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Electrical Power Exchange in GMS and Its Influence on Power Systems in Vietnam and Thailand

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Abstract— **The paper aims to identify the development of power interconnection network in the Greater Mekong Sub-region (GMS) which is a part of the major energy infrastructure mandated by ASEAN delegates in 1997. An overview of power systems in the region is introduced. The combined load curve for Vietnam and Thailand are formed to show the benefit of power grid interconnection of GMS. The paper also concentrates on simulation, analysis and evaluation of power transfer in 500kV and 220kV interconnection transmission lines in GMS for the planning horizon of 2010-2020. Reliability and environmental benefits of the interconnection are discussed due to interconnection. Based on the simulation results few recommendations are given.**

Keywords- Combined Load Curve, Environmental Benefits, Greater Mekong Sub-region, Interconnection of large power systems

I. INTRODUCTION

The Greater Mekong Sub-region (GMS), includes six countries, namely Lao PDR, Cambodia, Myanmar, Thailand and Vietnam located in South East Asia and China (Yunnan Province and Guangxi Zhuang Autonomous Region of the People's Republic of China). The GMS has abundant and diverse sources of primary energy such as coal, oil, natural gas and hydropower. Some countries in the region are extraordinary rich in hydraulic power potential such as Lao PDR, Myanmar and Yunnan province. Other countries like Thailand and Vietnam have enormous amount of coal, oil and gas reserve, but still looking for cheap energy as demand for electricity is growing more rapidly than other members of GMS. There is also a significant potential of renewable energy like biomass, solar and wind energy in the region.

To ensure continuous supply of electrical energy for every member countries in the GMS, the need to have cooperation through integration of energy infrastructure becomes essential. This is because Thailand and Vietnam have high demand for power supply but lacking of cheap power generation capacity. Meanwhile Cambodia, Lao PDR and Myanmar have plenty of primary energy resource but power demand growth is not that high. Hence, electric power system interconnection is the region can provide more secure, efficient, reliable and environmentally friendly electricity supply to the region while paving platform for economic corporation [1].

This paper tries to study the interconnection of power utilities in GMS. Rest of the paper is organized as follows. Section 2 provides an overview of GMS member countries. Typical load curves of the two ambitious countries, namely Thailand and Vietnam, aggregated load pattern and benefits are discussed in Section 3. Section 4 presents energy and power demand forecast for the GMS members during 2010 to 2020. Generation expansion planning is briefly summarized in Section 5. Power flow studies, including contingency analysis and reliability and environment benefits of the interconnections are presented in Section 6. Finally, contributions of the work and recommendations are given in Section 7.

II. OVERVIEW OF GMS COUNTRIES

Power systems in GMS have various characteristics of natural and human resource conditions. The GMS also has many advantages for enhancement of cross-border energy exchange. The population, Gross Domestic Product (GDP), installed capacity, energy consumption per capital of the region vary widely as shown in Table I [2]. Most of the figures presented in the table are based on the data from 2006. Thailand is the key energy market in the GMS with more than 50% of total energy consumption in the region in 2006. Vietnam and Yunnan together accounts for 42% of total energy demand. The remaining 4% is consumed by Cambodia, Lao PDR and Myanmar [3], [4].

In the GMS, major load centers concentrates in capitals of the member countries except the case of Vietnam as shown in Figure 1. In Vietnam, the highest energy consumption is in Ho Chi Minh city, which is accounts for 40% of total energy consumption of the whole country in 2005 [5]. Among the members of GMS, Vientiane is the capital with the highest ratio of energy consumption with 75%. The next capitals are

Phnom Penh with 56%, Kunming with 50%, Bangkok with 30% and Hanoi with 19% [6]-[12].

TABLE 1: OVERVIEW OF MEMBER COUNTRIES IN THE GMS

Country	Cambodia	Lao PDR	Myanmar	Thailand	Vietnam	Yunnan (2005)
Area ($1000km^2$)	181.04	236.8	676.58	513.12	331.69	394.1
Population (million)	13.97	6.5	48.7	62.8	87.3	44.2
GDP (US$ billions)	36.82	13.75	91.13	596.5	262.8	51.7
Installed capacity (GW)	0.262	0.668	1.561	24.76	11.65	13.5
Energy (TWh)	0.975	2.283	6.014	144.08	60.623	52.0
Energy/capital (kWh/capital)	70	351	124	2294	694	1176

