The 2017 Programme for Infrastructure Development in Africa (PIDA)
Ethiopia- Sudan Extra High Voltage Power System Interconnector Project
Blue Nile Energy Corridor (BNECO)

11-14 December 2017, Namibia
Ethiopia-Sudan Power Interconnector (BNECO)

Project Location
Region of Eastern Africa Power Pool (Ethiopia & Sudan)

Owners & Project Sponsors
Government of Sudan
Government of Ethiopia

Implementing Partners
Sudanese Electricity Transmission Company (SETCO)
Ethiopian Electrical Power (EEP)

Regional Economic Community
Intergovernmental Authority on Development (IGAD)
I. Introduction.

II. Feasibility Study

III. Main outcomes

IV. Project Status
I. Introduction

- **Background**
  - Sudan and Ethiopia have already interconnected their transmission grids at 220 kV voltage level. And now they are desirous to interconnect their power systems at Extra high voltage level.
  - A contract signed in 2015 for conducting techno-economic Feasibility Study, technical specifications, Tender document and drafting of Interconnection Agreements with international consultant (CESI of Italy).
  - The study was financed jointly by the two countries from their own resources about (2.4 million Euro).
  - The final Feasibility Study report was submitted since Feb.2017.
I. Introduction

*The Project*

- Techno-economic feasibility study for Extra High Voltage (EHV) Interconnection between Ethiopia and Sudan *(completed)*
- Different alternative options investigated
- Selection of the most technically, environmentally economically and financially feasible alternative.
Challenges of the Project

- Selection of the best connecting points of the existing network
- Identification of the best route of the line
- Identification of the technology of the line
- Reinforcements of the existing electric grid
- Environmental and Social Impact Assessment (ESIA & RAP)
- Design & tender documents of the transmission line
- Design & tender documents of the new substations for the connection or extension of the existing ones
I. Introduction

Main Benefits of the Project

The designed interconnection allows to get the Benefits from Technical viewpoint

- Enhancement of the security of the system
- Improvement of the reliability of the system (sharp reduction power outages)
- Optimization of the generating resources in Ethiopia and Sudan
- Future power exchanges (power trade) with third Countries (e.g. with Egypt) i.e. enhance regional economic integration.
I. Introduction

- Main Benefits of the Project
  The designed interconnection allows to get the Benefits from Economic and Financial viewpoints:
  - Extremely positive economic impacts, robust to all sensitivity analyses.
  - Sharp reduction in losses Expected Energy Not Supplied (EENS).
  - Sharp reduction in system marginal prices.
  - Sharp reduction of CO2 emissions.
  - High levels of financial viability.
  - Promote the economic development of both Countries.
  - Attract investors to invest in agriculture sector in the region (land, water, energy). also will drive industrial sector in Sudan.
  - Creates a lot of jobs direct and indirect.
II. Feasibility Study

1. Generation expansion plan and load forecast review
2. Selection of the best alternative: technical, economic and environmental perspectives
3. Network impact analysis of interconnection
4. Demand supply analysis & exchanges valuation
5. Economic, financial & risk analysis
II. Feasibility Study

*Alternative of Interconnection*

Five alternatives considered for the Ethiopian-Sudan UHV interconnection:

- Alternative 1: Renaissance Dam to Khartoum, 550 km
- Alternative 2: Renaissance Dam to Khartoum, via Rabak, 580 km
- Alternative 3: Renaissance Dam to Khartoum, via Sennar/Hasahessa, 550 km
- Alternative 4: Renaissance Dam to Khartoum, via Gadaref, 650 km
- Alternative 5: Renaissance Dam to Khartoum/Bagair or El-Kabashi, 615 km.
II. Feasibility Study

- Several alternatives have been investigated between Grand Renaissance to Khartoum area.

