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การจัดการผลกระทบด้านความมั่นคงและความเชื่อถือได้ของระบบไฟฟ้า จากกรณีศึกษาในประเทศไทย

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บทคัดย่อ

แผนพัฒนาพลังงานไฟฟ้าของประเทศไทยฉบับ พ.ศ. 2553 หรือ แผนพัฒนาพลังงานไฟฟ้าสีเขียว ได้ถูกจัดทำขึ้นเพื่อส่งเสริมการใช้พลังงานอย่างมีประสิทธิภาพ และเพื่อกระจายการใช้เชื้อเพลิงให้เกิดความหลากหลาย อันเป็นการลดความเสี่ยงในการพึ่งพาพลังงานชนิดใดชนิดหนึ่งมากเกินไป และเพื่อลดการการปลดปล่อยก๊าซเรือนกระจกจากภาคพลังงานอันเป็นสาเหตุสำคัญส่วนหนึ่งของปัญหาการเปลี่ยนแปลงสภาพภูมิอากาศที่เป็นปัญหาใหญ่ของทุกประเทศทั่วโลกในปัจจุบัน และเพื่อรักษาความมั่นคงทางพลังงานของประเทศ

ในการดำเนินการให้บรรลุเป้าหมายของแผนพัฒนาพลังงานไฟฟ้าฉบับดังกล่าว การจัดการด้านผู้ใช้พลังงานเป็นกิจกรรมเพื่อให้เกิดการใช้พลังงานอย่างมีประสิทธิภาพได้ถูกบรรจุในแผนพัฒนาพลังงานไฟฟ้าของชาติเป็นครั้งแรก ส่วนการลดสัดส่วนการพึ่งพาก๊าซธรรมชาติ ซึ่งปัจจุบันพึ่งพาก๊าซธรรมชาติถึงร้อยละ 72 ของกำลังการผลิตไฟฟ้ารวมของประเทศ การผลิตไฟฟ้าจากเชื้อเพลิงและพลังงานประเภทต่างๆ เช่น พลังงานหมุนเวียน เป็นต้น ได้ถูกเสนอเป็นทางเลือกในการลดการพึ่งพาก๊าซธรรมชาติ โดยคำนึงถึงการลดการปลดปล่อยก๊าซเรือนกระจกจากภาคพลังงาน ด้วยการนำเสนอเทคโนโลยีสมัยใหม่ที่สามารถลดการปล่อยก๊าซเรือนกระจกได้อย่างมีประสิทธิภาพและประสิทธิผล นอกจากนี้แผนดังกล่าวยังคาดหวังให้สามารถรักษาความมั่นคงและความเชื่อถือได้ของระบบพลังงานไฟฟ้าด้วยเช่นกัน อย่างไรก็ตาม ทางเลือกในการผลิตไฟฟ้าประเภทต่างๆ ประกอบด้วยคุณลักษณะและคุณสมบัติข้อดีและข้อด้อยที่ต่างๆกันสามารถก่อผลกระทบต่อความมั่นคงและความเชื่อถือได้ของระบบพลังงานไฟฟ้าในมิติที่เหมือนและต่างกัน ในการศึกษานี้ ผลกระทบและสาเหตุที่เกิดจากทางเลือกในการผลิตไฟฟ้าประเภทต่างๆในแผนพัฒนาพลังงานไฟฟ้าของประเทศไทยฉบับ พ.ศ. 2553 ได้ถูกนำมาศึกษา วิเคราะห์ และเสนอแนวทางในการกำหนดนโยบาย และการกำกับสำหรับแต่ละเทคโนโลยี ทั้งนี้เพื่อให้สามารถรักษาความมั่นคงและความเชื่อถือได้ของระบบพลังงานไฟฟ้าของประเทศให้อยู่อย่างยั่งยืนต่อไป

คำสำคัญ: นโยบายพลังงาน, แผนพัฒนาพลังงานไฟฟ้า, ทางเลือกการผลิตไฟฟ้า, ความมั่นคงและความเชื่อถือได้ของระบบพลังงานไฟฟ้า

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*บทความนี้เป็นส่วนหนึ่งของวิทยานิพนธ์ ระดับปริญญาเอก

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Power security and reliability impact management: Case study of Thailand*

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Abstract

Thailand's power development plan (PDP) 2010, which is so-called green PDP, intends to promote energy efficiency, fuel diversification, greenhouse gas emission reduction and power sustainability. Demand side management has been firstly introduced in the PDP. To decrease the natural gas shared that currently being about 72% of total generating capacity, several power generation options such as renewable energies etc., have been introduced. The future emission level is expected to be reduced by increasing additional cleaner power generation options and promoting energy efficiency. The plan is hoped to sustain the national power security and reliability. However, each power option, which has various characteristics both pros and cons creates similar and different impacts on security and reliability of the power system. In this study, sources of power security and reliability impacts for each power generation option within PDP 2010 are identified and analyzed and the policy and regulation recommendations for each technology are suggested

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Keywords: Energy policy, Power development plan, Power generating options, Power security and reliability

Introduction

Significance of Power Security in Thailand

Electrical energy or power is one of significant key factors to drive the national economy as can be seen in Figure 1. Power consumption growth rate is continuingly decreasing follow to gross domestic product (GDP) from 2004 to 2009 and both power consumption and GDP growth rate are drastically increasing in 2009 to 2010. As a result, Thailand cannot avoid sustaining national power security

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alongside the development of sustainable economy. Currently, one major difficulty for sustaining Thailand power security is overdependence on natural gas. Figure 2 shows that power sector in Thailand is mainly relied on natural gas up to 72 % of net power generation shared. In order to mitigate the difficulty, a new power development plan has been introduced with an intention to secure the power system and, to minimize the gas power generation shared and greenhouse gas emissions as well.

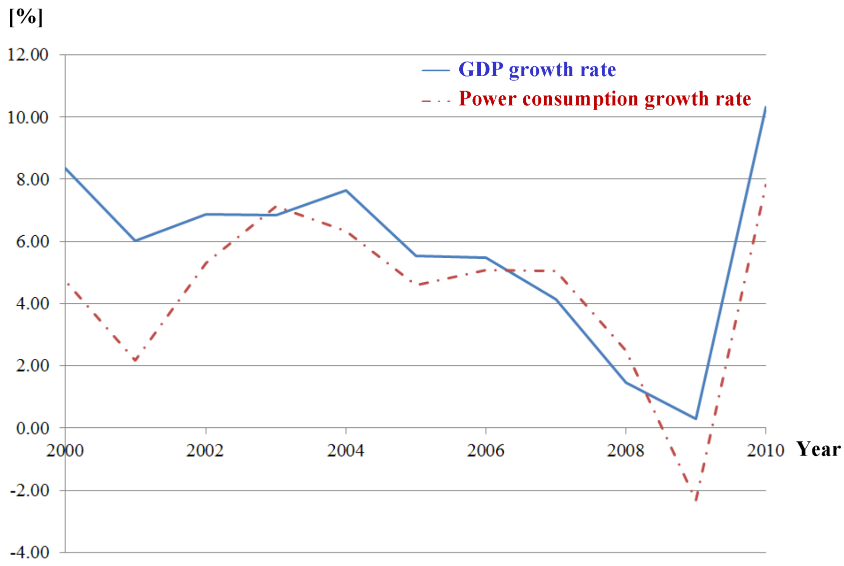

Figure 1 Thailand GDP and Power consumption growth rate (EPPO, 2011a)

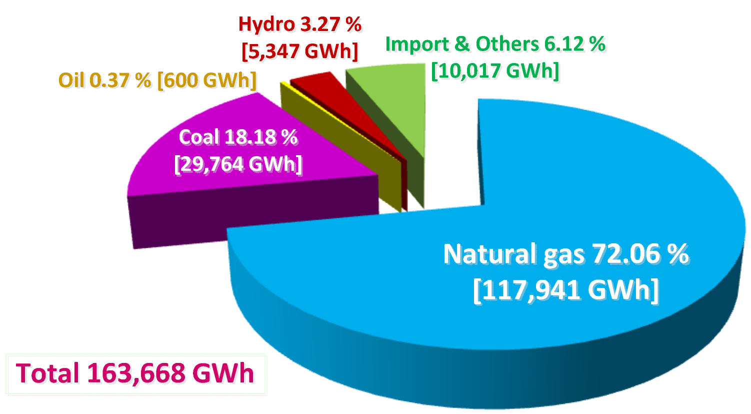

Figure 2 Net generation shared by fuel type in 2010 (EPPO, 2011a)

Thailand Power Development Plan (PDP) (EGAT, 2010)

Recently, the twenty-year plan of Thailand Power Development (2010-2030), also known as Power Development Plan 2010 (PDP 2010) or green PDP, was approved by the National Energy Policy Committee (NEPC) on 12 March 2010 and the Thai Cabinet on 23 March 2010, respectively.

