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

FEASIBILITY REPORT
VOLUME 3 A – UGANDA-RWANDA INTERCONNECTION
MAIN REPORT

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LIST OF ABBREVIATIONS

AFSEC	African Electrotechnical Standardization Commission / Commission Electrotechnique Africaine de Normalisation
BAD	Banque Africaine de Développement
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 Budjagali 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 103 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 60 km, 110 kV power line between Goma (DRC) and Mukungwa (Rwanda), closing thereby the loop around Lake Kivu and
- constructing a 19 km, 110 kV power line between Bujumbura and Kiliba (DRC).

1.2. PURPOSE OF VOLUME 3

This volume provides technical and economical considerations regarding the design of the interconnection transmission lines from Uganda to Rwanda. The main objective of this transmission line study is 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 three countries, as well as design assumptions for the transmission line.

The importance of this interconnection is to provide a new energy corridor from a potential producer, Uganda, to a principal load centre, Kigali, Rwanda. The terms of reference for this interconnection have defined the terminal points as Mbarara, Uganda and Kigali, Rwanda, with an energy transit of 20 MW. The future planned production and transit will be far greater than this value. Since this time, Uganda has planned a new substation at Mirama near the Rwanda border and Rwanda has planned a new substation at Birembo at the outskirts of Kigali. These two new substations are effectively the new terminal points for the interconnection and will also serve as important distribution substations for the territories around each of them.

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

The analysis of interconnected networks including Kenya, Uganda, Burundi, DRC and Tanzania is presented in volume 6.

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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 30 m and 20 m contour intervals have been studied along with Landsat 7 satellite images and SRTM 3D numerical terrain models. 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 Maps, which is presented in Volume 3C of this Feasibility Report.

The route of the selected line has been shown afterwards on the topographic maps, measured so as to give a plan and a precise profile and to identify obstacles, environmental constraints and access tracks.

2.3. LINE ROUTE SURVEYS

Line route surveys include topographical survey and soil investigations. The survey work and its results are presented in Volume 3C of this Feasibility Report.

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

2.4. ENVIRONMENTAL MANAGEMENT

For a detailed study of the environmental assessment reference is made to the Environmental Impact Assessment in Volume 3B of this Feasibility Report.

Socioeconomic surveys and consultations with the chiefs of all the villages along the route have also been undertaken. The results are presented in volume 3B, Environmental Study and Social Impact.

The following principles were adopted:

2.4.1. 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.

2.4.2. CONSTRUCTION STAGE

- Limit right-of-way to 30 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.

2.5. VISUAL IMPACTS, NOISE, ELECTRIC AND MAGNETIC FIELDS

In general the line route will be directed close to existing roads. 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. At the stage of this Feasibility Study, the transmission line corridor has been selected to avoid main roads and population centres. It has been chosen to avoid tops of mountain ranges and the bottom of valleys.

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 30 meters right-of-way, the impact from electric and magnetic fields will be accordingly minimal. The analysis details are given in volume 6.

2.6. 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. NETWORK STUDY

3.1.1. INTRODUCTION

This section provides all conclusions and recommendations of network studies concerning the interconnection from Uganda to Rwanda. All these conclusions and recommendations are included and detailed in volume 6 "Power System Design".

3.1.2. LOAD FLOW ANALYSIS AND REACTIVE COMPENSATION REQUIREMENTS

Load flow studies were carried out for 2015 and 2022. A total of four scenarios were studied for 2015 and a total of two scenarios were studied for 2022. Main conclusions and recommendations are summarized below for 2015 and 2022 and a summary of the recommended compensation is also provided.

3.1.2.1. LOAD FLOW ANALYSIS FOR 2015

Whatever the power transfer scenario for the Uganda – Kenya interconnection, the conclusion is the same for the Uganda – Rwanda interconnection: it will be possible to transfer 50 MW on a single 132 kV circuit from Mirama (Uganda) to Birembo (Rwanda), but before transferring more power, it would be advisable to complete the 220 kV line over its total length from Masaka to Birembo and operate it at its rated voltage instead of building it partially and operate it at 132 kV.

The Uganda-Rwanda Power transfer have no impact on the recommendations regarding the Uganda-Kenya interconnection. The 220 kV bus-bar voltage at Lessos depends more on the bus load than on the interconnection loading itself. If most of the load on the 220 kV Lessos bus-bar, the maximum transfer between Uganda and Kenya is approximately 160 MW. If the Lessos load is moved for one-half to 132 kV bus-bar at the Lessos substation and for the other half to the 220 kV bus-bar at the Nairobi substation, the maximum transfer is increased to 300 MW.

3.1.2.2. LOAD FLOW ANALYSIS FOR 2022

In steady-state, all the equipment being in service or in a (N-1) contingency transferring 150 MW from Uganda to Rwanda creates no problem, considering of course the choice of 220 kV double circuits line for the interconnection.

The upgrade to 110 kV of the former 70 kV grid in DRC and the new Mukungwa – Goma and Kigoma – Rwegura greatly improve the supply reliability of the Burundi-Rwanda-DRC system substations.

In the steady-state regime, with the help of few shunt capacitor banks, all the voltages are acceptable

The new Kigoma – Rwegura line improves the supply reliability of Burundi, as it can sustain well the system despite the unavailability or the loss of either the 110 kV Mururu 2 – Bubanza line, either the future Rusumo-Falls – Gitega tie-line or either one section of the Mururu 2 – Kigoma line.

Despite the improvements brought by the voltage upgrade and the two recommended lines, we still see some remaining weaknesses on the network. In the facts, the greatest weakness of the Biembo – Jabana interconnection is the unique circuit between Birembo and Jabana. Whenever this strongly over-loaded circuit trips, the system will become unstable and there will be a cascade of tripping that will make the system collapse. As for the complete loss of the Uganda-Rwanda interconnection, in such a severe case, specific action should be taken in order to isolate the Burundi-Rwanda-DRC system from the main grid. Clearly, there should be another circuit between Birembo and Jabana.

3.1.2.3. COMPENSATION REQUIREMENTS

In order to maintain a good voltage profile on the interconnection lines themselves and in their neighbourhoods, shunt capacitive support is needed in many substations. Their commissioning should take place as requested by the load growth and the power transfers.

Table 3.1 - Shunt capacitor units recommended for 2022

Country	Substation	Number of banks	Units
Rwanda	Birembo	2	10 MVARs
Rwanda	Gikondo	1	10 MVARs
Rwanda	Jabana	1	10 MVARs
DRC	Goma	3	10 MVARs
Burundi	Bujumbura-RN1	4	10 MVARs
Uganda	Tororo	1	50 MVARs
Kenya	Musaga	1	50 MVARs
Kenya	Lessos	1	50 MVARs

The needs for Gikondo and Jabana may however be modified according to the actual distribution of load between Gikondo, Jabana and Birembo. Nevertheless, the total equipment for these three substations should be four banks of 10 MVARs.

For Goma, due to the very poor voltage support and considering a possible load growth greater than presumed, it would be advisable to examine seriously the possibility of dynamic compensation instead of switched shunt capacitors, e.g. SVCs or synchronous condensers.

3.1.3. HIGH VOLTAGE LINE

Selection of conductors, conductor type, conductor size and electrical characteristics of the proposed 110 kV and 220 kV lines are summarized below. Lightning performance analysis and environmental studies that were carried out are also summarized.

3.1.3.1. LIGHTNING PERFORMANCE

The software “Flash 1.7” included in the IEEE Standard 1243 was used for the study of lighting performance of both the existing and new transmission lines.

The flashover rate of existing 110 kV lines in Rwanda have very high flashover rate. The worst being between Mururu II and Karongi substations. The calculated flashover rate of the proposed 220 kV line is always under 9 flashover per 100 km-per years. For the proposed new 110 kV, the calculated performance is not as good as for the new 220 kV line and reach up to 24 flashover per 100 km per years on the new Mukungwa – Goma 110 kV line

To improve reliability and availability, single phase auto reclose (SPAR) is recommended on all lines. For double circuits lines, in addition to (SPAR) and the (N-1),criterion, it is recommended to select “ABC-CAB” phasing to minimise the predominant critical stroke current on only one phase at a time.

3.1.3.2. CONDUCTOR SELECTION

Following capital cost estimate and electrical losses comparison a bundle of two Hawk conductors was selected.

3.1.3.3. ENVIRONMENTAL STUDIES

The calculated value of the peak electrical fields for the proposed 220 kV double circuit line are smaller than 5,0 kV/m and at the edge of the row are all equal to 1,21 kV/m. These value are acceptable.

For the two Ostrich per phase at 220 kV the 52,5 dB (A) criterions can be easily met even if the right-of-way is reduced to 30 m. For all new and upgraded 110 kV lines, all design criteria for corona performance, audible noise, radio interference (RI) and television interference (TVI) can all be easily met. For the 220 kV double circuit lines with two Hawk conductors, the corona performance limit of 52,5 HB along with all other design criteria can easily be met.

3.1.4. SHORT-CIRCUIT

Three phases short-circuit level are well under recommended initial symmetrical values of short-circuit rating of equipment at 110 kV,132 kV and 220 kV.

To complete single phase-to-earth fault analysis and EMTP studies, KPLC, UETCL and Tanesco must provide negative and zero sequence impedance of all equipment. The winding configuration are also required for all existing transformer.

On EGL network, the HV winding neutral of some transformer especially in Rwanda are not solidly earthed. For proper operation of single pole auto reclose (SPAR), the system should be solidly grounded. For this reason the transformer HV winding neutral should be solidly earthed.

If the design of the power transformers allows this, their HV neutral should be solidly earthed. If such a solution is impossible, an additional grounding power transformers or the replacements of the power transformers is required in all of the critical substations. The substation owned by SNEL in Bujumbura and the Gikondo substations in Rwanda are judged critical. The substation of Jabana in Rwanda will become critical after relocation of its 110/70 autotransformer to Birembo substation.

For single pole auto reclose (SPAR) on three terminal lines, the HV winding neutral of the diverted line transformer should not be earthed. If star configuration is selected, neutral point should not be grounded. As an alternative, high voltage winding with delta winding is also acceptable. Generating unit should never be connected to the low voltage side of these transformers. For proper detection of single phase-to-earth fault the system should be solidly grounded. In conclusion, all HV neutral of power transformer should be solidly grounded with the exception of located at the diverted line.

3.1.5. SINGLE POLE AUTO RECLOSE (SPAR)

To increase reliability and availability of the integrated network and avoid the need for resynchronization of isolated network, independent pole switching should be installed on most of 110 kV, 132 kV and 220 kV lines to allow single pole auto reclosure (SPAR). Delayed three phase auto reclose on double circuits line when only one circuit is in operation should be prohibited.

For 110 kV line on EGL network single pole auto reclosure is also recommended on most of these line. Unfortunately since some of these line are formed by three terminals and also because existing telecommunication systems are either not operational or of low telecommunication capacity, detection of single phase-to-earth will not be guaranteed. as mentioned previously, earthing of transformer HV neutral should be revised.

For successful operation of single phase-to-ground autoreclosure (SPAR), not any shunt reactor should be installed on interconnection between Mbarara and Birembo when its operating voltage is at 132 kV. However when its operating voltage increases at 220 kV shunt reactor complete with neutral reactor must be added.

3.1.6. TRANSIENT STABILITY

3.1.6.1. STABILITY CRITERIA

System stability should be maintained following a permanent three phase fault on each interconnector. The fault is assumed to clear by tripping the line in less than 7 cycles at 110 kV and 132 kV and in less than 5 cycles at 220 kV.

System stability should also be maintained following temporary and permanent single phase-to-ground faults. A temporary single phase fault is assumed to be cleared by single pole tripping of the faulted phase in less than 7 cycles at 110 kV and 132 kV and n less than 5 cycles at 220 kV. The dead time before reclosing is selected at 450 ms to reduce disturbance on the network and limit the phase unbalance on the tripped line. If this criterion is fulfilled, reclosing should be successful on temporary single phase-to-ground faults. For any permanent fault, the fault will be re-established following circuit breaker reclosing and must be cleared by tripping the line in time specified above. A second reclose attempt will not be allowed following reclosure failure.

3.1.6.2. EXCITATION SYSTEM

All excitation systems for new units must be of static type, with positive celling voltage of 3.5 P.U. and with negative ceiling voltage of – 1.0 P.U. The static excitation systems must also be included with stabilizers and minimum and maximum excitation limiter must also be included.

