Republic of Cote d'Ivoire
Ministry of Petroleum, Energy and Renewable Energy
CI-ENERGIES

PREPARATORY SURVEY FOR THE PROJECT ON REINFORCEMENT OF THE NORTH CORRIDOR (TAABO-KOSSOU-BOUAKE)

FINAL REPORT (PREVIOUS EDITION)

March 2021

Japan International Cooperation Agency

NEWJEC Inc.

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21-005

Preparatory Survey
for the Project on Reinforcement of the North Corridor
(Taabo-Kossou-Bouake)

FINAL REPORT

Table of Contents

Chapter 3 Necessity and adequacy of this project

Chapter 4 Results of Site Survey

Chapter 5 Environmental and Social Considerations

Chapter 6 Preliminary Design

List of Figures

List of Tables

Abbreviations

Symbol	Abbreviations
WAPP	West Africa Power Pool
AAAC	All Aluminum Alloy Conductor
ABC	Aerial bundled cables
ACSR	Aluminum Conductor Steel Reinforced
AFD	Agence Francaise de Developpement
AfDB	African Development Bank
AIS	Air Insulated Switch
Al	Aluminium
AMT	Amorphous Transformer
ANDE	Agence Nationale de l’Environnement
BCC	Dispatch Center
BCU	Bay Control Unit
BOOT	Build-Own-Operate-Transfer
BT	Basse tension (jusqu’à 1000 V)
CIE	Compagnie Ivoirienne d’Electricité
CIPREL	Ivory Coast Electricity Production Company
CRGOT	Cold Rolled Grain Oriented Electrical Steel Transformer
CRT	Regional Technical Center
Dia	Diameter
ECOWAS	The Economic Community of West African States
EECI	Energie Electrique de Cote d'Ivoire
EIA	Environmental Impact Aassessment
EU	European Union
F/S	Feasibility Study
GDP	Gross Domestic Product
GIS	Gas Insulated Switchgear
GIS	Geographic Information System
HTA (MT)	Medium Voltage / Moyenne tension
HTB	High Voltage / Haute tension (équivalent à HT)
IACM	les Interrupteurs aériens à commande manuelle
IAT	les Interrupteurs aériens télécommandés
JICA	Japan International Cooperation Agency
LL-ACSR	Low Loss Aluminum Conductor Steel Reinforced
MP2015	PLAN DIRECTEUR DES OUVRAGES DE PRODUCTION ET DE TRANSPORT D’ENERGIE ELECTRIQUE DE LA COTE D’IVOIRE POUR LA PERIODE 2014-2030
NCB	National Competitive Bidding
O&M	Operation & Maintenance
OPGW	Optical-Fiber Composite Overhead Ground Wire
PBX	Private Branch Exchange
PMU	Project Management Unit
PND	Plan National de Développement
PRONER	National Program of Rural Electrification
RAP	Resettlement Action Plan
ROW	Right of Way
SCADA	Supervisory Control and Data Acquisition
ToR	Terms of Reference
TR	Transformer
UTS	Ultimate Tensile Strength
XLPE	Cross - linked Polyethylene

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE SURVEY

The government of COTE D'IVOIRE has prioritized the following strategies in the National Development Plan (2016-2020): "Strengthening human capital and extending social well-being" and "Promoting the transformation of economic structure through industrialization". According to these strategies, the government aims to increase the electrification rate from 40% in 2014 to 77% by 2020, in order to improve the living environment of the people and support sustainable growth. To achieve this target, the government plans to (1) increase electricity generation capacity from 1,409 MW (2011) to 5,691 MW by 2030 and (2) extend the transmission and distribution network to approximately 5,500 km nationwide and construct 46 substations (based on the Master plan for the production and transport of electrical energy (developed in June 2015), hereinafter referred to as "PD 2015"). Although electricity production capacity has steadily increased because of private investment, there has been significant losses in transmission and distribution, and frequent power outages, etc. have been observed due to aging and inadequacy of transmission and distribution facilities. Thus, there is an urgent need to develop and reinforce the infrastructure of transmission and distribution. The composition of power sources in COTE D'IVOIRE is: 60% thermal energy and 40% hydroelectric energy. In terms of fuel utility, the thermal power stations are concentrated in Abidjan, which is located in the south of the country and has port facilities. The hydroelectric power stations are distributed in the water systems of southwestern, central and southeastern regions. Therefore, the northern part of the country where there are no power plants, and the adjacent countries in the north, namely, the Republic of Mali (hereinafter referred to as "Mali") and Burkina Faso, are supplied electricity mainly via the 225 kV trunk transmission line, which runs across the north and the south of the country.

However, even though this north-south trunk transmission line is a very vital facility, the Taabo-Kossou-Bouake section of the line consists of a single-line transmission line, which is a bottleneck in terms of transmission capacity. In addition, in case of any accident in this section, the electric power is transmitted via another system, and there is a high possibility that a large-scale nationwide power outage will occur. Therefore, it is highly urgent to stabilize the power supply, improve the supply reliability and increase the transmission capacity by upgrading the section to two circuits.

Furthermore, there is a framework called West Africa Power Pool (hereinafter referred to as "WAPP") in West Africa. It allows electricity to be exchanged between countries, and COTE D'IVOIRE plays an important role as a power supplier in the framework. Therefore, the government needs to satisfy not only the domestic electricity demand, but it has to also supply electricity to neighboring countries such as Mali and Burkina Faso, and from that perspective, it is vital to increase the transmission capacity.

Based on the above, this project is recognized as one of the highly prioritized projects by the government of COTE D'IVOIRE, and it aims at upgrading the transmission line to two circuits and strengthening the distribution network. It aims to increase the transmission capacity and stabilize the power supply to the central and northern regions and to the neighboring countries, and consequently improve the living environment of local residents and promote industrial activities.

1.2 OBJECTIVE OF THE SURVEY

The objective of the Survey is to conduct the feasibility study for the Project on Reinforcement of the North Corridor (Taabo-Kossou-Bouake) (hereinafter called "the Project") and to carry out the necessary study to evaluate the project as an ODA loan project. The survey includes a study on the purpose of the project, outline, project cost, implementation system, operation and maintenance organization, environmental and social consideration, etc.

1.3 SCOPE OF THE SURVEY

1.3.1 Outline of the Survey

Items	Contents
Object	1) Objective of the Project In the Addis Ababa capital city, the objective is to upgrade the transmission line to plural circuit and strengthen the distribution network. It aims to increase the transmission capacity and stabilize the power supply to the central and northern region and to the neighboring countries, and consequently improve the living environment of local residents and promote industrial activities. 2) Objective of this Preparatory Survey For the above Project, the following items are conducted in this preparatory survey. In addition, a study on the necessary evaluation for the execution of Japanese ODA Loan is also done. ✓ purpose of the project ✓ outline, project cost ✓ implementation system ✓ operation and maintenance organization ✓ environmental and social consideration,
Target Area	Région de l'Agnéby-Tiassa, Région du Bélier and Région du Gbêké
Related authorities (Implementation Agency)	1) Authorities: Ministry of Petroleum, Energy and Renewable Energy Development 2) Implementation Agency: CI-ENERGIES
Scope of Work	1) Transmission line of 225 kV Taabo-Yamoussoukro-Kossou, 2) Transmission line of 225 kV Kossou-Bouaké 2-Bouaké 3 3) Construction of Bouaké 3 and Yamoussoukro 2 substation 4) Extension of Taabo and Kossou and Bouaké 2 Substation 5) Extension of distribution network in Bouaké and Yamoussoukro

1.4 FLOW OF THE SURVEY

Flow chart of the entire Survey work is shown in Fig. 1.4-1.

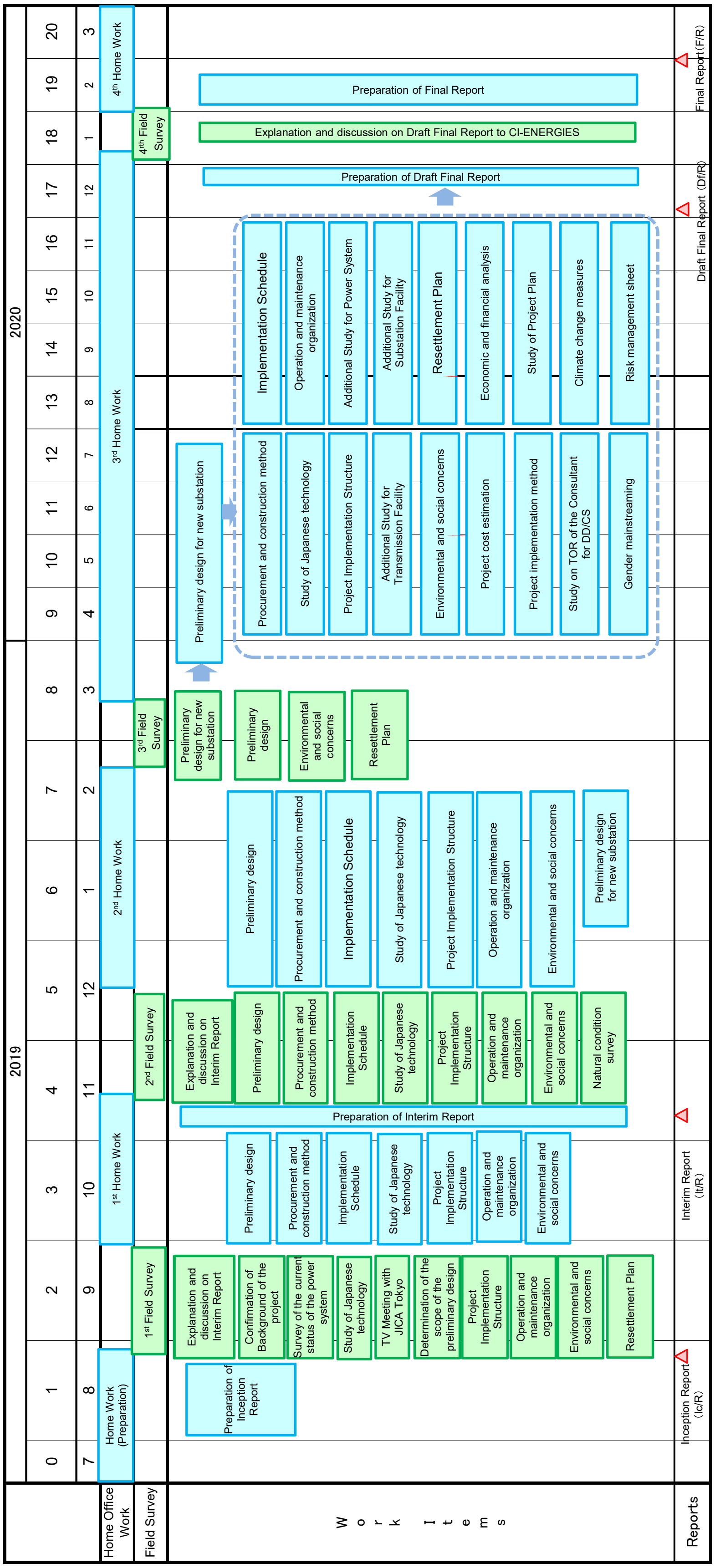


Fig. 1.4-1 Work Flow

1.5 IMPLEMENTATION STRUCTURE

1.5.1 Counterpart of CI-ENERGIES

CI-ENERGIES assigned the following members as counterparts for this Preparatory Survey.

Table 1.5-1 CI-ENERGIES Counterpart

Name	Assignment	Organization
M. ANOH Angaman	Project Manager	CI-ENERGIES
M. AMARI EDJEMS A. Stéphane / M. COULIBALY Mohamed	Demand Forecast	CI-ENERGIES
M. ADJEI Jean Marc / M. OUATARRA Dognymé / M. SYLLA Mohamed	Network System Analysis	CI-ENERGIES
M. KONE Wihon / M. KONE Seydou / M. NENE	Transmission Facility	CI-ENERGIES
M. KONE El hadj / M.ASSY Jackson / M. KONE Wihon / M NENE	Substation Facility	CI-ENERGIES
M. YAO Mbra / Mlle AFFAINIE Marie-Emmanuelle / M TCHA Camille	Distribution Facility	CI-ENERGIES
M. ASSY/M. LAGAHUZERE	Protection Design	CI-ENERGIES
M. DOUMBIA	SCADA design	CI-ENERGIES
M. DOUMBIA	Communication design	CI-ENERGIES
M. AHOUSSOU Mathieu	Civil Design	CI-ENERGIES
M. OUATTARA Oumar	Environmental and Social Consideration	CI-ENERGIES
Mme. ABOUA Flora / M. SERIFOU Mamery	Economic and Financial Analysis	CI-ENERGIES
M. ABLINGUE Serge-Pacôme	Procurement	CI-ENERGIES
M. KOUASSI Abel (CI-ENERGIES) / M. GNADRO Désiré Oku + M. EBOUA (CIE)	Implementation Structure & Maintenance	CI-ENERGIES CIE

Source: JICA Study Team

1.5.2 JICA Study Team Members

This survey was implemented by the following team members (JICA Study Team).

Table 1.5-2 Member of JICA Study Team

Name	Assignment	Organization
Mr. Kenichiro YAGI	Team Leader/ Planning	NEWJEC Inc.
Mr. Takeshi ABE	Deputy Team Leader/ Civil Engineering	NEWJEC Inc.
Mr. Kiyotaka UENO	System Analysis	NEWJEC Inc.
Mr. Takato.TSUTSUI	Demand Forecast	NEWJEC Inc.
Mr. Kazuo MURAI	Transmission Facility	NEWJEC Inc.
Mr. Shinichi KAWABE	Distribution Planning	NEWJEC Inc.
Mr. Akira KAWABE	Substation Facility	NEWJEC Inc.
Mr.Kazutoshi NISHIMURA	Substation Facility 1	NEWJEC Inc.
Mr.Masayoshi OHARA	Substation Facility 2	NEWJEC Inc.
Mr. Akihiro OSADA	Environmental and Social Consideration	NEWJEC Inc.
Mr.Sho SHIBATA	Economic and Financial Analysis	NEWJEC Inc.
Ms.Yukiko AKIYAMA	Procurement / Cost Estimate / Project Coordinator	NEWJEC Inc.
Mr. Fumihiro TAMURA	Implementation Structure & Maintenance 1	NEWJEC Inc.
Mr. Katsunori MORI	Implementation Structure & Maintenance 2	NEWJEC Inc.

CHAPTER 2

CURRENT SITUATION AND ISSUES OF THE POWER ENERGY SECTOR

CHAPTER 2 CURRENT SITUATION AND ISSUES OF THE POWER ENERGY SECTOR

2.1 ECONOMIC AND SOCIAL SITUATION IN CÔTE D'IVOIRE

General information on Côte d'Ivoire is described in Table 2.1-1, and the Fig. 2.1-1 shows the map of Côte d'Ivoire in West Africa. Côte d'Ivoire is a country in sub-Saharan Africa that borders Liberia and Guinea at the west, Mali and Burkina Faso at the north, Ghana at the east and the Gulf of Guinea (Atlantic Ocean) at the south. It is connected to Ghana, Burkina Faso and Mali with transmission lines through their interconnection from the WAPP framework.

Table 2.1-1 General information on Côte d'Ivoire

Item	Outline
Area	322,436km^2
Population	24.29 million
Capital	Yamoussoukro (Practical administrative and economic function is in Abidjan)
Peoples	There are more than 60 ethnic groups, such as Akan (Baoulé, Agnis etc.) in the south-east、Krou (Bétes, Guéré etc.) in the south-west, Voltaïque (Sénoufos, Koulango, Lobi etc.) in the north-east、Mandé (Malinkés, Dan etc.) in the north-west
Languages	French (official), ethnic languages
Religions	Christianity 39.1%, Islam 33.7%, Traditional 4.4%, Other 0.6% and No religion 22.2%

Fig. 2.1-1 Location of Côte d'Ivoire

2.1.1 Political Situation

Côte d'Ivoire, after its independence from France in 1960, established a stable administration for more than 30 years and achieved an average annual economic growth of 8%. Its development has been called the "Ivorian Miracle". It has also played a leading role in the West African region because of its great political stability. However, the politico-military crisis that the country has experienced has resulted in a lack of structuring investments in all sectors of the Ivorian economy.

With the end of the crisis in 2011, the government has been working on a national reconstruction policy based on three pillars: security measures, reconstruction and national reconciliation. In

December 2011, the first legislative election in 11 legislative years took place. In October 2015, presidential elections were held in a calm atmosphere with the re-election of the current president, which encourages national reconciliation and economic reconstruction. The policy that he has prioritized in his second term has been to commit to promoting national reconciliation, balancing the benefits of economic growth, reducing poverty, promoting youth employment and improving the treatment of women. Also, in November 2016, after a referendum, a new constitution was promulgated, establishing the post of Vice-President and the Senate.

2.1.2 Economic Situation

At the national level, in the year 2019, the economic activities continued to evolve within a sound macroeconomic framework with a relatively calm socio-political environment, a favorable business climate and strengthened governance. It continues to benefit from the implementation of the National Development Plan (NDP) 2016-2020, which mainly aims at the structural transformation of the Ivorian economy through industrialization. GDP at constant 2009 prices in 2019 will amount to 21 434.8 billion FCFA (against 19 940.9 billion FCFA recorded in 2018); a growth of +7.50% (against +7.43% in 2018). The growth in 2019 will be mainly due to performances in the tertiary and industrial sectors, and also due to tax revenues. National economic growth should stabilize at around +7.3% in 2019.

With regard to supply, production should be dynamic thanks to all sectors with the implementation of the 2016-2020 NDP.

The primary sector experienced a growth of +1.7% in 2019 (against +4.2% in 2018) mainly due to food agriculture and livestock (+3.9% against +2.1% in 2018). As in the previous years, this sector will continue to benefit from the implementation of the National Agricultural Investment Programme (PNIA) which allocates 10% of the state budget to the agricultural sector. In 2020, the growth of the primary sector will rise to +3.01% due to the resumption of growth in export agriculture and food-producing agriculture.

Activities in the secondary sector recorded a growth of +10.1% in 2019 (against +7.1% in 2018 and +3.0% in 2017). This sector is mainly driven by construction (+18% against +16.5% in 2018), petroleum products (+24.9% against -7.2% in 2018) and agri-food industries (+16.0% against +15.4% in 2018). The Energy sector (Electricity, gas and water) recorded a growth of 7.0% (against +4.0% in 2018). The projected growth in 2020 for this sector is 10.0%.

In 2019, the growth projected for the tertiary sector is +9.2%. This growth will be driven mainly by the telecommunications (+12.2% vs. 12.4% in 2018), transportation (+9.4% vs. +9.0% in 2018) and trade (+8.6% vs. +8.4% in 2018) sectors. The projected growth for 2020 is +9.1%.

Demand should benefit from the consolidation of economic growth.

The non-market sector is expected to grow by +3.4% in 2019 compared to +7.9% in 2018 and a growth of +0.9% is projected for 2020. Duties and Taxes are expected to grow by +9.8% in 2019, compared to +7.5% in 2018, and it is projected to grow by +7.6% in 2020.

Inflation (UEMOA standard: 3% maximum) for the year 2019 should come out at 1.0% (against +0.4% in 2018).

The GDP growth rates projected by the Ministry of Economy and Finance are 7.5% for 2019 and 7.3% for 2020.

There is a definite correlation between economic growth and the level of electricity consumption. Therefore, the mission of the power sector is to guarantee a level of power that will enable the Nation's economic growth forecasts to materialize.

2.2 ELECTRIC POWER POLICY

A brief history of Côte d'Ivoire's energy sector is given below. The Electricity Law came into force in 2014 and is applied to the current electricity activities.

1952	The entire electricity sector is managed by the EECI (Energie Electrique de Côte d'Ivoire).
1985	The law formulates the legal framework of the electricity sector (dated 29 July).
1990	First reform of the electricity sector, granting a public service concession to the EECI.
1994	First electricity production company (hereinafter referred to as "CIPREL") (BOOT-type project) enters the market.
1997	AZITO Energie (BOOT-type project), the second producer enters the market.
1998	Second reform of the electricity sector - creation of SOPIE and SOGEPE
2005	The public service concession to CIE is extended for 15 years.
2010	AGGREKO (lease), the third producer enters the market.
2011	Third reform of the electricity sector - creation of CI-ENERGIES, - dissolution of SOPIE and SOGEPE
2014	Promulgation of the new Electricity Law
2020	The public service concession to CIE is extended by 12 years.

2.2.1 Legal System and Regulation of the Power Sector

In 2014 and 2015, the new framework was introduced on the basis of new laws and regulations (Law No. 2014-132 of 24 March 2014 Electricity Code). The objective of the law mentioned in Article 2 is to define the general principles of the institution, operation and production in the electricity sector as shown below:

- to guarantee the independence and security of electrical energy ;
- to promote the development of new and renewable energies;
- to develop electric power and promote access to this energy;
- promoting energy management;
- creating the economic conditions for the return on investment;
- promote consumer rights; and
- promote competition and the rights of operators.

These laws, which strengthen the power and capacity of the regulatory authority and affect the development of new and renewable energies, include penal clauses to deal with fraud and illegal acts that cause significant technical and commercial losses (such as the theft of electricity). They are linked to the further liberalisation of the electricity market by officially ending the state monopoly on the transmission, distribution, sales, export and import of electricity.

The main changes compared to the old law of 1985 are the following:

- the reduction of the scope of the state monopoly;
- the introduction of the principle of competition through liberalisation (excluding certain projects). For example, access to the power system by a third party is, in principle, granted, allowing the user to receive electricity via the operator of his choice ;
- confirmation of the policy for the development of new and renewable energies ;
- the introduction of individual tax and customs measures that favour companies in the electricity sector;
- the reinforcement of fraud prevention measures; and
- the establishment of an independent electricity sector regulatory authority responsible for proposing to the country the charges applicable to the electricity sector.

2.2.2 Structure of the Electricity Sector

(1) History of Electricity Sector Structure

In Côte d'Ivoire, the Electricity Law of 1985 opened up the electricity generation sector to private companies. Three private power generation companies entered the market, but areas such as transmission, distribution, import and export of electricity remained state monopolies. In 1990, the government granted a private company, Compagnie Ivoirienne l'Electricité (CIE), a concession on the generation, transmission, distribution, import and export of electricity for a period of 15 years (in 2005 extended to the year 2020).

In December 1998, the government reformed the institutional framework of the sector to limit the authority of the CIE and created two state-owned companies, SOGEPE and SOPIE. SOGEPE was founded with the aim of taking charge of the sector's assets and financial flows, while SOPIE plays a role in the long-term planning of the sector's investments.

Following the new reform in 2010, SOGEPE and SOPIE were merged and a new public energy company, Société des énergies de Côte d'Ivoire, was created by a decree published in December 2011. The Société des énergies de Côte d'Ivoire continued to carry out the operations of the two previous companies. In addition to supplying electricity to the state, it manages projects in the electricity sector as a concession holder.

Under a new decree published in November 2017, the assets were transferred to the state-owned company, Energies de Côte d'Ivoire (renamed "CI-ENERGIES"), which is also responsible for the operation and maintenance of certain power plants.

(2) Current System in the Electricity Sector

1) Stakeholders in the Electricity Sector

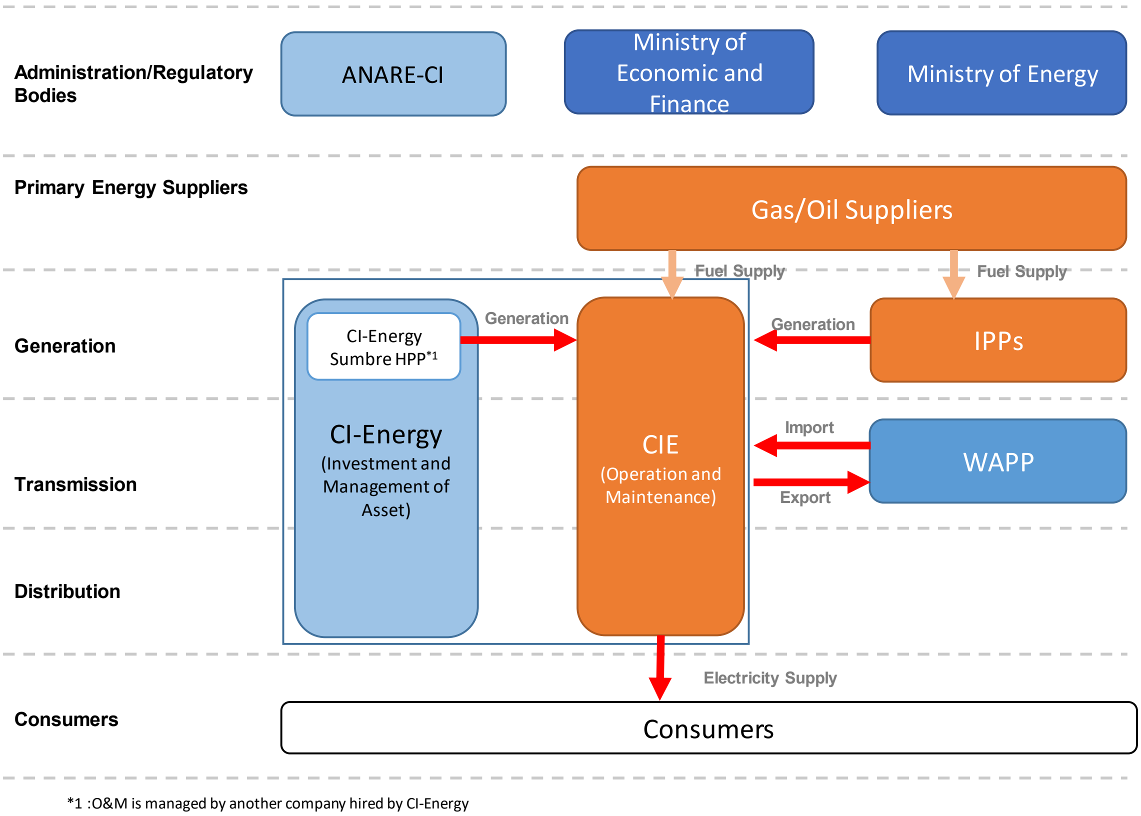
The stakeholders in the electricity sector in Côte d'Ivoire are CI-ENERGIES supervised by the Ministry of Petroleum, Energy and Renewable Energies and placed under the authorities of the said Ministry and the Ministry of Economy and Finance, the National Energy Regulatory Authority (hereinafter referred to as "ANARE"), gas suppliers, the IPPs (Independent Power Producers), the WAPP where the member countries are interconnected by an international power system, the CIE which ensures the operation and maintenance of generation, transmission and distribution facilities in the form of a concession contract, and finally the consumers. These stakeholders are listed in Table 2.2-1.

Table 2.2-1 Stakeholders in the Power Sector

Stakeholder	Organization	Role
Ministry	Ministry of Petroleum, Energy and Renewable Energies	Technical control authority in charge of formulating all strategies for electricity generation, transmission and distribution activities.
	Ministry of Economy and Finance	Financial control authority in charge of approving budgets and loans related to ANARE and CI-ENERGIES projects.
Public Power Utility	CI-ENERGIES	Owner in charge of asset and financial flow management, planning, construction supervision of the sector concerned, technical supervision of the electric power sector and implementation of the rural electrification project. The operation and maintenance of the generation, transmission and distribution facilities are subcontracted to CIE through a concession contract, under the supervision of CI-ENERGIES. However, the operation and maintenance of the Soubré hydroelectric power plant is the responsibility of CI-ENERGIES.
Regulatory Authority	ANARE	In place of the government, in charge of controlling the concessionaires (CIE for the transmission and distribution of electricity), the independent electricity production company and the gas company which supplies fuel to the electricity production company, in collaboration with CI-ENERGIES.
Primary Energy Supplier	PETRO-CI, CNR, FOXTROT (Natural Gas), SIR (Heavy Oil)	Under the concession contract, gas deposits are developed in areas designated by the government and the gas is sold to the state for the supply of fuel to the thermal power plants.
Private Power Utility	CIE	Hydroelectric (dam operation) and thermal power plants are also realized through the concession contracts granted by the State. As regards to thermal power generation, electricity is produced in its own thermal power plants using gas supplied by the gas companies. In addition, electricity is purchased from independent thermal power generation companies. It supplies electricity to consumers (domestic and export customers) via transmission and distribution lines.
IPPs	AGGREKO、AZITO、CIPREL	Thermal power generation company that uses the gas supplied by the gas company to produce electricity supplied to CIE. In August 2019, there were no independent power producers (IPP).
Consumers	Domestic and International Consumers	

2) The Sequence of Generation, Transmission and Distribution

Fig. 2.2-1 shows the sequence of primary energy supply and generation, transmission and distribution.



Source : JICA Study Team

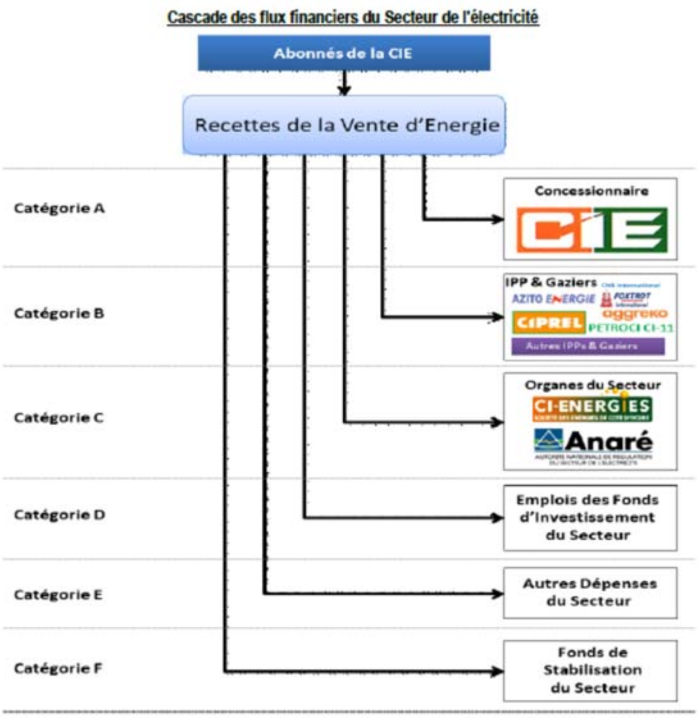
Fig. 2.2-1 Sequence of generation, transmission and distribution

The CIE, which concluded the concession contract with CI-ENERGIES, is the main player in the field of power generation, transmission and distribution. CIE is in charge of the operation and maintenance of hydroelectric power plants, except for Soubré, and the thermal power plants (Vridi-1) except for IPPs. In the field of transmission, it is in charge of purchasing electricity from the IPPs and purchasing and supplying it to the international market, as well as operating and maintaining transmission lines and substations, including the power system. In the field of distribution, it is also responsible for the operation and maintenance of distribution facilities and supply to consumers.

As far as primary energy is concerned, fuel is supplied to CIE and IPPs by gas suppliers such as CNR, FOZTRO, PETROCI, and the heavy oil supplier SIR. Regarding investment for facilities of the electric sector, CI-ENERGIES is responsible for the planning, design and construction, and is the executing agency for the development of new power plants and transmission and distribution facilities..

3) Trade Flows in the Field of Power Generation, Transmission and distribution.

As mentioned above, electricity trade in Côte d'Ivoire is conceded to CIE in the form of a concession contract. The flow of trade in power generation, transmission and distribution is regulated by law. The trade flow is in cascade（Fig. 2.2-2） regulated via CIE.



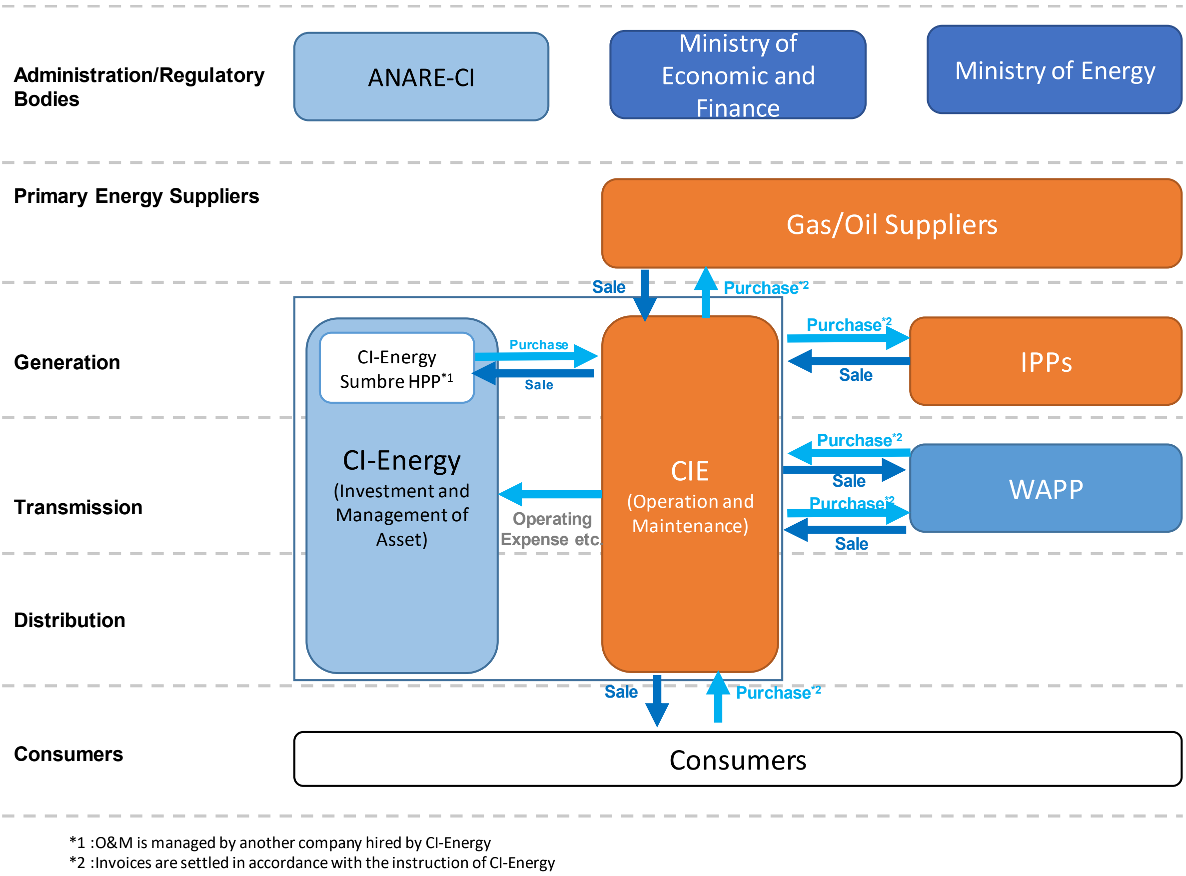
Source：CI-ENERGIES

Fig. 2.2-2 Cascade Cashflow of the Power Sector

In detail, CIE first collects electricity bills from consumers and then distributes the income to the six categories A to F mentioned below. In this cash flow, CIE collects bills from consumers and makes payments A to F. In terms of process, payment is made through CIE, but CI-ENERGIES is the legal enabling authority.

Category A	CIE remuneration for concessionaire services (Payment on a monthly basis)
Category B	Electricity purchase costs from IPPs such as AZITO Energie. Fuel costs from gas and oil suppliers such as Foxtrot
Category C	Management and supervision fees for organizations in the electricity sector such as CI-ENERGIES and ANARE
Category D	Investment in the electricity sector, excluding debt repayment.
Category E	Other expenditure including debt repayment in the electricity sector.
Category F	Savings for the electricity sector stabilization and reconstruction fund.

Fig. 2.2-3 shows the trade flows between organizations involved in primary energy procurement, electricity generation, transmission and distribution. The Soubré hydropower plant owned by CI-ENERGIES was commissioned in 2017, and the electricity generated is sold to CIE.



Source : JICA Study Team

Fig. 2.2-3 Commercial flows of power generation, transmission and distribution

4) Electricity Tariff

The electricity tariff is prepared by ANARE in collaboration with CI-ENERGIES and approved by the government, taking into account the investments in works, acquisition of the fund, operation, maintenance and consumers. There are three (03) categories of electricity tariff; BT : 5A with 1.1kVA, MT :15kV - 90kV and HT :over 90kV. The most recent electricity tariff order No. 002 / MPEER / MEF / SEPMBPE is published in January 2019 and lowered the price of LV by 20%. Table 2.2-2 shows the total energy sales and consumption per consumer, and the unit price per kWh in 2019.

Table 2.2-2 Energy sales and consumption in 2019 per consumer

Items	BT (Low Voltage)	MT/HT (Mille/High Voltage)	Export
National energy sales Billions of FCFA	298 000	232 200	77 300
National energy consumption in GW h in 2019	4 145,0	3 494,8	1 179,1
Price in FCFA per kWh excluding taxes	71,9	66,4	65,5

Table 2.2-3 Energy sales and consumption in 2019 per BT

TARIF (Domestic)	FCFA	TVA (18%)	FCFA
Fixed premium per two months	559,0	0,0	559,0
Price per kWh up to 80kWh	28,8	0,0	36,1
Price per kWh above 80kWh	50,2	9,0	59,2
Rural electrification charge per			100,0
Rural electrification charge per kWh			1,0
RTI fee per kWh			2,0
Abidjan communal tax per kWh			2,5
Communal tax other area / kWh			1,0

The electricity tariff per consumer as of December 2020 is shown in Table 2.2-3 and Table 2.2-4. Bills for BT category is calculated on a bi-monthly basis, following the reading of the electricity meter according to the 80kWh threshold, in addition to the fixed premium. In addition, the rural electrification and RTI charges and the municipal tax are also charged. The MV/HV bill is calculated per year, following the hourly electricity meter reading, in addition to the fixed charge. In addition, the rural electrification and RTI charges are also charged.

Table 2.2-4 Electricity tariff for MV/HV consumers

Items	MT (Middle Voltage)			HT (High Voltage)		
	FCFA	TVA (18%)	FCFA	FCFA	TVA (18%)	FCFA
Fixed annual premium per kW (FCFA)	19330,01	3479,4	22809,42	47844,57	8612,02	56456,59
Price of FCFA/kWh						
Peak rates（7h30 à 19h30, 23h00-24h00）	66,84	12,03	78,87	53,38	9,61	62,99
Peak rates in night (19h30-23h00)	103,42	18,62	122,04	67,81	12,21	80,02
Off Peak rates (24h00-7h30)	48,45	8,72	57,17	46.41	8.35	54,77
RTI of FCFA/kW			1000			1000
Annual rural electrification charge per kW (FCFA)			1870			1870

(3) Balance of Incomes and Expenses in the Electricity Sector

The cascading cash flow is described in the annual report published by ANARE. The balance of payments of the electricity sector over the last ten years is explained below :

1) Balance of Payments from 2010 to 2015

From 2010 to 2012, a deficit of CFAF 81 billion were recorded in 2010, CFAF 107 billionin 2011 and CFAF 44 billion in 2012 due to the global rise in fuel costs. In 2013 and 2014, measures such as expenditure reductions and tariff revisions were carried out, and a surplus was generated. In 2015, following the decline in hydropower production due to drought, the consumption of heavy oil used for thermal power generation increased. Expenditure then increased considerably with exchange rate fluctuations against the US dollar (1 USD = 490 → 590 FCFA), and a deficit of 40 billion FCFA was recorded despite the July 2015 tariff revision.

2) Balance of payments from 2016 to 2019

Electricity revenues and expenditures from 2016 to 2019 are shown in Table 2.2-5 and Fig. 2.2-4. Revenues in 2016 amounted to FCFA 569.3 billion, expenditure to FCFA 563.1 billion, revenues in 2017 to FCFA 563.8 billion and expenditure to FCFA 563.75 billion. Until 2017, the sector was in deficit, with delays in the collection of export sales and compensated by subsidies. However, in 2018 and 2019 revenues exceeded expenses.

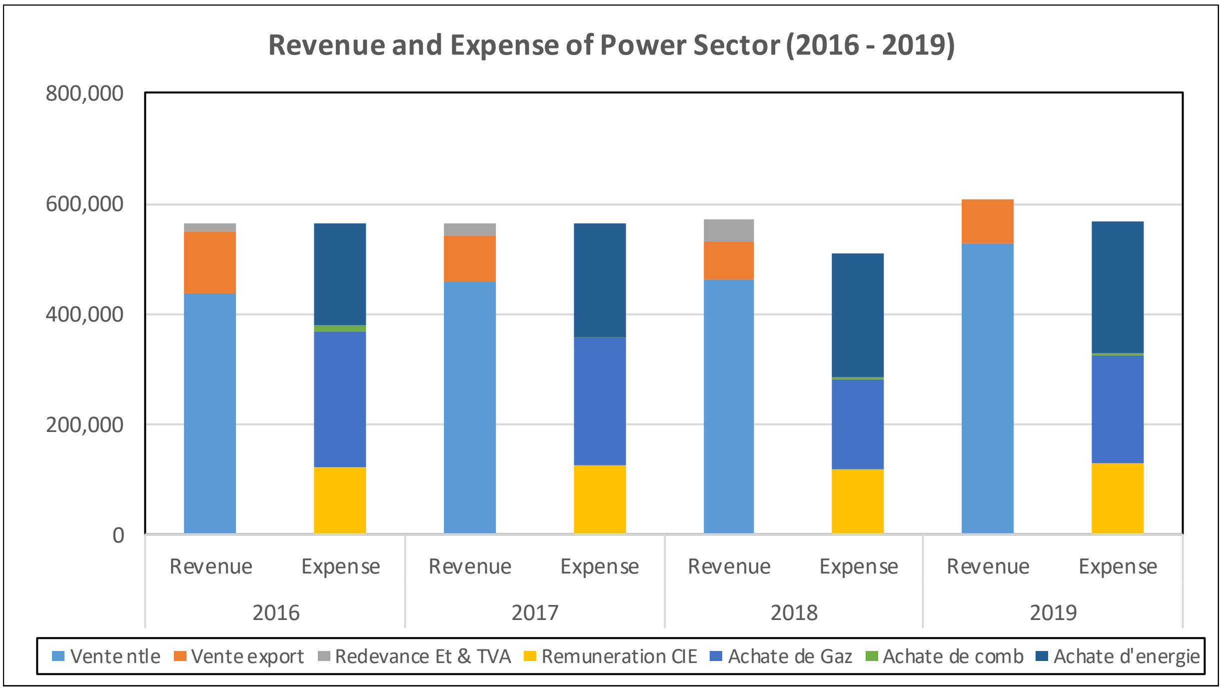
The 2018 annual report of CI-ENERGIES explains the balance of payments by citing favorable factors such as the increase of sales in the domestic market and the reduction of fuel costs. On the other hand, it cites, the reduction in exports due to the drop in demand in other countries as an unfavorable factor. It is considered that the commissioning of the Soubré power plant in 2017 has contributed to the reduction in fuel costs.

Since 2010, the power sector has been in deficit due to soaring fuel costs, reduced hydropower production due to drought and delays in the collection of sales in international trade with neighboring countries. However, thanks to the revision of electricity tariffs in 2015 and the reduction in dependence on fossil fuels, the balance of payments has recently improved.

Table 2.2-5 Balance of payments in the electricity sector from 2016 to 2019

	Item	2016	2017	2018	2019
Revenue	Domestic Sales	438,400	460,900	463,292	530,200
	Export Sales	110,900	81,500	70,396	77,300
	Royalty & VAT	13,700	21,400	38,996	0
	Total	**563,000**	**563,800**	**572,684**	**607,500**
Expense	Remuneration for CIE	123,400	125,270	120,145	129,900
	Purchase of Gas	245,600	232,260	162,929	196,100
	Purchase of Oil	9,600	1,720	2,077	2,900
	Purchase of Electricity	184,500	204,500	224,302	239,900
	Total	**563,100**	**563,750**	**509,453**	**568,800**

Unit :million FCFA (1 Euro = 656 FCFA)
Source :ANARE and CI-ENERGIES



Source :ANARE and CI-ENERGIES

Fig. 2.2-4 Revenues and Expenses in the Power Sector

2.2.3 Overview of Electric Power Master Plans

There are three master plans for electric power in Côte d'Ivoire as shown in Table 2.2-6 below. The first is the medium and long term master plan for Côte d'Ivoire addressed for the year 2030 (Plan Directeur Production-Transport 2014-2030), the second shows the future vision of electric power in the WAPP system, and the third shows the medium and long term plan for rural electrification.

Table 2.2-6 Electric power master plans in Côte d'Ivoire

No.	Plans directeur	Entité en charge	Période cible	Etablissement
1	PLAN DIRECTEUR DES OUVRAGES DE PRODUCTION ET DE TRANSPORT D'ENERGIE ELECTRIQUE DE LA COTE D'IVOIRE POUR LA PERIODE 2014-2030 : (Plan Directeur Production-Transport 2014-2030)	Tractebel Engineering (Financement de la Banque Mondiale)	de 2014 à 2030	juin 2015
2	MISE A JOUR DU PLAN DIRECTEUR REVISE DE LA CEDEAO POUR LE DEVELOPPEMENT DE LA CAPACITE DE PRODUCTION ET DE TRANSPORT D'ENERGIE ELECTRIQUE	Tractebel Engineering (Financement de l'Union Européenne)	de 2019 à 2033	décembre 2018
3	PLAN DIRECTEUR D'ELECTRIFICATION RURALE	Innovation Energy Development	de 2013 à 2030	2014

(1) Master plan for power generation and transmission (Plan Director Production-Transport 2014-2030)

1) Overview

The 2014-2030 Generation-Transmission Master Plan analyses the actual situation of the power system in 2013, which is the base year at the time of formulation. It then analyses the situation of the power system in 2015, 2017, 2020, 2025 and 2030 on the basis of the electricity installation plan and demand forecasts, and formulates plans for additional installations and the necessary investments.

2) National demand forecast and role in the WAPP

The forecast for national power demand indicates a threefold growth with the electricity consumption rising from 7,332 GWh in 2014 to 22,799 GWh in 2030, and the maximum power of electrical energy increasing from 1,153 MW to 3,518 GWh in 2030, due to the high population growth rate, the rural electrification plan and the growth in industrial demand.

Table 2.2-7 Power Demand Forecast in Master Plan until 2030

		2014	2015	2017	2020	2025	2030
Consommation d'électricité	[GWh]	7 332	8 251	9 945	12 662	17 598	22 799
Puissance de production	[MW]	1 153	1 260	1 521	1 941	2 708	3 518

Source : Plan Directeur Production-Transport 2014-2030

The electricity trade within the WAPP Côte d'Ivoire, which is located in the centre of West Africa, is forecasting an increase in energy exports from 2015 to 2025. As the energy hub of the region, Côte d'Ivoire will play a significant role and will need to promote electricity exports through new connections with Liberia, Sierra Leone and Guinea, in addition to those with Burkina Faso and Mali.

Table 2.2-8 Power Export Plan until 2030

		2014	2015	2017	2020	2025	2030
Consommation d'électricité	[GWh]	975	1,020	1,245	1,695	2,700	2,700
Puissance de production	[MW]	115	120	150	200	320	320

Source : Plan Directeur Production-Transport 2014-2030

3) Electric Power Development Plan

The plan for the development of electrical energy focuses on the diversification of the energy mix, which is currently more focused on gas-fired power plants and aims to improve the reliability and stability of supply by diversifying energy sources through the development of new hydroelectric, coal-fired, biomass and solar power plants.

The capacity of the 1,632 MW installations in 2014 will be multiplied by 3.5 to reach 5,691 MW in 2030. In addition, another 1,000 MW coal-fired power plant is planned as an energy source for the mine.

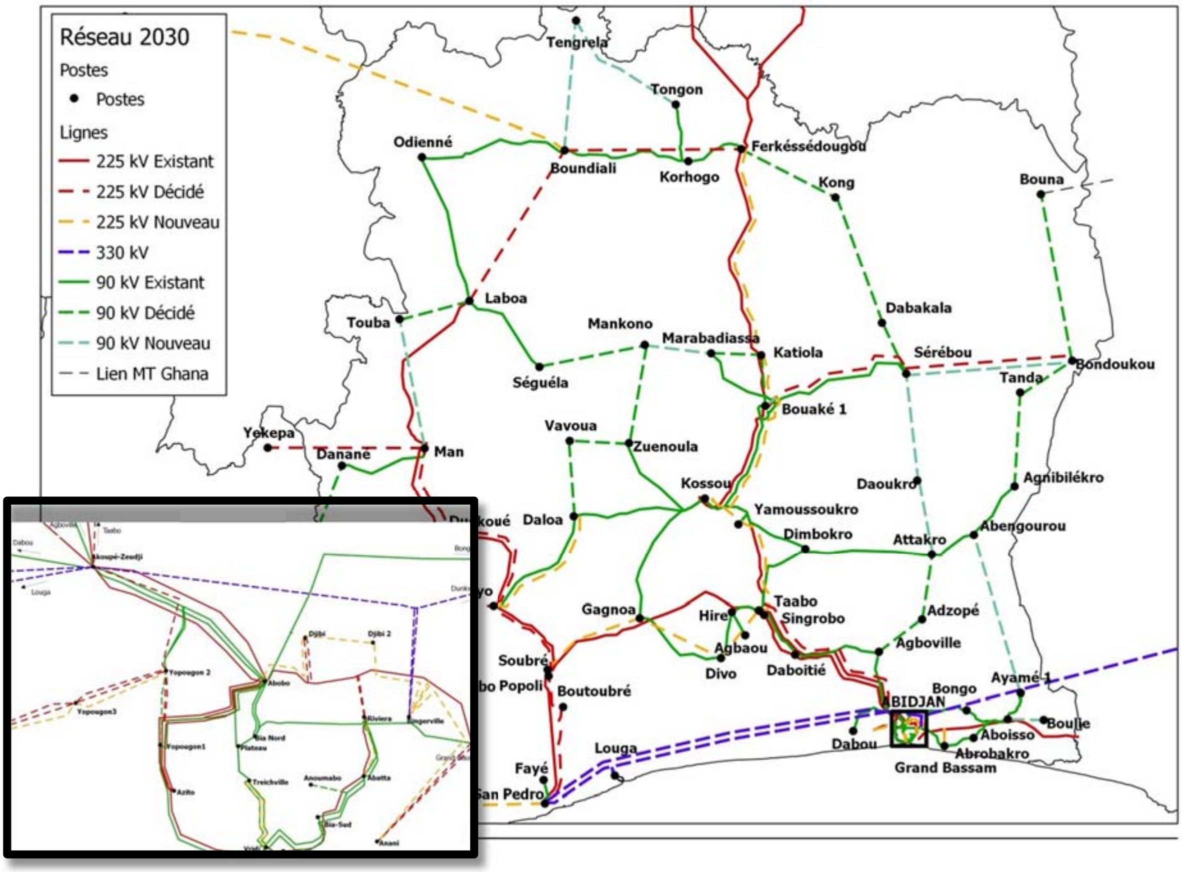
With regard to the energy mix, the percentages will be diversified as follows: The distribution in 2014 was strongly centered on gas-fired thermal energy with 20% for hydroelectricity and 80% for gas. While in 2030 the distribution will be 24% for hydroelectricity, 41% for gas thermal energy, 4% for coal thermal energy and 17% for renewable energy.

