

Interconnections of Transmission Networks in Southeast Asia: A Preliminary Assessment for Thailand

Somboon Nuchprayoon

Abstract— This paper presents a preliminary assessment of the interconnections of transmission networks between Thailand and other countries in Southeast Asia under the ASEAN Power Grid (APG) program. This paper initially reviews the electric supply industry of Thailand which is under regulatory and market reforms. Given a new market structure, this paper attempts to assess opportunities and risks for the country from both technical and economic aspects. Load forecasting as well as generation and transmission expansion plans are prepared for different scenarios. Market concentration, transmission facilities, security and reliability of network interconnections are evaluated before and after the interconnections. An impact of interconnections on competition of the electric supply industry of the country is discussed.

Index Terms— electricity restructuring, electric supply industry, market power.

I. OVERVIEW OF THAI ELECTRIC SUPPLY INDUSTRY

ALTHOUGH the Thai government publicly announced its intention to reform the electric supply industry (ESI), the Thai ESI has been reformed slowly over the last decade in terms of its structure and organization [1], [2]. This slow progress is due to lack of industry direction, economic crisis in 1997, international experiences of restructuring, reactions from existing electric utilities, and political uncertainty within the country. By far, the Electricity Generating Authority of Thailand (EGAT), a single state-owned utility on the generator and transmission sectors, has been forced to postpone new power generation projects, acquire generation requirements from small and independent power producers (SPPs and IPPs) under the so-called Power Purchase Agreements (PPAs), and privatize two power plants into public companies. On the distribution sector, there are two distribution utilities, namely, the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA). While the EGAT has been encountered many changes, both the MEA and PEA still purchase electricity from the EGAT and then resell to their customers as usual, without any sign of reform. Given the most recent statement from the Ministry of Energy [3], the only viable changes for the Thai ESI are to transform the EGAT into an enhanced single buyer and to establish a system operator (SO) to oversee the market on the transmission level. Fig.1 illustrates the proposed

structure of the Thai ESI. The existing EGAT would split into two entities. One entity controls generation facilities and another entity control transmission facilities. The later would be responsible for purchasing electrical energy from the EGAT generators, SPPs and IPPs, and neighboring countries under PPAs. So, the SO would be established to ensure that all transactions under this model would be carried out on a nondiscriminatory manner.

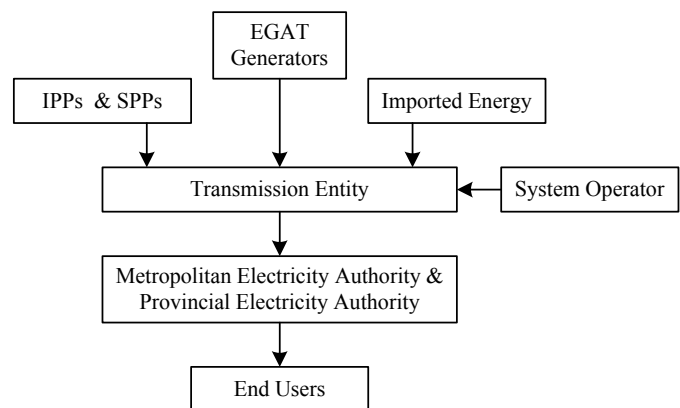


Fig. 1. Enhanced single buyer model of the Thai electric supply industry.

As of the year 2003, Thailand had 25.6 GW of installed capacity, from which it produced approximately 116 billion kWh of electricity per annum [4]. The system peak generation was approximately 18 GW. Half of the energy generation was purchased from domestic IPPs and SPPs as well as imported from Malaysia and Lao PDR. The average wholesale price was 2.08 Baht/kWh (0.052 USD/kWh). Energy sales to the MEA and PEA were approximately one-third and two-third of the total energy generation, respectively. Energy sales to EGAT's direct customers were accounted for just one percent. The EGAT transmission network ranges from 69-kV to 500-kV voltage levels. The total line length is approximately 28,297 circuit-kilometers. The key generation data of Thailand in the fiscal year 2003 are shown in Tables I and II.

To support the government policy of promoting energy generation from non-utility generators and renewable sources, the EGAT is enhancing transmission systems in both the eastern region. The EGAT is also planning to upgrade the transmission facilities in the northeastern and southern regions to increase the level of energy purchases from Lao PDR and Malaysia, respectively. It is anticipated that 500-kV transmission lines would be built in the northern region for grid interconnections with neighboring countries such as

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The author is with the Electrical Engineering Department, Chiang Mai University, Chiang Mai, THAILAND (e-mail: sn@eng.cmu.ac.th).

