Federal Republic of Nigeria

FY2021 Ex-Post Evaluation Report of
Japanese Grant Aid Project
"The Project for Emergency Improvement of Electricity Supply Facilities in Abuja in the Federal Republic of Nigeria"

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0. Summary

The project aimed to reduce transmission power loss and improve the power supply to the Abuja Federal Capital Territory and the surrounding area (Nasarawa State) by installing power capacitors at the Apo and Keffi Substations, thereby contributing to the promotion of economic and social development of the target area. The project was consistent with Nigeria's development policies and needs at the time of the planning and the ex-post evaluation, and the project plan and approach were appropriate based on lessons learned from similar past projects. As for the internal coherence, there was no specific coordination with other JICA projects, which was initially expected. As for the external coherence, there was some coordination with other projects through the executing agency. However, the implementation of those projects was significantly delayed, and the results of the coordination were limited. On the other hand, the consistency with Japan's ODA policy at the time of planning was observed. Therefore, its relevance and coherence are high. Although the project period slightly exceeded the plan, the project cost remained within the plan, and the efficiency of the project is high. The project increased the rate of voltage improvement in the target area, which was assumed at the time of planning, and stable and efficient power supply was realized mainly for large-scale facilities. Although some issues persist, such as unstable power supply due to the population growth in the target area, the effectiveness and impacts of the project are high, as it achieved the overall expected effects and impacts, and no negative impacts were observed. There were no organizational, technical, or financial issues in the operation and maintenance of the project, and the facilities were operating without any issues. Therefore, the sustainability of the project effects is high.

In the light of the above, this project is evaluated to be highly satisfactory.

1. Project Description

Project Location
(source: external evaluator)

Power Capacitor Equipment installed in the Project
(source: external evaluator)

1.1 Background

Nigeria has a large number of power generation facilities in southern region where the natural gas is produced, while the northern region does not have sufficient power generation facilities. Therefore, Nigeria's central region, where Abuja Federal Capital Territory (FCT) is located, and the northern region require long-distance power transmission from the southern region, resulting in significant voltage drops, and the transmission losses are also significant. In addition, the voltage drop associated with the low proportion of dynamic reactive power (power that is not consumed as energy by only traveling back and forth between the power source and the load) has been an obstacle to a stable and quality power supply. The voltage drops were particularly severe in the capital and the surrounding areas far from power generation facilities, resulting in an unstable power supply for an average of only about eight hours per day.

As a measure to improve the situation, it was necessary to introduce phase modifiers such as power capacitors (equipment that controls dynamic reactive power to keep the system voltage constant) at substations and other power supply facilities. In the capital and the surrounding areas, it was an urgent issue to improve the facility in the Apo Substation, which is a key substation distributing power to Abuja FCT. It was also urgent for the Keffi Substation, which is an important substation as it is located in an area where the power system will be expanded in the future, and is transmitting power to substations that are planned to be newly constructed. Therefore, this project supported the installation of power capacitors at both the Apo and Keffi Substations to realize efficient and stable power supply to Abuja area.

1.2 Project Outline

The objective of this project is to reduce transmission losses and improve the reliability of power supply in the Abuja FCT and the surrounding area (Nasarawa State) by installing power capacitors, thereby contributing to the promotion of economic and social development in the area.

<Grant Aid Project>

Grant Limit / Actual Grant Amount		1,317 million yen / 1,303 million yen
Exchange of Notes Date / Grant Agreement Date		February 2016 / February 2016
Executing Agency		Responsible authority: Federal Ministry of Power (FMOP) Executing agency: Transmission Company of Nigeria (TCN)
Project Completion		August 2018
Target Area		Abuja Federal Capital Territory and the surrounding area (Nasarawa State)
Main Contractors	Consultant	Yachiyo Engineering Co., Ltd.
	Equipment Procurement	Toyota Tsusho Corporation
Basic Design / Preparatory Survey		October 2014 - November 2015
Related Projects		<Technical Cooperation> - The Project for Master Plan Study on National Power System Development in the Federal Republic of Nigeria (2015-2019) - The Project for Improving Electricity Distribution Sector Capacity in the Federal Republic of Nigeria (2022-2025) <Other International Organizations> Agence Française de Développement: Secure Power Supply in the Federal Capital (2014-2020)[1]

2. Outline of the Evaluation Study

2.1 External Evaluator

Keisuke Nishikawa, Sayaka Ando and Hiroshi Nishino, Metrics Work Consultants Inc.[2]

2.2 Duration of Evaluation Study

This ex-post evaluation study was conducted with the following schedule.

Duration of the Study: October 2021 - January 2023

Duration of the Field Study: May 7 - May 19, 2022 and October 6 - October 13, 2022

[1] Secure Power Supply in the Federal Capital, Agence Française de Développement, https://www.afd.fr/en/carte-des-projets/secure-power-supply-federal-capital (accessed November 7, 2022)

[2] Nishikawa and Ando participated as reinforcement from Qunie Corporation. Nishino was in charge of satellite data analysis, while Nishikawa and Ando were in charge of the other work (including field study).

2.3 Constraints during the Evaluation Study

None

3. Results of the Evaluation (Overall Rating: A[3])

3.1 Relevance/Coherence (Rating: ③[4])

3.1.1 Relevance (Rating: ③)

3.1.1.1 Consistency with the Development Plan of Nigeria

At the time of planning this project, Nigeria's national development policy, *Nigeria Vision 20: 2020* (2009-2020), called for Nigeria to become one of the top 20 economies in the world by 2020. The policy cited the need for infrastructure development in order to make strides toward further social and economic development, and a stable and inexpensive power supply was considered an important goal. The *National Implementation Plan* (2010-2013), a concrete action guideline for the policy, identified infrastructure development (electricity and transportation) as one of the top priorities.

In *Nigeria's Medium Term National Development Plan 2021-2025*, the national development plan at the time of the ex-post evaluation, one of the nine priorities is to achieve self-sufficiency in electricity and petroleum products. Specific strategies include large-scale financing to improve power generation capacity, establishing infrastructure to supply natural gas used for power generation, and upgrading the power grid.

In addition, the goals for the power sector in the above development plan include increasing transmission capacity, reducing transmission losses[5] and improving people's access to electricity[6].

Based on the above, the stable supply of electricity is of great importance in the policies in Nigeria at both the planning and ex-post evaluation stages. Since the project aims at efficient and stable power supply by expanding substation facilities, the project is consistent with Nigeria's development policy at both the time of planning and ex-post evaluation.

