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ASIAN DEVELOPMENT BANK

RETA No. 6440

"FACILITATING REGIONAL POWER TRADING AND ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT OF ELECTRICITY INFRASTRUCTURE IN THE GREATER MEKONG SUBREGION"

FINAL REPORT

COMPONENT 1

MODULE 1

UPDATE OF THE GMS REGIONAL MASTER PLAN

MAIN REPORT

DATE: 15 OCTOBER 2010

LIST OF UNITS AND ABBREVIATIONS

CCGT	Combined Cycle Gas Turbine
CUE	Cost of Unserved Energy
DO	Diesel Oil
FDI	Foreign direct investment
GJ	Giga Joule
GWh	Giga Watt hours
HV	High Voltage
HFO	Heavy Fuel Oil
HPP	Hydro power plant
IPP	Independent Power Producer
LOLP	Loss of Load Probability
LV	Low Voltage
m	meter
MV	medium voltage
MW	Megawatts
NG	Natural Gas
NE	National experts
O&M	Operating and Maintenance
NPV	Net Present Value
TPP	Thermal Power Plant

LIST OF ACRONYMS

EDL / EdL	Electricité du Laos
EGAT	Electricity Generation Authority of Thailand
EVN	Electricity of Vietnam
GMS	Greater Mekong Sub-region
Lao PDR	Lao People’s Democratic Republic
MEM	Ministry of Energy and Mines (Lao PDR)
MIME	Ministry of Industry, Mines and Energy of Cambodia)
PDP	Power Development master Plan
PEA	Provincial Electricity Authority of Thailand
PRC	People’s Republic of China

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1. OVERVIEW

1.1 ORGANISATION OF THE REPORT

The objective of the present Task 5.3 report is to present the 2010 update of the GMS regional Master Plan for the period 2009-2025 and the list of priority transmission projects to develop.

The report is organized along the following paragraphs:

- Objectives.
- OPTGEN planning and operation software.
- High level view of the target interconnection scheme in 2025.
- Interconnection grid and node modeling.
- Master plan simulation results : base and alternate cases.
- Resilience analysis.
- Multi-criteria ranking of interconnection projects.
- Conclusions and recommendations.

1.2 OBJECTIVES

As per the TOR of the RETA-6440 project, the objectives of the GMS Master Plan update are to:

- Update the GMS Master Plan for the period 2009-2025 by simulating the regional power system with existing and potential planned power interconnections.

- Run simulations of the model for a variety of regional power system scenarios.

- Identify the potentially beneficial regional interconnection projects based on the Master Plan, and compile a list of priority projects according to their merits.

1.3 OPTGEN PLANNING AND OPERATION SOFTWARE

The optimal operation of the GMS power system over the 2010-2025 period is simulated with OPTGEN planning and operation software developed by PSR Company (Brazil).

<u>Key features</u>:

The key features of OPTGEN for the present Study are the ability to:

- Simulate the optimal operation of several power systems (ie. several countries) linked by interconnections over a large time horizon (e.g., 2010-2025),

- Determine the optimal capacity and commissioning dates of future interconnections linking the different power systems,

- Determine the optimal operation of hydro reservoirs, based on inflows data (wet/average/dry historical hydro series) and hydro plant characteristics: capacity (MW), storage (hm^3), energy ($MW.m^{-3}.s^{-1}$).

Objective function:

The objective cost function given to OPTGEN is:

Min [NPV (Investment costs + O&M costs + Fuel costs + Unserved energy cost + Externalities)]

Within the following constraints:

- For each node : balance between demand and supply (including import / export).
- For each interconnection: power transit lower or equal to interconnection capacity.

The variables of decisions are the interconnection capacities and commissioning dates. The commissioning dates for generation are given to the model as per national PDPs.

In other words, OPTGEN has two main functions:

- Optimal operation : simulation of the operation of an optimal power market taking advantage, at each time step, of the lowest cost available in any country, within the limits allowed by the capacity of the interconnections linking the countries.
- Optimal decision on interconnection capacities: determination of the optimal capacity and commissioning date of candidate interconnections.

1.4 HIGH LEVEL VIEW OF THE TARGET INTERCONNECTION SCHEME IN 2025

The next figure outlines a realistic picture of the GMS interconnection backbone in 2025.

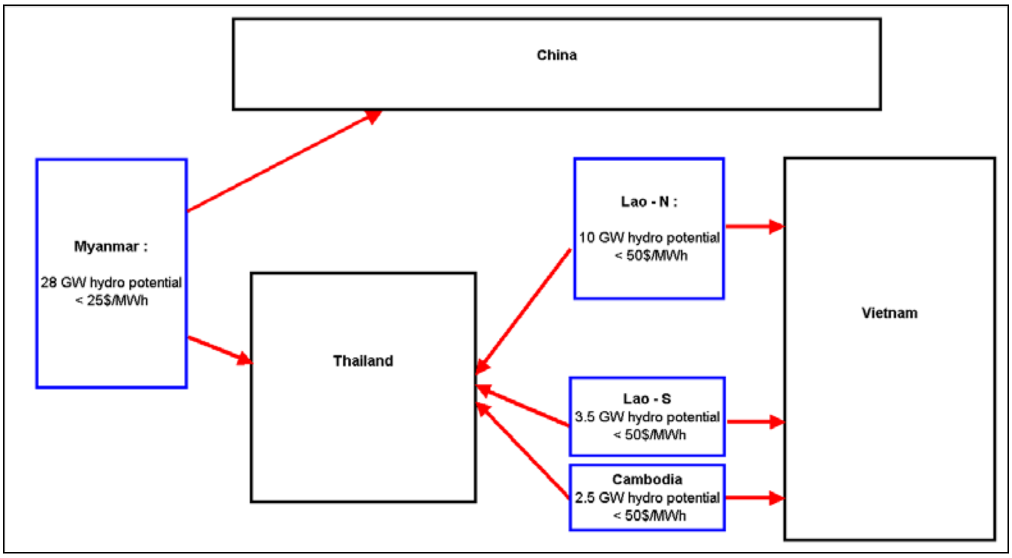


Figure 1.4-1 : High level view of the GMS target interconnection scheme in 2025

The analysis carried out in Task 5.1 confirmed the general economic justification of the various interconnections depicted above on the basis of generation and transmission costs.

The following comments can be made on this target interconnection grid.

<u>Two East-West backbones between Thailand / Vietnam</u>:

One of the key elements of the proposed scheme is the two East-West routes linking:

- In the "North" : Thailand / North Laos / North Vietnam,
- In the "South" : Thailand / South Laos & Cambodia / Central & South Vietnam[1].

These two East-West backbones will allow hydro power exports from Laos/Cambodia to Thailand/Vietnam, but also will provide:

- Iindirect link for possible power exchanges between Thailand and Vietnam (through Laos or Cambodia),
- Power exchanges to Cambodia and Laos to support these power systems from thermal generation in Thailand or Vietnam on very dry hydro conditions.

<u>Vietnam North / South grid balance:</u>

Because of its long North – South span, and the location of demand centres (40% of Vietnam demand is in the Northern area, 40% in the Southern area) it is preferable to feed power exports to Northern and Southern Vietnam in order to balance the load flow within Vietnam internal grid. This is made possible by the proposed interconnection scheme. However, specific network study (not within the scope of the present RETA-6440 study) would be necessary to investigate the appropriate balance between North, Central and South imports.

<u>South Laos, Cambodia, South/Central Vietnam</u>:

Because of the number and geographic proximity of hydro projects in Southern Laos, Cambodia on one hand, and the proximity to load areas in Center and Southern Vietnam on the other hand, there is a variety of possible interconnections between these four areas. More detailed investigations and focussed studies (eg. RETA Package III) would be necessary to evaluate the different possibilities, which are largely dependant on national grid development and the actual hydro projects selected for development.

<u>Laos North / South internal connection</u>:

91 % of Laos demand is located in Laos North/Central 1 areas. Laos South demand could be covered by the development of export IPP in the South. Accordingly, there is no need to develop a major North to South Laos backbone to support future export/import routes in the GMS market.

<u>China - Laos</u>:

No interconnection project between China and Laos was identified at Workshop n°2 (Bangkok, September 2009). However, the possibility of an interconnection giving the possibility to import power from Laos was evoked at Workshop n°2 (Bangkok January 2010). This option will be considered in the sensitivity analysis.

[1] At this level of analysis, "South" should be understood as "South and Centre" Vietnam (i.e from Da Nang to Southern Vietnam)

China - Vietnam interconnection:

As discussed in Task 5.1 report, a China-Vietnam interconnection does not appear relevant for large scale power flows because China and Vietnam are both importers. The connections between Laos and Vietnam have more economic justification (because of larger hydro potential in Laos and price gap between Laos HPP and Vietnam TPP).

Export from hydro generation in Myanmar to Vietnam through China (or Laos) could be an option, but would probably be less competitive[2] than direct imports of hydro generation from Laos North / Central 1 to Vietnam.

1.5 INTERCONNECTION GRID AND NODE MODELING

Further to the first views on the GMS interconnection scheme presented above, the present paragraph details the interconnection and node modelling actually adopted in OPTGEN software.

Load-flow studies and national grid representation:

According to the TOR of RETA-6440, load-flow studies, whether internal to the grid of a country or for interconnections between countries are not within the scope of the present study. The Consultant will determine whether load-flow analysis is needed in particular cross-border connections, and if so, prepare terms of reference for such studies, in consultation with the GMS countries.

Accordingly, the adopted modeling of the GMS grid is focused on cross-border interconnections and does not consider national grids (and possible internal national congestion), with the exception of Vietnam (see hereafter).

GMS node modelling adopted for the Study:

The following figure describes the transmission network and node modelling adopted for the GMS Master Plan update (version 2010):

[2] HPP generation cost in Myanmar are lower than 25$/MWh, transmission cost from Myanmar to Vietnam, if through a 1500 km HVDC line would add about 20$/MWh, resulting in a 45 $/MWh of the energy delivered to Vietnam. By comparison, more than 6000 MW hydro potential is available in North/Central 1 areas in Laos at a cost lower than 40$/MWh. More accurate information of Myanmar HPP would be necessary to clear out this possibility.

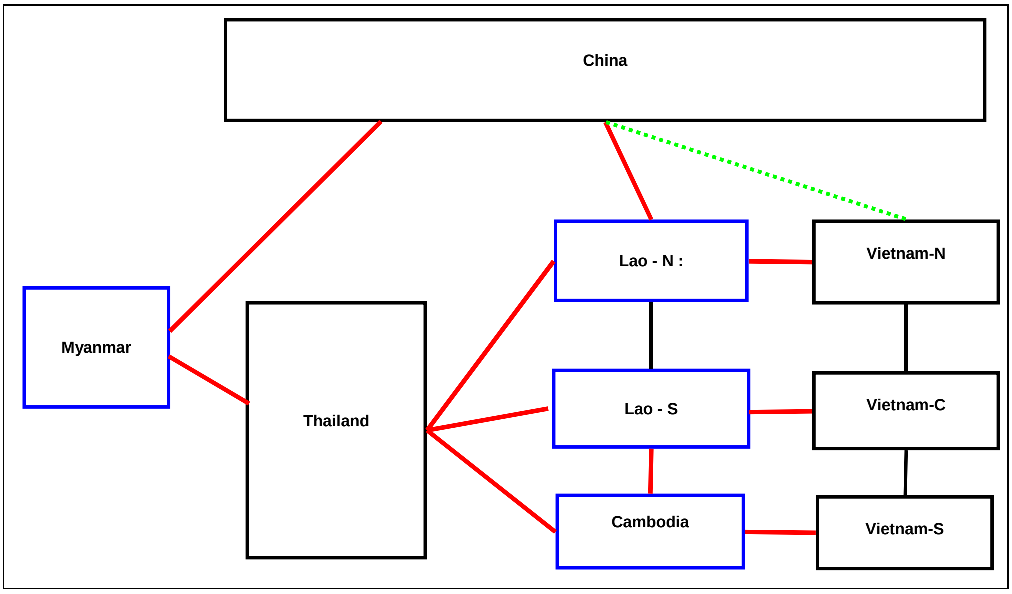


Figure 1.5-1 : Interconnection grid and node modelling for GMS Master Plan 2010

Colour code:

Green colour: existing interconnections.

Red colour: interconnections (existing or candidates).

Black colour: internal transmission routes.

The rational for this modelling is the following:

- China (Yunnan and Guangxi provinces): modelled as one node because of highly meshed transmission networks.
- Cambodia: modelled as one node, because most of the power demand is located in the Phnom Pen area.
- Laos: modelled as two nodes, Laos-N (in fact gathering Northern and Central 1 areas) and Lao-S, because of the two distinct geographical locations of Laos hydro potential. About 91% of the country demand is in Laos-N and 10% in Laos-S. The demand of Laos-S is provided by Laos-S IPP. There is no need for a major Laos-N to Laos-S link for import / export purpose. A 200 MW link is assumed to be available from 2016 between Laos-N and Laos-S as suggested by Laos PDP grid map.
- Myanmar: modelled as one node, since its local demand is small compared to the power exports to China and Thailand.
- Thailand: modelled as one node, because of its strong and developed transmission grid. Internal transmission congestions resulting from the development of power exchanges will have to be checked in load-flow studies outside the scope of the present Study.
- Vietnam: modelled as three nodes because the internal transmission limits will have a direct impact on the amount of possible power import coming from Laos-N, Laos-S, or Cambodia. About 10% of the country demand is in Vietnam-C (Pleiku), 40% in Vietnam-N (Nho Quan, Ha Tinh, Da Nang) and 50% in Vietnam-S (Than Dinh).

In absence of complementary load-flow studies, and on the basis of the information provided by IEV (Hanoi meeting, January 2010), a constant 1200 MW maximum capacity is assumed between Vietnam-C and Vietnam-N, and 2000 MW between Vietnam-C and Vietnam-N.

- Laos-S to Cambodia interconnection: while this link is not suggested by the analysis carried out in §3.2, this interconnection candidate was included in the modelling in order to deal with the congestion observed between Vietnam-S and Vietnam-C (see simulation results in § 3.6.3.2).

Additional information on GMS modelling with OPTGEN software:

- Cambodia, Laos, Thailand and Vietnam will be fully modelled in OPTGEN: demand projection and complete description of generation mixes.
- China: will become the largest power importer in the GMS region, targeting a total of 30 GW import. Accordingly, China will be represented in the modelling through its importing capacity from the GMS countries (i.e. not modelled as a node with demand projection and description of generation mix). Considering the large size of Guangxi and Yunnan generation mix, a detailed modelling would be very complex and would take a long time for limited additional benefits in the results. Furthermore, the West to East large power flow through Guangxi and Yunnan resulting from import from Myanmar and export to Guangdong would require a careful study – largely outside the scope of RETA 6440 - in order to properly model the Yunnan + Guangxi system.
- Myanmar: no PDP is available for Myanmar. Furthermore, the national demand of Myanmar is low compared to the amount of power export. Accordingly, only the hydro projects dedicated to power export will be modelled in Myanmar node.

The various interconnections are described more thoroughly in the following paragraph.

1.5.1 LIST OF EXISTING INTERCONNECTION SCHEMES

The following table (from Module 3 report) presents data on existing interconnections between GMS countries.

Project reference	Location 1	Location 2	Voltage	Capacity	Length	Year
A	Xinqiao, Yunnan, China	Lao Cai, Vietnam	220 kV	250 – 300 MW	56 km (in China)	2006
B	Maguan, Yunnan, China	Ha Giang, Vietnam	220 kV	200 MW	51 km (in China)	2007
C	Shewli I HPP, Myanmar	Dehong, Yunnan, China	220 kV double circuit	600 MW	2 x 120 km	2008

D	Chau Doc, Vietnam	Phnom Penh, Cambodia	220 kV (Vietnam) 230 kV (Cambodia) double circuit	100 MW in 2009 and 200 MW from 2010 onwards.	111 km	2009
E	Nam Theun 2 HPP, Laos	Roi Et 2 substation (via Savannakhet, Laos), Thailand	500 kV double circuit	1,000 MW	304 km (Roi Et to NT2)	December 2009
F	Houayho HPP, Laos	Ubon 2, Thailand	230 kV	150 MW	230 km	1999
G	Theun Hinboun HPP, Laos	Sakhonnakhon, Thailand	230 kV	200 MW	176 km	1998

Table 1.5-1 : Existing interconnections (as per end 2009)

In additional to these, lower voltage interconnection exist between:

- Laos and Cambodia : for 10 MW export capacity to Cambodia,
- Thailand and Cambodia: for a 40 MW export capacity to Cambodia.

These, along with national infrastructure at 500 kV, are illustrated on the map below. The energy flows are currently as follows:

- China is importing from Myanmar (the Shweli 1 HPP)
- Vietnam (north) is importing from China
- Thailand is importing from the HPPs in Laos
- Cambodia is importing from Laos, Thailand and Vietnam.

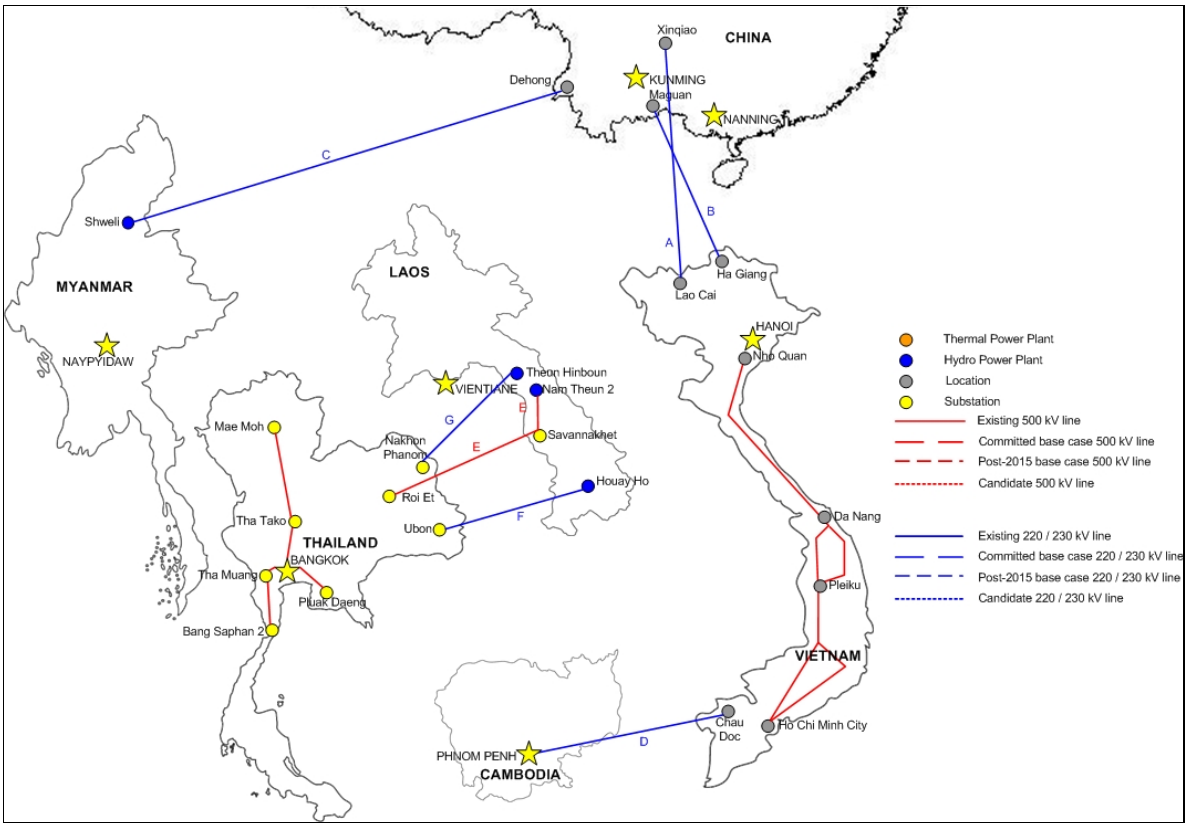


***Figure 1.5-2** – GMS map showing existing interconnections (as per 2009)*

As the above diagram indicates, there is currently relatively little interconnection capacity between the GMS countries. Such interconnections that do exist are primarily associated with specific hydro schemes, and take the form of connections into the neighboring power network to deliver power exports from these power plants.

1.5.2 Committed and Candidates Interconnection Projects Considered in MP2010

The list of interconnection projects considered in the MP2010 are those described in Figure 3.3-1 : Interconnection grid and node modelling for GMS Master Plan 2010 reminded below:

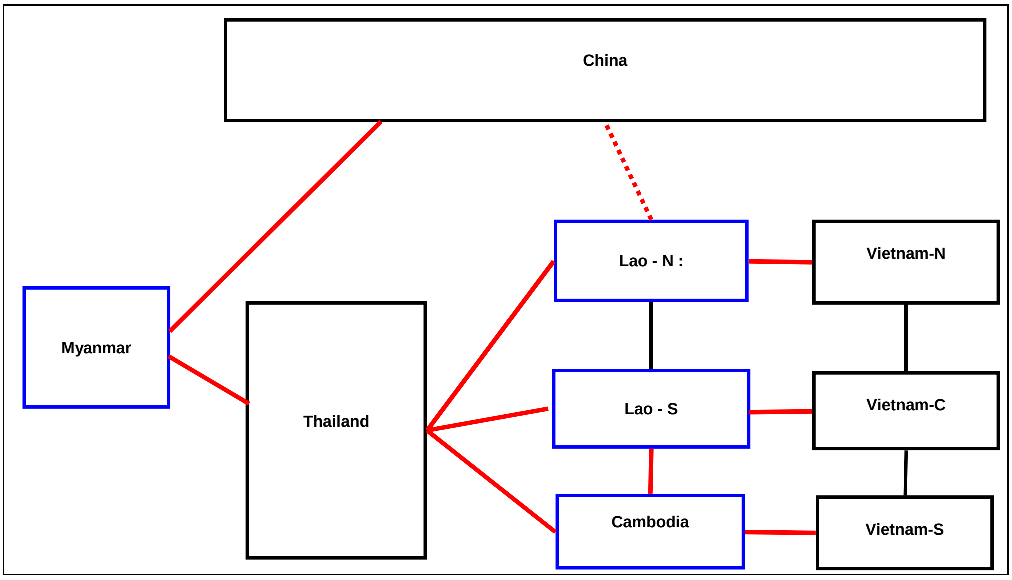


Figure 1.5-3 : Node modelling of the GMS power system

As such, the following pairs of countries require interconnection schemes:

- Myanmar – China
- Myanmar – Thailand
- Laos North – Thailand
- Laos South – Thailand
- Laos North – Vietnam North
- Laos South – Vietnam Centre
- Cambodia – Vietnam South
- Cambodia – Laos South
- Cambodia – Thailand

These interconnection projects can be classified in two types:

- "Committed" interconnection projects:

  They are due to be commissioned up to and including 2015 – these are "committed base case" projects. These projects are considered as being already approved.

- Generic interconnections projects:

  For the base case scenario to make up for the shortfall between expected levels of import in national PDPs and the committed base case projects, and also for possible alternate development scenarios.

As explained in Module 3 report, the candidate projects that have been identified from sources other than the countries' PDPs will not get used in the model directly. However, it is important that the information gathered about these projects is retained for future reference. The intention is therefore to compare the out-turn interconnection requirements with the known candidate schemes once the model has been run; where interconnection requirements have been identified, these can be associated with base case projects post-2015[3] or candidate projects where possible. For example, the results of running the model may show that a certain amount of capacity is required between two countries. If there is a candidate or post-2015 base case project between these two countries, that will be identified as being a possible solution. Where such an identified project does not exist, a generic interconnection would be proposed.

[3] 2015 being the cut-off date for the commissioning of committed projects, i.e. those whose planning and/or construction is already under way.

1.5.2.1 List of committed interconnection projects

These are the projects committed before 2015 and considered to be already approved. They are illustrated in the map and table below :

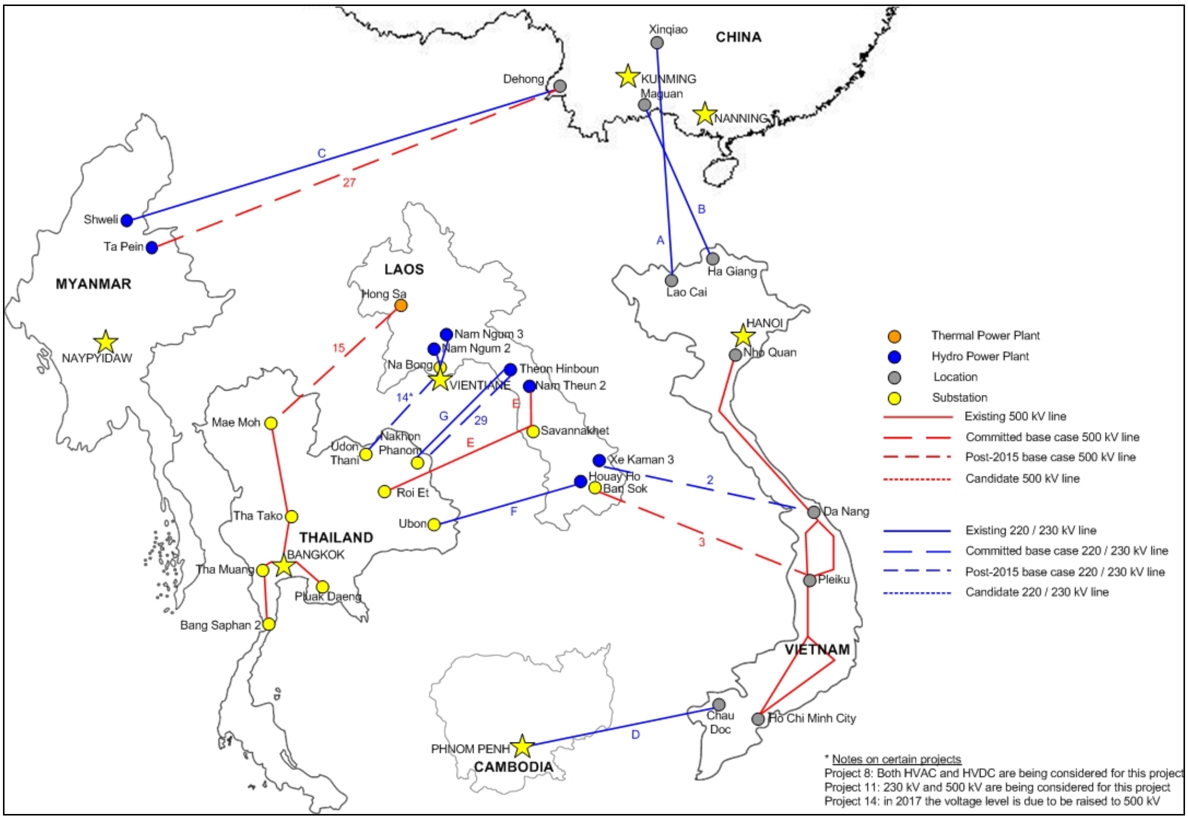


Figure 1.5-4 : Map of committed interconnection projects

Project reference number	Location 1	Location 2	Voltage	Capacity	Length	Year
2	Xe Kaman 3 HPP, south Laos	Da Nang (Hoa Khanh substation), central Vietnam	220 kV double circuit	250 MW	135 km	2010
3	Ban Soc / Ban Hat, south Laos	Pleiku, Vietnam	500 kV double circuit	1,000 MW	190 km	2014
7a	Lower Se San 2 HPP, Cambodia	Pleiku, Vietnam	230 kV double circuit	200 MW	230 km	2016
14	Na Bong, Laos (Ngum2 and Ngum3 HPP)	Udon Thani, Thailand	230 kV in 2010 500 kV in 2015	605 MW in 2011 and additional 440 MW in 2017	107 km	2010 (230kV) 2017 (500kV)
15	Hong Sa TPP, Laos	Mae Moh, Thailand	500 kV Three or four circuits	1470 MW	340 km	2015
27	Dapein HPP Myanmar	Daying Jian (near Dehong) China	500 kV single circuit	240 MW	120 km (estimated)	2011
29	Theun Hinboun expansion HPP Laos	Nakhon Phanom Thailand	230 kV single circuit	220 MW	90 km	2012

Table 1.5-2 : List of committed interconnections - MP 2010

The construction costs of these projects are not considered in the analysis (sunk costs).

1.5.2.2 List and characteristics of candidates projects

OPTGEN will select the optimal interconnection projects to be commissioned from 2015 to 2028 from a list of generic candidates of various capacities.

A range of capacity will be examined for each interconnection in order to select the optimal commissioning date and capacity for each interconnection.

These interconnection projects are not actual projects, which may vary on actual line route and connecting points at both ends. They are generic projects meant to realistically represent the cost of delivering power from one node to another in order for OPTGEN to take the correct decision.

The following table presents the list of candidates:

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos North (Luang Prabang)	China (Mojiang)	350 km	600 MW	2	279.5
			1200 MW	3	443.9
			1800 MW	4	559.0
Myanmar (Shamo)	China (Dali)	350 km	500 MW	2	250.4
			1000 MW	3	397.6
			1500 MW	4	500.7
			2000 MW	5	648.0

Table 1.5-3 : Cost of interconnection candidates with China

NB: The large hydro "Seven projects" in Myanmar totalizes a 16 500 MW export capacity to China, assumed to be progressively put in operation from 2018 to 2025 by blocks of 2000 MW. Accordingly, it is also assumed the associated interconnection is gradually put in operation by blocks (and cost) of 2000 MW.

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Myanmar (Minesat)	Thailand (Mae Moh)	250 km	600 MW	2	188.7
			1200 MW	3	299.8
			1800 MW	4	377.5
			2400 MW	5	488.6
			3000 MW	6	566.1
			3600 MW	7	677.2
			4200 MW	8	754.8
			4800 MW	9	865.9
Laos North (Luang Prabang)	Thailand (Mae Moh)	300 km	600 MW	2	221.4
			1200 MW	3	351.6
			1800 MW	4	442.8
			2400 MW	5	573.0
			3000 MW	6	664.2
Laos South (Ban Sok)	Thailand (Ubon Rat.)	150 km	500 MW	2	119.7
			1000 MW	2, with compensators	131.6
			1500 MW	3, with compensators	209.1
Cambodia (Phnom Penh)	Thailand (Pluak Daeng)	400 km	500 MW	2	283.0
			1000 MW	3	449.5
			1500 MW	4	566.0

Table 1.5-4 : Cost of interconnection candidates with Thailand

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos North (Luang Prabang)	Vietnam North (Son La)	250 km	600 MW	2	188.7
			1200 MW	3	299.8
			1800 MW	4	377.5
			2400 MW	5	488.6
			3000 MW	6	566.1
Laos South (Ban Sok)	Vietnam Centre (Pleiku)	200 km	500 MW	2	152.3
			1000 MW	3	242.0
			1500 MW	4	304.7
Cambodia (Phnom Penh)	Vietnam South (HCMC)	200 km	500 MW	2	152.3
			1000 MW	3	242.0
			1500 MW	4	304.7
			2000 MW	5	394.3

Table 1.5-5 : Cost of interconnection candidates with Vietnam

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos South (Bansok)	Cambodia (Phnom Penh)	400 km	500 MW	2	283.0
			1000 MW	3	449.5
			1500 MW	4	566.0
			2000 MW	5	732.5

Table 1.5-6 : Cost of interconnection candidates with Cambodia

The following table presents the cost of reinforcement of the Vietnam Center to South transmission (not considered as candidates but as alternatives):

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Vietnam Center	Vietnam South	350 km	1500 MW	4	500.7
			2000 MW	5	648.0
			3000 MW	6	838.5

Table 1.5-7 : Cost of transmission reinforcement between Vietnam Center and Vietnam South

Other characteristics associated with interconnections:

- Annual O& M cost: 2% investment cost.
- Duration of construction: 3 years.
- Disbursement schedule: 25%, 50%, 25%.

1.6 MASTER PLAN SIMULATION RESULTS

1.6.1 SUMMARY LIST OF SIMULATION RUNS

Eight different cases were simulated with OPTGEN software:

Name	Description
Base case	- 10% discount rate. - Expansion of interconnections as required by the power exchanges considered in the current national PDPs. - Optimal transmission capacity between Vietnam Center and South determined by OPTGEN (5000 MW from 2015).
Case-2000MW	- Idem to base case, but with constant 2000 MW transmission capacity between Vietnam Center and South.
High export	- Idem to base case, but with 2400 MW additional export from Laos North to China, and 1200 MW additional export from Laos North to Vietnam North
No-expansion	Only existing and committed interconnection projects until 2015 are considered. No additional interconnection is added to the system after 2015.
CO2	Same four cases as above, but with CO_2 cost = 50$/t until 2020, and 65 $/t beyond.

Table 1.6-1 : List of simulation runs

1.6.2 GMS MASTER PLAN "BASE CASE"

1.6.2.1 Definition

The base case corresponds to the level of development of interconnections required by the power imports expected in the current versions of China, Thailand and Vietnam PDPs, complemented and amended by the assumptions agreed at Workshop 3 (January 2010, Bangkok) .

Indeed, these different PDPs as provided by the countries were not up to date (eg. Vietnam PDP MP VI was outdated), nor completely defined (generation export oriented projects were not systematically identified), nor completely consistent between themselves.