Myanmar and the Yunnan Province of China.

II. ASEAN POWER INTERCONNECTION PROJECTS

The Association of Southeast Asia Nations (ASEAN) was established on the 8th of August, 1967 in Bangkok, Thailand by the five original member countries, namely, Indonesia, Malaysia, Philippines, Singapore, and Thailand [5]. The two primary objectives of the ASEAN are (a) to accelerate the economic growth, social progress, and cultural development in the region; and (b) to promote regional peace and stability. The ASEAN currently consists of ten member countries, namely, Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The total population of over 500 million, a total area of 4.5 million square kilometers, a combined gross domestic product of USD 737 billion, and a total trade of USD 720 billion. The outline map of the member countries is shown in Fig. 2. Under the economic cooperation of the Association, the coordination of energy strategies to facilitate trade among the member countries and to strengthen the region's capability of energy resources is addressed in this paper. Specifically, three major power interconnection projects associating with Thailand's transmission network are mentioned.



Fig. 2. Outline map of ten member countries of the ASEAN.

TABLE I
GENERATION INSTALLED CAPACITY OF THAILAND IN THE FISCAL YEAR 2003

Source	Installed Capacity (%)	Peak Demand (%)
EGAT's power plants		
Thermal	24.39	26.99
Combined Cycle	19.79	15.02
Hydro	11.39	13.23
Gas Turbine	3.04	0.58
Diesel & Renewable	0.02	
Subtotal	58.63	55.82
Purchase from		
Domestic IPPs & SPPs	38.87	
Neighboring Countries	2.50	
Subtotal	41.37	44.18
Grand total	100.00	100.00

TABLE II
ELECTRICITY GENERATION PROFILE OF THAILAND IN THE FISCAL YEAR 2003

Source	Billion kWh	Percentage
EGAT's power plants		
Natural Gas	31.97	27.38
Lignite	17.13	14.68
Hydro	7.74	6.63
Fuel Oil	2.12	1.81
Diesel Oil & Renewable	0.05	0.04
Subtotal	59.01	50.54
Purchase from		
Domestic IPPs & SPPs	55.19	47.28
Neighboring Countries	2.54	2.18
Subtotal	57.74	49.46
Grand total	116.74	100.00

A. The Thailand-Malaysia HVDC Interconnection

In 1981, the first interconnection of power networks between Thailand and Malaysia was built between *Sadao* substation of the EGAT and *Bukit Keteri (Chuping)* substation of the Tenaga Nasional Berhad (TNB), via a 115/132-kV transmission line of 24.5-kilometer length [6]. In the late 1980s, the HVDC interconnection was adopted between *Khlong Ngae* converter station in Songkla, Thailand and *Gurun* converter station in Kedah, Malaysia to expand the power transfer capability. Both converter stations are linked by a 300-kV DC overhead line of 110 kilometers. A new construction of the 300-MW Thailand-Malaysia HVDC Interconnection is being done to accommodate increasingly power demand in the southern provinces of Thailand. This upgraded interconnection will greatly improve power system reliability of the Southern Thailand because the EGAT would not put new generating facilities into the region, although it plans to upgrade for a 500-kV tie line linked between the central-southern regions.

B. The Greater Mekong Region (GMR) Interconnection

The Greater Mekong Region consists of Cambodia, Lao PDR, Myanmar, Thailand, Vietnam, and the Yunnan Province of China [7]. By far, the energy cooperation within the region has taken place on a bilateral basis. The most active project is the export of electrical energy from *Nam Ngum* and *Nam Theun* hydropower plants in Lao PDR, via 115/230-kV transmission lines, to Thailand [1], [6]. The interconnection plan between the GMR countries is mandated by ASEAN delegates in 1997, as part of the energy infrastructure. The reinforcements of transmission lines interconnecting Lao PDR, Thailand, Vietnam, the Yunnan province of China, and possibly Myanmar are under feasibility studies. Those projects include, for example, the construction of 500-kV transmission lines linked from (a) Vietnam via *Suvanakheth* in Lao PDR to

Roi Ed in Thailand, (b) *Hongsa* power plant in Lao PDR to *Mae Moh* power plant in Thailand.