3.1.1.2 Consistency with the Development Needs of Nigeria

Nigeria's national peak electricity demand was 9,571 MW in 2016 at the time of planning, while peak electricity supply was 5,074 MW[7], which indicates that the electricity supply was not keeping up with the demand. When peak electricity demand was checked during the ex-

[3] A: Highly satisfactory, B: Satisfactory, C: Partially Satisfactory, D: Unsatisfactory

[4] ④: Very high, ③: High, ②: Moderately Low, ①: Low

[5] In *Nigeria's Medium Term National Development Plan 2021-2025*, the indicator is the amount of energy in the national grid, with a target of 10,000 MW in 2025 (baseline is 3,592 MW).

[6] In *Nigeria's Medium Term National Development Plan 2021-2025*, the indicator is the percentage of the population with access to electricity, with a target of 75% in 2025 (baseline is 55.4%).

[7] It is the amount of electricity sent to the power grid and does not include off-grid, such as on-site power generation.

post evaluation, it had further increased year by year since 2016, reaching 15,532 MW in 2021 (about 62% increase compared to the demand in 2016). In contrast, peak electricity supply remained at 5,802 MW. Installed generation capacity increased from 2016, reaching 12,974 MW as of 2020. However, the generation capacity remained at 5,758 MW as of 2020.[8] According to the Transmission Company of Nigeria (TCN), the reason for the generation capacity being far below the installed capacity is the unstable procurement of natural gas used for power generation.[9] However, as noted above, the peak electricity demand has been increasing year after year until the time of the ex-post evaluation, and the efficient and stable power supply continues to be a challenge.

In addition, there are few power plants around Abuja FCT, and the electricity is transmitted through a long distance from the south, resulting in significant voltage drops associated with the low proportion of dynamic reactive power in Abuja and the surrounding areas. The subsequent transmission losses were also significant and the power supply was unstable, with an average of only about 8 hours per day at the time of planning the project. As a measure to improve the situation, it was necessary to introduce phase modifiers such as power capacitors at the power supply facilities such as substations. At the time of the ex-post evaluation, Abuja and the surrounding areas were still dependent on power supply from other states, and the demand for the equipment remained high.

Consequently, it can be said that the project is consistent with the development needs, since the demand for a stable power supply exists in the target area at the time of planning and ex-post evaluation, and the project plays an important role in addressing the demand.

3.1.1.3 Appropriateness of the Project Plan and Approach

In the past, the results of the ex-post evaluation of similar projects indicated that the project was delayed due to the lack of necessary budget allowance from the counterpart government. Therefore, the consultant was expected to fully explain and discuss the counterpart government's burden, and promptly confirm and follow up on the budgetary measures and the detailed schedule. This was undertaken by the implementing consultant, and there was no delay in the implementation of the project due to the delay in the budgetary measures by the counterpart government. It was also confirmed that the Nigerian side properly implemented the power outage of the connection segment during the construction period, leading to a smooth implementation of the construction work on the Japanese side. There was no significant difference between the planned and actual results, and the project was handled

[8] Installed generation capacity refers to the capacity of a power generation facility, while generation capacity refers to the actual capacity of a power generation facility based on the availability of generating fuel and other factors.

[9] Two reasons for the unstable procurement of natural gas were cited by TCN: (1) high pricing by natural gas suppliers and (2) the need for timely payment for natural gas that can be purchased with government subsidies.

based on lessons learned from similar projects in the past. Based on the above, there are no problems with the appropriateness of the project plan and approach.

3.1.2 Coherence (Rating: ②)

3.1.2.1 Consistency with Japan's ODA Policy

At the time of planning the project, Japan had identified priority areas of support for Nigeria, including core infrastructure development. Also in the "JICA Country Analysis Paper for the Federal Republic of Nigeria" (formulated in May 2015), stable electricity supply was identified as an important issue, which is consistent with Japan's ODA policy.

3.1.2.2 Internal Coherence

A related project to this project is the "The Project for Master Plan Study on National Power System Development in the Federal Republic of Nigeria (2015-2019)." According to the JICA Nigeria office, while this was not the intended coordination, data from this grant aid project was used in the development of the master plan. However, no specific outcomes were identified.

In addition, as another related project, JICA technical cooperation project for the Abuja Electricity Distribution Company (AEDC), entitled "The Project for Improving Electricity Distribution Sector Capacity in the Federal Republic of Nigeria (2022-2025)" has been initiated. The project is to provide technical assistance to AEDC in facility design, maintenance management, etc., by conducting training programs that will contribute to the reduction of power distribution losses and improvement of supply reliability. This technical cooperation project and this grant aid project have a high affinity, and synergistic effects are expected. However, this technical cooperation project just started in April 2022, and the synergistic impact was not yet achieved at the time of the ex-post evaluation.

Based on the above, although a certain degree of synergy was confirmed in the "The Project for Master Plan Study on National Power System Development in the Federal Republic of Nigeria," the synergy was identified as a result, without the specific coordination that was initially intended.

3.1.2.3 External Coherence

At the time of planning the project, the Agence Française de Développement (French Development Agency, AFD) planned to implement the related projects (e.g., construction of new transmission lines, installation of new transformers to the Apo Substation, etc), and this grant aid project was planned based on that information. Although no direct coordination or collaboration between JICA and the AFD was observed, both projects were planned under the coordination of TCN. The AFD's project consists of the enhancement of five substations etc.,

including the Apo Substation covered by this grant aid project. According to TCN, the AFD's project is generally scheduled to be completed by the end of 2022 due to delays caused by the spread of COVID-19, delays in customs clearance procedures at the port, and issues related to land and easement acquisition. After the completion of the AFD's project, it is expected that the two projects will stabilize the power supply through different approaches: the expansion of substation and transmission capacity through the AFD's project, and the improvement of facility utilization (improvement of power factor and increase of dynamic reactive power) through this grant aid project. However, no synergistic effects were identified as of the ex-post evaluation.

In addition, the government of Nigeria has been undertaking several projects for the rehabilitation and the expansion of substations and transmission lines with its own funds. Although there was no direct coordination or cooperation between these projects and this grant aid project, as with the AFD's project, there was coordination under TCN, and no overlap in the scope of support was identified.

Based on the above, the AFD's project was significantly delayed and no synergies were identified at the time of the ex-post evaluation. Although there was no direct coordination or cooperation with the projects implemented by the government of Nigeria, synergies were considered to have emerged under TCN's coordination.

The project was consistent with Nigeria's development policies and needs at the time of the planning and the ex-post evaluation, and the project plan and approach were appropriate. The project was also consistent with Japan's ODA policy at the time of planning. As for the internal coherence, there was no specific coordination with other JICA projects, which was originally assumed. As for the external coherence, though not direct, there was some coordination with other projects through TCN. However, the implementation of some of these projects had been delayed significantly and the synergistic effects were limited at the time of the ex-post evaluation.

