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The Power of Regional Interconnections

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Abstract

Existing electricity networks were designed to transport power from generating stations to load centres within their service territory. As demand grew, limits on the existing transmission systems became increasingly constrained. Interconnections from adjacent systems became an economic way of increasing supply at reasonable cost. With the advent of regional electricity markets, there has been increased growth in developing transnational power transmission infrastructure.

With rapid increase of regional interconnection projects, there is an emerging knowledge base related to the development of these projects. This paper summarizes some of the current lessons learned from five regional projects in Central America, the Middle East, Central Asia and East Africa. The highlighted projects are in various phases of completion from initial design to feasibility study to recent commissioning. The case studies highlight key issues and lessons learned related to design, financing, operational and organisational issues.

1. Introduction

There are numerous regional interconnections around the world that have been implemented and each has its own story to tell. Based on SNC-Lavalin's experience with regional transmission projects, this paper looks at five regional projects in four distinct geographical regions and each at various stages of development:

- Central America SIEPAC interconnection *(Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama)* which will be commissioned in 2010;
- Gulf Cooperation Council Interconnection linking six countries in the Persian Gulf area *(Kuwait, Saudi Arabia, Bahrain, Qatar, UAE, and Oman)* which had its first on-power in late 2009;
- Central Asia South Asia Interconnection to bring power from Central Asia *(the Kyrgyz Republic, Tajikistan)* to South Asia *(Afghanistan, Pakistan)*;
- Saudi Arabia-Egypt Interconnection to facilitate power exchanges between Saudi Arabia and Egypt; and,
- East Africa Power Pool project to study the feasibility of interconnecting ten countries in East Africa *(Burundi, Djibouti, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda)*

There have been a number of papers already written on the theory and benefits of regional interconnections. This paper, however, focuses on the lessons learned from the regional projects that SNC-Lavalin has worked on extensively during various phases of each of the selected projects. In addition to the project descriptions, items to be touched on each project would include:

- Project Design – getting consensus on cooperation and design
- Project Financing – sharing costs and benefits
- Organisational Structure of Interconnection Authorities
- Operational issues and Regulatory Frameworks
- Impact of Energy Markets and Barriers to trade
- Lessons Learned

The purpose of the paper is to give examples of regional interconnection projects and success stories in the making for cross-border interconnections.

2. Regional Interconnection Projects

SNC-Lavalin was involved in each of the regional interconnection projects presented below and lessons learned are based on direct experiences.