4) Transmission Lines and Substations

Fig. 2.2-5 shows the projected power system in 2030.

The power plants in Côte d'Ivoire are mainly located in the south of the country (Soubré / San Pédro and Abidjan), and the south-western region is powered by hydropower plants. In Abidjan about 400 MW are exchanged with other regions at peak load. The northern, western and eastern regions have almost no means of generating electricity and therefore receive electricity from other regions.

In order to improve the quality of the power supply, it is necessary to considerably expand the national electricity grid, particularly in the period 2015-2020. This will make it possible to comply with the N-1 standard (No interruption of supply during an incident on one of the elements of the electricity network) and to stabilize the power system.



Source：Plan Directeur Production-Transport 2014-2030

Fig. 2.2-5 Power System in 2030

5) Investment Plan for the Generation and Transmission of Electricity

The investment cost required for the installations during the period from 2014 to 2030 is 7,717 billion FCFA, of which 6,609 billion FCFA is for production and 1,108 billion FCFA for transmission. Adding the investment in the mining which amounts to 1,465 billion FCFA for generation and 112 billion FCFA for transmission, a total of 9,294 billion FCFA will be necessary.

6) Summary of the 2014-2030 Generation - Transmission Master Plan

The summary of the 2014-2030 Generation -Transmission Master Plan is shown in Table 2.2-9. Comparing the actual value of 2019 with the forecast value of 2020, the maximum demand forecast is 3,298MW (including 1,000MW from the mine and 200MW from export), the actual value is 1,443MW. The forecast of power consumption is 12,662.5GWh, the actual value is 7,616.5GWh. The forecast capacity of the facilities is 4,428MW, the actual value is 2,214MW.

Due to the stagnation of the mine development, the implementation of the 2014-2030 Generation - Transmission Master Plan is delayed. However, regarding the power consumption, 37% of the growth for 5 years is noted (5,561GWh in 2014, 7,616.5GWh in 2019).

Table 2.2-9 Summary of Power Development Plan until 2030

Item		Unit	2,020	2,030
Power Demand	Power Consumption	GWh	12,662	22,799
	Peak Demand (Total)	MW	3,298	4,935
	- Peak Demand (Domestic)	MW	1,941	3,518
	- Peak Demand (Mines)	MW	1,150	1,150
	- Peak Demand (Import)	MW	200	320
	- Improvement of Energy Efficiency	MW	-54	-54
Grid Interconnection	Export	GWh	1,695	2,700
		MW	200	320
Generation * for Mines	**Installed Capacity**	**MW**	**4,428**	**6,691**
	- Hydropower	MW	1,030	1,670
	- Thermal (Gas)	MW	1,913	2,036
	- Thermal (Coal)	MW	250+1,000*	1000+1,000*
	- Renewable Energy	MW	235	985
	Reserve Capacity	%	50%	>40%
	LOLP	>hour	24	24
Transmission	330kV	km	177	761
	225kV	km	3,474	4,542
	90kV	km	4,497	4,857

(2) Master Plan for the Development of the ECOWAS Electric Power Generation and Transmission Capacity

1) Overview

The Master Plan for the Development of Electric Power Generation and Transmission (hereinafter referred to as the "WAPP MP") was drafted in 2012 by the Economic Community of West African States (hereinafter referred to as the "ECOWAS") created in 1975 by fifteen West African countries for medium and long term planning and was updated following funding from the World Bank. The WAPP-MP is a development plan to achieve a stable and reliable supply of electricity at a reasonable price through the WAPP power system comprising fourteen countries.

The WAPP MP by revolutionizing the supply of electricity in the main and independent grids through the use of the huge amount of untapped renewable energy (solar, wind, bio and hydro) in the West African region, aims to decentralize and concentrate renewable energy activities through flexible demand management by developing micro-grids based on hybrid generation, electricity storage and smart meters.

The four topics studied are

- To clarify the state of implementation of the priority projects identified in the WAPP MP 2012 and summaries their progress and obstacles.
- Identify critical factors affecting the implementation of major projects and electricity related activities in the public sector and propose long-term action plans and mitigation measures for these constraints.
- Study the renewable energy supply potential and its constraints in the West African region.
- Create a plan for the development of generation and transmission from a comprehensive and coherent perspective, and present a list of priority projects based on the current WAPP situation

2) Power Development Plan

ECOWAS electricity demand is expected to reach 15.3 GW in 2018, 21.3 GW in 2022, 36.4 GW in 2029 and 50.8 GW in 2033; which represents an increase of 3.3 times in 15 years. In order to meet this strong increase in demand, the WAPP MP's Power Development Plan is formulated with the aim of achieving the following three points :

- Optimum integration of renewable energies in the WAPP, taking into account economic and environmental considerations and technical constraints ;
- Guarantees of energy supply in the short, medium and long term taking into account technical

constraints in the generation and transmission of electricity ;

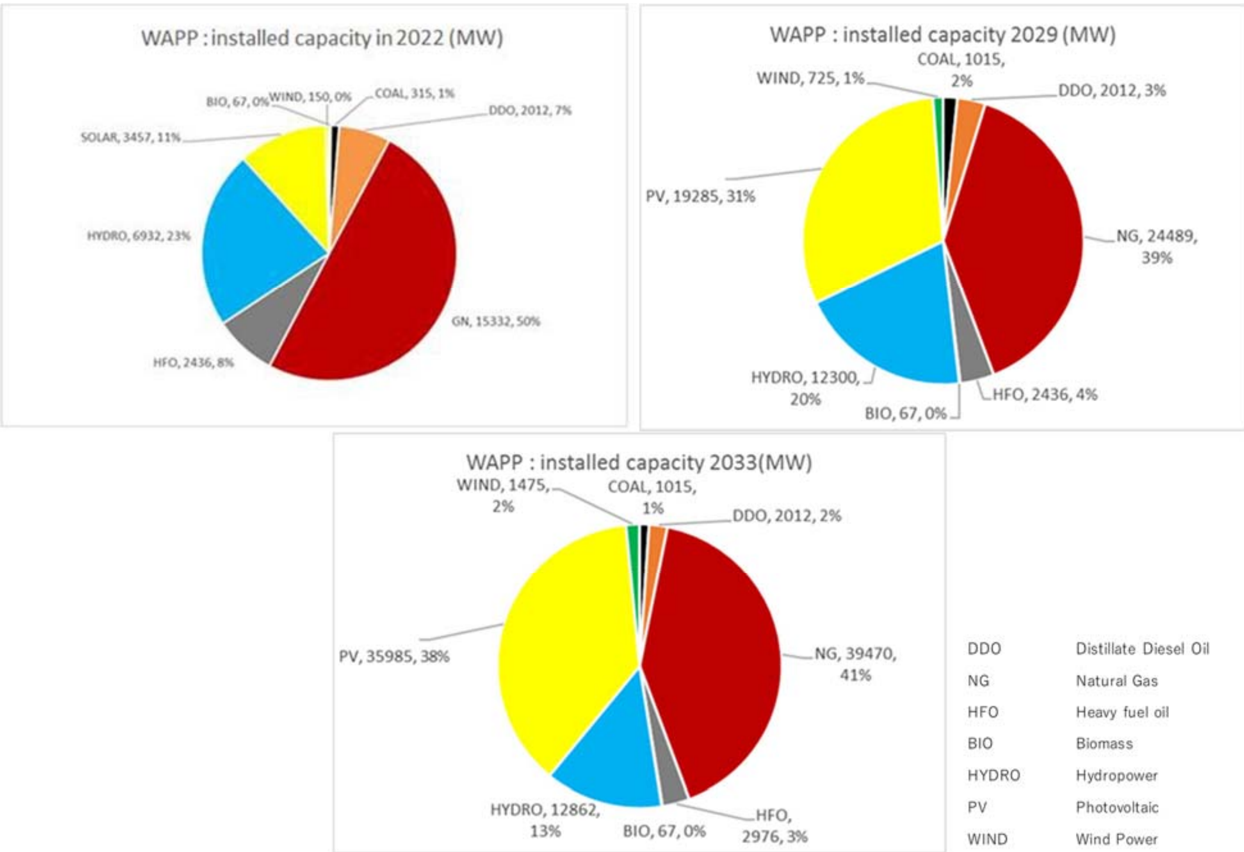
- Construction of the transmission facilities necessary to establish the WAPP market taking into account the operating restrictions of the grid system.

By integrating the generation and power system development plans thus formulated, the problems encountered in the short, medium and long term have been clarified. In addition, in the framework of the extension of power system for the interconnection, preliminary studies on the interconnection of networks to North and Central Africa are also underway.

The installed capacity by type of energy up to 2033 is shown as a percentage in Fig. 2.2-6.

In 2022, thermal energy accounts for 66% (20.1 GW), hydropower 22% (6.9 GW) and renewables 12%（3,6GW）. In 2029, thermal energy represents 49% (30.0 GW), hydropower 19% (11.6 GW) and renewables 32%（20,1 GW）. In 2033, thermal energy represents 48% (45.4 GW), hydropower 13% (12.8 GW) and renewable energies 39%（37,5 GW）.

After 2029, renewable energies excluding hydropower will exceed 30% and solar energy will be the main source of renewable energy in 2033 with 38% (36 GW).



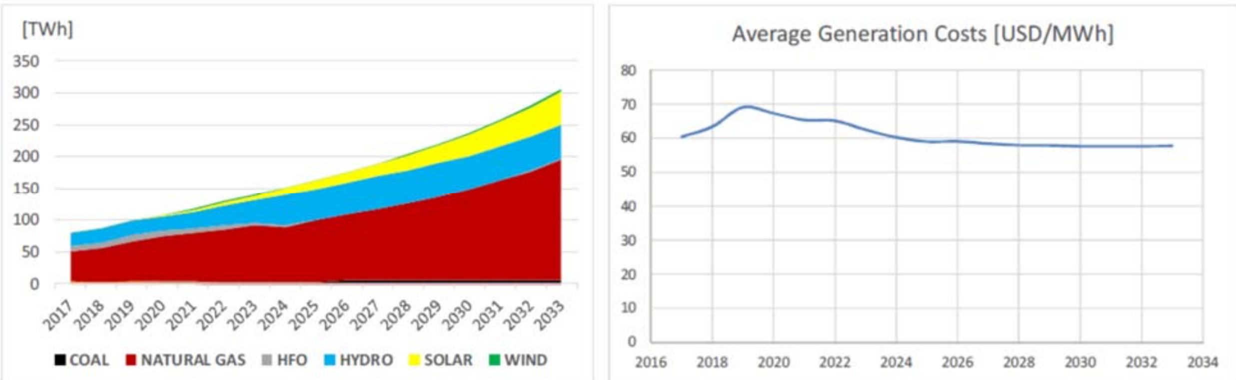
Source :WAPP/MP 2018 - 2033

Fig. 2.2-6 Generation Mix of WAPP in 2022, 2029 and 2033

Fig. 2.2-7 shows the evolution of annual electricity generation (TWh) and the cost of generation (USD/MWh) until 2033.

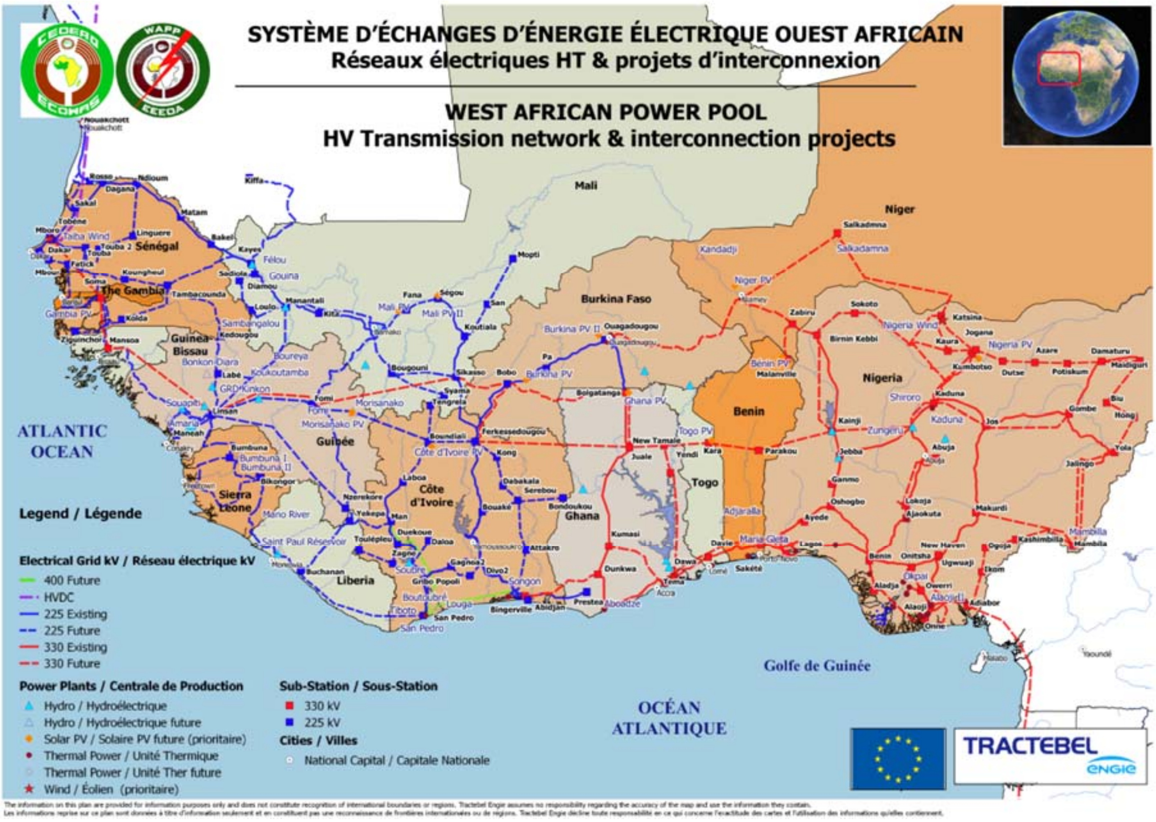
Although renewables account for 39% of the installed capacity, their annual operating capacity factors are low because renewables vary according to climatic conditions. Therefore, in terms of annual energy production, in 2033, thermal power generation is about 65%, hydropower about 17% and renewables about 18%. It is estimated that the generation costs will be less than USD 60/MWh after 2024, and that the introduction of renewables will contribute to reducing the high costs of fossil fuels.

The projected WAPP power system in 2040 is shown in Fig. 2.2-8. The 400kW power system is planned in Côte d'Ivoire.



Source :WAPP/MP 2018 - 2033

Fig. 2.2-7 Annual Power Generation (TWh) and Generation Cost (USD/MWh)



Source :WAPP/MP 2018 - 2033

Fig. 2.2-8 WAPP Power System in 2040

3) Selection of Priority Projects

As a result of these power generation and power system development plans, WAPP MP selected 75 priority projects and estimated the investment cost to be US$36.39 billion. Of these, 28 projects are in the field of transmission and represent a total length of 22,932 km and a total cost of US$10.48 billion. The remaining 47 projects are in the field of electricity generation, and represent a total production of 15.49 GW and a total cost of 25.91 billion USD.

The priority projects in Côte d'Ivoire are shown in Table 2.2-10 and Table 2.2-11.

Table 2.2-10 Priority Projects for Transmission Lines

Project	Voltage (kV)	Length (km)	Cost (MUSD)	Commissioning
Laboa-Boundiali-Ferkéssedougou	225	310	115	2019
Interconnection CLSG (Interconnection Côte d'ivoire-Liberia- Sierra Leone-Guinea)	225	1,303	517	2020
Second circuit of the CLSG interconnection to be commissioned in the same time as the first circuit	225	1,303	131	2020
Line Buchanan (Liberia)-San Pédro (Côte d'Ivoire)	225	520	129	2028
Strengthening interconnection Côte d'ivoire-Ghana	330	387	156	2029
Line Boundiali (Côte d'Ivoire)- Tenrgela (Côte d'Ivoire)-Syam a (Mali) - Bougouni (Mali)	225	339	96	2029
Line Fomi (Guinea)-Boundiali (Côte d'ivoire)	225	380	96	2025 Recommended
Median Backbone (Nigeria-Benin- Togo-Ghana-Côte d'Ivoire)	330	1,350	813	2025 Recommended
Link Bobo (Burkina Faso)-Ferké (Côte d'Ivoire) to connect the W estern Backbone to the Median	330	213	126	2033 Recommended

Source :Prepared by JICA Study Team based on WAPP/MP

Table 2.2-11 Priority Projects for Power Generation

Project	Installed Capacity (MW)	Cost (MUSD)	Commissioning
Gribo-Popoli Hydropower plant	112	345	2021
Azito IV Thermal Power Plant CC	253	302	2020
Ciprel V Thermal Power Plant CC	412	505	2021
Boutoubre Hydropower plant	150	343	2022 Recommended
Louga Hydropower plant	246	647	2023
Tiboto Hydropower plant	225	599	2028
San Pédro Thermal (coal) Power Plant	700	1,900	2026-2029
Solar Farm PV	150	143	2022-2024 Recommended
Songon Thermal power plant	369	480	2031 Recommended

Source :Prepared by JICA Study Team based on WAPP/MP

(3) Rural Electrification Master Plan (PDER)

The electrification of non-electrified areas, such as small villages and localities, is one of the major objectives of the NDP, with the aim of improving local life, ensuring economic development by providing the means to increase the income of local residents, adding value and creating a regional value chain.

Rural electrification is promoted by the National Rural Electrification Programme (PRONER) and the Rural Electrification Master Plan (PDER).

The objectives for the whole of country and the concrete measures to achieve them through electrification of non-electrified areas are specified in PDER. The objectives for electrification are established on the basis of demand forecasting and the following priorities:

i. Aim to achieve a minimum penetration rate of 30% in all regions in order to balance the regions.

ii. Aiming to electrify in the short term all administrative centres in sub-departments and localities with more than 500 inhabitants in 1998.

iii. Aim to electrify the entire territory of Côte d'Ivoire.

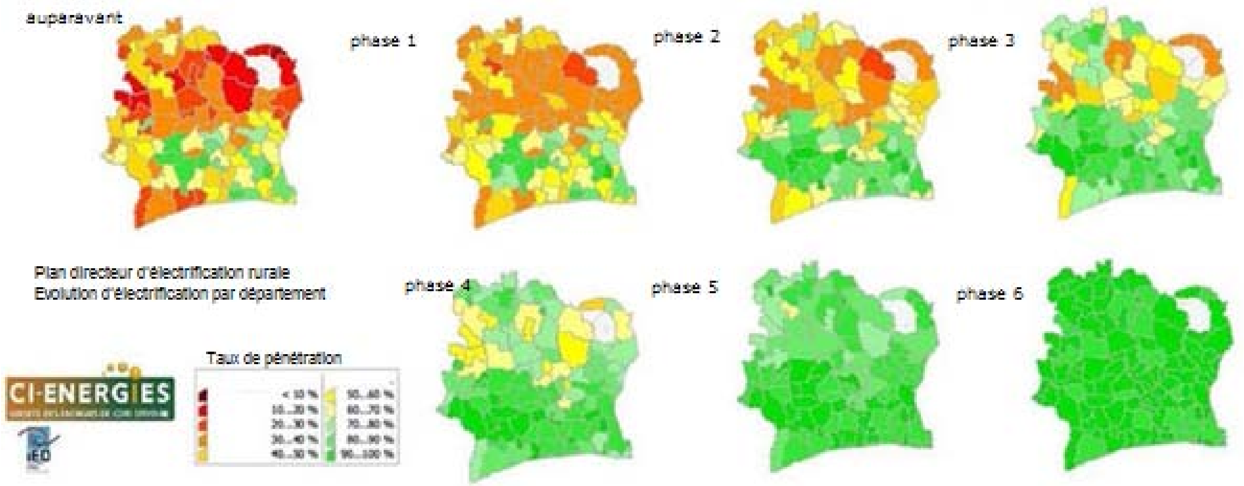
After analysing the socio-economic impact of rural electrification and the problem of voltage drops, taking into account the views of the population covered and the basis for economic development, the priority for additional investment in the regions is determined in order to improve i) those regions meeting demand by strengthening the electricity network, (ii) areas requiring additional measures at the operating level, (iii) voltage planning (temporary solution by renewable energy at the end of the grid and autotransformer, and construction of distribution substations at all 4 sites for additional supply in the future). In addition, following a techno-economic evaluation standard for selecting low-cost supply solutions, the connection of distribution lines in the target area is classified into six phases.

Table 2.2-12 shows the number of areas electrified and the population per phase, and Fig. 2.2-9 shows the evolution of electrification at the regional level.

Table 2.2-12 Number of Electrified Areas and Population per Phase

<table>
<tr><th>Phase</th><th>Nb de localités électrifiées</th><th>Population additionnelle couverte</th><th>Scénario volontariste</th><th>Scénario 2015-2020</th><th>Scénario 2015-2025</th><th>Scénario 2015-2030</th></tr>
<tr><td>Phase 1</td><td>495</td><td>1.836.566</td><td>2015</td><td>2015</td><td>2015-16</td><td>2015-17</td></tr>
<tr><td>Phase 2</td><td>727</td><td>1.620.337</td><td>2015</td><td>2016</td><td>2017-18</td><td>2018-20</td></tr>
<tr><td>Phase 3-1</td><td>628</td><td>620.086</td><td>2015</td><td>2017</td><td>2019-20</td><td>2021-23</td></tr>
<tr><td>Phase 3-2</td><td>359</td><td>252.653</td><td></td><td>2017</td><td></td><td></td></tr>
<tr><td>Phase 4</td><td>985</td><td>180.705</td><td rowspan="3">623 localités par an (2016-20)</td><td rowspan="3">836 localités par an (2018-20)</td><td rowspan="3">623 localités par an (2021-25)</td><td rowspan="3">445 localités par an (2024-30)</td></tr>
<tr><td>Phase 5</td><td>992</td><td>324.560</td></tr>
<tr><td>Phase 6</td><td>782</td><td>297.609</td></tr>
</table>

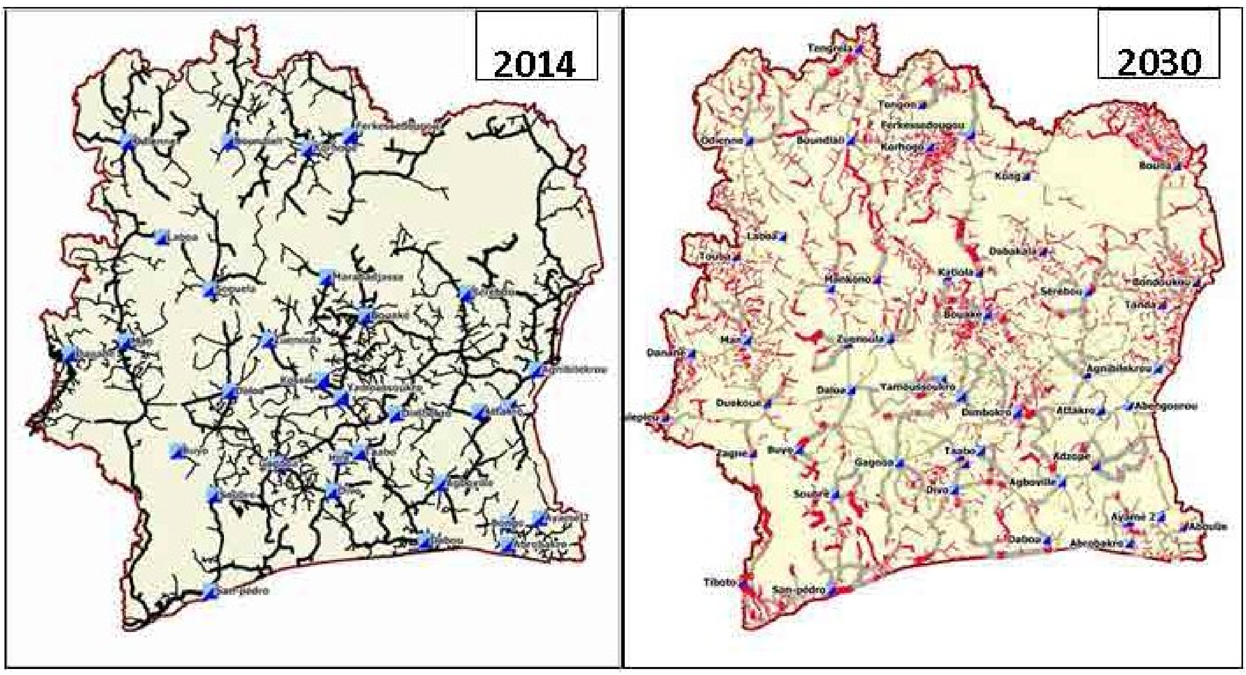
Source：Etude de collecte des données relatives au secteur de l'énergie électrique de la JICA



Source：Etude de collecte des données relatives au secteur de l'énergie électrique de la JICA

Fig. 2.2-9 Development of the Rural Electrification until 2030

The electrification strategy is based on the fact that most local government offices and villages of more than 500 people are located less than 20 km from the existing 33 kV distribution network. Based on the distance from the distribution substation and the mapping study of the network, the replacement of the existing 33 kV distribution line and the creation of networks are planned. Fig. 2.2-10 shows the extension of the 33 kV distribution network.



Source：Plan directeur d'électrification rurale 2013-2030

Fig. 2.2-10 Extension of the 33kV Power System from 2014 to 2030

These measures will make it possible to extend the 33 kV distribution network from around 20,500 km in 2014 to around 40,000 km in 2030. Rural electrification is an important objective of the NDP, but to achieve it, funds will be needed to purchase the conductors, equipment and materials needed to build about 19,500 km of lines, and to develop industries so that some of the equipment and materials are available on the national market.

2.3 POWER DEMAND AND SUPPLY

2.3.1 Demand forecast

Demand forecasts for Côte d'Ivoire have been implemented during the MP 2015 and the WAPP/MP of December 2018 creation work, and reported respectively.

In the demand forecast for MP2015, a regression equation was calculated from the correlation between past electricity demand results, GDP and total population. Then, based on that equation, calculate the power demand from the forecast of future GDP and total population and add the influence of new power connection to non-electrified rural areas, supply plan to mines and factories and energy efficiency improvement. In addition, as shown in Table 2.3-1, three types of power demand scenarios, “high”, “medium” and “low” are being considered in consideration of the differences in future forecast growth rates.

Table 2.3-1 Assumptions for the 2014 electricity demand scenario

	"Medium" scenario	"High" scenario	"Low" scenario
Population	+ 2.2% annually until 2023 + 2.1% annually after 2023	+ 3.0% annually until 2023 + 2.8% annually after 2023	+ 1.7% annually until 2023 + 1.6% annually after 2023
GDP	+ 8% /year from 2014 to 2015 + 5% /year after 2016	+ 10% /year from 2014 to 2015 + 8% /year from 2016 to 2018 + 6% /year after 2019	+ 7% /year from 2014 to 2015 + 3.5% /year after 2016
Mine	25 MW power supply per year	25 MW power supply per year	10 MW power supply per year
Energy Efficiency	Lighting equipment with low power consumption (50-100MW) Street light (0.5-1.5 MW)	Lighting equipment with low power consumption (50-100MW) Street light (0.5-1.5 MW)	Lighting equipment with low power consumption (50-100MW) Street light (0.5-1.5 MW) Public building (4MW)

Source: JICA Information Collection / Confirmation Survey P.5-2 Table 5.2 edited by JICA Survey Team

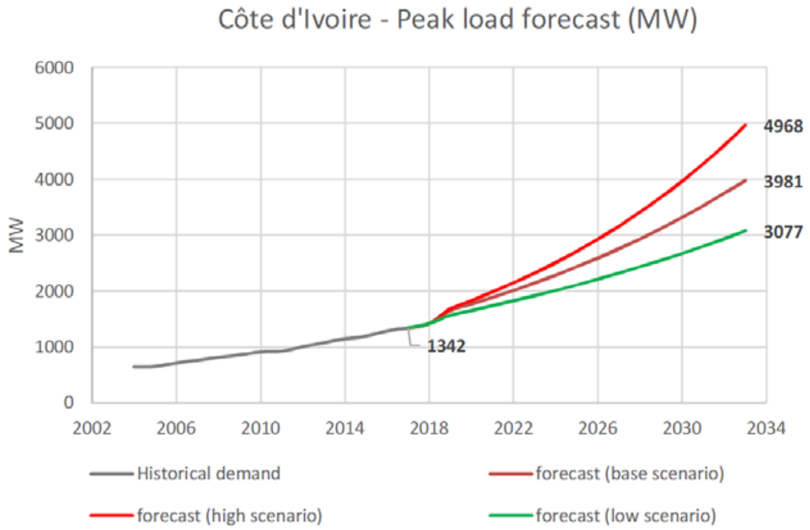
On the other hand, the demand forecast for WAPP / MP in 2018 calculates the power demand from the regression equation based on GDP and total population as in MP2015, but the new power connection to non-electrified rural areas, supply plans to mines and factories and impacts of energy efficiency that were implemented in MP2015 are not considered. The reason for this is that WAPP / MP is aimed at power operation in grid interconnection between member countries and it is probable that it was necessary to make some agreement between countries regarding the demand estimation method. Furthermore, unlike MP2015, the power demand dealt with here is also the generated power including the power loss due to the power system, and it is considered that this is also consistent with each country. Table 2.3-2 shows the analysis results.

Table 2.3-2 Analysis result by regression method in WAPP

	Coefficients	Standard deviation	t Stat	P-value
constant	-3672724.84	229072.52	-16.03	1.22 e-15
Population	203712.42	27943.55	7.29	6.16 e-08
PIB	409.24	46.17	8.86	1.29 E-09
R^2	0.98			

Source : WAPP : Update of the ECOWAS revised master plan for the development of power generation and transmission of electrical energy, December 2018

According to Table 2.3-2, the coefficient of determination R2 in the regression equation is 0.98, which shows that a very high correlation is obtained. The future forecast values of GDP have a range (125%, 100%, 75%) and demand forecast scenarios of "high", "medium" and "low" are considered respectively. The demand forecast for each scenario is shown in Fig. 2.3-1.



Source：WAPP：Update of the ECOWAS revised master plan for the development of power generation and transmission of electrical energy, December 2018

Fig. 2.3-1 Peak demand forecast at WAPP

Based on the results of these master plans, the JICA study team confirmed the demand forecast with CI-ENERGIES in the first survey, and as a result, five years have already passed since the last MP2015. So in Cote d'Ivoire, currently, they are working on reviewing the demand forecast, and in 2021 they plan to hire a consultant to start the MP revision. Similar to MP2015, this review of demand assumptions calculates electricity demand from future GDP and total population forecasts based on regression equations obtained from past electricity demand, GDP and total population. Then, the impact of new power connections to non-electrified rural areas, supply plans for mines and factories and energy efficiency will be calculated in addition to this. In MP2020, the demand forecast up to 2040, which is longer than MP2015, is planned and the development plan for electric power facilities also needs to correspond to the demand forecast up to 2040. The data related to the demand forecast obtained from CI-ENERGIES will be explained below.

Table 2.3-3 shows the actual power demand since MP2015.

Table 2.3-3 Recent electricity demand in Côte d'Ivoire

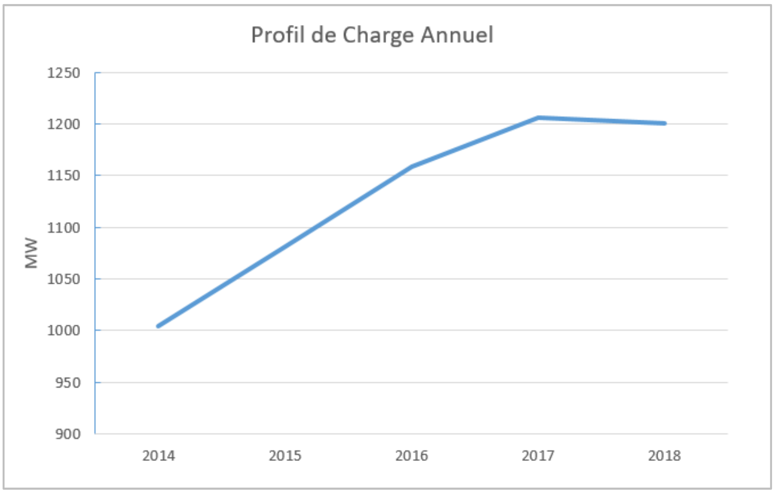
Ref. Unités	Monotône de Charge (MW)	Pointe Nationale (MW)	Totale des Exportations (RI) (GWh)	Puissance Maximale Exportée (MW)
2014	1005	1148	903	69
2015	1082	1193	873	63
2016	1159	1288	1655	57
2017	1206	1341	1247	62
2018	1201	1388	1156	-19

Source: CI-ENERGIES

From the left of each year's item, the maximum power supply, maximum power generation, annual export power, and maximum export power are shown. The maximum power supply and the maximum generated power are both values for the domestic market of Côte d'Ivoire (excluding exports), and the difference between the two is the power loss, and the ratio of this power loss to the generated power is expressed as the loss rate. The loss rate between 2014 and 2018 has changed between 9.3% and 13.5%, and the loss rate can be considered to be about 10%. In general, the demand power indicates the power supply obtained by subtracting the power loss from the generated power, and Fig. 2.3-2 shows a graph of the transition of the maximum value of the power supply (demand power). In addition, details by year are shown in Attachment 3.

From Fig. 2.3-2, the demand for electricity, which grew steadily from 2014 to 2016, slowed down a little in 2017 and fell below the previous year in 2018, showing a tendency for growth to be slightly restrained.

Based on these past records, the demand forecast prepared by CI-ENERGIES is shown in Table 2.3-4.



Source: CI-ENERGIES

Fig. 2.3-2 Peak demand results in recent years

Table 2.3-4 Demand Forecast by CI-ENERGIES (2020-2040)

		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Production brute nationale (MW)	a	1774	1960	2147	2455	2640	2988	3519	3777	3896	4035	4222
Exportation (MW)	b	229	292	387	437	512	587	707	732	732	747	747
Pointe nationale (MW)	c = (a-b)	1545	1668	1760	2018	2128	2401	2812	3045	3164	3288	3475
Pertes (%)	d	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Charge totale Postes (MW)	e = c x (1-d)	1391	1501	1584	1816	1915	2161	2531	2741	2848	2959	3128

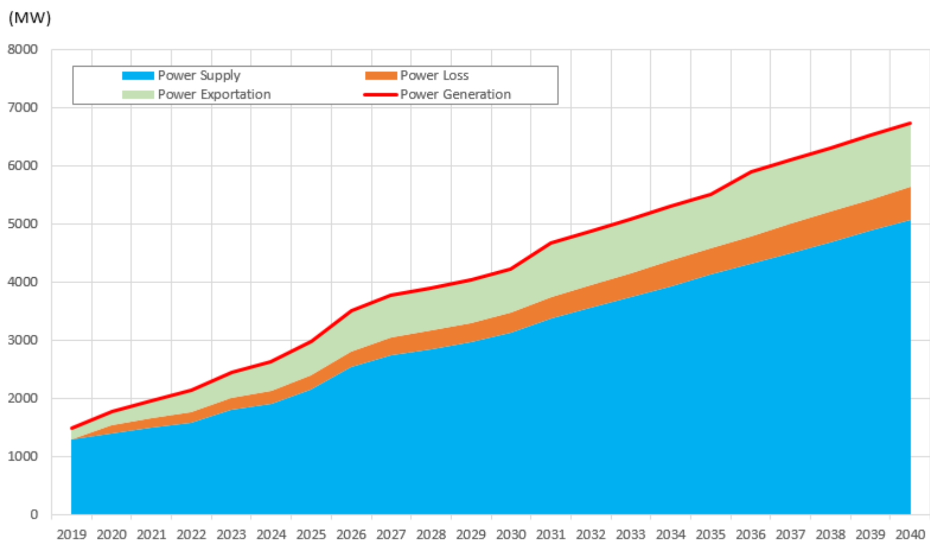
		2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production brute nationale (MW)	a	4222	4663	4873	5083	5293	5502	5887	6097	6307	6517	6726
Exportation (MW)	b	747	922	922	922	922	922	1097	1097	1097	1097	1097
Pointe nationale (MW)	c = (a-b)	3475	3741	3951	4161	4371	4580	4790	5000	5210	5420	5629
Pertes (%)	d	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Charge totale Postes (MW)	e = c x (1-d)	3128	3367	3556	3745	3933	4122	4311	4500	4689	4878	5067

Source: CI-ENERGIES

From the top of the items on the left side of the table, the total generated power, the exported power, the generated power for domestic use, the loss rate and the supplied power are shown. The loss rate remains constant at 10% until 2040, which is considered to reflect the actual loss rate mentioned above. A graph of this table is shown in Fig. 2.3-3.

The feature of this demand forecast is that it considers stable demand growth over the long term as in the past and specifically incorporates the increase in demand caused by the national mining project that supports national economic development. Furthermore, in order to achieve harmony and integration in strengthening exports to West African countries, it also considers strengthening exports to Mali and Burkina Faso by strengthening the northern corridor.

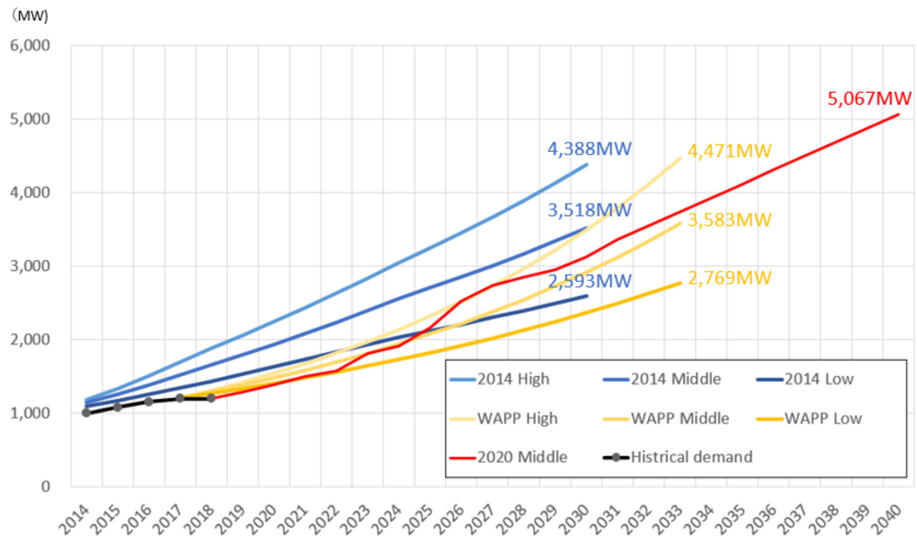
From Fig. 2.3-3, it can be seen that the total power generation, export power, power loss and power supply are increasing concretely as the project progresses.



Source: CI-ENERGIES materials edited by JICA research team

Fig. 2.3-3 Breakdown of demand forecast

Next, the current demand forecast and the past demand forecasts and actual results will be summarized in one graph for comparison and evaluation. Since the demand forecast in WAPP / MP is considered to correspond to the generated power, the one recalculated in consideration of the power loss is used. (Loss rate 10% was applied according to this forecast) The results are shown in Fig. 2.3-4.



Source: CI-ENERGIES, WAPP materials edited by JICA study team

Fig. 2.3-4 Comparison with the demand forecast by the past master plan

From Fig. 2.3-4, it can be seen the current demand forecast has remained low until 2023, but it has increased significantly due to the subsequent increase in demand due to mining projects, and will shift to a stable increasing trend again from the first half of the 2030s. The actual demand in recent years is lower than the forecast of MP2015, so the demand at the starting point assumed this time is low. Except for the sharp increase in demand in the medium term due to the mining project, the growth of general demand is lower than the middle case of MP2015 and close to the slope of the low case from the slope of the graph, which is almost the same as the low case of WAPP / MP. Considering that the actual demand is lower than the past forecast, the growth rate of the current demand forecast which is close to the past low case is considered to be appropriate. As a result, electricity demand will more than 4 times from the current level in about 20 years until 2040, and will increase to 5,067 MW by 2040. Although it is different in the final year, this value is higher than the high case of the value of the final year of the demand assumption in the past master plan.

Next, Table 2.3-45 shows specific plans for electricity exports.

Table 2.3-5 Electricity export plan (2019-2040)

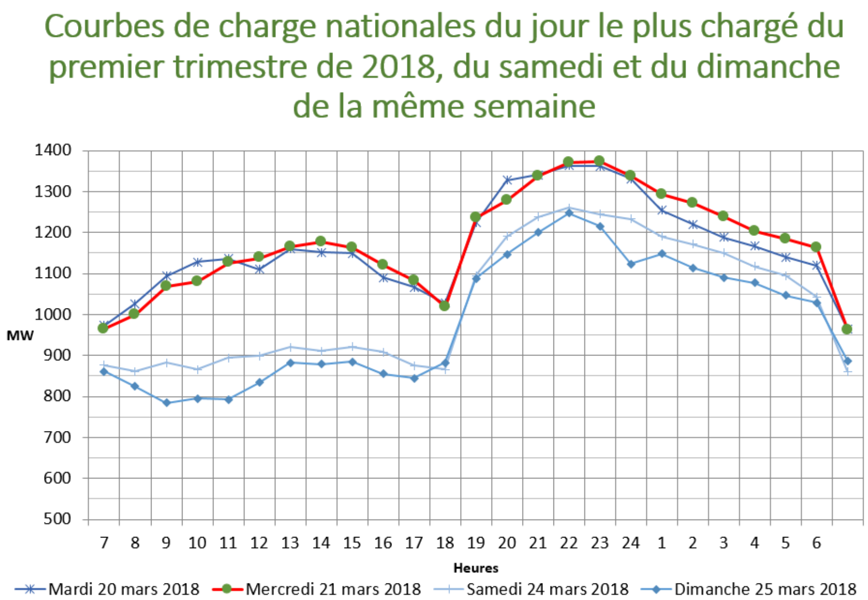
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Puissance (MW)	**229**	**292**	**387**	**437**	**512**	**587**	**707**	**732**	**732**	**747**	**747**	**922**	**922**	**922**	**922**	**922**	**1097**	**1097**	**1097**	**1097**	**1097**
VRA (Ghana)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEB (Benin)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SONABEL (Burkina)	100	110	110	110	160	210	270	270	270	270	270	370	370	370	370	370	470	470	470	470	470
EDM (Mali)	100	100	100	150	150	175	200	225	225	225	225	300	300	300	300	300	375	375	375	375	375
LEC (Libéria)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
CLSG	27	80	175	175	200	200	235	235	235	250	250	250	250	250	250	250	250	250	250	250	250

Source: CI-ENERGIES

Table 2.3-45 shows the electricity export plans for each country and project from 2019 to 2040. Electricity exports of 1,000 MW or more are planned to be stable up to 2040. A characteristic point is that electricity exports to Burkina Faso and Mali, which are located north of Côte d'Ivoire, account for more than 800 MW, accounting for 80% of the total, and when examining the domestic power system, it is necessary to give due consideration to the transmission of these power exports.

Fig. 2.3-5 shows the 2018 daily load curve obtained from CI-ENERGIES. The daily load curve before 2017 is shown in Attachment 6.

Fig. 2.3-5 shows the latest 2018 data obtained from the 2016, 2017, and 2018 data, but the trend of the daily load curve is the same for all three years. In general, the daily load curve of developing countries often has a peak at night due to the demand for the light demand rather than the industrial demand during the day, and the daily load curve in Côte d'Ivoire also has a late peak time from 22:00 to 23:00 at night. Although peak of demand occurs late night, it shows the trend of developing countries. In addition, judging from this daily load curve, it is considered that solar power generation in the power development of Côte d'Ivoire will not be a facility for peak demand measures unless a power storage system is also used.



Source: CI-ENERGIES

Fig. 2.3-5 Daily load curve in Côte d'Ivoire (2018)

2.3.2 Electric Power Development Plan

(1) Existing Plants

At the end of 2017, Côte d'Ivoire had power plants with a capacity of 2,199 MW, producing 9,941 GWh per year, of which 1,191 GWh is exported. National electricity consumption is 8,716 GWh and the quantity sold is 6,603 GWh. Peak electricity production is 1,342 MW.

With regard to the production of hydroelectric power, the Ayamé No. 2 power station on the Bia River was commissioned in 1965, followed by the Ayamé No. 1 power station in 1959. On the Bandama River, the Kossou power station was commissioned in 1972 and the Taabo power station in 1979. On the Sassandra River, the Buyo Power Station was commissioned in 1980 and on the Grah River, the Faye Power Station in 1984. The 275 MW Soubré power station on the Sassandra River was commissioned in 2017, and its installed capacity increased to 879 MW by the end of 2017.

As regards to thermal power generation, since the commissioning of the Vridi power station in 1984, a new thermal power station has been installed instead of the hydroelectric power station, which requires a longer construction period, in order to meet the increase in demand resulting from the economic recovery following the devaluation of the FCFA after 1994. As a result, IPPs of the Vridi2 plant of CIPREL, the Azito plant of AZITOENERGIE, and the Aggreko plant of AGGREKO are in operation. The installed capacity of the thermal power plants at the end of 2017 is 1,320 MW.

Table 2.3-6 List of Existing Power Plants

Centrale hydroélectrique	Capacité installée (MW)	Mise en service (année)	Centrale thermique	Capacité installée (MW)	Mise en service (année)
Ayame 1	20	1959	Vridi1 (TG1-4)	100	1984
Ayame 2	30	1965	CIPREL2 (TG5-8)	220	1995/1997
Buyo	165	1980	CIPREL2 (TG9)	115	1997
Kossou	174	1972	CIPREL2 (TG10)	115	2013
Tabbo	210	1979	CIPREL2 (TAV)	119	2015
Faye	5	1987	Azito (TG1, 2)	296	1999/2000
Soubré	275	2017	Azito (TAV)	145	2015
			Aggreko (TG1-5)	210	2010/2013
Hydroélectricité totale	879		Energie thermique totale	1 320	
Total				2 199	

Source：CI-ENERGIES

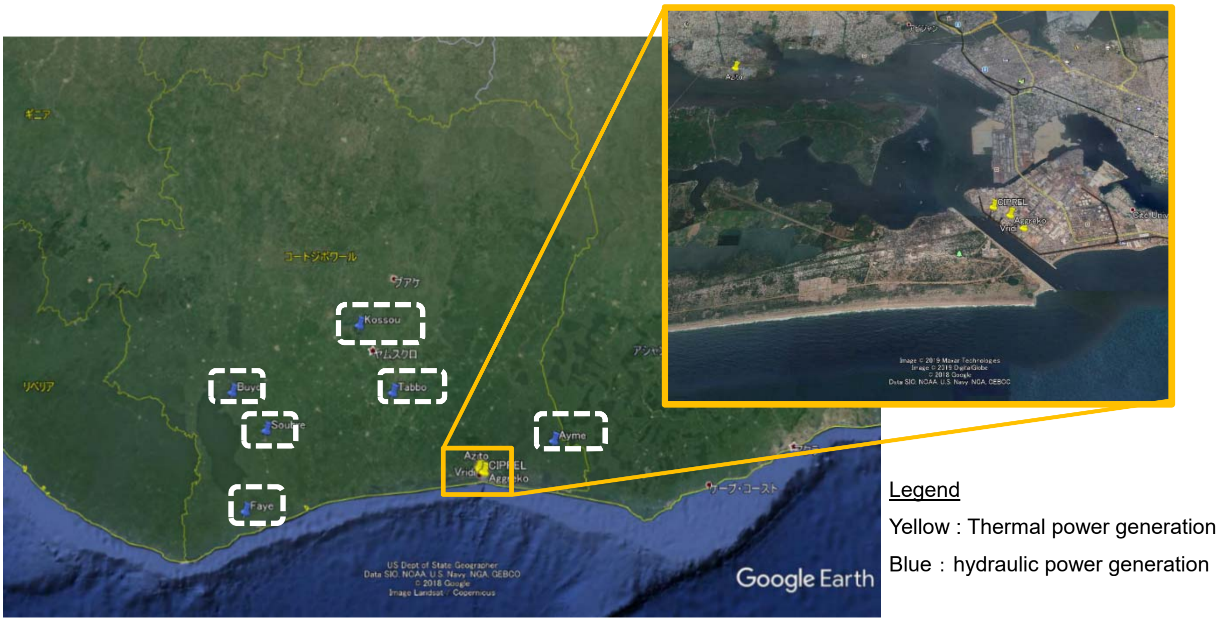


Fig. 2.3-6　Location of Existing Power Plants

Following the commissioning of the Soubré power station, the electric power generation ratio is made up of 40% hydroelectric units and 60% thermal units. Côte d'Ivoire has established a balanced strategy between hydropower (varying according to the quantity of water) and thermal energy (affected by the price of fuel) drawing the lessons from the economic crisis of the early 1980s, the deadlock in the "conversion to hydropower" policy following the 1983 drought, and the major cuts in transmission. It is recommended that the dependence on a specific energy source be reduced to less than 60%.

(2) Power Development Plan

Table 2.3-7 to Table 2.3-11 show the power development plan from 2018 to 2030 provided by CI-ENERGIES. Details of the power generation expansion plans per plant and per year are attached in Appendix 5.