Therefore, its relevance and coherence are high.

3.2 Efficiency (Rating: ③)

3.2.1 Project Outputs

Table 1 shows the planned and actual outputs of the project, and Table 2 shows the planned and actual project items borne by the Nigerian executing agency.

Table 1: Planned and Actual Outputs from the Project

Planned	Actual
Apo 132/33 kV Substation	
1. Power capacitor facility (132 kV, 60 MVar)	Implemented as planned
2. Special high-voltage switchgear	Implemented as planned
3. Protection and control panel	Implemented as planned
4. Substation grounding equipment	Implemented as planned
5. Low-voltage equipment	Implemented as planned
6. Foundations for equipment	Implemented as planned
Keffi 132/33 kV Substation	
1. Power capacitor facility (132 kV, 25 MVar)	Implemented as planned
2. Special high-voltage switchgear	Implemented as planned
3. Protection and control panel	Implemented as planned
4. Substation grounding equipment	Implemented as planned
5. Low-voltage equipment	Implemented as planned
6. Foundations for equipment	Implemented as planned
7. Underground cable for electric power (132 kV)	Implemented as planned
8. DC power supply	Implemented as planned

Source: Information provided by JICA

Table 2: Planned and Actual Items Borne by Nigerian Executing Agency

Planned	Actual
Apo 132/33 kV Substation	
1. Renewal of transformers, switchgear, girders, lightning protection equipment, etc., damaged by lightning strike in September 2014	Implemented as planned
2. Replacement and repair of damaged control panels and related equipment in the control building	Implemented as planned
3. Project site preparation	Implemented as planned
4. Check and ensuring of the grounding resistance (1 Ω or less) of the existing grounding equipment	Implemented as planned
5. Relocation of existing lighting	Implemented as planned
6. Securing of a location for installation of control and protection panels in the existing control building	Implemented as planned
7. Provision of control power (DC and AC) for control and protection panels to be procured	Implemented as planned
Keffi 132/33 kV Substation	
1. Calibration of indicating meters such as wattmeters and reactive power meters on the 132 kV control panel in the control building of the existing transformer	Implemented as planned
2. Removal of obstructions on the project site	Implemented as planned
3. Project site preparation	Implemented as planned
4. Check and ensuring of the grounding resistance (1 Ω or less) of the existing grounding equipment	Implemented as planned
5. Relocation of existing lighting	Implemented as planned
6. Securing of a location for installation of control and protection panels in the existing control building	Implemented as planned
7. Provision of control power (AC) for control and protection panels to be procured	Implemented as planned

Source: Prepared by the evaluators based on the information provided by JICA and interviews with the executing agency

Table 1 and Table 2 show that the outputs from the project and the items borne by the Nigerian executing agency were implemented as planned.

3.2.2 Project Inputs

3.2.2.1 Project Cost

The planned Japanese portion of the project cost was 1,317 million yen, while the actual cost was 1,303 million yen, which was within the plan (99% of the originally planned amount). Nigeria's share of the planned project cost was 3 million yen, while the actual cost was the same 3 million yen, which was within the plan (100% of the originally planned amount).

3.2.2.2 Project Period

The project period exceeded the plan (107% of the plan) with an actual period of 31 months compared to the planned 29 months. The construction period was extended for 3 months due to a defect in the discharge coil, a component of the power capacitor, which occurred during the acceptance test of the equipment to be installed at the Keffi Substation.[10]

The training programs were implemented for 9 weeks, compared to the planned 14 weeks. The reason for the shortened duration was that the Nigerian side was unable to secure a budget for travel and daily allowances for the training participants. Although the duration was shortened, the training was provided as originally planned through the deployment of additional personnel and the implementation of intensive classroom lectures, etc.

Based on the above, the outputs of the project were implemented as planned for both the items borne by Japan and Nigeria. Although the project period slightly exceeded the plan, the project cost was kept within the planned budget. Therefore, the efficiency of the project is high.

3.3 Effectiveness and Impacts[11] (Rating: ③)

3.3.1 Effectiveness

3.3.1.1 Quantitative Effects (Operation and Effect Indicators)

Five operation and effect indicators were set as measures of quantitative effectiveness for the project, and the target values were set for 2021, three years after the project completion, using the values in 2014 as a baseline.[12] Table 3 shows the planned and actual comparisons of the indicators of the quantitative effectiveness.

[10] Since some training programs were implemented during the procurement and installation of materials and equipment, the extended construction period does not coincide with the extended project period.

[11] When providing the sub-rating, Effectiveness and Impacts are to be considered together.

[12] Although the target year was 2020 in the ex-ante evaluation paper, the analysis is based on actual results for the year 2021, as three years after the project completion is in 2021.

Table 3: Comparison of Planned and Actual Indicators of Quantitative Effectiveness

Indicator		Baseline Value	Target Value	Actual Value			
		2014	2021	2018	2019	2020	2021
(1) Voltage improvement rate at receiving end (%)	Apo Substation (132 kV incoming side)	N/A	2.9	2.95	2.94	3.06	2.9
	Apo Substation Note 1 (33 kV outgoing side)	N/A	3.01	13.44	12.79	12.6	12.73
	Keffi Substation (132 kV incoming side)	N/A	6.19	2.96	2.94	3.01	2.95
	Keffi Substation (33 kV outgoing side)	N/A	6.84	12.93	13.1	13.01	12.71
(2) Transmission loss in 132-kV transmission lines (MW/(%)) (for the area covered by the project)		N/A	101.4 (6.85)	N/A	N/A	N/A	6.05 (4.04) Note 2
(3) Reduction amount of greenhouse gas emission (t/year)		N/A	6,404	N/A	N/A	N/A	13,141 Note 2
(4) Number of households benefiting from improved supply of electricity (households/day)	Apo Substation	N/A	5,400	N/A	N/A	N/A	7,450
	Keffi Substation	N/A	1,700	N/A	N/A	N/A	1,887
(5) Number of consumers benefiting from improved supply of electricity (persons/day)	Apo Substation	N/A	24,300	N/A	N/A	N/A	33,525 Note 3
	Keffi Substation	N/A	9,350	N/A	N/A	N/A	10,379

Note 1: The improvement ratio on the 33 kV outgoing side of the Apo Substation is an average value because there are several transformers to be measured.
Note 2: Since the executing agency did not maintain actual data for (2) transmission losses, the values calculated by the evaluator were listed as estimates. The estimated values were also used to calculate (3) GHG reductions.
Note 3: As the executing agency did not have actual data on the number of households supplied at the Apo Substation, which is necessary for the calculation of the number of households supplied for the purpose of (4), the figure in the Preparatory Survey Report was used.
Source: Prepared by the evaluators based on the information provided by JICA and the executing agency

Indicator (1) Voltage improvement rate at receiving end (%)

The voltages with and without power capacitors in operation at both substations measured at 20:00 on March 2, 2022 are shown in Table 4.