The PDP 2010 was based on three major criteria; (1) system reliability, (2) green energy and efficient utilization, and (3) new power demand forecast. Reserved margin within the twenty-year plan was kept over 15 % of the demand forecast. Moreover, fuel diversification was continuously introduced for reducing the risk due to over dependence on natural gas. The promising candidates such as renewable energy, clean-coal and nuclear power were introduced to decrease the portion of natural gas-fired power plant. The power generating options were carefully chosen for optimizing the economic risk due to the energy cost and reducing the environmental impacts and emissions. Target of Demand Side Management (DSM) or power energy saving programs was to deduct the demand load forecast by 1,170 MWh per year in 2030. The twenty-year load forecast, which was done by the Load Forecast Working Group (LFWG), was calculated based on the forecasted Thailand Gross Domestic Products (GDP) and decreasing with DSM target.

After the nuclear crisis (Bhanthumnavin and Bhanthumnavin, 2011) in Japan that caused by the great earthquake and gigantic tsunami waves on 11 March 2011, NEPC decided to delay the commercial startup of the nuclear power plan for three years and replaced with gas-fired power generating option (EPPO, 2011b).The projection of modified annual generating capacity classified by fuel type and annual fuel shared of PDP 2010 are shown in Figure 3 and 4, respectively.

The portion of the gas fired power generating option is greatly reduced to 27 % of total generation in 2030 for mitigating the risk due to the overdependence on natural gas while renewable energy, clean coal, hydro and nuclear power are increasingly introduced instead of natural gas for sustaining national energy security and economy.

The PDP is obviously balanced the resource usages by separating the fuel mixed into five balanced groups for a more flexible and easier to manage risk on energy security. Doubtless, all the available generating options for the future are being promoted to serve the future demand, to secure national energy security, and to sustain national economy because conventional energy resource is going to be depleted and to be more and more expensive. However, each energy option, which has specific characteristics, will directly affect to energy system on different aspects. To realize and harmonize these energy options, impacts from each power generating

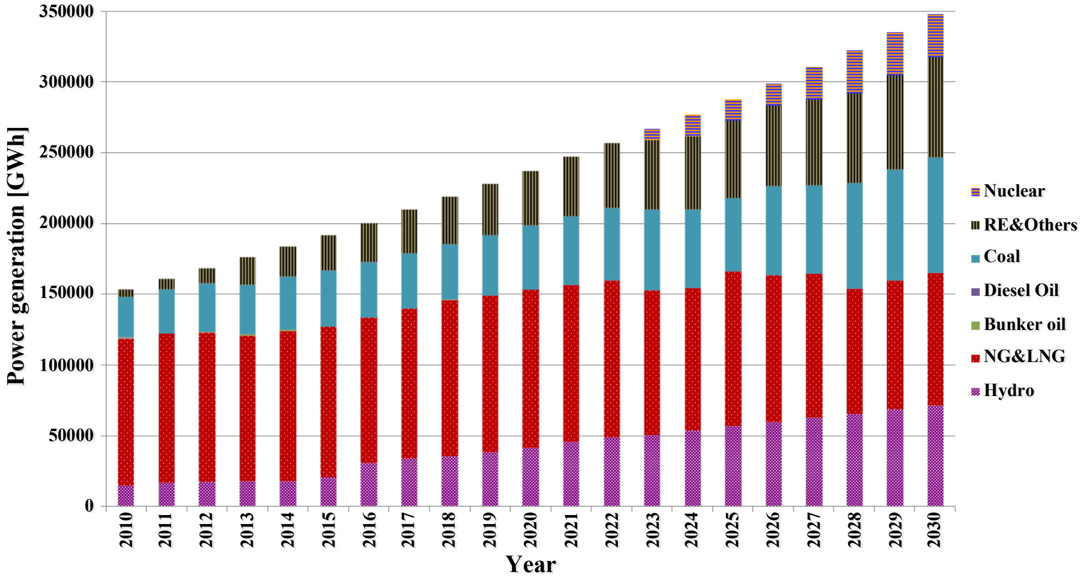

Figure 3 Projection of annual generating capacity classified by fuel type of PDP2010

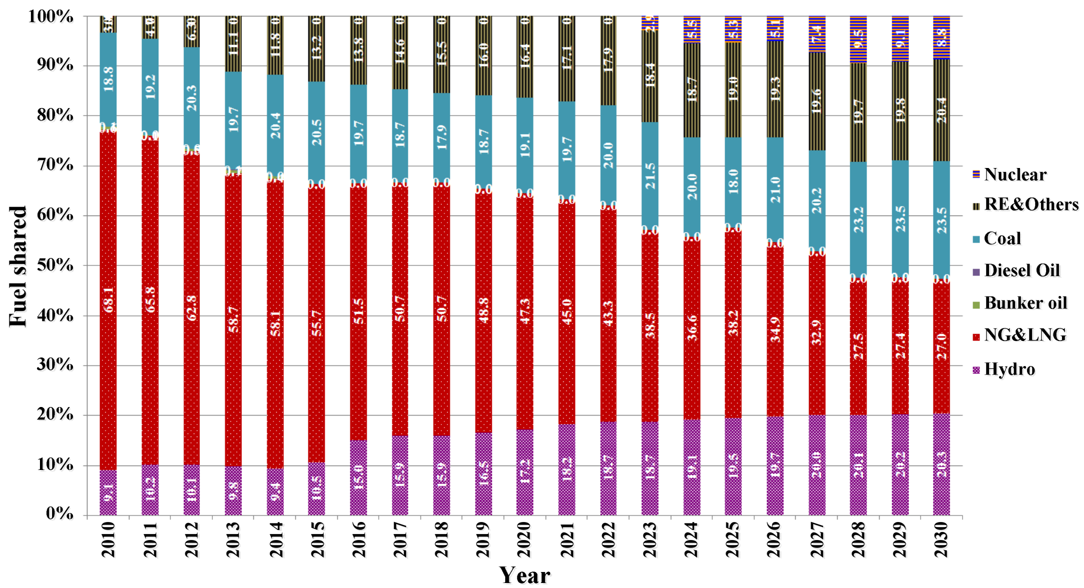

Figure 4 Annual fuel mixed of PDP 2010

option have to be studied and analyzed. In this study, five power generating options are systematically analyzed and then appropriate policy will be recommended.

Power system concepts

Power system is typically composed of four components; Generation, Transmission, Distribution and Consumer or Load as shown in Figure 5 and 6. When power transmits to power consumers, potential of generated electricity from power generations is stepped up for long distance delivery through transmission system and then stepped down in distribution systems before the power is transferred to customers. Moreover, system operator (SO), which is responsible for generation planning, and system operating management, has to maintain the power system reliably and effectively, while distributed generator (DG), which is small-scale power generator connected on distribution system, can effectively reduce technical loss of the system for its shorter distance to load.

