Accessing Renewable Energy Resources and Electrical Integration in the Asian Region

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Abstract – *This paper discusses possible and future electric power interconnections between Asian countries: China, Russia, Mongolia, Malaysia, Korea, and Japan, etc. It considers accessing renewable energy resources and electrical integration in the Asian Region together with the generation of electricity from sources that are not fully utilized. Benefits of electrical interconnections include abundant cheap and cleaner electricity in the Asian region that will be made possible by an East Asian power grid. A proposal for a feasibility study of the East Asia transmission projects is first reviewed. The project represents possible and future electric power transmission interconnections between Russia, Mongolia, China, North and South Korea and Japan. The proposed transmission projects are to enable countries of East Asia and Russia to trade in electric energy. The central part of the paper considers development of the Nationwide Interconnected Grid of China. Purposes of the interconnection, basic structure, key projects and some technical problems are reviewed. The nationwide interconnected grid will be basically established in 2020 and will become one of the largest power systems in the world, where installed capacity at that time will be of the order of 700 GW. The final part of the paper focuses on requirements for coordinated development of transmission systems to meet rapidly growing demand in Asian countries. General trends, generation resources, electricity transmission systems, structure of the electricity industry, and upgrading of transmission systems are discussed.*

Résumé – *Cet article aborde la possibilité et la prochaine interconnections, de la puissance électrique, entre les pays asiatique: Chine, Mongolie, Malaisie, Corée, et Japon, etc. Il prend en considération l'accès aux ressources des énergies renouvelables et l'intégration de l'électricité dans l'ensemble des régions asiatique avec génération de l'électricité a partir de sources qui ne sont pas complètement utilisées. Les bénéfices de l'interconnections électrique, dans la région asiatique qui peut être assurer par le réseau de puissance de l'est asiatique, sont une réduction du coût et une électricité propre. Une proposition pour l'étude de la faisabilité des projets de transmission de l'est Asiatique est avant tout revue. Le projet représente la possibilité et la prochaine interconnections et la transmission de la puissance électrique entre la Russie, la Mongolie, la Chine, la Corée du nord, la Corée du sud, et le Japon. Les projets de transmission proposes sont inities pour favoriser le commerce de l'énergie électrique entre l'Asie de l'Est et la Russie. Le chapitre essentiel de l'article prend en considération le développement du réseau de connexion international de la chine. Les raisons de l'interconnections, les structures de base, les projets clés et quelques problèmes techniques sont re-examines. Le réseau de connexion international devrait entre fondamentalement établi en 2020 et devenir l'un des systèmes de puissance le plus important au monde, et les condensateur utilises en cette époque serait de l'ordre de 700 GW. La dernière partie de l'article se concentre sur les exigences de coordination du développement des systèmes de transmission affin de répondre a la demande croissante des pays asiatiques. Les tendances générales, la génération des ressources, les systèmes de transmission électrique, la structure de l'industrie électrique, et les améliorations des systèmes de transmission sont abordes.*

Keywords: Electric power system interconnection – Accessing renewable energy resources – Electricity system integration in Asia – Bulk electricity transmission system feasibility studies – Interconnected grid networks in China – Coordinated electricity system development requirements – Hydro power development.

1. INTRODUCTION

This paper examines in a form not presented in the literature in a convenient form heretofore possible and future electric power interconnection between Asian countries: China, Russia, Mongolia, Malaysia, Korea, and Japan, etc. It considers accessing renewable energy resources and electrical integration in the Asian Region together with the generation of electricity from sources that are not fully utilized. It also focuses on development of national interconnected grids in China and the requirements for development of transmission systems in Asia to meet rapidly growing demand.

2. PROPOSAL FOR A FEASIBILITY STUDY OF EAST ASIA TRANSMISSION PROJECTS

The title of "PEACE Network" has been applied to represent the possible and future electric power interconnections between Russia, Mongolia, China, North and South Korea, and Japan. The term "*PEACE*" is derived from *P*ower, *E*conomy *A*nd *C*lean *E*nvironment and symbolizes the intent of the Task Force which has been assembled to undertake the Feasibility Studies.

The proposed transmission projects will enable the countries of East Asia and Russia to trade in electric energy. Collectively, they represent large resources of clean electrical energy. It is only a matter of time before the means for international trade in electricity will be demanded. Government policies and laws need to be charted, and the results of the Feasibility Studies are expected to play a valuable role in guiding their formulation.

