NILE BASIN INITIATIVE

NILE EQUATORIAL LAKES SUBSIDIARY ACTION PROGRAMME (NELSAP)

STUDY ON THE INTERCONNECTION OF THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES

FEASIBILITY REPORT
VOLUME 2 A – UGANDA-KENYA INTERCONNECTION
MAIN REPORT

OCTOBER 2007

N° 1 36 0300

FINAL

SOGREAH CONSULTANTS · RSW INTERNATIONAL inc. · Hydro Québec International · Hifab

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LIST OF ABBREVIATIONS

AFSEC	African Electrotechnical Standardization Commission / Commission Electrotechnique Africaine de Normalisation
BAD	Banque Africaine de Développement
CAPP / PEAC	Central Africa Power Pool / Pool énergétique de l'Afrique Centrale
CEEAC	Communauté Economique des Etats de l'Afrique Centrale (ECCAS)
CEPGL	Communauté Economique des Pays des Grands Lacs
DEM	Digital Elevation Model
DRC / RDC	Democratic Republic of Congo / République Démocratique du Congo
EAPP	East African Power Pool / Pool énergétique de l'Afrique de l'Est
EGL	Energie des pays des Grands Lacs (Burundi, RDC, Rwanda)
EDF / FED	European Development Fund / Fond Européen de Développement
ERA	Electricity Regulatory Authority (Uganda)
KenGen	Kenya Electricity Generating Company Ltd
KPLC	The Kenya Power and Lighting Co. Ltd
MEM	Ministère de l'Energie et des Mines / Ministry of Energy and Mining
MoI	Ministry of Infrastructures / Ministère des Infrastructures
MNT	Modèle numérique de terrain
NBI / IBN	Nile Basin Initiative / Initiative du Bassin du Nil
NEL	Nile Equatorial Lakes
NEL-CU	Coordination unit for NELSAP
NELSAP	Nile Equatorial Lakes Subsidiary Action Programme
PAALEN	Programme Auxiliaire d'Action des pays des Lacs Equatoriaux du Nil
PPA	Power Purchase Agreement / Contrat d'achat d'énergie
PREBU	Programme de réhabilitation du Burundi
SADC	Southern Africa Development Community / Communauté pour le développement de l'Afrique Australe
SAPP	Southern Africa Power Pool / Pool énergétique de l'Afrique Australe
SINELAC	Société internationale d'électricité des pays des grands lacs
SNEL	Société National d'Electricité (RDC)
SRTM	Shuttle Radar Topography Mission
UEGCL	Uganda Electricity Generation Company Ltd
UETCL	Uganda Electricity Transmission Company Ltd
UPDEA	Union des Producteurs, Transporteurs et Distributeurs d'Energie Electrique d'Afrique / Union of Producers, Transporters and Distributors of Electric Power in Africa
USAID	Agence pour le Développement International des Etats Unis
WAPP	West Africa Power Pool

1. INTRODUCTION

1.1. GENERAL

The project background and the project presentation are enclosed in Volume 1 of the feasibility study report. Briefly, the project includes the following interconnections:

a. Uganda – Kenya interconnection.

The project consists in constructing a 230 km HV power line between Bujagali in Uganda and Lessos in Kenya, duplicating the existing 45-year old, double 3-phase 132 kV power line.

b. Uganda – Rwanda interconnection

The project consists constructing an HV power line, 230 km long, between the substations at Mbarara in Uganda and Birembo in Rwanda.

c. Burundi – Rwanda interconnection

The project consists in constructing an HV power line, approximately 109 km long, between the Rwegura hydroelectric power station in Burundi and the Kigoma substation in Rwanda.

d. Strengthening the interconnection between Burundi, DRC and Rwanda

The purpose of the project is to increase the transmission capacity and working flexibility of the transmission network and to improve the security of the electricity supply in Burundi, DRC eastern grid and Rwanda. The project involves:

- increasing the operating voltage of the 112 km power line between the hydro-electric power station at Rusizi I (DRC) and Bujumbura (Burundi) from 70 kV to 110 kV,
- increasing the operating voltage of the 150 km power line between Rusizi I and Goma in DRC from 70 kV to 110 kV,
- constructing a 62 km, 110 kV power line between Goma (DRC) and Mukungwa (Rwanda), closing thereby the loop around Lake Kivu and
- constructing a 15 km, 110 kV power line between Bujumbura and Kiliba (DRC).

1.2. PURPOSE OF VOLUME 2

This volume provides technical and economical considerations regarding the design of the interconnection transmission lines from Uganda to Kenya to connect the networks of the two countries. The main objective of the study of transmission lines has been to ensure the connection of the two networks in a safe, cost effective and reliable manner. In doing this, the studies address various technical, economical and environmental aspects regarding the line route selection between the appropriate two countries, as well as design assumptions for the transmission line.

This interconnection study is based on the result of Demand and Supply analysis presented in Volume 1.

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2. SELECTION OF TRANSMISSION LINE ROUTES

2.1. APPROACH AND METHODOLOGY

The line routes (and separate environmental) considerations as accounted for in this study are initially based on a desk study comprising of map studies followed by subsequent field survey of the line alignment options, and above all, the findings of former feasibility studies and the collected data e.g. maps of present and future electricity transmission networks of Uganda and Kenya. The aim of the study has been set up to assess the technical and economic viability, and environmental acceptability of the interconnection transmission lines. In this relation the study address legislation requirements, physical, biological and human environmental considerations, urban development as well as design, construction, maintenance and reliability considerations. The recommendations from a separate environmental study will be adopted, such as to avoid creating an additional corridor of disturbance by following existing roads/tracks and power lines as far as possible. The primary factors in selection of the interconnection transmission line routes have been access and reliability considerations, which comply with this recommendation.

2.2. MAP STUDIES

Topographical maps in scale 1:50,000 with 20 m contour intervals have been studied and potential line route options were identified on these maps for route options evaluation and identification during the preliminary field survey.

The line route options are plotted on the Transmission Line Route Map, which is presented in Volume 2C of this Feasibility Report.

2.3. LINE ROUTE SURVEY

Line route survey of Kenya – Uganda interconnection included topographical survey and soil investigations. The survey work and its results are presented in Volume 2C of this Feasibility Report.

2.4. LAND ACQUISITION AND LAND USE

Land acquisition will be limited to tower sites where the line passes through cultivation lands and/or pasture, except at particular locations required by the utility. Since farming relies on manual planting and harvesting, the production area actually lost is minimal. Details are presented in the environmental study.

2.5. ENVIRONMENTAL MANAGEMENT

For a detailed study of the environmental assessment reference is made to the Environmental Impact Assessment in Volume 2B of this Feasibility Report.

The following principals were adopted in choice of a feasible line route:

2.5.1. ALIGNMENT SURVEY AND DESIGN STAGE

- Avoid sitting transmission line through protected areas, other environmentally sensitive areas or through mature forest stands;
- Avoid cultural and heritage sites;
- Site transmission line towers on high points of land such that conductors can be strung over valleys thereby eliminating the need to remove trees;
- Locate transmission lines along base of mountain slopes, rather than down centre of valleys where heavy birds could come into contact with conductors;
- Locate transmission lines to avoid running through villages; run lines behind villages;
- Consult villagers regarding location of valued village resources and locate transmission lines to avoid these features;
- Situate transmission lines not far away from roads, but behind roadside forested areas so as to minimize visual intrusion;
- Minimize the need to construct of new access tracks wherever possible;
- Employment of existing access roads and tracks wherever available; and
- Ensure minimum clearance distances between conductors and ground, waterways, road crossings, buildings, communication systems etc. are incorporated into design.

2.5.2. CONSTRUCTION STAGE

- Limit right-of-way to 40 meters width, however, the undergrowth in the right-of way should be allowed while only leaving a narrow strip to be completely cleared to allow stringing of the line conductors;
- Clear only narrow path to facilitate pulling the nylon rope between towers to string the conductors;
- Strictly define right-of-way clearing activities in the contract specifications and environmental special provisions;
- String conductors under tension to minimize potential damage to remaining ground vegetation;
- Use existing access roads and tracks wherever available;
- Decommission additional temporary access tracks at end of construction;
- Where access is required across agriculture lands use temporary access paths during dry season involving placement of geotextile over which aggregates shall be placed;
- Design and construct transmission line towers with staggered legs so as to eliminate the need to cut a level pad into slopes on which to construct the towers;
- Minimize the need for access tracks whenever possible;
- Construction to proceed in the dry season if possible to minimize soil erosion and mass wasting – where construction is required in the rainy season, potentially unstable slopes to be avoided;

- Scaffoldings to be placed over roadways at locations conductors are being strung to ensure traffic flow is maintained and public safety is provided.

2.6. VISUAL IMPACTS, NOISE, ELECTRIC AND MAGNETIC FIELDS

In general the line route is directed close to existing or planned transmission lines. With the lattice design of towers, the solid impact will be small. The visual impact will be greatest where the line passes through open cultivated or pasture land. The following transmission lines exist and have the same directions as the interconnection transmission line routes:

In Kenya:

The proposed line route of Uganda – Kenya interconnection in Kenya side follows the existing Tororo – Lessos 132 kV transmission line.

In Uganda:

The proposed line route of Uganda – Kenya interconnection in Uganda side follows the existing Owen Falls – Tororo 132 kV transmission line.

The extra visual impact will be minimal on these sections. The noise caused by corona will be small due to large conductor size. As the line in general passes houses and buildings with good clearance due to 40 meters right-of-way, the impact from electric and magnetic fields will be accordingly minimal.

2.7. CONSTRUCTION AND OPERATION

The construction specification will require drainage and surface re-vegetation on tower sites that have to be cleared. This is not only for environmental reasons but also of more importance to avoid erosion compromising the tower foundations.

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3. STUDY OF STRUCTURE AND EQUIPMENT CHARACTERISTICS

3.1. TRANSMISSION LINE DESIGN

3.1.1. GENERAL DESIGN

The interconnection line would be constructed by using International Competitive Bidding (ICB). It is recommended that the principles of the International Electrotechnical Commission (IEC) standards 826-1, 2, 3 and 4 for a Security Class I line (50-year return period of ultimate conditions) will be adopted for the design. The high altitudes influence on both the thermal rating and the insulation coordination due to the change in air density. Accordingly, a correction factor is assumed for the impulse and withstand voltages at altitudes above 1,000 m. The line routes of all options are considered as light polluted corresponding to level 1 of IEC 815.

3.1.2. DESIGN LOADING

When designing the line structures the following assumed climatic conditions should be taken into consideration:

- in calculation of clearances, the maximum temperature of:	
conductor without current	+ 35 °C
current carrying conductor	+ 75 °C
- minimum temperature	+ 10 °C
- everyday (EDS) temperature	+ 25 °C
- temperature during max. wind	+ 10 °C
- maximum gust wind speed (10 m above ground level)	36 m/s

Tower loadings should be calculated according to IEC 826-2 and –3 with wind and temperature loadings for (i) normal transverse (conductor on whole wind span, insulator string on projected area and tower structure on projected area) and (ii) vertical loads (weight of conductors and ground wires over weight span, weight of conductors and ground wires over the uplift span and tower weight taken at 100%). Special loadings will apply without wind load at minimum temperatures (broken wire, either one conductor or ground wire and stringing loads as per IEC). Overhead factors of 1.2 for structural steel to allow for fluctuations in the steel supply and 1.5 for foundation stability to allow for uncertainties in soil characteristics are allowed for. Earthquake loadings have been assessed to 0.1 g horizontally and 0.05 g vertically.

3.1.3. VOLTAGE LEVEL

The existing transmission voltage levels in Kenya are 132 kV and 220 kV, i.e. the highest operation voltage is 245 kV (according to the IEC voltage series), whereas in Uganda the transmission voltage level is 132 kV. Considering the projected power transfers between Uganda and Kenya, and the existing network layout and voltage levels, 245 kV proves to be the optimal voltage solution for this interconnection. This enables a transfer of 150 – 250 MW.

3.1.4. NUMBER OF CIRCUITS

A double-circuit line gives increased transmission capacity and better reliability compared to a single-circuit line.

Furthermore, a double-circuit line is more flexible in planning maintenance procedures on line itself and in substations as well.

3.1.5. PROVISION FOR ELECTRICITY RURAL DISTRIBUTION

Distribution lines already exist in all the areas along the projected interconnection line and most of the villages are electrified. As a result, provision for rural distribution such as insulated ground wire distribution system is not necessary.

3.1.6. DESIGN STANDARDS

It is assumed that the interconnection line will be constructed using International Competitive Bidding (ICB). Hence, it is recommended that the principles of the International Electro Technical Commission (IEC) standards 826-1, 2, 3 and 4 for a Security Class I line (50-year return period of ultimate conditions) will be adopted for the design of the line.

3.1.7. ELECTRICAL CHARACTERISTICS

3.1.7.1. HIGH ALTITUDE

The high altitudes influence on both the thermal rating and the insulation coordination due to the change in air density. Accordingly, a correction factor is assumed for the impulse and withstand voltages at altitudes above 1,000 m.

3.1.7.2. POLLUTION

The line routes of both interconnection lines are considered as light polluted corresponding to level 1 of IEC 815 with a minimum creepage distance of 20 mm/kV.

3.1.7.3. LIGHTNING

Isokeraunic level is 180 Td/year and the value is valid for both interconnection lines.

3.1.7.4. SEISMIC ASPECT

Seismic level is 0.1 g for both interconnection lines.

3.1.7.5. GROUND RESISTANCE

The ground resistance should be aimed to 20 Ω except for the first and last three kilometers from/to substation where the resistance is recommended aimed at 10 Ω.

3.1.7.6. LINE ELECTRICAL CHARACTERISTICS

The line electrical characteristics are assumed to be as follows:

Table n° 1 - BUJAGALI–TORORO–LESSOS LINE ELECTRICAL CHARACTERISTICS

Nominal voltage of a three-phase system	220	kV
Highest voltage of a three-phase system	245	kV
Rated short duration power frequency withstand voltage (Altitude =1,000 m / > 1,000 m)	395 / 460	kV
Rated lightning impulse withstand voltage (peak) (Altitude =1,000 m / > 1,000 m)	950 / 1050	kV
Rated frequency	50	Hz
Minimum insulator creepage distance	25	mm/kV
Maximum shielding angle to outer phase conductor in towers	10	°
Maximum operating conductor temperature	75	°C
Maximum air temperature	35	°C
Average air temperature	20	°C
Minimum air temperature	10	°C
Humidity	90 – 100	%
Gust wind speed (3 seconds at 10 m above ground level)	36	m/s

3.1.8. CONDUCTOR CLEARANCES

The following minimum vertical conductor clearances should be maintained at a maximum conductor temperature in still air and final sag, i.e., tower spotting temperature of 80 ºC:

Object	Vertical clearance in meters
Roads	9.0
Land accessible to pedestrians only	8.0
Overhead line	5.0
Telecommunication lines	4.6

The phase-to-phase or phase-to-earth wire distance (dm) shall not be less than:

$$d_m \geq 0.9 \cdot \sqrt{(F+L)} + C$$

Where:
- F = sag of the conductor (m) at maximum temperature (+80 ºC)
- L = length of the insulator string (m), for tension string L = 0
- C = constant for 220 kV = 1.5 m

3.1.9. PHASE CONDUCTORS

An aluminium conductor steel reinforced (ACSR) is the most commonly used conductor type in the world and also in Africa. Its usage is justified because of its strength, which is needed for long spans and heavy loadings. The other alternative, which has been used also in Africa, is all aluminium alloy conductor (AAAC). In the countries where ice loads are not expected and where there is no firm commitment to any particular conductor type, the use of all aluminium alloy conductor is a good alternative.

The current raw material price (LME price in USD/t) is 3 % higher for aluminium alloy than for pure aluminium. Due to higher resistivity, AAAC conductor must have bigger cross-section than equivalent aluminium cross-section of ACSR conductor in order to have the same current carrying capacity. On the other hand adding of steel wires increases the cost of ACSR conductor because steel part cannot be counted to increase current carrying capacity of the conductor. Table n° 2 compares equivalent AAAC and ACSR conductors of one manufacturer.

Table n° 2 - COMPARISON BETWEEN AAAC AND ACSR CONDUCTORS

Type of Conductor	Aluminium Area		Overall Conductor					Price (USD/km)
	Nominal (mm^2)	Actual (mm^2)	Diameter (mm)	Rated Strength (kN)	Weight (kg/km)	D.C. Resistance at 20 °C (ohms/km)	Current Rating (A) 30 °C / 80 °C, 0.6 m/s wind, 1000 W/m^2 sun	
AAAC-300	300	299.4	22.5	83.63	827	0.112	696	3293
ACSR/Hawk	240	241.7	21.8	86.5	975	0.1194	658	2922

Note:

- Conductor price for AAAC has been calculated by using LME aluminium price assuming its weight being 75 % of the final conductor price.
- Conductor price for ACSR has been calculated by using LME aluminium price assuming its weight being 75 % of the final conductor price + price of steel wires.

The following conclusions can be drawn:

- Overall conductor diameters are close to each other, which means that wind load is the same for both conductor types;
- Rated strength is almost at the same level with both AAAC and ACSR;
- AAAC is 15 % lighter than ACSR conductor, allowing longer span for AAAC, or lighter towers with same span length;
- The prices of the conductors are roughly on the same level.

Based on the above advantages and prices, the adoption of ACSR is recommended. Duplex ACSR 240/40 mm2 (Hawk) conductor is recommended to be selected for construction of new line.

Selection of conductor cross-section is based on a least-cost analyse. Total costs, i.e. investment and losses, of several conductors are compared and the least-cost conduc¬tor is selected. Total losses include the capitalized annual thermal and corona losses. Duplex ACSR 240/40 mm2 (Hawk) conductor (aluminium equivalent) has the lowest total costs considering the utilization time for losses and discounting interest rate.

The recommended ACSR conductor should comply with the characteristics shown as follows:

Type of conductor		ACSR 240/40 (Hawk)
Standard		IEC
Conductor designation per phase		2
Stranding		
Aluminium wires	No./mm	26/3.439
Steel wires	No./mm	7/2.675
Sectional area		
Aluminium	mm2	241.5
Steel	mm2	39.34
Cross section	mm2	280.84
Overall diameter	mm	21.78
Unit weight	kg/m	976.5
Minimum ultimate tensile strength	kN	87.083
Current rating	A	658
Rated DC resistance at 20 ˚C	Ω/km	0.1194

3.1.10. GROUND WIRES

According to the electrical requirements, like earth fault currents, one steel wire with a cross section of 70 mm2 would be sufficient. This wire type is also used as earth wire in both countries.

The high reliability requirements of the line shall be considered when designing the protection against lightning. The average height of highest phase conductor from ground is about 30 m. According to the recommendations in "Transmission Line Reference Book" the Shielding Angle should be 10...15 deg. When increasing the shielding angle from 15 deg to 30 deg, the probability of shielding failure becomes three times higher. If only one shield (ground) wire is used, the shield wire support would become very high in order to meet the requirements of 15 deg. shielding angle. When using two ground wires instead of one, the weight of the tower decreases, and total line costs including earth wires will be a cheaper solution than a higher tower with one ground wire. Therefore, a two ground wire solution is recommended. In this case one ground wire is assumed to be optical ground wire (OPGW) and the other conventional galvanized steel ground wire (GSW).

The recommended GSW should comply with the characteristics shown as follows:

Type of ground wire	GSW 70	
Standards	IEC	
Cross sectional area	mm2	68.1
Overall diameter	mm	10.6
Unit weight	kg/m	310
Minimum ultimate tensile strength	kN	51.9

The recommended OPGW should comply with the characteristics shown as follows:

a. Ground wire properties

Type of conductor	ACS/AAC (Aluminium clad steel + aluminium alloy wires)	
Standards	IEC, IEEE, ASTM and ITU-T	
Suspension of optical fibers	Aluminium tube	
Cross sectional area	mm^2	44
Overall diameter	mm	10
Unit weight	kg/m	297
Minimum ultimate tensile strength	kN	47
DC resistance at 20 °C	Ω/km	0.90

b. Fiber cable properties

Optical fiber type		Single mode
Standard		ITU-T G652
No. of fibers		24
Coating diameter	µm	250±15
Coating concentricity		≥ 0.7
Attenuation		
At 1310 nm	dB/km	≤0.38
At 1550 nm	dB/km	≤0.25
Lifetime expected	years	40

3.1.11. INSULATORS

The insulator(string)s will be (a) cap and pin class or (b) composite type.

a. (a) Class Insulators

The insulator strings will be equipped with cap and pin class insulators U120 BS for 220 kV of IEC 305 or equivalent. The following strings will be used:

- Single suspension string with two arching horns .... 1*18 units
- Double suspension string with two arching horns... 2*18 units
- Single tension string with two arching horns.. 1*19 units
- Double tension string with two arching horns .... 2*19 units

18 (19) units will provide adequate electrical strength even on the highest altitude level faced along the interconnection line route Bujagali – Tororo - Lessos.

The recommended insulator should comply with the characteristics shown as follows:

Type		U120BL
Standard		IEC 60305
Disc diameter	mm	255
Unit spacing	mm	146
Minimum creepage distance	mm	295
Electromechanical failing load	kN	120
Ball and socket size	mm	16
Net weight (approx.)	kg	4.2
Material	Toughened glass (or porcelain)	

b. Composite Insulator

The insulator strings will be equipped with composite insulators for 220 kV of IEC 61109 or equivalent. The following strings will be used:

- Single suspension string with two arching horns ....section length 2020 mm
- Double suspension string with two arching horns..................section length 2020 mm
- Single tension string with two arching horns.........................section length 2215 mm
- Double tension string with two arching horns ....section length 2215 mm

Above section lengths will provide adequate electrical strength even on the highest altitude level faced along the interconnection line route Bujagali – Tororo - Lessos.

The recommended insulator string should comply with the characteristics shown as follows:

Type		Suspension	Tension
Standard		IEC 61109	
Shed diameter (big/small)	mm	164/130	
Number of sheds (big/small)	nos	26/25	28/27
Minimum leakage distance	mm	7077	7629
Electromechanical failing load	kN	120	
Ball and socket size (IEC 120)	mm	16	
Net weight (approx.)	kg	12.5	14.0
Material			composite

3.1.12. TOWER OPTIMIZATION

Conventional lattice self-supported steel towers for double- circuit/single-circuit with two ground wires are assumed. Furthermore, it is recommended to optimize the tower design according to the following guidelines:

- The transmission line should be divided in defined sections with traditional tension towers in each end point of the sections. The length of the sections to be decided should be based on access conditions, topography and usable stringing sites.

- Angle and uplift tension towers within each section should be designed with a safety factor for broken wire load case as for suspension towers. For wind load cases the same safety factor applies for all towers.

- Suspension towers, which have substantial lower weights and costs, should be used where possible including angles up to 10 degrees.

With an estimated ruling span for the 220 kV line of approximately 350 meters the tower heights (from top of foundation to the cross arm) would range from 28 to 43 meters.

3.1.13. TOWER TYPES

The line routes of the interconnection lines are mostly flat or slightly hilly, only short sections are slightly mountainous (see Volume 2C of this feasibility Report).

The self-supported steel lattice towers with steel grillage foundations or concrete foundations are used in Kenya and Uganda. Both of these foundations types are possible for the interconnection line.

For cost estimation purposes a normal suspension tower and a tension tower has been designed (see Annex B). The number of heavier towers has been estimated (angle and terminal towers) and taken into account in transmission line cost estimates.

3.1.14. TRANSPOSITION

Transpositions are assumed to be installed by jumper arrangements at special tension towers. There will be two transpositions between line sections Lessos – Tororo (in Kenya) and Bujagali – Tororo (in Uganda).

3.1.15. FOUNDATIONS

Both steel grillage and concrete foundations are commonly used for high voltage overhead transmission lines in Kenya and Uganda. Concrete foundations in some locations, especially, in Mbarara – Mirama section, would be more expensive, mainly due to very high transport costs. Materials such as cement, rebar steel, crushed stones and to some extent proper sand would have to be brought by manpower in some tower locations

Generally, steel grillage foundations are basically acceptable technical solution, as long as there is no damage to the galvanizing and all steel to be buried is painted with two layers of bituminous paint for extra protection. In the event of unfavourable soil acidity (corrosive environment), which normally is rare in this part of Africa, concrete foundations are the only solution.

Ground conditions seem to be fairly homogenous along the transmission line routes, being mainly residual soil comprising silty clay as well as disintegrated rock that should be encountered at different depths. It is assumed that extensive soil investigations are carried out during the detail design stage.

As a conclusion the foundations are mostly concrete foundations for the suspension towers but steel grillage type shall be used in special conditions, too. The foundations of tensions and terminal towers shall be of concrete.

For cost estimation purposes model foundation types (a bad and chimney, a concrete block, a rock anchor and a grillage foundation) have been drafted (see Annex C).

3.1.16. CLEARING OF RIGHT-OF-WAY (ROW)

The right-of-way (ROW) width is proposed to set to a maximum of 40 meters. Complete clearing of the ROW where the line passes through forested areas should be limited to a 5 to 10 meters strip in the centre line to allow for stringing of the conductors. Outside this strip but within the ROW all vegetation above 3 meters height needs to be cleared including possible danger trees outside the ROW. Although this approach with respect to maintenance aspects could be found hard to accept, experience from other projects in the region has shown that by engaging the local communities along the line in maintenance and monitoring of the line these ROW requirements could be achieved. This approach has also proved to be effective in reducing theft of steel bracing and grounding materials from towers to a minimum.

Again utilization of the terrain when selecting the final line route and spotting the towers are factors which, if skillfully performed, could further reduce the clearance requirements.

3.1.17. GROUNDING

All towers are assumed to be permanently grounded with an individual tower footing resistance aimed to be less than 20 Ω. Over the first 1.4 km or three spans out of any substation, all towers, including the terminal towers, should be connected together by continuous counterpoise cable, which also should be connected to the substation-earthing grid. At tower sites in urban areas often frequented by people, additional protective earthing should be carried out aimed at less than 10 Ω.

3.1.18. MAINTENANCE

3.1.18.1. INTERCONNECTION

Because of high reliability requirements set for the Interconnection, the efficiency of the maintenance of the line (and substations, as well) the efficiency of supply restoration activities in interruption cases become important. Maintenance groups shall carry out regular inspections and maintenance of the line and substations, and quick repair of faults. These groups could do maintenance and repair work in other lines, but should be ready to carry out immediate repairs on the Interconnection, if needs may arise.

3.1.18.2. MAINTENANCE PROCEDURES

The Operation Working Group shall meet periodically, at minimum annually, to co-ordinate maintenance schedules and to co-ordinate other maintenance activities in their power system in order to minimize restrictions on the transmission capacity. Each planned and agreed maintenance requires a specific Maintenance Request and a final Outage Order.

3.2. SUBSTATION DESIGN

3.2.1. GENERAL

The proposed terminal points of Kenya-Uganda interconnection are at Lessos 220/132 kV substation in Kenya and Bujagali HPP's 220/132 kV substation in Uganda.

Lessos is an existing 220/132 kV substation with a radial 220 kV line feeder to Turkwel HPP and with two interbus transformers for interconnection to Kenyan 132 kV transmission system.

Bujagali 220/132 kV substation will be built in connection with the Bujagali 200 MW HPP project, scheduled to be commissioned in 2011. The plant and the associated substation will be located near town of Jinja, ca. 10 km northwest from existing Nalubaale HPP, which currently is the main source of generation in Uganda. The station will be connected to Kampala area, Kawanda substation via 220 kV double circuit line (initially operated at 132 kV) and by two interbus transformers to Ugandan 132 kV transmission system.

The voltage level of the interconnection would be 220 kV (Um = 245 kV) and terminal stations would be Lessos in Kenya and Bujagali in Uganda. Based on n-1 system planning principle, a double circuit transmission line has been recommended.

As both the terminal stations are located quite far from the border, construction of a new 220 kV substation is recommended in vicinity to the border, roughly in the middle of the Bujagali - Lessos transmission line route in order to bring the point of sales / point of supply (as well as the revenue metering) close to the Uganda-Kenya border.

The obvious choice for location would be next to the existing Tororo 132/33 kV substation in Uganda side ca. 5 km from the border as the proposed line route passes the said station. Furthermore, UETCL has expressed interest to interconnect the 220 kV and 132 kV systems in Tororo station through interbus transformers in near future for supply of the Tororo area load.

Other planned projects related to the interconnection project include construction of 220 kV line(s) between Lessos and Olkaria. This would facilitate higher rate of transmission than presently planned and agreed upon.