Table 2.3-7　List of electric power development plans （Hydropower）

Name of plant	Planned commissioning	Output (MW)	Name of plant	Planned commissioning	Output (MW)
Singrobo G1	2022	22	Ferké	2026	8
Singrobo G2	2022	22	Haut Bandaman	2028	12
Gribopopoli G1	2021	37	Man	2028	3
Gribopopoli G2	2021	37	Marabadiassa	2028	15
Gribopopoli G3	2021	37	Zégbéry	2026	13
Boutoubre	2024	150	Mankono	2026	8
Louga 1	2025	126	Téhini	2030	4
Louga 2	2027	128	Aboisso	2030	6

Source ： CI-ENERGIES

Table 2.3-8 List of electric power development plans （Thermal）

Name of plant	Planned commissioning	Output (MW)	Name of plant	Planned commissioning	Output (MW)
AZITO IV TAG	2020	179	Gas to Power TAG	2023	120
AZITO IV TAV	2021	74	Songon TAG 2	2024	123
Ciprel V - 1er Tranche TAG	2021	255	Gas to Power TAV	2024	60
Ciprel V - 2eme Tranche TAV	2022	135	Songon TAG 3	2025	123
Songon TAG 1	2023	123			

Source：CI-ENERGIES

Table 2.3-9 List of electric power development plans （Biomass）

Name of plant	Planned commissioning	Output (MW)	Name of plant	Planned commissioning	Output (MW)
BIOKALA 1.1	2022	23	Biomasse Cacao	2030	20
BIOKALA 1.2	2022	23	Yakro 1.1	2030	40
Biomasse 1	2030	10	Yakro 1.2	2030	40
Biomasse 2	2030	10	Boundiali	2030	25
Biomasse 3	2030	20	Abidjan 1.2	2030	50
Biomasse Coton	2030	25	San-Pédro 1.1	2030	25

Source：CI-ENERGIES

Table 2.3-10 List of electric power development plans （Solar）

Name of plant	Planned commissioning	Output (MW)	Name of plant	Planned commissioning	Output (MW)
KORHOGO SOLAIRE (RECA)	2021	20	Centrale solaire 1	2023	25
PORO POWER (GALILEA)	2021	50	Centrale solaire 2	2024	50
Centrale solaire FERKE (BIOTHERM)	2022	20	Centrale solaire 3	2025	50
Centrale solaire BOUNDIALI (CI-ENERGIES)	2020	30	Centrale solaire 4	2026	50
Scaling Solar	2021	60	Centrale solaire 5	2027	undecided
Odiénné Solaire (AVAADA)	2022	20	Centrale solaire 6	2028	100

Source：CI-ENERGIES

Table 2.3-11 List of electric power development plans （Coal）

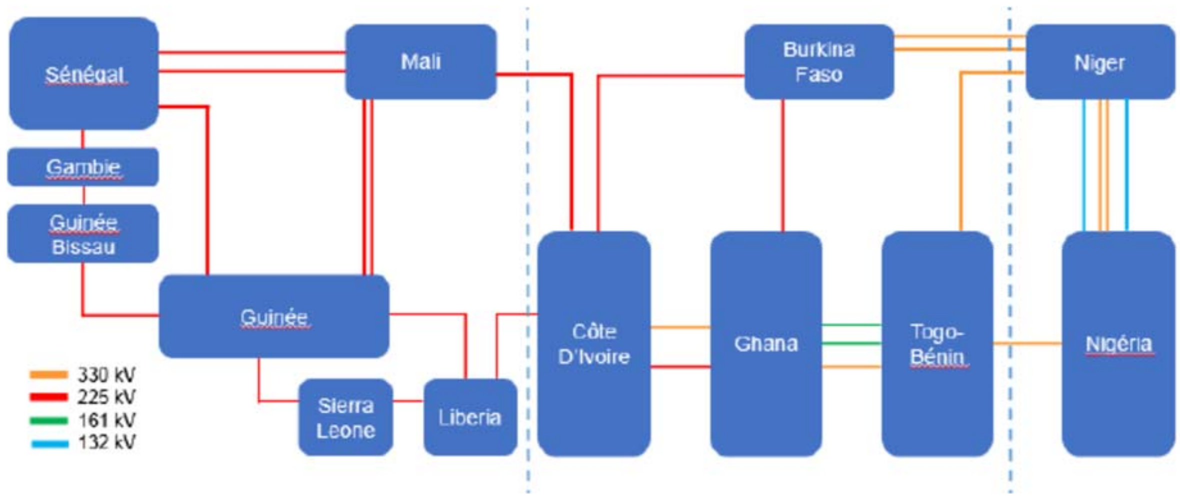
Name of plant	Planned commissioning	Output (MW)	Name of plant	Planned commissioning	Output (MW)
Centrale à charbon-Tranche TAC1	2026	350	Centrale à charbon-Tranche TAC2	2030	350

Source：CI-ENERGIES

2.3.3 Electricity Exchange Plan by International Connection under the EEAEOA

15 years ago, the electricity grid of the 14 member countries of the West African Electric Electricity Exchange System (EEAEOA) was made up of independent power system in each country, but over the past 10 years many international interconnection contracts have been concluded and continue to be considered. In 2015, the EEAEOA Zone A groups (Ivory Coast, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria) and Zone B (Mali, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia) were connected by a 225 kV transmission line between Ferké in Côte d'Ivoire and Sikasso in Mali. The contract between the CLSG system (Ivory Coast - Liberia - Sierra Leone - Guinea) and the OMVG loop (The Gambia River Development Organization), which will be concluded within three years, will be dominant in allowing the exchange of electricity between 14 countries. This improvement in line interconnection will expand the possibilities for energy exchange (Refer Fig. 2.3-7).

Exports to Burkina Faso, Côte d'Ivoire's main export partner, have been on the rise since 2009. In addition, demand from Mali has begun to increase since 2011. In 2017, electricity exports to both countries amounted to 340 GWh/year for Mali and 583.1 GWh/year for Burkina Faso. In this project, the future situation of the energy flow associated with the export of electricity is taken into account.



Source：EEEOA/PD

Fig. 2.3-7 Outline of power system Interconnection in EEAEOA

2.4 CURRENT CONDITION OF TRANSMISSION FACILITIES AND DEVELOPMENT PLAN

2.4.1 Current Condition of Transmission Facilities

1) Existing facilities

Most of the existing power transmission system above 90 kV in Côte d'Ivoire is overhead transmission lines, with only about 1% underground transmission. The latest power transmission system of Cote d'Ivoire is shown in Fig. 2.4-1, and Table 2.4-1 shows the trend in the number and length of power system.

The voltage level of transmission line in Cote d'Ivoire is 225 kV and 90 kV, but 330 kV and 400 kV international transmission lines are planned. As of January 2019, the construction of 400kV international transmission line has started in Benin. The 400 kV transmission line interconnects the gas power plants in Senegal and hydroelectric power in Guinea.

The 225kV transmission line is backbone of the power transmission of Côte d'Ivoire, connecting the coastal Abidjan region to the capital Yamoussoukro and major cities in the north, and also acts as an international interconnection line to Mali and Burkina Faso to the north of Côte d'Ivoire.

In December 2018, two new transmission lines were built between Laboa substation and Boundiali substation and between Boundiali substation and Ferké substation. As a result, the country's 225 kV transmission lines can be operated as the loop system, from the conventional system as radial system (south-to-north) from Taabo and Kossou substations (near Yamoussoukro) to the Ferké substation.

The number of 225kV substations is 18 and 90 kV substations is 32. The total transformer capacity is 5,396 MVA at the end of 2018. The trends in the number of substations and transformer capacity are shown in Table 2.1-2 and the list of existing 225 kV substations is shown in Table 2.1-3.

As for 225 kV substations, the Bingerville substation was put into operation in January 2018, the Boundiali substation was upgraded from 90 kV to 225kV in December 2018, and the transformer capacity has been steadily increasing. On the other hand, in terms of reliability, 6 substations (33%) out of 18 substations of 225kV have only one transformer (225/90 kV) installed, and one of the issues is N-1 reliability.

Source：CI-ENERGIES

Fig. 2.4-1　　Power System of Cote d'Ivoire (2019 September)

Table 2.4-1 Number and Length of Transmission Line

Item		Voltage (kV)	Unit	2014	2015	2016	2017	2018
Overhead Transmission line	Number	225	Number	18	19	23	23	25
		90	Number	52	52	54	54	53
		Total	Number	70	71	77	77	78
	Length	225	km	2,088	2,088	2,469	2,469	2,790
		90	km	2,613	2,613	2,624	2,624	2,830
		Total	km	4,701	4,701	5,093	5,093	5,620
Underground cable	Number	90	Number	9	9	10	10	10
	Length		km	32	32	40	40	40

Source：CI-ENERGIES

Table 2.4-2 Number of Substation and Capacity of Transformer

Item	Voltage (kV)	Unit	2014	2015	2016	2017	2018
Number of Substation	225	Number of Substation	14	14	15	15	18
	90		32	32	33	33	32
	total		46	46	48	48	50
Capacity of Transformer	more than 90kV	MVA	4,361	4,823	5,669	5,074	5,396

Source：CI-ENERGIES

Table 2.4-3 List of existing substation and switchyard

NO.	Name of Substation	Area	Capacity of Transformer			
			Interconnection	Distribution		
			225/90	225/30	225/20	225/15
1	Abobo	Abidjan	70MVA× 4 Units			
2	Azito	Abidjan				50MVA× 3 Units
3	Bingerville	Abidjan			50MVA× 4 Units	
4	Bouake 2	Center	65MVA× 1 Unit			
5	Boundiali	Abidjan				
6	Buyo	Western	70MVA× 1 Unit			
7	Djibi	Abidjan				50MVA× 3 Units
8	Ferke	North	65MVA× 1 Unit			
9	Kossou	Center	65MVA× 1 Unit			
10	Laboa	Western	70MVA× 1 Unit			
11	Man	Western	70MVA× 1 Unit			
12	PK24	Abidjan		60MVA× 2 Units		
13	Riviera	Abidjan	100MVA× 2 Units			
14	San Pedro	Western				
15	Soubre	Western	70MVA× 2 Units			
16	Taabo	Center	70MVA× 2 Units			
17	Vridi	Abidjan	70MVA× 3 Units			
18	Yopougon2	Abidjan				

Source：CI-ENERGIES

2) Power flow of the existing transmission line

Table 2.4-4 shows the power flow of 225 kV transmission line in Côte d'Ivoire. 9 lines of the 25 lines (36%) of 225 kV capacity are concentrated in the Abidjan region, where there is a geographic concentration of electricity power consumption and generation facilities (mainly thermal).

The transmission lines from Taabo substation to Kossou substation (Line No. 14) and from Kossou substation to Bouaké2 substation (Line No. 6), which are the subjects of this project, are highlighted in yellow. Both lines are operating at a higher utilization rate than the other 225 kV transmission lines in Côte d'Ivoire, relative to their transmission capacity, resulting in a shortage of transmission capacity (discussed in detail later in Chapter 3).

As for the international transmission lines, there is no problem in the utilization rate of the transmission lines as they are interconnected with Sikasso substation in Mali (line No. 13), Kodeni substation in Burkina Faso (line No. 12), and Prestea substation in Ghana (line No. 5).

Table 2.4-4 Power Flow of existing 225kV transmission line (2019 April)

No.	Name of Transmission line	Area	From (1)	To (2)	Active Power (1) [MW]	Active Power (2) [MW]	Utilization rate [%]
1	ABO_AZI 225kV 1	Réseau_Abidjan	Abobo-2 225	Azito-2 225	-161.92	162.42	49.02
	ABO_AZI 225kV 2	Réseau_Abidjan	Abobo-2 225	Azito-2 225	-161.92	162.42	49.02
2	AZI-YOP2 225KV	Réseau_Abidjan	Azito-2 225	Yopougon2-2 225	178.69	-178.08	53.81
3	AZI_VRI 225kV	Réseau_Abidjan	Azito-1 225	Vridi-2 225	-94.37	94.50	30.24
4	BING- RIVI 225KV	Réseau_Abidjan	Bingerville-1 225	Riviera-2 225	-30.20	30.23	9.77
5	BING-PRES 225KV	Réseau_intérieur	Bingerville-1 225	Prestea 225KV	30.20	-30.00	10.59
6	**BOUA_KOS 225kV**	**Réseau_intérieur**	**Kossou 225kV**	**Bouake 2 225kV**	**219.09**	**-212.67**	**68.43**
7	BOUN-FERK -225KV	Réseau_intérieur	Boundiali 225kV 2	Terminal(14)	64.65	-64.65	24.29
	BOUN-FERK -225KV_a	Réseau_intérieur	Terminal(11)	Ferke 225kV 2	63.63	-63.63	24.30
	BOUN-FERK -225KV_b	Réseau_intérieur	Terminal(14)	Terminal(11)	64.65	-63.63	24.29
8	BUY_SOU 225kV	Réseau_intérieur	Buyo 225kV-2	Soubre 225kV 1	-150.65	152.92	47.47
9	DJIB-ABO 225KV	Réseau_Abidjan	Djibi-2 225	Abobo-2 225	-3.31	3.31	3.73
10	DJIB-RIV 225KV	Réseau_Abidjan	Riviera-2 225	Djibi-1 225	51.72	-51.70	17.52
11	FER_BOUA 225kV	Réseau_intérieur	Bouake 2 225kV	Ferke 225kV 2	180.94	-171.01	58.17
12	FER_KOD	Réseau_intérieur	Kodéni	Terminal(12)	-100.00	100.00	33.37
	FER_KOD_a	Réseau_intérieur	Terminal(12)	Ferke 225kV 2	-100.00	103.51	37.34
13	FER_SIK 225kV	Réseau_intérieur	Sikasso 225kV	Terminal(13)	-80.00	80.00	26.59
	FER_SIK 225kV_a	Réseau_intérieur	Terminal	Ferke225kV-1	-82.49	82.49	28.70
	FER_SIK 225kV_b	Réseau_intérieur	Terminal(13)	Terminal	-80.00	82.49	31.21
14	**KOS_TAA 225kV**	**Réseau_intérieur**	**Taabo 225kV 1**	**Kossou 225kV**	**265.70**	**-249.34**	**108.90**
15	LABOA-BOUND 225KV	Réseau_intérieur	Boundiali 225kV 2	Terminal(15)	-99.72	99.72	34.92
	LABOA-BOUND 225KV_a	Réseau_intérieur	Terminal(15)	Terminal(16)	-99.72	102.47	36.96
	LABOA-BOUND 225KV_b	Réseau_intérieur	Terminal(16)	Laboa 225KV-2	-102.47	102.47	36.96
16	MAN-LABOA 225KV	Réseau_intérieur	Laboa 225KV-2	Man-2 225	-135.56	139.82	47.37
17	MAN_BUY 225kV	Réseau_intérieur	Man-1 225	Buyo 225kV 1	-185.31	194.81	62.87
18	PK24-ABO 225kV	Réseau_intérieur	PK24 225KV 2	Abobo-2 225	-87.44	87.73	35.43
19	RIV_VRI 225kV	Réseau_Abidjan	Vridi-1 225	Riviera-1 225	194.05	-193.28	58.34
20	SOU_SAN 225kV	Réseau_intérieur	Soubre 225kV 2	San Pedro 225kV	37.36	-37.17	11.74
21	SOU_TAA 1 225kV	Réseau_intérieur	Soubre 225kV 1	Taabo 225kV-2	27.90	-27.62	13.65
	SOU_TAA 2 225kV	Réseau_intérieur	Soubre 225kV 1	Taabo 225kV-2	27.45	-27.18	13.54
22	TAA_ABO 225kV 1	Réseau_intérieur	Taabo 225kV 1	Abobo-2 225	-74.35	75.45	22.90
23	TAA_PK24 225kV-1	Réseau_intérieur	Taabo 225kV 1	PK24 225KV 1	-67.91	69.22	28.36
24	TAA_YOP2 225kV	Réseau_intérieur	Taabo 225kV 1	Yopougon2-2 225	-76.67	77.78	23.57
25	YOP2_ABO 225kV	Réseau_Abidjan	Yopougon2-2 225	Abobo-2 225	-18.31	18.32	5.59

2.4.2 Development Plan

Development plans of major transmission and substation facilities (mainly new facilities) and upgrade plans of existing substations by CI-ENERGIES are shows in Table 2.4-5 to Table 2.4-7.

For the long-term plan up to 2040, demand forecasts by substation have been conducted, but specific specifications and funding sources for the long-term plans will be considered after the short- and medium-term plans in the future.

Table 2.4-5 Major Development Plan for power transmission system

Tr: Transmission Line, SS: Substation

N°	Name of Project	Components	Composition					Donor
			225kV Tr	225kV SS	90kV Tr	90kV SS	Other	
1	Poste 225/15 kV d'Anani	Création d'un poste 225/15 kV incluant 3 transformateurs 225/15 kV 50 MVA à Anani		#				BOAD
		Construction de la ligne 225 kV Anani-Bingerville (22 km)	#					
		Restructuration du réseau HTA Anani					#	
2	Poste 90/33/16,5 kV de Bassam 2	Création du poste 90 kV incluant 2 transformateurs 90/16,5 kV 50 MVA et un transformateur 90/33-15 kV 40 MVA				#		BOAD
		Enrée en coupure du poste sur la ligne 90 kV Riviera-Abrobakro (0,5 km)			#			
		Restructuration du réseau HTA Bassam					#	
3	Poste 90kV de Tanda	Extension et Réhabilitation du poste 90 kV d'Agnibilékro				#		EB. CHINE
		Création d'un poste 90/33 kV incluant 1 transformateur 90/33/15 kV 24 MVA à Tanda				#		
		Construction d'une ligne 90kV Tanda - Agnibilékrou (84km)			#			
		Construction d'une ligne 90kV Bondoukou- Tanda (52km)			#			
4	Poste 225 kV de Bondoukou	Création d'un poste 225 kV incluant 2 transformateurs 225/90 kV 70 MVA + 1 transformateur 90/33 kV 40 MVA+ 1 transformateur 90/15 kV 50 MVA + 1 transformateur 33/15 kV 10 MVA à Bondoukou		#		#		EB. CHINE
		Construction d'une ligne 225 kV Sérébou - Bondoukou (146km)	#					
		Installation d'un compensateur statique de puissance réactive SVC +/- 50 MVar en 90 kV à Bondoukou					#	
		Restructuration des réseaux HTA					#	
5	Poste 225 kV de Sérébou	Extension et Réhabilitation du poste 225 kV de Bouaké 2		#				EB. CHINE
		Création d'un poste 225 kV incluant 1 transformateur 225/33 kV 24 MVA + 1 transformateur 90/33 kV 24 MVA		#		#		
		Construction de la ligne 225 kV Bouaké2 - Sérébou (132 km)	#					
		Restructuration des réseaux HTA					#	
6	Poste 90/33 kV de Bouna	Création d'un poste 90 kV ncluant 1 transformateur 90/33/15 kV 24 MVA + 1 transformateur 90/15 kV 24 MVA à bouna				#		EB. CHINE
		Construction d'une ligne 90 kV Bouna - Bondoukou (172 km)			#			
		Restructuration de réseau HTA et extension					#	
7	Doublement de la file 225 kV Man-Duékoué-Buyo	Extension et Réhabilitation du poste 225 kV de Buyo		#				EB. CHINE
		Extension et Réhabilitation du poste 225 kV de Man		#				
		Extension et Réhabilitation du poste 225 kV de Soubré incluant 1 transformateur 90/33 kV de 40 MVA		#		#		
		Extension et Réhabilitation du poste 225 kV de Duékoué		#				
		Construction d'une 2ème ligne 225 kV Soubré - Buyo (84 km)	#					
		Construction d'une ligne 225 kV Buyo - Duékoué (109 km)	#					

N°	Name of Project	Components	Composition 225kV Tr	225kV SS	90kV Tr	90kV SS	Other	Donor
		Construction d'une ligne 225 kV Duékoué - Man (86 km)	#					
8	Poste 225 kV de Gagnoa 2	Création d'un poste 225 kV incluant 2 transformateurs 225/90 kV 100 MVA, 1 transformateurs 90/15 kV 24 MVA et 1 transformateurs 90/30 kV 24 MVA à Gagnoa		#		#		BM
		Entrée en coupure sur la ligne 225 kV Soubré-Taabo au poste 225 kV de Gagnoa 2 (0,5 km) Entrée en coupure sur la ligne 90 kV Divo-Gagnoa 1 (0,5 km) au poste 225/90 kV Gagnoa 2 (5 km)	#	#	#	#		
		Restructuration de réseau HTA et créations de départs.					#	
9	Postes 225/33 kV Duékoué et Zagné	Création d'un poste 225/33 kV incluant 2 transformateurs 225/33 kV de 40 MVA à Duékoué (2019)		#				BAD
11	Poste 225 kV Katiola	Construction du poste 225/90/33 kV Katiola incluant 1 transformateurs 225/90 kV 100 MVA et 2 transformateurs 90/33 kV 24 MVA		#		#		EB. CHINE
		Entrée en coupure sur la ligne 225 kV Bouaké-Ferké (2 km)	#					
		Constrcution de la ligne 90 kV Katiola-Marabadiassa (39 km)			#			
		Extension Poste 90 kV Marabadiassa				#		
12	Poste 90/33 kV de Vavoua	Extension et Réhabilitation du poste 90 kV de Daloa				#		EB. CHINE
		Extension et Réhabilitation du poste 90 kV de Zuenoula				#		
		Création d'un poste 90/33 kV incluant 2 transformateurs 90/33 kV 24 MVA à Vavoua				#		
		Construction d'une ligne 90kV Daloa- Vavoua (56km)			#			
		Construction d'une ligne 90kV Vavoua- Zuénoula (57km)			#			
13	File LABOA-BOUNDIALI-FERKE et Poste 225 kV de Boundiali	Construction du poste 225 kV incluant un transformateur 225/90 kV 100 MVA à Boundiali		#				BIDC/ INDE
		Acquisition et installation d'un Compensateur Statique de puissance réactive SVC +/- 50 MVAr au poste 225 kV de Ferké					#	
14	Poste 225 kV de Dabakala	Création d'un poste 225/33 kV incluant 2 transformateurs 225/33 kV 24 MVA à Dabakala		#				EB. CHINE
		Construction d'une ligne 225kV Sérébou- Dabakala (67km)	#					
		Restructuration des réseaux HTA					#	
15	Poste de Korhogo	Création du poste 225/90 kV Korhogo incluant 2 transformateurs 225/90 kV 70 MVA		#				EB. CHINE
		Entrée en coupure double terne sur la ligne 225 kV Boundiali-Ferké Lignes 225 kV Boundiali-Korhogo: 104 km et Korhogo-Ferké: 48 km)	#					
16	Poste de Kong	Création du poste 225/90 kV Kong incluant 2 transformateurs 225/33 kV 24 MVA		#				EB. CHINE
		Construction d'une ligne 225 kV Dabakala - Kong (98km)	#					
		Construction d'une ligne 225 kV Ferké - Kong (85km)	#					
17	Mine Ity	Poste 90/11 kV 40 MVA				#		Mine Ity
		Ligne Danane - Ity (56,4 km)				#		
18	Taabo- Kossou-Bouake	Construction d'une ligne 225 kV Taabo- Kossou-Bouake (1.cct)	#					CI-ENERGIES

Source : AADMP

BOAD : Banque Ouest Africaine de Developpement)

EB : Exim Bank

BM : World Bank

BAD : African Development Bank (ADB)

BIDC : Economic Community of West African States Investment and Development Bank

Ity Mine : Mining company

Table 2.4-6 Development plan for substations 1

N°	Name of project	Component	Donor
1	Renforcement 225/90 kV à Ferké	Création d'une travée transformateur 225/90 kV au poste de Ferké et installation de 2 transformateurs 225/90 kV 100 MVA	BM
2	Renforcement 225/90 kV à Man	Création d'une travée transformateur 225/90 kV équipée d'un transformateur 225/90 kV 70 MVA au poste de Man	
3	Renforcement 225/90 kV à Taabo	Acquisition et installation de 2 transformateurs 225/90 kV 100 MVA au poste de Taabo	
4	Renforcement 225/90 kV à Abobo	Acquisition et installation de 4 transformateurs 225/90 kV 100 MVA au poste d'Abobo	
5	Renforcement 225/90 kV à Kossou	Création d'une travée transformateur 225/90 kV au poste de Kossou et installation de 2 transformateurs 225/90 kV 100 MVA	
6	Renforcement et sécurisation 90/33 kV à Agboville	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste d'Agboville	
7	Renforcement et sécurisation 90/33 kV à Attakro	Remplacement du transfmateur 90/33 kV 20 MVA par un transformateur 90/33 kV 40 MVA au poste d'Attakro	
8	Renforcement et sécurisation 90/33 kV à Ayamé 2	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste d'Ayamé 2	
9	Renforcement et sécurisation 90/33 kV à bongo	Modernisation du poste de Bongo par création de 2 travées 90 kV lignes et TFO équipés de 2 transformateurs 90/33 kV 24 MVA	
10	Renforcement et sécurisation 90/33 kV à Bouaké 1	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Bouaké 1	
11	Renforcement et sécurisation 90/15 kV à Abengourou	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 36 MVA au poste d'Abengourou	
12	Renforcement et sécurisation 90/33 kV à Dabou	Acquisition et installation d'un tranformateur 90/30 kV 40 MVA au poste de Dabou dans une travée existante	
13	Renforcement et sécurisation 90/33 kV à Daba	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Daba	
14	Renforcement et sécurisation 90/33 kV à Danané	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Danané	
15	Renforcement et sécurisation 90/33 kV à Dimbokro	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Dimbokro	
16	Renforcement 225/90 kV à Laboa	Création d'une travée transformateur 225/90 kV au poste de Laboa équipée d'un transformateur 225/90 kV 70 MVA	BAD 5
17	Renforcement 225/90 kV à Boundiali	Création d'une travée transformateur 225/90 kV au poste de Boundiali équipée d'un transformateur 225/90 kV 100 MVA	
18	Renforcement 225/90 kV à Bouaké 2	Acquisition et installation d'un transformateur 225/90 kV 70 MVA au poste de Bouaké 2	

Source : CI-ENERGIES

Table 2.4-7 Development plan for substations 2

N°	Name of project	Component	Donor
19	Renforcement et sécurisation 90/33 kV à Divo	Acquisition et installation d'un transformateur 90/30 kV 40 MVA au poste de Divo pour remplacer le transformateur 24 MVA existant	BAD 4
20	Renforcement et sécurisation 90/15 kV à Ferkéssédougou	Acquisition et installation d'un tranformateur 90/15 kV 24 MVA au poste de Ferkéssédougou dans une travée existante	BAD 4
21	Renforcement et sécurisation 90/33 kV à Hiré	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Hiré	BAD 4
22	Renforcement et sécurisation 90/33 kV à Korhogo	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Korhogo	BAD 4
23	Renforcement et sécurisation 90/33 kV à Laboa	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 16 MVA au poste de Laboa	BAD 4
24	Renforcement et sécurisation 90/33 kV à Man	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Man	BAD 4
25	Renforcement et sécurisation 90/33 kV à Marabadiassa	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Marabadiassa	BAD 4
26	Renforcement et sécurisation 90/33 kV à San-Pedro (PRETD)	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de San pedro	BAD 4
27	Renforcement et sécurisation 90/16,5 kV à San-Pedro (ENERGOS)	Création d'une travée transformateur 90/16,5 kV passage d'un Transformateur 40 MVA	FED 1
28	Renforcement et sécurisation 90/16,5 kV à San-Pedro (PRETD)	Création d'une travée transformateur 90/16,5 kV équipé d'un transformateur de 50 MVA	BAD
29	Renforcement et sécurisation 33/15 kV à Séguéla	Création d'une travée transformateur 33/15 kV équipée d'un transformateur 10 MVA au poste de Séguéla	BAD 4
30	Renforcement et sécurisation 90/33 kV à Sérébou	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Sérébou	BAD 4
31	Renforcement et sécurisation 90/33 kV à Tongon	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 10 MVA au poste de Tongon	BAD 4
32	Renforcement et sécurisation 90/33 kV à Zuenoula	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Zuénoula	BAD 4
33	Renforcement et sécurisation 90/33 kV à Abengourou	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Abengourou	BOAD
34	Renforcement et sécurisation 90/33 kV à Abrobakro	Création d'une travée transformateur 90/33 kV équipée d'un transformateur 24 MVA au poste de Abrobakro	BOAD
35	Renforcement et sécurisation 90/33 kV à Agnibilekro	Création d'une travée transformateur 90/33/16,5 kV équipée d'un transformateur 24 MVA au poste de Agnibilekro	BOAD
36	Renforcement et sécurisation 90/33 kV à Man	Création d'une travée transformateur 90/33/16,5 kV équipée d'un transformateur 24 MVA au poste de Man	BOAD
37	Renforcement et sécurisation 90/15 kV à Boundiali	Acquisition et installation d'un tranformateur 90/15 kV 24 MVA au poste de Boundiali dans une travée existante	

Source : CI-ENERGIES

2.5 ASSISTANCE FROM OTHER DONORS

2.5.1 World Bank

The World Bank is one of the major traditional donors. The projects related to the power sector and currently supported by the World Bank are listed below.

Table 2.5-1 List of the Projects supported by the World Bank

No.	Project	Content	Type	Amount	Situation
1	CI-ENERGIES Guarantee Project	Improvement of the electricity sector's financial performance by refinancing the short-term liabilities of CI-ENERGIES	Loan	240 million EUR	Approved in 2018 (ongoing)
2	Electricity Transmission and Access Project	1.Reinforcement of transmission systems 2.Rehabilitation, reinforcement, and extension of distribution systems in Abidjan and selected 10 regional capital cities 3.Rural electrification and support to electricity for all programs 4.Strengthening institutional capacity of the electricity sector and project management	Loan	325 million USD	Approved in 2017 (ongoing)

Source: Website of the World Bank and Interview

At Kossou Substation which is the site of this project, the transformer will be installed by the project No. 2 listed in the above table. The World Bank initiated the working group on renewable energy in December 2017 together with the Ministry of Petroleum, Energy and Renewable Energy, to encourage the investment in power sector. The activities are implemented through the sub-working groups in various fields such as hydroelectric, biomass, solar, wind power, off-grid, mini-grid, policy and financial system, etc.

2.5.2 African Development Bank

The projects related to the power sector and currently supported by the African Development Bank are listed below.

Table 2.5-2 List of the Projects supported by the African Development Bank

No	Project	Content	Type	Amount	Situation
1	ATINKOU (CIPREL IV) 390MW Gas Power Project and Azito Power Expansion Project (Phase IV)	Construction of the gas combined cycle power plant in Taboth, Jacqueville of CIPREL	Loan	100 million EUR	Approved in 2019 (ongoing)
		Installation of additional capacity at the gas combined cycle power station of Azito		50 million EUR	
2	Project to Improve Access to Electricity in Rural Areas	・Power infrastructure ・Social connections ・Institutional support ・Project management	Loan	27.3 billion FCFA	Approved in 2018 (ongoing)
3	Power Transmission and Distribution Networks Reinforcement Project	・Power infrastructure (Bingerville Substation 225/20kV, Duékoué and Zagné Substation 225/33kV, Extension of Soubré and San Pédro station, Transmission Line 225kV of Soubré-San Pédro (128km) and Duekoué-Zagné (77km), High Voltage Line in Bingerville, Duékoué, Zagné and Taï, Distribution Networks in 42 villages in Cavally, 82 villages in Guémon and 128 villages in Tonkpi) ・Environmental and social mitigation ・Project management	Loan	91.8 billion FCFA	Approved in 2016 (ongoing)
4	CLSG Inter Connection - Cote d'Ivoire	Construction of a 1,357-km-long double circuit high voltage (225 kV) line to connect the national networks of the four countries (Côte d'Ivoire, Liberia, Sierra Leone and Guinea)	Grant	49 million USD	Approved in 2013 (ongoing)

Source: Website of the African Development Bank and Interview

2.5.3 Agence Française de Développement (AFD)

AFD supports the implementation of the power sector projects by European Union, emphasizing the rural electrification initiated by the Government of Cote d'Ivoire. In addition, the studies on solar or biomass power generation are conducted.

2.5.4 Others

The projects related to the power sector and currently supported by other donors are mentioned below.

(1) European Union

The European Union is one of the major traditional donors.

Table 2.5-3 List of the Projects supported by the European Union

<table>
<tr><th>No.</th><th>Project</th><th>Content</th><th>Type</th><th>Amount</th><th>Situation</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">CI-ENERGIES Network Upgrade and Energy Efficiency (ENERGOS) I</td><td rowspan="2">・Access to electricity (Distribution network reinforcement and extension in Bouaké, Sanpedro and Abidjan, connection, etc.)
□Distribution system (construction of the dispatching center, installation of street lamps, etc.)
・Institutional support</td><td>Grant</td><td>70,735,000 EUR (European Development Fund)</td><td rowspan="2">Conducted by the AFD, except the fund management) (ongoing)</td></tr>
<tr><td>Loan</td><td>117,649,000 EUR (European Investment Bank)</td></tr>
<tr><td>2</td><td>CI-ENERGIES Network Upgrade and Energy Efficiency (ENERGOS) II</td><td>・Increase of subscribers in rural area (electrification)
・Increase of generation capacity of renewable energy
・Reduction of energy consumption (encouragement of investment to energy efficiency)</td><td>Grant</td><td>68,265,000 EUR (European Development Fund)</td><td>Conducted by the Expertise France, a part of the fund is extended to the African Investment Facility (ongoing)</td></tr>
</table>

Source: Website of the European Union and Interview

ENERGOS I also targets the reinforcement of distribution network in Bouaké; however, there is no duplication in the project component.

(2) West African Development Bank

Table 2.5-4 List of the Projects supported by the West African Development Bank

No.	Project	Content	Type	Amount	Situation
1	Construction of the Evacuation Network related to the Power Plants of CIPREL5 and AZITO4	Construction of the evacuation network related to the power plants of CIPREL5 and AZITO4	Loan	20 billion FCFA	Approved in 2020 (ongoing)
2	Guarantee for a Short-Term Loan granted by Société Générale de Banques in Côte d'Ivoire to Compagnie Ivoirienne d'Electricité	Guarantee for a short-term loan granted by Société Générale de Banques in Côte d'Ivoire	Loan	25 billion FCFA	Approved in 2017 (ongoing)
3	Counter-Guarantee for a Short-Term Loan granted by Société Générale de Banques in Côte d'Ivoire (SGB-CI) to Société des Energies de Côte d'Ivoire (CI-ENERGIES)	Counter-Guarantee for a short-term loan granted by Société Générale de Banques in Côte d'Ivoire (SGB-CI)	Loan	5 billion FCFA	Approved in 2017 (ongoing)
4	Construction and Operation of a 44-MW Hydropower Plant under Build-Own-Operate and Transfer (BOOT) contract at Singrobo-Ahouaty by Ivoire Hydro Energy (IHE) SA in Côte d'Ivoire	44-MW hydropower plant under Build-Own-Operate and Transfer (BOOT) contract at Singrobo-Ahouaty	Loan	15 billion FCFA	Approved in 2016 (ongoing) Contractor: Eiffage
5	Project of Reinforcement of Transmission and Distribution Network Facility of CI-ENERGIES	Reinforcement of transmission and distribution network facility	Loan	25 billion FCFA	Approved in 2013 (ongoing)
6	Participation in the Capital of CIPREL	Participation in the capital of power generation company	Investment	400 million FCFA	Approved in 2013 (ongoing)
7	Partial Finance to the Project of reinforcement of transmission and distribution network facility of CI-ENERGIES	Reinforcement of transmission and distribution network facility	Loan	25 billion FCFA	Approved in 2012 (ongoing)

Source: Website of the West African Development Bank and Interview

(3) Government of China

Table 2.5-5 List of the Projects supported by the Government of China

No.	Project	Content	Type	Amount	Situation
1	Gribo Popoli Dam	Construction of hydropower plant 112MW (downstream of Soubré dam, on the Sasandra river)	Loan	169.4 billion FCFA	Via The Export-Import Bank of China (ongoing)
2	National Grid Development and Renovation Project	Construction and renovation of power lines, transformer substations and electric power grids in 500 villages	Grant	818 million USD	Implemented by SINOMACH and China National Electric Engineering (on going)
3	Contribution to Master Plan	Finance to the study	Loan	135.94 billion FCFA	Via The Export-Import Bank of China (ongoing)

Source: Website of SINOMACH and Interview

(4) Kuwait Fund for Arab Economic Development

Table 2.5-6 List of the Projects supported by the Kuwait Fund for Arab Economic Development

No.	Project	Content	Type	Amount	Situation
1	Construction of Adzope 225/33kv Substation	・Construction of the Adzope 225/33kv 2x60MVA substation ・Zeudju substation extensions ・Linkage of 225kV overhead transmission line between Adzope to Zeudji ・extension and modification of MV network in Adzope department, etc.	Loan	7 million KWD	Agreement in 2016 Implemented by CI-ENERGIES (ongoing)

Source: Kuwait Fund for Arab Economic Development and Interview

(5) KfW Bankengruppe (KfW)

Table 2.5-7 List of the Projects supported by KfW

No.	Project	Content	Type	Amount	Situation
1	Construction of Solar Power Plant Boundliali	37.5MW	Loan	36.7 million EUR (including 9.7 million from EU)	Agreement in 2018 (ongoing)

Source: Interview

CHAPTER 3

NECESSITY AND ADEQUACY OF THIS PROJECT

CHAPTER 3 NECESSITY AND ADEQUACY OF THIS PROJECT

3.1 ISSUES OF POWER SYSTEM AND NECESSITY OF THE PROJECT

3.1.1 Issues of Power System

225 kV transmission line connecting the Taabo substation-Kossou substation-Bouaké 2 substation, which is the target power system of the Project, is part of the most important backbone transmission power system in Cote d'Ivoire, which sends the power to north through the central part of the country.

This backbone transmission power system is very important because it supplies power from the south, where most of the power plants are located, to the capital Yamoussoukro and the second largest city Bouaké in the central part of the country, as well as to the major cities in the north and to Mali and Burkina Faso in the north of the country.

This backbone transmission power system has the following technical issues due to the 225 kV Taabo substation-Kossou substation-Bouaké 2 substation section.

(1) Capacity shortage of transmission lines
(2) Insufficient reliability of the backbone transmission power system (N-1)
(3) Capacity shortage of transmission lines for Mali and Burkina Faso

(1) Capacity shortage of transmission lines

The existing 225 kV transmission power system (April 2019) is shown in Section 2.4.1 "CURRENT CONDITION OF TRANSMISSION FACILITIES", the power flow of the transmission line of the project is shown in Fig. 3.1-1. The basic specifications of the transmission line for the section are also shown in Table 3.1-1.

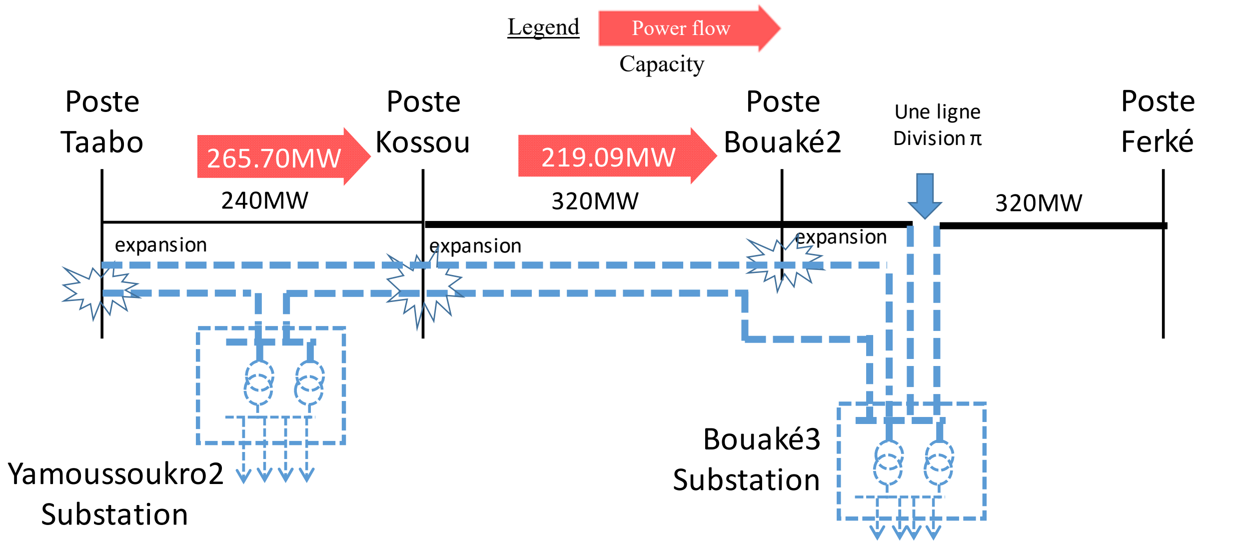
Between Taabo substation and Kossou substation, the conductor size of the transmission line is 366mm^2 and the transmission capacity is 245MVA, which has a smaller diameter than the other sections and is a bottleneck in terms of transmission capacity.

Between Taabo substation and Kossou substation, the conductor size of transmission line is 366mm^2 and the transmission capacity is 245MVA, which has a smaller diameter than the other sections and is a bottleneck in terms of transmission capacity.

The power flow of this section is 265MW, and even now the power flow is exceeding the transmission capacity, so there is an urgent need to increase the transmission capacity.

In addition, between Kossou substation and Bouaké 2 substation, the transmission line capacity is 330 MVA and the power flow is 219 MW, which is more than 60% of the transmission capacity. Considering that the growth rate of the latest demand assumption is more than 5%/year, it is assumed that the transmission capacity will be exceeded within 10 years.

Therefore, it is an urgent issue to address the shortage of transmission line capacity in all the project sections. Comparison between the power flow and the transmission capacity of the target sections is shown in Table 3.1-2.



Source: JICA Study Team

Fig. 3.1-1 Power flow between Taabo, Kossou and Bouake2

Table 3.1-1 Basic Specification of Transmission Line between Taabo, Kossou and Bouake2

Section	Number of Circuit	Specification /Size	Lengths	Number of tower	Average Span	Transmission Capacity[1]
Taabo Substation－Kossou Substation	1	AAAC 366 mm^2	124km	325	App. 380m	245 MVA
Kossou Substation－Bouaké 2 Substation	1	AAAC 570 mm^2	109km	231	App, 470m	330 MVA

Source: CI-ENERGIES

[1] CI-ENERGIES

Table 3.1-2 Power Flow of Transmission Line between Taabo, Kossou and Bouake2

Section	Power Flow (Peak)[2]	Transmission Capacity	Evaluation
Taabo Substation－Kossou Substation	**265.70 MW**	245 MVA	Capacity shortage
Kossou Substation－Bouaké 2 Substation	**219.09 MW**	330 MVA	Capacity shortage in the near future

Source: CI-ENERGIES

(2) Insufficient reliability of the backbone transmission power system (N-1)

In Cote d'Ivoire, to ensure N-1 reliability is one of the important goals for the entire power systems.

From the transmission power system (April 2019) of Cote d'Ivoire in Chapter 2 (Figure 2.4-1), it can be seen that of the backbone transmission power system connecting the north and south, the Abobo substation to Taabo substation has two routes (three lines), and the Bouaké substation to Ferké substation has two routes (one routes is under planning).

On the other hand, there is only one route between Taabo, Kossou and Bouaké 2, which is a bottleneck in terms of reliability.

In recent years, a transmission line from Taabo station to Ferké substation, which bypasses the western part of Cote d'Ivoire, has been constructed, which has slightly improved the transmission capacity and reliability to the northern part of the country, but because it is a long-distance transmission line, it is difficult to maintain the transmission capacity and power quality to the northern part of the country and the neighboring countries in the event of an accident on the transmission power system. Therefore, there is a high urgency to strengthen this section in terms of reliability.

(3) Capacity shortage of transmission lines for Mali and Burkina Faso

As shown in Table 2.4-4 "Power flow of existing 225 kV transmission lines" in Section 2.4.1, a total of more than 180 MW of power electricity is exported, including 80 MW for Mali and 100 MW to Burkina Faso.

It is assumed from WAPP/MP that the demand in both countries will continue to grow steadily, and the project section needs to be expanded in order to secure transmission capacity for further exports.

[2] Peak in the past one year

3.1.2 Necessity of The Project

In the Cote d'Ivoire power system with the technical issues mentioned above, the upgrading of the target facilities (Taabo-Kossou-Bouaké) is essential to ensure the stable power supply to the north and the fulfillment of Cote d'Ivoire's role in the WAPP as described in Section 1.1 "Background of the Project". It is also in line with the Côte d'Ivoire National High Level Policy and MP2015.

This Project aims to address the above-mentioned technical issues of insufficient power supply and reliability in the backbone transmission power system in the north and south of the country by constructing a new 225 kV transmission facilities between the Taabo - Kossou - Bouaké 3, in order to increase the stability of power supply and to meet the increasing demand in the central region including the capital Yamoussoukro, the second largest city Bouaké, the major cities in the north and the neighboring countries.

3.2 REINFORCEMENT PLAN

3.2.1 Power System Reinforcement Plan by MP2015

Plans to reinforce the project's target section outlined below are specified in the 2014-2030 Generation -Transmission Master Plan outlined in Chapter 2.2.3.

Table 3.2-1 Positioning of the project at MP2015

NO.	Plan	Area	Description
27	Main transmission line in central region	Corridor Est	New 225kV transmission line between Bouaké 2 and Bouaké 3 （approx. 10 km）
		Corridor Nord	New 225kV transmission line between Bouaké 3 and Kossou （approx. 110 km）
		Yamoussoukro	New transmission line between Kossou and Taabo

Source : Plan Directeur Production-Transport 2014-2030

The following plan is also included in CI-ENERGIES's list of projects (Transmission Projects under funding 2019-2020):

Table 3.2-2 Registration of Project List of CI-ENERGIES

NO.	Année d'achèvement （Prévue）	Description
30	2020	New 225kV transmission line Taabo－Kossou－Bouaké 2

The above plan aims to increase supply capacity and improve reliability of several circuits by adding a 225 kV line to the project target section. This plan is based on the demand forecast mentioned in the Generation-Transmission Master Plan 2014-2030.

3.2.2 Taabo – Kossou – Bouake Transmission line Project financed by CI-ENERGIES

The 225 kV transmission facilities project between Taabo, Kossou and Bouake, which is the subject of Section 3.2-1 "Enhancement Plan in MP2015", was planned as a Japanese Yen Loan project at the initial stage of this study.

However, in March 2020, the Plan to construct a 225kV transmission line (one line) using CI-ENERGIES' own funds (hereinafter referred to as the "CI-ENERGIES Project") was confirmed a separately from the Japanese Yen Loan project mentioned above. A summary of CI-ENERGIES Project is shown in Table 3.2-3.

This study took into account the above impacts.

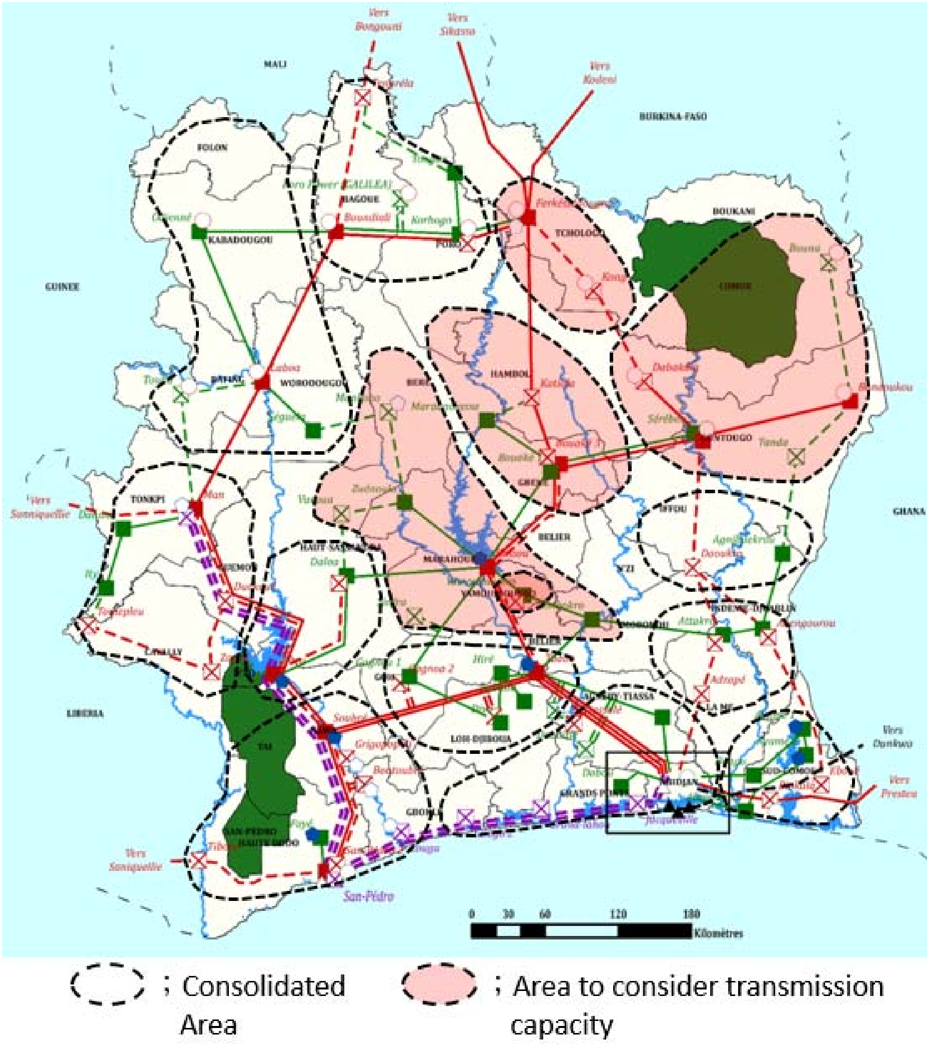
Table 3.2-3 Summary of CI-ENERGIES Transmission line Project

Items	内容
Project Name	PROJET DE RENFORMCEMENT DU CORRIDOR NORD
Finance	CI-ENERGIES (2019 Investment Budget)
Procurement	NCB（National Competitive Bidding）
Compornet	Construction of 225kV Transmission facilities between Taabo-Kossou-Bouaké(1 circuit)
Issue of bidding document	Febrary 2020
Cliant	CI-ENERGIES
Lot	LOT1：Construction of 225kV Transmission facilities between Taabo-Kossou Expansion of Kossou substation and Taabo substation LOT2：Construction of 225kV Transmission facilities between Kossou-Bouaké Expansion of Buaké3 substation
Project Period	18 months
Deadline for bids	March 27, 2020, 10:00 a.m.
Bid opening	March 27, 2020, 10:30 a.m.
Language	French

3.2.3 Electricity demand forecast for the target grid

In the demand forecast in Section 2.3.1, the electricity demand forecast for the entire Côte d'Ivoire was described. When considering the power system targeted for the project, it is necessary to forecast the demand not only for the substations in the target area but also for the substations nationwide. CI-ENERGIES has provided demand forecast data for all substations that correspond to demand forecasts nationwide and the list is shown in Attachment 4.

In order to examine the transmission capacity and analyze the system for this project, power demand in each area including the demand of the main substations connected to the target transmission line and the downstream substations that supply power from those main substations needs to be aggregated. Considering the nationwide backbone transmission system of Côte d'Ivoire, the demand for substations is consolidated into the 15 areas as shown in Fig. 3.2-1.



Source: CI-ENERGIES materials edited by JICA Survey Team

Fig. 3.2-1 Area division in system analysis

In addition, it is necessary to consider the amount of electricity exported to Mali and Burkina Faso in the transmission capacity of the target line. Table 2.3-5 "Electricity Export Plan (2020-2040)" in Section 2.3.1 "Demand Forecast" shows electricity exports by country to Mali, Burkina Faso and so on. Furthermore, although the electricity demand provided this time is only in the middle case, considering that it will be higher, the high case of + 10% increase is estimated. Table 3.2 4 shows the demand for each area that should be considered for the transmission capacity in this project.

