Chapter 5

Determination of Reliability Must-Run Units

Must-run and must-take units are two new terms in power industry. These two terms are introduced since they affect reliability and commercial viable of the deregulated power system. In the past, when power industry was a regulated business, the terms must-run and must-take units seem to be insignificant since generation units in power system were regulated and operated under the responsibility of central control center. Under this bundled structure, power system planning and operation criteria were based on economic and security of the system. The problem shows up when generation utilities are operated under competitive market since some units in the systems may not suitable to be deregulated owning to different reasons.

Because electricity is a unique merchandise having its specific characteristics. A successful transaction depends upon constraints including both price mechanisms and system security. Therefore, some generation units are not suitable to be totally involved in the competitive market if they provide voltage or security supports.

Definition and selection of reliability must-run and must-take units are important issues in deregulated power market. Reliability must-run units play very important role in maintaining reliable system operation since they supply real and reactive power to the systems in order that satisfy both customer requirements and reliability standards. On the other hand, must–take units are qualified generation units that are eligible to sell power to the systems owning to other reasons than security issue. Therefore, must-run and must-take units are exceptional units to competitive market. One can expect that existence of must-run and must-take units in power system may directly affect the number of sellers in the deregulated power system.

Selected generation units, which are classified as reliability must-run or must-take units are subjected to the agreement. This agreement influences both tariff structure and dispatching scheme of must-run and must-take units. For instance, must-run units may have to be available for the period of time or deliver power to the systems upon the requested of ISO. This obligation of must-run units may obstruct these units from competing in deregulated market. Furthermore, instead of receiving the payment in market clearing price (MCP), must-run and must-take units may be paid by the fixed amount according to the agreements.

Generally, the term must-run units compose of two types of generation units, the regulatory must-run units and reliability must-run units respectively. Regulatory must-run units are the pre-specified units since they comply with the rules or laws issued by the governing jurisdictional authority while reliability must-run units are determined based on the system security point of view.

Slightly different from must-run units, must-take units contain only regulatory quantity since the motivation to determine must-takes originates only from the laws or rules that different from must-run units that can be determined by security reason. However, it is obvious that both must-run and must-take units are planning quantities since they are usually determined from off-line study during the planning stage.

Although determination processes of these quantities are employed during the planning period, they directly affect the operation of power system by defining the initial conditions of the systems during operation time frame as well as number of units in competitive market.

According to the concepts of must-run and must-take units, only the selection of reliability must-run units require specific calculation procedures. Regulatory units are assigned by contracts or rules of the power pool and treated as fixed transaction in the system. Therefore, this chapter will concentrate on the algorithm to select the reliability must-run units accordance with the possible transactions of the real-time market in Thailand power system. Purpose of the calculation is to find a practical approach to select the reliability must-run units and explicit them from the scheduling process. Must-runs units should not be allowed to participate in the competitive market and will receive a fixed price based on the must-run units agreement in order to maintain reliable system operation. Once reliability must-run and must-take units are identified, these information can be used to specify ATC interfaces in the system.

This chapter starts with the definitions and background of Must-Run and Must-Take Units. The security constraints of Thailand power system will then be discussed. The selection criterion of the reliability must-run units under a real-time deregulated power market is established through the computer simulation. The results are determined based on information of the current status and new structure of Thailand power system provided by National Energy Policy Office [8] and Electricity Generation Authority of Thailand [66]. Finally, information of reliability must-run units and must-take units will be used to generate ATC interfaces.

5.1 Background and Definitions

The must-run units are established from the concept of ensuring the security and reliability of power system in day-ahead, next-hour or real-time market [67-71] when power system is deregulated. The selection of must-run units will result in a group of generation units who have to engage in reliability must-run agreement and will be pulled out from the competitive market.

Must-run and must-take units are considered as quantities defined during power system planning state. However, they directly affect the real-time operation by decreasing number of generation units in the competitive market, maintaining system security by supplying power to the system as ISO required and eliminating so call "Local Area" in the system [71], the area which transmission system capability is insufficient to exchange electricity power. Therefore, the processes to calculate the reliability must-run units must include not only the selection of must-run units due to security reasons but also bottlenecks which define local areas.

Definitions and concepts of terms relating to the processes of must-run units selection and local areas determination are explained in the following sections.

