Chapter 4

Preliminary Assessment of Possible Interconnection

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CHAPTER 4

PRELIMINARY ASSESSMENT OF POSSIBLE INTERCONNECTION

This chapter will select candidates for interconnection that would conceivably be effective based on the considerations of the previous chapter, and attempt to calculate the economic effects, including a rough estimation of the cost of constructing interconnected transmission lines. After these considerations, priorities are set for these selected interconnection lines.

4.1. Exploring interconnection cases

Based on the results from the previous chapter, interconnection lines that appear to have significant advantages will be selected, and the economic effects arising from each interconnection will be calculated and compared.

The main criterion for selection is the amount of estimated power flow. Among a number of possible interconnection lines, the lines that are estimated to have larger power flows than the others will be selected.

In this regard, the following cases were explored:

Case A: Thailand (THA) – Cambodia (KHM)
Case B: Thailand (THA) – Laos (LAO)
Case C: Thailand (THA) – Myanmar (MYA)
Case D: Myanmar (MYA) – Thailand (THA) – Malaysia (MYS) – Singapore (SGP)
Case E: Viet Nam (VNM) – Laos (LAO) – Thailand (THA)
Case F: Malaysia (MYS) – Indonesia (IDN)
Case G: Laos (LAO) – Thailand (THA) – Malaysia (MYS) – Singapore (SGP)

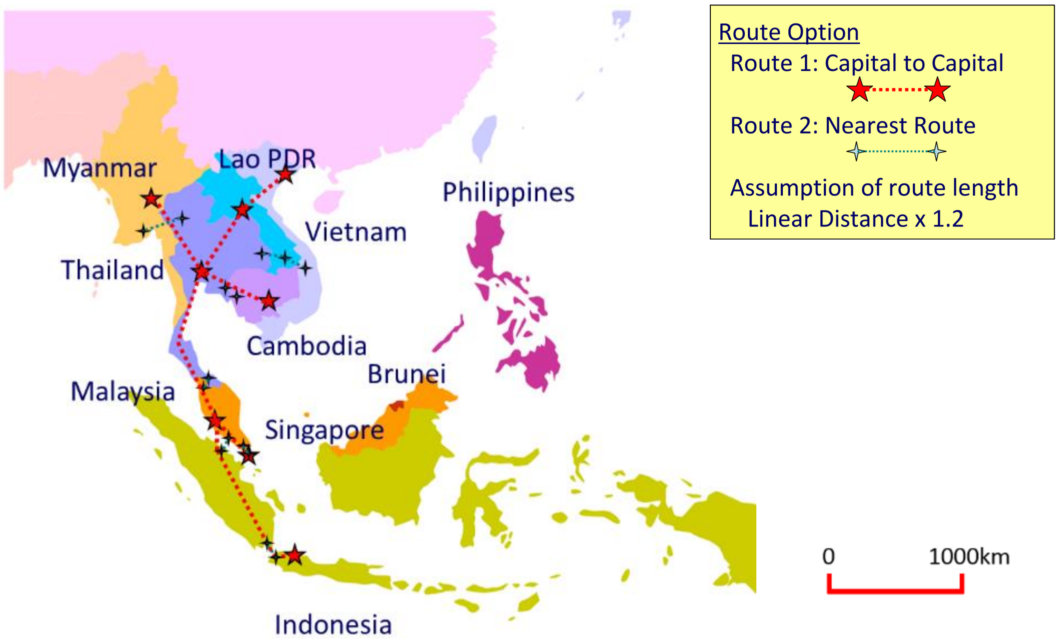
4.2. Route considerations for interconnected transmission lines

When considering ~~a~~ transmission system interconnection between two countries, it is necessary to confirm the condition of the transmission systems of each country in detail, and then decide the optimum connection points and detailed interconnection routes. However, the goal of this study is a preliminary assessment of the relationship between the effects of interconnection and the cost. Hence, issues such as connection points and detailed routes will be the subject of future investigation. Taking that into consideration and given the need to determine routes as a reference for transmission line costs, the most appropriate approach is to configure two routes – a comparatively long-distance route and the shortest possible route – and present the hypothetical costs as a range.

Based on this assumption, Route 1 shall be a comparatively long-distance route linking capital cities, and Route 2 shall be linking short distance points with existing substations wherever possible.

Additionally, because it is not possible to establish detailed routes in this study, the transmission route length shall be set as 1.2 times the linear distance between two points.