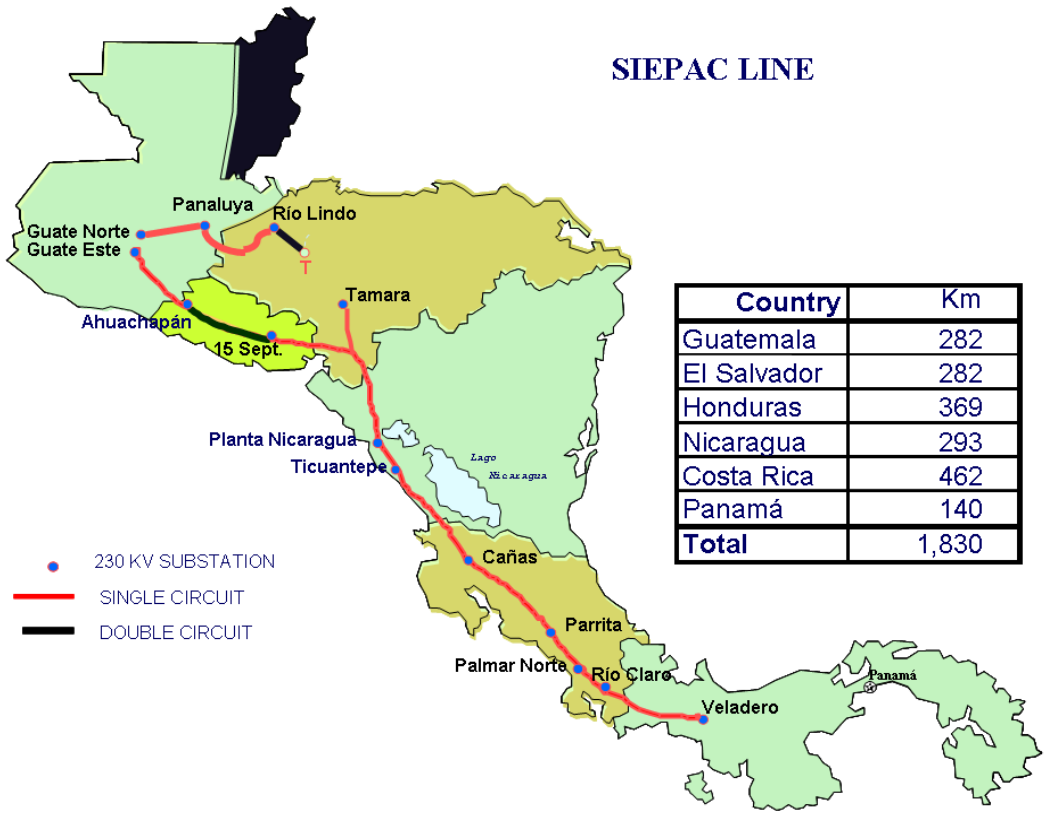
2.1 Central America – SIEPAC

SIEPAC Project Description

The six republics of Central America: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama have signed in 1996 (ratified in 1998) a Treaty where they agreed on the creation of a regional market of electricity (MER) in Central America. The MER will allow market participants of the six countries cross border trading of energy coordinated by a regional system and market operator (EOR).

The agreement includes the development of a regional 220kV transmission system (SIEPAC) of more than 1800 km in length and 14 substations, reinforcing the existing interconnections of the region and providing at least 300MW of firm transfer capacity in each border (see Figure 1)

The SIEPAC project seeks to achieve two main objectives: (i) the gradual formation and consolidation of a regional electricity market through the creation and establishment of appropriate legal, institutional, and technical mechanisms to promote private sector participation, particularly in the development of additional generating capacity; and (ii) the development of an electric interconnection infrastructure (230 kV transmission lines with a capacity of 300 MW with the corresponding substations) to facilitate trading of electric power among the agents of the regional electricity market.



Country	Km
Guatemala	282
El Salvador	282
Honduras	369
Nicaragua	293
Costa Rica	462
Panamá	140
Total	1,830

Figure 1 – Countries of MER and SIEPAC line

The SIEPAC is expected to enable the following:

a. Development of larger power plants with lower unit costs and benefits stemming from economies of scale.
b. Economic benefits from coordinating the operation among the systems in the six countries, taking advantage of the diversity in the electricity supply sources in the region, with reduction in operating costs
c. Reduction in new reserve requirements due to diversity of the maximum demand in the countries of the region.
d. Assistance for any country with deficit problems.
e. Greater reliability in the systems' operation and greater security in meeting demand.

An additional benefit of the project was eligibility for carbon finance under the Clean Development Mechanism of the Kyoto Protocol.

The construction of the SIEPAC line and national reinforcements are currently under way and expected to be finalized by the end of 2010. The regional institutions EOR and CRIE have already been established and the energy market and transmission codes approved.

Lessons Learned

This project has shown that electrical interconnection spanning several countries can be shown to give benefits to all parties involved, and this as we have seen, is a key requisite for all projects of this type. All parties and stakeholders must share a "regional vision" of the project. A clear mechanism should be designed in advance allowing efficient and fair pricing schemes for transmission and a playing level fields for all potential users and beneficiaries of

the infrastructure. Secondly the institutional aspects of a complex projects such as this cannot be overlooked. Creation of a credible and transparent legal and institutional framework for managing, building and then operating and maintaining the project are as important as getting the financing, engineering procurement and construction right. As regional electricity trade will impact on the national energy markets, the collaboration of national institutions such as Ministries of energy and Energy Regulators is also an essential success factor.