3.2.2. ENVIRONMENTAL CHARACTERISTICS IN UGANDA

Ambient air temperature	**Indoor**	**Outdoor**
Maximum	+ 35°C	+ 35°C
24 hour average, max		+ 26°C
Minimum	+ 10°C	+ 8°C
Humidity:	90 %	100 %
Seismic Acceleration	0.1 g	
Isoceraunic Level	150	
Rainfall average annual	1100 mm	

3.2.3. ELECTRICAL CHARACTERISTICS AT UGANDA SUBSTATIONS

Table n° 3 - UGANDA SUBSTATIONS CHARACTERISTICS

132 kV system requirements:

Maximum operating voltage	170 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	750 kV peak
Rated power-frequency short duration withstand voltage	325 kV
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	30 mm/kV

220 kV system requirements:

Maximum operating voltage	245 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	1050 kV peak
Rated power-frequency short duration withstand voltage	460 kV
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	30 mm/kV

3.2.3.1. BUJAGALI HYDRO POWER PLANT

3.2.3.1.1. GENERAL

Bujagali 200 MW hydro power station site is located near town of Jinja, ca. 5 km northwest from existing Nalubaale HPP, along the river Nile. Altitude of substation site is 1140 m. The first unit of the HHP is scheduled to be commissioned in 2011.

3.2.3.1.2. HPP PROJECT SCOPE

According to the preliminary drawings available the Bujagali HPP 220/132 kV substation scope will consist of:

220 Kv Switchgear

- AIS switchgear with double busbars system and with bus couplers and bus sectionalizers
- five 220 kV generator unit bays
- two 220/132 kV interbus transformer bays
- two line bays to Kawanda substation
- two line bays for Tororo (Kenya interconnection)
  (busbars only, space reservation for feeders)

132 kV switchgear

- 132 kV AIS switchgear with double busbars system and with bus coupler
- two 220/132 kV interbus transformer bays
- four line bays to Nalubaale (Owen Falls) and to Tororo substations (loop in/loop out of existing Nalubaale - Tororo 132 kV transmission line)

Transformers

- two 150 MVA, 220/132 kV interbus transformers

Reactive power compensation equipment

No compensation equipment has been proposed within the HPP Project scope.

Auxiliary Systems

Sufficient facilities to cover the Interconnection Project needs will be provided within the HPP Project scope. Furthermore, systems provided within the HPP Project scope have been assumed to be extendable.

Control Building

Sufficient space, cable routes etc. to facilitate the Interconnection Project equipment and needs will be provided within the HPP Project scope.

Substation Area

220 kV busbars as well as sufficient space, cable routes etc. to facilitate the switchgear extension of two (2) 220 kV line feeder bays related to the Interconnection Project will be provided within the HPP Project scope.

220 kV Protection Systems

No Interconnection Project related facilities will be provided within the HPP Project scope. However, the busbar protection system has been assumed to be either provided or, as minimum, extendable.

Control System

Preliminary information available indicated that the control system provided within the HPP Project scope consists of:

- Bay level local emergency control from the switching equipment local control panels (LCP) within the switchgears
- Centralized remote control from conventional remote control panel (RCP) located in the control room in control building
- SCADA control from National Control Center (NCC) through remote terminal unit (RTU) with hard wired process connections (For details, see Chapter SCADA and Teletransmission).

No Interconnection Project related facilities will be provided within the HPP Project scope, however the above control systems have been assumed to be extendable.

3.2.3.1.3. NELSAP SCOPE

The proposed scope of NELSAP project outlined in detail in drawings (see drawing in Annexes)

- H P KU 001A / June 2007
- H P KU 011- / June 2007

consists of the following:

220 kV switchgear

2 sets of line feeders (Tororo 1 and Tororo 2) for double busbars system. The actual busbars are deemed to be provided by the HPP Project. The circuit breakers shall have single pole tripping facility.

132 kV switchgear

None

Transformers

none

Reactive power compensation equipment

None

Auxiliary Systems

Facilities provided by the HPP Project scope will be utilized and extended where applicable.

Control Building

None

Substation Area

- Extension of gantry structures
- Civil works associated to the two line feeder bays. Cable routes and channels etc. are deemed to be provided by the HPP Project

220 kV Protection Systems

OHTL Feeder Protection:

When applying the n-1 system planning principle for important cross border interconnection system, two independent main protection systems fed from different DC sources and connected to different CT cores will be required. Suitable communication and back-up facilities need to be provided as well.

The two main protection systems could be based on similar measuring principles (e.g. two distance relays), however more secure arrangement -in order to reliably detect different types of faults- would be systems based on different measuring principles. Therefore, the following OHTL feeder protection facilities are proposed:

- Main 1 Protection, consisting of:
  - Full scheme distance protection with minimum four independent impedance measuring zones and with six independent measuring loops (ph to ph and ph to earth).
  - The first zone shall be complemented with teleprotection scheme (permissive under-reach) over multiplexed communication link to cover the complete length of the protected line. The second zone would act as back-up for the first zone, the third zone as for back-up in busbar faults at remote station and the fourth zone could be a reverse zone and act as back-up for busbar faults at local station
  - The distance protection would be backed-up with directional earth fault protection (intended for high resistance faults) also complemented with teleprotection scheme (directional comparison) over multiplexed communication link.
- Main 2 Protection, consisting of:
  - Longitudinal differential protection over multiplexed communication link to cover the complete length of the protected line.
  - To cover the possible failures in communication link, the line differential protection would be backed up with directional over current and directional earth fault protections without teleprotection schemes. These functions may be integrated in to the line differential relay.

For network stability reasons it is necessary to complement the protection system with single phase rapid auto-reclosing (SPAR) as well as with three phase delayed auto-reclosing facilities.

For circuit breaker faults, breaker failure protection system with Direct Intertrip (DIT) to remote end over dedicated teleprotection channel in multiplexer (MUX) equipment shall be planned.

Under voltage tripping facility should also be provided and over voltage protection should be considered in case the shunt reactor (at remote station) is for some reason disconnected.

Busbar Protection:

At the moment, the detailed scope of HPP project is not known. Therefore, it has been assumed, that the busbar protection system provided by the HPP project will only cover the HPP needs and has to be extended by NELSAP project, as appropriate.

Control System

Control facilities will be provided in line with the practice adopted in the HPP project. Facilities provided by the HPP project will be suitably extended to cover NELSAP need.

(For details, see Chapter SCADA and Teletransmission)

3.2.3.2. TORORO SUBSTATION

3.2.3.2.1. GENERAL

The substation was initially built in 1950s. The altitude of facilities is 1100 m. 132/33 kV, 20 MVA transformers have been manufactured in 1985 and outdoor 33 kV switchgear has been replaced by an indoor AIS switchgear located in a separate building in year 2000.

3.2.3.2.2. EXISTING FACILITIES AT TORORO

Currently, Tororo is a 132/33 kV transmission substation with following facilities:

132 kV switchgear

- AIS switchgear with double busbars system and with bus coupler
- two 132/33 kV transformer bays
- five OHTL feeder bays (two to Nalubaale (Owen Falls), two to Lessos, Kenya and one to Lira)

Transformers

Two 20 MVA, 132/33 kV network supply transformers

Reactive power compensation equipment

None

Auxiliary Systems

Single system 110 VDC and 48 VDC auxiliary supplies with no feasible extension facilities and reaching the end of their life span.

Control Building

The existing control room is quite large, ca. 150 m2. Sufficient space for 220 kV control and protection equipment is available.

Telecommunication and auxiliaries room is quite full.

Some unused rooms are available due to dismantled air compressor plant.

The control building is not air conditioned.

As a whole, the extension possibilities within the existing control building are limited or unpractical for the proposed 220 kV facilities, therefore it is proposed that a new control building with auxiliaries will be constructed to cover the 220 kV system needs. The existing control building should, however, remain in service for 132 kV system.

Substation Area

The present substation plot is nearly fully built with no space available for the 220 kV system.

Protection Systems

No Interconnection Project related facilities exist.

Control System

The existing control system facilities consist of:

- Bay level local emergency control from the switching equipment local control panels (LCP) within the switchgears
- Bay level local control from a mimic fitted in the bay outdoor marshalling panel
- Centralized remote control from conventional remote control panel (RCP) located in the control room in control building
- SCADA control from NCC through remote terminal unit (RTU) with hard wired process connections (For details, see Chapter SCADA and Teletransmission)

No Interconnection Project related facilities exist.

3.2.3.2.3. *NELSAP SCOPE*

The proposed scope of NELSAP project outlined in detail in drawings (See Drawing in annexes)

- H P KU 002B / September 2007
- H P KU 012A / September 2007

consists of the following:

220 kV switchgear

Construction of a complete new 220 kV switchgear is proposed.

The n-1 system planning criteria should be fulfilled also in selection of the busbar system, i.e. even a fault in busbars within the substation should not cause unavailability of the both the interconnection circuits, therefore a single busbar system should not be considered. The most feasible way to achieve the above requirement is to provide the switchgear with double busbar system and a bus coupler. The feeders should be suitable grouped in different busbars and the busbars should be provided with two bus zone busbar protection system.

Regarding circuit breaker maintenance, some additional benefits could be achieved by providing the feeders with CB by-pass disconnectors or by provision of an auxiliary busbar with by-pass disconnectors. However, these arrangements would increase the implementations costs by more than 25% with no real effect on reliability. Even with the double busbar system, all circuit breakers can be maintained with at least one interconnection circuit in operation.

Due to above, a double busbar system and a bus coupler are proposed for Tororo 220 kV switchgear. Similar choice has already been made in Bujagali HPP project for Bujagali 220 kV switchgear.

Furthermore, in order to facilitate a compact space saving layout design, the busbars should be tubular (AlMgSi) and the busbar disconnectors of pantograph (vertical reach) type.

In addition to above, the switchgear in proposed extent consists of:

- 4 sets of 220 kV OHTL feeder bays (Bujagali 1 and 2, Lessos 1 and 2) for double busbar system (tubular busbars). The circuit breakers shall have single pole tripping facility.
- 1 set of 220 kV bus coupler bay for double busbar system (tubular busbars).
- -2 sets of 220 kV capacitor bank feeder bays for double busbar system (tubular busbars). The circuit breakers shall have single pole tripping facility with point of wave synchronizing facilities
- 4 sets of 220 kV shunt reactor branches on line side-one of each 220 kV OHTL, without switching. However, provision in layout should be made to install circuit breakers at later stage.
- 4 sets of 10 MVAr, YN-connected 230 kV shunt reactors complemented with 4840 Ω neutral compensating reactors (NCR).
- 2 nos of 25 MVAr grounded Y connected 220 kV capacitor banks complete with inrush current limiting reactor and unbalance CT
- 220 kV control building with AC and DC auxiliaries

It is to be noted, that UETCL intends to extend the 220 kV switchgear by two 220/132 kV interbus transformer feeder bays within a scope of another project in near future. It is considered feasible and thereby recommended to extend the 220 kV busbars to cover this requirement within NELSAP scope.

<u>132 kV switchgear</u>

Due to new Bujagali 220 kV OHTLs the existing 132 kV Lira OHTL entry to 132 kV switchgear needs to be relocated within NELSAP project scope. For this purpose, the following is needed:

- Provision of new line entry gantry structure with necessary insulator strings and accessories as well as shifting the 132 kV Lira OHTL from the existing gantry to the new one
- Provision of ca. 115 meters of 132 kV 3-phase underground cable circuit with associated cable terminations, surge arrestors and steel supports from existing line entry gantry to the new gantry structure

It is to be noted, that UETCL intends to extend the 132 kV switchgear by two 220/132 kV interbus transformer feeder bays within a scope of another project in near future.

<u>Transformers</u>

None.

However it is to be noted, that UETCL intends to install two 220/132 kV interbus transformers at site to interconnect the 220 kV and 132 kV systems within a scope of another project in near future.

<u>Reactive power compensation equipment</u>

As mentioned above, 4 nos of 10 MVAr, YN-connected 230 kV shunt reactors complete with 36 kV neutral compensating reactors should be provided on Bujagali and Lessos lines to compensate the capacitive charge of the lines and to support the successful single phase rapid auto-reclosing. These reactors should not be switched.

Furthermore -anticipating considerable load growth in near future- a 50 MVAr capacitor bank switched in two equal 25 MVAr steps should be provided for voltage support.

Auxiliary Systems

Complete, new auxiliary systems are needed for the 220 kV secondary facilities. The 400/230 VAC and 110 VDC auxiliary supply systems should be doubled while a single battery / double charger system would be sufficient for 48 VDC supply feeding the communications loads.

The 400/230 VAC should be fed from the existing facilities at 132 kV substation as well as from separate source from neighboring LV distribution network.

A separate UPS system to feed the Station Automation (SA) system Human Machine Interface (HMI) equipment etc. should be provided.

Control Building

A new, air conditioned control building to house the 220 kV switchgear secondary and auxiliary systems should be provided as the extension possibilities within the existing 132/33 kV control building are limited or unpractical.

Substation Area

The present substation plot is not sufficient for the proposed 220 kV switchgear. More land, ca. 18,750 m2 (125 m x 150 m) should be obtained by UETCL by the existing plot. There should be no major obstacles in this as the neighboring areas are vacated. The existing 33 kV line entries, however, have to be relocated by extending the 33 kV cable connections.

220 kV Protection Systems

OHTL Feeder Protection:

When applying the n-1 system planning principle for important cross border interconnection system, two independent main protection systems fed from different DC sources and connected to different CT cores will be required. Suitable communication and back-up facilities need to be provided as well.

The two main protection systems could be based on similar measuring principles (e.g. two distance relays), however more secure arrangement -in order to reliably detect different types of faults- would be systems based on different measuring principles. Therefore, the following OHTL feeder protection facilities are proposed:

- Main 1 Protection, consisting of:
  - Full scheme distance protection with minimum four independent impedance measuring zones and with six independent measuring loops (ph to ph and ph to earth).
  - The first zone shall be complemented with teleprotection scheme (permissive under-reach) over multiplexed communication link to cover the complete length of the protected line. The second zone would act as back-up for the first zone, the third zone as for back-up in busbar faults at remote station and the fourth zone could be a reverse zone and act as back-up for busbar faults at local station

  - The distance protection would be backed-up with directional earth fault protection (intended for high resistance faults) also complemented with teleprotection scheme (directional comparison) over multiplexed communication link.
- Main 2 Protection, consisting of:
  - Longitudinal differential protection over multiplexed communication link to cover the complete length of the protected line.
  - To cover the possible failures in communication link, the line differential protection should be backed up with directional over current and directional earth fault protection functions, however, without teleprotection schemes. These functions may be integrated in to the line differential relay.
  - For Bujagali lines, the line differential projection shall be implemented as a three-branch scheme in order to take the effect of the non-switched shunt reactor into account.

For network stability reasons it is necessary to complement the protection system with single phase rapid auto-reclosing (SPAR) as well as with three phases delayed auto-reclosing facilities.

For circuit breaker faults, breaker failure protection system with direct intertrip (DIT) to remote end over dedicated teleprotection channel in MUX equipment should be planned.

Under voltage tripping facility should also be provided and over voltage protection should be considered in case the shunt reactor (at local station or at remote station) is for some reason disconnected.

Shunt Reactor Protection:

The recommended main protection for the shunt reactors are the mechanical protection devices included in the reactor assembly, i.e. Buchholz device (gas relay), oil temperature monitor, winding temperature monitor and pressure relief relay. Furthermore, the neutral compensating reactor (NCR) should be provided with oil temperature monitor and pressure relief relay for protection purposes.

The electrical protection scheme is proposed to utilize restricted earth fault protection (REF) as reactor unit protection. This protection shall trip instantaneously for all internal phase to ground faults. For internal phase-to-phase fault detection, overcurrent protection is recommended. Earth over-current protection connected to the star point CT of the reactor is used as backup protection for ground faults and as main protection for circuit breaker pole discrepancy condition.

Moreover, the line distance protection would act as a general back-up for reactor protection, even though not detecting turns faults.

As the reactor would be non-switched, all protection devices trip-stage operations shall send DIT to remote end circuit breaker over dedicated teleprotection channel in MUX equipment.

Capacitor Bank Protection

The recommended protection system for capacitor banks consists of un-balance protection, over load protection, over current protection and under current protection.

The un-balance protection is intended to detect asymmetry in capacitor bank due to failed internal fuses of capacitor units while the under current protection should be used to prevent the charged capacitor to be reconnected when a short loss of supply voltage occurs.

Since overload of capacitors is mainly caused by over voltages, the over load protection could - in principle- be implemented by simple over voltage relay. However, since the capacitors are connected in series with inrush current limiting reactors it is recommended that the over load protection should be based on measured current signal, which is then transformed to correspond the actual voltage over the capacitors.

For circuit breaker faults, breaker failure protection system with direct intertrip (DIT) to adjacent circuit breakers should be planned.

The circuit breakers switching the capacitor banks should be single pole operated and provided with point of wave synchronizing facilities.

As the capacitor banks are intended for voltage support, the automatic switching scheme should be based on automatic voltage regulation relay operating with first in - first switching logic. The regulation relay should be connected to the busbar VTs

Bus Coupler Protection:

A simple over-current / earth fault protection scheme is deemed sufficient for bus coupler protection.

For circuit breaker faults, breaker failure protection system with direct intertrip (DIT) to adjacent circuit breakers should be planned.

Busbar Protection:

As discussed earlier, a two bus-zone busbar protection should be provided for fast and selective zone-by-zone clearing of busbar faults in the station.

Control System

Even though traditionally the control system in Ugandan transmission network consists of conventional control mimics in various control panels with SCADA interface to NCC through hard wired RTU, introduction of new technology is considered feasible in this conjunction.

The recommended control system should be computer based Station Automation (SA) system with distributed microprocessor based bay control units (BCU). The control system structure would be:

- Bay level local emergency control from the switching equipment local control panels (LCP) within the switchgears
- Bay level local control from bay specific BCUs fitted in the bay specific protection panels
- Centralized station level control from Station Automation system HMI operator's workstation PC located in the control room in control building
- SCADA control from NCC without RTU, through NCC gateway of SA system. (For details, see Chapter SCADA and Teletransmission)

The process interface should be hardwired through various Intelligent Electronic devices (IED) such as bay controllers, protection relays, alarm annunciators, regulators etc. The IEDs should be installed in air-conditioned facilities. It is not recommended to locate any IED, not even BCU in outdoor marshalling panels. BCUs are recommended to be installed in to bay specific protection panels.

The IEDs, Operator's workstation, Engineering work station, printers and other related devices shall be connected to station level LAN network. The communications protocol should not be vendor specific, therefore IEC 61850 standard protocol is recommended, therefore all IEDs and workstations planned within NELSAP project scope should be compatible with the said protocol.

The Operator's workstation shall accommodate the station level Human Machine Interface (HMI) and run the SA system software package to perform the necessary station level control and data accusation etc. functions.

The system shall be provided with centralized time synchronization facility e.g. through GPS receiver.

For SCADA Interface, a communication gateway to NCC should be provided. The gateway shall be connected to the SA system through Station LAN. For upward connections to NCC the system shall support at least IEC 870-5-101 and IEC870-5-104 over TCP/IP protocols.

(For details, see Chapter SCADA and Teletransmission)

As the technology is new to UETCL, specific attention must be paid in specifying a suitable, comprehensive training package.

Cost vise there would be no major difference between the convention control system and the proposed station automation system. Costs saved from conventional control / metering facilities and related exhaustive copper wiring covers the cost of BCUs and LANs while costs saved from conventional RTU and related interfacing equipment and copper wiring more or less covers the cost of SA system hardware and software. Furthermore, a great deal of modern protection relays already have the necessary communication interface and protocol support available as standard option.

3.2.4. ENVIRONMENTAL CHARACTERISTICS IN KENYA

Ambient air temperature	Indoor	Outdoor
Maximum	35°C	+ 35°C
24 hour average, max		+ 25°C
Minimum	+10°C	7°C
Humidity	90 %	100 %
Seismic Acceleration	0.1 g	
Isoceraunic Level	100	
Rainfall average annual	1100 mm	

3.2.5. ELECTRICAL CHARACTERISTICS AT KENYA SUBSTATIONS

Table n° 4 - KENYA SUBSTATIONS CHARACTERISTICS

132 kV system requirements:

Maximum operating voltage	170 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	750 kV peak
Rated power-frequency short duration withstand voltage	325 kV
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	30 mm/kV

220 kV system requirements:

Maximum operating voltage	245 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	1050 kV peak
Rated power-frequency short duration withstand voltage	460 kV
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	30 mm/kV

3.2.5.1. LESSOS SUBSTATION

3.2.5.1.1. GENERAL

Lessos 220/132 kV substation is located some 350 km North-West from Nairobi. The altitude of facilities is 2140 m. Substation was initially commissioned in 1954 and thereafter extended in 1984 and 1991 with 220 kV OHTL to Turkwel Power Plant and with two 220 /132 kV interbus transformers.

3.2.5.1.2. EXISTING FACILITIES AT LESSOS

Currently, Lessos is a 220/132 kV transmission substation with following facilities:

220 kV switchgear

- AIS switchgear with 4/3 breaker busbar system with one diameter. Only three circuit breakers are present at the time.
- two 220/132 kV interbus transformer bays
- one OHTL feeder bay (Turkwel)
- bay width = 15 m

132 kV switchgear

- AIS switchgear with 4/3 breaker busbar (tubular) system with one diameter.
- two 220/132 kV interbus transformer bays
- six OHTL feeder bay (two to Tororo, two to Juja Road, one to Eldoret and one to Muhoroni)

Transformers

- two 220/132 kV, 75/75/15 MVA autotransformers in interbus service
- one 132/33 kV, 20 MVA network supply transformer

Reactive power compensation equipment

- two 15 MVAR, 11 kV oil insulated shunt reactors connected to the tertiary of the interbus transformers

Auxiliary Systems

- single 110 VDC auxiliary system with newly installed alkaline batteries for 132 kV system auxiliary services
- double 110 VDC and 48 VDC systems for 220 kV system auxiliary services and for communications system supply, respectively. Sufficient capacity and extension provisions exist for NELSAP project needs
- 400/230 VAC auxiliary supply with sufficient capacity and extension provisions exist for NELSAP project needs.

Control Building

The control building consists of following rooms: control room, relay protection room, three battery rooms, carrier room, radio room, energy transmission room, wash/toilet room, office and main entrance.

The control room is quite full but on the other hand, there is a lot of vacant space in relay room, therefore, with minor civil modification works the necessary space for 220 kV system extensions can be made available.

Substation Area

There is 20 m strip land behind the fence owned by KPLC. One “diameter” more can be installed without shifting the fence. Obtaining of more land for third "diameter" is possible.

If the 220 kV feeder(s) to Olkaria would be implemented, the dead end tower of Eldoret 132 kV line has to be dismantled and 132 kV short cable connection is needed.

Turkwel 220 kV line has to be shifted to a new bay to avoid crossing with new Tororo 220 kV lines.

Protection Systems

No Interconnection Project related facilities exist.

Control System

The existing control system facilities consist of:

- Bay level local emergency control from the switching equipment local control panels (LCP) within the switchgears
- Centralized remote control from conventional remote control panel (RCP) located in the control room in control building. The control panel cannot be extended to facilitate NELSAP project needs.
- SCADA control from NCC through remote terminal unit (RTU) with hard wired process connections. For details, (For details, see Chapter SCADA and Teletransmission).

No Interconnection Project related facilities exist.

3.2.5.1.3. *NELSAP SCOPE*

The proposed scope of NELSAP project outlined in detail in drawings (See Drawing in Annexes)

- H P KU 003B / September 2007
- H P KU 013A / September 2007

consists of the following:

220 kV switchgear

The existing 220 kV switchgear should be extended with second and third "diameter" facilitating the connection of two 220 kV OHTLs and two capacitor banks as well as providing future reservation for connection of the third interbus transformer and two 220 kV OHTLs to Olkaria.

The detailed scope consists of:

- One "diameter" consisting facilities to connect three feeders, however, at present stage only three of the four breaker branches need to be equipped. The "diameter" should be complete with OHTL connection branches with associated reactor connection branches for two feeders.
- -One "diameter" consisting facilities to connect three feeders, however, at present stage only two of the four breaker branches need to be equipped. The "diameter" should be complete with Capacitor Bank connection branches for two feeders.
- Shifting the existing Turkwel line entry with associated wave traps, CVTs and surge arrestors to a new bay to avoid crossing with new Tororo 220 kV lines.
- Completing the un-equipped fourth breaker branch existing "diameter" with circuit breaker, two disconnectors, two 3-phase current transformers and associated equipment and works
- Extension of busbars HB1 and HB2
- Extension of the gantry structures
- Provision of new CVTs and surge arrestor to replace the ones shifted from the existing Turkwel bay
- 2 sets of 10 MVAr, YN-connected 230 kV shunt reactors complemented with 4840 Ω neutral compensating reactors (NCR).
- 2 sets of 25 MVAr grounded Y connected 220 kV capacitor banks complete with inrush current limiting reactor and unbalance CT
- Replacement of the existing Turkwel feeder CTs as there are no metering cores for revenue metering purposes

It is to be noted, that KPLC has plans to further extend the 220 kV switchgear by two OHTL feeder bays for Olkaria lines within a scope of another project in near future. Space reservation for bays has been considered herein.

<u>132 kV switchgear</u>

Due to implementation of the third "diameter" the existing 132 kV Eldoret OHTL entry to 132 kV switchgear needs to be relocated within NELSAP project scope. For this purpose, the following is needed:

- Provision of new line entry gantry structure with necessary insulator strings and accessories as well as shifting the 132 kV Eldoret OHTL from the existing EOL tower to the new gantry. The existing EOL tower shall be dismantled.
- Provision of ca. 100 meters of 132 kV 3-phase underground cable circuit with associated cable terminations, surge arrestors and steel supports from existing line entry gantry to the new gantry structure

<u>Transformers</u>

None

<u>Reactive power compensation equipment</u>

As mentioned above, 2 nos of 10 MVAr, YN-connected 230 kV shunt reactors complete with 36 kV neutral compensating reactors should be provided on Tororo lines to compensate the capacitive charge of the lines and to support the successful single phase rapid auto-reclosing. These reactors should not be switched.

Furthermore -anticipating considerable load growth innear future- a 50 MVAr capacitor bank switched in two equal 25 MVAr steps should be provided for voltage support

Auxiliary Systems

Existing facilities will be utilized and extended where applicable.

Control Building

Minor civil modification works within the existing 220 kV control building are needed in order to accommodate the new equipment provided under the interconnection project. Mainly, this means shifting the location of the wall between control room and main entrance hall. Furthermore, the existing 48 VDC battery chargers located in the main entrance hall need to be re-located.

Substation Area

The present substation plot is not sufficient for the proposed 220 kV switchgear extension. More land, ca. 3,920 m2 (28 m x 140 m) from the north side and 4,900 m2 (30 m x 150 m + 20 m x 20 m) from the east side of the existing 220 kV switchyard should be obtained by KPLC. There should be no major obstacles in this as the neighboring areas are vacated. Existing 33 kV line feeders Fluospar-Kabarnet No 1 and Eldoret No 2, however, have to be re-routed from the 220 kV extension area by relocating the existing EOL towers and by extending the 33 kV underground cable connections to the EOL towers.

220 kV Protection Systems

OHTL Feeder Protection:

When applying the n-1 system planning principle for important cross border interconnection system, two independent main protection systems fed from different DC sources and connected to different CT cores will be required. Suitable communication and back-up facilities need to be provided as well.

The two main protection systems could be based on similar measuring principles (e.g. two distance relays), however more secure arrangement -in order to reliably detect different types of faults- would be systems based on different measuring principles. Therefore, the following OHTL feeder protection facilities are proposed:

- Main 1 Protection, consisting of:
  - Full scheme distance protection with minimum four independent impedance measuring zones and with six independent measuring loops (ph to ph and ph to earth).
  - The first zone shall be complemented with teleprotection scheme (permissive under-reach) over multiplexed communication link to cover the complete length of the protected line. The second zone would act as back-up for the first zone, the third zone as for back-up in busbar faults at remote station and the fourth zone could be a reverse zone and act as back-up for busbar faults at local station
  - The distance protection would be backed-up with directional earth fault protection (intended for high resistance faults) also complemented with teleprotection scheme (directional comparison) over multiplexed communication link.
- Main 2 Protection, consisting of:
  - Longitudinal differential protection over multiplexed communication link to cover the complete length of the protected line.

- To cover the possible failures in communication link, the line differential protection should be backed up with directional over current and directional earth fault protection functions, however, without teleprotection schemes. These functions may be integrated in to the line differential relay.
- The line differential projection shall be implemented as a three-branch scheme in order to take the effect of the non-switched shunt reactor into account.

For network stability reasons it is necessary to complement the protection system with single phase rapid auto-reclosing (SPAR) as well as with three phases delayed auto-reclosing facilities.

For circuit breaker faults, breaker failure protection system with direct intertrip (DIT) to remote end over dedicated teleprotection channel in MUX equipment should be planned.

Under voltage tripping facility should also be provided and over voltage protection should be considered in case the shunt reactor (at local station or at remote station) is for some reason disconnected.

Shunt Reactor Protection:

The recommended main protection for the shunt reactors are the mechanical protection devices included in the reactor assembly, i.e. Buchholz device (gas relay), oil temperature monitor, winding temperature monitor and pressure relief relay. . Furthermore, the neutral compensating reactor (NCR) should be provided with oil temperature monitor and pressure relief relay for protection purposes.

The electrical protection scheme is proposed to utilize restricted earth fault protection (REF) as reactor unit protection. This protection shall trip instantaneously for all internal phase to ground faults. For internal phase-to-phase fault detection, overcurrent protection is recommended. Earth over-current protection connected to the star point CT of the NCR is used as backup protection for ground faults and as main protection for circuit breaker pole discrepancy condition.