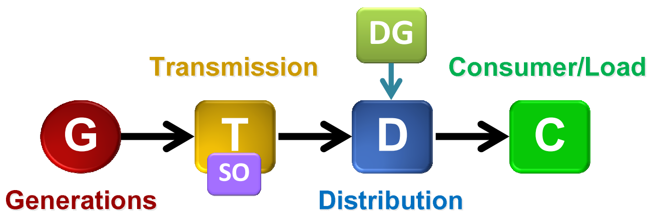

Figure 5 Power transfer in power system

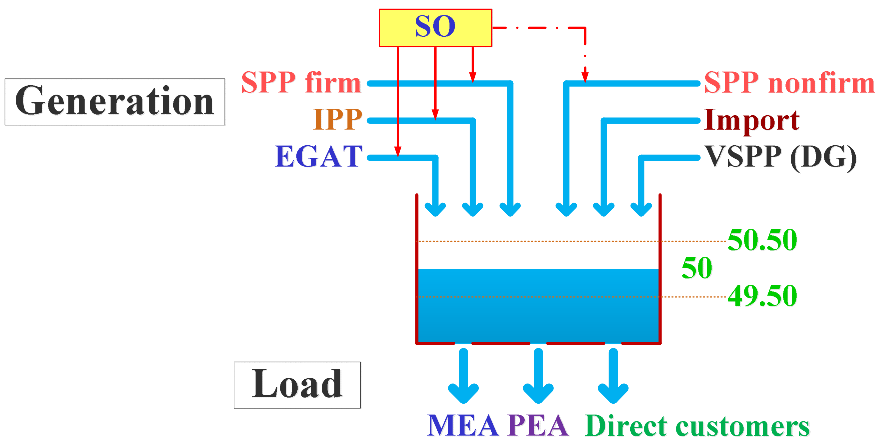

Figure 6 Principle of system frequency control in Thailand

Frequency control

Frequency[1], which is the most significant key index for monitoring the system operation, has to be regulated by SO, Electricity Generating Authority of Thailand (EGAT) followed the Thailand grid code[2] (EGAT, 1994; 2007) that the acceptable frequency range is between 50 ± 0.5 Hz. In order to control the frequency steadily, the generation and load including loss have to maintain equally. However,

Daily load forecast

Indeed, load cannot be controlled but its pattern can be forecasted. Typically, daily load profile in Thailand may classify into two major patterns; weekday and holiday. Figure 7 shows power generation profile on Sunday 9 and Monday 10 May 2010. The load profile on Monday 10 May, 2011 is not merely a typical daily load profile for weekday but being the maximum demand of the year 2010 (peak demand of year 2010 at 24,009.90 MW) as well, while the daily load profile on Sunday 9 May 2010 can represent a typical load profile for holiday and Sunday. Currently, daily load profile of week day has three peaks; morning, afternoon and evening peak, while daily load profile of holiday has only one peak in the evening. Furthermore, load is proportional to ambient temperature as can be seen that higher demand is always in summer. Thus, the load can be forecasted by using recorded load profile data and forecasted weather data. Then the generation can be planned by considering system constraint or limitation, merit order, security and reliability standard, and system standard.

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[1] **Frequency** means the number of alternating current cycles per second at which the System is running [expressed in Hz].

[2]**Grid Code** means collection of procedures and other documents, known as the Grid Code, prepared and issued by EGAT, as from time to time revised and re-issued.

electrical load, which refers to the use of electricity of all sectors in the power network system, is changed depending on power user so that the frequency can be controlled by adjusting the generations to meet the demand. Figure 6 shows the system frequency control in Thailand. When the load, which is referred to Metropolitan Electricity Authority (MEA), Provincial Electricity Authority (PEA) and EGAT's direct customers load, is increasing, this can cause the frequency drop, the SO will order to increase the generations in the system to compensate the frequency. In contrast, if the load is suddenly dropped, this can cause the frequency increase, the generations have to be reduced equally to the demand drop. To secure the power system, an optimum number of power generations must be standby on the system for serving the moving demand. Too many generations can enhance the generation cost, while too few generations can directly affect the power security. To maintain the power security and to keep a reasonable electrical generation cost, a proper daily load forecast and generation plan have to be systemically developed.

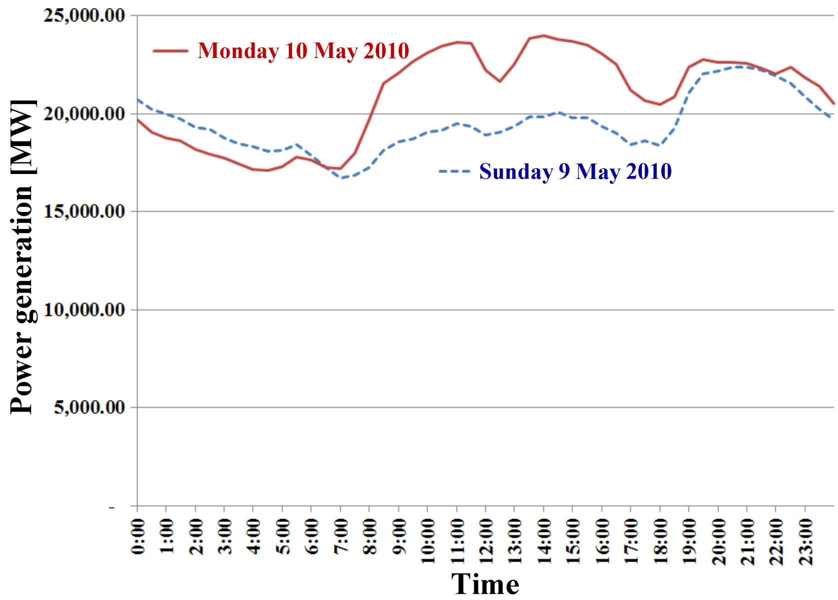

Figure 7 Power generation profile on Sunday9 and, Monday 10 May 2010

Power security and reliability

Power security and reliability means that the electric system is able to supply adequate power demand and requirements of the power users at all times under designed criteria and standards, and to withstand such an abrupted incident under the contingency criteria.

Generally, power users expect maximum power security and reliability or non-outage, and acceptable power quality with a low power tariff. However, the high power security and reliability require an enormous investment causing a high tariff. Furthermore, the lower power security and reliability, lower investment, increase risk to generate outage incident causing a high damage cost because an outage cost (ERI, 2001) is generally higher than a typical power tariff. Hence, power security and reliability standard should be optimally defined for each power system. The most significant reliability standard to secure the power system in Thailand is “N-1 contingency criteria”. The N-1 contingency criteria means the system must maintain stability during and after any disturbance in the system resulting in the loss of one generating unit or one circuit of transmission lines, as well as, loss of load is allowed (EGA, 2007). Since the current biggest generating unit in Thai power system is about 700 MW, therefore, the SO has to keep a spinning reserve[3] above 700 MW at all times excepting an emergency incident in order to meet the N-1 contingency

[3]**Spinning reserve** means the capacity on synchronized generating units which is not providing output but which is realizable in dispatch timescales.

criteria. Besides, being designed under the N-1 contingency criteria, the power system has to generate and deliver acceptable quality power to customers. Two major key indexes for the power quality monitoring are frequency and voltage level. In this study, several power generation options are analyzed for power security and reliability. Impact, policy and regulation suggestions are introduced.

Gas-fired power generation option

Natural gas supply

As mentioned previously, Thailand relies mainly on natural gas for power generation due to having an enormous natural gas supply and reserves especially in the gulf of Thailand, and gas-fired power generation being generally accepted by public for its clean and green or environmental friendly. Additionally, Thailand ranked 39th in terms of proved gas reserves with 342 billion cubic meters and 27th in terms of natural gas production with 28.76 billion cubic meters (US CIA, 2011). Although, Thailand has the vast natural gas reserves and the production capacity, the national production is still not enough to fulfill the national demand. Therefore, the natural gas has been imported since 2000 as in Figure 8 and 9. Furthermore, natural gas demand in Thailand is growing up rapidly from 327 million standard cubic feet per day (MMSCFD) in 1986 to 4,039 MMSCFD in 2010.

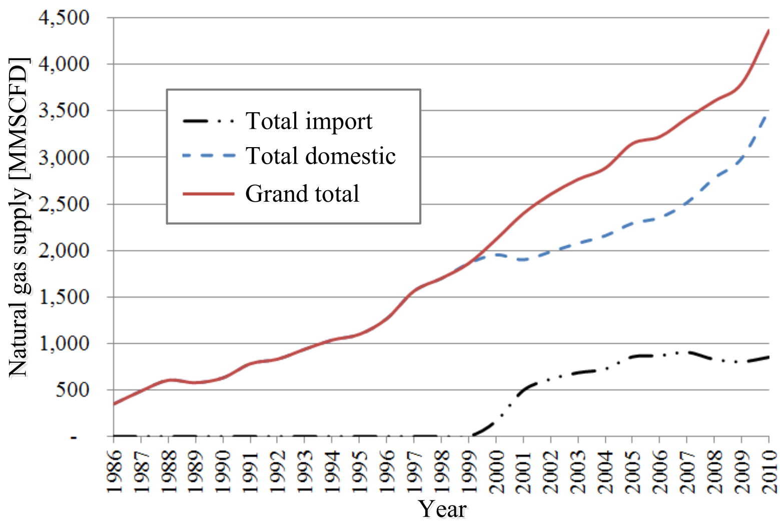

Figure 8 Thailand natural gas supply, 1986 to 2010 (EPPO 2011a)

