 | 2 | 44.5 | 40 | 111.2 |
| 82010 | UYO 1 | 132 | 85007 | UYO 33 | 33 | 3 | 95.2 | 60 | 158.7 |
| 82010 | UYO 1 | 132 | 85030 | UYO T2B | 33 | 1 | 51 | 40 | 127.4 |
| 82010 | UYO 1 | 132 | 85030 | UYO T2B | 33 | 2 | 51 | 40 | 127.4 |

#### 7-5-4-3 Reactive Power Compensation Requirements

**(1) SVC requirements**

No SVC is needed in 2025, but more detailed and dedicated studies will subsequently be necessary stage to determine any need for such equipment in the post-2025 period.

In 2025, in addition to the reactors and capacitors listed in Table 7-5.9, Table 7-5.10, Table 7-5.11 and

Table 7-5.12, reactive power compensation (150 MVar capacitors) will be required at Bernin Kebbi due to export requirements to WAPP. It should be noted however that in 2030, the proposed supergrid will be extended with a Kainji-Bernin Kebbi line. Once this is implemented, there will be no further need for reactive power compensation at Bernin Kebbi.

With regards to Gombe, should additional reactive power compensation be required at lightly loaded conditions, instead of SVC, a more cost-effective option would be relocating from other S/S to Gombe approximately 100-150 MVar of reactors that, as this analysis has shown, are no longer needed there.

As was shown in the static security analysis for 2025, a more appropriate candidate for an SVC (or in fact only capacitors, given the lack of MVars) could be the Lagos/Ikeja/Eko region, where there is a reactive power deficit of approximately 400-500 MVar. It should be noted however that this deficit is expected to ease when the DisCos implement the reactive power control program at distribution level, as proposed and in line with the Grid Code requirements, as well as when transmission lines and transformers are upgraded, as has been shown in previous chapters of this report.

### (2) Reactors

The status of reactors required in the Dry Season Peak case is shown in Table 7-5.9.

**Table 7-5.9 Reactor requirements for the 2025 Dry Season Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | B-Shunt (MVar) |
|---|---|---|---|---|---|
| 63005 | MAIDUGURI 3 | 330 | 2 | 1 | -75 |
| 65001 | YOLA T1 33 | 33 | 1 | 1 | -30 |
| 65014 | GOMBE T4A | 33 | 1 | 1 | -30 |

Source: JICA Study Team

The status of reactors required in the Dry Season Off-Peak case is shown in Table 7-5.10.

**Table 7-5.10 Reactor requirements for the 2025 Dry Season Off-Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | B-Shunt (MVar) |
|---|---|---|---|---|---|
| 53001 | KANO 3 | 330 | 1 | 1 | -75 |
| 53005 | KANO_NEW330 | 330 | 1 | 1 | -75 |
| 63001 | JOS 3 | 330 | 1 | 1 | -75 |
| 63002 | YOLA 3 | 330 | 1 | 1 | -75 |
| 63002 | YOLA 3 | 330 | 2 | 1 | -75 |
| 63005 | MAIDUGURI 3 | 330 | 2 | 1 | -75 |
| 63000 | GOMBE 3 | 330 | 1 | 1 | -50 |
| 63000 | GOMBE 3 | 330 | 2 | 1 | -50 |
| 65001 | YOLA T1 33 | 33 | 1 | 1 | -30 |
| 65014 | GOMBE T4A | 33 | 1 | 1 | -30 |
| 63006 | JALINGO_3 | 330 | 1 | 1 | -10 |

Source: JICA Study Team

### (3) Capacitors

The status of capacitors required in the Dry Season Peak case is shown in Table 7-5.11.

**Table 7-5.11 Capacitor requirements for the 2025 Dry Season Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 75004 | AWKA 33 | 33 | 1 | 1 | 10 |
| 75012 | OJI RIVER 33 | 33 | 1 | 1 | 10 |
| 15002 | AGBARA 33 | 33 | 1 | 1 | 20 |
| 15011 | ABEOKUTA OLD | 33 | 2 | 1 | 20 |
| 15022 | IKORODU 33 | 33 | 2 | 1 | 20 |
| 15027 | ILUPEJU 33 | 33 | 1 | 1 | 20 |
| 15030 | OJO 33 | 33 | 1 | 1 | 20 |
| 25004 | AYEDE 33 | 33 | 1 | 1 | 20 |
| 25012 | ISEYIN 33 | 33 | 1 | 1 | 20 |
| 25018 | AKURE T3A 33 | 33 | 1 | 1 | 20 |
| 25035 | SHAGAMU 33 | 33 | 1 | 1 | 20 |
| 25038 | IJEBU-ODE 33 | 33 | 1 | 1 | 20 |
| 35000 | AKWANGA 33 | 33 | 1 | 1 | 20 |
| 35001 | APO 33 | 33 | 2 | 1 | 20 |
| 35009 | KONTAGORA 33 | 33 | 1 | 1 | 20 |
| 35012 | MINNA 33 | 33 | 1 | 1 | 20 |
| 35048 | MINNA T2 | 33 | 2 | 1 | 20 |
| 42014 | EFFURUN 1 | 132 | 2 | 1 | 20 |
| 42015 | AMUKPE 1 | 132 | 1 | 1 | 20 |
| 45003 | OKENE 33 | 33 | 1 | 1 | 20 |
| 52022 | HADEJIA 1 | 132 | 1 | 1 | 20 |
| 55001 | DAN AGUNDI 3 | 33 | 2 | 1 | 20 |
| 55010 | KATSINA 33 | 33 | 1 | 1 | 20 |
| 55011 | ZARIA 33 | 33 | 1 | 1 | 20 |
| 55032 | MALUMFASHI_3 | 33 | 1 | 1 | 20 |
| 55051 | DAKATA T2 | 33 | 1 | 1 | 20 |
| 55057 | KUMB T2 | 33 | 1 | 1 | 20 |
| 55069 | KD TWN T2 | 33 | 1 | 1 | 20 |
| 55072 | KD TWN T3 | 33 | 1 | 1 | 20 |
| 72009 | AWKA 1 | 132 | 1 | 1 | 20 |
| 75002 | APIR 33 | 33 | 1 | 1 | 20 |
| 75017 | YANDEV 33 | 33 | 1 | 1 | 20 |
| 75048 | APIR_33B | 33 | 1 | 1 | 20 |
| 15006 | AKANGBA 33 | 33 | 1 | 1 | 24 |
| 15007 | AKOKA T1 33 | 33 | 1 | 1 | 24 |
| 15009 | ALAUSA 33 | 33 | 1 | 1 | 24 |
| 15010 | ALIMOSHO 33 | 33 | 1 | 1 | 24 |
| 15014 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 15015 | IJORA 33 | 33 | 1 | 1 | 24 |
| 15018 | OGBA 33 | 33 | 1 | 1 | 24 |
| 15028 | ISOLO 33 | 33 | 1 | 1 | 24 |
| 15079 | OTTA T2 | 33 | 1 | 1 | 24 |
| 15080 | OLD ABEOK T2 | 33 | 3 | 1 | 24 |
| 15128 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 22017 | ONDO2 1 | 132 | 1 | 1 | 24 |
| 25011 | ILORIN 33 | 33 | 1 | 1 | 24 |

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 25012 | ISEYIN 33 | 33 | 2 | 1 | 24 |
| 42008 | IRRUA 1 | 132 | 1 | 1 | 24 |
| 45027 | IRRUA BBII33 | 33 | 1 | 1 | 24 |
| 32012 | KEFFI 1 | 132 | 1 | 1 | 25 |
| 82006 | ITU 1 | 132 | 1 | 1 | 40 |
| 22015 | OMUARAN 1 | 132 | 1 | 1 | 50 |
| 35036 | GWAGWALAD 33 | 33 | 1 | 1 | 50 |
| 52022 | HADEJIA 1 | 132 | 2 | 1 | 50 |
| 53001 | KANO 3 | 330 | 2 | 1 | 50 |
| 53001 | KANO 3 | 330 | 3 | 1 | 50 |
| 32006 | APO 1 | 132 | 1 | 1 | 60 |
| 32017 | SULEJA 1 | 132 | 1 | 1 | 60 |
| 12004 | AKANGBA BBII | 132 | 1 | 1 | 72 |
| 12032 | OGBA 1 | 132 | 1 | 1 | 72 |
| 82010 | UYO 1 | 132 | 1 | 1 | 100 |

Source: JICA Study Team

The status of capacitors required in the Dry Season Off-Peak case is shown in Table 7-5.12.

**Table 7-5.12 Capacitor requirements for the 2025 Dry Season Off-Peak**

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 15002 | AGBARA 33 | 33 | 1 | 1 | 20 |
| 15011 | ABEOKUTA OLD | 33 | 2 | 1 | 20 |
| 15022 | IKORODU 33 | 33 | 2 | 1 | 20 |
| 15027 | ILUPEJU 33 | 33 | 1 | 1 | 20 |
| 25004 | AYEDE 33 | 33 | 1 | 1 | 20 |
| 25012 | ISEYIN 33 | 33 | 1 | 1 | 20 |
| 25018 | AKURE T3A 33 | 33 | 1 | 1 | 20 |
| 25035 | SHAGAMU 33 | 33 | 1 | 1 | 20 |
| 25038 | IJEBU-ODE 33 | 33 | 1 | 1 | 20 |
| 35001 | APO 33 | 33 | 2 | 1 | 20 |
| 35012 | MINNA 33 | 33 | 1 | 1 | 20 |
| 42014 | EFFURUN 1 | 132 | 2 | 1 | 20 |
| 42015 | AMUKPE 1 | 132 | 1 | 1 | 20 |
| 45003 | OKENE 33 | 33 | 1 | 1 | 20 |
| 52022 | HADEJIA 1 | 132 | 1 | 1 | 20 |
| 55001 | DAN AGUNDI 3 | 33 | 2 | 1 | 20 |
| 55010 | KATSINA 33 | 33 | 1 | 1 | 20 |
| 15006 | AKANGBA 33 | 33 | 1 | 1 | 24 |
| 15007 | AKOKA T1 33 | 33 | 1 | 1 | 24 |
| 15009 | ALAUSA 33 | 33 | 1 | 1 | 24 |
| 15010 | ALIMOSHO 33 | 33 | 1 | 1 | 24 |
| 15014 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 15015 | IJORA 33 | 33 | 1 | 1 | 24 |
| 15028 | ISOLO 33 | 33 | 1 | 1 | 24 |
| 15079 | OTTA T2 | 33 | 1 | 1 | 24 |
| 15128 | EJIGBO 33 | 33 | 1 | 1 | 24 |
| 22017 | ONDO2 1 | 132 | 1 | 1 | 24 |
| 25011 | ILORIN 33 | 33 | 1 | 1 | 24 |
| 25012 | ISEYIN 33 | 33 | 2 | 1 | 24 |
| 42008 | IRRUA 1 | 132 | 1 | 1 | 24 |

| Bus Number | Bus Name | Voltage (kV) | Id | In Service | Capacity (MVar) |
|---|---|---|---|---|---|
| 45027 | IRRUA BBII33 | 33 | 1 | 1 | 24 |
| 52022 | HADEJIA 1 | 132 | 2 | 1 | 24 |
| 32012 | KEFFI 1 | 132 | 1 | 1 | 25 |
| 82006 | ITU 1 | 132 | 1 | 1 | 40 |
| 32021 | NIAMEY 1 | 132 | 2 | 1 | 45 |
| 22015 | OMUARAN 1 | 132 | 1 | 1 | 50 |
| 32006 | APO 1 | 132 | 1 | 1 | 60 |
| 12004 | AKANGBA BBII | 132 | 1 | 1 | 72 |
| 82010 | UYO 1 | 132 | 1 | 1 | 100 |

Source: JICA Study Team

### 7-5-5 Expansion Plan for 2025

In addition to the projects undertaken by TCN and NIPP, the following 330 and 132 kV lines, shown in Table 7-5.13, are included in the 2025 model. These are also in addition to those included in the 2020 model. A priority ranking from 1 to 3 has been included in the table, with 1 denoting the highest priority.

**Table 7-5.13 Additional lines required by 2025 (1)**

| No | Area | From | To | | Voltage (kV) | Length (km) | Remarks | Priority/ Ranking |
|---|---|---|---|---|---|---|---|---|
| 1 | | Ejio (Arigbajo) | Ayede | SC | 330 | 50 | Turn-in/out Ejio (Arigbajo)-Osogbo line at Ayede, or have one direct line Ikeja West-Ayede, instead of two lines: Ikeja West Ejio (Arigbajo) and Ejio (Arigbajo)-Osogbo | 1 |
| 2 | Part of North-West Ring | Birnin-Kebbi | Sokoto | DC | 330 | 130 | in parallel of existing 132 kV | 3 |
| 3 | | Sokoto | Talata Mafara | DC | 330 | 100 | | 3 |
| 4 | | Talata Mafara | Gusau | DC | 330 | 125 | | 3 |
| 5 | | Gusau | Funtua | DC | 330 | 70 | | 2 |
| 6 | | Funtua | Zaria | DC | 330 | 70 | | 2 |
| 7 | | Olorusongo | Ejio (Arigbajo) | DC | 330 | 20 | JICA.<br>Already a DC. 4 circuits are required, or conversion of the two circuits from twin to Quad-bundle conductors. | 2 |
| 8 | | Katsina | Daura | DC | 330 | 40 | Undertaken by TCN as part of the Northern Corridor Transmission projects 2, to be financed by AFD | 2 |
| 9 | | Daura | Kazaure | DC | 330 | 25 | Undertaken by TCN as part of the Northern Corridor Transmission projects 2, to be financed by AFD | 2 |
| 10 | Part of North-East Ring | Damaturu | Maiduguri | DC | 330 | 260 | If not by 2020, implement as soon as possible thereafter (An SC already exists.) | 3 |
| 11 | | Gombe | Daimaturu | DC | 330 | 160 | If not by 2020, implement as soon as possible thereafter (An SC already exists.) | 3 |
| 12 | | Gombe | Yola | DC | 330 | 240 | If not by 2020, implement as soon as possible thereafter (An SC already exists.) | 3 |
| 13 | | Yola | Jalingo | DC | 330 | 160 | If not by 2020, implement as soon as possible thereafter (1 SC via Mayo Belwa) | 3 |
| 14 | Mambila evacuation | Mambila | Jalingo | 2xDC | 330 | 95 | 2xDC only if N-2 is adopted, otherwise 1xDC | 1 |

| No | Area | From | To | | Voltage (kV) | Length (km) | Remarks | Priority/ Ranking |
|---|---|---|---|---|---|---|---|---|
| 15 | | Mambila | Wukari | 2xDC | 330 | 159 | 2xDC only if N-2 is adopted, otherwise 1xDC | 1 |
| 16 | | Wukari | Makurdi | DC | 330 | 159 | | 1 |
| 16 | | Wukari | Lafia | DC | 330 | 95 | after 2025 | 3 |
| 18 | | Shiroro | Kaduna | DC | 330 | 96 | or upgrade to 4-b (Quad). Two DC project with Quad conductors is undertaken by TCN as part of the Northern Corridor Transmission projects 2, to be financed by AFD | 3 |
| 19 | | Ejio (Arigbajo) | Ajegunle (New Agbara) | DC | 330 | 40 | JICA. | 2 |
| 20 | | Ejio (Arigbajo) | Likosi (Ogijo) | DC | 330 | 48 | JICA. | 2 |
| 21 | | Ajegunle (New Agbara) | Badagry | DC | 132 | 32 | JICA. | 2 |
| 22 | | Ejio (Arigbajo) | New Ajeokuta | DC | 132 | 37 | JICA. | 2 |
| 23 | | Gwangwalada | Shiroro | DC | 330 | | a SC exists | 1 |
| 24 | | Benin North | Omotosho | DC | 330 | 110 | Quad conductors. May be required before 2025 and as early as 2022 for the evacuation of new Ethiope PP | 1 |
| 25 | | Zungeru | Kainji | DC | 330 | 200 | | 2 |
| 26 | | Zungeru | Shiroro | DC | 330 | 25 | | 2 |
| 27 | Part of the future Supergrid | Ikot-Ekpene | Makurdi | DC | 330 | 320 | | 1 |
| 28 | | Makurdi | Gwangwalada | DC | 330 | 180 | | 1 |
| 29 | | Ajaokouta | Gwangwalada | DC | 330 | 150 | | 1 |
| 30 | | Osogbo | Gwangwalada | DC | 330 | 250 | | 1 |
| 31 | | Gwangwalada | Funtua | DC | 330 | 250 | | 1 |

Source: JICA Study Team

Furthermore, since a number of undervoltages were encountered in the Dry Season Peak case and also to meet the N-1 security criterion, the following additions, shown in Table 7-5.14, were made at 132 kV level:

**Table 7-5.14 Additional 132 kV lines required by 2025 (2)**

| No | From | To | | Voltage (kV) | Length (km) | Remarks | Priority/ Ranking |
|---|---|---|---|---|---|---|---|
| 1 | Shiroro | Tegina | SC | 132 | 65 | SC only exists. Add a second SC | 1 |
| 2 | Tegina | Kontagora | SC | 132 | 90 | SC only exists. Add a second SC | 1 |
| 3 | Kontagora | Yelwa-Yauri | SC | 132 | 88 | SC only exists. Add a second SC | 1 |
| 5 | Ganmo | Ilorin | SC | 132 | 10.5 | SC only exists. Add a second SC | 3 |
| 6 | Obajana | Egbe | DC | 132 | 97 | new DC | 1 |
| 7 | Omotosho | Ondo | DC | 132 | 98 | new DC | 1 |
| 8 | Benin | Irrua | SC | 132 | 88 | SC only exists. Add a second SC | 2 |
| 9 | Irrua | Ukpilla | SC | 132 | 43 | SC only exists. Add a second SC | 2 |
| 10 | Ukpilla | Okene | SC | 132 | 33 | SC only exists. Add a second SC | 3 |
| 11 | Shagamu | Ijebu-Ode | SC | 132 | 41 | SC only exists. Add a second SC | 3 |
| 12 | Dakata | Gagarawa | SC | 132 | 89 | SC only exists. Add a second SC | 3 |
| 13 | Gagarawa | Hadejia | SC | 132 | 60 | SC only exists. Add a second SC | 3 |
| 14 | Dakata | Kumboso | SC | 132 | 30 | SC only exists. Add a second SC | 3 |
| 15 | Obajana | Okene | DC | 132 | 97 | New DC | 2 |
| 16 | Kainji | Iseyin | DC | 132 | 200 | New DC | 1 |

Source: JICA Study Team

Due to the thermal overloads encountered under normal (N-0) operation, it is necessary for a number of 132kV lines rated 125 MVA to be reconductored with ZTACIR conductors or ACCC Oriole CTC Global conductors, already used by TCN.