Moreover, the line distance protection would act as a general back-up for reactor protection, even though not detecting turns faults.

As the reactor would be non-switched, all protection devices trip-stage operations shall send direct intertrip (DIT) to remote end circuit breaker over dedicated teleprotection channel in MUX equipment.

Capacitor Bank Protection

The recommended protection system for capacitor banks consists of un-balance protection, over load protection, over current protection and under current protection.

The un-balance protection is intended to detect asymmetry in capacitor bank due to failed internal fuses of capacitor units while the under current protection should be used to prevent the charged capacitor to be reconnected when a short loss of supply voltage occurs.

Since overload of capacitors is mainly caused by over voltages, the over load protection could - in principle- be implemented by simple over voltage relay. However, since the capacitors are connected in series with inrush current limiting reactors it is recommended that the over load protection should be based on measured current signal, which is then transformed to correspond the actual voltage over the capacitors.

For circuit breaker faults, breaker failure protection system with direct intertrip (DIT) to adjacent circuit breakers should be planned.

The circuit breakers switching the capacitor banks should be single pole operated and provided with point of wave synchronizing facilities.

As the capacitor banks are intended for voltage support, the automatic switching scheme should be based on automatic voltage regulation relay operating with first in - first switching logic. The regulation relay should be connected to the busbar VTs

Busbar Protection:

Presently, there is no 220 kV busbar protection in Lessos. Provision of one should be considered, however, as only a single zone protection could be provided due to complicated busbar arrangements.

Control System

Control facilities will be provided and existing facilities extended as appropriate in line with the existing practice in substation. It is to be noted, that the existing 220 kV control panel cannot be further extended, therefore it is recommended to replace the complete panel with new one within NELSAP project scope. Future extension possibilities should be taken into account, (For details, see Chapter SCADA and Teletransmission).

3.2.6. NELSAP SCADA AND TELETRANSMISSIONS

3.2.6.1. INTERCONNECTION UGANDA – KENYA

The new interconnection will be Bujagali – Tororo – Lessos at 220 kV. The existing interconnection Nalubaale – Tororo – Lessos at 132 kV will remain in service, however, looped in/out at Bujagali; the circuit will be Nalubaale – Bujagali – Tororo – Lessos.

3.2.6.1.1. PROPOSED OPERATION OF INTERCONNECTION

In general, the operation of power systems with interconnections to neighbouring countries should fulfill the obligations laid down in power import / export agreements.

Operational aspects in power exchange agreements concern matters which deal with the normal routines to handle the interconnection. Rules and procedures to handle different situations, ranging from long term operations planning to daily power exchange and emergency situations should be included in the agreements. These rules have to be clear enough to be handled as routine by the operational staff in associated control centers.

In the Uganda – Kenya case, it is seen advisable to review and amend the operational aspects in the power import / export agreement in connection with the implementation of the interconnection at 220 kV.

It is also essential for successful joint operation to agree on all organizational institutions which will be necessary. It is preferable to establish a joint operations committee which will handle all contractual aspects, decide on occasional disputes, approve long term plans, etc. There should also be regular meetings between staff working in dispatching centers, for detailed planning. They should discuss network operational security issues and agree on how daily operational questions shall be worked out.

In view of the above, the following operational issues should be reviewed in connection with the implementation of the interconnection at 220 kV:

- Review and amend the operational issues in the power exchange agreement;
- Recommend models for organizations and institutional arrangements necessary for the operation of the interconnection;
- Assess the need for training programmes for the operational personnel, to manage the interconnected operation.

In the balance management, Kenya being the larger system should have the main responsibility for frequency control, while Uganda should maintain the tie-line flows within agreed limits.

For optimal management and operation, data exchange between the two national control centers is required, for two reasons:

- Managing the interconnection,
- Improved modelling of the external networks by the control centers network analysis applications; in the Ugandan network analysis the Kenyan network is an external network, and vice versa.

The data exchange should be implemented on Inter Center Communication Protocol (ICCP - TASE.2). A separate agreement between the two utilities is required for the data exchange, when implementing the ICCP link. The agreement consists of two standardised forms. The first defines the parameters for the link itself (servers, IP addresses, etc.). The second one defines the data to be interchanged.

3.2.6.1.2. *UGANDA NATIONAL CONTROL CENTER*

The Uganda National Control Center (NCC) was recently upgraded. The handing-over was in June, 2006, when the twelve months defects liability period started. The Contractor was ABB Power Technologies AB from Sweden, and the system bears their brand name Network Manager.

The NCC is located in Lugogo substation near Kampala. The system is equipped with SCADA functions and a comprehensive set of Network Analysis functions. In view of the interconnection Uganda – Kenya and forthcoming upgrade of the Kenyan NCC, the system was equipped with Inter Center Communication Protocol (ICCP – TASE.2).

The ICCP software runs in the Online SCADA Server, and uses the SCADA LAN for communication. In order to connect to the remote site, the ICCP link should connect through (at least) one outgoing Router. There should be a Wide Area Network (WAN) connection at E1 (2 Mbits/s) that connects to the remote site. The remote site should have a Router as the entry point.

The system functions of the Ugandan NCC are considered adequate for interconnected operation. A display with variables Momentary Interchange Error (MW), Momentary Interchange Error (MW-curve), Accumulated Interchange Error (MWh/hour) and Accumulated Interchange Error (MWh/day) can be generated. The NCC is already equipped with a System Clock with Frequency Error (Hz) and Time Error (s).

Summarized scope:

- NELSAP Project
  - Technical support for ICCP Agreement;
  - Commissioning of the ICCP link Uganda – Kenya.

3.2.6.1.3. *UGANDA SCADA RTUS*

In the upgrade of the SCADA/EMS System, the existing Remote Terminal Units (RTUs) were kept as they are. The communications protocol is ABB RP 570. Twelve (12) new RTUs were installed at 33/11 kV substations, with protocol IEC 60870-5-101.

The interconnection to Kenya involves two RTUs (or Substation Control Systems - SCS), Bujagali and Tororo.

According to current planning in the Bujagali project, the station will be equipped with an RTU. The RTU for Bujagali is expected be delivered with adequate capacity to cater for the two 220 kV line bays towards Lessos via Tororo.

In Tororo 132/33 kV substation, there is an existing UETCL RTU of type ABB RTU 400. For the 220 kV extension of Tororo, there are four alternatives for UETCL RTU:

- Alt. No. 1. Extension of the existing UETCL RTU. This is not seen feasible as the RTU is of old model, and the additional I/O cards are very expensive.
- Alt. No. 2 Replacing the existing UETCL RTU. In this alternative, the I/O modules of the replaced RTU could be used for extensions and spare parts at other substations.
- Alt. No. 3. Provision for a new UETCL RTU for the 220 kV. In this alternative, there would be two UETCL RTUs at Tororo: the old one for 132/33 kV and the new one for 220 kV and 220/132 kV transformers.
- Alt. No. 4. Provision for a new UETCL Substation Control System (SCS) for the 220 kV. In this alternative, the existing UETCL RTU would cater for the 132/33 kV system and the new SCS for 220 kV and 220/132 kV transformers.

Alt. Nos. 3 and 4 are considered as the best options. Alt. No. 4 is recommended in line with the recommendations for the protection and control for the 220 kV substation. Alt. No. 2 is not feasible since the cabling distance between the existing control building for 132 kV and the new control building for 220 kV is about 200 m.

Eventually Tororo 132 kV substation will be extended by two 132 kV bays for 220/132 kV interbus transformers by UETCL. The 132 kV RTU can then be extended by modules released from e.g. the Mbarara North RTU, proposed be replaced in this Report.

Summarized scopes:

- Bujagali project
  - Provision of an RTU with adequate capacity at Bujagali.
- NELSAP project
  - Provision of an SCS for Tororo 220 kV.
- Separate UETCL project
  - Extension of the RTU for Tororo 132 kV, to cater for the two 132 kV bays of 220/132 kV interbus transformers.

3.2.6.1.4. KENYA NATIONAL CONTROL CENTRE

The Kenyan National Control Centre (NCC) and Regional Control Centers are currently being upgraded, as a sub-project to the Energy Sector Recovery Project. The consultant for the upgrade of the SCADA/EMS and Telecommunications Systems is Fichtner, Germany. The selection of the Contractor is reaching finalization. The commissioning of the system is scheduled for 2009.

The system functions of the new Kenyan NCC are considered adequate for interconnected operation. The new system will be equipped for Automatic Generation Control (AGC) for selected hydro units. In view of the interconnection Uganda – Kenya, the system will be equipped with Inter Center Communication Protocol (ICCP – TASE.2).

One of the Regional Control Centers (RCCs) will be located at Lessos substation.

Summarized scopes:

- KPLC's SCADA and Telecommunications Upgrade project
  - Provision of Router(s) at Juja Rd NCC for the ICCP link.
- NELSAP Project
  - Technical support for ICCP Agreement;
  - Commissioning of the ICCP link Uganda – Kenya.

3.2.6.1.5. *KENYA SCADA RTUS*

In the upgrade project of the SCADA/EMS System, it is currently expected that all existing RTUs will be replaced by new ones. In addition, new RTUs will be installed at substations without existing RTU. Dual port functionality has been specified for the new RTUs utilizing different protocols (IEC 60870-5-101 and -104) at minimum two separate communication ports simultaneously.

The interconnection to Uganda involves two RTUs (or Substation Control Systems - SCS), Lessos and Tororo.

The RTU for Lessos is expected be delivered in the SCADA and Telecommunications Upgrade project, with adequate capacity to cater for the two 220 kV line bays towards Tororo, and the other planned extensions of the Lessos 220 kV system.

In Tororo 132/33 kV substation, there is an existing KPLC RTU of type Asea Collector 300. The contractual framework for having a KPLC RTU in Tororo should be reviewed in connection with the interconnection at 220 kV.

Technically, there are seven alternatives for KPLC RTU in Tororo:-

- Alt. No. 1. Extension of the existing KPLC RTU. This is not seen feasible as the RTU is of old model, and the additional I/O cards are very expensive. Furthermore, the expected decision is to replace all old RTUs.
- Alt. No. 2 Replacing the existing KPLC RTU. In this alternative, the I/O modules of the replaced RTU could be used for extensions and spare parts at other substations. However, since the expected decision is to replace all old RTUs, there is no need for such spare parts.
- Alt. No. 3. Provision for a new KPLC RTU for the 220 kV. In this alternative, there would be two KPLC RTUs at Tororo: the old one for 132 kV and the new one for 220 kV. However, the expected decision is to replace all old RTUs.
- Alt. No. 4. The 220 kV RTU for UETCL recommended under item “Uganda SCADA RTUs” would be a two port RTU polled by both UETCL NCC and KPLC NCC. The old KPLC RTU would cater for 132 kV. However, the expected decision is to replace all old RTUs.
- Alt. No.5. The 220 kV SCS for UETCL recommended under item “Uganda SCADA RTUs” would be a two port SCS polled by both UETCL NCC and KPLC NCC. The old KPLC RTU would cater for 132 kV. However, the expected decision is to replace all old RTUs.
- Alt. No. 6. There will be no KPLC RTUs at Tororo, since the real-time data will be available for KPLC through the intercentre link (ICCP). In this alternative, the old KPLC RTU would be dismantled.
- Alt. No. 7. The ICCP link serves as the main route, and an RTU (or SCS) of Alt. Nos. 4 (or 5) serves as a back-up.

Alt. No. 6 is recommended. In case KPLC wish to have a RTU in Tororo, UETCL should reciprocally have a RTU in Lessos. However, such arrangements are seen unnecessary due to the ICCP link.

Summarized scopes:

- KPLC’s SCADA and Telecommunications Upgrade project
  - Provision of an RTU with adequate capacity at Lessos.
- NELSAP project
  - Dismantling the KPLC RTU in Tororo

3.2.6.1.6. *TELECOMMUNICATIONS*

The existing services using telecommunications between UETCL and KPLC are:

- Operational telephone
- KPLC RTU at Tororo

The telecommunication media is PLC link on the 132 kV line Tororo – Lessos.

In the new scheme, the following services require telecommunications between UETLC and KPLC:

- Teleprotection:
- ICCP link (E1 2 Mbits/s) (Lugogo NCC - Juja Rd NCC)
- Operational telephone
- Hot line between control centers (Lugogo NCC - Juja Rd NCC)
- KPLC RTU at Tororo (if any)
- UETCL RTU at Lessos (if any)

The telecommunications media is proposed to be fiber optic (OPGW) link on the 220 kV interconnection Tororo – Lessos, 24-core, single mode. The PLC link on the 132 kV line Tororo-Lessos is proposed be maintained as back-up.

3.2.6.1.7. *UGANDA TELECOMMUNICATIONS*

The backbone telecommunications network is based on optical fiber links (OPGW and Wrap), 24-core single mode. Optical fiber terminals, at, among others, Lugogo, Nalubale and Tororo 132, provide the interface described below, for transfer of data, speech and teleprotection signals:

- Cross connect capacity of up to 128 x 2 Mbits/s
- System management based on LAN
- SDH integration with same NMS (Network Management System)
- Integrated teleprotection, configured through the NMS
- Base T Ethernet interface
- Interfaces for V.36, X.21/V.11, G703 (64 kbits/s co-directional), G703 (2 Mbits/s), RS232, Optical Interface

As regards the new interconnection, the optical fiber terminal for Bujagali is expected to be provided in the Bujagali project. The optical fiber terminal at Tororo 132 should be upgraded to establish the fiber optic link to Lessos. The routing from Tororo through to NCC in Lugogo may require additional interface cards at intermediate stations.

The operational telephone system of UETCL is based on ten (10) digital telephone exchanges type DCX 600/700 (Teamcom, Norway) and two (2) of type Meridien1 (Nortel, USA) configured along a 4-digit numbering plan (2XXX and 7XXX). However a digit pattern 10XXXX is programmed in all exchanges in order to access the telephone network of KPLC. This implies that the border telephone exchange at Tororo 132 kV substation is configured to translate and perform a digit conversion from 10XXXX to XXXX towards Kenya.

Summarized scopes:

- Bujagali project
  - Provision of a optical fiber terminal at Bujagali;
  - Provision of the telecommunication link from Bujagali RTU to NCC at Lugogo;
  - Provision of operational telephone facilities at Bujagali;

  - Rearrangement of PLC related to 132 kV loop in/out at Bujagali.

- NELSAP project
  - OPGW on the 220 kV interconnection Bujagali - Tororo – Lessos;
  - Upgrading the optical fiber terminal at Tororo 132;
  - Routing the ICCP link (E1 2 Mbit/s) from Lugogo NCC through Tororo and onwards to Juja Rd NCC;
  - Routing the hot line from Lugogo NCC through Tororo and onwards to Juja Rd NCC;
  - Implementing an operational telephone exchange interface at Tororo towards Kenya on the fiber optic link (while maintaining the existing operational telephone exchange interface at Tororo towards Kenya on PLC as back-up).

3.2.6.1.8. KENYA TELECOMMUNICATIONS

The upgrade project of the SCADA/EMS and telecommunications system will provide a backbone telecommunications network based on optical fiber links (OPGW), 48-core single mode. SDH STM-1 optical fiber terminals, at, among others, Juja Rd and Lessos, provide each for two fully equipped access multiplexers.

As regards the new interconnection, the optical fiber terminal at Lessos should be equipped for the fiber optic link to Tororo. The routing from Lessos through to NCC in Juja Rd may require additional interface cards at intermediate stations. It is considered feasible to provide the optic fiber terminal at Lessos and routing through to NCC in Juja Rd in the upgrade project of the SCADA/EMS and telecommunications system.

The operational telephone system of KPLC is kept as it is in the upgrade project except the addition of one PAX at RCC Mt. Kenya, and the associated upgrading of PAX's at other RCCs and NCC.

Summarized scopes:

- KPLC's SCADA and Telecommunications Upgrade project
  - Provision of the optical fiber terminal at Lessos;
  - Routing the ICCP link (E1 2 Mbit/s) from Juja Rd NCC through Lessos and onwards to Lugogo NCC (provision);
  - Routing the hot line from Juja Rd NCC through Lessos and onwards to Lugogo NCC (provision).

  Note. In KPLC's SCADA and Telecommunications Upgrade project, at least for the moment, no explicit consideration has been given to interconnection with UETCL under NELSAP project. The project currently assumes that connection with UETCL remains as it is at the moment.

- NELSAP project
  - OPGW on the 220 kV interconnection Bujagali – Tororo – Lessos;
  - Implementing an operational telephone exchange interface at Lessos towards Uganda on the fiber optic link (while maintaining the existing operational telephone exchange interface at Lessos towards Uganda on PLC as back-up).

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4. COST OF EQUIPMENT AND PROJECT SCHEDULE

4.1. TRANSMISSION LINES

The base cost of the project has been calculated on January 2007 price level. An overall 10% physical contingency has been included in all project components. Price contingency has been calculated by using an average inflation of 5% per year. The following table shows a summary of project cost by main components in each country.

4.1.1. KENYA

(Tororo) – Ugandan Border – Lessos

Line Parameters

Line length	127.21 km
Voltage level	220 kV
Circuits	2
Number and type of phase conductors	2 ACSR 240/40 Hawk
Number and type of ground wires	1 GSW 70 + 1 OPGW 44
Insulators	U 120 BS or composite
Average span length	350 m
Number of towers	363

Cost Estimation

Table n° 5 - LINE COST UGANDAN BORDER-LESSOS

	Description	Cost/km USD	Total Cost USD
1.	General works	3 496	446 264
2.	Foundations	15 266	1 948 705
3.	Earthing	2 641	337 124
4.	Towers	61 241	7 817 414
5.	Tower tests	2 256	287 978
6.	Insulators and accessories of conductors	15 360	1 960 704
7.	Ground wire and OPGW accessories	2 128	271 639
8.	Conductor, ground wire and OPGW	88 158	11 253 369
9.	Spare parts	3 037	387 673
SUB-TOTAL	193 583	193 583	24 710 870
10.	Management and quality assurance works (6%)	11 615	1 482 652
11.	Contingency (10%)	19 358	2 471 087
TOTAL		224 556	28 664 609

4.1.2. UGANDA

Bujagali – Tororo – Kenyan Border (- Lessos)

Line Parameters:

Line length	127.65 km
Voltage level	220 kV
Circuits	2
Number and type of phase conductors	2 ACSR 240/40 Hawk
Number and type of ground wires	1 GSW 70 + 1 OPGW 44
Insulators	U 120 BS or composite
Average span length	350 m
Number of towers	362

Cost Estimation:

Table n° 6 - LINE COST KENYAN BORDER-BUJAGALI

	Description	Cost/km USD	Total Cost USD
1.	General works	3 496	444 726
2.	Foundations	15 266	1 941 988
3.	Earthing	2 641	335 962
4.	Towers	61 241	7 790 468
5.	Tower tests	2 256	286 986
6.	Insulators and accessories of conductors	15 360	1 953 946
7.	Ground wire and OPGW accessories	2 128	270 703
8.	Conductor, ground wire and OPGW	88 158	11 214 579
9.	Spare parts	3 037	386 337
SUB-TOTAL	193 583	193 583	24 625 693
10.	Management and quality assurance works (6%)	11 615	1 177 542
11.	Contingency (10%)	19 358	2 462 569
TOTAL		224 556	28 565 804

4.2. SUBSTATIONS

The base cost of the project has been calculated on January 2007 price level. An overall 10% physical contingency has been included in all project components. Price contingency has been calculated by using an average inflation of 5% per year. The following table shows a summary of project cost by main components in each country.

4.2.1. BUJAGALI HYDRO POWER PLANT EXTENSION

The costs spread over various facilities are as follows:

Table n° 7 - BUJAGALI EXT. SUBSTATION COST

Items	Price Foreign Currency (USD)
220 kV Switchgear	731,000
Control, Protection and Auxiliaries	484,900
SCADA and Tele (incl' NCC works)	48,200
Civil and Mechanical works	342,100
Erection and Installations	339,000
Spare Parts	73,700
Contingency (10%)	201,900
Total Substations	**2,220,800 USD**

Engineering, project management and training costs have been included in material costs.

4.2.2. TORORO SUBSTATION

The costs spread over various facilities are as follows:

Table n° 8 - TORORO SUBSTATION COST

Items	Price Foreign Currency (USD)
220 kV Switchgear	2,954,000
132 kV Arrangements	137,900
Shunt Reactors	5,400,000
Capacitor Banks	1,201,500
Control, Protection and Auxiliaries	1,502,020
SCADA and Tele (incl' NCC works)	116,240
Civil and Mechanical works	1,432,460
Erection and Installations	1,460,000
Spare Parts	324,800
Contingency (10%)	1,452,900
Total Substations	**15,981,800 USD**

Engineering, project management and training costs have been included in material costs.

4.2.3. LESSOS SUBSTATION

The costs spread over various facilities are as follows:

Table n° 9 - LESSOS SUBSTATION COST

Items	Price Foreign Currency (USD)
220 kV Switchgear	2,954,700
Shunt Reactors	2,700,000
132 kV Switchgear	123,000
Capacitor Banks	1,201,500
Control, Protection and Auxiliaries	1,037,260
SCADA and Tele (incl' NCC works)	154,700
Civil and Mechanical works	852,940
Erection and Installations	1,132,000
Spare Parts	177,400
Contingency (10%)	1,033,400
Total Substations	**11,366,900 USD**

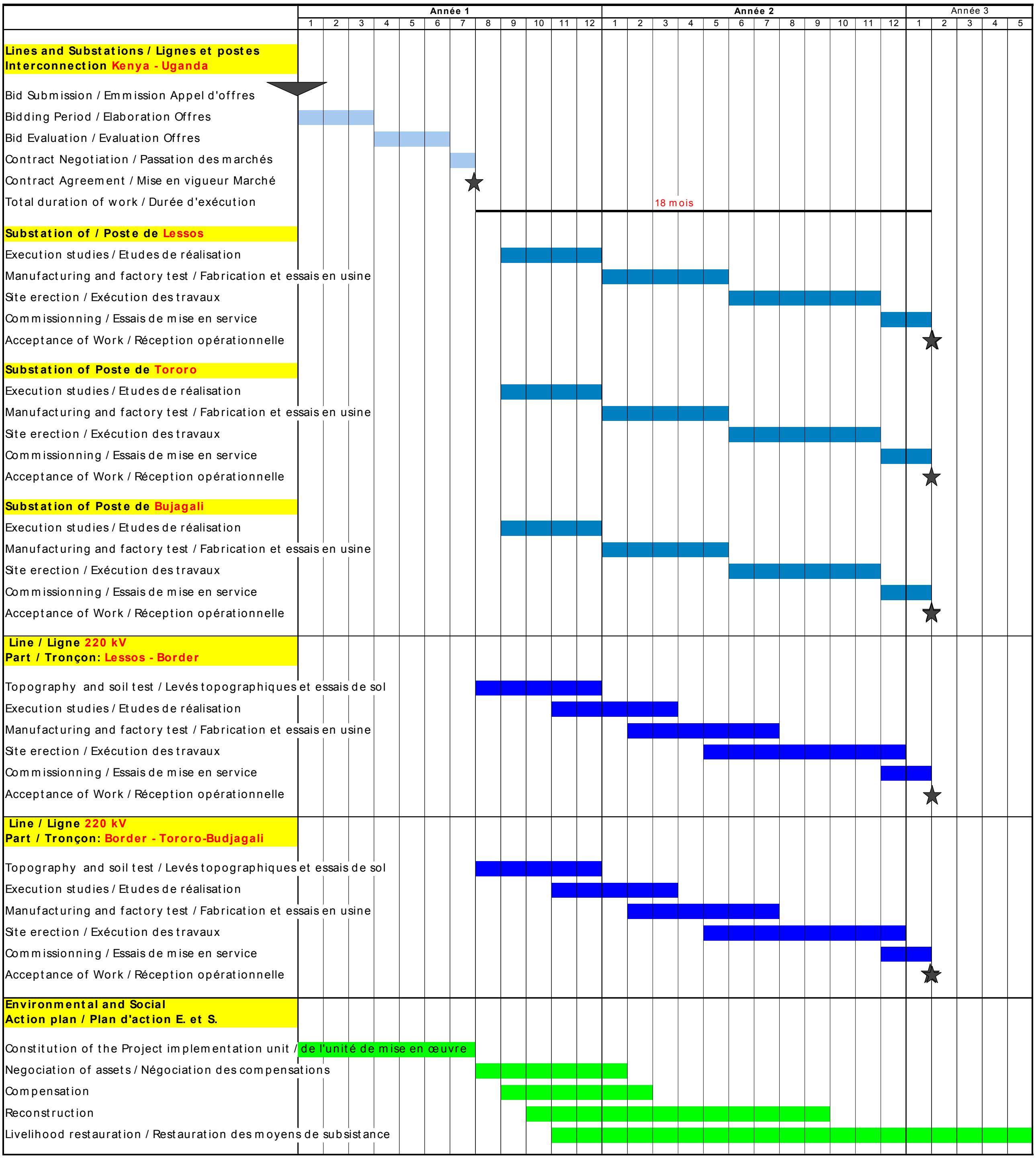
Engineering, project management and training costs have been included in material costs.

4.3. PROJECT SCHEDULE

The project schedule includes the following main steps:

- Bidding and Contract process
- Line and Substation :
  - Detailed studies
  - manufacturing
  - Site work
  - Acceptance

INTERCONNEXION: KENYA - UGANDA
Project Schedule / Programme Prévisionnel de Travaux



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5. ECONOMIC AND FINANCIAL STUDIES

5.1. METHODOLOGY

5.1.1. INTRODUCTION

5.1.1.1. STUDY PRINCIPLES

The proposed interconnection projects between the five considered countries will allow for power and energy exchanges in order to optimize overall energy generation in the region, using in particular cheap and clean renewable energy resources in the form of large and medium-sized hydropower stations.

This optimization consists in adapting the overall supply to the demand at a lower cost and at any moment. From this point of view, the interconnection links will allow to export the produced energy from a given country to another one, when the first one has surpluses which the second one may use in place of more expensive local generation. This can happen in several cases:

- Emergency situations: available reserves (or stand-by generation) in one (or more) country (ies) can be mobilized when not enough generation is available in another one (s);
- Occasional transfers, for instance when a country has hydro generation surpluses due to abundant rains, or if another one is experiencing a particularly dry year;
- Systematic transfers, either daily (for instance when the peak load periods of two countries are not at the same time) or seasonal;
- Bulk transfers: continuous energy exports for long periods (generally more than one year)

The Terms of Reference of the study define the general method to be used for economic and financial justification of the interconnections. Two options are to be considered and they consist in evaluating the interconnection advantages for the concerned countries, comparing the two following situations:

- First option: without interconnection project
- Second option: with interconnection project.

The expected interconnection advantages are:

- Overall generation development at lower cost,
- Sharing production reserves,
- Lower overall peak demand due to non-simultaneity between the considered countries.

The energy demand of each one of the five countries was analyzed in Volume 1 of the present study. Based on the pre-feasibility study, it has been possible to define three main interconnected power systems: The Burundi-Rwanda-Congo (DR) system, the Ugandan system, and the Kenyan one. In this document, existing and future generation means have also been analyzed, according to three demand scenarios and two main interconnection scenarios; the result of the analysis is that important regional power exchanges are possible between these main systems, provided that the interconnection links are sufficient. Detailed annual power and energy transfers have been calculated in Volume 1, which will serve as a basis for the present economic and financial studies.

5.1.1.2. MAIN ORIENTATION FOR THE STUDY APPROACH

A number of orientations for the economic and financial study may be taken from the previously mentioned Volume 1 analysis.

At first, it we will concentrate on interconnection possibilities between the three main systems as mentioned earlier:

- Burundi-Rwanda-Congo (DR) with Uganda;
- Uganda with Kenya.

Concerning the other interconnections as mentioned in the Terms of Reference of the study, namely the Rwanda-Burundi, Rwanda-Congo (DR), and the Burundi-Congo (DR) interconnections, the assessment of the power transfer needs is done with the help of specific network studies (in particular load flow and contingency analyses). This aspect will be considered separately (see Volumes 4, 5 and 6).

The present Volume 2 is dedicated to the Uganda-Kenya interconnection, while Volume 3 covers the Rwanda-Uganda interconnection. The Volume 1 analysis of possible exchanges has shown that the Uganda-Kenya interconnection is overwhelmingly meant to supply the Kenyan system in the form of medium and long-term bulk transfers of future expected Ugandan hydro generation surpluses. But in case of shortage in Uganda after commissioning of the interconnection, the link will allow to bring short term emergency electricity from Kenya, which in turn may come from Tanzania and/or Ethiopia through other planned large-scale interconnections.

In the same way, it is noticed that the Rwanda-Uganda interconnection will serve to export the possible surpluses of the Kivu region to Uganda, which can consequently be exported to Kenya, as well. It is then clear that the study of the Uganda-Kenya interconnection is also linked to the possible options for the Rwanda-Uganda interconnection.