5.1.1 Generation Facilities in Thailand Power System

According to information of generation facilities in Thailand power system during 1999-2004 with moderate economic recovery as presented in Thailand Power Pool and Electricity Supply Industry Reform Study – Phase 1 (ESI) [8], there are five categories of generation units in the systems The Medium Economic Recovery (MER) as the future situation of Thailand systems is selected in this dissertation since a more severe or stress situations is preferred to be the test case for demonstration purpose.

Consistent with five categories of generation facilities as mentioned above, these quantities are thermal power plant owned by Electricity Authority of Thailand (EGAT), Hydro power plants owned by EGAT, Independent Power Producers (IPPs), Small Power Producers (SPPs) and energy purchased from neighboring countries. These units share 55.7%, 11.7%, 23.1%, 7.3% and 2.1% of total generation capacity respectively. Information of these facilities is summarized and discussed in table 5-1 to table 5-3 and figure 5-1 below.

5.1.1.1 EGAT Fossil Fuel Power Plants

Thermal power plants in Thailand power system owned by EGAT are given in table 5-1 below

Table 5-1. Thermal power plants in Thailand power system

Unit Name	Type	Region	Capacity	Retirement Date
Wang Noi	CC (1,2,3)	5	2,031	2018
Mae Moh	TH (1-3)	4	225	2001
	TH (4-7)	4	600	2015
	TH (8-13)	4	1,800	2025
South Bangkok	TH (1-5)	1	1,330	2007
	CC (1,2)	1	958	2017
Bang Pakong	TH (1,2)	6	1,100	2014
	TH (3,4)	6	1,200	2021
	CC (1,2)	6	761	2007
	CC (3,4)	6	614	2016
Nam Phong	CC (1,2)	2	710	2014
Nong Chok	GT (1-4)	1	488	2015
Sai Noi	GT (1,2)	5	244	2015
North Bangkok	TH (1,2,3)	1	238	2008
Lan Krabu	GT	4	154	2050
Ratchaburi	TH	7	3,645*	
Surat Thani	TH	3	25	2000

* The commissioning of the Ratchaburi Power plant will be completed in the year 2000. At the first stage, 2x725 MW thermal units (oil-fired) are scheduled to be in service followed by 2x735 MW combined cycle (natural gas) in the second stage of power plant construction.

However, four units composing of Mae Moh, South Bangkok, Wang Noi and Bang Pakong are not qualified as sellers in ATC interfaces since they were determined as reliability must-run units according to the reliability must-run units study results given in chapter 5. Allowing these units to involve in scheduling processes implies that these units may be outbid which may cause severe security problem in the system.

In addition to four units above, the Surat Thani unit is also excluded from ATC interfaces since it is scheduled to be shut down before the deregulated market has begun in 2003.

As a result, thermal units, which qualified as sellers in Thailand competitive market, are summarized again in table 5-2.

Table 5-2. Qualified thermal power plants for ATC interfaces in Thailand power system

Unit Name	**Type**	**Region**	**Capacity**	**Retirement Date**
Nam Phong	CC (1,2)	2	710	2014
Nong Chok	GT (1-4)	1	488	2015
Sai Noi	GT (1,2)	5	244	2015
North Bangkok	TH (1,2,3)	1	238	2008
Lan Krabu	GT	4	154	2050
Ratchaburi	TH	7	3,645*	

5.1.1.2 EGAT Hydro Power Plants

In addition to the thermal units given in 5.1.1.1), Electricity Generation Authority of Thailand (EGAT) also owns a variety of size and amount of hydro power plants as shown in table 5-3

Table 5-3. Hydro power plant in Thailand power system

No.	Area	Unit Name	Capacity (MW)
1	2	Chulabhorn	840.00
2	2	Ubolrattana	25.20
3	2	Sirindhorn	36.00
4	2	Pak Mun	136.00
5	3	Rajjaprabha	240.00
6	3	Bang Lang	72.00

Table 5-3. Hydro power plant in Thailand power system (cont.)