The following lines shall be reconductored, as per Table 7-5.15.

The table shows the new ratings after reconductoring:

**Table 7-5.15 132 kV lines to be reconductored**

| From Bus | Bus name | To bus | Bus name | Id | Rating (MVA) | Length (km) |
|---|---|---|---|---|---|---|
| 12002 | EGBIN 1 | 12025 | IKORODU | 1 | 225 | 20 |
| 12002 | EGBIN 1 | 12025 | IKORODU | 2 | 225 | 20 |
| 12046 | OGIJO 1 | 22027 | SHAGAMU 1 | 1 | 188 | 16 |
| 12046 | OGIJO 1 | 22027 | SHAGAMU 1 | 2 | 188 | 16 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 1 | 188 | 12 |
| 22000 | AYEDE 1 | 22006 | IBADAN NORTH | 2 | 188 | 12 |
| 22000 | AYEDE 1 | 22012 | JERICHO 1 | 2 | 188 | 6 |
| 82001 | ALAOJI 1 | 82026 | ABA 1 | 1 | 188 | 10 |
| 82001 | ALAOJI 1 | 82026 | ABA 1 | 2 | 188 | 10 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 1 | 188 | 45 |
| 82005 | EKET 1 | 82024 | IBOM IPP 1 | 2 | 188 | 45 |
| 82007 | PHCT MAIN1 | 82009 | PHCT TOWN2 1 | 1 | 188 | 6 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 1 | 188 | 10 |
| 82007 | PHCT MAIN1 | 82036 | RUMUSOI 1 | 2 | 188 | 10 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 1 | 225 | 20 |
| 82019 | OMOKU 1 | 82036 | RUMUSOI 1 | 2 | 225 | 20 |

Source: JICA Study Team

## 7-6 Examination of the Need for a Supergrid

### 7-6-1 Requirement for Supergrid (330, 500 or 750 kV)

The load-flow simulations with generation and load, as detailed in the previous Section, showed that without a major upgrade of the transmission system, widespread undervoltages and overloads will proliferate throughout the system and at all voltage levels, leading to high system losses. It is therefore considered necessary and appropriate at this stage to roll out the new “supergrid” in full, i.e. a backbone for bulk transmission at 330, 500 or 750 kV. In addition to the supergrid transmission lines, other 330 kV transmission lines have also been considered and assessed, as per TCN’s request, such as:

- Yola-Little Gombi-Biu-Damaturu
- Damaturu-Potiskum-Azare-Dutse-Jogana
- Osogbo-Okene-Ajeokuta-Ayangba-Makurdi
- Mambila-Kashimbila-Ogoja-Ibom-Calabar
- Ugheli (Delta)-Onne (PH)
- Ugheli-Okpai

The following lines, requested to be assessed by TCN, were already introduced in 2025:

- Zunkeru-Kainji
- Zunkeru-Shiroro

With regards to the conductor necessary for each supergrid option, the following arrangements are recommended:

- At 330 kV a Double-Circuit is proposed with 4-bundle (Quad) Bison conductors for each circuit.
- At 500 kV a Single-Circuit is proposed with 4-bundle (Quad) Bison conductors.
- At 750 kV a Single-Circuit is proposed with 5-bundle Bison conductors, which is typical at this voltage level due to corona phenomenon.

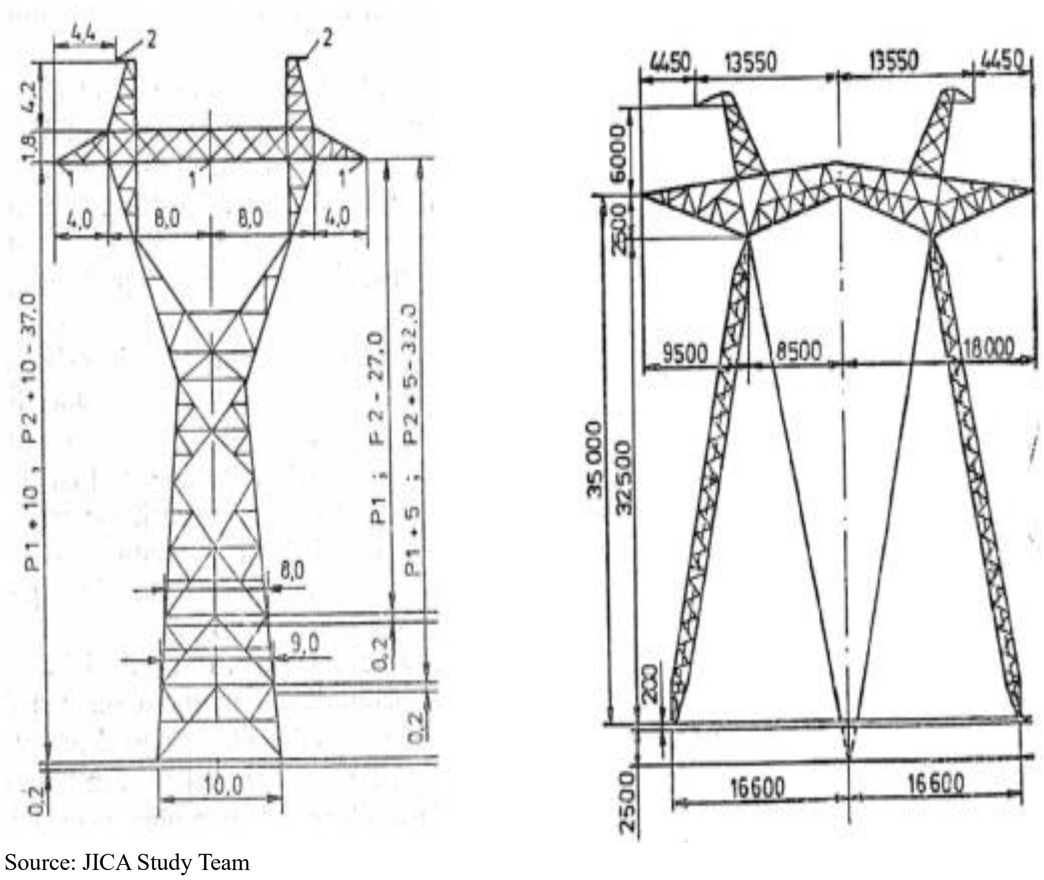
The main electrical characteristics are summarized in Table 7-6.1.

**Table 7-6.1 Conductor parameters for the proposed supergrid**

| Voltage Level | | No of Conductors of bundle | R (omhs/km) | L (mH/km) | X (Ω/km) | C (μF/km) | C (nF/km) | Thermal Rating (MVA) | Zs (ohms) | SIL (MW) |
|---|---|---|---|---|---|---|---|---|---|---|
| 330 kV | DC | 4 | 0.019 | 0.7962 | 0.25 | 0.014 | 14 | 2x1,550 | 238.5 | 456 |
| 500 kV | SC | 4 | 0.019 | 0.8908 | 0.2797 | 0.0127 | 12.7 | 2,350 | 264.8 | 944 |
| 750 kV | SC | 5 | 0.015 | 0.9201 | 0.2889 | 0.0123 | 12.3 | 4,400 | 273.5 | 2,057 |

Source: JICA Study Team

The proposed tower configurations for a typical SC 500 and/or 750 kV EHV grid are shown in Figure 7-6.1.



Source: JICA Study Team

**Figure 7-6.1 Towers for 500 and 750 kV EHV Grids**

### 7-6-1-1 Comparison of Load-flow Results Between the Two EHV Options

The comparison of load-flow results for 2030 between the two EHV options is summarized in Table 7-6.2. The system loading is taken between the peak and off-peak values.

**Table 7-6.2 Load-flow results for 2030**

| Voltage Level (kV) | O/V and U/V of 330 kV and above (outside 0.9-1.05) | O/L of 330 kV above 80% | Losses (MW) | Remarks |
|---|---|---|---|---|
| 330 | None | 7 circuits* | 1,124 (4.69%) | Lower losses than 500 kV (line losses are higher but no transformer losses are involved) |
| 500 | None | 12 circuits * | 1,264 (5.25%) | 206 MW (0.85%) higher losses compared to the 750-kV option |
| 750 | None | 6 circuits** | 1,058 (4.42%) | Slighter lower losses than the 330-kV option |

Source: JICA Study Team

#### (1) 330 kV System

```
BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
23001 OSOGBO 3    330.00*    2  23003 GANMO 3     330.00     2  1    626.5   777.3    80.6
23005 AKURE 3     330.00     2  43011 EYEAN_3     330.00*    4  3    641.0   777.3    82.5
43000 AJAOKUTA 3  330.00     4  43005 GEREGU      330.00*    4  1    647.7   777.3    83.3
43000 AJAOKUTA 3  330.00     4  43005 GEREGU      330.00*    4  2    647.7   777.3    83.3
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  1    648.7   777.3    83.5
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  2    648.7   777.3    83.5
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  3    648.7   777.3    83.5
```

#### (2) 500 kV System

```
BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
13000 AJA 3       330.00*    1  13034 LEKKI 330   330.00     1  1    637.0   777.0    82.0
13000 AJA 3       330.00*    1  13034 LEKKI 330   330.00     1  2    637.0   777.0    82.0
13028 ARIGBAJO    330.00*    1  23000 AYEDE 3     330.00     2  1    689.7   777.3    88.7
23001 OSOGBO 3    330.00*    2  23003 GANMO 3     330.00     2  1    651.0   777.3    83.7
23005 AKURE 3     330.00     2  43011 EYEAN_3     330.00*    4  3    760.6   777.3    97.9
43000 AJAOKUTA 3  330.00     4  43005 GEREGU      330.00*    4  1    648.6   777.3    83.4
43000 AJAOKUTA 3  330.00     4  43005 GEREGU      330.00*    4  2    648.6   777.3    83.4
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  1    651.2   777.3    83.8
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  2    651.2   777.3    83.8
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  3    651.2   777.3    83.8
43008 LOKOJA _3   330.00     4  43012 ZUMA        330.00*    4  1    662.9   777.3    85.3
43008 LOKOJA _3   330.00     4  43012 ZUMA        330.00*    4  2    662.9   777.3    85.3
```

#### (3) 750 kV System

```
BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
23005 AKURE 3     330.00     2  43011 EYEAN_3     330.00*    4  3    648.8   777.3    83.5
43000 AJAOKUTA 3  330.00*    4  43005 GEREGU      330.00     4  1    662.1   777.3    85.2
43000 AJAOKUTA 3  330.00*    4  43005 GEREGU      330.00     4  2    662.1   777.3    85.2
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  1    631.4   777.3    81.2
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  2    631.4   777.3    81.2
43002 BENIN 3     330.00     4  43004 SAPELE 3    330.00*    4  3    631.4   777.3    81.2
```

### 7-6-1-2 Conclusion on Supergrid/EHV Options

The load-flow simulations have shown that without a major upgrade of the transmission system, widespread undervoltages and overloads will proliferate system-wide and at all voltage levels, meaning high system losses.

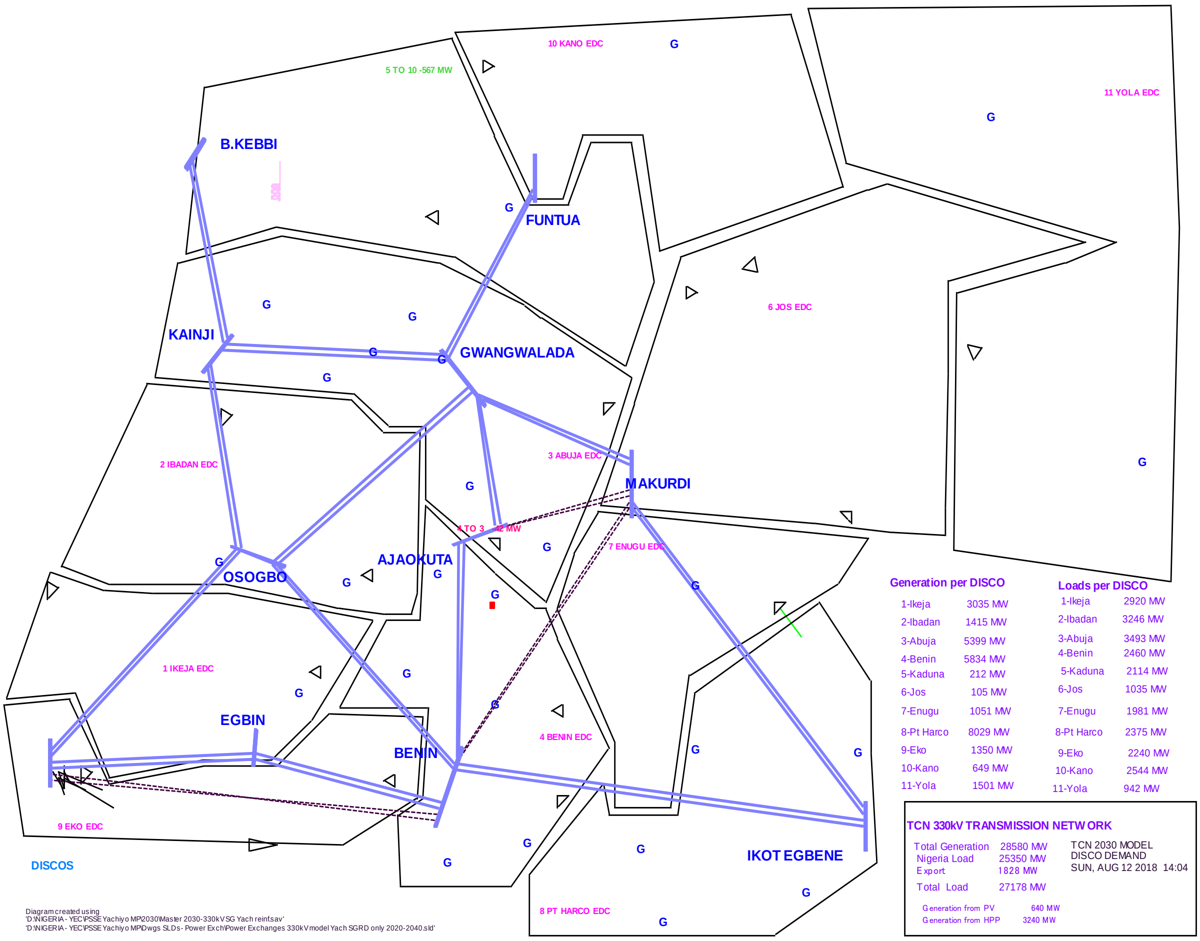
It is therefore considered necessary and appropriate at this stage to introduce the full new “supergrid”, i.e. a backbone for bulk transmission at either 330, 500 or 750 kV. It was found necessary to introduce part of this supergrid.

A number of configurations have been examined and compared in terms of efficacy in voltage support, system losses and easing the line loadings of the existing and planned 330 kV systems.

The optimum configuration of a 330, 500 or 750 kV EHV grid is shown in Figure 7-6.2.

**Table 7-6.3 Evaluation of 330, 500 or 750 kV supergrid**

| Voltage level | Voltage support | System loss | Stability | Cost | Comprehensive evaluation |
|---|---|---|---|---|---|
| 330 kV | A | A | A | B | 1 |
| 500 kV | B | A | B | A | 2 |
| 750 kV | B | A | B | C | 3 |




Source: JICA Study Team

**Figure 7-6.2 Supergrid Configuration**

The supergrid will encompass the following substations: Ikot-Ekpene, Benin, Egbin, Ajegunle (New Agbara), Osogbo, Gwangwalada, Makurdi, Ajeokuta, Funtua, Kainji, Bernin Kebbi.

From technical perspectives, both the 330 and 500 kV options are adequate. Furthermore, taking into consideration that:

- Capacity of 330 kV supergrid lines: 3,100 MVA
- Capacity of 500 kV supergrid lines: 2,350 MVA
- Difference in losses between 330 and 500 kV supergrids: Marginal
- Impact on O/U voltages and overloads: 330 kV advantageous
- Higher static N-1 security of the 330 kV supergrid due to the Double-Circuit lines involved

It appears that the 330 kV supergrid system is technically the preferred option.

There is no justification to adopt and/or consider further any higher (750 kV) option for the EHV grid, particularly when the implications in cost differences are taken into account.

The higher transmission capacity (4,400 MVA) is not required at this stage and the marginal differences in losses cannot offset the high investment cost required in the planning horizon of this Master Plan.

### 7-6-1-3 Supergrid Transmission Lines

The following table summarizes the Double-Circuit 330kV transmission lines required to complete the supergrid for the 2030 system requirements. Part of this supergrid transmission system is required by 2025, as mentioned in the previous sections:

**Table 7-6.4 Supergrid lines for 2030**

| From | To | Thermal rating (MVA) | Length (km) | Remarks |
|---|---|---|---|---|
| Ikot-Ekpene | Benin | 2 x 1,550 | 300 | |
| Ikot-Ekpene | Makurdi | 2 x 1,550 | 320 | Required in 2025 |
| Benin | Egbin | 2 x 1,550 | 230 | |
| Egbin | Ajegunle (New Agbara) | 2 x 1,550 | 50 | |
| Benin | Osogbo | 2 x 1,550 | 200 | |
| Ajegunle (New Agbara) | Osogbo | 2 x 1,550 | 150 | |
| Osogbo | Kainji | 2 x 1,550 | 200 | |
| Benin | Ajeokuta | 2 x 1,550 | 150 | |
| Ajeokuta | Gwangwalada | 2 x 1,550 | 150 | Required in 2025 |
| Gwangwalada | Makurdi | 2 x 1,550 | 180 | Required in 2025 |
| Gwangwalada | Kainji | 2 x 1,550 | 250 | |
| Gwangwalada | Funtua | 2 x 1,550 | 260 | Required in 2025 |
| Gwangwalada | Osogbo | 2 x 1,550 | 250 | Required in 2025 |
| Kainji | Bernin Kebbi | 2 x 1,550 | 300 | |

Source: JICA Study Team

(*) Note on the introduction of the “supergrid” in 2025:

The supergrid is to be fully rolled out in 2030 and its necessity is demonstrated in Section 7-6. However, due to the forecast high increase in load demand in the Abuja region and elsewhere by 2025 plus resulting overloads and undervoltages, the most cost-effective approach will involve introducing part of the supergrid in 2025, to avoid other temporary and potentially costly measures which will not be needed after the full roll-out of the supergrid in 2030.

A full analysis of the supergrid and justifications for the selection of the appropriate voltage level and conductor type option is given in Section 7-6.