5.1.2. GLOBAL APPROACH FOR THE ECONOMIC STUDY

Since there are obvious links between the three main interconnected systems, the overall approach for the Uganda-Kenya interconnection analysis includes first a common system approach for the B-R-C system, the Ugandan system and the Kenyan system, which involve the parallel development of the Rwanda-Uganda and Uganda-Kenya interconnections. From the Volume 1 analysis, this approach is quite obvious ant it has not been necessary to examine partial scenarios involving only one interconnection without the other. The common system approach is explained as follows:

5.1.2.1. COMMON SYSTEM APPROACH: UGANDA-KENYA AND UGANDA-RWANDA TOGETHER

From the year 2010, which is the earliest possible commissioning date of the interconnection project, the two following options must be compared from the economic point of view:

- First option: without interconnection projects, or reference option
- Second option: with interconnection projects

The first option is easy to conceive: it is the continuation of the present situation in which each of the three main systems develops independently on the basis of the existing internal connections, and considering only the limited existing interconnection between Uganda and Kenya; in the future, these connections may require maintenance or rehabilitation works, but no specific new interconnection would be considered in this case;

The second option, with interconnections, opens a large sphere of possibilities according to the transmission capacity of the considered links. As explained in Volume 1, it is proposed to limit these capacities according to two main alternatives as proposed hereafter:

5.1.2.1.1. ALTERNATIVE N°1

The generation means in each of the main systems are commissioned according to their mere internal needs. Since the capacity of these projects is high when compared to the internal demand, exportable surpluses appear.

These surpluses will continue as far as all the potential new generation developments are not absorbed by the demand of the considered system.

In principle, there is an optimum between the interconnection capacity and annual surplus volumes to be transferred from one system to another. However, interconnection costs (made of line and substation costs) are extremely low when compared to power transfer costs and benefits. In this case, it has been assumed that each year, the capacities of the links will be sufficient to transfer the expected surpluses as calculated in Volume 1.

5.1.2.1.2. ALTERNATIVE N°2

The hydro power plants of the exporting systems (B-R-C and Uganda in the medium term, and Uganda only in the long term) are being commissioned in such a way that they replace, at a lower cost, important thermal generation means which would be necessary to satisfy the Kenyan demand. In this case, much larger export possibilities can be envisaged.

In the two alternatives, the interconnection advantages always include the sharing of power reserves and the reduction of overall peak demand due to non-simultaneity between the systems.

In fact, the main difference between the two alternatives lies in the quantity of thermal generation which is avoided by the hydropower production. This quantity is smaller in the first alternative than in the second one, and it will be necessary to find which alternative is optimal on the economic point of view; as a rule, such alternatives must also be less expensive than the reference option.

5.1.2.2. ECONOMIC COST-BENEFIT ANALYSIS

The cost-benefit economic analysis of the alternative options "with project" will consist of comparing the discounted cost of these alternative options, in each case, to the discounted cost of the reference option. For each option "with project", we assume that the discounted generation cost of overall interconnected systems, is Cpi, while the discounted cost of reference generation (without interconnection) is Cri. The benefit of the interconnection option is therefore equal to:

Bli = Cri – Cpi.

This benefit is normally positive since interconnection allows for a reduction in complementary thermal generation, both in terms of energy (by a better use of the hydroelectric plants) and of installed power (by the reduction of the overall necessary reserves). Furthermore, due to non-simultaneity of the individual systems' peak demand, the overall demand of systems is inferior to the sum of their individual demands (of about 2.5 % for the whole Uganda – Kenya, according to the detailed load curves obtained in 2005). On the basis of the costs and discounted benefits, we will proceed to the calculation of the following values:

- Discounted net benefit or Net Present Value (NPV); Bli-Cli, for selected discount rate values, where Cli is the overall cost of the interconnection;
- Internal rate of return(IRR): value of the discount rate for which NPV is equal to zero;

These calculations will be carried out for each interconnection alternative as indicated above, considering the basic values of the main parameters of the project, then the variations for sensibility analyses (in parentheses below):

- Middle demand growth scenario (low and high scenarios)
- Discount rate of 10 % (8 and 12%)
- Price of fuels : middle (low and high)

5.2. MAIN STUDY HYPOTHESES AND DATA

The following basic assumptions have been taken into account in the study:

5.2.1. STUDY DURATION AND ECONOMIC PARAMETERS

5.2.1.1. STUDY PERIOD

Beginning of the study: Earliest possible commissioning date of the planned interconnection, that is to say 2010;

Duration of the study: The life duration of such interconnections is generally 30 years, which would bring us to the year 2040. But practically, reasonable projections can be done only for a period of 20 to 25 years from today (2007), which leads up to 2030. In fact, practically after 15 or 20 years the discounting of the costs “erases” the effect of the years to come.

5.2.1.2. DISCOUNT RATE

The chosen rate is 10% with variation of 8% and 12%. The 10% rate is high, compared to the world inflation and the usual interest rates. It is therefore unfavourable to the projects whose use of capital is high such as the interconnections with the promotion of hydropower developments. But if the economic interest of the project is proved in these conditions, this interest will still be reinforced in case of lower discounting rates.

5.2.1.3. PRICE OF FUELS

The prices of fuels are assumed related to international prices; in this study, all costs are corresponding to the price of a barrel of common crude oil (ex. Brent) amounting to 60 USD. This is one of the main parameters of the study, and due to its possible large variations during the project life it is proposed to consider a fixed value with important variations to be considered in sensitivity studies. The following values are proposed concerning the price of the crude oil:

- Base value : 60 USD/bbl
- Low hypothesis : 40 USD/bbl
- High hypothesis : 80 USD/bbl

For each case, it will be assumed that the price of fuels remains constant during the period of the study. Indeed, the recognized fluctuations of the world prices during the last thirty years and also the high rise registered since 2004, do not give any clear view for possible development in the long term. The values as proposed below seem to be located in a reasonable range, since values of 100 USD and above are now frequently conceivable, but it is difficult to imagine whether they should last for long periods of time. In any case, since we have chosen “reasonable” values, the interest of the interconnections will only be reinforced if fuel prices du jump above the proposed range. The following values will be proposed:

Fuel	Unit	USD	Coefficient
Crude Oil –World	1 bbl = 158,98l	60	1
HFO Kenya (average)	1bbl	60	1
Coal Mombasa	1 tonne	60	1
IDO - Diesel (BCR)	1 bbl	120	2

It is supposed that in the long term, the relationship between the prices of fuels remains proportional.

5.2.2. SUMMARY OF INTERCONNECTION CHARACTERISTICS

5.2.2.1. PRESENT SITUATION

At present, the only high voltage interconnection which is in operation connects Uganda and Kenya. The main characteristics are the following:

Voltage level:	132 kV
Length:	256 km
Method of operation:	Exportations towards Kenya (Until 2004 included) and exchanges and assistance (since 2005)
Outgoing substation in Uganda:	Tororo
Incoming substation in Rwanda:	Lessos
Transit capacity:	50 MW in base load, 80 MW max
Transited energy / year:	185 GWh (average 2000-2004); 3 GWh (2005) (Net Exports)

5.2.2.2. FUTURE SITUATION : CANDIDATE PROJECTS

UGANDA – KENYA INTERCONNECTION

Voltage level:	220 kV
Length:	256 km
Method of operation:	Exportations towards Kenya
Outgoing substation in Uganda:	Tororo
Incoming substation in Rwanda:	Lessos
Transit capacity:	100 MW in base load, 150 MW max (Alternative 1)
	250 MW in base load, 300 MW max (Alternative 2)

5.3. COST CALCULATIONS FOR REFERENCE OPTION: WITHOUT INTERCONNECTION PROJECT

The study of the reference option has been broken down into three parts:

- Least cost expansion plan of electricity production within the whole unit B-R-C, in self – sufficient operation.
- Least cost expansion plan of electricity production in Uganda, with a possibility of exchange of 50 MW as base load (80 MW maximum) with Kenya;
- Least cost expansion plan of electricity production in Kenya, with a possibility of exchanges of 50 MW as base load (80 Mw maximum) with Uganda.

These costs are based on the best imported thermal power plants in each system. These thermal plants are often named “Reference Plants”, but in order to avoid any confusion with the reference option as defined in the ToRs of the present study, these thermal plants will be named “Complementary”. The following is a summary of the main results; the details are found in the Excel model as presented in Annex.

5.3.1. GENERATION EXPANSION PLAN OF THE B-R-C GROUP

As a preliminary manner, the following comments can be made:

- 2010 to 2013: there are no large candidate power stations, so the production consists of existing and committed power stations, the remaining will be supplied by the complementary thermal means (here diesels);
- 2013 to 2017: the proposed candidates are over abundant in comparison with the demand ; it is necessary to determine investment priorities on the basis of the candidate plants’ generation costs;
- 2022 to 2030: In most of the cases, the candidate power plants are insufficient; the deficit should be caught up by complementary thermal production.

5.3.2. GENERATION EXPANSION PLAN OF UGANDA

In this case, there is a permanent potential surplus of installed power and annual average generated energy, even taking into account the existing Jinja – Lessos 132 kV interconnection which enables to export from 50 MW (normal conditions) up to 80 MW to Kenya; it has therefore been necessary consider the priority candidate power stations on the basis of the cost of the kWh. The eventual complementary thermal generation then depends on the guaranteed power and energy available from the future hydropower plants.

5.3.3. DETERMINATION OF THE EXPANSION PLAN OF KENYA

Here, the results are consistent with the expansion plan provided by KPLC (document dated May 2005), with the necessary adjustments, in particular related to the fuel prices. It will be considered that the complementary thermal generation should be based on diesel for the short term, then on coal from 2012 onwards.

5.3.4. CALCULATION OF THE COST OF THE REFERENCE OPTION

The principle of the cost calculation of the reference option is simple: we consider the sum of discounted annual investment and operation and maintenance costs of the candidate power plants using local energy resources; then we add the discounted costs of the complementary thermal generation that is estimated on the basis of annual energy generated and of the corresponding cost of kWh.

5.4. CALCULATION OF THE OPTIONS "WITH PROJECT"

For these cases, the following cases are considered, based on the annual power and energy exchanges which have been determined as the result of Volume 1 analysis:

- Uganda – Rwanda and Uganda-Kenya, Alternative 1;
- Uganda – Rwanda and Uganda-Kenya, Alternative 2.

In each case, we will determine the expansion plan of the three interconnected systems, on the basis of the global demand (taking into account the non-simultaneity of demand) and of the transit capacity of the interconnections as indicated above. The discounted generation cost calculations will be made in each case following the same method as presented for the reference option.

After that, we will calculate the discounted costs of investment and of operation / maintenance of studied interconnections according to the corresponding case (lines and substations) as calculated by the Consultant.

5.4.1. DESCRIPTION OF BENEFIT EVALUATION MODEL

In order to calculate the generation costs of the options "without interconnection" and "with interconnection" according to the alternatives, the Consultant has developed an Excel model which establishes an approximation for the least-cost generation plan of each considered case. The model can be described in the following way.

5.4.2. DEMAND SCENARIOS AND CONSIDERATED RATES

The developed model has considered three demand scenarios, according to their description which is included in Volume 1 of the present report. Their representation, as shown in the same Volume, considers the expected annual peak load and energy generation at HV level, for every year between 2010 (the soonest possible commissioning date for the interconnections) and 2030.

5.4.3. COMPLEMENTARY THERMAL GENERATION

As explained before, complementary thermal generation may be needed when the possible candidate plants cannot meet the demand in a given year. According to the annual energy and installed capacity needed, these generation means are either working in "base load", or in "peak load", sometimes in a combined way. .

5.4.4. SELECTION OF CANDIDATE PLANTS

Possible candidate plants for future power generation are selected on the basis of the priority order given by their generation cost per kWh as calculated in Volume 1; in a general way, when its whole potential annual energy is not needed in a given year (which is often the case for large hydroelectric power stations), a candidate may be selected if at least half of its annual producible energy can be used. This has been applied with very few exceptions where the Consultant's judgment has been used.

5.4.5. RESERVE AND INERCONNECTIONS

At the end of 2005 and the beginning of 2006, all considered electric systems in the region were working without an adequate reserve margin for normal operation. As a consequence, and as explained in Volume 1, there was an important amount of suppressed demand in each country. For future years, it is assumed that the installed capacity should allow for a minimum reserve margin of 10% of the peak load of each country, which is consistent with the planning criteria used by KPLC in its 2006-2026 generation planning update, as established in May 2005. In this document, the reliability criteria adopted was a loss of load expectation (LOLE) of 10 days per year and 0.1% of energy demand as expected un-served energy (EUE); both criteria together under critical drought conditions. The application of these criteria by KPLC gives a consistent annual difference of 10% between the total installed capacity of the system and the peak load.

So in the present document, this value of 10% has been applied to all considered systems. By experience, and taking into account the specific drought conditions prevailing in the region in the last 10 years, this value seems low, in particular for the Ugandan system and the Burundi-Rwanda-Congo (DR) system.

When interconnected, several systems can share their reserves depending on the interconnection capacities. The maximum possible reserve savings between two interconnected systems is equal to the maximum interconnection capacity between both systems. However, the exact amount of reserve which can be saved cannot be calculated without a detailed and precise evaluation of daily and seasonal operating conditions. Moreover, the expected medium and long-term expansion of HV interconnections in the region, shows that the B-R-C system should be connected to North-Western Tanzania (as soon as the Rusumo Falls multinational project is implemented), while the Kenyan system will soon be itself interconnected with Eastern Tanzania, and probably with Southern Ethiopia in the longer term.

In spite of the theoretically favourable reserve conditions due to the future diversity of interconnected systems, a conservative assumption has been made, which states that the amount of reserve which can be saved is at least equal to half (instead of 100%) of the interconnection capacity under normal operating conditions. This has been applied from 2013 onwards in all cases of interconnected systems as described below.

5.4.6. REDUCTION OF PEAK LOAD DUE TO INTERCONNECTIONS

The Consultant has analysed the load curves of the different systems, as obtained during the first field mission in February-March 2006: a sample of representative daily load curves in Rwanda and Burundi, complete hourly load curves from June 2005 to December 2005 in Uganda, and the complete chronological hourly loads of the Kenyan system in 2005. With some complementary statistical information, the Consultant could generate a complete and realistic set of hourly un-constrained loads for Uganda in 2005, and combine it with the corresponding Kenyan system loads. The main result shows that the peak load of the combined systems is lower than the sum of both peak loads, by 2.5%. This difference can be considered small according to the Consultant's experience, which shows « normal » values of around 5%. The analysis of the load curves is shown in Appendix.

For the corresponding systems in Rwanda and Burundi, the same analysis could not be made due to the absence of detailed information on hourly loads; in any case, such evaluation may have been seriously biased by the presence of large suppressed demands in both systems.

In order to use again a conservative assumption, it has been considered that the future interconnections will bring an overall reduction of peak loads of 2.5%. This will lead to further savings in installed capacities of each system.

5.4.7. COST OF COMPLEMENTARY THERMAL GENERATION AND RESERVE

Based on reference international costs, and on information obtained from the existing and/or planned thermal projects in the region, the Consultant has established the expected generation costs (investment, O&M, fuel) of the possible future complementary thermal generation means in each of the considered systems (refer to Annex F).

The calculated costs are variable according to the expected international fuel costs, taking as reference the cost of one barrel of Brent crude oil in the international markets; a relationship has been assumed between this cost and the costs of all fuels considered in this study (see the basic study assumptions above).

As a result, and corresponding to the « base case » value of 60 US$/bbl, the following costs have been considered:

5.4.7.1. RWANDA-BURUNDI-CONGO (DR) OR B-R-C SYSTEM

Complementary generation: diesel (HSD)	Fuel and O&M variable cost:	0.26 US$/kWh
	Investment and fixed O&M:	1000 US$/kW

In this system, it is also assumed that complementary reserve means shall be based on High-Speed diesel sets, thus with a fixed cost of 1000 US$ per installed kW. This has been considered for the short and medium-term years (up to 2013, after what most large hydropower candidate plants become available).

5.4.7.2. UGANDA

In this system, complementary generation means should be a mix of diesel-fired thermal power stations, part of them based on Heavy Fuel Oil (when available in the country), and the rest being HSD units as in B-R-C. The following costs have been considered:

Complementary generation: diesel	Fuel and O&M variable cost:	0.23 US$/kWh
	Investment and fixed O&M:	1000 US$/kW

Here again, the effect of these costs will be limited to the short and medium term, until large hydropower generation comes in line.

5.4.7.3. KENYA

Various combinations are possible in order to define complementary generation means. Due to the size of the country and of the system, various generation means can be considered:

- Steam power plants: they can use either HFO or coal (mostly imported). The cost of HFO being prohibitive, only coal power stations seem suitable. Due to their size and operability conditions (mainly base load operation) they are considered as candidate generation means;
- Diesel plants using HFO: can be used as base load generation, but due to the transportation cost of fuel, should be limited to Mombasa, Nairobi and Lake Victoria areas;
- Diesel plants using HSD: only in very limited areas, due to the high fuel costs and investment costs;
- Gas turbines using Light Fuel-Oil or kerosene (eventually LPG or LNG in the distant future): mostly interesting for very limited uses (extreme peak and/or reserve), and in low altitude areas (near Mombasa mostly, for efficiency and fuel costs reasons). Investment costs are about half of diesel costs per installed kW.

Due to the complexity of the future Kenyan system, and the objectives of the present study, it is not possible, nor necessary to determine which would be the most accurate combination of complementary generation and reserve means in this system. The following values have been assumed by the Consultant, which are reflecting the diversity of the possible generation means and scenarios:

Complementary generation and reserve:

Fuel and O&M variable cost:	0.14 US$/kWh
Investment and fixed O&M:	1000 US$/kW (base load generation and reserve)
	500 US$/kW (peak load generation and reserve)

5.4.7.4. OTHER COUNTRIES TO BE INTERCONNECTED

In addition, it has been assumed that for the long term (from year 2020 onwards), all regional African networks should be fully interconnected whatever would be the outcome of the present study. So the study assumes that complementary thermal generation by these years should come from coastal areas and/or countries with adequate fuel supply. As a consequence, the long-term cost of complementary thermal generation has been assumed equal to the one we proposed for Kenya. The effect of this assumption is really important on the B-R-C system, and only from 2025.

5.4.8. LOSSES

Since interconnections will modify the power transits in all systems, it is theoretically necessary to evaluate power losses in the situation « without project » and compare them with the situation « with project ». For an accurate evaluation, it would be necessary to run load flow analyses for a wide range of situations (each system without interconnection, plus each interconnection alternative), years (short, medium and long term horizons at least), seasons (dry and wet) and moments of a day (peak time or low time). For the present study, it is not necessary to propose such precise evaluations for the power loss differences between options "without" and "with" project. If we assume that power losses within the main systems do not significantly change when interconnections are added (which is generally true for complex and diverse systems), only the losses in the interconnection links should be considered.

In the evaluation model, the percentage of losses in the interconnection links has been assumed according to the considered project alternative and the considered period. The values are indicated below in the description of each considered alternative. The costs of these losses is difficult to estimate precisely, since it depends on the available generation, and its distribution according to the years, seasons, time of day in particular. In this case an average cost of 0.04 US$/kWh has been chosen, which reflects the long-term base load generation costs of all systems considered together.

5.4.9. ECONOMIC BENEFITS OF ALTERNATIVE 1

5.4.9.1. TOTAL BENEFITS

Based on the above-mentioned generation plans "with project" and "without project", the Consultant calculated the discounted benefits of Alternative 1 vs. the reference solution. The benefits include the following items:

Generation benefits

For each considered year between 2010 and 2030, the model has calculated the difference in generation costs between the reference option and the option "with project" as defined above.

Generally, the option “with project” has an additional “indigenous” generation when compared to the reference option, while the reference option has a greater thermal generation (based on imported fuels). Since the considered indigenous generation means are cheaper, the result is a positive generation benefit for the Option 1.

The Appendix LDC UGANDA-KENYA, FEUILLE PLACEMENT 2017 shows the effect of a large interconnection between Uganda and Kenya, with a better use of cheap hydro resource in Uganda, and a reduced use of relatively more expensive thermal resources (mostly coal) in Kenya

Reserve benefits

The expected reserve benefits have been calculated as explained above.

Cost of losses

The total power losses on the interconnection links have been assumed at 2% when the overall transited power is less than or equal to 50 MW, up to 4% for transits of 150 MW; the annual energy losses have been derived assuming a constant 50% utilisation factor in the whole period. When the generation benefits are nil, the cost of losses is zero (it corresponds to very limited energy exchanges).

The total benefits are then defined as generation benefits plus reserve benefits minus cost of losses. The following values have been obtained for Alternative 1, with a discount rate of 10% and cost of fuels consistent with a crude oil cost of 60 US$/bbl:

TOTAL BENEFITS	MUS$
Medium Demand	293
Low Demand	241
High Demand	446

5.4.9.2. BREAKDOWN OF BENEFITS

As could be seen before, the situation of power generation in all the considered systems has shown that the interest of Rwanda-Uganda and Uganda-Kenya new links should be examined together. Effectively, according to the demand scenarios, there are periods where both B-R-C and Ugandan systems present potential excesses in indigenous energy potentials, and in this case both interconnections can be used as exports towards Kenya ; there are other periods when only Uganda has excess energy, and in this case both interconnections can be used in order to export energy from the Ugandan system towards Kenya and Rwanda ; and when no excesses are available in any system, like in the High Demand scenario and in the long term, the use of both interconnections together allows for a reduction of the overall power reserve needed.

At this level of study, it is not possible to precisely define what percentage of economic benefits should be attributed to one or the other. It is proposed here to share the benefits in proportion with the power transfer capacity of each scheme, calculated as a weighted average of the annual transfer capacities over the whole study period. In the present Alternative 1 case, this would give between 41% and 47% for Rwanda-Uganda, and consequently between 59% and 53% for Uganda-Kenya. The following benefits can then be proposed for both schemes (same assumptions as indicated before on discount rate and fuel costs):

TOTAL BENEFITS	MUS$	Rwanda-Uganda	Uganda-Kenya
Medium Demand	293	122	171
Low Demand	241	104	137
High Demand	446	211	234

5.4.10. ECONOMIC BENEFITS OF ALTERNATIVE 2

5.4.10.1. TOTAL BENEFITS

Based on the above-mentioned generation plans "with project" and "without project" the Consultant calculated the discounted benefits of Alternative 2 vs. the reference solution. The benefits include the following items:

Generation and reserve benefits

The corresponding benefits have been calculated in the same way as indicated for Alternative1.

Cost of losses

In this case, the total power losses on the interconnection links have been assumed at 2% for transits of 50 MW or less, up to 6% for 300 MW transits, and the annual energy losses have been derived as indicated for Alternative 1 above.

The following total benefits have been obtained for Alternative 2, with a discount rate of 10% and cost of fuels consistent with a crude oil cost of 60 US$/bbl:

TOTAL BENEFITS	MUS$
Medium Demand	446
Low Demand	334
High Demand	554

5.4.10.2. BREAKDOWN OF BENEFITS

In the present Alternative 2 case, the application of the same method for determining the breakdown of benefits between both schemes has been applied. The following benefits can then be proposed for both schemes (same assumptions as indicated before on discount rate and fuel costs):

TOTAL BENEFITS	MUS$	Rwanda-Uganda	Uganda-Kenya
Medium Demand	446	131	314
Low Demand	334	89	245
High Demand	554	175	379

5.5. COST BENEFIT ANALYSIS: UGANDA-KENYA

5.5.1. COST ANALYSIS FOR ALTERNATIVE 1

5.5.1.1. INVESTMENT COSTS

As indicated in the description of the proposed project, the future Uganda-Kenya interconnection will be constituted by a Bujagali-Tororo-Lessos double circuit line and associated substations, operated at 220 kV. Since most new large hydropower stations can be available in Uganda from 2013, it has been considered in the cost-benefit analysis, that this new link should become available at the same time. In Alternative 1 described hereafter, it is assumed that the interconnection will bring an additional possible continuous transfer capacity of 100 MW in the first years, increasing in the long term as indicated in Volume 1.

Based on Volume 2 project description, the following cost summary can be presented:

Costs in MUS$	Uganda	Kenya
Lessos-Border line		29.3
Border-Bujagali line	28.2	
Lessos substation		9.7
Tororo Substation	11.6	
Bujagali Substation	2.2	
Land acquisition	0.8	0.8
Total	42.8	39.8

5.5.1.2. OPERATION AND MAINTENANCE COSTS

Such costs are generally extremely variable according to the areas and the organisation of operation and maintenance of the concerned company. However, these costs are generally low and an annual value of 1% of investment costs is currently used. This value shall then be used in this analysis.

5.5.1.3. COST AND BENEFIT COMPARISON

The discounted costs and benefits of Alternative 1 have been calculated for a « base case » set of economic and technical parameters:

- Discount rate : 10%
- Fuel cost basis :60 US$/bbl
- Power stations' availability and earliest commissioning dates as indicated above
- Investment costs (power stations, interconnection option) as indicated above

Detailed results are shown in Annex, in the Summary sheet.

The Net Present Value (NPV) of the Alternative 1 for the Uganda - Kenya Interconnection is calculated as the sum of discounted benefits minus the sum of discounted investment and O&M costs of the interconnection. The various results can be presented as follows:

Case Studied	NPV (MUS$)	EIRR
Base Case	103	75%
Low Demand	70	95%
High Demand	167	75%
Discount Rate: 8%	133	N/A
Discount Rate: 12%	81	N/A
Fuel Costs: 80 US$/bbl	156	80%
Fuel Costs: 60 US$/bbl	51	60%

As can be seen, the Economic Internal Rate of Return (EIRR) of the scheme has been calculated in each significant case. The values are all higher than 60%. Such high benefits can be explained by the fact that future hydro generation is considerably cheaper than thermal generation.

It is also important to note that, in the case when a significant HV interconnection can become available between the South African Power Pool (SAPP) interconnected system, including not only the Tanzania-Kenya proposed project, but also a HV interconnection from the SAPP to the Rwanda-Burundi-Congo (DR) system via Tanzania, it will be possible to consider that there is an additional reserve-sharing benefit with the presence of a Rwanda-Uganda-Kenya interconnection operated at 220 kV. In this case, the above-mentioned NPV can be even increased by an estimated 26 MUS$ (if in 2017). It is interesting to note that in this case, the reserve benefits brought by the Uganda-Kenya interconnection almost exactly match its costs, which means that even with important reductions in the hydropower investment programme in Uganda, the proposed interconnection should be economically attractive.

5.5.2. COST ANALYSIS FOR ALTERNATIVE 2

5.5.2.1. INVESTMENT COSTS

In the Alternative 2 a transfer capacity of up to 250 MW is considered, which is possible through the 220 kV double circuit line as described before. The following costs should then be proposed :

Costs in MUS$	2013	
Lessos-Border line		29.3
Border-Bujagali line	28.2	
Lessos substation		9.7
Tororo Substation	11.6	
Bujagali Substation	2.2	
Land acquisition	0.8	0.8
Total	42.8	39.8

5.5.2.2. OPERATION AND MAINTENANCE COSTS

Additional annual operation and maintenance costs of 1% of the above investment cost have been included.

5.5.2.3. COST AND BENEFIT COMPARISON

The Net Present Value (NPV) of the Alternative 2 for the Uganda-Kenya Interconnection is calculated as the sum of discounted benefits minus the sum of discounted investment and O&M costs of the interconnection. The various results can be presented as follows:

Case Studied	NPV (MUS$)	EIRR
Base Case	247	>100%
Low Demand	178	>100%
High Demand	312	>100%
Discount Rate: 8%	293	N/A
Discount Rate: 12%	212	N/A
Fuel Costs: 80 US$/bbl	364	>100%
Fuel Costs: 60 US$/bbl	130	>100%

The results are similar to the ones found for Alternative 1, but in this case all results are always higher. It comes from the fact that the expected reserve benefits, which exist in all cases, are higher than the total cost of the link. In addition, if the above-mentioned SAPP link becomes available, the NPV should be further increased by an estimated 64 MUS$ (if in 2017).

5.6. LEGAL, INSTITUTIONAL AND FINANCIAL ANALYSIS

The countries concerned with the interconnections examined so far, are found in different situations (see Volume 1) concerning the structure of their power sector. The following is an overall review of the power sector structure of each country, and the consequences on the future possible institutional and legal set-ups of the proposed interconnections.

5.6.1. KENYA

5.6.1.1. STRUCTURE OF POWER SECTOR

As a reminder, in Kenya, the power sector has been structured according to the Electric Power Act of 1997. The electricity generation is open to the private sector, with a main actor in a privatisation process (KenGen) and several Independent Power Producers (IPPs). The Transmission and Distribution activities are still under the monopoly of KPLC, which is also the only entity to purchase power, either from KenGen and the IPPs, or from interconnections with foreign countries (at present only with UETCL in Uganda). These purchases are regulated by individual Power Purchase Agreements between each mentioned actor and KPLC.

KPLC has also the exclusive rights to sell electricity to the consumers, through tariffs which are regulated by the Electricity Regulatory Board (ERB).