No.	Area	Unit Name	Capacity (MW)
7	4	Bhumipol	718.00
8	4	Sirikit	500.00
9	6	Kiridharn	612.80
10	7	Tha Tung Na	38.00
11	7	Srinagarind	720.00
12	7	Khao Laem	300.00
13	7	Kaeng Krachan	17.50

Since the obligations of most of hydro power plants in Thailand power system are not restricted to only the business point but also the irrigation and other water use agencies, it is difficult to maintain both responsibilities of this kind of generation units under competitive environment especially for agricultural country such as Thailand. Therefore, these units should be regulated and comply with special contract when delivering electricity to the power grid. Hydro power plants will be discussed again in this chapter.

5.1.1.3 Independent Power Producers (IPPs)

Until the end of year 1999, seven IPP projects have been approved to deliver electricity to the power grid based on the power purchase agreements (PPAs) between IPPs and EGAT. These projects exclude the PPA between EGAT and the Electricity Generating Company (EGCO) who holds the largest IPP projects in the country. Currently, EGCO is operating two power plants purchased from EGAT, Rayong and Khanom, with total capacity of 2,056 MW. When most of IPP projects are fully operated, it is expected by the current Power Development Plant (PDP) that total generation capacity shared by IPPs will reach 20% of the total system in 2007.

Currently, IPPs are subjected to PPAs with EGAT which is usually based on long-term contract. However, these contracts require a slightly modification in order to allow IPPs to be able to be involved in the competitive market. According to the current contracts, IPPs are classified as regulatory must-take units owning long-term power purchase agreements. The modification of agreement will transform IPPs from regulatory must-take units to participants in competitive market. For better Information of IPP projects in Thailand power system, the phase-I (1996-2002) and phase-II (2002-2007) IPP projects are given in table 5-4.

Table 5-4. Thailand Power System IPP Awards*

No	Company	Region	Capacity (MW)	Fuel Used
Phase I (1996-2002)				
1	Independent Power (Thailand)	6	700.0	Natural gas
2	Eastern Power & Electric Co., Ltd.	1	350.0	Natural gas
3	Tri Energy Co., Ltd.	7	700.0	Natural gas
Phase II (2002-2007)				
1.	Union Power Development Co., Ltd.	7	1,400.0	Coal
2	Bowin Power Co., Ltd.	6	713.0	Natural gas
3	BLCP Power Limited	6	1,346.5	Coal
4	Gulf Power Generation Co., Ltd.	7	734.0	Coal

* Note: Base on 1999 information

5.1.1.4 Small Power Producers (SPPs)

Presently, 50 SPP proposals have been approved by the end of fiscal year 1999. Among these 50 proposals, 39 projects have start delivering electricity to the power grid.

Basically, most of SPPs are similar to IPPs since they have signed long-term power purchases contracts with EGAT. However, only less than 1% of these SPPs are qualified as Qualified Facilities (QFs) which are automatically become the regulatory must-take units. Therefore, it is reasonable to revise contract and allow non-regulatory must-take units of SPPs to participate in deregulated power market. Information of small power producers are shown again in table 5-5.

Table 5-5. Small Power Producers in Thailand Power system

No.	Unit Name	Region	Transaction (MW)	Remarks
1	Ruampol Enterprise	4	2.50	SPP
2	Thai Identity Sugar Factory	4	3.00	SPP
3	Kaset Thai Sugar	4	8.00	SPP
4	Defence Energy	4	9.00	SPP
5	Mitr Phol Sugar	5	6.00	SPP
6	T.N. Sugar	5	6.00	SPP
7	Refine Chaimongkol Sugar	5	3.00	SPP
8	Rojana Power	5	90.00	SPP
9	Gulf Cogeneration	5	75.00	SPP
10	Punjapol Pulp Industry	5	10.00	SPP

Table 5-5. Small Power Producers in Thailand Power system (cont)