<table>
<thead>
<tr>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
<th>Alternative 4</th>
<th>Alternative 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct, to Khartoum South</td>
<td>Via New Rabak</td>
<td>Via Sennar/ Hsaessa</td>
<td>Via Gadaref</td>
<td>Direct, to Khartoum W/N</td>
</tr>
</tbody>
</table>

- One option
- Seven options
- Two options
- One option
- Two options
II. Feasibility Study

Network impact analysis of the interconnection

Set of detailed studies in order to evaluate the impact of the new interconnection on the Sudanese and Ethiopian networks

- Review transmission expansion plans
- Steady state studies
- PV and QV analysis
- Transient stability study
- Electromagnetic switching Studies
- Reliability analysis

Tools → PSS/E → ATP → GRARE
The AHP method has been applied using the following indicators: i) the Environmental and Socio-economic KPI, ii) the Total Technical Performance KPI and iii) the Total CAPEX KPI.

<table>
<thead>
<tr>
<th>RANKING</th>
<th>Environmental and socio-economic KPI</th>
<th>Total Technical Performance KPI</th>
<th>Total CAPEX KPI</th>
<th>Final KPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ALTERN 2 OPT 2</td>
<td>1.00</td>
<td>0.99</td>
<td>0.96</td>
</tr>
<tr>
<td>2</td>
<td>ALTERN 2 OPT 1</td>
<td>0.93</td>
<td>0.99</td>
<td>0.92</td>
</tr>
<tr>
<td>3</td>
<td>ALTERN 2 OPT 3</td>
<td>0.83</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>4</td>
<td>ALTERN 2 OPT 6</td>
<td>0.70</td>
<td>0.99</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>ALTERN 2 OPT 4</td>
<td>0.71</td>
<td>0.99</td>
<td>0.91</td>
</tr>
<tr>
<td>6</td>
<td>ALTERN 3 OPT 1</td>
<td>0.69</td>
<td>0.97</td>
<td>0.90</td>
</tr>
<tr>
<td>7</td>
<td>ALTERN 3 OPT 2</td>
<td>0.69</td>
<td>0.96</td>
<td>0.88</td>
</tr>
<tr>
<td>8</td>
<td>ALTERN 2 OPT 5</td>
<td>0.55</td>
<td>0.99</td>
<td>0.96</td>
</tr>
<tr>
<td>9</td>
<td>ALTERN 2 OPT 7</td>
<td>0.52</td>
<td>0.99</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>ALTERN 5 OPT 2</td>
<td>Unfeasible</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>ALTERN 1</td>
<td>Unfeasible</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>ALTERN 5 OPT 1</td>
<td>Unfeasible</td>
<td>0.94</td>
<td>0.82</td>
</tr>
</tbody>
</table>

The final ranking shows that the best interconnection solution is the Alternative 2, option 2 (via New Rabak).
Location

Ethiopia-Sudan Power Interconnector

• The Project will connect the Grand Renaissance Dam in Ethiopia with Sudan and ultimately Egypt.
The selective alternative, alternative2 Option2

Interconnection between Grand Renaissance and the Khartoum area (New Jebel Aulia), via New Rabak
Configuration of the interconnection after the technical analyses

- **Project Component:**

![Diagram showing interconnection configuration]
Main features of the selected interconnector

- On the basis of the analyses performed in the Feasibility Study, the best alternative is the interconnection *Grand Renaissance — New Jebel Aulia substation with intermediate substation in New Rabak.*

- The main technical characteristics;
  - Double circuit AC line.
  - Voltage level: 500 kV.
  - The capacity of the interconnection (3000 MW)
  - Length *Grand Renaissance – New Rabak 330 km* and
  - *New Rabak – New Jebel Aulia 260 km,*
Demand supply analysis & exchanges evaluation

Scenario 1: Reference Scenario
Scenario 2: Coordinated Scenario
Scenario 3: Integrated Scenario
Scenario 4: Electricity Market
Scenario 5: Regional Market

Same Generation Expansion Plan
Different Expansion Plan
Scenario 1 – Reference Scenario

Under the Reference Scenario Ethiopian and Sudanese power systems are developed and operated independently from each other’s and schedule their generations annually to meet their electricity demand and long term trade contracts.
Scenario 2: Coordinated Scenario