Figure 4.1: How routes are considered in each case



The route lengths that were calculated on that basis are as follows:

Table 4.1: Route length calculation results (Route 1)

Case		Point Name	Linear Distance [km]	Route Distance [km]
A	THA-KHM	Bangkok-Phnom Penh	530	636
B	THA-LAO	Bangkok-Vientiane	530	636
C	THA-MYA	Bangkok-Naypyidaw	800	960
D	MYA-THA-MYS-SGP	Naypyidaw-Bangkok	800	960
		Bangkok-Kuala Lumpur	1350	1620
		Kuala Lumpur-Singapore	350	420
E	VNM-LAO-THA	Hanoi-Vientiane	480	576
		Vientiane-Bangkok	530	636
F	MYS-IDN	Kuala Lumpur-(coast of Malay Peninsula)	50	60
		Malay Peninsula - Sumatra Island	90	108
		in Sumatra Island	1200	1440
		Sumatra Island - Java Island	50	60
		(coast of Java Island)-Jakarta	120	144
G	LAO-THA-MYS-SGP	Vientiane-Bangkok	530	636
		Bangkok-Kuala Lumpur	1350	1620
		Kuala Lumpur-Singapore	350	420

Table 4.2: Route length calculation results (Route 2)

Route		Point Name	Linear Distance [km]	Route Distance [km]
A	THA-KHM	Chanthaburi SS - Lower Stug Russey SS	100	120
B	THA-LAO	Ubon 3 SS - Ban Sok SS	200	240
C	THA-MYA	Mae Moh 3 SS - Yangon	450	540
D	MYA-THA-MYS-SGP	Yangon - Mae Moh 3 SS	450	540
		Khlong Ngae SS - Gurun SS	110	132
		Top of Malay Peninsula - Singapore	20	24
E	VNM-LAO-THA	Pleiku SS - Ban Sok SS	120	144
		Ban Sok SS- Ubon 3 SS	200	240
F	MYS-IDN	Malay Peninsula - Sumatra Island	90	108
		Sumatra Island - Java Island	50	60
G	LAO-THA-MYS-SGP	Ban Sok SS- Ubon 3 SS	200	240
		Khlong Ngae SS - Gurun SS	110	132
		Top of Malay Peninsula - Singapore	20	24

4.3. Cost considerations for interconnected transmission lines

4.3.1. Cost components of interconnected transmission lines

When establishing interconnected transmission lines, the necessary costs can be broadly categorised as 1) construction costs; and 2) operating and maintenance (O&M) costs.

The cost of constructing transmission lines would generally be the cost of obtaining (purchasing) the land, the cost of the materials (transmission towers, electric cables, insulators, etc.), the construction labor costs, and so on. However, these costs will change depending on various elements, including the country, location, and environmental condition where the lines are being constructed. For a rigorous cost estimate, it would be necessary to confirm and configure each of those elements in detail. However, because this study only involves a preliminary assessment, the construction costs are simplified.

That being the case, in preliminary assessments, the general approach taken in calculating transmission line construction costs is to establish a unit construction cost per unit length (1 km) and then multiply it with the route length. This is also the approach taken in this study.

It should be pointed out that in all the cases, the interconnected transmission lines to be constructed are assumed to be 500kV transmission lines. The unit construction costs for overhead lines and undersea cables are calculated and set based on actual market prices in recent years.

Where O&M costs are concerned, conceivable costs include the cost of labor for regular patrols, the cost of fuel for traveling, the cost of materials when making repairs, insurance costs when working in high places, and so on. However, due to the difficulty in setting and adding up these costs in detail, generally speaking again, in many cases, a certain annual amount is assumed as the cost, and that amount is established as a fixed ratio of the construction cost. As such, O&M costs in this study are established as an annual cost that is 0.3 percent of the construction costs.

4.3.2. Setting unit construction costs

Unit construction costs (unit cost per km) were calculated as follows:

Figure 4.2 plots the actual contract costs of major transmission line construction projects (500kV) in Southeast Asia in recent years (the past decade) against the transmission line route lengths (two circuits for overhead transmission lines and one circuit for undersea cable).

