

TCN Transmission System Development Plan and Capital Funding Requirements

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1.0 Report Objectives

The objectives of this report are to summarise TCN's Transmission System Development Plan and associated capital funding requirements, as approved by the Supervisory Board in February 2014. If properly funded, this plan will improve the overall security and quality of supply of electricity, and ensure that the system can efficiently evacuate unrestricted power from the generators to the distribution companies and large industrial and commercial users.

This report covers:

- a summary of the results of the TCN Transmission Development Plan as prepared by MHI;
- a prioritized list of transmission network capital projects currently underway and proposed to reach a total system capacity of 10 GW by 2017, and 20 GW by 2020; and
- a summary of the phased capital funding requirements for the TCN Transmission Development Plan.

2.0 Transmission Planning Study for 10 GW System

2.1. Introduction

Nigeria's transmission system, which consists of 330kV and 132kV high voltage lines, substations, and control facilities is owned and operated by the Transmission Company of Nigeria (TCN). Within TCN, the Transmission Services Provider Business Unit is responsible for constructing and maintaining the transmission system infrastructure.

The transmission system has problems with reliability and security, and is currently inadequate for the major generation expansion projects that are in the planning or construction phases. As the NIPP transmission construction program nears completion, the capacity of the transmission system is expected to reach around 7,000 MW. This represents the estimated total capacity of the network to wheel energy from generation to load over the 330/132 kV system. TCN aspires to increase the capacity of the grid from 7 GW up to 10 GW by 2017, and up to 20 GW by 2020. At the same time, TCN will need to refurbish older facilities to improve reliability and security.

In support of the initial goal to reach 10 GW by 2017, MHI and TCN system planning experts have prepared a Transmission Development Plan using the PSSE planning software. The first step in the planning process involved converting TCN's existing NEPLAN model to PSSE. MHI planning engineers and TCN planning engineers worked on the conversion of the initial NEPLAN based 4,500 MW model and subsequent development of the PSSE 10,000 MW model over a period of many months both in Abuja and at the engineering offices in Manitoba.

The 10 GW model was completed in July 2013. Since then, MHI and TCN engineers have continued to refine the Transmission Development Plan. This has resulted in some additions to the list of required substations, lines and voltage compensation facilities. The lists of projects shown in this report reflect all additions made subsequent to publication of the MHI report.

2.2. Executive Summary of MHI Transmission Development Plan Report

Below is an excerpt from the executive summary of the report presenting the results for the 10 GW model. Please see Appendix A for the full report.

In early 2013 Manitoba Hydro International Ltd. (MHI) was contracted to assist Transmission Company of Nigeria (TCN) with model development and system studies related to the ongoing system expansion projects.

The existing generation and network resources cannot sustain the entire load and hence load rotation schemes have been adopted. This results in daily power cuts to customers. The proposed system expansions are aimed at serving the existing loads as well as catering the potential load growth over the next five years.

The model development and study results reported here focused on two specific stages of TCN system:

1. 4.5 GW network model: This is considered as the base system with a load of 4.5 GW and is a representative of the TCN network as of December 2012.
2. 10 GW network model: This is the projected TCN network with 10 GW of load and is expected to be in operation by December 2016.

When developing the transmission models, certain assumptions had to be made when the required data was not available. These assumptions were made with the consent of TCN engineers and details are discussed in the report.

The following tasks have been accomplished under this project:

1. Conversion of 4.5 GW model representing the network as of the 4th Quarter of 2012 from NEPLAN to PSS/E. Converted PSS/E model was submitted to TCN.
2. Converted 4.5 GW model was expanded by incorporating generation, transmission and substation projects planned for 10 GW network expansions. Projects planned to complete by December 2016 were included in 10 GW model. In order to complete the model, MHI had to perform a preliminary reactive power requirement analysis considering only the peak load conditions. Based on this analysis, additional shunt devices (not listed in the TCN project list provided to MHI) were added to the model. While the equipment identified by MHI is adequate to operate the system with peak load according to TCN Grid Code criteria, the locations and sizes (to some extent) are not optimized. Reactive power compensation scheme design is a separate task undertaken by TCN. This 10 GW model was further validated by TCN.
3. Base cases were analyzed for steady state performances under system intact and N-1 contingency conditions. Steady state voltage violations and thermal overloads were identified. Most of violations existing in the 4.5 GW network will be mitigated by network expansions identified for 10 GW network. However, remaining violations and new violations introduced due to the increased load and network expansions are required to be addressed for the 10 GW system. These issues are identified in this study and potential mitigation measures are proposed.
4. A cursory transfer facility study was performed to identify network resources required to facilitate generation re-dispatch between hydro generation and thermal generation. This is important since hydro generation may vary from 1500 MW in wet season to 150 MW in dry season.
5. The following four critical interfaces were identified in the 330 kV, 10 GW network during system studies.
 - Transmission interface across areas Osogbo, Benin and Enugu
 - Transmission interface across Kaduna and Kano
 - Transmission interface across Katampe, Shiroro and Gwagwalada
 - Transmission interface across Kainji to Birnin Kebbi (BKebbi)

These four interfaces have voltage related issues which has been analysed in detail. The first three issues can be mitigated by adding reactive power support which has been proposed in the report. *However, it should be noted that the root cause of most of these issues is insufficient capacity of the transmission network to carry the increased power transfer.* The fourth issue cannot be mitigated by reactive power support and requires building of new transmission lines. TCN should analyse these issues further and determine the most suitable upgrades (either adding shunts or building more lines) by considering technical and economic viability.

6. During the base case analysis and transfer facility studies, many steady state voltage violations and thermal overloads were identified. Worst overloading has been listed in this report for TCN to determine suitable mitigation measures. In order to mitigate voltage violations and achieve N-1 compliance for 10 GW system, the following mitigation measures have been proposed.
 - A. **Tapping identified for 330 kV lines:** In selected locations, it is recommended to tap both circuits of a 330 kV double circuit transmission line instead of one circuit.
 - B. **Adding shunt reactive power devices:** Mechanically switched shunt capacitors and several variable shunts (Potentially a SVC or a combination of mechanically switched shunts and SVC) were identified as mitigation measures for voltage violations. This is mainly due to low power factor assumed for the load. The proposed reactive power scheme could be used as the initial setting for reactive power study planned by TCN. Details are presented in the report.
 - C. **Building new transmission lines and sub-stations:** Building new lines and adding new transformers were identified as the last resort to prevent voltage violations and voltage depressions causing non-converged post-contingency networks.

The details of the proposed network additions are listed in the main body of the attached report.

7. A preliminary investigation was carried out to identify system expansion projects which should be prioritized to minimize the system issues and improve system reliability during the expansion from 4.5 GW network to 10.0 GW network. Nine projects with system level impacts and twenty six projects with area level importance have been identified as projects with high priority.

3.0 Transmission Development Plan

TCN's Transmission Development Plan includes all of the line, substation and voltage compensation projects needed for the 10 GW system model as described in Section 2.0 of this report. The projects are bundled into the following categories:

1. Rehabilitation of existing facilities
2. Financing Package 1 – New projects currently underway that need incremental funding
3. Financing Package 2 – New projects in the plan for 10 GW system

TCN has developed a preliminary list of additional projects that will be needed to increase system capacity from 10 GW to 20 GW. These projects are grouped into three additional financing packages consistent with the staged development of the system.

3.1. Rehabilitation of Existing Facilities

MHI and TCN surveyed the rehabilitation requirements for each of the eight transmission regions within TSP, as shown in Table 3-1. In addition to the costs developed through the survey, NIAF has identified the costs for other likely rehabilitation requirements using an age methodology applied to the entire network, as described further in Appendix G, and these funding amounts were added to bring the total to approximately \$947 Million USD. None of these rehabilitation projects is funded at present.