Accordingly, the Consultant took hypotheses to update, complete and fill the gaps in these PDPs[4].

More precisely, the man hypotheses in the "base case" are as follows:

- Up to 2015: the development of "committed" interconnection projects is as described in 3.3.2.1.
- The level of power import is given in the following table :

Importing country	Import in 2025	Percentage of country 2025 peak demand[5]
China	18 900 MW (from Myanmar)	14%
Thailand	Total import : 7 700 MW - 5100 MW from Laos N & C - 150 MW from Laos S - 2100 MW from Myanmar - 330 MW from Malaysia	15%
Vietnam	Total import : 5100 MW - 2600 MW from Laos-N & C - 2100 MW from Laos-S 400 MW from Cambodia	6.5%

Table 1.6-2 : "Base case": level of imports

Explanations and justification of hypotheses are provided in part 3.6.2.1.

[4] See Task 3 'Review of PDP" country reports and Task 5.3 Appendix given a synthesis of the list of generation export projects for each country.
[5] For China : percentage of peak demand + export to Guangdong

1.6.2.2 Results

The following table presents the schedule of existing, committed and candidate interconnection projects in the GMS Master Plan base case:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Laos-S	Cambodia	20					40														0

Table 1.6-3: Base case - Schedule of new interconnections (MW)

Benefits provided by the expansion of interconnections:

Compare to a “no expansion” case, where only the interconnection projects committed up to 2015 are developed, this “base case” provides :

- A global cost savings for the Greater Mekong Subregion of 14 310 M$ (discounted value over the 2010-2030 period). These savings come mainly from the substitution of hydro generation[6] to fossil fuel generation (coal-fired and gas-fired). More precisely, a total reduction of the fuel cost of 19390 M$ is observed over the 2010-2030 (in Present Worth Value) associated with an increase of 5 080 M$ of the investment (in both interconnection and HPP cost) over the same period of time.

- A reduction of CO_2 emission by 14.2 Mt / year in 2020.

Remarks on Vietnam PDP:

- Because of the structure of Vietnam future generation mix considered in MP VI (dominated by low cost coal-fired STPP in the North, and more expensive gas-fired CCGT in the South), the Study showed that a constant 2000 MW transmission capacity between Vietnam South and Center is suboptimal. Going up to 5000 MW would be beneficial, allowing additional power "import" from coal-fired STPP located in Vietnam North to save the generation from more expensive NG-fired CCGT located in Vietnam South.

- However, these remarks on the optimal transmission capacity within Vietnam national transmission grid are largely dependant on the hypotheses considered for the development Vietnam power generation mix, which are known to be largely obsolete in the Vietnam MP VI used for the study (Vietnam MP VII will be released by end of 2010?). Indeed, from 2013-2015 Vietnam will start to import part of the coal necessary to the coal-fired STPP. This leads to the opportunity to "re-balance" the future Vietnam generation mix, developing more coal-fired

[6] Strictly speaking, there is also some substitution of lignite-fired generation to gas-fired generation (import from Laos Hongsa lignite TPP to Thailand, and import from Myanmar Maikhot lignite TPP to Thailand).

STPP in Vietnam South than considered in MP VI, which would in turn reduce the need of large power transit between North and South Vietnam.

1.6.3 CASE 2000 MW

The main results of this case concerns the Vietnam transmission grid :

- If no cost CO_2 emission is considered, a 2000 MW transmission capacity between Vietnam Center and South is suboptimal, a 5000 MW capacity would be beneficial for the reasons explained in "base case".
- If a cost for CO_2 emission is considered (50$/t$CO_2$ until 2020 and 65 $/t$CO_2$ beyond), the price gap between natural gas fired CCGT in Vietnam South and coal-fired STPP in Vietnam North reduces and a constant 2000 MW transmission capacity becomes sufficient.
- As for the base case, the validity of this conclusion is limited by the obsolescence of the present Vietnam Master Plan VI.

1.6.4 HIGH EXPORT CASE

In the “base case”, the remaining hydro potential left in 2028 is concentrated in Myanmar (about 7 GW), and on the mainstream of Mekong river : 9 large scale run of river HPP projects from 1000 to 1400 MW installed capacity (out of a total of 11 identified hydro projects).

Increasing the hydro based export compared to the “base case” situation would obviously increase the generation savings for the region, but a realistic evaluation of the Mekong River potential (number and capacity of the hydro projects) could only be made through a Cumulative Impact Assessment study of the mainstream Mekong River.

1.6.5 CO2 EMISSIONS

- Compared to the "no expansion case", the CO_2 emission in the “base case" are reduced by 46.4 Mt per year in 2020, and by an additional 14.5 Mt / year in the "high export" case.
- One third of these savings is in Vietnam, the other two third in China.

1.6.6 COMPARISON WITH GMS MASTER PLAN 2008 RESULTS

The main differences of hypotheses with the MP 2008 are:

- Use of international fuel price instead of local / subsidized price,
- Use of consistent investment and homogeneous costs for generation and transmission projects for the whole region,
- Mostly hydro-based power export instead of thermal-based power export,
- Updated demand projection.

The MP2010 reaches most of the same conclusions as MP2008, except for the following lines which are not developed or reinforced in MP2010:

- Thailand-China,
- Thailand- Laos South,
- China- Vietnam North.

1.6.7 COMPARISON OF GENERIC INTERCONNECTION REQUIREMENTS WITH IDENTIFIED PROJECTS

As discussed in Module 3 report, a set of interconnection projects were identified; some of these were classified as committed base case, and these have been used in the base case model (see §1.5.2.1). The rest of these projects (referred to as post-2015 base case and candidates) are to be compared with the requirements identified in the model.

The following table shows the interconnection requirements identified by the base case model run, and the identified projects which are consistent with these interconnection requirements.

Interconnection requirement				Identified projects				
Importing country	Exporting country	MW required	Year	Project reference number	Location 1	Location 2	Capacity	Year
China	Myanmar	2000	2018					
		2000	2019					
		2000	2020					
		2000	2021					
		2000	2022					
		2000	2023					
		2000	2024					
		2000	2025					
		4000	2028					
Thailand	Myanmar	400	2017	28	Mai Khot substation, Myanmar (export)	Mae Chan substation, Thailand (import)	369	2016
		1200	2020	As below.				
		600	2023	As below.				
		3600	2028	16	Ta Sang HPP, Myanmar (export)	Mae Moh, Thailand (import)	7100	2029
Thailand	Laos North	600	2017	26	Saiyaburi, Laos north (export)	Khon Kaen, Thailand (import)	1200 - 2600	2016
		300	2022	As above				
		1200	2024	As above				
Vietnam North	Laos North	600	2016	5b	Xam Nau, Laos north (export)	Nho Quan, VN north (Import)	2500	2016
		1800	2020	As above				
Vietnam Centre	Laos South	900	2020					
Vietnam South	Cambodia	200	2016	7a	Lower Se San 2 HPP, Cambodia (export)	Pleiku (or Tay Ninh), Vietnam South (import)	200	2017

Table 1.6-4: Comparison of identified projects with interconnection requirements

It can be seen that a number of the identified projects are consistent with the interconnection requirements. In these cases, the capacity of the identified projects closely matches that of the requirement. It is notable that the projects that the GMS countries have identified and are considering are consistent with the results of the base case model results.

In some cases, the scheduling of the line could be reconsidered. For example, the model has identified a need for increasing amounts of import from Myanmar to Thailand from 2020 to 2028. A single project, with project reference number 16, has been identified which meets this need, but is not planned to be operational until 2029. If this project were to be commissioned earlier (from 2020) with phased increases, this project would meet the interconnection requirements identified by the base case model.

- The table also shows that there are some requirements that are not covered by any interconnection projects that have been identified during the course of this project. Most notably, the significant import requirements from Myanmar to China. Interconnection between these two GMS countries has been identified as a priority in Section 1.8. There is another gap between the requirements and the identified projects, between Vietnam Centre and Laos South. Projects will therefore need to be developed by the GMS countries to address these requirements.

1.7 RESILIENCE ANALYSIS

This paragraphs complements the analysis made previously through simulations of the interconnected GMS system with OPTGEN, in order to evaluate the resilience (or robustness) of the GMS Master Plan base case, and more precisely the resilience of interconnection investment decisions under variation of key economic factors.

The evaluation of the benefits of interconnections between GMS countries is based upon projections of key parameters whose values could be different than anticipated in the future : interconnections investment costs, HPP investment costs and fuel prices.

The hypotheses taken for the base case are presented in Task 2 report (investment cost of new generation units, fuel price projections), and § 1.5.2.2 of present Task 5.3 report (investment cost of interconnections.

The resilience analysis consists in determining, for each interconnection, the break even point, related to each of these parameters, beyond which the interconnection would turn unprofitable.

The levelized cost of the interconnection projects considered above ranges from 7 to 12 USD/MWh, which is much lower than the price gap observed between the importing and exporting countries, ranging from 30$/MWh (for coal-fired STPP dominated importing power system) to 50 $/MWh (for gas-fired CCGT dominated importing power system).

Accordingly, all these interconnection projects are largely profitable as shown by the following table giving the economic savings provided by each interconnection, evaluated as the difference between the price gap (between importing and exporting countries) and the cost of interconnection[7]):

	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
benefits of the interconnection ($/MWh)	13	5	74	42	20	38	33 to 59

Table 1.7-1 : Economic savings ($/MWh) provided by candidate interconnections

The resilience analysis shows that the profitability of the interconnection projects between GMS countries resists negative price shocks (either interconnection and HPP costs, or fuel price). The following table gives in percentage the maximum increase of interconnection investment cost, the maximum increase of HPP investment cost, or decrease of fuel cost, compatible with the profitability of the interconnection projects (breakeven points):

[7] For further details on the calculation, see part 3.7.2 and 3.7.3.

	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
resilience to interconnection costs	144%	50%	1057%	525%	286%	240%	471% to 842%
resilience to HPP costs	52%	15%	296%	102%	49%	85%	57% to 184%
resilience to fuel price	-37%	-15%	-59%	-59%	-57%	-41%	-42% to -76%

Table 1.7-2 : Resilience of interconnection projects

- Interconnection investment costs can be multiplied by 2 to 10 (depending on interconnection project) without affecting the profitability (except China-Laos North: +50% in interconnection costs can turn the interconnection unprofitable).

- HPP investment costs can be multiplied by 1.5 to 4 (depending on interconnection project) without affecting the profitability (except China-Laos North: +15% in HPP costs in Laos can turn the interconnection unprofitable).

- Fuel price can decrease by 35 to 70% (compared to fuel price projection in the base case) without affecting the profitability (except China-Laos North: -15% in coal price in China can drive the interconnection to be unprofitable).

The interconnection projects linking hydro to gas-fired CCGT dominated thermal systems[8] are the most resilient to any cost or price shocks: Cambodia-Vietnam South, Laos South -Vietnam South, Laos North -Thailand and Myanmar-Thailand.

Interconnection projects linking hydro systems to coal-fired STPP dominated thermal power systems have a lower, but still good resilience, especially to the HPP costs: Myanmar-China and Laos North-Vietnam North. An increase in HPP costs by +50% may cancel their profitability.

One interconnection project is not very resilient to cost shocks: the interconnection project between China and Laos North. A slight increase of the HPP investment costs in Laos (+15%), or a decrease of the coal price (-15%), or an increase of the interconnection (+50%) can turn this project unprofitable. But some other – non economic - drivers might motivate the development of this project (huge power demand in China).

1.8 MULTI-CRITERIA RANKING AND PRIORITY INTERCONNECTION PROJECTS

1.8.1 RATIONALE AND CRITERIA

The Master Plan approach is an important input to the ranking of regional interconnection projects. However, ranking and defining priority projects interconnection projects involves several aspects:

- Economic criteria.

[8] gas-fired CCGT dominated generation system will experience the higher marginal costs because of the increase of gas price.

- Potential for export and import.
- Supply safety and diversification of import.
- Grid and PDP issues.

These different aspects are discussed more in details hereafter.

- 1 - Economic criteria:

The economic criterion is obviously the one and foremost criterion.

- o Price gap compared to interconnection cost :

A first way to rank interconnection is to calculate the economic benefit derived from each interconnection; this benefit is calculated as the difference between the price gap between both countries and the transmission cost.

Table 1.7-1 reminds the economic savings provided by each interconnection, evaluated as the difference between the price gap (between importing and exporting countries) and the cost of interconnection[9]: It can be seen that the most profitable interconnections (based upon economic evaluation) are those allowing exports from export oriented hydro generation project to countries (or areas) dominated by gas-fired power generation (Thailand and Vietnam South), because of the high cost of NG generation in the future (leading to huge price gap).

- o Resilience (or robustness) to changes of key factors (investment costs and fuel prices) :

A complementary way to determine an economic ranking of interconnections is to examine the resilience of their profitability to changes of the key economic factors: investments costs of hydro power plants dedicated to export, investment costs of interconnections, and fuel price (coal or NG).

In the Table 1.7-2, it can be seen that the profitability of all interconnections is very resilient to interconnect investment cost increase: the interconnection investment cost can be multiplied by more than 2 without affecting the profitability of the project. The only exception is the interconnection between China and Laos North: the price gap is very low, mainly because coal generation costs are low in China (because of low investment cost). But the main driver for the development of this interconnection is not the economic driver, but the increasing China demand, as seen afterward.

- o Synthesis of economic ranking:

[9] For further details on the calculation, see part 3.7.2 and 3.7.3.

The following table shows a ranking of all these interconnections based upon the previous economic criteria (rank 1 = highest priority):

Ranking benefits/resilience	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
benefits of the interconnection ($/MWh)	6	7	1	3	5	4	2
resilience to HPP costs	5	7	1	3	5	4	2
resilience to fuel price	6	7	1	1	1	5	1
Economic ranking (benefits+resilience to cost shocks)	6	7	1	3	4	5	2

Table 1.8-1 : Economic ranking of interconnection projects

According to a pure economic ranking, the interconnections with countries dominated by NG power generation (Thailand and Vietnam South) would be preferred.

The interconnections with China come at the end of this pure economic ranking because of the lower price gap between China and HPP in Myanmar or Laos.

However, the only economic point of view is not sufficient to determine which interconnection projects have the highest priority. Other complementary parameters have to be considered.

- <u>2 - Potential of export and need for import</u>:

  o Potential of export:

Some countries (especially Laos) have a large and diversified potential of hydro projects that could be dedicated to exports (these projects are distributed over a large area of the country: in the North, Central 1 and South areas). This means that interconnection projects in this type of country are less risky and non dependant on specific hydro project. Even if an interconnection project is implemented, and not the HPP project that was supposed to be commissioned in order to provide export through this line, it will be possible to find other cost effective hydro projects in the same area in order to use this interconnection line.

Moreover, because of this large hydro potential and the large demand of neighboring countries, there is no doubt there will be future increase in the transmission capacity. Accordingly, it might be justified to build interconnections with capacities larger than expected by the strict least cost approach.

Regarding the type of hydro plant, and from the generation point of view, hydro projects with seasonal reservoirs give more flexibility in operation than run of river projects.

  o Need for import :

In some situations, interconnections are not only a way to benefit from a price gap between two countries, but also the only way to balance an increasing demand in the long term. That is the case for China, which is looking to import 25 – 30 GW from the neighboring countries in order to balance its huge future demand. In this case, a low or even slightly negative price gap can be accepted.

- 3 – Supply safety / Diversification of power imports:

  - Supply safety is increased through diversification of import sources: geographic diversification to mitigate hydro risk (different hydro regimes), country origin diversification to mitigate supply risks, increase of grid mesh to mitigate grid contingencies. This is the case for Thailand for example.

  - Ratio of import : even if the price gap is high with neighboring countries, most countries would like to limit their share of imports in the total power supply in order to keep the control on the main part of power supply with a large part of domestic supply. This is the case with Thailand: the price gap with the neighboring countries is high and the hydro potential in these countries is also high, but Thailand doesn't want to import more than 15% - 20% of its national peak demand[10].

- 4 - Grid and PDP aspects / Level of studies:

  - Regional integration (number of countries involved in the interconnection) :

Some interconnections allow a real regional integration between GMS countries by creating a link between several importing and exporting countries. This type of interconnection favors regional integration and the development of regional power trades.

  - Increased meshed grid:

Provides better resilience to grid contingencies.

  - Interconnection projects impacted by options taken in national PDPs:

An example is given by the PDP of Vietnam. From about 2015, Vietnam will have to import part of its coal. This opens the possibility to develop coal-fired STPP directly close to the load center in Vietnam South. If such an option is taken, the price gap between Laos-S (or Cambodia) and Vietnam South will be reduced and become comparable to the price gap between Laos-N and Vietnam-N. The profitability of interconnections between Laos South (or Cambodia) and Vietnam South would be lower (but still high).

[10] This ratio depends on the number of exporting countries

- o Level of advance of related studies :

Developing an interconnection project is a rather long process involving different steps of technical and non technical studies for the interconnection project, but also for the associated generation export projects (Desktop Study, Feasibility Study, Design Study, tendering process, commercial agreement, etc). Accordingly, the priority projects for the next 10 years are necessarily among the projects which have been studied to the more advanced level.

Further more, a number of more related and more focused studies are either ongoing : Package III (Cambodia – Laos Vietnam interconnection study), China – Vietnam interconnection study, Thailand PDP, Vietnam PDP, or have just been started :Cumulative Impact Assessment of some of the HPP projects on mainstream Mekong River, Vietnam grid reinforcement study. These studies will bring significant new information and / or data for the next update of the GMS Master Plan, and would possibly answer issues that could not be tackled within the time frame and scope of works given to the present RETA-6440 Study.

1.8.2 ANALYSIS BY COUNTRY

In this paragraph, each interconnection project is evaluated along the previous criteria from the point of view of the importing country.

1.8.2.1 Projects to China

China – Myanmar interconnection:

Economy	- Economic benefit : 13 $/MWh (saves coal-fired generation) - Resilience HPP investment cost : 52% - Resilience fuel price : -37%
Export potential / need for import	- Export potential : Myanmar = very large potential = 28 GW (to be shared with Thailand) - China target for import : China : 30 GW in 2030
Diversification	- Hydro regime different than China / Laos
Grid / PDP / studies	- Huge imports are necessary to balance the China demand
Base case	- 18 000 MW import from Myanmar to China in 2028

Table 1.8-2 : Evaluation of China - Myanmar interconnection

China – Laos interconnection:

Economy	- Economic benefit : 5 $/MWh (saves coal-fired generation) - Resilience HPP investment cost : +15% - Resilience fuel price : -15%
Export potential / need for import	- Export potential : Laos = large potential = 10 GW in Laos North - China target for import : 30 GW in 2030
Diversification	- Hydro regime different than Myanmar / China. - Diversification of imports (Myanmar + Laos)
Grid / PDP / studies	
Base case	0 MW

Table 1.8-3 : Evaluation of China - Laos interconnection

<u>Conclusion for China</u>:

- The interconnection project between Myanmar and China ranks first because of larger price gap and the huge Myanmar hydro potential.
- China-Laos ranks second because of a lower price gap and hydro potential in Laos (shared with Thailand and Vietnam).

1.8.2.2 Project to Thailand

Thailand – Myanmar interconnection:

Economy	- Economic benefit : 74 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +296% - Resilience fuel price : -59%
Export potential / need for import	- Export potential : Myanmar = very large potential = 28 GW (to be shared with China) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime different than Laos N / S / Cambodia
Grid / PDP / studies	
Base case	- 5500 MW import from Myanmar to Thailand in 2025

Table 1.8-4 : Evaluation of Thailand - Myanmar interconnection

Thailand - Laos N and Thailand - Laos S interconnection:

Economy	- Economic benefit : 42 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +102% - Resilience fuel price : -59%
Export potential / need for import	- Export potential : Laos N = 10 GW, Laos S = 3.5 GW (to be shared with Vietnam) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime different than Myanmar - Number of seasonal reservoirs larger in Laos North than Laos Sout (given the list of Laos South HPP projects devoted to export to Vietnam)
Grid / PDP / studies	- To be checked with grid study - Tariff MOU already discussed (though now obsolete) for HPP in Laos North
Base case	- Import from Laos - N : 2400 MW in 2025 - Import from Laos - S = 150 MW in 2025

Table 1.8-5 : Evaluation of Thailand - Laos interconnection

Thailand – Cambodia interconnection:

Economy	- Economic benefit : 39 to 65 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +57% to +184% - Resilience fuel price : -42% to -76%
Export potential / need for import	- Limited Export potential : Stung Treng (980 MW) and Sambor : 450 MW (up to 2600 MW depending on studies) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime less favorable; inflows in dry season are lower than in Laos - Only run of rivers projects (for large scale projects)
Grid / PDP / studies	- To be checked with grid study
Base case	- 60 MW export from Thailand to Cambodia (no additional exchanges between Cambodia to Thailand over 2010-2028

Table 1.8-6 : Evaluation of Thailand – Cambodia interconnection

Conclusions for Thailand:

- All of these interconnections are largely profitable (compared to domestic gas-fired CCGT generation).
- Diversification of imports (countries and hydrology) favors the development of these interconnections, at least between Myanmar-Thailand and Laos North -Thailand.
- The list of the first interconnection projects to be developed depends largely on the list of most promising exported oriented generation projects. This list corresponds to the HPP (or TPP) having being studied at the most advanced level, from technical studies and commercial point of view (tariff MOU). Grid study would be necessary. Accordingly, the priority would be on Myanmar – Thailand interconnection and Laos North- Thailand interconnection, as indicated in the GMS Master Plan “base case”.
- Thailand - Cambodia interconnection seems less promising because of much lower hydro potential, less favorable hydro regime, and technical study of HPP projects at a less advanced level.
- These “North” or “South” interconnections will contribute to build a future East-West backbone between Thailand, Laos and Vietnam.

1.8.2.3 Projects to Vietnam

Laos North - Vietnam North interconnection:

Economy	- Economic benefit : 20 $/MWh (saves coal-fired generation)l - Resilience HPP investment cost : +49% - Resilience fuel price : -57%
Export potential / need for import	- Export potential from Laos N = 10 GW (to be shared with Thailand and possibly China) - Vietnam need for import : expected 2600 MW in Vietnam PDP
Diversification	- Between Laos N and Laos S
Grid / PDP / studies	- Pending studies : Package III (Cambodia-Laos-Vietnam) interconnection study, Vietnam MP VII, Vietnam grid reinforcement study
Base case	- 2600 MW transmission capacity in 2025

Table 1.8-7 : Evaluation of Laos North – Vietnam North interconnection

Laos South - Vietnam South (via Vietnam Center) interconnection:

Economy	- Economic benefit : 38 $/MWh (saves NG in Vietnam South) - Resilience HPP investment cost : +85% - Resilience fuel price : -41%
Export potential / need for import	- Export potential from Laos S = 3.5 GW (to be shared with Thailand) - Need of import : 2200 MW in the PDP
Diversification	- Between Laos N and Laos S
Grid / PDP / studies	- Depends on Vietnam National PDP, impact N/S flow within Vietnam grid => requires transmission study, - Pending studies: Package III (Cambodia-Laos-Vietnam) interconnection study, Vietnam MP VII, Vietnam grid reinforcement study.
Base case	- 2100 MW transmission capacity in 2025

Table 1.8-8 : Evaluation of Laos South– Vietnam South interconnection

Cambodia - Vietnam South interconnection:

Economy	- Price gap : 39 to 65 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +57% to 184% - Resilience fuel price : - 42% to –76%
Export potential / need for import	- Export potential: low = Stung Treng: 980 MW – Sambor: 450 MW, no seasonal regulation, only daily peaking reservoirs. - Need of import : target 400 MW import from Cambodia in Vietnam PDP
Diversification	- Between Laos N and Laos S and Cambodia hydrology
Grid / PDP / studies	- Origin of power is closer to load center (HCMC) than power coming from Laos South (or Laos North)
Base case	400 MW in 2025 (L. Sessan II + complementary exchanges)

Table 1.8-9 : Evaluation of Cambodia – Vietnam South interconnection

Conclusions for Vietnam:

- The Vietnam grid is characterized by :
  - Two large demand centers located in the North (Hanoi region with 40% of the country demand) and in the South (HCMC region with 40% of the country demand).
  - A long North – South grid span.

  Accordingly, even if the North-South Vietnam capacity transmission can be enhanced (a study on this issue is currently carried out in Vietnam), balancing the Vietnam grid will require power imports both to the North region and to the Center / South region.

  Both types of transmission projects are profitable, and will be needed at 2020-2025 horizon. The economic advantage is for Laos South to Vietnam Center / South interconnection because of the highest generation cost experienced in Vietnam South (gas-fired CCGT versus coal-fired STPP in Vietnam North). However, because Vietnam is expected to become a net coal importer by 2013-2015, this situation might evolve in the future and become less so clear-cut. Indeed, it would be possible to import coal directly in the South region, and develop coal-fired generation close to HMCC demand center, thus reducing the pressure for significant North to South transmission capacities within Vietnam grid. These issues are largely outside the scope of the present GMS Master Plan study but have a direct impact on what could be the priority transmission projects to develop between Vietnam, Laos and Cambodia.

- Economic benefits of these interconnections (in other words the ranking between the North and South interconnections) will depend largely on the options taken in the new Vietnam PDP: possibility to import coal and develop coal-fired STPP in the South, reinforcement of the grid North / Center / South transmission capacity.

- In first analysis, interconnection with Cambodia might look more favorable from the grid point of view (closer to the Ho Chi Minh City large load center), and from economic point of view (larger price gap), however :

    - Cambodia hydrology is less favorable (drier dry season) and both Cambodia large HPP projects offer no seasonal regulation[11] (Stung Treng and Sambor are both daily peaking plants).

    - Hydro projects in Cambodia need to be studied at a more advanced level in order to determine more precisely their design (especially the installed capacity and the storage capacity) and their construction costs.

    - Moreover the price gap might be reduced (and become equivalent to Laos North to Vietnam North exchanges) if coal was imported in Vietnam South in order to develop coal-fired STPP in the South.

- Diversification of hydro regimes would support the development of both North and Center / South interconnection projects.

- A cumulative Impact assessment is highly recommended on Mekong River for better evaluation and combined design of Cambodia / Laos South HPP projects.

- In conclusion, the development of both North and South interconnections is promising :

    - A North interconnection (Laos North – Vietnam North),

    - A South interconnection (Laos – South / Cambodia – Vietnam Center / South).

- As for the "South" interconnection[12], the ranking and choice between the various routes ("Laos-South -> Vietnam Center -> Vietnam South", "Laos-South -> Cambodia -> Vietnam South", "Cambodia -> Vietnam South") should be made in more focused studies (e.g., Package III), on the basis of actual network transmission studies, refined evaluation of Cambodia Mekong River projects[13], and in the lights of the new elements that will be provided by the Vietnam MP VII (once completed by the end of 2010), in particular considering the various options between developing coal-fired STPP burning imported coal in Vietnam South versus increasing the capacity of the North / South Vietnam transmission line. Other issues such as the operation of a bilateral or a trilateral transmission line should be evaluated.

- NB: China – Vietnam North interconnection is currently under study in Vietnam, and was not selected as explained in Task 5.1 report.

1.8.3 PRIORITY PROJECTS FOR THE NEXT 10 YEARS

In the next 20 - 30 years all the countries of the GMS will become interconnected, either for large scale power trades based on hydro export, or for lower scale opportunity power exchanges taking advantage of temporary surplus or needs in the different countries.

[11] Except Lower Sessan II HPP
[12] This remark does not refer to the export of Lower Sessan II HPP which is in the GMS Master Plan "base case".
[13] Eg 450 MW (?) Sambor and 980 MW Stung Treng HPP

If the focus is set on the 2015-2025 period, the priority interconnection projects would be those allowing large scale power exchanges between hydro rich countries and thermal dominated importing countries. Looking at the whole GMS region, the previous discussion allows identifying these priority interconnection projects:

- Between Myanmar to China: because of the hydro potential in Myanmar and the huge needs of imports for China.
- Between Myanmar to Thailand: because of the price gap between the two countries and the important hydro potential in Myanmar.
- Between Laos North to Thailand: because of the huge hydro potential in Laos and the large price gap between the two countries.
- Between Laos S to Vietnam S (through Vietnam C): Because of the hydro potential in Laos south (3,5 GW in South) and the large price gap between the two countries.
- Between Laos North to Vietnam North: Because of the hydro potential in Laos and the price gap between the two countries.
- Between Cambodia to Vietnam South: for the export of Lower Sessan II HPP.

With a levelized cost of transmission between 7 to 11 $/MWh, to be compared to a price gap between importing and exporting countries of 30$/MWh (for coal-fired STPP dominated generation mix) to 50 $/MWh (for gas-fired CCGT dominated generation mix), all these projects are largely profitable.

For the following group of other interconnection projects, complementary studies and / or the completion of ongoing studies, are required to identify the best among the possible options:

- Interconnection between Thailand and Laos South.
- Trilateral interconnection between Laos South / Cambodia / Vietnam Center and South.
- Interconnection between Cambodia and Thailand.

This does not mean these projects are a bad choice, but that additional studies are required. Accordingly, this second group of interconnection projects are for a further time horizon (beyond 2025).

1.9 CONCLUSIONS

1.9.1 THREE POLES OF DEVELOPMENT

The findings of the GMS Master Plan 2010 Study allow to outline the picture of future medium term (2025 horizon) power market in the GMS region:

- The largest power exchanges between the GMS countries will be based on hydro power export from Laos and Myanmar, toward China, Thailand and Vietnam[14].
- Because of the anticipated continuous fuel price increase, the interconnections selected in the GMS Master Plan 2010 are largely resilient (ie. robust) to an increase of the interconnection construction costs.
- The GMS regional transmission grid will develop around three main poles :

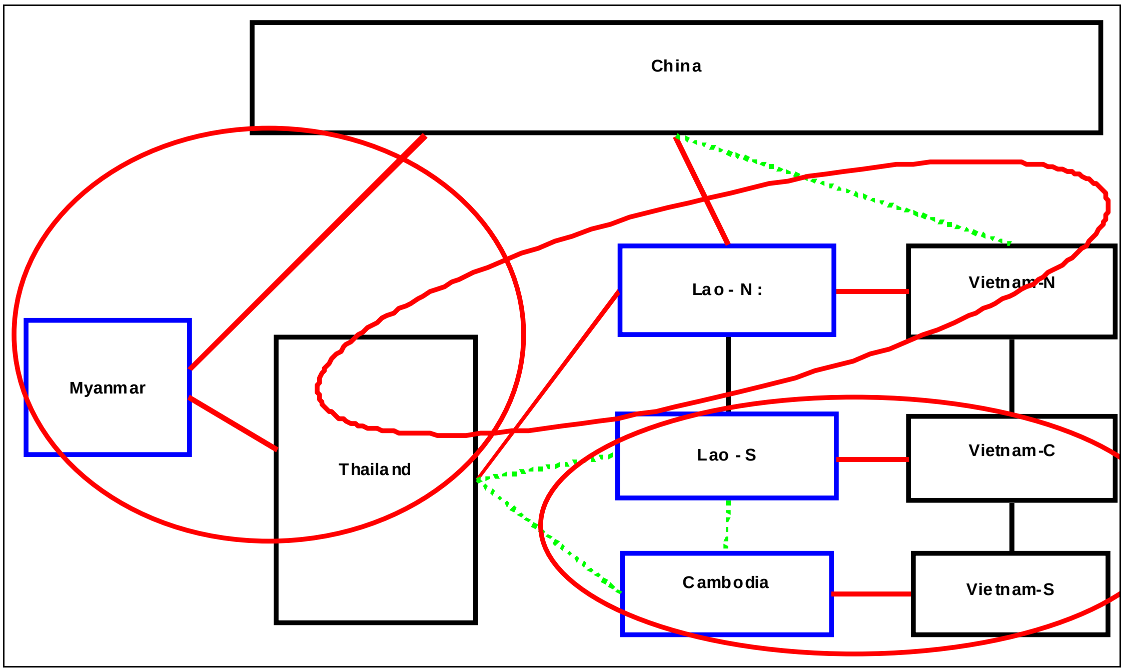


Figure 1.9-1 : Main poles of development of the future GMS transmission grid

NB: dashed green line = existing interconnections (in 2010).

- A - The North West pole will connect Myanmar to China and Thailand:
    - Taking advantage of a 28 GW hydro potential in Myanmar, substituting to more expensive thermal coal-fired generation in China and gas-fired generation Thailand.
    - Large power interconnections (up to about 20 GW in 2028) between Myanmar and China will be developed: the development of these interconnections will be paced

[14] With the addition of specific lignite-fired thermal projects.
This large scale power exchanges do not exclude lower scale opportunity exchanges taking advantage of temporary surplus situation in either countries.

along the possible schedule of development of the associated large scale HPP projects in Myanmar, and also by the development of the Chinese internal transmission infrastructure necessary to transmit this large West to East power transits within CSG grid up to Guangdong region.

- Large power interconnections between Myanmar and Thailand will be developed (> 5500 MW in 2028).