Ethiopian and Sudanese power systems in the Coordinated Scenario are considered as two interconnected systems scheduling their annually hydro-thermal generation and coordinating operation to minimize their operating costs having as objective covering their electricity demand with daily power exchanges.
Ethiopian & Sudanese power systems are considered as one interconnected system (Integrated system) scheduling their annually hydro-thermal generation to minimize their operating costs and having as objective covering their electricity demand with daily power exchanges.
Ethiopia and Sudan are member of the Eastern Africa Power Pool (EAPP) whose main objective in long-term, is the development of an electricity market using the planned pool interconnectors in order to optimize the use of energy resources available in the region.
Scenario 5: Regional Market

The long term vision of Regional Electricity Market (REM) is a competitive whole sale market at the regional level comprising a range of bilateral contracts and a spot market to determine a common clearing price. In considering the development of a regional electricity market, the most difficult contractual issue is likely to be related to the new contractual framework and pricing.
III. Main out comes

- Project Cost

The total estimated cost is USD $566.01 million USD according to the Feasibility Study.

- Sudan portion is $536.980 million USD and
- Ethiopia portion is $29.030 million USD
III. Main out comes

- The economic analysis was done to determine whether the proposed project has economic benefit for both Ethiopia and Sudan or not?

Below we present the results of the economic analysis of all five scenarios and then we compare the four interconnected scenarios with the reference scenario in order to test whether the interconnector has a net positive impact in terms of welfare. The details of each scenario can be found in the demand and supply analysis.

<table>
<thead>
<tr>
<th></th>
<th>Coordinated</th>
<th>Integrated</th>
<th>Market</th>
<th>Regional</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV (kilo$)</td>
<td>10,209,305</td>
<td>41,080,515</td>
<td>39,665,209</td>
<td>38,999,634</td>
</tr>
<tr>
<td>IRR</td>
<td>169%</td>
<td>186%</td>
<td>168%</td>
<td>171%</td>
</tr>
<tr>
<td>Benefit/Cost Ratio</td>
<td>20.56</td>
<td>79.70</td>
<td>13.27</td>
<td>12.30</td>
</tr>
</tbody>
</table>
IV. Project Status

- Feasibility Study, Environmental and Social Impact Assessment (ESIA), Resettlement Action Plan & (RAP), Engineering Design and Tender documents had been finalized.
- **Interconnection Agreements** documents are under negotiations and will be finalized and singing in Dec, 2017.
- The two countries seeking for finance to the project, a Joint Letters of Requested finance was issued by the two finance Ministers to the African Development Bank (AfDB). The two governments of Ethiopia and Sudan was full committed to this project.
- The project proposed to be commissioned in year 2021 as agreed in Road Map.
IV. Project Status

Way Forward

- Joint data validation, load forecasting, and network analysis meeting (Khartoum) - Feb 2016
- Joint power system analysis and expansion planning seminar (Ethiopia) - Apr 2016
- Final Feasibility Study Report - Oct 2016
- Joint tender documents and procurement workshop (Ethiopia) - Dec 2016
- Final Transmission and Substation Engineering Design Report - Jan 2017
- Final Joint Feasibility Meeting (Khartoum) - TBC
- Update financial model, including Affordability assessment by the utilities - TBC
- RFQ/RFP process to appoint EPC contractor
- Market soundings with DFIs and institutional investors
- Negotiations with lenders, and possible funding application(s)
Financial Analysis & Revenue Model
Ethiopia-Sudan Power Interconnector

• The Feasibility Study assumed that the two utilities will finance the Project with a combination of equity (20%) and debt (80%) whilst recovering costs and returns through tariffs.

• The tariffs required by EEP and SETCO to undertake the Project were calculated using a rate of return calculation.

• The Feasibility Study assumed that EEP will be able to raise long term corporate debt at 6% and SETCO at an effective interest rate 6.5%* (in US$ terms).

• US$ based project IRRs of 10.2% (Ethiopia) and 13.8% (Sudan) are forecast in the Feasibility Study – based on the tariffs calculated, debt assumptions, capex and opex.

* 6% corporate debt, 8% for SUKUK
Funding Opportunities
Ethiopia-Sudan Power Interconnector

• GCF funding could be explored, due to the Project’s strong CO2 reduction potential, to unlock a mixture of concessionary loans, grants and guarantees for SETCO.

• A Sukuk funding opportunity exists for local/regional institutional investors, however the assumed funding costs will need to be market tested.

