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Large Scale Power Exchange in the Greater Mekong Subregion

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ABSTRACT

The Indicative Master Plan on Power Interconnection in the GMS Countries comprises, among other things, a demand forecast, sub-regional generation and interconnection expansion plans and an economic analysis. The Study was funded by the Asian Development Bank and conducted by Norconsult International AS. The Indicative Master Plan studies the implications of a Limited Power Cooperation Scenario and several Extended Power Cooperation Scenarios. In the former case, countries rely mostly on domestic power generation, and only minor new interconnections between the countries are built. With Extended Cooperation, large scale hydro generation in Lao PDR, Yunnan and possibly Myanmar substitutes gas- and coal-fired generation in Thailand and to some extent Vietnam. The latter scenarios require the establishment of a strong 500 kV grid, interconnecting Vietnam, Lao PDR and Thailand (and possibly Myanmar) together with a 500 kV HVDC link to the Yunnan province of the PRC. The economic analysis shows that the discounted costs of the most favorable Extended Cooperation Scenario are 914 million USD lower than the corresponding costs of the Limited Cooperation Scenario. Without the 3600 MW low cost but highly uncertain Tasang project in Myanmar the cost savings are 645 million USD. In addition, these two Extended Cooperation Scenarios result in accumulated savings of 395 and 250 million ton CO_2 respectively. If a value of 5 USD/ton is assumed for CO_2 reductions, the savings increase to 1324 and 933 million USD for the alternatives with and without Tasang, respectively.

1. INTRODUCTION

The Greater Mekong Sub-region consists of Thailand, Cambodia, Vietnam, Lao PDR, Myanmar and the Yunnan province of the PRC. The area is endowed with substantial and diverse energy resources which are, however, unevenly distributed. Lao DPR, Myanmar, Vietnam and Yunnan have large untapped hydro resources. Vietnam and Yunnan have significant coal deposits, while substantial natural gas reserves have been identified mainly in offshore fields off Myanmar, Thailand, Vietnam, and in the joint development area between Thailand and Malaysia. Thailand is energy deficient and will increasingly depend on imports.

Sub-regional electricity trade based on interconnected power grids can provide significant economic and environmental benefits like:

- sharing of common reserve capacities to meet peak demand and thus reduce investments
- ensure a more reliable electricity supply in case of power failures
- lower operational costs
- reduce emissions of greenhouse gases and other pollutants
- provide customers access to the cheaper and more sustainable energy resources

Power trade within the GMS has to date taken place on a bilateral basis, mainly through long-term power purchase agreements. There is a growing interest in cross-border power trade, spearheaded by regional and international developers who have commenced hydropower development in the Lao PDR to sell power to Thailand. Large hydropower facilities for export to Thailand are also being planned in Yunnan. Bilateral trade will bring about some benefits, but the full potential will not be realized unless an advanced degree of grid interconnection is achieved, that is until the power grid is developed and operated in a coordinated manner within some form of sub-regional power market.

Several earlier studies have assessed the opportunities for power exchange in the GMS [1], [2], [3]. There was, however a need for a reassessment, due to several factors:

- slower growth in economic and energy terms in the sub-region as a result of the financial crisis in 1997/98
- ongoing power sector reforms, especially in Thailand
- the availability and improved economic viability of the use of gas for power generation

On this background, the Expert Group on Power Interconnection and Trade of the GMS initiated the preparation of an Indicative Master Plan on Power Interconnection in the GMS Countries, funded by the Asian Development Bank. The Study was conducted by Norconsult International AS of Norway between October 2000 and May 2002. The present paper presents the main findings of the Study. It should, however, be noted that no investment decisions will be based on this Study. More detailed feasibility studies, including EIA and SIA, should be carried out for the most promising projects identified in this study.

Under the Climate Change Convention, signed by all GMS countries, the countries are likely to increase their shares of renewable energy in the future power generation and electrification plans. By 2005, the Global Environment Facility, the World Bank and several other funding agencies intend to support the development of Climate Change Adaptation Strategies with high emphasis on improving energy efficiency. Possibly, these efforts will lead to more off-grid small-scale electricity facilities. If also developing countries are required to cut down on their greenhouse gas emissions after 2012, increasing energy efficiency will become highly prioritized in these countries. A number of these factors may result in reductions in the need for grid-based power supply in excess of the conservation effects already taken into account in the demand forecast. However, with per capita consumption levels of between 34 kWh/yr for Cambodia and 1300 kWh/yr for Thailand (as compared to typical levels of 5-8000 kWh/yr for industrialized countries in Europe), it is difficult to see how these countries can meet their development targets without substantial contribution from large-scale electricity generation. The central question to be answered by this Study was then if such large-scale generation should come from domestic generation or from the development of more economic sources of energy in other GMS countries through the implementation of interconnected transmission grids.

2. POWER MARKET

2.1 Regional Overview

The GMS countries are in transition from centrally planned, inward-looking economies to more market-based, open economies. While the constituent national economies differ considerably in structure and size, all have recorded high economic growth rates during the years before the Asian economic and financial crisis in 1997/98. Their population densities, incomes per capita, measures of electrification and electricity use, as well as tariffs vary significantly, see Table 1.