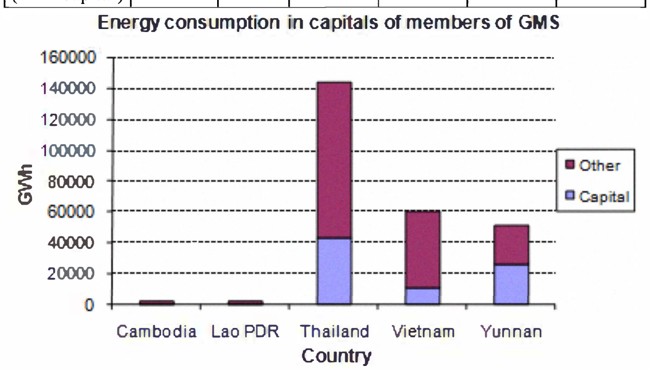

Figure 1 Energy consumption in members of the GMS.

III. LOAD CURVES

Peak load time in the daytime of major load centers like Thailand and Vietnam is difference from the peak load time of countries which have potential to export power such as China and Laos. The peak load time of Thailand and Vietnam are 14.00 and 18.00 respectively. Meanwhile, the peak load time of Yunnan province and Laos are around 10.00 and 19.00, respectively.

The daily load curves for Thailand and Vietnam for a typical summer and winter days are as shown in Figures 2 and 3. As the night and day time peaks vary for these two countries, installed capacities and other transmission facilities can be easily shared for power exchange between them. In the summer, Thailand can export energy to Vietnam in the evening time and import energy from Vietnam in the daytime. Meanwhile, in the winter, with high demand in both day and night-time, Vietnam should import energy from Thailand because Thailand demand is rather low in this period.

The aggregated load curve of the GMS region as depicted in Figure 4 is formed by adding all the load curves of all countries in the GMS except Myanmar and Yunnan province (no data for Myanmar and Yunnan load curves). Peak demand of aggregated load curve happens at 11.00 a.m with the value of 33,426MW. The secondary peak load is 33,271MW at 20.00p.m [6]-[12].

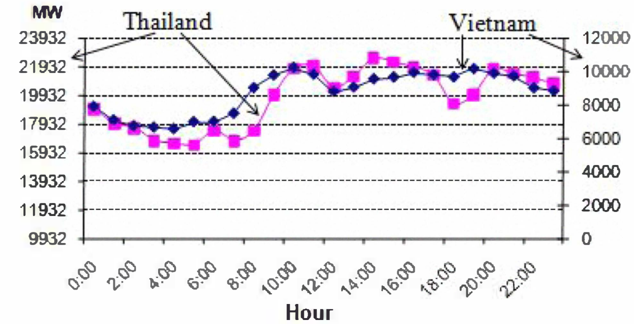

Figure 2 Summer load curves of Thailand and Vietnam.

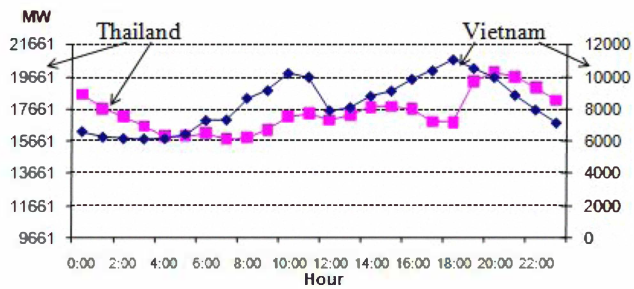

Figure 3 Winter load curves of Thailand and Vietnam.

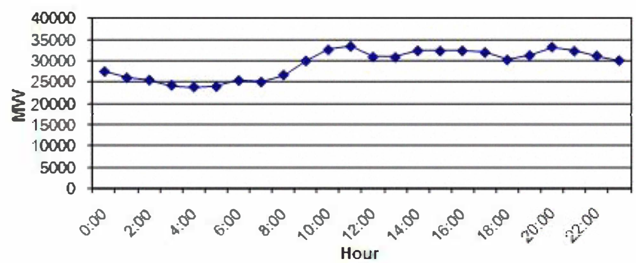

Figure 4 Aggregated load curves of the GMS, except Myanmar and Yunnan.

Overall, the combined load curve shows that almost a flatter load profile afternoon and evening times compared to the individual load curve of each country. When combining all the load curves, the difference between peak load and off peak load also become smaller than that in the individual load curves. This has a lot of meaning for system operators and the whole power system. The smaller difference in peak and off-peak load goes together with reducing investment for power plants which only run in the peak load time.