No.	Unit Name	Region	Transaction (MW)	Remarks
11	Thai Acrylic Fibre	5	6.00	SPP
12	Suan Kitti Reforestation	6	6.4	SPP
13	Thai Power Supply	6	36	SPP
14	Advance Agro	6	16.86	SPP
15	Soon Hua Seng	6	1.5	SPP
16	Thai Petrochemical Industrial	6	30	SPP
17	The Cogeneration (Gas #1)	6	60	SPP
18	The Cogeneration (Gas #2)	6	60	SPP
19	Thai Cogeneration (Coal #1)	6	90	SPP
20	Thai Cogeneration (Coal #2)	6	90	SPP
21	Amata-EGCO Power	6	90	SPP
22	Industrial Power 1	6	55	SPP
23	Industrial Power 2	6	55	SPP
24	Bangkok Cogeneration	6	90	SPP
25	Sahacogen	6	90	SPP
26	National Petrochemical	6	25	SPP
27	Samutprakarn Cogeneration	6	90	SPP
28	MTP Cogeneration 1	6	60	SPP
29	MTP Cogeneration 2	6	60	SPP
30	Thai Oil Power	6	55	SPP
31	Tuntex Petrochemicals1	6	12	SPP
32	National Power Supply 1	6	90	SPP
33	National Power Supply 2	6	90	SPP
34	Ratchaburi Sugar	7	2.5	SPP
35	Ban Pong Sugar	7	3.0	SPP
37	United Farmer & Industry	2	6.00	SPP
38	Korat Industry	3	8.00	SPP
39	Mitr Phu Wiang	3	6.00	SPP

As seen from table 5-5, most of SPPs units deliver relatively small amount of energy to the system, it is expected that these units will not be allowed to perform bilateral contracts individually that is identical to the current contracts they signed with EGAT. However, SPP traders, group of SPP units, are allowed to participate in the deregulated market.

5.1.1.5 Power purchased from neighboring countries

Thailand has conducted the power purchase agreements (PPAs) with Laos PDR and Malaysia under the interconnection projects among Asian nations. Currently, two PPAs between Thailand and Laos PDR (Nam Theun-Hinboun 187 MW and Houay-Ho projects 126 MW) are commissioning as well as 300 MW High

Voltage Direct Current (HVDC) are expected to be fully operated between Thailand and Malaysia in 2000. In addition, several other projects with Laos PDR are currently signed and schedule to be commissioned in several years as presented. This information, as well as memorandum of understanding, MOU, of PPAs signed between Thai government and Myanmar and The People Republic of China are listed in table 5-6. This table gives information of current power purchase contracts between Thailand and Laos since Laos is the only one country who is currently interconnected and making transaction with Thailand power system as the following (table 6 provide both current and future projects)

Table 5-6. Power purchase projects from Laos PDR

Project	**Sale (MW)**	**Commissioning Date**	**Status**
Nam Theun-Hinboun	187	March. 1998	Operated
Houay Ho	126	September 1999	Operated
Sub-Total	**313**		
Nam Theun 2	900	December 2006	MOU approved
Nam Ngum 3	430	December 2006	MOU approved
Nam Ngum 2	553	December 2006	MOU approved
Sub-Total	**1,883***		
Hongsa Lignite (Stage 1,2)	608	March 2008	March 2008*
Xe Kaman 1	407	March 2008	March 2008*
Xepian – Xenamnoi	365	March 2008	March 2008*
Sub-Total	1,380		
Grand Total	**3,576***		

* Due to economic crisis, EGAT plans to change the contents of contracts to purchase 1600 MW in December 2006 and 1700 MW in March 2008 instead of the old plan

As seen from the above information, power purchase agreements from neighboring countries based on long-term contracts between Thailand government and other countries that becoming the obligations to deregulated power system to comply with. Therefore, these PPAs are automatically qualified as regulatory must-take units.

For better information of Thailand system, load forecasting during the first stage of industry deregulation based on LER and MER economic situation, percentage of each type of power plant in the system and geographical locations of items are shown in figure 5-1 to figure 5-3 (SPPs will not exist in this figure owning to there are too many SPPs to shown in the figure). The reason behind the choosing of MER as the base line of study is because a more risky are pessimistic situations are preferred to be the representative of the systems more than the optimistic expectation.