Table 1 GMS Countries – Selected Indicators, 1999

Indicator	Units	Cam-bodia	Lao PDR	Myanmar	Thailand	Vietnam	Yunnan
Land Area	1000 km^2	181	237	677	513	332	394
Population	Million	11.6	5.1	48.1	61.8	76.3	41.9
GNP/capita	USD/cap.	260	280	n.a.	1960	370	750[1]
GDP	USD billion	3.1	1.4	n.a.	123.9	28.6	n.a.[1]
Electricity Use	kWh/yr/cap	34	113	60	1300	257	606
Electrification	%	13	34	15	82	70	92
Installed Capacity [2]	MW	150	635	1300	22300	6200	7600
Average Tariffs [2]	USc/kWh	16.0	2.3	5.0	5.3	5.2	3.7

Source: ADB, World Bank estimates, and country sources

[1] Applies to PRC. Yunnan's GNP per capita is estimated at 2/3 of national average.

[2] Year 2000. Note: Figures expressing tariffs are indicative and expressed on the basis of prevailing exchange rates.

Thailand is the principal market for power in the GMS, representing around 60% of total demand. Yunnan and Vietnam are the two other major markets. Cambodia, Laos and Myanmar combined account for only 3-4% of the total present GMS power demand.

With the exception of Thailand and Yunnan, demand is at present constrained mainly by the lack of generation capacity as is the case for Cambodia, Myanmar and southern Vietnam or by constraints in the transmission and distribution systems as exhibited by high system losses in Cambodia, Myanmar, and Laos.

Electricity consumption in the region has in the more recent past been typified by rapid growth, driven by economic growth, industrialization, urbanization, and globalization of trade. During the first half of the 1990s the increase in electricity sales reached double digit rates in most of the countries. Because of capacity limitations, growth has, as indicated, nevertheless been constrained and the underlying demand often met by captive generation plants.

From 1996-97 there was a marked reduction in growth rates in most of the countries, but only in Thailand did the economic and financial crisis result in reduced electricity consumption (1998 and 1999. By 2000, electricity sales in Thailand exceeded pre-crisis levels, and in all the countries growth rates in 2000 exceeded those in 1999, several even at double digit figures.

2.2 Forecast

Forecasts have been prepared in terms of energy requirements and peak demand for the individual countries for the period 2001-2020. The energy and peak demand projections are shown in Table 2 for each country and for the sub-region. Aggregate generation requirements will increase from around 160 TWh in 2000 to some 600 TWh in 2020. Average annual growth amounts to 6.9% over the forecasting period, with higher annual rates to begin with and subsequently tapering somewhat off. The corresponding sum of non-coincident power demand grows from 26 GW in 2000 to slightly above 100 GW in 2020, or by 7.0% p.a. In comparison, growth between 1990 and 2000 amounted on average to approximately 9% p.a. for the sub-region.

Thailand's share of total demand in the sub-region in 2000 was 60% in terms of energy and 57% in terms of peak load (see Table 2). Consequently, the country is the major force behind the regional increase over the forecasting period. In percentage terms, however, the country exhibits the second lowest growth, with Yunnan Province projected to have the lowest relative increase. The countries with the smaller power sectors (Cambodia, Laos and Myanmar) plus Vietnam are expected to grow the most rapidly. By 2020, Thailand's share will have fallen to the lower 50s in percentage terms, while Vietnam should reach around 27-28% of the total sub-regional market.

Table 2 GMS – Country and Sub-regional Demand Forecasts

	Energy Requirements (GWh)							
	Thailand	Laos	Cambodia	Vietnam	Yunnan	Myanmar	TOTAL	Annual Growth
2000	96781	865	586	26722	31635	4401	160991	
2005	134794	1528	1329	44230	43571	5695	231148	7.5 %
2010	184213	2468	2502	72014	57976	7883	327057	7.2 %
2015	245948	3472	3848	111333	73994	11322	449918	6.6 %
2020	328429	4437	5720	169428	91689	16378	616082	6.5 %

	Peak Demand (MW) – Non Coincident							
	Thailand	Laos	Cambodia	Vietnam	Yunnan	Myanmar	TOTAL	Annual Growth
2000	14918	167	114	4890	5257	780	26126	
2005	21222	280	280	7877	7554	1067	38280	7.9 %
2010	28912	442	529	12589	10227	1510	54210	7.2 %
2015	38519	618	799	19169	13099	2218	74421	6.5 %
2020	51359	784	1156	28739	16231	3280	101548	6.4 %

2.3 Demand Coincidence

It is expected that interconnection of the GMS power systems will result in peak load reduction[1]. The load pattern for each country has been established on the basis of information collected from different sources. There are however at present considerable constraints with respect to power supply in several of the countries. As a basis for investigating the potential reduction in sub-regional peak load, unrestricted load patterns have been established for each country. On the basis of monthly peak loads, hourly load variation for a typical working day, and the projected non-coincident peak demand, the coincident sub-regional load has been calculated. Table 3 presents the potential peak load savings for stages 2000, 2010 and 2020 based on present load patterns.

Table 3 Potential Peak Load Reduction through Interconnection

Stage	Sub-Regional Peak Loads		Peak Load Reduction	
	Non-coincident (MW)	Coincident (MW)	(MW)	(%)
2000	26124	25445	679	2.6
2010	54211	52834	1377	2.5
2020	101549	98995	2554	2.5

[1] The peak load reduction refers to a reduction in overall (sub-regional) peak load, or in other words a reduction in generation requirements for GMS. National peak loads as such are unaffected by the interconnection.