• Both utilities should conduct market soundings with DFIs to understand their appetite and return requirements.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>ETHIOPIA</th>
<th>SUDAN</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity</td>
<td>5,806</td>
<td>107,400</td>
<td>-</td>
</tr>
<tr>
<td>Senior Debt</td>
<td>23,224</td>
<td>322,200</td>
<td>-</td>
</tr>
<tr>
<td>Zero-Coupon Bond</td>
<td>-</td>
<td>107,400</td>
<td>-</td>
</tr>
<tr>
<td>Latest Capex (Excl. Vat)</td>
<td>29,030</td>
<td>537,000</td>
<td>566,030</td>
</tr>
</tbody>
</table>
JOB CREATION
ANNEX
The Ethiopian Sudan Power Interconnector Will Create an Estimated 717,000 Job Years over Its Useful Life of 35 Years

37,000 JOB YEARS FROM PROJECT DEVELOPMENT, CONSTRUCTION, AND OPERATION

<table>
<thead>
<tr>
<th>PHASE</th>
<th>Ethiopia</th>
<th>Sudan</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
<td>Indirect</td>
<td>Induced</td>
</tr>
<tr>
<td>Project Preparation</td>
<td>172</td>
<td>48</td>
<td>359</td>
</tr>
<tr>
<td>Construction</td>
<td>220</td>
<td>108</td>
<td>440</td>
</tr>
<tr>
<td>Total One-Time</td>
<td>392</td>
<td>156</td>
<td>799</td>
</tr>
<tr>
<td>O&amp;M (over 35 years)</td>
<td>805</td>
<td>385</td>
<td>1575</td>
</tr>
<tr>
<td>Total Primary effects</td>
<td>1,197</td>
<td>541</td>
<td>2,374</td>
</tr>
</tbody>
</table>

680,000 JOB YEARS FROM SECONDARY SPILL OVER EFFECTS ON THE ECONOMY

<table>
<thead>
<tr>
<th>Country</th>
<th>Annual Electricity Supply (million US$)</th>
<th>Direct</th>
<th>Indirect</th>
<th>Induced</th>
<th>Total</th>
<th>Direct</th>
<th>Indirect</th>
<th>Induced</th>
<th>Over Useful Life (35 years)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan</td>
<td>$315,887,060</td>
<td>6,793</td>
<td>4,838</td>
<td>5,150</td>
<td>16,781</td>
<td>169,825</td>
<td>120,950</td>
<td>128,750</td>
<td>419,525</td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>$160,310,920</td>
<td>3,282</td>
<td>502</td>
<td>297</td>
<td>4,080</td>
<td>82,050</td>
<td>12,550</td>
<td>7,425</td>
<td>102,000</td>
<td></td>
</tr>
<tr>
<td>Djibouti</td>
<td>$14,708,040</td>
<td>316</td>
<td>225</td>
<td>240</td>
<td>781</td>
<td>7,900</td>
<td>5,625</td>
<td>6,000</td>
<td>19,525</td>
<td></td>
</tr>
<tr>
<td>Ethiopia</td>
<td>$34,688,140</td>
<td>4,507</td>
<td>351</td>
<td>548</td>
<td>5,407</td>
<td>112,675</td>
<td>8,775</td>
<td>13,700</td>
<td>135,175</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>14,898</td>
<td>5,916</td>
<td>6,235</td>
<td>27,049</td>
<td>372,450</td>
<td>147,900</td>
<td>155,875</td>
<td>676,225</td>
<td></td>
</tr>
</tbody>
</table>
The Ethiopian Sudan Interconnector will Create an Estimated 30,500 Average Annual Jobs (based on preliminary assumptions)

- **Project Preparation** (3 years)
- **Construction** (3 years)
- **Operations** (35 years useful life)

**Number of Average Annual Jobs**

- 260 direct, indirect, induced jobs
- 2,400 jobs direct, indirect, induced
- 820 O&M jobs (of which 80 are direct)
- 27,000 Secondary effects (direct, indirect, induced)

*Source: GlobalDF analysis*
METHODOLOGY FOR ESTIMATING JOB CREATION IN ELECTRICITY GENERATION AND TRANSMISSION INFRASTRUCTURE

PRIMARY EFFECT (jobs created as a result of infrastructure deployment)

DIRECT JOBS (actual jobs required for project development, construction, operation phases over project’s useful life)

INDIRECT JOBS (employment generated by businesses providing inputs for project preparation (studies, etc.), construction, operation (e.g., raw materials, equipment, etc.)