Table 4: Measured Voltages at the Apo and Keffi Substations with and without Power Capacitors in Operation

Apo Substation (132 kV incoming side):

Measured Value	Equipment to be Measured	2018	2019	2020	2021
Voltage when capacitor is in operation (kV)	132 kV Transmission line	132.8	133	128	134.8
Voltage when capacitor is not in operation (kV)		129	129.2	124.2	131

Source: Prepared by the evaluators based on the information provided by JICA and the executing agency

Apo Substation (33 kV outgoing side):

Measured Value	Equipment to be Measured	2018	2019	2020	2021
Voltage when capacitor is in operation (kV)	132 kV/33 kV transformer 45 MVA[13] (a)	33.9	33.1	33.4	34
Voltage when capacitor is not in operation (kV)		30.1	29.3	29.6	30
Voltage when capacitor is in operation (kV)	132 kV/33 kV transformer 45 MVA (b) Note 1	33.9	N/A	N/A	N/A
Voltage when capacitor is not in operation (kV)		30.1	N/A	N/A	N/A
Voltage when capacitor is in operation (kV)	132 kV/33 kV transformer 100 MVA (a)	34	33.7	34.2	34
Voltage when capacitor is not in operation (kV)		29	29.9	30.4	30.2
Voltage when capacitor is in operation (kV)	132 kV/33 kV transformer 100 MVA (b)	34.1	33.7	34.3	34.7
Voltage when capacitor is not in operation (kV)		30.6	29.9	30.5	30.9

Note 1: There was no record since 2019, as 132 kV/33 kV transformer 45 MVA (b) has not been in operation since 2019 due to transformer breakdown caused by fire accident, and will be replaced with 100 MVA transformer by 2023.
Source: Prepared by the evaluators based on the information provided by JICA and the executing agency

Keffi Substation (132 kV incoming side):

Measured Value	Equipment to be Measured	2018	2019	2020	2021
Voltage when capacitor is in operation (kV)	132 kV transmission line	132	133	130	132.5
Voltage when capacitor is not in operation (kV)		128.2	129.2	126.2	128.7

Source: Prepared by the evaluators based on the information provided by JICA and the executing agency

Keffi Substation (33 kV outgoing side):

Measured Value	Equipment to be Measured	2018	2019	2020	2021
Voltage when capacitor is in operation (kV)	132 kV/33 kV transformer 30 MVA	33.2	32.8	33	33.7
Voltage when capacitor is not in operation (kV)		29.4	29.0	29.2	29.9

Source: Prepared by the evaluators based on the information provided by JICA and the executing agency

The voltage when the capacitor is operating is compared to that when the capacitor is not operating, then the rate of increase is the voltage improvement ratio at receiving end (%) (the percentage increase is stated in Table 3 in the actual values). The voltage at receiving end on the incoming and outgoing sides of the Apo Substation and the outgoing side of the Keffi Substation

[13] MVA stands for "mega volt ampere," which is the unit of apparent power used in power equipment. The appropriate value for a 132 kV transmission line is around 132 MVA, and the one for a 132 kV/33 kV transformer is around 33 MVA, with lower values indicating low voltage conditions.

achieved the target values. Although only the incoming side of the Keffi Substation did not meet the target, the voltage was confirmed to be an appropriate value and not an issue.[14]

Based on the above, the indicator of the voltage improvement ratio at receiving end was achieved.

Indicator (2) Transmission loss in 132-kV transmission lines (MW/(%)) (for the area covered by the project)

The 132-kV transmission lines to which the power capacitors installed through the project mainly contributed are the following sections from A to E, at the time of the ex-post evaluation. The amount of power transmission with and without power capacitors in operation on these lines, and the amount and percentage of reduction in transmission losses calculated by comparing them, are shown in Table 5. Since some data was not maintained by the executing agency, estimates of the figures calculated by the evaluators are shown.

Table 5: Measured Results on a 132-kV Transmission Line with and without Power Capacitors in Operation and Transmission Losses Calculated by Comparison of the Results

132 kV Transmission Line	Amount of Electricity Transmitted (MW)		Reduction in Transmission Losses (MW)	Percentage of Reduction in Transmission Losses (%)
	Capacitor not in Operation	Capacitor in Operation		
A. Gwagwalada - Apo	30.8	32.4	1.6	4.94
B. Katampe - Apo	34.9	36.03	1.13	3.14
C. Apo - Kalu	41.46 Note 1	43.2	1.74	4.04 Note 1
D. Kalu - Keffi	24.95 Note 1	26	1.05	4.04 Note 1
E. Keffi - Akwanga	12.48 Note 1	13 Note 2	0.52	4.04 Note 1
Total amount	144.58	150.63	6.05	4.04

Note 1: The amount of power transmission when power capacitors were not in operation in sections C-E was not available from the executing agency, so it was estimated using the average transmission loss rate of 4.04% between Gwagwalada and Apo, which was available.
Note 2: Since the amount of transmission when the capacitor was in operation in section E could not be obtained from the executing agency, the amount was assumed to be half of the amount of transmission in section D (assuming that half is supplied to Keffi and half to Akwanga).
Source: Prepared by the evaluators based on the information provided by JICA and the executing agency

The actual reduction in transmission losses (MW) was 6.05 MW compared to the target of 101.4 MW, which was a significant underachievement. The main reason for this can be attributed to large-scale projects such as the construction of new substation underway with the

[14] Appropriate value was around 132 kV, with 132.5 kV in 2021 result.

AFD's support. The target value was set based on a tidal flow analysis assuming that the AFD's project, which was scheduled for completion in 2017, had actually been completed. However, since the completion of the project has been delayed and the synergistic effects of the project have not been realized at this point, the realization of the effects at the time of the ex-post evaluation is considered to be limited compared to the target values. The actual reduction rate of transmission loss (%) was 4.04% compared to the target of 6.85%, and although it was below the target, it was not as large as the reduction amount. It can be inferred that the reduction amount of transmission loss will increase significantly as the scope of benefits is expanded after the completion of the AFD's project.

Based on the above, it can be concluded that the indicator of transmission loss for the 132-kV transmission lines was not achieved at the time of ex-post evaluation.

Indicator (3) Reduction amount of greenhouse gas emission (t/year)

The GHG emission reductions were calculated using the same method as in the planning phase.[15] The actual result was 13,141 t/year, compared to the target of 6,404 t/year, confirming that the GHG reductions were achieved to a large extent. This is due to the fact that the transmission loss reduction of electricity from thermal power plants supplied to the Apo and Keffi Substations was larger than the value assumed when the target was set.