The calculations indicate a peak load reduction of about 2.5 %. The calculations presume that the monthly peak loads of each country occur on the same day. This assumption represents a possible underestimation of the potential for peak load reduction due to interconnection. On the other hand, DSM measures will most probably be directed towards system peak load reduction which therefore might reduce the benefits of interconnection.

3. GENERATION EXPANSION SCENARIOS

3.1 Existing Generation System - By Plant Category

Table 4 gives an overview of installed capacity at the beginning of 2001:

Table 4 Installed generation capacity in the GMS countries

Source	Installed Capacity (MW)						
	Thailand	Lao PDR	Cambodia	Vietnam	Yunnan	Myanmar	*GMS Total*
Hydro	2886	628	1	3291	5150	360	*12316*
Coal				645	2419		*3064*
Lignite	2625						*2625*
Fuel oil	238		71	573		815	*1697*
Gas	13941			1338			*15279*
Diesel	230	14	57	828		65	*1194*
Small Power Plants	1613						*1613*
Import	340						*340*
Total	*21873*	*642*	*129*	*6675*	*7569*	*1240*	*38128*

3.2 Generation Expansion Alternatives

3.2.1 Thailand

Candidates for future supply in Thailand are

- Hydro import from Lao PDR
- Hydro import from Yunnan
- Hydro import from Myanmar
- Combined cycle gas plants based on domestic and imported gas
- Thermal plants based on imported coal

The use of coal is controversial due to environmental concerns. However, the use of coal should not be completely ruled out because of fuel diversification. With gas as the only thermal alternative, Thai generation would depend heavily on gas by between 75 and 90 % of its installed capacity in 2020, depending on the import share. In the present Study, a maximum share of gas-fired capacity of 70 % has been assumed as recommended by Electricity Generation Authority of Thailand (EGAT). The impact of this choice on the conclusions of the Study is limited, because the assumed costs of gas- and coal-fired generation in Thailand are similar. However it does have an impact on greenhouse gas emissions, which would be lower in the case of unlimited gas generation.

3.2.2 Lao PDR

Future supply in Lao PDR will in principle be based exclusively on hydro. In addition Lao PDR has an active policy for developing export-oriented projects. A considerable number of projects are considered. This Study considers a number of projects for export. Some of these projects appear to have favorable economic characteristics, while the economic viability of others is doubtful.

3.2.3 Cambodia

Candidates for future supply in Cambodia are:

- oil based thermal generation in Phnom Penh
- oil based thermal generation in Sihanoukville
- gas based thermal generation in Sihanoukville
- hydropower in the west and north-east
- import from Vietnam and Thailand

In Cambodia there are also some projects that could be eligible for export to Vietnam, notably Lower Se San 2 and a 465 MW Sambor diversion project in the main Mekong river.

In the south-western part of Cambodia, close to the border between Thailand and Cambodia, there are a few promising hydropower projects. Available information on these projects has been too limited to include them in this Study. Because the projects are in the border area, they could potentially form the backbone of profitable power cooperation between Thailand and Cambodia in this area.

3.2.4 Vietnam

In Vietnam many alternatives for future generation are available: hydro, coal, oil and gas and geothermal heat. Vietnam also contemplates the use of nuclear power in the last part of the planning period.

3.2.5 Yunnan

Yunnan province, PRC, is rich with energy resources. Presently only 5 % of the estimated 400 TWh hydro resources have been exploited, leaving a huge development potential. Of this potential, 15,500 MW is situated in the lower and middle reaches of the Lancang river, as the Mekong is called in Yunnan, with an estimated average annual generation of 73.8 TWh. The other alternative is generation based on the considerable coal resources in Yunnan. Important projects for export are Jinghong (1500 MW) and Nuozhadu (5500 MW) in the Lancang River, and Malutang (460 MW) close to the border with North Vietnam.

3.2.6 Myanmar

Myanmar's resources include coal, oil, gas and hydropower. The main source for future generation is hydropower. In addition it is the intention to build some gas-based generation.

The hydropower potential exceeds by far the domestic needs within the study period 2001-2020. There are several projects that could be developed for export to Thailand. Most of the projects in the border areas have not been studied in sufficient detail. Available information has been too limited to include the projects in the analysis of the present Study. However, export from the proposed 3600 MW Tasang project, for which some data has been obtained, has been considered. The inclusion of the project in the Study does not imply a recommendation of the project by Norconsult. No studies of the project have been available to be able to make any such recommendations. The objective is to analyze the technical and economic impact on the total GMS power sector of including a project with physical characteristics and cost level as of Tasang.

3.3 Environmental and Social Aspects

The Study uses information collected from studies carried out by other consultants or provided by the utilities of each country. The study levels vary greatly. Most of the studies include assessment of environmental and social aspects associated with development of the projects. It is obvious that many hydropower projects have environmental and social implications, specifically large hydropower projects including high dams in the main rivers. Assessment of environmental and social impacts of the candidate hydropower generation projects or the interconnection transmission line projects was not included in the scope of the Study. However, the economic impacts estimated by previous studies are included in the projects' costs.