In addition to the supergrid transmission lines, other 330 kV transmission lines have also been considered and assessed, as per TCN's request, such as:

- Yola-Little Gombi-Biu-Damaturu
- Damaturu-Potiskum-Azare-Dutse-Jogana
- Osogbo-Okene-Ajeokuta-Ayangba-Makurdi
- Mambila-Kashimbila-Ogoja-Ibom-Calabar
- Ugheli (Delta)-Onne (PH)
- Ugheli-Okpai

However, with the introduction of the supergrid, these lines will be lightly loaded. Furthermore, during off-peak loading periods their charging MVar will necessitate the operation of reactors, particularly in the north-eastern area of Nigeria. Accordingly, before a final decision is made, it is recommended that their benefits be reassessed at a later stage, once more updated information is available on load demand in the corresponding regions.

## 7-7 Expansion Plan for 2030

### 7-7-1 2030 Base Cases Load-flow Analysis

#### 7-7-1-1 Load demand

The demand load in 2030 in each DisCo area is shown in Table 7-7.1.

**Table 7-7.1 Load demand per DisCo**

| DisCo | | Load Demand 2025 (MW) | Increase (2025-2030) | Load Demand 2030 (MW) |
|---|---|---|---|---|
| IKEDC | 1-Ikeja | 2,058 | 42% | 2,921 |
| IBEDC | 2-Ibadan | 2,285 | 43% | 3,267 |
| AEDC | 3-Abuja | 2,329 | 50% | 3,500 |
| BEDC | 4-Benin | 1,852 | 34% | 2,489 |
| KAEDCO | 5-Kaduna | 1,169 | 81% | 2,117 |
| JEDC | 6-Jos | 646 | 60% | 1,035 |
| EEDC | 7-Enugu | 1,668 | 19% | 1,979 |
| PHEDC | 8-Port Harcourt | 1,762 | 35% | 2,385 |
| EKEDC | 9-Eko | 1,837 | 22% | 2,240 |
| KEDCO | 10-Kano | 1,565 | 64% | 2,570 |
| YOLA | 11-Yola | 532 | 77% | 942 |
| Total | - | 17,703 | 43.75% | 25,447 |
| Export* | - | 1,541 | - | 1,831 |
| Total load | - | 19,244 | - | 27,278 |

Source: JICA Study Team

Ref: 330 kV export lines: To Sakete 550 MW, To Faraku 500 MW, To Zabori 631 MW

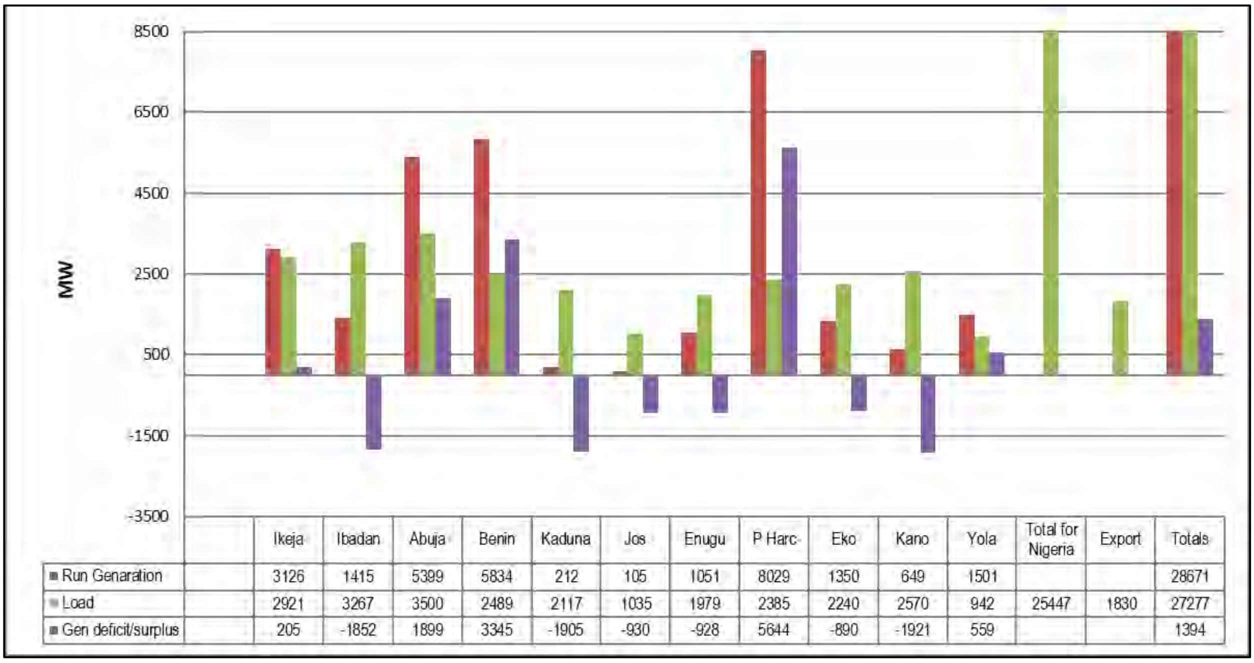
The total generation assumed to be running in each DisCo area is shown in Table 7-7.2 and Figure 7-7.1. It includes 640 MW from PV and 3,240 MW from HPP.

**Table 7-7.2 Generation per DisCo running in 2030**

| DisCo | | Generation (MW) |
|---|---|---|
| IKEDC | 1-Ikeja | 3,041 |
| IBEDC | 2-Ibadan | 1,415 |
| AEDC | 3-Abuja | 5,399 |
| BEDC | 4-Benin | 5,834 |
| KAEDCO | 5-Kaduna | 212 |
| JEDC | 6-Jos | 105 |
| EEDC | 7-Enugu | 1,051 |
| PHEDC | 8-Port Harcourt | 8,029 |
| EKEDC | 9-Eko | 1,350 |
| KEDCO | 10-Kano | 649 |
| YOLA | 11-Yola | 1,501 |

Source: JICA Study Team

The load and total running generation for each DisCo is shown graphically in Figure 7-7.1.




| | Ikeja | Ibadan | Abuja | Benin | Kaduna | Jos | Enugu | P Harc | Eko | Kano | Yola | Total for Nigeria | Export | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run Genaration | 3126 | 1415 | 5399 | 5834 | 212 | 105 | 1051 | 8029 | 1350 | 649 | 1501 | | | 28671 |
| Load | 2921 | 3267 | 3500 | 2489 | 2117 | 1035 | 1979 | 2385 | 2240 | 2570 | 942 | 25447 | 1830 | 27277 |
| Gen deficit/surplus | 205 | -1852 | 1899 | 3345 | -1905 | -930 | -928 | 5644 | -890 | -1921 | 559 | | | 1394 |

Source: JICA Study Team

**Figure 7-7.1 2030 Generation and Loads Per DisCo**

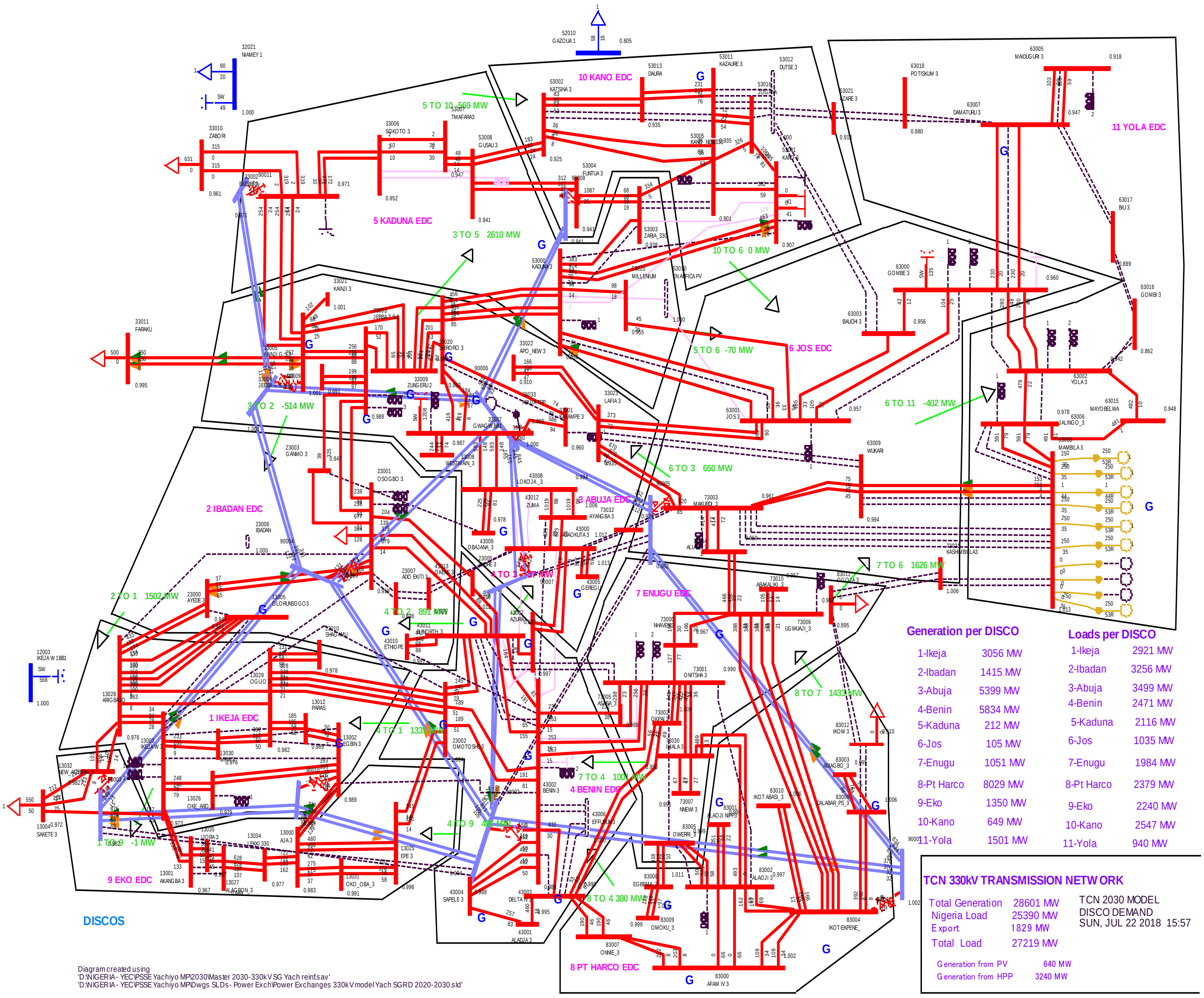
Analytically, the generation assumed running is listed in Table 7-7.3. The new generation added, or increase in power plant output, in comparison to the 2025 case, is shown in bold.

**Table 7-7.3 Generation running in 2030**

| Bus Number | Bus Name | $P_{Gen}$ (MW) | Bus Number | Bus Name | $P_{Gen}$ (MW) | Bus Number | Bus Name | $P_{Gen}$ (MW) |
|---|---|---|---|---|---|---|---|---|
| 86012 | AFAM VI GT11 | 150 | 86069 | GBARAIN_GTB2 | 102 | 46026 | NIPP2 ST | 257 |
| 86013 | AFAM VI GT12 | 150 | 86055 | GEN_AMADI | 45 | 96007 | OATS | 270 |
| 86014 | AFAM VI GT13 | 105 | 56010 | GEN_KADUNA | 194 | 96021 | ODUGPANI NIP | 508 |
| 86015 | AFAM VI ST10 | 180 | 46023 | GER NIPPGT21 | 140 | 96020 | ODUGPANI NIP | 229 |
| 86003 | AFAM2 GT5-6 | 48 | 46024 | GER NIPPGT22 | 140 | 76000 | OKPAI GT11 | 149 |
| 86004 | AFAM2GT 7-8 | 48 | 96015 | GEREGU 2 | 266 | 76001 | OKPAI GT12 | 148 |
| 86005 | AFAM3 GT9-10 | 54 | 96014 | GEREGU 2 | 248 | 76020 | OKPAI GT4PH2 | 135 |
| 86006 | AFAM3GT11-12 | 54 | 46020 | GEREGU GT11 | 124 | 76021 | OKPAI GT5PH2 | 135 |
| 86080 | AKWA-IBOM NU | 1800 | 56003 | GURARA GBUS | 18 | 76002 | OKPAI ST18 | 126 |
| 86039 | ALAOJI_GTB1 | 112.5 | 96002 | HUDSON | 135 | 76022 | OKPAI STPH2 | 135 |
| 86040 | ALAOJI_GTB2 | 112.5 | 86025 | IBOM GT1 | 32 | 16064 | OLOR NIPPST1 | 100 |
| 86041 | ALAOJI_GTB3 | 112.5 | 86026 | IBOM GT2 | 32 | 16065 | OLOR NIPPST2 | 100 |
| 86042 | ALAOJI_GTB4 | 112.5 | 86027 | IBOM GT3 | 32 | 16060 | OLORNIPPGT11 | 100 |
| 86043 | ALAOJI2_STB1 | 257 | 86028 | IBOM II | 497 | 16061 | OLORNIPPGT12 | 100 |
| 86031 | ALSCON GT1 | 90 | 96013 | IHOVBOR 2 | 229 | 16062 | OLORNIPPGT21 | 100 |
| 86032 | ALSCON GT2 | 117 | 46031 | IHOVBOR_GTB1 | 110 | 16063 | OLORNIPPGT22 | 100 |
| 46027 | ASCO G1 | 50 | 46032 | IHOVBOR_GTB2 | 110 | 16050 | OLORUNSO GT1 | 30 |
| 46028 | ASCO G2 | 50 | 46033 | IHOVBOR_GTB3 | 110 | 16055 | OLORUNSO GT6 | 15 |
| 96011 | AZIKEL | 440 | 46034 | IHOVBOR_GTB4 | 110 | 16057 | OLORUNSO GT8 | 30 |
| 46035 | AZURA GT | 280 | 66033 | JBS WIND | 70 | 86047 | OMA_GT | 450 |
| 96001 | BRESSON | 135 | 36006 | JEBBA 2G1 | 80 | 86022 | OMOKU2 GT2 | 102 |
| 16008 | BRESSON GTS | 80 | 36007 | JEBBA 2G2 | 80 | 26026 | OMOTNIPP GT1 | 115 |
| 96009 | CABLE INLAND | 1350 | 36008 | JEBBA 2G3 | 80 | 26027 | OMOTNIPP GT2 | 115 |

| Bus Number | Bus Name | $P_{Gen}$ (MW) | Bus Number | Bus Name | $P_{Gen}$ (MW) | Bus Number | Bus Name | $P_{Gen}$ (MW) |
|---|---|---|---|---|---|---|---|---|
| 86061 | CALABAR_GTB2 | 100 | 36009 | JEBBA 2G4 | 80 | 26030 | OMOTOSHO 2+ | 230 |
| 86060 | CALABAR_GTB3 | 100 | 36011 | JEBBA 2G6 | 80 | 26020 | OMOTOSO GT1 | 74 |
| 76011 | CENTURY IPP | 223 | 36004 | KAINJ 1G11 | 80 | 96008 | ONDO IPP | 400 |
| 96006 | CHEVRON TEX | 702 | 36005 | KAINJ 1G12 | 80 | 16012 | PARAS | 270 |
| 86030 | CUMMINS | 135 | 36000 | KAINJ 1G5 | 80 | 16011 | PARASGT1-9 | 54 |
| 46006 | DELTA IV 2-1 | 140 | 36001 | KAINJ 1G6 | 80 | 46070 | PROTON | 135 |
| 46007 | DELTA IV 2-2 | 140 | 36002 | KAINJ 1G7-8 | 160 | 86070 | QUA IBOE PP | 468 |
| 46008 | DELTA IV 2-3 | 140 | 36003 | KAINJ 1G9-10 | 160 | 86035 | RIVERS _GT1 | 172 |
| 46010 | DELTAIV GT19 | 133 | 76013 | KASHIMB HPP | 21 | 46050 | SAP_NIPP_GT1 | 100 |
| 46011 | DELTAIV GT20 | 133 | 56011 | KAZAURE PV1 | 80 | 46051 | SAP_NIPP_GT2 | 100 |
| 66005 | DKOWA G1 | 14 | 56012 | KAZAURE PV2 | 80 | 46052 | SAP_NIPP_GT3 | 100 |
| 96018 | EGBEMA II | 114 | 56013 | KAZAURE PV3 | 80 | 46012 | SAPELE GT1-2 | 180 |
| 86067 | EGBEMA_GTB3 | 100 | 56014 | KAZAURE PV4 | 80 | 46013 | SAPELE GT3-4 | 90 |
| 16000 | EGBIN GT 1 | 254.1 | 56015 | KAZAURE PV5 | 80 | 46060 | SAPELE ROT | 140 |
| 16001 | EGBIN GT 2 | 254.1 | 56016 | KAZAURE PV6 | 80 | 46061 | SAPELE ROT 2 | 140 |
| 16002 | EGBIN GT 3 | 254.1 | 56017 | KAZAURE PV7 | 80 | 46062 | SAPELE ROT 2 | 130 |
| 16003 | EGBIN GT 4 | 254.1 | 56018 | KAZAURE PV8 | 80 | 36012 | SHIROR 411G1 | 120 |
| 16004 | EGBIN ST 5 | 254.1 | 46080 | KOJI NUCLEAR | 1800 | 36013 | SHIROR 411G2 | 120 |
| 16005 | EGBIN ST 6 | 254.1 | 55075 | KT WF 33 | 9 | 36014 | SHIROR 411G3 | 120 |
| 86050 | ELEME | 68 | 16010 | LAFARAGE 2 | 200 | 96016 | TURBINE DR | 300 |
| 86056 | ESSAR GTS | 150 | 66008 | MAMBILA GT2 | 250 | 96004 | WESCOM | 225 |
| 86057 | ESSAR ST | 140 | 66009 | MAMBILA GT3 | 250 | 96017 | YELLOW STONE | 324 |
| 96012 | ETHIOPE | 450 | 66010 | MAMBILA GT4 | 250 | 46029 | ZUMA | 810 |
| 46037 | ETHIOPE GTS | 310 | 66011 | MAMBILA GT5 | 250 | 86071 | ZUMA (GAS) | 337 |
| 46038 | ETHIOPE ST | 140 | 66014 | MAMBILA GT8 | 250 | 36024 | ZUNGE_G1 | 150 |
| 86048 | GBARAIN 2 GT | 511 | 66015 | MAMBILA GT9 | 250 | 36025 | ZUNGE_G2 | 150 |
| 86068 | GBARAIN_GTB1 | 102 | 96005 | MBH | 270 | | | |