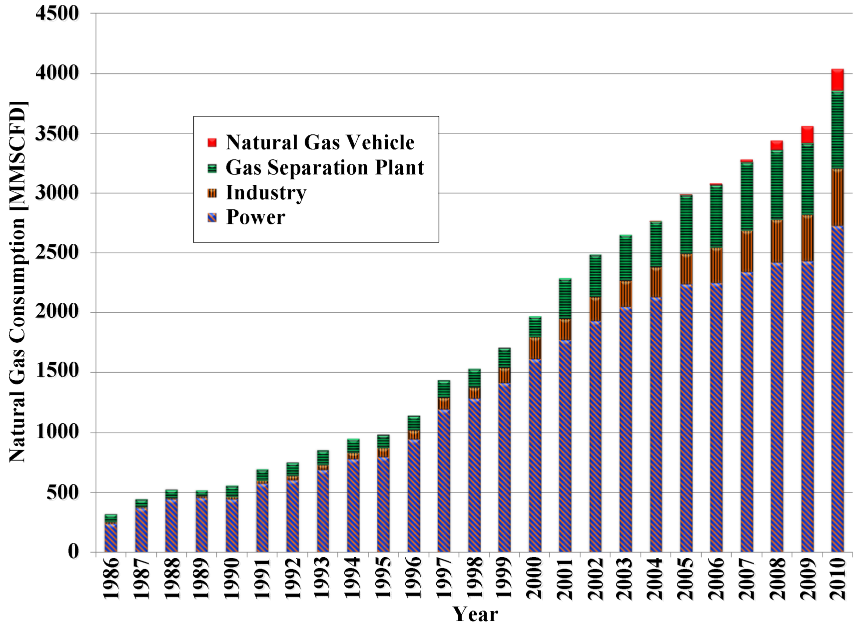

Figure 9 Thailand natural gas supply classified by natural gas users, 1986 to 2010 (EPPO, 2011a)

NEPC has approved a new revision of natural gas providing plan of Thailand on 28 June 2010 (EPPO 2011b). The forecasted national gas demand of the natural gas providing plan in 2020 is estimated to 5,542 MMSCFD. To fulfill future demand, new natural gas supplies are introduced for instance liquefied natural gas (LNG) import, gas production in joint development area, import natural gas from neighboring country etc. Moreover, the natural gas providing plan also includes main transmission pipeline network development plan. The new main transmission pipeline network development plan increases transmission capacity to 7,520 MMSCFD in 2026.

Although the PDP 2010 intends to mitigate the risk of natural gas supply by diversifying the fuel types and resources, the natural gas demand is still as high as current demand. To secure the national gas supply, additional gas supply needs to be imported. Practically, natural gas pools of neighboring countries, such as, Malaysia, Myanmar and Cambodia are primarily targeted to import because of its shorter distance for the gas delivery. For this purpose, royal Thai government has to keep a good relationship with neighboring countries.

Recently, LNG terminal, which is built in Map Ta Phut with capability to support 5 to 10 million tons LNG per year, has already begun to supply natural gas to natural gas transmission network. The LNG terminal can assist the power system and natural gas system management, especially during an emergency event as effective energy storage since LNG is capable of converting back to gas state by using gas regasification system. However, LNG should be used carefully for its higher cost compared to natural gas and coal.

Natural gas transmission

Practically and economically, if delivering distance is shorter than 2,000 kilometers, natural gas can be delivered through gas pipeline network using pressure difference to move natural gas. On the other hand, the expensive way, if delivering distance is further than 2,000 kilometers, natural gas has to be changed into LNG form, and delivered by LNG ship to offloading into to storage tank at LNG terminal and re-gasified gas, which is converted from stored LNG into gas phase, is fed into the gas transmission pipeline network to deliver to gas user.

Most of the pipeline including onshore and offshore pipeline are connected as network and using compressors to create natural gas movement. Figure 10 shows the natural gas transmission pipeline network in Thailand that is connected to national and international network. Although these pipelines are connected as one network, but natural gas properties from the gulf of Thailand, one from Myanmar and one from LNG terminal are different depending on the composition of the gas. One of the most important properties is high heating value (HHV) of the natural gas that is specific heat energy generated by fuel. Table 1 shows heating value of natural gas in Thailand's pipeline network.

Table 1 High heating value of natural gas and gas supply in Thailand's pipeline network

Natural gas location			Volume [MMSCFD]	High heating value (HHV) [BTU/scf]	Mixed high heating value (HHV) [BTU/scf]
East gas	The gulf of Thailand		~2,700	1,160 – 1,280	
	LNG		≤700		
West gas	Myanmar	Yadana	~700	720	838
		Yetagun	~460	1,020	

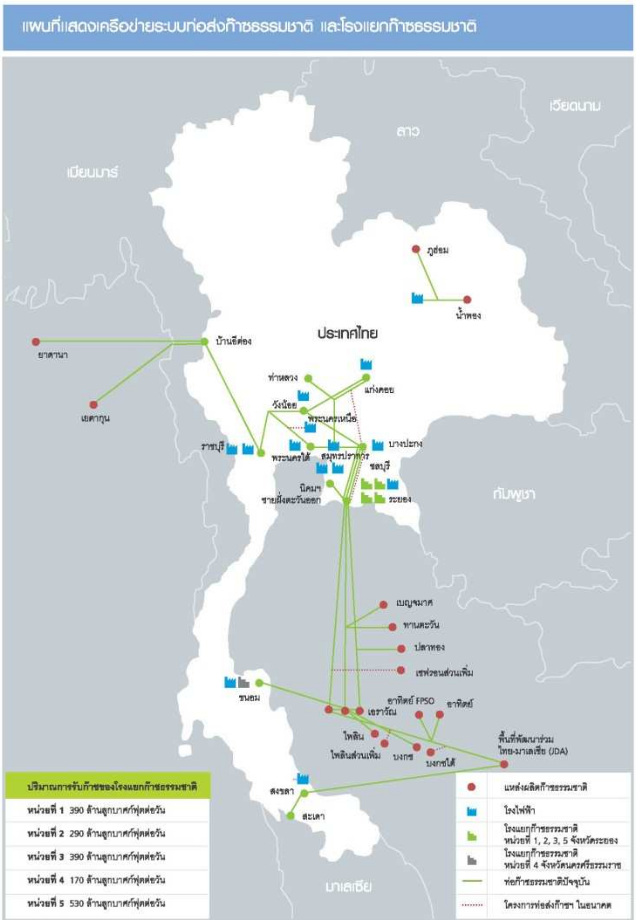

Figure 10 Natural gas pipeline in Thailand (PTT, 2011)

Difficulty from difference HHV

HHV, which varies from natural gas compositions, can directly affect to power generating capacity and security. Generally, power plant prefers fuel that contains fairly constant HHV in order to easily control the power output steady and to keep a higher efficient operation. Therefore, each typical thermal power plant, especially for a combine-cycle power plant, normally requires fuel with a specific HHV range to perform optimum power generation. If the HHV of the natural gas completely deviates from the original design, the composition of gas may be changed by mixing with other composition or removing some compositions of the natural gas, such as, CO_2 etc., for optimizing the HHV, or the power plant may need to be modified for accepting a new HHV range.

In Thailand, HHV of east and west gas are obviously different so that they cannot be used replaceable to each other even the pipeline network is connected together. Moreover, whenever one of the Myanmar gases is missing, HHV of west gas can greatly change and may impact to the power plant operation.

Power security and reliability impacts management due to natural gas power generation option

Sources of power security and reliability can be affected by natural gas power generation option, which are over dependence, natural gas supply limit, gas short fall event, and gas quality difference.

Over dependence on natural gas will be a high risk for Thai power system. It can be mitigated by diversifying the fuel mix. The most difficulty to diversify the fuel mix is introducing other power generations since some technology, such as, nuclear technology will be objected by the local community. One good solution is to inform and educate public with the truth about advantages and disadvantages, risks, impacts and necessity of all the power generation options.

Natural gas supply limit, because of a high demand growth, can be solved by improving energy usage efficiency for decreasing the demand, introducing an alternative resource, and/or developing a novel natural gas supply, such as, joint development area in Thai-Cambodia border. In order to prolong the gas supply in the gulf of Thailand as long as possible, the gas supply rate should be constant so the fluctuation followed the natural gas demand can swing by LNG.

Gas short fall event, which may occur by several reasons, for example, natural gas exploration and production, and/or transmission incident natural disaster etc., can be minimized by performing a routine maintenance, and/or developing and implementing an emergency response planning.