INDUCED JOBS (Employment generated by household spending based on the income earned by direct and indirect workers engaged in project)

SECONDARY EFFECT (jobs created from the economic spillover of infrastructure once it is deployed)

DIRECT, INDIRECT & INDUCED JOBS (employment resulting from new business creation and existing enterprises expanding as the result of additional power supply)

BEST PRACTICE: INPUT-OUTPUT ANALYSIS (used worldwide based on subsectorial economic national data)

• Estimate cost of inputs by country source
  - Project preparation (studies, project staff & experts)
  - Construction (labour, supervision, equipment, raw materials, etc.)
  - Operations & Maintenance
• Enter inputs in Input-Output Tables (developed from GTAP data base for all African countries)
• Tables estimate jobs

INPUT-OUTPUT ANALYSIS (based on IFC approach)

• Estimate incremental energy generated by new infrastructure
• Convert to Kw$
• Split power by destination country
• Enter incremental power in National Input-Output Tables
**TO GENERATE THE DATA REQUIRED FOR ESTIMATING JOBS, MAJOR ASSUMPTIONS WERE MADE**

<table>
<thead>
<tr>
<th>Phases</th>
<th>Assumptions</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project preparation</td>
<td>Considering that CESI, an Italian consultancy, conducted most of the preparation studies (Feasibility, ESIA) it was assumed this component to generate out-of-Africa jobs</td>
<td>If some tasks were provided by African firms, it would result in a higher job creation potential</td>
</tr>
<tr>
<td></td>
<td>The organization of a Power Coordination Unit depending from the local utilities (<em>Ethiopia-Sudan Interconnector PIM, pp. 6-7</em>), was assumed to generate local jobs; Project preparation costs of Power Coordination Unit were assumed to be equally split between Ethiopia and Sudan</td>
<td>While PIM was clear about co-sponsorship of utilities, information of responsibilities for each was missing</td>
</tr>
<tr>
<td>Construction</td>
<td>Engineering, administration, and supervisory costs were assumed to be provided by an out of Africa EPC firm, and consequently jobs created were not included in construction related estimates; It was assumed that all substation and line equipment would be imported from out-of-Africa sources</td>
<td>Could result in under estimation of jobs</td>
</tr>
<tr>
<td></td>
<td>Labor costs were not included in project documents; consequently a benchmark ratio (labor costs as percent of total investment of transmission lines) provided by the ZTK Feasibility Study was utilized</td>
<td>If labor costs in Ethiopia-Sudan are different, the benchmark ratio could result in either under or overestimation of construction effects</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>The Feasibility Study provides a ratio of O&amp;M annual costs to project capital costs (1%) but does not break it down between labor and spare parts; the estimates assume all of it to be labor; O&amp;M Supervisory costs was assumed to be 10% of total O&amp;M costs</td>
<td>This could be an overestimation of O&amp;M jobs</td>
</tr>
</tbody>
</table>
## Opportunities to unlock projects

<table>
<thead>
<tr>
<th>Role</th>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFIs / ICPs</td>
<td>• Unlock climate financing (GCF guarantees/concessionary loans/grants)</td>
</tr>
<tr>
<td></td>
<td>• Extend concessionary loans</td>
</tr>
<tr>
<td></td>
<td>• Guarantee debt</td>
</tr>
<tr>
<td>Institutional Investors</td>
<td>• Market projects to funders</td>
</tr>
<tr>
<td>Commercial Banks &amp; Developers</td>
<td>• Invest in Sukuk/zero coupon bond</td>
</tr>
<tr>
<td>Governments</td>
<td>• Guarantee debt</td>
</tr>
<tr>
<td>NEPAD/RECs</td>
<td>• Coordinate technical teams between countries</td>
</tr>
<tr>
<td></td>
<td>• Market projects to funders</td>
</tr>
<tr>
<td></td>
<td>• Provide political support</td>
</tr>
</tbody>
</table>
Thank you