The difference between peak load time of energy importing-countries such as Thailand and Vietnam and energy exporting-countries like Cambodia, Lao PDR, Myanmar and Yunnan province can be a good condition for cross-border energy exchange in the GMS. If the exporting countries like Yunnan province, Laos and Myanmar have the surplus electricity available at the cost lower than the marginal generating cost of importing countries like Thailand and Vietnam, the pressure of investment in power generation will decrease in the “energy hungry” countries. Therefore, interconnection will increase the effectiveness of system operation and use of the existing facilities.

IV. POWER DEMAND FORECAST

Power demand of energy is closely linked to the economic growth of each country in the GMS. Future energy consumption in the region was derived from various mathematical and statistical models and variables, e.g. population behaviors, income, population sizes and growth primary data [13], [14]. Energy requirement and peak demand of member countries and the whole GMS are shown in Tables II.

TABLE II: ENERGY REQUIREMENT IN THE GMS IN PERIOD 2006-2020

Year	Energy requirement (GWh)				Total Energy	Total Demand (MW)
	Cambodia, Laos and Myanmar	Thailand	Vietnam	Yunnan		
2006	8,953	152,958	45,603	52,000	259,514	45,935
2010	15,937	184,634	97,111	87,900	385,582	63,050
2015	30,006	248,580	164,961	116,000	559,547	99,856
2020	41,825	331,269	257,260	160,000	790,354	136,256

Total energy consumption and power demand of the region will increase by more than 3 times in period 2006-2020. Thailand will still be the major energy-consumption center with 41% and 36% total shares in terms of energy consumption and peak demand respectively in 2020. The countries which will see most rapid growths will be small countries such as Cambodia, Lao PDR and Myanmar.

V. GENERATION EXPANSION PLANNING

Overview of installed capacity in the GMS in 2006 and 2020 is shown in Table III. In the planning, hydro power will be the core for development in most part of GMS which includes Cambodia, Lao PDR, Myanmar and Yunnan province. There will be some major projects which will be oriented for exporting such as "SeSan hydro power" plants from Cambodia, hydro power plants from Central to Southern region of Lao PDR, Tasang hydropower plant (3600MW) in Myanmar, Nouzhahu (5500MW) and Jinghong (1500MW) from Yunnan province.

The two major energy-importing countries Thailand and Vietnam have been developing power generation differently from other countries in GMS do. Thailand will increase installed capacity of gas-fired power plants to 90% by 2020. Meanwhile Vietnam which uses variety sources in power generation will contemplate the use of nuclear power plant in the end of study-period in 2020.

TABLE III: OVERVIEW OF INSTALLED CAPACITY IN THE GMS

Installed capacity (MW)	Cambodia, Laos and Myanmar	Thailand	Vietnam	Yunnan	Total
2006	2,491	28,532	11,654	13,500	56,177
2020	21,407	55,251	66,970	74,000	217,628

VI. POWER FLOW STUDY AND RESULTS

The simulation cases are categorized based on the year that new interconnection lines will be in operation in the GMS during the period 2010-2020 as follow and all the simulations are carried out with PSS/E analytical software tool [15].

A. *Casses studied:*

Case 2010: Thailand will be interconnected to Lao PDR via one 500kV double circuit. Two 230kV interconnection lines operated since 2002 will continue supplying power for Thailand from Huay Ho and Theun – Hinboun hydro power plants of Lao PDR. Vietnam will sell electricity to Cambodia via one 220kV transmission lines and import power from China through two 220kV transmission lines in Tan Kieu and Ma – Guan city of Yunnan, China.

Case 2012: Thailand will increase power import from Lao PDR via one more 500kV transmission line. The new 500kV will connect Udon Thani 3 substation and Nam Ngum 3 hydro power plant. Thailand will also continue to import energy through 230kV level from Huay Ho and Theun – Hinboun hydro power plants of Lao PDR.

Vietnam will import power from Lao PDR via two 500kV double circuits and two 220kV transmission lines. One of the two 500kV transmission lines will connect to Savanakhet substation creating the first interconnection line among Thailand – Lao PDR – Vietnam. Vietnam will continue import power from China via two 220kV transmission lines and sell power to Cambodia via one 220kV transmission line. A single line diagram of interconnection topological map of GMS is given in Appendix A.

Case 2015: Vietnam will continue importing power from Lao PDR and China via 500kV and 220kV transmission lines. Starting from 2015, the power plants of Cambodia can supply enough for domestic demand. Cambodia will stop importing electricity from Vietnam via 220kV line.

Case 2017: One 500kV double circuits will connect Yunnan province of China and the North of Vietnam. Vietnam will also import power from the series of SeSan hydro power plants in Cambodia through four 220kV transmission lines. Lao PDR will continue sell electricity to Vietnam via the 500kV and 220kV transmission lines.