2.2 Middle East - Gulf Cooperation Council Interconnection Authority (GCCIA)

Project Description

The initial concept for the GCCIA was discussed in the early 1980's and a number of studies were commissioned to prepare the technical and financial feasibility studies of the project. The studies recommended an AC interconnection of the 50 Hz systems in Kuwait, Bahrain, Qatar, United Arab Emirates and Oman to 60 Hz system in Saudi Arabia with an HVDC back to back converter. It was decided to create the GCC interconnection Authority and in 2003/4 the study was updated to:

- Reconfirm the feasibility study;
- Prepare a market study;
- Prepare a financing plan;
- Develop inter-country agreements; and,
- Prepare an implementation strategy.

A decision to proceed was made in 2004 and the GCC Interconnection Authority oversaw the building of the project whose first phase was completed in 2009. The three phases of the project are:

- Phase I: Interconnection of the Northern Systems (Kuwait, Saudi Arabia, Bahrain and Qatar)
- Phase II: The internal interconnection of the Southern Systems (UAE and Oman) to form the UAE National Grid and the Oman Northern Grid (GCCIA is not involved in this Phase).
- Phase III: Interconnection of the Northern and Southern Systems in 2010.

The interconnection route is illustrated below in Figure 2 and the interconnection configuration is shown in Figure 3.

The project includes over 1000 km of 400 kV double circuit line, a back-to-back HVDC converter station and a submarine cable. The value of the contracts awarded for Phase I (Kuwait, Saudi Arabia, Bahrain and Qatar) was about US$ 1.1 billion. The feasibility studies showed a benefit to cost ratio of 1.77 based on savings in investments from sharing installed capacity reserves. The participating countries agreed to share the cost of the project based on the relative proportion of cost saving resulting from reduced reserve capacity requirements in each country. It was also recognized that the benefits would increase with the establishment of a regional electricity markets.

Figure 2 - GCCIA Project

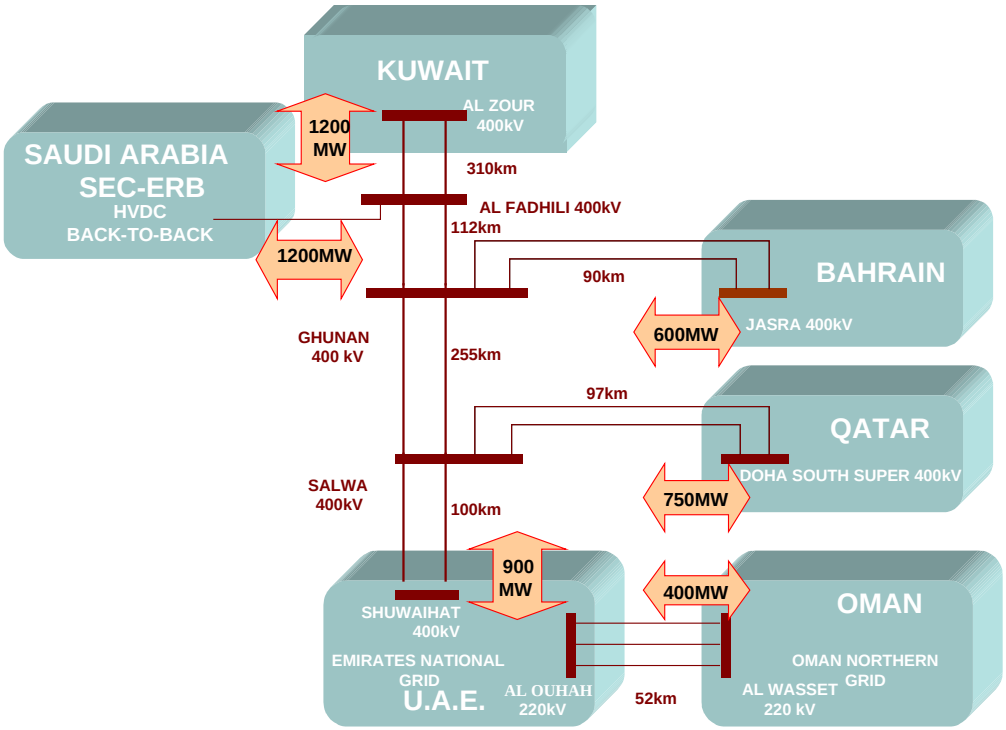


Figure 3 – GCCIA – Project Configuration

The principal benefits of the interconnection include:

- Reduced generating capacity in each country through shared reserves;
- Sharing of spinning reserves during emergency conditions; and
- Opportunities for developing trading amongst the countries.

