SUMMARY REPORT

SECOND WORKSHOP ON REGIONAL POWER GRID INTERCONNECTION IN NORTHEAST ASIA

May 6th to 8th, 2002 in Shenzhen, China

1. Nautilus Regional Grid Project Overall Description

1.1. Goal and Objectives of the Grid Project

The overall goal of the Nautilus Regional Grid Project is to examine the economic and technical feasibility of electric power grid interconnections in the Northeast Asian region, which is broadly defined as the Russian Far East (RFE), China, Democratic People's Republic of Korea (DPRK), Republic of Korea (ROK), Mongolia and Japan. The project focuses especially on practical and implementation-phase aspects of creating power grid interconnections, and aims to conduct detailed quantitative pre-feasibility analysis in order to demonstrate the value of, and barriers to, establishing power inter-ties between countries. These analytical explorations will also need to consider the impacts of the security, environmental, and political situations in each country on any regional grid (and vice versa).

An additional specific and key objective of the Regional Grid Connection Project is to determine the technical, economic, and commercial feasibility of different ways of providing reliable grid support for the safe operation of the Korean Peninsula Energy Development Organization's (KEDO) Light Water Reactors (LWR) currently under construction in the DPRK.

The Grid project has three phases and the following key objectives:

- Initiating collaboration between energy policy researchers, power system experts, and engineers from the Northeast Asia region and from other areas of the world, in order to identify the potential benefits of, constraints to, and barriers in implementing electric power grid interconnections in the Northeast Asia region. **(Phase I)**
- Opening communication channels to develop a common understanding on topics associated with regional grid interconnection between national researchers in the region. **(Phase I)**
- Identifying and discussing practical procedures for achieving regional grid interconnection, for example, identifying practical financing mechanisms and necessary institutional structures. **(Phase II)**
- Providing training to energy experts from the region in key topics related to regional grid interconnection, such as aspects of international electricity trade and energy markets. **(Phase II, III)**
- Conducting one or more pre-feasibility studies to show the economic and technical feasibility of regional grid interconnections. (Including developing the detailed concepts of the studies, collecting and assembling datasets for input into simulation software, running economic and technical simulations, and compiling results). **(Phase III)**
- Discussing, evaluating, interpreting, and disseminating the results of the pre-feasibility studies. **(End of Project, Final Phase)**

- Creating a context for friendly and meaningful ROK-DPRK dialogue and collaborative work on a significant energy security issue. **(Phase I, II, III)**
- Increasing the DPRK's cognizance of critical elements of grid-LWR operational and safety issues that bear heavily on the KEDO mission in support of the US-DPRK Agreed Framework and nuclear non-proliferation goals in Korea. **(Phase I, II, III)**

1.2. Brief summary of the Phase I of the Grid project

In the first phase, of the grid interconnection project, Nautilus assembled a regional and international network of people who are active in the fields of the electricity trading and power grid interconnection. The primary task for the first phase of the Grid project was to hold a regional workshop on power grid interconnection where all of the countries in the region, including the Democratic People's Republic of Korea (DPRK), were represented and participated.

The Nautilus Institute (Nautilus) and the Chinese State Power Corporation co-hosted the first Grid workshop in Beijing in May of 2001. Participants included engineers from the Chinese utility in the area of Northeast China adjacent to the DPRK, as well as representatives of Chinese central agencies, scholars, electrical engineers from the DPRK, leading power system engineers from the ROK, power system experts from Japan and Russia, and economists and energy policy analysts from the region, Europe, and the United States. The workshop successfully provided a forum for the sharing of the latest research related to regional grid interconnection issues among workshop participants from the region, as well as information about the development of the electricity sector in each of the region's nations. Through the workshop's activities, we developed common knowledge among workshop participants regarding the technical aspects of grid connections, energy and electricity markets (such as global trends in market deregulation), and other general issues (for example, climate change, acid rain, and others) related to electricity generation and grid operation. The workshop also provided the opportunity for participants to hear the perspectives of individual countries on potential power grid interconnections.