- B - The East-West Northern link will connect Thailand, Laos North, Vietnam North and possibly China :

  - Taking advantage of the 10 GW hydro potential in Laos North, substituting to thermal generation in Thailand, Vietnam North, and possibly China.

  - This link will open the possibility to opportunity exchanges between Thailand and Vietnam if any surplus situation was to occur in one of these countries, as well as exchanges between Laos and Thailand or Vietnam in case of very dry hydrological conditions in Laos.

- C - The Southern pole will connect Cambodia, Laos South, Vietnam Center and South :

  - Taking advantage of the 5 GW hydro potential in Cambodia and Laos South[15].

- This development of the GMS power market along these three relatively independent sub regional poles is in line with the emergence of subregional markets preceding the development of an integrated regional market, as explained further in Module 4 report. Indeed the full development of an integrated regional market does take a significant length of time as shown by the following figure presenting the various sub-regional power markets currently existing in Western Europe (2010).

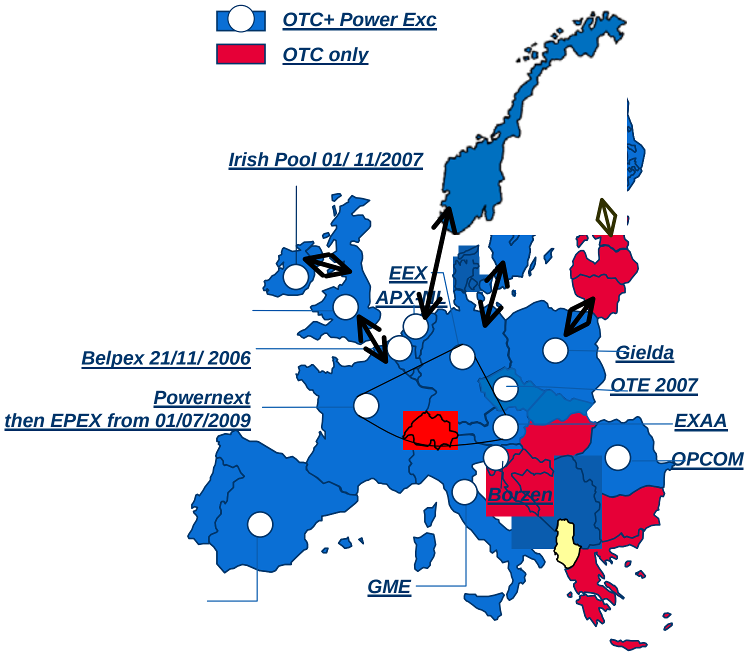


Figure 1.9-2: Current existing sub-regional power market in Western Europe

[15] Or 7 GW potential if the capacity of Cambodia Sambor HPP is assumed to be 2000 MW instead of 450 MW)

1.9.2 GMS MASTER PLAN 2010

The following table presents the schedule of existing, committed and candidate interconnection projects in the GMS Master Plan base case:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	Committed					Projects													Total projects
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Laos-S	Cambodia	20					40														0

Table 1.9-1: Base case - Schedule of new interconnections (MW)

<u>Benefits provided by the expansion of interconnections</u>:

Compare to a “no expansion” case, where only the interconnection projects committed up to 2015 are developed, this “base case” provides :

- a global cost savings for the Greater Mekong Subregion of 14 310 M$ (discounted value over the 2010-2030 period),

- a reduction of CO_2 emission by 14.2 Mt / year in 2020.

<u>High export case</u>:

In the “base case”, the remaining hydro potential left in 2028 is concentrated in Myanmar (about 7 GW), and on the mainstream of Mekong river : 9 large scale run of river HPP projects from 1000 to 1400 MW installed capacity (out of a total of 11 identified hydro projects).

Increasing the hydro based export compared to the “base case” situation would obviously increase the generation savings for the region, but a realistic evaluation of the Mekong River potential (number and capacity of the hydro projects) could only be made through a Cumulative Impact Assessment study of the mainstream Mekong River.

<u>Remarks on Vietnam PDP</u>:

- Because of the structure of Vietnam future generation mix considered in MP VI (dominated by low cost coal-fired STPP in the North, and more expensive gas-fired CCGT in the South), the Study showed that a constant 2000 MW transmission capacity between Vietnam South and Center is suboptimal. Going up to 5000 MW would be beneficial, allowing additional power "import" from coal-fired STPP located in Vietnam North to save the generation from more expensive NG-fired CCGT located in Vietnam South.

- However, if a cost for CO_2 emission is considered (50$/t$CO_2$ until 2020 and 65 $/t$CO_2$ beyond), the price gap between the coal-fired STPP in the Vietnam North and gas-fired CCGT in Vietnam South will be reduced and a constant 2000 MW transmission capacity would be sufficient.

-

- These remarks on the optimal transmission capacity within Vietnam national transmission grid are largely dependant on the hypotheses considered for the development Vietnam power generation mix, which are known to be largely obsolete in the Vietnam MP VI used for the study (Vietnam MP VII will be released by end of 2010 ?). Indeed, from 2013-2015 Vietnam will start to import part of the coal necessary to the coal-fired STPP. This leads to the opportunity to "re-balance" the future Vietnam generation mix, developing more coal-fired STPP in Vietnam South than considered in MP VI, which would in turn reduce the need of large power transit between North and South Vietnam.

Comparison with GMS Master Plan 2008 results:

The main differences of hypotheses with the MP 2008 are:

- Use of international fuel price instead of local / subsidized price,
- Use of consistent investment and homogeneous costs for generation and transmission projects for the whole region,
- Mostly hydro-based power export instead of thermal-based power export,
- Updated demand projection.

The MP2010 reaches most of the same conclusions as MP2008, except for the following lines which are not developed or reinforced in MP2010:

- Thailand-China,
- Thailand- Laos South,
- China- Vietnam North.

1.9.3 PRIORITY INTERCONNECTION PROJECTS

All transmission projects planned until 2015 are considered as committed, i.e., already approved:

Project reference number	Location 1	Location 2	Voltage	Capacity	Length	Year
2	Xe Kaman 3 HPP, south Laos	Da Nang (Hoa Khanh substation), central Vietnam	220 kV double circuit	250 MW	135 km	2010
3	Ban Soc / Ban Hat, south Laos	Pleiku, Vietnam	500 kV double circuit	1,000 MW	190 km	2014
7a	Lower Se San 2 HPP, Cambodia	Pleiku, Vietnam	230 kV double circuit	200 MW	230 km	2016
13	Nam Theun 2 HPP,	Roi Et 2, Thailand	500 kV	1,000 MW	304 km	2010

	Laos		double circuit			
14	Na Bong, Laos	Udon Thani, Thailand	230 kV in 2010 500 kV in 2015	225 MW in 2010 1,000 MW in 2015	107 km	2010 2015
15	Hong Sa TPP, Laos	Mae Moh, Thailand	500 kV Three or four circuits	1,700 MW	210 km	2015

Table 1.9-2 : List of interconnections projects committed up to 2015

Accordingly, this paragraph considers the priority between the interconnection projects beyond 2015 and up to 2025.

The question of priority between the interconnection projects can be tackled from the country or from the regional point of view.

In addition to the economic criterion (i.e., savings provided by the interconnection project) other criteria are involved in ranking the interconnection projects: :

- The volume of potential export (ie. resources in the exporting country).
- Level of advance of the export-oriented hydro generation project study (desktop study, pre-feasibility study feasibility study, design study), of the associated agreement (MOU, PPA), and the duration of the construction of underlying HPP (or TPP) projects. As a thumb rule, the study process can last a total of 2 to 5 years, and the construction between 3 to 6 years depending on the project characteristics.

  This implies that the interconnection projects to be built in the period 2015-2020 will be associated with hydro projects which are already at an advanced stage of study.
- The need for import of the receiving country (in that case, a lower price gap between both countries would be accepted),
- Complementary aspects :
  - Diversification of sources of import,
  - Grid conditions,
  - Uncertainties or incompleteness of data: some projects might be affected by data gaps, associated studies available only at early stage, dependence on evolution of other factors.

1.9.3.1 Priority per country

Projects to China:

- o The interconnection project between Myanmar and China ranks first because of larger price gap and the huge Myanmar hydro potential.

- China-Laos ranks second because of a lower price gap and hydro potential in Laos (shared with Thailand and Vietnam).

Projects to Thailand:

- Interconnections between Thailand and Myanmar, Laos and Cambodia are largely profitable (compared to domestic CCGT generation).
- Diversification of imports (countries and hydrology) favors the development of these interconnections, at least between Myanmar-Thailand and Laos North -Thailand.
- The list of the first interconnection projects to be developed depends largely on the list of most promising exported oriented generation projects. This list corresponds to the HPP (or TPP) having being studied at the most advanced level, from technical studies and commercial point of view (tariff MOU). Grid study would be necessary. Accordingly, the priority would be on Myanmar – Thailand interconnection and Laos North- Thailand interconnection, as indicated in the GMS Master Plan "base case".
- Thailand - Cambodia interconnection seems less promising because of much lower hydro potential, less favorable hydro regime, and technical study of HPP projects at a less advanced level.
- These "North" or "South" interconnections will contribute to build a future East-West backbone between Thailand, Laos and Vietnam.

Projects to Vietnam:

- The Vietnam grid is characterized by :
  - Two large demand centers located in the North (Hanoi region with 40% of the country demand) and in the South (HCMC region with 40% of the country demand).
  - A long North – South grid span.

Accordingly, even if the North-South Vietnam capacity transmission can be enhanced (a study on this issue is currently carried out in Vietnam), balancing the Vietnam grid will required power imports both to the North region and to the Center / South region.

Both types of transmission projects are profitable, and will be needed at 2020-2025 horizon. The economic advantage is for Laos South to Vietnam Center / South interconnection because of the highest generation cost experienced in Vietnam South (gas-fired CCGT versus coal-fired STPP in Vietnam North). However, because Vietnam is expected to become a net coal importer by 2013-2015, this situation might evolve in the future and become less so clear-cut. Indeed, it would be possible to import coal directly in the South region, and develop coal-fired generation close to HMCC demand center, thus reducing the pressure for significant North to South transmission capacities within Vietnam grid. These issues are largely outside the scope of the present GMS Master Plan study but have a direct impact on what could be the priority transmission projects to develop between Vietnam, Laos and Cambodia.

- Economic benefits of these interconnections (in other words the ranking between the North and South interconnections) will depend largely on the options taken in the new Vietnam PDP: possibility to import coal and develop coal-fired STPP in the South, reinforcement of the grid North / Center / South transmission capacity.

- In first analysis, interconnection with Cambodia might look more favorable from the grid point of view (closer to the Ho Chi Minh City large load center), and from economic point of view (larger price gap), however :

  - Cambodia hydrology is less favorable (drier dry season) and both Cambodia large HPP projects offer no seasonal regulation[16] (Stung Treng and Sambor are both daily peaking plants).

  - Hydro projects in Cambodia need to be studied at a more advanced level in order to determine more precisely their design (especially the installed capacity and the storage capacity) and their construction costs.

  - Moreover the price gap might be reduced (and become equivalent to Laos North to Vietnam North exchanges) if coal was imported in Vietnam South in order to develop coal-fired STPP in the South.

- Diversification of hydro regimes would support the development of both North and Center / South interconnection projects.

- A cumulative Impact assessment is highly recommended on Mekong River for better evaluation and combined design of Cambodia / Laos South HPP projects.

- In conclusion, the development of both North and South interconnections is promising :

  - a North interconnection (Laos North – Vietnam North),

  - a South interconnection (Laos – South / Cambodia – Vietnam Center / South).

- As for the "South" interconnection[17], the ranking and choice between the various routes ("Laos-South -> Vietnam Center -> Vietnam South", "Laos-South -> Cambodia -> Vietnam South", "Cambodia -> Vietnam South") should be made in more focused studies (e.g., Package III), on the basis of actual network transmission studies, refined evaluation of Cambodia Mekong River projects[18], and in the lights of the new elements that will be provided by the Vietnam MP VII (once completed by the end of 2010), in particular considering the various options between developing coal-fired STPP burning imported coal in Vietnam South versus increasing the capacity of the North / South Vietnam transmission line. Other issues such as the operation of a bilateral or a trilateral transmission line should be evaluated.

[16] Except Lower Sessan II HPP
[17] This remark does not refer to the export of Lower Sessan II HPP which is in the GMS Master Plan "base case".
[18] Eg 450 MW (?) Sambor and 980 MW Stung Treng HPP

1.9.3.2 Priority projects for the next 10 years

In the next 20 - 30 years all the countries of the GMS will become interconnected, either for large scale power trades based on hydro export, or for lower scale opportunity power exchanges taking advantage of temporary surplus or needs in the different countries.

If the focus is set on the 2015-2025 period, the priority interconnection projects would be those allowing large scale power exchanges between hydro rich countries and thermal dominated importing countries. Looking at the whole GMS region, the previous discussion allows identifying these priority interconnection projects:

- Between Myanmar to China: because of the hydro potential in Myanmar and the huge needs of imports for China.
- Between Myanmar to Thailand: because of the price gap between the two countries and the important hydro potential in Myanmar.
- Between Laos North to Thailand: because of the huge hydro potential in Laos and the large price gap between the two countries.
- Between Laos S to Vietnam S (through Vietnam C): Because of the hydro potential in Laos south (3,5 GW in South) and the large price gap between the two countries.
- Between Laos North to Vietnam North: Because of the hydro potential in Laos and the price gap between the two countries.
- Between Cambodia to Vietnam South: for the export of Lower Sessan II HPP.

With a levelized cost of transmission between 7 to 11 $/MWh, to be compared to a price gap between importing and exporting countries of 30$/MWh (for coal-fired STPP dominated generation mix) to 50 $/MWh (for gas-fired CCGT dominated generation mix), all these projects are largely profitable.

Assuming the transmission projects listed in § 1.5.2.1 are operational before 2015, the next group of transmission projects to be developed in the 2015-2020 horizon are:

	Additional transmission capacity required in the 2015-2020 horizon
Myanmar-China	6 000 MW
Myanmar - Thailand	1600 MW
Thailand – Laos North	600 MW
Vietnam North – Laos N Vietnam Center- Laos C Vietnam South - Cambodia	2400 MW 900 MW 200 MW (associated with Lower Sesan 2)

Table 1.9-3: Priority projects for 2015-2025

The development of these interconnections will be paced along the development of the associated generation export oriented projects.

For the following group of other interconnection projects, complementary studies and / or the completion of ongoing studies are required to identify the best among the possible options:

- Interconnection between Thailand and Laos South.
- Trilateral interconnection between Laos South / Cambodia / Vietnam Center and South.
- Interconnection between Cambodia and Thailand.

This does not mean these projects are a bad choice, but that additional studies are required. Accordingly, this second group of interconnection projects are for a further time horizon (beyond 2025).

1.10 RECOMMENDATIONS

The Consultants recommends developing future actions along three main directions:

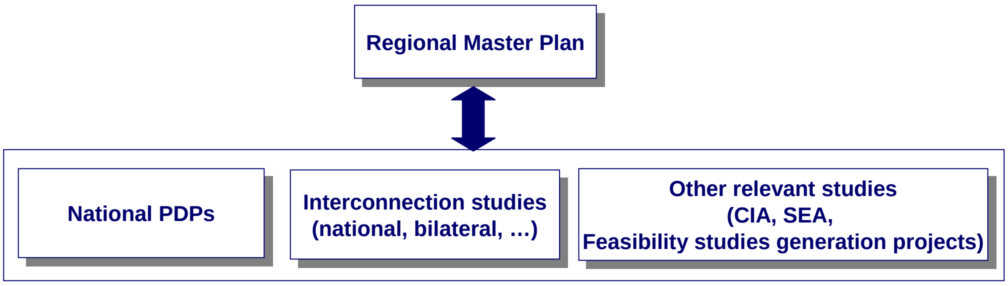
- Better assessment of the hydro generation potential,
- Regional and national studies,
- Capacity building.

Better assessment of hydro generation potential :

- The main mechanism for power exchanges in the GMS will be based on large scale hydro generation export. Accordingly, one of the main determinants of the development of the GMS interconnection grid is the list and location of the “best” and “more promising” export-oriented hydro projects in the GMS region. As a consequence :
    - There is a need to refine investment costs, hydrology, and social / environmental impacts of these hydro export projects.
    - A large part of the economical power export potential in Cambodia and Laos is from large (1000 to 1400 MW) HPP projects on Mekong River. Accordingly, the Consultant recommends to carry out a cumulative impact of these Mekong River projects to answer the following questions: What are the impacts of such projects on fishery, navigation, resettlement, etc…? What is the realistic potential considering social and environmental impacts? What is the “realistic” dimensioning of these projects? What is the global ranking of these Mekong River HPP projects (based on all these elements) and the “best group of HPP projects”?
    - Assessment of the environmental and social impacts of all major hydro projects is required in order to take into account these externalities in the planning model.
    - Improvement of the hydrology of Myanmar and Vietnam HPP projects is required. Historical inflows series in m3/s were not available for Myanmar and Vietnam HPP projects. A better representation of hydro variability in these countries is possible in the future version of GMS Master Plan provided these inflows series are made available.

Regional and national studies:

- A regional Master Plan study is part of an iteration process involving wide scope analyses (regional SEA, regional Master Plan) and more focussed studies (national studies, interconnection studies, CIA, EIA, feasibility studies of HPP projects, etc) :



- A number of national or regional studies are currently undergoing :
  - National PDP updates in China, Thailand, Vietnam,
  - Cambodia-Laos-Vietnam interconnection study (ADB- Package III),
  - Vietnam grid reinforcement study,
  - China – Vietnam interconnection study,
  - Cumulative Impact Assessment of hydro projects on mainstream Mekong River.

  The general vision of the GMS Master Plan will be certainly enriched by the results of these new studies. Accordingly, the Consultant recommends reviewing the findings of the 2010 GMS Master plan in views of these future new results.

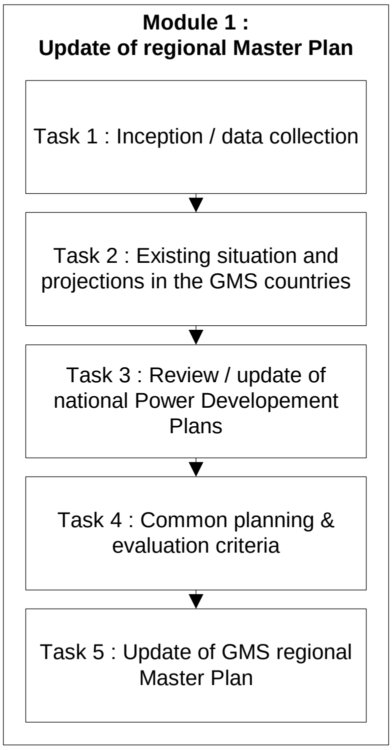
- Transmission study on the North – South transits on Vietnam national grid :
  - There is a need for load flow studies, stability analysis, evaluation of maximum transit capacity and options of grid reinforcements, impact on Vietnam North / Center South PDP, impact on the possible amount of import from Laos South and Laos North. At Workshop n°4 (Bangkok, June 2010) the Vietnam representatives indicated that a Consultant has been selected to study to the various options of reinforcement of the Vietnam grid.
  - The outcome of the new Vietnam PDP update will probably have a strong impact on the options of transmission development between Laos South, Cambodia, Vietnam Center and South. In particular: how much power can be imported from Laos South through Vietnam Center to Vietnam South load Center, how many HPP projects can be developed in Vietnam Center.

- Further to the previously mentioned studies, there is a need to launch studies on :
  - Priority interconnection projects.
  - Large scale HPP projects (in particular on Mekong River mainstream).

- <u>Capacity building</u>:
  - It is recommended to enhance the development of transmission and generation investment planning skills in the GMS. It particular, it is recommended to create a devoted Power Development Plan team in Cambodia.

2. OBJECTIVES OF TASK 5 OF MODULE 1

Module 1 "Update of the regional GMS Master Plan" of RETA-6440 Study is divided in five Tasks:



Tasks 1 and 2 findings are presented in the associated Tasks 1, 2 and 3 country reports.

Task 4 findings are presented in Task 4 report.

The purpose of Task 5 is to refine the previous indicative regional Master Plan (version June 2008) in order to come up with an updated regional Master Plan, based on new or updated data, and on country representatives' feedbacks or analysis. This task is broken into the following sub-tasks:

Sub-task 5.1:
- Analysis of the potential power trades between the GMS countries.

Sub-task 5.2:
- Review of the indicative regional master plan prepared under AFD TA 2006.

Sub-task 5.3:
- Update of the GMS regional Master Plan for the period 2009-2025.
- Identification of target interconnection scheme for year 2025.
- Update of list and characteristics of the regional generation and interconnection candidates
- Simulation of the regional power system for the selected scenarios.
- Evaluation of the benefits resulting from each scenario.
- Ranking of the interconnection projects, list of priority projects for the period 2009-2015.

Sub-task 5.4:
- Conclusions and recommendations.

The present report presents the first results of Sub-task 5.3.

3. UPDATE OF THE GMS REGIONAL MASTER PLAN (VERSION 2010)

Further to the findings of the previous Tasks of Module 1:

- Fuel price projections (cf Task 2.3 report).
- Review of national PDPs (cf. Task 3 report).
- Recommended planning criteria (cf Task 4 report).
- Analysis of the potential power trade between the GMS countries (cf Task 5.1&2 report).
- Review of the GMS Master Plan version 2008 (cf Task 5.1&2 report).

This paragraph presents the first results of the GMS Master Plan update:

- Presentation of the methodology,
- Proposed target interconnection scheme for the GMS in 2025,
- Presentation of the interconnection grid and node modelling adopted for the GMS Master Plan update,
- Presentation of the interconnection candidates list,
- Results of the base case and of first sensitivity analyses,
- Proposed additional sensitivity cases.

3.1 GMS MASTER PLAN UPDATE

3.1.1 OBJECTIVES

As per the TOR of the RETA-6440 project, the objectives of the GMS Master Plan update are to:

- Update the GMS Master Plan for the period 2009-2025 by simulating the regional power system with existing and potential planned power interconnections.
- Run simulations of the model for a variety of regional power system scenarios.
- Identify the potentially beneficial regional interconnection projects based on the Master Plan, and compile a list of priority projects according to their merits.

Further to these objectives, the Client expressed some additional expectations at Workshop 1 (HCMC September 2008): The determination of a “Master Plan” is a theoretical high level exercise evaluating and comparing various options / scenarios and scheme. However, following the Master

Plan 2008 update, the Client expressed the concern to have a regional Master Plan which can be termed as "operational", i.e., more realistic and capturing more economic meaning.

In line with its own methodology, the Consultant grounds the GMS Master Plan update of the planning and operation model presented hereafter (§ 3.1.2), but first and foremost on a global economic analysis of power supply balance / opportunity in the GMS region (see §3.2).

3.1.2 OPTGEN PLANNING AND OPERATION SOFTWARE

The optimal operation of the GMS power system over the 2010-2025 period will be simulated with OPTGEN planning and operation software developed by PSR Company (Brazil).

Key features:

The key features of OPTGEN for the present Study are the ability to:

- Simulate the optimal operation of several power systems (i.e., several countries) linked by interconnections over a large time horizon (i.e., 2010-2025),
- Determine the optimal capacity and commissioning dates of future interconnections linking the different power systems,
- Determine the optimal operation of hydro reservoirs, based on inflows data (wet/average/dry historical hydro series) and hydro plant characteristics: capacity (MW), storage (hm^3), energy ($MW.m^{-3}.s^{-1}$).

Input data:

The input data used in the modelling of the power systems are:

- Description of the different nodes of the regional power system. One node = one country (or a sub-region of a country).
- List and characteristics of:
  - existing interconnections between nodes (MW & losses),
  - Interconnection projects: MW, losses, investment cost, disbursement schedule.

  NB: Interconnections are not dedicated to specific generation projects but are shared by all generation belonging to the same node.
- For each node:
  - Demand projection over 2010-2025.
  - Characteristics of existing generation mix (TPP, HPP, renewable).
  - Investment costs, disbursement schedule and commissioning schedule of new plants (MW, year): taken as per country national PDP.

- Fuel price projections over 2010-2025.
- Time step: each year divided in 12 months. Each month divided in 5 load blocks[19].
- Cost of Unserved energy.

Objective function:

The objective cost function given to OPTGEN is:

Min [NPV (Investment costs + O&M costs + Fuel costs + Unserved energy cost + Externalities)]

Within the following constraints:

- For each node: balance between demand and supply (including import / export).
- For each interconnection: power transit lower or equal to interconnection capacity.

The variables of decisions are the interconnection capacities and commissioning dates. The commissioning dates for generation are given to the model as per national PDPs.

In other words, OPTGEN has two main functions:

- Optimal operation : simulation of the operation of an optimal power market taking advantage, at each time step, of the lowest cost available in any country, within the limits allowed by the capacity of the interconnections linking the countries.
- Optimal decision on interconnection capacities: determination of the optimal capacity and commissioning date of candidate interconnections.

Outputs data:

- Generation by generation unit (HPP, TPP), type of fuels (coal, NG, etc).
- Optimal capacity (MW) and schedule (year) of new interconnection projects.
- Power exchanges through each interconnection (GWh): the amount and direction depending on surplus available and costs differences between nodes.
- Cost information over the planning period: investment costs for generation and interconnection, fuel cost; O&M cost, Unserved energy, by year, month and time step.
- Net Present Value of the total cost over the planning period.
- These data are provided for each year, month, time block of the planning period.

OPTGEN and SDDP:

[19] The duration of these five blocks from peak load to off-peak is : 2h, 210h, 230 h, 210, 78 hours.

- For some studies, OPTGEN planning software can be associated with SDDP operation software in order to improve the modelling of hydro constraints and capabilities (irrigation withdraw, energy coefficient = f (head), volume of reservoir = f (head), evaporation = f (month), etc).

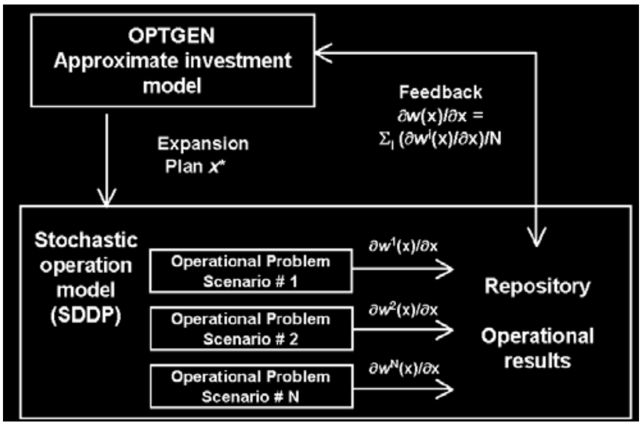


Figure 3.1-1 : OPTGEN and SDDP iterations

- This possibility was not used in the present Study because of the lack of relevant data.

3.1.3 ADDITIONAL MODELING ASPECTS

Hydro plant modelling:

- Hydro plants are modelled either as seasonal reservoirs, run of river plant or daily / weekly peaking plants.
  - Seasonal reservoir operation is optimised by OPTGEN in order to minimise the operation cost.
  - Run of river have no storage capacity, the outflow is equal to the inflows.
  - Daily / weekly peaking plans concentrate outflow on the peak hours of each month. The concentration capacity is defined by a concentration factor whose value is between 0 and 1 (equal to 0, when maximum concentration on peak hours of the month, equal to 1 when the plant is a run of river).
- Three hydro inflow scenarios are defined: wet / average / dry year.
  - The probability of wet and dry scenarios is 10%. The probability of the average scenario is 80%.
  - The hydro inflows are defined in average m3/s on a monthly time step (i.e., 12 values for each year).

3.1.4 DEFINITION OF THE SIMULATION RUNS

Each simulation run will be characterised by the following input data set:

- Demand projection in each country,
- Fuel prices projection,
- PDP of each country (schedule of commissioning dates of all HPP and TPP),
- Level of power import (and more precisely list of the regional generation projects with their capacity (MW) and commissioning dates),
- Cost and capacity of candidate interconnection projects (investment decision is made by OPTGEN),
- Discount rate.

The following figure summarizes the input and results of each simulation runs:

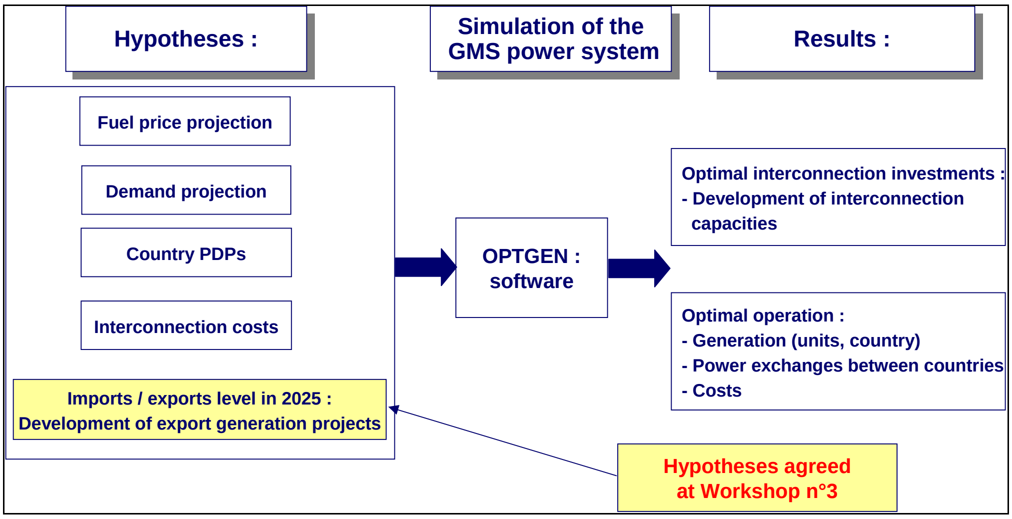


Figure 3.1-2 : Hypotheses and results of a simulation run

The comparison of various simulation runs will permit to compare various possible commissioning dates and capacities for interconnection projects, and also various possible commissioning dates for regional generation projects, and accordingly identify a realistic and improved indicative GMS Regional Master Plan.

Given the potentially infinite number and combination of simulation runs (in particular list and commissioning dates of export generation projects) the Consultant proposes to focus on the most relevant simulation runs.

These runs are described in §3.6 (“base case”, “high export case”, “coal export case”), and in the list of proposed sensitivity cases §3.6.8.

3.2 HIGH LEVEL VIEW OF THE TARGET INTERCONNECTION SCHEME IN 2025

3.2.1 RATIONALE

The purpose of this paragraph is to identify and propose a high level view on target interconnection scheme for the GMS in 2025. Indeed, building an interconnection grid on the basis of successive short term choices might lead to a less satisfactory final global scheme. Once the global scheme (or the possible global schemes) is identified, the possible tracks to develop this scheme can be determined.

The proposed high level analysis does not focus on actual interconnection projects (which might differ on actual connecting points, line routes, capacities and associated generation projects), but rather on the backbone of the GMS grid resulting directly from the demand/supply balance of each country.

The key factors taken into consideration in the design of the future interconnection grid are:

- The geographical location of the future key power exporters of the GMS (Cambodia, Myanmar and Laos), the associated export potential and cost,
- The geographical location of the future largest power importers of the GMS (China, Thailand, Vietnam).

At this stage, this high level analysis does not consider any of the following constraints:

- Possible grid congestions in the different countries,
- Limit on the feasibility of the implementation of the hydro power potential identified in Task 5.1.

The GMS Master Plan simulation runs (cf §3.6) will show that these two issues introduce some necessary amendments to these first views

3.2.2 KEY POWER EXPORTERS AND IMPORTERS IN THE OF THE FUTURE GMS POWER MARKET

Key exporters:

As discussed in Task 5.1 report, Cambodia, Myanmar and Laos will evolve as the key power exporters of the region.

The geographic proximity between the hydro projects in South Laos and in Cambodia is to be noted[20].

Key importers:

As discussed in Task 5.1 report, the three largest destinations of hydro power export will be China, Thailand and Vietnam[21].

[20] Sambor (2600 MW) and Stung Treng (980 MW) HPP projects are located close to Laos south border (< resp. 50 km and <150 km). The group of HPP projects in Southern Laos and Cambodia are spread over an area similar (in fact smaller) than the area covered by the HPP in Northern / Central 1 Laos.