An East Asian power grid will be a major contribution to stimulating sound economic development for participating countries with overall reductions in greenhouse gas emissions. Efforts are being made to include North Korea since without North Korea, the Studies will be incomplete.

2.1. Background

The countries and territories of East Asia are characterized by their economic systems being geographically close, that they have different levels and rates of economic development, that they possess different reserves of energy resources, that they complement each other, and can interact to their benefit [1-45].The main electricity grids of the East Asia Region are shown in Figure 1. Table 1 summarizes the installed generating capacity and power generation for the territories of interest in East Asia. Estimates of future directions and amounts of power flows from areas with surplus energy to areas with increasing energy demand are shown in Figure 2.

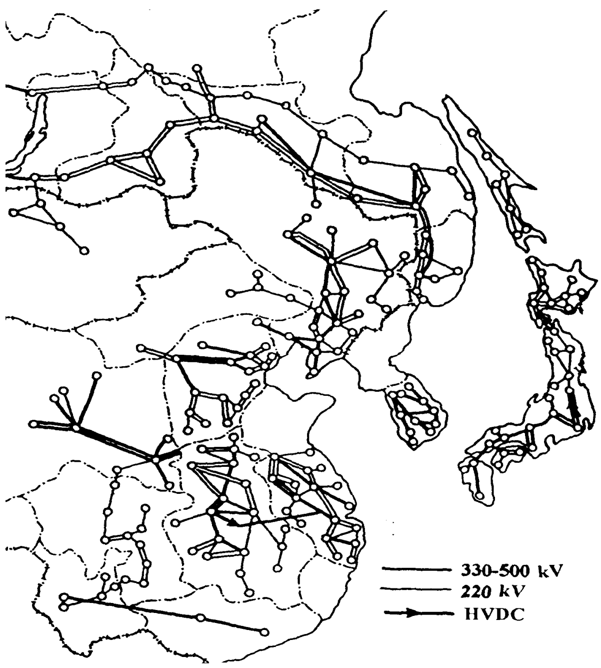

Fig. 1: Main grids in the east Asia region

They are obtained by generalized analysis of prospects and peculiarities of the economies and energy developments of the various countries and territories. Possible locations of power plants with available energy resources are taken into account. Consideration of system effects such as non-coincident seasonal and daily load curves as well as sharing of capacity reserves will result in additional power flows in both the forward and backward directions.

Table.1 : Electricity production and capacity in the east Asia region in 1997

Country, Territory	Electricity Production, TWh	*Installed Capacity of Power Plants, GW*			
		Total	Hydropower plants	Thermal power plants	Nuclear power plants
East Russia*	156.7	41.3	23.1	18.2	-
N.E. China	143.2	30.1	5.1	25.0	-
N.China	176.4	34.5	2.0	32.5	-
N.W. China	70.0	15.8	6.3	9.5	-
Mongolia	2.9	0.9	-	0.9	-
N.Korea	33.7	9.5	5.0	4.5	-
S.Korea*	215.3	43.4	3.1	28.3	12.0
Japan	1038.0	220.9	43.9	132.0	45.0

* 1998

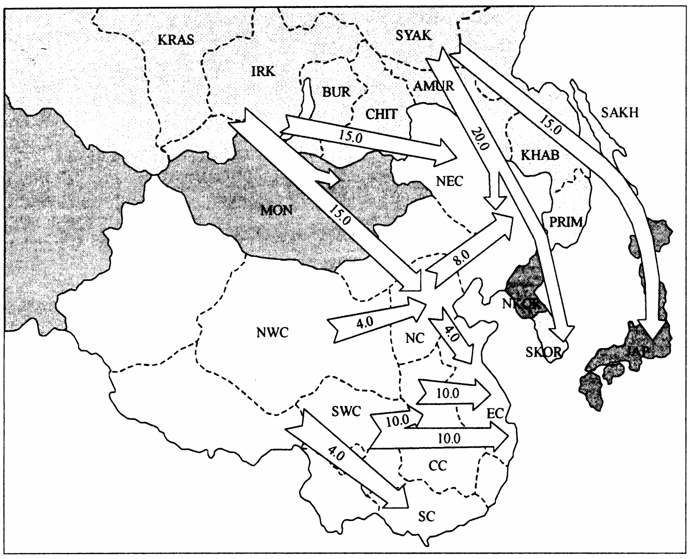

Fig. 2: Prospects for electricity exchanges in the east-Asia region, TWh/year

2.2. Objectives of the feasibility study

The main objectives of the Feasibility Study are:

a) To select and rank projects with the best return on investment with the greatest potential for realizing seasonal load and maximum diversity between electric power systems of the region; for reliable supply of electricity from the energy surplus areas of East Siberia, Far East of Russia, and West of China for transmission to the load growth areas of East Asia; and to provide the greatest opportunities for regional trade in electricity.

b) To demonstrate in detail commercial and technical viability of selected projects such that national and international investors in association with governments, regional utilities and project originators can create dedicated project partnerships or companies for each identified project.

c) For the load growth areas of East Asia, provide reliable energy which is sustainable, virtually free from global warming effects, and which displaces use of non-renewable energy.