The May 2001 workshop also provided training and background for regional researchers on technical issues associated with grid interconnection. This technical element was particularly valuable in providing information to North Korean experts on general issues associated with the development and operation of regional international power grids, as well as on the realities of the KEDO reactor/power grid interactions and plausible ROK-DPRK grid connections. In particular, the DPRK experts who attended the workshop now have complete information on the link between grid reliability and the scale of a nuclear power plant operating within the grid, as well as the linkage between grid reliability and the safe operation of LWR nuclear power plants. The information provided to DPRK participants during the workshop included a full set of US and international regulations and standards concerning grid-LWR connection and auxiliary power requirements for safe LWR operation

The Final Report and the workshop materials from the First Regional Grid Interconnection Workshop are available at: http://www.nautilus.org/energy/grid/index.html

2. Summary of the Second Grid Workshop

The following sections provide a summary of the proceedings of the Second Grid Workshop held from May 6th to 8th, 2002 in Shenzhen, China. Participants in the workshop included electric engineers and power system experts from China (the State Power Corporation, the Ministry of Science and Technology, the Liaoning Electric Power Corporation, Tsinghua University, the Shenzhen Power System Research Institute, the Electric Power Research Institute, and Hong Kong University), Russia (Far East State Transport University, the High Voltage Direct Current Power Transmission Research Institute, the Unified Power Grid of Russia, and Energy Systems Institute), South Korea (the Korea Electric Power Corporation, the Korea Electric Power Research Institute, the Korea Electrotechnology Research Institute, and the Korea Institute of Nuclear Safety), and the United States (Nautilus Institute and Evergreen Safety & Reliability Technologies). Also attending were two observers from the Korean Peninsula Energy Development Organization (KEDO).

The workshop was co-hosted by Professor Felix Wu and the Tsinghua University - Hong Kong University Shenzhen Power System Research Institute. The Shenzhen Power System Research Institute (SZPSRI) was established in April 1999 in Shenzhen city, Mainland China, and specializes in the field of power systems engineering. The SZPSRI is supported by the well-known Power System National Key Lab in Tsinghua University, P.R.China, and the Centre for Electrical Energy Systems of Hong Kong University. The activities of the SZPSRI include power systems studies, software development, training in power system analysis, and consulting activities undertaken for utilities. The SZPSRI also works as the distributor in China for power system companies from around the world. More information about SZPSRI is available at: *http://www.eee.hku.hk/~cees/framemain.htm*

Final Report and the workshop materials for the Second Regional Grid Workshop are available at: http://www.nautilus.org/energy/grid/2002Workshop/index.html

2.1. Workshop agenda

The main goal of the Second Regional Grid Workshop was to reach a consensus regarding the creation and mission of a pre-feasibility working group of regional researchers that would conduct quantitative, collaborative analysis. The workshop focused primarily on reviewing the economic and technical feasibility of power grid interconnection routes linking the countries of the region. Nautilus commissioned Dr. Sergei Podkovalnikov and his research group of the Energy Systems Institute of Russia to synthesize results from previous economic pre-feasibility studies on the possible interconnection routes from the RFE to the ROK through the DPRK or through the DPRK and China. The workshop used the Russian study as a springboard to initiate discussion of interconnection issues, and then elaborated on the collaboration and practical procedures for conducting the pre-feasibility study proposed by Nautilus. Workshop agenda items were roughly divided into three main topics: 1) economic and technical analysis of

possible interconnection routes, 2) organization of a pre-feasibility working group of regional researchers, and 3) analytical methodology and common tools for ongoing joint study, including data sharing mechanisms. We also discussed safety and grid stability issues related to the KEDO LWR nuclear power plant.

The workshop was divided into the following seven sessions:

2.1.1. National Updates on Grid Development and Grid Interconnection Investigations

Participants from each country on the proposed route gave a brief presentation on the major and recent power grid developments in their own country. Participants also reported on any discussions underway in their countries regarding grid interconnections.

Russian Far East

Dr. Alexander Ognev of the Far Eastern Representation Vostokenergo, Unified Power Grid of Russia, reviewed electric power development in the Russian Far East.

According to his report, the Russian economy is still largely stagnant, and power sector development has been on hold. There has been no major construction of power plants or transmission lines in the last year. Liberalization of the domestic electric power markets in the RFE continues to progress.