C. The ASEAN Power Grid (APG) Program

The ASEAN Power Grid program is a principal initiative to cooperate energy infrastructure among member countries [8]. Under ASEAN vision 2020, the APG program has 11 interconnection projects in progress. Table III shows the details of those projects. Currently, the three of them are in operation, i.e. (a) Malaysia and Singapore, (b) Malaysia and Thailand, and (c) Lao PDR and Thailand. The remaining projects have been studying under the interconnection master plan, partially supported by the Asian Development Bank (ADB). The ultimate goal of the program is to interconnect transmission networks of all member countries to become the ASEAN power grid.

TABLE III
LIST OF ASEAN INTERCONNECTION PROJECTS BY 2020

Interconnection Project	Capacity (MW)	Year
Lao PDR – Thailand	2,015	2008
	1,578	2010
Myanmar – Thailand	1,500	2013
Cambodia – Thailand	300	2016
Lao PDR – Vietnam	1,887	2012
Cambodia – Vietnam	80	2003
	120	2006
Peninsular Malaysia – Sumatra	600	2008
Peninsular Malaysia – Singapore	700	2012
Sumatra – Singapore	600	2014
Brtam – Singapore	200	2014
	200	2015
	200	2017
Brunei – Sabah/Sarawak	300	2019
West Kalimantan – Sabah/Sarawak	300	2007

III. ASSESSMENT OF TRANSMISSION INTERCONNECTIONS

The Thai government has seriously declared a strategic plan to develop Thailand to become the *Regional Energy Center* of Southeast Asia because it believes that Thailand would have opportunities to access energy supply and could reduce the risks of energy supply disruption [9]. This vision is set by considering that Thailand has geographical advantage, large domestic energy market, adequate energy infrastructure, and good opportunities to expand energy trade with neighboring countries. Therefore, one of the strategies being adopted is to develop power transmission networks through domestic grid enhancements and utilization of network interconnections with neighboring countries. To promote the APG program, the EGAT launched a campaign “connecting nations, linking people” to the public in 2003. Several research projects on feasibility studies and impact analyses are in progress. In this work, a preliminary assessment on various scenarios of transmission interconnections is performed. The assessment focuses on the interconnection projects that are

being operated or likely to be operated between Thailand and selected neighboring countries. As a consequence, the key statistical data of Cambodia, Lao PDR, Malaysia, Singapore, Thailand, and Vietnam were collected and compared [5], as shown in Table IV.

TABLE IV
KEY STATISTICAL DATA OF SELECTED ASEAN COUNTRIES IN 2002

Country	GDP per capita (US Dollar)	Installed Capacity (GW)	Generation (GWh)
Cambodia	296	0.14	0.11
Lao PDR	333	0.64	3.56
Malaysia	3,914	13.80	66.87
Singapore	20,823	7.70	32.18
Thailand	2,050	23.20	102.38
Vietnam	439	8.30	34.48

A. Electricity Energy-Demand Forecasting

A sound forecasting of energy consumption and peak demand of electricity is the first step in assessing the impact of transmission interconnections between the EGAT and the neighboring countries. In this work, a forecasting method is based on using the decomposition technique [10], given 16-year monthly historical data (1988-2003) [11]. By assuming that the load factor is constant at 70 percent throughout the study period, the peak demand is then forecasted from the forecasted energy consumption. The forecasting results for a 10-year period (2004-2013) under high- and low-economic growth scenarios are shown in Table V.

TABLE V
ENERGY CONSUMPTION AND PEAK DEMAND FORECASTS FOR THAILAND

Year	Energy Consumption (GWh)		Peak Demand (MW)	
	H*	L**	H*	L**
2004	131,200	109,334	21,396	17,830
2005	136,749	113,957	22,301	18,584
2006	142,228	118,524	23,194	19,329
2007	147,710	123,092	24,088	20,074
2008	153,191	127,659	24,982	20,818
2009	158,670	132,225	25,876	21,563
2010	164,148	136,790	26,769	22,307
2011	169,624	141,354	27,662	23,052
2012	175,100	145,917	28,555	23,796
2013	180,575	150,479	29,448	24,540