Based on the above, the GHG reduction indicator was achieved.

Indicator (4) Number of households benefiting from improved supply of electricity (households / day)

As a result of the calculation in accordance with the methodology defined in the Preparatory Survey Report for the Project[16], the number of households benefiting from electricity supply in

[15] The following steps (1) and (2) were used to calculate the GHG emission reductions. Since Nigeria's main thermal power generation facilities are gas turbines, the thermal efficiency of the power generation facilities was set to 0.37 and the emission factor of natural gas was set to 0.0139, as in the planning.

(1) The offset calorific value of 257,828 (GJ/year) was calculated from the reduction in transmission losses 26,499* (MWh/year) × 3,600 (GJ/1,000MWh) ÷ 0.37 thermal efficiency of the power generation facility.

(2) The GHG emission reduction amount of 13,141 (t/year) was calculated from the reduced calorific value of 257,828 (GJ/year) × emission factor of 0.0139 (t C/GJ) × 44/12.

*An estimate of the transmission loss reduction for electricity generated by the thermal power plant supplying the Apo and Keffi Substations. The same reduction of 6.05 MW calculated in Indicator (2) is 52,998 MWh/year. Since approximately 50% of the electricity supplied to the Apo and Keffi Substation was generated by thermal power plants, this was set at half, or 26,499 MWh/year.

[16] Calculated according to the following steps (1) through (6). (1) Calculate apparent power (MVA) based on peak demand (MW), (2) Calculate dynamic reactive power (MVar) before the power capacitors were turned on, (3) Calculate dynamic reactive power (MVar) after the power capacitors were turned on, (4) Calculate active power (MW) after the power capacitors were turned on, (5) Calculate increased active power (MW), and (6) Calculate the number of households supplied with additional electricity by dividing by the average household power demand (kW/household) in the power supply area of the subject substations.

*The actual data on the number of supplied households is required for the calculation. However, since the executing agency and the distribution company did not have the data for the Apo Substation, the number of consumers in the substation's distribution area of approximately 160,000 households, as stated in the Preparatory Survey Report, was utilized.

the distribution area of the Apo Substation was 7,450 households/day, achieving the target of 5,400 households/day (138% compared to the target). The number of households served by the Keffi substation was 1,887 households/day, achieving the target of 1,700 households/day (111% of the target).

Based on the above, the indicator of the number of households benefiting from the improved supply of electricity was achieved.

Indicator (5) Number of consumers benefiting from improved supply of electricity (persons / day)[17]

The number of consumers benefiting from the improved electricity supply in the distribution area of the Apo Substation, calculated based on the results of indicator (4), is 33,525 persons/day, achieving the target of 24,300 persons/day (138% of the target). The number of beneficiaries at the Keffi Substation was 10,379 persons/day, achieving the target of 9,350 persons/day (111% of the target).

Based on the above, the indicator of the number of consumers benefiting from the improved supply of electricity was achieved.

3.3.1.2 Qualitative Effects (Other Effects)

None

3.3.2 Impacts

3.3.2.1 Intended Impacts

At the time of planning, the following two points were envisioned as the impact of the project implementation.

- Improved reliability of power supply
- Promotion of economic and social development

Although transmission losses improved as a result of the project implementation compared to before the start of the project, stable power supply still did not keep pace with the increase in power demand due to the population growth, etc., at the time of the ex-post evaluation, and improving power reliability remains an issue.

On the other hand, the satellite data analysis shows an increase in nighttime light in the districts of Abuja and Keffi, where the target substations are located, since 2019 after the completion of the project, indicating an increase in economic activity (see Box on the following pages for details).

[17] The number of consumers benefiting from improved supply of electricity (persons/day) was calculated by multiplying the number of beneficiary households in indicator (4) by 4.5 persons/household for Apo Substation and 5.5 persons/household for Keffi Substation, respectively, in accordance with the assumptions in the Preparatory Survey Report.

In the ex-post evaluation, a qualitative study was conducted to observe the qualitative effects of stabilizing electricity supply.[18] The results of the qualitative study are summarized in Table 6.

Table 6: Summary of Qualitative Survey Results

Expected Impact	Actual Impact
① Longer service life of electrical equipment due to high quality power supply close to rated voltage	In the period from 2019 to 2022, many respondents reported that malfunctions of several electrical equipment occurred (e.g., television malfunctions were identified in 4 out of 10 households). Although the implementation of the project resulted in a more stable electricity supply, the increase in the number of residents and appliances used has since further increased the demand for electricity, resulting in a situation where the electricity is again not adequately supplied or the supply voltage is unstable. As a result, the project was not able to supply high quality electricity close to the rated voltage compared to before the implementation of the project, and its contribution to extending the service life of electrical equipment is considered to be limited.
② Reduction of planned outage duration to develop and promote socioeconomy	Although no data on planned power outages were obtained from TCN, satellite data analysis showed an increase in nighttime light in the districts of Abuja and Keffi, where the target substations are located, since 2019 after the completion of the project. It can be inferred that the project has contributed to a certain extent to the stimulation of the economic activity.[19]
③ Stable use of medical equipment in hospitals	Hospitals reported that the high-quality power supply had reduced the frequency of breakdowns of medical equipment and the use of generators (e.g., generators no longer need to be used for surgeries that require a stable power supply). It was also confirmed that in the event of a power outage, the hospital contacted the power distribution company, and in some cases, adjustments were made on a priority basis for early restoration of power, indicating a more stable power supply among power consumers. The project is considered to have contributed to the stable use of medical equipment at the hospitals.
④ Improving the learning efficiency of school children	Schools commented that the use of stable electricity had allowed them to expand ICT classes, utilize handouts, and improve the efficiency of teachers' management of student information. In addition, some schools were providing high-quality education to more students by installing additional PCs, printers, and other equipment as the number of students increased. From the above, it can be assumed that the project has contributed to the improvement of the learning efficiency of school children.
⑤ Maintaining public safety in the project area through prolonged use of streetlights and security lighting	Based on interviews with nearby residents, there was no improvement in the available hours of streetlights and security lighting, and it appears that they are not contributing to maintaining public safety. All five households interviewed in the vicinity of the Keffi Substation reported a decrease in the number of hours that security lighting is available each day (10 to 6 hours, 8 to 3 hours, 4 to 1-2 hours, etc.). In addition, three of the five households interviewed reported an increase in nighttime thefts and snatch-and-grabs compared to before. The above results suggest that the contribution to the improvement of public safety has been limited.

[18] In the areas served by the Apo and Keffi Substation, three medical and health facilities, three schools, and eleven resident households (22 people) were selected using a purposive sampling method, and individual interviews based on a questionnaire were conducted.