3.1.6.3. DYNAMIC SIMULATION FOR 2015

For 2015 four different scenarios were studied. For the two first scenario which are quite similar, the power transfer from Uganda to Rwanda is 50 MW and the power transfer from Uganda to Kenya is 160 MW. The Rusumo- Falls hydropower plant is not yet included in the second scenario. In the third and fourth scenarios the power transfer from Uganda to Kenya is 100 MW. The power transfer from Uganda to Kenya is 160 MW in scenario three and 300 MW in scenario four. Two 132kV lines from Uganda to Rwanda are in operation in the third and fourth scenario.

The transient stability simulation of a three-phase fault lasting 7 cycles on the 132 kV bus-bar at Birembo followed by the tripping of the faulted circuit on the Birembo-Mirama section, shows that the system recovers promptly, with an acceptable voltage of 0.96 P.U. at Birembo. Of course, the Burundi-Rwanda-DRC power system is unable to withstand the complete lossof the interconnection as it contributes 30% of the total system load. In less than four seconds, the frequency drops below 47 Hz and cannot recover. The same remark applies to the subsystem that would be isolated following the tripping of the single circuit between Birembo and Jabana. It is therefore mandatory to double this circuit as soon as possible. The events related to this Uganda-Rwanda interconnection have no significant impact on the Uganda-Kenya-Tanzania power system. Even after the Uganda-Rwanda interconnection tripping, the voltage and frequency conditions recover rapidly. The frequency increases to 50.12 Hz and recovers normally to its rated value.

The dynamic simulation of a 7 cycles three-phase fault on the 132 kV bus-bar at Birembo, cleared by the tripping of the single Mirama-Birembo circuit, shows that the system is promptly stabilized, with voltages around 1 P.U. at the Birembo and the neighbouring substations. The voltages on the Uganda side return to their initial values. As the loss of the Mirama-Birembo single circuit causes the isolation of the Burundi-Rwanda-DRC grid, there is a negative unbalance between the generation and the load. But as the spinning reserve is approximately 65 MW, it is more than enough to recover from the 50 MW loss of import: the isolated system frequency decreases to 48.9 Hz and recovers around 49.7 Hz after 40 seconds due to the speed governor reaction. One must be aware however that the imported power should be less than the spinning reserve. The loss of the Uganda-Rwanda interconnection has a negligible effect on the Uganda-Kenya-Tanzania power system. The frequency reaches a maximum value of 50.07 Hz, which would be almost imperceptible. Considering a system weakly loaded with halved total inertia, the maximum frequency value would reach 50.14 Hz, which is not preoccupying.

3.1.6.4. DYNAMIC SIMULATION FOR 2022

3.1.6.4.1. THE UGANDA-RWANDA INTERCONNECTION

As in the case in steady-state, the transient stability analysis shows that the results pertaining to the Uganda-Rwanda interconnection are quite similar whatever the loading scenario of the Uganda-Kenya interconnection.

The stability criterion is fulfilled The system can easily withstand a three-phase fault cleared after 5 cycles by the tripping of the faulted circuit on any 220 kV bus-bar on the interconnection line.

The most severe contingency for voltage is the loss of the Rusumo-Falls–Birembo interconnection. Though this contingency is not a (N-1) type, we do consider it might happen that only one circuit of this interconnection be in service. The system is stable, with very few oscillations and the stabilized voltage at Birembo is 0.96 P.U., above the 0.95 P.U. criterion limit.

3.1.6.4.2. THE BURUNDI-RWANDA-DRC INTERCONNECTIONS

The upgrade to 110 kV of the former 70 kV grid in DRC and the new Mukungwa-Goma and Kigoma-Rwegura greatly improve the supply reliability of the Burundi-Rwanda-DRC system substations.

The transient stability studies show that most of the contingencies under the stability criterion do not threat the interconnected grid stability.

Because of the new Mukungwa–Goma line, the loss of the Kasha-Goma line will no more cause the loss of supply of the Goma area. The loss of the Mukungwa–Goma line is more severe, but in both cases, the system gets stabilized promptly after a 7 cycle three-phase fault cleared by the tripping of the faulted circuit. These results are all for three-phase faults and it is assumed that protection system detect the fault in prescribed time which is not obvious.

The new Kigoma-Rwegura line improves the supply reliability of Burundi, as it can sustain well the system despite a three-phase fault on one of the following circuits: the 110 kV Mururu 2-Bubanza line, the future Rusuma-Falls-Gitega tie-line, one section of the Mururu 2-Kigoma line and the Kigoma-Rwegura line itself. Among these four cases, the most severe is the loss of the Rusumo-Falls-Gitega line.

Despite the improvements brought by the voltage upgrade, the stability of the Burundi-Rwanda-DRC network cannot be maintained in the case of the tripping of the unique circuit between Birembo and Jabana. Whenever this strongly over-loaded circuit trips, the system will become unstable and there will be a cascade of tripping that will make the system collapse.

3.1.7. INSULATION COORDINATION

Preliminary insulation coordination studies were carried out on all new and modified 110 kV, 132 kV and 220 kV substations. These insulation coordination studies were based on procedure included in IEC Standards 60071-1 and 60071-2.

EMTP studies were not carried out at this stage of the project. The switching overvoltage values were estimated from figures included in IEC Standard 60071-2, but the slow-front switching overvoltages due to energization of capacitor banks could not be estimated since slow-front overvoltages values for this type of switching operation is excluded in this standard.

The selected withstand voltages are summarized below for each system voltage.

- At a rated operating voltage of 220 kV, a standardized value of 460 kV for short-duration power frequency and a value of 1050 kV for lightning impulse withstand are required for all equipment with external insulation and also with internal insulation. This also include all 132 kV and 220 kV installed at Birembo substation when the lines and the substation are temporary operated at a voltage of 132 kV. Further studies including EMTP studies are required to defined phase-to-phase insulation. These studies are required on all 220 kV substation but selection of accurate insulation withstand voltage is a major concern at existing Lessos substation.
- At a rated voltage of 132 kV, standardized values of 325 kV for short-duration power frequency and of 750 kV for lightning impulse withstand are required for all equipment with external insulation. Standardized values of 275 kV for short-durations power frequency and 650 kV for lightning impulse withstand are also required for all equipment with internal insulation.
- At a rated voltage of 110 kV, standardized values of 275 kV for short-duration power frequency and of 650 kV for lightning impulse withstand are required for all equipment with external insulation. Standardized values of 230 kV for short-duration power frequency and 550 kV for lightning impulse are also required for equipment with internal insulation with the exception of 110 kV Birembo substation where the requirements for internal insulation should be the same as for external insulation.
- For lightning protection, the defined acceptable rate is 1 per 400 years can only be guaranteed if separation distance from surge arresters to protected equipment is always equal and smaller to the values included in table N° 16.3. Since flashover rate is high on almost all studied lines, the separation distance is small. With such values of flashover rate it is important to confirm regularly that all surge arresters are not defective and to replace all surge arresters which are found defective.

3.2. TRANSMISSION LINE DESIGN

3.2.1. 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 60826-1, 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 heavy polluted corresponding to level 3 of IEC 60815.

3.2.2. 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 3 sec. gust wind speed (10 m above ground level)	36 m/s

Tower loadings should be calculated according to IEC 60826-2 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). Overload 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 0.1g horizontally and 0.05g vertically.

3.2.3. VOLTAGE LEVELS

Voltage levels of the existing lines in Uganda and in Rwanda are different. Uganda is exploiting a 132 KV network and Rwanda a 110 KV network. At the time of the start up of Bujagali power station, Uganda plans the establishment of a new 220 KV network for covering up the load increase and to allow the integration of new hydro-electric power stations and the export of the surpluses towards Kenya and Rwanda as described in article 3.1.

These two last networks must be connected thereafter to Tanzania network to form a looping around lake Victoria as well as to create an integrated network including Burundi, the RDC, Rwanda, Uganda and Tanzania. In order to allow the substantial increase in the load and to increase the reliability of the new integrated network, 220 KV and 330 KV lines forming the loop around lake Victoria and connecting the significant centers of production, must meet in short term the criterion of redundancy (N-1). For this reason, lines of a tension equal and higher than 220 KV must be doubled or comprised two double system lines.

The previous and recent studies as well as master plans all justify increase of minimal tension to 220 KV for networks of Kenya and Uganda. Since Birembo-Mirama line belongs to the frame of future looping around lake Victoria, its minimal ultimate tension must be 220 KV, and must include two double system lines to meet the criterion of reliability (N-1).

Power transfer between Uganda and Rwanda is initially projected to 20 MW for the continuation to increase to a maximum of 200 MW in 2030. Since transfer of power is relatively weak at the time of line startup and that it doesn't exist any network of 220 KV in proximity, a double system lines of this line will be initially operated with a tension of 132 KV until the load increases to approximately 50 MW. In order to increase power transfer towards Rwanda to a value higher than 50 MW, two double system lines of this line must be energized and operated with their nominal voltage of 220 KV. The interconnection between Mirama and Birembo must interconnect two networks during at least 25 years. It is thus recommended to design a new interconnection for a level of tension of 220KV.

3.2.4. NUMBER OF CIRCUITS

A line 200 KV double system lines will permit to meet the criterion of reliability (N-1). The capacity of double system lines must meet the future needs for power transfer of this interconnection. This type of electrical line is however oversized at the time of initial exploitation of interconnection, and it is thus recommended to install only one circuit, isolated to 220 KV and to exploit it to 132 KV until a tension of 220 KV is necessary and that the transit of envisaged energy exceeds 50 MW.

3.2.5. PROVISION FOR ELECTRICITY RURAL DISTRIBUTION

3.2.5.1. POSSIBLE TECHNIQUES AND SOLUTIONS

Leaving aside the basic solution, which involves creating a simplified HV/MV substation and constructing MV lines parallel to the HV line, four rural electrification solutions are possible:

- capacitive coupling,
- capacitive transformer substations,
- SF6 single-phase voltage transformers,
- Insulated overhead earth wires.

These techniques are described in the Annexes to the present volume. Analysis shows that the best solution is that involving insulated overhead earth wires

3.2.5.2. ANALYSIS OF RURAL ELECTRIFICATION POTENTIAL

The rural electrification areas are situated along the interconnection lines, about 15 kilometres on either side of the corridor. All the project interconnections are concerned, apart from the Uganda-Kenya interconnection along which rural electrification is already well developed.

The interconnections and potential villages to be electrified are represented on drawing in Annex. These drawings also indicate the existing HV lines and projects already in progress.

3.2.5.3. UGANDA – RWANDA INTERCONNECTION

The project involves building an HV line between the substations at Mbarara in Uganda and Kigali in Rwanda. About 35 villages liable to be electrified via this line have been identified, as well as two tea factories (Mulindi and Chohoha Rucyeri).

In Uganda, several HV lines are already planned, including two parallel and close to the interconnection line: between Kafunzo and Nyalubale and between Rwoho and Kitwe.

In Rwanda, the planned interconnection line is situated between two existing 33 kV lines, the first connecting Kabarondo to Umutara, and the second connecting Rulundi to Kabare in Uganda. There are also a number of projects for lines from the two main lines.

Consequently, rural electrification from the HV interconnection line between Uganda and Rwanda is not justified.

3.2.5.4. CONCLUSION

All the villages to be electrified are situated less than 20 km from existing or planned HV structures (lines or substations). Consequently, it is not pertinent to provide rural electrification for these villages from higher-voltage interconnections, as this would result in higher costs and technological adaptations, particularly with regard to the neutral point system.

As the 33 kV lines reaching beyond Nyagatare in northern Rwanda are extremely long, it is recommended to open this length of line near Rugarama or Nayamanyoni and to connect this northern part of the grid to the Mirama substation in Uganda.

3.2.6. 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 60826-1, 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.