SNC-Lavalin's role in the project was to prepare the feasibility studies and to act as owner's engineer.

Lessons Learned

The primary success of the project was due to the full financial commitment of the participating countries. This is what triggered the implementation of the project. In addition, each of the countries appointed Board of Directors from both the Ministries of Electricity and Senior Utility Directors. The GCCIA took the decision early on to be a lean organisation with a small core team lead by a very active Board of Directors.

Additional factors for success were:

- Early financial agreements to fund the project;
- International competitive bidding for the principal elements of the project;
- Close collaboration between GCCIA and the consultants / experts working on the project; and
- Direct involvement of the GCCIA Board of Directors during the early phases of the project.

2.3 Central Asia South Asia Interconnection (CASA-1000)

Project Description

The objective of the project is to promote electricity exports from Tajikistan and Kyrgyz Republic to Afghanistan and Pakistan.

Afghanistan, the Kyrgyz Republic, Pakistan and Tajikistan have been pursuing the development of electricity trading arrangements and the establishment of a Central Asia - South Asia Regional Electricity Market (CASAREM). These four countries have intensified their cooperation since 2005 among themselves and with the International Financial Institutions (IFIs) comprising the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), the International Finance Corporation (IFC), the Islamic Development Bank (IsDB) and the World Bank (WB).

The initiative to develop the regional market is based on the following considerations:

a. Expectations that sufficient quantities of surplus electricity are available in the Central Asian countries (the Kyrgyz Republic and Tajikistan);
b. Significant need for electricity imports in South Asia to meet existing and projected demand;
c. Differences in the cost of electricity between the importing and exporting countries that potentially provide a justifiable rationale to make transmission investments in order to support the electricity trade; and
d. Expectation that the establishment of the transmission interconnection and the trading mechanisms would attract future private investment to enhance the electricity trade in the entire region.

The interconnection is shown in Figure 4 below.