Source: JICA Study Team

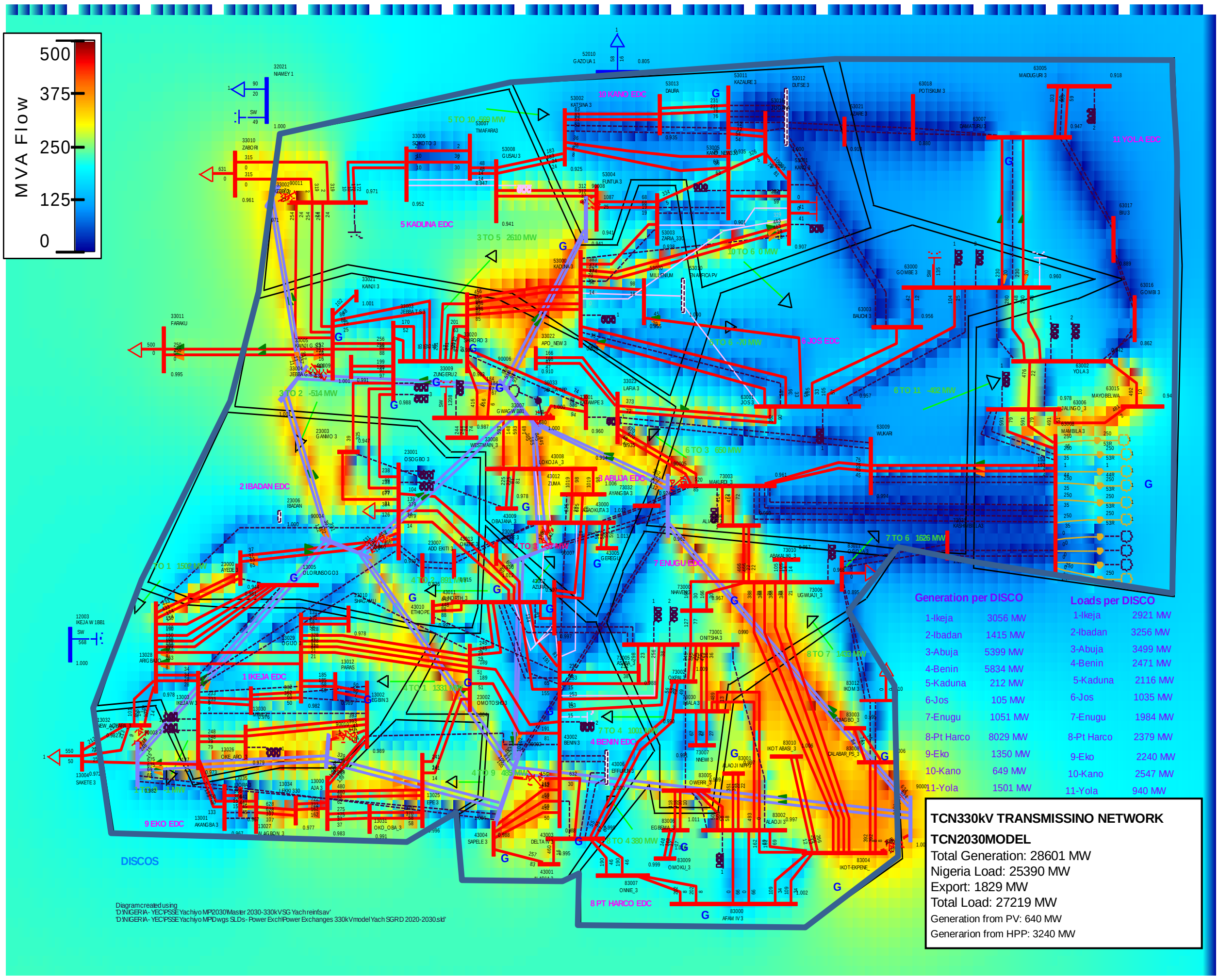



Source: JICA Study Team

**Figure 7-7.2 Configuration of the 330-kV grid in 2030**

## 7-7-2 Summary of the Load-flow Calculations for 2030

The ratings of the 330kV DC option are found adequate for meeting the Grid Code requirements. Using this option, the transmission system loading is shown in Figure 7-7.3.




Source: JICA Study Team

**Figure 7-7.3 Transmission Line Loadings in 2030**

No overloads or voltage violation encountered in the 330 and 132 kV systems.

One or two minor voltage violations at 132 kV (0.84 pu) will be corrected when the 132-kV network is reinforced to meet the N-1 criterion, as proposed earlier.

### 7-7-3 Reactive Power Compensation

In addition to the requirements described for the 2025 case, the following reactive power compensation would be required by 2030:

- At 330 kV Gombe substation, 100 MVar Capacitors or SVC.
- With regards to Bernin Kebbi, for the 2025 case, power compensation (150 MVar capacitors) will be required at Bernin Kebbi due to export requirements to WAPP. It should be noted however that in 2030 the proposed supergrid will be extended with a Kainji-Bernin Kebbi line. Once this implemented, there will be no further need for reactive power compensation at Bernin Kebbi.
- Due to the sharp increase in forecast load in Abuja, the largest reactive power compensation is required at the Abuja area (Gwangwalada 330kV substation) of approx. 700 MVar. It is recommended that this,

too, be the subject of a separated and dedicated reactive power compensation study, to determine the optimum locations and sizes required. Such a study shall be conducted at a later stage, when the current information on generation expansion plans and load forecast is updated.

However, if the Gwangwalada Power Plant of 1,000MW is in operation in 2030, instead of later, there will be no need for reactive power compensation in that area.

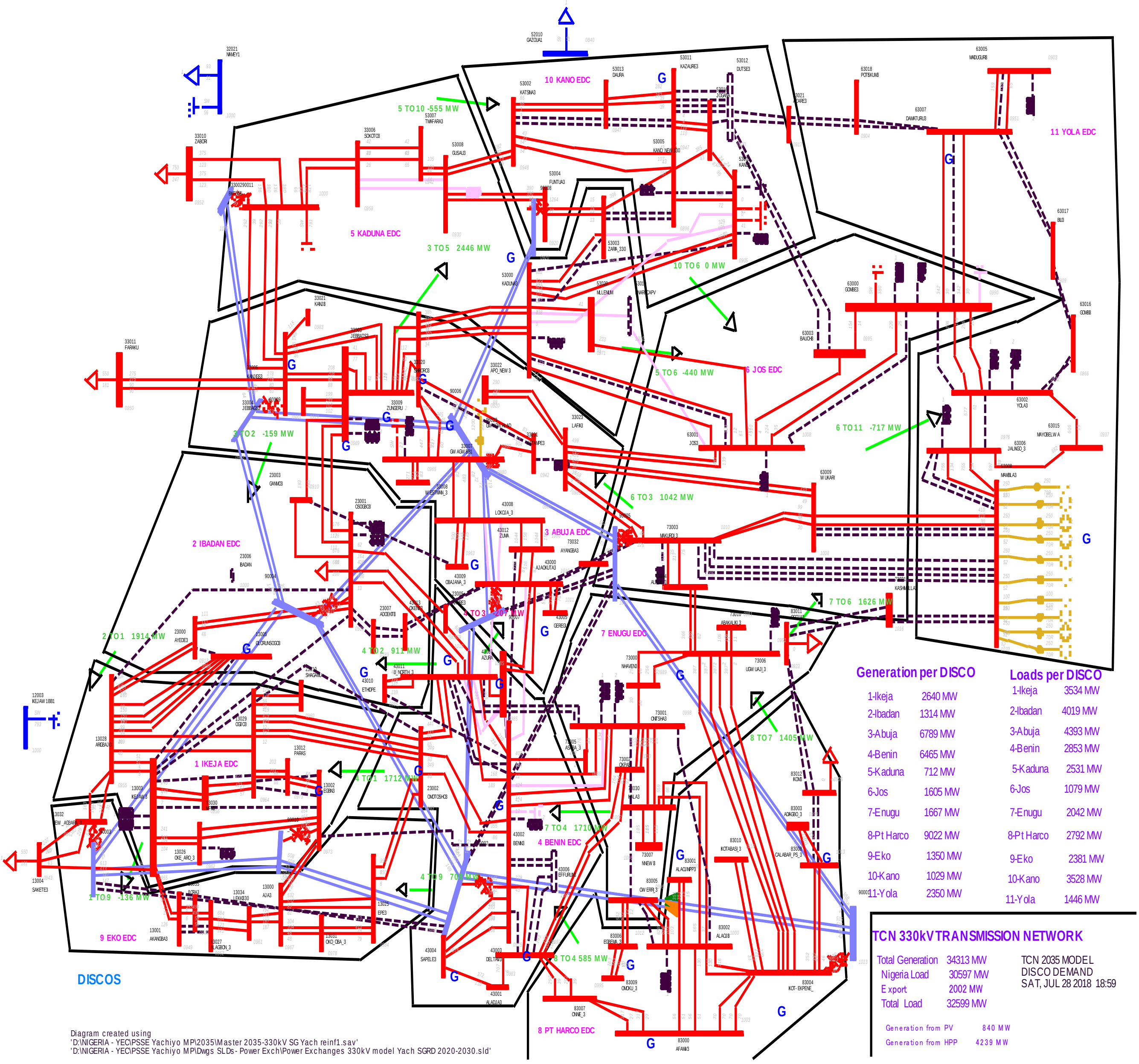
- 20 MVar capacitor at Gashuwa 132 kV
- 60 MVar capacitor at Apo 132 kV
- 25 MVar capacitor at Keffi 132 kV
- 40 MVar capacitor at Uba 132kV

## 7-8 Expansion Plan for 2035

### 7-8-1 2035 Base Cases Load-flow Analysis

#### 7-8-1-1 Transmission system

Figure 7-8.1 below shows the 330kV transmission system in 2035.




Source: JICA Study Team

**Figure 7-8.1 Configuration of 330 kV grid in 2035**

Table 7-8.1 shows that the increase in load demand in 2035.

**Table 7-8.1 Load demand per DisCo**

| DisCo | | Load Demand 2030 (MW) | Increase (2030-2035) | Load Demand 2035 (MW) |
|---|---|---|---|---|
| IKEDC | 1-Ikeja | 2,921 | 21.06% | 3,536 |
| IBEDC | 2-Ibadan | 3,267 | 24.08% | 4,054 |
| AEDC | 3-Abuja | 3,500 | 25.66% | 4,398 |
| BEDC | 4-Benin | 2,489 | 16.54% | 2,901 |
| KAEDCO | 5-Kaduna | 2,117 | 19.61% | 2,533 |
| JEDC | 6-Jos | 1,035 | 4.24% | 1,079 |
| EEDC | 7-Enugu | 1,979 | 2.93% | 2,037 |
| PHEDC | 8-Port Harcourt | 2,385 | 17.49% | 2,802 |
| EKEDC | 9-Eko | 2,240 | 6.33% | 2,382 |
| KEDCO | 10-Kano | 2,570 | 38.06% | 3,549 |
| YOLA | 11-Yola | 942 | 53.72% | 1,448 |
| Total | - | 25,447 | 20.72% | 30,719 |
| Export* | - | 1,830 | - | 2,000 |
| Total load | - | 27,277 | - | 32,719 |

Source: JICA Study Team

Ref: 330 kV export lines: To Sakete 550 MW, To Faraku 550 MW, To Zabori 750 MW

### 7-8-1-2 Generation

The total generation assumed to be running in each DisCo area is shown in Table 7-8.2, as well as in Figure 7-8.1. It includes 840 MW from PV and 4,239 MW from HPP.

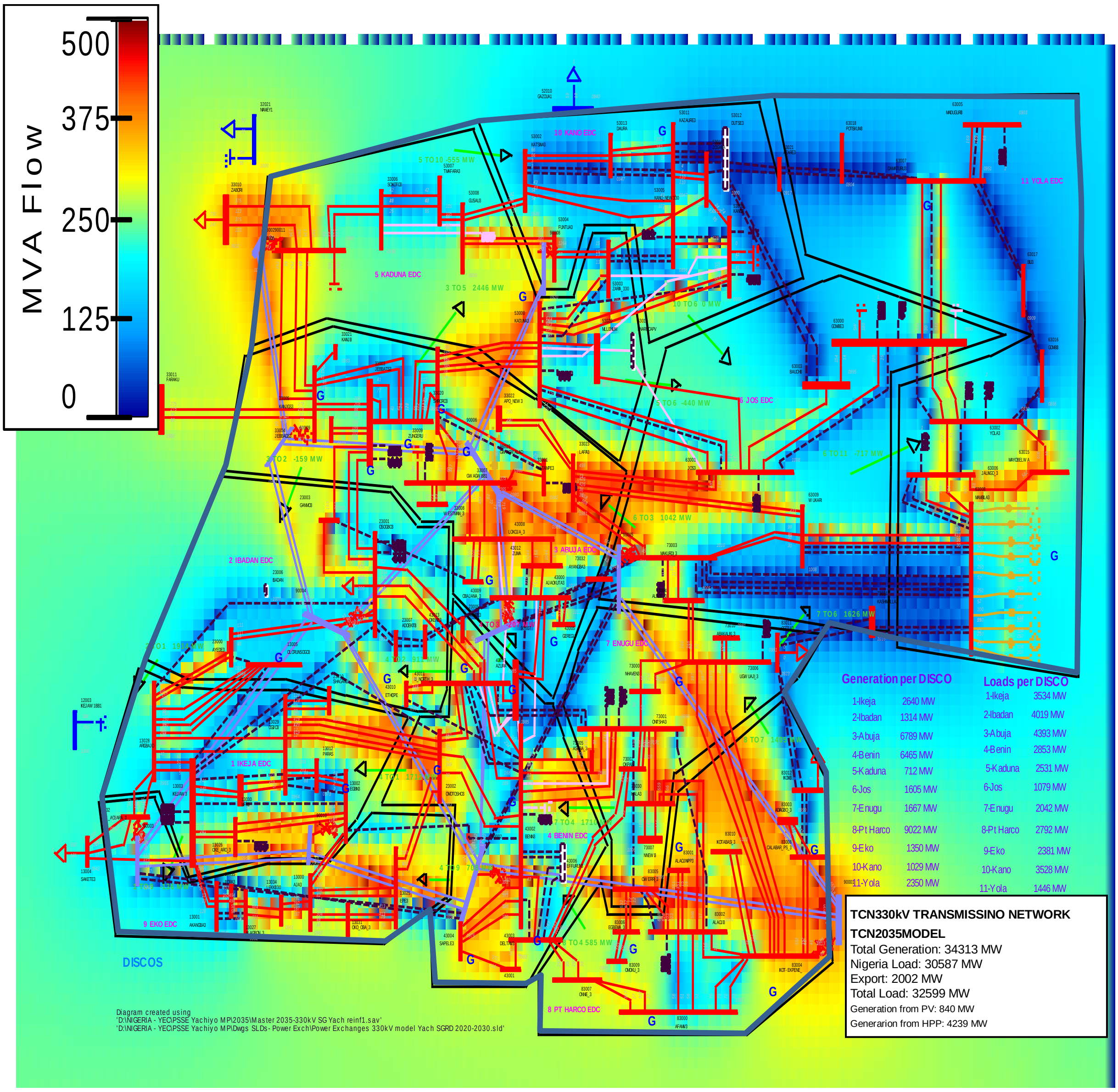
**Table 7-8.2 Generation per DisCo running in 2035**

| DisCo | | Generation (MW) |
|---|---|---|
| IKEDC | 1-Ikeja | 2,640 |
| IBEDC | 2-Ibadan | 1,314 |
| AEDC | 3-Abuja | 6,789 |
| BEDC | 4-Benin | 6,465 |
| KAEDCO | 5-Kaduna | 712 |
| JEDC | 6-Jos | 1,605 |
| EEDC | 7-Enugu | 1,667 |
| PHEDC | 8-Port Harcourt | 9,022 |
| EKEDC | 9-Eko | 1,350 |
| KEDCO | 10-Kano | 1,029 |
| YOLA | 11-Yola | 2,350 |

Source: JICA Study Team

## 7-8-2 Summary of the Load-flow Calculations for 2035

The loading of the transmission system is shown in Figure 7-8.2.




Source: JICA Study Team

**Figure 7-8.2 Transmission Line Loadings in 2035**

#### 7-8-2-1 Transmission Line Overloads and Voltage Violations

No overloads or voltage violations encountered in the 330 and 132 kV systems.

Two or three minor voltage violations at 132 kV (0.84 pu) will be corrected when the 132-kV network is reinforced to meet the N-1 criterion, as proposed earlier.

### 7-8-3 New Transmission Lines and Reactive Power Requirements

#### 7-8-3-1 New transmission lines

- The 330 kV DC line Zuma-Lokoja (25 km) is overloaded due to the Zuma power plant output. Reconductoring is recommended to Quad conductors.
- The 330 kV DC line Makurdi-Lafia is overloaded due to the new Ramos 900 MW coal-fired power plant.

A new Wukari-Lafia 330 kV DC line (95 km) is proposed, which will remove these overloads and improve voltage profiles.

- The following 330 kV lines are overloaded between 101 and 107% under normal (N-0) operation and need to be converted to Quad conductors

  Aja - Lekki

  Benin North - Akure

- To meet the N-1 criterion and also remove undervoltages, a conversion to a DC circuit is recommended for the following SC 132 kV lines:

  Kwaya Kusar - Biu

  Biu - Damboa

  Damboa - Maiduguri

To meet the N-1 criterion and also eliminate overload, new transmission lines are required, as listed in Table 7-8.3.

**Table 7-8.3 New transmission lines and reinforcements required for 2035**

| Substation Name | Substation Name | Voltage (kV) | Length (km) | Type | Proposed Solution |
|---|---|---|---|---|---|
| Wukari | Lafia | 330 | 95 | DC | New DC transmission line |
| Zuma | Lokoja | 330 | 25 | DC | Reconductoring of DC to Quad conductor |
| Aja | Lekki | 330 | 7 | DC | Reconductoring of DC to Quad conductor |
| Benin North | Akure | 330 | 130 | SC | Reconductoring to Quad conductor or conversion to DC |
| Kwaya Kusar | Biu | 132 | 42 | SC | Convert from SC to DC |
| Biu | Damboa | 132 | 140 | SC | Convert from SC to DC |
| Damboa | Maiduguri | 132 | 64 | SC | Convert from SC to DC |

Source: JICA Study Team

### 7-8-3-2 Reactive Power Compensation

In addition to the requirements described for the 2030 case, the following reactive power compensation would be required by 2035:

- Due to the sharp increase in forecast load in Abuja, reactive power compensation is required at the Abuja area (Gwangwalada 330 kV substation).

  However, if the Gwangwalada Power Plant of 1,200 MW is in operation in 2035, instead of later, there will be no need for reactive power compensation in that area.

- 250 MVar capacitors at Gombe 330 kV
- 700 MVar capacitors at Bernin Kebbi 330 kV
- 300 MVar capacitors at Ikeja West 132 kV

### 7-8-3-3 Comparison of Load-flow Results Between the EHV Options

The comparison of load-flow results for 2035 between the two EHV options is summarized in Table 7-8.4.

