

1. Introduction

1.1. General Introduction

International power grid interconnections provide links between the electricity transmission systems of two or more adjoining countries, and thus allow those countries to share power generation resources. As different countries are differently endowed with natural resources, energy trade among countries, as it has for centuries (perhaps millennia) helps to reduce energy prices and increase energy supply in importing countries, while providing a means of income for exporting countries. Most fuels can be transported by land or sea, by cart, freighter, truck, train, or tanker. Electricity, however, is generally not (yet) easily “storable” in bulk quantities, and must therefore be transferred by power lines².

International grid interconnections can be as modest as the one-way transfer of a small amount of electricity from one country to another, or as ambitious as the full integration of the power systems and markets of all of the countries in a region. Whatever the scale, international power grid interconnections can help to contribute toward the process of sustainable development. Grid interconnections can help to increase the supply and/or reliability of electricity for use in education, employment generation, health care, and many other development related activities, and can contribute toward the formation of competitive markets for electricity on national and regional scales, helping to potentially reduce the cost of electricity to developing economies. International power grid interconnections are often, however, extremely complex undertakings, with technical, economic, legal, political, social, and environmental issues—costs, benefits, and considerations—that must be taken carefully into account before and as arrangements for power sharing are made.

A small sampling of the many issues associated with international power grid interconnections includes:

- **Technical** issues, such as grid stability benefits, potential costs in the form of impacts on the national grid of technical problems in an interconnected network, and considerations in transferring power between grids with different technical standards of power quality and reliability.
- **Economic** issues, such as benefits in the form of avoided fuel, capacity, and operating requirements for one or both countries (for example, through taking advantage of economies of scale), costs in the form of required payments for transmission infrastructure, and considerations such as deciding on electricity pricing, national contributions toward interconnection costs, and the impact of power from interconnections on local economies.
- **Legal** issues, including benefits in the form of model legal standards for cooperative activities of all types, costs such as the need to adapt National laws and practices to international standards, and complications such as determining jurisdictions for settling disputes, deciding on protocols for selecting contractors, and determining liability for third-party injuries due to activities related to the power line.

2 The most ubiquitous form of electricity storage available today, electric batteries, generally store electricity in small quantities and at high cost. The purchase of batteries for lanterns and entertainment devices can be a major expense for non-grid-connected households in developing areas.

- **Political** issues, for example, benefits such as increasing cooperation and understanding between governments linked by the interconnections, liabilities such as additional exposure to potential political instabilities in a neighboring country, and considerations such as existing political rivalries between would-be electricity trading partners.
- **Social** issues, with benefits in the form of improved access to electricity for development-related activities, but potential costs in the form, for example, of intrusion of power lines into traditional areas used by indigenous peoples, and considerations such as providing opportunities for all affected social groups to provide input into the interconnection planning process.
- **Environmental** issues, including potential benefits such as avoided greenhouse gas, regional, local, and indoor air pollution, possible costs such as the impacts of power lines on animal populations, and considerations such as compliance with local and international regulations and protocols, and coordination in operation of grid interconnections so as to maximize environmental benefits.

As such, any development of international electricity grid interconnections requires thorough analysis that crosses a number of disciplines, from engineering and economics/finance through sociology and environmental science³. A thorough treatment of all of the issues noted above is well beyond the scope of this Report. What this document seeks to provide, rather, is a survey of the costs, benefits, and other considerations that would require analysis in the evaluation and implementation of international grid interconnections, with some guidance as to tools and resources that can be used in grid interconnection planning.

1.1. Background of Report

1.1.1. *Energy as an input to Sustainable Development*

The improvement in the supply of energy services—the cooking of a meal, the cold-storage of food and medicines, the lighting of a room for reading, or the movement of goods or people from one place to another—is a crucial input to the development process. Electricity is arguably the most versatile of fuels, able to provide a wide variety of energy services, from running electronics, to providing light, motive power, and heat, typically as or more conveniently than other fuels, at high end-use efficiency, and with very low impacts on the environment and human health at the end-use level. The development (both in capacity and in stability) of a nation's electric power sector is thus to a large degree a prerequisite for growth in other sectors and for overall economic and social development. Unfortunately, a combination of factors ranging from small market size, inability to attract investments, poor management and maintenance of existing infrastructure, damages due to war and conflict, and inadequate and inappropriate tariffs and revenue collection often contribute to irregularities and shortages in electricity supply in

3 A set of documents that maps out a recommended approach to evaluating many, if not all, of the key aspects of electricity interconnections, as well as indicating some of the steps toward undertaking interconnections, is the *Regional Electricity Cooperation and Integration (RECI)* compilation, which are “E7 Guidelines for the pooling of resources and the interconnection of electric power systems”. This set of documents, consisting of a “Guidelines” overview, an Introduction, eight “Modules” and several attachments volumes, provides advice from the E7 Group of representatives of large utilities from the G7 group of industrialized nations. These documents are available from <http://www.e7.org>.

developing regions, including in many areas of Africa.