2.3. Contents of feasibility study

The contents of the Feasibility Study include:

(i) General conditions for studies on interconnection of electric power systems (EPSs) in East Asia (initial assessment)

(ii) Analysis of EPSs to be interconnected (pre-feasibility)

(iii) Preferred alternative for each Inter State Tie (IST).

(iv) Cost assessment

(v) Benefit analysis

(vi) Social and environmental considerations

(vii) Financial planning.

2.4 Organization

The organization chart for the Feasibility Study is given in Figure 3.

A significant consideration in the management and organization of the Feasibility Study will be to maintain good communication channels so that the various participants in different countries are coordinated in their activities.

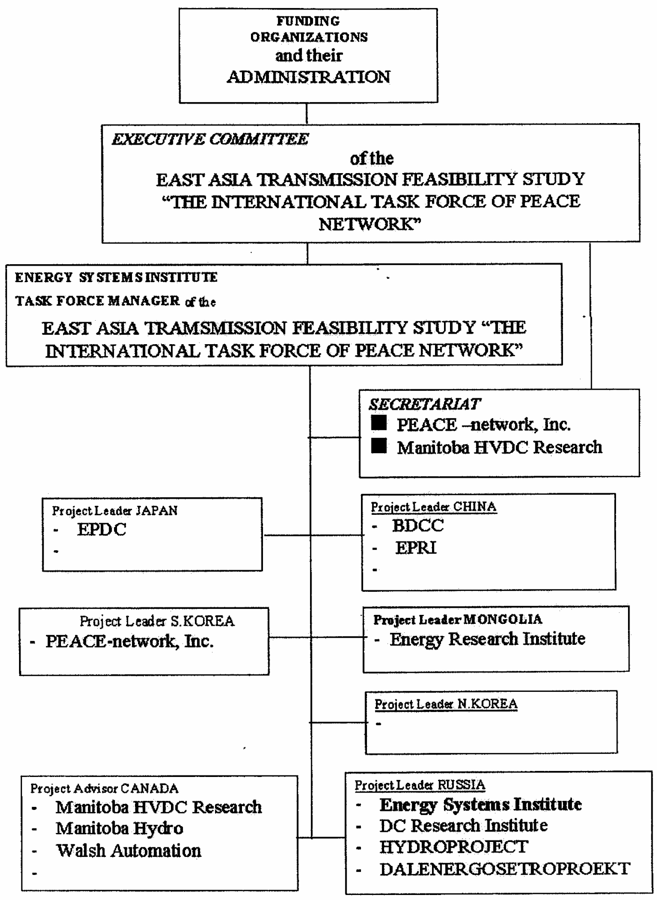

Fig. 3: Organization chart

2.5. Budget

A budget based on costs to undertake the Tasks of the Feasibility Study has been prepared. Labour and expense costs for Working Group study services may be charged either (i) against funds provided from outside sources specifically for the Feasibility Study, or (ii) from self-financing.

Labour charges are the dominant factor of the budget. The funding required for the study of four ISTs is estimated to be $5,428,000.

The Feasibility Study for four ISTs will require 66 person-years of effort. For one month at maximum effort, active labour working on the various Working Groups will average 34 experts assembled from all participants including administration.

2.6. Feasibility study funding

The Feasibility Study requires support of national governments of the region for it to be acceptable and successful. A successful Feasibility Study is essential for attracting investment in development of any of the identified ISTs. Its objective is to provide opportunity for each member organization to either be fully compensated for contributions made to the study, or receive share credit and rights in the study so that any investment is redeemable. Proposed funding for undertaking the Feasibility Study will be sought in order of preference from:

(a) World Bank, Asian Development Bank, etc.

(b) National contributions.

(c) Potential investors in the transmission projects.