As to the activities regarding regional electricity trades, Russia and China have begun a collaborative pre-feasibility study on the grid interconnection between the RFE and North East China. However, this collaboration has been put on hold recently. Interconnection studies between RFE and Japan have been intensively conducted, and a collaborative feasibility study with Japanese trading companies has been conducted. A study on a small capacity connection (<500MW) between the DPRK and Russia is proposed as a collaboration between the Russian and DPRK Academies of Science. Renewable sources of energy and ecologically safe types of fuel in the RFE are also viewed as a possible solution of the regional environmental problem in Northeast Asia.

In the Northeast Asian region, Russia is the only country that can be an energy exporter to the rest of the region. It is important for regional resource planning to know the projections of future energy demand and the power sector development plans of the RFE. Currently, Russia is willing to export energy. Their willingness is based on the fact that the electricity demand declined by 25 percent during 1992-1998. The current tend of demand, however, is in the opposite direction, as demand for electricity increased 11.3 percent in the RFE during 1999 to 2001, accompanying a slow but continuous economic recovery.

China

There were three presentations by the leading energy policy and technology experts on the development of the Chinese power industry. The findings of Dr. Shao Liqin, of the Department of High and New Technology, Ministry of Science and Technology, Dr. Wei Quangyao Director General of International Cooperation Department, State Power Corporation of China, and Dr. Zhou Xiaoshin from the Electric Power Research Institute of China are summarized as follows:

China's energy priority is currently to achieve sustainable development of the power industry more or less internally and to improve energy independence through development of the nationwide power transmission system (especially development of transmission lines from the western part of China to the eastern part), by integrating regional power networks, by restructuring the energy sector including the electric power industry, and by liberalizing and further developing national energy markets through competition. Because China has emphasized national power network integration, the national electric power system has been strengthened and the power generation structure has been optimized. Current development policy continues the trend toward implementation of large generation units, large power stations, large networks, the expanded use of extra high voltage power transmission and automation in network control, and the institutional separation of generation and transmission functions. As of 2001, trans-regional power exchanges in China stood at 23.45 TWh.

Other priorities for China's power grid system are to build major transmission corridors, enhance individual, regional and provincial grids, continue urban and rural network construction and renovation, and strengthen the construction of a secondary system (40% of electric industry investment is for the grid enforcement and expansion.)

China is reluctant to connect power lines to the DPRK's small, unstable network or (when they are complete) to the DPRK's LWRs based on China's experience with the Daya Bay nuclear power plant. The situation of the Daya Bay nuclear plants in 1990's could be instructive for the current DPRK situation. In the early 1990s, a trip of 1GW nuclear unit on the Guangdong power grid caused a loss in stability of the South China interconnected power system. This is an instance of the operational problems that can be caused by having a single generation unit that is comparatively large relative to the power system in which it operates.

ROK

Dr. Yoon from the Korean Electrotechnical Research Laboratory emphasized that a pre-feasibility study on the grid interconnection should be done as soon as possible to show the South Korean government that the project could be economically beneficial. Since the investment capability of the ROK is very limited, the government must decide whether power grid interconnection or natural gas pipeline development would reap greater benefits. In fact, natural gas pipeline development and feasibility studies are far more advanced than grid studies at present.

The ROK cannot, however, simply use criteria of economic and/or technical feasibility to decide whether a grid interconnection connection would be beneficial or not. Grid interconnection is very much a political issue for the Korean peninsula, as well being an issue regionally in NE Asia as a whole. Taking into account political and geographical viewpoints, other advantages gained from the electricity trades should be considered. An especially key issue is how to bring the DPRK to the discussion table.

DPRK

Dr. Peter Hayes of Nautilus Institute explained to workshop participants that DPRK colleagues unfortunately were not able to come to the Second Regional Grid Workshop, and surmised that the reason they did not attend could have been in part due to the pending resumption of

communications between the DPRK and the United States and between the DPRK and the ROK. Dr. Hayes emphasized that Nautilus' information is that our DPRK colleagues remain keenly interested in the issue of power grid integration, and wish to remain participants in the workshop and pre-feasibility study process.