Table 3.2-4　Demand and area to consider when studying transmission line capacity for the project

(unit：MW)

item (Area/Country)	2040 demand Middle case	2040 demand High case	Substations consolidated
KOSSOU	241.6	265.8	Kossou, Kossou Mine, Dimbokro, Mankono, Sinfra, Vavoua, Yamouss1, Zuenoula
YAMOUSSOUKRO2	39.8	43.8	Yamoussoukro2
BOUAKE	206.5	227.2	Bouake1, Bouake2, Bouake3
FERKE	106.1	116.7	Ferke, Kong
SEREBOU	148.4	163.2	Bondoukou, Bouna, Dabakala, Serebou, Tanda
Domestic demand	742.4	816.6	
Mali	845.0	929.5	
Burkina Faso			
Exportation	845.0	929.5	
Total	1,587.4	1,746.1	

Source: CI-ENERGIES materials edited by JICA Survey Team

3.2.4 Verification of the Reinforcement Plan in Mater Plan

As stated in Chapter 3.2.1, the Generation-Transmission Master Plan 2014-2030 considers increasing the number of circuits by building a new line of one circuit to strengthen the target section of the project. To address the need to reinforce transmission capacity and ensure N-1 reliability, explained in Chapter 3.1.1, the audit of the Generation-Transmission 2014-2030 Master Plan and the study on the number of circuits of that section were carried out, taking into account the recent trend of demand and the construction plan (project funded by CI-ENERGIES).　In order to guarantee N-1 reliability, while considering the use of the existing (one circuit) transmission line on the same section, the following conditions were taken into account.

・Transmission load Middle scenario 1587 MW、High scenario 1746 MW

・Accident-eligible transmit capacity Line capacity×110 %[3]

・Existing transmission line capacity Between Taabo and Kossou : 240 MW（245 MVA）

Between Kossou and Bouaké : 320 MW（330 MVA）

If in the JICA project a line of one circuit is constructed, as planned in the Generation-Transmission Master Plan 2014-2030 , the load of this transmission line will have to be less than 110% of the capacity of the existing transmission line to guarantee N-1[6]. In other words, in order to maintain N-1, the load must be less than 264 MW between Taabo and Kossou, or 352MW between Kossou and Bouaké. As shown in Figure 3.1 1, the peak load for the Kossou in the Taabo station over the past year is 265 MW, which already exceeds 110% of the existing capacity. Circuits including the existing line and the new line cannot therefore guarantee the N-1 criteria, even with the current load.

On the other hand, the capacity of the transmission line between Kossou and Bouaké is slightly larger, and currently, the N-1 limit of 325 MW has some reserve compared to the peak load of the past year, i.e., 219 MW. However, taking into account a growth rate of 5.3%/year, the load is expected to exceed the N-1 guarantee limit[7] in the next 10 years. The two circuits including the existing line will therefore not be able to guarantee the N-1 criteria in the near future.

To guarantee the N-1 criteria, it is possible to increase the capacity of the existing transmission line by replacing towers. However, since the transmission line of that section was built 30 to 40 years ago, it is estimated that a significant number of towers will have to be rebuilt due to aging and the unavailability of design, manufacturing and construction records. For this reason, the replacement of towers over 200 km, which will require a large-scale power cut of at least several months, is not realistic[8][9].

To guarantee N-1, it is therefore necessary to build a new double circuit transmission line with

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[3] Given by CI-ENERGIES

[6] It is possible to build a new high-capacity transmission line. But because of the low capacity of the existing line, the N-1 charge (when a new line is incidental) is limited to the capacity of the existing line.

[7] If 219.09MW (in 2019) increases with a growth of 5.3% for 10 years, the load will be 367MW (>352MW).

[8] The transmission of electricity to the Ferké station via the western network during the works (power cut), is also not feasible due to the voltage problem and the large-scale load limitation. (based on the survey with CIE at the dispatching centre). Therefore, the increase in the capacity of the existing transmission line is not feasible. CI-ENERGIES wishes to minimize the execution period.

[9] According to CIE at the dispatching centre, the allowable power outage period for the 225 kV base network is about 3 days. (This will have to be confirmed during the execution)

sufficient transmit capacity, as existing facilities of aging and insufficient capacity cannot be relied upon.

Therefore, a new double circuit transmission line should be built off the existing transmission line to guarantee the N-1 criterion as part of Japan's loan project, and this was therefore proposed by the JICA mission. After consultation with CI-ENERGIES on the basis of Table 3.2-5, we concluded that Scenario 2 is appropriate.

In the case of taking into account the project funded by CI-ENERGIES, the adequacy of the conductor number of the transmission line was confirmed by considering the increased load. If Japan’s loan project is one circuit transmission line, over load will happen in the N-1 contingency. Therefore, double circuit transmission line is necessary. The existing transmission line will be operated as reserve one because the facility of aging and insufficient capacity cannot be relied upon

Table 3.2-5 Comparison of number of circuits

	Composition of circuit	Reliability	Cost	Evaluation
Scenario 1	Existing 1c.c.t. + New 1c.c.t. (JICA)	Reliability N-1 Not guaranteed	Cheaper	
Scenario 2	Existing 1c.c.t.(*1) + New 2c.c.t. (JICA)	Reliability N-1 Guaranteed	Standard	**adopt**
Scenario 3	Removal of existing transmission line New 2c.c.t. (JICA)	Reliability N-1 Guaranteed	Slightly high (removal cost)	

(*1) : The objective of keeping the existing transmission line is to provide the way when rebuilding the towers in the future and the bypass connection for maintenance.

Source : JICA Study Team

3.3 POWER SYSTEM ANALYSIS

The power system configuration was considered as follows. The basic model is shown in Fig. 3.3-1. Referring to the basic model, the consultation with CI-ENERGIES was conducted as outlined below. The comparison of power system configurations is shown in Fig. 3.3-2. In Option A, the number of πoff at Yamoussoukro is 1, instead of 2 . In this case, the length of the transmission line is about 5% shorter than that of the base model. N-1 reliability is also assured.

In Option B, the number of πoff at the Kossou is 1, as is the Yamoussoukro 2. In this case, the length of the line is shorter, but the voltage problem will happen during the accident. (Table 3.3-1). After consultation with CI-ENERGIES, Option A, which is reliable and more economical compared to the basic model, was selected. About the connection with the Bouaké 2 station, the number of πoff is 1 because of the voltage problem. The connection allows the transmission line to be built between the Taabo, Kossou and Bouaké stations, as soon as possible, regardless of the completion of the construction of the Bouaké 3.

The power flow, voltage and short-circuit current analyses were carried out on the basis of a new 225 kV power system model as of 2040 with the double circuit transmission line. The results of the analysis are shown in Fig. 3.3-3 to Fig. 3.3-8. In this analysis, the project funded by CI-ENERGIES is taken into account.

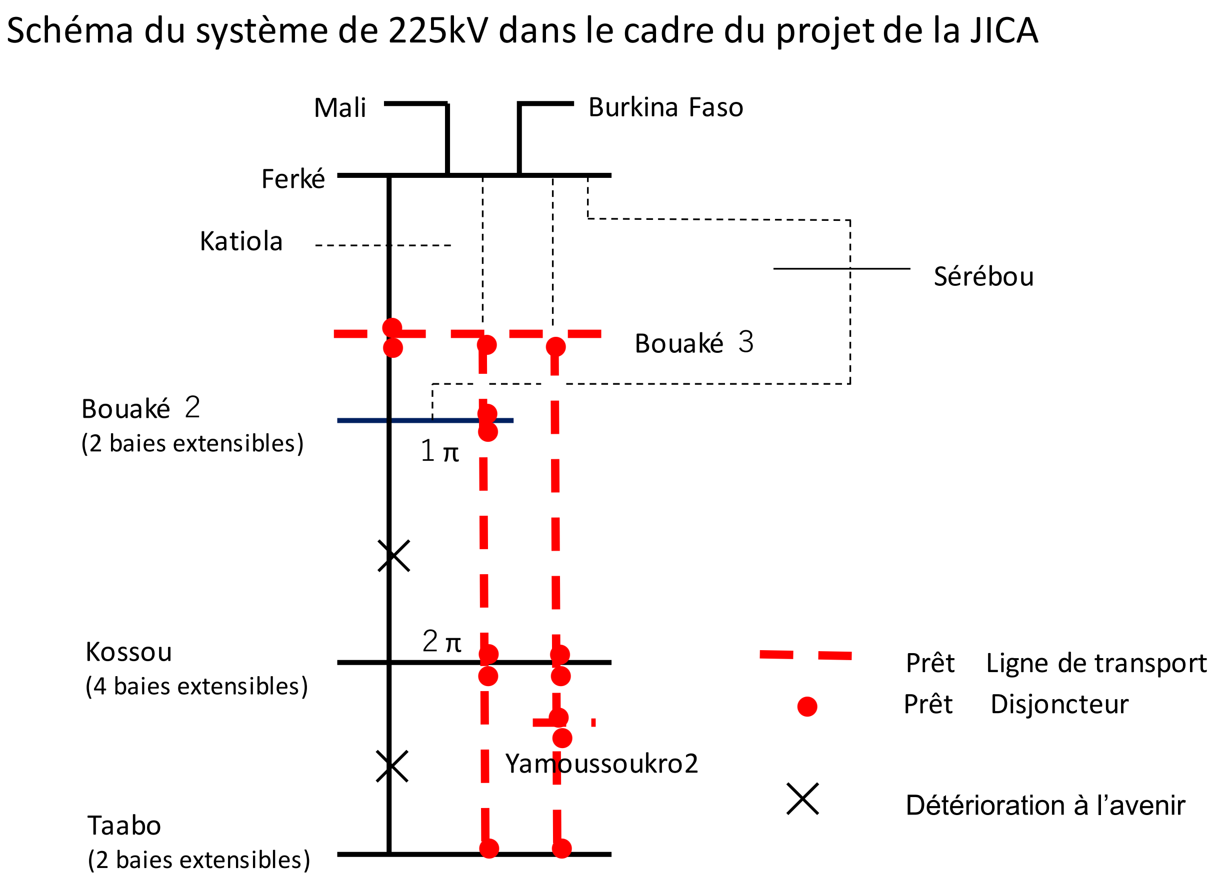
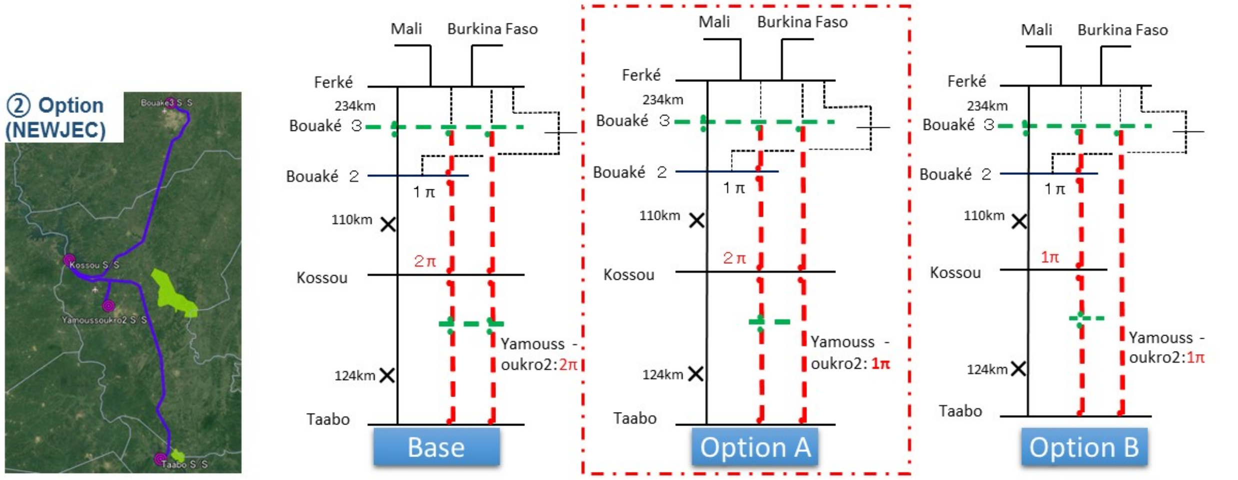


Fig. 3.3-1 Configuration of power system （Base model）

Unité: km

Nom	Taabo – Kossou	Branche Yamousoukro2	Kossou - Buaké3	Total	Référence
NEWJEC (1 c.c.t)	123	28,8 (14,4 x 2 lines)	129	280,8	Poste Kossou :1π Poste Yamoussoukro 2 :1π
NEWJEC (2 c.c.t) BASE	246 (123x2)	57,6 (14,4 x 4 lines)	264.4 (129x2+3.2*1x2)	568,0	Poste Kossou :2π Poste Yamoussoukro 2 :2π
Option A (2 c.c.t)	-	-28,8 (14,4 x 2 lines)	-	539,2 (95%)	Poste Kossou :2π Poste Yamoussoukro 2 : 1π
Option B (2 c.c.t)	-41,4 (-46,7*2+26*2)	-28,8 (14,4 x 2 lines)	-	497,8 (88%)	Poste Kossou : 1π Poste Yamoussoukro 2 : 1π

*1: L'entrée en coupure π à Bouaké 2 y compris le câble souterrain (1,1km), La distance des lignes de transport est mesurée par Google Earth.



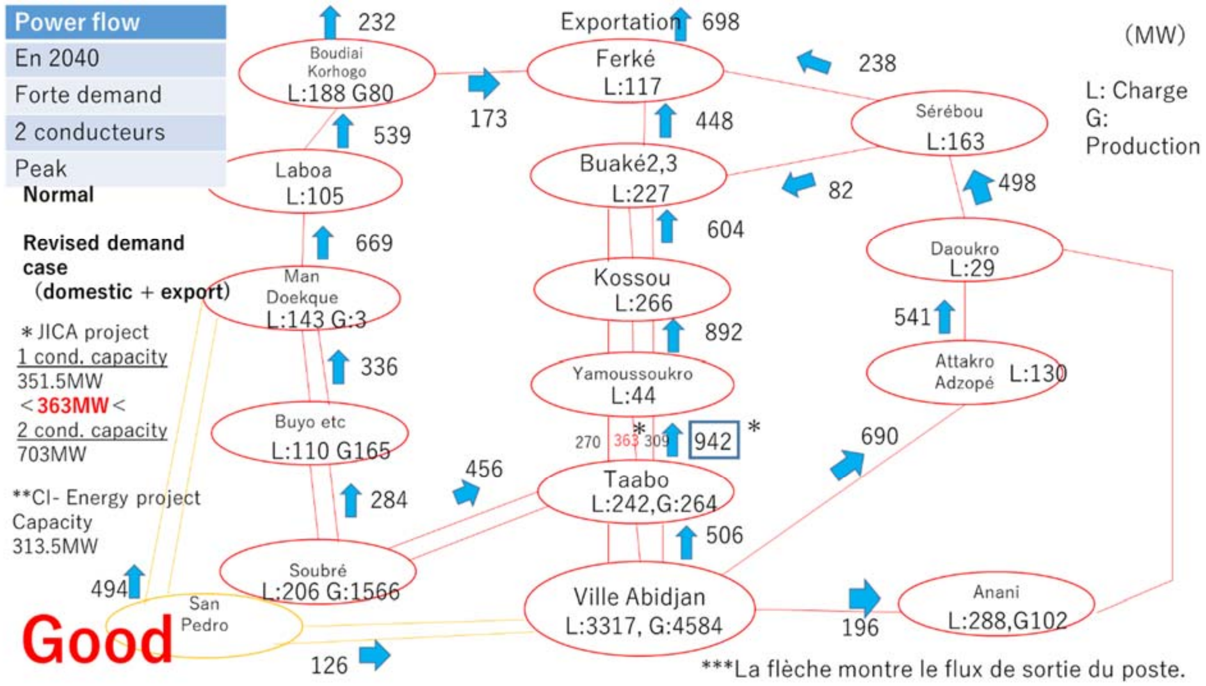
Source : JICA study team

Fig. 3.3-2 Comparison of power system configurations

Table 3.3-1 Result of the analysis for study of configuration of power system

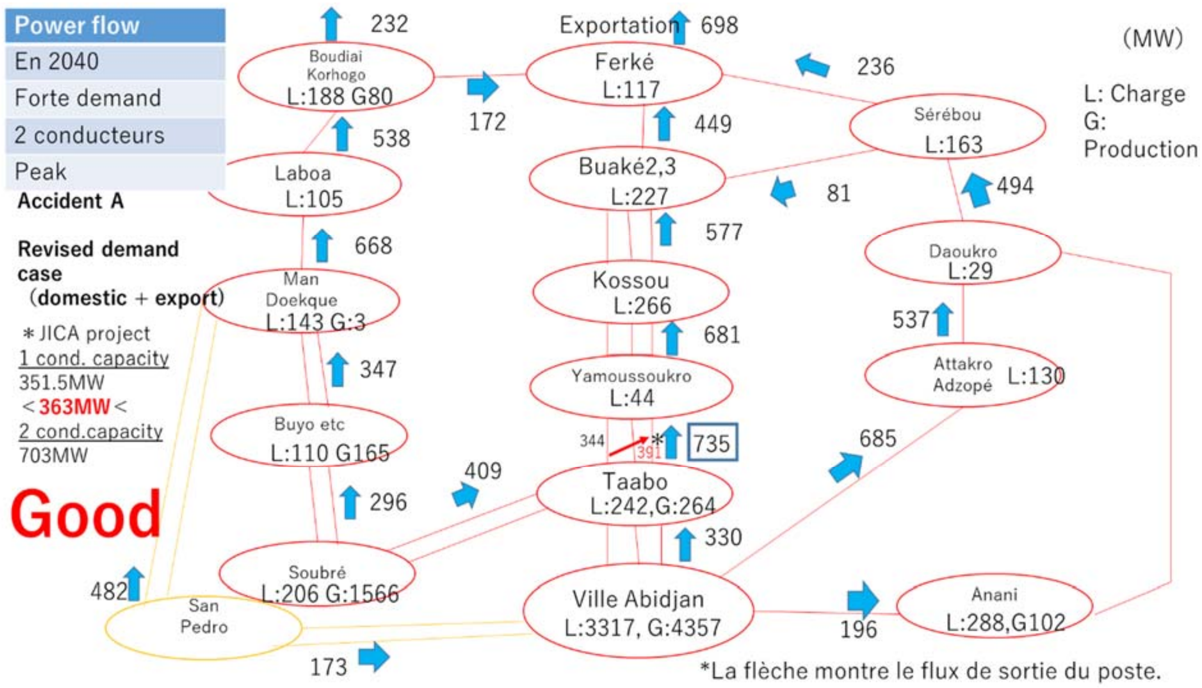
	Kossou 2π	Kossou 1π
Normal	Good	Good
Accident (N-1)	Good	Not good

Source : JICA study team



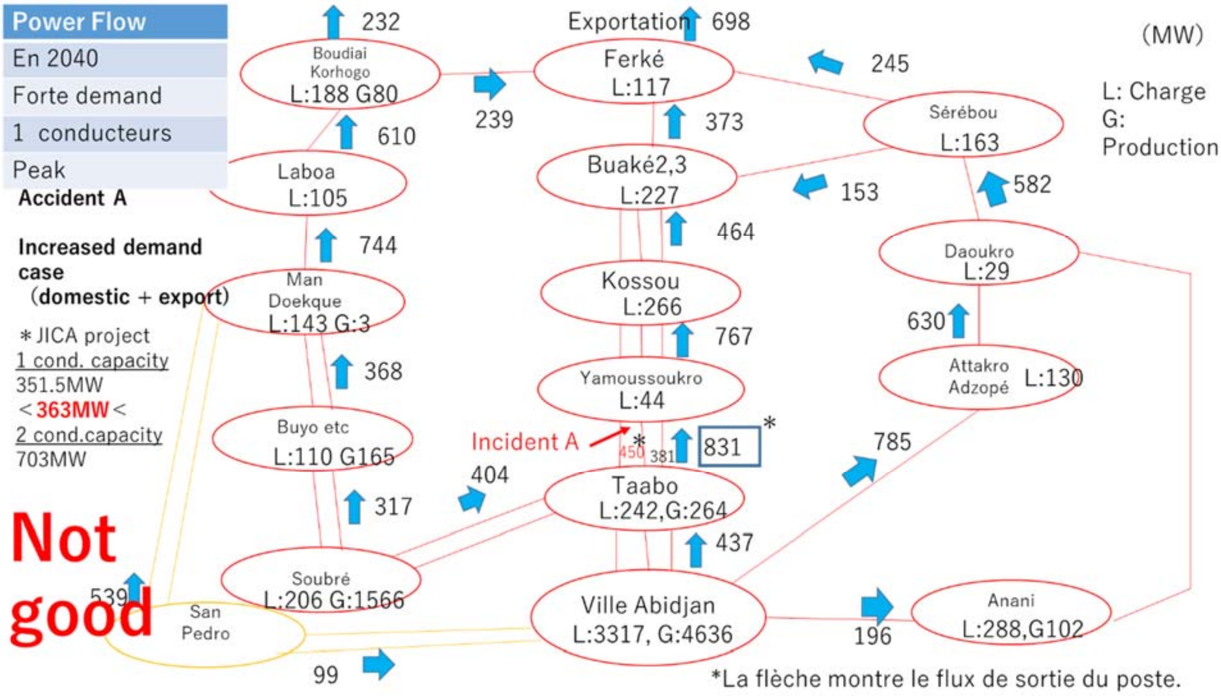
Source : JICA study team

Fig. 3.3-3 Result of power flow analysis（2 conductors, normal）



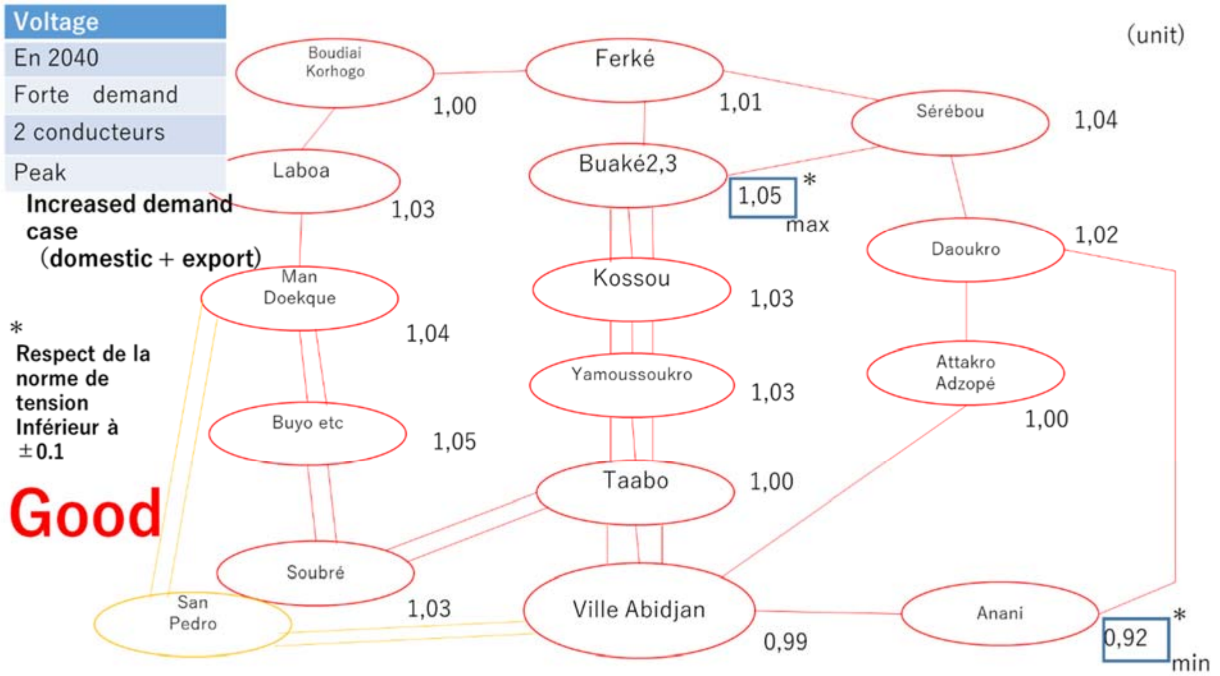
Source : JICA study team

Fig. 3.3-4 Result of power flow analysis（2 conductors, accident）



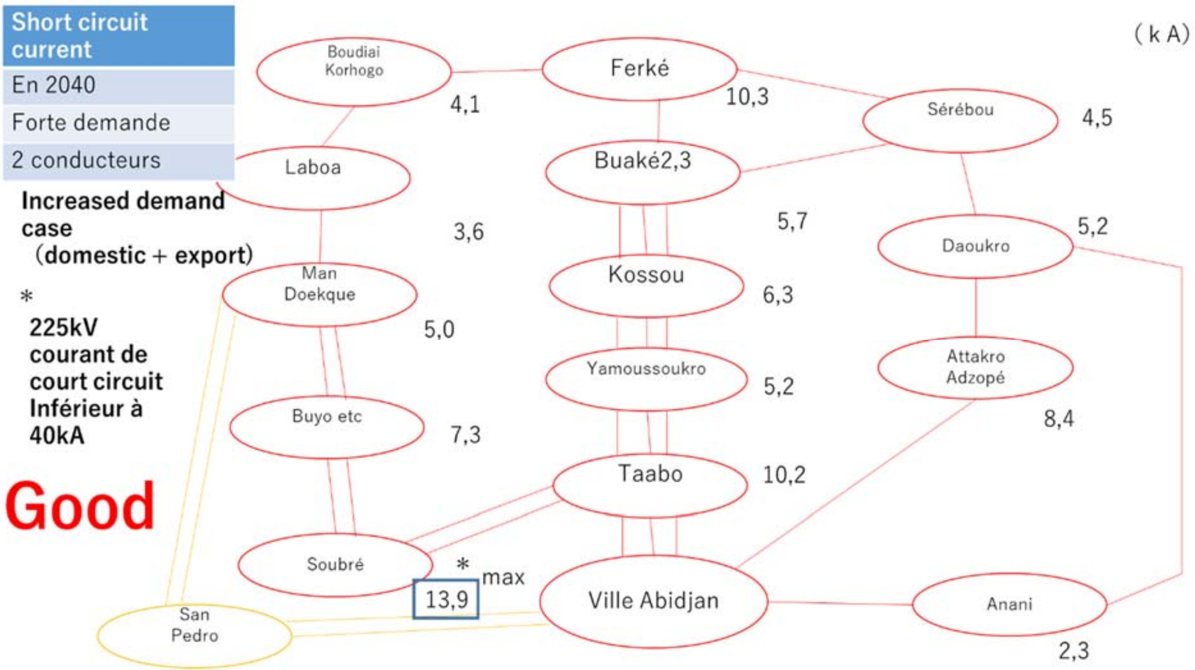
Source : JICA study team

Fig. 3.3-5 Result of power flow analysis (1 conductor, accident)



Source : JICA study team

Fig. 3.3-6 Result of voltage analysis



Source：JICA study team

Fig. 3.3-7 Result of short circuit current analysis

Number of conductor	Demand revised by CI Energy	Power flow result under transmission capacity considering N-1	Voltage result ±10%	Short circuit current result 225kVsystem under 40kA
1	High case	Not good	Good	Good
2	High case	Good	Good	Good

Source：JICA study team

Fig. 3.3-8 Result of power system analysis

3.4 NECESSITY AND VALIDITY OF REINFORCEMENT FOR DISTRIBUTION NETWORK

CI-ENERGIES is considering reinforcement for the distribution network in Yamoussoukro and Bouaké, which is related to the construction of Yamoussoukro 2 Substation and Bouaké 3 Substation, planned as a part of this project. Regarding this reinforcement, CI-ENERGIES has already conducted a feasibility study (F/S). The details of this F/S survey are described below.

3.4.1 Reinforcement Plan for the Yamoussoukro Distribution Network

(1) Current situation of the Yamoussoukro Distribution Network

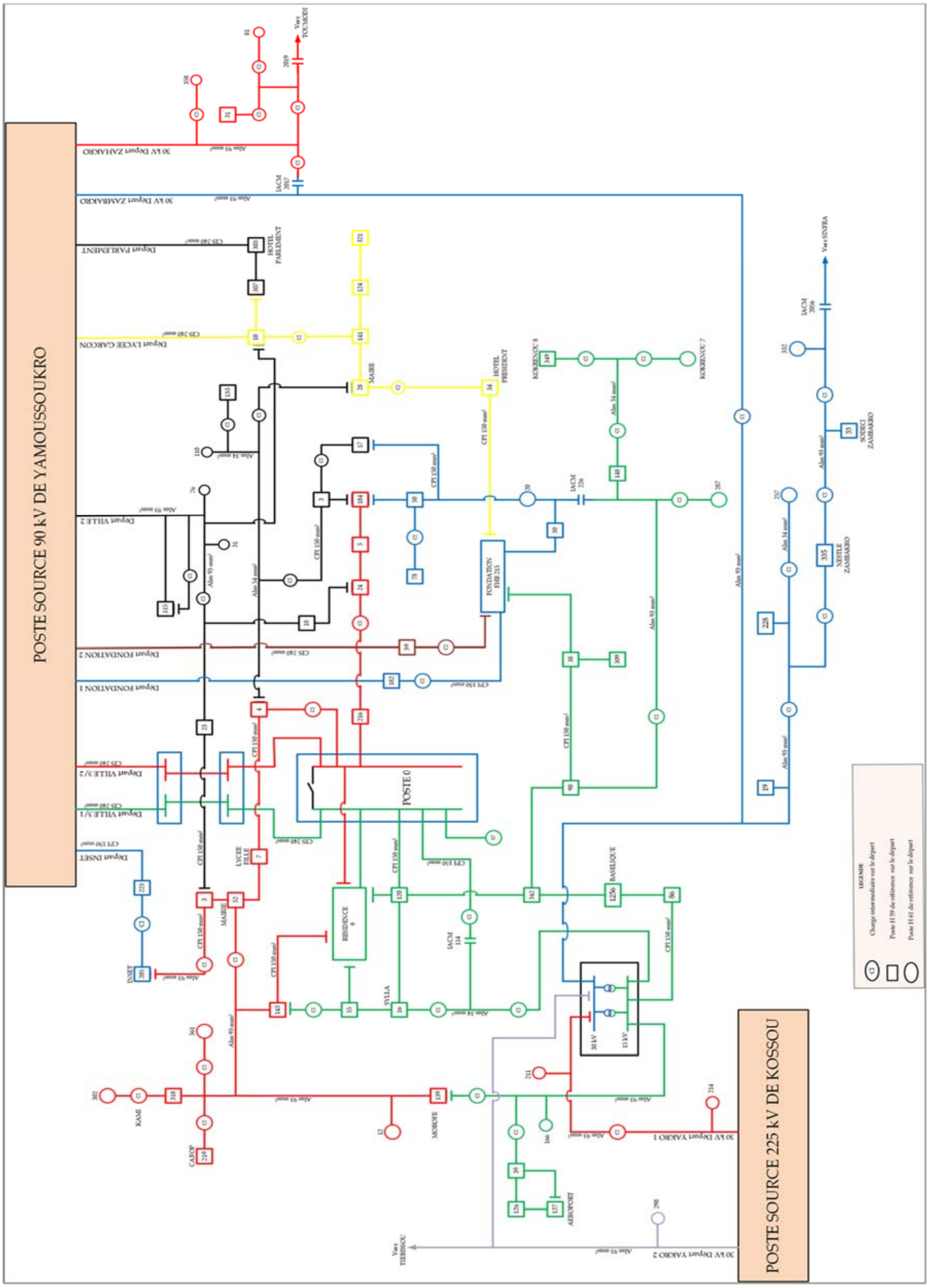
The city of Yamoussoukro is currently powered by the Yamoussoukro 1 substation, which is connected to the main trunk transmission line by 90kV Dimbokro – Yamoussoukro line and Kossou – Yamoussoukro line. The Yamoussoukro 1 substation has three transformers, one 90/30kV - 24MVA and two 90/15kV - 40MVA. In addition, two 30kV distribution lines from Kossou substation are installed in Yamoussoukro city, and are connected to the 15kV distribution network in the city via the 30/15kV substation installed in the city.

The distribution feeders from the Yamoussoukro 1 substation are currently operating 10 feeders, 15kV - 8 lines and 30kV - 2 lines. A list of distribution feeders is shown in Table 3.4-1, and a single line diagram of distribution network is shown in Table 3.4-1.

Table 3.4-1 The List of Distribution feeders in Yamoussoukro

Name of Feeder	Load (MW)	Underground (km)	Overhead (km)	TOTAL (km)
15 kV FONDATION 2	1.7	8.9	4.0	12.9
15 kV HOTEL DEPUTE	1.0	9.5	0.0	9.5
15 kV INSET	2.6	15.3	0.0	15.3
15 kV LYCEE GARCON	3.9	13.3	0.0	13.3
15 kV VILLE 3/1	4.3	27.0	37.6	64.6
15 kV VILLE 3/2	5.4	22.7	19.5	42.2
15 kV VILLE 2	4.8	6.0	19.2	25.2
15 kV FONDATION 1	4.5	12.1	4.0	16.1
30 kV ZAAKRO	4.9	9.7	92.2	101.9
30 kV ZAMBAKRO	8.4	3.0	87.4	90.4
TOTAL		127.4	264.0	391.4

Source: F/S document conducted by CI-ENERGIES



Source: F/S document conducted by CI-ENERGIES

Fig. 3.4-1 Single line diagram of Yamoussoukro Distribution Network

(2) Diagnosis of existing network

In the F/S conducted by CI-ENERGIES, simulation using a network analysis software called "NEPLAN" was conducted, based on the current distribution network and load (as of 2017), as well as the expected load as of 2030. This simulation was done for both the normal situation and N-1 (when an incident occurs on an adjacent distribution feeder), and 3 elements of the distribution feeder were analyzed, namely the load, the voltage drop and the technical loss. The criteria used for the analysis are shown below. The analysis results shown in the following sections are evaluated according to the criteria below and are classified into three categories. The following explains what each color indicates: green: no problem, yellow: exceeding specified value for normal situation, red: exceeding specified value for emergency situation.

- Allowable current in normal situation: 65% of the conductor capacity
- Allowable current in emergency situations: 110% of conductor capacity
- Allowable voltage drop in normal situation: ± 7.5%
- Allowable voltage drop during emergency: ± 10%
- Distribution technical loss limit: 2% （MV only）

1) Diagnosis result based on current load (as of 2017)

○ Diagnosis result in Normal situation (Situation N)

The results of normal situation analysis based on 2017 loads are shown in Table 3.4-2, Table 3.4-3 and Table 3.4-4.

Although one feeder has a load exceeding 65% of the conductor capacity, which is the allowable current in normal situation, there is almost no problem because the majority of the network is within the limit value. However, the load on each feeder is unbalanced, so it is recommended to reconfigure the network to level the loads of each feeder.

The voltage drop and loss that exceed the specified values are observed on 6 feeders. Despite the normal situation analysis, there are some feeders that have a large voltage drop that exceeds the emergency specified value and distribution loss. Therefore, it is necessary to urgently reinforce the distribution network.

Table 3.4-2 Results of load factor simulation in situation N with load of 2017

Substation	Transformer 90kV/HTA	Distribution	Load at 2017 (MW)	Feeder	
				Size	Utilization
YAMOUSSOUKRO	TFO 90/15 kV 40MVA N°2	15 kV FONDATION 2	1.7	CIS 240 mm²	16.3%
		15 kV HOTEL DEPUTE	1.0	CIS 240 mm²	9.5%
		15 kV INSET	2.6	CIS 240 mm²	25.8%
		15 kV LYCEE GARCON	3.9	CIS 240 mm²	38.2%
		15 kV VILLE 3/1	4.3	CIS 240 mm²	41.5%
	TFO 90/15 kV 40 MVA N°1	15 kV VILLE 3/2	5.4	CIS 240 mm²	55.0%
		15 kV VILLE 2	4.8	Alm 93 mm²	66.3%
		15 kV FONDATION 1	4.5	CIS 240 mm²	46.2%
	TFO 90/33 kV 24 MVA N°1	30 kV ZAAKRO	4.9	Alm 93 mm²	23.1%
		30 kV ZAMBAKRO	8.4	Alm 93 mm²	55.2%

Source: F/S document conducted by CI-ENERGIES

Table 3.4-3 Results of voltage drop simulations in situation N with load of 2017

Transformer 90 kV/ HTA	Feeder	Load at 2017 (MW)	Voltage Drop
TFO 90/15 kV 40MVA N°2	15 kV FONDATION 2	1.7	1.3%
	15 kV HOTEL DEPUTE	1.0	1.5%
	15 kV INSET	2.6	3.2%
	15 kV LYCEE GARCON	3.9	2.8%
	15 kV VILLE 3/1	4.3	6.4%
TFO 90/15 kV 40 MVA N°1	15 kV VILLE 3/2	5.4	8.2%
	15 kV VILLE 2	4.8	10.0%
	15 kV FONDATION 1	4.5	7.9%
TFO 90/33 kV 24 MVA N°1	30 kV ZAAKRO	4.9	5.7%
	30 kV ZAMBAKRO	8.4	10.2%

Source: F/S document conducted by CI-ENERGIES

Table 3.4-4 Results of simulations of technical losses in situation N with load of 2017

Transformer 90 kV/ HTA	Feeder	Load at 2017 (MW)	Technical losses
TFO 90/15 kV 40MVA N°2	15 kV FONDATION 2	1.7	0.2%
	15 kV HOTEL DEPUTE	1.0	0.8%
	15 kV INSET	2.6	1.9%
	15 kV LYCEE GARCON	3.9	1.3%
	15 kV VILLE 3/1	4.3	4.1%
TFO 90/15 kV 40 MVA N°1	15 kV VILLE 3/2	5.4	3.6%
	15 kV VILLE 2	4.8	7.9%
	15 kV FONDATION 1	4.5	3.3%
TFO 90/33 kV 24 MVA N°1	30 kV ZAAKRO	4.9	4.7%
	30 kV ZAMBAKRO	8.4	1.0%

Source: F/S document conducted by CI-ENERGIES

○ Diagnosis result in incident situation (Situation N-1)

In the event of an N-1 accident, it is necessary to supply electricity using another feeder to the accident feeder excluding fault section. Therefore, there is an increase to the load and supply area of the adjacent feeders. The results of the analysis in situation N-1 based on the load of 2017 are shown in Table 3.4-5 and Table 3.4-6.

The load of all the distribution feeders is less than 110% of the conductor capacity, which is the allowable value during emergency situation. However, there are many distribution feeders whose load value measured is close to the allowable current value. Therefore, it is necessary to reinforce these distribution feeders in the near future according to the increase in demand.

The voltage drop exceeds the allowable limit in 7 feeders. In particular, in certain distribution feeders, a significant voltage drop of more than 30% is expected. Therefore, it is necessary to reinforce the distribution networks in order to avoid a significant degradation to the quality of electricity.

Table 3.4-5 Results of load rate simulations in situation N-1 with load of 2017

Feeder	Accident feeder	Load at accident (MW)	Feeder at substation		Other section	
			Size	Utilization	Size	Utilization
15 kV FONDATION 2	15 kV FONDATION 1	6.2	CIS 240 mm²	63.3%	CPI 150 mm²	81.2%
15 kV HOTEL DEPUTE	15 kV LYCEE GARCON	4.9	CIS 240 mm²	46.7%	CPI 150 mm²	42.1%
15 kV INSET	15 kV VILLE 3/2	8.0	CIS 240 mm²	81.0%	CIS 150 mm²	84.4%
15 kV LYCEE GARCON	15 kV HOTEL DEPUTE	4.9	CIS 240 mm²	47.9%	CPI 150 mm²	84.6%
15 kV VILLE 3/1	15 kV VILLE 3/2	9.7	CIS 240 mm²	97.7%	CPI 150 mm²	47.9%
	30 kV ZAMBAKRO	12.7	Alm 93 mm²	90.2%	CIS 150 mm²	100.3%
15 kV VILLE 3/2	15 kV INSET	8.0	CIS 240 mm²	82.9%	CPI 150 mm²	107.3%
	15 kV VILLE 3/1	9.7	CIS 240 mm²	97.3%	CPI 150 mm²	59.2%
15 kV VILLE 2	15 kV LYCEE GARCON	8.7	CIS 240 mm²	87.5%	CPI 150 mm²	48.0%
15 kV FONDATION 1	15 kV FONDATION 2	6.2	CIS 240 mm²	62.5%	CPI 150 mm²	36.7%
30 kV ZAAKRO	30 kV ZAMBAKRO	13.3	Alm 93 mm²	85.8%		
30 kV ZAMBAKRO	30 kV ZAAKRO	13.3	CIS 240 mm²	64.4%		

Source: F/S document conducted by CI-ENERGIES

Table 3.4-6 Results of simulations of voltage drops in N-1 situation with load of 2017

Substation	Feeder	Accident feeder	Load at accident (MW)	Voltage Drop
YAMOUSSOUKRO	15 kV FONDATION 2	15 kV FONDATION 1	6.2	9.2%
	15 kV HOTEL DEPUTE	15 kV LYCEE GARCON	4.9	4.0%
	15 kV INSET	15 kV VILLE 3/2	8.0	10.2%
	15 kV LYCEE GARCON	15 kV HOTEL DEPUTE	4.9	7.5%
	15 kV VILLE 3/1	15 kV VILLE 3/2	9.7	11.8%
		30 kV ZAMBAKRO	12.7	31.2%
	15 kV VILLE 3/2	15 kV INSET	8.0	18.5%
		15 kV VILLE 3/1	9.7	11.4%
	15 kV VILLE 2	15 kV LYCEE GARCON	8.7	5.7%
	15 kV FONDATION 1	15 kV FONDATION 2	4.5	6.7%
	30 kV ZAAKRO	30 kV ZAMBAKRO	13.3	13.4%
	30 kV ZAMBAKRO	30 kV ZAAKRO	13.3	11.3%

Source: F/S document conducted by CI-ENERGIES

2) Diagnosis result based on expected load (as of 2030)

○ Diagnosis result in Normal situation (Situation N)

The results of normal situation analysis based on the expected load of 2030 are shown in Table 3.4-7, Table 3.4-8 and Table 3.4-9.

Regarding the loads, 5 out of 10 feeders will exceed 65% of the conductor capacity in normal situation by 2030. In addition, 2 of them will be overloaded by more than 100%. Regarding voltage drop and loss of distribution lines, more than half of the distribution feeders will exceed the specified values. If there is no investment in the distribution network in the city of Yamoussoukro, where a constant increase in demand is expected, then it is expected that a shortage of supply capacity and a significant drop in the quality of electricity will occur. Therefore, it is necessary to reinforce the distribution network in order to avoid such problems.

Table 3.4-7 Results of load factor simulation in situation N with load of 2017 to 2030

Feeder	Utilization of distribution line (%)													
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
15 kV FONDATION 2	16.3	17.0	18.1	19.3	20.5	21.7	22.8	24.0	25.2	26.3	27.5	28.7	29.9	31.1
15 kV HOTEL DEPUTE	10.0	10.1	10.1	10.1	10.1	10.1	10.1	10.2	10.2	10.2	10.2	10.2	10.2	10.2
15 kV INSET	25.9	27.0	28.8	30.5	32.4	34.1	36.0	37.8	39.7	41.4	43.2	45.1	46.9	48.8
15 kV LYCEE GARCON	38.3	39.9	43.6	45.2	47.9	50.6	53.4	56.1	58.8	61.5	64.2	67.0	69.7	72.6
15 kV VILLE 3/1	41.7	43.5	46.4	49.3	52.3	55.3	58.3	61.2	64.3	67.3	70.3	73.4	76.5	79.4
15 kV VILLE 3/2	55.5	57.9	61.8	65.7	69.8	73.8	77.8	81.8	85.8	89.9	94.1	98.1	102.2	106.3
15 kV VILLE 2	66.3	69.1	73.8	78.5	83.1	87.9	92.6	97.5	102.3	107.2	112.0	116.9	122.0	126.9
15 kV FONDATION 1	46.6	48.6	51.8	55.2	58.5	61.8	65.1	68.4	71.8	75.1	78.5	81.9	85.3	88.7
30 kV ZAAKRO	23.1	23.4	23.6	23.9	24.2	24.5	24.7	25.0	25.4	25.6	25.9	26.3	26.5	26.9
30 kV ZAMBAKRO	55.2	55.8	56.5	57.1	57.8	58.5	59.2	60.0	60.7	61.4	62.1	62.8	63.6	64.4

Source: F/S document conducted by CI-ENERGIES

Table 3.4-8 Results of voltage drop simulations in situation N with load of 2017 to 2030

Feeder	Voltage drop (%)													
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
15 kV FONDATION 2	1.3	1.3	1.5	1.6	1.7	1.9	2.0	2.1	2.3	2.4	2.5	2.7	2.8	3.0
15 kV HOTEL DEPUTE	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9
15 kV INSET	3.5	3.6	3.9	4.1	4.3	4.8	4.5	4.8	5.1	5.3	5.6	5.9	6.1	6.4
15 kV LYCEE GARCON	2.8	2.9	3.0	3.2	3.6	3.9	4.1	4.4	4.6	4.9	5.1	5.3	5.6	5.8
15 kV VILLE 3/1	6.4	6.7	7.2	7.6	8.1	8.7	9.2	9.7	10.2	10.7	11.2	11.7	12.3	12.8
15 kV VILLE 3/2	8.2	8.5	8.5	9.6	10.1	10.6	10.6	11.1	11.6	12.1	12.7	13.2	13.7	14.2
15 kV VILLE 2	10.0	10.4	11.1	11.7	12.4	13.1	13.7	14.4	15.1	15.8	16.5	17.2	17.9	18.7
15 kV FONDATION 1	7.9	8.1	8.6	9.1	9.6	10.1	11.1	11.7	12.2	12.8	13.3	13.9	14.4	15.0
30 kV ZAAKRO	5.7	5.9	6.1	6.2	6.4	6.6	6.8	7.0	7.3	7.5	7.7	7.9	8.1	8.4
30 kV ZAMBAKRO	10.2	10.4	10.7	10.9	11.2	11.4	11.7	12.0	12.2	12.5	12.8	13.1	13.4	13.7

Source: F/S document conducted by CI-ENERGIES

Table 3.4-9 Results of simulations of technical losses in situation N with load of 2017 to 2030

Feeder	Technical losses (%)													
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
15 kV FONDATION 2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
15 kV HOTEL DEPUTE	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3
15 kV INSET	1.9	1.8	1.9	2.0	2.2	2.3	2.4	2.5	2.7	2.8	3.0	3.1	3.2	3.3
15 kV LYCEE GARCON	1.3	1.4	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
15 kV VILLE 3/1	4.1	3.2	3.5	3.7	3.9	4.2	4.4	4.6	4.9	5.1	5.4	5.6	5.9	6.1
15 kV VILLE 3/2	3.6	3.8	4.0	4.3	4.6	4.9	5.2	5.4	5.7	6.0	6.3	6.6	6.9	7.2
15 kV VILLE 2	7.9	8.3	8.9	9.5	10.1	10.7	11.3	12.0	12.6	13.3	13.9	14.6	15.3	13.0
15 kV FONDATION 1	3.3	3.4	3.6	3.9	4.2	4.4	4.7	4.9	5.2	5.4	5.7	6.0	6.2	6.5
30 kV ZAAKRO	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6
30 kV ZAMBAKRO	5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0

Source: F/S document conducted by CI-ENERGIES

(3) Reinforcement Plan for Yamoussoukro distribution network

As a result of the above analysis, the project to reinforce the distribution network shown in Fig. 3.4-2 has been formulated. It should be noted that the same network analysis was also performed on the distribution network model after the reinforcement, and it was confirmed that there would be no problems in supply capacity and quality. Example of the simulation results is shown in Table 3.4-10.

Table 3.4-10 Results of simulations of voltage drop

Feeder	Voltage drop (%)													
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
15 kV FONDATION 2	1.3	1.4	1.5	1.6	1.73	1.9	2	2.13	2.3	2.4	2.5	2.7	2.8	3
15 kV HOTEL DEPUTE	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.4	2.5	2.6	2.7	2.8	2.9
15 kV INSET	3.5	3.6	3.9	4.1	4.3	4.5	4.8	4.8	5.07	5.3	5.6	5.9	6.1	6.4
15 kV LYCEE GARCON	2.8	2.9	3	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.2	4.4	4.6
15 kV VILLE 3/1	6.4	6.7	7.2	3	3.3	3.5	3.7	3.9	4.1	4.3	4.6	4.8	5	5.2
15 kV VILLE 3/2	8.2	8.5	8.5	5.9	6.2	6.5	6.8	7.1	7.4	7.6	8	8.3	8.6	8.9
15 kV VILLE 2	8.7	9.4	9.9	5.9	6.2	6.5	6.8	7.1	7.4	7.50%	7.9	8.3	8.6	8.9
15 kV FONDATION 1	7.9	8.1	8.6	6	6.1	6.2	6.5	6.8	7.1	7.4	7.7	8	8.3	8.6
30 kV ZAAKRO	5.7	5.9	6.1	6.2	6.4	6.6	6.8	7	7.3	7.5	7.7	7.9	8.1	8.4
30 kV ZAMBAKRO	10.2	10.4	10.7	5.9	5.9	6.2	6.4	6.5	6.7	6.8	7	7.2	7.3	7.5

Source: F/S document conducted by CI-ENERGIES

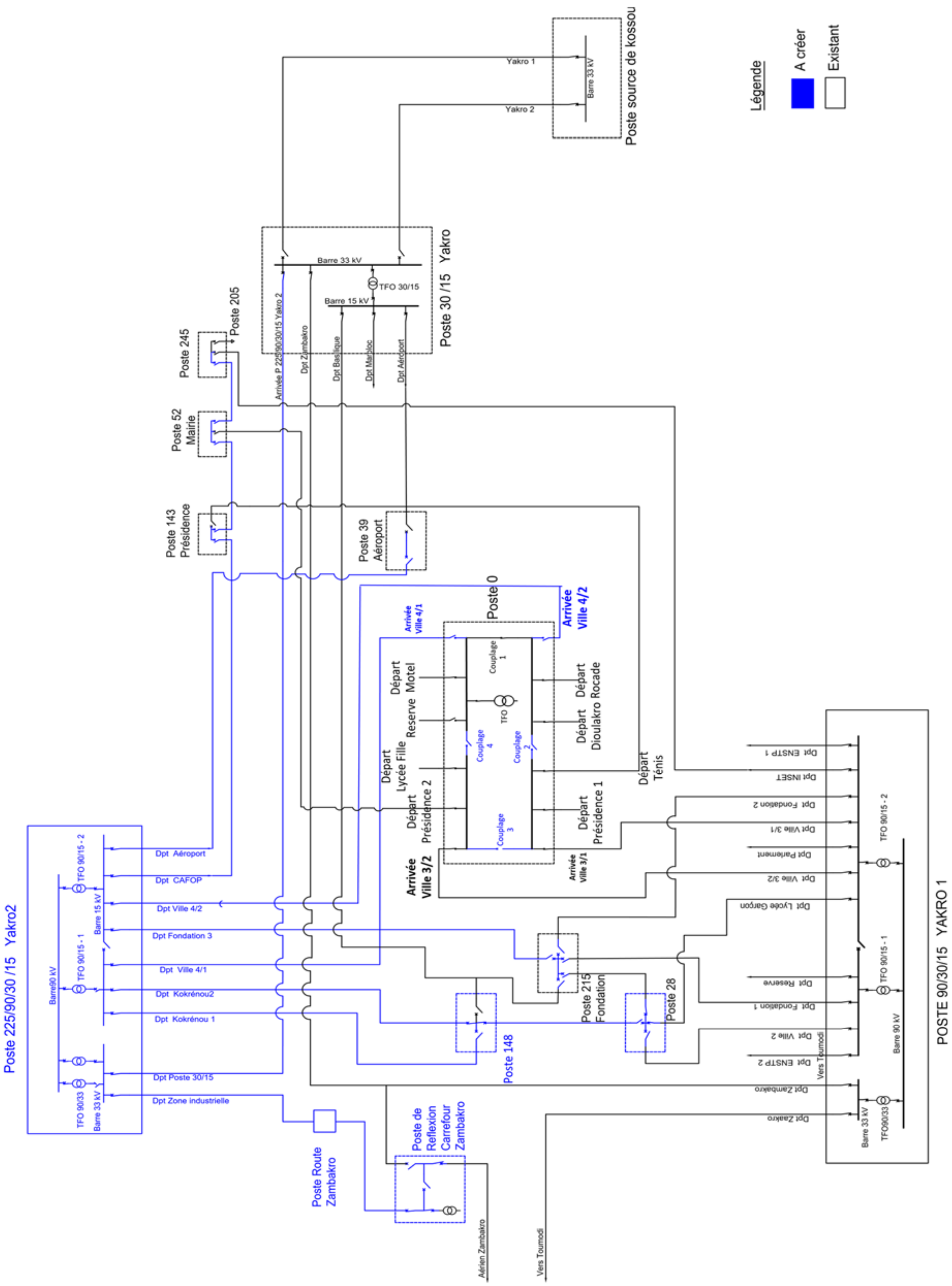


Fig. 3.4-2 Reinforcement plan for Yamoussoukro distribution network

3.4.2 Reinforcement Plan for the Bouaké Distribution Network

(1) Current situation of the Bouaké Distribution Network

The distribution network in Bouaké is supplied by two source substations: the Bouaké 1 substation (90/30/15 kV) and the Bouaké 2 substation (225/90 / 15kV)

The Bouaké 1 substation is connected to the trunk transmission line by two 90kV transmission line, Bouaké 1 – Kossou line and Bouaké 1 – Bouaké 2 line. The substation consist of three transformers, one unit of 90 / 30kV- 10MVA and two units of 90/15kV - 36MVA.