* High economic-growth scenario

** Low economic-growth scenario

B. Projection of Electric Supply Industry Structure

As shown in Table V, it has been forecasted that the peak generation requirement would be increased to 24,540-29,448 MW over the next ten years. However, the Thai government would not support the EGAT to develop more generation facilities. Thus, the EGAT would have to rely on generation resources of IPPs, SPPs, and the neighboring countries. As a result, a generation capacity portfolio of Thailand would be dramatically changed over the next decade. Table VI shows

the projected generation capacity of Thailand, given that the government policies to accelerate domestic power purchases and to gain benefits from transmission interconnections are implemented effectively. The projection in Table VI is made by considering that (1) the EGAT will purchase 1600 MW and 1700 MW of electricity from Lao PDR in 2007 and 2008, respectively, (2) a generation of 1346 MW from a domestic IPP will come into service in 2007, (3) the PPA between EGAT and Myanmar is ignored because the agreement is highly uncertain. It is assumed that the capacity addition from domestic SPPs, which are mostly renewable energy, will be 100 MW annually. Note that the privatized generators in Table VI refer to those generators of the Electricity Generating PCL (EGCO) and the Ratchaburi Electricity Generating Holding PCL. The generation facilities of both companies had been privatized from EGAT generation assets.

TABLE VI
PROJECTED GENERATION CAPACITY OF THAILAND

Source	End-of-Year Capacity (%)			
	2004	2007	2010	2013
EGAT	54.61	46.36	45.18	46.02
Privatized Generators	20.00	18.90	17.19	16.83
Domestic IPPs & SPPs	23.15	27.32	25.76	25.52
Neighboring Countries	2.24	7.42	11.87	11.64

C. Determination of Market Concentration

It is found that, over the study period, the generation capacity proportion of the EGAT facilities slightly decreases, while those of the two privatized generating companies, domestic IPPs and SPPs are relatively constant. The imported power from Lao PDR increases significantly.

To measure the market concentration on generation sector, the demand-supply ratio [12] and the Herfindahl-Hirschman Index (HHI) [13] are computed. To compute the demand-supply ratio, the projected demand is taken from the forecasted peak demand in Table V, while the projected supply is referred to available generation capacity which is assumed to be 90% of installed capacity. The demand-supply ratio increases from 83% in 2004 to 97% in 2013 under low-economic growth scenario. Similarly, under high-economic growth scenario, the demand-supply ratio increases from 69% to 80%. The HHI drops from 3,300 in 2004 to 2,502 in 2013 because the capacity share of the EGAT decreases from 54 to 46 percent, while the capacity share of imported power from Lao PDR increases from 2 to 11 percent. However, it should not be misunderstood that the potential to impose market power would be less because (1) the capacity share of Lao PDR is actually owned by the EGAT and (2) the capacity shares of domestic IPPs and SPPs depend on the PPAs signed with the EGAT. So, a more accurate measure of market concentration should be obtained by computing the HHI based on output shares. Based on this consideration, the EGAT remain has a considerable potential to impose market power on generation sector.

D. Evaluation of Transmission Facilities

When a geographic scope of the market is considered, it is found that the service territories may practically be divided into four areas, i.e. north, northeast, central and south areas. Most generators are located in the northern and central regions of the country (more than 85%) because the demand is concentrated in these two regions. The generators in the north supply electricity consumption primarily within the area. The generators in the central area supply electricity consumption within the area as well as in the northeast and south areas.

As a result, the existing eight 500-kV substations were linked between the north and central areas. In Fig. 3, it is shown that two substations (MM3 and TTK) are located in the north, while the others are located in the central. The lines connecting between MM3-TTK-WN substations, which are linked between the northern and central regions, have been lightly loaded, compared with other lines.

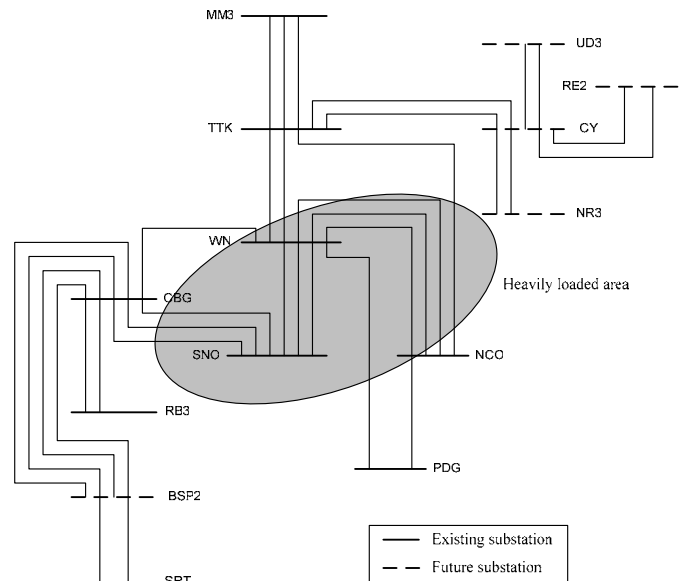


Fig. 3. Schematic diagram of EGAT 500-kV substations.