In the absence of DPRK participation in the Second Workshop, Dr. David Von Hippel provided a presentation based on Nautilus research on the DPRK electricity sector. The goal of this presentation was to provide workshop participants with a brief overview of the DPRK's electricity infrastructure and of the issues associated with power generation facilities and the transmission and distribution grid in the DPRK. Dr. Von Hippel's presentation included a summary of the background to DPRK energy analyses carried out by Nautilus, including the history and analytical approach used. The presentation continued with an overview of the DPRK energy sector and economic situation, including the recent history of the sector, indicators of 1990 and 1996 energy supply and demand, a discussion of the DPRK's electricity production, electricity transmission and distribution, and coal mining infrastructure, and a discussion of the impact of end-use efficiency on overall energy, and especially electricity, use in the DPRK. Dr. Von Hippel also provided a brief, introductory treatment of the problems associated with using the nuclear reactors now being built by KEDO within the existing DPRK transmission grid. A copy of Dr.

Key Points from National Presentations:

- There has been little change in electric power system (or network) development and energy policy in the countries in the region, with the exception of China, during the last year.
- Given that China's energy priority is on national energy issues, China is not enthusiastic to be actively involved in the process of regional interconnection or in conducting a feasibility study. However, it remains important to discuss the role China could play in the collaboration. One suggested role is as a technical advisor and technologies provider. Prof. Zhou mentioned that China has a significant accumulation of experiences with integrating power networks, stabilizing power systems, and solving reliability problems (for example, the problem of low frequency oscillation, which is the most common stability problem, has occurred in China when provincial grids are connected).
- Lessons that China has learned from the experience with the Daya Bay nuclear power plants could be of significant help in sorting out the North Korean LWR situation.
- A pre-feasibility study should be done to prove that power grid connection is economically, technically, and potentially politically beneficial to the countries involved, and also to show that its costs and benefits are competitive with those of international natural gas pipeline development.
- The participants from each of the regional countries represented at the workshop agreed that collaboration with the DPRK on grid interconnection issues is challenging but crucial to the ultimate development of the international power trade in Northeast Asia.
- It is uncertain how the liberalization of the electric power industry, especially the separation of generation and transmission sectors and the potential privatization of the transmission

sector, would affect the prospects for large international projects like a regional grid interconnection.

2.1.2. Presentation of Analysis of a RFE/DPRK/ROK Grid Interconnection

Dr. Podkovalnikov presented a study on the economic feasibility of a RFE-DPRK-ROK power grid interconnection. The research group in the Energy Systems Institute conducted the study. (His full paper is available on the Nautilus Grid project web site.) The Energy Systems Institute study illustrated a possible transmission route from the RFE to the ROK through the DPRK, plus a variant including a routing through China (discussed further below), and simulated preliminary costs-benefit analysis for those routes. His simulation method, the ORIRES model developed by the ESI, optimizes the generation of electricity in each country with and without a regional grid interconnection, and also optimizes the transfer capability of the grid interconnection, using as an objective function the economic costs of generation to each country. A second model, the YANTAR model, was used by the ESI group to study the reliability of the grid interconnection..

Key conclusions in the study:

- The power systems of RFE, DPRK and ROK are complimentary in terms of the diversity of available power resources and power demand over the course of an average year. There is a lack of energy resources in some regions and there are abundant energy resources in others; in some regions the peak in power demand comes in winter, in others – in summer; some regions have available hydropower capacity, and other regions lack capacity for meeting cycling demand of consumers.
- Local scale power connections between adjacent countries allow small cross-border trading without attaining all of the positive benefits of a major regional interconnection.
- Preliminary analysis showed that there is an already-developed transport and power grid infrastructure along a large part of the expected routes of ISETs (Inter State Electric Ties). This makes the routes more accessible and reduces the cost of construction of the ISETs.
- The year for which the ORIRES model optimization was performed is 2020, however many participants offered concerns abut the timeline used because if the LWR is part of the transmission route, the timeline of these power plants should be considered and included in the economic analysis.
- There is as yet no estimate as to the cost of upgrading the NK grid.