3.2.7. DESIGN CRITERIA

The transmission line design must respect the criteria presented below :

Table 3.2 – Design Criteria

Conductors	2 ACSR HAWK
Optical Ground Wire (OPGW)	IT4-T-G652
Ground Wire (GW)	10.6 mm GSW 70
Number of insulator units - Suspension - Anchor	 18 (avec cornes d'arche) 19 (avec cornes d'arche)
Maximum conductor temperature	75°C
Maximum ground wire temperature	50°C
Ruling span	350 m
Wind span	420 m (1,2 P.E.)
Weight span	1000 m (2,8 P.E.)
GW angle of protection	10°
Conductor exit angle	-5° à +20°
Maximum wind on cables	725 Pa (26m/s ou 94km/h)
Clearance to tower mass - Everyday - Reduced wind of 300 Pa - Maximum wind of 725 Pa	 2,77 m 1,31 m 0,83 m
Tower steel	350 MPa
Tower utilisation factor	0,9
Clearance to ground	8,0 m

3.2.8. ELECTRICAL CHARACTERISTICS

3.2.8.1. HIGH ALTITUDE

The influence of high altitudes on the thermal capacity and insulation coordination must be included due to the change in density of air. As a result, a correction factor is applied to thermal capacities and to lightning impulse withstand voltage for elevations above sea level.

3.2.8.2. POLLUTION

The line routes of both interconnection lines are considered as light polluted corresponding to level III of IEC 60815 with a minimum creepage distance of 25 mm/kV.

3.2.8.3. LIGHTNING

Keraunic levels are high throughout the Equatorial Lakes Region reaching 150 Td/year in the area of this interconnection

(See Details in annexe D)

3.2.8.4. SEISMIC ASPECT

Seismic level is 0.1 g for both interconnection lines.

3.2.8.5. GROUND RESISTANCE

The ground resistance should be aimed to 18 Ω except for the first and last three kilometres from/to substation where the resistance is recommended aimed at 10 Ω. Two counterpoises are therefore required over the full length of the line.

3.2.8.6. LINE ELECTRICAL CHARACTERISTICS

The line electrical characteristics are assumed to be as follows:

Tableau n° 1 - MBARARA – MIRAMA -BIREMBO LINE ELECTRICAL CHARACTERISTICS

Nominal voltage of a three-phase system	220	kV
Highest voltage of a three-phase system	245	kV
Minimum distance between arcing horns	2,45	m
Rated short duration power frequency withstand voltage	815	kV
Rated lightning impulse positive withstand voltage (peak)	1250	kV
Rated lightning impulse negative withstand voltage (Peak)	1715	kV
Rated frequency	50	Hz
Minimum insulator creepage distance	20	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	%
Reference Gust wind speed (3 sec. At 10 m. height)	36	m/s

3.2.9. 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 75 ºC:

Object	Vertical clearance in metres
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 (+75 ºC)

L = length of the insulator string (m), for tension string L = 0

C = constant for 220 kV = 1.5 m

3.2.10. 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.

There are some advantages in a homogenous conductor compared with an ACSR type conductor, e.g. ACSR:

Corrosion problems are not encountered because corrosion mainly affects steel;

Joints are simpler and jointing easier.

Equally, there are some advantages to the ACSR conductor including:

- It's heavier weight results in less fly-out under heavy wind conditions and less way-leave width requirement.
- For the same reason, cross-arm lengths can be slightly shorter for electrical clearances to the tower body.

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. Quotations from different supplier indicate that the prices for both conductor types are virtually the same for the equivalent current carrying capacity. Sag and tensions were also virtually the same. As such, conductor type selection becomes a matter of utility preference.

Upon verification with the Utilities involved with these NELSAP projects, a preference for ACSR type conductors has been indicated.

In accordance with the conductor optimisation study presented in volume 6, twin ACSR HAWK conductors have been chosen. This conductor is also commonly used on existing transmission lines throughout this region.

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

Type of conductor		ACSR HAWK (242-A1/51A-26/7
Standard		IEC
Conductor designation per phase		2
Cross section	mm^2	281.2
Overall diameter	mm	21.8
Stranding aluminium	No x mm	26 x 3.44
Steel stranding	No x mm	7 x 2.68
Unit weight	kg/m	977
Minimum ultimate tensile strength	kN	86.1
Rated DC resistance at 20 ˚C	Ω/km	0.1195

3.2.11. GROUND WIRES

According to the electrical requirements, like earth fault currents, one steel wire cable 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.

In accordance with the lightning performance study presented in volume 6, a shielding angle of 10deg. maximum is specified. When increasing the shielding angle from 10 deg to 30 deg, the probability of shielding failure becomes more than 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 10 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 analysis of lightning performance of the 220 kV line is presented in Volume 6. Article 3.1 presents a summary of the results. This study resulted in the selection of tower geometry, the location of the overhead ground wires and the level of insulation for the line.

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 (to be verified for sag & tension compliance)

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

3.2.12. INSULATORS (TO BE MODIFIED FOR POLYMER TYPE 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

3.2.13. TOWER OPTIMIZATION

Conventional lattice self-supported steel towers for double- circuit/single-circuit with two ground wires are assumed. Furthermore, it is recommended to optimise 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 overload factor applies for all towers.

Suspension towers, which have substantial lower weights and costs, should be used where possible.

With an estimated ruling span for the 220 kV line of approximately 350 metres the tower heights (from top of foundation to the cross arm) would range from 15 to 32 metres.

Optimisation of tower types and heights has been accomplished using the actual terrain profile and the PLS CADD tower spotting program.

3.2.14. 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 family of towers have been designed (see Annex A)along with a preliminary tower spotting along the line route in order to accurately estimate tower quantities for each tower type.

The family of towers consists of the following types:

- 0° - 2° Suspension Tower;
- 2° - 15° Tension Tower and Long Span Suspension;
- 15° - 60° Tension Tower and Dead-End;
- 60° - 90° Tension Tower;

3.2.15. TRANSPOSITION

In accordance with the requirements of the SPAR system, transpositions are required on these interconnection lines between Mbarara-Mirama and Mirama-Birembo substations.

3.2.16. FOUNDATIONS

Both steel grillage and concrete foundations are commonly used for high voltage overhead transmission lines in Rwanda and Uganda. Concrete foundations in some locations, especially, in hilly poor access sections, 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. Detailed soil investigations are being carried out for the detail design stage and will be presented with the technical specifications.

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 tension and terminal towers shall be of concrete. Special pile type foundations will be required in low lying wet regions.

For cost estimation purposes model foundation types (pad and chimney, concrete block cast in roc or rock anchors and a grillage foundation) have been drafted (see Annex B).

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

The right-of-way (ROW) width is proposed to set to a maximum of 30 metres. Complete clearing of the ROW where the line passes through forested areas should be limited to a 5 to 10 metre strip in the centre line to allow for stringing of the conductors. Outside this strip but within the ROW all vegetation above 3 metres height needs to be cleared including possible danger trees outside the ROW. Clearances however, are sufficient to pass over banana plantations. 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 utilisation of the terrain when selecting the final line route and spotting the towers are factors which, if skilfully performed, could further reduce the clearance requirements.

3.2.18. MAINTENANCE

3.2.18.1. 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.

3.2.18.2. 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.

3.3. SUBSTATION DESIGN

3.3.1. GENERAL

Plans by both countries have defined two new substations at Mirama in Uganda near Rwandan border and Birembo in Rwanda in the outskirts of Kigali. These two new substations will serve local distribution and are planned for future extension. The Uganda side terminal point of the interconnection project will, however be at Mbarara North substation, and the whole interconnection is Mbarara North - Mirama - Birembo.

Mbarara North is an existing 132/33 kV substation with a radial 132 kV line feeder to Masaka West. Plans to extend the 220 kV transmission network from Bujagali HPP through Kampala area substations and Masaka substation to Mbarara exist.

The initial voltage level of the interconnection would be 132 kV (Um = 145 kV), however, the transmission line would be planned for 220 kV (245 kV) level. Based on n-1 system planning principle, a double circuit transmission line has been recommended, however, only one circuit would initially be strung.

As both the terminal stations are located quite far from the border, construction of a new 132 kV substation is recommended in vicinity to the border in order to bring the point of sales / point of supply (as well as the revenue metering) close to the Uganda-Rwanda border.

The recommended location would be in Mirama in Uganda side ca. 7 km from the border as UETCL has distribution needs in the area as well.

3.3.2. 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	

3.3.3. ELECTRICAL CHARACTERISTICS AT UGANDA SUBSTATIONS

Tableau n° 2 - UGANDA SUBSTATIONS CHARACTERISTICS

Existing 132 (145) kV system:

Maximum operating voltage	145 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	650/750 kV peak (internal/external)
Rated power-frequency short duration withstand voltage	275/325 kV (internal/external)
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	30 mm/kV

Future 220 (245) kV system:

Maximum operating voltage	245 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	950/1050 kV peak (internal/external)
Rated power-frequency short duration withstand voltage	395/460 kV (internal/external)
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	30 mm/kV

3.3.3.1. MBARARA NORTH SUBSTATION

3.3.3.1.1. GENERAL

The substation is located some 250 km west from Kampala. The altitude of facilities is 1417 m. The substation was commissioned in 1994.

The substation is presently been extended with second power transformer and related facilities.

3.3.3.1.2. EXISTING FACILITIES AT MBARARA NORTH

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

132 kV switchgear

- AIS switchgear with single busbar (flexible) system
- two 132/33 kV transformer bays
- one OHTL feeder bay (to Masaka West)
- single flexible busbar

Transformers

- two 20 MVA, 132/33 kV network supply transformers

Reactive power compensation equipment

- two 33 kV, 4 Mvar shunt capacitor banks provided with individual switching

Auxiliary Systems

- 400/230 VAC auxiliary distribution system with sufficient capacity for NELSAP needs, however, the distribution board needs to be extended.
- Doubled 110 VDC auxiliary supply system with sufficient capacity for NELSAP needs, however, the distribution board needs to be extended.
- A single battery / double charger 48 VDC auxiliary supply system with sufficient capacity for NELSAP needs.

Control Building

The control building consists of control room with relay area, auxiliaries room, battery room, wash room, 33 kV switchgear room, auxiliary transformer room and diesel generator room. Sufficient space for NEPSAP needs is available within the control/relay room.

Substation Area

The fenced area offers some extension possibilities, however these have mainly been reserved for UETCL's future developments.

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 separate chapter in this report.

No Interconnection Project related facilities exist; however, the system can be extended to cover NELSAP needs.

3.3.3.1.3. *NELSAP SCOPE*

The proposed scope of NELSAP project outlined in detail in drawings

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consists of the following:

132 kV switchgear

Extension of the existing 132 kV switchgear is proposed.

Currently the busbar structure in Mbarara North is of flexible single busbar system, which cannot be extended to double busbar system. From interconnection system point of view, double busbar would not, however, bring additional reliability since the connection is only a single circuit and there is only one radial 132 kV feeder to Mbarara substation. Therefore, extension of the existing single bubsbar system is sufficient for the time being.

The busbar should be extended to accommodate two 132 kV interconnection feeders out of which only one would be equipped in this stage. These two bays could be reconfigured to interbus transformer feeder bays once the 220 kV system reaches Mbarara, Mbarara 220 kV substation has been built and the interconnection feeder re-connected to the new 220 kV switchgear and taken in to 220 kV service.

To facilitate the above, the extension of the 132 kV busbar should be constructed diagonally to the existing one and tubular busbars should be used. This would provide simple yet practical interconnection possibilities to the future 220 kV switchgear with minimum land acquisition. Furthermore, the arrangement would leave extension possibilities for three feeders in to the existing part of the 132 kV busbar.

In addition the switchgear extension consists of:

- 1 set of 132 kV OHTL feeder bay (to Mirama) for single busbar system (tubular busbars). The circuit breakers shall have single pole tripping facility.

Transformers

None.

Reactive power compensation equipment

None.

Auxiliary Systems

Existing auxiliary systems should be extended as appropriate. Sufficient capacity, however, is available within the existing systems.

Control Building

Sufficient space and facilities are available for NELSAP project needs within the existing building.

Substation Area

The present substation plot is nearly sufficient for the proposed 132 kV switchgear extension, however, not quite. Additional land, ca. 5000 m2 (11 m x 45 m) should be obtained by UETCL next to the existing plot.

132 kV Protection Systems

Even though the interconnection circuit would initially be operated in 132 kV level, it is recommended to take the future up-grade to 220 level in to consideration already in this stage and provide the feeder with 220 kV protection system which could be re-located and re-utilized once 220 kV substation has been built while 132 kV line protection system would become obsolete.

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 is 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 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 MUX equipment should be planned.