[19] It should be noted that the increase in night light cannot be entirely attributed to the project.

Box: Satellite Data (Nighttime Light) Analysis

In this ex-post evaluation, satellite data (nighttime light[20]) was used to analyze the project's impact. It has been confirmed that nighttime light correlates with local economic activities and can be used as a proxy to measure the "promotion of economic and social development" envisioned in this project. Specifically, we calculated the average intensity of nighttime light for each of 19 local government areas (LGAs) in the target area, six LGAs in Abuja Federal Capital Territory and 13 LGAs in Nasarawa State, and then examined if the project contributed to the "promotion of economic and social development" by carefully observing the trends of nighttime light from 2014 to 2021 (see Figure 1 for target areas).

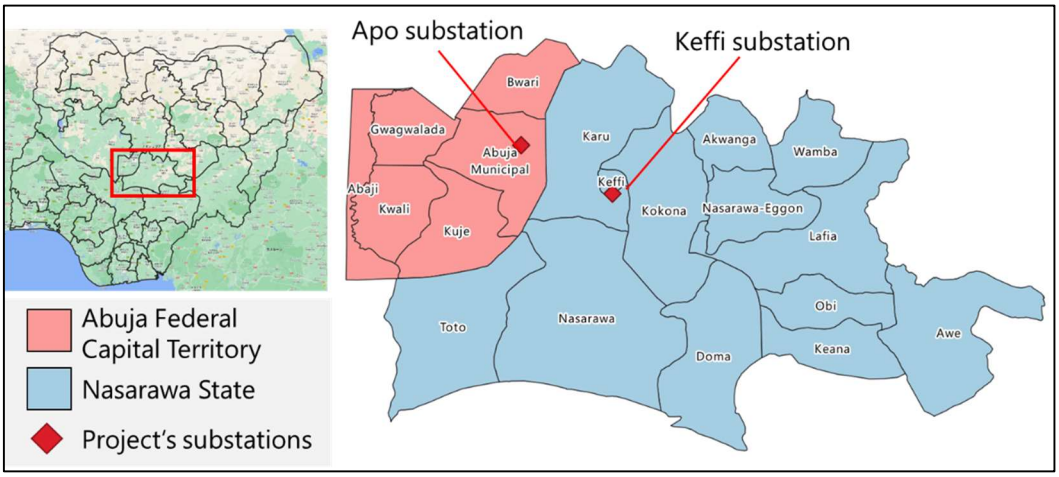

Figure 1: Project Target Areas

The results of the analysis are shown in Figures 2 and 3. Figure 2 shows that nighttime light has increased since 2019 in Abuja Municipal, where the project's substation is located. The adjacent Bwari also shows an increase compared to other administrative districts. Figure 3, which shows the results for Nasarawa State, also confirms an increasing trend from 2019 in Keffi, where the other project's substation is located. On the other hand, no specific trend was observed in the remaining LGAs. Based on the above results, it can be said that in Abuja Federal Capital Territory and Nasarawa State, there was a trend of increase in night light after 2019 in Abuja Municipal, Bwari, and Keffi, which are LGAs that had been economically active before the project. In particular, because Abuja Municipal and Keffi are the LGAs where the project's substations are located, it can be considered that the project contributed to the "promotion of economic and social development" in the project areas to a certain extent.

[20] The data used are Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). Their resolution is 464 m, and they show the intensity of nighttime light (nanoWatts/cm2/sr) in the range of -1.5 to 193,565. The data from the eight years between 2014 and 2021, which were available at this time, were used for this analysis.