Since many studies were carried out before year 2000, the 2000 World Commission on Dams report may have an impact on further planning of many of the hydropower candidates considered in this Study. Depending on how much weight the countries choose to put on the recommendations in the report, characteristics and cost parameters of the projects may change considerably, and this may change the conclusions of the Study. However, there is also uncertainty with respect to the only alternative for large-scale electricity generation, namely thermal plants. Depending on the future international treatment of climate gas emissions, a shadow cost may have to be added to the use of fossil fuels, which may also change the conclusions.

3.4 Methodology

Existing project development plans for the GMS countries have formed the basis for creating the generation expansion plans for two scenarios; a Limited Power Cooperation (LPC) Scenario and several Extended Power Cooperation (EPC) Scenarios. A common methodology has been adopted to modify existing plans. Reserve margins referred to dependable capacity have been used as the principal criterion to establish generation plans that cover the power demand and electric energy consumption throughout the study period.

Table 5 Reserve margins used for preparation of Project Development Plans

Country	Reserve Margin	Reference Capacity
Thailand	15 %	Dependable capacity
Cambodia	20 %	Installed capacity hydro[2], dependable capacity thermal
Lao PDR	20 % / 2 largest units	Dependable capacity
Vietnam	20 %	Dependable capacity
Yunnan	10 %	Dependable capacity

Plans for the LPC Scenario have been prepared, substituting import in existing plans with alternative thermal generation. In Thailand this is mostly coal, to avoid a too great dependency on gas, while in Vietnam this is a combination of coal and gas.

[2] The study level of hydropower in Cambodia is very low, and insufficient information is available to estimate dependable capacity.

Plans for the EPC Scenarios are based on a set of export-oriented projects in Lao PDR, Yunnan and Myanmar, the most important of which are shown in Table 6:

Table 6 Major export hydropower projects in the GMS countries

Project	Year	From	To	Installed Capacity (MW)	Firm Capacity (MW)
Nam Theun 2	2008	Lao PDR	Thailand	1088	937
Nam Ngum 2	2008	Lao PDR	Thailand	615	415
Hongsa Lignite	2010	Lao PDR	Thailand	720	641
Se Pian – Xe Namnoy	2010	Lao PDR	Thailand	390	362
Xe Kaman 1	2010	Lao PDR	Thailand	468	408
Tasang	2012	Myanmar	Thailand	3600	3000
Jinghong	2013	Yunnan	Thailand	1500	863[2]
Nuozhadu	2014	Yunnan	Thailand	5500	2393[2]
Sambor CPEC	2019	Cambodia	Vietnam	465	347[1]

[1] Estimate

[2] After completion of Lancang cascade

The basis for the estimation of project costs varies considerably. For thermal alternatives data from the utilities in the respective countries were used. Data for hydropower in Lao PDR are based on existing pre-feasibility and feasibility studies, with a varying degree of detail, especially [4]. The cost estimates include all costs related to the projects like civil works, mechanical and electrical equipment, necessary transmission lines from the project site to the main grid, and socio-economic costs. Hydropower project costs in Yunnan are based on information from Yunnan Electric Power Group, while data for Vietnam were partly available from Electricity of Vietnam and partly from ongoing studies by other consultants. For Cambodia only very limited data were available and considerable judgment had to be used.

Table 7 shows the main EPC scenarios:

Table 7 Extended Power Cooperation, main scenarios

Scenario	Comment
2A	All projects indicated by the GMS countries
2B	All projects except projects deemed economically non-viable
2C	As 2B but without Tasang

Scenario 2A was created based on the desire of the participating countries to evaluate a maximum power interchange scenario. Although such a scenario may have a lower economic cost than a self-supply oriented strategy, it is clearly not optimal, because the exclusion of a number of high cost projects would reduce the total cost. Thus Scenario 2B is a much closer to an optimal scenario, leaving out a number of high cost hydropower projects in Lao PDR. The reason to run a separate Scenario without Tasang was the size of this very low-cost project (3600 MW) together with the high degree of uncertainty for this project.

In Lao PDR and Cambodia, generally a 5 % share domestic firm power off-take is assumed.

The countries' existing generation plans were modified to:

- ensure a consistent use of the export oriented projects
- adapt to the new demand forecast
- take into account estimated peak load reduction due to interconnected operation
- ensure a consistent reserve margin

The following table shows the resulting composition of the generation system for the various scenarios in 2020.

Table 8 Installed capacity by source in 2020

Scenario	Hydro		Gas		Lignite/Coal		Nuclear		Other		*Total*
	GW	%	GW	%	GW	%	GW	%	GW	%	*GW*
Limited 1	37.9	27	59.0	42	39.6	28	1.2	0.9	1.7	1.2	*139.4*
Extended 2A	48.6	35	57.2	41	29.7	21	1.2	0.9	1.7	1.2	*138.3*
Extended 2B	46.8	34	56.9	41	31.3	23	1.2	0.9	1.7	1.2	*138.0*
Extended 2C	43.2	31	56.7	41	34.8	25	1.2	0.9	1.7	1.2	*137.7*

On balance, coal- and lignite based generation is substituted by hydro in the EPCs. Total installed capacity is lower in these Scenarios due to the effect of peak load reduction in the interconnected system.