Under voltage tripping facility should also be provided and over voltage protection should be considered due to possible future non-switched shunt reactors on line side.

Busbar Protection

There is no busbar protection at Mbarara North substation at the moment. Busbar faults will be cleared by distance protection second zones at remote stations as well as by reverse zone at local station.

<u>Control System</u>

Existing control system should be extended in line with the adapted practices in existing control system installations.

(For detail see Chapter SCADA and teletransmission).

3.3.3.2. MIRAMA SUBSTATION

3.3.3.2.1. GENERAL

The substation is a new facility to cover the Uganda-Rwanda Interconnection requirement as well as the local distribution needs. The altitude of facilities would be 1410 m.

3.3.3.2.2. EXISTING FACILITIES AT MIRAMA

None

3.3.3.2.3. NELSAP SCOPE

The proposed scope of NELSAP project outlined in detail in drawings

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consists of the following:

<u>132kV switchgear</u>

Construction of a complete new 132 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 is proposed for Mirama 132 kV switchgear, however, at the present stage only one of the busbars is recommended to be implemented (space reservation for the second busbar) as the interconnection is a single circuit configuration.

The busbar provided under NELSAP scope should accommodate five 132 kV bays (feeders to Mbarara and Birembo, spare feeders to Mbarara and Birembo and future bus coupler).

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.

Thereafter, the switchgear consist of :

- 2 sets of 132 kV OHTL feeder bays (Mbarara North 1 and Birembo 1) for double busbar system (tubular busbars). The circuit breakers shall have single pole tripping facility.
- 2 sets of space reservations for 132 kV OHTL feeder bays (Mbarara North 2 and Birembo 2)
- 1 no of space reservation for 132 kV bus coupler bay (busbar 1 VTs and earthing switches, however, to be provided at this stage)
- 132 kV control building with AC and DC auxiliaries and with space reservation for future extensions by UETCL including space for 33 kV distribution indoor switchgear

It is to be noted, that UETCL intends to further extend the 132 kV switchgear by two 132/33 kV network supply transformer feeder bays as well as with two OHTL feeder bays within a scope of another project. Most likely at least one of the 132/33 kV transformers and the related 33 kV distribution switchgear would be realized simultaneously with NELSAP project implementation.

Transformers

None.

Reactive power compensation equipment

None.

Auxiliary Systems

Complete, new auxiliary systems are needed for the 132 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 neighboring LV distribution network. Provision for infeed from station supply transformer (provided under another project) should be included.

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

All auxiliary systems should be dimensioned to cover the known future extension requirements.

Control Building

A new, air conditioned control building to house the 132 kV switchgear secondary and auxiliary systems should be provided.

Space reservations to cover the known future extension requirements -including the 33 kV distribution indoor switchgear- should be considered.

Substation Area

The required plot size for the new station -including know future extension plans- is ca. 125 x 145 m, i.e. 18,125 m2. This includes the future 220 kV switchgear as well. The actual plot needed for the 132/33 kV substation in about 8,200 m2. The land has already been acquired by UETCL.

132 kV Protection Systems

Even though the interconnection circuit would initially be operated in 132 kV level, it is recommended to take the future up-grade to 220 level in to consideration already in this stage and provide the OHTL feeders with 220 kV protection system which could be re-located and re-utilized once 220 kV substation has been built while 132 kV line protection system would become obsolete.

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 is 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 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 due to possible future non-switched shunt reactors on line side.

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. However, since the second busbar has not been recommended to be implemented at this stage, a single zone protection would be sufficient with provision for future up-grade to double zone. Known future extensions to 132 kV switchgear should be considered.

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 separate chapter in this report.

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 detail 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 has the necessary communication interface and protocol support available as standard option.

3.3.4. BIREMBO SUBSTATION

3.3.4.1. DESIGN CRITERIA

In general, stations are designed according to the needs of energy planned for 2030. The drawings show thus the installations envisaged within the framework of this mandate of NELSAP, in are added the future installations which will be necessary in 2030.

The transformers for supplying circuits of medium voltage distribution as well as the transformers are dimensioned according to criterion of N-1 reliability. Thus stations, in 2030, will be able always to compromise the necessary total power despite the loss of one of their power transformers.

High voltage capacitor banks consist of groups of capacitor shunt which can be individually ordered by the operators in order to maintain bars voltage inside the limits of operation voltage. Each group of capacitor shunt comprise a disconnecting isolation switch as well as a high voltage circuit breaker to command and protect this group of capacitors. In addition, a main circuit breaker protects capacitor banks busbars as well as all capacitor shunt groups. In shifting This main circuit breaker allows to protect capacitor shunt groups at the time of a failure of capacitors groups circuit breaker or protection failure . This permit to avoid the setting out of network tension. All circuit breakers of capacitor shunt group as well as main circuit breaker must have an unipolar command/ and must be able to be operated in sequence to limit the currents ringing capacitor banks.

3.3.4.2. ENVIRONMENTAL CHARACTERISTICS AT BIREMBO SUBSTATION

Ambient air temperature	**Indoor**	**Outdoor**
Maximum	35°C	+ 35°C
24 hour average, max		+ 21°C
Minimum	+5°C	+5°C
Humidity	90 %	100 %
Seismic Acceleration	0.1 g	
Isoceraunic Level	150	

3.3.4.3. ELECTRICAL CHARACTERISTICS AT BIREMBO SUBSTATIONS

220/245 kV Substation :

Maximum operating voltage	145 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	1050/1050 kV peak (internal/external)
Rated power-frequency short duration withstand voltage	460/460 kV (internal/external)
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	25 mm/kV

Proposed 110 (123) kV system:

Maximum operating voltage	123 kV, 3-phase, 50 Hz
Neutral earthing	Solidly earthed
Impulse withstand voltage	650/650 kV peak (internal/external)
Rated power-frequency short duration withstand voltage	275/275 kV (internal/external)
Short-circuit withstand ability	31.5 kA, 1 s/ 80 kA
Creepage distance	25 mm/kV

3.3.4.4. BIREMBO SUBSTATION DESCRIPTION

3.3.4.4.1. GENERAL

The Birembo substation is a new substation that will be built by Electrogaz on the outskirts of Kigali. At final stage, it will become the main substation of the Electrogaz grid and the main feeder substation for the Kigali distribution system. Altitude of the substation is 1 600 m.

3.3.4.4.2. ELECTROGAZ SCOPE

110 kV switchgear

The Birembo substation will be operating for a certain period of time before the construction of the Uganda – Rwanda interconnection. The following items will be provided by Electrogaz.

1. 110 kV switchgear

A double busbar system with one bus installed, AIS switchgear, and provision for a second busbar system;

One line bay, from Jabana substation;

One line bay, to Gasogi substation, complete with the installation of 110/70 kV transformer previously installed at Jabana;

One transformer bay;

One future transformer bay;

One future line coupler;

Future bays for reactive power compensation.

2. Transformers

One 110/70 kV, 10 MVA autotransformer, Ynyno with solidly grounded neutral;

One 110/15 kV, 20 MVA transformer, YNynod11, with high voltage and low voltage neutral solidity grounded;

Two 110/15 kV, 20 MVA future transformers.

3. Reactive Power Compensation Equipment

There is no power compensation equipment presently planned at the substation. All required reactive compensation must be added by Electrogaz. Electrogaz, however, will have the responsibility to increase the power factor on the power transformer secondary to 0,95 seconds (criteria described in Volume 6).

4. Auxiliary Systems

All required auxiliary system will be provided by Electrogaz.

5. Control Building

Electrogaz must provide enough space in the substation control building for any additional control boards, relay panels, and telecommunication equipments required for the new 220 kV interconnection initially operated at 132 kV controlled by the high voltage shunt capacitors and all future equipment to be installed. Space should also be planned for the future double circuit 220 kV interconnection between Uganda and Rwanda.

6. Substation Area

Substation area will be obtained by Electrogaz.

3.3.4.4.3. PLANNED WORKS WITHIN THE NELSAP CONTEXT

When it will be completed to satisfy the assumed demand in 2030, the 220 kV part of Birembo substation will be composed of a double set of busbars comprising a circuit breaker. Three transformer spans of 75/93.8MVA will be connected to that set of bars for a total power of 281.3MVA.That power will be transmitted via four line starting-points to the Mirama and Rusumo falls substations.

Within the present NELSAP mandate, it will be installed one 220kV set of bar on which it will be connected a new 220kV line span that will be initially operated at 132kV. A span with auto-transformer 220.kV-132/110kV is needed to interconnect the 132kV Ugandan net work and the 110kV Electrogaz net work. The 110kV set of bar will also have to be completed so as to carry out that interconnection. A capacitor bank will be connected to the 110 kV bus bars.

The new 220kV line span (initially operated at 132kV), from the Mirama substation, will be composed of:

- Lightning arresters;
- 132 kV voltage transformers for measuring and protection;
- A communication link by optical fibre;
- A 220 kV line disconnect with grounding disconnect;
- 220 kV current transformers for measuring and protection;
- A 220kV circuit breaker;
- Two 220 kV busbar dividers disconnects (a future one included).

The new bay with auto-transformer 132-220/110kV connecting the 110kv double busbars to the 220kV double busbars will be composed of:

- Two busbar disconnects (a future one included) 220kV;
- Current transformers for measuring and protection 220kV;
- A 220kV circuit breakers;
- One (1) auto-transformer 132-220/110 kV, 75/93.8MVA, YNynod11, with solidly earthed neutral;
- Lightning arresters;
- 110 kV current transformers for measuring and protection;
- A 110kV circuit breakers;
- 110 kV equipment;

The 110 kV capacitor bay includes:

- Three pantograph type busbar disconnect switch including one for the future;
- One typical 110 kV disconnect switch;

- Two 110 kV circuit breakers;
- 110 kV current transformers for measuring and protection;
- A capacitor bank with reactors and voltage transformers.

3.3.4.4.4. FUTURE INSTALLATIONS

To satisfy the assumed demand in 2030, the 220kV section of Birembo substation will be composed of three bays for additional lines, a second set of busbars with circuit breaker, two new transformer bays and additional 110 kV capacitor banks. The lightning arresters and the voltage transformers of the first line bay will be replaced by 220kV equipment. The three 120 kV lightning arresters temporarily installed on the 220kV sets of bars will have to be withdrawn.

The first 220kV bus set will have to be completed and the second one will have to be installed, including the bus coupler which is composed of:

- A 220kV circuit breaker;
- 220 kV current transformers for measuring and protection;
- Two bus disconnects 220kV.

The three additional line bays will be composed, for each one, of:

- Lightning arresters;
- 220 kV Voltage transformers for measure and protection;
- A communication link by optical fibre;
- A 10 MVAR shunt reactor of 10MVAR with 220kV disconnect and neutral reactor;
- A 220 kV line disconnect and grounding disconnect;
- 220 kV current transformers for measuring and protection;
- A 220kV circuit breaker;
- Two bus disconnects 220kV;

Two additional transformer bays will also be required; each one will be composed of:

- Two 220kV bus disconnects;
- 220 kV current transformers for measuring and protection;
- A 220kV circuit breaker;
- An auto-transformer 220kV/110, 75/93.8 MVA, YNynod11, with solidly earthed neutral;
- Lightning arresters;
- 110 kV current transformers for measuring and protection;
- A 110kV circuit breaker.

An additional 110 kV capacitor bay will be required, this bay will include :

- One pantograph type bus bar disconnector switch;
- One 110 kV circuit breakers;
- 110 kV current transformers for measuring and protection;
- A capacitor bank with reactors and voltage transformer.

3.3.4.4.5. REFERENCE DRAWINGS

INTERCONNECTION OUGANDA-RWANDA R P BI 001 0
Poste Birembo Substation
Unifilaire / Single line diagram

INTERCONNECTION OUGANDA-RWANDA R P BI 002 0
Poste Birembo Substation
Vue en plan / Plan view

INTERCONNECTION OUGANDA-RWANDA R P BI 003 0
Poste Birembo Substation
Coupes / Sections

3.3.4.4.6. ELECTRIC PROTECTION EQUIPMENT

Since the two new organizations for gathering installations of electric production of concerned regions is "Central African Power Pool" (CAPP) and "East African Power Pool" (EAPP) are formed than in 2003 and 2005 respectively, norms and guides concerning networks planning and equipment protection are not always available. For this reason, it was decided to base our criteria of conception for equipment protection on criteria of planning included in guide entitled "network code" which is part of document entitled "South African Grid Code". As it is defined in that guide, the equipment having nominal tension equal and less than 132 KV has its proper requirements of electric protection, whereby the equipment having a nominal tension equal or more than 220 KV has also its proper criteria of electric protection which are very exigent.