Figure 4.2: Actual transmission line construction costs in neighbouring countries (500kV overhead lines)

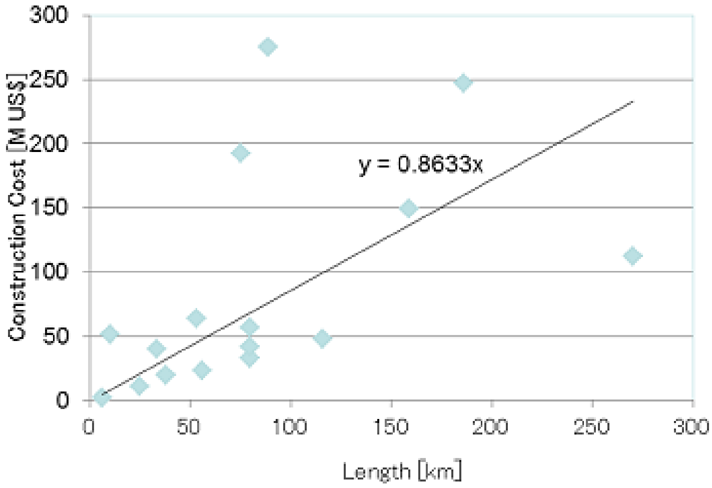
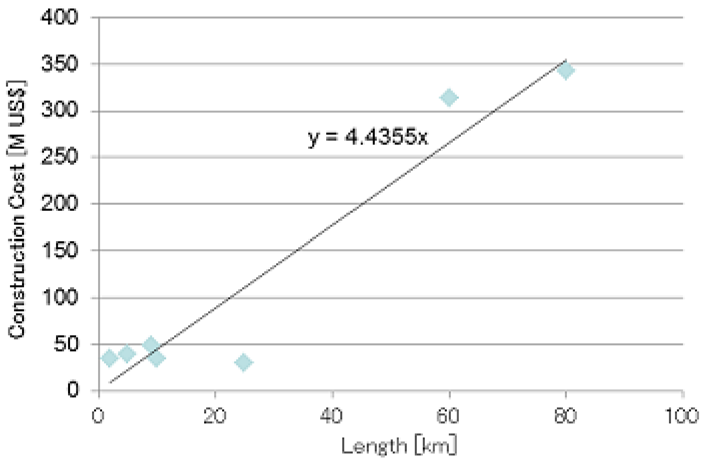


Figure 4.3: Actual transmission line construction costs in neighbouring countries (500kV undersea cable)



Seeking an average value by adding an approximate straight line to each graph based on these data produced the following results:

<Overhead line>

According to the approximate line y=0.8633x, the cost is roughly 0.9 million USD/km/2 circuits overhead lines, so a unit construction cost figure of 0.45 million USD/km/circuit overhead line is established.

<Undersea cable>

According to the approximate line y=4.4355x, the cost is roughly 4.5 million USD/km/1 circuit undersea cable, so a unit construction cost figure of 5 million USD/km/1 circuit undersea cable is established.

4.3.3. Setting conditions for alternative current (AC) transmission lines

Next, the following respective conditions are set as conditions for calculating the construction costs of AC transmission lines. Note that AC overhead lines should be applied to all of Cases A to E.

(1) Voltage

In the region that is subject to this study, 500kV transmission lines are currently widely used as transmission lines for carrying large quantities of power. For the purposes of this study, the interconnected transmission lines shall also be considered as 500kV transmission lines in all cases.

(2) Transmission capacity

A single circuit power line (wire) has a threshold figure for the power it can stably transmit. To carry power in excess of that threshold, it is necessary to increase the number of circuits. As a result, the number of circuits must be set according to the maximum amount of power that may be carried.

This study assumes the use of wires that are commonly utilised in many projects, and sets the transmission capacity per circuit at 1.8GW.

(3) Number of circuits

As stated in (2) above, it is necessary to set the number of circuits according to the maximum power that may be carried. Usually, a spare circuit is allocated to prevent accidental disconnection of electric power flow. Thus, in addition to the number of circuits required to transmit the maximum power, an additional circuit is added as a spare.

(4) Intermediate switching stations (or substations)

In the case of AC transmission lines, intermediate switching stations are generally set up when the route length is long in order to stabilise the voltage and partition circuits during accidents. This study assumes that one switching station (or substation) is set up for every 160km. Switching station construction costs were considered as follows:

(a) Cost components of switching station construction

The costs of constructing switching stations include the cost needed to acquire and develop the land where the switching stations will be located and the facilities and equipment costs (including the installation cost). However, in order to simplify cost estimation, land-related and common equipment costs are consolidated as “fixed costs” and viewed as necessary costs common to a single switching station. Meanwhile, costs associated with the equipment required according to the number of circuits are added to this as “additional costs,” with the total amount being a sum of these components. For the additional cost, the unit cost per circuit is multiplied by the number of circuits.