(d) Shares sold to interested organizations and companies

3. DEVELOPMENT OF NATIONAL INTERCONNECTED GRID IN CHINA

This section examines development of the national interconnected grid in China. Purposes of interconnection, basic structure, key projects and some technical problems are discussed [46-48]. The nationwide interconnected grid will be basically established in 2020. It will become one of largest power systems in the world.

The China power industry began in 1882, and installed capacity reached just 1.85GW with an annual generation of 4.3TWh when the People's Republic of China was established in 1949. By the end of 1999, installed capacity reached 294GW and the nation's total electricity generation amounted to 1230TWh. The first 220kV transmission line was put in operation in 1943. During the 1950s and 1960s, provincial power grids were gradually formed. In 1972, the first 330kV transmission line was built to establish a cross-provincial power grid, the Northwest Power Network. In 1981, 500kV was introduced in the China power grid. The first interconnection project of regional power grids was commissioned in 1989. It was a DC tie line rated at ±500kV, 1200MW from Gezhouba Hydroelectric Station to the East China Power Network (ECPN). It was designed to transmit hydroelectric power from Gezhouba to ECPN. Gezhouba Hydroelectric Station is at Yichang City and 40km downstream from the Three Gorges Hydroelectric Station.

Since the second half of 1996, power supply and demand became basically balanced. 5 regional power networks, namely (i) Northeast China, (ii) North China, (iii) East China, (iv) Central China and (v) Northwest China power networks; the interconnected network of 4 southern provincial power grids; 4 independent provincial power grids, namely (a) Shandong, (b) Fujian, (c) Chongqing and (d) Sichuan provincial power grids; have been formed.

Construction of the Three Gorges Hydropower Project will push forward the implementation of a nationwide interconnection program. China's total installed capacity will reach 436GW in the year 2010, and a total capacity of 540GW will be needed by the year 2015. By the year 2020, a nationwide interconnected grid will be basically established, which will cover major regional and provincial power grids with a total installed capacity of about 700GW.

3.1. Power resource in China

Distribution of the resource in China is quite unbalanced geographically. Proven coal deposits are about 900 billion tons; 82% of coal deposits are scattered in the north and southwest. Exploitable hydropower capacity is 378 GW and average annual electricity production corresponding to this is 1920TWh. 67% of hydropower is concentrated in the southwest. The generation of renewable energy will consist of windpower, geothermal power and solar power, etc. The exploitable wind energy is 250GW and is mainly scattered in the eastern coastal region and islands, Northeast, Gansu, Xinjiang and Inner Mongolia. The proven geothermal power resource is equal to 3.16 billion tons standard coal. China is a developing country and electricity demand is rising at a relatively high rate. Therefore, power system developments rely mainly on coal and hydro resources under recent economics and technology. The share of power generated by thermal, hydro, nuclear, and renewable energy power plants is given in Table 2.

3.2. Basic structure of China national interconnected grid

By the year of 2020, the national interconnected grid will cover most of the existing regional and provincial networks in China. These are the Northeast Power Network (NEPN), the North China Power Network (NCPN), CCPN, ECPN, the Northwest Power Network (NWPN), the Sichuan Provincial Grid and the Chongqing Power Grid (CYPG), the Southern China Interconnected Network, the Shangdong Provincial Grid (SDPG), the Fujian Provincial Grid (FJPG), the Hong Kong Special Administrative Region, and the Macao Special Administrative Region.

Table 2: Power share in China

Years	Thermal	Hydro	Nuclear	Renewable Energy
1998	75.7%	23.5%	0.8%	-
2010	75.3%	20.0%	3.8%	0.9%
2020	70.6%	21.5%	6.1%	1.8%

According to the study on distribution of energy resources, regional relations and interconnections, the nationwide interconnected grid will be likely divided into three interconnected sections: the North Section, the Central Section and the South Section.

The North Section: The North Section will be comprised of NCPN, NEPN and NWPN as well as the Shangdong provincial grid.

The Central Section: The Central Section will be mainly comprised of CCPN, ECPN and CYPG as well as the Fujian provincial grid.

The South Section: The South Section will be comprised of the Guangdong, Guangxi, Guizhou and the Yunnan provincial power grid.

In the year of 2020, it is planned that installed capacity of the main power deficiency area, such as Central China, East China and South China, will reach 100GW to 150GW. It is difficult to import a large amount of electric power from outside due to restrictions of the environment and exploiting speed of hydro and thermal power bases, as well as transmission corridors. It is optimistic that imported power will account for 10-20% of capacity of the receiving system.