Gas quality difference problem, especially for HHV's shortcoming as mentioned previously, may be minimized by increasing reserve margin standard of the power system, installing more thermal power plant that can accept a wider range of HHV.

Coal-fired power generation option

Coal supply

Coal-fired power generation is selected power option for its high coal reserve, low generation cost and less fuel cost fluctuation. Additionally, coal reserves around the world are estimated at 909.4 billion tons reflecting a current reserves-to-production ratio of 129 years(US EIA, 2010).Most of coal in the northern part of Thailand, which is lignite, is being used for power generation in Thailand.

Public resistance and generation technology

Due to a low production cost, coal-fired power generation is operated as base load power plant. To diversify the fuel mixed in power production, new 7,600 MW of coal-fired power plant is settled in PDP 2010.However, the novel coal-fired power generations have confronted with serious and strong resistance from local communities, who concerned about pollutions from the power plant, such as, greenhouse gas (GHG) emissions, NOx and SOx emissions, noise pollution, dust, etc. Currently, several advanced clean coal technologies for instance carbon capture storage (CCS), integrated coal gasification combine cycle (IGCC), etc., have been practically demonstrated with lower pollutions. These technologies can greatly reduce pollution compared to the old-day technologies, but the generation cost of the cleaner technologies is higher than the old one. To gain the public acceptance, current standard and regulation about pollution should be revised and the cleaner technologies should be adapted.

Power security and reliability impacts management due to coal power generation option

Sources of power security and reliability impacts *due to* coal power generation option are public acceptance and emission problem.

Public acceptance problem, because coal power generation option generates a high pollution emission, it can be mitigated by adapting new emission standards and technologies, and/or educating public with the facts. The new regulatory standards regarding coal-fired power plant emission should be revised to a clean gas-fired power plant. Public should be well informed and educated with the facts about advantages and disadvantages of all the power generation options, risks, impacts and necessity of all the power generation options.

Emission problem, the environmental law and regulation will limit the power generating capacity. This problem can be minimized by alternating or adding with a pioneer cleaner technology, such as, CCS, IGCC etc.

Hydro power generation option

Power for serving peak demand

Hydro power generation can be operated with a very low cost and non GHG-emission. It suits for generating power at the demand peak because of its quick start up and fast response property. However, reservoir of hydro power plant is mainly limited by irrigation purpose and festival request, such as, Loy-kratong festival, etc. During a very low power consumption period, the designed hydro power plant may use excess power in the system to pump water back to store in the dam, that is so-called pump storage. Because of these unique and outstanding engineering merits, hydro power generation does not followed the merit order and mainly serve to peak demand excepting the import hydro power from neighboring countries that performs as a base load power plant due to designed power purchase agreement (PPA). Since most of potential large hydro power plant sites are in neighboring countries, Thailand imports a large amount of hydro power from Lao PDR.

Power security and reliability impacts management due to hydro power generation option

Sources of power security and reliability impacts *due to* hydro power generation option are reservoir limit and international relationship.

Reservoir limit, which is majorly due to irrigation purpose, can be mitigated by developing a long, medium and short reservoir usage plan.

Inter-relationship, due to most of hydro power nowadays relies on neighboring countries, should be maintained properly. To secure the power system sustainably, information between contract partners should be regularly shared.

Renewable energy power generation options

Potential of renewable energy power generation

The renewable energies (RE),which are solar, wind, small hydro, biomass, biogas, municipal solid waste (MSW), and hydrogen, are promising for Thailand's power system because it is environmental friendly, reproducible, and sustainable. Moreover, construction period of most renewable energy power plant is very short compared to conventional fossil fuel power plant. Thailand has high potential in several REs for instance solar energy, biomass, biogas, municipal solid waste (MSW), etc. Table 2 shows potential and national targets of renewable energy power generation in the PDP 2010.

Table 2 Potentials and national targets of renewable energy power generation [EGAT, 2010]

Type	Potential [MW]	Existing* [MW]	2012 to 2016		2017 to 2022	
			[MW]	[ktoe]	[MW]	[ktoe]
Solar	50,000	32	95	11	500	56
Wind	1,600	1	375	42	800	89
Small hydro	700	56	281	73	324	85
Biomass	4,400	1,610	3,220	1,682	3,700	1,933
Biogas	190	46	90	40	120	54
MSW	400	5	130	58	160	72
Hydrogen		0	0	0	3.5	1
Total		1,750	4,191	1,907	5,608	2,290

* Existing installed capacity as of 2010

RE power generation is generally in small size so it is appropriated to be Distributed Generation (DG) that can potentially eliminate the transmission technical loss for its shorter distance. Although most RE resources are free, such as, wind, solar etc., return of RE power plant project nowadays, which calculated with a typical power tariff, is not so attractive because of high investment cost and low capacity factor that is generating capacity of the power plant. To overcome the shortcoming, an incentive scheme; adder scheme, which is an additional feed-in for generated power, has been introduced for specific REs for instance solar power, wind power etc. The adder scheme can effectively drive the growth of RE markets in Thailand as can be seen in a number of applicants for adder program.

Solar Power Generation option

Power from the sun

Solar energy, which is energy from the sun, is promising energy for sustaining our future for its non-energy cost, abundance and sustainability. Thailand located in the Sun Belt area, has a high global solar radiation potential estimated to be 18.0 MJ/m^2-d (DEDE, 2010a). Figure 11 shows annual averaged-global solar radiation potential map of Thailand.

The high averaged-global solar radiation areas, which are mostly located in north-eastern part of Thailand, are the high potential solar power generation site as

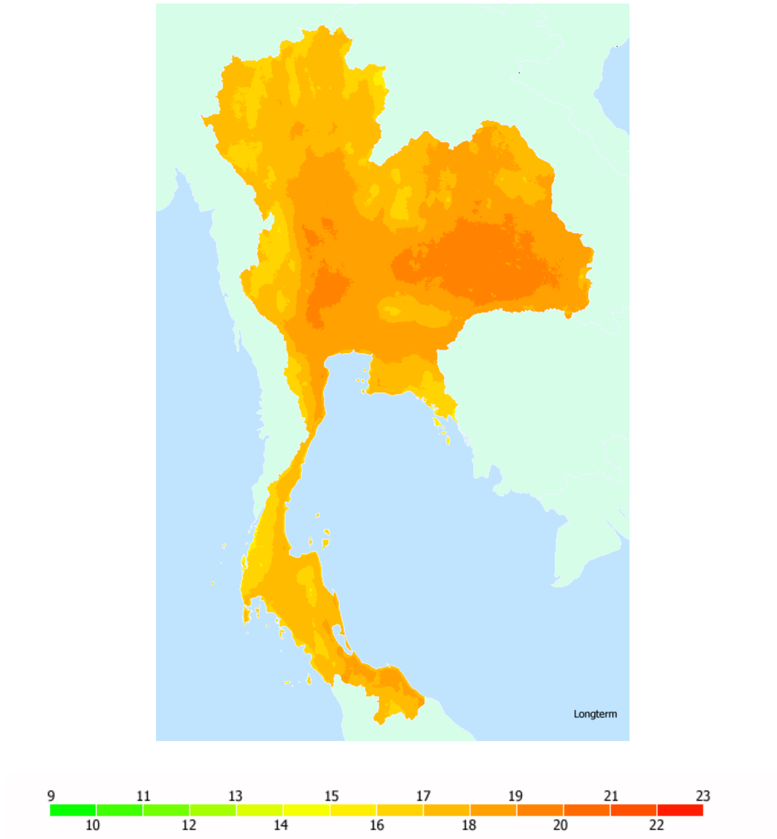

Figure 11 Annual averaged-global solar radiation potential map of Thailand

well. To produce solar power, photovoltaic (PV) and concentrating solar power (CSP) are two common technologies. PV technology applies the photo-electric effect to generate power so the solar radiation that has enough energy can be used to generate solar power. CSP technology uses the sun as a heat source to heat working fluid and then to drive sterling engine or turbine engine for producing electricity. The heating process is conducted by concentrating direct sunlight that has a predictable direction because the solar radiation is not strike any matter during travel from the sun to the earth. The direct radiation in Thailand is approximately 60 % of global solar radiation, while the other 40 % of global solar radiation is diffuse radiation that is the scattered-solar radiation.