Case 2020: There will not be any additional interconnection lines constructed in Vietnam in this period. Instead of this, Vietnam will develop the 500kV transmission lines to connect nuclear power plant and some thermal power plants to the system.

B. *Summary of results:*

Power transfer of 500kV transmission lines:

The maximum power transfer reaches 39% in year 2012 in the line Son La – Dong Anh. Other 500kV transmission lines have the used capacity less than 39%.

The 500kV transmission system of Thailand can meet the demand of load growth until 2012 and this system does not have any serious problem in transferring power. Until 2020, power transfer will increase from the Central to the North and from the South to Central of Vietnam. Load flow between Da Nang and Pleiku can exceed its ratings at N-1 criteria.

Bus voltage Profile of 500kV transmission system:

The range of 500kV bus voltage profiles in Thailand system is from 1.01p.u to 1.04p.u. The major substations in the

Metropolitan area of Thailand do not require shunt reactor equipment because of heavy loads in this area. But 500kV transmission lines connecting large power plants such as Mae Moh 3 and hydro power plants importing from Lao PDR need shunt reactor compensation to reduce voltage in the acceptable range. In Vietnam power system, voltage at bus bar of major load center such as Hanoi and Ho Chi Minh city is rather low but still within the acceptable range. The 500kV transmission system does not have serious problem with the voltage drop limitation.

Bus voltage Profile of 220-230 kV transmission system:

In Thailand, voltage profiles of 230kV transmission system are maintained in the required range from 0.95 to 1.05p.u. However, some 230kV substations need switchable shunt compensation to achieve the acceptable voltage. Most of required shunt compensation substations concentrated in the Metropolitan area where load is heavy and getting heavier. On the other hand, some 220kV substations in load center in Hanoi and Ho Chi Minh City require shunt compensation because of the heavy load. From 2015 to 2020, two major 220kV transmission lines in Hanoi area are overload and need to increase the power transfer capacity.

Contingency analysis:

In 500kV transmission system of Vietnam, power tends to flow from South to Central and from Central to the North. Power transfer in 500kV transmission lines from Ha Tinh to Nho Quan and from Pleiku to Da Nang has high ratio comparing to power transfer in other 500 kV transmission lines in all the cases. When Vietnam interconnects with Lao PDR via 500kV transmission lines at Ha Tinh and Pleiku substation, the ability of overload in these 500kV lines above is very high if fault happens in one circuit in the double circuits as shown in Table IV.

TABLE IV: POWER TRANSFER WITH N-1 CONTINGENCY

Line	**Power transfer (%)**			
N-1 criteria	2012	2015	2017	2020
Ha Tinh – Nho Quan	28	40	44	42
Da Nang – Pleiku	85	85	87	89

Table IV describes the percentage of power transfer in 500kV transmission lines in Ha Tinh – Nho Quan and Da Nang – Pleiku when fault happens in one circuit. Voltage at bus bar Ha Tinh, Nho Quan, Pleiku, Da Nang will be affected when fault as indicated in Table V.

TABLE V: BUS VOLTAGE WITH N-1 CONTINGENCY

Line	**Voltage (kV)**				
N-1 criteria	Bus	2012	2015	2017	2020
Ha Tinh to Nho Quan	Nho Quan	1.0	0.96	0.96	0.94
	Ha Tinh	1.0	0.99	0.98	0.97
	Da Nang	1.0	0.99	0.99	0.98
	Pleiku	1.03	1.02	1.0	1.0
Da Nang to Pleiku	Nho Quan	1.01	0.98	0.98	0.96
	Ha Tinh	1.01	1.0	1.0	0.98
	Da Nang	0.99	0.98	0.97	0.95
	Pleiku	1.03	1.02	1.0	1.0

Power transfer in 500kV transmission lines Ha Tinh – Nho Quan and Da Nang – Pleiku within N-1 outage is in the acceptable range, but voltage at bus Nho Quan and Da Nang are low. To deal with the problem, EVN should install shunt capacitors at bus bar Nho Quan, Da Nang or reduce the power transfer in these 500kV transmission lines above by reducing the amount of power supply from the South and replace by increasing power generation in the North of Vietnam.

C. Reliability and environmental benefits:

Reliability benefit:

The reliability of electric service in Thailand and Vietnam can be increased by increasing the use of hydropower resources in China, Cambodia, Lao PDR and Myanmar. Interconnection also helps improving the reserve margin capacity of Thailand and Vietnam system as shown in Table VI.