4. INTERCONNECTION PLANNING

4.1 Methodology

Even though the transmission systems of each country has to be reinforced in all parts of the countries, this Study only focuses on the particular parts of the system where power interconnection changes the national transmission extension plans in terms of technical solution or in terms of timing. Power interconnection implies investments in cross-border transmission lines and substations. In addition, the national transmission systems may have to be reinforced. The basis for development of transmission systems and interconnections are the generation expansion plans.

Only differences in transmission system developments and costs for the two scenarios have been considered. Focus has been on:

- investments requirements
- timing
- transmission losses
- operation and maintenance costs

Transmission and interconnection planning have been based on the (n-1)-planning criteria. This criterion decides the timing of necessary investments. For LPC Scenario the timing of new network components is determined by transmission requirements at the time of country or area peak load, while for EPC Scenarios the timing is determined by one or several of the following objectives:

- area/country peak load
- sub-regional transmission requirements associated with generation project developments
- sub-regional peak load reduction achievements

The transmission losses have been computed for all scenarios at the time of coincident sub-regional peak load. The generation dispatch and associated power exchange between the countries have been assumed to be in accordance with the agreements made on power development.

On the technical side, both stationary load flow and power system dynamics calculations have been performed. The software used was PSS/E.

4.2 Limited Power Cooperation

In the LPC Scenario, no major new interconnections between countries are implemented. However, the design and commissioning time of a number of country specific transmission lines and substations in this scenario differs from the others. The cost of these elements must be taken into account also in the LPC Scenario.

The following transmission projects are included in the economic analysis of LPC Scenario 1:

- 115 kV internal interconnection in Lao PDR in 2006
- Reinforcements of the 500 kV north-eastern and central grids in Thailand in 2013 and 2016
- Reinforcement of the 500 kV grid between north-eastern and central Thailand in 2019
- Building of a 230 kV transmission line from Lower Sre Pok via Sambor to Phnom Penh in 2019

In addition, two new substations are built, while a number of others are upgraded. The most important projects for comparison of scenarios are shown in Fig. 1.

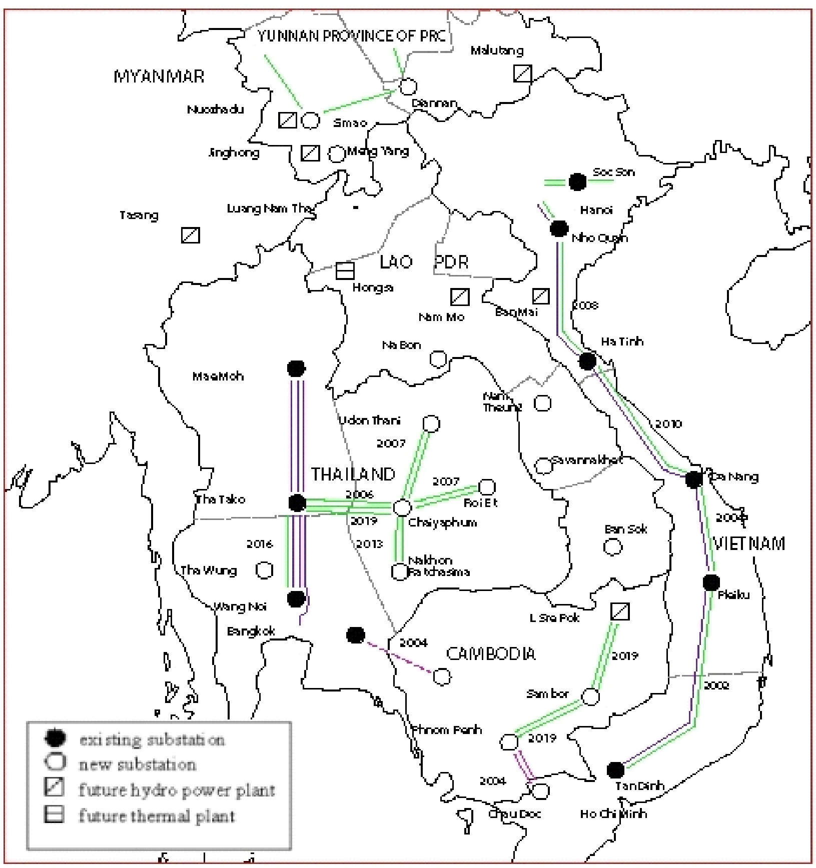

Fig. 1 Major transmission lines involved in Scenario 1

4.3 Extended Power Cooperation

The main basis for development of a sub-regional grid is power generation development in one country for export to a neighbouring country. Unless a strong network already exists in the exporting country, the location of the export project will determine the starting point of an interconnection between the countries. The termination point of the interconnection will in most cases be either the location of the nearest power market in importing country, or a substation in a strong network capable to transfer the power further to the consumers.

The sources of power identified for export are as follows:

- Hydropower in Lao PDR for export to Thailand
- Hydropower in Lao PDR for export to Vietnam
- Hydropower in Yunnan for export to Thailand
- Hydropower in Myanmar for export to Thailand
- Hydropower in Yunnan for export to Vietnam

In addition, due to substantial load shedding in Cambodia interconnections are planned for power import from both Vietnam and Thailand, with implementation in a few years.

Construction of transmission lines and interconnections has environmental implications. The final selection of line routes will be done in later feasibility studies on specific projects, and were not within the scope of the indicative master plan. The transmission line corridors used in this Study are selected from other studies and based on recent information received from the authorities in the different countries.