**Table 7-8.4 LF results for 2035**

| Voltage Level (kV) | Generation (MW) | O/V and U/V of 330 kV and above (outside 0.9-1.05) | O/L of 330 kV above 80% | Losses (MW) | Remarks |
|---|---|---|---|---|---|
| 330 | 28763 | 5 buses | 16 circuits* | 1,471 (5.11%) | Slightly lower losses compared to the 500-kV option |
| 500 | 28974 | 10 buses | 20 circuits * | 1,737 (5.99%) | 266 MW (0.91%) higher losses compared to the 330-kV option |
| 750 | 28688 | 1 bus | 12 circuits** | 1,359 (4.73%) | Slightly lower losses compared to the 330-kV option |

Source: JICA Study Team

### 7-8-3-4 Conclusion on EHV Options for 2035

The conclusions are the same as for 2030 cases. Based on technical considerations both the 330 and 500 kV options are adequate. Furthermore, taking into consideration that:

- Capacity of 330 kV supergrid lines: 3,100 MVA
- Capacity of 500 kV supergrid lines: 2,350 MVA
- Difference in losses between 330 and 500 kV supergrids: Marginal
- Impact on O/U voltages and overloads: 330 kV advantageous
- Higher static N-1 security of the 330 kV supergrid due to Double-Circuit lines involved

It appears that the 330 kV supergrid system is technically the preferred option.

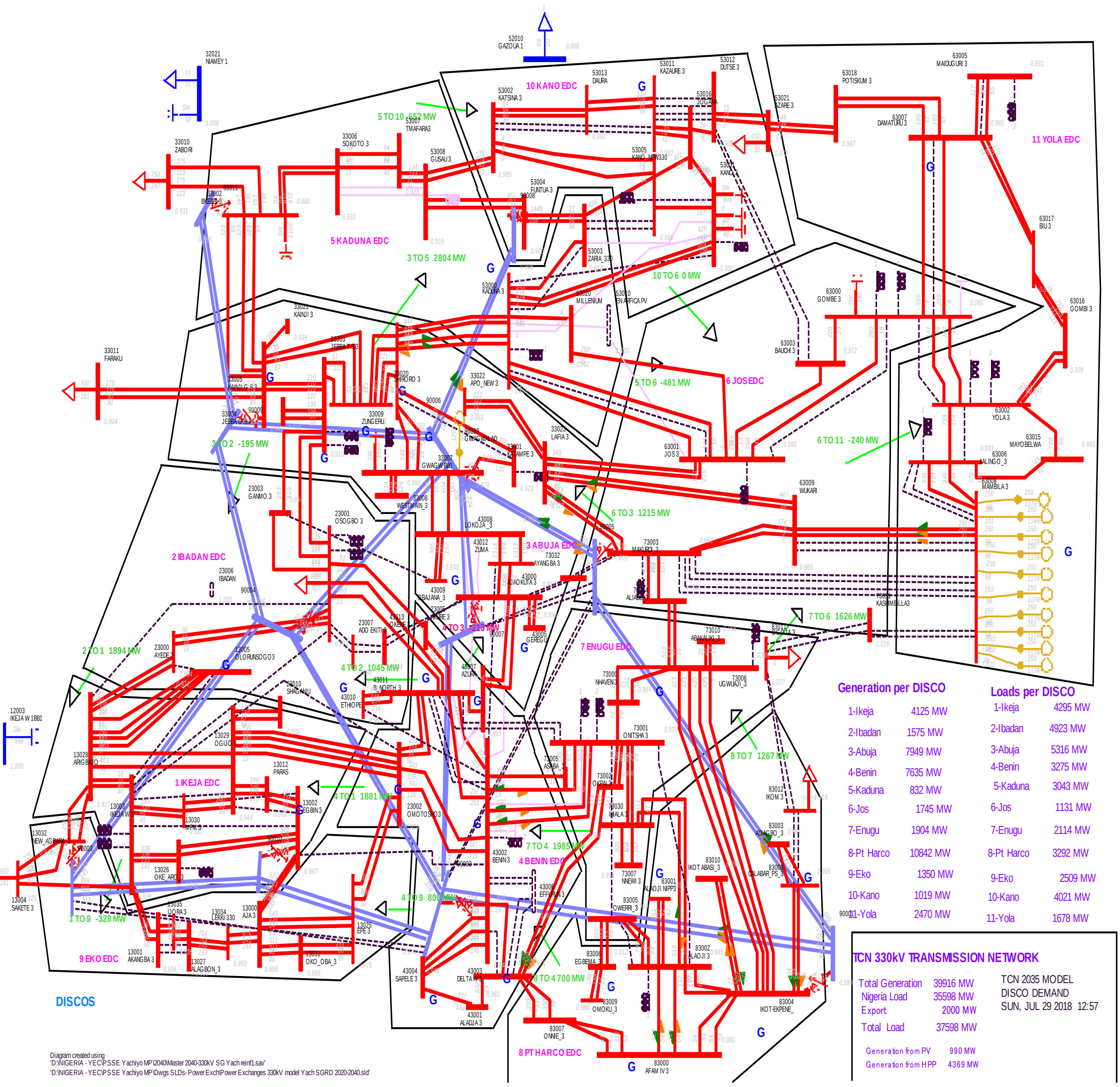
There is no justification for adopting and/or further considering any higher (750 kV) option for the EHV grid, particularly when the implications in cost differences are taken into account. The higher transmission capacity (4,400 MVA) is not required at this stage and the marginal differences in losses cannot offset the high investment cost required in the planning horizon of this Master Plan.

## 7-9 Expansion Plan for 2040

### 7-9-1 2040 Base Cases Load-flow Analysis

#### 7-9-1-1 Transmission system

Figure 7-9.1 below shows the 330kV transmission system in 2040.




Source: JICA Study Team

**Figure 7-9.1 Configuration of 330 kV grid in 2040**

#### 7-9-1-2 Load demand

Table 7-9.1 shows that the increase in load demand follows approximately the same increase (in percentage) as in the load forecast detailed in Section 5.4.2.

Table 7-9.1 Load demand per DisCo

| DisCo | | Load Demand 2035 (MW) | Increase (2035-2040) | Load Demand 2040 (MW) |
|---|---|---|---|---|
| IKEDC | 1-Ikeja | 3,536 | 21.61% | 4,300 |
| IBEDC | 2-Ibadan | 4,054 | 24.70% | 5,055 |
| AEDC | 3-Abuja | 4,398 | 21.31% | 5,336 |
| BEDC | 4-Benin | 2,901 | 16.90% | 3,391 |
| KAEDCO | 5-Kaduna | 2,533 | 20.23% | 3,045 |
| JEDC | 6-Jos | 1,079 | 4.83% | 1,131 |
| EEDC | 7-Enugu | 2,037 | 3.67% | 2,112 |
| PHEDC | 8-Port Harcourt | 2,802 | 17.94% | 3,305 |
| EKEDC | 9-Eko | 2,382 | 5.44% | 2,512 |
| KEDCO | 10-Kano | 3,549 | 13.38% | 4,023 |
| YOLA | 11-Yola | 1,448 | 16.05% | 1,680 |
| Total | - | 30,719 | 16.83% | 35,890 |
| Export | - | 2,000 | - | 2,000 |
| Total load | - | 32,719 | - | 37,890 |

Source: JICA Study Team

Ref: 330 kV export lines: To Sakete 550 MW, To Faraku 550 MW, To Zabori 750 MW

### 7-9-1-3 Generation

The total generation assumed to be running in each DisCo area is shown in Table 7-9.2 as well as in Figure 7-9.1 and includes 990 MW from PV and 4,369 MW from HPP.

Table 7-9.2 Generation per DisCo running in 2040

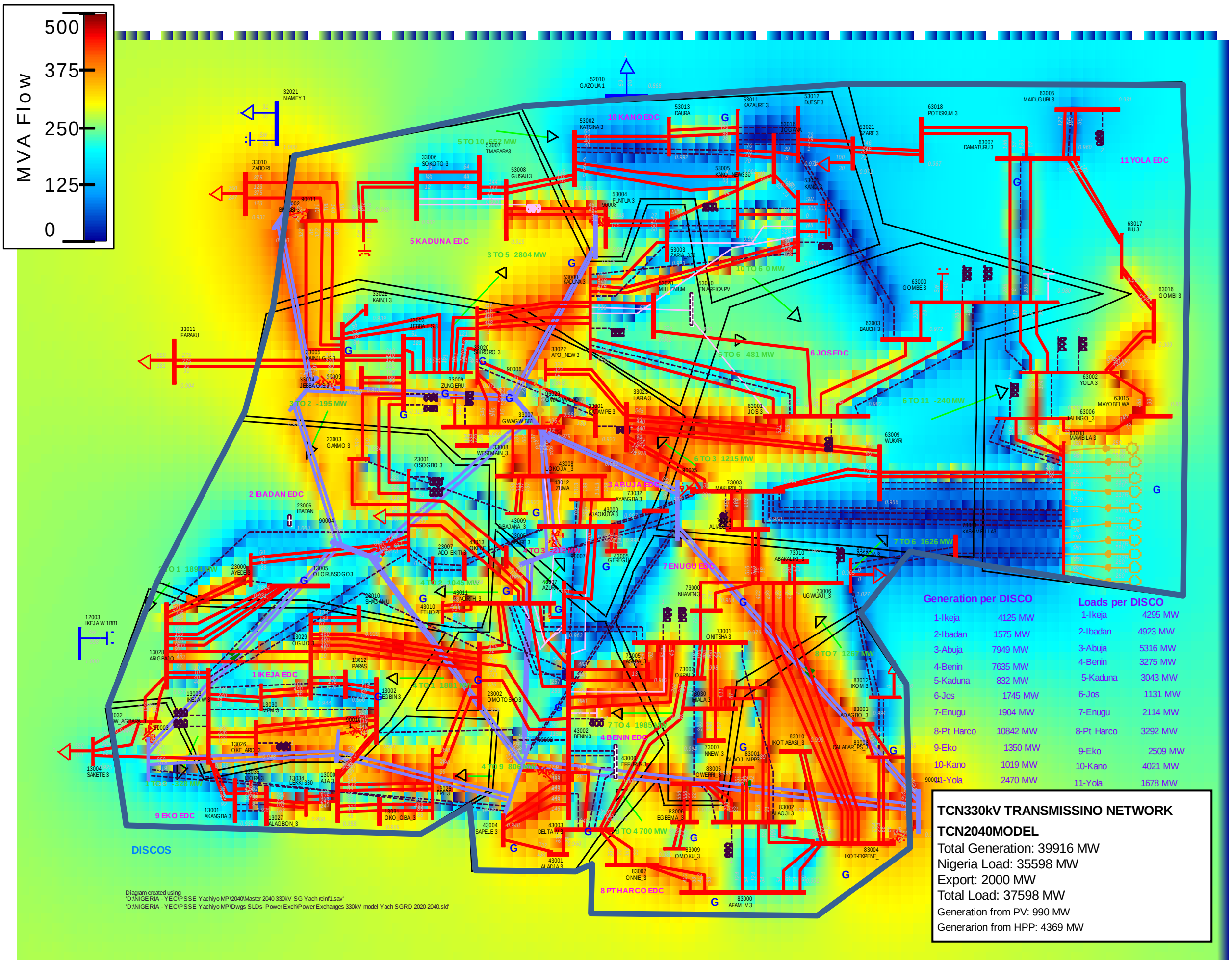
| DisCo | | Generation (MW) |
|---|---|---|
| IKEDC | 1-Ikeja | 4,125 |
| IBEDC | 2-Ibadan | 1,575 |
| AEDC | 3-Abuja | 7,949 |
| BEDC | 4-Benin | 7,635 |
| KAEDCO | 5-Kaduna | 832 |
| JEDC | 6-Jos | 1,745 |
| EEDC | 7-Enugu | 1,904 |
| PHEDC | 8-Port Harcourt | 10,842 |
| EKEDC | 9-Eko | 1,350 |
| KEDCO | 10-Kano | 1,019 |
| YOLA | 11-Yola | 2,470 |

Source: JICA Study Team

It should be noted that to meet the high load forecast for 2040, an additional power plant is necessary with a minimum capacity of 1,000 MW (such as Ethiope ph 2) to be located near Egbin S/S.

## 7-9-2 Summary of Load-flow Calculations for 2040

The loading of the transmission system is shown in Figure 7-9.2.




Source: JICA Study Team

**Figure 7-9.2 Transmission Line Loadings in 2040**

#### 7-9-2-1 Transmission Line Overloads and Voltage Violations

No voltage violation encountered in the 330 and 132 kV systems.

A few minor voltage violations at 132 kV will be corrected when the 132-kV network is reinforced to meet the N-1 criterion, as proposed earlier.

With regards to thermal overloads of the 330-kV system, the following lines are overloaded and need to be reinforced:

- Aladja - Delta IV
- Osogbo – Ganmo

### 7-9-3 New Transmission Lines and Reactive Power Requirements

#### 7-9-3-1 New transmission lines

The following new 330 kV transmission lines are recommended at this stage in the North and North-East of the country:

- Yola-Little Gombi-Biu-Damaturu
- Damaturu-Potiskum-Azare-Dutse-Jogana

The required new transmission lines for 2040 are shown in Table 7-9.3.

**Table 7-9.3 New transmission lines and reinforcements required for 2040**

| Substation Name | Substation Name | Voltage (kV) | Length (km) | Type | Proposed Solution |
|---|---|---|---|---|---|
| Aladja | Delta IV | 330 | 32 | SC | Convert to DC |
| Osogbo | Ganmo | 330 | 50 | SC | Convert to DC |
| Yola | Little Gombi | 330 | 100 | DC | New DC transmission line |
| Little Gombi | Biu | 330 | 80 | DC | New DC transmission line |
| Biu | Daimaturu | 330 | 130 | DC | New DC transmission line |
| Daimaturu | Potiscum | 330 | 100 | DC | New DC transmission line |
| Potiscum | Azare | 330 | 100 | DC | New DC transmission line |
| Azare | Dutse | 330 | 90 | DC | New DC transmission line |
| Dutse | Jogana | 330 | 76 | DC | New DC transmission line |

Source: JICA Study Team

### 7-9-3-2 Reactive Power Compensation

In addition to the requirements described for the 2035 case, reactive power compensation would be required by 2040, considering the following:

- Due to the sharp increase in the forecast load in Abuja, there is an additional reactive power deficit in the Abuja area of approx. 1,500 MVar.
- Additional reactive power deficit at Kano of approx. 600 MVar
- Additional reactive power deficit at Bernin Kebbi of approx. 400 MVar
- Additional reactive power deficit at Ikeja West of approx. 200 MVar

It is recommended that more detailed reactive power compensation studies be conducted at a later stage to determine the optimal sizes and locations of the reactive power equipment for 2040.

## 7-10 Cost Estimation of Transmission Network Development Plan

### 7-10-1 Basis for Cost Estimation

For calculation of cost of new transmission lines and substations of the proposed transmission system expansions, a simplified cost model has been prepared. For transmission lines it is based on cost per km of transmission line for each voltage level. For substations, the costs for high-voltage feeders have been estimated and comprise two components: one for high-voltage equipment and another for all other substation components (civil works, steel protection & control equipment, auxiliary power supply, etc.). Furthermore, the costs for main power transformers, reactors and capacitors have also been estimated.

For new 132/33 kV substations, the costs for new 33 kV switchgear have been taken into account. If increasing the transformer capacity in existing 132/33 kV substations, it has been assumed that additional 33 kV switchgear will also be installed. Based on this approach, cost estimation accuracy of ±25% can usually be assumed. Table 7-10.1 below shows the cost components considered in the cost estimation, based on experience with similar projects. The cost estimation is compared with TCN's cost estimations and both agreed that they generally correlate effectively.

**Table 7-10.1 Cost components**

| Unit Costs | |
|---|---|
| Transmission Lines (million US$/km) | |
| 132 kV SC Line | 0.17 |
| 330 kV SC Line | 0.22 |
| 500 kV SC Line | 0.28 |
| 750 kV SC Line | 0.35 |
| 132 kV DC Line | 0.26 |
| 330 kV DC Line | 0.45 |
| 132 kV SC Line Reconductoring | 0.04 |
| 330 kV SC Line Reconductoring | 0.08 |
| 132 kV DC Line Reconductoring | 0.08 |
| 330 kV DC Line Reconductoring | 0.15 |
| Substations (million US$) | |
| 132 kV HV equipment | 0.70 |
| 330 kV HV equipment | 1.00 |
| 500 kV HV equipment | 1.30 |
| 750 kV HV equipment | 2.20 |
| 132 kV feeder (= 132 kV HV equipment + Other components) | 1.60 |
| 330 kV feeder (= 330 kV HV equipment + Other components) | 1.90 |
| 30 MVA Transformer 132/11 kV | 0.60 |
| 60 MVA Transformer 132/33 kV | 0.80 |
| 150 MVA Transformer 330/132 kV | 1.50 |
| 1000 MVA Transformer 750/330 kV | 10.00 |
| 11 kV Switchgear | 0.50 |
| 33 kV Switchgear | 0.70 |
| 30 MVar Shunt Reactor – 33 kV (including 33 kV switchgear) | 0.50 |
| 75 MVar Shunt Reactor – 330 kV | 0.80 |
| 25 MVar Shunt Capacitor – 33 kV (including 33 kV switchgear) | 0.25 |
| 25 MVar Shunt Capacitor – 132 kV | 0.30 |
| 100 MVar Shunt Capacitor – 330kV | 1.00 |
| Other components (Civil Works, Steel, Protection, Station Control, Auxiliary Power Supply, Installation etc.) | 0.90 |

Source: JICA Study Team

The following are needed to enhance the power transmission line:

- SC : Installation of Single-Circuit transmission line/Installing a second parallel circuit
- DC : Installation of Double-Circuit transmission line
- RE(SC) : Reconductoring of Single-Circuit transmission line
- RE(DC) : Reconductoring of Double-Circuit transmission line

### 7-10-2 Transmission Reinforcements Required by 2020

Power system studies have shown that most of the transmission system expansion required by 2025 is needed in northern Nigeria, particularly for the 330-kV system. Under the current transmission system expansion program of TCN and NIPP (see Annexes 7.2a and 7.2b) most of the transmission system expansions have been commissioned in the southern and central parts of Nigeria. Some of the transmission system expansions have already been completed and it is expected that the remainder will be commissioned by 2020 or very soon afterwards.

Based on the results of Chapter 8: Power System Analysis, the costs of additional 330 and 132 kV transmission lines, additional 330/132 kV, 132/33 kV and 132/11 kV transformers as well as additional shunt reactors and shunt capacitors have been estimated.

Although it will be challenging to implement all measures by 2020 as required for over 9 GW power supply of the Nigerian transmission network, a major part of the network expansions is related to the 132-kV network and to additional 330/132 kV and 132/33 kV transformers.