TABLE VI: RESERVE MARGIN WITH AND WITHOUT INTERCONNECTION

Country	**Year**	**Installed capacity (MW)**	**Import (MW)**	**Total (MW)**	**Peak demand (MW)**	**Reserve margin (%)**	
						Before	**After**
Thailand	2010	32,109	1400	33,509	26,310	22.0	27.4
	2012	33,866	1990	35,856	28,415	19.2	26.2
Vietnam	2010	20,522	220	20,742	16,470	24.6	25.9
	2012	28,439	1,995	30,434	22,608	25.4	34.3
	2015	39,942	2,075	42,017	31,930	25.0	31.5
	2017	46805	3,255	50,060	36,850	27.2	36.0
	2020	58700	3,300	62,000	46,350	26.6	33.7

The reserve margin of Thailand and Vietnam are all above 25% from 2010 onward as a result of interconnection. If one considers GMS as one large integrated grid, the reserve margin can even be higher than the number calculated above. For example, Thailand can use the spare capacity of not only Thailand but also Vietnam and other countries in the GMS for emergency condition with the help of interconnection lines.

Environmental benefit:

The GMS has a significant amount of thermal power plants, especially coal-fired power plants. Enhanced interconnection in the GMS can bring substantial benefits through the displacement of coal-fired power plants by hydropower plants.

TABLE VII: CO2 EMISSION WITH AND WITHOUT INTERCONNECTION

	Thailand (2012)		**Vietnam (2020)**	
	Base scenario	Recommend scenario	Base scenario	Recommend scenario
Million Tons CO_2	123.9	113.7	169.7	146.6

The study compare two scenarios: base scenario and recommended scenario in the year-end of the simulation period. Base scenario will be the scenario without interconnection. Deficit power will be replaced by power produced from coal-fired power plants. Recommended scenario will be the scenario with interconnection, where energy from coal fired power plants will be replaced by energy from hydro power plants. The amount of CO_2 emission in two scenarios is presented in Table VII.

As a result, carbon dioxide emissions decline by 10.2 million tons (8.2%) in the case of Thailand in 2012 and 23.1 million tons (13.6%) in the case of Vietnam in 2020 with interconnection. Grid enhancement can reduce significant amount of carbon dioxide emission by allowing substitution of hydropower for fossil-fuel power.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions:

The results show that the selected interconnections between Thailand and Lao PDR and between Vietnam and Yunnan province, Cambodia and Lao PDR are viable in terms load flow analysis. There is no serious problem with power transfer in 500kV and 220kV Thailand power system because the study only develops power flow in Thailand grid until 2012. Thailand will interconnect to Lao PDR by 500kV system in 2010 and 2012. Maximum 500kV power transfer is 23% in 2012. Voltage varies in the range from 1.01p.u to 1.04p.u in 500kV transmission system and change from 0.95p.u to 1.05p.u in 230kV transmission system.

Simulation in Vietnam case shows that the Vietnam power system can meet the requirement of load growth until 2020. Vietnam will import power from Lao PDR by 500kV in 2012, from Cambodia by 220kV in 2017 and from China by 220kV in 2010 and by 500kV in 2017. Interconnection lines between Vietnam and Cambodia, Lao PDR and China have enough capacity to transfer power until end of calculating period. Voltage at 500kV and 220kV transmission system varies in the criteria range.

Relating to environment impact, cross-border power exchange can help to reduce CO_2 emission of 8.2% in the case of Thailand in 2012 and 13.6% in the case of Vietnam in 2020 compare to the scenarios without interconnection. Importing electricity to Thailand and Vietnam will decrease capacity addition of new thermal power plants that would leads to the reduction of total pollutant emissions. Hence, the power exchanges in the GMS contribute to protect the environment of each country in the region.

In the GMS region where grids are still in the process of development, interconnection becomes the right choice to satisfy the load demand. Expanding cross-border power grids in the GMS holds the promise of delivering economic and environment benefits without compromising the reliability of service.

B. Recommendations:

To stabilize operation of 500kV transmission system, EGAT (Thailand) and EVN (Vietnam) should install shunt reactor at the sending ends of Banabong, Savanakhet, Ban Sok and Malutang (Yunnan province) buses. Also negotiation to buy power at the fixed voltage (automatic voltage control) at these buses should be implemented.

To ensure operation effectively of the competitive power market in the future, Thailand and Vietnam should pay attention to the load transfer ability and overload in the transmission lines. EGAT and EVN can apply FACTS controller technology to strengthen load transfer ability and improve the reliability as well as stability of the system.

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APPENDIX: INTERCONNECTION OF GMS IN 2012