In this scenario the sub-regional grid was established step-wise with the implementation of new generation. This simplifies the financing process of transmission projects, because they are directly linked to a specific generation project or group of projects. The transmission solution has to satisfy the (N-1) planning criterion from the time of commissioning of each project.

EPC Scenario 2A

Major transmission system features of this Scenario are (cf. Fig. 2):

- Establishment of a 500 kV link from Ha Tinh in Vietnam via Nam Theun 2 and Savanakhet in Lao PDR to Roi Et in Thailand in 2008, related to the commissioning of Nam Theun 2
- Establishment of a 500 kV transmission line from Hongsa Lignite in Lao PDR to Mae Moh in Thailand in 2009
- Establishment of a 500 kV transmission line from Na Bon in Lao PDR to Udon Thani in Thailand in 2009
- Establishment of a 500 kV transmission line from Savanakhet to Ban Sok in Lao PDR in 2010 and from there to Pleiku in Vietnam in 2012
- Establishment of a 500 kV transmission line from Tasang in Myanmar to Mae Moh in Thailand and reinforcement of the 500 kV Thai grid in 2012
- Establishment of a 500 kV HVDC link from the Jinghong and Nuozhadu projects in Yunnan to Thailand in 2013
- Reinforcement of the 500 kV north-eastern grid in Thailand in 2015
- Building of a 230 kV transmission line from Lower Sre Pok via Sambor to Phnom Penh and from Sambor to Tan Dinh in Vietnam in 2018/19
- Building of a 230 kV transmission line from Malutang in the south-eastern part of Yunnan to northern Vietnam in 2019

In addition comes building of new substations as well as extension of existing ones.

With the proposed plan, a strong interconnected network between Vietnam, Lao PDR and Thailand is created, giving considerable opportunities for power exchange, utilizing the specific characteristics of hydropower in Vietnam and Lao PDR and thermal plants in Thailand to the benefit of all countries.

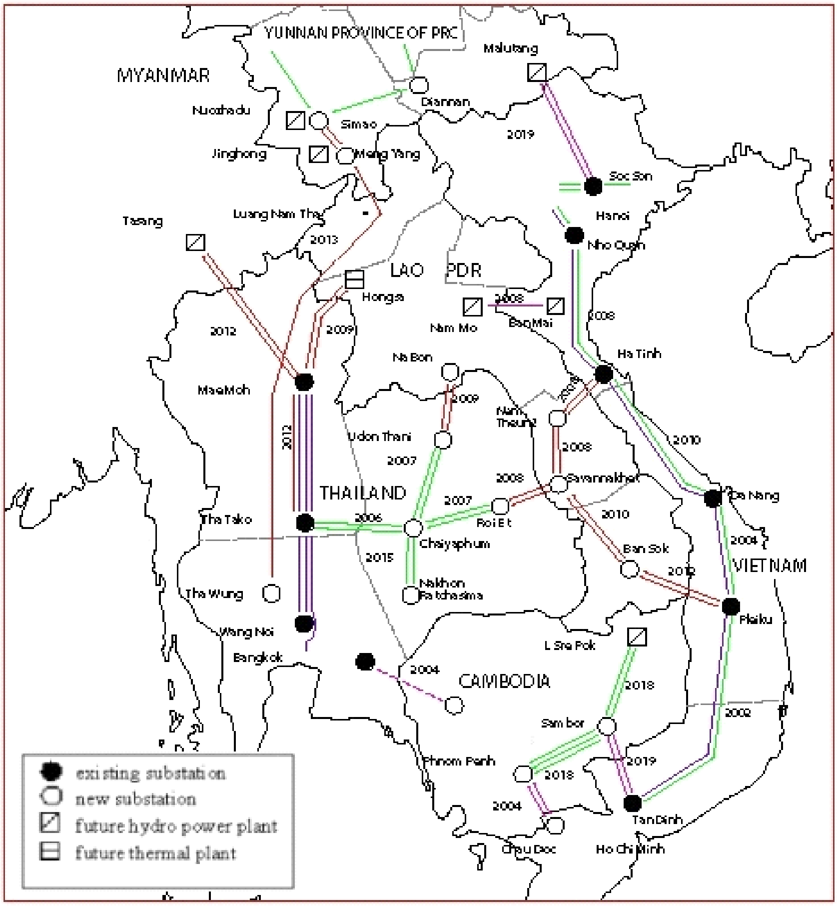

Fig. 2 Major transmission lines involved in Scenario 2A

EPC Scenario 2B

This scenario is equal to the previous Scenario 2A with the exception that the most expensive export projects in Lao PDR and Cambodia are assumed abandoned. This has of course some impact on the optimal grid configuration:

- There is no need for the 500 kV transmission line from Hongsa Lignite
- Due to the reduced number of projects, a 230kV line is a better solution than a 500 kV line from Na Bon
- Reduction of the capacity of the 230 kV grid in Eastern Cambodia

EPC Scenario 2C

This scenario is equal to the previous Scenario 2B with the exclusion of the 500 kV transmission line to Tasang.