#### 7-10-2-1 Cost estimation of each project

Table 7-10.2 to Table 7-10.8 show the cost estimations for the individual groups of system expansion measures, i.e. transmission lines, transformers and reactive power compensation.

Table 7-10.9 summarizes all additional investments in transmission lines and substations by 2020.

**Table 7-10.2 Reinforcements of 132 kV lines overloaded under N-0**

| Cost Estimation of Reinforcement of 132 kV Transmission Lines overloaded under N-0 by 2020 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | | | | | Substation | | | | | |
| | | Rated Voltage | Length | Alternative 1 | | Alternative 2 | | Cost of Alternative 1 (Length × Unit Cost) | Cost of Alternative 2 (Length × Unit Cost) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | Reinforcement | Unit Cost (Million US$/km) | Reinforcement | Unit Cost (Million US$/km) | (Million US$) | (Million US$) | | | | | | (Million US$) |
| Overhead Lines | | | | | | | | | | | | | | | |
| 1 | Ibom IPP - Ikot Abasi | 132 | 30 | SC | 0.17 | DC | 0.26 | 5.1 | 7.8 | | | | | | |
| Subtotal I | | | | | | | | 5.1 | 7.8 | | | | | | |
| Substations | | | | | | | | | | | | | | | |
| 1 | Ibom IPP | | | | | | | | | 0 | 1 | 0 | 0 | 0 | 1.6 |
| 2 | Ikot Abasi | | | | | | | | | 0 | 1 | 0 | 0 | 0 | 1.6 |
| Subtotal II | | | | | | | | | | | | | | | 3.2 |
| Grand Total (Alternative 1) | | 8.3 | | | | | | | | | | | | | |
| Grand Total (Alternative 2) | | 14.2 | | | | | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.3 Reinforcements of 132 kV transmission lines overloaded under N-1

| Cost Estimation of Reinforcement of 132 kVTransmission Lines overloaded under N-1 by 2020 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | | | | | Substation | | | | | |
| | | Rated Voltage | Length | Alternative 1 | | Alternative 2 | | Cost of Alternative 1 (Length × Unit Cost) | Cost of Alternative 2 (Length × Unit Cost) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | Reinforcement | Unit Cost (Million US$/km) | Reinforcement | Unit Cost (Million US$/km) | (Million US$) | (Million US$) | | | | | | (Million US$) |
| **Overhead Lines** | | | | | | | | | | | | | | | |
| 1 | Gombe - T-Junction | 132 | 40 | SC | 0.17 | DC | 0.26 | **6.8** | **10.4** | | | | | | |
| 2 | Yola - T-Junction | 132 | 56 | SC | 0.17 | DC | 0.26 | **9.5** | **14.6** | | | | | | |
| 3 | Omoku - Rumusoi | 132 | 20 | RE | 0.08 | DC | 0.26 | **1.6** | **5.2** | | | | | | |
| 4 | PHCT Main - Rumusoi | 132 | 10 | RE | 0.08 | DC | 0.26 | **0.8** | **2.6** | | | | | | |
| 5 | Ajaokuta - Okene | 132 | 60 | SC | 0.17 | DC | 0.26 | **10.2** | **15.6** | | | | | | |
| 6 | Benin - Irrua | 132 | 88 | SC | 0.17 | DC | 0.26 | **15.0** | **22.9** | | | | | | |
| 7 | Mando - Kudenda | 132 | 20 | RE | 0.08 | DC | 0.26 | **1.6** | **5.2** | | | | | | |
| 8 | Osogbo - Iwo | 132 | 80 | SC | 0.17 | DC | 0.26 | **13.6** | **20.8** | | | | | | |
| 9 | Yenagoa - Gbarain | 132 | 5 | RE | 0.08 | DC | 0.26 | **0.4** | **1.3** | | | | | | |
| 10 | Afam 1-2-3 - Afam IV | 132 | 1 | RE | 0.08 | DC | 0.26 | **0.1** | **0.3** | | | | | | |
| 11 | Ikeja West - Alimoso | 132 | 4 | RE | 0.08 | DC | 0.26 | **0.3** | **0.9** | | | | | | |
| 12 | Biu - Dadinkowa | 132 | 82 | SC | 0.17 | DC | 0.26 | **13.9** | **21.3** | | | | | | |
| 13 | Yenagoa - Ahoada | 132 | 46 | RE | 0.08 | DC | 0.26 | **3.7** | **12.0** | | | | | | |
| 14 | Ayede - Idaban North | 132 | 12 | SC | 0.17 | DC | 0.26 | **2.0** | **3.1** | | | | | | |
| 15 | Eket - Ibom IPP | 132 | 45 | RE | 0.08 | DC | 0.26 | **3.6** | **11.7** | | | | | | |
| 16 | Onne - Tramadi | 132 | 10 | RE | 0.08 | DC | 0.26 | **0.8** | **2.6** | | | | | | |
| 17 | PHCT Main - Rivers IPP | 132 | 12 | RE | 0.08 | DC | 0.26 | **1.0** | **3.1** | | | | | | |
| 18 | Zaria - Funtua | 132 | 7 | SC | 0.17 | DC | 0.26 | **1.2** | **1.8** | | | | | | |
| **Subtotal I** | | | | | | | | **86.1** | **155.4** | | | | | | |
| **Substations** | | | | | | | | | | | | | | | |
| 1 | Ajaokuta | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 2 | Okene | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 3 | Yenagoa | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 4 | Gbarain | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 5 | Osogbo | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 6 | Iwo | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 7 | Biu | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 8 | Dadinkowa | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 9 | Benin | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 10 | Irrua | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 11 | Ikeja West | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 12 | Alimosho | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 13 | Mando | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 14 | Kudenda | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 15 | PHCT Main | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 16 | Rumusoi | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 17 | Eket | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 18 | Zaria | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 19 | Funtua | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 20 | Onne | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 21 | Tramadi | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| **Subtotal II** | | | | | | | | | | | | | | | **17.6** |
| **Grand Total - Alternative 1** | | | | | | | | **103.7** | | | | | | | |

Source: JICA Study Team

## Table 7-10.4 Upgrading requirements of 330/132 kV 3-winding transformers overloaded under N-0

| Cost Estimation of Upgrading of 330/132 kV 3-winding Transformers overloaded under N-1 by 2020 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | (Million US$) |
| **Overhead Lines** | | | | | | | | | | | |
| **Subtotal I** | | | | | **0.0** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Benin | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 2 | Benin North | | | | | 1 | 1 | 0 | 1 | 0 | **5.0** |
| 3 | Birnin Kebbi | | | | | 1 | 1 | 0 | 1 | 0 | **5.0** |
| 4 | Ganmo | | | | | 1 | 1 | 0 | 1 | 0 | **5.0** |
| **Subtotal II** | | | | | | | | | | | **25.0** |
| **Grand Total** | | | | | | **25.0** | | | | | |

Source: JICA Study Team

## Table 7-10.5 Upgrading requirements of 132/33 kV and 132/11 kV transformers under N-0 by 2020

| Cost Estimation of Upgrading of Transformers overloaded under N-0 by 2020 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | 30 MVA、132/11 kV Transformer | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | | | (Million US$) |
| **Overhead Lines** | | | | | | | | | | | | | |
| **Subtotal I** | | | | | **0.0** | | | | | | | | |
| **Substations** | | | | | | | | | | | | | |
| 1 | Suleja | | | | | 0 | 1 | 0 | 1 | 0 | 0 | 1 | **2.7** |
| 2 | Benin | | | | | 0 | 3 | 3 | 0 | 0 | 3 | 0 | **9.3** |
| 3 | Benin North | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **3.1** |
| 4 | Kano | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **3.1** |
| 5 | Funtua | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **3.1** |
| 6 | Funtua | | | | | 0 | 1 | 0 | 1 | 0 | 0 | 1 | **2.7** |
| 7 | Ojo | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **3.1** |
| 8 | Omuaran | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | **3.1** |
| **Subtotal II** | | | | | | | | | | | | | **30.2** |
| **Grand Total** | | | | | | **30.2** | | | | | | | |

Source: JICA Study Team

## Table 7-10.6 Upgrading requirements of 330/132 kV, 132/33 kV and 132/11 kV transformers loaded above 85% under N-0 by 2020

| Cost Estimation of Upgrading of Transformers loded about 85% under N-0 by 2020 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | |
| | | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | 30 MVA、132/11 kV Transformer | Cost (Million US$) |
| Overhead Lines | | | | | | | | | | | | | |
| Subtotal I | | | | | 0.0 | | | | | | | | |
| Substations | | | | | | | | | | | | | |
| 1 | Kano | | | | | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 5.0 |
| 2 | Benin North | | | | | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 5.0 |
| 3 | Odogunyan | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 4 | Ganmo | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 5 | Ejigbo | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 6 | Ojo | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 7 | Alimosho | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 8 | Ughelli | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 9 | Paras | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 10 | Shagamu | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 11 | Afam 1-2-3 | | | | | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 2.7 |
| 12 | Iwo | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| 13 | Shiroro | | | | | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3.1 |
| Subtotal II | | | | | | | | | | | | | 43.7 |
| Grand Total | | 43.7 | | | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.7 New reactors and capacitors

| Cost Estimation of New Reactors and Capacitors required by 2020 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | |
| | | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11kV Switchgear | 132 kV Capacitor | 330 kV Reactor | 32 kV Reactor | Cost (Million US$) |
| Overhead Lines | | | | | | | | | | | | | |
| Subtotal I | | | | | 0.0 | | | | | | | | |
| Substations | | | | | | | | | | | | | |
| 1 | Maiduguri | | | | | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2.7 |
| 2 | Ondo2 | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1.9 |
| 3 | Irrua | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1.9 |
| 4 | Gusau | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1.9 |
| Subtotal II | | | | | | | | | | | | | 8.4 |
| Grand Total | | 8.4 | | | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.8 New transmission lines required by 2020

| Cost Estimation of New 132 kV Transmission Lines required by 2020 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | |
| | | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost (Million US$) |
| Overhead Lines | | | | | | | | | | | |
| 1 | Kaduna - Kano | 330 | 230 | 0.45 | 103.5 | | | | | | |
| 2 | Akangba - Ijora | 330 | 14 | 0.45 | 6.3 | | | | | | |
| 3 | Ijora - Alagbon | 330 | 8 | 0.45 | 3.6 | | | | | | |
| 4 | Arigbso - New Agbara | 330 | 40 | 0.45 | 18.0 | | | | | | |
| 5 | Ugwaji - Abakaliki | 330 | 85 | 0.45 | 38.3 | | | | | | |
| 6 | Osogbo - Arigbajo | 330 | 183 | 0.45 | 82.4 | | | | | | |
| 7 | Ayede - Idaban North | 132 | 15 | 0.26 | 3.9 | | | | | | |
| 8 | New Agbara - Agbara | 132 | 18 | 0.26 | 4.7 | | | | | | |
| 9 | Ogijo - Redeem | 132 | 14 | 0.26 | 3.6 | | | | | | |
| 10 | Birmin Kebbi - Dosso | 132 | 128 | 0.26 | 33.3 | | | | | | |
| | Subtotal I | | | | 297.5 | | | | | | |
| New Substations / Extension of Substations | | | | | | | | | | | |
| 1 | Kaduna | | | | | 4 | 2 | 1 | 2 | 2 | 16.1 |
| 2 | Kano | | | | | 2 | 1 | 1 | 1 | 1 | 8.4 |
| 3 | Akangba | | | | | 4 | 2 | 1 | 2 | 2 | 16.1 |
| 4 | Ijora | | | | | 4 | 2 | 1 | 2 | 2 | 16.1 |
| 5 | Arigbajo | | | | | 12 | 2 | 1 | 2 | 2 | 31.3 |
| 6 | Agbara | | | | | 0 | 2 | 1 | 0 | 1 | 4.7 |
| 7 | New Agbara | | | | | 4 | 2 | 1 | 2 | 2 | 16.1 |
| 8 | Ugwaji | | | | | 2 | 0 | 0 | 0 | 0 | 3.8 |
| 9 | Abakaliki | | | | | 2 | 0 | 0 | 0 | 0 | 3.8 |
| 10 | Osogbo | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| 11 | Ayede | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| 12 | Ibadan North | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| 13 | Ogijo | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| 14 | Redeem | | | | | 0 | 4 | 1 | 0 | 2 | 8.7 |
| 15 | Dosso | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| 16 | Ibom IPP | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| 17 | Ikot Abasi | | | | | 0 | 2 | 0 | 0 | 0 | 3.2 |
| | Subtotal II | | | | | | | | | | 147.5 |
| | Grand Total | 445.0 | | | | | | | | | |

Source: JICA Study Team

Note: The 330 kV lines which are part of the North-East Ring and North-West Ring, are considered in the cost estimation for 2025 because implementation by 2020 is not possible.

#### 7-10-2-2 Summary of Additional Investments by 2020

Table 7-10.9 shows a summary of all additional investments in transmission lines and substations by 2020. The 330 kV North-East Ring and the 330-kV line Kainji - Birnin-Kebbi are also necessary to supply the forecast load of over 9 GW. However, considering the necessary implementation time, these lines are more likely to be available between 2020 and 2025. Accordingly, these costs are included in the 2025 investment costs.

**Table 7-10.9 Summary of additional investments by 2020**

| Total Cost required by 2020 | | | |
|---|---|---|---|
| **Transmission System Expansions** | **Transmission Line** | **Substation (Million US$)** | **Total Cost (Million US$)** |
| Reinforcements of 132 kV lines overloaded under N-0 | 5.1 | 3.2 | **8.3** |
| Reinforcements of 132 kV lines overloaded under N-1 | 86.1 | 17.6 | **103.7** |
| Upgrading requirements of 330/132 kV 3-winding transformers overloaded under N-0 | 0.0 | 25.0 | **25.0** |
| Upgrading requirements of 132/33 kV and 132/11 kV transformers overloaded under N-0 | 0.0 | 30.2 | **30.2** |
| Upgrading requirements of 330/132 kV, 132/33 kV and 132/11 kV transformers overloaded loaded over 85% under N-0 | 0 | 43.7 | **43.7** |
| New Reactor and Capacitors | 0 | 8.4 | **8.4** |
| New Transmission Lines by 2020 | 297.5 | 147.5 | **445.0** |
| **Total Additional Investment Cost by 2020** | | | **664.3** |

Source: JICA Study Team

### 7-10-3 Transmission Reinforcements Required by 2025

To allow power transmission of approximately 20 GW by 2025, it will be necessary to build numerous new 330 and 132 kV transmission lines, to increase the transmission capacity of existing 132 kV transmission lines by reconductoring existing lines and installing additional 330/132 kV and 132/33(11) kV transformers.

#### 7-10-3-1 Cost Estimation of Each Project

The cost estimate for additional 132 kV lines, 330/132 kV transformers and 132/33 (11) kV transformers is shown in Table 7-10.10 to Table 7-10.19.

**Table 7-10.10 Additional Lines by 2025 - North-West Ring**

| Cost Estimation of Additional Transmission Lines required by 2025（330 kV North West Ring） | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transmission Line | | | | Substation | | | | | |
| No. | Project | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost (Million US$) |
| Overhead Lines | | | | | | | | | | | |
| 1 | Kainji - Birnin Kebbi 330 kV DC Line | 330 | 310 | 0.45 | **139.5** | | | | | | |
| 2 | Birnin Kebbi - Sokoto 330 kV DC Line | 330 | 130 | 0.45 | **58.5** | | | | | | |
| 3 | Sokoto - Talata Mafara 330 kV DC Line | 330 | 125 | 0.45 | **56.3** | | | | | | |
| 4 | Talata Mafara - Gusau 330 kV DC Line | 330 | 85 | 0.45 | **38.3** | | | | | | |
| 5 | Gusau - Funtua 330 kV DC Line | 330 | 70 | 0.45 | **31.5** | | | | | | |
| 6 | Funtua - Zaria 330 kV DC Line | 330 | 70 | 0.45 | **31.5** | | | | | | |
| **Subtotal I** | | | | | **355.5** | | | | | | |
| Substations | | | | | | | | | | | |
| 1 | Kainji | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 2 | Birnin Kebbi | | | | | 7 | 1 | 1 | 1 | 1 | **17.9** |
| 3 | Sokoto | | | | | 7 | 9 | 1 | 2 | 1 | **32.2** |
| 4 | Talata Mafara | | | | | 7 | 9 | 1 | 2 | 1 | **32.2** |
| 5 | Gusau | | | | | 7 | 9 | 1 | 2 | 1 | **32.2** |
| 6 | Funtua | | | | | 7 | 9 | 1 | 2 | 1 | **32.2** |
| 7 | Zaria | | | | | 4 | 2 | 1 | 2 | 1 | **15.3** |
| **Subtotal II** | | | | | | | | | | | **165.8** |
| **Grand Total** | | **521.3** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.11 Additional Lines by 2025 - North-East Ring

| No. | Project | Transmission Line: Rated Voltage (kV) | Transmission Line: Length (km) | Transmission Line: Unit Cost (Million US$/km) | Transmission Line: Cost (Million US$) | Substation: 330 kV Feeder | Substation: 132 kV Feeder | Substation: 33 kV Switchgear | Substation: 150 MVA、330/132kV Transformer | Substation: 60 MVA、132/33 kV Transformer | Substation: Cost (Million US$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Estimation of Additional Transmission Lines required by 2025（330 kV North East Ring）** | | | | | | | | | | | |
| **Overhead Lines** | | | | | | | | | | | |
| 1 | Jos - Gombe 330 kV DC Line | 330 | 270 | 0.45 | **121.5** | | | | | | |
| 2 | Gombe - Damaturu 330 kV DC Line | 330 | 180 | 0.45 | **81.0** | | | | | | |
| 3 | Damaturu - Maiduguri 330 kV DC Line | 330 | 260 | 0.45 | **117.0** | | | | | | |
| 4 | Gombe - Yola 330 kV DC Line | 330 | 240 | 0.45 | **108.0** | | | | | | |
| 5 | Yola - Jalingo 330 kV DC Line | 330 | 160 | 0.45 | **72.0** | | | | | | |
| **Subtotal I** | | | | | **499.5** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Jos | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 2 | Gombe | | | | | 9 | 7 | 1 | 2 | 2 | **33.6** |
| 3 | Damaturu | | | | | 7 | 7 | 1 | 2 | 2 | **29.8** |
| 4 | Maiduguri | | | | | 5 | 5 | 1 | 2 | 2 | **22.8** |
| 5 | Yola | | | | | 7 | 7 | 1 | 2 | 2 | **29.8** |
| 6 | Jailingo | | | | | 7 | 9 | 1 | 2 | 1 | **32.2** |
| **Subtotal II** | | | | | | | | | | | **152.0** |
| **Grand Total** | | **651.5** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.12 Additional Lines by 2025 - Mambilla Network Connection