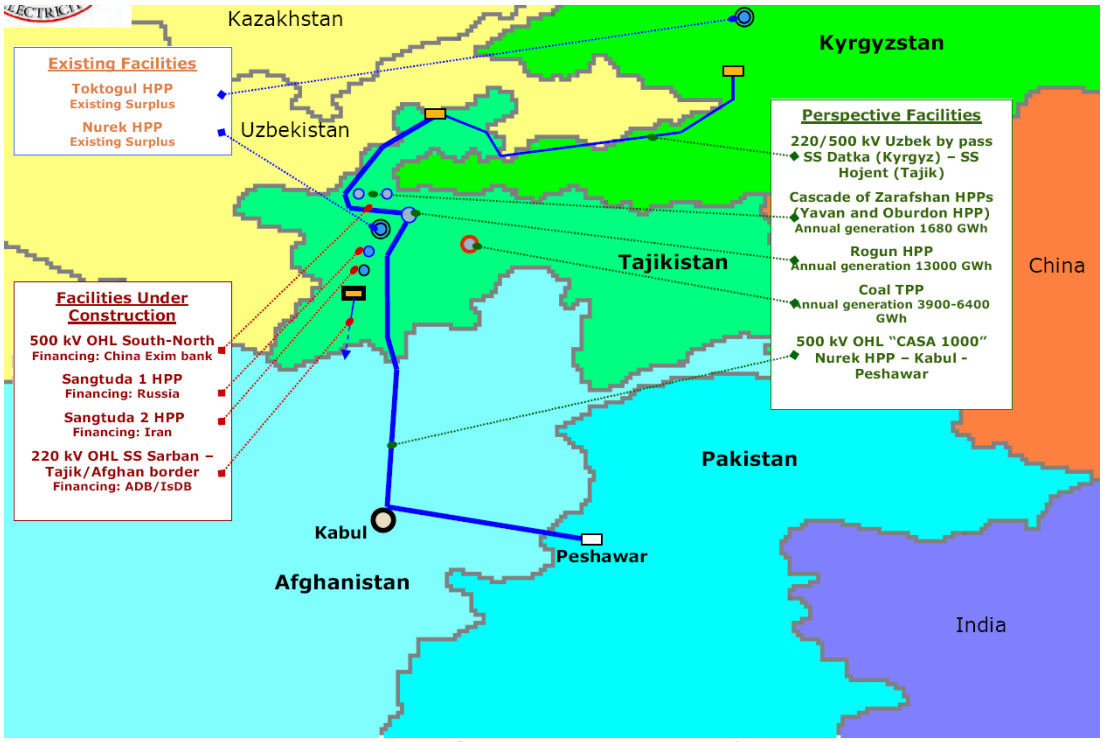


Figure 4 - CASA-1000 Project

One of the key components of this initiative is the development of the cross-border transmission interconnection linking the four countries to facilitate the transfer of surplus power that would be made available in the Kyrgyz Republic and Tajikistan to Pakistan and Afghanistan.

The CASA 1000 Project as currently envisaged comprises of:

a. A 750 km High Voltage Direct Current (DC) transmission system between Tajikistan and Pakistan via Afghanistan;
b. A DC to Alternate Current (AC) converter station in Kabul to supply Kabul area;
c. An AC transmission link between the Kyrgyz Republic and Tajikistan to supply the Kyrgyz electricity to South Asia via Tajikistan; and
d. The concomitant institutional and legal framework to enable such electricity trade.

The technical and financial assessment of the project started in 2007 and there was an agreement signed by all the participating countries to go ahead with the project in November 2008. However, due to the high cost of project and changes in regional priorities, one of the key sponsoring development banks withdrew financial support for the project. In early 2010, the mandate to update the technical feasibility study, requested by the CASA-1000 Intergovernmental Council (IGC) and funded by the World Bank, was given to SNC-Lavalin (SNC-Lavalin completed the first prefeasibility study under funding from the Asian Development Bank).

Lessons Learned

This project is a highly complex project that has to address many fundamental issues such as:

a. Four countries with a diverse political objectives, power sector infrastructure and financial capacity;
b. High cost of developing the projects;
c. Numerous funding agencies, each with their specific regional objectives; and,
d. Proliferation of advisors.

The first lesson learned is that the project should not be rushed. When the technical and financial consultants were engaged in April 2009, the intent was to have functional specifications and financing options in place within eight months. While all parties were committed to the process and the objectives of the project, the speed at which governments could react and respond to each of the hurdles was underestimated. There was not enough time given to assimilate the information provided by the participating countries. Even though each of the participating governments had signed Memorandum of Understanding, the modalities related to implementation needed more time to be fully vetted and agreed upon. **Gaining consensus takes time when there are significant financial commitments involved.**

The second lesson learned relates to getting agreement on the approaches to making the project work. The World Bank, the Islamic Development Bank and the Asian Development Bank were the primary financial backers to the project. However, their structure for providing loans is based on country allocations, which looks at the respective borrowing limits and level of grants available to each country. Thus the economic analysis to support the viability of the project in each country had to take into account the costs and benefit allocation by each country. Plus, given that the legal framework in each country is different, a Project Organisation had to be developed to take into account the many legal factors. With the help of the International Finance Corporation (IFC), a workable project structure was developed along with a financial model to ensure an adequate return on investment. **The complexity of setting up the Project Company was greatly underestimated.**

The project from the outset assumed that there was sufficient energy available for transmission to Afghanistan and Pakistan. However, during the detailed simulations, the power generation studies showed that there would only be sufficient water for less than six months of the year for export on a firm basis. The export potential was a function of each of the exporting countries, Tajikistan and Kyrgyz Republic, to accumulate sufficient capacity in their multi-year reservoirs. However, due to hydrological and domestic energy requirements, there would be difficulty in meeting the initial export commitments. Part of the availability also depended on other factors such as the completion of new committed generation that was not taking place. Furthermore, the capacity limits of the proposed transmission line limited the amount of energy that could be transmitted during the peak availability of the year. While the project looked very good during the initial assessment, the initial evaluation was based on average availability of power. **Detailed analysis can change the viability of the project.**

2.4 Saudi Arabia – Egypt Interconnection (SEI)

SEI Project Description

The electricity utilities of the Kingdom of Saudi Arabia (Saudi Electric Company-SEC) and Egypt (Egyptian Electricity Holding Company-EEHC) carried out a Feasibility Study to interconnect their Electrical Networks and found sound benefits in doing so. SNC-Lavalin has been mandated to complete the next phase prior to full implementation.