5. POWER SYSTEM SIMULATIONS

All scenarios were simulated with EFI's Multi-area Power market Simulator (EMPS), which is specifically designed for simulation of the operation of mixed hydro-thermal power systems consisting of several interconnected areas. The model consists of a strategy evaluation part, computing the water values and a simulation part, simulating the operation of the system using historical inflow records. The basic time step of the model is one week. Within the week a load-duration curve is used to represent demand.

The interconnected power system is divided into regional subsystems, based on hydrological characteristics or on constraints in the transmission systems. Hydropower may be represented in a considerable degree of detail, depending on available data. Thermal generation can be represented either on a plant basis, or on an aggregate level. Import from and export to areas outside the system in focus is based either on simulated prices or on contractual obligations. Demand is either inelastic, given by annual consumption and profiles describing variations within the year and the week respectively, or elastic, depending on simulated prices.

The model results include hydro system operation (reservoirs, generation, discharge), thermal generation, power consumption, load curtailment, power exchange, and economic results.

The study period for the simulations and the corresponding economic calculations is 2005-2020, because both scenarios are equal up to 2005. Investments made before 2005 for project that only occur in one scenario are taken into account by the addition of interest during construction.

The following table shows simulated generation in 2020 for the main scenarios.

Table 9 Annual generation by source in 2020

Scenario	Hydro		Gas		Lignite/Coal		Nuclear		Other		*Total*
	TWh	%	TWh	%	TWh	%	TWh	%	TWh	%	*TWh*
Limited 1	147.0	23	261.2	42	210.0	33	8.8	1.4	0.8	0.1	*628*
Extended 2A	203.6	32	264.4	42	150.4	24	8.8	1.4	0.8	0.1	*628*
Extended 2B	196.0	31	259.3	41	163.0	26	8.8	1.4	0.8	0.1	*628*
Extended 2C	173.2	28	257.0	41	188.4	30	8.8	1.4	0.8	0.1	*628*

6. ECONOMIC ANALYSIS

The main objective of the Study is to identify the least-cost of the several power development scenarios. Whether interconnected or not, it is a requirement that the forecasted peak load and energy consumption requirements of all countries be met throughout the whole study period. The costs are measured in terms of the present value of all cost components necessary to cover the load. Residual values at the end of the study period are taken into account. The cost elements comprise:

- Generation investment costs
- Hydropower operation and maintenance costs
- Thermal plant operation and maintenance costs
- Transmission system investments
- Transmission operation and maintenance costs
- Transmission loss differences between the scenarios
- Residual values

The Study takes a sub-regional perspective, and the economic evaluation / comparison is carried out in economic terms. The reference date for costs and exchange rates is the beginning of calendar year 2001. Since new 500 kV interconnections will not be in service before 2005, the generation expansion and energy simulations are carried out for the period 2005-2020. All costs are discounted to the beginning of year 2001.

6.1 Additional benefits

Large scale system interconnection and the use of hydropower results in a number of additional benefits that are not included in the calculation of investment- and operational costs:

- increased reliability
- reduced operating reserve costs
- reduction of climate gas emissions

Determination of these benefits in economic terms is very complex. However, estimates have been made to get an idea of the possible order of magnitude of the economic benefits.

Increased reliability occurs because of higher availability and better operating characteristics of hydropower. The characteristics of hydropower (mainly the difference between installed and dependable capacity) also result in a somewhat higher installed capacity than for thermal alternatives. This normally leaves some excess capacity during long periods of the year, resulting in increased reliability. The discounted value of these effects has been conservatively estimated to 100-165 million USD depending on scenario.

Reduced reserve costs also result from the more favourable operating characteristics of hydropower. The resulting discounted savings have been estimated to 20-45 million USD depending on scenario.

Savings in CO_2 emissions have also been estimated for the EPC scenarios. The value of these savings is not easily assessed, and extremely dependent on a number of highly uncertain factors. The GMS countries do not belong to the Annex I Parties of the Kyoto Protocol, and therefore are at present not eligible for quota trading. However, they could come in under the Clean Development Mechanism (CDM) in the protocol, and estimated quota prices can be used as an indication of their value. Conservatively, a value of 5 USD/ton can be used, which is well below the estimated price for most scenarios [5].

With the differences in generation as shown in Table 9, the following savings in CO_2 emissions can be calculated:

Table 10 CO_2 emission savings and their tentative value

Scenario	Savings ref Scenario 1 (million ton CO_2)	Discounted value @ 5 USD/ton (million USD) and different discount rates		
		12 %	10 %	14 %
Scenario 2A	475	485	617	385
Scenario 2B	395	410	520	327
Scenario 2C	250	288	359	233

In addition to the estimated value of CO_2 reductions, come reductions in other climate gas emissions, for which however, no value has been estimated.

Potentially, hydro reservoirs also emit greenhouse gases (GHG). However, according to the WEA report [6]: "The peak greenhouse gas emissions, however, are unlikely to rival those of a similarly sized fossil power plant, emissions from which would not decrease with age like that from a reservoir. In addition, it is difficult to determine the baseline in tropical forests – that is, how much methane and other non-carbon dioxide greenhouse gases are released in natural conditions". Greenhouse gases from hydro reservoirs have consequently not been included in the subsequent calculations.