3.3.4.4.6.1 REQUIREMENTS FOR THE ELECTRIC PROTECTION OF EQUIPMENT HAVING A TENSION WHICH IS EQUAL OR LOWER THAN 132KV

Equipment having a nominal voltage equal or lower than 132 KV must be protected by a primary protection system including a remote or differential protection. A secondary protection to maximum of current and groundphase and delayed at definite or opposite time (IDMT) must also be included.

Protections of lines having a nominal voltage equal or higher than 110 KV must include a function of reset, single-phase current and three-phase current, while the arteries of distribution require only one function of three-phase reset.

i) Requirement for electric protection of equipment having a voltage equal or more than 220 KV

Equipment having a nominal voltage equal or more than 220 KV of new installations or installations which need major modifications must be protected by two equivalent primary protections, protection "A" and protection "B". Protections "A" and "B" must be completely separated and supplied by the voltage rolling-up and independent current as well as two systems of battery of independent accumulators.

A secondary protection delayed to maximum of current of phase and of ground must be incorporated in primary protection or installed separately for palliate in possible weakness of ground default detection having a high ground resistance

ii) Line protection

Birembo-Mirama-Mbarara line will be designed for an operational tension of 220 KV but will be initially operated with a tension of 132 KV. Since this line is designed for a nominal voltage of 220 KV, requirements for equipment having a tension equal or more than 220 KV apply. Since these lines will have a second double system lines later. and that to maintain the synchronization of networks, releases and resets single-phase currents are required, protection must meet a very high level of reliability. In order to meet these raised requirements, the two following primary principles of protection are recommended.

A) The first protection consists of a differential longitudinal protection of line. In order to detect defects with the ground having a raised ground resistance, delays of protection must include an accelerated directional protection of phase and ground. A protection of distance of release must also protect the equipment during telecommunication defects.

B) The second protection consists of an accelerated protection of distance including a minimum of three steps. In order to detect defects to the ground having a raised ground resistance, an accelerated directional protection of phase and ground is necessary to identify defects to the ground of three-phase defects. A minimum of four telecommunication channels are necessary. Identification of phases is particularly critical at the time of localized defects close to bars on lines of double double system lines.

3.3.4.4.6.2 DIFFERENTIAL PROTECTION OF BAR

At the initial stage no bar protection was necessary on the 220 KV bar. During the additional applying voltage two differential protections of independent bars will be necessary. Protections distributed to low impedances of two different manufacturing are recommended.

The 110 KV bar must include a bar protection distributed to low impedance.

3.3.4.4.6.3 PROTECTION OF 132-220/110 KV AUTO-TRANSFORMER

The 132/220/110KV auto-transformer must include two differential primary protections as well as a minimum of secondary protection of phase and ground over current.

3.3.4.4.6.4 PROTECTION OF CAPACITOR BANKS

Condensation banks must include following protections:

- An phase and ground over current protection;
- An opposite sequence over current protection;
- A differential protection of power to detect balancing due to capacitor defects;
- A over power relay
- An over loading protection.

3.3.4.4.6.5 FAILURE OF CIRCUIT BREAKER AND DISCORDANCE

Each circuit breaker must include a failure protection as well as a discordance protection of phase.

3.3.4.4.7. CONTROL SYSTEM

The order of Rwegura and Kigoma substations must be locally accessibly to the following places:

i) local panel

A local control panel localized near each apparatus of high voltage such as the circuit breakers, disconnecting switches and power transformers will be provided with each one of these high voltage apparatus.

ii) Bay panel control

Each line bay, bar, inductance shunt, capacitor shunt and power transformer must include a control panel located in the station control room. Each one of these panels must include a synoptic comprising push buttons and switches for manual and local operations of the station.

iii) centralized order Center

A computerized control system is at present included at Birembo substation. The bay control units will communicate directly with existing computer system. A network of Ethernet type with speed of 100 MB/s, and in conformity CEI 61850-8 standard is proposed.

3.3.5. 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 Rwanda involves two RTUs (or Substation Control Systems - SCS), Mirama and Mbarara North.

For Mirama, a new SCS or RTU required. In case of an SCS (Substation Control System with gateway to NCC), an RTU is not required. SCS is recommended in line with the recommendations for the protection and control for the Mirama substation.

In Mbarara North 132/33 kV substation, there is an existing RTU of type ABB RTU 400. For the 132 kV extension of Mbarara North, there are two alternatives for RTU:-

- Alt. No. 1. Extension of the existing 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 RTU. In this alternative, the I/O modules of the replaced RTU could be used for extensions and spare parts at other substations, e.g. in the extension of the RTU for Tororo 132.

Alt. No. 2 is recommended.

In addition, the option for having a two port RTU or SCS at Birembo, polled by both the Ugandan NCC and the future Rwandan NCC, should be considered. Once the latter NCC has been implemented, the best option at that time will be an ICCP-link between the two control centres.

Summarised scope:

NELSAP project

- Provision of an SCS for Mirama;

Replacing the RTU at Mbarara North.

3.3.6. TELECOMMUNICATIONS

The existing services using telecommunications between UETCL and ELECTROGAZ are:

- None

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

- Teleprotection
- ICCP link (at 2 Mbits/s) (in future)
- Operational telephone
- Hot line between control centres (Lugogo NCC – Rwanda NCC)
- Polling of Birembo RTU or SCS by the Ugandan NCC in Lugogo (optional).

The Rwandan NCC above refers to the location from where the generation and transmission facilities are centrally controlled.

The telecommunications media is proposed to be fibre optic (OPGW) link on the 132 kV interconnection Mbarara North - Mirama - Birembo, 24-core, single mode.

3.3.6.1. UGANDA TELECOMMUNICATIONS

The backbone telecommunications network is based on optical fibre links (OPGW and Wrap), 24-core single mode. UETCL has completed the extension of the optical fibre network towards western region, i.e. to Masaka West and Mbarara North. Optical fibre terminals, at, among others, Lugogo and eventually Mbarara North, 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, an optical fibre terminal is required at Mirama. The optical fibre terminal at Mbarara North should be upgraded to establish the fibre optic link to Mirama. The routing through from Mirama 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).

Mirama is proposed to be a remote subscriber of the PAX of Mbarara North. Also Birembo is proposed to be a remote subscriber of the PAX of Mbarara North. As regards the Rwandan NCC (for the time being, without computerised control), there should be a hot line from the Ugandan NCC in Lugogo to the Rwandan NCC:

Summarised scopes:

Separate UETCL project

- Supply of an optical fibre terminal at Mbarara North.

NELSAP project

OPGW on the 132 kV interconnection Mbarara North – Mirama – Biremobo;

- Supply of an optical fibre terminal at Mirama;
- Routing the Mirama RTU data to Lugogo NCC;
- Routing the Biremobo RTU data to Lugogo NCC (optional);
- Routing the hot line from NCC in Lugogo through Mirama onwards to Birembo;
- Arranging Mirama as remote subscriber of Mbarara North exchange;
- Arranging Birembo as remote subscriber of Mbarara North exchange.

3.3.6.2. PROPOSED TELECOMMUNICATION SYSTEM

An optical fibre communication network must be installed to transmit data, telephone calls and teleprotection channels between the Kigoma and Rwegura substations and, subsequently, the Mirama and Mbarara substations. The communication system must be designed to meet current and future communication needs. However, no predictions are made as regards needs to transmit information other than that required to operate the future integrated high-voltage transmission network that is the subject of this project.

The communication system will be based on the SDH (Synchronous Digital Hierarchy) principle. SDH optical multiplexing devices will have to be capable of both multiplexing and receiving signals. All the communication device access points will have to be redundant and enable operation in 1 + 1 protected mode when used for point-to-point links. On the other hand, “East/west” mode will have to be used when they are integrated into a chain link.

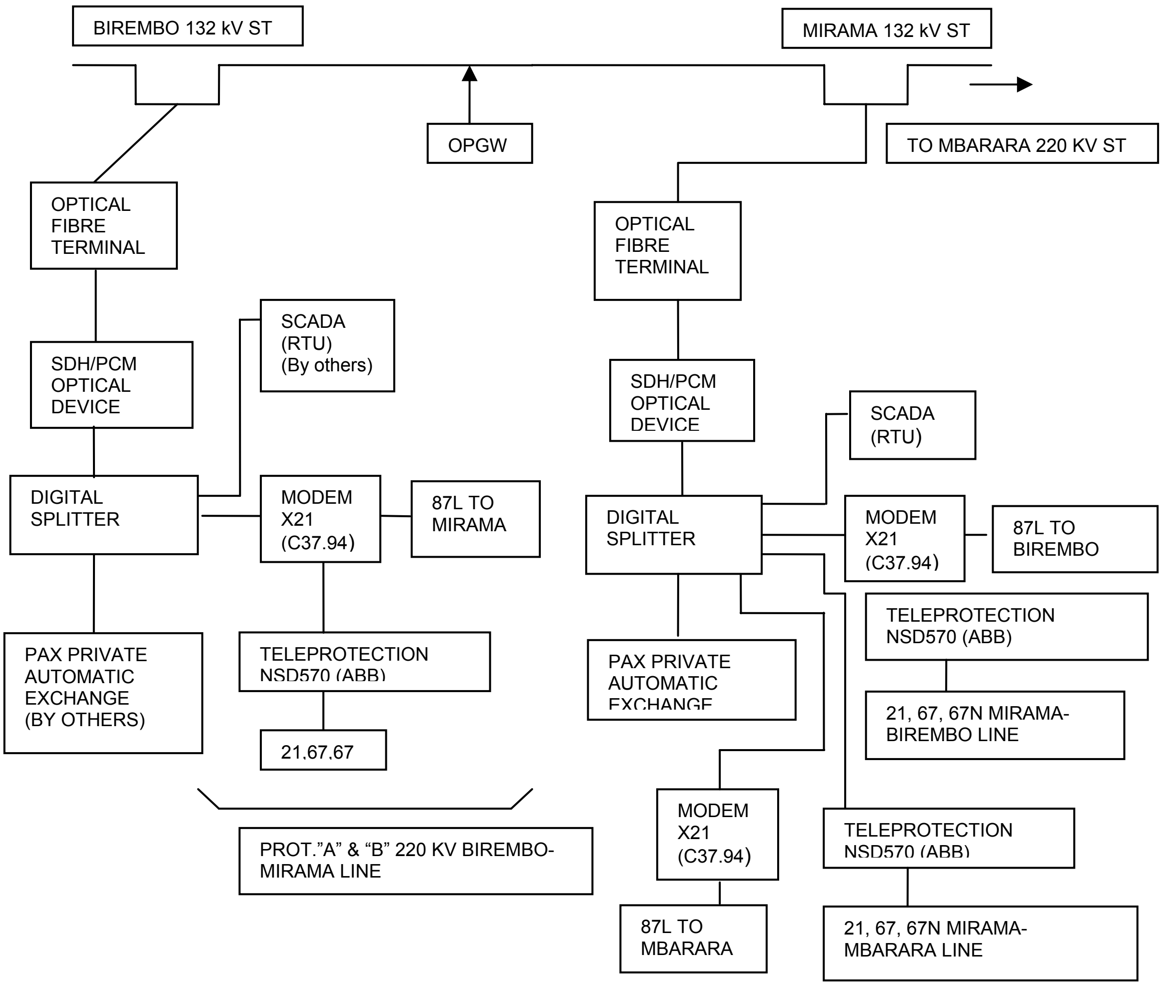


Figure 3-1

Functional block diagram of the proposed optical fibre communication network between Birembo, Mirama and Mbarara

The essential items required to operate the communication system include the workstations, the wide area network (WAN) routers and the local area network (LAN) routers.

SDH optical fibre terminals, telephones, telephone switchboards, teleprotection equipment and wiring must be added at Birembo, Mirama and Mbarara substations. A new PAX private automatic exchange and DC power supplies (charger and 48 V battery) must be added at the Mirama substation. This equipment exists at the existing Birembo and Mbarara substations, and was supplied by Électrogaz and UETCL. Only the interfaces required to connect the new equipment must be supplied.