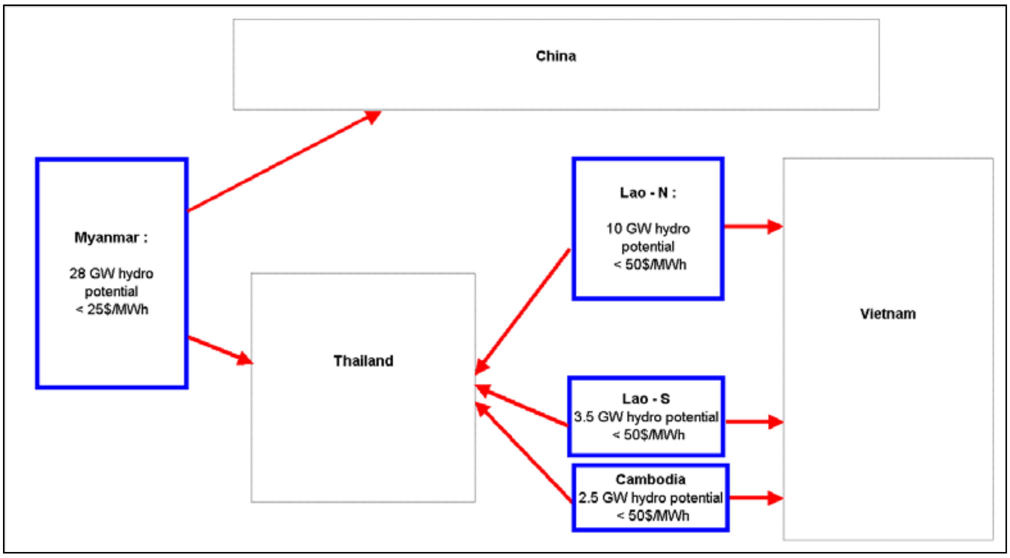


Figure 3.2-1 : Main sources and destinations of hydro power exports

[21] This does not exclude the possibility to have other types and directions of power exchanges (eg. thermal / hydro complementarities of power mixes to supply Cambodia, Laos and Myanmar during dry season from neighbouring thermal generation).

3.2.3 HIGH LEVEL VIEW OF THE TARGET INTERCONNECTION SCHEME IN 2025

The previous figure outlines a realistic picture of the GMS interconnection backbone in 2025.

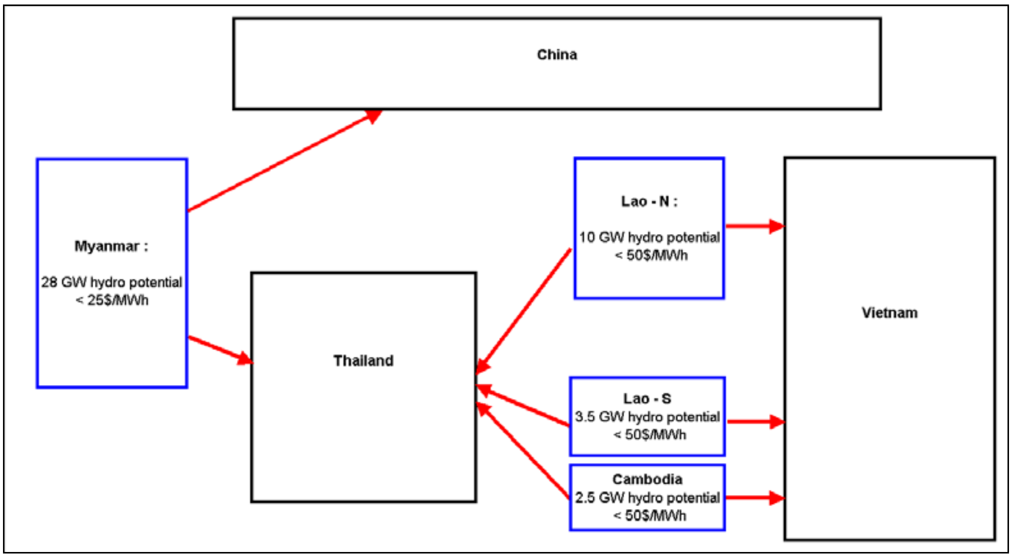


Figure 3.2-2 : High level view of the GMS target interconnection scheme in 2025

The analysis carried out in Task 5.1 confirmed the general economic justification of the various interconnections depicted above on the basis of generation and transmission costs.

The following comments can be made on this target interconnection grid.

Two East-West backbones between Thailand / Vietnam:

One of the key elements of the proposed scheme is the two East-West routes linking:

- In the "North" : Thailand / North Laos / North Vietnam,
- In the "South" : Thailand / South Laos & Cambodia / Central & South Vietnam[22].

These two East-West backbones will allow hydro power exports from Laos/Cambodia to Thailand/Vietnam, but also will provide:

- Indirect link for possible power exchanges between Thailand and Vietnam (through Laos or Cambodia),
- Power exchanges to Cambodia and Laos to support these power systems from thermal generation in Thailand or Vietnam on very dry hydro conditions.

Vietnam North / South grid balance:

Because of its long North – South span, and the location of demand centres (40% of Vietnam demand is in the Northern area, 40% in the Southern area) it is preferable to feed power exports to Northern and Southern Vietnam in order to balance the load flow within Vietnam internal grid. This

[22] At this level of analysis, "South" should be understood as "South and Centre" Vietnam (i.e from Da Nang to Southern Vietnam)

is made possible by the proposed interconnection scheme. However, specific network study (not within the scope of the present RETA-6440 study) would be necessary to investigate the appropriate balance between North, Central and South imports.

South Laos, Cambodia, South/Central Vietnam:

Because of the number and geographic proximity of hydro projects in Southern Laos, Cambodia on one hand, and the proximity to load areas in Center and Southern Vietnam on the other hand, there is a variety of possible interconnections between these four areas. More detailed investigations and focussed studies (e.g., RETA Package III) would be necessary to evaluate the different possibilities, which are largely dependant on national grid development and the actual hydro projects selected for development.

Laos North / South internal connection:

91 % of Laos demand is located in Laos North/Central 1 areas. Laos South demand could be covered by the development of export IPP in the South. Accordingly, there is no need to develop a major North to South Laos backbone to support future export/import routes in the GMS market.

China - Laos:

No interconnection project between China and Laos was identified at Workshop n°2 (Bangkok, September 2009). However, the possibility of an interconnection giving the possibility to import power from Laos was evoked at Workshop n°2 (Bangkok January 2010). This option will be considered in the sensitivity analysis.

China - Vietnam interconnection:

As discussed in Task 5.1 report, a China-Vietnam interconnection does not appear relevant for large scale power flows because China and Vietnam are both importers. The connections between Laos and Vietnam have more economic justification (because of larger hydro potential in Laos and price gap between Laos HPP and Vietnam TPP).

Export from hydro generation in Myanmar to Vietnam through China (or Laos) could be an option, but would probably be less competitive[23] than direct imports of hydro generation from Laos North / Central 1 to Vietnam.

3.3 INTERCONNECTION GRID AND NODE MODELING

Further to the first views on the GMS interconnection scheme presented above, the present paragraph details the interconnection and node modelling actually adopted in OPTGEN software.

Load-flow studies and national grid representation:

According to the TOR of RETA-6440, load-flow studies, whether internal to the grid of a country or for interconnections between countries are not within the scope of the present study. The Consultant will determine whether load-flow analysis is needed in particular cross-border

[23] HPP generation cost in Myanmar are lower than 25$/MWh, transmission cost from Myanmar to Vietnam, if through a 1500 km HVDC line would add about 20$/MWh, resulting in a 45 $/MWh of the energy delivered to Vietnam. By comparison, more than 6000 MW hydro potential is available in North/Central 1 areas in Laos at a cost lower than 40$/MWh. More accurate information of Myanmar HPP would be necessary to clear out this possibility.

connections, and if so, prepare terms of reference for such studies, in consultation with the GMS countries.

Accordingly, the adopted modeling of the GMS grid is focused on cross-border interconnections and does not consider national grids (and possible internal national congestion), with the exception of Vietnam (see hereafter).

GMS node modelling adopted for the Study:

The following figure describes the transmission network and node modelling adopted for the GMS Master Plan update (version 2010):

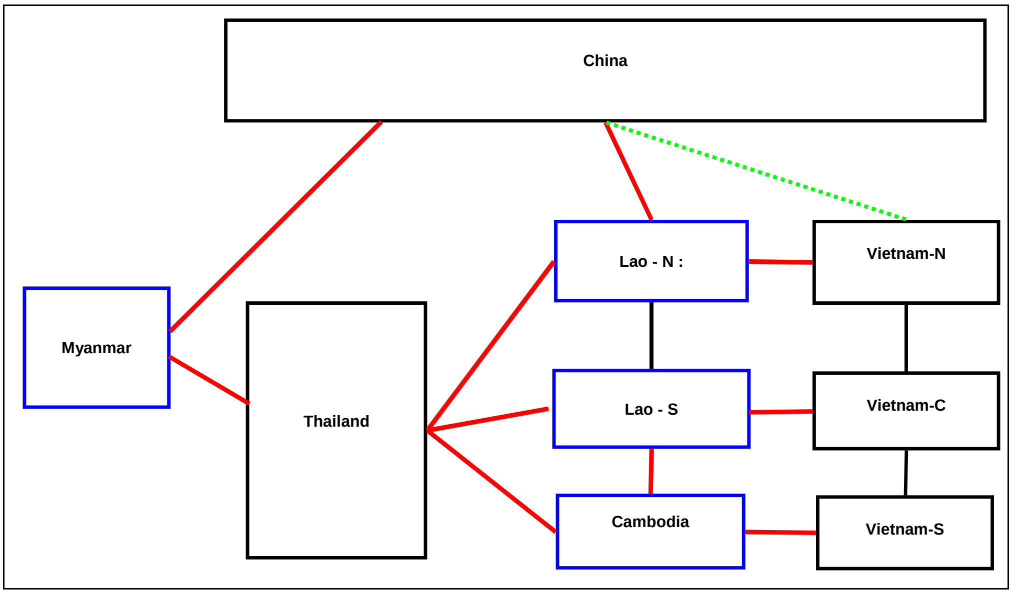


Figure 3.3-1 : Interconnection grid and node modelling for GMS Master Plan 2010

Colour code:

Green colour: existing interconnections.

Red colour: interconnections (existing, committed or candidates).

Black colour: internal transmission routes.

The rational for this modelling is the following :

- China (Yunnan and Guangxi provinces): modelled as one node because of highly meshed transmission networks.
- Cambodia: modelled as one node, because most of the power demand is located in the Phnom Pen area.
- Laos: modelled as two nodes, Laos-N (in fact gathering Northern and Central 1 areas) and Lao-S, because of the two distinct geographical locations of Laos hydro potential. About 91% of the country demand is in Laos-N and 10% in Laos-S. The demand of Laos-S is provided by Laos-S IPP. There is no need for a major Laos-N to Laos-S link for import / export purpose. A 200 MW link is assumed to be available from 2016 between Laos-N and Laos-S as suggested by Laos PDP grid map.

- Myanmar: modelled as one node, since its local demand is small compared to the power exports to China and Thailand.

- Thailand: modelled as one node, because of its strong and developed transmission grid. Internal transmission congestions resulting from the development of power exchanges will have to be checked in load-flow studies outside the scope of the present Study.

- Vietnam: modelled as three nodes because the internal transmission limits will have a direct impact on the amount of possible power import coming from Laos-N, Laos-S, or Cambodia. About 10% of the country demand is in Vietnam-C (Pleiku), 40% in Vietnam-N (Nho Quan, Ha Tinh, Da Nang) and 50% in Vietnam-S (Than Dinh).

  In absence of complementary load-flow studies, and on the basis of the information provided by IEV (Hanoi meeting, January 2010), a constant 1200 MW maximum capacity is assumed between Vietnam-C and Vietnam-N, and 2000 MW between Vietnam-C and Vietnam-N.

- Laos-S to Cambodia interconnection: while this link is not suggested by the analysis carried out in §3.2, this interconnection candidate was included in the modelling in order to deal with the congestion observed between Vietnam-S and Vietnam-C (see simulation results in § 3.6.3.2).

Additional information on GMS modelling with OPTGEN software:

- Cambodia, Laos, Thailand and Vietnam will be fully modelled in OPTGEN: demand projection and complete description of generation mixes.

- China: will become the largest power importer in the GMS region, targeting a total of 30 GW import. Accordingly, China will be represented in the modelling through its importing capacity from the GMS countries (i.e. not modelled as a node with demand projection and description of generation mix). Considering the large size of Guangxi and Yunnan generation mix, a detailed modelling would be very complex and would take a long time for limited additional benefits in the results. Furthermore, the West to East large power flow through Guangxi and Yunnan resulting from import from Myanmar and export to Guangdong would require a careful study – largely outside the scope of RETA 6440 - in order to properly model the Yunnan + Guangxi system.

- Myanmar: no PDP is available for Myanmar. Furthermore, the national demand of Myanmar is low compared to the amount of power export. Accordingly, only the hydro projects dedicated to power export will be modelled in Myanmar node.

The various interconnections are described more thoroughly in the following paragraph.

3.3.1 LIST OF EXISTING INTERCONNECTION SCHEMES

The following table (from Module 3 report) presents data on existing interconnections between GMS countries.

Project reference	Location 1	Location 2	Voltage	Capacity	Length	Year
A	Xinqiao, Yunnan, China	Lao Cai, Vietnam	220 kV	250 – 300 MW	56 km (in China)	2006
B	Maguan, Yunnan, China	Ha Giang, Vietnam	220 kV	200 MW	51 km (in China)	2007
C	Shewli I HPP, Myanmar	Dehong, Yunnan, China	220 kV double circuit	600 MW	2 x 120 km	2008
D	Chau Doc, Vietnam	Phnom Penh, Cambodia	220 kV (Vietnam) 230 kV (Cambodia) double circuit	100 MW in 2009 and 200 MW from 2010 onwards.	111 km	2009
E	Nam Theun 2 HPP, Laos	Roi Et 2 substation (via Savannakhet, Laos), Thailand	500 kV double circuit	1,000 MW	304 km (Roi Et to NT2)	December 2009
F	Houayho HPP, Laos	Ubon 2, Thailand	230 kV	150 MW	230 km	1999
G	Theun Hinboun HPP, Laos	Sakhonnakhon, Thailand	230 kV	200 MW	176 km	1998

Table 3.3-1 : Existing interconnections

In additional to these, lower voltage interconnections exist between:

- Laos and Cambodia : for 10 MW export capacity to Cambodia,
- Thailand and Cambodia: for a 40 MW export capacity to Cambodia.

These, along with national infrastructure at 500 kV, are illustrated on the map below. The energy flows are currently as follows:

- China is importing from Myanmar (the Shweli 1 HPP)
- Vietnam (north) is importing from China

- Thailand is importing from the HPPs in Laos
- Cambodia is importing from Laos, Thailand and Vietnam.

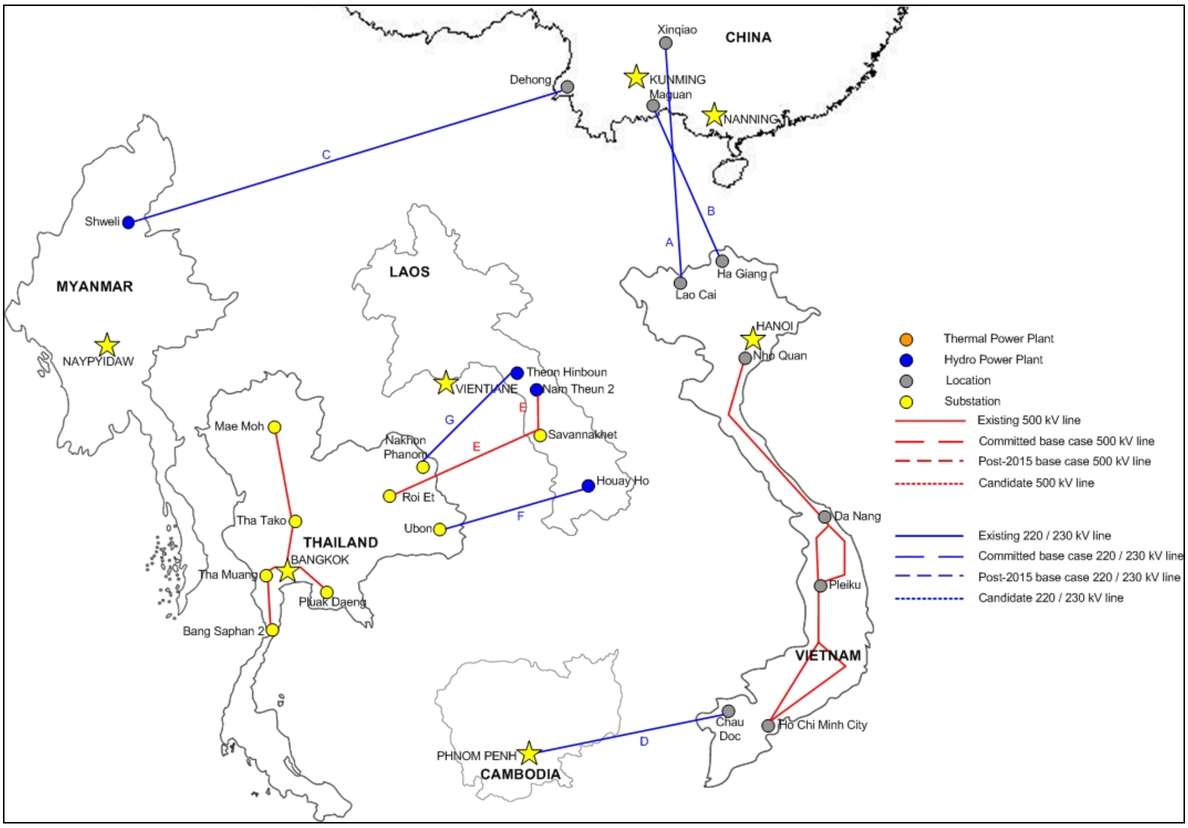


Figure 3.3-2 – GMS map showing existing interconnections (as per 2009)

As the above diagram indicates, there is currently relatively little interconnection capacity between the GMS countries. Such interconnections that do exist are primarily associated with specific hydro schemes, and take the form of connections into the neighboring power network to deliver power exports from these power plants.

3.3.2 COMMITTED AND CANDIDATES INTERCONNECTION PROJECTS CONSIDERED IN MP2010

The list of interconnection projects considered in the MP2010 are those described in Figure 3.3-1 : Interconnection grid and node modelling for GMS Master Plan 2010) reminded below[24] :

[24] Green lines : existing lines
Red lines : existing, committed or candidates lines.

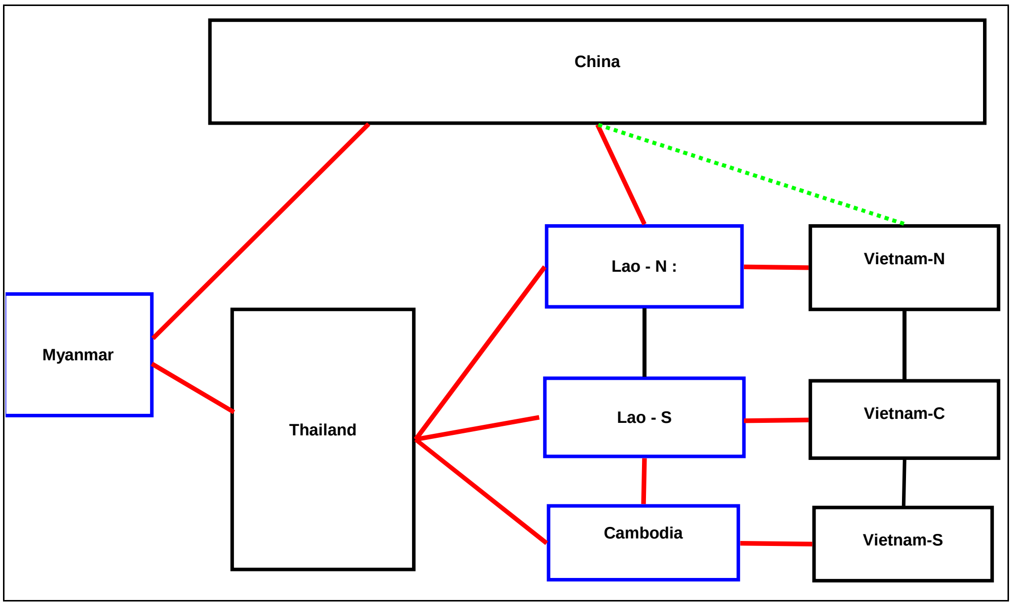


Figure 3.3-3 : node modeling of the future GMS transmission system

As such, the following pairs of countries require interconnection schemes:

- Myanmar – China
- Myanmar – Thailand
- Laos North – Thailand
- Laos South – Thailand
- Laos North – Vietnam North
- Laos South – Vietnam Centre
- Cambodia – Vietnam South
- Cambodia – Laos South
- Cambodia – Thailand

These interconnection projects can be classified in two types:

- "Committed" interconnection projects:

They are due to be commissioned up to and including 2015 – these are "committed base case" projects. These projects are considered as being already approved.

- Generic interconnections projects:

For the base case scenario to make up for the shortfall between expected levels of import in national PDPs and the committed base case projects, and also for possible alternate development scenarios.

As explained in Module 3 report, the candidate projects that have been identified from sources other than the countries' PDPs will not get used in the model directly. However, it is important that the information gathered about these projects is retained for future reference. The intention is therefore to compare the out-turn interconnection requirements with the known candidate schemes once the model has been run; where interconnection requirements have been identified, these can be associated with base case projects post-2015[25] or candidate projects where possible. For example, the results of running the model may show that a certain amount of capacity is required between two countries. If there is a candidate or post-2015 base case project between these two countries, that will be identified as being a possible solution. Where such an identified project does not exist, a generic interconnection would be proposed.

3.3.2.1 List of committed interconnection projects

These are the projects committed before 2015 and considered to be already approved. They are illustrated in the map and table below :

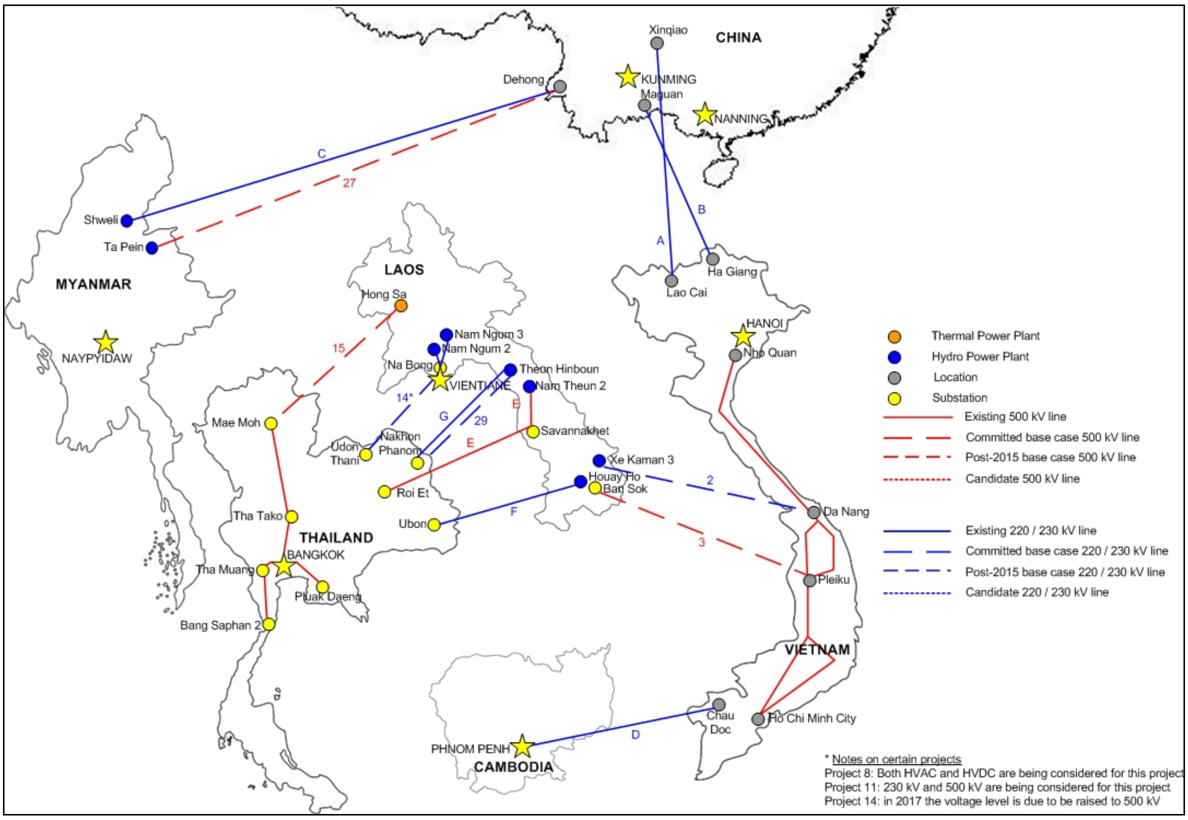


Figure 3.3-4 : Map of committed interconnection projects

[25] 2015 being the cut-off date for the commissioning of committed projects, i.e. those whose planning and/or construction is already under way.

Project reference number	Location 1	Location 2	Voltage	Capacity	Length	Year
2	Xe Kaman 3 HPP, south Laos	Da Nang (Hoa Khanh substation), central Vietnam	220 kV double circuit	250 MW	135 km	2010
3	Ban Soc / Ban Hat, south Laos	Pleiku, Vietnam	500 kV double circuit	1,000 MW	190 km	2014
7a	Lower Se San 2 HPP, Cambodia	Pleiku, Vietnam	230 kV double circuit	200 MW	230 km	2016
14	Na Bong, Laos (Ngum2 and Ngum3 HPP)	Udon Thani, Thailand	230 kV in 2010 500 kV in 2015	605 MW in 2011 and additional 440 MW in 2017	107 km	2010 (230kV) 2017 (500kV)
15	Hong Sa TPP, Laos	Mae Moh, Thailand	500 kV Three or four circuits	1470 MW	340 km	2015
27	Dapein HPP Myanmar	Daying Jian (near Dehong) China	500 kV single circuit	240 MW	120 km (estimated)	2011
29	Theun Hinboun expansion HPP Laos	Nakhon Phanom Thailand	230 kV single circuit	220 MW	90 km	2012

Table 3.3-2 : List of committed interconnections - MP 2010

The construction costs of these projects are not considered in the analysis (sunk costs).

3.3.2.2 List and characteristics of candidates projects

OPTGEN will select the optimal interconnection projects to be commissioned from 2015 to 2028 from a list of generic candidates of various capacities.

A range of capacity will be examined for each interconnection in order to select the optimal commissioning date and capacity for each interconnection.

These interconnection projects are not actual projects, which may vary on actual line route and connecting points at both ends. They are generic projects meant to realistically represent the cost of delivering power from one node to another in order for OPTGEN to take the correct decision.

The following table presents the list of candidates:

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos North (Luang Prabang)	China (Mojiang)	350 km	600 MW	2	279.5
			1200 MW	3	443.9
			1800 MW	4	559.0
Myanmar (Shamo)	China (Dali)	350 km	500 MW	2	250.4
			1000 MW	3	397.6
			1500 MW	4	500.7
			2000 MW	5	648.0

Table 3.3-3 : Cost of interconnection candidates with China

NB: The large hydro "Seven projects" in Myanmar totalizes a 16 500 MW export capacity to China, assumed to be progressively put in operation from 2018 to 2025 by blocks of 2000 MW. Accordingly, it is also assumed the associated interconnection is gradually put in operation by blocks (and cost) of 2000 MW.

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Myanmar (Minesat)	Thailand (Mae Moh)	250 km	600 MW	2	188.7
			1200 MW	3	299.8
			1800 MW	4	377.5
			2400 MW	5	488.6
			3000 MW	6	566.1
			3600 MW	7	677.2
			4200 MW	8	754.8
			4800 MW	9	865.9
Laos North (Luang Prabang)	Thailand (Mae Moh)	300 km	600 MW	2	221.4
			1200 MW	3	351.6
			1800 MW	4	442.8
			2400 MW	5	573.0
			3000 MW	6	664.2
Laos South (Ban Sok)	Thailand (Ubon Rat.)	150 km	500 MW	2	119.7
			1000 MW	2, with compensators	131.6
			1500 MW	3, with compensators	209.1
Cambodia (Phnom Penh)	Thailand (Pluak Daeng)	400 km	500 MW	2	283.0
			1000 MW	3	449.5
			1500 MW	4	566.0

Table 3.3-4 : Cost of interconnection candidates with Thailand

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos North (Luang Prabang)	Vietnam North (Son La)	250 km	600 MW	2	188.7
			1200 MW	3	299.8
			1800 MW	4	377.5
			2400 MW	5	488.6
			3000 MW	6	566.1
Laos South (Ban Sok)	Vietnam Centre (Pleiku)	200 km	500 MW	2	152.3
			1000 MW	3	242.0
			1500 MW	4	304.7
Cambodia (Phnom Penh)	Vietnam South (HCMC)	200 km	500 MW	2	152.3
			1000 MW	3	242.0
			1500 MW	4	304.7
			2000 MW	5	394.3

Table 3.3-5 : Cost of interconnection candidates with Vietnam

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos South (Bansok)	Cambodia (Phnom Penh)	400 km	500 MW	2	283.0
			1000 MW	3	449.5
			1500 MW	4	566.0
			2000 MW	5	732.5

Table 3.3-6 : Cost of interconnection candidates with Cambodia

The following table presents the cost of reinforcement of the Vietnam Center to South transmission (not considered as a candidates but as alternatives) :

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Vietnam Center	Vietnam South	350 km	1500 MW	4	500.7
			2000 MW	5	648.0
			3000 MW	6	838.5

Table 3.3-7 : Cost of transmission reinforcement between Vietnam Center and Vietnam South

Cost of transmission projects versus transmission capacity:

The capacity of the generic lines increase in increments of the maximum capacity of a single circuit (for a given length, voltage and configuration etc.). To maintain n-1 security, the minimum number of circuits is 2, and there is always one more circuit than is required for the given capacity. So, for example, assuming the capacity of one circuit is 500 MW:

- The lowest capacity (i.e. 500 MW) requires 2 circuits,
- The above capacity plus an increment (i.e. 500 MW + 500 MW = 1000 MW, or base capacity x 2) requires 3 circuits,
- The above capacity plus an increment (i.e. 1,000 MW + 500 MW = 1,500 MW, or base capacity x 3) requires 4 circuits
- Etc…

The cost for even numbers of circuits is proportional, e.g. 4 circuits is twice the cost of 2 circuits, 6 circuits is 3 times the cost of 2 circuits. However, the same does not hold where there is an odd number of circuits. This is because the cost of a single circuit line is more than half the cost of a double circuit line (because there is a set of fixed costs for both, i.e. installing the towers):

Cost of double circuit line = 1.7 * cost of single circuit line

The relationship between the capacity, the number of circuits and the investment cost is therefore:

Number of circuits	Capacity in N-1	Investment cost
2	P	N
3	2 x P	1.59 x N
4	3 x P	2 x N
5	4 x P	2.59 x N
6	5 x P	3 x N

Table 3.3-8 : Relation between cost and transmission capacity

Other characteristics associated with interconnections:

- Annual O& M cost: 2% investment cost.
- Duration of construction: 3 years.
- Disbursement schedule: 25%, 50%, 25%.

3.4 GENERATION CANDIDATES

Generation candidates and potential for power exports are presented in Task 3 "PDP review" country reports and Task 5.1 report and appendix.

3.5 OTHER RELEVANT INFORMATION

The following assumptions were taken on country internal grid capacities:

- Vietnam:
  - The following maximum N-1 transit capacities were agreed with Vietnam representatives (Hanoi, January 2010): 2000 MW between Vietnam Center and Vietnam South, 1200 MW between Vietnam Center and Vietnam North.
  - However, simulations with OPTGEN shown that a 2000 MW transmission capacity between Vietnam Center and South was underrated (see “case-2000 MW” in §3.6.3), the optimal capacity being 5000 MW from 2015 (see “base case” in § 3.6.2).
- Laos: on the base of the Laos PDP, the Consultant assumes a 200 MW capacity in N-1 between Laos N&C and Laos S from 2016. This hypothesis was confirmed by Lao representatives during Workshop 4 (Bangkok, June 2010).

3.6 MASTER PLAN SIMULATION RESULTS

This paragraph presents the results of the various simulation runs simulated with OPTGEN software.

3.6.1 SUMMARY LIST OF SIMULATION RUNS

Eight different cases were simulated with OPTGEN software:

Name	Description
Base case	- 10% discount rate. - Expansion of interconnections as required by the power exchanges considered in the current national PDPs. - Optimal transmission capacity between Vietnam Center and South determined by OPTGEN (5000 MW from 2015).
Case-2000MW	- Idem to base case, but with constant 2000 MW transmission capacity between Vietnam Center and South.
High export	- Idem to base case, but with 2400 MW additional export from Laos North to China, and 1200 MW additional export from Laos North to Vietnam North
No-expansion	Only existing and committed interconnection projects until 2015 are considered. No additional interconnection is added to the system after 2015.
CO2	Same four cases as above, but with CO_2 cost = 50$/t until 2020, and 65 $/t beyond.

Table 3.6-1 : List of simulation runs

3.6.2 BASE CASE

3.6.2.1 Definition

The base case corresponds to the level of development of interconnections required by the power imports expected in the current versions of China, Thailand and Vietnam PDPs, complemented and amended by the assumptions agreed at Workshop 3 (January 2010, Bangkok) .

Indeed, these different PDPs as provided by the countries were not up to date (eg. Vietnam PDP MP VI was outdated), nor completed (generation export oriented projects were not systematically identified), nor completely consistent between themselves.

Accordingly, the Consultant took hypotheses to update, complete and fill the gaps in these PDPs[26].