However, in the near future ERB should be granted enough power to ensure competition in the power sector, in particular in generation and transmission, which should give way to future private investors in these fields. The operation of a future Uganda-Kenya interconnection by a private or public-private company should then be possible in a few years.

5.6.1.2. ELECTRICITY TARIFFS

ERB is empowered to process and recommend applications to set, review and adjust transmission and distribution tariffs. The tariff structure and terms of supply need to take into account a licensee's total revenues from tariffs covering all reasonable costs and a reasonable return. It is anticipated that Kenya should enjoy an Open Access Transmission Tariff within 3 years, which should be the basis for a future organised electricity market, with competition at generation, distribution and supply level; in the same way, such a tariff policy should facilitate the operation of a future "Interconnection Company" working as a classic Transmission System Operator between Uganda and Kenya.

5.6.1.3. GENERAL RULES ON INVESTMENT IN THE POWER SECTOR

One of the important aspects of the power sector legislation concerning future interconnections is the possibility to expropriate for public purposes; compulsory acquisitions for generation and transmission facilities must be authorised by the Minister and follow the rules set out in Section 110 of the Electric Power Act. Although this aspect is often difficult to overcome in a lot of countries, no overwhelming difficulties should be found for future transmission companies in order to get the necessary land for their infrastructure.

As for foreign investment in the sector, it would be governed by the Foreign Investments Protection Act (FIPA) under which no limitations are being mentioned on the percentage of foreign ownership of companies operating in Kenya. However, a preference is being granted to projects including a substantial Kenyan participation, guaranteed export markets, potential for local labour employment in particular.

5.6.2. UGANDA

5.6.2.1. STRUCTURE OF POWER SECTOR

The Ugandan power sector has been structured according to the Electricity Act of 1999 and subsequent revisions. The electricity generation is open to the private sector, with a main actor (UEGCL) which has been privatised in 2002 through a 20-year concession agreement with ESKOM Enterprises Ltd. Several IPPs are also present and there is an important number of private projects. The Transmission and Distribution activities are under the monopoly of UETCL, which is also the only entity to purchase power from the generators or from interconnections with foreign countries (at present only with KPLC in Kenya). These purchases are regulated by individual Power Purchase Agreements.

UETCL has also the exclusive rights to sell electricity to the existing distribution company, through a PPA. This company, created with the name of UEDCL, has been privatised through a 20-year concession agreement in March 2005 and has become UMEME, a British/South African company.

The sector is regulated by ERA, the Electricity Regulatory Authority, which is responsible for licensing and establishing tariffs.

For the moment, it seems that Transmission activities are not open to the private sector, although UETCL is practically operating like a private company. The operation in Uganda of a future Uganda-Kenya interconnection by a private or public-private company would then require a legal act. At this moment it is not clear whether it would be an amendment of the Electricity Act, or a Government Decree; this should be investigated during project preparation activities, in such a way that the proper legal framework for transmission companies could be ready within 4 to 5 years.

5.6.2.2. ELECTRICITY TARIFFS

ERA is empowered to process and recommend applications to set, review and adjust generation, transmission and distribution tariffs. The tariff structure takes also into account reasonable costs and a reasonable return. No mention has been found on the possibility to have an Open Access Transmission Tariff like in Kenya. The presence in Uganda of a future "Interconnection Company" working as a classic Transmission System Operator between

Uganda and Kenya would be possible if such a tariff possibility is implemented by ERA within the next 4 to 5 years, which seems relatively easy.

5.6.2.3. GENERAL RULES ON INVESTMENT IN THE POWER SECTOR

Concerning the possibility to expropriate for public purposes; compulsory acquisitions for power sector facilities are ruled by Part VIII of the Electricity Act, 1999. Again here, no large difficulties should be found for future transmission companies in order to get the necessary land for their infrastructure.

As for foreign investment in the sector, it would be facilitated by the Multilateral Investment Guarantee, and bilateral agreements.

5.6.3. UGANDA-KENYA INTERCONNECTION: PROPOSED INSTITUTIONAL SET-UP

As mentioned in the Pre-Feasibility Study, two possible institutional set-ups can be proposed for the interconnection:

5.6.3.1. A CLASSIC UETCL-KPLC ARRANGEMENT:

In this case, there would be an agreement between both companies (similar to the one governing the existing interconnection), which would stipulate the general and particular operating conditions, and the commercial rules for exchanges of energy and power reserve between the two companies. The infrastructure would be constructed and operated by each company in its own territory, and the financing would be made in a classic way, with financing agreements being set-up by each company separately with multilateral and/or bilateral financing institutions and commercial banks. In this case, it is assumed that both UETCL and KPLC are fully prepared to implement the institutional and financial aspects of the project, in cooperation with the interested multilateral and bilateral financing agencies (in particular the AfDB and the World Bank).

5.6.3.2. TRANSMISSION SYSTEM OPERATOR

As indicated before, future transmission companies could be able to operate in Kenya in a few years, with generators and large consumers / power suppliers having open access to the network. In Uganda, some progress is needed in the legal framework, but it is achievable in a few years and the Government has the will to improve competition and foreign investment in the sector. In this case, one could imagine another institutional set-up, focused on an independent company for the transport of electricity “Transmission System Operator” that could be totally or partially private-owned, and operate on the basis of remuneration for transmission services “wheeling tariff” or “cost plus fee”. At this level of the Feasibility Study, the Consultant recommends a simple financial analysis of this type of set-up, since it is already under preparation or planned in the concerned countries. Since interconnections are going to be implemented in the whole African continent, with substantial economic benefits, the Consultant recommends studying this kind of set-up in priority because it should attract substantial foreign and local private investment to complement classic multilateral funding.

The following Financial Analysis is then based on the proposed set-up.

5.6.4. FINANCIAL EVALUATION

The financial analysis normally consists in a cost-benefit evaluation taking into account the real costs of the project for each entity (taxes included) and considering also the hypotheses which are reasonable for project financing (breakdown into loan and equity, and main loan conditions in particular); concerning benefits, it is proposed to remunerate the rendered services with a cost plus fee tariff based on reasonable costs and reasonable fees.

5.6.4.1. OVERALL COST AND TARIFF ESTIMATE FOR ALTERNATIVE N°1

According to the calculations made in Annex, Alternative 1 interconnection would allow mainly bulk transfer from Uganda to Kenya. The overall discounted investment + Operation and Maintenance cost, calculated for the base case scenario from 2013 to 2030, is 63 Million US$, while the overall discounted transferred energy in the period is 4259 GWh.

A very rough calculation shows that the average discounted transmission cost would be 1.5 US Cents/kWh. It means that a tariff of 1.5 cents/kWh would guarantee a 10% return on the global investment.

5.6.4.2. PRELIMINARY FINANCIAL ANALYSIS FOR ALTERNATIVE N°1

In order to make this type of project more attractive to private investors, it could be possible to imagine a financing structure which would be defined as follows:

Loan / Equity breakdown: 70% - 30%

Multilateral / Commercial loan breakdown: 50% - 50%

Multilateral loan duration: 15 years Rate: 7% Grace period: 3 years

Commercial loan duration: 7 years Rate: 10%

Bulk transfer remuneration: Flat rate: 1.5 cents US$/kWh

Based on these assumptions, a simplified financial analysis has been made, without taking into account inflation rates, taxes or duties, and assuming perfect technical operation. The detailed calculations appear in Annex.

The most interesting result is that the return on equity would be of 22% per annum, which makes it attractive to private investment.

5.6.4.3. PRELIMINARY FINANCIAL ANALYSIS FOR ALTERNATIVE N°2

Based on the same overall assumptions, but assuming a higher transfer capacity, the same financial calculations have been made, which in this case give a higher return on equity of % per annum.

5.7. CONCLUSIONS AND RECOMMENDATIONS

- The Uganda-Kenya interconnection is very attractive on the economic point of view, since it will allow for huge overall generation cost reductions in both countries. There should be also indirect benefits for both economies, since it should allow for relatively low electricity tariffs over a long period, which would further enhance industrial and commercial investment in both countries.
- Although the amount of benefits depend very much on the implementation of several large hydro generation projects, some of which could be delayed or even cancelled, the interconnection presents substantial benefits in overall reserve sharing and peak demand reduction of both countries. Since other large interconnections are seriously planned in this African region, the Uganda-Kenya interconnection (together with the Rwanda-Uganda interconnection) should bring other substantial generation and reserve benefits in neighbouring countries in the future, in particular in Tanzania (and the rest of the SAPP system) and Ethiopia.
- For these reasons it is recommended to implement the project as soon as possible; the development of this project should also provide incentive for the fast development of large hydropower plants in Uganda.
- The project could be implemented without particular problem together by UETCL and KPLC; it is also possible to implement it via private or public-private schemes. This can be done through adaptation of the existing legal framework of the power sectors of Uganda (with a particular effort) and Kenya in order to permit the operation of independent Transmission Systems Operators, with a corresponding adapted tariff system; this should also be developed in the frame of increasing free access to the transmission networks of both countries.
- Under these conditions, and under acceptable financing rules and set-ups, the financial feasibility of a private (or public-private) investment looks promising, and with reasonable price impacts on the respective power systems of the countries.

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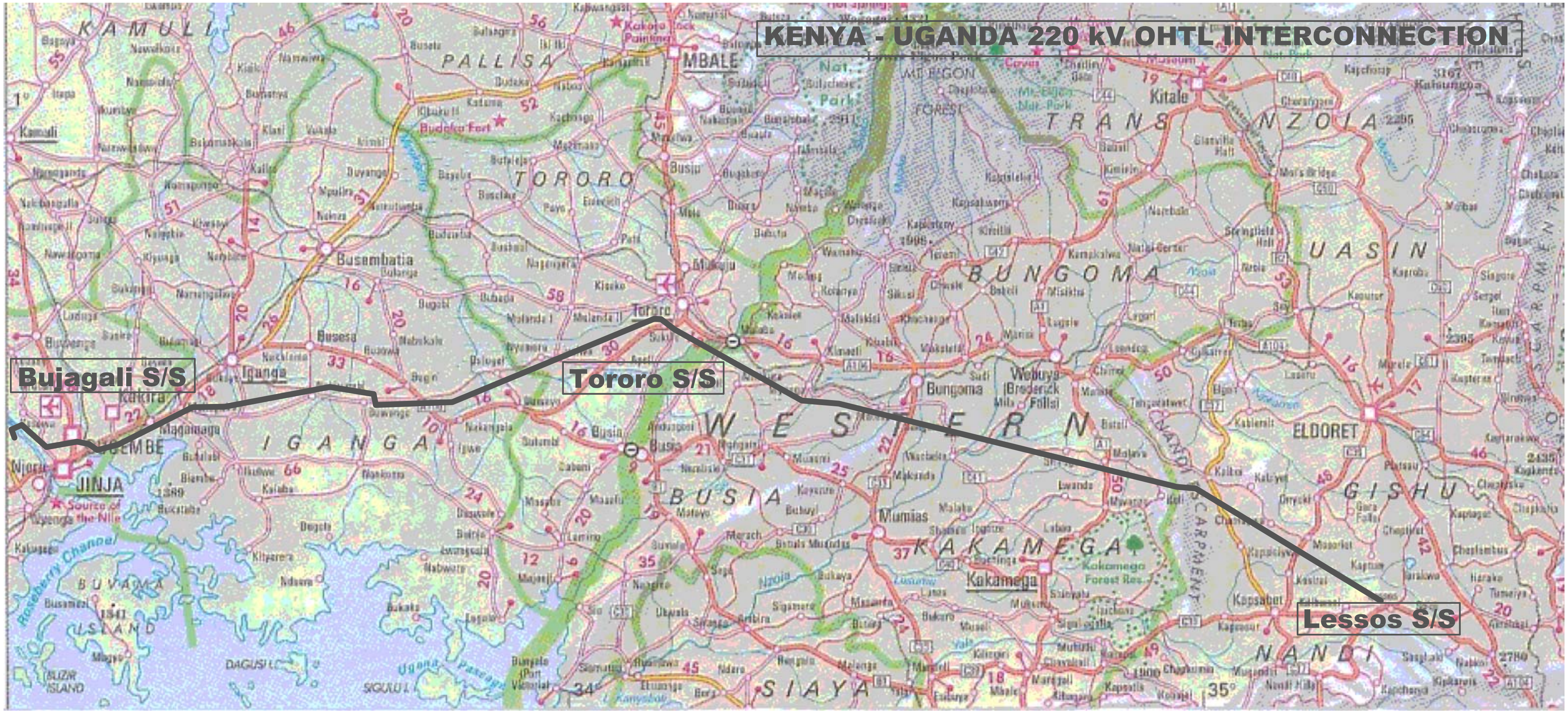
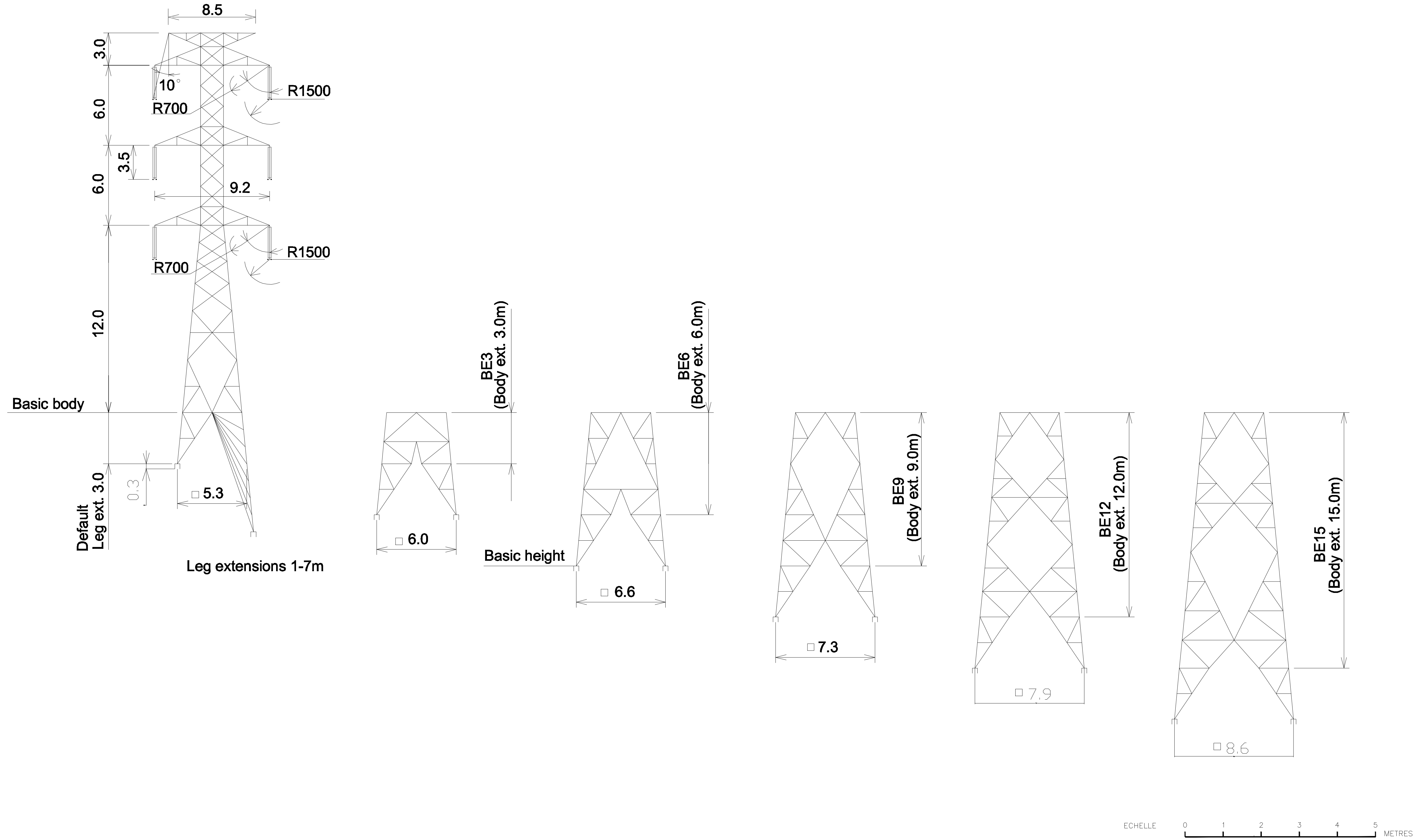
ANNEX A – INTERCONNECTION LINE ROUTE GENERAL MAP


KENYA - UGANDA 220 kV OHTL INTERCONNECTION
Bujagali S/S
Tororo S/S
Lessos S/S

ANNEX B – TOWER MODELS

Dessiné par: ALX Controlé par: XDS
Référence informatique:P:\BRC\ENE\

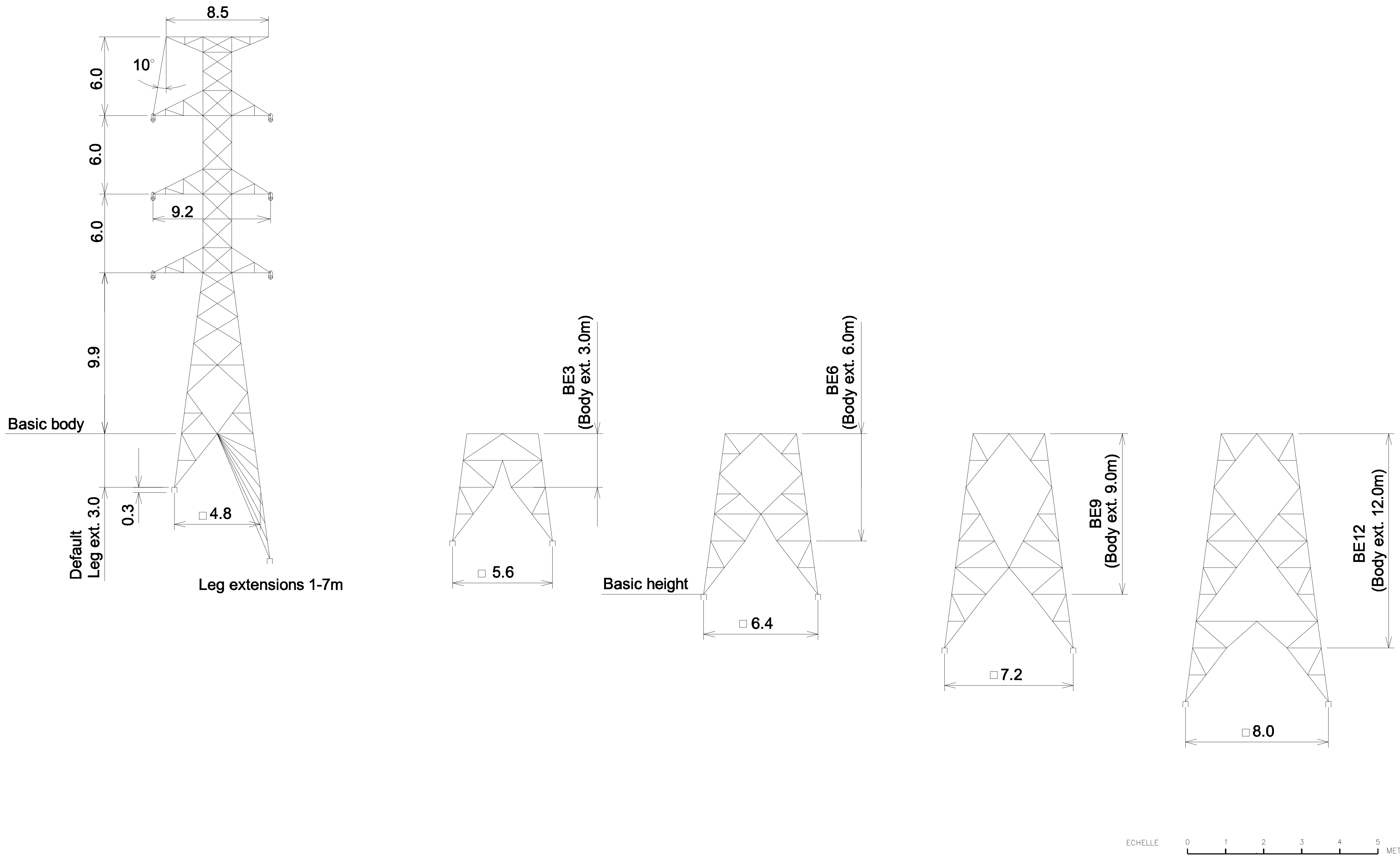


NELSAP STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES	PAALEN ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

PREFEASIBILITY REPORT / RAPPORT DE PREFAISABILITE

KENYA- UGANDA - INTERCONNECTION
220 kV SUSPENSION TOWER - DOUBLE CIRCUIT
OUTLINE DRAWING

N° H L KU 110 a
Date : 26 April 2007



Dessiné par: ALX Controlé par: XDS

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NELSAP
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES

PAALEN
ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

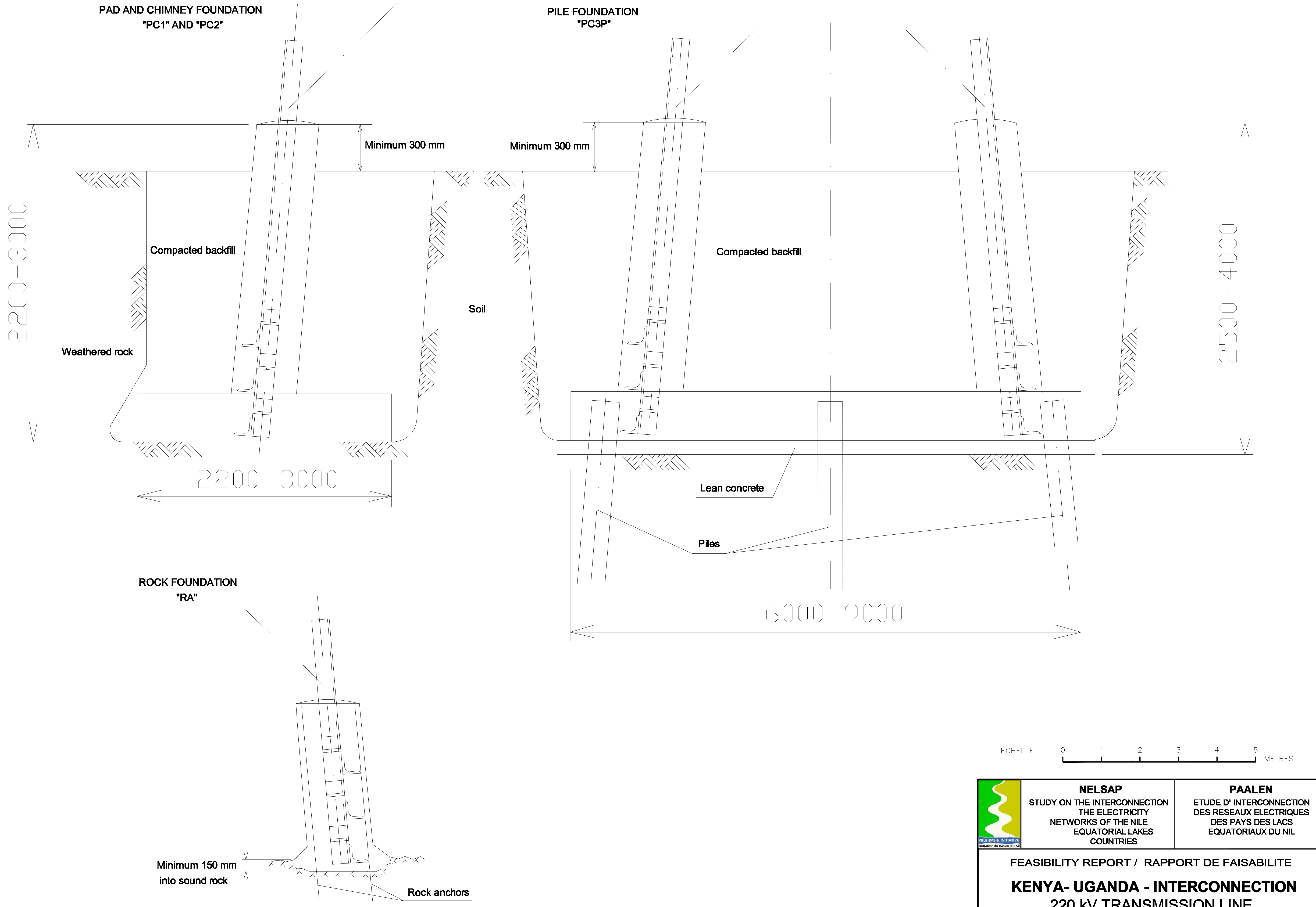
FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA - UGANDA - INTERCONNECTION
220 kV TENSION TOWER - DOUBLE CIRCUIT
OUTLINE DRAWING

N° H L KU 111 a

Date : 26 April 2007

ANNEX C – FOUNDATION MODELS



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NELSAP
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES

PAALEN
ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

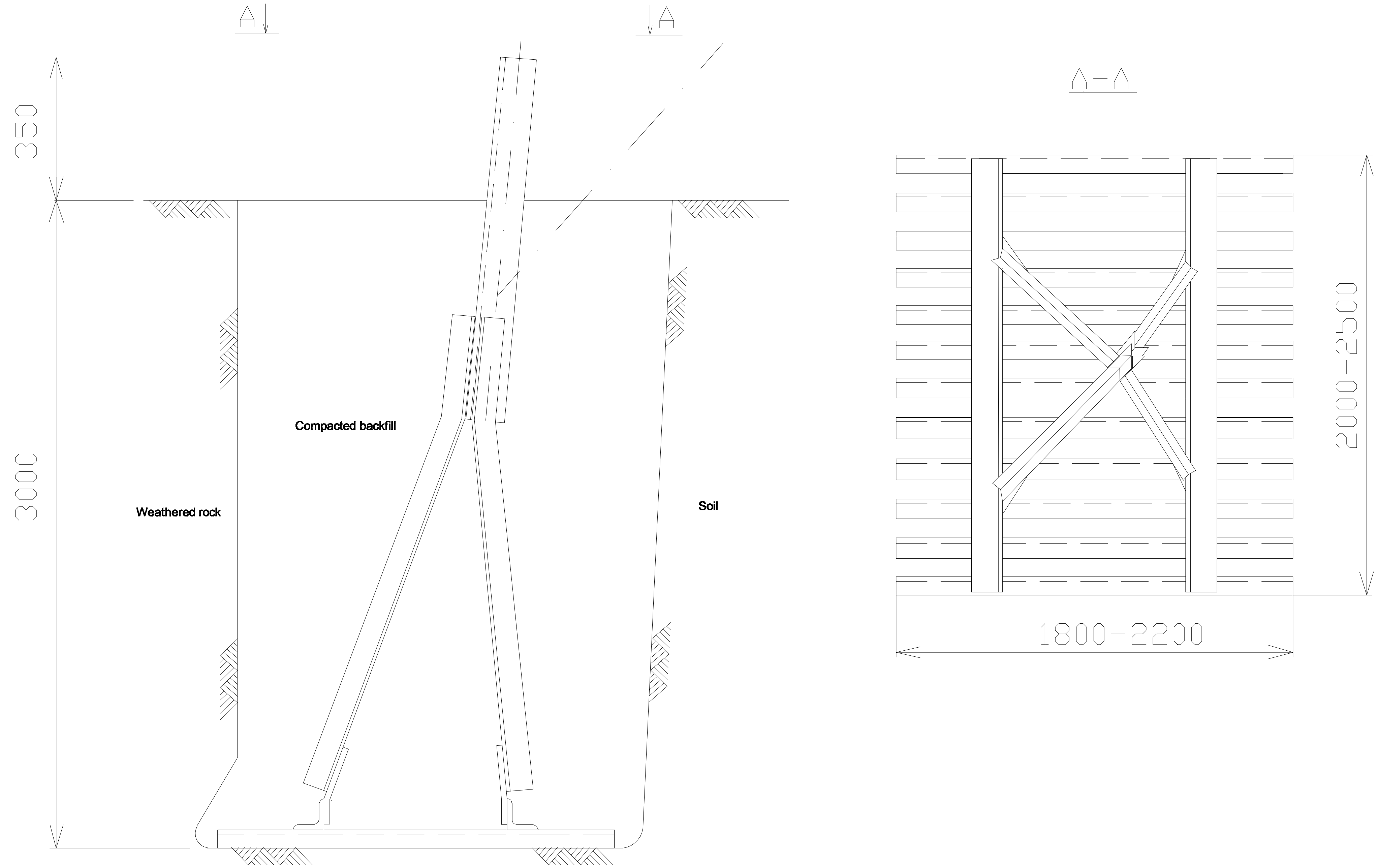
FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION
220 kV TRANSMISSION LINE
OUTLINE OF CONCRETE FOUNDATIONS

SOGREAH
RSW INTERNATIONAL
Hydro Québec International

N° H L KU 112 a

Date : 25 April 2007



ECHELLE 0 1 2 3 4 5 METRES

NELSAP	PAALEN
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES	ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION
220 kV TRANSMISSION LINE
OUTLINE OF GRILLAGE FOUNDATION