3.3.6.2.1. STANDARDS

The equipment and hardware designs must comply with IEC standards, CCITT (International Telegraph and Telephone Consultative Committee) recommendations and ITU-T ETSI SDH standards.

3.3.6.2.2. PDH/SDH OPTICAL MULTIPLEXING EQUIPMENT

In order to maximise equipment availability, the following protection functions must be included:

- power supplies and control units must be redundant
- optical fibre telecommunication traffic protection must be based on a redundant system.

The teleprotection interfaces must be integrated into the PDH/SDH multiplexer.

3.3.6.2.3. TELEPROTECTION INTERFACES

These interfaces must be capable of transferring four two-way channels in compliance with IEC standard 834-1. It must also be possible to synchronise them with a GPS station.

3.3.6.2.4. PAX PRIVATE AUTOMATIC EXCHANGE

The PAX private automatic exchange at Birembo is supplied by Électrogaz and must include at least a 2 MB interface card.

3.3.6.2.5. TELEPHONE

All the telephones required will be installed in the substation courtyard.

3.3.6.2.6. DIGITAL SPLITTER

A digital splitter will be included in each of the substations mentioned above.

3.3.7. SCADA/EMS

The interconnection will be Mbarara North – Mirama – Birembo, initially at 132 kV. Mirama will be located on the Ugandan side of the border. Birembo will be located near Kigali. The 132/110 kV transformation to the 110 kV system voltage in Rwanda will be done in Birembo.

3.3.7.1. PROPOSED OPERATION OF INTERCONNECTION

In general, the operation of power systems with interconnections to neighbouring countries should fulfil 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 centres.

In the Uganda – Rwanda 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.

It is also essential for successful joint operation to agree on all organisational 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 centres, 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:

- Review and amend the operational issues in the power exchange agreement;

- Recommend models for organisations 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, Uganda (supported by Kenya) being the larger system should have the main responsibility for frequency control, while Rwanda should maintain the tie-line flows within agreed limits.

For the time being, there is no computerised control centre system in Rwanda. In the long run, once a computerised control centre has been established in Rwanda, for optimal management and operation, data exchange between the two national control centres is required, for two reasons:

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

The data exchange should be implemented on Intercentre 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.

3.3.7.2. UGANDA NATIONAL CONTROL CENTRE

The Uganda National Control Centre (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, 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 Uganda - Rwanda, the system was equipped with Intercentre Communication Protocol (ICCP - TASE.2). The procurement included a licence for one ICCP data exchange partner, KPLC. Another licence can be procured once a computerised control centre has been established in Rwanda.

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).

Summarised scopes:

None

oOo

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. UGANDA

Tableau n° 3 - LINE PARAMETERS - MBARARA - MIRAMA

Line length	57 km
Voltage level	220 kV
Circuits	2
Number and type of phase conductors	2 ACSR HAWK
Number and type of ground wires	1 GSW 70 + 1 OPGW 44
Insulators	U 120 BS
Average span length	350 m
Number of towers	174

Tableau n° 4 - LINE COST MBARARA - MIRAMA

Description	Cost/km	Total Cost
1. General works	3 496 $	199 272 $
2. Foundations	15 266 $	870 162 $
3. Earthing	2 641 $	150 537 $
4. Towers	61 241 $	3 490 737 $
5. Tower tests (included in Mirama-Birembo)		0 $
6. Insulator and accessories of conductors (1 circuit)	7 680 $	437 760 $
7. Ground wire and optical fibre ground wire accessories	2 128 $	121 296 $
8. Conductor and ground wire (1 circuit)	48 221 $	2 748 597 $
9. Spare parts	3 037 $	173 109 $
SUB-TOTAL	143 710 $	8 191 470 $
10. Management and quality assurance of works (6%)	8 623 $	491 488 $
11. Contingency (10%)	14 371 $	819 147 $
TOTAL : (1 circuit installed)	**166 704 $**	**9 502 105 $**

Installation of 2nd circuit		
1. Insulator and accessories of conductors (1 circuit)	7 680 $	437 760 $
2. Conductor	39 937 $	2 276 409 $
SUB-TOTAL	47 617 $	2 714 169 $
3. Management and quality assurance of works	9 523 $	542 834 $
4. Contingency	4 762 $	271 417 $
TOTAL : (2nd circuit installed)	**61 902 $**	**3 528 420 $**
TOTAL : (Both circuit installed)	**228 606 $**	**13 030 525 $**

Mirama – Rwanda Border

A detailed analysis of costs has been done for the line connecting Mirama to the border. The analysis includes direct and indirect costs. The line characteristics are summarized in the following table:

Tableau n° 5 - LINE PARAMETERS

Longueur de la ligne (estimée)	9 km
Niveau de tension	132/220 kV
Circuit	Double
Nombre et type de conducteurs par phase	2 - ACSR HAWK
Câbles de garde	CGFO : ITU-T-G652 CG : GSW 70
Portée équivalente	350 m
Nombre de pylônes	25

4.1.2. RWANDA

The following table presents the cost for different items. A more detailed table is presented in annex.

Tableau n° 6 - LINE COST MIRAMA – RWANDA BORDER (USD)

Description	Cost/km	Total Cost
1. General works	3 496 $	31 464 $
2. Foundations	15 266 $	137 394 $
3. Earthing	2 641 $	23 769 $
4. Towers	61 241 $	551 169 $
5. Tower tests	2 256 $	20 304 $
6. Insulator and accessories of conductors (1 circuit)	7 680 $	69 120 $
7. Ground wire and optical fibre ground wire accessories	2 128 $	19 152 $
8. Conductor and ground wire (1 circuit)	48 221 $	433 989 $
9. Spare parts	3 037 $	27 333 $
SUB-TOTAL	145 966 $	1 313 694 $
10. Management and quality assurance of works (6%)	8 758 $	78 822 $
11. Contingency (10%)	14 597 $	131 369 $
TOTAL : (1 circuit installed)	**169 321 $**	**1 523 885 $**

Installation of 2nd circuit		
1. Insulator and accessories of conductors (1 circuit)	7 680 $	69 120 $
2. Conductor	39 937 $	359 433 $
SUB-TOTAL	47 617 $	428 553 $
3. Management and quality assurance of works	9 523 $	85 711 $
4. Contingency	4 762 $	42 855 $
TOTAL : (2nd circuit installed)	**61 902 $**	**557 119 $**
TOTAL : (Both circuit installed)	**231 223 $**	**2 081 004 $**

4.1.3. RWANDA

Ugandan Border - Birembo

A detailed analysis of costs has been done for the line connecting Birembo to Mirama. The analysis includes direct and indirect costs. The line characteristics are summarized in the following table:

Tableau n° 7 - LINE PARAMETERS

Line length	106 km
Voltage level	132/220 kV
Circuits	2
Number and type of phase conductors	2 – ACSR HAWK
Number and type of ground wires	CGFO : ITU-T-G652 CG : GSW 70
Insulators	U 120 BS
Average span length	350 m
Number of towers	289

The following table presents the cost for different items. A more detailed table is presented in annex.

Tableau n° 8 - LINE COST UGANDAN BORDER – BIREMBO (USD)

Description	Cost/km	Total Cost
1. General works	3 496 $	370 576 $
2. Foundations	15 266 $	1 618 196 $
3. Earthing	2 641 $	279 946 $
4. Towers	61 241 $	6 491 546 $
5. Tower tests	2 256 $	239 136 $
6. Insulator and accessories of conductors (1 circuit)	7 680 $	814 080 $
7. Ground wire and optical fibre ground wire accessories	2 128 $	225 568 $
8. Conductor and ground wire (1 circuit)	48 221 $	5 111 426 $
9. Spare parts	3 037 $	321 922 $
SUB-TOTAL	145 966 $	15 472 396 $
10. Management and quality assurance of works (6%)	8 758 $	928 344 $
11. Contingency (10%)	14 597 $	1 547 240 $
TOTAL : (1 circuit installed)	**169 321 $**	**17 947 979 $**

Installation of 2nd circuit		
1. Insulator and accessories of conductors (1 circuit)	7 680 $	814 080 $
2. Conductor	39 937 $	4 233 322 $
SUB-TOTAL	47 617 $	5 047 402 $
3. Management and quality assurance of works	9 523 $	1 009 480 $
4. Contingency	4 762 $	504 740 $
TOTAL : (2nd circuit installed)	**61 902 $**	**6 561 623 $**
TOTAL : (Both circuit installed)	**231 223 $**	**24 509 602 $**

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. MBARARA NORTH SUBSTATION

The total estimated cost for the construction is USD 1,117,100. The costs spread over various facilities as follows:

Tableau n° 9 - MBARARA SUBSTATION COST

Items	Price Foreign Currency (in USD)
132 kV Switchgear	287,000
Control, Protection and Auxiliaries	185,500
SCADA and Tele (incl' NCC works)	113,900
Civil and Mechanical works	252,100
Erection and Installations	147,400
Spare Parts	29,500
Contingency (10%)	101,600
Total Substation	**1,117,100 USD**

All figures are in USD. Engineering, project management and training costs have been included in material costs.

4.2.2. MIRAMA SUBSTATION

The total estimated cost for the construction is USD 2,457,100. The costs spread over various facilities as follows:

Tableau n° 10 - MIRAMA SUBSTATION COST

Items	Price Foreign Currency (in USD)
132 kV Switchgear	547,700
Control, Protection and Auxiliaries	673,800
SCADA and Tele (incl' NCC works)	36,200
Civil and Mechanical works	651,700
Erection and Installations	280,100
Spare Parts	44,100
Contingency (10%)	223,400
Total Substation	**2,457,100 USD**

All figures are in USD. Engineering, project management and training costs have been included in material costs.

Note : Additional equipment by UETCL and distribution : two transformers 10 MVA, 132/32 kV, two cells 132 kV, 33 kV equipment and control building.

4.2.3. BIREMBO SUBSTATION

The total estimated cost for the construction is USD 4,364,204. The costs spread over various facilities as follows:

Tableau n° 11 - BIREMBO SUBSTATION COST

Item No.	Items	Price Foreign Currency (in USD)
1	LIGHTNING ARRESTER	$ 34 860
2	CAPACITIVE VOLTAGE TRANSFORMER	$ 67 320
3	DISCONNECTOR	$ 126 510
4	CURRENT TRANSFORMER	$ 231 114
5	CIRCUIT BREAKER	$ 475 340
6	POWER TRANSFORMER / REACTIVE COMPENSATION	$ 1 506 108
7	BUS BARS & ELICTRICAL CONNECTIONS	$ 65 600
8	FIBRE OPTIQUE COMMUNICATION/PLC	$ 181 591
9	JUNCTION BOXES	$ 49 284
10	MONITORING, CONTROL AND PROTECTION PANELS	$ 194 340
11	GALVANIZED STRUCTURES	$ 145 920
12	RTU/SCADA INTERFACE PANEL	$ 11 540
11	EARTHING SYSTEM	$ 62 394
12	GROUND WIRES	$ 9 612
13	MISCELANEOUS	$ 110 883
14	CIVIL WORKS	$ 457 670
15	SUB – TOTAL	$ 3 730 089
16	WORK SUPERVISION (7%)	$ 261 106
17	CONTINGENCY (10%)	$ 373 009
18	**TOTAL SUBSTATION**	**$ 4 364 204**

4.2.4. FUTUR SUBSTATION EXTENSION (2013)

In accordance with the previsions, the interconnection will be exploited at 220 kV after 2013. It is proposed at this time, that the Mirama Substation would be loaded through a 220 kV interbus transformer interconnection. The following equipment should be installed.