Table 3-1: Rehabilitation and Repair Costs by Region

Region	Subtotal
Kaduna	10,325,722,661
Enugu	5,935,158,643
Bauchi	14,011,765,700
Shiroro	1,632,955,280
Benin	1,216,297,000
Osogbo	10,727,214,163
Port Harcourt	3,589,853,438
General Infrastructure Repair Requirements Due to Ageing of Components	105,555,033,115

Total (NAIRA):	152,994,000,000
Total (USD):	\$947,000,000

3.2. Financing Package 1 – Ongoing Projects that Need Incremental Funding

Appendix B shows the list of projects and a map for Financing Package 1, which includes all ongoing TCN transmission line and substation projects that require additional capital funds to complete construction, make operational, and pay all project related costs. These projects underpin the subsequent expansion of the transmission system, and it is critically important to complete them as a high priority. The total cost to bring these projects to conclusion is approximately \$989 Million USD.

The objective of completing the ongoing projects is to stabilize the system and address the following persistent reliability and security issues:

- **Rotating Customer Outages** – It is well recognized that there is insufficient generation/transmission/distribution to serve customer demand in Nigeria. As a result, rotating customer outages are used to balance supply and demand on a daily basis.
- **Limited ability to withstand single equipment outage** – The TCN network has been designed to a N-0 reliability standard for the most part, which focuses on delivering energy when all transmission elements are in service. Thus when a single transmission element is out of service there is a good chance that load will not be served. Many power systems are designed to an N-1 (or higher) criteria that provides for all load to be served even in one element is out of service. In addition, the TCN network currently has voltage problems that are in large part due to insufficient means of supplying the reactive requirements of loads. Coupling the N-0 design and the limited reactive sources, the TCN network is prone to experience a partial or total blackout when a single transmission element is forced out of service.
- **Frequent System Collapses** – The Nigerian power system suffers from frequent partial or total system collapses when compared to the average power systems in the world. Currently the system experiences about two per month on average. There are many contribution factors to these outages but it is clear that the undersized TCN network, the lack of ability to withstand single contingencies and the lack of proper means of control voltage within reliability criteria are major contributors.

Package 1 Projects have the following characteristics:

- 122 projects; 330kV and 132kV transmission lines and substations
- All projects are ongoing;
 - 25% are substantially complete (>90%)
 - 25% are partially complete (50% - 90%)
 - 50% just started (0% – 50%)
- Completion by 2015, if funding can be expedited
- Transmission system benefits include:
 - increase the transmission grid capability to 7 GW with adequate reliability and security
 - reinforce poor performing grid system
 - establish a foundation for next phases of 20 GW transmission system expansion

3.3. *Financing Package 2 – New Projects for 10 GW System*

Financing Package 2 consists of new projects to be initiated on an expedited basis to reach a total system capacity of 10 GW. Appendix C shows the list of projects for Financing Package 2. The appendix also provides a map of the projects and a 1-page summary for each individual project.

The total cost to complete the Package 2 projects is approximately \$2.2 Billion USD. The estimated costs for Projects listed in Financing Package 2 were developed by TCN and reviewed by JICA engineers. The project costs are estimated using the unit costs of TCN’s ongoing projects, \$/km for transmission lines and \$/MVA for substations. Reference unit costs are selected depending on line voltage (330kV or 132kV), number of circuits and conductors (single/double/quad) and transformer configuration (330/132kV, 2x150MVA or 132/33kV, 2x60MVA or both).

The projects in Financing Package 2 have been organized into 5 orderly groupings based on geographical regions, as listed in Table 3-2 and shown on the TCN Transmission System Map in Appendix C. Projects are grouped to optimize the overall benefits, as projects in Groups are interdependent and must be completed together. Grouping projects within the same geographical area may be advantageous for mobilizing construction work, since all components of the group will be within the same proximity.

It is the hope of TCN that funders will support a specific group of projects, or combine with others to fund a group. Once funding is in place for a specific group, contractors (or consortiums) will be invited to bid for EPC contracts for that group.