1.1.2. UN/DESA's roles in promoting development in the energy sector

The United Nations Department of Economic and Social Affairs (UN/DESA) has as one of its key goals the advancement of accessibility, availability, and acceptability of energy in all its forms to promote economic growth, environmental protection and social development. In developing countries, provision and consumption of energy and energy services will have to increase substantially to allow those countries to achieve development objectives and improve the quality of life for their citizens. The increased demand from developing countries will put upward pressure on the national and, ultimately, international supplies and prices of fuels, further compounding the challenge of delivering energy services to the poor, and further necessitating the need for multiple and complementary energy supply and distribution options.

Energy is one of the most internationally traded commodities. A dynamic perspective over time would reveal that this trade is continuously increasing both at the international level and at the regional level. The trade in energy is a positive factor in economic growth, and the international cooperation which supports it has become a major consideration in the evaluation of energy security issues today. International electricity grid interconnections affect and are affected by a host of issues closely associated with energy security; supporting developing country decision-makers in carefully evaluating and addressing these issues is a key goal of UN/DESA's activities, and is the major focus of this Report.

1.1.3. New Partnership for Africa's Development's objectives

An overview of the electrical power sector in Africa reveals several common trends that are of relevance to an overall examination of trans-border electricity grid interconnections:

- Varying degrees of privatization and restructuring of government-owned power companies have been undertaken by a number of countries, and are in varying stages of implementation;
- Shortages and irregularities in power supplies have forced many countries to look more closely at supplementing domestic supplies with trans-border networks and power pools; and
- Serious policy, investment, capacity and infrastructure challenges (including electricity theft, aging equipment, and infrastructure damage) continue to be associated with improving access to electricity in rural and peri-urban areas.

These difficulties are hardly unique to Africa, among developing nations and regions, but are perhaps more widespread in African countries than in any other region.

The Plan of Implementation (POI) of the World Summit on Sustainable Development (WSSD), recognizes that "access to energy facilitates the eradication of poverty" and underscores the critical linkages

between meeting Africa's energy needs and achieving African sustainable development objectives⁴. More specifically, the POI calls for supporting Africa's efforts to implement the New Partnership for Africa's Development's (NEPAD) objectives on energy which seek to secure access to "clean and affordable commercial energy supply" for at least 35 percent of the African population within 20 years, especially in rural areas⁵.

Noting that the development of cross-border energy trades is one of the goals for the energy sector of NEPAD, a recent DESA paper proposed the need for studies for electric power grid interconnections in Africa, and provided brief summaries of several ongoing interconnection projects in Africa that are in the planning and/or implementation phases⁶. To address this need, UN/DESA has agreed with the "E7" group of major utilities and utility organizations from industrialized nations to initiate a series of seminars on grid interconnection seminars in selected African countries. These seminars will consist of the presentation of general guidelines and an overview of interconnection issues for certain regions in Africa.

1.1.1. Goal of the Report

The purpose of this document, in keeping with UN/DESA's support for sustainable development in Africa, is to provide input to the seminar series referenced above, but more generally to provide a review of the multi-disciplinary issues associated with grid interconnections worldwide. The overall goal of this Report is to identify the issues associated with international electricity grid interconnection so as to provide a resource for decision makers (and the engineers, economists, environmental and social scientists, and others that support them) in developing countries to analyze the roles that grid interconnections can play in the sustainable development of their countries and their regions, including the full costs, benefits, risks, and requirements of interconnection options. In so doing, the Report is designed to help in the definition of a framework for cooperation between energy sector decision makers in countries considering grid interconnections.

4 The World Summit on Sustainable Development was held in Johannesburg, South Africa, from 26 August to 4 September 2002. The overriding theme of the Summit, as described in the Conference Press Release (<http://www.un.org/events/wssd/pressreleases/finalrelease.pdf>), "was to promote action and major progress was made in Johannesburg to address some of the most pressing concerns of poverty and the environment. Commitments were made to increase access to clean water and proper sanitation, to increase access to energy services, to improve health conditions and agriculture, particularly in dry lands, and to better protect the world's biodiversity and ecosystems. The major outcome document, the Plan of Implementation, contains targets and timetables to spur action on a wider range of issues, including halving the proportion of people who lack access to clean water or proper sanitation by 2015, to restoring depleted fisheries to the preserving biodiversity by 2015, and phasing out of toxic chemicals by 2005. In addition, for the first time countries adopted commitments toward increasing the use of renewable energy "with a sense of urgency." Although a proposed target for this was not adopted. But rather than concluding with only the words of an agreed document, the Summit has also generated concrete partnership initiatives by and between governments, citizen groups and businesses. These partnerships are bringing with them additional resources and expertise to attain significant results where they matter—in communities across the globe." Additional reports from the Summit are available at http://www.un.org/jsummit/html/documents/summit_docs.html. The main Report of the Summit, including the Plan of Implementation, can be found at <http://daccessdds.un.org/doc/UNDOC/GEN/N02/636/93/PDF/N0263693.pdf?OpenElement>.