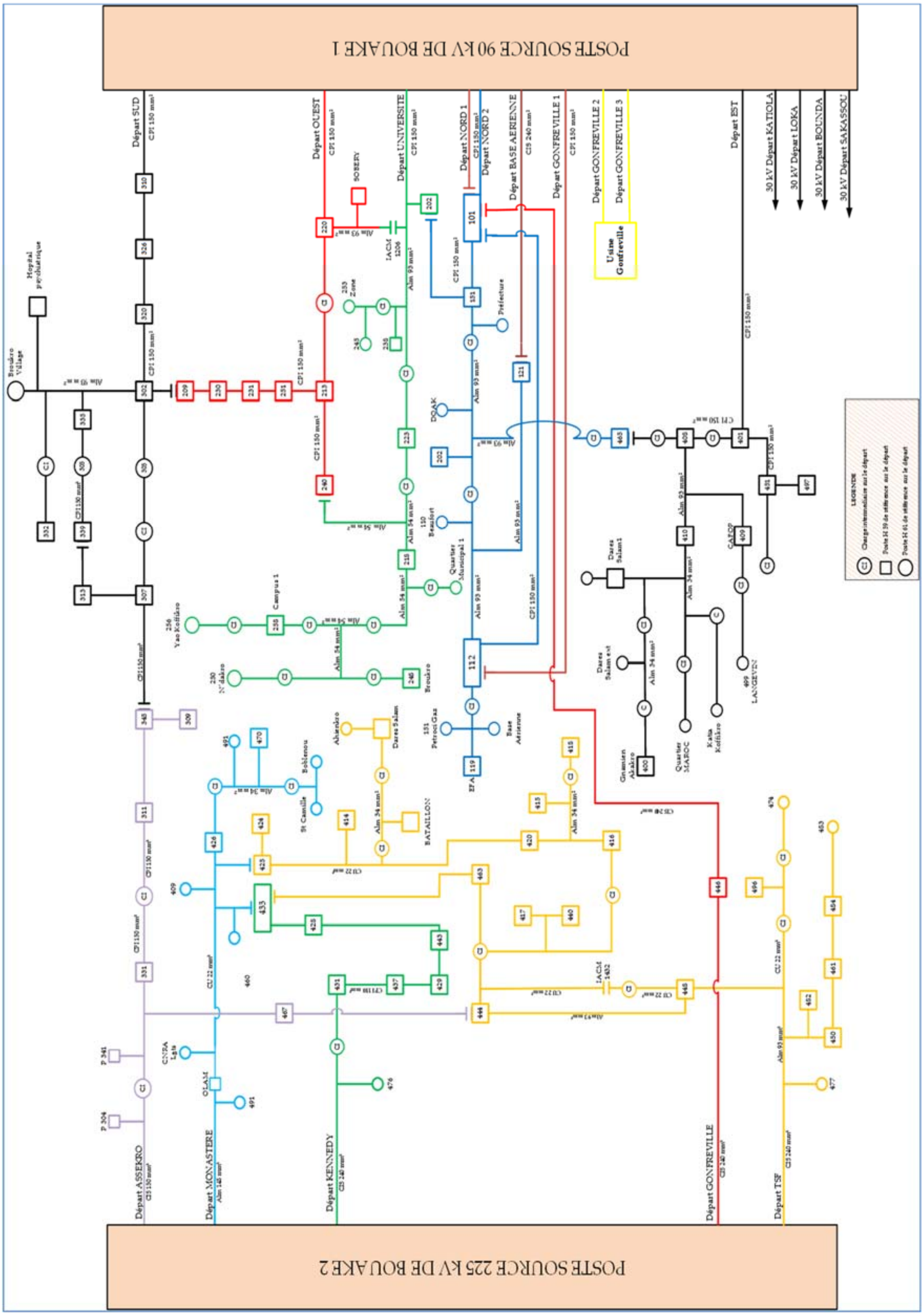
The Bouaké 2 substation is connected to the 225 kV Bouaké 2-Kossou and Bouaké 2-Ferké trunk transmission lines, and is connected to the distribution network via two unit of 90/15 kV, 36 MVA transformers.

The distribution feeders from the above two substation are currently operating 19 feeders, 15kV - 15 lines and 30kV - 4 lines. The list of distribution feeders is shown in Table 3.4-11, and the single line diagram of distribution network is shown in Table 3.4-11.

Table 3.4-11 The List of Distribution feeders in Bouaké

Substation	Name of Feeder	Load (MW)	Underground (km)	Overhead (km)	TOTAL (km)
BOUAKE 1	15 kV Nord	3.1	0.8	15.3	16.1
	15 kV Nord 2	0.0	0.8	0.0	0.8
	15 kV EST	6.3	5.0	13.8	18.8
	15 kV OUEST	4.3	5.0	2.7	7.7
	15 kV SUD	3.7	7.5	6.5	14.0
	15 kV UNIVERSITE	5.4	2.6	22.9	25.4
	15 kV BASE AERIENNE	0.0	1.8	2.0	3.8
	15 kV GONFREVILLE 1	0.0	5.5	0.0	5.5
	15 kV GONFREVILLE 2	0.0	3.9	0.0	3.9
	15 kV GONFREVILLE 3	0.0	3.9	0.0	3.9
	33 kV BOUNDA	1.0	0.0	0.0	0.0
	33 kV KATIOLA	3.3	0.0	0.0	0.0
	33 kV LOKA	1.1	0.0	0.0	0.0
	33 kV SAKASSOU	3.6	0.0	0.0	0.0
BOUAKE 2	15 kV ASSEKRO	4.3	6.4	5.2	11.7
	15 kV KENNEDY	0.8	3.0	6.6	9.5
	15 kV MONASTERE	3.9	0.0	28.6	28.6
	15 kV TSF	4.5	5.9	23.4	29.3
	15 kV GONFREVILLE	0.6	6.9	0.0	6.9
	TOTAL		59.0	126.9	185.9

Source: F/S document conducted by CI-ENERGIES



Source: F/S document conducted by CI-ENERGIES

Fig. 3.4-3 Single line diagram of Bouaké Distribution Network

(2) Diagnosis of existing network

Similar to the city of Yamoussoukro, the necessity to reinforce the distribution network is examined using network analysis based on the load of 2017 and 2030.

1) Diagnosis result based on current load (as of 2017)

○ Diagnosis result in Normal situation (Situation N)

The results of normal situation analysis based on the load of 2017 are shown in Table 3.4-12, Table 3.4-13 and Table 3.4-14.

Although the load of two distribution feeders exceeds the allowable current of normal situation, as a whole there is no problem since majority of the feeders are within the limit. However, since there is an imbalance in the load of each distribution feeder, it is recommended to level the load of each feeder by reconfiguring the network. The 15kV GONFREVILLE 1/2/3 is a dedicated feeder for Gonfreville, however it is currently out of operation for some reason.

The voltage drop and loss that exceed the specified values are observed on 5 feeders. Some distribution feeders suffer significant voltage drop and loss, which exceed the values specified for emergency situation, even in normal situations. Therefore, it is necessary to reinforce the distribution network.

Table 3.4-12 Results of load factor simulation in situation N with load of 2017

Substation	Transformer 90kV/HTA	Distribution	Load at 2017 (MW)	Feeder	
				Size	Utilization
BOUAKE 1	TFO 90/15 kV 36 MVA N°1	15 kV NORD 2	3.1	CIS 150 mm²	42.1%
		15 kV UNIVERSITE	5.4	Alm 93 mm²	73.2%
		15 kV SUD	3.7	CIS 150 mm²	50.0%
		15 kV EST	6.3	CIS 150 mm²	85.6%
		15 kV GONFREVILLE 1	0	CIS 150 mm²	0.0%
		15 kV GONFREVILLE 2	0	CIS 150 mm²	0.0%
		15 kV GONFREVILLE 3	0	CIS 150 mm²	0.0%
	TFO 90/15 kV 36 MVA N°2	15 kV OUEST	4.3	CIS 150 mm²	56.0%
BOUAKE 2	TFO 90/36 kV 36 MVA N°1	15 kV MONASTERE	3.9	Alm 148 mm²	40.2%
		15 kV KENNEDY	0.8	Alm 148 mm²	7.8%
		15 kV ASSEKRO	4.3	CIS 150 mm²	58.0%
		15 kV GONFREVILLE (BKE	0.6	CIS 240 mm²	5.8%
		15 kV TSF	4.5	CIS 240 mm²	45.7%

Source: F/S document conducted by CI-ENERGIES

Table 3.4-13 Results of voltage drop simulations in situation N with load of 2017

Substation	Transformer 90 kV/ HTA	Feeder	Load at 2017 (MW)	Voltage Drop
BOUAKE 1	TFO 90/15 kV 36 MVA N°1	15 kV NORD 2	3.1	4.4%
		15 kV UNIVERSITE	5.4	6.9%
		15 kV SUD	3.7	3.9%
		15 kV EST	6.3	4.6%
	TFO 90/15 kV 36 MVA N°2	15 kV OUEST	4.3	1.5%
BOUAKE 2	TFO 90/36 kV 36 MVA N°1	15 kV MONASTERE	3.9	12.3%
		15 kV KENNEDY	0.8	3.0%
		15 kV ASSEKRO	4.3	5.2%
		15 kV GONFREVILLE (BKE 2)	0.6	2.0%
		15 kV TSF	4.5	6.2%

Source: F/S document conducted by CI-ENERGIES

Table 3.4-14 Results of simulations of technical losses in situation N with load of 2017

Substation	Transformer 90 kV/ HTA	Feeder	Load at 2017 (MW)	Technical losses
BOUAKE 1	TFO 90/15 kV 36 MVA N°1	15 kV NORD 2	3.1	1.0%
		15 kV UNIVERSITE	5.4	2.6%
		15 kV SUD	3.7	0.9%
		15 kV EST	6.3	2.8%
	TFO 90/15 kV 36 MVA N°2	15 kV OUEST	4.3	0.9%
BOUAKE 2	TFO 90/36 kV 36 MVA N°1	15 kV MONASTERE	3.9	7.5%
		15 kV KENNEDY	0.8	0.4%
		15 kV ASSEKRO	4.3	2.3%
		15 kV GONFREVILLE (BKE 2)	0.6	0.2%
		15 kV TSF	4.5	2.1%

Source: F/S document conducted by CI-ENERGIES

○ Diagnosis result in incident situation (Situation N-1)

In the event of an N-1 accident, it is necessary to supply electricity using another feeder to the accident feeder excluding the fault section. Therefore, there is an increase to the load and supply area of the adjacent feeders. The results of the analysis in situation N-1 based on the load of 2017 are shown in Table 3.4-15 and Table 3.4-16.

The load of the distribution feeders at the time of the incident N-1 exceeds 110% of the conductor capacity with 8 feeders, and there is a concern that a supply capacity shortage will occur during an accident. In addition, there are many distribution feeders whose load value measure is close to the allowable current. Therefore, it is expected that significant reinforcement will be required in the coming years in response to the future increase in demand.

During the N-1 simulation, the voltage drop exceeds the allowable limit in 6 feeders. In some distribution feeders, a significant voltage drop of more than 30% is expected, which represents a significant degradation in the quality of electrical energy. In addition, the voltage drop of 6 feeders exceeds 7.5%, which is the allowable value under normal situation. Therefore, the reinforcement of distribution network is an urgent task for the city of Bouake.

Table 3.4-15 Results of load rate simulations in situation N-1 with load of 2017

Substation	Feeder	Accident feeder	Load at accident (MW)	Feeder at substation		Other section	
				Size	Utilization	Size	Utilization
BOUAKE 1	15 kV NORD 2	15 kV NORD 1	3.1	CIS 150 mm²	42.1%	Alm 93 mm²	39.5%
		15 kV BASE AERIENNE	3.1	CIS 150 mm²	41.4%	Alm 93 mm²	40.0%
		15 kV GONFREVILLE (BKE 2)	3.7	CIS 150 mm²	37.5%	Alm 93 mm²	38.8%
	15 kV UNIVERSITE	15 kV OUEST	9.7	CIS 150 mm²	129.7%	Alm 93 mm²	84.6%
		15 kV NORD 2	8.5	CIS 150 mm²	115.9%	Alm 93 mm²	67.3%
	15 kV SUD	15 kV OUEST	8.0	CIS 150 mm²	105.6%		
	15 kV EST	15 kV NORD 2	9.4	CIS 150 mm²	130.7%	Alm 34 mm²	127.3%
	15 kV OUEST	15 kV UNIVERSITE	9.7	Alm 93 mm²	130.2%		
		15 kV SUD	8.0	CIS 150 mm²	108.9%		
BOUAKE 2	15 kV MONASTERE	15 kV KENNEDY	4.7	Alm 148 mm²	48.2%	CU 22 mm²	43.0%
		15 kV TSF	8.3	Alm 93mm²	112.4%	CU 22 mm²	26.9%
	15 kV KENNEDY	15 kV MONASTERE	4.7	Alm 148 mm²	48.8%	CU 22 mm²	44.2%
		15 kV TSF	5.3	Alm 93mm²	70.1%		
	15 kV ASSEKRO	15 kV TSF	8.8	Alm 93mm²	117.2%	CIS 150 mm²	41.4%
	15 kV GONFREVILLE (BKE 2)	15 kV NORD 2	3.7	CIS 150 mm²	48.1%		
	15 kV TSF	15 kV ASSEKRO	8.8	CIS 150 mm²	118.6%	CIS 150 mm²	78.1%
		15 kV MONASTERE	8.3	Alm 148 mm²	88.5%	CU 22 mm²	158.0%
		15 kV KENNEDY	5.3	Alm 148 mm²	43.4%	CIS 150 mm²	63.0%

Source: F/S document conducted by CI-ENERGIES

Table 3.4-16 Results of simulations of voltage drops in N-1 situation with load of 2017

Substation	Feeder	Accident feeder	Load at accident (MW)	Voltage Drop
BOUAKE 1	15 kV NORD 2	15 kV NORD 1	3.1	4.4%
		15 kV BASE AERIENNE	3.1	3.0%
		15 kV GONFREVILLE 1	3.1	5.2%
		15 kV GONFREVILLE	3.7	5.7%
	15 kV UNIVERSITE	15 kV OUEST	9.7	8.3%
		15 kV NORD 2	8.5	7.8%
	15 kV SUD	15 kV OUEST	8.0	4.5%
	15 kV EST	15 kV NORD 2	9.4	7.5%
	15 kV OUEST	15 kV UNIVERSITE	9.7	9.5%
		15 kV SUD	8.0	6.2%
BOUAKE 2	15 kV MONASTERE	15 kV KENNEDY	4.7	10.6%
		15 kV TSF	8.3	15.1%
	15 kV KENNEDY	15 kV MONASTERE	4.7	16.5%
		15 kV TSF	5.3	7.5%
	15 kV ASSEKRO	15 kV TSF	8.8	8.4%
	15 kV GONFREVILLE	15 kV NORD 2	3.7	2.3%
	15 kV TSF	15 kV ASSEKRO	8.8	11.1%
		15 kV MONASTERE	8.3	33.0%
		15 kV KENNEDY	5.3	12.0%

Source: F/S document conducted by CI-ENERGIES

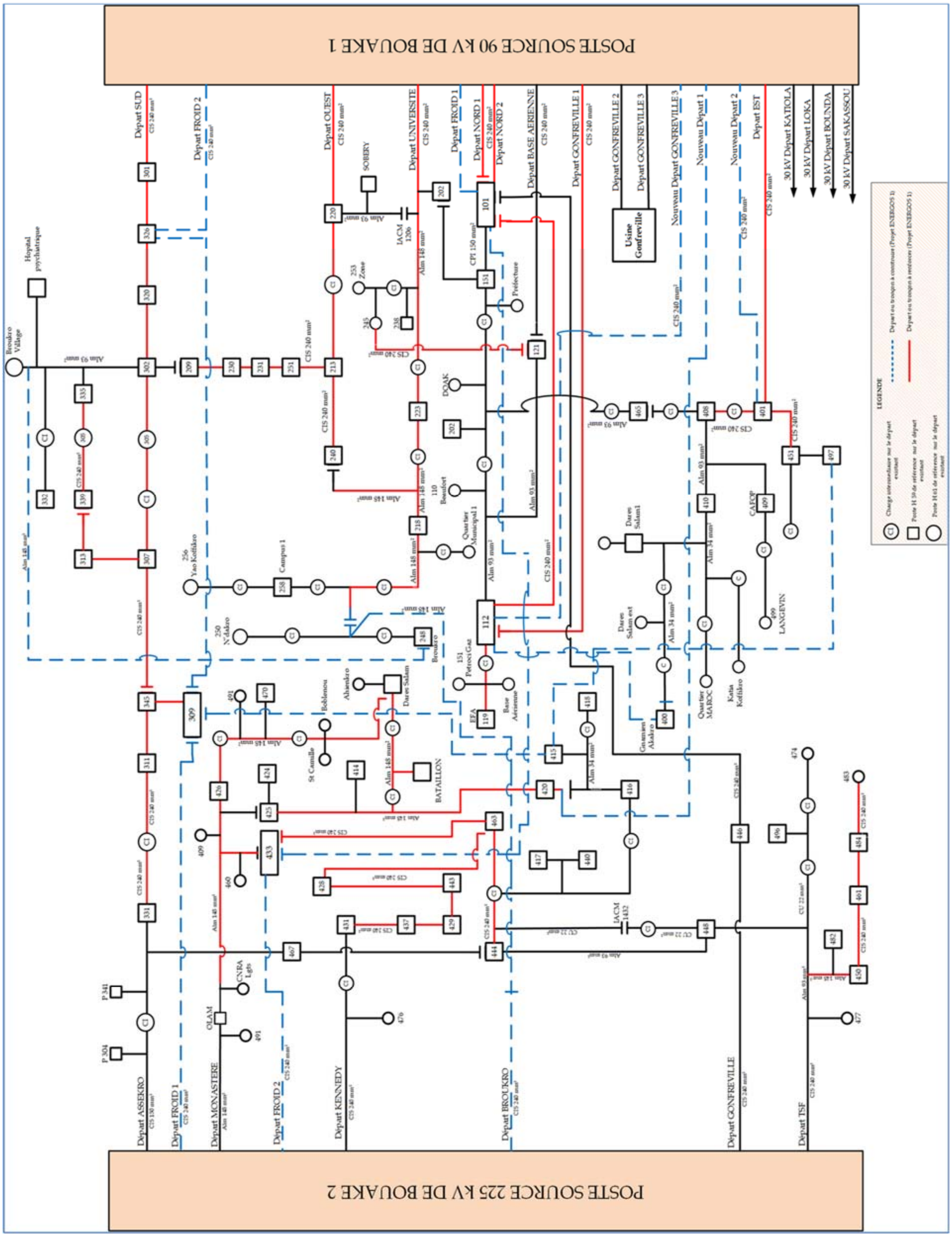
2) Reinforcement of the distribution network within the framework of the ENERGOS I project

In the city of Bouaké, a project to rehabilitate and extend the distribution network, which is called as ENERGOS I, is being implemented with the assistance of EU. This is being implemented to improve the situation of distribution network mentioned above. The objective of this project includes:

- Reinforcement and rehabilitation of existing distribution network
- Expansion of distribution network
- Automation and remote control of distribution network

In this project, in response to the above-mentioned objectives, several components have been formulated, such as 8 new distribution feeders, rehabilitation of existing distribution feeders, strengthening of interconnections between feeders, reinforcement of low-voltage distribution substations (45 renovation and 30 new installations), and expansion of low-voltage distribution network, etc. This project is currently in progress and is set for completion in 2020. Figure 3.4 4 shows the single-line diagram for the city of Bouaké after the completion of ENERGOS I project.

In the F/S conducted by CI-ENERGIES, the same network analysis was conducted on the distribution network after the implementation of the ENERGOS I project. It has been confirmed that the problems related to the Bouaké distribution network under the load of 2017 will be improved, in general.



Source: F/S document conducted by CI-ENERGIES

Fig. 3.4-4 Distribution network in the city of Bouaké after the completion of ENERGOS I

3) Diagnosis result based on expected load (as of 2030)

In the F/S study conducted by CI-ENERGIES, the network analysis of Bouaké distribution network after the completion of ENERGOS I project is carried out based on the expected load of 2030. The details of the analysis are shown below.

○ Diagnosis result in Normal situation (Situation N)

The results of normal situation analysis based on the expected load of 2030 are shown in Table 3.4-17, Table 3.4-18 and Table 3.4-19.

Regarding the loads of distribution feeders, 7 feeders will exceed 65% of the conductor capacity by 2030, which is the allowable current in normal situation. In addition, 4 of them will be overloaded by more than 100%. Regarding voltage drop and loss of distribution feeders, more than half of the distribution feeders will exceed the specified limits. If there is no investment in the distribution network for the city of Bouaké, where a constant increase in demand is expected, then it is expected that a shortage of supply capacity and a significant degradation in the quality of the electricity will occur. Therefore, it is necessary to reinforce the distribution network in order to avoid such problems in the city of Bouake.

Table 3.4-17 Results of load factor simulation in situation N with load of 2017 to 2030

Feeder	Utilization of distribution line (%)													
PS BOUAKE 1	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV NORD 2	22.7	24.8	26.9	29.1	32.2	34.4	36.6	38.7	42	44.2	47.5	49.8	53.1	56.5
15 kV NORD 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV UNIVERSITE	45.8	51.1	55.3	59.6	65	69.3	73.7	79.2	84.7	89.2	94.8	101.5	107.3	114.2
15 kV SUD	36.9	42.2	45.3	48.5	52.8	57.1	60.4	64.7	69.1	73.5	78	82.5	88.1	92.7
15 kV EST	46.8	52.1	56.3	61.6	66	71.3	75.6	81.1	85.5	91	96.6	103.3	108.9	115.8
15 kV GONFREVILLE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV GONFREVILLE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Nveau Dpt Gonf3	6.9	7.4	8	8.5	9	9.9	10.9	12	13.2	14.5	15.9	17.5	19.3	21.2
15 kV OUEST	42.2	47.2	51.1	55.1	60.2	64.2	68.2	72.2	77.3	81.4	85.8	90.4	95.3	100.4
15 kV BASE AERIENNE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Départ 1 BKE1	31.4	34.4	37.5	40.6	43.7	46.8	49.9	53	56.1	60.3	64.84	69.71	74.94	80.56
15 kV Départ 2 BKE1	23.1	24.1	25.1	26.1	27.1	28.2	29.3	30.5	31.7	33	34.3	35.7	37.1	38.6
15 kV Dpt froid 1 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 k V Dpt froid 2 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PS BOUAKE 2	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV MONASTERE	19	21.1	23.1	24.2	26.3	28.4	30.6	32.7	34.9	37.1	39.3	41.5	43.8	47.1
15 kV KENNEDY	8.6	9.6	10.7	11.7	12.7	12.8	13.8	14.9	15.9	17	18.1	19.1	20.2	21.3
15 kV ASSEKRO	57.2	64.1	69.7	75.3	82.3	88	93.7	99.5	106.7	112.5	119.7	127.1	134.5	143.4
15 kV GONFREVILLE 4	5.7	6.7	6.8	7.8	7.8	8.8	9.9	9.9	10.9	10.9	12	13.1	14.1	14.2
15 kV TSF	29.9	34.1	37.2	40.4	43.5	46.7	49.9	53.1	56.4	59.6	62.9	67.2	71.6	75
15 kV Nveau Dpt Broukro	9.2	11.2	11.2	12.3	13.3	14.4	15.5	16.5	17.6	18.7	19.8	20.9	22	23.1
15 kV Dpt froid 1 BKE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Dpt froid 2 BKE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: F/S document conducted by CI-ENERGIES

Table 3.4-18 Results of voltage drop simulations in situation N with load of 2017 to 2030

Feeder	Voltage drop (%)													
PS BOUAKE 1	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV NORD 2	2.2	2.5	2.7	3.0	3.3	3.6	3.8	4.1	4.5	4.8	5.1	5.5	5.9	6.3
15 kV NORD 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV UNIVERSITE	4.4	5.0	5.4	5.9	6.5	7.0	7.4	8.0	8.6	9.1	9.8	10.5	11.2	11.9
15 kV SUD	3.0	3.5	3.8	4.1	4.5	4.9	5.2	5.6	6.0	6.4	6.8	7.3	7.9	8.4
15 kV EST	3.6	4.0	4.5	4.9	5.3	5.7	6.1	6.6	7.1	7.5	8.0	8.6	9.2	9.8
15 kV GONFREVILLE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV GONFREVILLE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Nveau Dpt Gonf3	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.9
15 kV OUEST	1.4	1.5	1.6	1.7	1.9	2.2	2.3	2.3	2.5	2.6	2.8	2.9	3.0	3.2
15 kV BASE AERIENNE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Départ 1 BKE1	2.7	3.0	3.2	3.5	3.8	4.3	4.4	4.5	4.9	5.3	5.6	6.0	6.4	6.9
15 kV Départ 2 BKE1	1.1	1.1	1.2	1.2	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	2.0
15 kV Dpt froid 1 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 k V Dpt froid 2 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PS BOUAKE 2	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV MONASTERE	3.7	4.3	4.7	5.0	5.6	6.0	6.5	6.6	7.5	8.0	8.5	9.1	9.6	10.4
15 kV KENNEDY	1.9	2.2	2.5	2.7	3.0	3.2	3.5	3.6	4.1	4.3	4.7	5.0	5.4	5.7
15 kV ASSEKRO	4.2	4.8	5.3	5.8	6.3	6.8	7.3	7.4	8.5	8.9	9.6	10.2	10.9	11.6
15 kV GONFREVILLE (BKE 2)	1.4	1.6	1.8	2.0	2.2	2.4	2.6	3.1	3.0	3.2	3.5	3.7	4.0	4.3
15 kV TSF	2.5	2.9	3.3	3.6	3.9	4.2	4.5	4.6	5.2	5.5	6.0	6.4	6.8	7.3
15 kV Nveau Dpt Broukro	2.0	2.1	2.4	2.6	2.9	3.1	3.5	3.8	4.2	4.6	5.1	5.6	6.1	6.7
15 kV Dpt froid 1 BKE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Dpt froid 2 BKE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: F/S document conducted by CI-ENERGIES

Table 3.4-19 Results of simulations of technical losses in situation N with load of 2017 to 2030

Feeder	Voltage drop (%)													
PS BOUAKE 1	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV NORD 2	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%
15 kV NORD 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV UNIVERSITE	1.2%	1.4%	1.5%	1.6%	1.7%	1.9%	2.0%	2.1%	2.3%	2.4%	2.6%	2.8%	3.0%	3.2%
15 kV SUD	2.1%	2.1%	2.3%	2.4%	2.6%	2.8%	3.0%	3.2%	3.5%	3.8%	4.1%	4.5%	4.9%	4.9%
15 kV EST	2.6%	2.9%	3.1%	3.4%	3.7%	4.0%	4.2%	4.6%	4.8%	5.1%	5.5%	5.9%	6.2%	6.7%
15 kV GONFREVILLE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV GONFREVILLE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Nveau Dpt Gonf3	0.0%	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	0.5%	0.5%	0.6%	0.7%	0.8%	0.8%
15 kV OUEST	0.6%	0.6%	0.8%	0.9%	1.0%	1.2%	1.4%	1.7%	2.0%	2.4%	2.9%	3.4%	4.1%	4.9%
15 kV BASE AERIENNE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Départ 1 BKE1	2.1%	2.1%	2.3%	2.4%	2.6%	2.8%	3.0%	3.2%	3.5%	3.8%	4.1%	4.5%	4.9%	5.4%
15 kV Départ 2 BKE1	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%	0.6%	0.6%	0.6%	0.7%
15 kV Dpt froid 1 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 k V Dpt froid 2 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PS BOUAKE 2	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV MONASTERE	3.3%	3.7%	4.1%	4.3%	4.8%	5.1%	5.6%	6.0%	6.4%	6.8%	7.2%	7.7%	8.1%	8.7%
15 kV KENNEDY	0.4%	0.5%	0.6%	0.6%	0.7%	0.7%	0.7%	0.8%	0.9%	0.9%	1.0%	1.0%	1.1%	1.2%
15 kV ASSEKRO	2.1%	2.3%	2.5%	2.8%	3.1%	3.3%	3.5%	3.7%	4.0%	4.2%	4.5%	4.8%	5.1%	5.5%
15 kV GONFREVILLE 4	0.0%	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	0.5%	0.5%	0.6%	0.7%	0.8%	0.8%
15 kV TSF	0.9%	1.1%	1.1%	1.3%	1.4%	1.5%	1.6%	1.7%	1.8%	1.9%	2.0%	2.1%	2.3%	2.4%
15 kV Nveau Dpt Broukro	0.0%	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	0.5%	0.5%	0.6%	0.7%	0.8%	0.8%
15 kV Dpt froid 1 BKE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Dpt froid 2 BKE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-

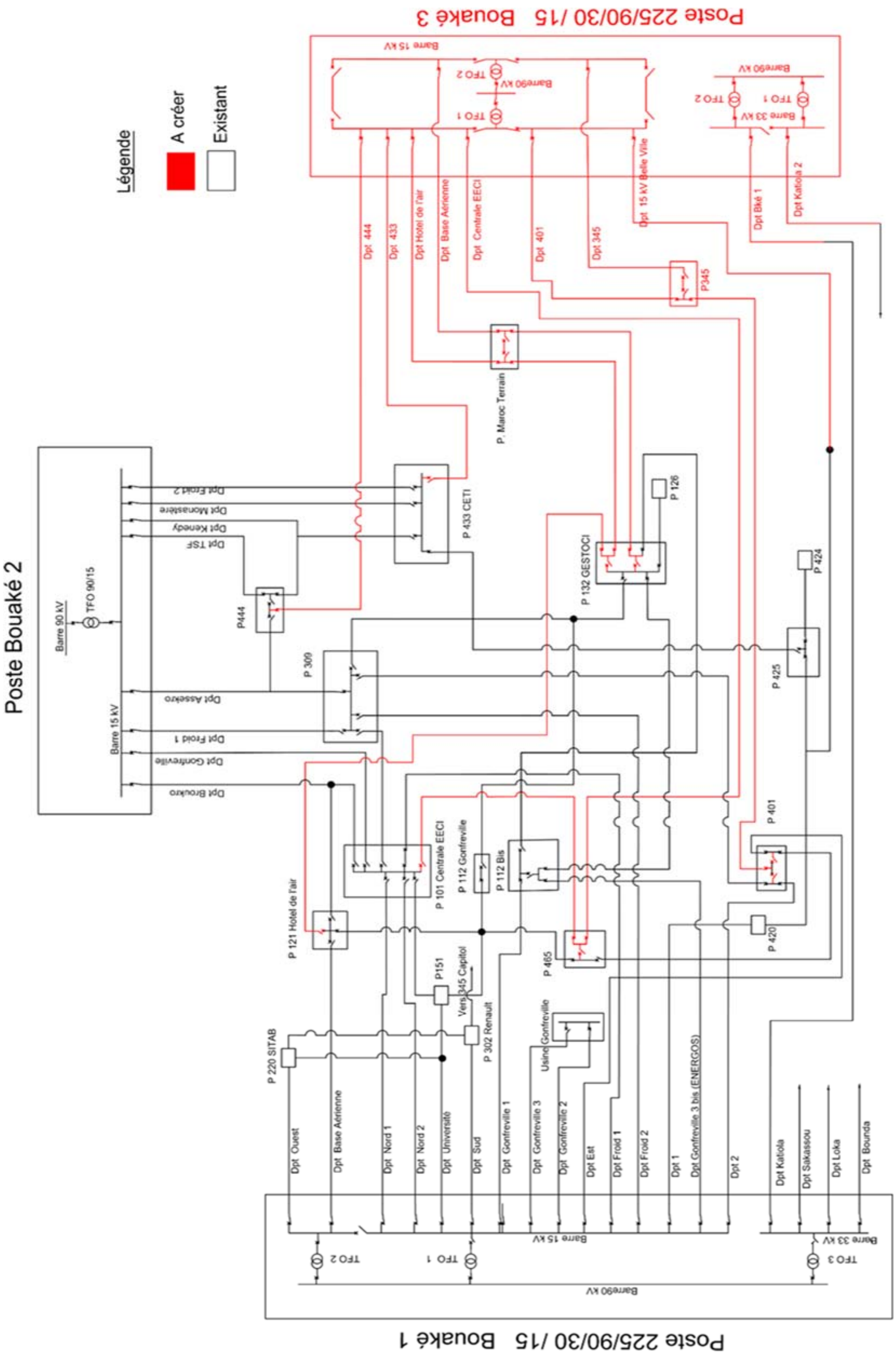
Source: F/S document conducted by CI-ENERGIES

(3) Reinforcement Plan for Bouake distribution network

As a result of the above analysis, the project to reinforce the distribution network shown in Table 3.4-19 has been formulated. It should be noted that the same network analysis was also performed on the distribution network model after the reinforcement, and it was confirmed that there would be no problems in supply capacity and quality. Example of the simulation results is shown in Table 3.4-20.

Table 3.4-20 Results of simulations of voltage drop

Feeder	Voltage drop (%)													
PS BOUAKE 1	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
15 kV NORD 2	1.6	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.4	3.7	4.0	4.4	4.8	5.2
15 kV NORD 1														
15 kV UNIVERSITE	2.2	2.5	2.7	2.9	3.2	3.4	3.7	4.0	4.4	4.7	5.1	5.6	6.0	6.5
15 kV SUD	2.4	2.8	3.0	3.3	3.6	3.9	4.2	4.6	5.0	5.5	5.9	6.5	7.0	7.4
15 kV EST	2.5	2.9	3.1	3.4	3.7	4.0	4.4	4.7	5.1	5.6	6.0	6.6	7.1	7.5
15 kV GONFREVILLE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV GONFREVILLE2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 kV Nveau Dpt Gonf3	2.5	2.5	2.6	2.7	2.8	3.0	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.2
15 kV OUEST	1.4	1.6	1.7	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.4	3.7	4.1	4.4
15 kV BASE AERIENNE														
15 kV Départ 1 BKE1	2.7	3.0	3.2	3.5	3.8	4.3	4.4	4.5	4.9	5.3	5.6	6.0	6.4	6.9
15 kV Départ 2 BKE1	1.1	1.1	1.2	1.2	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	2.0
15 kV Dpt froid 1 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 k V Dpt froid 2 BKE1	-	-	-	-	-	-	-	-	-	-	-	-	-	-



Source: F/S document conducted by CI-ENERGIES

Fig. 3.4-5 Reinforcement Plan for Bouake distribution network

3.4.3 Summary of Distribution Network Enhancement Plan

In the previous sections, the outline of the F/S carried out by CI-ENERGIES for the reinforcement of distribution network in the cities of Yamoussoukro and Bouaké are described. In the two cities, the distribution network does not have major problems as far as the current demand situation is concerned. However, there is a need to reinforce the distribution network to cope with the steady demand growth of the future. Therefore, it can be said that the reinforcement plan formulated in the F/S is necessary and valid. The overview of the plan is shown in Table 3.4-21.

Table 3.4-21 Overview of the distribution reinforcement plan in the two cities

City	Name of distribution		Length (km)	New post (Location)	Extension post (Location)	Additional Transformer (Unit)
Yamoussoukro	15kV	Ville 4/1	3.7	0	0	0
		Ville 4/2	3.7	0	0	0
		Cafop	17.7	1	8	1
		Kokrenou 1	13.8	1	7	1
		Kokrenou 2	9.4	0	2	0
		Fondation 3	8.4	0	6	1
		Aéroport	15.1	1	3	1
	33kV	Zone Industrielle	9.6	1	1	3
		Poste 30/15	0.2	0	0	0
	Total		81.6	4.0	27.0	7.0
Bouake	15kV	BASSE AERIENNE	13.3	2	4	3
		HOTEL DE L'AIR	10.9	0	3	0
		401	8.8	1	1	1
		345	10.7	0	1	0
		433	12.6	2	1	2
		tronçon EECI 1	12.4	0	3	1
		444	11.3	0	3	1
		BELLE VILLE	6.3	0	0	0
	33kV	BKE1	0.2	0	0	0
		KATIOLA	0.2	0	0	0
	Total		86.8	5	16	8

Source: F/S document conducted by CI-ENERGIES

3.5 SCOPE OF THE PROJECT

The scope of the project is shown below. The scope of the project was confirmed in consultation with CI-ENERGIES during the first field survey. Subsequently, the Yamoussoukro 2 substation and Bouake 3 substation (both newly constructed) were subject to the following process.

At the time of the first field survey, it was considered to form a separate project for the above two substations, but it was finally decided that the two substations would be included in the scope of the Project .

1) Transmission facilities

No.	From	To	Voltage (kV)	C.C.T	Remarks
1	Taabo Substation（Existing)	Kossou Substation（Existing)	225	2	Construction of Transmission line
2	Kossou Substation（Existing)	Bouaké 3 Substation（New)	225	2	Construction of Transmission line

2) Substation facilities

No.	Name of Substation	Voltage (kV)	Main contents	Remarks
3	Taabo Substation（Existing)	225	Extension of Substation	
4	Kossou Substation（Existing)	225	Extension of Substation	
5	Bouaké 2 Substation（Existing)	225	Extension of Substation	
6	Yamoussoukro2（New)	225	Construction of Substation	
7	Bouaké 3（New)	225	Construction of Substation	

3) Distribution facilities

No.	City	Main contents	Remarks
8	Yamoussoukro	Reinforcement of distribution network from Yamoussoukro 2 substation	Fig. 3.4-2
9	Bouaké	Reinforcement of distribution network from Bouaké 3 substation	Fig.3.4-7

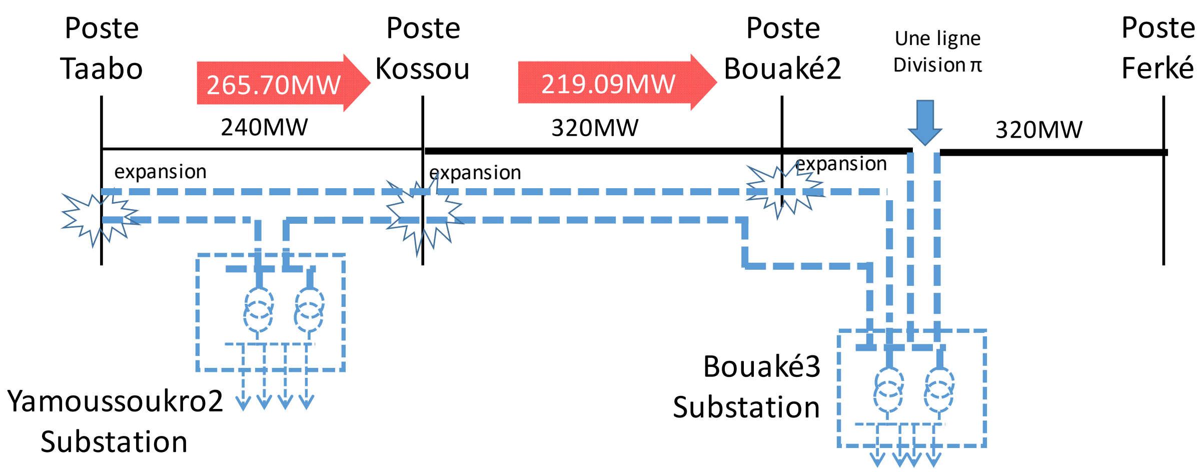


Fig. 3.5-1 Scope of the Project

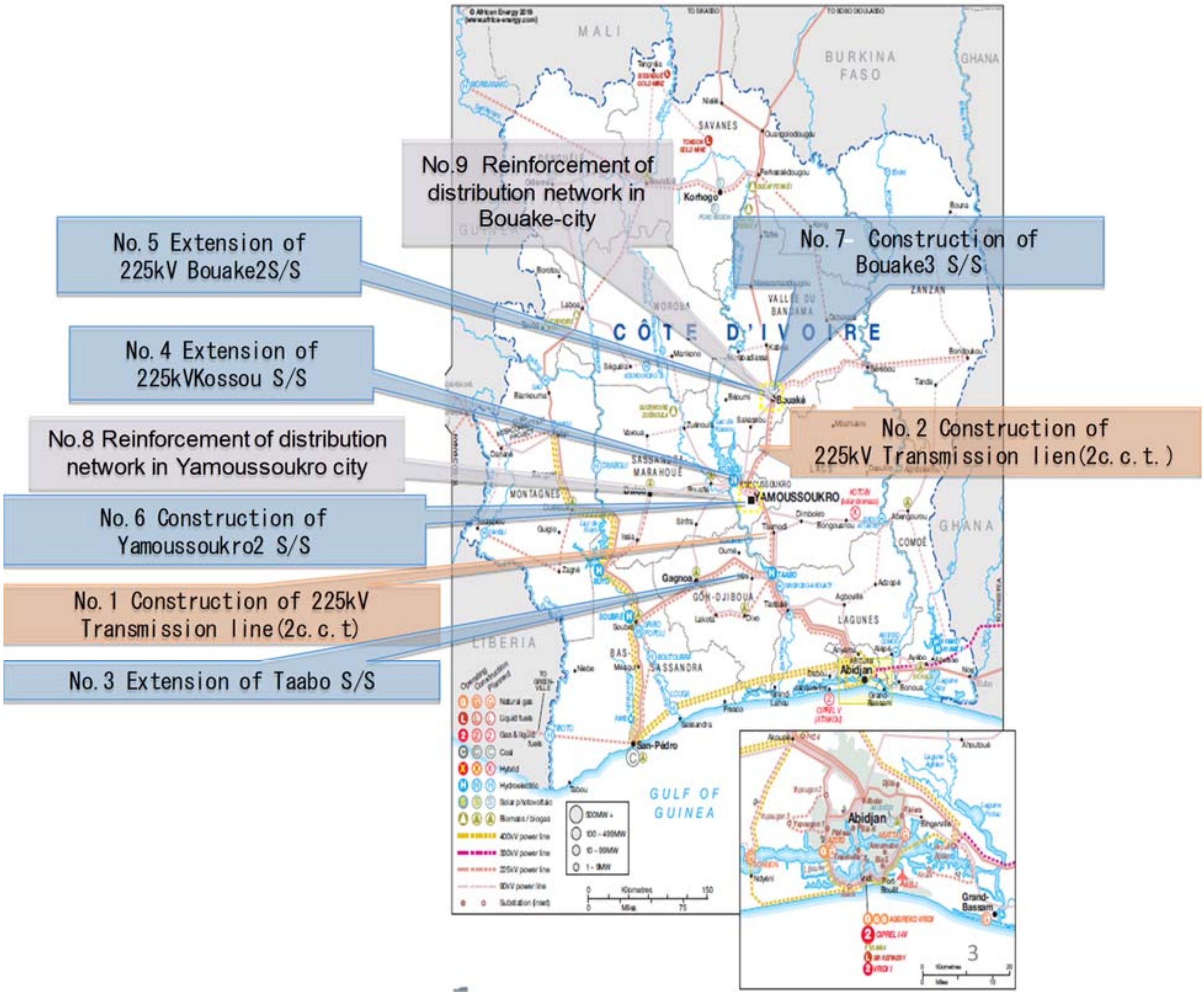


Fig. 3.5-2 Location of the Project

CHAPTER 4

RESULTS OF SITE SURVEY

CHAPTER 4 RESULTS OF SITE SURVEY

4.1 TRANSMISSION LINE

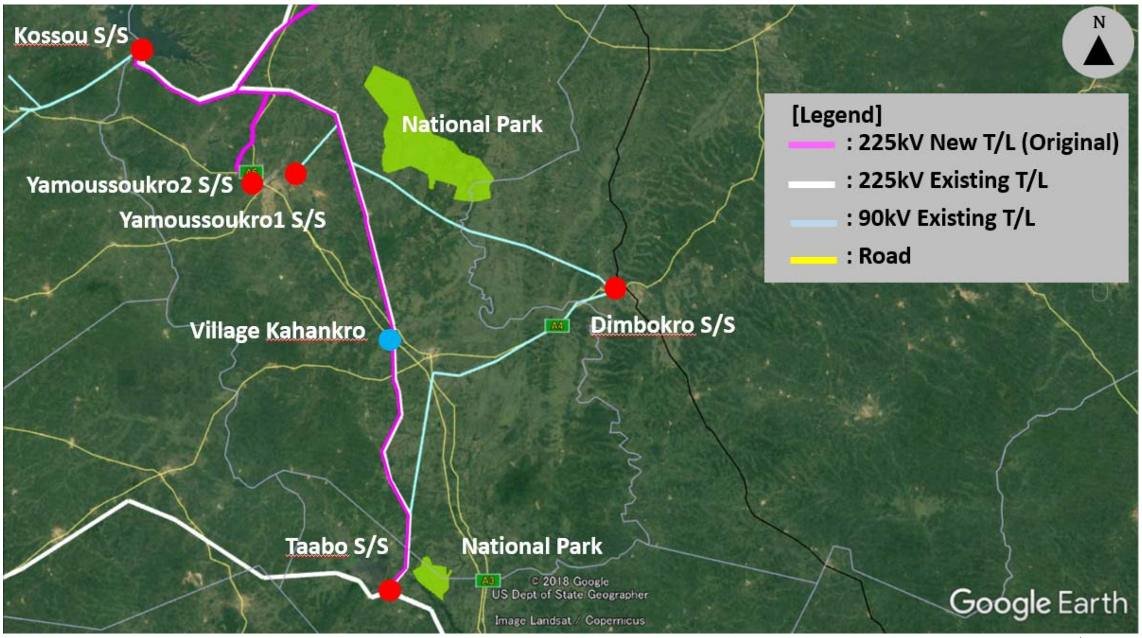
4.1.1 Transmission Line Route

(1) Transmission Line Route

Figure 4.1-1 shows the overhead transmission line route (Single Circuit) examined by POWER COM, a local consultant, in the F / S conducted by CI-ENERGIES.

A new 225kV overhead transmission line is planned between Taabo S/S - Kossou S/S – Bouaké 3 S/S. Also, π branch to Yamoussoukro 2 S/S is planned between Taabo S/S and Kossou S/S. In addition, π branch to Bouaké 2 S/S is planned between Kossou S/S and Bouaké 3 S/S.

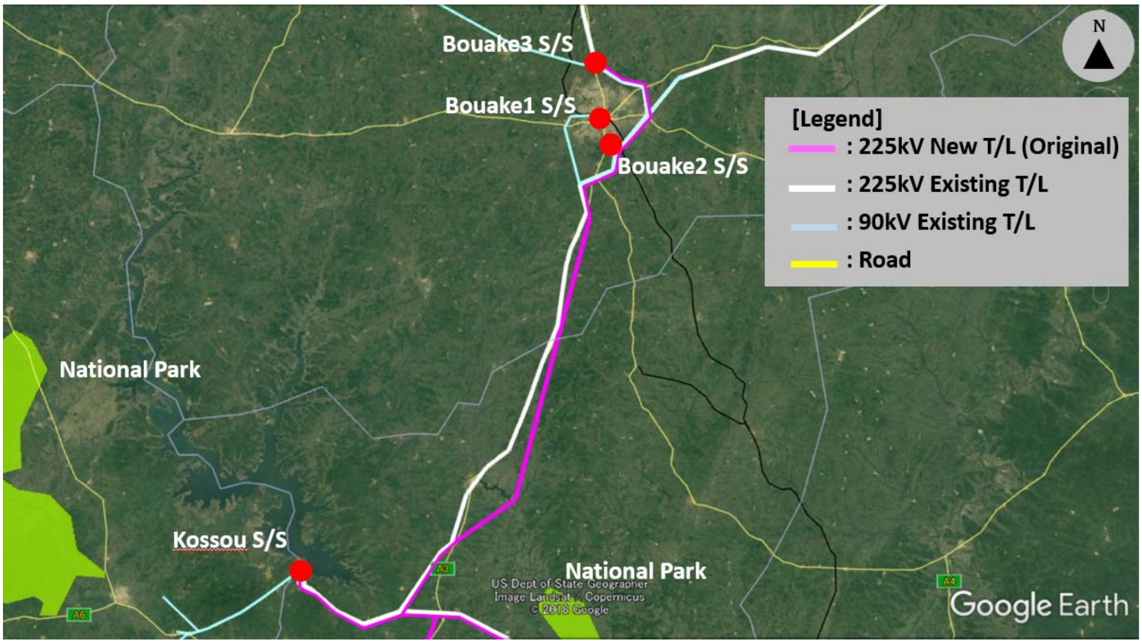
The route from Taabo S/S to Kossou S/S will be connected from the underground transmission line to the overhead transmission line on the north side of Taabo S/S. After that, the route almost runs parallel to the existing 225kV T/L, and the route partially detours near Kahankro village. The route to Yamoussoukro 2 S/S runs parallel to the main road.