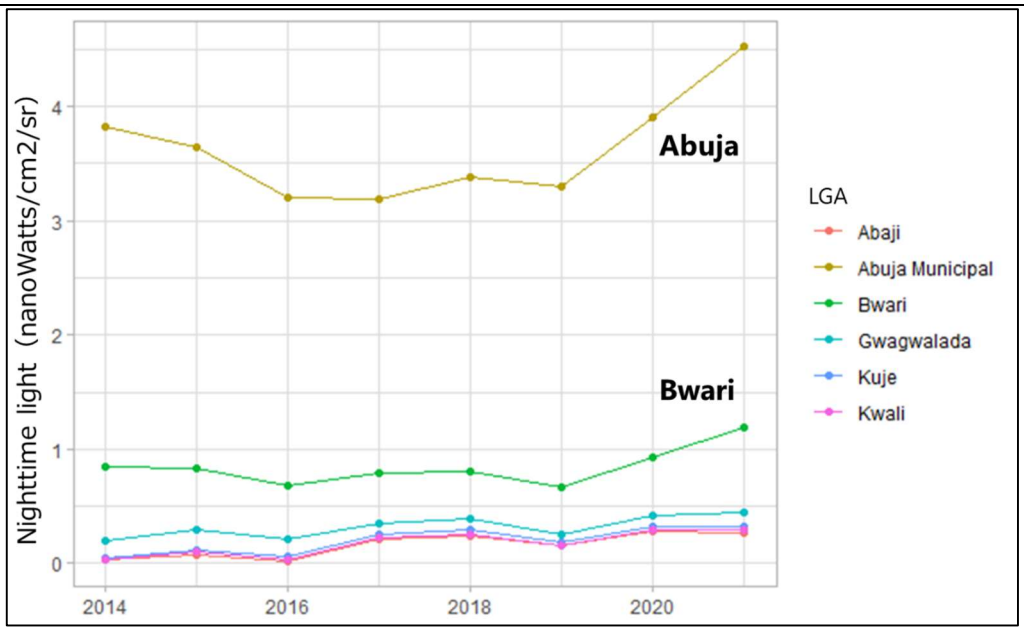

Figure 2: Changes in Nighttime Light in Abuja Federal Capital Territory

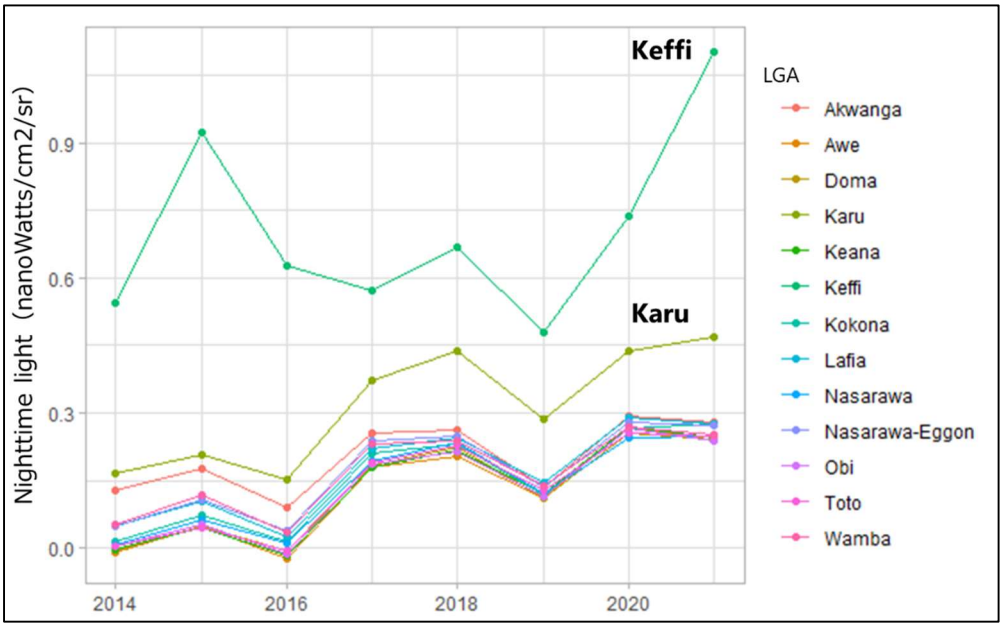

Figure 3: Changes in Nighttime Light in Nasarawa State

Overall, positive aspects were seen in large medical and educational facilities, where stable power supply led to the reduced operating costs and improved the quantity and the quality of services.[21] On the other hand, there were also aspects where the power supply remained unstable and the contribution to improved security was limited.

[21] The coordination was made with the power distribution company at the hospital, for early restoration of power during power outages, leading to a stable supply of electricity, in particular.

3.3.2.2 Other Positive and Negative Impacts

1) Impact on the Natural Environment

This project was classified as Category C based on the "Guidelines for Environmental and Social Considerations" (April, 2010). According to the interviews with the implementing consultant, no negative impacts on the natural environment occurred during the procurement and installation of the equipment. According to the executing agency, no negative impacts on the natural environment were identified by the time of the ex-post evaluation.

In addition, the reduction of transmission losses contributes to the reduction of fuel used for thermal power generation and thus to the reduction of greenhouse gases, which has a positive impact on the natural environment.

2) Resettlement and Land Acquisition

The project was conducted on TCN's sites, and no resettlement or land acquisition occurred.

3) Gender Equality, Marginalized People, Social Systems and Norms, Human Well-being and Human Rights

The results of the interviews with TCN did not identify any negative impacts on gender equality, marginalized people, social systems and norms, human well-being or human rights. Cases were identified where people, including women, started small businesses (hair salons, grain and other crushing, weaving, etc.).

The implementation of the project improved the rate of voltage improvement in the target area, which was assumed at the time of planning, and stable and efficient power supply was realized mainly in large-scale facilities. Interviews with hospitals and schools also confirmed that power outages had decreased. As a result, the frequency of breakdowns of medical equipment and the use of generators decreased, enabling the stable and efficient use of medical equipment at hospitals. In schools, the learning efficiency of school children improved through the expansion of ICT classes, the use of handouts, and more efficient information management of students by teachers. The analysis using nighttime light also indicates that economic activities have been stimulated in the feeding areas of both the Abuja and Keffi Substations where power capacitors were installed. On the other hand, in the residential areas, it was seen that demand of electricity had been growing faster than the supply, as many residents said that the power supply had been more unstable in recent years than in the past due to the increase in the number of residents moving into the area with stable power supply. In addition, no natural environmental or other negative impacts were identified. The reduction in transmission losses contributed to the reduction of greenhouse gases generated by thermal power generation, which can be said to have a positive impact on the natural environment.

As a result of the above, this project has mostly achieved its objectives. Therefore, effectiveness and impacts of the project are high.

3.4 Sustainability (Rating: ③)

3.4.1 Policy and System

Targets for the power sector for the period up to 2025 in the national development plan *Nigeria's Medium Term National Development Plan 2021-2025* include increasing transmission capacity of electricity, reducing its transmission losses, and improving access to electricity.

The project is consistent with the government of Nigeria's development plan up to 2025, and the sustainability of the project's effects is ensured in terms of policies and systems.

3.4.2 Institutional/Organizational Aspect

The organizational structure of TCN consists of 34 departments with a total staff of 3,821 (as of 2020). The number of staff belonging to the departments in charge of operation and maintenance of the facilities covered by the project is shown in Table 7.

Table 7: Number of People Belonging to the Department in Charge of Operation and Maintenance at the Facilities Covered by the Project

Name of Department	Role	Apo Substation (persons)	Keffi Substation (persons)
System Operation (SO)	Operation and daily inspection	13	6
	Data recording and management		
Transmission Service Provider (TSP)	Periodic inspection and maintenance	80	10
	Repair in case of breakdown		

Source: Prepared by the evaluators based on the information provided the executing agency

The human resources and organizational structure necessary for operation and maintenance of the equipment installed in this project are in place. As planned, maintenance and management are handled by the System Operation department (the department responsible for operation, daily inspections, data recording and management) and the Transmission Service Provider department (the department responsible for periodic inspections, maintenance, and repairs in case of breakdowns), each with the necessary skills. The daily operation and monitoring of each facility are also handled by dedicated operators. No breakdowns or malfunctions due to insufficient personnel or skills have been observed.

Based on the above, the sustainability of the project's effects in institutional and organizational aspects is considered to be high.

3.4.3 Technical Aspect

According to TCN, the personnel in charge of maintenance and operation possess the technical skills necessary to maintain the equipment, and no maintenance and operation issues have occurred. The technicians have acquired the knowledge to operate and maintain the installed facilities through technical guidance in the training programs. In addition, necessary training has been provided, including induction training, HSE (health, safety, and environment) training, on-the-job training, and training by outside instructors. Furthermore, they refer to the manuals provided by the project for troubleshooting, etc.

Based on the above, there are no particular technical issues.

3.4.4 Financial Aspect

TCN's published income and expenditure statements for 2018-2020 are cited in Table 8.

Table 8: Statement of Income and Expenditure of TCN[22]

(In millions of Naira)

Item	2018	2019	2020
1. Sales	109,870	112,300	156,990
2. Cost of sales	(15,440)	(20,840)	(22,640)
Repair and maintenance expenses for facilities and equipment	(4,290)	(4,880)	(6,510)
Depreciation and amortization	(11,150)	(15,960)	(16,130)
3. Gross profit	94,430	91,460	134,350
4. Other income	3,160	130	600
5. Administrative expenses	(84,110)	(87,680)	(101,530)
6. Operating Income	13,480	3,910	33,420
7. Net financial income/(expense)	(440)	1,080	4,540
8. Income before income taxes	13,040	4,990	37,960
9. Net income	4,620	(1,770)	18,860

Source: Prepared by the evaluators based on the information provided by the executing agency

TCN's operation was profitable in 2018 and 2020. Although a deficit occurred in 2019, it was mainly due to a large investment in transmission lines, and no issues were identified with the operating status itself. TCN confirmed that it has a sufficient budget for the maintenance of the equipment installed by the project.