(b) Setting an amount for the fixed cost

The fixed cost will change according to the location of the switching station and the equipment types, but for the purpose of this study, it is necessary to estimate the cost on the safe side. Examining actual cost of new substation construction projects in neighbouring countries show~~s~~ that in many cases, this fixed cost component was around 10 million USD and is consequently assumed here that:

Fixed cost = 20 million USD

(c) Setting an amount for the unit additional cost

Similarly, examining actual cases in neighbouring countries shows that unit additional costs mostly fluctuated around several million US dollars. Consequently, this study assumed that:

Unit additional cost = 10 million USD / line

(d) Switching station construction cost

Based on the above, the cost of constructing a switching station is found using the following formula:

Switching station construction cost = fixed cost + unit additional cost × number of circuits = 20 million USD + 10 million USD × number of circuits.

4.3.4. Setting the conditions for direct current (DC) transmission lines

In Case F, if the power systems of Malaysia and Indonesia were to be interconnected, then connecting the Malay Peninsula and Sumatra, and Sumatra and Java, would be unavoidable. In other words, it would initiate crossing the sea in two places whereby undersea cables would be required.

With undersea cables, the charging current grows too high if AC is used and so equipment is needed at mid-course to compensate. However, when the undersea cable is long (generally 30km or longer), compensation equipment requires land for installation for every around 30km; hence, DC line is used.

If DC is used, the issue of stability does not arise even in cases of long distance transmission. However, equipment for converting the AC and DC (an AC/DC converter) is needed at both ends of the AC system.

(1) Voltage

As with AC, it is assumed that 500kV (±500kV for DC) will be employed.

(2) Transmission capacity

DC transmission can generally carry higher currents than AC transmission. Here, the transmission capacity per line is set as 3.0 GW for overhead lines and undersea cables. Accordingly, in Case F, the transmission capacity is up to 2.2 GW, so only a single circuit is required.

(3) Number of circuits and unit construction costs

With DC transmission systems, in the event of an accident, the impact on the system can be controlled using the AC/DC converters at the connection points. Therefore, in general, backup lines are not set up.

The construction costs concerning the overhead line portion will be lower because the towers are simple compared to AC transmission. Therefore, the unit construction cost for DC overhead transmission lines is assumed to be two-thirds of the unit cost of two circuits AC lines (0.9 million USD/km) and is set at 0.6 million USD/km. With regards to the undersea cable portion, the unit construction cost is set as 5 million USD/km, as found in section 4.3.2.

(4) AC/DC conversion stations

As stated above, DC transmission systems require installations of AC/DC converters at the points of connection with the AC system. Generally, these facilities resemble large substations, and the AC/DC converters are costly. Here, a unit cost per 1 GW is set at 150 million USD/GW. Because the transmission capacity in Case F is 2.2GW, the cost per site will be 330 million USD.

With regards to the necessary number of converters, they will be required at both ends (the Malaysia side and the Indonesia side) or at two sites because with Route 1, DC transmission is to be applied on all lines and with Route 2, they will be needed at both ends of the two sections where crossing the sea takes place. Hence, a total of four sites will be needed.

4.3.5. Cost calculation results

Based on the above assumptions, the construction costs that were calculated for the interconnected transmission lines in the respective cases are shown in Table 4.3.

Table 4.3: Transmission line construction costs (Route 1)

Case		Point Name	No. of Circuit	No. of SS	Cost of 1 SS	Construction Cost [Mil USD]	
A	THA-KHM	Bangkok-Phnom Penh	3	3	50		1,009
B	THA-LAO	Bangkok-Vientiane	6	3	80		1,957
C	THA-MYA	Bangkok-Naypyidaw	8	5	100		3,956
D	MYA-THA-MYS-SGP	Naypyidaw-Bangkok	8	5	100	3,956	6,272
		Bangkok-Kuala Lumpur	2	10	40	1,858	
		Kuala Lumpur-Singapore	2	2	40	458	
E	VNM-LAO-THA	Hanoi-Vientiane	3	3	50	928	2,885
		Vientiane-Bangkok	6	3	80	1,957	
F	MYS-IDN	Kuala Lumpur-(coast of Malay Peninsula)	2	1	330	366	1,901
		Malay Peninsula - Sumatra Island	1	0		302	
		in Sumatra Island	2	8		648	
		Sumatra Island - Java Island	1	0		168	
		(coast of Java Island)-Jakarta	2	1	330	416	
G	LAO-THA-MYS-SGP	Vientiane – Bangkok	6	3	80	1,957	4,273
		Bangkok – Kuala Lumpur	2	10	40	1,858	
		Kuala Lumpur – Singapore	2	2	40	458	