Source: JICA Study Team

Fig. 4.1-1 Transmission Line Route (Taabo S/S - Kossou S/S)

The route from Kossou S/S to Bouaké 3 S/S shown in Figure 4.1-2 is planned to run parallel to the existing 225kV T/L from Kossou S/S, slightly away from the existing 225kV T/L near the main road. The route is planned to run parallel to the existing 225kV T/L from the vicinity of Bouaké 2 S/S, and then lead to Bouaké 3 S/S.



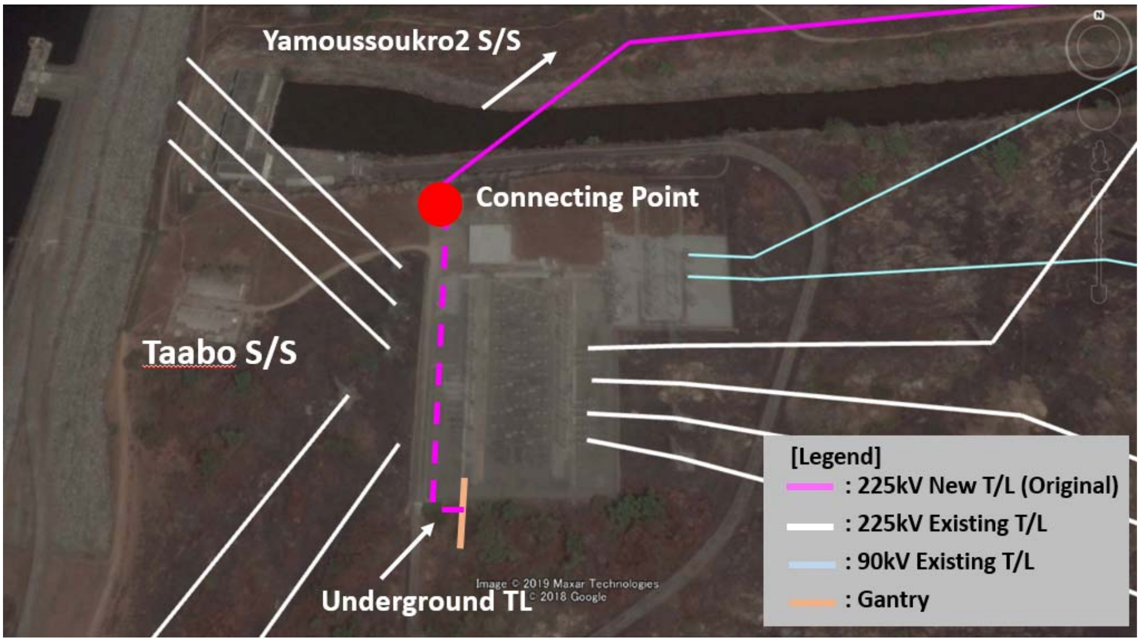
Source: JICA Study Team

Fig. 4.1-2 Transmission Line Route (Kossou S/S - Bouaké 3 S/S)

(2) Results of Route Survey of Transmission Line

1) Taabo S/S

The expansion space is located at the south of Taabo S/S, and the 225kV bus will be extended to the south. Figure 4.1 3 shows the route around Taabo S/S.



Source: JICA Study Team

Fig. 4.1-3 Route around Taabo S/S

In case that the transmission line is detoured from the south side, it is necessary to cross the existing 225kV transmission lines. So, it is planned that the underground transmission line is applied from the 225kV bus and the connecting point. After that, it will cross the spillway and go toward Kossou S/S.

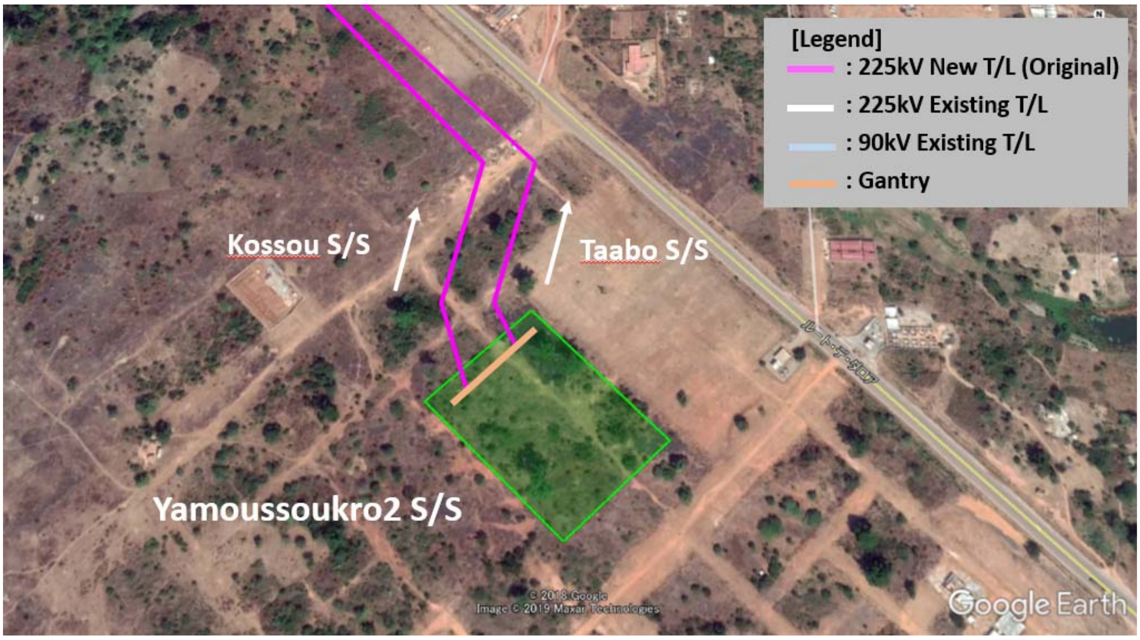
	
Taabo S/S	**Existing 225kV T/L at Taabo S/S** (Left T/L: to Kossou S/S, Right T/L's: to Abobo S/S)

Space for Connection Tower

Fig. 4.1-4 Photos of Taabo S/S and T/L

2) Yamoussoukro 2 S/S

Yamoussoukro 2 S/S will be installed on the southwest side of the dispatch center under construction. The below figure shows the route around Yamoussoukro 2 S/S. The transmission line will run parallel to the road from the northwest direction in order to avoid the residential area.



Source: JICA Study Team

Fig. 4.1-5 Route around Yamoussoukro 2 S/S

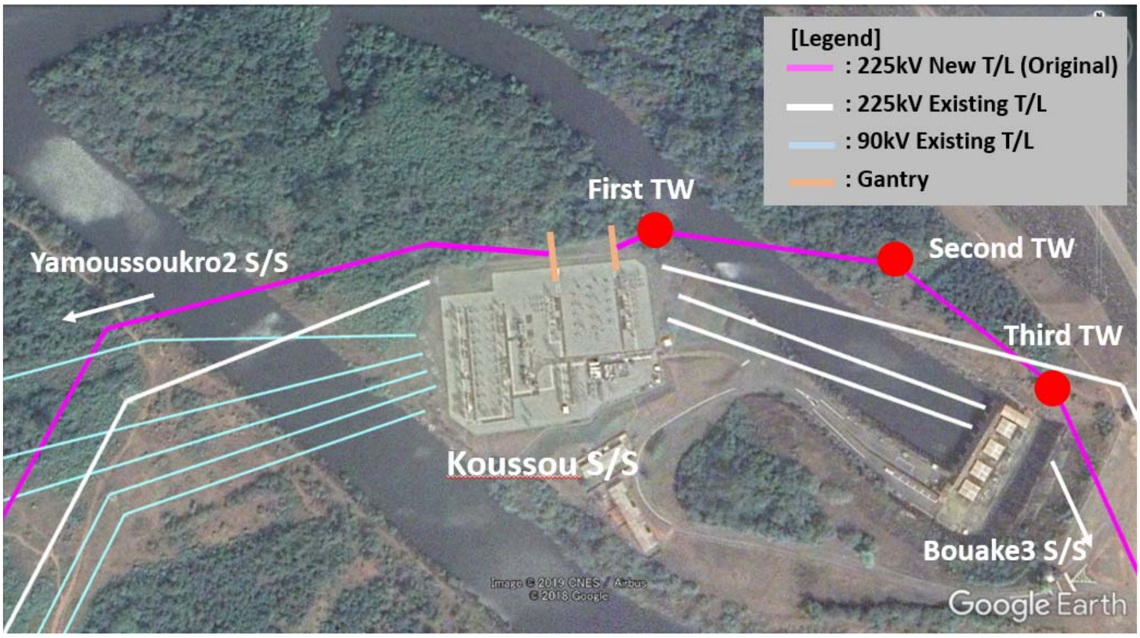
Construction Work of Dispatch Center

Substation Yard

Fig. 4.1-6 Photos of Dispatch Center and Substation Yard

3) Kossou S/S

The expansion space is located on the north side of Kossou S/S, and the 225kV bus will be extended to the north side. Figure 4.1-7 shows the route around Kossou S/S.



Source: JICA Study Team

Fig. 4.1-7 Route around Kossou S/S

The route from Yamoussoukro 2 S/S will come from the west side across the existing 90kV T/L near the substation. The route from Bouaké 3 S/S will come from the east side across the existing 225kV T/L near the substation. The location from the 1st tower to the 3rd tower is quite limited because it is necessary to come close to the spillway and cross the existing 225kV transmission line.

 Kossou S/S	 Existing 225kV T/L (to Taabo S/S)
 Existing 225kV T/L (Left T/L: to Bouaké 2 S/S, Right T/L's: to P/S)	 Existing 225kV T/L (2nd Tower from Kossou S/S to Bouaké 2 S/S)

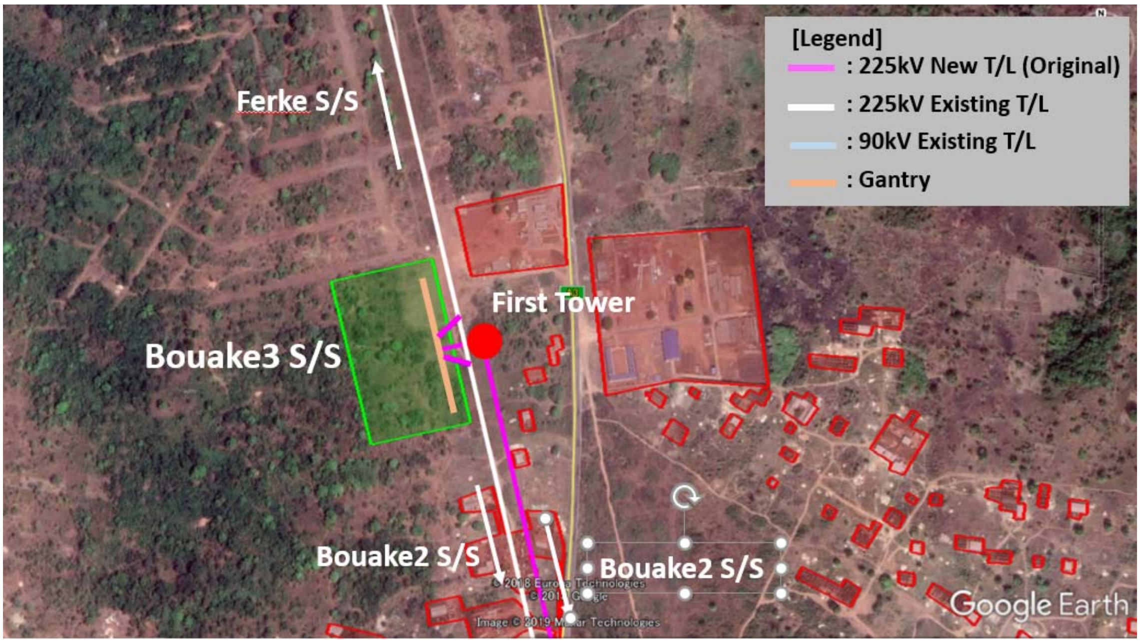
Source: JICA Study Team

Fig. 4.1-8 Photos of Transmission Line

4) Bouaké 3 S/S

Bouaké3 S/S will be constructed on the west side of the existing 225kV transmission line, and Source: JICA Study Team

Figure 4.1-9 shows the route around Bouaké3 S/S.



Source: JICA Study Team

Fig. 4.1-9 Route around Bouaké 3 S/S

The route from Kossou S/S will come from the south side and go into Bouaké 3 S/S through the 1st tower. As the houses are scattered around the substation, it is necessary to carry out large-scale relocation of residents. In addition, the existing 225kV transmission line is planned to be connected with π branch, and the transmission line from Kossou S/S is planned to be connected between the bays of π branch. The 1st tower needs to be installed at a distance from the existing 225kV transmission line.

	
Existing 225kV T/L (to Bouaké 2 S/S)	Existing 225kV T/L (to Ferke S/S)

Fig. 4.1-10 Photos of Transmission Line

5) Bouaké 2 S/S

Source: JICA Study Team

Fig. 4.1-11 shows the route around Bouaké 2 S/S.

Source: JICA Study Team

Fig. 4.1-11 Route around Bouaké 2 S/S

Since there is the graveyard on the north side of Bouaké 2 S/S, it is necessary to apply the underground transmission line in case of using the north area.

	
Existing 225kV T/L (Left T/L: to Ferke S/S, Right T/L: to Kossou S/S)	**Existing 225kV T/L** (to Serebou S/S)

Fig. 4.1-12 Photos of Transmission Line

(3) Candidate Route

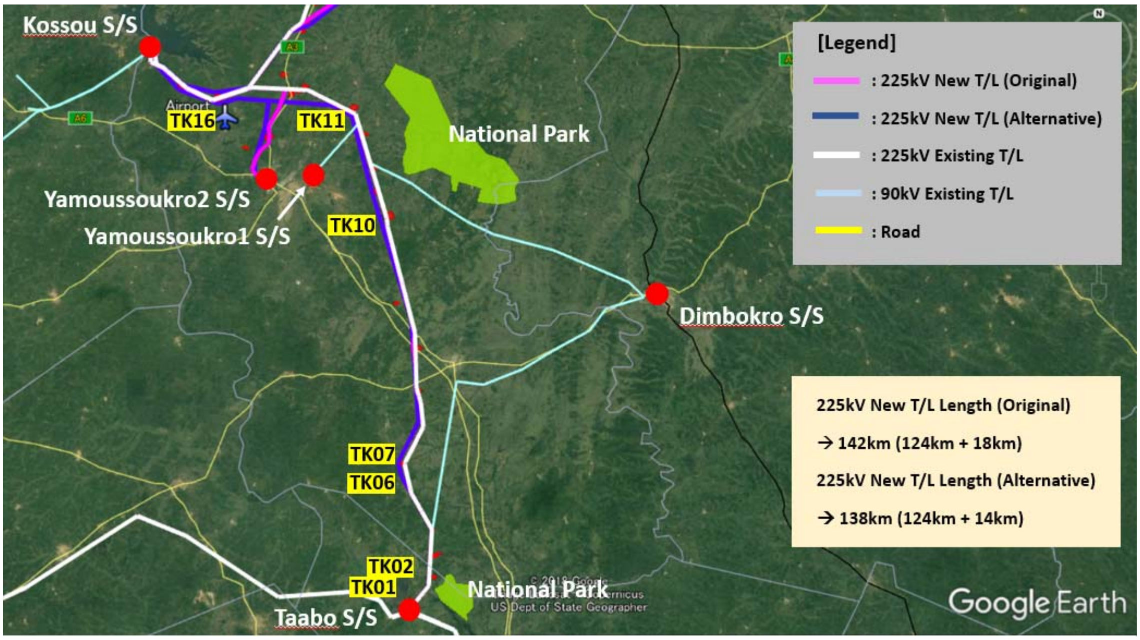
Since the route examined by POWER COM runs parallel to the existing overhead transmission line, it is necessary to pass through some villages. Thus, the large-scale relocation of residents is required.

In order to avoid the large - scale relocation of residents, a route survey was conducted based on the candidate route.

The candidate route avoids Bringakro village (near survey point TK07), Tenikro village and Amonkro village (near survey point TK16). Fig. 4.1-13 and Fig. 4.1-14 show the candidate routes and survey points.

【Survey Point】 7 points

TK01, TK02, TK06, TK07, TK10, TK11, TK16

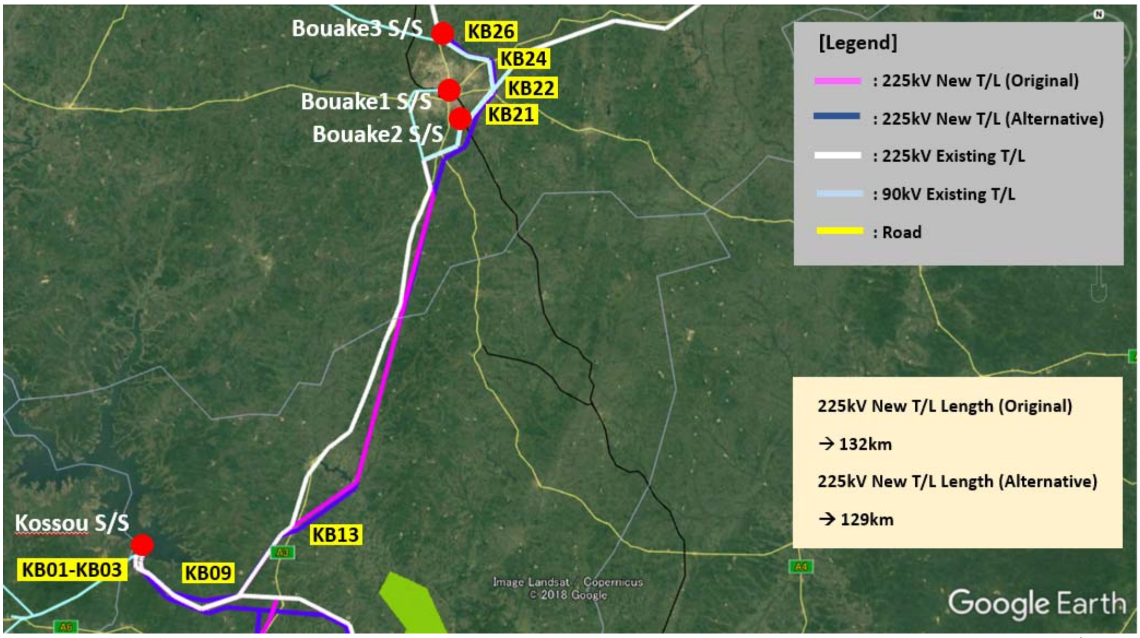


Source: JICA Study Team

Fig. 4.1-13 Candidate Route (Taabo S/S – Kossou S/S)

【Survey Point】8 points

KB01, KB02, KB03, KB09, KB13, KB21, KB22, KB24, KB26



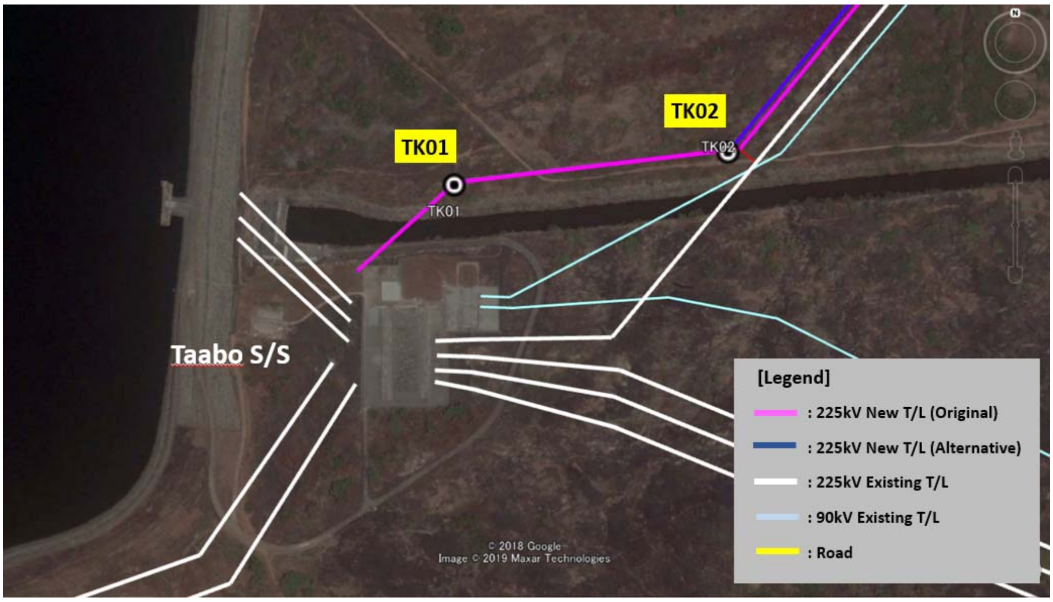
Source: JICA Study Team

Fig. 4.1-14 Candidate Route (Kossou S/S - Bouaké 3 S/S)

(4) Results of Route Survey of Candidate Route

1) TK01

TK01 Point is located on the north side of Taabo S/S and the spillway. Although there are miscellaneous trees around TK01, the tower site can be sufficiently secured and there is no problem with the route. Fig. 4.1-15 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK01 to Taabo S/S

(Miscellaneous Trees)

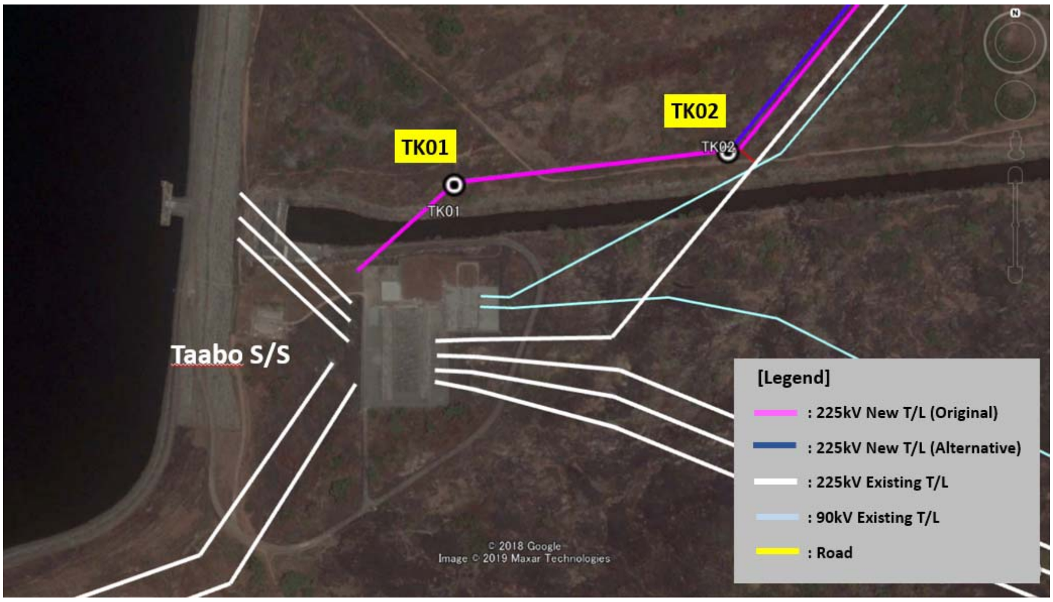
Photo from TK01 to Kossou S/S

(Miscellaneous Trees)

Fig. 4.1-15 Location Map and Photos - TK01

2) TK02

TK02 Point is located on the northeast of Taabo S/S and on the west of the existing transmission line. In addition, TK02 point is about 20m north of the road, and the surrounding area is covered with miscellaneous trees. But, the tower site can be sufficiently secured and there is no problem with the route. Fig. 4.1-16 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK02 to Taabo S/S

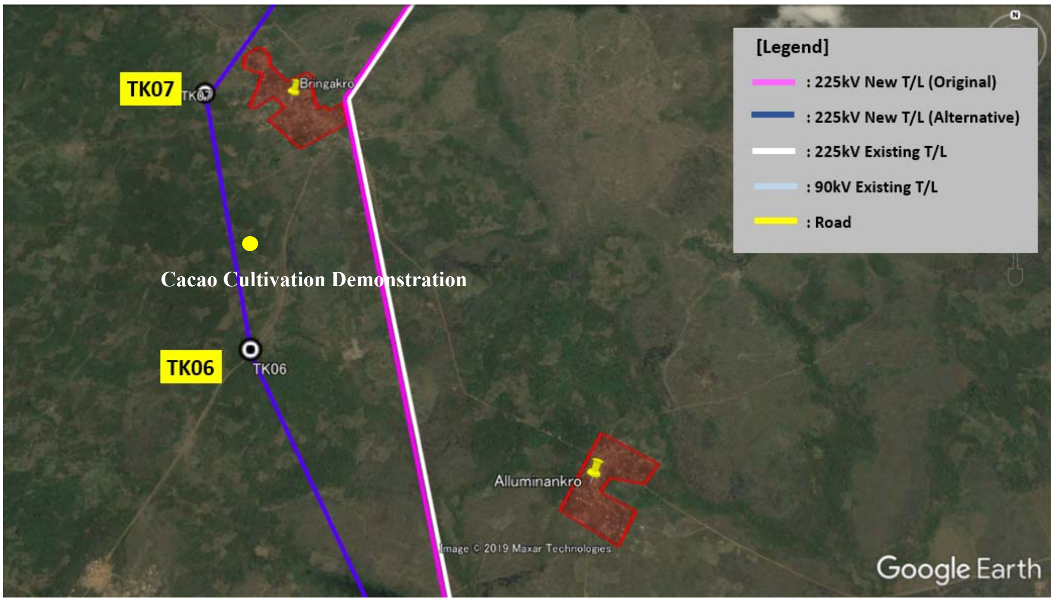
Photo from TK02 to Kossou S/S

Fig. 4.1-16 Location Map and Photos - TK02

3) TK06

TK06 Point is about 1.5 km south of Bringakro village and about 20 m east of the road. Although TK06 Point is in the banana field, the tower site can be secured sufficiently and there is no problem with the route.

There is a sign board about cacao cultivation between Bringakro village and TK06 Point, which is about 650m north of TK06 Point. Fig. 4.1-17 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK06 to Taabo S/S

(Banana Field)

Photo from TK06 to Kossou S/S

(Banana Field)

Sign Board for Cacao Cultivation

【Contents of Sign Board】

Demonstration of Cacao Cultivation

Date: 28/July/2016

Producer: BRINGA N'GORAN

Area: 0.5ha

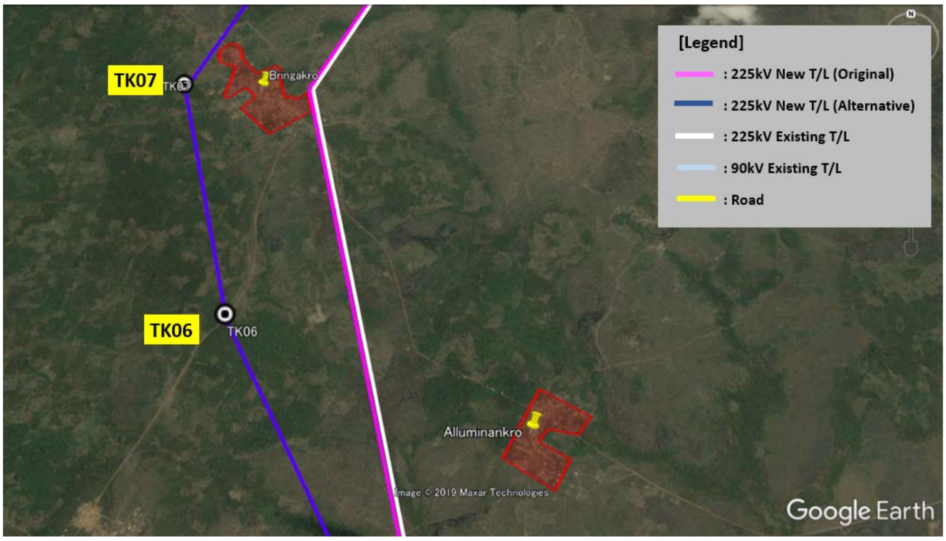
Coordinate: 6.40348N, -5.093131W

Location: Bringakro

Fig. 4.1-17 Location Map and Photos - TK06

4) TK07

TK07 Point is located on the west side of Bringakro village, and the surrounding area is covered with miscellaneous trees and weeds. The village is expanding northwest along the road, and it is thought that some house relocation will be required, so it is necessary to move Point TK07 to about 50m north. Fig. 4.1-18 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK07 to Taabo S/S

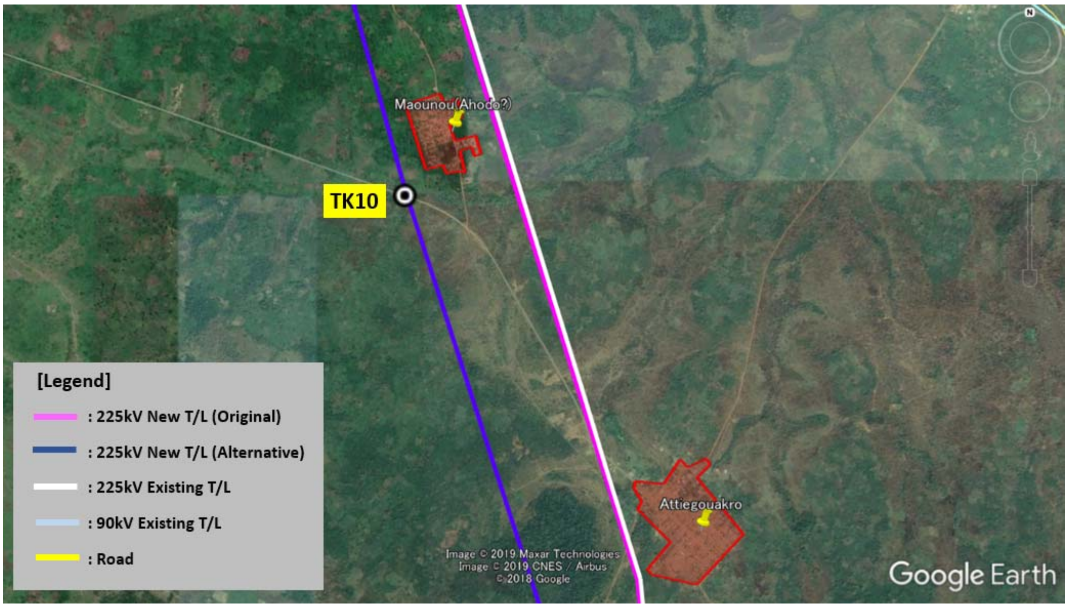
Photo from TK07 to Kossou S/S

Bringakro Village

Fig. 4.1-18 Location Map and Photos TK07

5) TK10

TK10 Point is located in a wooded area north of the road, about 20m southwest of Maounou village. As the route is far from the village, there is no problem. Fig. 4.1-19 shows the location map and the surrounding photos.



Source: JICA Study Team

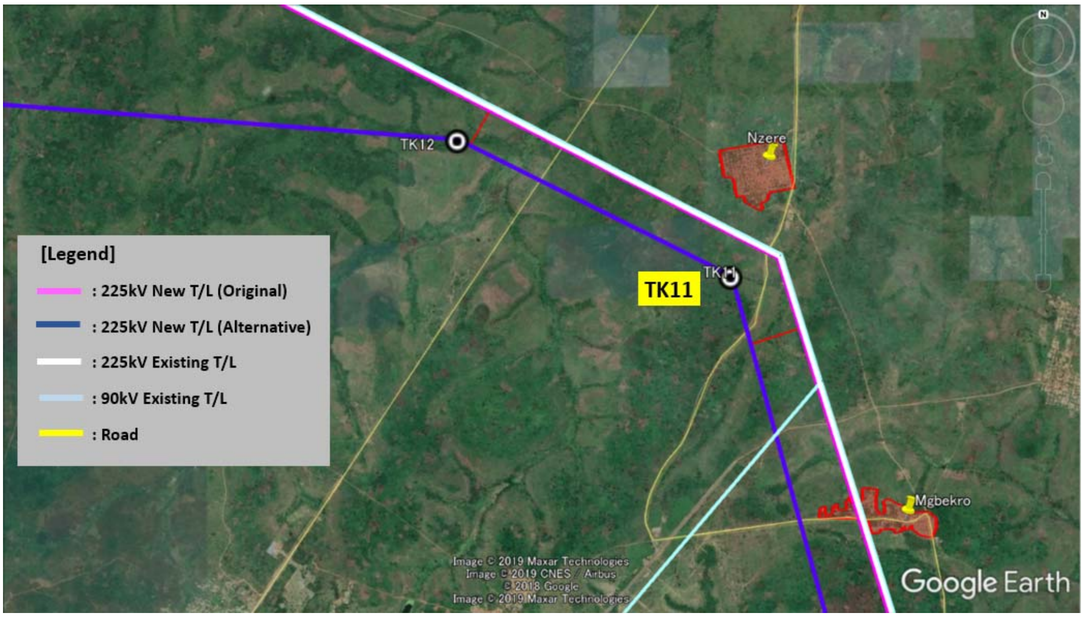
Photo from TK10 to Taabo S/S

Photo from TK10 to Kossou S/S

Fig. 4.1-19 Location Map and Photos - TK10

6) TK11

TK11 Point is located in the southwest of Nzere village, about 300m west of the road. The surrounding area is covered with miscellaneous trees and weeds, but the tower site can be secured sufficiently and there is no problem with the route. Fig. 4.1-20 shows the location map and the surrounding photos.



Source: JICA Study Team

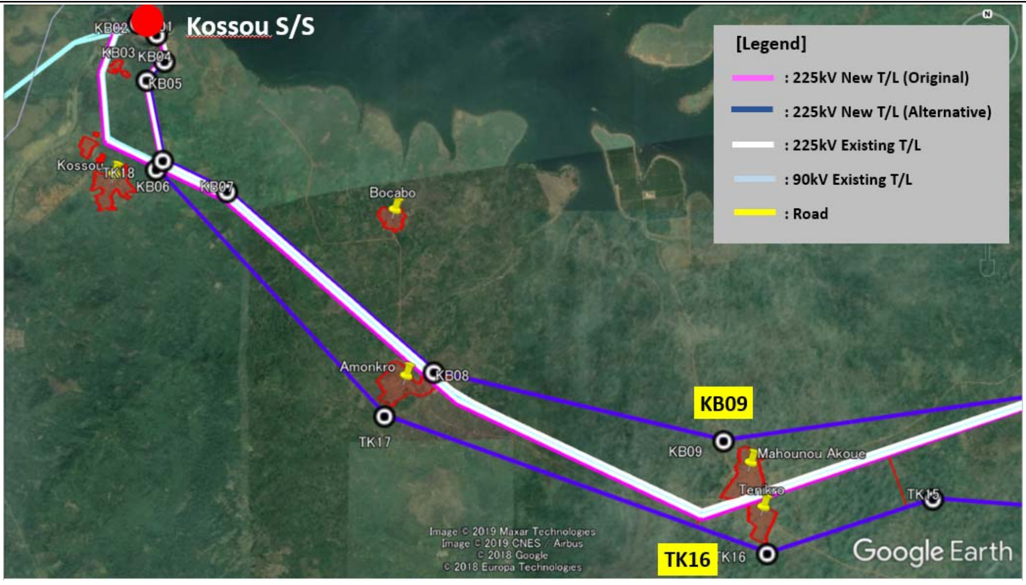
Photo from TK11 to Taabo S/S

Photo from TK11 to Kossou S/S

Fig. 4.1-20 Location Map and Photos - TK11

7) TK16

TK16 Point is located in the cacao field south of Tenikro village. It is far from the village and there is no problem with the route. Fig. 4.1-21 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK16 to Taabo S/S (Cacao Field)

Photo from TK16 to Kossou S/S (Cacao Field)

Growth of Cacao

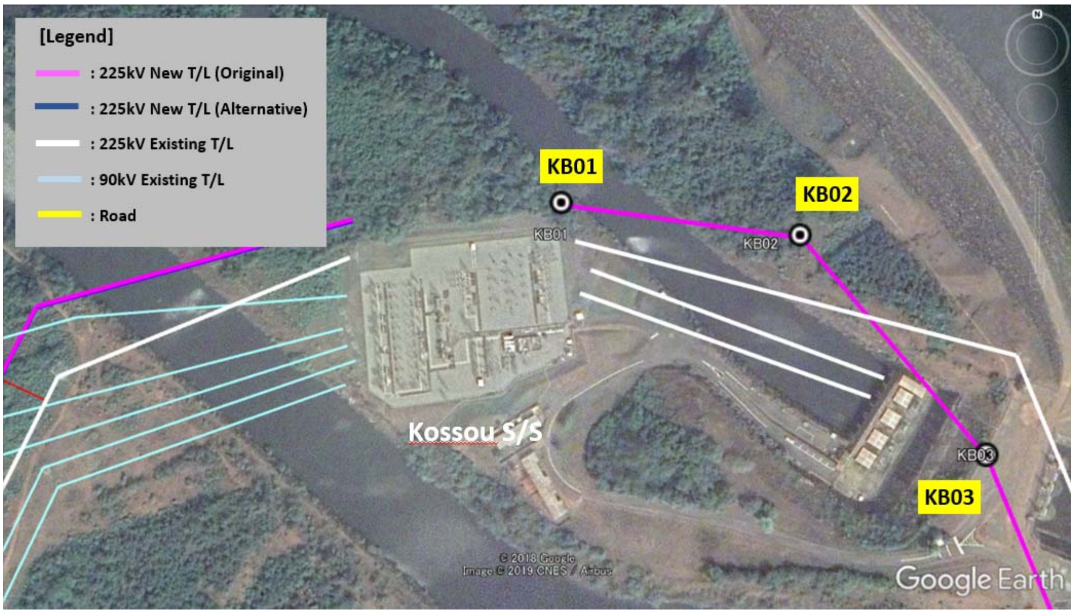
Tenikro Village

Fig. 4.1-21 Location Map and Photos - TK16

8) KB01

KB01 Point is adjacent to the spillway from the power plant, and the distance from the center of the tower site to the spillway is about 2 m, so it is extremely difficult to install a tower. Therefore, it is necessary to move the expansion bay of the substation slightly to the west, or install the 1st tower on the opposite.

In case the 1st tower is installed on the opposite bank, it is necessary to examine the strength of the gantry. In addition, the 1st tower of the existing 225kV transmission line is located slightly north of the gantry, so there is a possibility that sufficient clearance cannot be secured. Therefore, it is considered more appropriate to move the expansion bay slightly to the west. Fig. 4.1-22 and Fig.4.1-23 show the location map, the surrounding photos and image of the alternative route.



Source: JICA Study Team

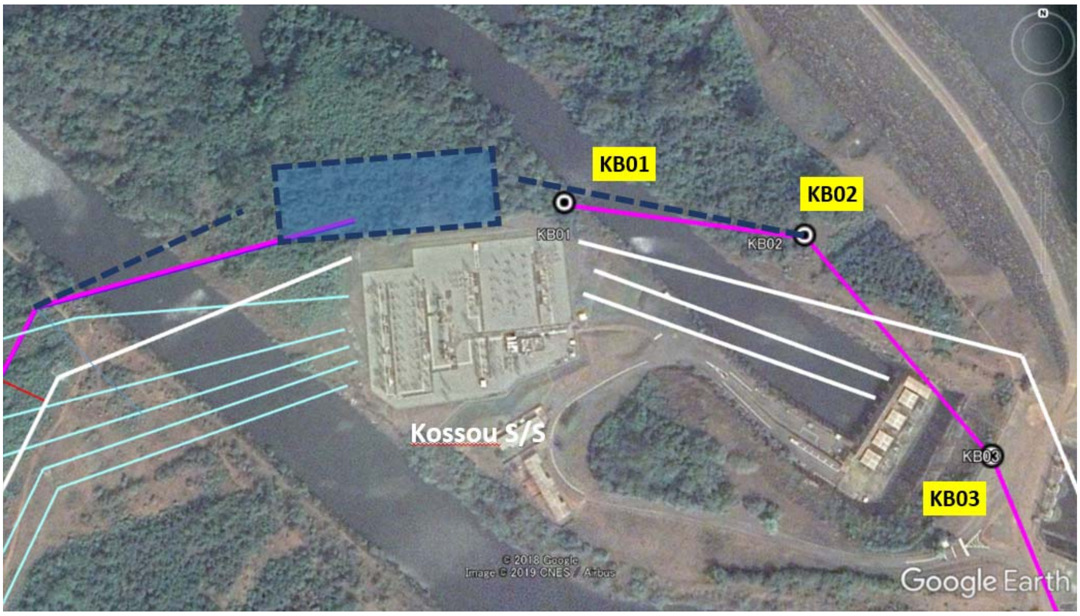
Photo from KB01 to Bouaké 3 S/S

Distance: Approx. 2m

(Center of Tower - Water Way)

First Tower of Existing 225kV T/L (Kossou S/S－Bouaké 2 S/S)

Fig. 4.1-22 Location Map and Photos - KB01

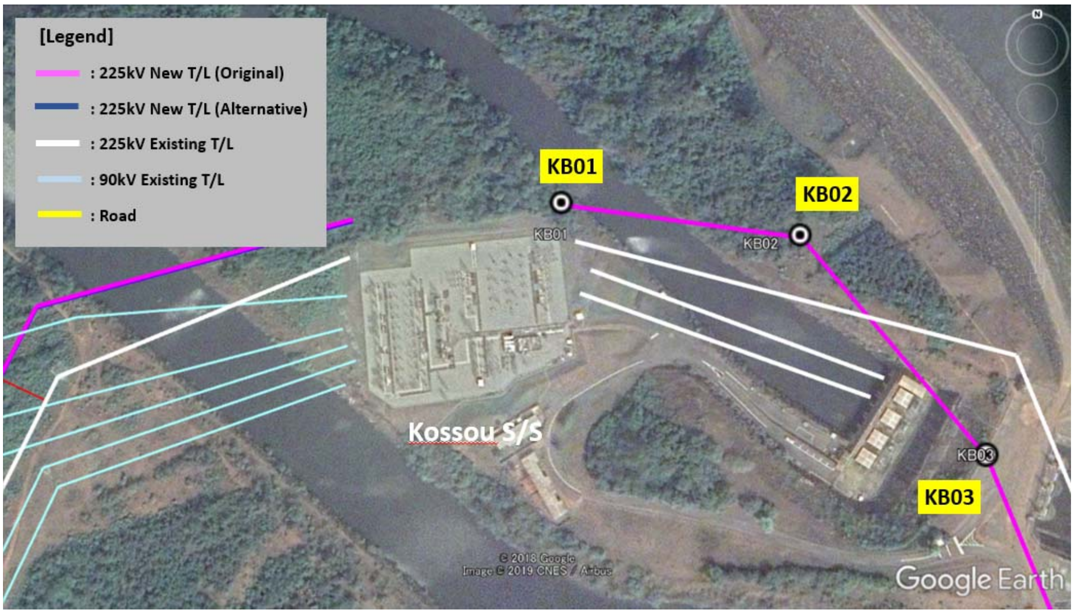


Source: JICA Study Team

Fig. 4.1-23 Image of Alternative Route at Kossou S/S

9) KB02

KB02 Point is located on the opposite bank of KB01 Point. The surrounding area is covered with miscellaneous trees and weeds. Since it is necessary to cross the existing 225kV transmission line and the existing 33kV distribution line between KB02 and KB03, the 2nd tower will be a high tower. But, it is considered that the tower site can be sufficiently secured. Fig. 4.1-24 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB02 to Kossou S/S (Miscellaneous Trees, Weeds)

Photo from KB02 to Bouaké 3 S/S (Miscellaneous Trees, Weeds)

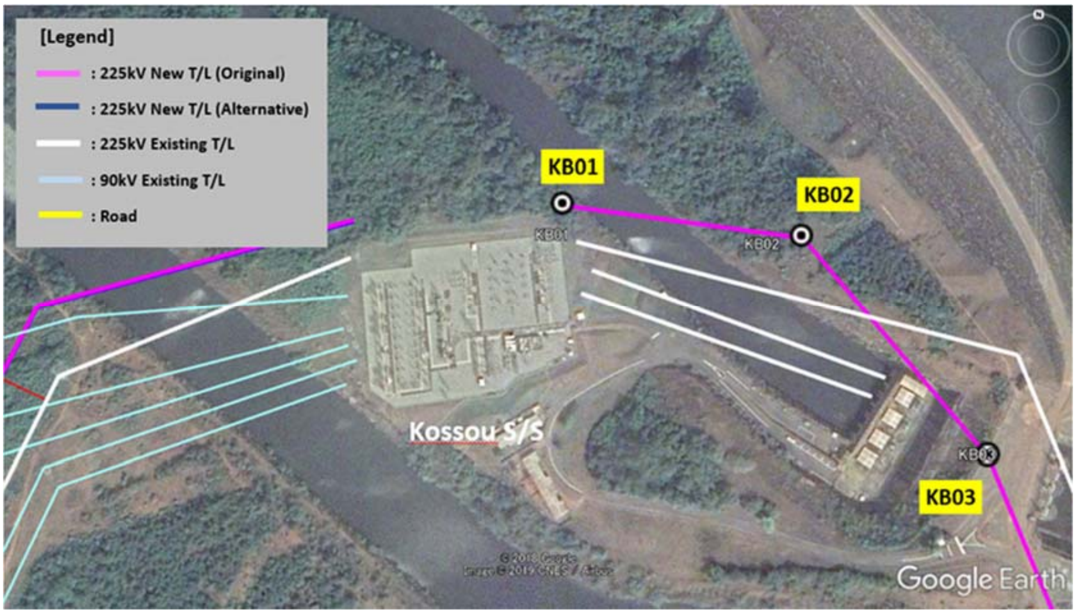
Existing 225kV T/L

Existing 33kV D/L

Fig. 4.1-24 Location Map and Photos - KB02

10) KB03

KB03 Point is located on the east side of the power plant at the same level as the dam embankment. Also, the 3rd tower will be a high tower, but it is thought that the tower site can be sufficiently secured. Fig. 4.1-25 shows the location map and the surrounding photos.



Source: JICA Study Team

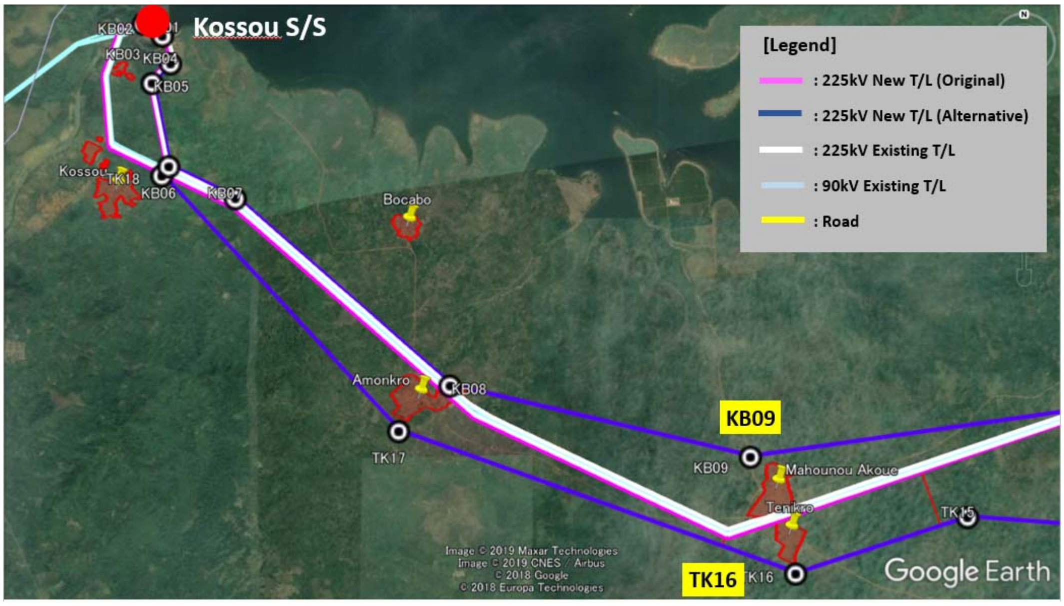
Photo from KB03 to Kossou S/S

Photo from KB03 to Bouaké 3 S/S

Fig. 4.1-25 Location Map and Photos - KB03

11) KB09

KB09 Point is located on the north side of Mahunou-Akoue village, about 30m east of the road, and the cacao fields are widespread. KB09 Point is far from the village and there is no problem with the route. Fig. 4.1-26 shows the location map and the surrounding photos.



Source: JICA Study Team

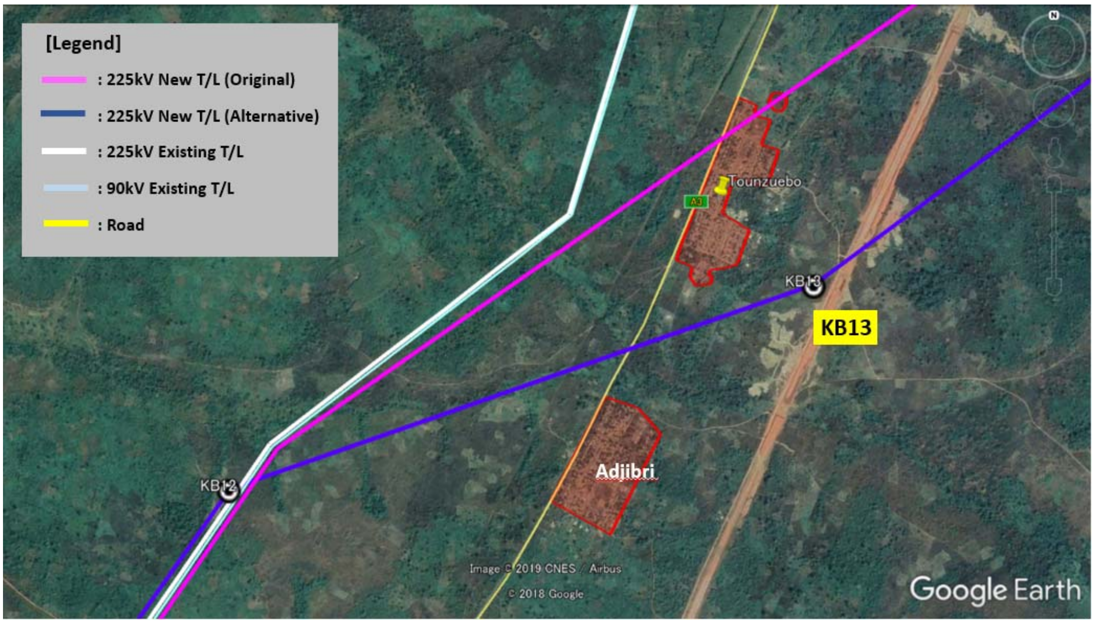
Photo from KB09 to Kossou S/S

Photo from KB09 to Bouaké 3 S/S (Cacao Fields)

Fig. 4.1-26 Location Map and Photos - KB09

12) KB13

KB13 Point is located in the southeast of Tounzuebo village, about 60m away from the highway. In addition, KB13 Point is covered with potato fields. The route from KB12 Point to KB13 Point will pass between Tounzuebo village and Adjibri village, but it is far from both villages and it is considered that there is no problem with the route. Fig. 4.1-27 shows the location map and the surrounding photos.