Mbarana Substation
- Two 220 kV bays

Mirama Substation
- One 220/132 kV, 20 MVA autotransformer
- One 220 kV bay

Birembo Substation
- One 220 kV bay

Tableau n° 12 - COST OF FUTUR EXTENSIONS

Item	Description	BIREMBO Total $	MIRAMA Total $	MBARARA Total $
1,0	Lightning Arrester	34 860	87 150	34 860
2.0	Capacitive Voltage Transformer	100 980	67 320	100 980
3.0	Disconnecter	99 168	344 984	146 648
4.0	Current Transformer	50 190	150 570	66 920
5.0	Circuit Breaker	101 680	508 400	203 360
6.0	Power Transformer / Reactance	651 640	3 460 930	651 640
9.0	Junction Box	24 642	73 926	32 856
12.0	Control and Protection Pannel	144 750	512 390	241 420
18.0	Grounding	2 704	10 816	5 408
19.0	Overhead Ground Wire	2 704	10 816	5 408
20.0	Miscellaneous	21 673	97 202	43 346
21.0	Civil Works	175 375	400 000	200 000
22.0	Sous-total	1 410 366	5 724 504	1 732 846
23.0	Supervision (7%)	98 726	400 715	121 299
24.0	Contingency (10%)	70 518	286 225	86 642
25.0	Total (Supply and erection)	1 579 610	6 411 444	1 940 788
TOTAL GÉNÉRAL :		9 931 842 USD		

4.3. PROJECT SCHEDULE

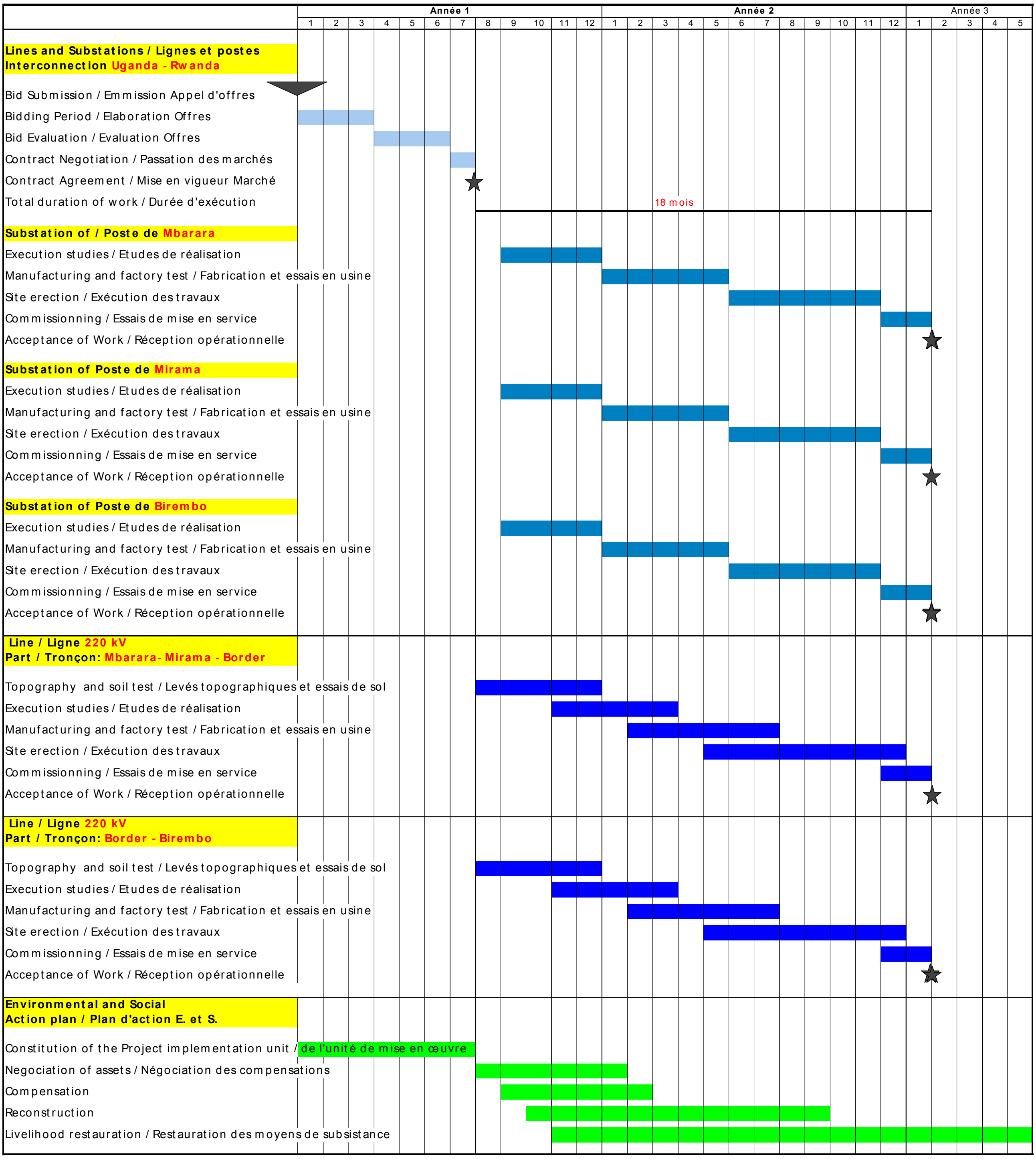
The project schedule includes the following main steps:

Bidding and Contract process

Line and Substation :

- Detailed studies
- manufacturing
- Site work
- Acceptance

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



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 3 covers the Rwanda-Uganda interconnection while Volume 2 is dedicated to the Uganda-Kenya interconnection. From Volume 1 analysis, it is noticed that the Rwanda-Uganda interconnection will be used a few years to export surpluses of the Kivu region to Uganda, which can consequently be exported to Kenya as well.

In the same way, and in the longer term, the Rwanda-Uganda link shall be primarily used to export Uganda surpluses to the Burundi-Rwanda-Congo system. But in case of shortage in Uganda and Kenya at this time, the Rwanda-Uganda link will also help bringing emergency electricity from Tanzania towards Uganda and eventually Kenya. For these reasons it is clear that the study of the Rwanda-Uganda interconnection is also linked to the possible options for the Uganda-Kenya interconnection.

Since there are obvious links between the three main interconnected systems, the overall approach for the Rwanda-Uganda 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:

5.1.1.3. 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:

5.1.1.3.1. *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.

5.1.1.3.2. *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.

5.1.1.4. 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 unfavorable 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 ton	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

RWANDA – UGANDA INTERCONNECTION

Voltage level:	132 kV or 220 kV
Length:	66 km (Uganda) + 106 km (Birembo)
Method of operation:	Exports B-R-C towards Uganda (case of production surplus in B-C-R) Imports from Uganda (following years)
Outgoing substation in Rwanda:	Birembo
Incoming substation in Uganda:	Mirama
Transit capacity:	50 MW to 150 MW base load, Alternative 1
	50 MW to 200 MW base load, 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 analyzed 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%.

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 (see Excel file in Annex).

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.

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: RWANDA-UGANDA

5.5.1. COST ANALYSIS

5.5.1.1. INVESTMENT COSTS

As indicated in the description of the proposed project, the future Rwanda-Uganda interconnection will be constituted by a Birembo-(Mirama)-Mbarara single, then double circuit line and associated substations, operated at 132 kV then 220 kV. It has been considered in the cost-benefit analysis, that this new link should become available in 2010 in a first phase, then 2013 in a second phase.

Based on Volume 3 project description, the following cost summary can be presented:

Costs in MUS$	2010		2013	
	Uganda	Rwanda	Uganda	Rwanda
Mirama – Mbarara line	9.84			
Mirama – border line	1.57			
Birembo – border line		18.4		
Mirama substation	2.46		6.42	
Mbarara substation	1.11		1.95	
Birembo substation		4.18		1.58
Total	**14.98**	**22.58**	**8.37**	**1.58**

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.

5.5.2. 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 Rwanda-Uganda 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$)	EIRR
Base Case	80	32%
Low Demand	62	135%
High Demand	170	38%
Discount Rate: 8%	108	N/A
Discount Rate: 12%	60	N/A
Fuel Costs: 80 US$/bbl	117	39%
Fuel Costs: 60 US$/bbl	44	26%

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 26%. 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. In this case, the above-mentioned NPV can be even increased by an estimated 15 MUS$ (if in 2017).

5.5.3. COST ANALYSIS FOR ALTERNATIVE 2

5.5.3.1. INVESTMENT COSTS

In the Alternative 2 a higher transfer capacity is considered as described in Alternative 1. The same investment sequence is considered, with the following costs:

Costs in MUS$	2010		2013	
	Uganda	Rwanda	Uganda	Rwanda
Mirama – Mbarara line	9.84			
Mirama – border line	1.57			
Birembo – border line		18.4		
Mirama substation	2.46		6.42	
Mbarara substation	1.11		1.95	
Birembo substation		4.18		1.58
Total	**14.98**	**22.58**	**8.37**	**1.58**

5.5.3.2. OPERATION AND MAINTENANCE COSTS

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

5.5.4. COST AND BENEFIT COMPARISON

The Net Present Value (NPV) of the Alternative 2 for the Rwanda-Uganda 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$)	EIRR
Base Case	90	65%
Low Demand	47	90%
High Demand	134	45%
Discount Rate: 8%	110	S. O.
Discount Rate: 12%	74	S. O.
Fuel Costs: 80 US$/bbl	137	75%
Fuel Costs: 60 US$/bbl	43	56%

The results are similar to the ones found for Alternative 1, but in this case most values are 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 25 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. UGANDA

5.6.1.1. 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 privatized in 2002 through a 20-year concession agreement with ESKOM Enterprises Ltd. Several IPPs are also present and there are 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 privatized 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 Rwanda-Uganda 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.

5.6.1.2. 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.

5.6.1.3. 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. 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.

5.6.2. RWANDA

5.6.2.1. STRUCTURE OF POWER SECTOR

ELECTROGAZ is a vertically integrated utility supplying electricity in Rwanda, which had a monopoly status over generation, transmission and distribution activities until Law N° 18/99 of 30/08/1999 formally abolished this status. Under this law, generation activities are open to private sector involvement and competition while ELECTROGAZ remains the single buyer and keeps its monopoly over transmission and distribution activities in principle until November 2008. ELECTROGAZ is therefore formally empowered to install and operate power lines and substations in the country, over public and private property.

The power sector is controlled by RURA, the Agency in charge of controlling public sectors in Rwanda (telecommunications, water, gas, electricity, transports and waste). This Agency was created in 2001. and started operating in 2003. Its main mandate is to promote efficient competition, in order to put an end to anti-competitive practices, in particular abuse of dominant position.

After November 2008, the operation in Rwanda of a future Rwanda-Uganda interconnection by a private or public-private company could be envisaged since the ELECTROGAZ monopoly should end. For this purpose, It would require a legal act setting up competition (to some extent) and free access to the national power networks. At this moment it is not clear whether it would be an amendment of the statutory power sector Laws, in particular Law N° 18/99, 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 3 years.

5.6.2.2. ELECTRICITY TARIFFS

As indicated in the Pre-Feasibility report and in Volume 1 of the Feasibility report, the prevailing tariff applied by ELECTROGAZ is a uniform, simple monomial cost per kWh over the country. Obviously, it is not suitable for the existence of separate transmission activities. In order to pave the way for competition in transmission and distribution, Rwanda will have to set up proper cost-reflective tariffs for these activities. This should be one of the priority tasks for RURA in the power sector. What could be recommended is to follow the general principles of the on-going evolution of the Kenyan power sector in this respect, in particular to grant free access to any point of the transmission network, allow deregulated sales of energy from generators to eligible customers (including possible future supply companies), and fix rules for transmission tariffs based on cost recovery plus reasonable profit margin.

5.6.2.3. GENERAL RULES ON INVESTMENT IN THE POWER SECTOR

At present, in all cases where private property must be used for power sector infrastructure and operation, ELECTROGAZ must compensate the owner, either under an agreed settlement or under a court decision. In the future case of presence of other transmission companies, the same should apply.

As in all sectors of Rwandan economy, foreign investors may invest and participate in the operation of any business of the country, and should enjoy incentives and facilities, no less favourable than those enjoyed by local investors (Art. 20 of the Law N° 19/98 which establishes the Rwanda Investment Promotion Agency, which is being revised). As mentioned before, the presence of RURA should also contribute to allow foreign investors to benefit from transparent investment rules and supply conditions.

5.6.3. RWANDA-UGANDA 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 ELECTROGAZ - UETCL ARRANGEMENT:

In this case, there would be an agreement between both companies (similar to the one governing the existing interconnection between Uganda and Kenya, for instance), 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 ELECTROGAZ 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 Uganda and Rwanda, with generators and large consumers / power suppliers having open access to the network. In both countries, some arrangements are needed in the legal framework, but it is achievable in a few years since the concerned Governments are committed 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 institutional set-up. 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 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 several types of exchanges of power from Rwanda to Uganda. In some periods, only reserve and/or peak load energy is provided by the interconnection; in other periods, full base load transfers are possible.