5 New Partnership for Africa's Development text, from a conference held in Abuja, Nigeria in October, 2001, can be found at http://www.uneca.org/eca_resources/Conference_Reports_and_Other_Documents/nepad/NEPAD.htm.

6 A. Cherian (2003), *Development And Operation of Trans-Border Interconnections Of Electric Power Grids In Africa (An Overview)*. Paper prepared for UN/DESA, and dated September 2003 [File name "Backup of African Grid Interconnection Sept 03.wbk"]. Another summary of many of the current and planned transmission interconnection projects in Africa is provided in section 6.2 of E.A.K. Kalitsi (2003), *Problems And Prospects for Hydropower Development in Africa* (prepared for the Workshop for African Energy Experts on Operationalizing the NGPAD Energy Initiative 2 – 4 June 2003 Novotel, Dakar, Senegal, and available as <http://www.un.org/esa/sustdev/ssissues/energy/op/nepadkalitsi.pdf>).

1.2. Existing Interconnections and Interconnections in Process

A number of interconnections in regions around the world are currently operating or in the planning phases, including⁷:

- **Europe's integrated markets:** Western and Central Europe, (UCTE); Scandinavia (NORD POOL); South-East Europe Regional Market; Baltic Electricity Market
- **CIS** (Commonwealth of independent States—the countries of the former Soviet Union) **countries:** increasing reintegration and trade
- **North America:** The United States and Canada have extensive electricity and gas trade
- **South American electricity markets:** South Cone countries and the Andean Community of Nations
- **Central America** (SIEPAC): efforts are under way to integrate electricity systems
- **Africa's integration efforts:** Southern Africa (The Southern African Power Pool, 1995); some interconnections and planned interconnections in the Nile River basin, West Africa, and East Africa
- **Southeast Asia:** The Greater Mekong Subregion initiative for integrated electricity markets

These and other interconnection efforts provide background and experience that can be drawn upon in the design of new interconnections. Virtually each new interconnection prospect, however, presents its own special set of multi-disciplinary issues that demand thorough and detailed consideration by a wide range of stakeholder groups.

1.3. Road Map of Document

The remainder of this Report is organized as follows:

- **Chapter 2** provides a review of the **technical** aspects of grid interconnection, including the requirements and options for creating electrical links between nations, and the types of information and modeling capacity needed to assure that grid interconnections result in improved grid performance in all of the interconnected nations.
- **Chapter 3** addresses the **economic and financial** aspects of grid integration, including noting the possible direct and indirect economic and financial costs and benefits of integration, as well as discussing some of the economic and financial arrangements needed between countries and with other participants in grid interconnection development.
- **Chapter 4** reviews some of the **legal** aspects of grid interconnection, including a definition of the types of institutions that are often involved in legal agreements related to grid interconnections, and the types of agreement used, a review of the national attributes that help to ease the way for legal agreements, and potential benefits to national legal systems from experience with interconnection-related legal arrangements.
- **Chapter 5** identifies some of the **political** aspects of the integration of electricity grids, including

⁷ Listing adapted from Vladislav Vucetic (2004), *South Asian Regional Energy Trade: Opportunities and Challenges*. Presentation provided at The World Bank/International Monetary Fund Annual Meetings, Washington, D.C., October 1, 2004. Available as http://siteresources.worldbank.org/INTSOUTHASIA/Resources/Energy_a.pdf.

a review of the political characteristics of national political systems and international political relations that favor or make more difficult interconnection agreements, as well as a summary of some of the political benefits and liabilities that interconnection arrangements can bring with them.

- **Chapter 6** describes some of the **social** aspects of grid interconnection, including the benefits of improved electricity supply and resource incomes for the interconnected societies, and the potential social liabilities of grid interconnection and the construction and operation infrastructure used to connect grids and produce electricity for trade.
- **Chapter 7** notes some of the **environmental** aspects of grid integration, including avoided air and water pollution from changes in the patterns of electricity generation and other fuel use, the potential environmental and human health consequences of grid interconnections themselves, and the environmental impact assessment requirements that often accompany multilateral financing of international grid interconnections.
- **Chapter 8** summarizes the potential benefits and costs of grid integration with regard to **energy security** of the nations involved.
- **Chapter 9** provides key conclusions from the materials presented in this Report, and offers recommendations for follow-up activities associated with the analysis of the multi-disciplinary aspects electricity grid interconnections.
- **Attachment materials** to this Report include a Glossary and List of Acronyms related to grid interconnections, as well as an annotated bibliography of additional reference materials.