More precisely, the man hypotheses in the "base case" are as follows:

- Up to 2015: the development of "committed" interconnection projects is as described in 3.3.2.1.
- The level of power import is given in the following table :

Importing country	Import in 2025	Percentage of country 2025 peak demand[27]
China	18 900 MW (from Myanmar)	14%
Thailand	Total import : 7 700 MW - 5100 MW from Laos N & C - 150 MW from Laos S - 2100 MW from Myanmar - 330 MW from Malaysia	15%
Vietnam	Total import : 5100 MW - 2600 MW from Laos-N & C - 2100 MW from Laos-S - 400 MW from Cambodia	6.5%

Table 3.6-2 : "Base case" : level of imports

- The detailed assumptions on the schedule of underlying generation export projects (mainly HPP) was validated by the Country Representatives at Workshop 4 (January 2010 – Bangkok) and is presented in the Appendix of Task 5.3 report.
- Share of imports from Laos N and S to Thailand:
    - o The current Thailand PDP provides the annual target of imports coming from the different neighbouring countries. No hypothesis is provided as for the share of import between Laos North and South.
    - o The Consultant considered for the "base case" that all hydro power import from Laos came from Laos North given that:
        - All the Lao hydro projects which have or had been considered for MOU between Thailand and Laos were situated in Laos N & C. Consequently, these projects are the ones possible to be built at the earliest (2015-2025 horizon).
        - These Laos N & C projects are mainly seasonal reservoirs, which is more favourable for generation regulation than the run of river projects left available in Laos South, once allocated the export projects for Vietnam.

[26] See Task 3 'Review of PDP" country reports and Task 5.3 Appendix given a synthesis of the list of generation export projects for each country.
[27] For China : percentage of peak demand + export to Guangdong

- The range of levelized cost of hydro hydro projects is similar in Laos N and Laos S.

- Share of imports from Cambodia, Laos N, Laos S and to Vietnam:

    - The hypotheses of imports from Cambodia, China, Laos North and South were provided by Vietnam representatives as preliminary views on Vietnam Master Plan VII (January 2010 meeting, Hanoi).

    - In addition the Consultant considered that no import would come from China from 2015 (see justifications in Task 5.1 & 2 report). The amount of anticipated import was considered to come from Laos North.

- Transmission capacity between Vietnam Center and South:

    - While a 2000 MW transmission capacity in N-1 was agreed with Vietnam representative for the base case (Hanoi meeting, January 2010), simulations with OPTGEN shown this capacity was underrated (see "case-2000 MW" in §3.6.3). Accordingly, this capacity have been optimised with OPTGEN software for the base case, resulting in a 5000 MW capacity from 2015

- Discount rate = 10%

- No cost for CO_2.

3.6.2.2 Results

3.6.2.2.1 Commissioning schedule of new interconnections

The following table presents the schedule of existing, committed and candidate interconnection projects as selected by OPTGEN model for the base case:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	Committed					Projects													Total projects
China	Laos																				0
	Myanmar	600	240				1440			2000	2000	2000	2000	2000	2000	2000	2000			4000	20000
Thailand	Myanmar								400			1200			600					3600	5800
	Laos-N	1140	600	220			1500	0	600	0	0	0	0	300	0	1200	0	0	0	0	2100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1800									2400
Vietnam-C	Laos-S		225			1000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Laos-S	Cambodia	20					40														0

Table 3.6-3: Base case - Schedule of new interconnections (MW)

Accordingly, new interconnections are developed between:

- China and Myanmar, and Thailand and Myanmar, for the export of Myanmar hydropower.

- Thailand, Laos North and Vietnam North, for the export of Laos North hydropower.

- Laos South and Vietnam Center for the export of Lao hydropower.

- And to a lesser extent, Cambodia and Vietnam South, for the export of Cambodia hydropower.
- Vietnam Center to South transmission line (not shown in the table) is reinforced in 2015 going from 2000 MW capacity to 5000 MW capacity.

Compared to the first view on the GMS grid (see Figure 3.2-2 : High level view of the GMS target interconnection scheme in 2025):

- No additional interconnection is developed between Laos South and Thailand, or between Thailand and Cambodia. This is in line with the hypotheses taken for the base case (no additional import from Laos South to Thailand compared to 2010 situation).
- No additional interconnection is necessary between Laos South and Cambodia.

The following figures present the evolution of the power transits between the countries in 2016, 2020 and 2025:

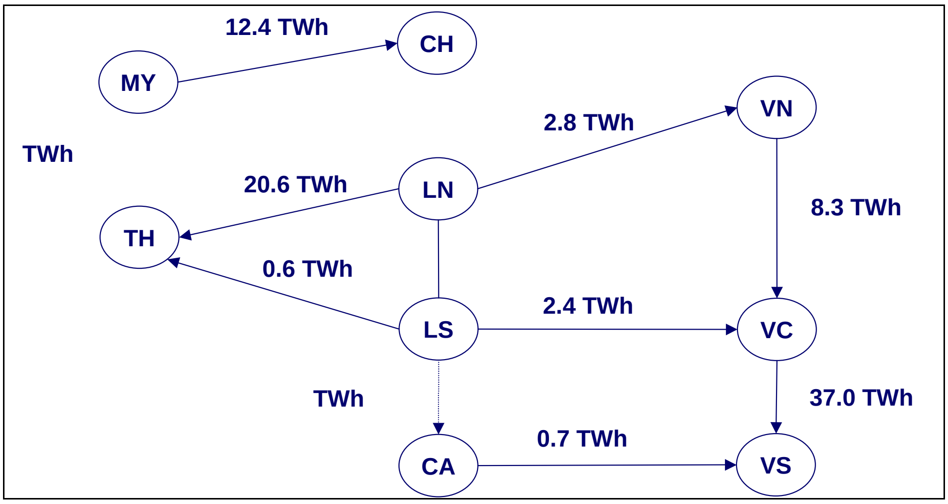


Figure 3.6-1 : Base case: average annual energy flows in year 2016

NB: the dash line between Laos South and Cambodia indicated the currently existing transmission line.

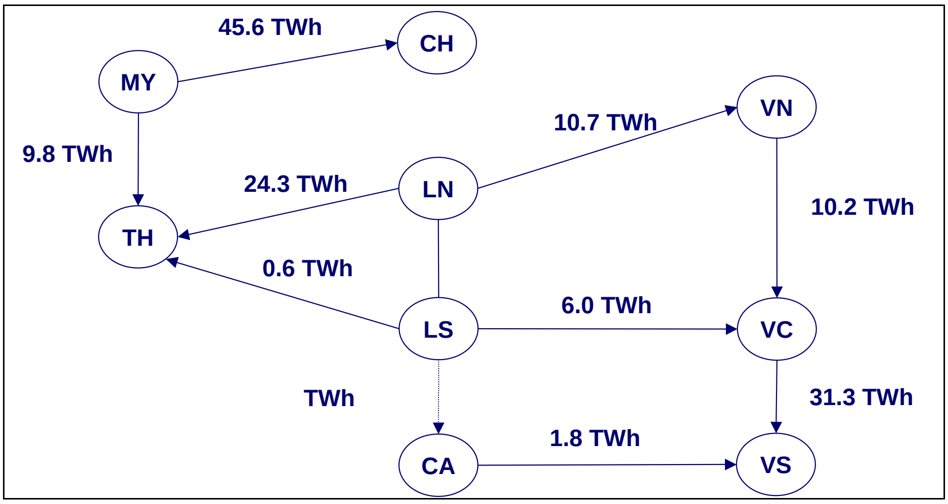


Figure 3.6-2 : Base case: average annual energy flows in year 2020

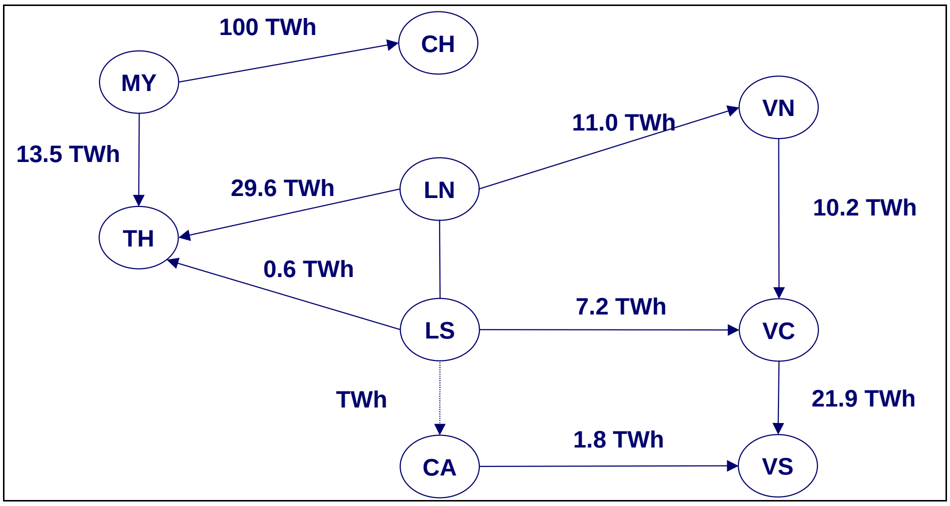


Figure 3.6-3 : Base case: average annual energy flows in year 2025

3.6.2.2.2 Average annual energy transit from 2010 to 2025

The following tables present the evolution of the average annual power exchanges[28] over the 2010 to 2028 period (2025-2028 results are indicative):

Interconnections between Myanmar and China:

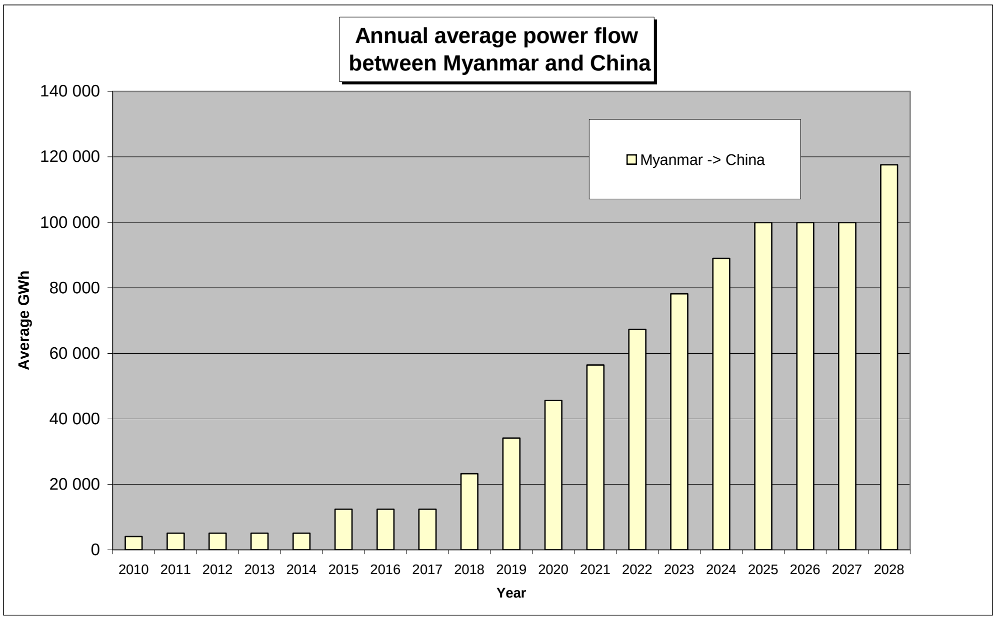


Figure 3.6-4 : Base case - Annual energy flow between Myanmar and China

[28] The results are averaged over the wet/average/dry hydro conditions.

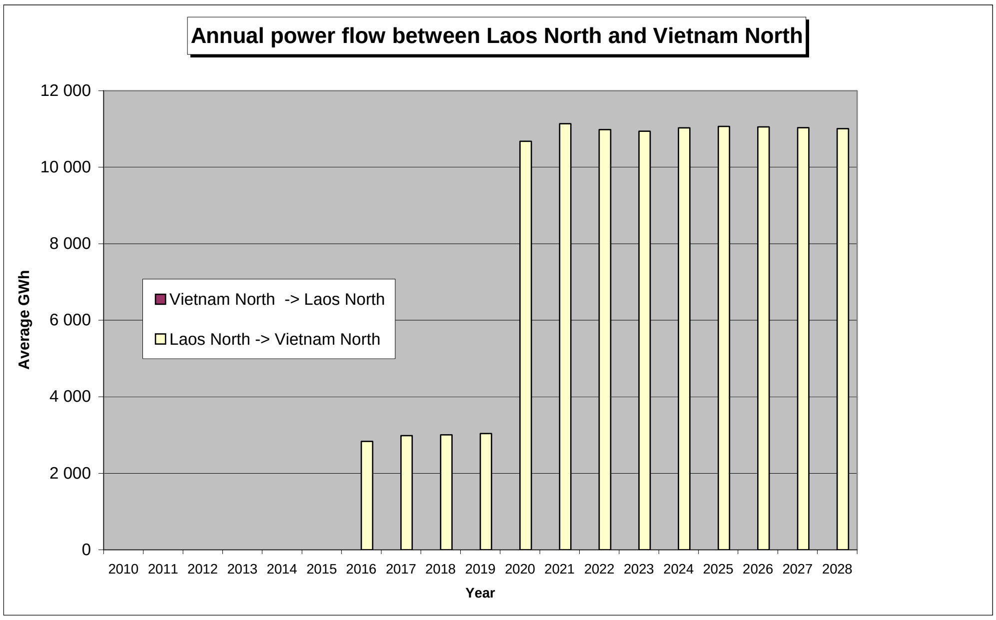


Figure 3.6-5 : Base case - Annual energy flow between Laos N and Vietnam N

The development of the power exchanges follows the pace of development of the hydro projects in Laos (e.g., Luang Prabang HPP project – 1400 MW – is commissioned in 2020).

The monthly power exchanges follow the seasonality of hydro generation (maximum during the wet season):

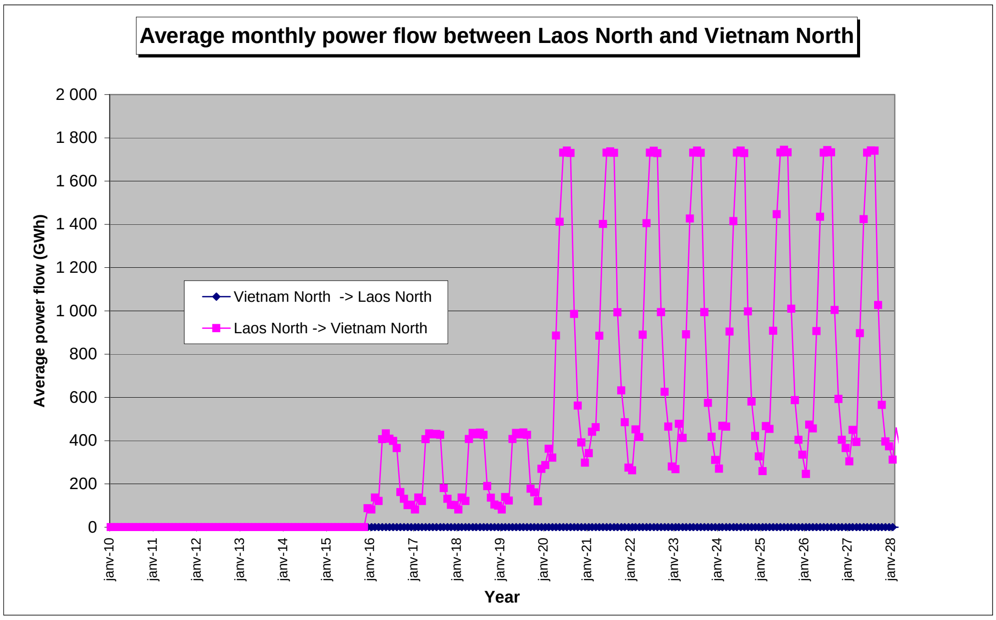


Figure 3.6-6 : Base case - Monthly energy flow between Laos N and Vietnam N

Interconnections between Laos and Thailand:

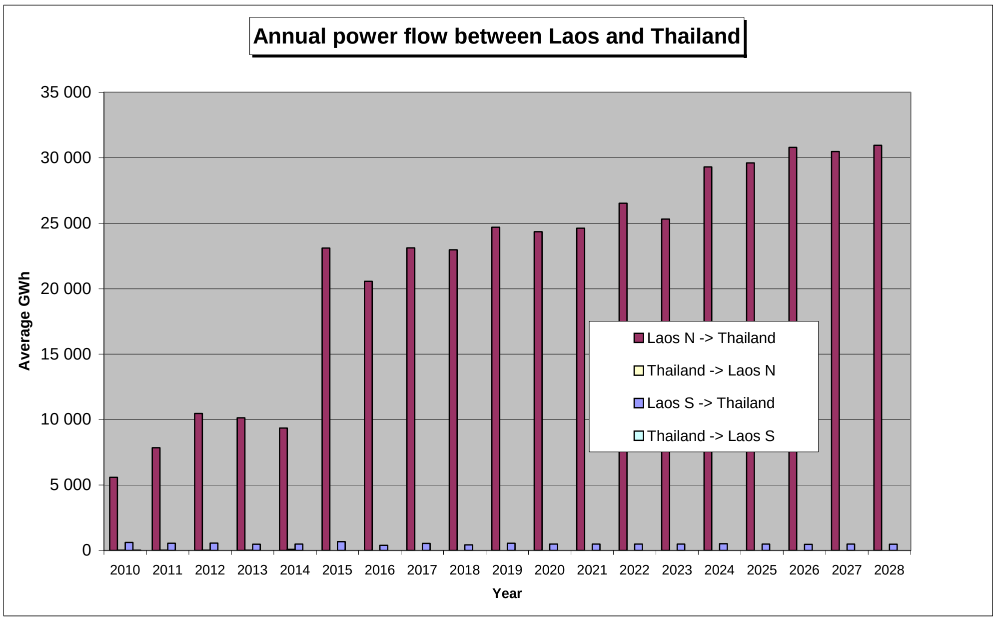


Figure 3.6-7 : Base case - Annual energy flow between Laos North and Thailand

The development of the power exchanges follows the pace of development of the hydro and thermal (Hongsa lignite 1470 MW is commissioned in 2015) projects in Laos.

Interconnections between Thailand and Myanmar:

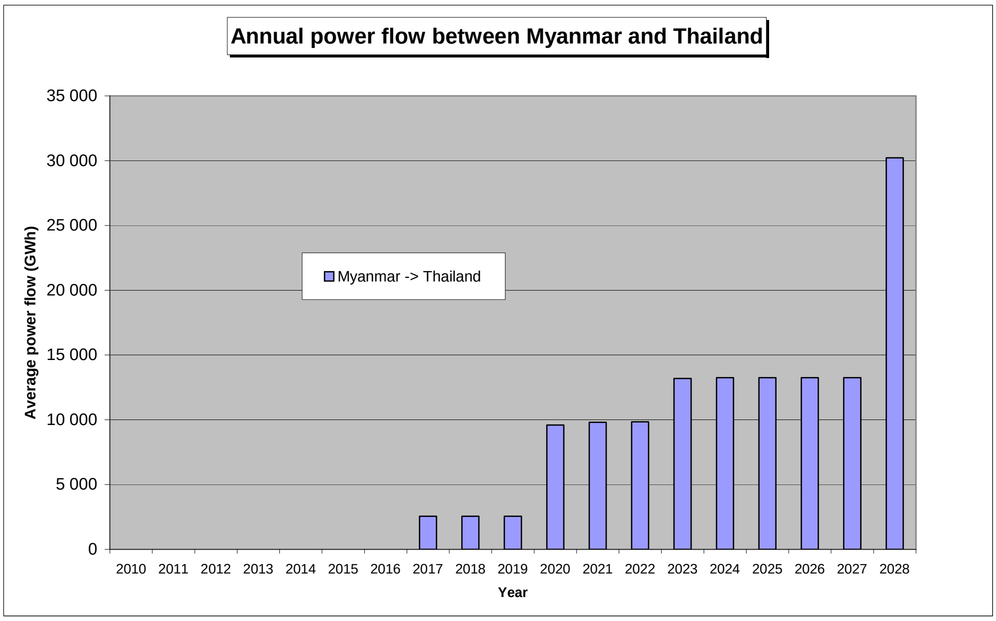


Figure 3.6-8 : Base case - Annual energy flow between Myanmar and Thailand

The development of the power exchanges follows the pace of development of the hydro and thermal projects designed for export to Thailand (Maikhot lignite 365 MW TPP in 2017, Hutgyi 1300 MW HPP in 2020, Tasang 3550 MW HPP in 2028).

Power transits within Vietnam grid:

The Vietnam grid is characterized by a North to South power flow explained by the nature of the Vietnam power mix in the North, Center and South regions:

- The North, representing 40% of the demand, is dominated by coal-fired plant and hydro (69% coal-fired STPP, 28% hydro in 2025).
- The Center, representing 10% of the demand, is dominated by hydro generation (68% hydro, coal-fired STPP in 2025).
- The South, representing 50% of the demand, is diversified between gas-fired CCGT, coal-fired STPP and hydro (21% NG and HFO, 44% coal, 28% hydro).

Accordingly, the highest generation costs are experienced in the South region leading to a North to South power flow (substitution of coal-fired generation from the North to gas-fired generation in the South) as shown by the following figure:

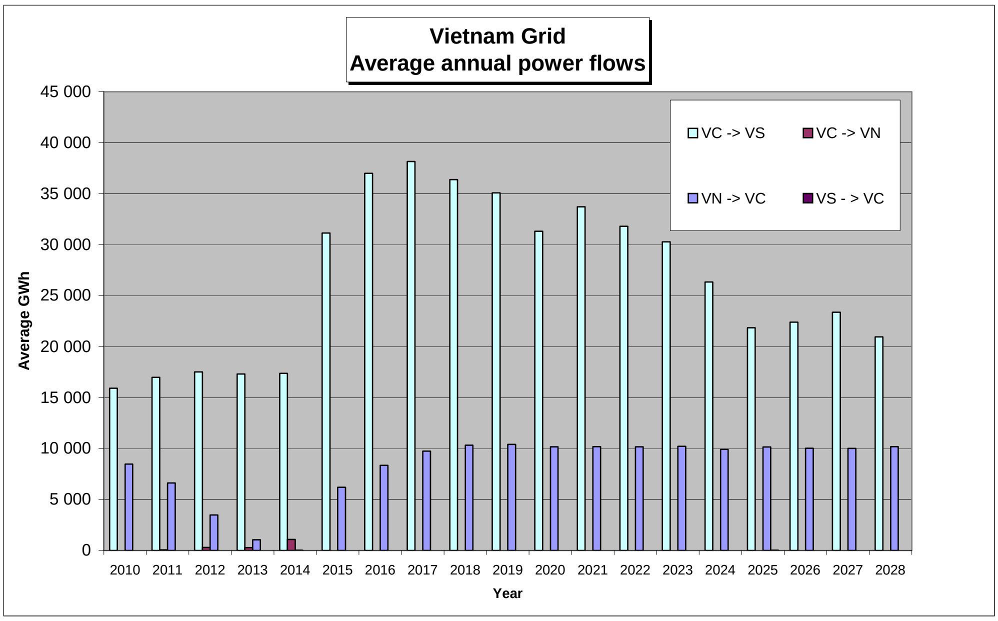


Figure 3.6-9: Base case: Average energy flow in the Vietnam grid

The Vietnam Center to Vietnam South capacity increases with the commissioning of an additional 3000 MW transmission capacity in 2015 (i.e., Reaching 5000 MW transmission capacity in 2015). This capacity allows the transmission of hydro power generation coming from Laos South (through Vietnam Center), domestic hydro generation in Vietnam center, thermal and / or hydro generation coming from Vietnam North.

In should be mentioned that these North to South energy flows are fully dependant on the composition of the Vietnam generation mix in North, Center and South Vietnam, and by the hypotheses of hydro import from Laos North, Laos South and Cambodia. These hypotheses might be updated with the release of the new Vietnam Master Plan VII (scheduled for late 2010) considering the full range of issues at stakes in the Vietnam MP (transmission & stability studies, possibility to import coal to South Vietnam, options of imports from Laos North, Laos South, Cambodia depending on costs and level of study of HPP projects).

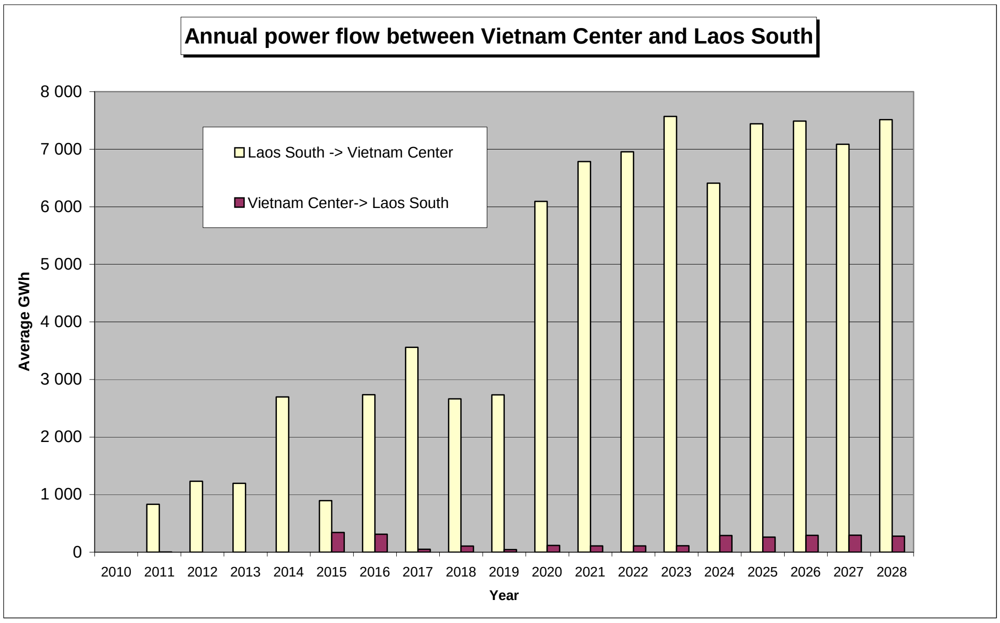


Figure 3.6-10 : Base case - Annual energy flow between Laos South and Vietnam Center

The hydro power flow coming from Laos South is transferred to Vietnam South demand center through Vietnam Center.

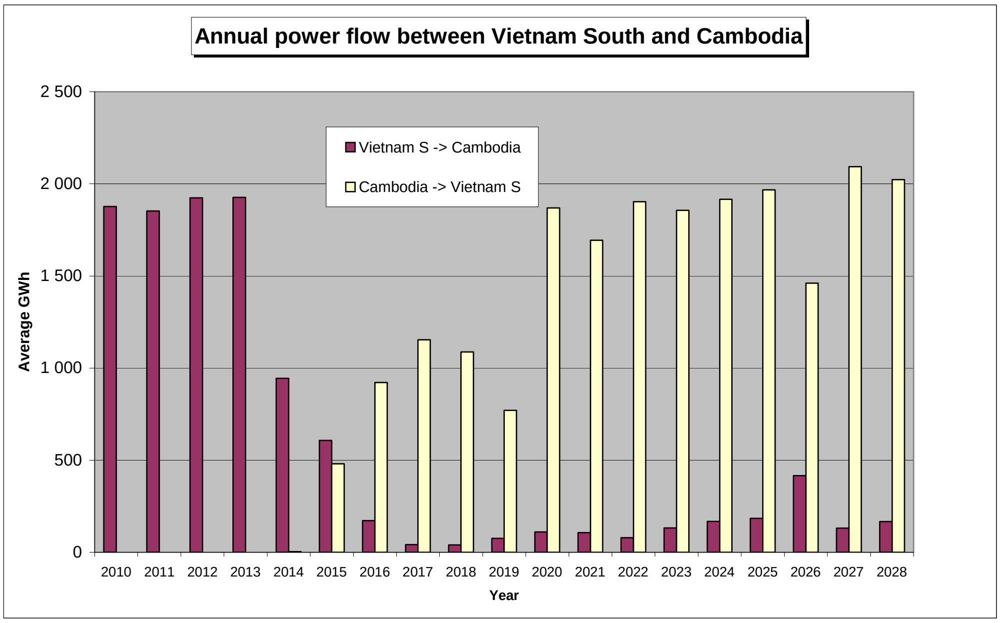


Figure 3.6-11 : Base case - Annual energy flow between Cambodia and Vietnam South

Before 2015, power imports from Vietnam South to Cambodia provide some reduction of load shedding in Cambodia.

3.6.2.2.3 Interconnection load factors

The following figure provides a look at the level of use (or load factor[29]) of the various interconnections.

[29] Load factor = Annual energy in MWh / (Interconnection capacity in MW * 8760 hours)

The load factors range between 40 to 70% between 2015 to 2025.

Slightly higher load factor is observed between Laos N and Thailand because of the share of Hongsa lignite plant in Laos North which, unlike seasonalised hydro generation, provides continuous base generation.

Exports from Myanmar also provide higher load factors. However, the accuracy of the hydrology for these hydro plants needs to be confirmed in a future study.

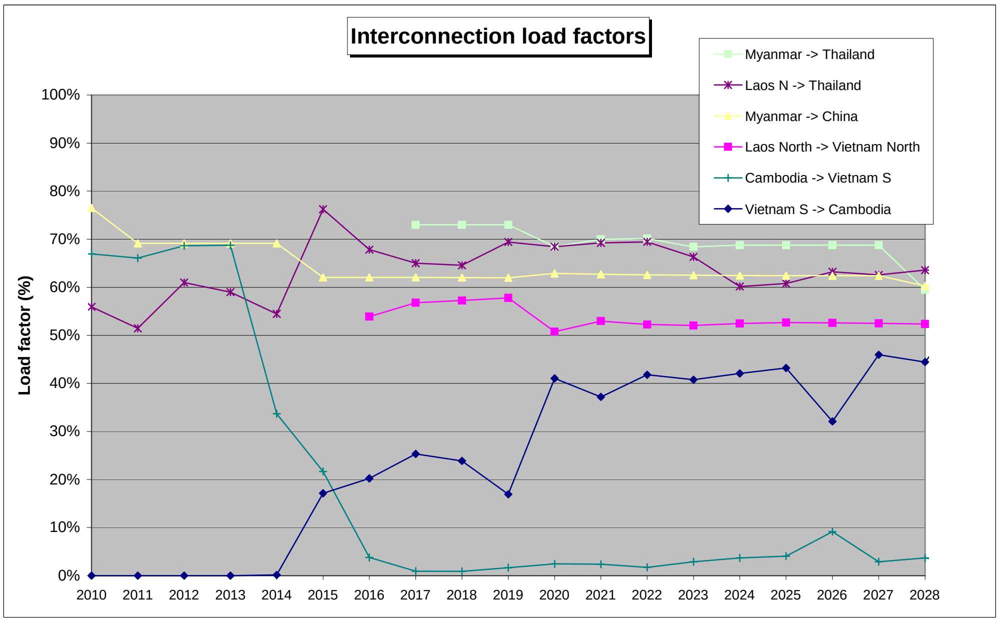


Figure 3.6-12 : Base case– Interconnection load factors

3.6.2.2.4 Comparison of generic interconnection requirements with identified projects

As discussed in Module 3 report, a set of interconnection projects were identified; some of these were classified as committed base case, and these have been used in the base case model (see § 3.3.2.1). The rest of these projects (referred to as post-2015 base case and candidates) are to be compared with the requirements identified in the model.

The following table shows the interconnection requirements identified by the base case model run, and the identified projects which are consistent with these interconnection requirements.

Interconnection requirement				Identified projects				
Importing country	**Exporting country**	**MW required**	**Year**	**Project reference number**	**Location 1**	**Location 2**	**Capacity**	**Year**
China	Myanmar	2000	2018					
		2000	2019					
		2000	2020					
		2000	2021					
		2000	2022					
		2000	2023					
		2000	2024					
		2000	2025					
		4000	2028					
Thailand	Myanmar	400	2017	28	Mai Khot substation, Myanmar (export)	Mae Chan substation, Thailand (import)	369	2016
		1200	2020	As below.				
		600	2023	As below.				
		3600	2028	16	Ta Sang HPP, Myanmar (export)	Mae Moh, Thailand (import)	7100	2029
Thailand	Laos North	600	2017	26	Saiyaburi, Laos north (export)	Khon Kaen, Thailand (import)	1200 - 2600	2016
		300	2022	As above				
		1200	2024	As above				
Vietnam North	Laos North	600	2016	5b	Xam Nau, Laos north (export)	Nho Quan, VN north (Import)	2500	2016
		1800	2020	As above				
Vietnam Centre	Laos South	900	2020					
Vietnam South	Cambodia	200	2016	7a	Lower Se San 2 HPP, Cambodia (export)	Pleiku (or Tay Ninh), Vietnam South (import)	200	2017

Table 3.6-4: Comparison of identified projects with interconnection requirements

It can be seen that a number of the identified projects are consistent with the interconnection requirements. In these cases, the capacity of the identified projects closely matches that of the requirement. It is notable that the projects that the GMS countries have identified and are considering are consistent with the results of the base case model results.