3.3. Some key projects

The first AC tie line of the inter-regional power network is between NCPN and NEPN. It will be commissioned in 2001. When the Three Gorges Project is completed, an interconnected grid will be established called the Three Gorges Power Grid (TGPG). The TGPG covers 8 provinces and metropolitan metron cities along with the Yangtze River. The provinces are Sichuan, Hubei, Henan, Hunan, Jiangxi, Anhui, Jiangsu; the cities include Zhejiang, Chongqing and Shanghai. The supply area of the Three Gorges Hydroelectric Station will probably extend to NCPN. The main purposes of the project are making most of the Three Gorges Hydro Station to supply peak load of NCPN (which is a nearly pure coal-fired power system) and level the load curve. The Three Gorges Project is a turning point for developing inter-regional power network connections and speeding up establishing the nationwide interconnected grid. TGPG will be heart of the nationwide interconnected grid.

Also, for a long-term plan, the TGPG will be connected with the Southern China Interconnected Network (SCIN). The significant benefit of this interconnection project is to obtain trans-valley compensation between the Yangtze River and the Lanchang River, and the Honghe River.

Some interconnection projects are planned and will be constructed before 2005. These are: a DC tie line between NWPN and CYPG; an AC tie line between ECPN and the Fujian Provincial Grid; an AC tie line between NCPN and the Shangdong Provincial Grid (because of transmitting power from the Wangqu Thermal Power Plant (in Shanxi) to Shangdong); and a DC back-to-back connection between NWPN and CCPN. The nationwide interconnected grid will be formed in the foreseen future.

3.4. Technical problems

According to preliminary simulation studies, some technical problems should be given attention despite some of them being found only in some special conditions.

- The inter-regional interconnection may affect system stability dependent on the network structure and operating condition. In some cases, transient stability of systems is improved, but it is found that transient stability is impaired in the interconnection project between NEPN and NCPN.
- If there are two or more AC link corridors between two regional power systems, investigation on loop flow, tie-line load flow control and measures for cascading should be made.
- More attention should be paid to problems of low frequency power oscillation and inadvertent power fluctuation on tie lines.
- For simultaneous faults on UHVAC (more than 1000kV) transmission corridors, effects on the interconnected power system are very severe, due to the large transmission power capacity on the corridors. So countermeasures to prevent collapse of the interconnected power system should be taken.
- When inverters are concentrated in the central load section, voltage collapse and simultaneous commutation failure of several HVDC inverters have been found. So measures, such as reasonably arranging the capacity and location of inverter stations, emergency drop of DC power, allocating SVCs, etc. should be considered when a large amount of power will be imported by means of HVDC.

Mutual impact between the AC and DC system both in the sending and receiving systems should be studied.

3.5. General conclusion on China interconnected system

i. In foreseen future, thermal power and hydro-power will still take the most important roles. Thermal power bases and hydro-power bases will be built in the west part of China and provide electricity to the central and coastal regions.

ii. In 2020, the nationwide interconnected grid will be basically established to transmit electricity from thermal and hydro-power bases to the central and coastal regions. The construction of the Three Gorges Hydropower Project will further push forward implementation of the nationwide interconnection program.

iii. The nationwide interconnected grid will cover most of existent regional and independent provincial power grids. Total installed capacity will reach 750GW. It will be composed of three sections in the early stage, namely the North, Central and South Section. The Central and South Section will likely merge into the southern part.

iv. Power flow is mainly from west to east and there is power exchange in the direction from north to south. It is expected that the North Section will be connected to the Central Section by HVDC.

4. REQUIREMENTS FOR COORDINATED DEVELOPMENT OF TRANSMISSION SYSTEMS TO MEET RAPIDLY GROWING DEMAND IN ASIAN COUNTRIES

This Section reviews the requirements for coordinated development of transmission systems to meet rapidly growing demand in Asian countries with particular reference to Japan.

4.1. General trend

Rapid demand growth of more than 10 % annually in some countries in Asia is expected in the mid- and long-term perspectives.

4.1.1. Electricity demand Figure 4 shows how peak load has grown in Tokyo, (Tokyo Electric Power Company (TEPCO)) from 1950. Growth is due to a combination of expansion in the economy, improvement in living standards such as wider use of air conditioning, and electrification in rural areas. The latter two factors are the driving force of demand growth regardless of the economic situation. Therefore, although some fluctuations might be predicted because of economical or political disturbances, the trend of relatively high demand growth will continue.