Currently, the EGAT plans to enhance transmission capacity within the central region to accommodate growing demand and to build more high-voltage transmission lines and substations in the northeastern and southern regions to accommodate power purchases from the neighboring countries. Based on power flow simulations, it is found that those expansion plans would not affect the power flow patterns in the transmission network because they are served only to changes in local demand and supply within their areas. Essentially, the central area is still vulnerable to transmission congestion. A major impact of interconnections would actually be the investment costs that the EGAT must spend for building more transmission lines and substations linked between the central and northeastern regions. As shown in Fig. 3, it is expected that the EGAT would have to build at least 6 new 500-kV substations (4 in the northeast and 2 in the south). Besides, a number of 230-kV and 115-kV substations

would also be reinforced as well.

E. Assessment of Economic Impact

Since the EGAT has not planned to build new generation facilities, a direct economic impact of interconnections with neighboring countries is cost savings gained from eliminating generation capacity addition. It is estimated that the EGAT could cut 1,500-2,000 MW of installed capacity, which is roughly equivalent to USD 1,000-1,500 million. Because the construction costs of transmission facilities are extremely high and uncertain, thus, financial risks would be considerable if the electricity demand is overestimated or the contracted power is underused. Economic assessment of interconnection is definitely complex and deserves serious consideration before investment decision is made. Essentially, a good judgment on adequate transmission capacity and well-defined investment options are needed.

The avoidable environmental impact from constructing new power plants as well as the improving reliability and stability of transmission grids in the south are economically valuable. But, it should be emphasized that the country's transmission network is vulnerable and subject to severe outages. If, for instance, there is a large power plant in the neighboring country is failed, it could cause a cascaded blackout in Thailand too. Therefore, the interconnections could stabilize and destabilize the transmission network of Thailand.

F. Assessment of Competition

Under existing PPAs, the EGAT has agreed to purchase power from Lao PDR and domestic IPPs & SPPs for 0.04 and 0.07 USD/kWh, respectively. Thus, the interconnections will negatively affect domestic IPPs & SPPs because the EGAT would prefer less expensive energy from Lao PDR. Suppose those IPPs and SPPs agree to sell power at lower prices, it would be beneficial for the EGAT. But, would the end users see lower prices of electricity?

Because the EGAT is a single buyer on the generation sector of Thailand, it can keep a monopoly status artificially in terms of control wholesale prices and retain ownership of the transmission network. Although the interconnections allow more generators to access the country and offer lower prices, but those generators cannot deal directly with the distributors or end users. As a consequence, the EGAT would continue to be a dominant buyer in Southeast Asia and control the supply sector of Thailand, while the electricity rates would remain set by the Thai government).

IV. CONCLUSION

A preliminary assessment of the interconnections of transmission networks between Thailand and neighboring countries is presented in this paper. The interconnection plans were initiated from the ASEAN power grid program. Based on forecasted demand and projected installed capacity of Thailand over the study period, it is found that the EGAT could gain generation cost savings, but would have to build and upgrade transmission facilities to accommodate power

purchases from the neighboring countries. The EGAT would continue to be a major supplier of Thailand and Southeast Asia because it is still a single buyer on the generation sector.

V. ACKNOWLEDGMENT

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VII. BIOGRAPHY

Somboon Nuchprayoon was born in Chiang Mai, Thailand. He received B.Eng. degree in Electrical Engineering from Chiang Mai University, Thailand in 1995, M.S. in Electric Power Engineering from Rensselaer Polytechnic Institute, Troy, New York in 1997, and Ph.D. in Electrical Engineering from Georgia Institute of Technology, Atlanta, Georgia in 2003. He is currently a lecturer in the Electrical Engineering Department, Chiang Mai University, Thailand. His research interests are in the area of power system operation and economics.