2.1.3. Discussion of Technical Aspects of an RFE/DPRK/ROK Power Grid Interconnection

This session of the workshop highlighted the technical issues associated with an ISET connecting the Russian Far East, the DPRK, and the ROK including a discussion of: 1) specific technical questions regarding assumptions in the Energy Systems Institute (ESI) Study presented in the previous session by Dr. Podkovalnikov, and 2) other technical requirements, difficulties, and alternatives regarding the RFE - DPRK - ROK interconnection. Discussants for this session (Taekyun Kim, Lev Koshcheev, Zhou Xiaoshin, and Boris Dynkin) gave short comments on technical issues from each country's perspective, and then discussed the technical aspects of the interconnection with other workshop participants. The discussion focused mainly on three

issues: long distance High Voltage Direct Current (HVDC) transmission technology, the technical difficulties with interconnection to the LWR nuclear power plants being built in North Korea, and potential network stability problems in the connected systems that would run through North Korea.

Key points from the discussion of the technical aspects of an interconnection:

- Given the physical distance between RFE and ROK through the DPRK, an HVDC connection should be used. The current voltage of DPRK's main transmission lines is 220 kV, but for the regional interconnection a higher voltage (500 or possibly 750 kV HVDC transmission line) would be needed. A more local interconnection between the DPRK and Russia could use a lower voltage AC line.
- There are at present few international examples of multi-terminals HVDC systems (systems with more than two points where power is put into or taken from the HVDC line), and there are some limitations as to the sizing of the terminals of the system--namely, all terminals need to be on the order of the same size. Additional studies are needed to fully understand the stability impacts os different configurations, and additional centralized control systems might be required for some types of HVDC connections between the countries.
- There is a railroad going through Russia to the DPRK, which uses mostly electric locomotives (operating on 50 Hz AC current). The right-of-way for this rail link would be an ideal location to construct a transmission line (alongside the rail). One problem, however, with constructing the transmission link in this rail right-of-way is that the link runs through a very narrow strip of Russian territory, about 40 km wide, on the Sea of Japan coast, and wetlands in this strip are ecologically sensitive.
- All participants were concerned about the quality (reliability and stability) of electricity of the DPRK grid. Connecting to an extremely unreliable network could cause serious damage on entire network.
- Participants addressed the question of whether the DPRK's LWR nuclear power plants, which will, when complete, have a total capacity of 2GW, operate safely within the regional grid network. It is possible that at 2 GW, the generation capacity of the LWRs is even too large for the HVDC connection. The question of whether it is possible to connect the LWRs directly to outside nations (the ROK or the RFE) without going through DPRK grid network was discussed.
- If it is too difficult to include a connection to the LWRs as part of the region-wide power network, then what are other solutions that would allow the LWRs to be run safely and reliably?
- Some of possible connections, including the KEDO/DPRK LWRs, discussed during the session are attached at the end of this report.

2.1.4. Discussion of Economic Aspects of an RFE/DPRK/ROK Power Grid Interconnection

This session of the Workshop highlighted the economic issues associated with a grid interconnection. Discussants (Jae Young Yoon, Cheol Suhmoon, and David Von Hippel) discussed 1) the economic assumptions included in the ESI study, 2) Key unknowns that need to be included in a full evaluation of the economics of the interconnection, and 3) other relevant topics related to the cost and benefit analysis carried out by Dr. Podkovalnikov and his group.

Key points from the discussion of ISET economic aspects:

- Most of participants agreed that the target years of an ISET study should be 2010 and 2020. However, in the assessment of the economic benefits of interconnection, there are large uncertainties that need to be taken into account, such as 1) whether the construction of the LWRs will be completed, and if so when, 2) whether the NK electric power network could be refurbished by the target year, and 3) whether transmission lines that are now part of the RFE domestic network will need to be refurbished in order to support the interconnection with the DPRK and the ROK.
- ESI's analysis showed that the payback time of the investment cost in the interconnection would less than one year. Although more detailed data and careful assumptions are needed to confirm and refine the analysis, the study shows that the regional grid connection could be economically feasible and beneficial for all countries.
- Given the currently weak DPRK economy and the deteriorating North Korean grid system, ESI's estimate of the electric power flow to and from DPRK in year 2020 could prove to be unrealistically optimistic.