| No. | Project | Transmission Line: Rated Voltage (kV) | Transmission Line: Length (km) | Transmission Line: Unit Cost (Million US$/km) | Transmission Line: Cost (Million US$) | Substation: 330 kV Feeder | Substation: 132 kV Feeder | Substation: 33 kV Switchgear | Substation: 150 MVA、330/132kV Transformer | Substation: 60 MVA、132/33 kV Transformer | Substation: Cost (Million US$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Estimation of Additional Transmission Lines required by 2025（330 kV Mambilla Network Con-nections）** | | | | | | | | | | | |
| **Overhead Lines** | | | | | | | | | | | |
| 1 | Mambilla - Wukari 330 kV DC Line | 330 | 159 | 0.45 | **71.6** | | | | | | |
| 2 | Mambilla - Jailingo | 330 | 95 | 0.45 | **42.8** | | | | | | |
| 3 | Wukari - Makurdi | 330 | 159 | 0.45 | **71.6** | | | | | | |
| 4 | Wukari - Lafia | 330 | 95 | 0.45 | **42.8** | | | | | | |
| **Subtotal I** | | | | | **228.6** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Mambilla | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 2 | Wukari | | | | | 5 | 5 | 0 | 2 | 2 | **22.1** |
| 3 | Makurdi | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 4 | Lafia | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 5 | Jalingo | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| **Subtotal II** | | | | | | | | | | | **37.3** |
| **Grand Total** | | **265.9** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.13 Other Additional Lines by 2025 (1)

| No. | Project | Transmission Line: Rated Voltage (kV) | Transmission Line: Length (km) | Transmission Line: Unit Cost (Million US$/km) | Transmission Line: Cost (Million US$) | Substation: 330 kV Feeder | Substation: 132 kV Feeder | Substation: 33 kV Switchgear | Substation: 150 MVA、330/132kV Transformer | Substation: 60 MVA、132/33 kV Transformer | Substation: Cost (Million US$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Estimation of Transmission Lines required by 2025 (Others 1)** | | | | | | | | | | | |
| **Overhead Lines** | | | | | | | | | | | |
| 1 | Arigbajo - Ayede Loop-in at Ayede | 330 | 1 | 0.22 | **0.2** | | | | | | |
| 2 | Katsina - Daura | 330 | 40 | 0.45 | **18.0** | | | | | | |
| 3 | Daura - Kazaure | 330 | 25 | 0.45 | **11.3** | | | | | | |
| 4 | Shiroro - Kaduna | 330 | 96 | 0.45 | **43.2** | | | | | | |
| 5 | Gwangwalada - Shiroro | 132 | 145 | 0.26 | **37.7** | | | | | | |
| 6 | Benin North - Omotosho | 330 | 110 | 0.45 | **49.5** | | | | | | |
| 7 | Zungeru - Kainji | 330 | 200 | 0.45 | **90.0** | | | | | | |
| 8 | Zungeru - Shiroro | 330 | 25 | 0.45 | **11.3** | | | | | | |
| **Subtotal I** | | | | | **261.1** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Ayede | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 2 | Katsina | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 3 | Daura | | | | | 4 | 0 | 0 | 0 | 0 | **7.6** |
| 4 | Kazaure | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 5 | Shiroro | | | | | 6 | 0 | 0 | 0 | 0 | **11.4** |
| 6 | Kaduna | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 7 | Gwangwalada | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 8 | Benin North | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 9 | Omotosho | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 10 | Zungeru | | | | | 4 | 0 | 0 | 0 | 0 | **7.6** |
| 11 | Kainji | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| **Subtotal II** | | | | | | | | | | | **57.0** |
| **Grand Total** | | **318.1** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.14 Other Additional Lines by 2025 (2)

| Cost Estimation of Transmission Lines required by 2025 (Others 2) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | (Million US$) |
| **Overhead Lines** | | | | | | | | | | | |
| 1 | Shiroro - Tegina | 132 | 65 | 0.26 | **16.9** | | | | | | |
| 2 | Tegina - Kontagora | 132 | 90 | 0.26 | **23.4** | | | | | | |
| 3 | Kontagora - Yelwa-Yauri | 132 | 88 | 0.26 | **22.9** | | | | | | |
| 4 | Ganmo - Ilorin | 132 | 10.5 | 0.26 | **2.7** | | | | | | |
| 5 | Obajana - Egbe | 132 | 97 | 0.26 | **25.2** | | | | | | |
| 6 | Omotosho - Ondo | 132 | 98 | 0.26 | **25.5** | | | | | | |
| 7 | Benin - Irrua | 132 | 88 | 0.26 | **22.9** | | | | | | |
| 8 | Irrua - Ukpilla | 132 | 43 | 0.26 | **11.2** | | | | | | |
| 9 | Ukpilla - Okene | 132 | 33 | 0.26 | **8.6** | | | | | | |
| 10 | Shamagu - Ijebu Ode | 132 | 41 | 0.26 | **10.7** | | | | | | |
| 11 | Dakata - Gagarawa | 132 | 89 | 0.26 | **23.1** | | | | | | |
| 12 | Gagarawa - Hadejia | 132 | 60 | 0.26 | **15.6** | | | | | | |
| 13 | Dakata - Kumbotso | 132 | 30 | 0.26 | **7.8** | | | | | | |
| 14 | Obajana - Okene | 132 | 97 | 0.26 | **25.2** | | | | | | |
| 15 | Kainji - Iseyin | 132 | 200 | 0.26 | **52.0** | | | | | | |
| **Subtotal I** | | | | | **293.7** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Shiroro | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 2 | Tegina | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 3 | Kontagora | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 4 | Yelwa-Yauri | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 5 | Ganmo | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 6 | Ilorin | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 7 | Obajana | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 8 | Egbe | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 9 | Omotosho | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 10 | Ondo | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 11 | Benin | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 12 | Ukpilla | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 13 | Shamagu | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 14 | Ijebu Ode | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 15 | Dakata | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 16 | Gagarawa | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 17 | Hadejia | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 18 | Dakata | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 19 | Kumbotso | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 20 | Birmin Kebbi | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 21 | Dosso | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| **Subtotal II** | | | | | | | | | | | **67.2** |
| **Grand Total** | | **360.9** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.15 First transmission lines of the Supergrid by 2025

| Cost Estimation of Transmission Lines for Supergrid required by 2025 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | (Million US$) |
| **Overhead Lines** | | | | | | | | | | | |
| 1 | Ikot-Ekpene - Makurdi | 330 | 320 | 0.45 | **144.0** | | | | | | |
| 2 | Makurdi - Gwangwalada | 330 | 180 | 0.45 | **81.0** | | | | | | |
| 3 | Ajaokuta - Gwangwalada | 330 | 150 | 0.45 | **67.5** | | | | | | |
| 4 | Osogbo - Gwangwalada | 330 | 250 | 0.45 | **112.5** | | | | | | |
| 5 | Gwangwalada - Funtua | 330 | 250 | 0.45 | **112.5** | | | | | | |
| **Subtotal I** | | | | | **517.5** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Ikot-Ekpene | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 2 | Markurdi | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 3 | Ajaokuta | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 4 | Gwangwalada | | | | | 8 | 2 | 0 | 2 | 0 | **21.4** |
| 5 | Osogbo | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 6 | Funtua | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| **Subtotal II** | | | | | | | | | | | **71.4** |
| **Grand Total** | | **588.9** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.16 Reconductoring of 132 kV lines by 2025

| Cost Estimation of Reconductoring of 132 kV Transmission Lines required by 2025 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | |
| | | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost (Million US$) |
| Overhead Lines | | | | | | | | | | | |
| 1 | Egbin - Ikorodu | 132 | 20 | 0.08 | **1.6** | | | | | | |
| 2 | Ogijo - Shagamu | 132 | 16 | 0.08 | **1.3** | | | | | | |
| 3 | Ayede - Idaban North | 132 | 12 | 0.04 | **0.5** | | | | | | |
| 4 | Ayede - Jericho | 132 | 6 | 0.08 | **0.5** | | | | | | |
| 5 | Alaoji - Aba | 132 | 10 | 0.08 | **0.8** | | | | | | |
| 6 | Eket - Ibom IPP | 132 | 45 | 0.08 | **3.6** | | | | | | |
| 7 | PHCT Main - PHCT Town | 132 | 6 | 0.04 | **0.2** | | | | | | |
| **Subtotal I** | | | | | **8.5** | | | | | | |
| Substations | | | | | | | | | | | |
| **Subtotal II** | | | | | | | | | | | **0.0** |
| **Grand Total** | | **8.5** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.17 Upgrading requirements of 330/132kV transformers

| Cost Estimation of Upgrading of 330/132 kV 3-winding Transformers required by 2025 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | |
| | | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost (Million US$) |
| Overhead Lines | | | | | | | | | | | |
| **Subtotal I** | | | | | **0.0** | | | | | | |
| Substations | | | | | | | | | | | |
| 1 | Adiagbo | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 2 | Aja | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 3 | Ajaokuta | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 4 | Akangba | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 5 | Akoka | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 6 | Akure | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 7 | Apapa | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 8 | Ayede | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 9 | Delta | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 10 | Ganmo | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 11 | Ihala | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 12 | Ikeja West | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 13 | Isolo | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 14 | Jericho | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 15 | Kano | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 16 | Kumbotoso | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 17 | Nnewi | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 18 | Omotosho | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 19 | Onitsha | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 20 | Osogbo | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 21 | Oweri | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| 22 | West Main | | | | | 2 | 2 | 0 | 2 | 0 | **10.0** |
| **Subtotal II** | | | | | | | | | | | **210.0** |
| **Grand Total** | | **210.0** | | | | | | | | | |

Source: JICA Study Team

# Table 7-10.18 Upgrading requirements of 132/33(11) kV transformers

| Cost Estimation of Upgrading of 132/33, 132/11 kV Transformers required by 2025 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | 30 MVA、132/11 kV Transformer | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | | | (Million US$) |
| Overhead Lines | | | | | | | | | | | | | |
| **Subtotal I** | | | | | **0.0** | | | | | | | | |
| Substations | | | | | | | | | | | | | |
| 1 | Aba | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 2 | Abakaliki | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 3 | Afam 1-2-3 | | | | | 0 | 2 | 0 | 2 | 0 | 0 | 2 | **5.4** |
| 4 | Ahoada | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 5 | Ajaokuta | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 6 | Akangba | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 7 | Akoka | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 8 | Akure | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 9 | Alagbon | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 10 | Alimosho | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 11 | Amukpe | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 12 | Arigbajo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 13 | Ayede | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 14 | Benin | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 15 | Dan Agundi | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 16 | Egbin | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 17 | Ejigbo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 18 | Eket | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 19 | Elelenwo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 20 | Ganmo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 21 | Gashuwa | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 22 | Gusau | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 23 | Idaban North | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 24 | Ijebu Ode | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 25 | Ijora | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 26 | Ikordu | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 27 | Ikot Abasi | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 28 | Ilesha | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 29 | Illupeju | | | | | 0 | 2 | 0 | 2 | 0 | 0 | 2 | **5.4** |
| 30 | Irrua | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 31 | Iseyin | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 32 | Isolo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 33 | Itire | | | | | 0 | 2 | 0 | 2 | 0 | 0 | 2 | **5.4** |
| 34 | Iwo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 35 | Jalingo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 36 | Jos | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 37 | Kaduna Town | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 38 | Kafanchan | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 39 | Kano | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 40 | Katsina | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 41 | Kazaure | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 42 | Makeri | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 43 | New Haven | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 44 | Nkalagu | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 45 | Odogunyan | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 46 | Ogba | | | | | 0 | 2 | 0 | 2 | 0 | 0 | 2 | **5.4** |
| 47 | Ojo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 48 | Ondo2 | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 49 | Onitsha | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 50 | Osogbo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 51 | Otta | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 52 | Oweri | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 53 | Oworosoki | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 54 | Paras | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 55 | PHCT Town | | | | | 0 | 2 | 0 | 2 | 0 | 0 | 2 | **5.4** |
| 56 | Rumusoi | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 57 | Savannah | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 58 | Shagamu | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 59 | Shagamu Cement | | | | | 0 | 2 | 0 | 2 | 0 | 0 | 2 | **5.4** |
| 60 | Shiroro | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 61 | Suleja | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 62 | Tegina | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 63 | Ughelli | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 64 | Umuahia | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| 65 | Uyo | | | | | 0 | 2 | 2 | 0 | 0 | 2 | 0 | **6.2** |
| **Subtotal II** | | | | | | | | | | | | | **398.2** |
| **Grand Total** | | **398.2** | | | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.19 New reactors and capacitors by 2025

| Cost Estimation of New Reactors and Capacitors required by 2025 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11 kV Switchgear | 132 kV Capacitor | 132 kV Reactor | 33 kV Capacitor | 33 kV Reactor | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | | | | (Million US$) |
| Overhead Lines | | | | | | | | | | | | | | |
| Subtotal I | | | | | 0.0 | | | | | | | | | |
| Substations | | | | | | | | | | | | | | |
| 1 | Iseyin | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | **0.50** |
| 2 | Irrua | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **0.25** |
| 3 | Keffi | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | **1.90** |
| 4 | Omuaran | | | | | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | **3.80** |
| 5 | Hadejia | | | | | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | **3.80** |
| 6 | Apo | | | | | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | **3.80** |
| 7 | Sulejia | | | | | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | **3.80** |
| 8 | Uyo | | | | | 0 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | **7.60** |
| 9 | Ondo | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | **1.90** |
| Subtotal II | | | | | | | | | | | | | | **27.35** |
| Grand Total | | 27.35 | | | | | | | | | | | | |

Source: JICA Study Team

### 7-10-3-2 Summary of Additional Investments between 2021 and 2025

Table 7-10.20 shows a summary of all additional investments in transmission lines and substations between 2021 and 2025.

## Table 7-10.20 Summary of additional investments in transmission lines and substations between 2021 and 2025

| Transmission System Expansions | Transmission Line (Million US$) | Substation (Million US$) | Total Cost (Million US$) |
|---|---|---|---|
| Project 1: 330 kV North West Ring by 2025 | 355.5 | 165.8 | **521.3** |
| Project 2: 330 kV North East Ring by 2025 | 499.5 | 152.0 | **651.5** |
| Project 3: 330 kV Mambilla Network Connections by 2025 | 228.6 | 37.3 | **265.9** |
| Additional Transmission Lines by 2025 - Part 1 | 261.1 | 57.0 | **318.1** |
| Additional Transmission Lines by 2025 - Part 2 | 293.7 | 67.2 | **360.9** |
| First Transmission Lines of the Supergrid by 2025 | 517.5 | 71.4 | **588.9** |
| Reconductoring of 132 kV Lines | 8.5 | 0.0 | **8.5** |
| Additional 330/132 kV Transformers by 2025 | 0.0 | 210.0 | **210.0** |
| Additional 132/33 and 132/11 kV Transformers | 0.0 | 398.2 | **398.2** |
| New Reactive Power Compensation | 0.0 | 27.4 | **27.4** |
| Costs for converting 330 kV DC lines to quad conductors | 10.0 | 0.0 | **10.0** |
| **Total Additional Investment Cost by 2025** | | | **3,360.7** |

Source: JICA Study Team

### 7-10-4 Transmission Reinforcements Required by 2030

A further extension of the 330 kV Supergrid will be required by 2030. Furthermore, there will be a need to install capacitor banks at various substations to maintain voltages within permissible limits.

### 7-10-4-1 Cost Estimation of Each Project

The cost estimate for the additional transmission lines, transformers and capacitor banks is shown in Table 7-10.21 and 7-10.22.

## Table 7-10.21 Additional investments in 330 kV Supergrid transmission lines and substations by 2030

| Cost Estimation of Additional 330 kV Supergrid Transmission Lines and Substations required by 2030 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transmission Line | | | | Substation | | | | | |
| No. | Project | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost (Million US$) |
| **Overhead Lines** | | | | | | | | | | | |
| 1 | Ikot Ekpene - Benin | 330 | 300 | 0.45 | **135.0** | | | | | | |
| 2 | Benin - Egbin | 330 | 230 | 0.45 | **103.5** | | | | | | |
| 3 | Egbin - New Agbara | 330 | 50 | 0.45 | **22.5** | | | | | | |
| 4 | Benin - Osogbo | 330 | 200 | 0.45 | **90.0** | | | | | | |
| 5 | Osogbo - Kainji | 330 | 200 | 0.45 | **90.0** | | | | | | |
| 6 | Benin - Ajeokuta | 330 | 150 | 0.45 | **67.5** | | | | | | |
| 7 | Gangwalada - Kainji | 330 | 250 | 0.45 | **112.5** | | | | | | |
| 8 | Kainji - Bernin Kebbi | 330 | 300 | 0.45 | **135.0** | | | | | | |
| 9 | New Agbara - Osogbo | 330 | 150 | 0.45 | **67.5** | | | | | | |
| **Subtotal I** | | | | | **823.5** | | | | | | |
| **Substations** | | | | | | | | | | | |
| 1 | Ikot Ekpene | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 2 | Benin | | | | | 6 | 5 | 0 | 0 | 0 | **19.4** |
| 3 | Egbin | | | | | 4 | 0 | 0 | 0 | 0 | **7.6** |
| 4 | New Agbara | | | | | 4 | 0 | 0 | 0 | 0 | **7.6** |
| 5 | Osogbo | | | | | 6 | 0 | 0 | 0 | 0 | **11.4** |
| 6 | Ajaokuta | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 7 | Gangwalada | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 8 | Kainji | | | | | 4 | 0 | 0 | 0 | 0 | **7.6** |
| 9 | Bernin Kebbi | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| **Subtotal II** | | | | | | | | | | | **68.8** |
| **Grand Total** | | **892.3** | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.22 Additional Capacitor Banks to be installed by 2030

| Cost Estimation of New Reactors and Capacitors required by 2030 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transmission Line | | | | Substation | | | | | | | | |
| No. | Project | Rated Voltage (kV) | Length (km) | Unit Cost (Million US$/km) | Cost (Million US$) | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11 kV Switchgear | 132 kV Capacitor | 132 kV Reactor | 33 kV Capacitor | 33 kV Reactor | Cost (Million US$) |
| **Overhead Lines** | | | | | | | | | | | | | | |
| **Subtotal I** | | | | | **0.0** | | | | | | | | | |
| **Substations** | | | | | | | | | | | | | | |
| 1 | Gombe | | | | | 0 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | **7.6** |
| 2 | Bernin Kebbi | | | | | 0 | 3 | 0 | 0 | 6 | 0 | 0 | 0 | **6.6** |
| 3 | Gashuwa | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | **1.9** |
| 4 | Apo | | | | | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | **3.8** |
| 5 | Keffi | | | | | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | **1.9** |
| 6 | Uba | | | | | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | **3.8** |
| **Subtotal II** | | | | | | | | | | | | | | **25.6** |
| **Grand Total** | | **25.6** | | | | | | | | | | | | |