In some cases, the scheduling of the line could be reconsidered. For example, the model has identified a need for increasing amounts of import from Myanmar to Thailand from 2020 to 2028. A single project, with project reference number 16, has been identified which meets this need, but is not planned to be operational until 2029. If this project were to be commissioned earlier (from 2020) with phased increases, this project would meet the interconnection requirements identified by the base case model.

The table also shows that there are some requirements that are not covered by any interconnection projects that have been identified during the course of this project. Most notably, the significant import requirements from Myanmar to China. Interconnection between these two GMS countries has been identified as a priority in Section 3.8. There is another gap between the requirements and the identified projects, between Vietnam Centre and Laos South. Projects will therefore need to be developed by the GMS countries to address these requirements.

3.6.3 CASE 2000 MW

3.6.3.1 Definition

This case is identical to the "base case", except for a 2000 MW transmission capacity between Vietnam Center and South (instead of 5000 MW).

This constant 2000 MW transmission capacity hypothesis was provided by Vietnam representatives (Hanoi meeting – January 2010) as a first view on the Vietnam Master Plan VII. The GMS Master Plan 2008 took this same constant 2000 MW capacity hypothesis[30].

The simulation by OPTGEN presented in the present paragraph demonstrated that:

- A constant 2000 MW transmission capacity between Vietnam Center and South is sub-optimal. It would result in large congestion between Vietnam Center and Vietnam South, associated with a transit loop from Vietnam Center to Vietnam South (through Laos South and Cambodia), and finally in global overcost.
- The development of the "South" GMS grid (interconnections between Laos, Cambodia, Vietnam) is largely correlated with the existence (or not) of congestions in the Vietnam South grid (i.e. between Vietnam Center and Vietnam South), and finally on the decision or not to reinforce the Vietnam Center to South transmission.

The study of these congestions internal to the Vietnam grid, and the different associated options, are within the scope of work of the update of Vietnam PDP currently carried out (the new Vietnam PDP will be available by the end of 2010?). Furthermore, Vietnam contracted a Consultant to study the various options of reinforcement of the Vietnam North / Center / South transmission grid (Inception report scheduled for September 2010).

3.6.3.2 Results

3.6.3.2.1 Commissioning schedule of new interconnections

The following table presents the schedule of existing, committed and candidate interconnection projects as selected by OPTGEN model for the base case:

[30] cf MP2008 report - page 35

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		20																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000		500	0	0	0		0	0	0	0	0	0	0	0	500
Vietnam-S	Cambodia	100	220					2 000													2 000
Laos-S	Cambodia	20					40	2000													2000

Table 3.6-5: Case 2000MW - Schedule of new interconnections (MW)

As in the “base case”, new interconnections are developed between:

- o China and Myanmar, and Thailand and Myanmar, for the export of Myanmar hydropower.
- o Thailand, Laos North and Vietnam North, for the export of Laos North hydropower.

Because of the congestion between Vietnam Center and South, and unlike the base case:

- o Additional transmission capacities are required between Laos South, Cambodia, Vietnam Center and Vietnam South (see discussion below).

Compared to the first view on the GMS grid (see Figure 3.2-2 : High level view of the GMS target interconnection scheme in 2025):

- An interconnection between Laos South and Cambodia is developed for the evacuation of Laos South hydro power, because of the congestion between Vietnam Center and South grid observed in the simulations (see further explanations hereafter).
- No additional interconnection is developed between Laos South and Thailand, or between Thailand and Cambodia. This is in line with the hypotheses taken for the base case (no additional import from Laos South to Thailand compared to 2010 situation).

The following figures present the evolution of the power transits between the countries in 2016, 2020 and 2025, where the transit loop between Vietnam Center, Laos South, Cambodia and Vietnam South is readily apparent:

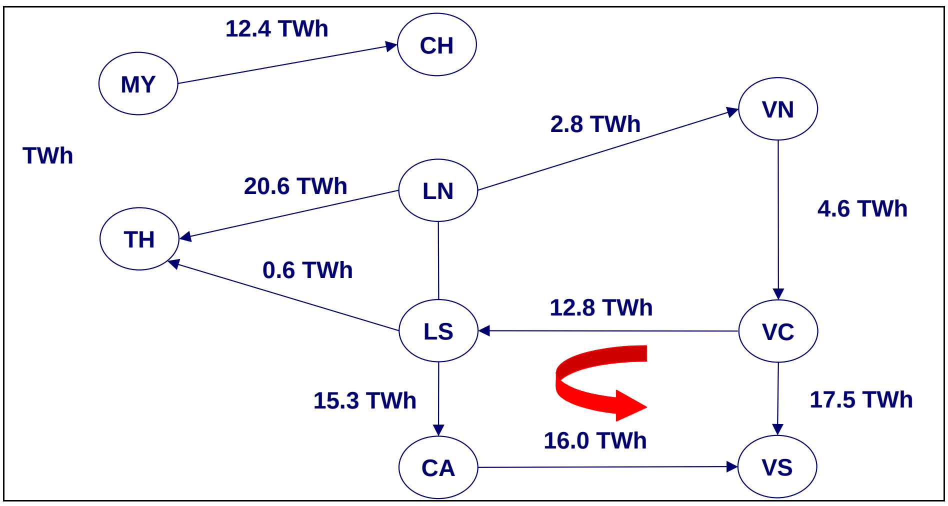


Figure 3.6-13 : Case 2000 MW: average annual energy flows in year 2016

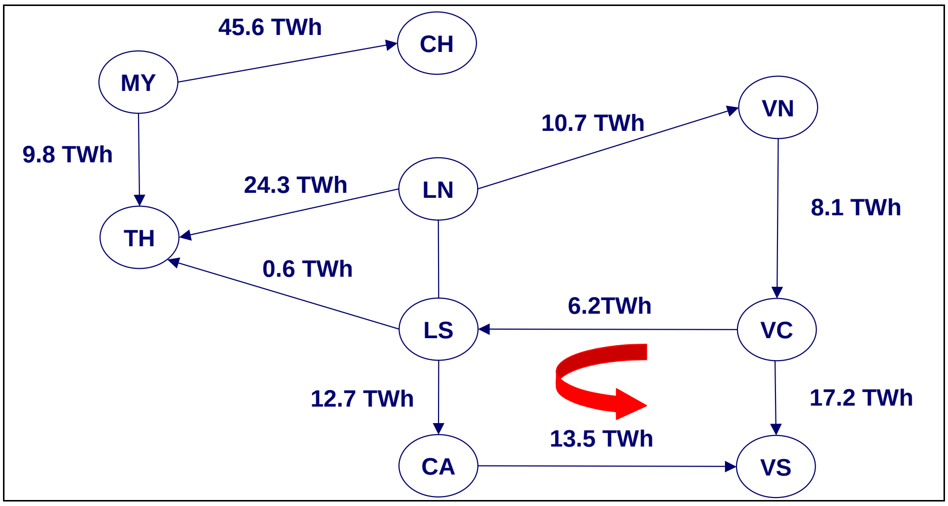


Figure 3.6-14 : Case 2000 MW: average annual energy flows in year 2020

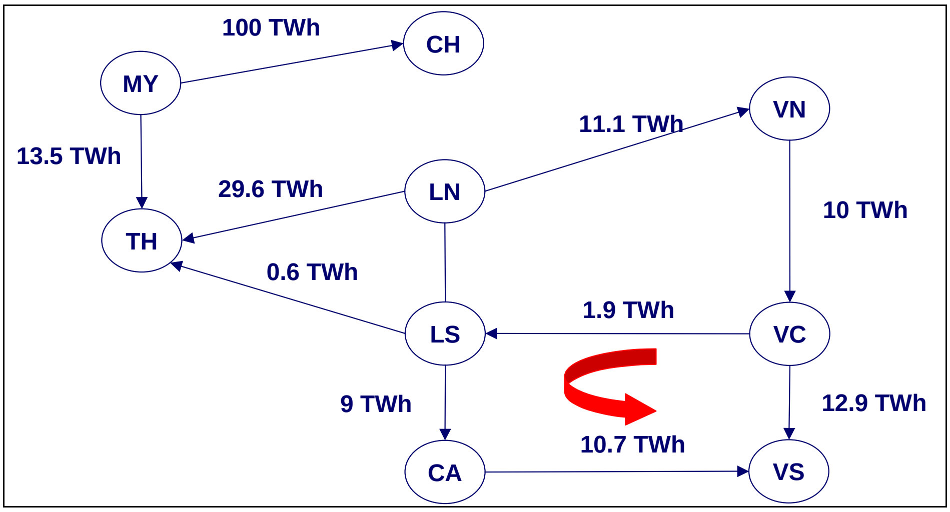


Figure 3.6-15 : Case 2000 MW: average annual energy flows in year 2025

3.6.3.2.2 Average annual energy transit from 2010 to 2025

The following figures present the evolution of the average annual power exchanges[31] over the 2010 to 2028 period (2025-2028 results are indicative) for the southern part of the GMS grid and within the Vietnam grid. Complementary results are presented in Task 5.3 Appendix.

Power transits within Vietnam grid:

The Vietnam grid is characterized by a North to South power flow explained by the nature of the Vietnam power mix in the North, Center and South regions:

- The North, representing 40% of the demand, is dominated by coal-fired plant and hydro (69% coal-fired STPP, 28% hydro in 2025).

[31] The results are averaged over the wet/average/dry hydro conditions.

- The Center, representing 10% of the demand, is dominated by hydro generation (68% hydro, coal-fired STPP in 2025).

- The South, representing 50% of the demand, is diversified between gas-fired CCGT, coal-fired STPP and hydro (21% NG and HFO, 44% coal, 28% hydro).

Accordingly, the highest generation costs are experienced in the South region, and in order to minimize the Vietnam operation cost, the best strategy is to partly substitute expensive gas-fired generation in the South by lower cost coal-fired generation from the North, leading to a North to South power flow shown in the following figure:

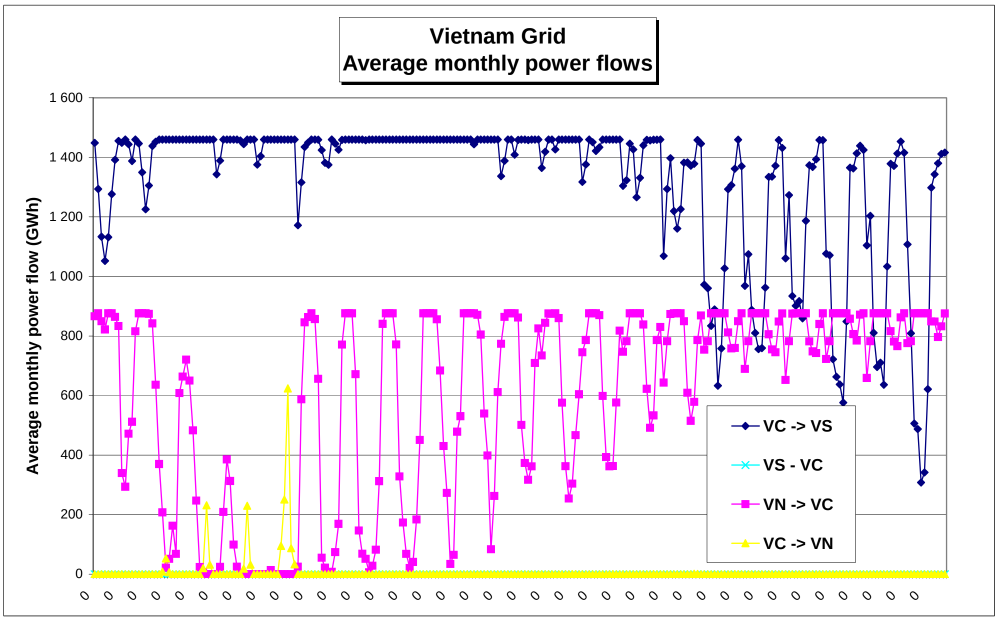


Figure 3.6-16: Case 2000 MW: Average energy flow in the Vietnam grid

The Vietnam Center to Vietnam South capacity is essentially saturated until 2025, while the Vietnam North to Vietnam Center becomes progressively saturated from 2020 to 2025.

These congestions within Vietnam grid lead to the power flows presented hereafter between Vietnam-Center, Laos South, Cambodia and Vietnam-South.

<u>Interconnections between Laos South, Cambodia and Vietnam-South</u>:

The main demand node in the Southern GMS grid is “Vietnam South”. Because of the saturation of the Vietnam Center – Vietnam South link, the power flow loop is observed to supply Vietnam South from Laos South HPP and from Vietnam North coal-fired TPP through Vietnam Center -> Laos South -> Cambodia -> Vietnam South.

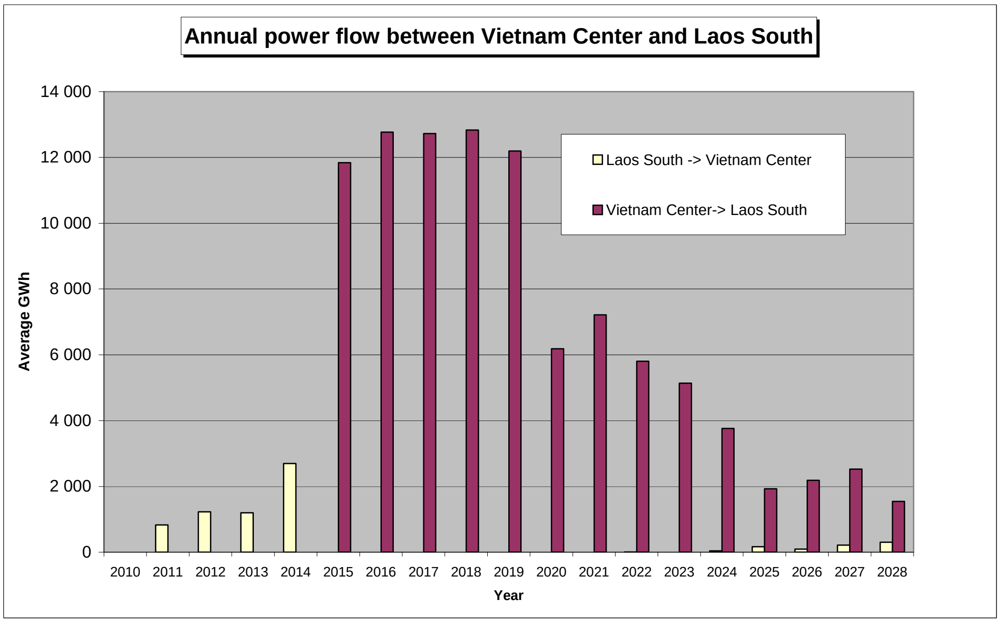


Figure 3.6-17 : Case 2000 MW - Annual energy flow between Laos S and Vietnam C

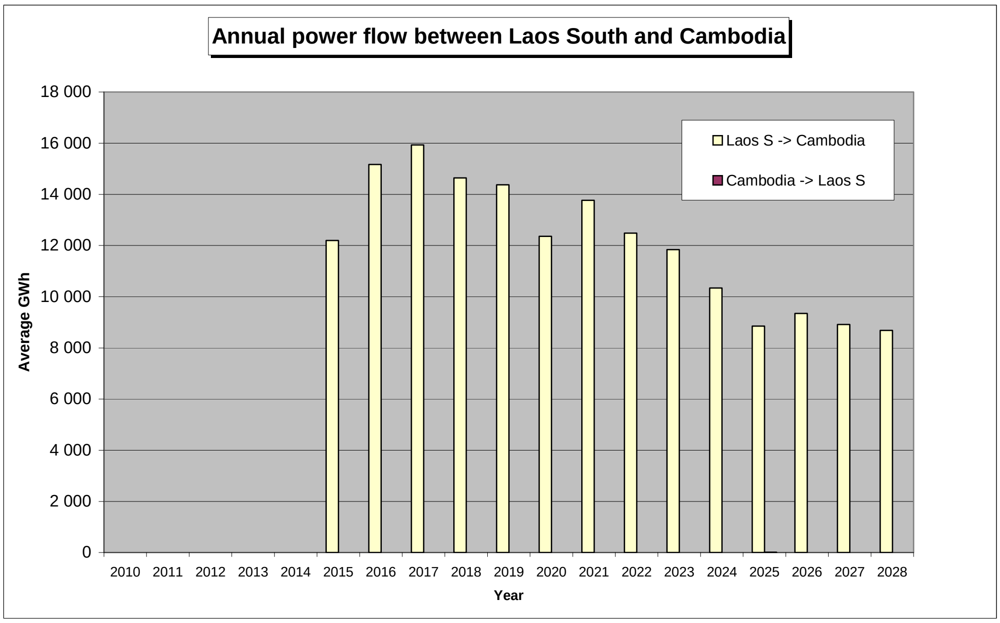


Figure 3.6-18 : Case 2000 MW - Annual energy flow between Laos S and Cambodia

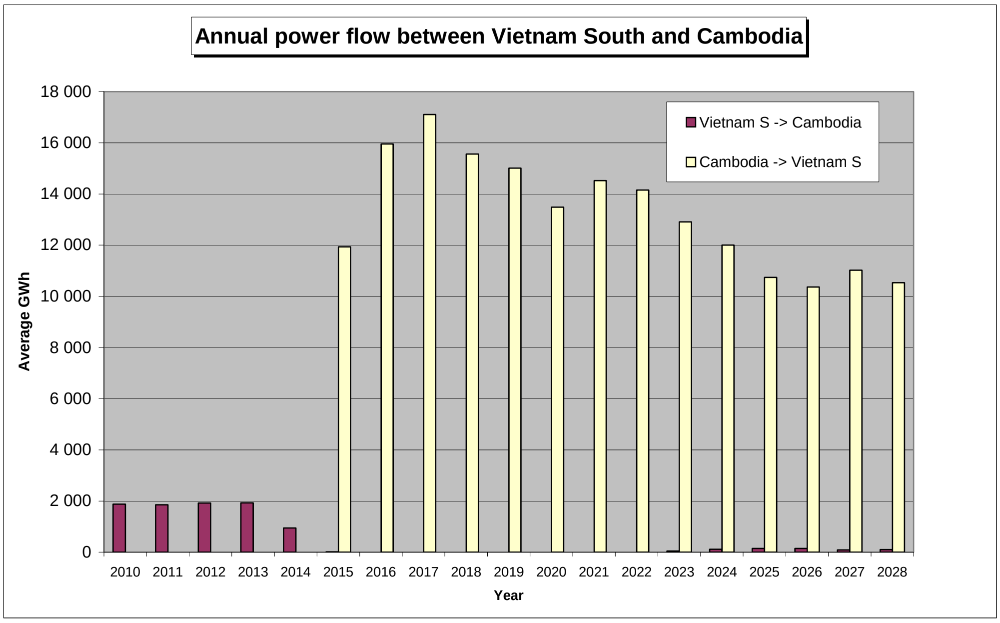


Figure 3.6-19 : Case 2000 MW - Annual energy flow between Cambodia and Vietnam South

The power flow coming from Laos South is transferred to Vietnam South demand center, with the addition of hydropower export from Cambodia.

Before 2015, power imports from Vietnam South to Cambodia provide some reduction of load shedding in Cambodia.

The cost results presented in § 3.6.7 show that this case is not optimal and that a reinforcement of Vietnam Center and South is preferable (i.e., "Base case").

3.6.3.2.3 Marginal costs

The load marginal cost (equivalent to short term marginal cost[32]) is an output of OPTGEN model[33].

The load marginal cost is in relation with the incremental cost of generation of the various TPP of the various generation mixes. The evolution of the incremental cost of the main thermal generation candidates is reminded for the planning period in the following figure. This evolution follows the fuel price evolution:

[32] STMC = incremental cost of an incremental MWh to be supplied by the power system, the structure and capacity of the generation being left unchanged (ie. No new capacity).
[33] Load marginal cost = derivative of the operation cost function with respect to the demand. In other words, the cost associated with an additional MWh of generation. This cost includes fuel cost and variable O&M costs.

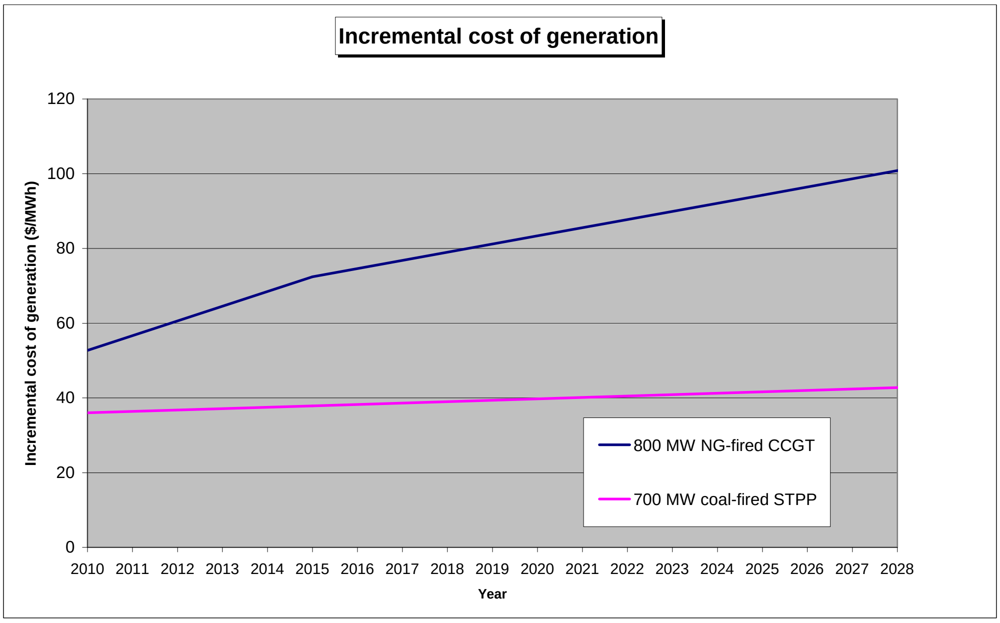


Figure 3.6-20 : Evolution of the incremental cost of thermal candidates

The following figure presents the evolution of the average annual marginal cost over the 2010-2028 period:

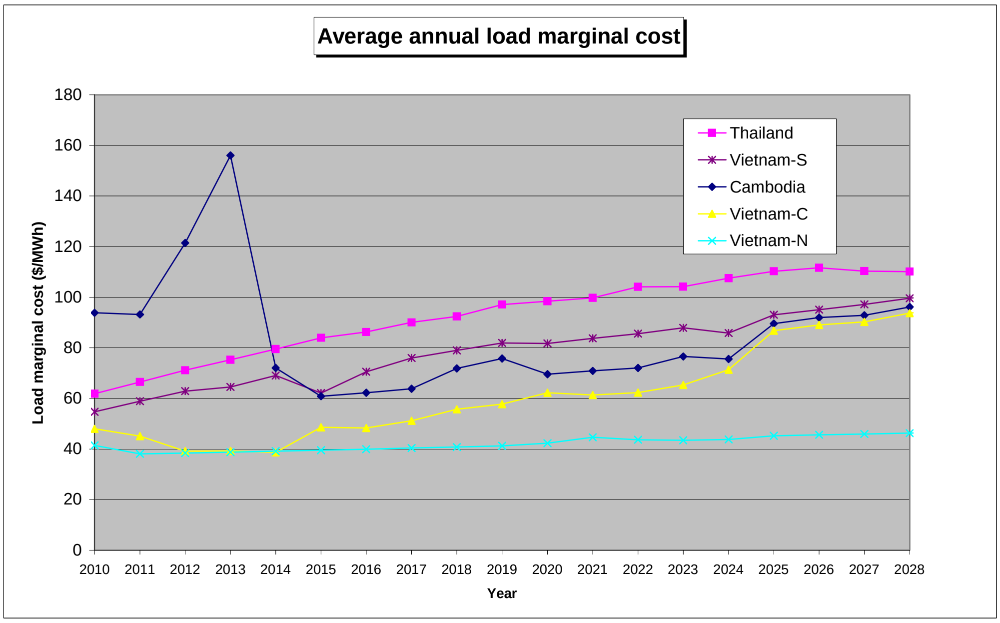


Figure 3.6-21 : Case 2000 MW – Average annual load marginal cost

Additional data and discussion on marginal costs are provided in Task 5.3 Appendix.

The marginal costs data provided by OPTGEN are one of the inputs given to Module 2 to refine the evaluation of the comparative benefits between the different cases.

3.6.3.2.4 Conclusions

- With a 2000 MW transmission capacity between Center and South Vietnam, the Vietnam national grid is close to saturation up to 2028. This saturation impacts the options of development in the GMS south grid (between Laos South, Cambodia, Vietnam South and Center).

- This situation is sub-optimal. A larger transmission capacity (see “base case”) is preferable.
- The implication of the congestions within Vietnam grid are :
    - The development of interconnection capacity from Laos South and Cambodia to feed Vietnam South.
    - Some of the potential Vietnam HP projects available in Vietnam Center can not be evacuated to Vietnam S before 2028 (2200 MW left).
- These conclusions are only valid on the basis of the data available to the Consultant. The new version of Vietnam PDP (available late 2010?) might lead to different conclusions.

3.6.4 HIGH EXPORT CASE

3.6.4.1 Definition

Remaining hydro potential left in 2028 in the base case:

In the “base case”, the remaining hydro potential left available in 2028 is as follow:

- Myanmar: 7 GW potential, with an assumed generation cost of 25 $/MWh.
- Laos North : 6240 MW potential with a generation cost lower than 50$/MWh, of which 6000 MW consisting in 5 large scale projects (from 1000 to 1400 MW) on Mekong river.
- Laos South: 2300 MW at a cost lower than 50$/MWh, consisting in two Mekong River run of river projects: 1872 MW Ban Kum HPP project and 360 MW Don Sahong HPP.
- Cambodia: 1500 MW at a cost lower than 60$/MWh, located on Mekong river, Sambor (whose capacity is estimated from 450 to 2600 MW depending on studies) and 980 MW Stung Treng.

Accordingly, apart from the Myanmar hydro projects, the remaining hydro potential is on Mekong River. This raises the questions of:

- The cumulative impact of these large scale Mekong river hydro projects (on fishing, navigation, irrigation, sediment deposit, resettlement, protected areas, etc),
- The realistic number and size of projects possible on Mekong River, down to the Mekong Delta.

These questions are largely out of the scope of the present Master Plan Study and the Consultant recommends analysing these issues in a further study (i.e. Cumulative Impact Assessment). A first contribution to this future work has been initiated by Component 2 of the RETA-6440 project with the training provided to country experts on social and environmental issues associated to generation and transmission development.

Proposed "high export case":

The "base case" and "case 2000 MW" showed that the South GMS grid options are fully dependant on the possible reinforcement of Vietnam Center to South transmission line, which is currently under investigated by Vietnam for its Master Plan VII[34] (possible release by end of 2010). Accordingly, the Consultant considers no additional Mekong river project in Laos South or Cambodia.

In absence of Cumulative Impact Assessment Study on Mekong river, and considering the fact that two Mekong river projects are already included in the base case (1400 MW Luang Prabang HPP project in Laos Central 1, and 800 MW Latsua HPP in Laos South region), the Consultant proposes a conservative approach including another 3 Mekong river projects in the "high export case" located in Laos North region, in order to export:

- Additional 2400 MW from Laos North to China (from 2020); and
- Additional 1200 MW from Laos North to Vietnam North (from 2020).

Accordingly, five out of the eleven identified Mekong river hydro projects will be considered in the "high export" case.

The following table compares the hypotheses of the "base case" and "high export" case:

	Base case		**High export case**	
Importing country	**Import in 2025**	**% of country 2025 peak demand**[35]	**Import in 2025**	**% of country 2025 peak demand**[36]
China	Total : 18900 MW - 18900 MW from Myanmar	14%	Total : 21300 MW - 18 900 MW from Myanmar - 2400 MW from Laos N	15%
Thailand	Total import : 7 700 MW - 5100 MW from Laos N&C - 150 MW from Laos S - 2100 MW from Myanmar - 330 MW from Malaysia	15%	Idem base case	15%
Vietnam	Total import : 5100 MW - 2600 MW from Laos-N&C	6.5%	Total import : 6300 MW - 3800 from Laos-N&C	8%

[34] Congestion between Vietnam South and Vietnam Center regions.
[35] For China : percentage of peak demand + export to Guangdong
[36] For China : percentage of peak demand + export to Guangdong

	- 2100 MW from Laos-S - 400 MW from Cambodia		- 2100 MW from Laos-S - 400 MW from Cambodia	

Table 3.6-6 : "High export case": level of imports

NB: The import level of Thailand is left unchanged (15% of peak demand) in line with Thailand PDP 2007 rev2.

3.6.4.2 Results

Because of the lack of study on the cumulative impact assessment of the Mekong river projects, the results of this "high export" case are probably less realistic that the ones of the base case.

3.6.4.2.1 Commissioning schedule of new interconnections

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos											2 400									2 400
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500		600					300		1 200					2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			0
Vietnam-N	Laos-N							600				3 000									3 600
Vietnam-C	Laos-S		225			1 000						900									900
Vietnam-S	Cambodia	100	220					200													200
Thailand	Cambodia	40		20																	0
Laos-S	Cambodia	20					40														0

Table 3.6-7: "High export" case - Schedule of new interconnection (MW)

In 2020, an additional 2400 MW interconnection is installed in 2020 between Laos and China, and additional 1200 MW interconnection between Laos N and Vietnam N.

3.6.4.2.2 Average annual energy transit from 2010 to 2025

<u>Average annual power import to China</u>:

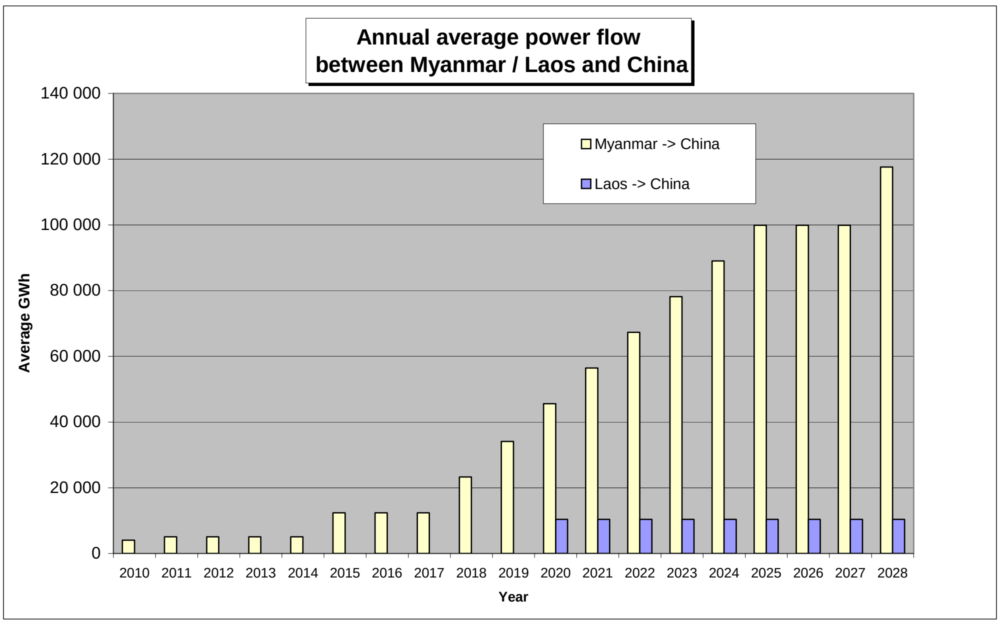


Figure 3.6-22 : "High export" case - Annual energy import to China

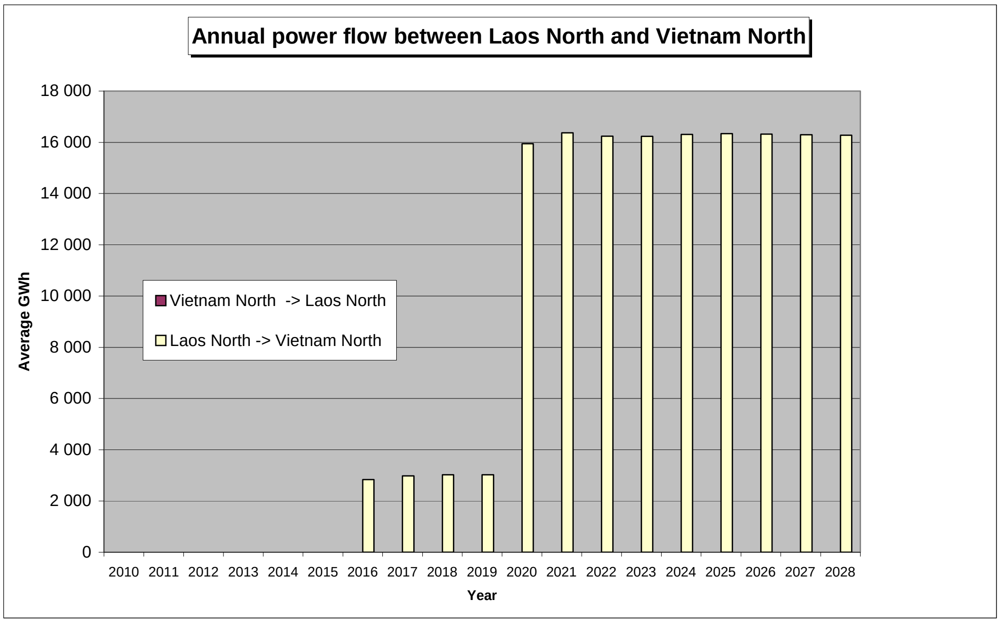


Figure 3.6-23 : "High export" case - Annual power flow between Laos N and Vietnam N

3.6.5 NO EXPANSION CASE

3.6.5.1 Definition

Contrary to the situation of MP 2008 study, an "Isolated case" - where no additional interconnection is developed compared to 2009 situation - is no longer of any relevance for the present Study. Indeed, the expansion of the GMS grid is on the track with 5 more interconnection projects planned before 2015, as well as the development of hydro export oriented projects in Cambodia, Laos and Myanmar.