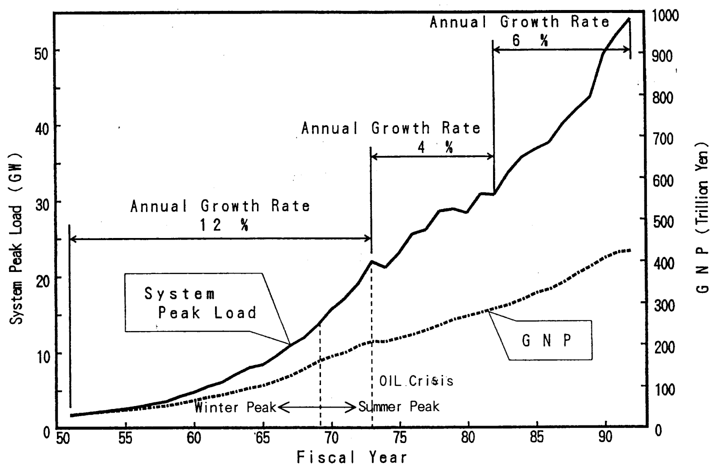

Fig. 4: Growth in peak electricity demand: Tokyo, Japan (Tokyo electric power company)

4.1.2. Generation resources Development of large-scale generation resource is predicted to meet growth in demand. Although dispersed energy resource development will play some part, especially for electrification in rural areas, it is not expected at the moment to become main stream.

4.1.3. Electricity transmission system Bulk power transmission systems, which are in process of expansion in most Asian countries, should be developed to transmit large amounts of power from new generation sources to dominant demand areas. Supply area systems should be reinforced to catch up with increase in demand in the areas, especially in areas where high load growth is expected.

4.1.4. Structure of electricity industry Introduction of free market mechanisms into the electricity supply industry is proceeding in most countries in Asia. This should encourage freer power transactions among areas or countries while pursuing cheaper electricity tariffs as well as inducing foreign investments.

4.1.5. Upgrading the transmission system Upgrading of reliability of the overall electricity supply system in important load areas or load centers should be included in transmission system development. This issue might be a critical factor because in many developing countries reliability of electricity supply is perceived to be reliability of the nation itself. Further, it should be proceeded by considering problems peculiar to the supply system such as measures against increase in fault current and reduction in transmission and supply system losses, etc.

4.2. Requirements for coordinated development of transmission System

The general features may be described as follows:

(a) Issues in the Process of Planning Bulk Transmission System Development Plans:

- Selection of method of power transmission; electricity or raw materials
- Selection of the method of electricity transmission: AC, DC, AC+DC (hybrid)
- Creation of framework of the system: radial, loop, meshed
- Planning of interconnection among wide areas or countries: DC, AC, AC+DC
- Creation of framework of load center (or important) areas
- Coordination between rural area electrification schemes

(b) Process of Screenings:

- Reliability assessment including improvement in supply quality
- Economical assessment of plans assuming uncertainty or risks such as rate of growth of demand, interest on borrowing, required investment recovery time
- Environmental impact assessment of the plans

4.2.1. Electricity supply to load centers Electricity supply to load centers is an essential issue because concentration of the population to specific cities is conspicuous in many Asian countries. For example, Tokyo has over 10 million people in only 600 km^2 area (30 million in the relatively small Kanto plain area).

4.3. Electrification

Electrification or efficiency improvement of power supply in rural areas should be promising fields for distributed type energy resources with renewable energy, such as mini-hydro, photo-voltaic and windpower as their economic competitiveness is relatively high.

4.4.Technological development

The strategy for electricity system development should be determined and advanced. It should reflect endemic conditions in each country or region. Synthesized analysis methods are required for assessing complicated factors and finding or creation of potential candidates among various options. Technological development in the facilities for more reliability and better economy are also key factors.

4.5.General summary

Planning based on comprehensive analysis with the assumption of proper technological development is essential to meet the complicated and varying conditions in Asian countries, especially from the long-term point of view. It will be a great challenge for engineers in the developing countries because they also should cope with the introduction of a freer market mechanism.

Practical step-by-step approach for realization of the plans considering the final goal should be a key attitude for proper system development.

Through these efforts, renewable energy development and its transmission will gain the support of the public or policy makers. It will also induce system interconnections with suitable transmission systems to be introduced in some preferable conditions, such as helping achieve better economy, and environmental improvement with suitable security levels.

Exchange of technological experiences among countries in this field will be required. The efforts have been already introduced such as in CIGRE activities (Study Committee 37 (System planning), etc.).

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