Source: JICA Study Team

## 7-10-5 Transmission Reinforcements Required by 2035

## Table 7-10.23 Additional investments in transmission lines and substations by 2035

| Cost Estimation of New Transmission Line required by 2035 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transmission Line | | | | | | | | Substation | | | | | |
| No. | Project | Rated Voltage | Length | Alternative 1 | | Alternative 2 | | Cost of Alternative 1 | Cost of Alternative 2 | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | Reinforcement | Unit Cost (Million US$/km) | Reinforcement | Unit Cost (Million US$/km) | (Million US$) | (Million US$) | | | | | | (Million US$) |
| **Overhead Lines** | | | | | | | | | | | | | | | |
| 1 | Wukari - Lafia | 330 | 95 | DC | 0.45 | DC | 0.45 | **42.8** | **42.8** | | | | | | |
| 2 | Zuma - Lokoja | 330 | 25 | RE | 0.15 | DC | 0.45 | **3.8** | **11.3** | | | | | | |
| 3 | Aja - Lekki | 330 | 7 | RE | 0.15 | DC | 0.45 | **1.1** | **3.2** | | | | | | |
| 4 | Benin North - Akure | 330 | 130 | RE | 0.08 | DC | 0.45 | **10.4** | **58.5** | | | | | | |
| 5 | Kwaya Kusar - Biu | 132 | 42 | SC | 0.17 | DC | 0.26 | **7.1** | **10.9** | | | | | | |
| 6 | Biu - Damboa | 132 | 140 | SC | 0.17 | DC | 0.26 | **23.8** | **36.4** | | | | | | |
| 7 | Damboa - Maiduguri | 132 | 64 | SC | 0.17 | DC | 0.26 | **10.9** | **16.6** | | | | | | |
| **Subtotal I** | | | | | | | | **99.8** | **179.6** | | | | | | |
| **Substations** | | | | | | | | | | | | | | | |
| 1 | Wukari | | | | | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 2 | Lafia | | | | | | | | | 2 | 0 | 0 | 0 | 0 | **3.8** |
| 3 | Zuma | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 4 | Lokoja | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 5 | Aja | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 6 | Lekki | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 7 | Benin North | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 8 | Akure | | | | | | | | | 0 | 0 | 0 | 0 | 0 | **0.0** |
| 9 | Kwaya Kusar | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| 10 | Biu | | | | | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 11 | Damboa | | | | | | | | | 0 | 2 | 0 | 0 | 0 | **3.2** |
| 12 | Maiduguri | | | | | | | | | 0 | 1 | 0 | 0 | 0 | **1.6** |
| **Subtotal II** | | | | | | | | | | | | | | | **17.2** |
| **Grand Total - Alternative 1** | | **117.0** | | | | | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.24 Additional Capacitor Banks to be installed by 2035

| Cost Estimation of New Reactors and Capacitors required by 2035 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11 kV Switchgear | 330 kV Capacitor | 132 kV Capacitor | 132 kV Reactor | 33 kV Capacitor | 33 kV Reactor | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | | | | | (Million US$) |
| Overhead Lines | | | | | | | | | | | | | | | |
| Subtotal I | | | | | 0.0 | | | | | | | | | | |
| Substations | | | | | | | | | | | | | | | |
| 1 | Gombe | | | | | 3 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 7.6 |
| 2 | Bernin Kebbi | | | | | 7 | 0 | 0 | 0 | 1 | 7 | 0 | 0 | 0 | 16.4 |
| 3 | Ikeja West | | | | | 0 | 12 | 0 | 0 | 1 | 12 | 0 | 0 | 0 | 23.8 |
| Subtotal II | | | | | | | | | | | | | | | 47.8 |
| Grand Total | | 47.8 | | | | | | | | | | | | | |

Source: JICA Study Team

## 7-10-6 Transmission Reinforcements Required by 2040

## Table 7-10.25 Additional investments in transmission lines and substations by 2035

| Cost Estimation of New Transmission Lines required by 2040 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | | | | | Substation | | | | | |
| | | Rated Voltage | Length | Alternative 1 | | Alternative 2 | | Cost of Alternative 1 | Cost of Alternative 2 | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 150 MVA、330/132kV Transformer | 60 MVA、132/33 kV Transformer | Cost |
| | | (kV) | (km) | einforcemer | Unit Cost (Million US$/km) | Reinforce ment | Unit Cost (Million US$/km) | (Million US$) | (Million US$) | | | | | | (Million US$) |
| Overhead Lines | | | | | | | | | | | | | | | |
| 1 | Aladja - Delta IV | 330 | 32 | SC | 0.22 | DC | 0.45 | 7.0 | 14.4 | | | | | | |
| 2 | Osogbo - Ganmo | 330 | 50 | SC | 0.22 | DC | 0.45 | 11.0 | 22.5 | | | | | | |
| 3 | Yola - Little Gombe | 330 | 100 | DC | 0.45 | DC | 0.45 | 45.0 | 45.0 | | | | | | |
| 4 | Little Gombi - Biu | 330 | 80 | DC | 0.45 | DC | 0.45 | 36.0 | 36.0 | | | | | | |
| 5 | Biu - Daimaturu | 330 | 130 | DC | 0.45 | DC | 0.45 | 58.5 | 58.5 | | | | | | |
| 6 | Daimaturu - Potiscum | 330 | 100 | DC | 0.45 | DC | 0.45 | 45.0 | 45.0 | | | | | | |
| 7 | Potiscum - Azare | 330 | 100 | DC | 0.45 | DC | 0.45 | 45.0 | 45.0 | | | | | | |
| 8 | Azare - Dutse | 330 | 90 | DC | 0.45 | DC | 0.45 | 40.5 | 40.5 | | | | | | |
| 9 | Dutse - Jogana | 330 | 76 | DC | 0.45 | DC | 0.45 | 34.2 | 34.2 | | | | | | |
| Subtotal I | | | | | | | | 322.2 | 341.1 | | | | | | |
| Substations | | | | | | | | | | | | | | | |
| 1 | Aladja | | | | | | | | | 2 | 0 | 0 | 0 | 0 | 3.8 |
| 2 | Osogbo | | | | | | | | | 2 | 0 | 0 | 0 | 0 | 3.8 |
| 3 | Ganmo | | | | | | | | | 2 | 0 | 0 | 0 | 0 | 3.8 |
| 4 | Little Gombi | | | | | | | | | 4 | 0 | 0 | 0 | 0 | 7.6 |
| 5 | Biu | | | | | | | | | 4 | 0 | 0 | 0 | 0 | 7.6 |
| 6 | Daimaturu | | | | | | | | | 4 | 0 | 0 | 0 | 0 | 7.6 |
| 7 | Potiscum | | | | | | | | | 4 | 0 | 0 | 0 | 0 | 7.6 |
| 8 | Azare | | | | | | | | | 4 | 0 | 0 | 0 | 0 | 7.6 |
| 9 | Dutse | | | | | | | | | 4 | 1 | 0 | 0 | 0 | 9.2 |
| 10 | Jogana | | | | | | | | | 2 | 2 | 0 | 0 | 0 | 7.0 |
| Subtotal II | | | | | | | | | | | | | | | 65.6 |
| Grand Total - Alternative 1 | | 387.8 | | | | | | | | | | | | | |

Source: JICA Study Team

## Table 7-10.26 Additional Capacitor Banks to be installed by 2040

| Cost Estimation of New Reactors and Capacitors required by 2040 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Line | | | | Substation | | | | | | | | | |
| | | Rated Voltage | Length | Unit Cost | Cost | 330 kV Feeder | 132 kV Feeder | 33 kV Switchgear | 11 kV Switchgear | 330 kV Capacitor | 132 kV Capacitor | 132 kV Reactor | 33 kV Capacitor | 33 kV Reactor | Cost |
| | | (kV) | (km) | (Million US$/km) | (Million US$) | | | | | | | | | | (Million US$) |
| Overhead Lines | | | | | | | | | | | | | | | |
| Subtotal I | | | | | 0.0 | | | | | | | | | | |
| Substations | | | | | | | | | | | | | | | |
| 1 | Abuja | | | | | 15 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 43.5 |
| 2 | Kano | | | | | 6 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 17.4 |
| 3 | Bernin Kebbi | | | | | 4 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 11.6 |
| 4 | Ikeja West | | | | | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5.8 |
| Subtotal II | | | | | | | | | | | | | | | 78.3 |
| Grand Total | | 78.3 | | | | | | | | | | | | | |

Source: JICA Study Team

## 7-10-7 Summary of Cost Comparison for Three Voltage Levels

This Section compares the cost of a super grid based on 330 kV (presently the highest voltage) with the costs of a super grid based on 500 and 750 kV nominal voltages (respectively 550- and 800 kV-rated voltages).

- In the case of a 330-kV super grid, it is assumed that the transmission line will be Double-Circuit lines with Quad Bison conductors.

- In the case of a 500-kV super grid, it is assumed that the transmission lines will be Single-Circuit lines with Quad Bison conductors.
- In the case of a 750-kV super grid, it is assumed that the transmission lines will be Single-Circuit lines with five-bundle Bison conductors.

Regarding substations, it is assumed that for a 330-kV double busbar system with an auxiliary busbar, a bus coupler will be installed whereas for 500 and 750 kV units, one-and-half circuit-breaker schemes will be installed.

Table 7-10.27, Table 7-10.28 and Table 7-10.29 show the cost estimation for the three voltage levels.

**Table 7-10.27 Cost estimation for the 330-kV super grid**

| Cost Estimation of 330 kV Super Grid | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Lines | | | | 変電所 | | | |
| | | Rated Voltage (kV) | Length (km) | Cost per km (Million US$/km) | Total Cost (Million US$) | 330 kV Line Feeder | 330 kV Transformer Feeder | 330 kV Shunt Reactor | Total Cost (Million US$) |
| **Overhead Lines** | | | | | | | | | |
| 1 | Ikot Ekpene - Benin | 330 | 300 | 0.45 | **135** | | | | |
| 2 | Ikot Ekpene - Makurdi | 330 | 300 | 0.45 | **135** | | | | |
| 3 | Benin - New Agbara | 330 | 250 | 0.45 | **113** | | | | |
| 4 | Benin - Osogbo | 330 | 160 | 0.45 | **72** | | | | |
| 5 | Benin - Ajaokuta | 330 | 300 | 0.45 | **135** | | | | |
| 6 | New Agbara - Osogbo | 330 | 160 | 0.45 | **72** | | | | |
| 7 | Osogbo - Gwagwalad | 330 | 260 | 0.45 | **117** | | | | |
| 8 | Makurdi - Gwagwalad | 330 | 200 | 0.45 | **90** | | | | |
| 9 | Makurdi - Ajaokuta | 330 | 200 | 0.45 | **90** | | | | |
| 10 | Ajaokuta - Gwagwalad | 330 | 200 | 0.45 | **90** | | | | |
| 11 | Gwagwalad - Funtua | 330 | 250 | 0.45 | **113** | | | | |
| | **Subtotal I** | | | | **1,161** | | | | |
| **Substations** | | | | | | | | | |
| 1 | Ikot Ekpene | | | | | 9 | 2 | 2 | **25** |
| 2 | Benin | | | | | 11 | 2 | 2 | **29** |
| 3 | Makurdi | | | | | 11 | 2 | 2 | **29** |
| 4 | Osogbo | | | | | 11 | 2 | 2 | **29** |
| 5 | New Agbara | | | | | 9 | 2 | 2 | **25** |
| 6 | Ajaokuta | | | | | 11 | 2 | 2 | **29** |
| 7 | Gwagwalad | | | | | 13 | 2 | 2 | **33** |
| 8 | Funtua | | | | | 7 | 2 | 2 | **21** |
| | **Subtotal II** | | | | | | | | **220** |
| | **Grand Total** | **1,381** | | | | | | | |

Source: JICA Study Team

**Table 7-10.28 Cost estimation for the 500-kV super grid**

| Cost Estimation of 500 kV Super Grid | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Lines | | | | Substations | | | | |
| | | Rated Voltage (kV) | Length (km) | Cost per km (Million US$/km) | Total Cost (Million US$) | 500kV feeder | 330kV feeder | 500MVA 500/330 kV Transformer | 500kV Shunt Reactor | Total Cost (Million US$) |
| **Overhead Lines** | | | | | | | | | | |
| 1 | Ikot Ekpene - Benin | 500 | 300 | 0.28 | **84** | | | | | |
| 2 | Ikot Ekpene - Makurdi | 500 | 300 | 0.28 | **84** | | | | | |
| 3 | Benin - New Agbara | 500 | 250 | 0.28 | **70** | | | | | |
| 4 | Benin - Osogbo | 500 | 160 | 0.28 | **45** | | | | | |
| 5 | Benin - Ajaokuta | 500 | 300 | 0.28 | **84** | | | | | |
| 6 | New Agbara - Osogbo | 500 | 160 | 0.28 | **45** | | | | | |
| 7 | Osogbo - Gwagwalad | 500 | 260 | 0.28 | **73** | | | | | |
| 8 | Makurdi - Gwagwalad | 500 | 200 | 0.28 | **56** | | | | | |
| 9 | Makurdi - Ajaokuta | 500 | 200 | 0.28 | **56** | | | | | |
| 10 | Ajaokuta - Gwagwalad | 500 | 200 | 0.28 | **56** | | | | | |
| 11 | Gwagwalad - Funtua | 500 | 250 | 0.28 | **70** | | | | | |
| | **Subtotal I** | | | | **722** | | | | | |
| **Substations** | | | | | | | | | | |
| 1 | Ikot Ekpene | | | | | 6 | 2 | 2 | 2 | **64** |
| 2 | Benin | | | | | 8 | 2 | 2 | 2 | **72** |
| 3 | Makurdi | | | | | 7 | 2 | 2 | 2 | **68** |
| 4 | Osogbo | | | | | 7 | 2 | 2 | 2 | **68** |
| 5 | New Agbara | | | | | 6 | 2 | 2 | 2 | **64** |
| 6 | Ajaokuta | | | | | 7 | 2 | 2 | 2 | **68** |
| 7 | Gwagwalad | | | | | 8 | 2 | 2 | 2 | **72** |
| 8 | Funtua | | | | | 5 | 2 | 2 | 2 | **60** |
| | **Subtotal II** | | | | | | | | | **533** |
| | **Grand Total** | **1,256** | | | | | | | | |

Source: JICA Study Team

**Table 7-10.29 Cost estimation for the 750-kV super grid**

| Cost Estimation of 750 kV Super Grid | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Project | Transmission Lines | | | | Substations | | | | |
| | | Rated Voltage (kV) | Length (km) | Cost per km (Million US$/km) | Total Cost (Million US$) | 750kV feeder | 330kV feeder | 500MVA 750/330 kV Transformer | 750kV Shunt Reactor | Total Cost (Million US$) |
| **Overhead Lines** | | | | | | | | | | |
| 1 | Ikot Ekpene - Benin | 750 | 300 | 0.35 | **105** | | | | | |
| 2 | Ikot Ekpene - Makurdi | 750 | 300 | 0.35 | **105** | | | | | |
| 3 | Benin - New Agbara | 750 | 250 | 0.35 | **88** | | | | | |
| 4 | Benin - Osogbo | 750 | 160 | 0.35 | **56** | | | | | |
| 5 | Benin - Ajaokuta | 750 | 300 | 0.35 | **105** | | | | | |
| 6 | New Agbara - Osogbo | 750 | 160 | 0.35 | **56** | | | | | |
| 7 | Osogbo - Gwagwalad | 750 | 260 | 0.35 | **91** | | | | | |
| 8 | Makurdi - Gwagwalad | 750 | 200 | 0.35 | **70** | | | | | |
| 9 | Makurdi - Ajaokuta | 750 | 200 | 0.35 | **70** | | | | | |
| 10 | Ajaokuta - Gwagwalad | 750 | 200 | 0.35 | **70** | | | | | |
| 11 | Gwagwalad - Funtua | 750 | 250 | 0.35 | **88** | | | | | |
| | **Subtotal I** | | | | **903** | | | | | |
| **Substations** | | | | | | | | | | |
| 1 | Ikot Ekpene | | | | | 6 | 2 | 2 | 2 | **82** |
| 2 | Benin | | | | | 8 | 2 | 2 | 2 | **92** |
| 3 | Makurdi | | | | | 7 | 2 | 2 | 2 | **87** |
| 4 | Osogbo | | | | | 7 | 2 | 2 | 2 | **87** |
| 5 | New Agbara | | | | | 6 | 2 | 2 | 2 | **82** |
| 6 | Ajaokuta | | | | | 7 | 2 | 2 | 2 | **87** |
| 7 | Gwagwalad | | | | | 8 | 2 | 2 | 2 | **92** |
| 8 | Funtua | | | | | 5 | 2 | 2 | 2 | **77** |
| | **Subtotal II** | | | | | | | | | **686** |
| | **Grand Total** | **1,589** | | | | | | | | |

Source: JICA Study Team

The cost comparison is summarized in Table 7-10.30.

Table 7-10.30 Summary of cost comparison

| Voltage Level | Transmission Lines (Million US$) | Substations (Million US$) | Total (Million US$) |
|---|---|---|---|
| 330 kV | 1,161 | 220 | **1,381** |
| 500 kV | 722 | 533 | **1,256** |
| 750 kV | 903 | 686 | **1,589** |

Source: JICA Study Team

A rough cost comparison indicates that the 500-kV super grid will require less investment. However, the cost difference to 330 kV is relatively small. Considering that in terms of technical performance (MVA transmission capacity, losses, impact on under/overvoltages and overloads as well as static security issues) the 330-kV system appears more advantageous, its 10% higher investment cost could be justified.

In view of the above, it is apparent that more detailed studies must confirm the conclusions of this study. It is therefore recommended to have these detailed studies carried out in due course and as soon as possible, before a final decision can be made on the selection of the voltage level (330 or 500 kV) for a future super grid.

The cost for 750 kV is far higher compared to 330 and 500 kV. The transmission capacity of a 330-kV Double-Circuit line and a 500-kV Single-Circuit line are 3,100 and 2,350 MVA respectively, compared to 4,400 MW for a 750-kV Single-Circuit line. The network calculations (Chapter 8), however, have indicated that the transmission capacity of the 330 and 500 kV supergrid systems suffices.

There is no justification for adopting and/or further considering any higher (750 kV) option for the EHV grid, particularly when the implications in cost differences are taken into account, as detailed in Section 8. The higher transmission capacity (4,400 MVA) is not required at this stage and the marginal differences in losses cannot offset the high investment cost required in the planning horizon of this Master Plan.