2.1.5. The KEDO LWRs and Grid Interconnection Options

This element of the workshop agenda highlighted technical issues associated with connection of the North Korean power system and the KEDO LWR nuclear power plants to a national or regional grid system. Dr. John Bickel, a nuclear safety expert from Evergreen Safety and Reliability Technologies, LLC, detailed mandatory nuclear safety regulations and concerns associated with the operation of nuclear power plants connected to an unstable or small power grid network. Two observers from KEDO were present during the discussion. The main issue discussed intensively was whether a connection with stable power network (through an interconnection), plus an extra power source from within or outside of the DPRK, would enable the operation of the LWRs once they are complete. Such a grid connection may be an essential element of regional energy security and stability in Korea and East Asian region. Whether such as connection can be utilized in this manner, however, is still a topic for discussion and analysis.

Key points related to the KEDO LWRs:

- Emergency AC back up ON-site power systems are mandatory not only to ensure nuclear safety, but also to enable the operation of the reactor. Technical reasons for this requirement include: 1) the possibility of load rejection, or sudden loss of electricity demand - by the operational failure of the local network, 2) the need for emergency power in the event of the sudden shutdown of a nuclear power plant (to remove decay heat in the reactor core that continues long after the nuclear chain reaction is stopped) and 3) the system startup requirements, which are at least 50-60 MW for a 1GW reactor (meaning that it is highly likely that the NK power system, in its present state, could not even start the LWR units).

- If additional emergency AC systems won't be available within the DPRK, it needs to be determined what type of additional power supplies for this purpose would be necessary via an interconnection.
- We might be able to learn from the United States 1960s plans to build nuclear power plants in Puerto Rico at a time when the relatively small power network of that island was not connected outside of the territory - an situation similar to the island-like circumstances in which we now find the DPRK. The US studied and surveyed the options for building a nuclear plant in Puerto Rico, and then gave up on building the plants, concluding that to do so was far from safe. We can also learn from the Daya Bay (South China) nuclear power plants, as they are in some respects similar to the LWRs in being built in the DPRK in terms of LWR-network capacity scales.
- KEDO has the authority to stop the LWR project if the local network quality cannot satisfy the required international standards. It is not clear, however, whether the obviously weak North Korean grid can be refurbished, and how long that would take to do so.

2.1.6. Grid Integration: RFE/DPRK/ROK and China

As an alternative means for regional power grid interconnection, a route from the RFE through or to China is also worthy of consideration. Dr. Podkovalnikov presented his studies on a Four-Country Grid Integration scheme that incorporated Northeast China (NEC) as an electricity-trading partner. Following the presentation, participants discussed the potential benefits of four-country versus three-country integration, and the barriers associated with Chinese participation.

Key conclusions and discussions on four-country grid interconnection possibilities:

- Preliminary studies showed power grid interconnections connecting "RFE-DPRK-ROK", "RFE-NEC-ROK" and "RFE-NEC-DPRK-ROK" all bring about high economic benefits for all participating countries.
- It seems reasonable to examine an "RFE-DPRK-ROK" ISET, extended with a section running between the DPRK and Northeast China ("DPRK-NEC"). Joining the NEC to an "RFE-DPRK-ROK" power interconnection seems to be mutually beneficial for all participating countries. Examining prospects for a "DPRK-NEC" ISET extension depends, however, on China's willingness to provide the necessary data and experts for the study.
- China's electric sector priority is currently on national grid integration.
- China's most important concern is network reliability problems. China has been working intensively on nationwide grid integration, so Chinese researchers and engineers have more experience than other regional countries regarding network reliability problems. In particular, for China, a potential connection to North Korea is of serious concern due to the reliability problems on the DPRK grid.
- Dr. Ge, Senior Power System Engineer from the Liaoning Province Electric Power Company of China, explained the current operational situation of four hydro power plants along the Yalu River, in which dam capacity is shared between the DPRK and China. Liaoning Province is significant in the context of regional grid interconnection, as it forms part of the Chinese national border with Russia and DPRK. The output of the generation

units that are dedicated for use by China within the four hydro plants are used for "Chinese peak load" purposes during most of the year because available water flow is very limited. The plants operate at or near full capacity only during the rainy season (July 15- August 25). Furthermore, the Chinese power company operates the input to the hydro plants both on the Chinese side and on the DPRK side, so that only when China starts operating the plants to fill peak load demand in China is electricity produced for use by the DPRK on the DPRK

3. Organization of a Pre-feasibility Study

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For the remainder of the workshop, the participants discussed the organization of a pre-feasibility study-working group to further explore the costs, benefits, and other issues associated with regional power grid integration in Northeast Asia. At the first workshop, regional researchers agreed that making a small but close-knit working group was a pre-condition for further progress on grid interconnection, given all of the barriers to grid integration. At this second workshop participants discussed 1) developing the common understandings among working group participants regarding the project's overall goals, 2) exploring possible analytical methodologies and tools available for the pre-feasibility study, 3) discussing the common methodologies and tools to be used for the study, and 4) discussing the short-tem work plan (data exchange, project time line, list of tasks for individual groups, the next workshop, and other elements) for the study.