Although the sun energy is green and free, solar power system cost is quite high and capacity factor (CF) of solar power, which is an indicator of produced energy in a particular place, is quite low because of a low efficiency and short sunshine hours. The CF in Thailand is about 15 %, equivalent to 3 hours per day. Fortunately, solar power generation system cost is continuously reducing, while power tariff, which reflects to the conventional power generation cost plus returns, is gradually increasing so grid parity, which is the time when solar power generation cost equal to power tariff, will occur in near future.

Distributed generation (DG)

Solar power generation system also has a high potential to operate as distributed energy resources because of its small scale and possible installation on the ruff and closed to the load. However, solar farm is mostly far from the load center so the loss can be high. In order to demonstrate a low loss DG system, policy and regulation should be encouraged investors to develop solar power projects in or closed to the load center by revising the current incentive scheme. Moreover, solar power generation is appropriated for operating with on-grid and off-grid system and be able to lift the voltage drop in radial line of distributed system.

Power generation transient instability and voltage fluctuation

During a daytime, solar radiation varies depending on cloud, vapor, gas, dust, season and weather. Therefore, solar radiation will be fluctuated during a cloudy day. If solar radiation is suddenly changed, the power output will change following the solar radiation. If the power output fluctuates but load is constant, then the voltage level will fluctuate following power output as well. This phenomenon may shift the voltage level out of acceptable length as assigned in the grid code. To solve this problem, several new technologies are available but the policy and regulation should be revised.

Islanding

Islanding, which is "that part of a power system consisting of one more power sources and load that is, for some period of time, separated from the rest of the system" (IEEE, 2000), is a major concern for network-workers during brownout recovery. The solar power generation system should be able to detect the islanding effect and move out of the network system. Therefore, safety regulation should cover this topic.

Power security and reliability impacts management due to solar power generation option

Sources of power security and reliability impacts from solar power generation option are power generation instability and power quality instability that usually happens during the cloudy day.

Power generation instability is occurred because solar radiation is available only on the day time and varies depending on cloud. During the cloudy day, solar radiation can suddenly fluctuate causing immediate fluctuation in solar power, especially for PV technology. This study will propose four solutions, which are energy storage, additional fast spinning reserve, demand response and daily forecast.

<u>Energy storage:</u> One easy approach to overcome the difficulty is applying the energy storage system such as battery etc., as energy buffer for absorbing the power fluctuation. However, the energy storage can greatly increase the power system cost so an optimum capacity of energy storage should be defined. The optimum capacity of energy storage should be estimated before using energy storage.

<u>Additional fast spinning reserve:</u> Currently, spinning reserve in the system is about 700 MW complying with N-1 contingency criteria. Similar to energy storage, an additional fast spinning reserve is able to swing followed to the solar power fluctuation while the load is constant but this approach highly increases the power system cost. Therefore, optimum spinning reserve should be identified. One interesting approach is to develop daily solar power generation forecasting for estimating the optimum required of spinning reserve.

<u>Demand response:</u> Another solution is to manage the demand side by using demand response (DR) that is intermediately power load cutting when the power supply is insufficient. Unfortunately, the DR is not capable of solving the power generation instability when oversupply. Therefore, DR requires additional tool to avoid oversupply situation, for example; modifying grid code and/or grid regulation to reject the over-generation etc.

Power quality instability occurs during power generation fluctuation. Assuming power load being constant, voltage level is proportional to solar power generation so that voltage quality changes following solar power generation. The previous solutions; energy storage, additional fast spinning reserve, demand response and daily forecasting, can apply to balance demand and supply of the system for maintaining voltage level within the acceptable range. Another approach is to develop a renewable grid code that assigning all renewable generators to provide reactive power to control system voltage.

Wind Power Generation option

Wind potential

Wind in Thailand, which is mainly influenced by north-east monsoon and south-west monsoon, averages annually more than 6 m/s for wind at 90 meters above ground (DEDE 2010b).Figure 12 shows annual-averaged wind potential map of Thailand at 90 meters above ground. Southern part is a high wind potential area compared to other areas in Thailand.

Wind power generation difficulties

Similarly to solar energy, wind energy is also green and free, but investment cost of wind power generation is quite high but not as much as cost of solar power generation. Indeed, most of wind speed in Thailand is quite low and does not match to a conventional speed for wind power generation. To fulfill national environment, a novel technology of wind power generation particularly for low wind speed needs to be developed. Wind power generation is suit for DG, on-grid system, off-grid system and lifting radial line’s voltage as solar power generation. However, wind power generation also suffers from islanding, power generation transient instability and voltage fluctuation but these problems are less severe than solar power generation because of having moment of inertia. In addition, some areas, where the wind power station has been settled, suffer from public resistance since it creates a noise pollution.

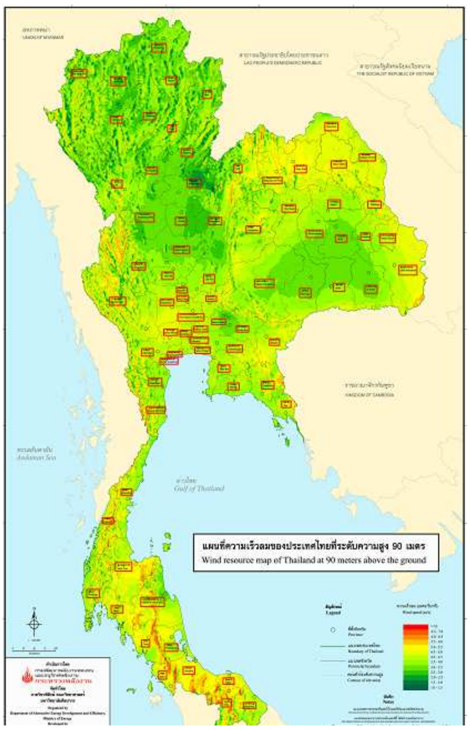

Figure 12 Annual averaged wind potential map of Thailand at 90 meters above ground

Power security and reliability impacts management due to wind power generation option

Sources of power security and reliability impacts due to wind power generation option are power generation instability, power quality instability and public resistance.

Power generation instability is able to be overcome by the same solutions as solar power generation; energy storage, additional fast spinning reserve, and DR. *Power quality instability y*is able to be overcome by the same solutions as solar power generation.

Public resistance, which may be mainly a noise pollution, can be mitigated by developing regulation to set a proper distance between wind turbine and households/communities.

Small Hydro Power Generation option

Small hydro power being green and cheap

Small hydro power generation is non GHG emission and low cost power generation technology. These attractions seem to be interested by the developers but majority of potential sites of small hydro power generation in Thailand are settled in restricted area that suits for off-grid generation and does not open for private sectors to implement. Moreover, Small hydro power generation, which is mainly limited by reservoir and water storage level, is non-firm generation for its season pattern generation.

Power security and reliability impacts management due to small hydro power generation option

Sources of power security and reliability impacts due to small hydro power generation option are reservoir limit.

Reservoir limit, which is majorly caused by reservoir and water storage level, can be minimized by collecting reservoir and water reserve information and developing a forecasting model using history records.

Biomass Power Generation option

Biomass resources

Biomass power generation in Thailand, which uses wastes and residues from agricultural industry as biomass resources such as rice husk etc., is currently a majority shared of renewable power generation since Thailand is a developing country mainly focuses on agricultural activities. Normally, potential of biomass power generation, which depends on biomass resources, is not always fixed at 4,400 MW but be able to increase following to the agricultural production yield. During the first introduction of biomass power generation, the biomass is free waste, but resource price has been raised after the biomass power market growing up. In some areas, the demand is more than the supply and may need to import extra biomass resources for maintaining the biomass power generation. This approach enhances generation cost of biomass power.

Green technology

Generally, biomass power generation uses conventional thermal power plant technology for generating power. Stream, which is generated by burning biomass, drives generating unit to produce biomass power. However, this technology emits high pollutions, such as, CO_2 etc. depending on generating technology, burning temperature, type of biomass, moisture, etc. And public reactions against these pollutions also are the problem to further develop this technology. To minimize the pollutions, several clean technologies such as gasification, carbon capture storage technology, etc., can be applied but the generating cost will increase.

Additionally, plant factor of biomass power generation technology, practically, does not depend on generating technology, but mainly depends on biomass resources.

Power security and reliability impacts management due to biomass power generation option

Power security and reliability impacts due to biomass power generation option are the lack of resources and limited production with pollution emissions.