The Project is an HVDC link between Egypt and Saudi Arabia consisting of two-pole ± 500 kV multi-terminal link, approximately 1400 km long between Badr Substation (Egypt) and Madinah - East Substation (KSA) with an intermediate HVDC terminal point at Tabuk (KSA). The capacity of the converter station at Badr and Madinah will be 3000 MW and the capacity of the converter station at Tabuk will be 1500 MW. The interconnection is shown in Figure 5 below.

The basic objective of this consultancy is to take the next step towards implementation of the interconnection between Egypt and Saudi Arabia. As part of this mandate, the Request for Proposal (RFPs) or Tender Documents will be developed for the main work packages for this project. In addition, the agreements to be made between Egypt and Saudi Arabia for the control of the execution and operation of the interconnection will be developed. The options for financing the Project will also be investigated.

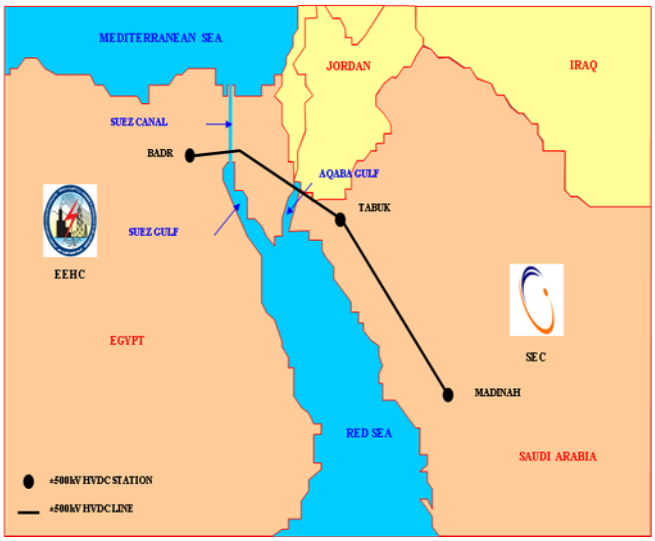


Figure 5 - Saudi Arabia - Egypt Interconnection

Lessons Learned

Although the feasibility study showed definite benefits in interconnecting the two countries, there is significant work required to take the project to the next stage of completion, namely the tendering process.

The first lesson learned is that cooperation between the countries is essential. Even though the countries are neighbors, there are significant differences in the organisational structure of the respective countries that must be considered in developing the final documents. The cooperation and coordination between the two countries has been excellent which has facilitated progress. **Cooperation and coordination of activities with project proponents is essential.**

The second lesson learned is that the project is up against a moving target with respect to some of the technical issues of the interconnections. The fact that the connection is a HVDC link greatly facilitates some of the operational coordination issues. However, the Saudi Electricity Company (SEC) internal transmission and generation facilities are undergoing continual extensive changes to adapt to the rapid growth of local demand. This has resulted

in numerous reworking of the requirements at the Madinah terminal. **It is essential to finalize the database as quickly as possible.**

The third lesson is that there has to be strong consensus on the financing and operational aspects of the interregional facility. Initial discussions are underway to develop a common legal and operational framework.

2.5 East Africa Power Pool (EAPP)

EAPP Project Description

The EAPP Study, which started in 2009, scopes out power development scenarios of the participating countries of the EAPP. The ten participating countries are: Burundi, Djibouti, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. The participating countries are shown in Figure 6 below.