Accordingly, the present "no expansion case" considers all existing and committed interconnection projects until 2015. No additional interconnection is added to the system after 2015.

3.6.5.2 Results

The regional benefits provided by the different scenarios can be measured through comparison with the "no expansion cases".

The cost results presented in § 3.6.7 allow to evaluate the savings provided by the different cases.

3.6.6 CO_2 CASES

3.6.6.1 Definition

The four previous cases ("no expansion case", "base case", "case-2000MW" and "high export") were simulated again, this time with a projected cost of CO_2 of 50$/t until 2020, and 65$/t beyond.

The CO_2 cost increases the cost of thermal generation which implies two type of impacts:

- Impact on the PDP of each country :
  - On generation side: choice made by the country between the relative development of gas, coal, clean coal technology (CSC), nuclear, renewal energy (biomass, solar, wind, etc).
  - On the demand side: demand side management, energy efficiency program.

  The evaluation of these impacts are largely outside of the scopes of the present Study, and are probably currently analysed in the ongoing update of the various national PDPs (eg. China, Thailand, Vietnam;

- The second type of impacts, this time from a regional perspective, will be an increase of the profitability of the hydro power exports compared to thermal generation.

The Consultant considered in the "CO_2 cases" only the second type of impacts, with the assumptions that the country national PDPs are left unchanged.

3.6.6.2 Results

3.6.6.2.1 Commissioning schedule of new interconnections

The addition of the CO2 cost reduces the difference of incremental costs between gas-fired and coal-fired generation as shown in the following figure:

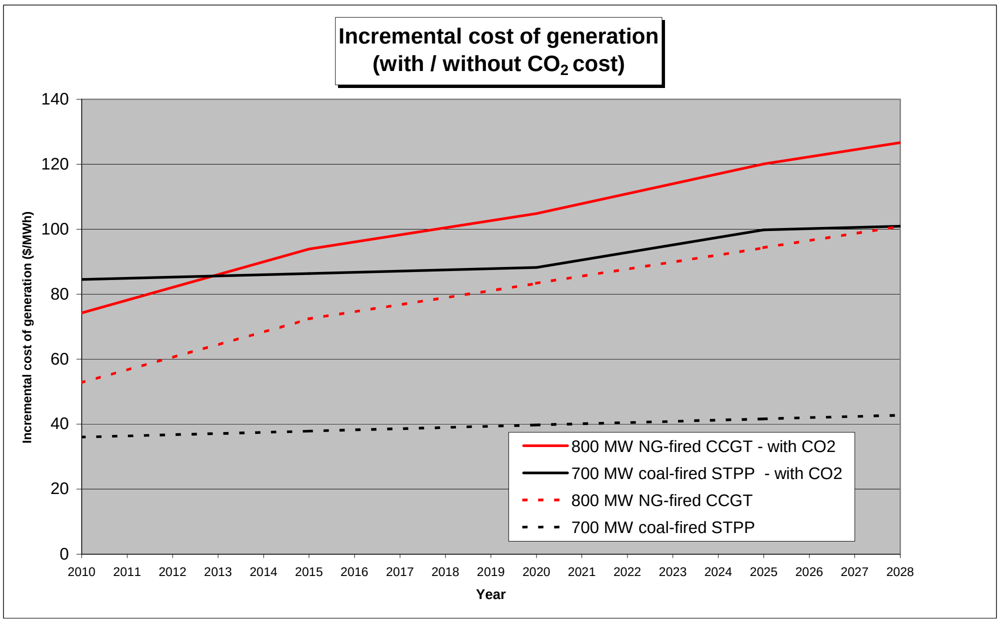


Figure 3.6-24 : Incremental costs of thermal generation with / without CO2 cost

Accordingly, the increase of the transmission capacity between Vietnam Center and South to 5000 MW from 2020 (as in the "base case" and "high export case" with no CO_2 cost) is no longer justified from the economic point of view.

The best option – for both the “base case” and “high export case” - is to keep a constant 2000 MW transmission capacity between Vietnam Center and South up to 2028.

“Base case CO_2“ :

This case is run with the same commissioning schedule as the “base case” in order to test its resilience to the integration of the cost of CO_2 emissions:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	Committed					Projects													Total projects
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Thailand	Cambodia	40		20																	0
Laos-S	Cambodia	20					40														0

Table 3.6-8: Base case CO_2 - Schedule of new interconnections (MW)

In fact, the cost results provided in § 3.6.7 show that this case with a 5000 MW transmission capacity between Vietnam Center and South is no longer optimal, a 2000 MW capacity being more economical.

“Case-2000MW-CO_2”:

When the cost of CO_2 emissions is considered, the optimization made by OPTGEN shows that a 2000 MW transmission capacity between Vietnam Center and South (instead of 5000 MW from 2020) becomes optimal. Because of the reduction in the difference between coal-fired and gas-fired generation, there is no more power loop transfer between Vietnam Center / Laos South / Cambodia and Vietnam South.

The schedule of new interconnections is then as follows :

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	Committed					Projects													Total projects
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		20																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000			0	0	0	500	0	0	0	0	0	0	0	0	500
Vietnam-S	Cambodia	100	220									500									500
Laos-S	Cambodia	20					40														0

Table 3.6-9: "Case-2000MW-CO_2” - Schedule of new interconnections (MW)

High-export-CO_2:

This case is run with the same commissioning schedule as the “high export case” in order to test its resilience to the integration of the cost of CO_2 emissions:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos											2 400									2 400
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500		600					300		1 200					2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			0
Vietnam-N	Laos-N							600				3 000									3 600
Vietnam-C	Laos-S		225			1 000						900									900
Vietnam-S	Cambodia	100	220					200													200
Thailand	Cambodia	40		20																	0
Laos-S	Cambodia	20					40														0

Table 3.6-10: "High export CO_2" case - Schedule of new interconnection (MW)

As for the "base case", the cost results provided in § 3.6.7 show that this case with a 5000 MW transmission capacity between Vietnam Center and South is no longer optimal, a 2000 MW capacity being more economical.

High-export-B-CO_2:

As for the base case, when the cost of CO_2 emissions is considered, the optimization made by OPTGEN shows that a 2000 MW transmission capacity between Vietnam Center and South (instead of 5000 MW from 2020) becomes optimal.

In this "high-export-B-CO_2" case, the schedule of new interconnections is identical to the "high-export" case without CO_2 emission cost, except for the 2000 MW transmission capacity between Vietnam Center and South (instead of 5000 MW from 2020):

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos											2 400									2 400
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500		600					300		1 200					2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			0
Vietnam-N	Laos-N							600				3 000									3 600
Vietnam-C	Laos-S		225			1 000						900									900
Vietnam-S	Cambodia	100	220					200													200
Thailand	Cambodia	40		20																	0
Laos-S	Cambodia	20					40														0

Table 3.6-11: "High export B CO_2" case - Schedule of new interconnection (MW)

3.6.6.2.2 Comparison of costs

Comparison of discounted cost over the planning period is provided in § 3.6.7.

3.6.7 COMPARISON OF COSTS AND CO_2 EMISSIONS

3.6.7.1 Operation and investment costs

Without CO_2 cost :

The following table compares the Net Present Value of the operation, investment and total costs over the planning period for the different cases when no cost is considered for the CO_2 emissions :

Net Present Value in M$:					Comparison to "no expansion case"		
	No expansion	Base case	Case 2000 MW	High export	Base case	Case 2000 MW	High export
Investment	23 380	28 460	28 660	28 960	5 080	5 280	5 580
Operation	197 040	177 650	178 090	176 030	-19 390	-18 950	-21 010
Total	220 420	206 110	206 750	204 990	-14 310	-13 670	-15 430

Table 3.6-12 : Comparison of operation and investment costs

NB: in this table, costs for China are only considered by difference to the “no expansion case”.

- The “case 2000 MW” with a transmission capacity between Vietnam Center and South limited to 2000 MW is significantly more expensive than the “base case” with a 5000 MW transmission capacity which is the optimal capacity found by OPTGEN software. The investment is greater because of the need to build a 2000 MW "transmission loop" between Laos South, Cambodia and Vietnam South.

- The increase of hydro exports in the “high export” case decreases the global regional cost at the expense of increased investment cost (for HPP and interconnection investments).

With CO_2 cost:

The following table compares the Net Present Value of the operation, investment and total costs over the planning period for the different cases[37], considering a projected cost of CO_2 emissions of 50$/t until 2020, and 65$/t beyond :

Net Present Value in M$:						Comparison to "no expansion case"			
	No expansion	Base case	Case 2000 MW	High export	High export B	Base case	Case 2000 MW	High export	High export B
Investment	23 310	28 360	27 910	28 850	28 270	5 050	4 600	5 540	4 960
Operation	322 610	283 030	283 330	278 910	279 360	-39 580	-39 280	-43 700	-43 250
Total	345 920	311 390	311 240	307 760	307 620	-34 530	-34 680	-38 160	-38 300

Table 3.6-13 : Comparison of operation and investment costs – with CO2 cost

- Savings for the region, compared to the “no CO_2 emission cost” situation are increased by more than two fold, which implies an increased profitability of the interconnection projects.

- As for the Vietnam grid, with the reduction of the cost difference between coal-fired generation in Vietnam North and gas-fired thermal generation in Vietnam South resulting from the CO_2 cost, a 5000 MW transmission capacity is no longer optimal between Vietnam Center and Vietnam South, a 2000 MW leads to a lower total cost.

3.6.7.2 CO_2 emissions

- Compared to the "no expansion case", the CO_2 emission in the “base case" are reduced by 46.4 Mt per year in 2020, and by an additional 14.5 Mt / year in the "high export" case.

- One third of these savings is in Vietnam, the other two third in China

[37] Base case : same schedule of new interconnection capacities as “base case” without CO2 cost (and with 5000 MW transmission capacity between Vietnam Center and South from 2020).
Case 2000 MW : with 2000 MW transmission capacity between Vietnam Center and South from 2010 to 2028.
High-export : with 5000 MW transmission capacity between Vietnam Center and South from 2020.
High-export-B : same schedule of new interconnection capacities as “high export”, but with 2000 MW transmission capacity between Vietnam Center and South from 2010 to 2028 instead of 5000 MW from 2020.

3.6.8 COMPLEMENTARY SENSITIVITY ANALYSIS

Given the time allocated for the Master Plan Study and the unexpected time spent during the first steps[38] of the Study, the nine cases presented above have been simulated with OPTGEN software.

The impact of the evolution of the following key macro-economic factors has been investigated hereafter:

- Demand projection,
- Interconnection investment cost,
- Fuel price projection.

3.6.8.1 Demand projection

- The draft Thailand PDP (2010) goes for a 5000 MW (i.e. 12%) reduction of the peak demand in 2020 compared to the PDP2007 rev2 considered the present RETA-6440 Study.
- Because of their high level (compared to the volume of realistic potential power imports), the demands projected in the importing countries have no impact on the power exchanges, which are mainly driven by the export capacities in Laos, Myanmar and Cambodia. Indeed, the level of marginal costs in the importing countries (China, Thailand and Vietnam) will remain virtually the same even if their demands decrease or increase by a few thousands of MW. The same economic drivers governing the profitability of interconnections will be at stake, resulting in no modification on the level of power exchanges.
- On the other hand, the demand in exporting countries (Laos, Myanmar) is relatively low compared to their hydro export potential. Accordingly, a realistic increase of their domestic demand (compared to the base case) would have very limited impacts on the volume of hydro export available.
- Accordingly, a realistic variation of the demand projections will have limited impact of the GMS Master Plan (anticipation or delay).

3.6.8.2 Interconnection investment cost

The increase of the investment cost of the interconnection could question the profitability of interconnection projects, reducing the economic advantage of power imports versus national generation.

In order to test the resilience of the Master Plan to an increase of the interconnection investment cost, the Consultant calculated the break even point where a balance is achieved between the

[38] In discrepancy with the project Contract :
- There was no regional data base gathering all the data necessary for the simulation of the regional power system.
- The SDDP modelling used in the previous Master Plan was too aggregated to be used for the present Study.
- While the PDP were declared to be readily available for all countries (except Cambodia), the Consultant received four different versions of the Laos PDP, and no PDP for the North / Center / South Vietnam regions.

national generation cost (i.e., cost of saved energy in the importing country) and the cost of imported generation (i.e., cost of the energy delivered to the importing country) (see § 3.7).

3.6.8.3 Fuel price projection

A reduction of fuel prices can hamper the profitability of interconnection, reducing the economic advantage of hydro power imports versus thermal generation.

In order to test the resilience of the Master Plan to a decrease of the fuel price, the Consultant calculate the break even point where a balance is achieved between the national generation cost (i.e., cost of saved energy in the importing country) and the cost of imported generation (i.e., cost of the energy delivered to the importing country) (see § 3.7).

3.7 RESILIENCE ANALYSIS

This paragraphs complements the analysis made through the simulations of the interconnected GMS system with OPTGEN, in order to evaluate the resilience (or robustness) of the GMS Master Plan base case, and more precisely the resilience of interconnection investment decisions under variation of key economic factors.

3.7.1 DEFINITION

The evaluation of the benefits of interconnections between GMS countries is based upon projections of key parameters whose values could be different than anticipated in the future: interconnections investment costs, HPP investment costs and fuel prices.

The hypotheses taken for the base case are presented in Task 2 report (investment cost of new generation units, fuel price projections), and § 1.5.2.2 of present Task 5.3 report (investment cost of interconnections.

The resilience analysis consists in determining, for each interconnection, the break even point, related to each of these parameters, beyond which the interconnection would turn unprofitable.

3.7.2 METHODOLOGY

Let's consider a country A with an HPP project with the following features: 1000 MW, 5 000 GWh (load factor = 5000h) and a levelized generation cost of 40$/MWh.

Let's now consider a country B with only thermal generation projects (coal power plants, with a level of liability of 90%).

Country B wants to know if it is better to build a new interconnection between countries A and B and to import hydro generation from the HPP project, or to build additional domestic thermal generation units.

First of all, it is important to determine what is the "equivalent" thermal project (in capacity and energy provided) in country B which can be substituted to the HPP project from country A, considering that an hydro project would be rarely strictly equivalent to a thermal project.

- First approach: 1000 MW of HPP may be substituted to 1000 MW of TPP => in this case, installed capacities are equivalent but not the generation supply; a TPP can have a load factor much higher (up to 90%), so this approach leads to a too high thermal investment level.

- Second approach: 1000 MW of HPP (with a load factor of 5000 h) may be substituted to 634 MW of TPP => in this approach, the construction cost of new TPP in country B is minimized, so the TPP is supposed to generate at its maximum load factor (90%, corresponding to its level of reliability). To generate 5 000 GWh (equivalent to the HPP generation in country A), it is necessary to build at least 634 MW of TPP in country B (634 MW x 90% x 8760 h = 5 000 GWh). In this approach capacity supply is not the same in both cases (1000MW vs. 634 MW). But its is the least cost option for country B without interconnection.

Considering the fact that the objective in this chapter is to determine the break even point for the profitability of each interconnection project, the Consultant choose the “second approach” which is more conservative in terms of profitability of interconnection.

The following tables present for each interconnection:

- The levelized cost of hydro generation,

- The levelized cost interconnection costs; and

- The substituted thermal generation costs; and

- For each of these parameters, the break even point is calculated, beyond which the interconnection project turns to be unprofitable.

All the break even points are calculated considering all other parameters remained constant.

3.7.3 RESILIENCE ANALYSIS RESULTS

3.7.3.1 Myanmar – China interconnection

($/MWh)	**MYANMAR**	**CHINA**
HPP generation cost	25	
Interco. Cost (load factor = 5000h)	9	
Import cost		34
Thermal generation cost (load factor = 7800h)		47
Benefits of interconnection		13
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	22	144%
HPP($/MWh)	38	52%
Fuel price cost (coal $/t)	58	-37%

Table 3.7-1: Resilience analysis - Myanmar / China interconnection

As presented in the above table,

- The cost of the MWh delivered from Myanmar to China (called "import cost") amounts to 34 $/MWh,
- The levelized cost of the alternate thermal generation in China to which the hydro import substitute amount to 47 $/MWh,
- Accordingly, the savings provided by the interconnection (and the hydro export project) amounts to 13 $/MWh,
- Interconnection cost between Myanmar and China should increase by 144% in order to cancel the benefits of this interconnection.
- HPP costs in Myanmar should increase by 52% (going from 25$/MWh to 38 $/MWh) to cancel the benefits of the interconnection.
- Coal price should decrease by 37% compared to the base case fuel price projections to cancel the benefits of interconnection.

3.7.3.2 Laos North – China interconnection

($/MWh)	**LAOS NORTH**	**CHINA**
HPP generation cost	33	
Interco. Cost (load factor = 5000h)	10	
Import cost		43
Thermal generation cost (load factor = 7800h)		48
Benefits of interconnection		5
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	15	50%
HPP($/MWh)	38	15%
Fuel price cost (Coal $/t)	80	-15%

Table 3.7-2: Resilience analysis – Laos North / China interconnection

3.7.3.3 Myanmar – Thailand interconnection

($/MWh)	**MYANMAR**	**THAILAND**
HPP generation cost	25	
Interco. Cost (load factor = 5000h)	7	
Import cost		32
Thermal generation cost (load factor = 7800h)		106
Benefits of interconnection		74
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	81	1057%
HPP($/MWh)	99	296%
Fuel price cost (NG $/MMBTU)	1,9	-59%

Table 3.7-3: Resilience analysis - Myanmar / Thailand interconnection

3.7.3.4 Laos North - Thailand interconnection

($/MWh)	**LAOS NORTH**	**THAILAND**
HPP generation cost	41	
Interco. Cost (load factor = 5000h)	8	
Import cost		49
Thermal generation cost (load factor = 7800h)		91
Benefits of interconnection		42
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	50	525%
HPP($/MWh)	83	102%
Fuel price cost (NG $/MMBTU)	4,5	-59%

Table 3.7-4: Resilience analysis – Laos North / Thailand interconnection

3.7.3.5 Laos North – Vietnam North interconnection

($/MWh)	**LAOS NORTH**	**VIETNAM NORTH**
HPP generation cost	41	
Interco. Cost (load factor = 5000h)	7	
Import cost		48
Thermal generation cost (load factor = 7800h)		68
Benefits of interconnection		20
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	27	286%
HPP($/MWh)	61	49%
Fuel price cost (Coal $/t)	41	-57%

Table 3.7-5: Resilience analysis – Laos North / Vietnam North interconnection

3.7.3.6 Laos South – Vietnam Center / South interconnection

For this interconnection, it is necessary to consider first the interconnection between Laos South and Vietnam Center (see the following table and results), and afterward to consider the cost of reinforcement of the transmission grid between Vietnam Center and Vietnam South (transmission cost of about 9$/MWh for a line of 1500 MW over 350 km).

($/MWh)	**LAOS SOUTH**	**VIETNAM CENTER**
HPP generation cost	45	
Interco. Cost (load factor = 5000h)	7	
Import cost		52
Thermal generation cost (load factor = 7800h)		99
Benefits of interconnection		47
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	54	671%
HPP($/MWh)	92	104%
Fuel price cost (NG $/MMBTU)	4,8	-60%

Table 3.7-6: Resilience analysis – Laos South / Vietnam Center interconnection

Here are the results with the total transmission cost (from Laos South to Vietnam South via Vietnam Center):

($/MWh)	**LAOS SOUTH**	**VIETNAM SOUTH (via Vietnam Center)**
HPP generation cost	45	
Interco. Cost (load factor = 5000h)	16	
Import cost		61
Thermal generation cost (load factor = 7800h)		99
Benefits of interconnection		38
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	54	240%
HPP($/MWh)	83	85%
Fuel price cost (NG $/MMBTU)	7,1	-41%

Table 3.7-7: Resilience analysis – Laos South / Vietnam Center – South interconnection

The benefits of this interconnection are obviously lower than without the cost of the reinforcement of Vietnam national transmission grid.

3.7.3.7 Cambodia – Vietnam Center / South interconnection

In Cambodia, only very few hydro projects are available for export at a competitive price (about 1500-3500 MW[39] at a cost lower than 60 MWh). The costs (and installed capacity) of these projects have to be refined in future studies, that is why a range of price is used here to determine the resilience of the interconnection project between Cambodia and Vietnam.

($/MWh)	**CAMBODIA**	**VIETNAM SOUTH**
HPP generation cost	32 to 58 (Sesan2-Stung Treng)	
Interco. Cost (load factor = 5000h)	7	
Import cost		39 to 65
Thermal generation cost (load factor = 7800h)		98
Benefits of interconnection		33 to 59
Break even points		**Δ base case hypotheses**
interconnection cost ($/MWh)	40-66	471% to 842%
HPP($/MWh)	91	57% to 184%
Fuel price cost (NG $/MMBTU)	2,9-7	-42% to -76%

Table 3.7-8: Resilience analysis – Cambodia / Vietnam South interconnection

3.7.4 COMPARISON WITH THE COST OF GENERIC TRANSMISSION PROJECTS OF "BASE CASE"

The generic interconnection costs in US$/MWh used in the above results is calculated from the construction costs (in MUS$) of the interconnection candidates listed in the part 3.3.1.2.

The following assumptions are taken into account in order to calculate the levelized transmission cost in US$/MWh:

- Load factor of 5000 hours.
- Disbursement schedule: 25%-50%-25%.
- O&M costs = 2% of construction cost per year.
- Losses = 2%.

[39] Depending on the design of Sambor HPP (from 450 MW to 2600 MW)

- Discount rate = 10%.
- Life duration = 40 years.
- Transmission capacity in N-1 : as listed in the following table.

Generic transmission line	Length (km)	Capacity (MW)	Number of circuits	Construction Cost (M US$)	Transmission Cost (US$/MWh)
Myanmar-China	350	2000	5	648	9
Myanmar-Thailand	250	1200	3	300	7
Laos North-Thailand	300	1200	3	352	8
Laos North-Vietnam North	250	1200	3	300	7
Laos South-Vietnam Center	200	1000	3	242	7
Cambodia-Vietnam South	200	1000	3	242	7
Laos South-Cambodia	400	1000	3	450	12
Laos North-China	350	1200	3	444	10
Vietnam Center-Vietnam South	350	1500	4	501	9

Table 3.7-9: Levelized cost of generic interconnection candidates

3.7.5 CONCLUSIONS ON RESILIENCE ANALYSIS

The levelized cost of the interconnection projects considered above ranges from 7 to 12 USD/MWh, which is much lower than the price gap observed between the importing and exporting countries, ranging from 30$/MWh (for coal-fired STPP dominated importing power system) to 50 $/MWh (for gas-fired CCGT dominated importing power system). Accordingly, all these interconnection projects are largely profitable.

The resilience analysis show that the profitability of the interconnection projects between GMS countries resists negative price shocks, either interconnection and HPP costs, or fuel price.

- Interconnection investment costs can be multiplied by 2 to 10 (depending on interconnection project) without affecting the profitability (except China-Laos North: +50% in interconnection costs can turn the interconnection unprofitable).
- HPP investment costs can be multiplied by 1.5 to 4 (depending on interconnection project) without affecting the profitability (except China-Laos North: +15% in HPP costs in Laos can turn the interconnection unprofitable).
- Fuel price can decrease by 35 to 70% (compared to fuel price projection in the base case) without affecting the profitability (except China-Laos North: -15% in coal price in China can drive the interconnection to be unprofitable).

The interconnection projects linking hydro to gas-fired CCGT dominated thermal systems[40] are the most resilient to any cost or price shocks: Cambodia-Vietnam South, Laos South -Vietnam South, Laos North -Thailand and Myanmar-Thailand.

Interconnection projects linking hydro systems to coal-fired STPP dominated thermal systems have a lower, but still good resilience, especially to the HPP costs: Myanmar-China and Laos North-Vietnam North. An increase in HPP costs by +50% may cancel their profitability.

[40] gas-fired CCGT dominated generation system will experience the higher marginal costs because of the increase of gas price.

One interconnection project is not very resilient to cost shocks: the interconnection project between China and Laos North. A slight increase of the HPP investment costs in Laos (+15%), or a decrease of the coal price (-15%), or an increase of the interconnection (+50%) can turn this project unprofitable. But some other – non economic - drivers might motivate the development of this project (huge power demand in China).

3.8 MULTI-CRITERIA RANKING AND PRIORITY INTERCONNECTION PROJECTS

3.8.1 RATIONALE AND CRITERIA

The Master Plan approach is an important input to the ranking of regional interconnection projects. However, ranking and defining priority projects interconnection projects involves several aspects:

- Economic criteria.
- Potential for export and import.
- Supply safety and diversification of import.
- Grid and PDP issues.

These different aspects are discussed more in detailed hereafter.

- 1 - Economic criteria:

The economic criterion is obviously the one and foremost criterion.

- o Price gap compared to interconnection cost:

A first way to rank interconnection is to calculate the economic benefit derived from each interconnection; this benefit is calculated as the difference between the price gap between both countries and the transmission cost.

Table 1.7-1 reminds the economic savings provided by each interconnection, evaluated as the difference between the price gap (between importing and exporting countries) and the cost of interconnection[41] : it can be seen that the most profitable interconnections (based upon economic evaluation) are those allowing exports from export oriented hydro generation project to countries (or areas) dominated by gas-fired power generation (Thailand and Vietnam South), because of the high cost of NG generation in the future (leading to huge price gap).

- o Resilience (or robustness) to changes of key factors (investment costs and fuel prices):

[41] For further details on the calculation, see part 3.7.2 and 3.7.3.

A complementary way to determine an economic ranking of interconnections is to examine the resilience of their profitability to changes of the key economic factors: investments costs of hydro power plants dedicated to export, investment costs of interconnections, and fuel price (coal or NG).

The tables presented in § 3.7.3, and summarized hereafter, show that the profitability of the interconnection projects between GMS countries resists negative price shocks (either interconnection and HPP costs, or fuel price). The following table gives in percentage the maximum increase of interconnection investment cost, the maximum increase of HPP investment cost, or decrease of fuel cost, compatible with the profitability of the interconnection projects (breakeven points):

	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
resilience to interconnection costs	144%	50%	1057%	525%	286%	240%	471% to 842%
resilience to HPP costs	52%	15%	296%	102%	49%	85%	57% to 184%
resilience to fuel price	-37%	-15%	-59%	-59%	-57%	-41%	-42% to -76%

Table 3.8-1 : Resilience of interconnection projects

- Interconnection investment costs can be multiplied by 2 to 10 (depending on interconnection project) without affecting the profitability (except China-Laos North: +50% in interconnection costs can turn the interconnection unprofitable).

- HPP investment costs can be multiplied by 1.5 to 4 (depending on interconnection project) without affecting the profitability (except China-Laos North: +15% in HPP costs in Laos can turn the interconnection unprofitable).

- Fuel price can decrease by 35 to 70% (compared to fuel price projection in the base case) without affecting the profitability (except China-Laos North: -15% in coal price in China can drive the interconnection to be unprofitable).

The only exception is the interconnection between China and Laos North: the price gap is very low, mainly because coal generation costs are low in China. But the main driver for the development of this interconnection is not the economic driver, but the increasing China demand, as seen afterward.

o Synthesis of economic ranking:

The following table shows a ranking of all these interconnections based upon the previous economic criteria (rank 1 = highest priority):

Ranking benefits/resilience	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
benefits of the interconnection ($/MWh)	6	7	1	3	5	4	2
resilience to HPP costs	5	7	1	3	5	4	2
resilience to fuel price	6	7	1	1	1	5	1
Economic ranking (benefits+resilience to cost shocks)	6	7	1	3	4	5	2

Table 3.8-2 : Economic ranking of interconnection projects

According to a pure economic ranking, the interconnections with countries dominated by NG power generation (Thailand and Vietnam South) would be preferred.

The interconnections with China come at the end of this pure economic ranking because of the lower price gap between China and HPP in Myanmar or Laos.

However, the only economic point of view is not sufficient to determine which interconnection projects have the highest priority. Other complementary parameters have to be considered.

- 2 - Potential of export and need for import:

  - Potential of export:

Some countries (especially Laos) have a large and diversified potential of hydro projects that could be dedicated to exports (these projects are distributed over a large area of the country : in the North, Central 1 and South areas). This means that interconnection projects in this type of country are less risky and non dependant on specific hydro project. Even if an interconnection project is implemented, and not the HPP project that was supposed to be commissioned in order to provide export through this line, it will be possible to find other cost effective hydro projects in the same area in order to use this interconnection line.

Moreover, because of this large hydro potential and the large demand of neighboring countries, there is no doubt there will be future increase in the transmission capacity. Accordingly, it might be justified to build interconnections with capacities larger than expected by the strict least cost approach.

Regarding the type of hydro plant, and from the generation point of view, hydro projects with seasonal reservoirs give more flexibility in operation than run of river projects.

  - Need for import:

In some situations, interconnections are not only a way to benefit from a price gap between two countries, but also the only way to balance an increasing demand in the long term. That is the case for China, which is looking to import 25 – 30 GW from the neighboring countries in order to balance its huge future demand. In this case, a low or even slightly negative price gap can be accepted.

- 3 – Supply safety / Diversification of power imports:
  - Supply safety is increased through diversification of import sources: geographic diversification to mitigate hydro risk (different hydro regimes), country origin diversification to mitigate supply risks, increase of grid mesh to mitigate grid contingencies. This is the case for Thailand for example.
  - Ratio of import : even if the price gap is high with neighboring countries, most countries would like to limit their share of imports in the total power supply in order to keep the control on the main part of power supply with a large part of domestic supply. This is the case with Thailand: the price gap with the neighboring countries is high and the hydro potential in these countries is also high, but Thailand doesn't want to import more than 15% - 20% of its national peak demand[42].

- 4 - Grid and PDP aspects / Level of studies:
  - Regional integration (number of countries involved in the interconnection):

Some interconnections allow a real regional integration between GMS countries by creating a link between several importing and exporting countries. This type of interconnection favors regional integration and the development of regional power trades.

  - Increased meshed grid:

Provides better resilience to grid contingencies.

  - Interconnection projects impacted by options taken in national PDPs:

An example is given by the PDP of Vietnam. From about 2015, Vietnam will have to import part of its coal. This opens the possibility to develop coal-fired STPP directly close to the load center in Vietnam South. If such an option is taken, the price gap between Laos-S (or Cambodia) and Vietnam South will be reduced and become comparable to the price gap between Laos-N and Vietnam-N. The profitability of interconnections between Laos South (or Cambodia) and Vietnam South would be lower (but still high).

[42] This ratio depends on the number of exporting countries

- o Level of advance of related studies:

Developing an interconnection project is a rather long process involving different steps of technical and non technical studies for the interconnection project, but also for the associated generation export projects (Desktop Study, Feasibility Study, Design Study, tendering process, commercial agreement, etc). Accordingly, the priority projects for the next 10 years are necessarily among the projects which have been studied to the more advanced level.

Further more, a number of more related and more focused studies are either ongoing : Package III (Cambodia – Laos Vietnam interconnection study), China – Vietnam interconnection study, Thailand PDP, Vietnam PDP, or have just been started :Cumulative Impact Assessment of some of the HPP projects on mainstream Mekong River, Vietnam grid reinforcement study. These studies will bring significant new information and / or data for the next update of the GMS Master Plan, and would possibly answer issues that could not be tackled within the time frame and scope of works given to the present RETA-6440 Study.

3.8.2 ANALYSIS BY COUNTRY

In this paragraph, each interconnection project is evaluated along the previous criteria from the point of view of the importing country.

3.8.2.1 Projects to China

China – Myanmar interconnection:

Economy	- Economic benefit : 13 $/MWh (saves coal-fired generation) - Resilience HPP investment cost : 52% - Resilience fuel price : -37%
Export potential / need for import	- Export potential : Myanmar = very large potential = 28 GW (to be shared with Thailand) - China target for import : China : 30 GW in 2030
Diversification	- Hydro regime different than China / Laos
Grid / PDP / studies	- Huge imports are necessary to balance the China demand
Base case	- 18 000 MW import from Myanmar to China in 2028

Table 3.8-3 : Evaluation of China - Myanmar interconnection

China – Laos interconnection:

Economy	- Economic benefit : 5 $/MWh (saves coal-fired generation) - Resilience HPP investment cost : +15% - Resilience fuel price : -15%
Export potential / need for import	- Export potential : Laos = large potential = 10 GW in Laos North - China target for import : 30 GW in 2030
Diversification	- Hydro regime different than Myanmar / China. - Diversification of imports (Myanmar + Laos)
Grid / PDP / studies	
Base case	0 MW

Table 3.8-4 : Evaluation of China - Laos interconnection

Conclusion for China:

- The interconnection project between Myanmar and China ranks first because of larger price gap and the huge Myanmar hydro potential.
- China-Laos ranks second because of a lower price gap and hydro potential in Laos (shared with Thailand and Vietnam).