Table 3-2: Geographic Project Groups for Financing Package 2

Group	Region	Total Funding Required	
		\$Million USD	Billion NGN
1	Kainji-Birnin Kebbi-Gusau	\$412	66
2	Lagos	\$548	88
3	Jos – Gombe – Damaturu	\$246	39
4	Awka – Ugwuaji – Jos	\$617	99
5	Benin – Katampe	\$385	62
Total		\$2,208	353

3.4. *Financing Packages 3-5 – Incremental Projects to Increase from 10-20 GW*

TCN has developed draft plans for phased expansion of the network to 20 GW by 2020. The engineering studies and models are currently being developed for Package 3 (10-13 GW), Package 4 (13-16 GW) and Package 5 (16-20 GW). Appendix D, Appendix E and Appendix F show maps and preliminary lists of projects for these financing packages.

3.5. Summary of Transmission Project Capital Funding Requirements

Table 3-3 shows the capital funding requirements for refurbishment of existing lines and substations, a TSP metering project, the completion of new projects already underway (Financing Package 1) and the initiation and completion of new projects to expand the system to 10 GW (Financing Package 2). The cost estimate for capital refurbishment was developed by NIAF (see Appendix G for assumptions). The cost estimate for Package 1 is based on signed contract amounts. The cost estimate for Package 2 was developed by JICA, as explained earlier.

Table 3-3: Capital Funding Requirements for Refurbishment and Expansion to 10 GW

Projects	\$Millions	GW Target	In Service
Capital Refurbishment	\$947	7,000	2015
TSP Feeder Verification Meters	\$1		2015
Package 1 - Projects under Construction	\$989	7-8,000	2015
Package 2 - 10 GW system	\$2,235	10,000	2017
<i>Sub-Total (\$USD Millions)</i>	\$4,172		

Table 3-4 shows the funding requirement for three additional project packages needed to expand the system to 20 GW by the year 2020. The estimated cost to expand from 10 GW to 20 GW was developed by TCN using cost data provided by NIAF for generic components of line and substation projects. The NIAF figures are based on actual recent costs for NIPP transmission projects. See Appendix G for NIAF assumptions used for estimating costs.

Table 3-4: Funding Requirements to go from 10 GW to 20 GW

Projects	\$Millions	GW Target	In Service
Package 3 (13 GW)	\$1,570	13,000	2018
Package 4 (16 GW)	\$1,000	16,000	2019
Package 5 (20 GW)	\$1,000	20,000	2020
<i>Sub-Total (\$USD Millions)</i>	\$3,570		

In summary, the total capital funding requirements to refurbish the existing system, improve reliability and security, and expand to 20 GW is estimated at \$7.7 Billion USD.

Table 3-5 shows the cash flow requirements to achieve the 20 GW build-out, based on a high level estimated construction schedule. The assumed disbursement profile of the investment plan is front loaded to open letters of credit covering 70% of project costs at the start of the construction contract.

Table 3-5: Capital Cash Flow Requirement (2014 – 2020) for the 20 GW Plan (M\$ USD)

Capital Cash Flow Requirement	2014	2015	2016	2017	2018	2019	2020	Totals
Capital Refurbishment	\$568	\$237	\$47	\$47	\$47			\$947
TSP Feeder Verification Meters	\$1							\$1
Package 1 - Projects under Construction	\$495	\$495						\$989
Package 2 - 10 GW system		\$1,565	\$335	\$335				\$2,235
Package 3 - 13 GW			\$1,099	\$236	\$236			\$1,570
Package 4 - 16 GW				\$700	\$150	\$150		\$1,000
Package 5 - 20 GW					\$700	\$150	\$150	\$1,000
Total for 20 GW by 2020	\$1,063	\$2,296	\$1,482	\$1,318	\$1,133	\$300	\$150	\$7,742

Appendix A MHI/TCN 10 GW PSSE Based System Study and Report

Appendix B Financing Package 1 – Ongoing Projects Needing Incremental Funding

Appendix C Financing Package 2 – New Projects for 10 GW System

Appendix D Financing Package 3 – Incremental Projects for 13 GW System

Appendix E Financing Package 4 – Incremental Projects for 16 GW System

Appendix F Financing Package 5 – Incremental Projects for 20 GW System

Appendix G NIAF Assumptions for Project Cost Estimates