Table 4.4: Transmission line construction costs (Route 2)

Route		Point Name	No. of Circuit	No. of SS	Cost of 1 SS	Construction Cost [Mil USD]	
A	THA-KHM	Chanthaburi SS - Lower Stug Russey SS	3	0	50		162
B	THA-LAO	Ubon 3 SS - Ban Sok SS	6	1	80		728
C	THA-MYA	Mae Moh 3 SS - Yangon	8	3	100		2,244
D	MYA-THA-MYS-SGP	Yangon - Mae Moh 3 SS	8	3	100	2,244	2,384
		Khlong Ngae SS - Gurun SS	2	0	40	119	
			2	0	40	22	
E	VNM-LAO-THA	Pleiku SS - Ban Sok SS	3	0	50	194	922
		Ban Sok SS- Ubon 3 SS	6	1	80	728	
F	MYS-IDN	Malay Peninsula - Sumatra Island	3	0	50	962	1790
		Sumatra Island - Java Island	3	0	50	828	
G	LAO-THA-MYS-SGP	Ban Sok SS- Ubon 3 SS	6	1	80	728	868
		Khlong Ngae SS – Gurun SS	2	0	40	119	
			2	0	40	22	

4.4. Comparative calculation of benefits

Using the results above, the benefits of each case were calculated and compared. In the previous chapter, the change in costs with or without interconnection between the two countries was calculated for each case (development cost increases for hydropower potential, reduced thermal power generation fuel costs result from power interchange, and reduced power plant development costs arise from lower reserve rates). The overall benefit outcomes were calculated by adding the cost of interconnected transmission lines.

Similar to the previous chapter's cost calculations, the method for adding the cost of the interconnected transmission lines was undertaken in the following way:

- The construction of the transmission lines was assumed to take place in 2025, with the full cost to be added that year.
- The O&M cost was assumed to be added annually from the following year of 2026.
- A discount rate of 10 percent was assumed, and net present value at the time of 2025 is calculated.
- The difference compared for both cases -- [without interconnection] minus [with interconnection] -- was calculated on a cumulative basis for the 10-year period from 2025 to 2035.

  * A plus value means gain in benefit.

The results of the above calculations are as follows:

Table 4.5: Estimated cost benefit of new transmission line

Case		Estimated cost benefit [mil.USD]		
		without interconnection line cost	net benefit with Route 1 line cost	net benefit with Route 2 line cost
A	THA-KHM	5,644	4,560	5,470
B	THA-LAO	21,387	19,282	20,604
C	THA-MYA	(352)	(4,607)	(2,766)
D	MYA-THA-MYS-SGP	5,628	(1,118)	3,064
E	VNM-LAO-THA	24,707	21,604	23,715
F	MYS-IDN	6,012	3,968	4,087
G	LAO-THA-MYS-SGP	27,490	23,217	26,557

* Numbers in brackets are negative.

Starting from the left, the table shows the results of calculating what the cost benefit would be in these cases:

- Interconnection line cost not included
- Interconnection line cost included for Route 1
- Interconnection line cost included for Route 2

4.5. Evaluating the calculation results

Based on the above calculation results, the following evaluations can be made:

- In Case G (interconnection between Laos, Thailand, Malaysia and Singapore) or in Cases E and B (interconnection between Thailand, Laos and Viet Nam), the cost-reduction arising from interconnection appears to be significant. Of the seven cases, the size of the cost benefit is largest in these cases.
- In Case A (interconnection between Thailand and Cambodia) and in Case F (between Malaysia and Indonesia), although the overall reduction amount is not as large as in B, E and G, there is a strong possibility of cost reductions even if the interconnection line cost is taken into account.
- In Case D (interconnection between Myanmar, Thailand, Malaysia and Singapore), a detailed assessment and cost reduction in constructing transmission line should be evaluated to uncover any potential benefit.

- In Case C (interconnection between Thailand and Myanmar), the cost increases following hydropower development; thus, immediate benefit from interconnected lines cannot be anticipated. However, it is possible to anticipate further increase of benefit in the longer term.

Because this study is a preliminary assessment, the cost estimation is not perfectly accurate. Therefore, while a comparative evaluation is possible to a certain extent, a detailed and definitive evaluation is not possible at present. In the future, it will therefore be necessary to utilise these cases and proceed with a more detailed evaluation.