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%

Base load energy remuneration: 1.2 to 2 cents US$/kWh

Peak load energy remuneration 5 cents US$/kWh

Reserve remuneration: 0,1 MUS$/MW/annum

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 21% 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 30% per annum.

5.7. CONCLUSIONS AND RECOMMENDATIONS

- The Rwanda-Uganda 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 and in Burundi and Congo (DR).

- Although the amount of benefits depends 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 Rwanda-Uganda interconnection (together with the Uganda-Kenya interconnection) should bring other substantial generation and reserve benefits in neighboring countries in the future, in particular in Tanzania (and the rest of the SAPP system).
- 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.
- Although the project could be implemented together by UETCL and ELECTROGAZ, it is also possible to adapt the legal framework of the power sectors of Uganda and Rwanda in order to permit the operation of independent Transmission Systems Operators, with a corresponding adapted tariff system; in this case it 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.

ANNEX A – LINE ROUTE GENERAL MAP

ANNEX B –TOWER MODELS

ANNEX C – FOUNDATION MODELS

ANNEX D – SUBSTATIONS DRAWINGS

Single Line Diagrams and Lay out:
- Mbarara Substation
- Mirama Substation
- Birembo Substation

ANNEX E – SUBSTATIONS COST ESTIMATE

Mbarara Substation extension cost estimate
Mirama Substation extension cost estimate
Birembo Substation extension cost estimate

ANNEX F – ECONOMIC STUDIES

ANNEX G – DISTANCE TO GROUND AND DISTANCE TO EARTH

ANNEX H – INSULATOR STRINGS

ANNEX I – REFERENCES

UGANDA REFERENCES

Eastern African Sub Regional Support Initiative for the Advancement of Women (EASSI), (1999),. Women and Land Rights in Uganda.

Forest Department. Land cover (Land use) Stratification Map Mbarara district. 1: 150,000.

Forest Department. Land cover (Land use) Stratification Map Ntungamo district. 1: 70,000.

Government of Uganda, (2002.), Uganda Poverty Assessment Process Phase II Report

Government of Uganda, (2005),. Water and Sanitation Sector Performance Report.

Government of Uganda. 2002. Uganda Poverty Assessment Process Phase II Report.

Government of Uganda. 2005. Water and Sanitation Sector Performance Report.

Mbarara district, 2004. Environmental Profile.

Mbarara district, 2004. State of the Environment Report. 42 p.

Mbarara District, 2005. Three – Year District Development Plan (2005-2008) Mbarara District

Mbarara district, 2005. Three – Year District Development Plan (2005-2008).

Mbarara District. Land cover (Land use) stratification Map Mbarara District ; Scale 1: 150,000

National Environmental Management Authority of Uganda (NEMAU), 2003. Environmental Legislation of Uganda, 2003, NEMA.

Ntungamo District, 2005. Environmental Profile. -Ntungamo District, 2005.

Ntungamo District, 2005. Three – Year District Development Plan (2005-2008) Ntungamo District

Ntungamo District. Land cover (Land use) stratification Map Ntungamo District; Scale 1: 70,000

Okoth-Ogendo H W, (1998.) Implementing land legislation in Uganda.

Owanji Odida Irene, (11999). Land Law Reform: Challenges and opportunities of securing women's land right's in Uganda.

Uganda Bureau of Statistics (UBOS), (2000),. Uganda National Household Survey

United Nations Development Program (UNDP), (2005)),. Uganda Human Development report: Linking Environment to Human Development. A deliberate Choice

RWANDA REFERENCES

Bart F. 1993. Montagnes d'Afrique; Terres paysannes. Le cas du Rwanda. CEGET-CNRS, PUB (Espaces tropicaux n° 7). 588 p.

MINAGRI. 2001. Schéma Directeur d'Aménagement des marais, de protection des bassins versants et de conservation de sols. Schéma de vocation des sols des marais. Étude environnementale. 20 p.

MINECOFIN. 2000. La vision 2020. Kigali. 54 p.

MINECOFIN. 20021. Enquête intégrale sur les conditions de vie des ménages au Rwanda.

MINECOFIN. 2004. Plan Directeur d'Alimentation en eau des communautés rurales et du Bétail de la Province d'Umutara. Kigali. 143 p.

MININFRA. 2004. Le projet de loi organique portant organisation de l'habitat au Rwanda. 27 p.

MINISANTE (Ministère de la Santé). 2001. Enquête Démographique et de Santé, Rwanda 2000. Kigali. Ministry of Health, Office National de la Population. Kigali, Rwanda

MINITERE. 2003. La politique nationale de l'environnement au Rwanda. Kigali. 40 p.

MINITERE. 2004. La polique nationale foncière. Kigali. 35 p.

National Environment Management Authority (NEMA). 2003. Environmental Legislation of Uganda.

Ntungamo district (Uganda). 2005a. Environmental Profile.

Ntungamo district (Uganda). 2005b. State of the Environment Report.

Ntungamo district (Uganda). Three – Year District Development Plan (2005-2008).

Nyakoojo, Evelyn. 2002. Women and Land Rights in Uganda. Eastern African Sub Regional Support Initiative for the Advancement of Women (EASSI). 48 p. 1999. Women and Land Rights in Uganda.

Office rwandais du Tourisme et des Parcs nationaux (ORTPN), 2005. Communication personnelle.

Oki, D. S., S. B. Gingerich and R. L. Whitehead. 1999. Hawaii In Ground Water Atlas of the United States, Segment 13, Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. U.S. Geological Survey Hydrologic Investigations Atlas 730-N, pp. N12-N22, N36.

Okoth-Ogendo H W. 1998. Implementing land legislation in Uganda.

Organisation mondiale de la santé (OMS). 2006. Travailler ensemble pour la santé. Rapport sur la santé dans le monde 2006. 287 p.

Owanji Odida Irene. 1999. Land Law Reform: Challenges and opportunities of securing women's land right's in Uganda.

République du Rwanda. MINECOFIN/SNR. 2004. Recensement général de la population et de l'habitat Rwanda : 16-30 août 2002. Atlas Geo-Démographique du Rwanda. Kigali, MINECOFIN/SNR. 113 p.

Sirven P. et al. 1974. Géographie du Rwanda. Bruxelles/Kigali, Editions A. de Boeck/Editions Rwandaises. 174 p.

Service National de Recensement (SNR). 2004. Recensement 2002 en bref. République du Rwanda. Ministère des Finances et de la Planification économique. Commission nationale de recensement. 90 p.

Uganda Bureau of Statistics. 2000. Uganda National Household Survey.

Uganda Bureau of Statistics. 2005. 2002 Ugnada Housing and Population Census: Main Report.

United Nations Development Program. 2005. Uganda Human Development report: Linking Environment to Human Development. A deliberate Choice.

Vande Weghe (J.P.). 1990. Akagera, l'eau, l'herbe et le feu. Imprimerie et Editions Lannoo. S.A. Bruxelles. Belgique.

WCS, IGCP, CARE. 2004. Socio-economic surveys around montane forests in Uganda, Rwanda and DRC. Draft report.

ANNEX J – CONSULTED PARTIES

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

RWANDA

Nom et prénom	Position	Institution
M Augustin HATEGEKA	Chargé d'étude et Planification	Projet UPEGAZ (10), MININFRA (11)
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M Charles Kanyamihigo	Directeur d'exploitation/électricité	ELECTROGAZ
M Gaspard Niyiragira	Assistant technique/Aménagement des marais	Projet d'Appui au Secteur Rural/MINAGRI
M Stany Nizeyimana	Chef de la Centrale Electrique de Gisenyi	ELECTROGAZ
M Paul Mbonimpa	Chef de la Station de Gisenyi	ELECTROGAZ
M Méthode Ntagungira	Chef de Poste de Ngoma/Butare	ELECTROGAZ
M Josaphate Mugemanyi	Chef de la Station Butare	ELECTROGAZ
M Jacinthe Sana	Chef de Poste de Kigoma	ELECTROGAZ
M Gaspard Niyiragira	Assistant technique/Aménagement des marais	Projet d'Appui au Secteur Rural/MINAGRI
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M Albert Yaramba	Coordinateur du projet	Projet National d'Alimentation en eau potable et Assainissement en Milieu Rural
M Frank Rutabingwa	Coordinateur du Projet	Projet d'Appui à la foresterie (PAFOR)
M Robert Kashemeza	Maire	District de Nyagatare/Province de l'Est
M Daniel	Chargé de la Carte pédologique	MINAGRI (12)
M Syldio Gakwisi	Chargé du service d'analyse des données météorologiques	Service National de Météorologie/MININFRA
M Vital Nzabanita	Chargé de la Cartographie	Service National des Statistiques/MINECOFIN (13)
M Innocent Gashugi	Chargé d'Etude d'Impact Environnemental	Rwanda Environment Management Authority/MINITERE
M Eugène Kayijamahe	Chargé de Recherche au Centre GIS de Butare	Université National de Butare

(10) UPEGAZ : Unité de Production et d'Extraction du Gaz

(11) MINIFRA : Ministère des Infrastructures

(12) MINAGRI : Ministère de l'Agriculture et de l'Elevage

(13) MINECOFIN : Ministère des Finances et de la Planification économique

Nom et prénom	Position	Institution
M Kayitaba Gallican	Coordinateur du Groupe de travail chargé de préparer le Schéma Directeur d'Utilisation des Terres au Rwanda	MINITERE (14)
Mme Prisca Mujawayezu	Secrétaire Exécutive	Conseil de Concertation des Organisations d'appui aux Initiatives de Base/CCOAIB
Mme Agnes Mujawayezu	Secrétaire Exécutive	Collectif des Organisations Rwandaises de Promotion de la Femme, de la Paix et du Développement (PROFEMME-TWESE HAMWE).
M Fidèle Ruzigandekwe	Directeur Exécutif	Agence Rwandaise de Conservation de la Faune et la Flore Sauvage/Rwanda Wildlife Agency
M Donatien	Chargé de l'expropriation	MINITERE
M Adrien Ruberanziza	Chargé des juridictions Gacaca/Habitant du Village de Birembo	Cellule Runyinya/Village de Birembo
M Roger MUGISHA	Agent	Institut National de Statistique/Kigali
M Denis	Chargé de la Cartographie	Electrogaz, Kigali
M Népomuscène RUGEMINTWAZA	Chargé du suivi-évaluation	Projet d'appui à la décentralisation /PNUD/MINALOC, Kigali
M Didace KAYIRANGA	Chercheur	Institut Agronomique du Rwanda (ISAR/Rubona)
M Ignace RWAKAYIRU	Consultant, Expert en Politique de population	Centre CIEDEP/Kigali
M Antoine KAPITENI	Coordinateur	Projet de Gestion intégré des écosystèmes critiques, MINITERE, Kigali
M Viateur NGIRUWONSANGA	Coordinateur	Projet SIG/HIMO(Système intégré de Gestion de Haute intensité de Main d' oeuvre)/Halpage Rwanda, Ruhengeri
Mme Rita RWIRANGIRA	Chargée du Rapatriement et Réintégration d es réfugiés	Conseil National pour les Réfugiés, Kigali
M Hycinthe SANA	Chef de poste de Transformation électrique	Kigoma
Mme Yvonne MUREBWAYIRE	Chargée des Relations Publiques	Association PRO-Femmes Twese Hamwe, Kigali
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		ORTPN, Kigali
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		Musée National du Rwanda, Butare

(14) MINITERE : Ministre des Terres, de l'Environnement, des Forêts, de l'Eau et des Mines

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Nom et prénom	Position	Institution
Mr. Musingwire Jeconius	District Environmental Officer	Mbarara District Local Government
Mr. Tumusiime Silver	District Planner, Mbarara	Mbarara District Local Government
Mr. Kanyesigye William	Deputy Chief Administrative Officer	Mbarara District Local Government
Mr. Byakakagb Bonifance	Customs Officer	Mirama Hills, Ntungamo District
Mr. Tumuhimbise Lewis	Resident	Mirama Hill Trading center, Ntungamo District
Mr. Tusubira Justus	District Environmental Officer	Ntungamo 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

ANNEX K – RURAL ELECTRIFICATION