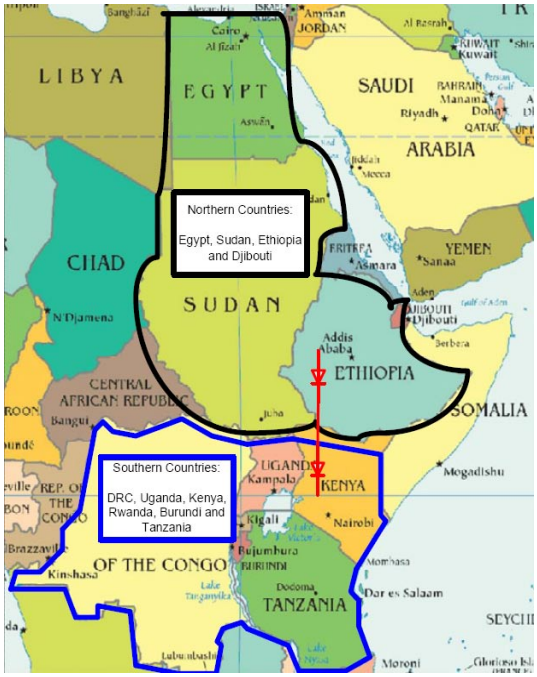


Figure 6 - EAPP Study Area

The objective of the EAPP Project is to identify power generation and interconnection projects, at Master Plan level, to interconnect the power systems of EAPP and East African Community (EAC) countries in short-to-long term. The study also aims at developing common Grid Code in order to facilitate the integrated development and operations of the power systems of EAPP and EAC countries.

The study further aims at contributing to the institutional capacity building for the EAPP and EAC staff through training of counterpart staff. The development of institutional capacity will enable EAPP / EAC to implement the subsequent activities, including the updating of both the Master Plan and the Grid Code reports.

SNC-Lavalin is the lead consultant in a Joint-Venture mandated to updating the Master Plan and Grid Code.

EAPP Lessons Learned

Although the project is still in its initial stages, there are a number of lessons that are worthwhile noting.

The first lesson is that this project could not have taken place without external funding. The financial means of each country is such that an outside coordinating sponsor is required to facilitate the development of the plans. Although the African Development Bank is facilitating the funding, there are bureaucratic roadblocks that are occasionally slowing

down the progress of the work. When it comes to development of the final recommended infrastructure, there will have to be strong agreements in place related to the financial participation of each country in supporting this project. **Funding for the project should be in place before the commencement of activities.**

A second lesson is that the shear magnitude of undertaking even a preliminary study requires extensive coordination and collaboration. It is essential that each of the countries be an active participant and contributes their respective knowledge to wealth of the EAPP community knowledge. Each of the countries has numerous studies developed over the years that need to be consolidated and put on a common basis. Although each participating country has designated representatives, these representatives participate on a part-time basis. Eventually it will be necessary to have a stronger commitment from each participating country to ensure buy-in from each country. **Active involvement by participating countries is essential to ensure that project meets its objective.**

3. Concluding Remarks

Some of the projects described above were conceived prior to the unbundling of the beneficiary vertically integrated utilities. While regional transmission projects are good for the people and the countries, they are not necessarily good for the transmission operators since they do not necessarily gain from the savings.

A critical element for success is that funding for the project be in place at the start. Other success factors for implementation of regional interconnection projects often include:

- All parties and stakeholders must share a "regional vision" of the project. A clear mechanism should be designed from the beginning providing efficient and fair pricing schemes for transmission and playing level fields for all potential users and beneficiaries of the infrastructure.
- Institutional aspects cannot be overlooked. Creation of a credible and transparent legal and institutional framework for managing, building and then operating and maintaining the project are as important as getting the financing, engineering, procurement and construction right.
- As regional electricity trade will impact on the national energy markets, the collaboration of national institutions such as Ministries of Energy and Energy Regulators is an essential success factor.

Dr. Willy Kotiuga is the Senior Director of SNC-Lavalin's Power Systems Group, which is active in over 25 countries. He is an electrical engineer with over 30 years of professional experience in North America, South East Europe, Asia and Africa. He has been advisor to numerous governments in the development of power sector policy related to sector structure and development of short and long term strategies. He has provided critical advice to senior management in the successful restructuring of power utilities in a number of jurisdictions. He has proven track record of managing complex power sector projects that involve stakeholders from multiple jurisdictions and has played a key role in regional power projects, including GCCIA, CASA-1000 and EAPP.