Source: JICA Study Team

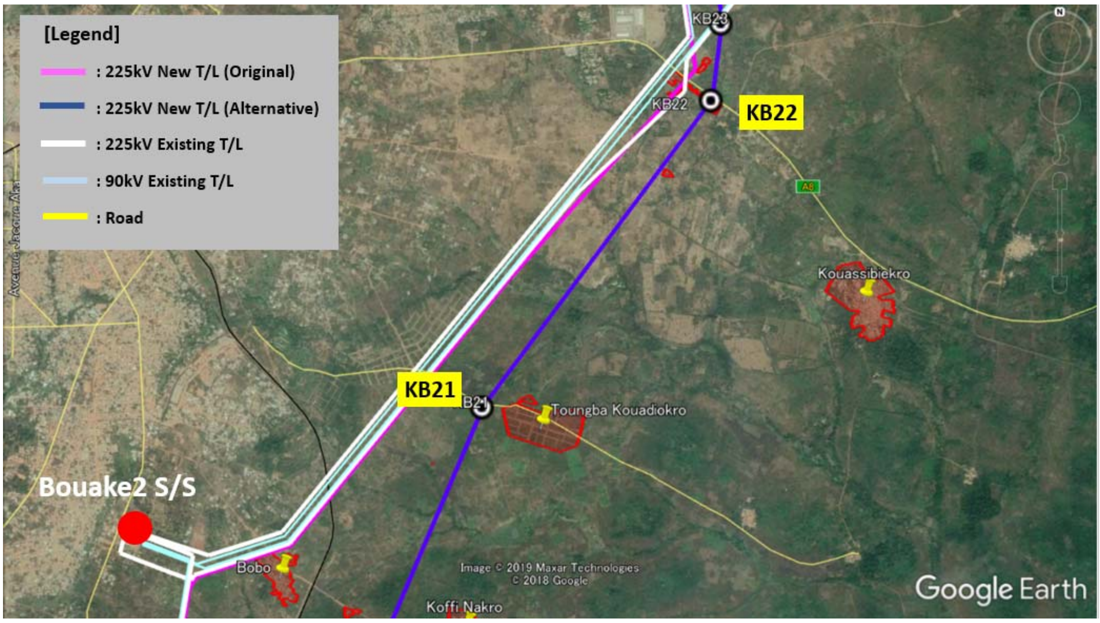
Photo from KB13 to Kossou S/S (Potato FIeld)

Photo from KB13 to Bouaké 3 S/S (Potato Field)

Fig. 4.1-27 Location Map and Photos - KB13

13) KB21

KB21 Point is located on the west side of Toungba Kouadiokro village, about 30m away from the road, and the surrounding area is covered with weeds. As KB21 Point is far from the village of Toungba Kouadiokro village, there is no problem with the route. Fig. 4.1-28 shows the location map and the surrounding photos.



Source: JICA Study Team

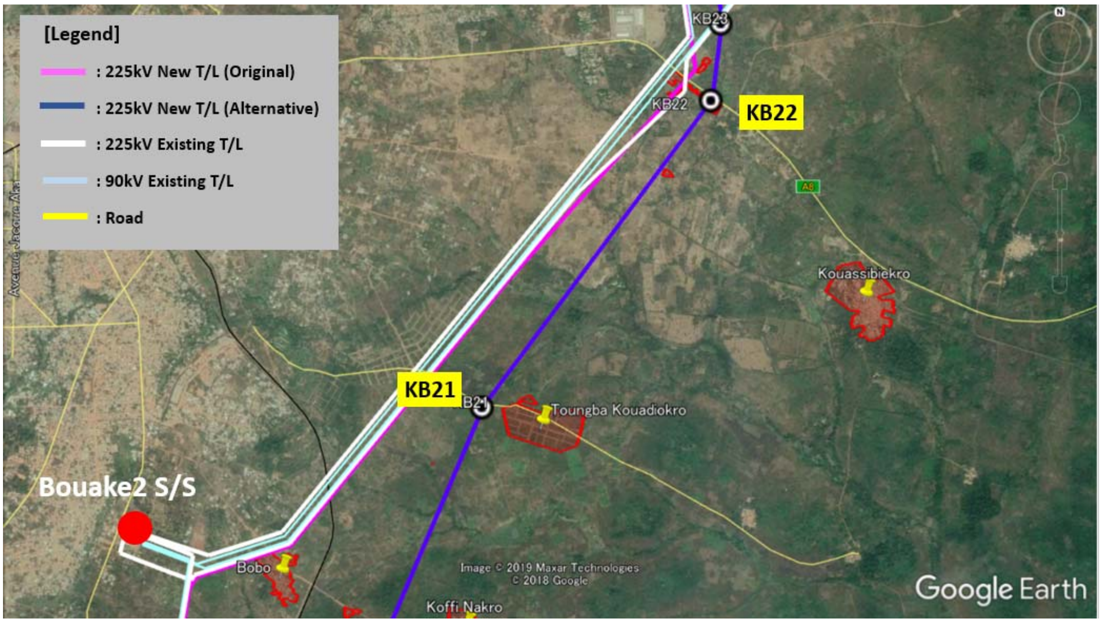
Photo from KB21 to Kossou S/S (Weeds)

Photo from KB21 to Bouaké 3 S/S (Weeds)

Fig. 4.1-28 Location Map and Photos -KB21

14) KB22

KB22 Point is about 20m away from the main road "A8", and the surrounding area is covered with miscellaneous trees and weeds, so the tower site can be secured sufficiently and there is no problem with the route. Fig. 4.1-29 shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB22 to Kossou S/S

(Miscellaneous Trees, Weeds)

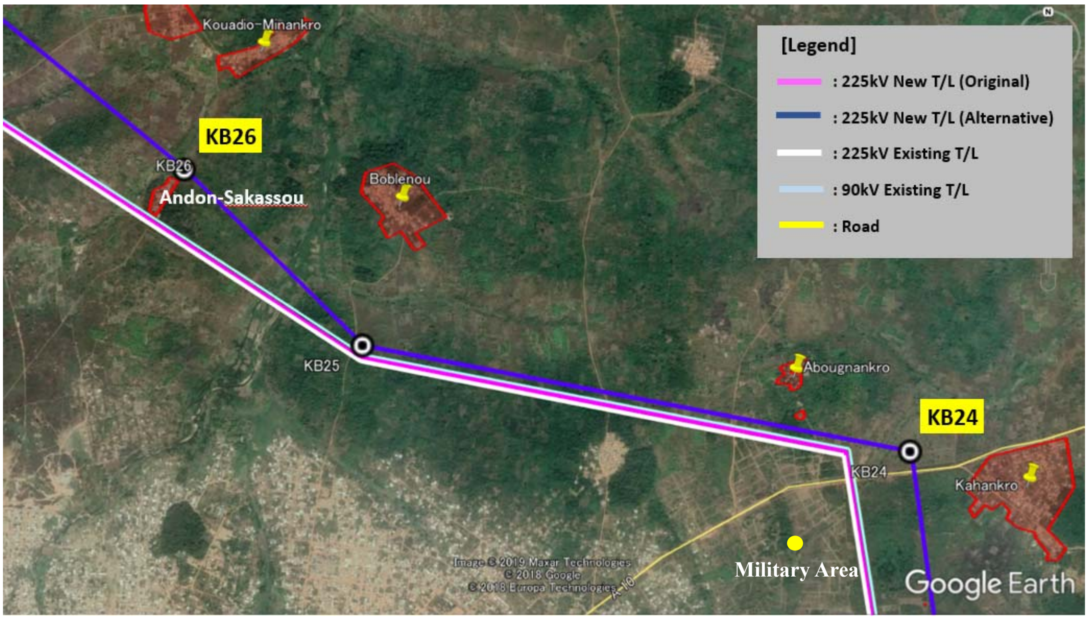
Photo from KB22 to Bouaké 3 S/S

(Miscellaneous Trees, Weeds)

Fig. 4.1-29 Location Map and Photos - KB22

15) KB24

KB24 Point is located in the bean field on the west side of Kanankro village. KB24 point is far from Kanankro village and there is no problem with the route. According to CI-ENERGIES engineer, the west side of the existing transmission line is a military area. Fig. 4.1-30 shows the location map and the surrounding photos.



Source: JICA Study Team

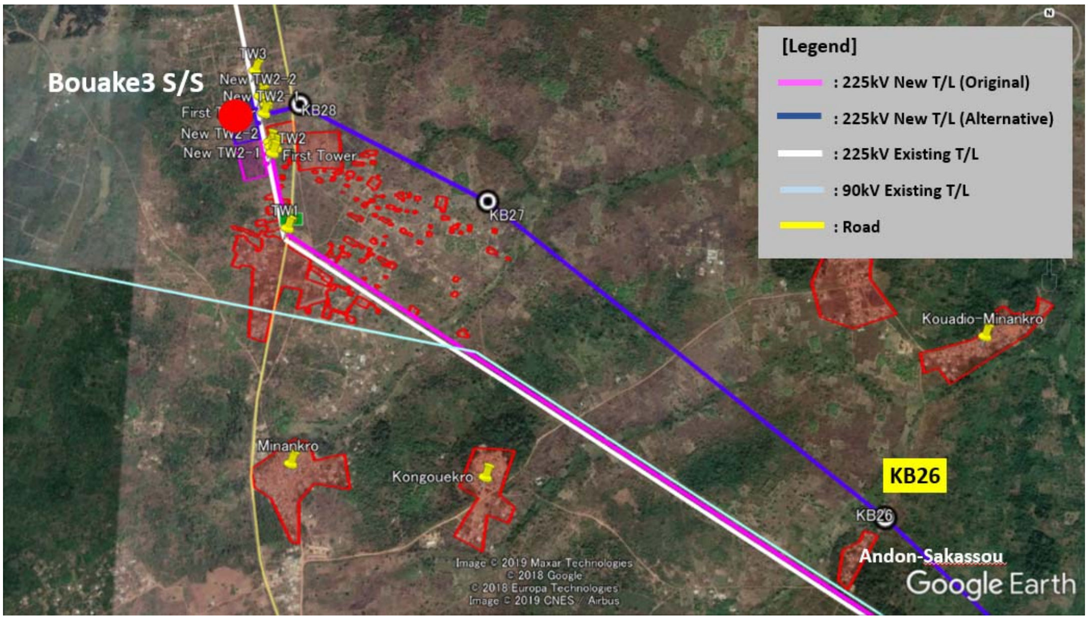
Photo from KB24 to Kossou S/S (Bean Field)

Photo from KB24 to Bouaké 3 S/S (Bean Field)

Fig. 4.1-30 Location Map and Photos - KB24

16) KB26

KB26 Point is located on the north side of Andon-Sakassou village, on the east side of the road, and the surrounding area is covered with miscellaneous trees and weeds. KB26 Point is far from the village and there is no problem with the route. Fig. 4.1-31 shows the location map and the surrounding photos.



Source: JICA Study Team

	
Photo from KB26 to Kossou S/S **(Miscellaneous Trees, Weeds)**	**Photo from KB26 to Bouaké 3 S/S** **(Miscellaneous Trees, Weeds)**

Andon-Sakassou Village

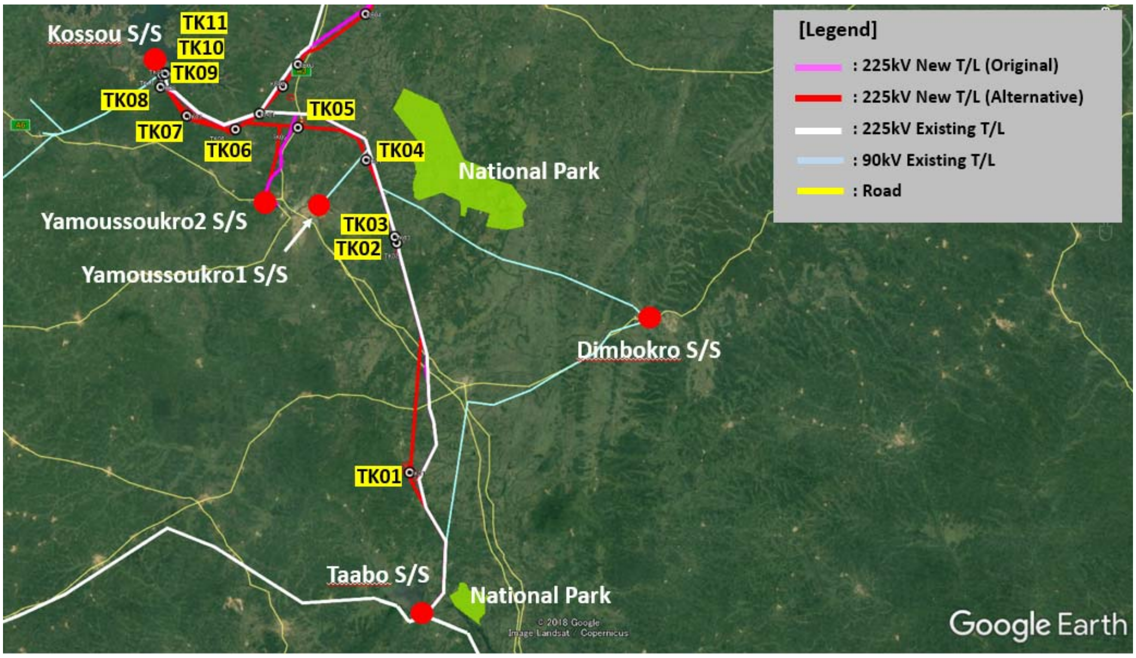
Fig. 4.1-31 Location Map and Photos - KB26

(5) Alternative Candidate Route

Since the proposed candidate route may affect the villages near Kossou S/S, there was a request from CI-ENERGIES to re-examine the route. So, the alternative candidate route was re-examined and the route survey was conducted. The alternative candidate route runs on the south side of the villages near TK06 Point and TK07 Point. Fig. 4.1-32 and Fig. 4.1-33 show the alternative candidate routes and survey points.

【Survey Point】 11 points

TK01, TK02, TK03, TK04, TK05, TK06, TK07, TK08, TK09, TK10, TK11

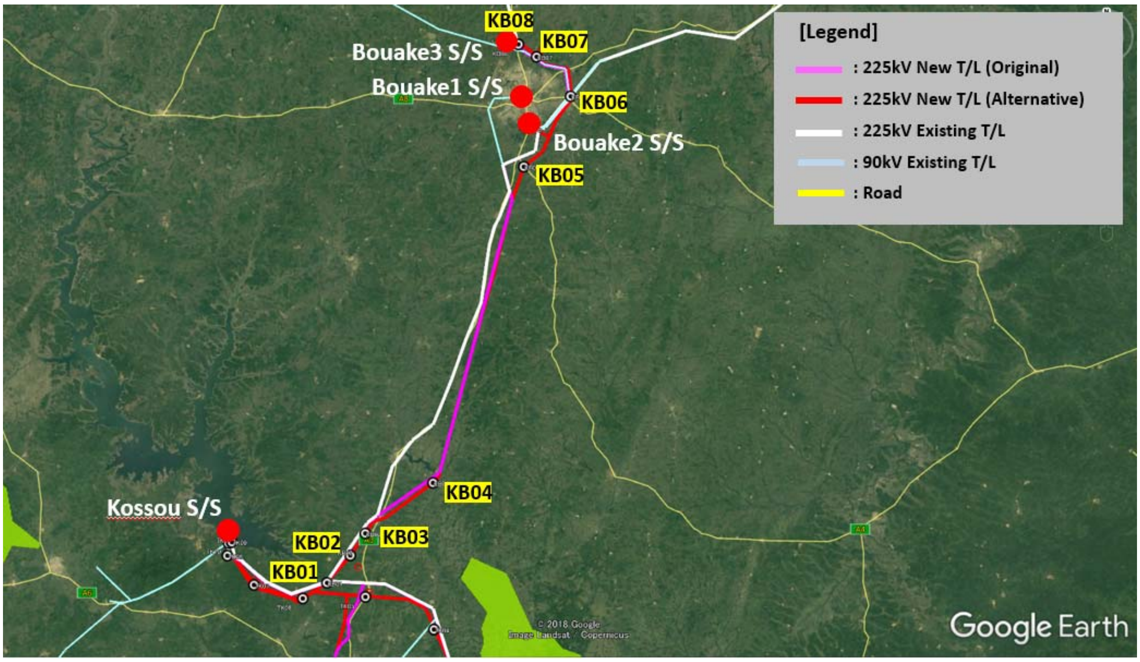


Source: JICA Study Team

Fig. 4.1-32 Alternative Candidate Route (Taabo S/S – Kossou S/S)

【Survey Point】 8 points

KB01, KB02, KB03, KB04, KB05, KB06, KB07, KB08



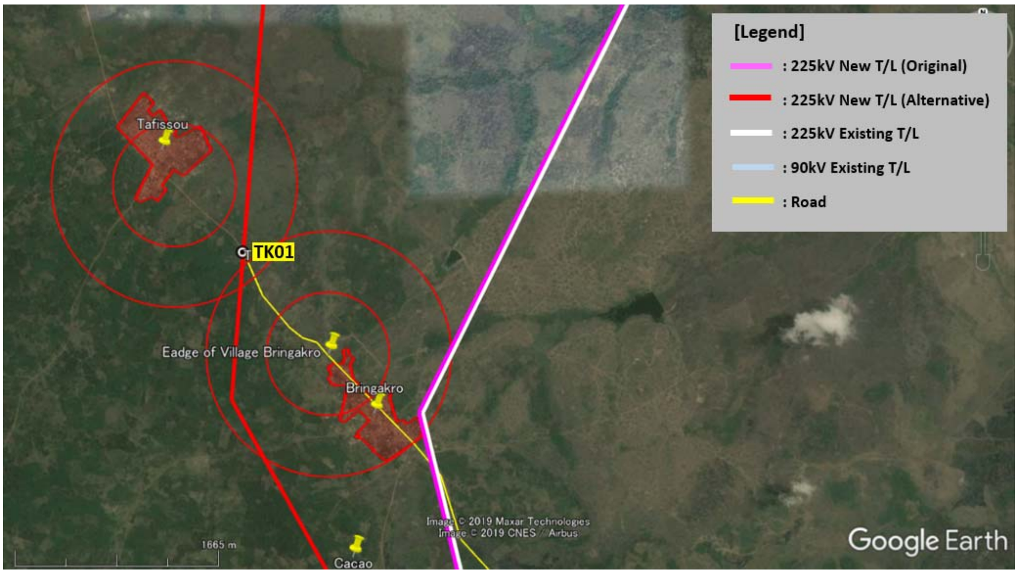
Source: JICA Study Team

Fig. 4.1-33 Alternative Candidate Route (Kossou S/S - Bouake3 S/S)

(6) Results of Route Survey of Alternative Candidate Route

1) TK01

TK01 Point is located between Bringakro and Tafissou village. The surrounding area is covered with miscellaneous trees and weeds, and TK01 Point is far from the two villages. So, it is considered that the route can be sufficiently secured, the environmental and social impact is small. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK01 to Taabo S/S

(Miscellaneous Trees, Weeds)

Photo from TK01 to Kossou S/S

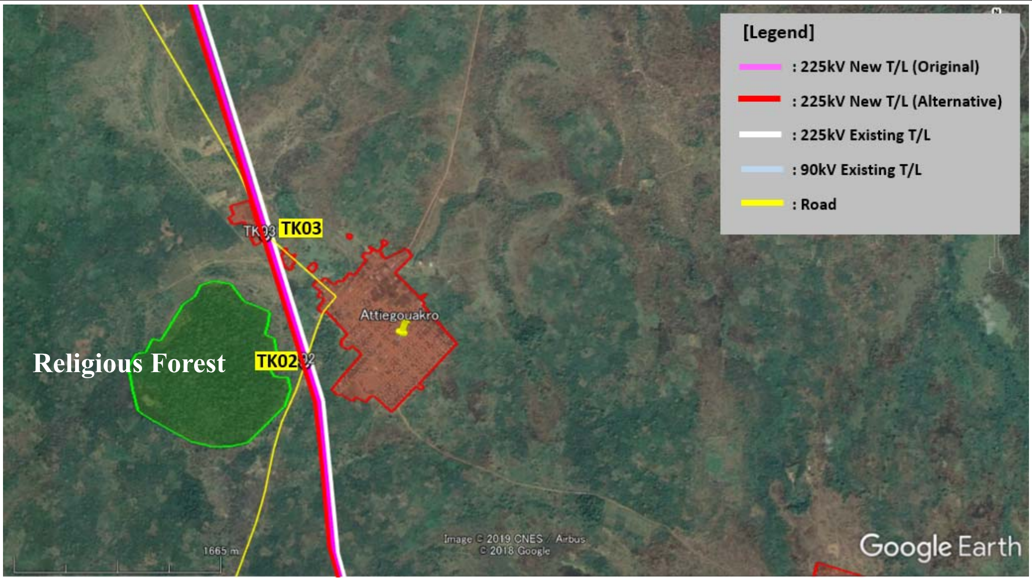
(Miscellaneous Trees, Weeds)

Bringakro Village

Fig. 4.1-34 Location Map and Photos

2) TK02

TK02 Point is located between the religious forest and Attiegouakro village, and the route runs parallel to the existing 225kV transmission line and crosses the existing 33kV distribution lines. The surrounding area is covered with miscellaneous trees and weeds, TK02 Point is far from the religious forest and the village. So, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK02 to Taabo S/S

(Miscellaneous Trees, Weeds)

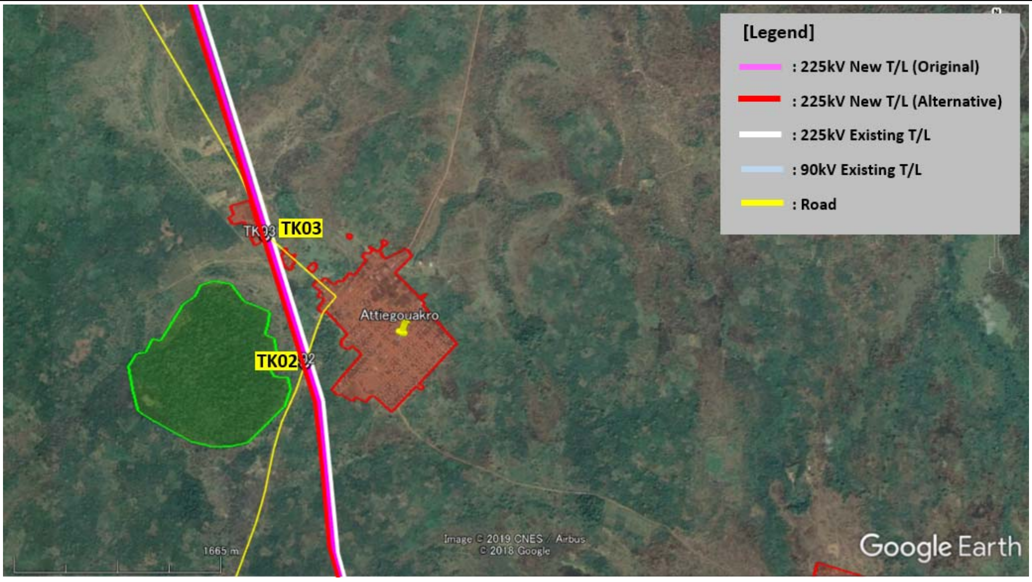
Photo from TK02 to Kossou S/S

(Miscellaneous Trees, Weeds)

Fig. 4.1-35 Location Map and Photos

3) TK03

TK03 Point is located northwest of Attiegouakro village, and the route runs parallel to the existing 225kV transmission line. Since it is covered with miscellaneous trees and it is sufficiently far from the residential area, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

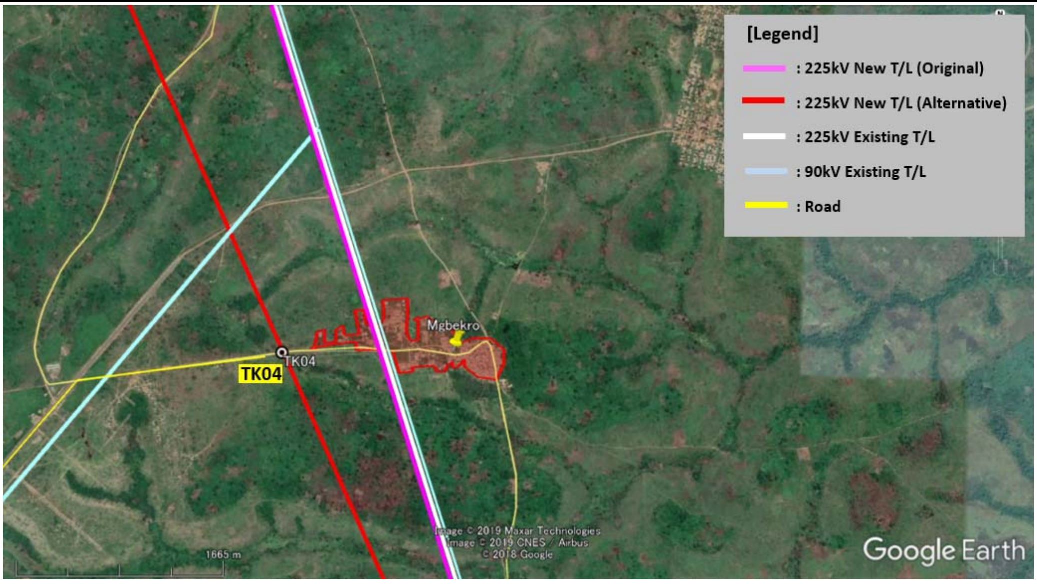
Photo from TK03 to Taabo S/S (Miscellaneous Trees)

Photo from TK03 to Kossou S/S (Miscellaneous Trees)

Fig. 4.1-36 Location Map and Photos

4) TK04

TK04 Point is located on the west side of Mgbekro village. It is covered with miscellaneous trees and weeds, and it is sufficiently far from Mgbekro village. Therefore, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK04 to Taabo S/S

(Miscellaneous Trees, Weeds)

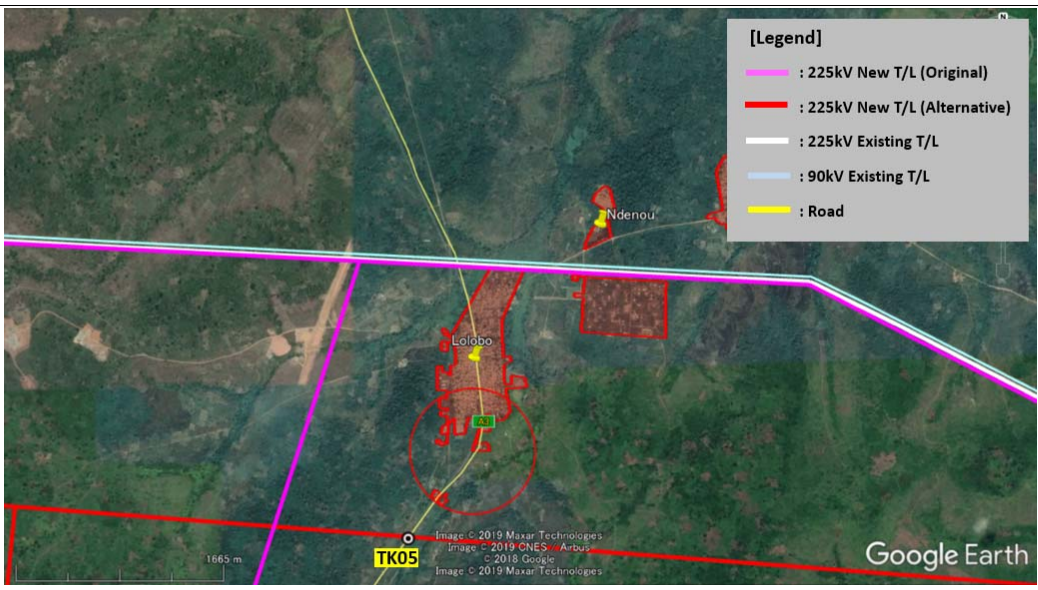
Photo from TK04 to Kossou S/S

(Miscellaneous Trees, Weeds)

Fig. 4.1-37 Location Map and Photos

5) TK05

TK05 Point is located on the south side of Lolobo village. It is covered with miscellaneous trees and weeds, and it is sufficiently far from Lolobo village. Therefore, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK05 to Taabo S/S

(Miscellaneous Trees, Weeds)

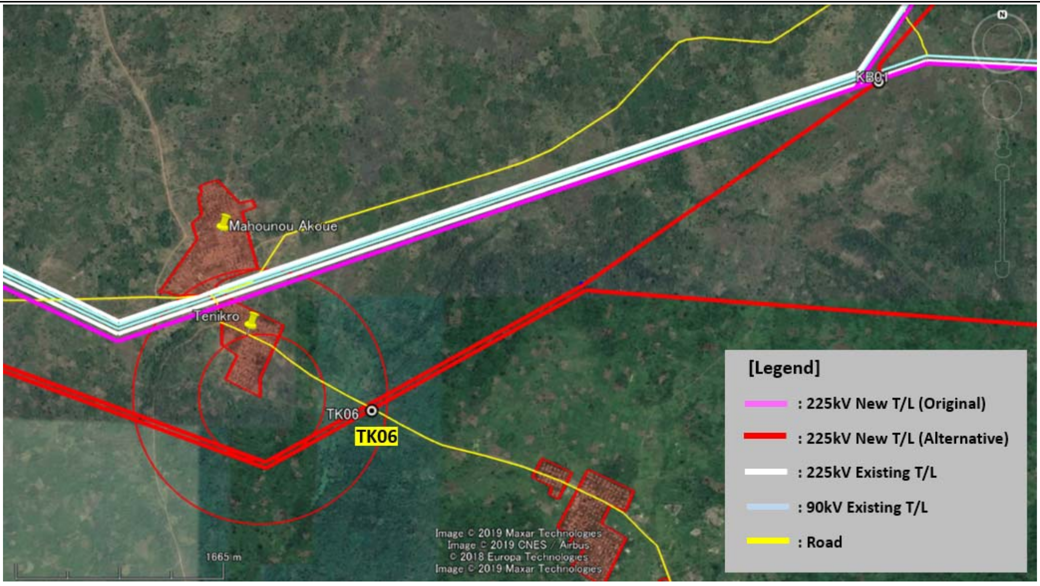
Photo from TK05 to Kossou S/S

(Miscellaneous Trees, Weeds)

Fig. 4.1-38 Location Map and Photos

6) TK06

TK06 Point is located southeast of Tenikro village. It is covered with miscellaneous trees and weeds, and it is sufficiently far from Tenikro village. Therefore, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK06 to Taabo S/S

(Miscellaneous Trees, Weeds)

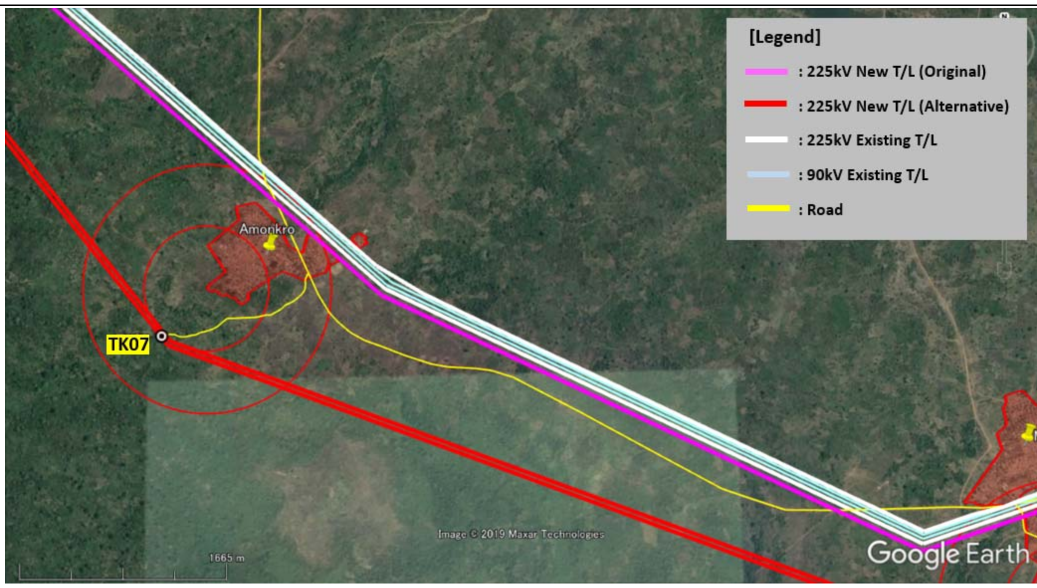
Photo from TK06 to Kossou S/S

(Miscellaneous Trees, Weeds)

Fig. 4.1-39 Location Map and Photos

7) TK07

TK07 Point is located southwest of Amonkro village. It is covered with banana field, miscellaneous trees and weeds, and it is sufficiently far from Amonkro village. Therefore, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

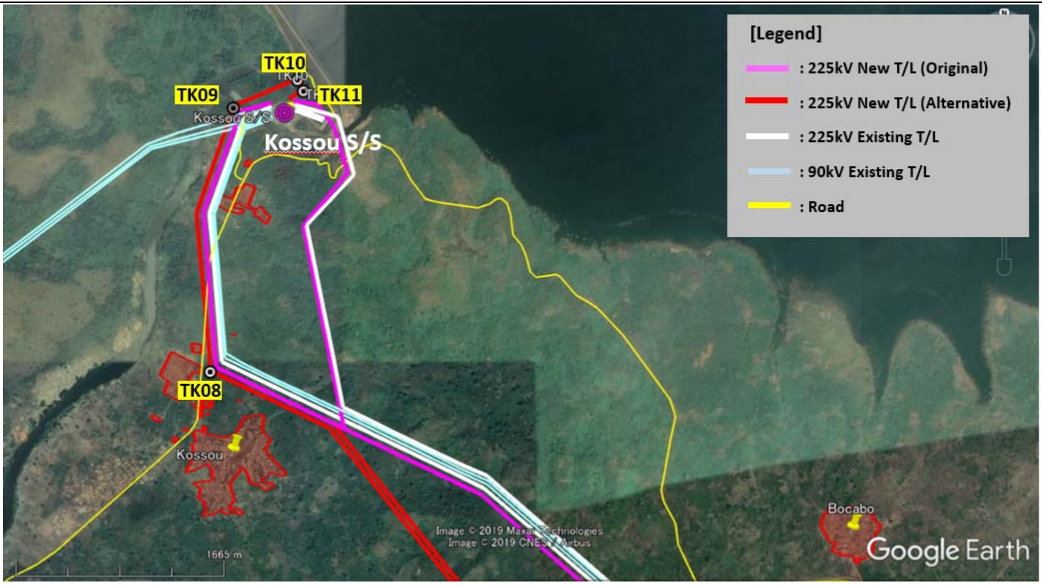
Photo from TK07 to Taabo S/S
(Banana Field, Miscellaneous Trees, Weeds)

Photo from TK07 to Kossou S/S
(Miscellaneous Trees, Weeds)

Fig. 4.1-40 Location Map and Photos

8) TK08

TK08 Point is located on the north side of Kossou village. Since the existing 33kV distribution line runs parallel to the existing 225kV transmission line near TK08 Point, it is necessary to slightly modify the route and cross the existing 33kV distribution line. In addition, there is one household on the route, so it is necessary to relocate the residents. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK08 to Taabo S/S

(Miscellaneous Trees, Weeds)

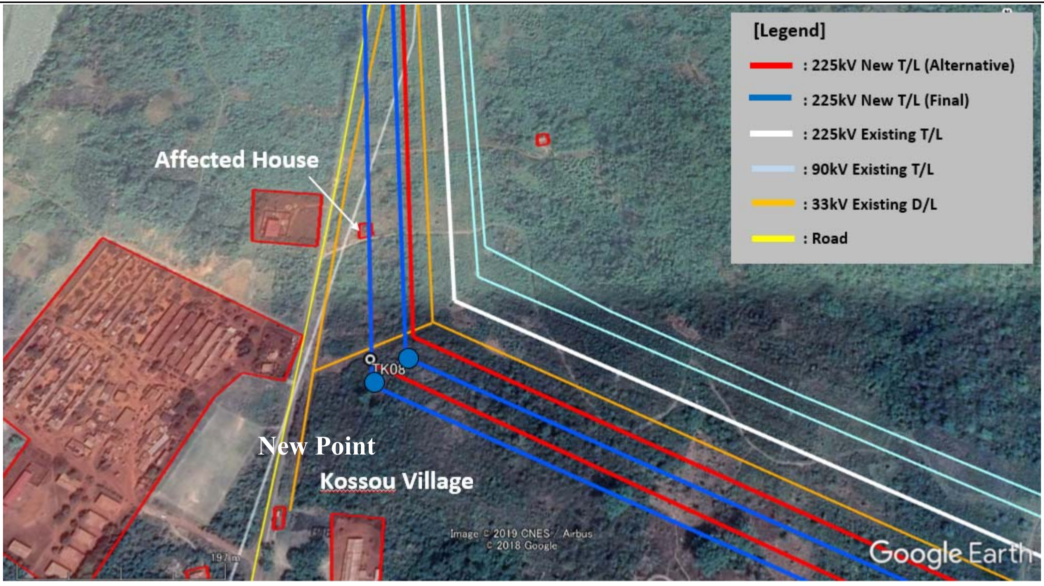
Photo from TK08 to Kossou S/S

(Miscellaneous Trees, Weeds)

Affected House (1 Household, 5 people)

Fig. 4.1-41 Location Map and Photos

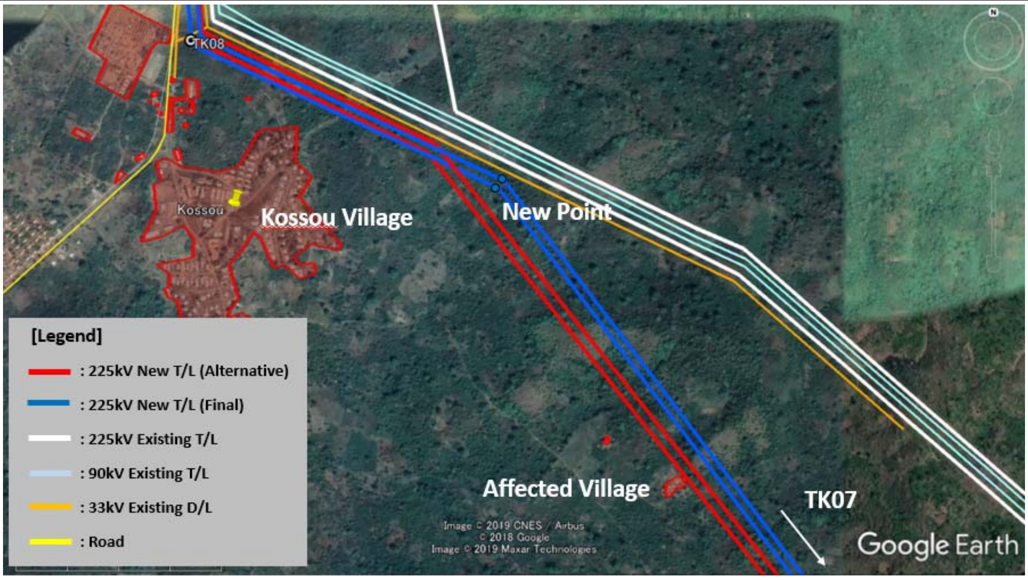
The below figure shows the modified route around Kossou village. The distance between the existing 225kV transmission line and the existing 33kV transmission line was assumed to be 25m. According to e CI-ENERGIES engineer, the distance between the transmission lines is more than 25 m. So the route was modified considering that it is approx. 30 m away from the existing 33 kV transmission line.



Source: JICA Study Team

Fig. 4.1-42 Modified Route around Kossou Village

Furthermore, since there is an affected village between TK07 Point and TK08 Point, the route was modified slightly. The below figure shows the modified route between TK07 and TK08 Points.

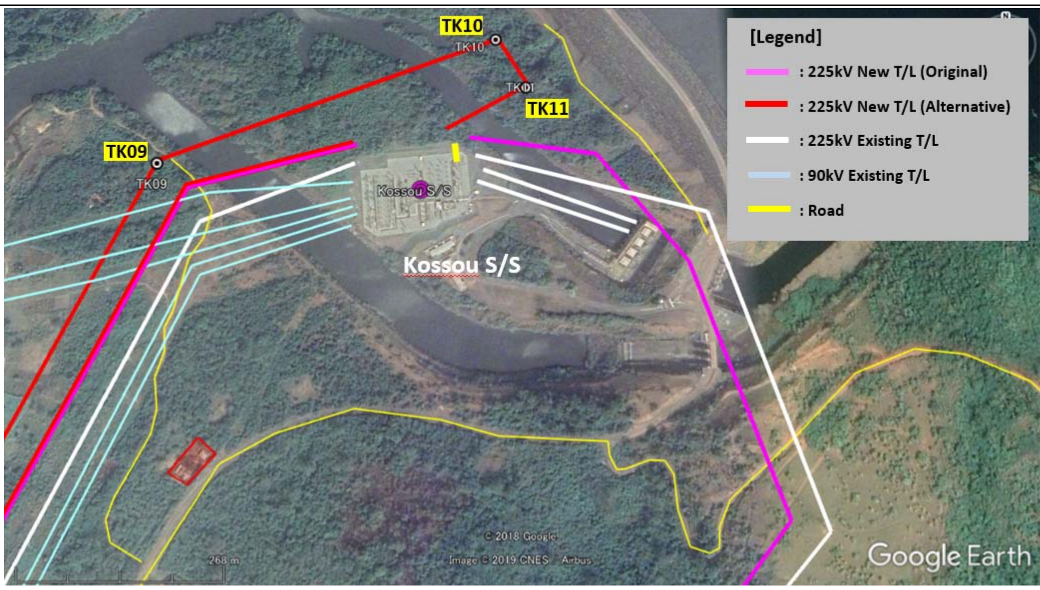


Source: JICA Study Team

Fig. 4.1-43 Modified Route between TK07 and TK08

9) TK09

TK09 Point is located on the west side of Kossou S/S, and it is covered with miscellaneous trees. It is necessary that the Point be more than 30m away from the existing 33kV distribution line like TK08 Point, so the route was slightly modified between TK08 Point and TK09 Point. In addition, there is a plan to construct a new 90kV transmission line from the northwest of Kossou S/S for a gold mine. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from TK09 to Taabo S/S

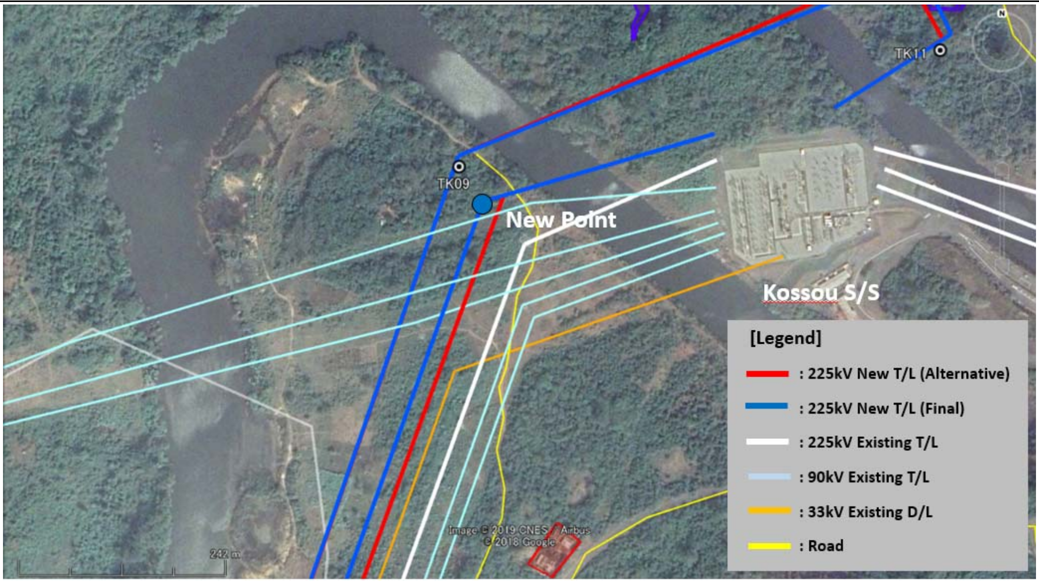
(Miscellaneous Trees)

Photo from TK09 to Kossou S/S

(Miscellaneous Trees)

Fig. 4.1-44 Location Map and Photos

The below figure shows the modified route around Kossou S/S.

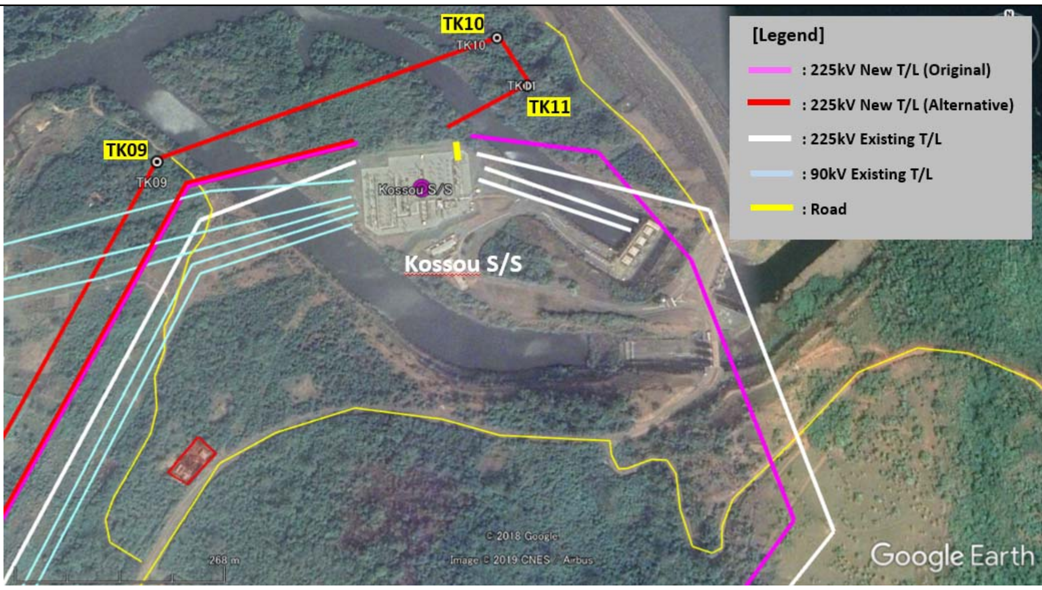


Source: JICA Study Team

Fig. 4.1-45 Modified Route around Kossou S/S

10) TK10 & TK11

TK10 and TK11 points are located on the northeastern opposite bank of Kossou S/S. Miscellaneous trees and weeds spread around the area. Since the waterways are complicated, it is necessary to carefully consider the location of the tower. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

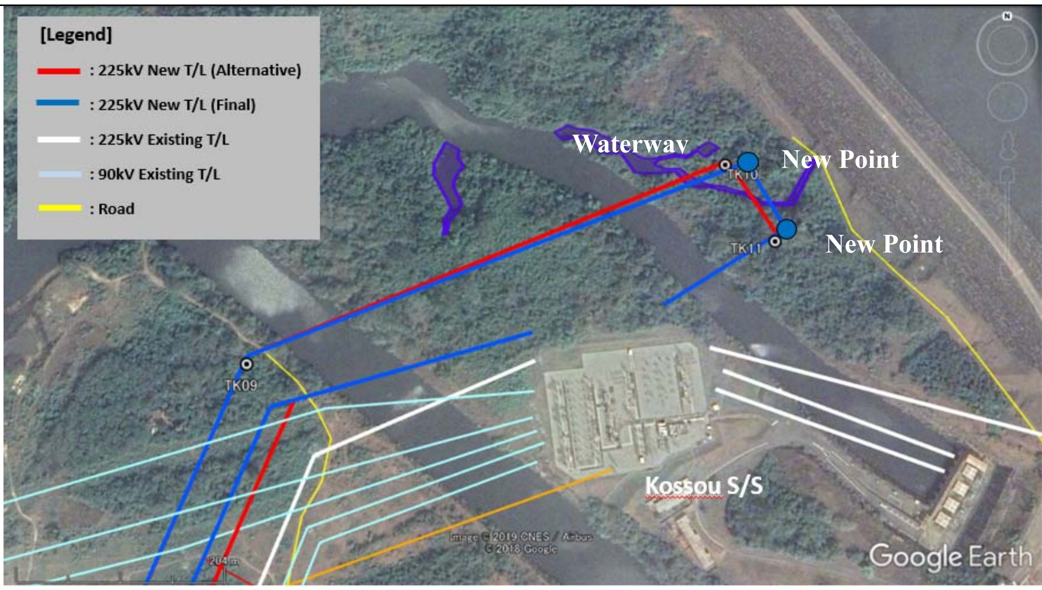
Photo around TK10

(Miscellaneous Trees, Weeds)

Water Way around TK10

Fig. 4.1-46 Location Map and Photos

The below figure shows the modified route around the waterway. It is considered that it is necessary to slighty shift the route to thee northeast in order to be away from the waterway.