Lacking of resource, which is mostly due to a high demand area, is possible to minimize by resource planning and management, and zoning regulation. Investors and also public should be educated and informed about the truth of power generation technologies with merits and obstacles of each technology. Particular to biomass power generation, biomass resources is a significant key to sustain the power generation. Therefore, general information about local demand and supply of biomass should be provided for avoiding an over-demand in the future. Furthermore, zoning regulation may be developed by determining a maximum installed capacity of the biomass power generation in a specific area for avoiding an over-demand in specific area in the future. However, market competition issue should be concerned to develop this approach.

Pollution emissions, which have been regulated, are mitigated by strong law enforcement. In additional, several new technologies should be introduced to the new investor and developer, or the regulation should be amended to the cleaner level, if the cost of new cleaner technology is not different from the conventional one.

Biogas Power Generation option

Biogas power

Biogas power generation option uses methane produced from biomaterial as fuel to produce stream for driving power generating unit to generate biogas power. The biogas power is not merely capable of massively decreasing GHG emission and promoting energy efficiency usage as well. Moreover, the generation cost of some biogas power generating technology is feasible to compete with commercial technology so the biogas power generating technology is a promising renewable energy nowadays. However, biogas power system is not easy to maintain and some part is flammable. Thus, operators should be well-educated and careful during working with this technology. Moreover, biogas production is quite difficult to control and manage.

Power security and reliability impacts management due to biogas power generation option

Sources of power security and reliability impacts due to biogas power generation option are biogas production safety.

Biogas production safety, which is quite difficult to control and manage, requires an expert or a well-trained operator to develop a production management plan for operation maintenance.

Municipal Solid Waste (MSW) to Power Generation option

Municipal solid waste (MSW) management

MSW to power generation, which is power conversion from wastes, is a wonderful approach to reduce GHG emission, to minimize waste and use energy efficiently. The MSW to power generating technology is quite reliable but the waste management is quite difficult since Thai people do not classify wastes. Hence, the wastes have to be classified before using as fuel resources for MSW to power generation.

Power security and reliability impacts management due to MSW to power generation option

Sources of power security and reliability impacts due to MSW to power generation option are poor waste management.

Poor waste management can be mitigated by waste classification. Indeed, waste classification should begin at home so government should strongly promote and try to change public attitude about waste classification.

Hydrogen Power Generation option

Hydrogen is a major component in water that is abundant around the world so that hydrogen potential is able to define as unlimited. Hydrogen extraction from water or the other materials requires high technologies and consumes very high cost. Moreover, hydrogen power generation also uses a very high technology and an extremely high cost. Because of the really high generating cost, hydrogen power generation option does not exist in the power system in Thailand even it is an environmental friendly technology and sustainable resources. The hydrogen power generation will be more interesting, if its technology is breakthrough state of art and the generating cost reduced to compete with other commercial generating technologies. *Additionally, portion of hydrogen power generation option in PDP 2010 is insignificant when compared to total power generation so that the hydrogen power generation option does not impact to the power security and reliability in Thailand.*

Nuclear power generation option

Nuclear power in PDP

The nuclear power generation option was first integrated into national power development plan (PDP); PDP 2007 during the oil price fluctuation period or oil crisis for being a future promising approach to solve energy and environmental crisis. Several preparatory works for the first nuclear power plant project in Thailand have been launched. Nuclear Power Infrastructure Establishment Plan (NPIEP) has been developed and implemented and, Nuclear Power Program Development Office (NPPDO) and Nuclear Power Infrastructure Establishment Coordination Committee (NPIECC), which is under the Ministry of Energy, have been appointed to coordinate the NPIEP implementation.

In 2009, PDP 2007 was revised because of the global economic recession and called Thailand's Power Development Plan 2008-2021 revision 2 (PDP 2007 rev. 2) (EGAT 2009). The nuclear power generation option in PDP 2007 rev. 2 was reduced from 4,000 MW to 2,000 MW of nuclear power generation.

As mentioned previously, the PDP 2010planned to introduce5,000 MW of nuclear power generation but then the first nuclear power plant was postponed for three years after nuclear crisis in Fukushima prefecture, Japan.

Progress of the first nuclear power project

To launch the preparatory work for the first NPP project in Thailand, the NEPC appointed the Nuclear Power Infrastructure Preparation Committee (NPIPC), which responds to develop The Preliminary Nuclear Power Infrastructure Establishment Plan (NPIEP) in April 2007. On 30 October 2007, the Thai Cabinet (Patchimpattapong, 2008; Kritayakirana, 2008) approved The Preliminary Nuclear Power Infrastructure Establishment Plan (NPIEP) and the establishment of the Nuclear Power Program Development Office (NPPDO), which was launched officially in January 2008, under the Ministry of Energy to coordinate the NPIEP implementation, and the work plan for NPPDO and the NPIEP implementation during 2008-2010 (3 years).

NPIEPwas composed of five phases; Phase 0.1 Preliminary phase, Phase 1 Pre-project activity phase, Phase 2 Program implementation phase, Phase 3 Construction phase, and Phase 4 Operation phase. Figure 13 shows NPIEP Milestones for Nuclear Power Program Implementation (EPPO 2009).

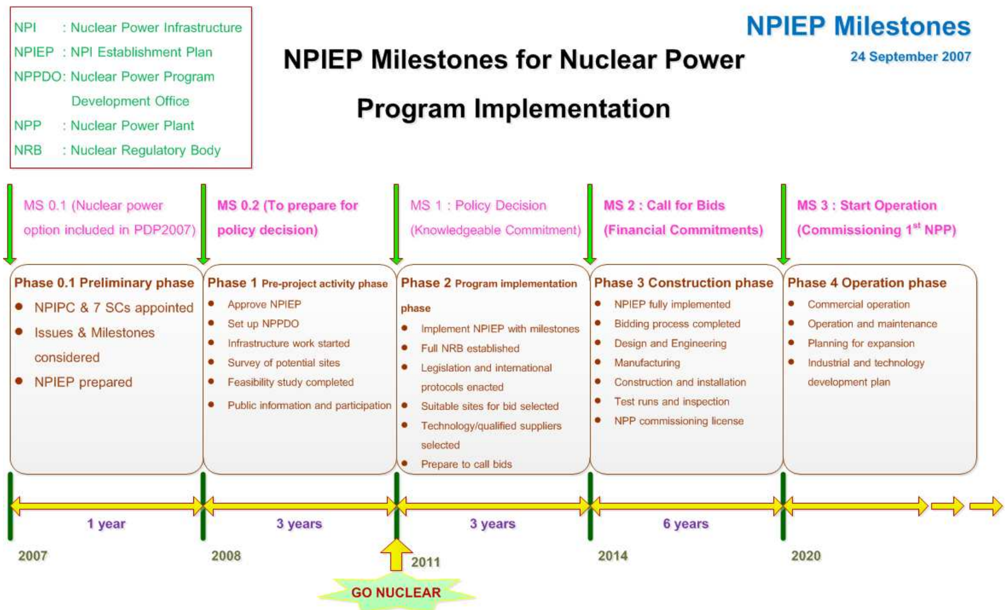

Figure 13 NPIEP Milestones for Nuclear Power Program Implementation (EPPO, 2009)

EGAT, who is responsible for the first NPP project under the supervision of NPIECC, has performed assessments on safety, economic and environmental aspects of the 17 potential sites and identified five candidate sites for further consideration (Ratanakorn, 2010).

Because of public concern after the nuclear crisis, the first nuclear power project has been already postponed and will be considered in the future.

Safety review

After the nuclear crisis in Japan, all nuclear countries are performing nuclear safety evaluation process and, reviewing nuclear safety standards and regulations. International Atomic Energy Agency (IAEA), which is the world’s center of cooperation in the nuclear field, is also learning the Fukushima Daiichi nuclear power plant’s lesson for improving nuclear safety guideline. Therefore, new nuclear safety guidelines and standards may be introduced in the near future. Indeed, new safety standards or regulations usually impact to investment, operation and maintenance (O&M) cost. Thus, NPPDO and EGAT may need to review the NPIEP to meet the new standard. Moreover, independent nuclear regulatory body, which responses for regulatory development, should be established as introduced by Siritiprussamee, Bhanthumnavin, and Chansa-ngavej (2011).

Generation cost

First investment cost is a major key to determine nuclear power generation cost because fuel cost per generation is low. Many countries introduce nuclear power as low cost power generation. However, some project suffers from cost over-run then the generation cost is high. Risk management should be conducted for assure that the budget of the project can be controlled. In addition, nuclear power generation is technically proper to operate as base load generation because the generation cost will greatly increase when reducing generation capacity. To minimize this shortcoming, Bhanthumnavin and Bhanthumnavin (2010) emphasized that small nuclear power plant can be another promising option for its smaller scale, lower overall investment cost, and easier to maintain.