6.2 Economic results

The results of the economic comparison of the power developments scenarios with a 12 % discount rate are given in the following table:

Table 11 Economic Comparison of Power Development Scenarios 2005-2020, Basic Parameters, Discounted values in billion USD

	Limited Power Cooperation	Extended Power Cooperation		
	Scenario 1	Scenario 2A	Scenario 2B	Scenario 2C
Generation System	44.354	42.457	42.283	42.755
Transmission System	0.056	1.499	1.213	1.010
Total Costs	44.410	43.956	43.496	43.765
Cost Savings ref Scenario 1	-	0.454	0.914	0.645
Tentative additional value of reduced emissions of GHG	-	0.485	0.410	0.288

It is observed that all EPC Scenarios are economically favourable compared to the LPC Scenario with a 12 % discount rate and otherwise basic parameters used in this Study. The value of reduced emissions of GHG is not included in the calculated savings, due to the high uncertainty in the estimated values. However, tentative values are shown explicitly in the last row of the table. If these values are included in the analysis, cost savings would lie between 0.9 and 1.3 billion USD, increasing the economic performance of the EPC Scenarios.

While the net present value of costs of Scenario 2A is lower than that of Scenario 1, comparison with Scenario 2B clearly shows the negative impact of the economically unfavorable projects in Scenario 2A. In Scenario 2B, both generation and transmission costs are lower than in Scenario 2A, resulting in total savings being almost twice as high. Even without taking into account the value of reduced GHG emissions, total savings for Scenario 2B are considerable.

The values for Scenario 2C show the importance of Tasang for the conclusions. However, even without Tasang, the present value of total savings amounts to 0.64 billion USD.

With a 10 % discount rate, the discounted total costs of the EPC Scenarios are calculated to be between 0.9 and 1.4 billion USD lower than for the LPC Scenario. With this discount rate, extended cooperation looks clearly favourable for all scenarios, and especially for Scenario 2B. Even with a 14 % discount rate, all EPC Scenarios compare favorable with the LPC.

It can be concluded that the results for Scenarios 2B and 2C are robust with respect to the discount rate. Other sensitivity analyses that have been carried out also indicate that the EPC Scenarios are robust against:

- increase in fuel costs (the benefit versus Scenario 1 increases with higher fuel costs)
- increased construction costs of export projects
- increased construction costs of transmission lines and sub-stations
- increased price of coal in Yunnan

Calculations have also been carried out to evaluate the effect of barriers to trade. These calculations also show the importance of establishing a well-functioning framework for market-based power exchange. Without power trading between the countries on the basis of true marginal production costs, the benefits of the Extended Power Cooperation Scenarios are considerably reduced.

7. CONCLUSIONS

This paper presents a summary of the technical and economic analyses performed in the Norconsult Study "Indicative Master Plan on Power Interconnection in the GMS Countries", funded by the Asian Development Bank. A demand forecast for the sub-region shows an annual growth of approximately 7 % between 2000 and 2020.

All countries within the sub-region have several supply alternatives for meeting future power requirements. While most countries completely or to a large extent can rely on domestic resources, Thailand will be dependent on considerable imports of either fuel or power. The Study focuses on two main Scenarios:

- a Limited Power Cooperation Scenario, where Thailand imports gas and coal and relies on thermal generation within its own borders
- three Extended Power Cooperation Scenarios, where a number of large scale hydro power projects in (mainly) the Yunnan province of the PRC and Lao PDR export power to Thailand and to some degree Vietnam.

In the Limited Power Cooperation Scenario, interconnections between the countries in the sub-region will mostly be limited to the present level, although some minor interconnections from Thailand and Vietnam to Cambodia are needed to relieve the precarious power situation in the latter country. In the Extended Power Cooperation Scenarios, a strong 500 kV grid will connect Vietnam, Lao PDR and Thailand, which also will be connected with a 500 kV HVDC link to Yunnan. This network will allow for considerable power exchange within the sub-region, resulting in large cost savings in system operation.

The economic analysis shows that the optimal Extended Power Cooperation scenario results in savings of 914 million USD for the period 2005-2020, discounted to 2001. This scenario includes only economically viable hydro projects, among them the 3600 MW Tasang project in Myanmar. Without the latter project, for which data are highly uncertain, calculated savings of Extended Power Cooperation are 645 million USD.

The indicated savings do not include the potential value of reduced CO_2 emissions. The accumulated savings are 395 and 250 million tons. If these quantities are valued at a conservative 5 USD/ton, total savings in the scenario with and without Tasang increase to 1324 and 933 million USD respectively. These figures do not include the potential value of reduced emissions of other greenhouse gases. Estimates of the value of some additional benefits of interconnected system operation are included in the analysis, notably the cost of reserves and increased reliability. Because of the conservative character of these estimates, total savings are more likely to be higher than lower than the presented results.

8. REFERENCES

[1] Norconsult Int. 1995. Subregional Energy Sector Study for the Greater Mekong Subregion. Final Report, An Asian Development Bank Publication , October 1995.

[2] Mekong Integrated Transmission System Study (Basin-Wide). Main Report, NEWJEC. Prepared for Mekong River Commission, September 1996.

[3] World Bank. 1999. Power Trade Strategy for the Greater Mekong Sub-Region.

[4] Hydropower Development Strategy Study. 2000. Worley/Lahmeyer.

[5] RIVM report 728001017/2001: The Bonn Agreement and Marrakesh Accords: An updated analysis.

[6] UNDP. 2000. World Energy Assessment. Energy and the challenge of sustainability.