As a part of the exploration of possible analytical methodologies and tools available for the pre-feasibility study, Prof. Wu completed a software investigation and corresponding analysis. Dr. Zheng Yan followed with a demonstration, "A Case Study on Its Application to Three-Gorges Power System," done by using the PSAPAC stability analysis software system.

Key points in discussions of a pre-feasibility study working group:

- Given the current situation that much analytical work has already been done to evaluate potential ISET options, participants agreed with Prof. Wu and Peter Hayes that the group needs a proof of concept of an ISET that also involves explicit consideration of the connection of the KEDO LWRs. Dr. Podkovalnikov's analysis showed that the payback time of the investment cost in an interconnection is within one year. Some participants felt that the method of calculating economic costs and benefits used in Dr. Podkovalnikov's study should be supplemented by further analysis, including the application of more detailed regional energy data. Prof. Wu emphasized, however, that Dr. Podkovalnikov's economic assessments support the conclusion that grid connection may by economically beneficial.
- The target years for the working group analysis should be 2010 and 2020, with consideration given to significant events, such as the completion of the LWR nuclear power plants (2007 or later), the Beijing Olympic in 2008 (and the infrastructure required to host the Games), the time-line of refurbishing the NK network, the time-lines for the liberalization of the energy markets and the separation of generation and transmission within the electricity sector (in the RFE, ROK, and China), other issues.
- Detailed studies of grid interconnections are necessary in the following three areas: 1) economic cost and benefit analysis, 2) analysis of the steady state stability of the regional

interconnected network, and 3) dynamic stability analysis. For the economic study, Dr. Podkovalnikov's economic assessment is a good start.

- The working group should develop a shared system and goal of slow but continuous accumulation of energy data and related information.

- ROK participants felt that it could not be decided whether the ROK could provide needed ROK grid data for rough stability analysis of inter-connected grids by the working group until some agreement is made on common methodologies and analytical tools, and pending discussions with other colleagues in the ROK.

- **A listing of data needed for the economic analysis, as discussed by the workshop participants, includes:**
  - Future scenarios (projections and growth rate) of electricity demand and supply in each of the countries of the region
  - Seasonal data or annual load patterns (Summer peak and Winter peak) for each nation or region (in the case of Northeast China)
  - Current annual, monthly, and daily load patterns
  - Cost data: fuel costs, capital costs, operating costs, generation costs, and other data on the generation resources used in each country, including an identification of which generators would either be used to provide power for an ISET or whose operation (and possibly construction) would be "avoided" if an ISET were to be implemented
  - Models and arrangements for the pricing of electricity transfers in each of the countries in the region
  - Potential regional grid designs, and, if the interconnection is achieved, individual countries avoided costs (to the extent calculated separately from power plant costs, as above)
  - A generation capacity expansion plan (including alternative plans as required) for each country of the region
  - Baseline projections of future energy and cost data for each country in the absence of an interconnection

- **Required data for the technical analysis**
  - The required technical parameters (relating to the electricity grids in each country) that will be needed for the quantitative network analysis depends on the common tools that will be used for the study. Participants discussed intensively which common tools a working group would work with. The group could not, however, reach a consensus to provide the data for the study. The types and form of data required for the technical analysis would strongly depend on which methodology and what tools researchers agree to use for the pre-feasibility study.