Non-GHG emission technology but public resistance

Nuclear power generation is generally accepted as non GHG emission power generation that is a good candidate to solve climate-change crisis. However, nuclear power generation generates a large amount of radioactive wastes and also emits radiation to environment surrounded the power plant. Because of a bad image from the past and fear from post incidents and accidents, nuclear power generation in many countries is resisted by the public. In Thailand, EGAT's survey shows that the nuclear power plant project is mainly refused by local communities in the potential site areas corresponding to "not in my backyard; NIMBY" (Patchimpattapong, 2010). To gain more public perception, Bhanthumnavin and Bhanthumnavin (2009) and, Siritiprussamee, Bhanthumnavin,and Chansa-ngavej (in press) suggested that correct information including both advantages and disadvantages regarding nuclear power generation option should be widely dispersed to public.

In order to make a decision on this generation option, the necessity of the nuclear power is an important part, if the others new power generation technologies can be technical and economic feasible in time, "go nuclear" will not be selected. However, neighboring country likes Vietnam will implement the nuclear power projects so Thai people should be continuously educated about radiation and nuclear safety, emergency response, and the truth of both advantages and disadvantages of nuclear power.

Power security and reliability impacts management due to nuclear power generation option

Sources of power security and reliability impacts due to nuclear power generation option are public resistance and regulatory incompletion.

Public resistance, which is majorly due to nuclear image and concerning about safety issues, can be mitigated by sincerely informing to public about radiation and nuclear safety, emergency response, the truth of both advantages and disadvantages of nuclear power.

Regulatory incompletion, which is one suggestion from IAEA's specialist, should be done along with the IAEA guidelines.

Summary

Significant sources of power security and reliability impacts can divide into four categories; resources problem, generating problem, out of acceptable quality and public opinion. Table 3 shows summarization of key solutions for each power generation option.

Table 3 Summarization of key solutions for each power generation option

Generation option		resources problem	generating problem	out of acceptable quality	public opinion
Natural gas		❖ Diversify fuel types ❖ Multi-root of gas pipe line		❖ Regulating heating value by using LNG	
Coal			❖ Cleancoal technologies	❖ low pollution regulations	❖ low pollution regulations
Hydro		❖ Water usage plan	❖ Water usage plan		
RE	Solar	❖ Weather forecast	❖ Energy storage ❖ Demand response	❖ Energy storage ❖ Demand response	
	Wind	❖ Weather forecast	❖ Energy storage ❖ Demand response	❖ Energy storage ❖ Demand response	❖ Site selection regulation
	Small hydro	❖ Water usage plan			
	Biomass	❖ Resources planning	❖ Clean technologies	❖ low pollution regulations	❖ low pollution regulations
	Biogas	❖ Safety production			
	MSW	❖ Waste management			
	Hydrogen	Insignificant portion in the PDP 2010			
Nuclear			❖ New safety standards and regulations		❖ Inform public with correct information

Conclusions

In this study, sources of power security and reliability impacts for each type of power generation option, or that can lead to power shortage and/or outage events, can be classified into four categories; resources problem, generating problem, out of acceptable quality and public opinion. To overcoming the shortcomings, one necessary activity is to disperse and to educate public about the correct information of both pros and cons of each power generation option. Fossil fuel power generation options, which are economical and technical feasible technologies, still require more public acceptance and some technical limits should be minimized. New hydro power generation options are mostly imported from neighboring countries so that the international relationship should be aware and maintained. RE power generation options needed to be further developed for a more reliable generation. Nuclear power generation option suffers from public resistance so the decision on this option should be carefully considered. All the power generation options, which are important to fulfill the national power demand, require difference technical policies and regulations to sustain the power security and reliability of Thailand. Therefore, policies and regulations for each power generation options should be tailored to fit its requirements.

References

Bhanthumnavin, V. & Bhanthumnavin, D. (2009).Nuclear power plant wastes: Impacts, management and social responses. ***Journal of Social Development, 11(1),*** 1-24.

Bhanthumnavin, V. & Bhanthumnavin, D. (2010). Small and medium nuclear reactor for development. ***Journal of Social Development, 12(2),*** 53-91.

Bhanthumnavin, V. &Bhanthumnavin, D. (2011). Fukushima Daiichi nuclear accident: Causes and social Impacts. ***Journal of Social Development, 13(1),*** 102-128.

Department of Alternative Energy Development and Efficiency (DEDE). (2010a). ***Solar energy map of Thailand 2010.*** Ministry of Energy. Royal Thai Government. Available at http://www.dede.go.th.

Department of Alternative Energy Development and Efficiency (DEDE). (2010b). ***Wind energy map of Thailand 2010.*** Ministry of Energy. Royal Thai Government. Available at http://www.dede.go.th.

Energy Generating Authority of Thailand (EGAT).(1994). ***Grid code 1994.*** Available at http://www.egat.go.th.

Energy Generating Authority of Thailand (EGAT).(2007). ***Grid code 2007.*** Available at http://www.egat.go.th.

Energy Generating Authority of Thailand (EGAT).(2009). ***Power Development Plan (PDP) 2007revision 2.*** Available at http://www.egat.co.th/enimages/stories/pdf/PDP2007Rev2-Mar2009-Eng(wo-invest).pdf

Energy Generating Authority of Thailand (EGAT). (2010). ***Power Development Plan (PDP) 2010.*** Available at http://www.egat.co.th/en/images/stories/pdf/Report%20PDP2010-Apr2010_English.pdf

Energy Policy and Planning Office (EPPO). (2009). ***Nuclear Knowledge Handbook.*** Ministry of Energy. Royal Thai Government. Available at http://www.eppo.go.th/nuclear/handbook.pdf

Energy Policy and Planning Office (EPPO). (2011a). ***Energy Information System Development Division.*** Ministry of Energy. Royal Thai Government. Retrieved from http://www.eppo.go.th.

Energy Policy and Planning Office (EPPO). (2011b). ***The National Energy Policy Committee (NEPC) Resolution***. Ministry of Energy. Royal Thai Government. Retrieved from http://www.eppo.go.th/nepc/.

Energy Research Institute (ERI). (2001). ***Outage cost study***. Chulalongkorn University.

IEEE. (2000). ***IEEE 100: The authoritative dictionary of IEEE standards terms.*** Available at http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4116787.

Kritayakirana, K. (2008). ***Thai National Nuclear Power Program: Outline, Projects and Required Experts.*** Nuclear Power Program Development Office (NPPDO).Ministry of Energy. Thailand. Franco-Thai Seminar on Climate Change.

Patchimpattapong, A. (2008). ***Nuclear Power Project in Thailand.*** ESI Conference 2008. Thailand.

Patchimpattapong, A. (2010). ***Insights on Thailand's Plan for Nuclear Power.*** Nuclear Power Asia 2010. Kuala Lumpur. Malaysia.

PTT Public Company Limited. (2011). ***Map of Natural Gas Transmission Pipeline System.*** Retrieved from http://www.pttplc.com/en/about-ptt-business-operations-gas-unit-transmission-pipeline.aspx.

Ratanakorn, S. (2010). ***Site selection and evaluation in Thailand.*** Technical Meeting on Tropic Issue on Infrastructure Development: Common Challenge on the Site Selection for Nuclear Power Plant. Vienna. Retrieved from http://www.iaea.org/NuclearPower/Downloads/ Infrastructure/meetings/2010-06-TM/SITE.SELECTION.AND.EVALUATION.IN.THAILAND.pdf.

Siritiprussamee, P. Bhanthumnavin, V. & Chansa-ngavej, C. (2011). Nuclear Power Regulation: Nuclear power plant project in Thailand. ***Journal of Social Development, 13(1),*** 129-143.

Siritiprussamee, P. Bhanthumnavin, V. &Chansa-ngavej, C. (in press). Impact management: Nuclear power plant project in Thailand. ***Journal of Sustainable Energy and Environment.*** XX(XX), xxx-xxx.

US Central Intelligence Agency (CIA).(2011). ***Country comparison information.*** Retrieved from https://www.cia.gov/library/publications/the-world-factbook/ rankorder/ 2179rank.html.

US Energy Information Administration (EIA). (2010). ***Coal.*** Retrieved from http://www. eia.gov/oiaf/ieo/coal.html.