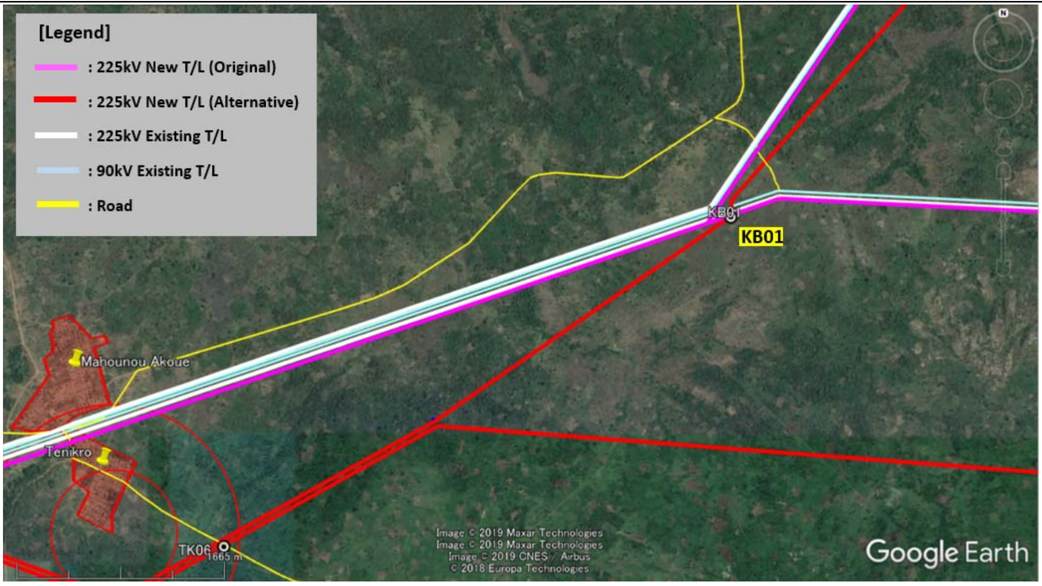


Source: JICA Study Team

Fig. 4.1-47 Final Route around Waterway

11) KB01

At KB01 Point, it is necessary to cross the existing 225kV transmission line (Taabo S/S - Kossou S/S) and the existing 90kV transmission line (Yamoussoukro S/S – Kossou S/S). Since it is covered with weeds, the tower site can be secured sufficiently, and there is no problem with the route. But it is necessary to examine the crossing point considering the ground wire height of the existing transmission line and the location of the existing tower. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

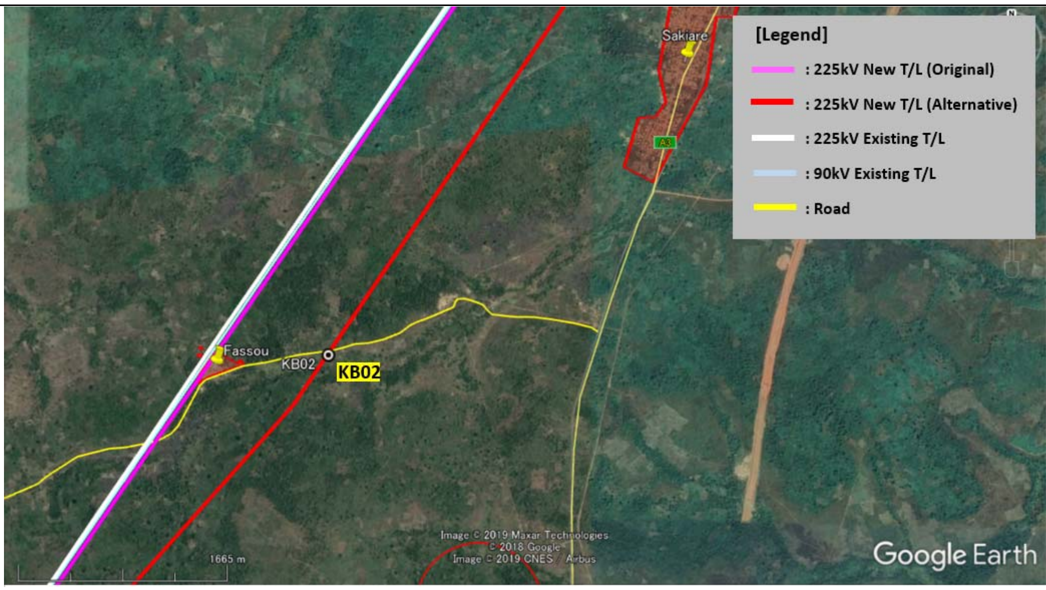
Photo from KB01 to Kossou S/S (Weeds)

Photo from KB01 to Bouaké 3 S/S (Weeds)

Fig. 4.1-48 Location Map and Photos

12) KB02

KB02 Point is located on the eastern side of Fassou village, and away from the village. It is covered with miscellaneous trees and weeds. So, it is considered that there is no problem with the route. However, the existing 33kV distribution line runs parallel to the road, and it is necessary to cross this distribution line. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB02 to Kossou S/S

(Miscellaneous Trees, Weeds)

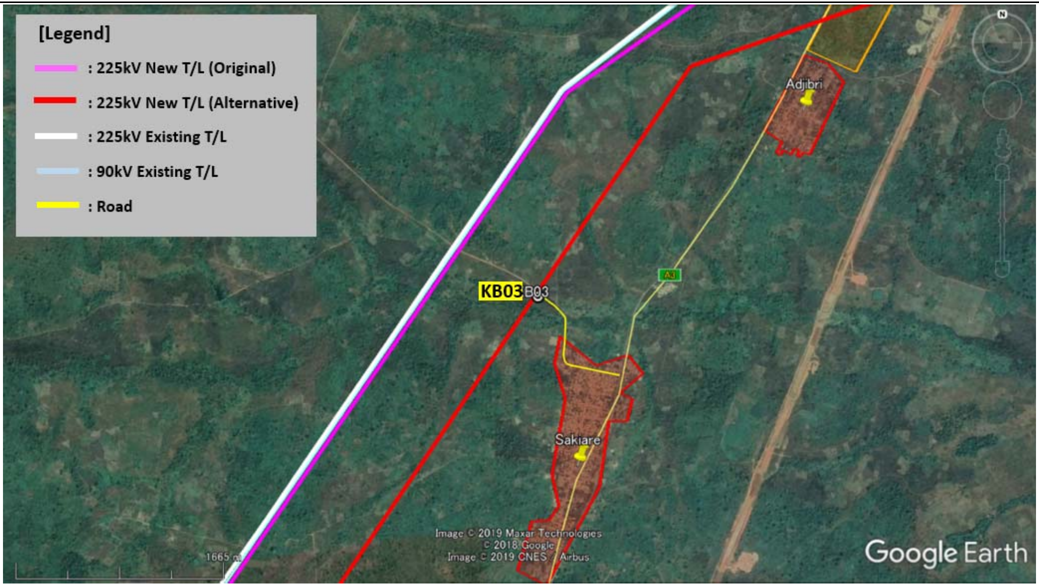
Photo from KB02 to Bouaké 3 S/S

(Miscellaneous Trees, Weeds)

Fig. 4.1-49 Location Map and Photos

13) KB03

KB03 Point is located northeast of Sakiare village, and away from the village. It is covered with miscellaneous trees and weeds. So, it is considered that there is no problem with the route. However, the existing 33kV distribution line runs along the road, and it is necessary to cross this distribution line. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB03 to Kossou S/S

(Miscellaneous Trees, Weeds)

Photo from KB03 to Bouaké 3 S/S

(Miscellaneous Trees, Weeds)

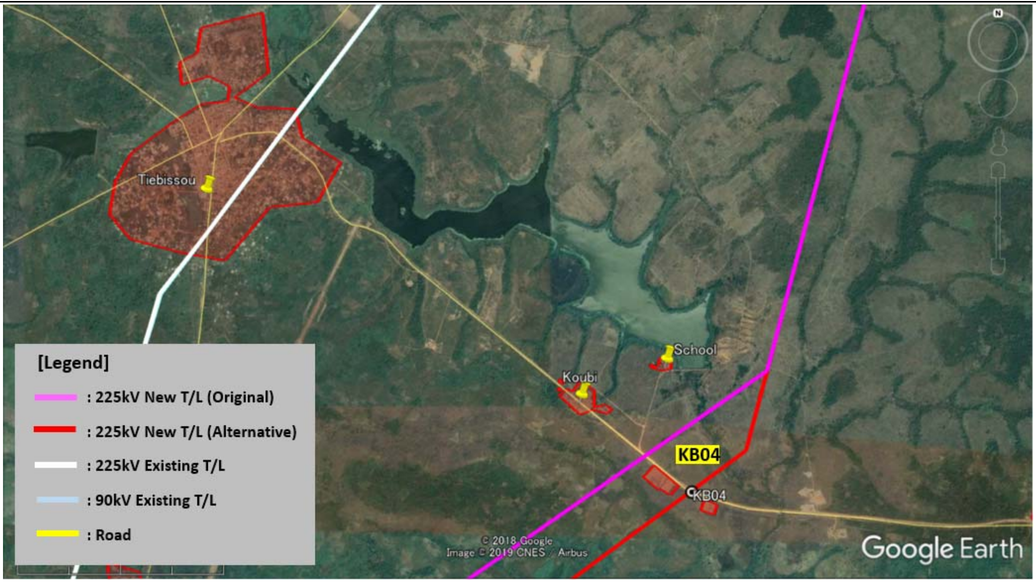
Existing 33kV D/L

Existing 33kV D/L

Fig. 4.1-50 Location Map and Photos

14) KB04

KB04 Point is located southeast of Koubi village, and away from the village. It is covered with miscellaneous trees and weeds. So, it is considered that there is no problem with the route. However, the existing 33kV distribution line runs around KB04 Point, and it is necessary to cross this distribution line. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

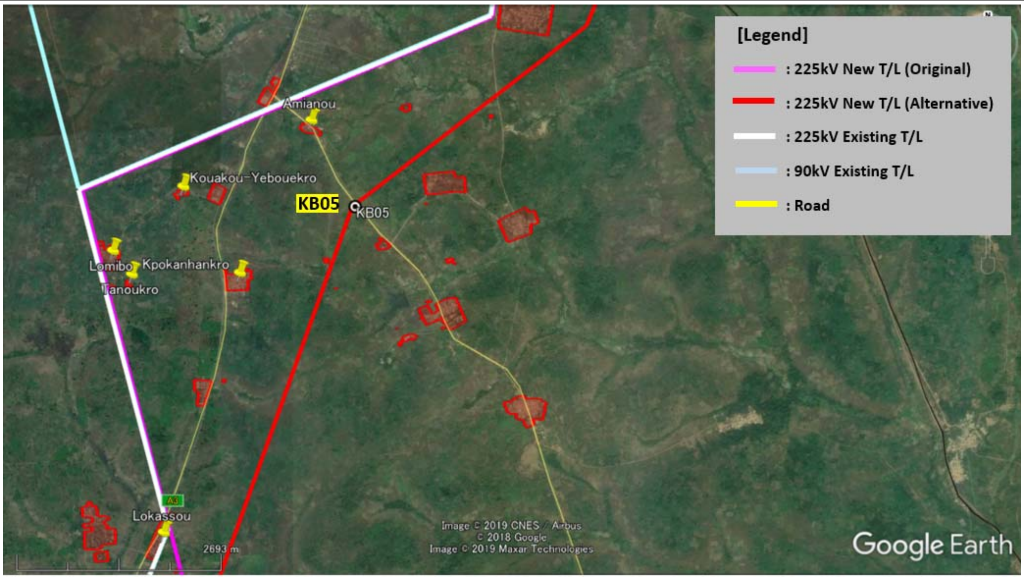
Photo from KB04 to Kossou S/S
(Miscellaneous Trees, Weeds)

Photo from KB04 to Bouaké 3 S/S
(Miscellaneous Trees, Weeds)

Fig. 4.1-51 Location Map and Photos

15) KB05

KB05 Point is located southeast of Amianou village, and away from the village. It is covered with miscellaneous trees and weeds. So, it is considered that there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

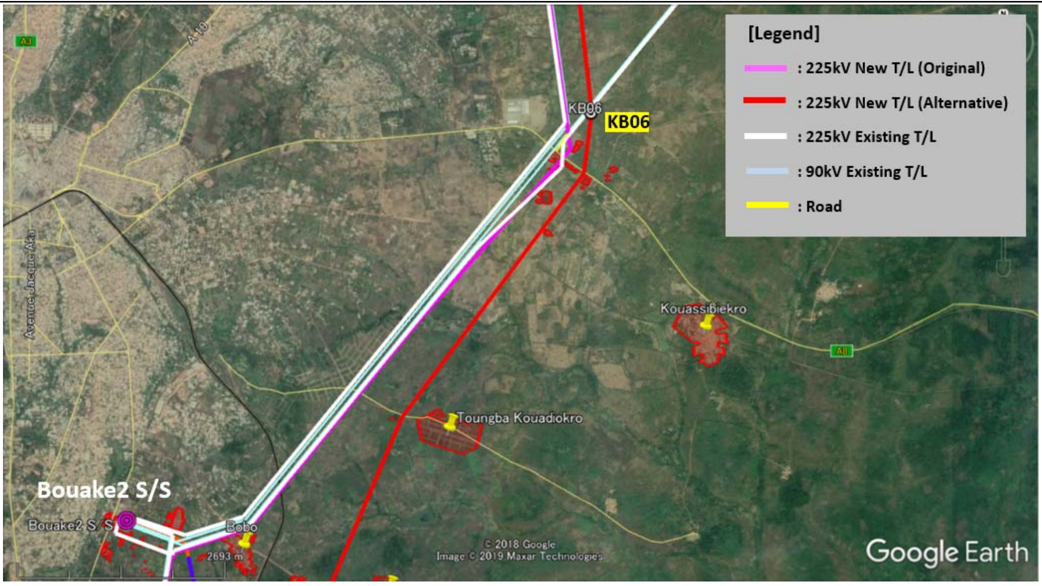
Photo from KB05 to Kossou S/S
(Miscellaneous Trees, Weeds)

Photo from KB05 to Bouaké 3 S/S
(Miscellaneous Trees, Weeds)

Fig. 4.1-52 Location Map and Photos

16) KB06

At KB06 Point, it is necessary to cross the existing 225kV transmission line (Bouake 2 S/S - Serebou S/S) and the existing 90kV transmission line (Bouake 2 S/S - Serebou S/S). Since it is covered with weeds, the tower site can be secured sufficiently, and there is no problem with the route. But it is necessary to examine the crossing point considering the ground wire height of the existing transmission line and the location of the existing tower. In addition, the tower layout was vertical on the existing 225kV transmission line with single circuit, and the height of the tower was about 33m.The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB06 to Kossou S/S (Miscellaneous Trees, Weeds)

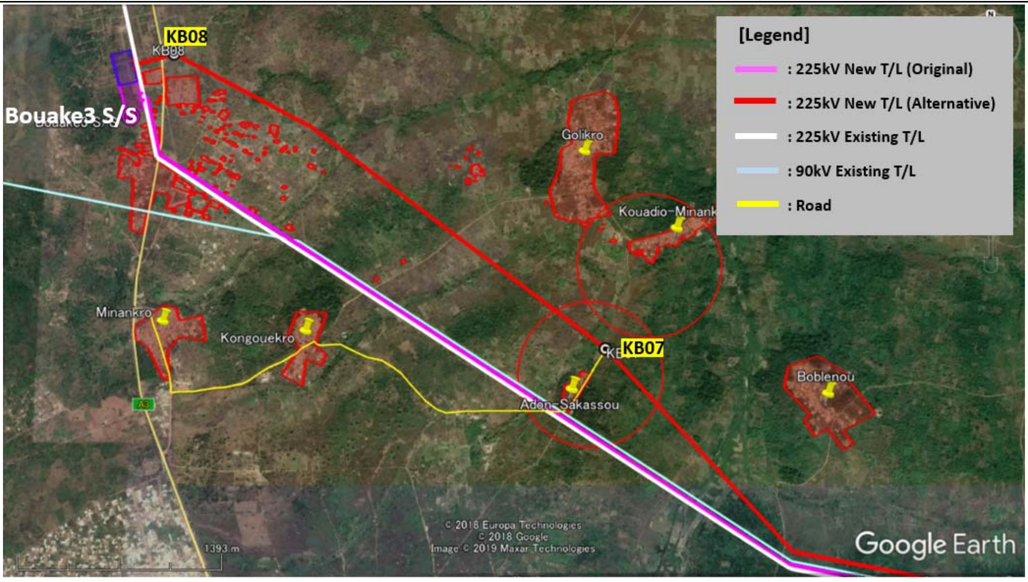
Photo from KB06 to Bouaké 3 S/S (Weeds)

Existing 225kV T/L
(Bouake2 S/S – Serebou S/S)

Fig. 4.1-53 Location Map and Photos

17) KB07

KB07 Point is located in the northeast of Adon-Sakassou village, and KB07 Point is far from the village. There are weeds and fields in the surrounding area, but it is considered that the tower site can be secured sufficiently and there is no problem with the route. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB07 to Kossou S/S (Weeds)

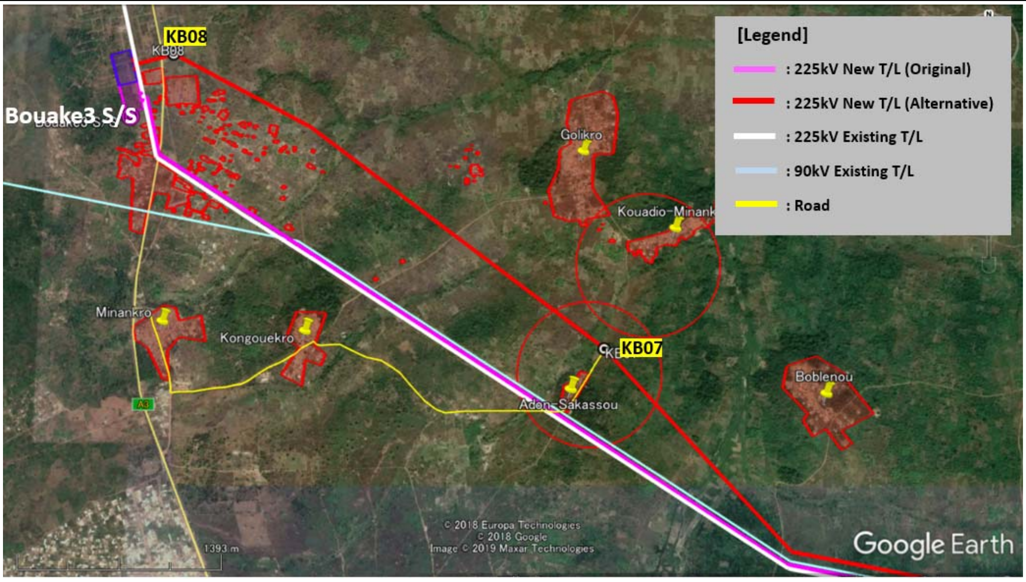
Photo from KB07 to Bouaké 3 S/S (Potato & Cacao Field)

Adon-Sakassou Village

Fig. 4.1-54 Location Map and Photos

18) KB08

KB08 Point is located on the east side of Bouake 3 S/S. There are miscellaneous trees, weeds, and potato fields in the surrounding area, but it is considered that the tower site can be secured sufficiently and there is no problem with the route. In addition, the distance to the warehouse on the south side is more than 150m. The below figure shows the location map and the surrounding photos.



Source: JICA Study Team

Photo from KB08 to Kossou S/S
(Miscellaneous Trees, Weeds)

Photo from KB08 to Bouaké 3 S/S
(Potato Field)

Distance to Warehouse: Approx. 15m	

Fig. 4.1-55 Location Map and Photos

4.1.2 Conductor and Ground Wire

Table 4.1-1 shows the thermal capacity of main conductors widely applied in the existing 225 kV and 90 kV transmission lines of Republic of Côte d'Ivoire. Table 4.1-2 shows the ambient conditions for the thermal capacity calculation. Also, Fig. 4.1-56 shows the structure of main conductors.

Table 4.1-1 Thermal Capacity of Conductors

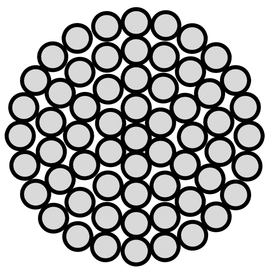
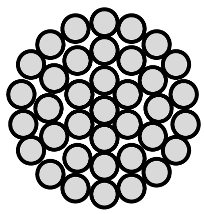
Nominal Voltage	Code Name	Al [mm^2]	St [mm^2]	Diameter [mm]	Thermal Capacity
225 kV	AAAC 570	570.2	-	31.1	840 A
	AAAC 366	366.2	-	24.9	650 A
90 kV	AAAC 570	570.2	-	31.1	840 A
	AAAC 366	366.2	-	24.9	650 A
	AAAC 228	227.8	-	19.6	480 A
	ACSR 228	184.7	43.1	19.6	470 A

Source: JICA Study Team

Table 4.1-2 Ambient Conditions

	Value
Ambient Temperature	30 ℃
Velocity	0.5 m/s
Solar Radiation	0.1 W/cm^2
Emissivity	0.9
Maximum Operating Temperature	75 ℃

Source: JICA Study Team

Code Name	AAAC 570	AAAC 366
Identification	AAAC: All Aluminium Alloy Conductors	AAAC: All Aluminium Alloy Conductors
Cross Section		
Al [mm^2]	570.2 (61/3.45)	366.2 (37/3.55)
UTS [daN]	18,533	11,536
Dia [mm]	31.1	24.9
Thermal Capacity	840 A	650 A

Source: JICA Study Team

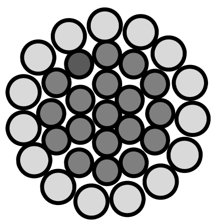
Fig. 4.1-56 Structure of Main Conductors

All Aluminum Alloy Conductor (AAAC) is mainly adopted in Republic of Côte d'Ivoire. Compared with Aluminum Conductor Steel Reinforced (ACSR), AAAC has the following features.

- ✓ It consists of all aluminum wires without steel wire.
- ✓ The hardness of aluminum wire is high to compensate for the lack of strength of aluminum wire.
- ✓ The conductivity is relatively low since impurities are mixed in the aluminum wire.
- ✓ The conductivity of aluminum wire is 53 % or 58 %. (The conductivity of ACSR is 61 %.)
- ✓ AAAC has electrical performance equivalent to or better than ACSR with the same outer diameter.
- ✓ Since the steel wire is not included, the rate of increase in creep growth is large at high temperature.

In Republic of Côte d'Ivoire, AAAC 570 mm^2 is adopted in the existing 225 kV transmission lines. But AAAC 366 mm^2 was initially adopted, so a shortage in thermal capacity is currently a problem.

AACSR PHLOX 94mm^2 is widely applied for the ground wire of the existing 225 kV transmission lines. Also, Optical-Fiber Composite Overhead Ground Wire (OPGW) is adopted too, it is used for control, protection and communication of the existing power system. Fig. 4.1-57 shows the structure of ground wire (PHLOX 94 mm^2).

Code Name	AACSR PHLOX94
Identification	AACSR: Aluminum Alloy Conductor Steel Reinforced
Cross Section	
Al [mm^2]	52 (15/2.1)
St [mm^2]	42.1 (19/1.68)
UTS [daN]	7,800
Dia [mm]	12.6

Source: JICA Study Team

Fig. 4.1-57 Structure of Ground Wire (PHLOX 94 mm^2)

4.1.3 Tower

According to CI-ENERGIES' transmission experts, there are no standard towers. The steel towers were designed for each project.

The below figures shows examples of towers for the existing 225 kV transmission lines.

The existing 225 kV transmission lines often use waist type towers with single circuit and horizontal arrangement. Square section towers with single circuit and triangular arrangement are also applied.

In the existing 90 kV transmission lines, many of the towers are square towers with single circuit and triangular arrangement.

The routes of the existing transmission lines are mostly straight line, and the suspension type towers are adopted. In addition, trees under the routes were securely managed.

Source: JICA Study Team

Fig. 4.1-58 Examples of Towers for Existing 225kV Transmission Lines

Regarding land acquisition, the tower sites and the area under the transmission lines are compensated by the government to the landowners and are managed by the government as public land. Land use within ROW (Right of Way) is not permitted, but in some cases it is partially used as residence or cultivated land. Under the transmission lines, the clearing is done at regular intervals to ensure the clearance between transmission lines and trees.

4.1.4 Insulator Materials

Glass insulators are mainly applied in the existing transmission lines in Republic of Cote d'Ivoire. In addition, as the pollution is considered to be severe in the southern regions of Republic of Cote d'Ivoire, composite insulators have been also applied.

Porcelain insulators and glass insulators are widely used as insulating materials for transmission lines. The porcelain insulators are widely applied in Japan, and the glass insulators are applied in Europe. Although the insulating performance is the same, a small crack on the glass insulator can cause destruction, which is called "shattering phenomenon". The shattering phenomenon doesn't occur in the porcelain insulators. In Europe, it is easy to detect broken insulators due to the shattering phenomenon, but there is a problem that the number of broken insulators becomes greater compared with porcelain insulators and the insulating strength is reduced. Fig. 4.1-59 shows examples of insulators.

Type	Porcelain	Glass	Composite (Polymer)
Cross Section			
Feature	Porcelain insulators with alumina are widely used.	Glass insulators have fine cracks on the surface layer, and cracks make progress by a light impact.	There is a possibility that FRP core breaks (brittle fracture).
	Porcelain insulators have good insulating properties.	Glass insulators have good insulating properties.	Polymer insulators have water repellency and excellent pollution characteristics.
	No deterioration by erosion or corona.	Erosion due to the surface leakage current is likely to occur.	Tracking and erosion may occur by the surface leakage current.
	To confirm the insulation performance, it is necessary to perform inspections.	It is possible to visually identify defective insulators.	Inspection technology has not been established.
	The weight is the heaviest.	Lighter than porcelain insulators.	The weight is the lightest.
	Cheaper than polymer.	The cheapest.	The most expensive.

Source: JICA Study Team

Fig. 4.1-59 Examples of Insulator

Fig. 4.1-60 shows the insulator assemblies on the existing transmission lines.

0

Suspension Insulator Assembly with Single String

Suspension Insulator Assembly with Double String

Suspension Insulator Assembly with Double String

Tension Insulator Assembly with Single String

Tension Insulator Assembly with Double String

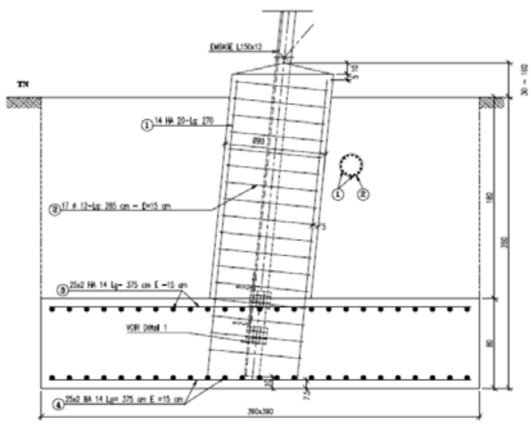
Source: JICA Study Team

Fig. 4.1-60 *Examples of Insulator Assemblies on Existing Transmission Lines*

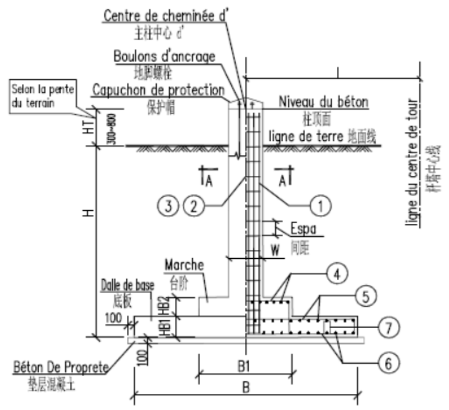
4.1.5 Foundation

As a result of hearing from CI-ENERGIES' transmission experts, we were able to confirm that pad and chimney foundations are mostly applied in Republic of Cote d'Ivoire, and the mat or the pile foundations are applied in the place of soft ground. Also, the foundations were designed for each project.

It is believed that the existing 225 kV transmission lines (Taabo S/S - Kossou S/S, Kossou S/S - Bouaké 2 S/S) had been installed in the 1970's. So it was not possible to get the foundation drawings. Fig. 4.1-61 shows the foundation drawings of other projects.



Foundation Stab Type



Anchor Bolt Type

Source: JICA Study Team

Fig. 4.1-61 Foundation Drawings

Fig. 4.1-62 shows photos of foundations in the lowest main post. The top of the concrete is at the same level as the ground in the left side photo, which may have a harmful influence on the main post. So it is necessary to raise the top of the concrete above the ground as shown in the right photo.

Foundation without a part of concrete on the ground

Foundation with a part of concrete on the ground

Source: JICA Study Team

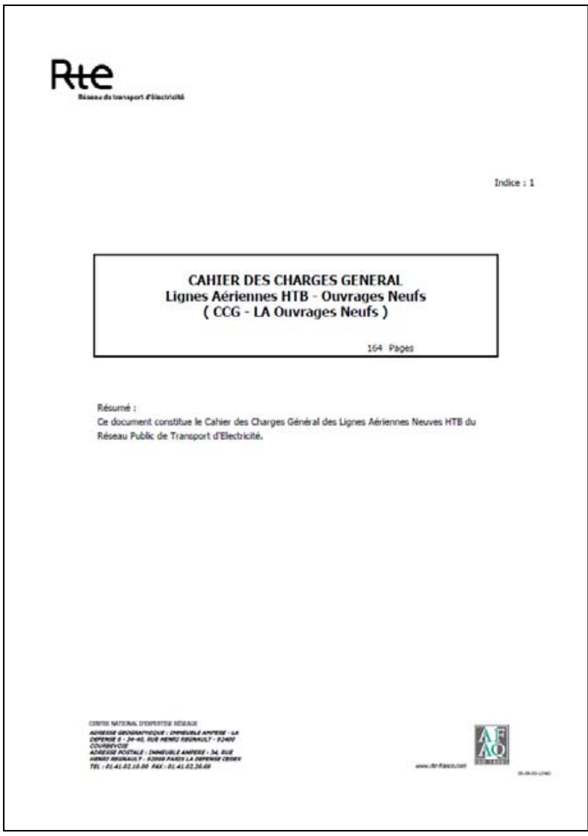
Fig. 4.1-62 Photos of Foundations

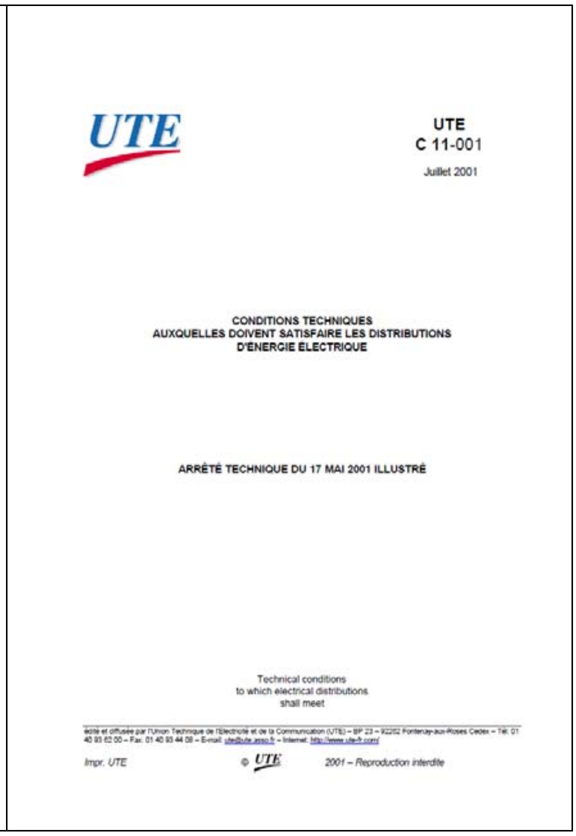
4.1.6 Design Standard and Criteria

There are no design standards in CI-ENERGIES, however the following standard and criteria are applied as design standards.

- ✓ CAHIER DES CHARGES GENERAL Lignes Aériennes HTB - Ouvrages Neufs (CCG - LA Ouvrages Neufs)
- ✓ CONDITIONS TECHNIQUES AUXQUELLES DOIVENT SATISFAIRE LES DISTRIBUTIONS D'ÉNERGIE ÉLECTRIQUE

Fig. 4.1-63 shows examples of the above design standard and criteria.


Rte
Indice : 1
CAHIER DES CHARGES GENERAL
Lignes Aériennes HTB - Ouvrages Neufs
(CCG - LA Ouvrages Neufs)
164 Pages
Résumé :
Ce document constitue le Cahier des Charges Général des Lignes Aériennes Neuves HTB du Réseau Public de Transport d'Electricité.


UTE
UTE
C 11-001
Juillet 2001
CONDITIONS TECHNIQUES
AUXQUELLES DOIVENT SATISFAIRE LES DISTRIBUTIONS
D'ÉNERGIE ÉLECTRIQUE
ARRÊTÉ TECHNIQUE DU 17 MAI 2001 ILLUSTRÉ
Technical conditions
to which electrical distributions
shall meet
Impr. UTE © UTE 2001 – Reproduction interdite

Reference: CI-ENERGIES

Fig. 4.1-63 Examples of Design Standard and Criteria

4.2 SUBSTATION

JICA Study team conducted a site survey of Taabo substation, Kossou substation, Bouaké 2 substation, candidate site of Yamamouskro 2 substation and candidate site of Bouaké 3 substation with CI-ENERGIES, CIE and Power Com (local consultant). In this site survey, we confirmed the design plan for constructing single circuit transmission line between Taabo-Kossou-Bouaké 2-Bouaké 3 by Power Com, which was carried out in 2018. We also confirmed the feasibility of constructing double circuit transmission lines requested by CI-ENERGIES.

4.2.1 Existing Taabo Substation

Taabo substation is one of the key substation for 225kV bulk power system. This substation is connected to Taabo power station (triple circuits), Kossou substation (single circuit), Soubre substation (double circuites), Abobo substation (single circuit), Yopougoan 2 subustation (single circuit) and Akoupe-Zeudji substation (single circuit). As a result of site survey, the expected single line diagram and layout of JICA project is shown in Fig. 4.2-1 and Fig. 4.2-2.

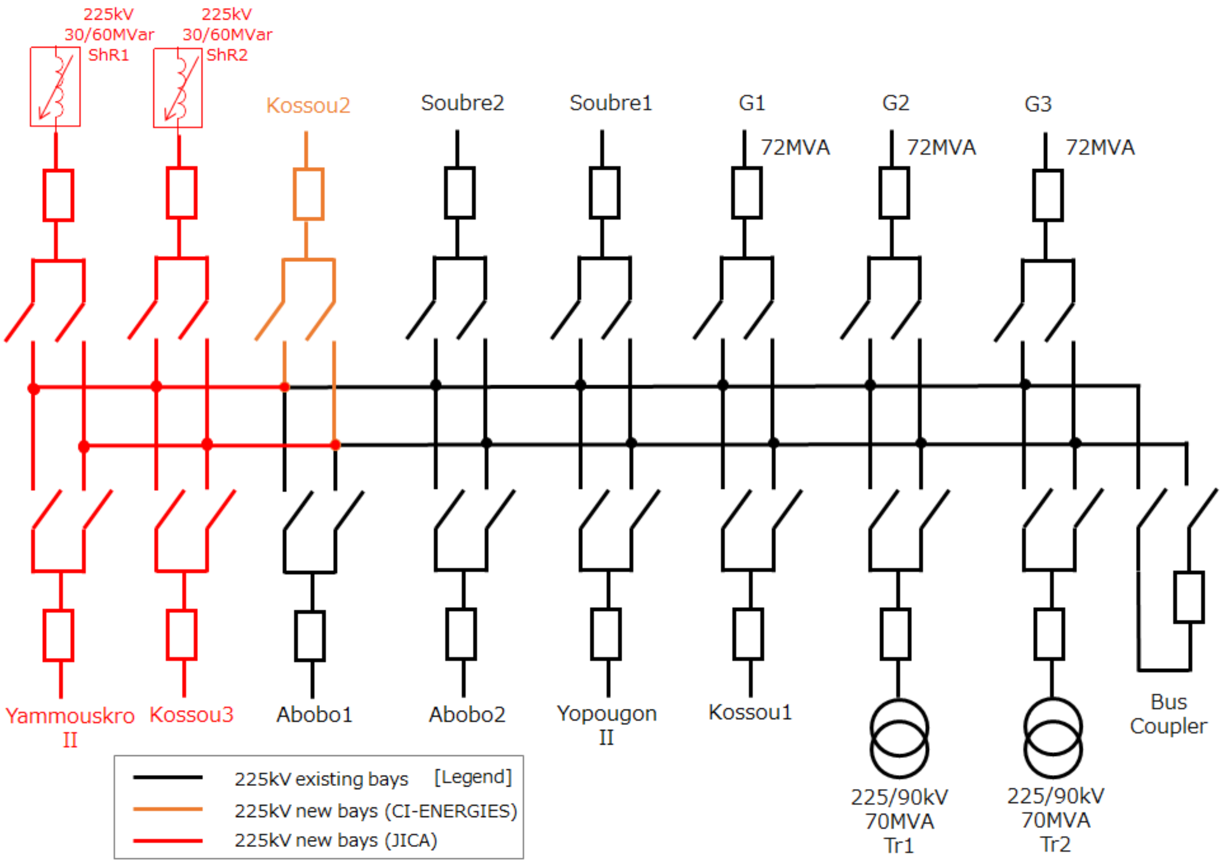


Fig. 4.2-1 Single line diagram of Taabo substation

Source: JICA Study Team

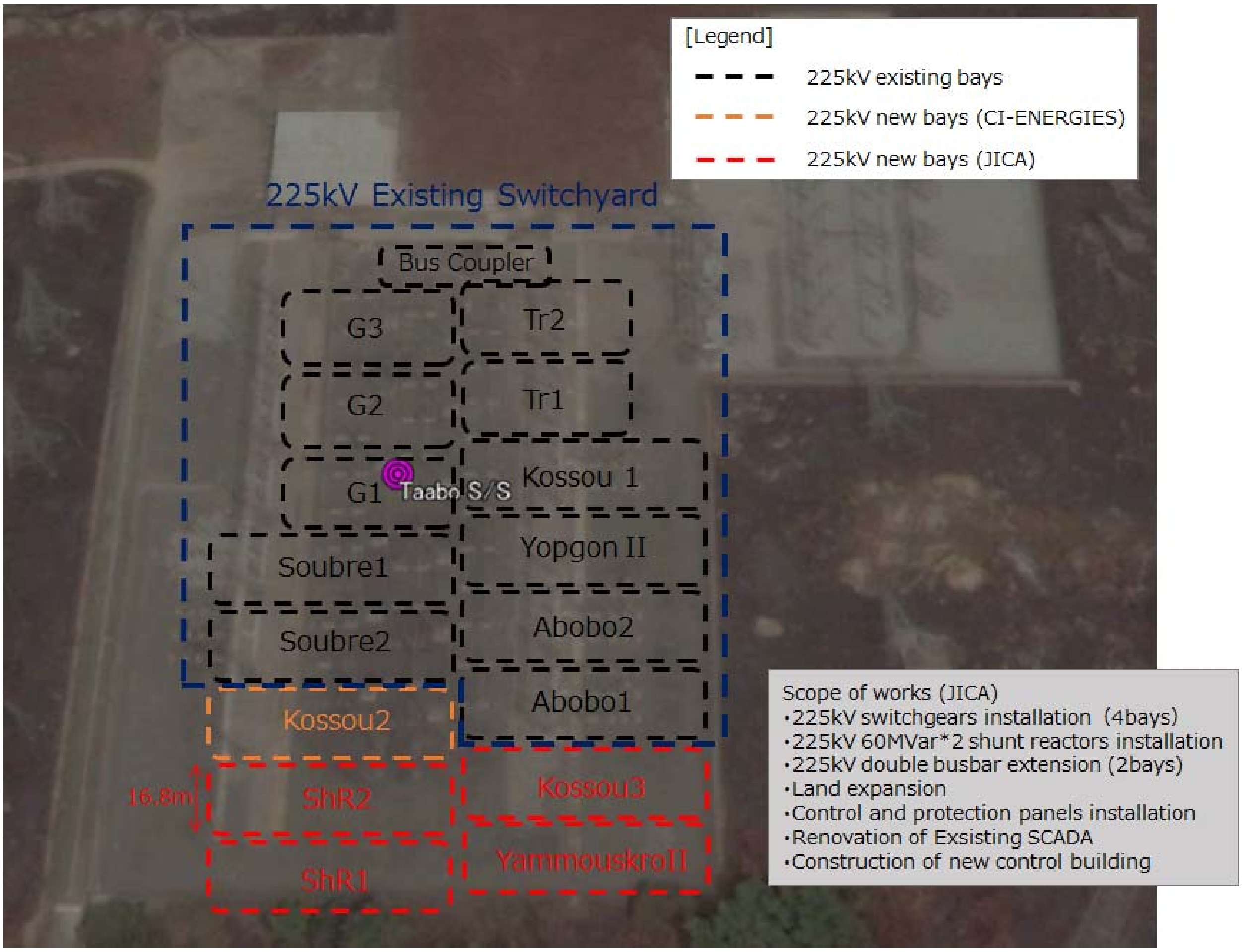


Fig. 4.2-2 Layout of Taabo substation

Source: JICA Study Team

The scope of CI-ENERGIES' self-financing project is a plan to install a 225kV transmission line bay (for Kossou substation), and the controls and protection panels. It is not necessary to extend the existing busbar.

The scope of JICA project is a plan to install two 225kV transmission line bays (for Kossou substation and Yammouskro 2 substation) , two 225kV 30/60 MVar shunt reactor bays, control and protection panels, and to renovate the exisiting SCADA system. The connection to the transmission line is an underground cable. A variable capacitance type (capacity can be adjusted from 30 to 60MVar) shall be installed to suppress voltage fluctuations when the circuit breaker of shunt reactor is open to close or close to open. One variable capacitance shunt reactor has been installed at Soubre substation in Côte d'Ivoire. It is necessary to extend the existing busbar and expand the site of the substation. There are no obstacles in the site expansion area, and according to interviews with CI-ENERGIES and CIE substation staff, the land is owned by CI-ENERGIES.

Taabo substation has an existing SCADA system made by Alstom. This SCADA system was installed with two 225kV transmission line bays (for Soubre substation and Yopougon 2 substation) in 2015. Therefore, the monitoring and control of these two transmission line bays has been incorporated into the SCADA system. In JICA project, it is necessary to renovate this existing SCADA system to incorporate the monitoring and control functions of two transmission line bays and two shunt reactors bays.

Due to the space limitation for installation of control and protection panels, and communication system, it is necessary to install a new control building at the area adjacent to the main building.

 Overall view	 Expansion Space for new 225kV Switchgears
 Existing 225kV switchgears	 Existing control panels

Fig. 4.2-3 Photos of Taabo substation

4.2.2 Existing Kossou Substation

Kossou substation is one of the key substation for 225kV bulk power system. This substation is connected to Kossou power station (double circuits), Bouake 2 substation (single circuit) and Taabo substation (single circuite). As a result of site survey, the expected single line diagram and layout of JICA project is shown in Fig. 4.2-4 and Fig. 4.2-5.

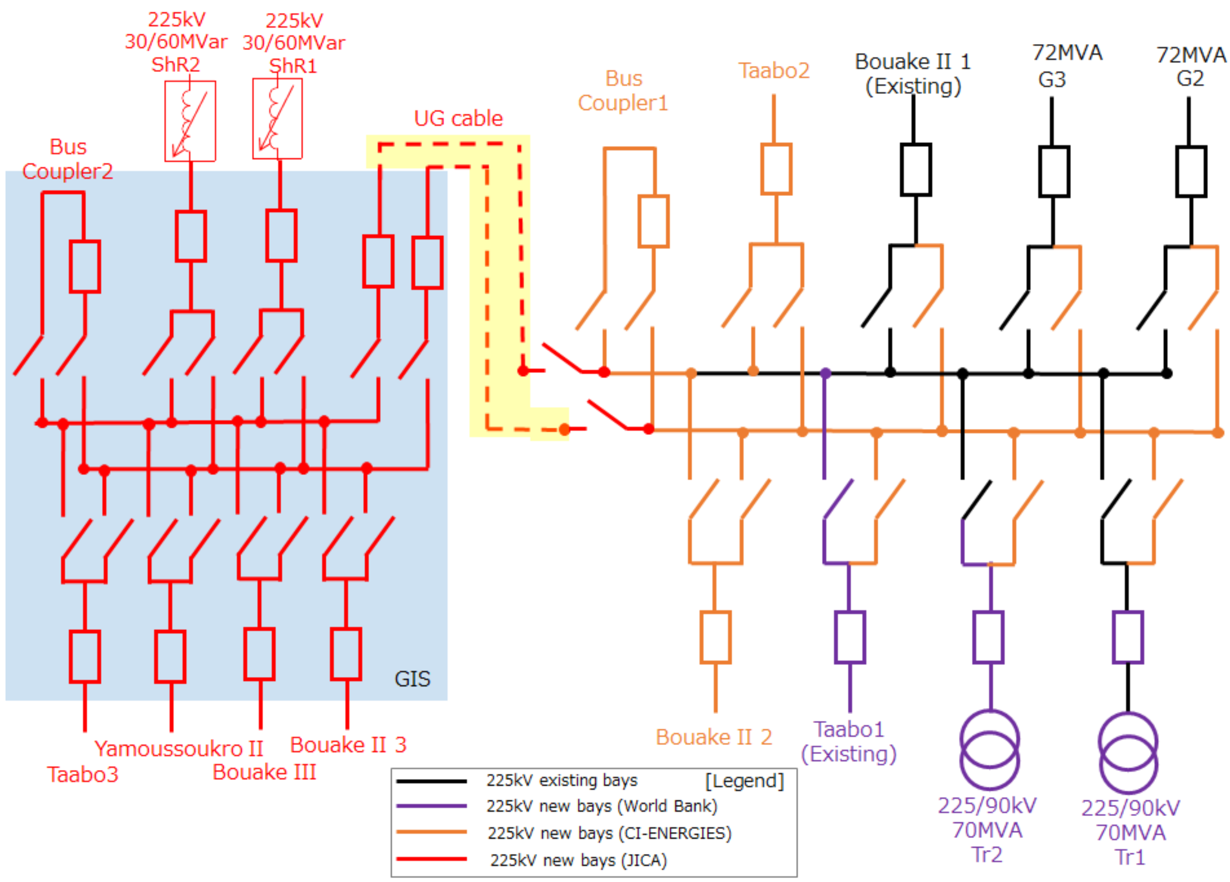


Fig. 4.2-4 Single line diagram of Kossou substation

Source: JICA Study Team

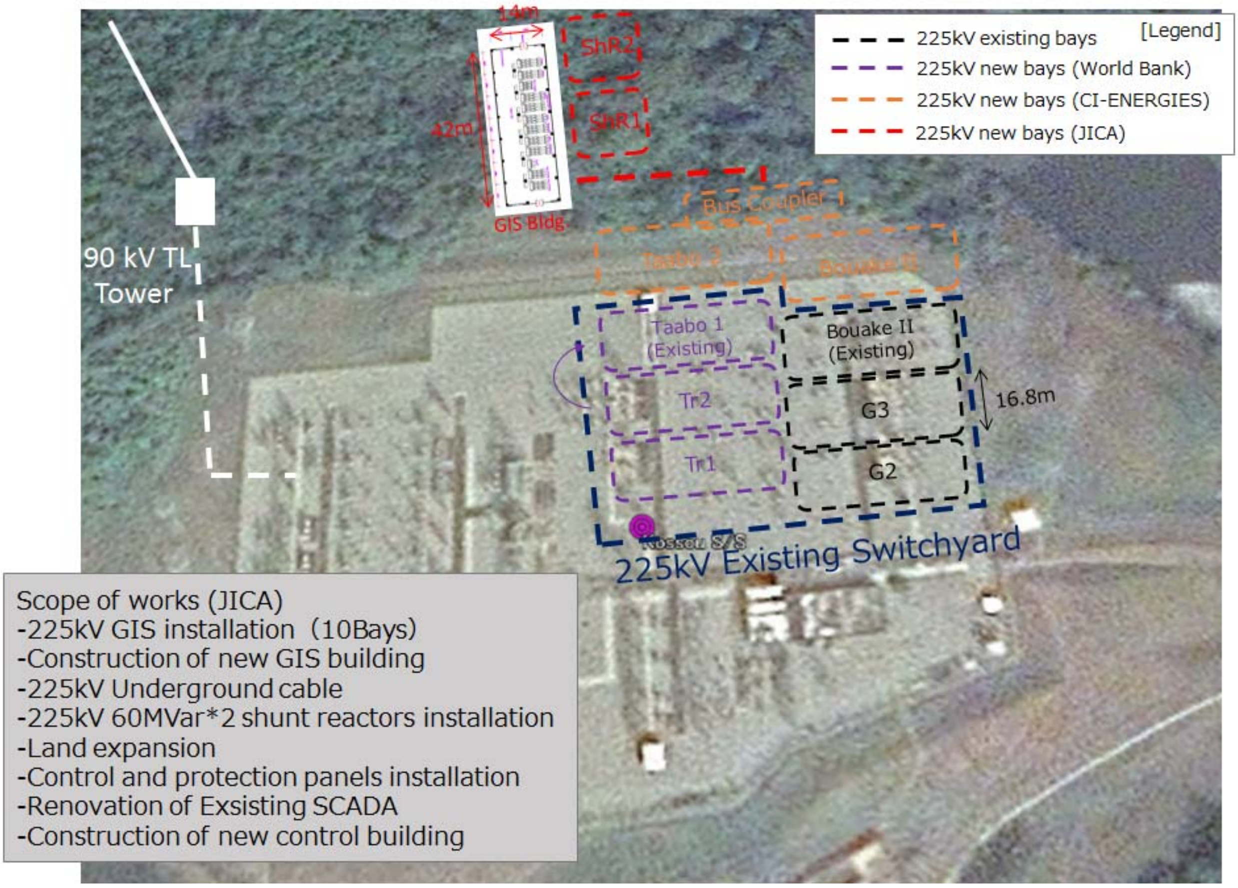


Fig. 4.2-5 Layout of Kossou substation

Source: JICA Study Team

In Kossou substation, the transformer installation works is planned with World Bank as a donor. The scope of World Bank project is a planto install a 225/90kV transformer, replace a 225/90kV transformer, relocate a 225kV transmission line bay (for Taabo substation) and install the control and protection panels and SCADA system. It is scheduled to be completed in March 2021.

The scope of CI-ENERGIES self-financing project is a plan to install two 225kV transmission line bays (for Taabo substation and Bouake2 substaion), 225kV double busbar, 225kV bus couplar and the control and protection panels. It is necessary to extend the existing busbar and expand the site of the substation.

The scope of JICA project is a plan to install four 225kV transmission line bays (for Taabo substation, Yammouskro 2 substation, Bouake 2 substation and Bouake 3 substation) , two 225kV 30/60 MVar shunt reactor bays, two bus section bays, a bus section bay, a bus voltage transformer bay, control and protection panels, and to renovate the exisiting SCADA system. A variable capacitance type (capacity can be adjusted from 30 to 60MVar) shall be installed to suppress voltage fluctuations when the circuit breaker of shunt reactor is open to close or close to open. Due to the land limitation, it is difficulet to expand using AIS. In addition, there is a waterway on the northeast side of the substation, and a 90kV transmission line tower newly constructed in 2020 in the northwest. However, it is judged that it can be installed by adopting indoor type GIS. Indoor type GIS has been installed at Yopougon 1 substation in Côte d'Ivoire. The connection to the transmission line is an underground cable.

In Kossou substation, SCADA system has not been installed yet. However, as mentioned above, it is planned to be install through the World Bank project. Based on the documents provided by CI-ENERGIES, the SCADA system will be made by SIFANG (China). The monitoring and control of two 225/90kV transformer bays and a relocated transmission line bay– these two transmission line bays will be incorporated into the SCADA system. In JICA project, it is necessary to renovate this SCADA system to incorporate the monitoring and control functions of four 225kV transmission line bays, two 225kV 30/60 MVar shunt reactor bays, two bus section bays, a bus section bay and a bus voltage transformer bay.

Due to the space limitation for installation of control and protection panels, and communication system, it is necessary to install a new control building at the area adjacent to the main building.