N° H L KU 113 a

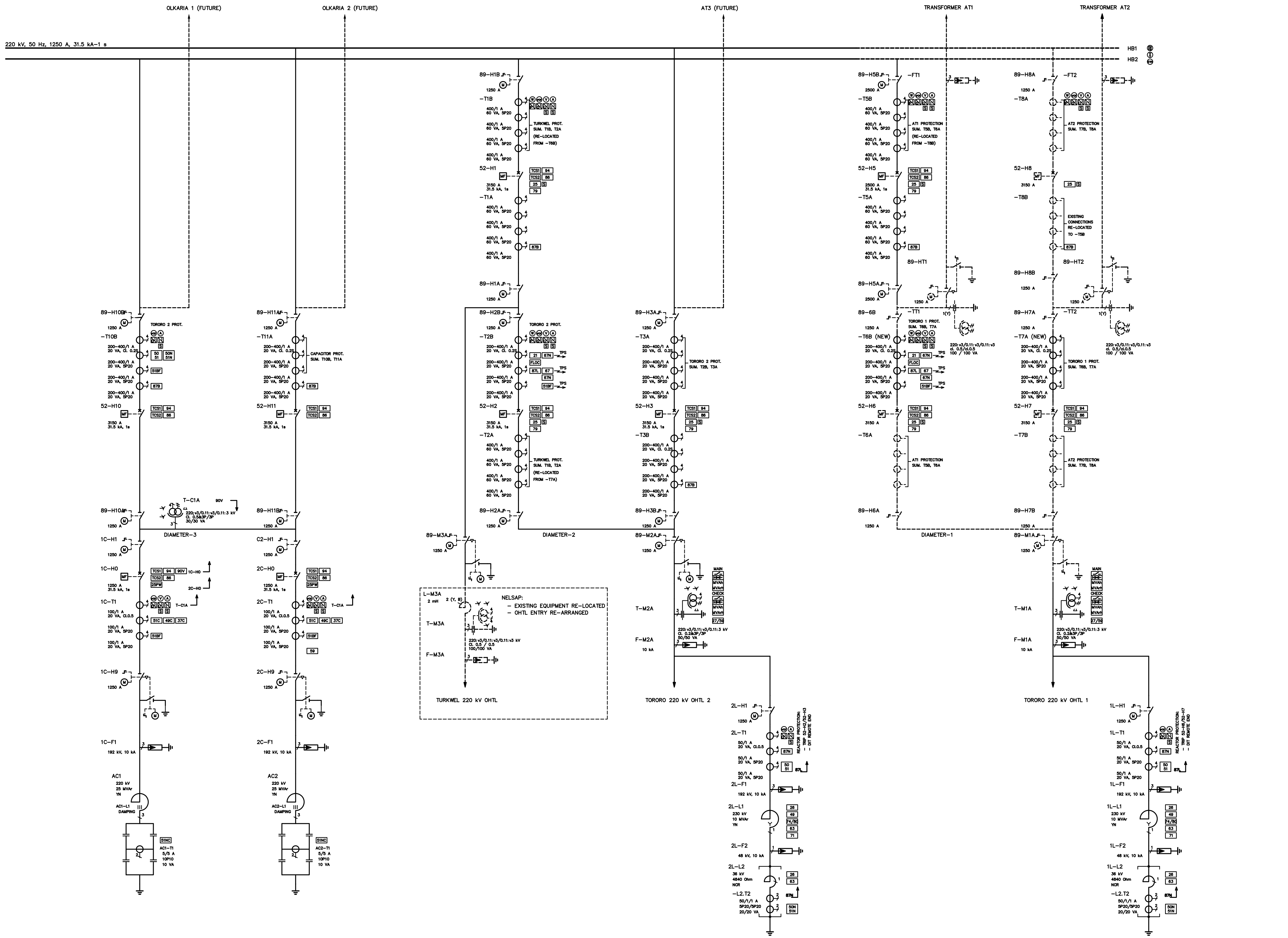
Date : 25 April 2007

Dessiné par: ALX Controlé par: XDS
Référence informatique:P:\BRC\ENE\

ANNEX D – SUBSTATIONS DRAWINGS

Single Line Diagrams and Lay out:

- Lessos Substation
- Tororo Substation
- Bujagali Substation



EXISTING OR FUTURE FACILITIES

LEGEND:

11	BAY CONTROL UNIT (BCU)
21	DISTANCE PROTECTION
25	SYNCHRO CHECK RELAY
26	REACTOR OIL TEMPERATURE DEVICE (ALARM/TRIP)
27/59	UNDER/OVER VOLTAGE RELAY
37C	UNDER CURRENT RELAY-CLOSE INHIBIT (CAPACITOR BANK)
49	REACTOR WINDING TEMPERATURE DEVICE (ALARM/TRIP)
49C	OVER LOAD RELAY (CAPACITOR BANK)
50 51	PHASE INSTANTANEOUS OVERCURRENT/INVERSE TIME CHARACTERISTICS OVERCURRENT PROTECTION
50N 51N	NEUTRAL INSTANTANEOUS OVERCURRENT/INVERSE TIME CHARACTERISTICS NEUTRAL OVERCURRENT PROTECTION
51BF	CIRCUIT BREAKER FAILURE PROTECTION
51C	INVERSE TIME CHARACTERISTICS O/C PROTECTION (CAPACITOR BANK)
51NC	UN-BALANCE PROTECTION (CAPACITOR BANK)
59	OVER VOLTAGE RELAY
63	REACTOR PRESSURE RELIEF DEVICE (TRIP)
67	DIRECTIONAL OVER CURRENT PROTECTION
67N	DIRECTIONAL EARTH FAULT PROTECTION
71	RECTOR OIL LEVEL GAUGE (ALARM)
74/80	RECTOR BUCHHOLZ DEVICE (ALARM/TRIP)
79	1/3 PHASE MULTI-SHOT AUTO-RECLOSING RELAY
86	LOCK-OUT (BLOCK CLOSE) RELAY
87B	2-ZONE BUSBAR PROTECTION
87N	RESTRICTED EARTH FAULT PROTECTION (REF)
87L	LINE DIFFERENTIAL PROTECTION
90V	VOLTAGE REGULATION RELAY (CAPACITOR BANK)
94	TRIP RELAYS
FLOC	FAULT LOCATOR
TCS1	TRIP CIRCUIT 1 SUPERVISION
TCS2	TRIP CIRCUIT 2 SUPERVISION
TPS	TELEPROTECTION SCHEME INTERFACE
S	SELECTOR SWITCH (A-or V-METER or SYNCHRO AUTO/MAN)

NELSAP
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES

PAALEN
ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

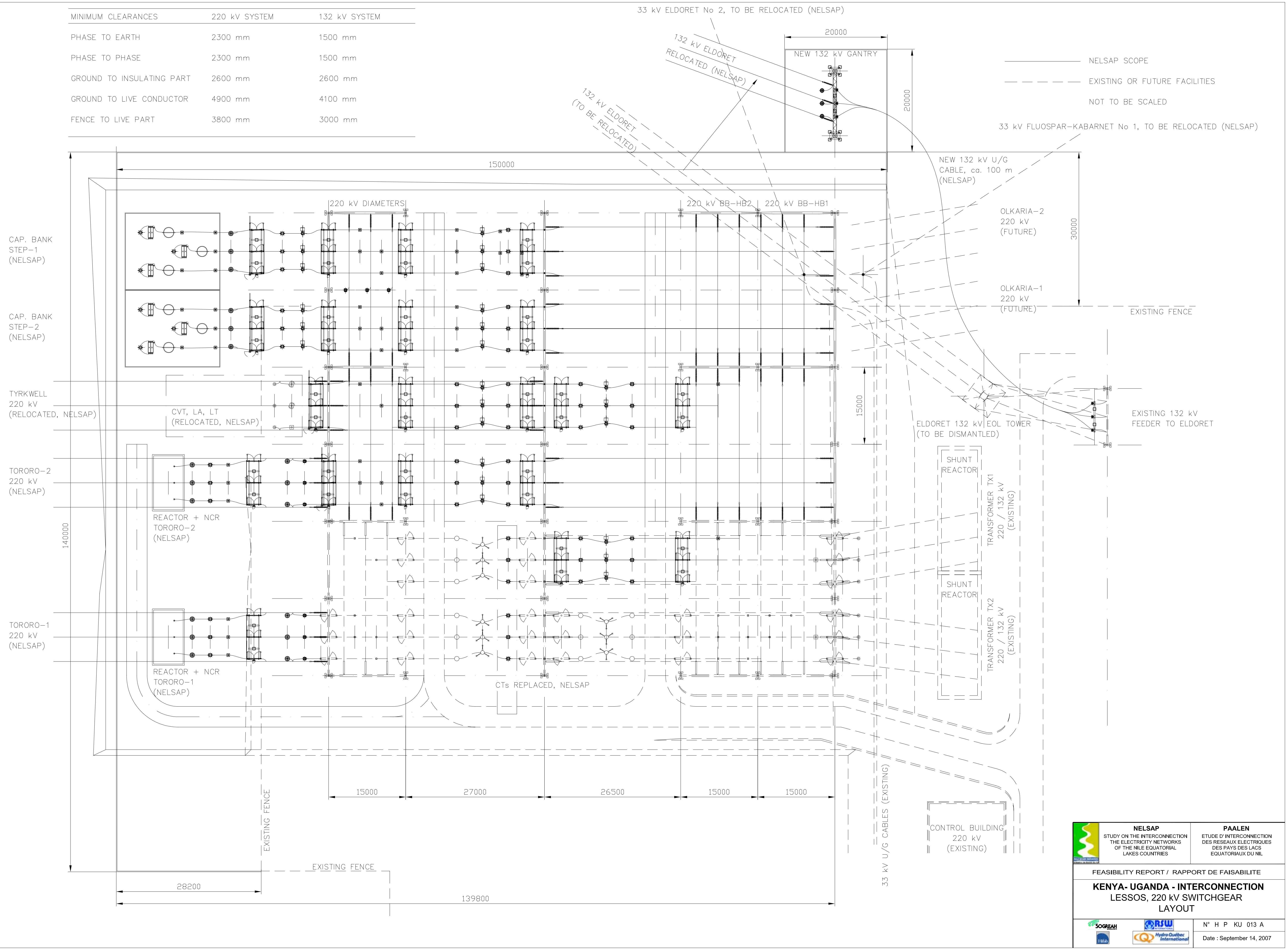
FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION
LESSOS, 220 kV SWITCHGEAR EXTENSION
SINGLE LINE DIAGRAM

N° H P KU 003 B

Date : September 14, 2007

MINIMUM CLEARANCES	220 kV SYSTEM	132 kV SYSTEM
PHASE TO EARTH	2300 mm	1500 mm
PHASE TO PHASE	2300 mm	1500 mm
GROUND TO INSULATING PART	2600 mm	2600 mm
GROUND TO LIVE CONDUCTOR	4900 mm	4100 mm
FENCE TO LIVE PART	3800 mm	3000 mm



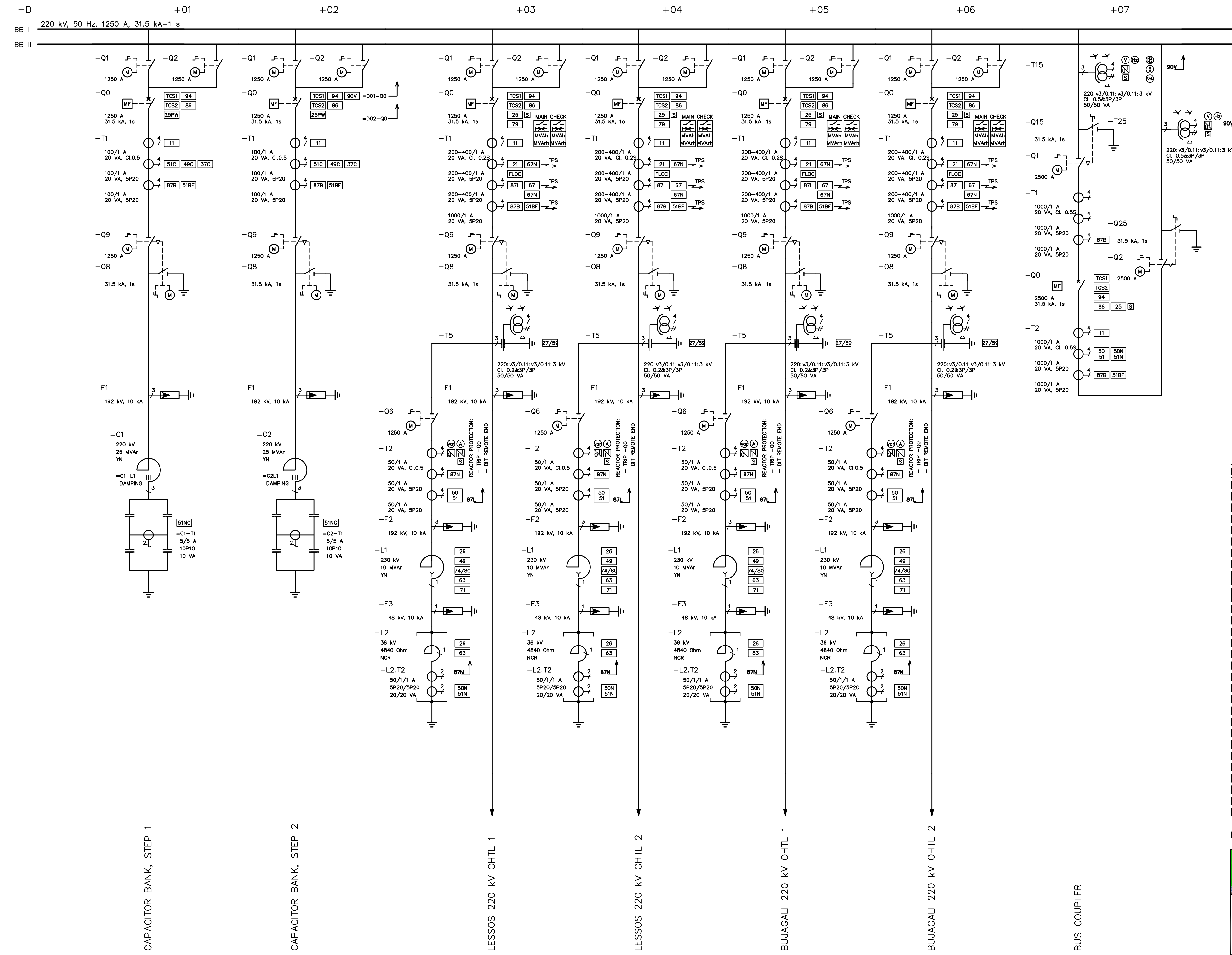
NELSAP	PAALEN
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES	ETUDE D'INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION
LESSOS, 220 kV SWITCHGEAR
LAYOUT

N° H P KU 013 A

Date : September 14, 2007



LEGEND:

11	BAY CONTROL UNIT (BCU)
21	DISTANCE PROTECTION
25	SYNCHRO CHECK RELAY
26	REACTOR OIL TEMPERATURE DEVICE (ALARM/TRIP)
27/59	UNDER/OVER VOLTAGE RELAY
37C	UNDER CURRENT RELAY–CLOSE INHIBIT (CAPACITOR BANK)
49	REACTOR WINDING TEMPERATURE DEVICE (ALARM/TRIP)
49C	OVER LOAD RELAY (CAPACITOR BANK)
50 51	PHASE INSTANTANEOUS OVERCURRENT/INVERSE TIME CHARACTERISTICS OVERCURRENT PROTECTION
50N 51N	NEUTRAL INSTANTANEOUS OVERCURRENT/INVERSE TIME CHARACTERISTICS NEUTRAL OVERCURRENT PROTECTION
51BF	CIRCUIT BREAKER FAILURE PROTECTION
51C	INVERSE TIME CHARACTERISTICS O/C PROTECTION (CAPACITOR BANK)
51NC	UN–BALANCE PROTECTION (CAPACITOR BANK)
59	OVER VOLTAGE RELAY
63	REACTOR PRESSURE RELIEF DEVICE (TRIP)
67	DIRECTIONAL OVER CURRENT PROTECTION
67N	DIRECTIONAL EARTH FAULT PROTECTION
71	RECTOR OIL LEVEL GAUGE (ALARM)
74/80	RECTOR BUCHHOLZ DEVICE (ALARM/TRIP)
79	1/3 PHASE MULTI–SHOT AUTO–RECLOSING RELAY
86	LOCK–OUT (BLOCK CLOSE) RELAY
87B	2–ZONE BUSBAR PROTECTION
87N	RESTRICTED EARTH FAULT PROTECTION (REF)
87L	LINE DIFFERENTIAL PROTECTION
90V	VOLTAGE REGULATION RELAY (CAPACITOR BANK)
94	TRIP RELAYS
FLOC	FAULT LOCATOR
TCS1	TRIP CIRCUIT 1 SUPERVISION
TCS2	TRIP CIRCUIT 2 SUPERVISION
TPS	TELEPROTECTION SCHEME INTERFACE
S	SELECTOR SWITCH (A–or V–METER or SYNCHRO AUTO/MAN)

NELSAP
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES

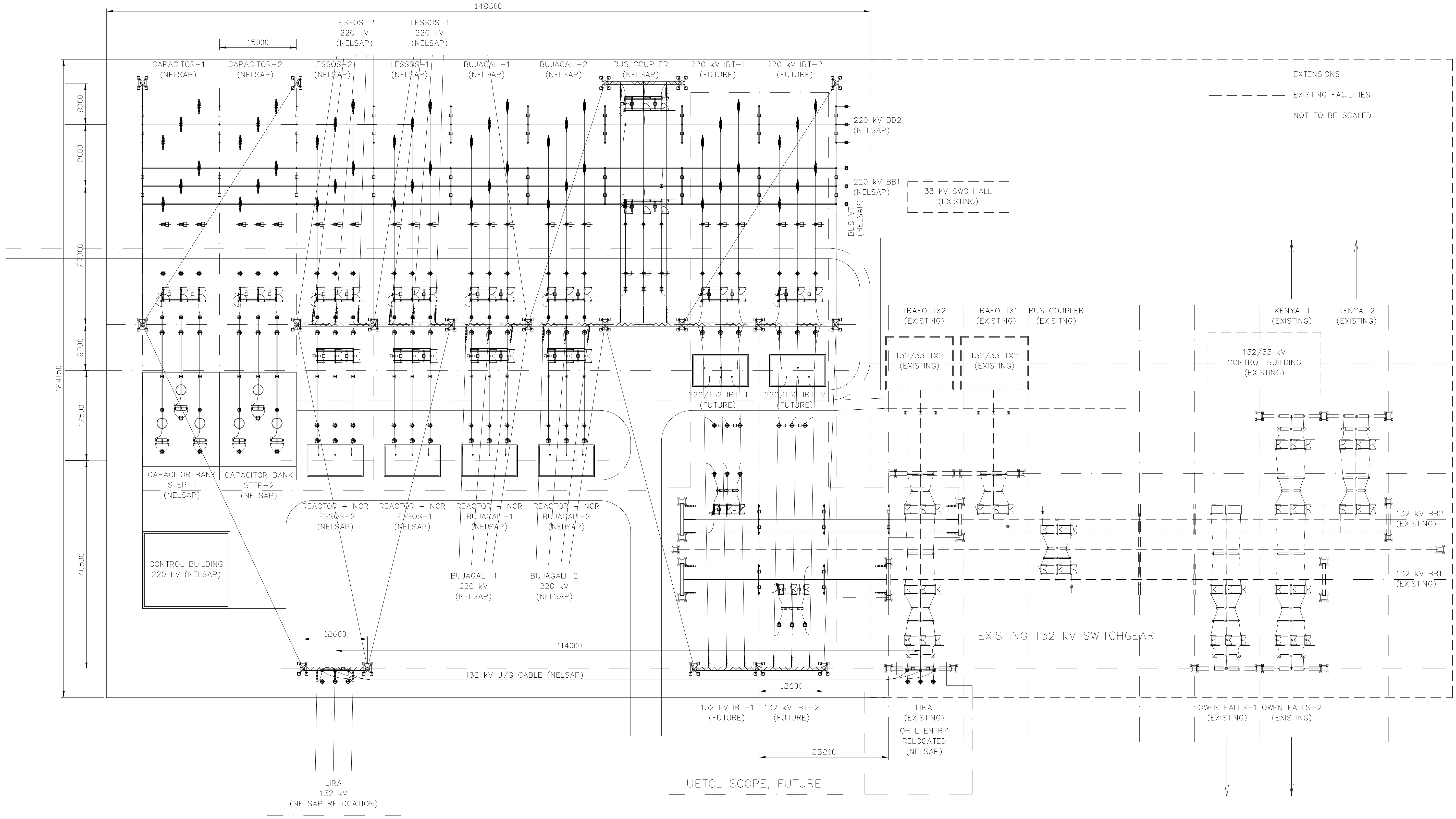
PAALEN
ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION
TORORO, NEW 220 kV SWITCHGEAR
SINGLE LINE DIAGRAM

N° H P KU 002 B

Date : September 14, 2007



MINIMUM CLEARANCES	220 kV SYSTEM	132 kV SYSTEM
PHASE TO EARTH	2100 mm	1500 mm
PHASE TO PHASE	2100 mm	1500 mm
GROUND TO INSULATING PART	2600 mm	2600 mm
GROUND TO LIVE CONDUCTOR	4700 mm	4100 mm
FENCE TO LIVE PART	3600 mm	3000 mm

NELSAP
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES

PAALEN
ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

FEASIBILITY REPORT / RAPPORT DE FAISABILITE

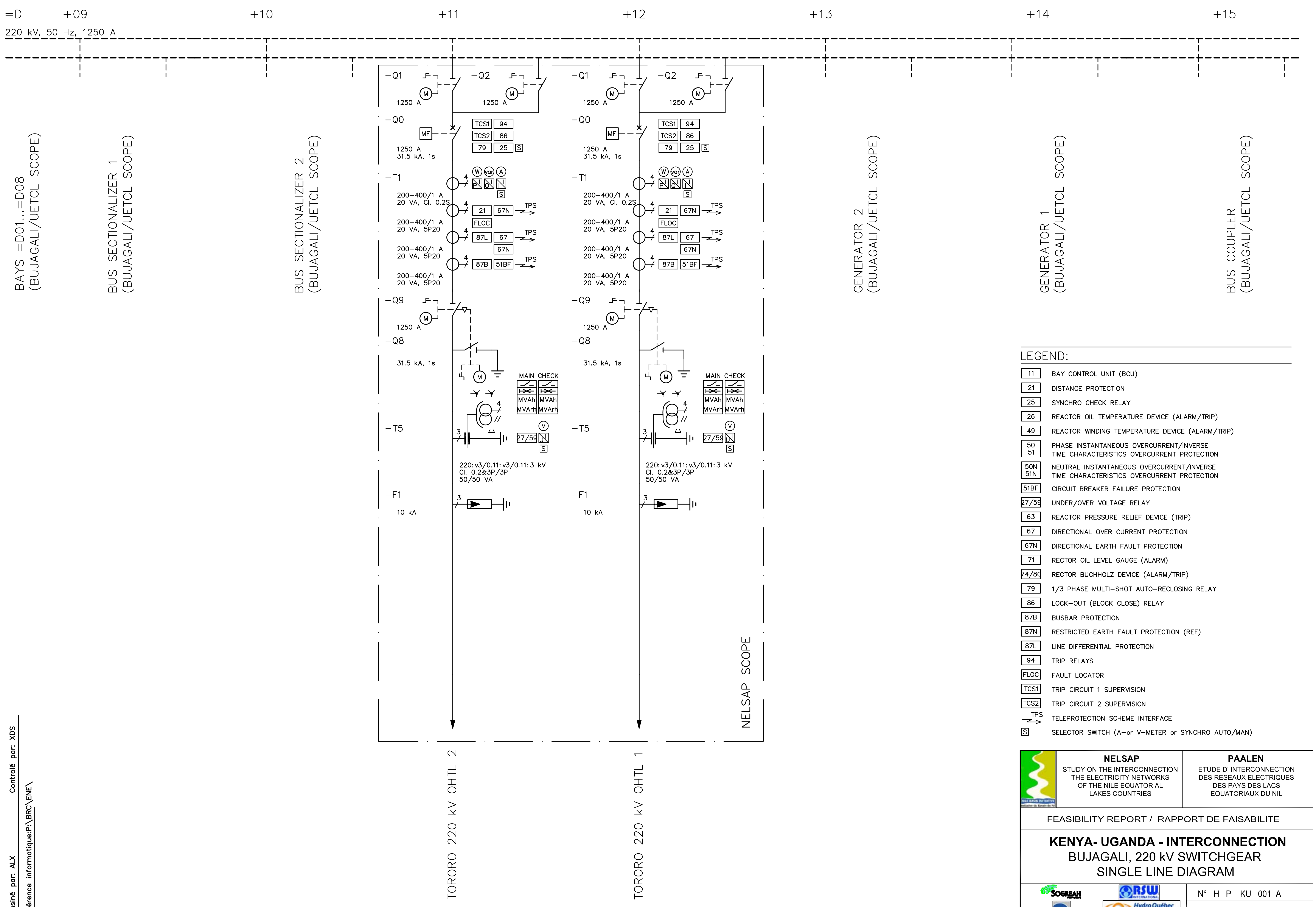
KENYA- UGANDA - INTERCONNECTION
TORORO, NEW 220 kV SWITCHGEAR LAYOUT

SOGREAH | RSW INTERNATIONAL | Hifab | Hydro Québec International

N° H P KU 012 A

Date : September 14, 2007

Dessiné par: ALX
Contrôlé par: XDS
Référence informatique:P:\BRC\ENE\



LEGEND:

11	BAY CONTROL UNIT (BCU)
21	DISTANCE PROTECTION
25	SYNCHRO CHECK RELAY
26	REACTOR OIL TEMPERATURE DEVICE (ALARM/TRIP)
49	REACTOR WINDING TEMPERATURE DEVICE (ALARM/TRIP)
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67N	DIRECTIONAL EARTH FAULT PROTECTION
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74/80	RECTOR BUCHHOLZ DEVICE (ALARM/TRIP)
79	1/3 PHASE MULTI-SHOT AUTO-RECLOSING RELAY
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87B	BUSBAR PROTECTION
87N	RESTRICTED EARTH FAULT PROTECTION (REF)
87L	LINE DIFFERENTIAL PROTECTION
94	TRIP RELAYS
FLOC	FAULT LOCATOR
TCS1	TRIP CIRCUIT 1 SUPERVISION
TCS2	TRIP CIRCUIT 2 SUPERVISION
TPS	TELEPROTECTION SCHEME INTERFACE
S	SELECTOR SWITCH (A-or V-METER or SYNCHRO AUTO/MAN)

NELSAP	PAALEN
STUDY ON THE INTERCONNECTION THE ELECTRICITY NETWORKS OF THE NILE EQUATORIAL LAKES COUNTRIES	ETUDE D' INTERCONNECTION DES RESEAUX ELECTRIQUES DES PAYS DES LACS EQUATORIAUX DU NIL

FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION

BUJAGALI, 220 kV SWITCHGEAR

SINGLE LINE DIAGRAM

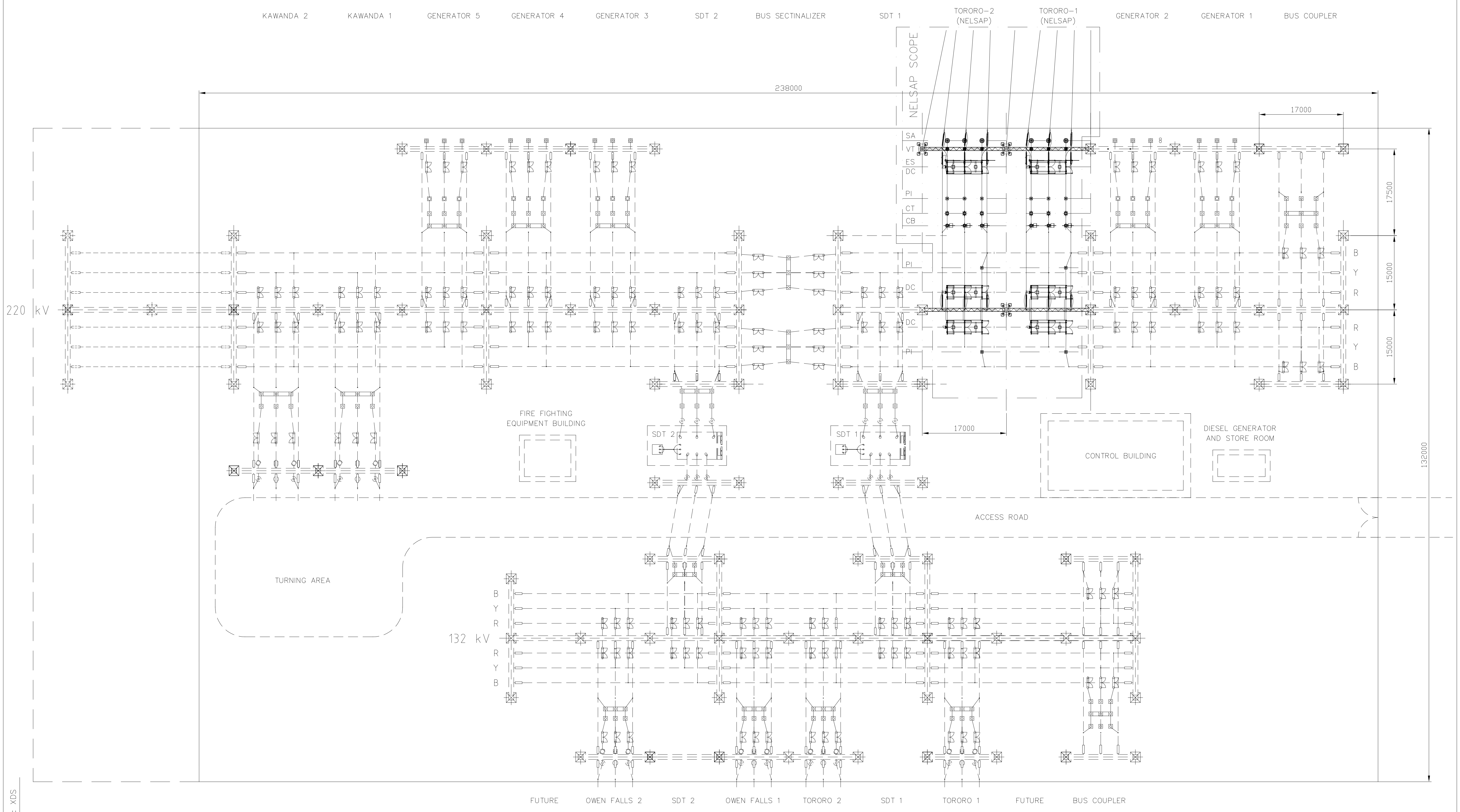
N° H P KU 001 A

Date : June 04, 2007

Dessiné par: ALX

Contrôlé par: XDS

Référence informatique:P:\BRC\ENE\



MINIMUM CLEARANCES	220 kV SYSTEM	132 kV SYSTEM
PHASE TO EARTH	2100 mm	1500 mm
PHASE TO PHASE	2100 mm	1500 mm
GROUND TO INSULATING PART	2600 mm	2600 mm
GROUND TO LIVE CONDUCTOR	4700 mm	4100 mm
FENCE TO LIVE PART	3600 mm	3000 mm

EXTENSIONS, NELSAP

EXISTING OR FUTURE FACILITIES

NOT TO BE SCALED

Dessiné par: ALX

Contrôlé par: XDS

Référence informatique:P:\BRC\ENE\

NELSAP
STUDY ON THE INTERCONNECTION
THE ELECTRICITY NETWORKS
OF THE NILE EQUATORIAL
LAKES COUNTRIES

PAALEN
ETUDE D' INTERCONNECTION
DES RESEAUX ELECTRIQUES
DES PAYS DES LACS
EQUATORIAUX DU NIL

FEASIBILITY REPORT / RAPPORT DE FAISABILITE

KENYA- UGANDA - INTERCONNECTION
BUJAGALI, 220/132 kV SUBSTATION
LAYOUT

SOGREAH RSW Hifab Hydro Québec International

N° H P KU 011 A

Date : September 14, 2007

ANNEX E – SUBSTATIONS COST ESTIMATE

- Lessos Substation extension cost estimate
- Tororo Substation extension cost estimate
- Bujagali Substation extension cost estimate

20070914KLA

Uganda-Kenya Interconnection
Cost estimate
Bujagali power station, 220 kV switchgear extension

Item	Unit	Qty	Unit Price USD	Total Price USD
220 kV circuit breakers	pcs	2	117 900	235 800
220 kV disconnectors	pcs	4	25 800	103 200
220 kV disconnectors with earthing switch	pcs	2	38 300	76 600
220 kV current transformers	pcs	6	19 900	119 400
220 kV voltage transformers	pcs	6	14 000	84 000
220 kV surge arresters	pcs	6	5 900	35 400
220 kV post insulators	pcs	6	2 200	13 200
220 kV busbars with clamps	lot	2	4 400	8 800
Insulator strings	lot	24	1 600	38 400
Stranded conductors and clamps	lot	2	8 100	16 200
Subtotal for 220 kV equipment				**731 000**
220 kV control system	lot	1	80 400	80 400
Alarm units	lot	2	5 900	11 800
Relay protection of 220 kV lines	pcs	2	81 100	162 200
MWh/Mvarh metering	lot	2	32 400	64 800
Marshalling cubicles for outdoor bays	pcs	2	3 200	6 400
Connection boxes for VT	pcs	2	1 600	3 200
Control cables	lot	2	32 400	64 800
Earthing	lot	2	8 800	17 600
Share of auxiliary systems	lot	1	73 700	73 700
Subtotal control, protection, earthing				**484 900**
SCADA & Tele (incl' NCC works)	lot	1	48 200	**48 200**
Subtotal SCADA & Tele				**48 200**
Steel constructions	lot	2	59 000	118 000
Foundations	lot	2	59 000	118 000
Cable ducts	lot	2	16 200	32 400
Earth works	lot	1	73 700	73 700
Subtotal civil works				**342 100**
Subtotal for materials				**1 606 200**
Installation works	lot	1	339 000	**339 000**
Spare parts	lot	1	73 700	**73 700**
Contingency	%	10		**201 890**
Total for substation				**2 220 790**

Scope: Drawing H P KU 001A/ June 2007
- two 220 kV line bays, double busbar system

20070914KLA

Uganda-Kenya Interconnection
Cost estimate
Tororo new 220 kV substation

Item	Unit	Qty	Unit Price USD	Total Price USD
230 kV, 10 MVAr shunt reactor	pcs	4	1 154 000	4 616 000
36 kV, 4840 Ohm NCR	pcs	4	196 000	784 000
Subtotal for shunt reactors				**5 400 000**
220 kV, 25 MVAr capacitor bank	pcs	2	600 750	1 201 500
Subtotal for capacitor banks				**1 201 500**
220 kV circuit breakers	pcs	7	117 900	825 300
220 kV disconnectors	pcs	16	25 800	412 800
220 kV disconnectors with earthing switch	pcs	8	38 300	306 400
220 kV current transformers	pcs	36	19 900	716 400
220 kV voltage transformers	pcs	18	14 000	252 000
220 kV surge arresters	pcs	24	5 900	141 600
36 kV surge arresters	pcs	4	2 700	10 800
220 kV post insulators	pcs	70	2200	154 000
220 kV busbars with clamps	lot	9	4 400	39 600
Insulator strings	lot	24	1 600	38 400
Stranded conductors and clamps	lot	7	8 100	56 700
Subtotal for 220 kV equipment				**2 954 000**
132 kV cable (Lira line)	lot	1	113 900	113 900
132 kV arresters	pcs	6	4 000	24 000
Subtotal for 132 kV equipment				**137 900**
220 kV control system	lot	1	262 640	262 640
Alarm units	lot	7	5 900	41 300
Relay protection of 220 kV lines	pcs	4	81 100	324 400
Relay protection of 230 kV shunt reactor	lot	4	25 100	100 400
Relay protection of 220 kV capacitors	lot	2	21 600	43 200
Busbar protection	lot	1	103 180	103 180
MWh/Mvarh metering	lot	4	32 400	129 600
Marshalling cubicles for outdoor bays	pcs	7	3 200	22 400
Connection boxes for VT	pcs	6	1 600	9 600
Control cables	lot	7	32 400	226 800
Earthing	lot	7	8 800	61 600
Auxiliary DC systems (2+2)	lot	1	176 880	176 880
Subtotal control, protection, earthing				**1 502 000**
SCADA & Tele (incl' NCC works)	lot	1	116 240	116 240
Subtotal SCADA & Tele				**116 240**
Control building	lot	1	201 000	201 000
Steel constructions	lot	5	59 000	295 000
Foundations	lot	7	59 000	413 000
Cable ducts	lot	9	16 200	145 800
Shunt reactor foundations and oil pits	pcs	4	32 400	129 600
Capacitor bank foundations with fence	pcs	2	24 500	49 000
Earth works	lot	1	147 400	147 400
Fence	lot	1	51 660	51 660
Subtotal civil works				**1 432 460**
Subtotal for materials				**12 744 100**
Installation works	lot	1	1 460 000	**1 460 000**
Spare parts	lot	1	324 800	**324 800**
Contingency	%	10		**1 452 900**
Total for substation				**15 981 800**

Scope: Drawing H P KU 002B/September 2007
- four 220 kV line bays, double busbar
- two 220 kV capacitor feeders, double busbar
- 220 kV bus coupler
- four 220 kV shunt reactor branches on line side without breakers
- four 10 Mvar, 230 kV shunt reactors with NCRs
- two 25 Mvar 220 kV capacitor banks, solidly earthed neutral

20070914KLA

Uganda-Kenya Interconnection
Cost estimate
Lessos 220 kV substation extension

Item	Unit	Qty	Unit Price USD	Total Price USD
230 kV, 10 MVAr shunt reactor	pcs	2	1 154 000	2 308 000
36 kV, 4840 Ohm NCR	pcs	2	196 000	392 000
Subtotal for shunt reactors				**2 700 000**
220 kV, 25 MVAr capacitor bank	pcs	2	600 750	1 201 500
Subtotal for capacitor banks				**1 201 500**
220 kV circuit breakers	pcs	8	117 900	943 200
220 kV disconnectors	pcs	16	25 800	412 800
220 kV disconnectors with earthing switch	pcs	4	38 300	153 200
220 kV current transformers	pcs	48	19 900	955 200
220 kV voltage transformers	pcs	9	14 000	126 000
220 kV surge arresters	pcs	18	5 900	106 200
36 kV surge arresters	pcs	2	2 700	5 400
220 kV post insulators	pcs	47	2 200	103 400
220 kV busbars with clamps	lot	4	4 400	17 600
Insulator strings	pcs	57	1 600	91 200
Stranded conductors and clamps	lot	5	8 100	40 500
Subtotal for 220 kV equipment				**2 954 700**
132 kV cable (Eldoret line)	lot	1	99 000	99 000
132 kV arresters	pcs	6	4 000	24 000
Subtotal for 132 kV equipment				**123 000**
New 220 kV control board	lot	1	206 360	206 360
Alarm units	lot	11	5 900	64 900
Relay protection of 220 kV lines	pcs	2	81 100	162 200
Relay protection of 230 kV shunt reactor	lot	2	25 100	50 200
Relay protection of 220 kV capacitors	lot	2	21 600	43 200
Busbar protection	lot	1	93 800	93 800
MWh/Mvarh metering	lot	3	32 400	97 200
Marshalling cubicles for outdoor bays	pcs	10	3 200	32 000
Connection boxes for VT	pcs	3	1 600	4 800
Control cables	lot	5	32 400	162 000
Modifications of secondary circuits	lot	2	29 500	59 000
Earthing	lot	7	8 800	61 600
Subtotal control, protection, earthing				**1 037 260**
SCADA & Tele (incl' NCC works)	lot	1	154 700	154 700
Subtotal SCADA & Tele				**154 700**
Steel constructions	lot	6	44 200	265 200
Foundations	lot	8	29 500	236 000
Cable ducts	lot	6	16 200	97 200
Shunt reactor foundations and oil pits	pcs	2	32 400	64 800
Capacitor bank foundations with fence	pcs	2	24 500	49 000
Earth works	lot	1	92 500	92 500
Fence	lot	1	48 240	48 240
Subtotal for civil works				**852 940**
Subtotal for material				**9 024 100**
Installation works	lot	1	1 132 000	**1 132 000**
Spare parts	lot	1	177 400	**177 400**
Contingency	%	10		**1 033 400**
Total for substation				**11 366 900**

Scope: Drawing H P KU 003B/ Septemner 2007
- two 220 kV line bays, 4/3 breaker busbar system
- two 220 kV shunt reactor branches on line side without breakers
- two 10 Mvar, 230 kV shunt reactors with NCRs
- two 25 Mvar 220 kV capacitor banks, solidly earthed neutral
- shift of Turkwel line bay

ANNEX F – ECONOMIC STUDIES

RWANDA-UGANDA and UGANDA-KENYA INTERCONNECTIONS

ALTERNATIVE 1 - RESUME

Discount Rate	10%
Fuel Cost Coefficient	1

Alternative 1 Cost-Benefit Analysis

Reserve Cost (MUS$/MW)	**1**		
ADDITIONAL CAPACITY (MW)		**Reserve Benefit (MUS$)**	
Medium Demand Scenario			
Rwanda - Uganda	44	22	41%
Uganda - Kenya	63	32	59%
Low Demand Scenario			
Rwanda - Uganda	46	23	42%
Uganda - Kenya	63	32	58%
High Demand Scenario			
Rwanda - Uganda	54	27	47%
Uganda - Kenya	60	30	53%

	2010	**2013**
INVESTMENT COST (MUS$)		
Rwanda-Uganda Lines	29,8	0
Rwanda Substations	4,2	1,6
Uganda Substations	3,6	8,4
	37,6	**10,0**
Uganda-Kenya Lines		59,1
Kenya Substations		9,7
Uganda Substations		13,8
		82,6
O&M COSTS (MUS$)		
Rwanda - Uganda	**3,9**	
Uganda-Kenya		**5,2**

TOTAL COSTS (MUS$)	
	TOTAL
Rwanda-Uganda	42
Uganda-Kenya	67
TOTAL	109

LOSSES	0,04	**US$/kWh**
	MUS$	
Medium Demand Scenario		
Rwanda - Uganda	2,2	
Uganda-Kenya	6,8	
Low Demand Scenario		
Rwanda - Uganda	1,0	
Uganda - Kenya	7,1	
High Demand Scenario		
Rwanda - Uganda	4,3	
Uganda - Kenya	6,8	

BENEFITS (MUS$)	**TOTAL**	**Rwanda - Uganda**	**Uganda - Kenya**
Medium Demand Scenario	293	122	171
Low Demand	241	104	137
High Demand	446	211	234

B-C or NPV (MUS$)		**Rwanda - Uganda**	**Uganda - Kenya**
Medium Demand Scenario	184	80	103
Low Demand	132	62	70
High Demand	337	170	167

REFERENCE SOLUTION (WITHOUT PROJECT): RWANDA-BURUNDI-DR CONGO SYSTEM GENERATION

ALTERNATIVE 1

SCENARIO: **MEDIUM**

R/B/C Group FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources		Complementary Thermal		Kibuye		Nyemanga		Ruzizi 3		Mule 34		Kabu 16		Bendera		Rusumo		Nyabarongp + Mpanda	
				GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW
2 010	911	186	205	745	148	133	44			4	1,7											29	11
2 011	976	199	219	745	148	198	58			4	1,7											29	11
2 012	1046	213	289	705	148	0	58	0	0	4	1,7							160	43			177	38
2 013	1121	228	309	663	148	0	58	0	0	4	1,7					117	20	160	43			177	38
2 014	1201	244	309	743	148	0	58	0	0	4	1,7					117	20	160	43			177	38
2 015	1288	261	326	683	148	0	58	0	0	4	1,7			147	17	117	20	160	43			177	38
2 016	1386	281	326	745	148	36	58	0	0	4	1,7			147	17	117	20	160	43			177	38
2 017	1485	301	367	611	148	0	58	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 018	1602	325	367	728	148	0	58	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 019	1720	349	384	745	148	101	76	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 020	1837	373	466	507	148	0	76	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 021	1979	402	466	649	148	0	76	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 022	2120	430	473	745	148	45	83	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 023	2289	464	511	745	148	214	120	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 024	2459	498	548	745	148	384	157	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 025	2628	532	586	745	148	553	195	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 026	2832	573	630	745	148	757	240	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 027	3036	614	675	745	148	961	285	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 028	3281	663	729	745	148	1206	339	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 029	3525	712	783	745	148	1450	393	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 030	3769	761	837	745	148	1695	447	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38

SCENARIO: **LOW**

2 010	847	172	189	745	148	89	28			2	1,7											11	11
2 011	895	181	199	745	148	117	39			4	1,7											29	11
2 012	946	191	269	674	148	0	39			4	1,7							160	43			108	38
2 013	1000	202	269	674	148	0	39			4	1,7							160	43			162	38
2 014	1057	213	269	716	148	0	39	0	0	4	1,7							160	43			177	38
2 015	1117	225	269	745	148	31	39	0	0	4	1,7							160	43			177	38
2 016	1184	237	289	726	148	0	39	0	0	4	1,7					117	20	160	43			177	38
2 017	1251	249	289	745	148	48	39	0	0	4	1,7					117	20	160	43			177	38
2 018	1329	263	306	724	148	0	39	0	0	4	1,7			147	17	117	20	160	43			177	38
2 019	1406	276	306	745	148	56	39	0	0	4	1,7			147	17	117	20	160	43			177	38
2 020	1484	290	347	610	148	0	39	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 021	1582	308	347	708	148	0	39	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 022	1680	327	360	745	148	61	51	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 023	1794	349	384	745	148	175	75	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 024	1908	371	466	578	148	0	75	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 025	2023	392	466	693	148	0	75	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 026	2157	418	466	745	148	82	75	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 027	2292	444	488	745	148	217	97	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 028	2449	473	521	745	148	374	130	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 029	2606	503	554	745	148	531	163	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 030	2764	533	587	745	148	689	196	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38

SCENARIO: **HIGH**

2 010	993	204	224	745	148	215	63			4	1,7											29	11
2 011	1082	222	245	745	148	304	84			4	1,7											29	11
2 012	1180	243	315	745	148	94	84	0	0	4	1,7							160	43			177	38
2 013	1287	265	335	745	148	84	84	0	0	4	1,7					117	20	160	43			177	38
2 014	1404	289	376	677	148	0	84	0	0	4	1,7					117	20	160	43	269	41	177	38
2 015	1532	316	376	745	148	60	84	0	0	4	1,7					117	20	160	43	269	41	177	38
2 016	1682	345	393	745	148	63	84	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 017	1831	375	475	501	148	0	84	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 018	2018	412	475	688	148	0	84	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 019	2206	449	494	745	148	131	104	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 020	2393	487	535	745	148	318	144	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 021	2605	529	582	745	148	530	191	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 022	2817	572	629	745	148	742	238	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 023	3077	624	687	745	148	1002	296	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 024	3337	677	744	745	148	1262	354	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 025	3597	729	802	745	148	1522	411	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 026	3917	793	873	745	148	1842	482	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 027	4237	858	943	745	148	2162	553	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 028	4631	937	1030	745	148	2556	640	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 029	5024	1016	1117	745	148	2949	727	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 030	5418	1095	1204	745	148	3343	814	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38

REFERENCE SOLUTION (WITHOUT PROJECT): UGANDA SYSTEM GENERATION

ALTERNATIVE 1

SCENARIO: **MEDIUM**

Uganda FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Bagasse GWh	MW	Karuma GWh	MW	Mini-Hydro GWh	MW	Kalagala GWh	MW	Murchison GWh	MW	Ayago GWh	MW	Export Kenya 50 MW GWh	MW
2 010	2874	500	629	2980	587	0	0	294	42											-400	-50
2 011	3081	535	639	3038	587	0	10	294	42											-251	-50
2 012	3303	573	713	3038	587	0	10	294	42			371	74							-400	-50
2 013	3541	612	723	3038	587	0	20	294	42			530	74							-321	-50
2 014	3796	655	923	3038	587	0	20	132	42	786	200	240	74							-400	-50
2 015	4069	701	923	3038	587	0	20	165	42	970	200	296	74							-400	-50
2 016	4373	752	923	3038	587	0	20	197	42	1183	200	355	74							-400	-50
2 017	4676	802	932	3038	587	0	29	232	42	1387	200	419	74							-400	-50
2 018	5038	862	998	3038	587	0	95	274	42	1625	200	501	74							-400	-50
2 019	5399	922	1448	3038	587	0	95	159	42	953	200	286	74	1363	450					-400	-50
2 020	5761	982	1448	3038	587	0	95	179	42	1081	200	323	74	1540	450					-400	-50
2 021	6117	1043	1448	3038	587	0	95	200	42	1202	200	360	74	1717	450					-400	-50
2 022	6473	1103	1448	3038	587	0	95	221	42	1322	200	398	74	1894	450					-400	-50
2 023	6885	1174	1448	3038	587	0	95	244	42	1467	200	440	74	2096	450					-400	-50
2 024	7298	1244	1448	3038	587	0	95	268	42	1612	200	482	74	2298	450					-400	-50
2 025	7710	1314	1670	3038	587	0	95	218	42	1293	200	392	74	1869	450	1300	222			-400	-50
2 026	8186	1395	1670	3038	587	0	95	238	42	1400	200	429	74	2045	450	1436	222			-400	-50
2 027	8663	1477	1674	3038	587	0	99	259	42	1518	200	466	74	2222	450	1560	222			-400	-50
2 028	9214	1571	1872	3038	587	0	99	282	42	1677	200	509	74	2424	450	1684	420			-400	-50
2 029	9766	1665	1881	3038	587	0	108	294	42	1747	200	530	74	2525	450	2032	420			-400	-50
2 030	10317	1759	1985	3038	587	0	212	294	42	1747	200	530	74	2525	450	2583	420			-400	-50

SCENARIO: **LOW**

Uganda FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Bagasse GWh	MW	Karuma GWh	MW	Mini-Hydro GWh	MW	Kalagala GWh	MW	Murchison GWh	MW	Ayago GWh	MW	Export Kenya 50 MW GWh	MW
2 010	2435	420	629	2645	587	0	0	190	42											-400	-50
2 011	2540	436	629	2740	587	0	0	200	42											-400	-50
2 012	2648	453	629	2838	587	0	0	210	42											-400	-50
2 013	2762	470	629	2942	587	0	0	220	42											-400	-50
2 014	2880	489	629	3038	587	0	0	242	42											-400	-50
2 015	3003	508	703	2700	587	0	0	260	42			443	74							-400	-50
2 016	3134	528	703	2800	587	0	0	270	42			464	74							-400	-50
2 017	3266	548	703	2900	587	0	0	280	42			486	74							-400	-50
2 018	3411	570	703	3000	587	0	0	290	42			521	74							-400	-50
2 019	3557	592	903	3038	587	0	0	106	42	622	200	191	74							-400	-50
2 020	3703	614	903	3038	587	0	0	121	42	727	200	217	74							-400	-50
2 021	3854	639	903	3038	587	0	0	138	42	829	200	249	74							-400	-50
2 022	4005	664	903	3038	587	0	0	156	42	930	200	281	74							-400	-50
2 023	4172	692	903	3038	587	0	0	176	42	1040	200	318	74							-400	-50
2 024	4338	719	903	3038	587	0	0	194	42	1156	200	350	74							-400	-50
2 025	4505	747	903	3038	587	0	0	215	42	1265	200	387	74							-400	-50
2 026	4689	778	905	3038	587	0	2	235	42	1392	200	424	74							-400	-50
2 027	4873	808	939	3038	587	0	36	256	42	1518	200	461	74							-400	-50
2 028	5075	842	976	3038	587	0	73	279	42	1654	200	504	74							-400	-50
2 029	5278	875	1013	3038	587	0	110	294	42	1747	200	530	74							-331	-50
2 030	5481	909	1050	3038	587	0	147	294	42	1747	200	530	74							-128	-50

SCENARIO: **HIGH**

Uganda FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Bagasse GWh	MW	Karuma GWh	MW	Mini-Hydro GWh	MW	Kalagala GWh	MW	Murchison GWh	MW	Ayago GWh	MW	Export Kenya 50 MW GWh	MW
2 010	3164	547	652	3038	587	0	23	294	42											-168	-50
2 011	3447	594	703	3038	587	115	74	294	42											0	-50
2 012	3755	644	777	3038	587	0	74	294	42			530	74							-107	-50
2 013	4090	699	819	3038	587	228	116	294	42			530	74							0	-50
2 014	4455	759	1019	3038	587	0	116	209	42	1232	200	376	74							-400	-50
2 015	4853	824	1019	3038	587	0	116	253	42	1506	200	456	74							-400	-50
2 016	5306	898	1469	3038	587	0	116	153	42	908	200	281	74	1326	450					-400	-50
2 017	5758	971	1469	3038	587	0	116	179	42	1078	200	323	74	1540	450					-400	-50
2 018	6320	1062	1469	3038	587	0	116	212	42	1270	200	382	74	1818	450					-400	-50
2 019	6881	1152	1469	3038	587	0	116	244	42	1463	200	440	74	2096	450					-400	-50
2 020	7443	1243	1469	3038	587	0	116	276	42	1658	200	498	74	2373	450					-400	-50
2 021	8062	1346	1691	3038	587	0	116	232	42	1377	200	419	74	1995	450	1401	222			-400	-50
2 022	8681	1450	1691	3038	587	0	116	259	42	1536	200	466	74	2222	450	1560	222			-400	-50
2 023	9433	1575	1889	3038	587	0	116	294	42	1747	200	530	74	2525	450	1699	420			-400	-50
2 024	10184	1701	1921	3038	587	0	148	294	42	1747	200	530	74	2525	450	2450	420			-400	-50
2 025	10936	1826	2155	3038	587	0	148	226	42	1345	200	408	74	1944	450	2796	420	1579	234	-400	-50
2 026	11846	1978	2226	3038	587	0	219	250	42	1485	200	451	74	2146	450	3133	420	1743	234	-400	-50
2 027	12755	2130	2530	3038	587	0	219	221	42	1310	200	398	74	1894	450	2759	420	3535	538	-400	-50
2 028	13859	2315	2596	3038	587	0	285	245	42	1457	200	442	74	2106	450	3068	420	3903	538	-400	-50
2 029	14963	2499	2799	3038	587	0	488	269	42	1600	200	485	74	2313	450	3370	420	4288	538	-400	-50
2 030	16067	2684	3002	3038	587	0	691	294	42	1747	200	530	74	2525	450	3679	420	4654	538	-400	-50

REFERENCE SOLUTION (WITHOUT PROJECT): KENYA SYSTEM GENERATION

ALTERNATIVE 1

SCENARIO: **MEDIUM**

KENYA LOAD FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources		Complementary Thermal		Coal		Import Uganda	
				GWh	MW	GWh	MW	GWh	MW	GWh	MW
2010	7838	1343	1478	5052	1039	65	89	2321	300	400	50
2011	8491	1456	1628	5052	1039	65	89	3123	450	251	50
2012	9183	1576	1778	5052	1039	65	89	3667	600	400	50
2013	9922	1703	1874	5052	1039	135	185	4415	600	321	50
2014	10711	1840	2174	5052	1039	135	185	5124	900	400	50
2015	11552	1985	2183	5052	1039	142	194	5958	900	400	50
2016	12470	2144	2483	5052	1039	142	194	6876	1200	400	50
2017	13387	2302	2532	5052	1039	178	243	7758	1200	400	50
2018	14492	2493	3132	5052	1039	178	243	8862	1800	400	50
2019	15596	2684	3132	5052	1039	178	243	9967	1800	400	50
2020	16701	2876	3163	5052	1039	200	274	11049	1800	400	50
2021	17987	3098	3763	5052	1039	200	274	12334	2400	400	50
2022	19272	3321	3763	5052	1039	200	274	13620	2400	400	50
2023	20812	3588	4363	5052	1039	200	274	15160	3000	400	50
2024	22351	3854	4363	5052	1039	200	274	16699	3000	400	50
2025	23891	4121	4533	5052	1039	324	444	18115	3000	400	50
2026	25699	4434	5133	5052	1039	324	444	19922	3600	400	50
2027	27506	4747	5222	5052	1039	389	533	21665	3600	400	50
2028	29664	5122	5822	5052	1039	389	533	23823	4200	400	50
2029	31822	5496	6422	5052	1039	389	533	25981	4800	400	50
2030	33980	5870	6457	5052	1039	414	568	28114	4800	400	50

SCENARIO: **LOW**

2010	7585	1299	1429	5052	1039	29	40	2104	300	400	50
2011	8153	1397	1579	5052	1039	29	40	2672	450	400	50
2012	8750	1500	1729	5052	1039	29	40	3269	600	400	50
2013	9381	1609	1770	5052	1039	59	81	3870	600	400	50
2014	10049	1724	2070	5052	1039	59	81	4538	900	400	50
2015	10756	1846	2070	5052	1039	59	81	5245	900	400	50
2016	11516	1977	2175	5052	1039	136	186	5928	900	400	50
2017	12276	2109	2475	5052	1039	136	186	6688	1200	400	50
2018	13173	2264	2491	5052	1039	147	202	7574	1200	400	50
2019	14070	2420	3091	5052	1039	147	202	8471	1800	400	50
2020	14967	2575	3091	5052	1039	147	202	9368	1800	400	50
2021	15988	2751	3091	5052	1039	147	202	10388	1800	400	50
2022	17008	2928	3221	5052	1039	242	332	11314	1800	400	50
2023	18207	3135	3821	5052	1039	242	332	12513	2400	400	50
2024	19405	3343	3821	5052	1039	242	332	13711	2400	400	50
2025	20604	3550	3905	5052	1039	304	416	14848	2400	400	50
2026	21998	3791	4505	5052	1039	304	416	16242	3000	400	50
2027	23392	4032	4505	5052	1039	304	416	17636	3000	400	50
2028	25026	4315	5105	5052	1039	304	416	19271	3600	400	50
2029	26661	4598	5105	5052	1039	304	416	20975	3600	331	50
2030	28296	4881	5705	5052	1039	304	416	22812	4200	128	50