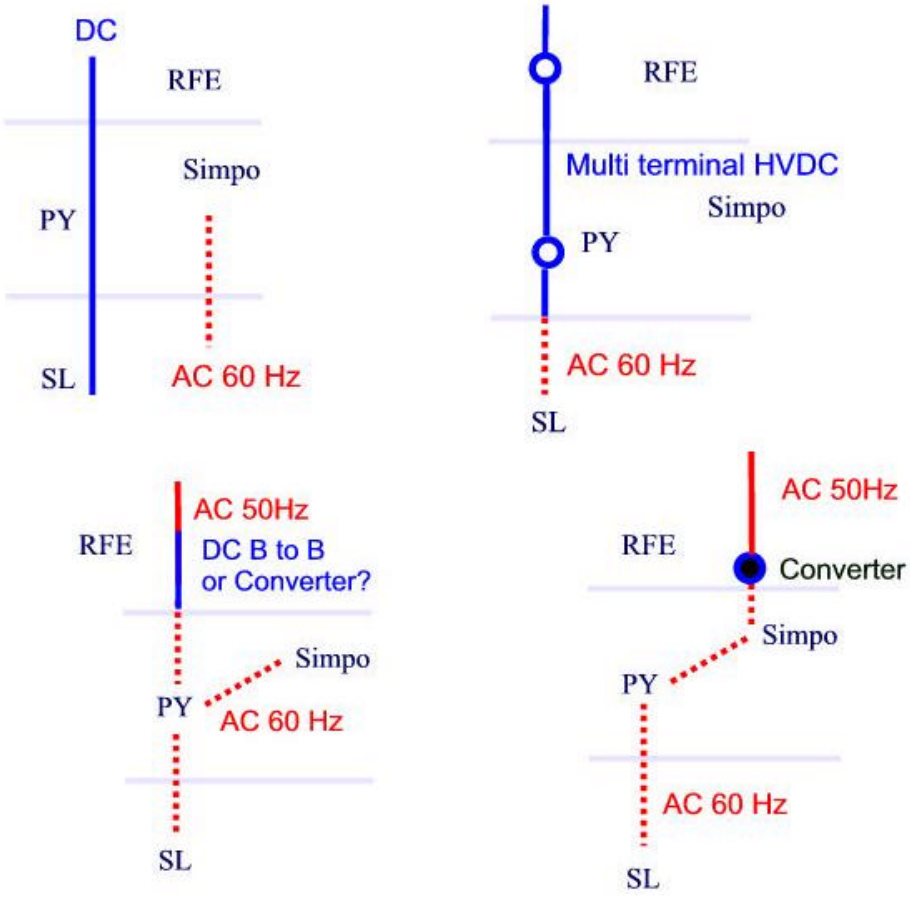
- DPRK participation is crucial for the pre-feasibility study in order to create a simplified but complete regional power network map and database for the quantitative analysis.

4. Suggested plan for the phase III

Nautilus will create or commission (possibly with the assistance of Prof. Wu or other power system experts) a concept paper on how to conduct the pre-feasibility study based on the discussions in the second workshop. The paper should describe detailed plans such as possible routes, proper technological choices, how to assemble datasets for input into simulation software, and other aspects of the study. Most of the plans for these activities were preliminary discussed at the Second Workshop except for the protocol to be used in assembling the datasets. The intent is for all working group members to consider and provide comments on the Nautilus concept paper, and ultimately to reach a consensus on the work plan. After the working group reaches a consensus over the work plan and study methodologies to be used, the group can start conducting economic and network stability analysis using a simplified regional map.

At the Third Regional Power Grid Interconnection Workshop (to be held in Fall or Winter, 2002), the Working Group will present the above-mentioned concept paper and verify the data of the combined three (ROK, Russian Far East and DPRK) or four (plus Liaoning province)-country simplified power system network diagram for use of the working group study

One difficult aspect of the study will likely prove to be the analysis of KEDO-specific issues that arise from the simulations. This aspect may prove especially difficult if the DPRK is reluctant to participate in the working group for political reasons (although it may also be difficult even with full DPRK participation, due to lack of data). It will therefore be a challenge to the group to sustain DPRK interest in and attention on the working group study, to ensure that the DPRK is able to make a meaningful contribution to the regional analysis, and to ensure that DPRK participants understand fully and respond to the KEDO-specific issues involved in the grid connection proposals. To facilitate the DPRK's participation, it may be necessary for one or more working group members to travel to Pyongyang to brief, provide training for, and work with group members from the DPRK, although the desirability, practicality, and availability of funding for such a "mission" is still very much under consideration as this report is being prepared.


DC
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DC B to B
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