3.8.2.2 Project to Thailand

Thailand – Myanmar interconnection:

Economy	- Economic benefit : 74 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +296% - Resilience fuel price : -59%
Export potential / need for import	- Export potential : Myanmar = very large potential = 28 GW (to be shared with China) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime different than Laos N / S / Cambodia
Grid / PDP / studies	
Base case	- 5500 MW import from Myanmar to Thailand in 2025

Table 3.8-5 : Evaluation of Thailand - Myanmar interconnection

Thailand - Laos N and Thailand - Laos S interconnection:

Economy	- Economic benefit : 42 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +102% - Resilience fuel price : -59%
Export potential / need for import	- Export potential : Laos N = 10 GW, Laos S = 3.5 GW (to be shared with Vietnam) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime different than Myanmar - Number of seasonal reservoirs larger in Laos North than Laos Sout (given the list of Laos South HPP projects devoted to export to Vietnam)
Grid / PDP / studies	- To be checked with grid study - Tariff MOU already discussed (though now obsolete) for HPP in Laos North
Base case	- Import from Laos - N : 2400 MW in 2025 - Import from Laos - S = 150 MW in 2025

Table 3.8-6 : Evaluation of Thailand - Laos interconnection

Thailand – Cambodia interconnection:

Economy	- Economic benefit : 39 to 65 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +57% to +184% - Resilience fuel price : -42% to -76%
Export potential / need for import	- Limited Export potential : Stung Treng (980 MW) and Sambor : 450 MW (up to 2600 MW depending on studies) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime less favorable; inflows in dry season are lower than in Laos - Only run of rivers projects (for large scale projects)
Grid / PDP / studies	- To be checked with grid study
Base case	- 60 MW export from Thailand to Cambodia (no additional exchanges between Cambodia to Thailand over 2010-2028

Table 3.8-7 : Evaluation of Thailand – Cambodia interconnection

Conclusions for Thailand:

- All of these interconnections are largely profitable (compared to domestic gas-fired CCGT generation).
- Diversification of imports (countries and hydrology) favors the development of these interconnections, at least between Myanmar-Thailand and Laos North -Thailand.
- The list of the first interconnection projects to be developed depends largely on the list of most promising exported oriented generation projects. This list corresponds to the HPP (or TPP) having being studied at the most advanced level, from technical studies and commercial point of view (tariff MOU). Grid study would be necessary. Accordingly, the priority would be on Myanmar – Thailand interconnection and Laos North- Thailand interconnection, as indicated in the GMS Master Plan "base case".
- Thailand - Cambodia interconnection seems less promising because of much lower hydro potential, less favorable hydro regime, and technical study of HPP projects at a less advanced level.
- These "North" or "South" interconnections will contribute to build a future East-West backbone between Thailand, Laos and Vietnam.

3.8.2.3 Projects to Vietnam

Laos North - Vietnam North interconnection:

Economy	- Economic benefit : 20 $/MWh (saves coal-fired generation)l - Resilience HPP investment cost : +49% - Resilience fuel price : -57%
Export potential / need for import	- Export potential from Laos N = 10 GW (to be shared with Thailand and possibly China) - Vietnam need for import : expected 2600 MW in Vietnam PDP
Diversification	- between Laos N and Laos S
Grid / PDP / studies	- pending studies : Package III (Cambodia-Laos-Vietnam) interconnection study, Vietnam MP VII, Vietnam grid reinforcement study
Base case	- 2600 MW transmission capacity in 2025

Table 3.8-8 : Evaluation of Laos North – Vietnam North interconnection

Laos South - Vietnam South (via Vietnam Center) interconnection:

Economy	- Economic benefit : 38 $/MWh (saves NG in Vietnam South) - Resilience HPP investment cost : +85% - Resilience fuel price : -41%
Export potential / need for import	- Export potential from Laos S = 3.5 GW (to be shared with Thailand) - Need of import : 2200 MW in the PDP
Diversification	- between Laos N and Laos S
Grid / PDP / studies	- depends on Vietnam National PDP, impact N/S flow within Vietnam grid => requires transmission study, - pending studies: Package III (Cambodia-Laos-Vietnam) interconnection study, Vietnam MP VII, Vietnam grid reinforcement study.
Base case	- 2100 MW transmission capacity in 2025

Table 3.8-9 : Evaluation of Laos South– Vietnam South interconnection

Cambodia - Vietnam South interconnection:

Economy	- Price gap : 39 to 65 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +57% to 184% - Resilience fuel price : - 42% to –76%
Export potential / need for import	- Export potential: low = Stung Treng: 980 MW – Sambor: 450 MW, no seasonal regulation, only daily peaking reservoirs. - Need of import : target 400 MW import from Cambodia in Vietnam PDP
Diversification	- between Laos N and Laos S and Cambodia hydrology
Grid / PDP / studies	- origin of power is closer to load center (HCMC) than power coming from Laos South (or Laos North)
Base case	400 MW in 2025 (L. Sessan II + complementary exchanges)

Table 3.8-10 : Evaluation of Cambodia – Vietnam South interconnection

<u>Conclusions for Vietnam</u>:

- The Vietnam grid is characterized by :
    - Two large demand centers located in the North (Hanoi region with 40% of the country demand) and in the South (HCMC region with 40% of the country demand).

  - A long North – South grid span.

Accordingly, even if the North-South Vietnam capacity transmission can be enhanced (a study on this issue is currently carried out in Vietnam), balancing the Vietnam grid will require power imports both to the North region and to the Center / South region.

Both types of transmission projects are profitable, and will be needed at 2020-2025 horizon. The economic advantage is for Laos South to Vietnam Center / South interconnection because of the highest generation cost experienced in Vietnam South (gas-fired CCGT versus coal-fired STPP in Vietnam North). However, because Vietnam is expected to become a net coal importer by 2013-2015, this situation might evolve in the future and become less so clear-cut. Indeed, it would be possible to import coal directly in the South region, and develop coal-fired generation close to HMCC demand center, thus reducing the pressure for significant North to South transmission capacities within Vietnam grid. These issues are largely outside the scope of the present GMS Master Plan study but have a direct impact on what could be the priority transmission projects to develop between Vietnam, Laos and Cambodia.

- Economic benefits of these interconnections (in other words the ranking between the North and South interconnections) will depend largely on the options taken in the new Vietnam PDP: possibility to import coal and develop coal-fired STPP in the South, reinforcement of the grid North / Center / South transmission capacity.

- In first analysis, interconnection with Cambodia might look more favorable from the grid point of view (closer to the Ho Chi Minh City large load center), and from economic point of view (larger price gap), however :

  - Cambodia hydrology is less favorable (drier dry season) and both Cambodia large HPP projects offer no seasonal regulation[43] (Stung Treng and Sambor are both daily peaking plants).

  - Hydro projects in Cambodia need to be studied at a more advanced level in order to determine more precisely their design (especially the installed capacity and the storage capacity) and their construction costs.

  - Moreover the price gap might be reduced (and become equivalent to Laos North to Vietnam North exchanges) if coal was imported in Vietnam South in order to develop coal-fired STPP in the South.

- Diversification of hydro regimes would support the development of both North and Center / South interconnection projects.

- A cumulative Impact assessment is highly recommended on Mekong River for better evaluation and combined design of Cambodia / Laos South HPP projects.

- In conclusion, the development of both North and South interconnections is promising :

  - A North interconnection (Laos North – Vietnam North),

  - A South interconnection (Laos – South / Cambodia – Vietnam Center / South).

[43] Except Lower Sessan II HPP

- As for the "South" interconnection[44], the ranking and choice between the various routes ("Laos-South -> Vietnam Center -> Vietnam South", "Laos-South -> Cambodia -> Vietnam South", "Cambodia -> Vietnam South") should be made in more focused studies (e.g., Package III), on the basis of actual network transmission studies, refined evaluation of Cambodia Mekong River projects[45], and in the lights of the new elements that will be provided by the Vietnam MP VII (once completed by the end of 2010), in particular considering the various options between developing coal-fired STPP burning imported coal in Vietnam South versus increasing the capacity of the North / South Vietnam transmission line. Other issues such as the operation of a bilateral or a trilateral transmission line should be evaluated.

- NB: China – Vietnam North interconnection is currently under study in Vietnam, and was not selected as explained in Task 5.1 report.

3.8.3 PRIORITY PROJECTS FOR THE NEXT 10 YEARS

In the next 20 - 30 years all the countries of the GMS will become interconnected, either for large scale power trades based on hydro export, or for lower scale opportunity power exchanges taking advantage of temporary surplus or needs in the different countries.

If the focus is set on the 2015-2025 period, the priority interconnection projects would be those allowing large scale power exchanges between hydro rich countries and thermal dominated importing countries. Looking at the whole GMS region, the previous discussion allows identifying these priority interconnection projects:

- Between Myanmar to China: because of the hydro potential in Myanmar and the huge needs of imports for China.

- Between Myanmar to Thailand: because of the price gap between the two countries and the important hydro potential in Myanmar.

- Between Laos North to Thailand: because of the huge hydro potential in Laos and the large price gap between the two countries.

- Between Laos S to Vietnam S (through Vietnam C): Because of the hydro potential in Laos south (3,5 GW in South) and the large price gap between the two countries.

- Between Laos North to Vietnam North: Because of the hydro potential in Laos and the price gap between the two countries.

- Between Cambodia to Vietnam South: for the export of Lower Sessan II HPP.

With a levelized cost of transmission between 7 to 11 $/MWh, to be compared to a price gap between importing and exporting countries of 30$/MWh (for coal-fired STPP dominated generation mix) to 50 $/MWh (for gas-fired CCGT dominated generation mix), all these projects are largely profitable.

[44] This remark does not refer to the export of Lower Sessan II HPP which is in the GMS Master Plan "base case".
[45] Eg 450 MW (?) Sambor and 980 MW Stung Treng HPP

Assuming the transmission projects listed in 3.3.2.1", are operational before 2015, the next group of transmission projects to be developed in the 2015-2020 horizon are:

	Additional transmission capacity required in the 2015-2020 horizon
Myanmar-China	6 000 MW
Myanmar - Thailand	1600 MW
Thailand – Laos North	600 MW
Vietnam North – Laos N	2400 MW
Vietnam Center- Laos C	900 MW
Vietnam South - Cambodia	200 MW (associated with Lower Sesan 2)

Table 3.8-11: Priority projects for 2015-2025

The development of these interconnections will be paced along the development of the associated generation export oriented projects.

For the following group of other interconnection projects, complementary studies and / or the completion of ongoing studies are required to identify the best among the possible options:

- Interconnection between Thailand and Laos South.
- Trilateral interconnection between Laos South / Cambodia / Vietnam Center and South.
- Interconnection between Cambodia and Thailand.

This does not mean these projects are a bad choice, but that additional studies are required. Accordingly, this second group of interconnection projects are for a further time horizon (beyond 2025).

4. CONCLUSIONS

4.1 THREE POLES OF DEVELOPMENT

The findings of the GMS Master Plan 2010 Study allow to outline the picture of future medium term (2025 horizon) power market in the GMS region:

- The largest power exchanges between the GMS countries will be based on hydro power export from Laos and Myanmar, toward China, Thailand and Vietnam[46].
- Because of the anticipated continuous fuel price increase, the interconnections selected in the GMS Master Plan 2010 are largely resilient (ie. robust) to an increase of the interconnection construction costs.
- The GMS regional transmission grid will develop around three main poles :

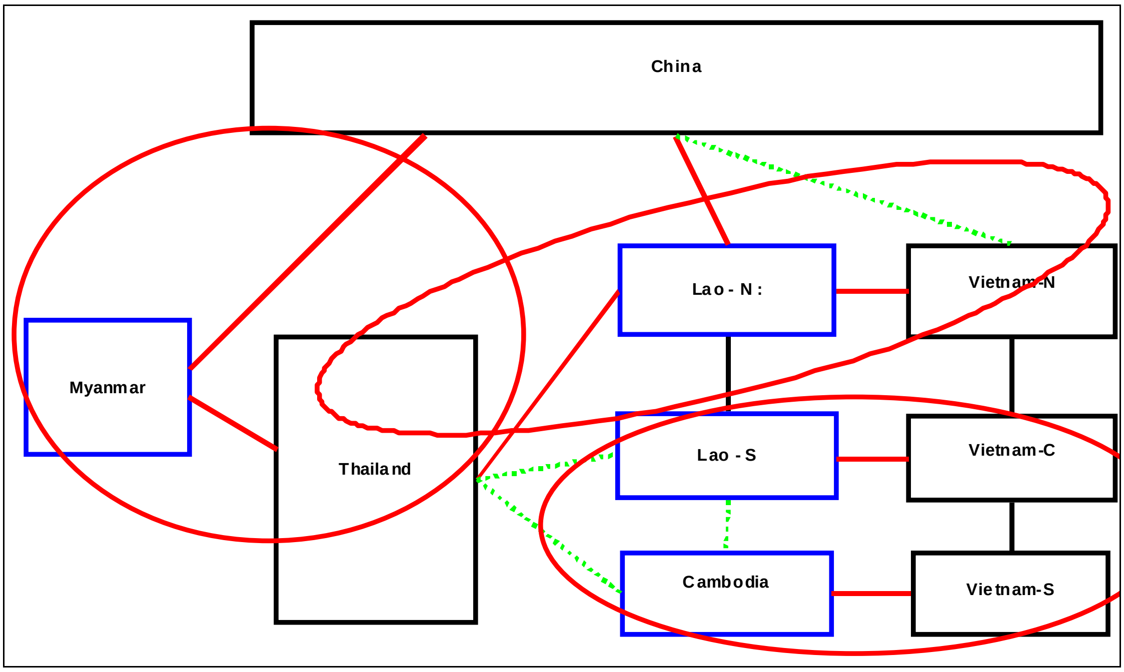


Figure 4.1-1 : Main poles of development of the future GMS transmission grid

NB: dashed green line = existing interconnections (in 2010).

- A - The North West pole will connect Myanmar to China and Thailand:
    - Taking advantage of a 28 GW hydro potential in Myanmar, substituting to more expensive thermal coal-fired generation in China and gas-fired generation Thailand.

[46] With the addition of specific lignite-fired thermal projects.
This large scale power exchanges do not exclude lower scale opportunity exchanges taking advantage of temporary surplus situation in either countries.

  - Large power interconnections (up to about 20 GW in 2028) between Myanmar and China will be developed: the development of these interconnections will be paced along the possible schedule of development of the associated large scale HPP projects in Myanmar, and also by the development of the Chinese internal transmission infrastructure necessary to transmit this large West to East power transits within CSG grid up to Guangdong region.

  - Large power interconnections between Myanmar and Thailand will be developed (> 5500 MW in 2028).

- B - The East-West Northern link will connect Thailand, Laos North, Vietnam North and possibly China :

  - Taking advantage of the 10 GW hydro potential in Laos North, substituting to thermal generation in Thailand, Vietnam North, and possibly China.

  - This link will open the possibility to opportunity exchanges between Thailand and Vietnam if any surplus situation was to occur in one of these countries, as well as exchanges between Laos and Thailand or Vietnam in case of very dry hydrological conditions in Laos.

- C - The Southern pole will connect Cambodia, Laos South, Vietnam Center and South :

  - Taking advantage of the 5 GW hydro potential in Cambodia and Laos South[47].

- This development of the GMS power market along these three relatively independent sub regional poles is in line with the emergence of subregional markets preceding the development of an integrated regional market, as explained further in Module 4 report. Indeed the full development of an integrated regional market does take a significant length of time as shown by the following figure presenting the various sub-regional power markets currently existing in Western Europe (2010).

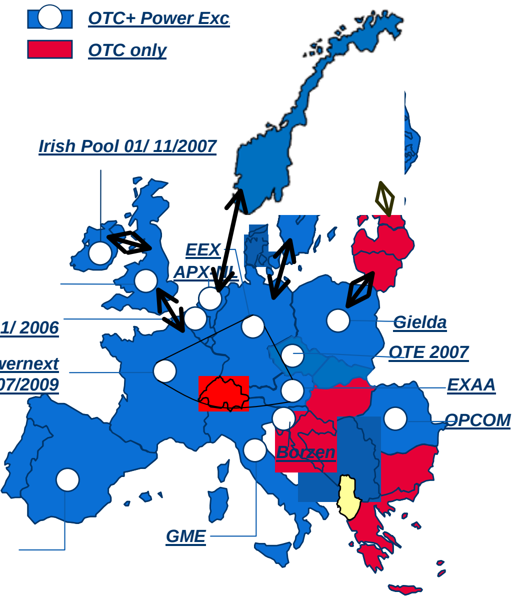


Figure 4.1-2: Current existing sub-regional power market in Western Europe

[47] Or 7 GW potential if the capacity of Cambodia Sambor HPP is assumed to be 2000 MW instead of 450 MW)

4.2 GMS MASTER PLAN 2010

The following table presents the schedule of existing, committed and candidate interconnection projects in the GMS Master Plan base case:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Laos-S	Cambodia	20					40														0

Table 4.2-1: Base case - Schedule of new interconnections (MW)

Benefits provided by the expansion of interconnections:

Compare to a "no expansion" case, where only the interconnection projects committed up to 2015 are developed, this "base case" provides :

- A global cost savings for the Greater Mekong Subregion of 14 310 M$ (discounted value over the 2010-2030 period),
- A reduction of CO_2 emission by 14.2 Mt / year in 2020.

High export case:

In the "base case", the remaining hydro potential left in 2028 is concentrated in Myanmar (about 7 GW), and on the mainstream of Mekong river : 9 large scale run of river HPP projects from 1000 to 1400 MW installed capacity (out of a total of 11 identified hydro projects).

Increasing the hydro based export compared to the "base case" situation would obviously increase the generation savings for the region, but a realistic evaluation of the Mekong River potential (number and capacity of the hydro projects) could only be made through a Cumulative Impact Assessment study of the mainstream Mekong River.

Remarks on Vietnam PDP:

Because of the structure of Vietnam future generation mix considered in MP VI (dominated by low cost coal-fired STPP in the North, and more expensive gas-fired CCGT in the South), the Study showed that a constant 2000 MW transmission capacity between Vietnam South and Center is suboptimal. Going up to 5000 MW would be beneficial, allowing additional power "import" from coal-fired STPP located in Vietnam North to save the generation from more expensive NG-fired CCGT located in Vietnam South.

However, if a cost for CO_2 emission is considered (50\$/tCO_2 until 2020 and 65 \$/tCO_2 beyond), the price gap between the coal-fired STPP in the Vietnam North and gas-fired CCGT in Vietnam South will be reduced and a constant 2000 MW transmission capacity would be sufficient.

These remarks on the optimal transmission capacity within Vietnam national transmission grid are largely dependant on the hypotheses considered for the development Vietnam power generation mix, which are known to be largely obsolete in the Vietnam MP VI used for the study (Vietnam MP

VII will be released by end of 2010?). Indeed, from 2013-2015 Vietnam will start to import part of the coal necessary to the coal-fired STPP. This leads to the opportunity to "re-balance" the future Vietnam generation mix, developing more coal-fired STPP in Vietnam South than considered in MP VI, which would in turn reduce the need of large power transit between North and South Vietnam.

Comparison with GMS Master Plan 2008 results:

The main differences of hypotheses with the MP 2008 are:

- Use of international fuel price instead of local / subsidized price,
- Use of consistent investment and homogeneous costs for generation and transmission projects for the whole region,
- Mostly hydro-based power export instead of thermal-based power export,
- Updated demand projection.

The MP2010 reaches most of the same conclusions as MP2008, except for the following lines which are not developed or reinforced in MP2010:

- Thailand-China,
- Thailand- Laos South,
- China- Vietnam North.

4.3 PRIORITY INTERCONNECTION PROJECTS

All transmission projects planned until 2015 are considered as committed, i.e., already approved:

Project reference number	Location 1	Location 2	Voltage	Capacity	Length	Year
2	Xe Kaman 3 HPP, south Laos	Da Nang (Hoa Khanh substation), central Vietnam	220 kV double circuit	250 MW	135 km	2010
3	Ban Soc / Ban Hat, south Laos	Pleiku, Vietnam	500 kV double circuit	1,000 MW	190 km	2014
7a	Lower Se San 2 HPP, Cambodia	Pleiku, Vietnam	230 kV double circuit	200 MW	230 km	2016
13	Nam Theun 2 HPP, Laos	Roi Et 2, Thailand	500 kV double circuit	1,000 MW	304 km	2010
14	Na Bong, Laos	Udon Thani, Thailand	230 kV in 2010 500 kV in 2015	225 MW in 2010 1,000 MW in 2015	107 km	2010 2015
15	Hong Sa TPP, Laos	Mae Moh,	500 kV	1,700 MW	210 km	2015

		Thailand	Three or four circuits			

Table 4.3-1 : List of interconnections projects committed up to 2015

Accordingly, this paragraph considers the priority between the interconnection projects beyond 2015 and up to 2025.

The question of priority between the interconnection projects can be tackled from the country or from the regional point of view.

In addition to the economic criterion (i.e., savings provided by the interconnection project) other criteria are involved in ranking the interconnection projects:

- The volume of potential export (i.e., resources in the exporting country).
- Level of advance of the export-oriented hydro generation project study (desktop study, pre-feasibility study feasibility study, design study), of the associated agreement (MOU, PPA), and the duration of the construction of underlying HPP (or TPP) projects. As a thumb rule, the study process can last a total of 2 to 5 years, and the construction between 3 to 6 years depending on the project characteristics.

  This implies that the interconnection projects to be built in the period 2015-2020 will be associated with hydro projects which are already at an advanced stage of study.
- The need for import of the receiving country (in that case, a lower price gap between both countries would be accepted),
- Complementary aspects:
  - Diversification of sources of import,
  - Grid conditions,
  - Uncertainties or incompleteness of data: some projects might be affected by data gaps, associated studies available only at early stage, dependence on evolution of other factors.

4.3.1 PRIORITY PER COUNTRY

Projects to China :

- The interconnection project between Myanmar and China ranks first because of larger price gap and the huge Myanmar hydro potential.
- China-Laos ranks second because of a lower price gap and hydro potential in Laos (shared with Thailand and Vietnam).

Projects to Thailand:

- Interconnections between Thailand and Myanmar, Laos and Cambodia are largely profitable (compared to domestic CCGT generation).

- o Diversification of imports (countries and hydrology) favors the development of these interconnections, at least between Myanmar-Thailand and Laos North -Thailand.

- o The list of the first interconnection projects to be developed depends largely on the list of most promising exported oriented generation projects. This list corresponds to the HPP (or TPP) having being studied at the most advanced level, from technical studies and commercial point of view (tariff MOU). Grid study would be necessary. Accordingly, the priority would be on Myanmar – Thailand interconnection and Laos North - Thailand interconnection, as indicated in the GMS Master Plan “base case”.

- o Thailand - Cambodia interconnection seems less promising because of much lower hydro potential, less favorable hydro regime, and technical study of HPP projects at a less advanced level.

- o These “North” or “South” interconnections will contribute to build a future East-West backbone between Thailand, Laos and Vietnam.

Projects to Vietnam:

- o The Vietnam grid is characterized by :

  - Two large demand centers located in the North (Hanoi region with 40% of the country demand) and in the South (HCMC region with 40% of the country demand).

  - A long North – South grid span.

Accordingly, even if the North-South Vietnam capacity transmission can be enhanced (a study on this issue is currently carried out in Vietnam), balancing the Vietnam grid will required power imports both to the North region and to the Center / South region.

Both types of transmission projects are profitable, and will be needed at 2020-2025 horizon. The economic advantage is for Laos South to Vietnam Center / South interconnection because of the highest generation cost experienced in Vietnam South (gas-fired CCGT versus coal-fired STPP in Vietnam North). However, because Vietnam is expected to become a net coal importer by 2013-2015, this situation might evolve in the future and become less so clear-cut. Indeed, it would be possible to import coal directly in the South region, and develop coal-fired generation close to HMCC demand center, thus reducing the pressure for significant North to South transmission capacities within Vietnam grid. These issues are largely outside the scope of the present GMS Master Plan study but have a direct impact on what could be the priority transmission projects to develop between Vietnam, Laos and Cambodia.

- o Economic benefits of these interconnections (in other words the ranking between the North and South interconnections) will depend largely on the options taken in the new Vietnam PDP: possibility to import coal and develop coal-fired STPP in the South, reinforcement of the grid North / Center / South transmission capacity.

- o In first analysis, interconnection with Cambodia might look more favorable from the grid point of view (closer to the Ho Chi Minh City large load center), and from economic point of view (larger price gap), however :

   - Cambodia hydrology is less favorable (drier dry season) and both Cambodia large HPP projects offer no seasonal regulation[48] (Stung Treng and Sambor are both daily peaking plants).
   - Hydro projects in Cambodia need to be studied at a more advanced level in order to determine more precisely their design (especially the installed capacity and the storage capacity) and their construction costs.
   - Moreover the price gap might be reduced (and become equivalent to Laos North to Vietnam North exchanges) if coal was imported in Vietnam South in order to develop coal-fired STPP in the South.

- Diversification of hydro regimes would support the development of both North and Center / South interconnection projects.
- A cumulative Impact assessment is highly recommended on Mekong River for better evaluation and combined design of Cambodia / Laos South HPP projects.
- In conclusion, the development of both North and South interconnections is promising :
   - A North interconnection (Laos North – Vietnam North),
   - A South interconnection (Laos – South / Cambodia – Vietnam Center / South).
- As for the "South" interconnection[49], the ranking and choice between the various routes ("Laos-South -> Vietnam Center -> Vietnam South", "Laos-South -> Cambodia -> Vietnam South", "Cambodia -> Vietnam South") should be made in more focused studies (eg Package III), on the basis of actual network transmission studies, refined evaluation of Cambodia Mekong River projects[50], and in the lights of the new elements that will be provided by the Vietnam MP VII (once completed by the end of 2010), in particular considering the various options between developing coal-fired STPP burning imported coal in Vietnam South versus increasing the capacity of the North / South Vietnam transmission line. Other issues such as the operation of a bilateral or a trilateral transmission line should be evaluated.

4.3.2 PRIORITY PROJECTS FOR THE NEXT 10 YEARS

In the next 20 - 30 years all the countries of the GMS will become interconnected, either for large scale power trades based on hydro export, or for lower scale opportunity power exchanges taking advantage of temporary surplus or needs in the different countries.

If the focus is set on the 2015-2025 period, the priority interconnection projects would be those allowing large scale power exchanges between hydro rich countries and thermal dominated importing countries. Looking at the whole GMS region, the previous discussion allows identifying these priority interconnection projects:

[48] Except Lower Sessan II HPP
[49] This remark does not refer to the export of Lower Sessan II HPP which is in the GMS Master Plan "base case".
[50] Eg 450 MW (?) Sambor and 980 MW Stung Treng HPP

- Between Myanmar to China: because of the hydro potential in Myanmar and the huge needs of imports for China.

- Between Myanmar to Thailand: because of the price gap between the two countries and the important hydro potential in Myanmar.

- Between Laos North to Thailand: because of the huge hydro potential in Laos and the large price gap between the two countries.

- Between Laos S to Vietnam S (through Vietnam C): Because of the hydro potential in Laos south (3,5 GW in South) and the large price gap between the two countries.

- Between Laos North to Vietnam North: Because of the hydro potential in Laos and the price gap between the two countries.

- Between Cambodia to Vietnam South: for the export of Lower Sessan II HPP.

With a levelized cost of transmission between 7 to 11 $/MWh, to be compared to a price gap between importing and exporting countries of 30$/MWh (for coal-fired STPP dominated generation mix) to 50 $/MWh (for gas-fired CCGT dominated generation mix), all these projects are largely profitable.

Assuming the transmission projects listed in § 3.3.2.1 are operational before 2015, the next group of transmission projects to be developed in the 2015-2020 horizon are:

	Additional transmission capacity required in the 2015-2020 horizon
Myanmar-China	6 000 MW
Myanmar - Thailand	1600 MW
Thailand – Laos North	600 MW
Vietnam North – Laos N Vietnam Center- Laos C Vietnam South - Cambodia	2400 MW 900 MW 200 MW (associated with Lower Sesan 2)

Table 4.3-2: Priority projects for 2015-2025

The development of these interconnections will be paced along the development of the associated generation export oriented projects.

For the following group of other interconnection projects, complementary studies and / or the completion of ongoing studies are required to identify the best among the possible options:

- Interconnection between Thailand and Laos South.

- Trilateral interconnection between Laos South / Cambodia / Vietnam Center and South.
- Interconnection between Cambodia and Thailand.

This does not mean these projects are a bad choice, but that additional studies are required. Accordingly, this second group of interconnection projects are for a further time horizon (beyond 2025).

5. RECOMMENDATIONS

The Consultants recommends developing future actions along three main directions:

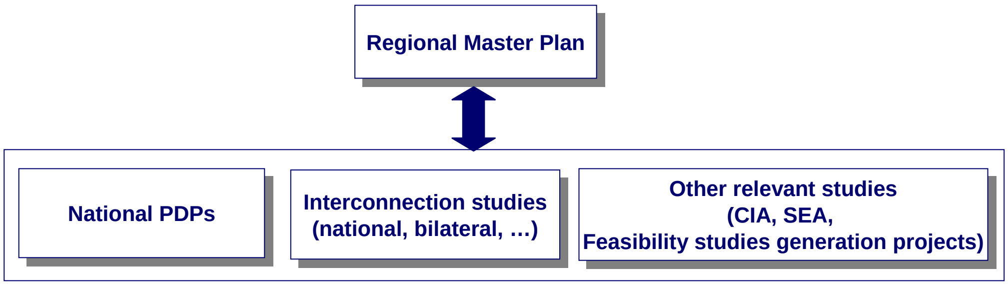
- Better assessment of the hydro generation potential,
- Regional and national studies,
- Capacity building.

Better assessment of hydro generation potential:

- The main mechanism for power exchanges in the GMS will be based on large scale hydro generation export. Accordingly, one of the main determinants of the development of the GMS interconnection grid is the list and location of the “best” and “more promising” export-oriented hydro projects in the GMS region. As a consequence :
    - There is a need to refine investment costs, hydrology, and social / environmental impacts of these hydro export projects.
    - A large part of the economical power export potential in Cambodia and Laos is from large (1000 to 1400 MW) HPP projects on Mekong River. Accordingly, the Consultant recommends to carry out a cumulative impact of these Mekong River projects to answer the following questions: What are the impacts of such projects on fishery, navigation, resettlement, etc...? What is the realistic potential considering social and environmental impacts? What is the “realistic” dimensioning of these projects? What is the global ranking of these Mekong River HPP projects (based on all these elements) and the “best group of HPP projects”.
    - Assessment of the environmental and social impacts of all major hydro projects is required in order to take into account these externalities in the planning model.
    - Improvement of the hydrology of Myanmar and Vietnam HPP projects is required. Historical inflows series in m3/s were not available for Myanmar and Vietnam HPP projects. A better representation of hydro variability in these countries is possible in the future version of GMS Master Plan provided these inflows series are made available.

Regional and National studies:

- A regional Master Plan study is part of an iteration process involving wide scope analyses (regional SEA, regional Master Plan) and more focussed studies (national studies, interconnection studies, CIA, EIA, feasibility studies of HPP projects, etc):



- A number of national or regional studies are currently undergoing:
    - National PDP updates in China, Thailand, Vietnam,
    - Cambodia-Laos-Vietnam interconnection study (ADB- Package III),
    - Vietnam grid reinforcement study,
    - China – Vietnam interconnection study,
    - Cumulative Impact Assessment of hydro projects on mainstream Mekong River.

  The general vision of the GMS Master Plan will be certainly enriched by the results of these new studies. Accordingly, the Consultant recommends reviewing the findings of the 2010 GMS Master plan in views of these future new results.

- Transmission study on the North – South transits on Vietnam national grid :
    - There is a need for load flow studies, stability analysis, evaluation of maximum transit capacity and options of grid reinforcements, impact on Vietnam North / Center South PDP, impact on the possible amount of import from Laos South and Laos North. At Workshop n°4 (Bangkok, June 2010) the Vietnam representatives indicated that a Consultant has been selected to study to the various options of reinforcement of the Vietnam grid.
    - The outcome of the new Vietnam PDP update will probably have a strong impact on the options of transmission development between Laos South, Cambodia, Vietnam Center and South. In particular: how much power can be imported from Laos South through Vietnam Center to Vietnam South load Center, how many HPP projects can be developed in Vietnam Center.

- Further to the previously mentioned studies, there is a need to launch studies on :
    - Priority interconnection projects.
    - Large scale HPP projects (in particular on Mekong River mainstream).

- <u>Capacity building</u>:
    - It is recommended to enhance the development of transmission and generation investment planning skills in the GMS. It particular, it is recommended to create a devoted Power Development Plan team in Cambodia.