SCENARIO: **HIGH**

2010	8165	1400	1540	5052	1039	545	151	2400	300	168	50
2011	8914	1530	1690	5052	1039	262	151	3600	450	0	50
2012	9715	1668	1840	5052	1039	110	151	4446	600	107	50
2013	10578	1817	2140	5052	1039	110	151	5416	900	0	50
2014	11506	1978	2176	5052	1039	136	187	5918	900	400	50
2015	12506	2151	2476	5052	1039	136	187	6918	1200	400	50
2016	13611	2342	2576	5052	1039	210	287	7950	1200	400	50
2017	14717	2533	3176	5052	1039	210	287	9055	1800	400	50
2018	16074	2768	3176	5052	1039	210	287	10412	1800	400	50
2019	17430	3003	3303	5052	1039	303	414	11676	1800	400	50
2020	18787	3238	3903	5052	1039	303	414	13032	2400	400	50
2021	20404	3518	3903	5052	1039	303	414	14649	2400	400	50
2022	22020	3798	4503	5052	1039	303	414	16266	3000	400	50
2023	23995	4140	4554	5052	1039	340	465	18203	3000	400	50
2024	25969	4483	5154	5052	1039	340	465	20177	3600	400	50
2025	27943	4825	5754	5052	1039	340	465	22151	4200	400	50
2026	30289	5232	5755	5052	1039	340	466	24497	4200	400	50
2027	32634	5638	6355	5052	1039	340	466	26842	4800	400	50
2028	35486	6133	6955	5052	1039	340	466	29694	5400	400	50
2029	38337	6627	7555	5052	1039	340	466	32545	6000	400	50
2030	41189	7122	7834	5052	1039	544	745	35193	6000	400	50

RWANDA-UGANDA and UGANDA-KENYA INTERCONNECTIONS

Discount Rate	10%
Fuel Cost Coefficient	1

Alternative 2 Cost-Benefit Analysis

Reserve Cost (MUS$/MW)	**1**		
ADDITIONAL CAPACITY (MW)		**Reserve Benefit (MUS$)**	
Medium Demand Scenario			
Rwanda - Uganda	65	33	29%
Uganda - Kenya	162	81	71%
Low Demand Scenario			
Rwanda - Uganda	60	30	26%
Uganda - Kenya	174	87	74%
High Demand Scenario			
Rwanda - Uganda	65	32	31%
Uganda - Kenya	143	71	69%

	2010	**2013**
INVESTMENT COST (MUS$)		
Rwanda-Uganda Lines	29,8	0
Rwanda Substations	4,2	1,6
Uganda Substations	3,6	8,4
	37,6	**10,0**
Uganda-Kenya Lines		59,1
Kenya Substations		9,7
Uganda Substations		13,8
		82,6
O&M COSTS (MUS$)		
Rwanda - Uganda	**3,9**	
Uganda-Kenya		**5,2**

TOTAL COSTS (MUS$)

	TOTAL
Rwanda-Uganda	42
Uganda-Kenya	67
TOTAL	109

LOSSES	0,04	**US$/kWh**
	MUS$	
Medium Demand Scenario		
Rwanda - Uganda	3,9	
Uganda-Kenya	21,6	
Low Demand Scenario		
Rwanda - Uganda	3,8	
Uganda - Kenya	22,7	
High Demand Scenario		
Rwanda - Uganda	5,0	
Uganda - Kenya	17,8	

BENEFITS (MUS$)	**TOTAL**	**Rwanda - Uganda**	**Uganda - Kenya**
Medium Demand Scenario	446	131	314
Low Demand	334	89	245
High Demand	554	175	379

B-C or NPV (MUS$)		**Rwanda - Uganda**	**Uganda - Kenya**
Medium Demand Scenario	337	90	247
Low Demand	225	47	178
High Demand	446	134	312

REFERENCE SOLUTION (WITHOUT PROJECT): RWANDA-BURUNDI-DR CONGO SYSTEM GENERATION

ALTERNATIVE 2

SCENARIO: **MEDIUM**

R/B/C Group FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources		Complementary Thermal		Kibuye		Nyemanga		Ruzizi 3		Mule 34		Kabu 16		Bendera		Rusumo		Nyabarongp + Mpanda	
				GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW
2 010	911	186	205	745	148	133	44			4	1,7											29	11
2 011	976	199	219	745	148	198	58			4	1,7											29	11
2 012	1046	213	289	705	148	0	58	0	0	4	1,7							160	43			177	38
2 013	1121	228	309	663	148	0	58	0	0	4	1,7					117	20	160	43			177	38
2 014	1201	244	309	743	148	0	58	0	0	4	1,7					117	20	160	43			177	38
2 015	1288	261	326	683	148	0	58	0	0	4	1,7			147	17	117	20	160	43			177	38
2 016	1386	281	326	745	148	36	58	0	0	4	1,7			147	17	117	20	160	43			177	38
2 017	1485	301	367	611	148	0	58	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 018	1602	325	367	728	148	0	58	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 019	1720	349	384	745	148	101	76	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 020	1837	373	466	507	148	0	76	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 021	1979	402	466	649	148	0	76	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 022	2120	430	473	745	148	45	83	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 023	2289	464	511	745	148	214	120	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 024	2459	498	548	745	148	384	157	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 025	2628	532	586	745	148	553	195	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 026	2832	573	630	745	148	757	240	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 027	3036	614	675	745	148	961	285	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 028	3281	663	729	745	148	1206	339	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 029	3525	712	783	745	148	1450	393	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 030	3769	761	837	745	148	1695	447	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38

SCENARIO: **LOW**

2 010	847	172	189	745	148	89	28			2	1,7											11	11
2 011	895	181	199	745	148	117	39			4	1,7											29	11
2 012	946	191	269	674	148	0	39			4	1,7							160	43			108	38
2 013	1000	202	269	674	148	0	39			4	1,7							160	43			162	38
2 014	1057	213	269	716	148	0	39	0	0	4	1,7							160	43			177	38
2 015	1117	225	269	745	148	31	39	0	0	4	1,7							160	43			177	38
2 016	1184	237	289	726	148	0	39	0	0	4	1,7					117	20	160	43			177	38
2 017	1251	249	289	745	148	48	39	0	0	4	1,7					117	20	160	43			177	38
2 018	1329	263	306	724	148	0	39	0	0	4	1,7			147	17	117	20	160	43			177	38
2 019	1406	276	306	745	148	56	39	0	0	4	1,7			147	17	117	20	160	43			177	38
2 020	1484	290	347	610	148	0	39	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 021	1582	308	347	708	148	0	39	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 022	1680	327	360	745	148	61	51	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 023	1794	349	384	745	148	175	75	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 024	1908	371	466	578	148	0	75	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 025	2023	392	466	693	148	0	75	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 026	2157	418	466	745	148	82	75	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 027	2292	444	488	745	148	217	97	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 028	2449	473	521	745	148	374	130	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 029	2606	503	554	745	148	531	163	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 030	2764	533	587	745	148	689	196	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38

SCENARIO: **HIGH**

2 010	993	204	224	745	148	215	63			4	1,7											29	11
2 011	1082	222	245	745	148	304	84			4	1,7											29	11
2 012	1180	243	315	745	148	94	84	0	0	4	1,7							160	43			177	38
2 013	1287	265	335	745	148	84	84	0	0	4	1,7					117	20	160	43			177	38
2 014	1404	289	376	677	148	0	84	0	0	4	1,7					117	20	160	43	269	41	177	38
2 015	1532	316	376	745	148	60	84	0	0	4	1,7					117	20	160	43	269	41	177	38
2 016	1682	345	393	745	148	63	84	0	0	4	1,7			147	17	117	20	160	43	269	41	177	38
2 017	1831	375	475	501	148	0	84	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 018	2018	412	475	688	148	0	84	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 019	2206	449	494	745	148	131	104	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 020	2393	487	535	745	148	318	144	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 021	2605	529	582	745	148	530	191	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 022	2817	572	629	745	148	742	238	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 023	3077	624	687	745	148	1002	296	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 024	3337	677	744	745	148	1262	354	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 025	3597	729	802	745	148	1522	411	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 026	3917	793	873	745	148	1842	482	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 027	4237	858	943	745	148	2162	553	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 028	4631	937	1030	745	148	2556	640	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 029	5024	1016	1117	745	148	2949	727	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38
2 030	5418	1095	1204	745	148	3343	814	0	0	4	1,7	456	82	147	17	117	20	160	43	269	41	177	38

REFERENCE SOLUTION (WITHOUT PROJECT): UGANDA SYSTEM GENERATION

ALTERNATIVE 2

SCENARIO: **MEDIUM**

Uganda FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Bagasse GWh	MW	Karuma GWh	MW	Mini-Hydro GWh	MW	Kalagala GWh	MW	Murchison GWh	MW	Ayago GWh	MW	Export Kenya 50 MW GWh	MW
2 010	2874	500	629	2980	587	0	0	294	42											-400	-50
2 011	3081	535	639	3038	587	0	10	294	42											-251	-50
2 012	3303	573	713	3038	587	0	10	294	42			371	74							-400	-50
2 013	3541	612	723	3038	587	0	20	294	42			530	74							-321	-50
2 014	3796	655	923	3038	587	0	20	132	42	786	200	240	74							-400	-50
2 015	4069	701	923	3038	587	0	20	165	42	970	200	296	74							-400	-50
2 016	4373	752	923	3038	587	0	20	197	42	1183	200	355	74							-400	-50
2 017	4676	802	932	3038	587	0	29	232	42	1387	200	419	74							-400	-50
2 018	5038	862	998	3038	587	0	95	274	42	1625	200	501	74							-400	-50
2 019	5399	922	1448	3038	587	0	95	159	42	953	200	286	74	1363	450					-400	-50
2 020	5761	982	1448	3038	587	0	95	179	42	1081	200	323	74	1540	450					-400	-50
2 021	6117	1043	1448	3038	587	0	95	200	42	1202	200	360	74	1717	450					-400	-50
2 022	6473	1103	1448	3038	587	0	95	221	42	1322	200	398	74	1894	450					-400	-50
2 023	6885	1174	1448	3038	587	0	95	244	42	1467	200	440	74	2096	450					-400	-50
2 024	7298	1244	1448	3038	587	0	95	268	42	1612	200	482	74	2298	450					-400	-50
2 025	7710	1314	1670	3038	587	0	95	218	42	1293	200	392	74	1869	450	1300	222			-400	-50
2 026	8186	1395	1670	3038	587	0	95	238	42	1400	200	429	74	2045	450	1436	222			-400	-50
2 027	8663	1477	1674	3038	587	0	99	259	42	1518	200	466	74	2222	450	1560	222			-400	-50
2 028	9214	1571	1872	3038	587	0	99	282	42	1677	200	509	74	2424	450	1684	420			-400	-50
2 029	9766	1665	1881	3038	587	0	108	294	42	1747	200	530	74	2525	450	2032	420			-400	-50
2 030	10317	1759	1985	3038	587	0	212	294	42	1747	200	530	74	2525	450	2583	420			-400	-50

SCENARIO: **LOW**

Uganda FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Bagasse GWh	MW	Karuma GWh	MW	Mini-Hydro GWh	MW	Kalagala GWh	MW	Murchison GWh	MW	Ayago GWh	MW	Export Kenya 50 MW GWh	MW
2 010	2435	420	629	2645	587	0	0	190	42											-400	-50
2 011	2540	436	629	2740	587	0	0	200	42											-400	-50
2 012	2648	453	629	2838	587	0	0	210	42											-400	-50
2 013	2762	470	629	2942	587	0	0	220	42											-400	-50
2 014	2880	489	629	3038	587	0	0	242	42											-400	-50
2 015	3003	508	703	2700	587	0	0	260	42			443	74							-400	-50
2 016	3134	528	703	2800	587	0	0	270	42			464	74							-400	-50
2 017	3266	548	703	2900	587	0	0	280	42			486	74							-400	-50
2 018	3411	570	703	3000	587	0	0	290	42			521	74							-400	-50
2 019	3557	592	903	3038	587	0	0	106	42	622	200	191	74							-400	-50
2 020	3703	614	903	3038	587	0	0	121	42	727	200	217	74							-400	-50
2 021	3854	639	903	3038	587	0	0	138	42	829	200	249	74							-400	-50
2 022	4005	664	903	3038	587	0	0	156	42	930	200	281	74							-400	-50
2 023	4172	692	903	3038	587	0	0	176	42	1040	200	318	74							-400	-50
2 024	4338	719	903	3038	587	0	0	194	42	1156	200	350	74							-400	-50
2 025	4505	747	903	3038	587	0	0	215	42	1265	200	387	74							-400	-50
2 026	4689	778	905	3038	587	0	2	235	42	1392	200	424	74							-400	-50
2 027	4873	808	939	3038	587	0	36	256	42	1518	200	461	74							-400	-50
2 028	5075	842	976	3038	587	0	73	279	42	1654	200	504	74							-400	-50
2 029	5278	875	1013	3038	587	0	110	294	42	1747	200	530	74							-331	-50
2 030	5481	909	1050	3038	587	0	147	294	42	1747	200	530	74							-128	-50

SCENARIO: **HIGH**

Uganda FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Bagasse GWh	MW	Karuma GWh	MW	Mini-Hydro GWh	MW	Kalagala GWh	MW	Murchison GWh	MW	Ayago GWh	MW	Export Kenya 50 MW GWh	MW
2 010	3164	547	652	3038	587	0	23	294	42											-168	-50
2 011	3447	594	653	3038	587	115	24	294	42											0	0
2 012	3755	644	758	3038	587	0	55	294	42			530	74							-107	-50
2 013	4090	699	769	3038	587	228	66	294	42			530	74							0	0
2 014	4455	759	969	3038	587	0	66	209	42	1232	200	376	74							-400	-50
2 015	4853	824	969	3038	587	0	66	253	42	1506	200	456	74							-400	-50
2 016	5306	898	1419	3038	587	0	66	153	42	908	200	281	74	1326	450					-400	-50
2 017	5758	971	1419	3038	587	0	66	179	42	1078	200	323	74	1540	450					-400	-50
2 018	6320	1062	1419	3038	587	0	66	212	42	1270	200	382	74	1818	450					-400	-50
2 019	6881	1152	1419	3038	587	0	66	244	42	1463	200	440	74	2096	450					-400	-50
2 020	7443	1243	1419	3038	587	0	66	276	42	1658	200	498	74	2373	450					-400	-50
2 021	8062	1346	1641	3038	587	0	66	232	42	1377	200	419	74	1995	450	1401	222			-400	-50
2 022	8681	1450	1645	3038	587	0	70	259	42	1536	200	466	74	2222	450	1560	222			-400	-50
2 023	9433	1575	1843	3038	587	0	70	294	42	1747	200	530	74	2525	450	1699	420			-400	-50
2 024	10184	1701	1921	3038	587	0	148	294	42	1747	200	530	74	2525	450	2450	420			-400	-50
2 025	10936	1826	2155	3038	587	0	148	226	42	1345	200	408	74	1944	450	2796	420	1579	234	-400	-50
2 026	11846	1978	2226	3038	587	0	219	250	42	1485	200	451	74	2146	450	3133	420	1743	234	-400	-50
2 027	12755	2130	2530	3038	587	0	219	221	42	1310	200	398	74	1894	450	2759	420	3535	538	-400	-50
2 028	13859	2315	2596	3038	587	0	285	245	42	1457	200	442	74	2106	450	3068	420	3903	538	-400	-50
2 029	14963	2499	2799	3038	587	0	488	269	42	1600	200	485	74	2313	450	3370	420	4288	538	-400	-50
2 030	16067	2684	3002	3038	587	0	691	294	42	1747	200	530	74	2525	450	3679	420	4654	538	-400	-50

REFERENCE SOLUTION (WITHOUT PROJECT): KENYA SYSTEM GENERATION

ALTERNATIVE 2

SCENARIO: **MEDIUM**

KENYA LOAD FORECAST	Net Energy GWh	Peak Load MW	Installed MW	Committed Local Resources GWh	MW	Complementary Thermal GWh	MW	Coal GWh	MW	Import Uganda GWh	MW
2010	7838	1343	1478	5052	1039	65	89	2321	300	400	50
2011	8491	1456	1628	5052	1039	65	89	3123	450	251	50
2012	9183	1576	1778	5052	1039	65	89	3667	600	400	50
2013	9922	1703	1874	5052	1039	135	185	4415	600	321	50
2014	10711	1840	2174	5052	1039	135	185	5124	900	400	50
2015	11552	1985	2183	5052	1039	142	194	5958	900	400	50
2016	12470	2144	2483	5052	1039	142	194	6876	1200	400	50
2017	13387	2302	2532	5052	1039	178	243	7758	1200	400	50
2018	14492	2493	3132	5052	1039	178	243	8862	1800	400	50
2019	15596	2684	3132	5052	1039	178	243	9967	1800	400	50
2020	16701	2876	3163	5052	1039	200	274	11049	1800	400	50
2021	17987	3098	3763	5052	1039	200	274	12334	2400	400	50
2022	19272	3321	3763	5052	1039	200	274	13620	2400	400	50
2023	20812	3588	4363	5052	1039	200	274	15160	3000	400	50
2024	22351	3854	4363	5052	1039	200	274	16699	3000	400	50
2025	23891	4121	4533	5052	1039	324	444	18115	3000	400	50
2026	25699	4434	5133	5052	1039	324	444	19922	3600	400	50
2027	27506	4747	5222	5052	1039	389	533	21665	3600	400	50
2028	29664	5122	5822	5052	1039	389	533	23823	4200	400	50
2029	31822	5496	6422	5052	1039	389	533	25981	4800	400	50
2030	33980	5870	6457	5052	1039	414	568	28114	4800	400	50

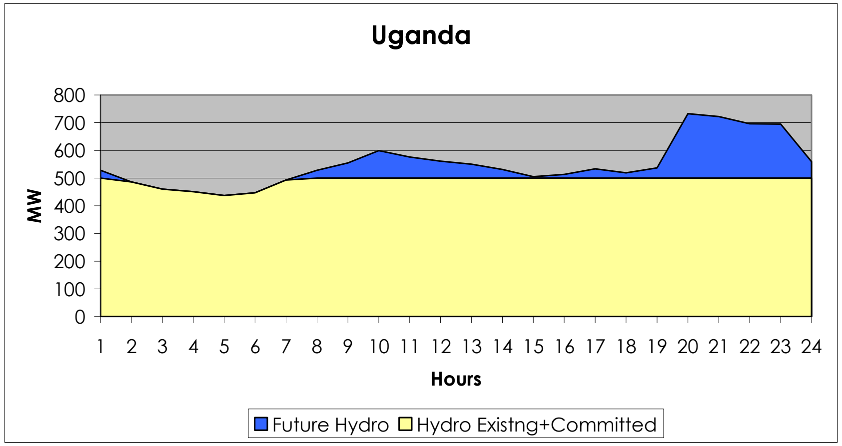
SCENARIO: **LOW**

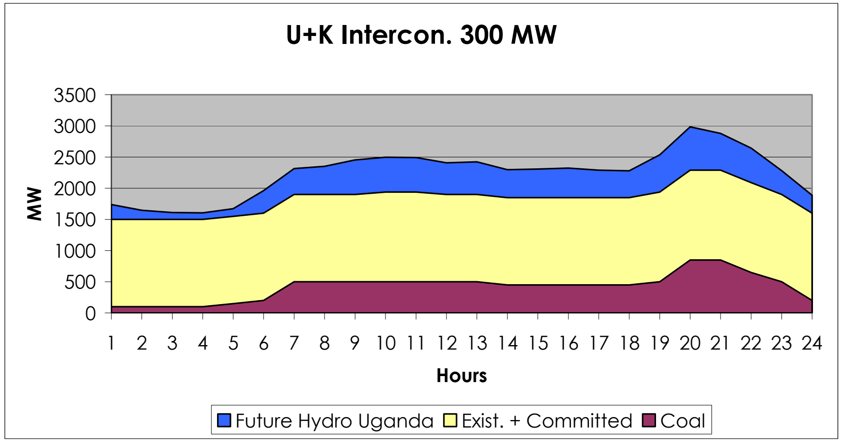
2010	7585	1299	1429	5052	1039	29	40	2104	300	400	50
2011	8153	1397	1579	5052	1039	29	40	2672	450	400	50
2012	8750	1500	1729	5052	1039	29	40	3269	600	400	50
2013	9381	1609	1770	5052	1039	59	81	3870	600	400	50
2014	10049	1724	2070	5052	1039	59	81	4538	900	400	50
2015	10756	1846	2070	5052	1039	59	81	5245	900	400	50
2016	11516	1977	2175	5052	1039	136	186	5928	900	400	50
2017	12276	2109	2475	5052	1039	136	186	6688	1200	400	50
2018	13173	2264	2491	5052	1039	147	202	7574	1200	400	50
2019	14070	2420	3091	5052	1039	147	202	8471	1800	400	50
2020	14967	2575	3091	5052	1039	147	202	9368	1800	400	50
2021	15988	2751	3091	5052	1039	147	202	10388	1800	400	50
2022	17008	2928	3221	5052	1039	242	332	11314	1800	400	50
2023	18207	3135	3821	5052	1039	242	332	12513	2400	400	50
2024	19405	3343	3821	5052	1039	242	332	13711	2400	400	50
2025	20604	3550	3905	5052	1039	304	416	14848	2400	400	50
2026	21998	3791	4505	5052	1039	304	416	16242	3000	400	50
2027	23392	4032	4505	5052	1039	304	416	17636	3000	400	50
2028	25026	4315	5105	5052	1039	304	416	19271	3600	400	50
2029	26661	4598	5105	5052	1039	304	416	20975	3600	331	50
2030	28296	4881	5705	5052	1039	304	416	22812	4200	128	50

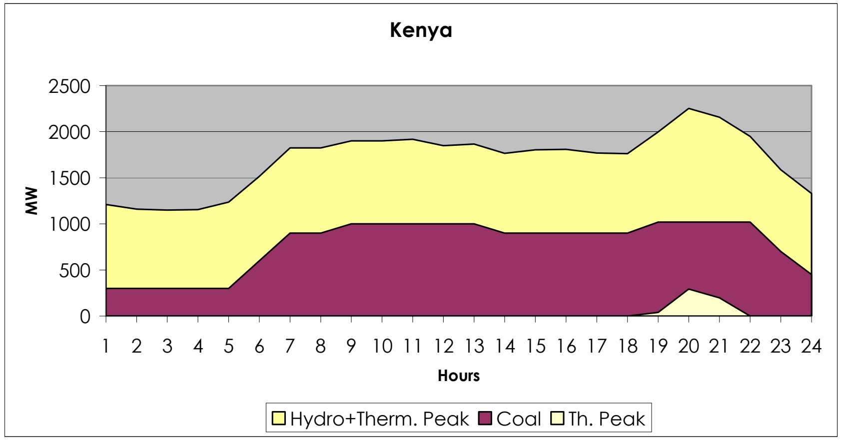
SCENARIO: **HIGH**

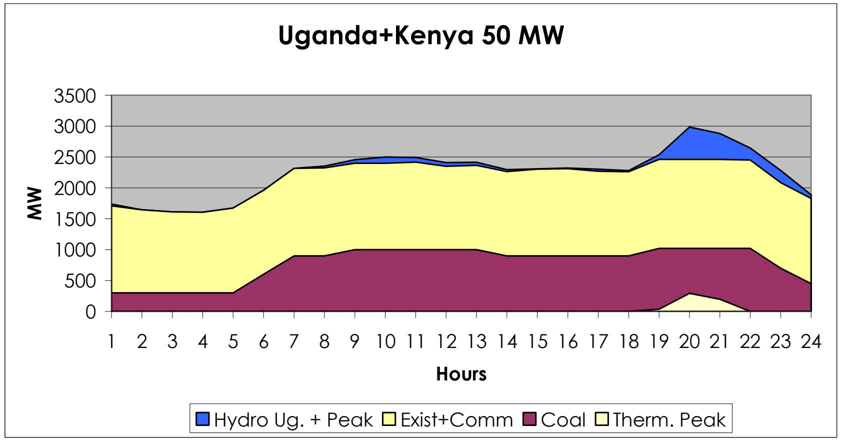
2010	8165	1400	1540	5052	1039	545	151	2400	300	168	50
2011	8914	1530	1683	5052	1039	262	194	3600	450	0	0
2012	9715	1668	1883	5052	1039	142	194	4414	600	107	50
2013	10578	1817	2133	5052	1039	142	194	5384	900	0	0
2014	11506	1978	2183	5052	1039	142	194	5912	900	400	50
2015	12506	2151	2483	5052	1039	142	194	6912	1200	400	50
2016	13611	2342	2576	5052	1039	210	287	7950	1200	400	50
2017	14717	2533	3176	5052	1039	210	287	9055	1800	400	50
2018	16074	2768	3176	5052	1039	210	287	10412	1800	400	50
2019	17430	3003	3303	5052	1039	303	414	11676	1800	400	50
2020	18787	3238	3903	5052	1039	303	414	13032	2400	400	50
2021	20404	3518	3903	5052	1039	303	414	14649	2400	400	50
2022	22020	3798	4503	5052	1039	303	414	16266	3000	400	50
2023	23995	4140	4554	5052	1039	340	465	18203	3000	400	50
2024	25969	4483	5154	5052	1039	340	465	20177	3600	400	50
2025	27943	4825	5754	5052	1039	340	465	22151	4200	400	50
2026	30289	5232	5755	5052	1039	340	466	24497	4200	400	50
2027	32634	5638	6355	5052	1039	340	466	26842	4800	400	50
2028	35486	6133	6955	5052	1039	340	466	29694	5400	400	50
2029	38337	6627	7555	5052	1039	340	466	32545	6000	400	50
2030	41189	7122	7834	5052	1039	544	745	35193	6000	400	50

ANNEX G – LOAD CURVES UGANDA-KENYA


Uganda
MW
Hours
Future Hydro
Hydro Existng+Committed


U+K Intercon. 300 MW
MW
Hours
Future Hydro Uganda
Exist. + Committed
Coal


Kenya
MW
Hours
Hydro+Therm. Peak
Coal
Th. Peak


Uganda+Kenya 50 MW
MW
Hours
Hydro Ug. + Peak
Exist+Comm
Coal
Therm. Peak

ANNEX H – DISTANCE TO EARTH

NOT USED

ANNEX I – INSULATORS

NOT USED

ANNEX J – REFERENCES

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Land cover (Land use) stratification Map - Iganga District ; Scale 1: 130,000

Land cover (Land use) stratification Map - Bugiri District; Scale 1: 110,000

Land cover (Land use) stratification Map - Jinja District; Scale 1: 50,000

Land cover (Land use) stratification Map - Tororo District; Scale 1: 80,000

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ANNEX K –CONSULTED PARTIES

List of authorities, institutions, NGO's and individuals that have been consulted

UGANDA

Name of the person	Position	Organization
Mr. Rufafa Dickson	District Environmental Officer	Jinja District Local Government
Mr. Mubiru Nathan	District Planner	Jinja District Local Government
Mr. Mununuzi Nathan	District Environmental Officer	Iganga District Local Government
Mr. Kondha Muhamoud	District Planner	District Local Government
Mr. Basoma Moses	District Environmental Officer	District Local Government
Mr. Gongo John	District Environmental Officer	District Local Government
Mr. Mulabye J	District Planner	District Local Government
Mr. Ben Mungyereza		Uganda Bureau of Statistics (UBOS)
Mr. Mwambi	Surveyor	UETCL
Mrs. Zelia Tibalwa	Planner	Planning unit, UETCL

KENYA

Name of the person	Position	Organization
Mrs. Catherine N. Mbaisi	District Environmental Officer	North Nandi
Mr. B. Omondi	Provincial Environmental Officer	Western Province
Mr. A.A.Saisi	District Environmental Officer	Kakamega District
Mr. K. Ronoh		National Environmental Management Authority (NEMA)
Dr. James Njogu	Head office	Kenya Wildlife Service
Dr. Benjamin Mwasi	School of Environmental Studies	Moi University
Mr John Mironga		Department of Geography Egertomn University, Njoro
		National Museums of Kenya. Antiquities and Heritage sites department
Dr. Otieno Agwanda	Senior Research Institute	University of Nairobi
Dr. Anne Khasakhala	Research Fellow. Population Studies Research Institute	University of Nairobi
Prof. Elijah Biama	Chairman, Department of environmental Engineering	University of Nairobi
Mr. Antony Lusuli	Ministry of Planning and National Development.	Central Bureau of Statistics
Ms. Mary Wanyonyi	Ministry of Planning and National Development	Central Bureau of Statistics
Mr. Awiti Kakumu	Lecturer, School of Built up Environment	University of Nairobi
Dr. Kapule, D.E	Lecturer. Department of Geography	University of Nairobi