Although the cost of each substation is not disclosed, it can be inferred that the necessary investments have been made to operate both the Apo and Keffi Substations, as the total investment in substation facilities and equipment has increased over the years.

Based on the above, the financial sustainability of the project's effects is high, as confirmed by its sound financial condition, adequate budget for equipment maintenance, and proactive investment in facilities and equipment.

[22] Numbers in parentheses indicate expenditures or negative values.

3.4.5 Environmental and Social Aspect

No negative impacts on the natural environment were identified. In addition, the project contributed to the reduction of greenhouse gas emissions through the reduction of transmission losses, which is considered to have a positive impact on the natural environment.

3.4.6 Preventative Measures to Risks

Although no malfunctions have occurred since the equipment was installed, malfunctions of the installed equipment are a risk. However, TCN has the human resources and budget to maintain and repair the equipment, and spare parts are available locally and can be procured promptly, and the manual provided by the project describes troubleshooting methods. Therefore, the company is considered to be able to handle issues that may arise.

Based on the above, it is concluded that there is no issue with the risk related to the operational sustainability.

3.4.7 Status of Operation and Maintenance

At the time of the ex-post evaluation, the equipment was in good working condition, and no malfunctions due to lack of maintenance had occurred since its installation. Voltage measurements and records, daily inspections, and periodic maintenance have been performed as planned. No issues were also observed in the procurement of spares parts. On the other hand, the status of installation and maintenance of the substations' equipment was not recorded in a ledger, and it was only managed on a map with no detailed information. The specifics of each item are as follows.

- Operation and inspection records were always kept, and it was confirmed that operational records and inspections were performed on a daily basis.
- The manuals were kept at the substations and used for troubleshooting.
- Regarding the ledgers of substation facilities, at both the Apo and Keffi Substations, only the layout of each facility was managed on a map, not on a ledger, and installation records, maintenance schedules, etc., were not centrally managed. In addition, the data such as transmission losses were not recorded and managed in the system. According to TCN, a project for asset and data management has recently been started and the asset and data will be managed in a database in a few years.
- It was confirmed that spare parts were well stored and that a system was in place for prompt supply of the parts from local distributors of Japanese companies.

Therefore, there are no particular issues in terms of operation and maintenance.

From the above, it can be said that although there were some minor issues in operation and maintenance, there are good prospects for improvement and resolution. Therefore, sustainability of the project effects is high.

4. Conclusions, Lessons Learned and Recommendations

4.1 Conclusion

The project aimed to reduce transmission power loss and improve the power supply to the Abuja Federal Capital Territory and the surrounding area (Nasarawa State) by installing power capacitors at the Apo and Keffi Substations, thereby contributing to the promotion of economic and social development of the target area. The project was consistent with Nigeria's development policies and needs at the time of the planning and the ex-post evaluation, and the project plan and approach were appropriate based on lessons learned from similar past projects. As for the internal coherence, there was no specific coordination with other JICA projects, which was initially expected. As for the external coherence, there was some coordination with other projects through the executing agency. However, the implementation of those projects was significantly delayed, and the results of the coordination were limited. On the other hand, the consistency with Japan's ODA policy at the time of planning was observed. Therefore, its relevance and coherence are high. Although the project period slightly exceeded the plan, the project cost remained within the plan, and the efficiency of the project is high. The project increased the rate of voltage improvement in the target area, which was assumed at the time of planning, and stable and efficient power supply was realized mainly for large-scale facilities. Although some issues persist, such as unstable power supply due to the population growth in the target area, the effectiveness and impacts of the project are high, as it achieved the overall expected effects and impacts, and no negative impacts were observed. There were no organizational, technical, or financial issues in the operation and maintenance of the project, and the facilities were operating without any issues. Therefore, the sustainability of the project effects is high.

In the light of the above, this project is evaluated to be highly satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

Recommendations to Nigeria's Federal Ministry of Power and TCN:

The transmission losses seem to have improved after the start of the project. However, the stable power supply was still not realized due to the increase in power demand caused by the population growth and other factors at the time of the ex-post evaluation, hence improving power reliability remains an important issue. Although this project supported the construction of substation facilities and the equipment installation, the main reasons for the unstable power

supply are that the population growth in the target areas is greater than expected, as well as the insufficient generation capacity, the aging transmission and distribution facilities, etc. To resolve the underlying factors, additional capital investment is considered to be necessary, not only in the transmission facility, but also in the generation and distribution facilities. In order to make capital investments, it will be necessary to take measures such as financing (procurement through investment financing, revision of generation tariffs, and improved collection rate of electricity charges from the users), the stable procurement of natural gas, and the promotion of the entry of independent power producers (private companies that sell electricity wholesale).

Recommendations to TCN:

Although the equipment and devices were inspected and maintained regularly and operated in good condition, the ledgers of substation equipment were only managed on a map at both the Apo and Keffi Substations, and the installation records and maintenance periods were not centrally managed. It is necessary to implement ledger management of facilities and formulate maintenance management plans, in order to build an environment where information is passed down over the years and appropriate operation is carried out.

4.2.2 Recommendations to JICA

None

4.3 Lessons Learned

Development of power grids with a view to providing a stable supply of electricity to end users (electricity consumers)

Although the project achieved its project objectives, the entire power grid in the target area still had an unstable supply of electricity, due to the insufficient power generation capacity, and the insufficient supply capacity caused by the population growth. The issues of the insufficient power generation capacity and the aging transmission/distribution facilities, which are outside the scope of this project, are major reasons for power supply instability. However, the situation of unstable electricity supply remains unchanged from the viewpoint of consumers. While this project supports the improvement of substation facilities, which was the urgent matter, other issues that exist on the power grid need to be resolved, and the entire power grid needs to be improved. In implementing this project, it would have been necessary for power supply agencies including TCN under Nigeria's Federal Ministry of Power to draw up an integrated development plan based on an overall picture of the power supply in the Abuja area, and to sequentially improve the facilities and the equipment starting with those of the highest priority. Therefore, when planning

similar projects, it is important for the executing agency and JICA to analyze the issues on the power grid, taking into account population growth and other matters first, and to set priorities then. After setting the priorities, clearly setting the responsible person(s) and schedule for improvement of necessary facilities and the equipment and implementing them sequentially will be essential for the stable supply of electricity to the target area. It is desirable that JICA analyze the implementation status of related projects in this context, and plan and implement effective projects.

(End)