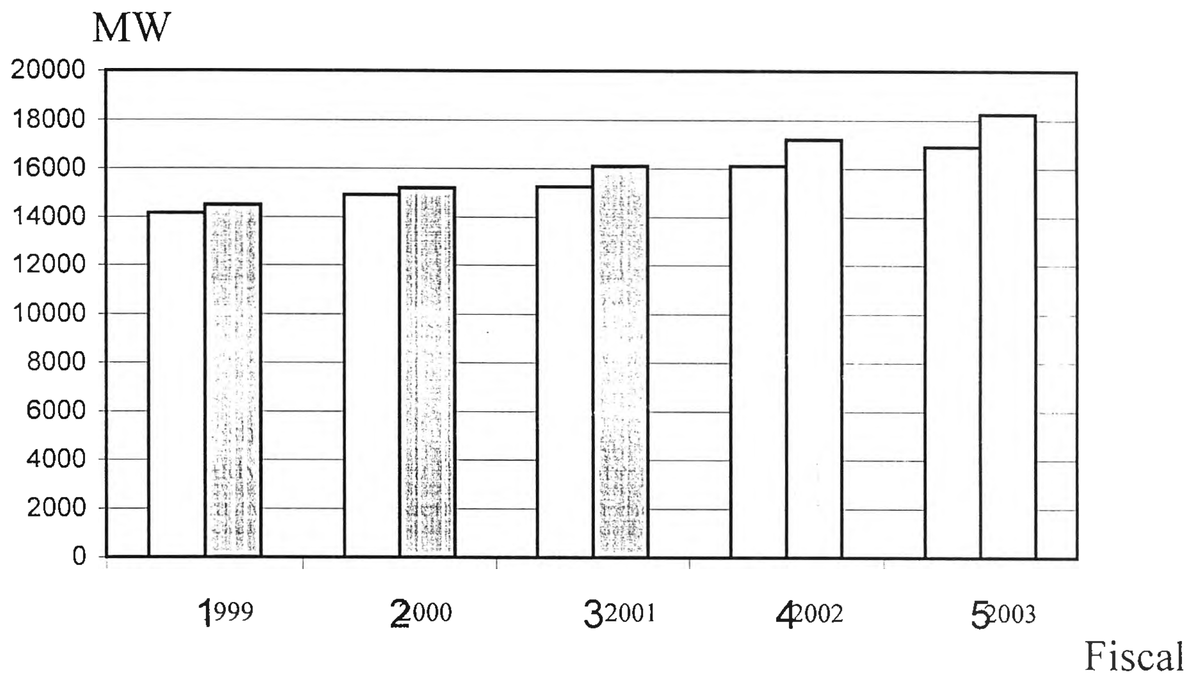

Figure 5-1. Load forecasting under different economic situations

Remarks

= Low Economic Recovery (LER) = Moderate Economic Recovery (MER

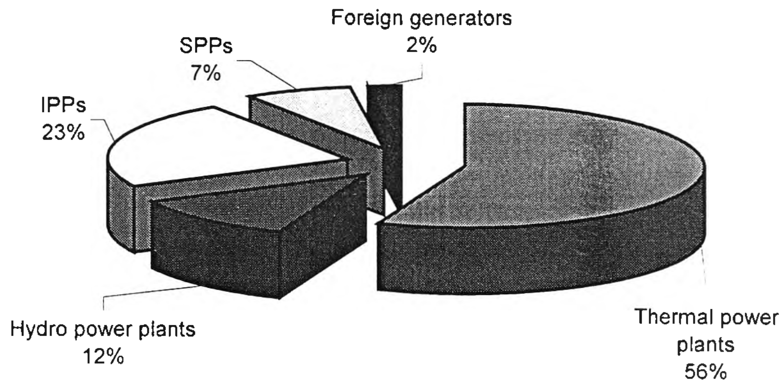

Figure 5-2. Percentage of generation units in Thailand Power system

5.1.2 Must-run contracts and Ancillary Services

Although the implementation of ancillary services market is not addressed in the first stage of power deregulation plan but it is meaningful to compare these two contracts since they always cause confusion.

It is important to understand that must-run units are different from generation units in ancillary market. These two types of generation units always cause confusion in determining and selection of must-run units since responsibilities of them are relatively similar but in fact, they are entirely different in concepts and details. Ancillary services are the interconnected operations services identified by the U.S. Federal Energy Regulatory Commission (Order No. 888 issued April 24,1996) as necessary to effect a transfer of electricity between purchasing and selling entities and which a transmission provider must include in an open access transmission tariff. Six products of ancillary services defined by the Federal Energy Regulatory Commission (FERC) [72-73] as shown below

a) Energy Imbalance Service – Provides energy correction for any hourly mismatch between a transmission customer's energy supply and the demand serve

b) Operating Reserve: Spinning Reserve Service – Provides additional capacity from electricity generators that are on-line, loaded to less than their maximum output, and available to serve customer demand immediately should a contingency occur.

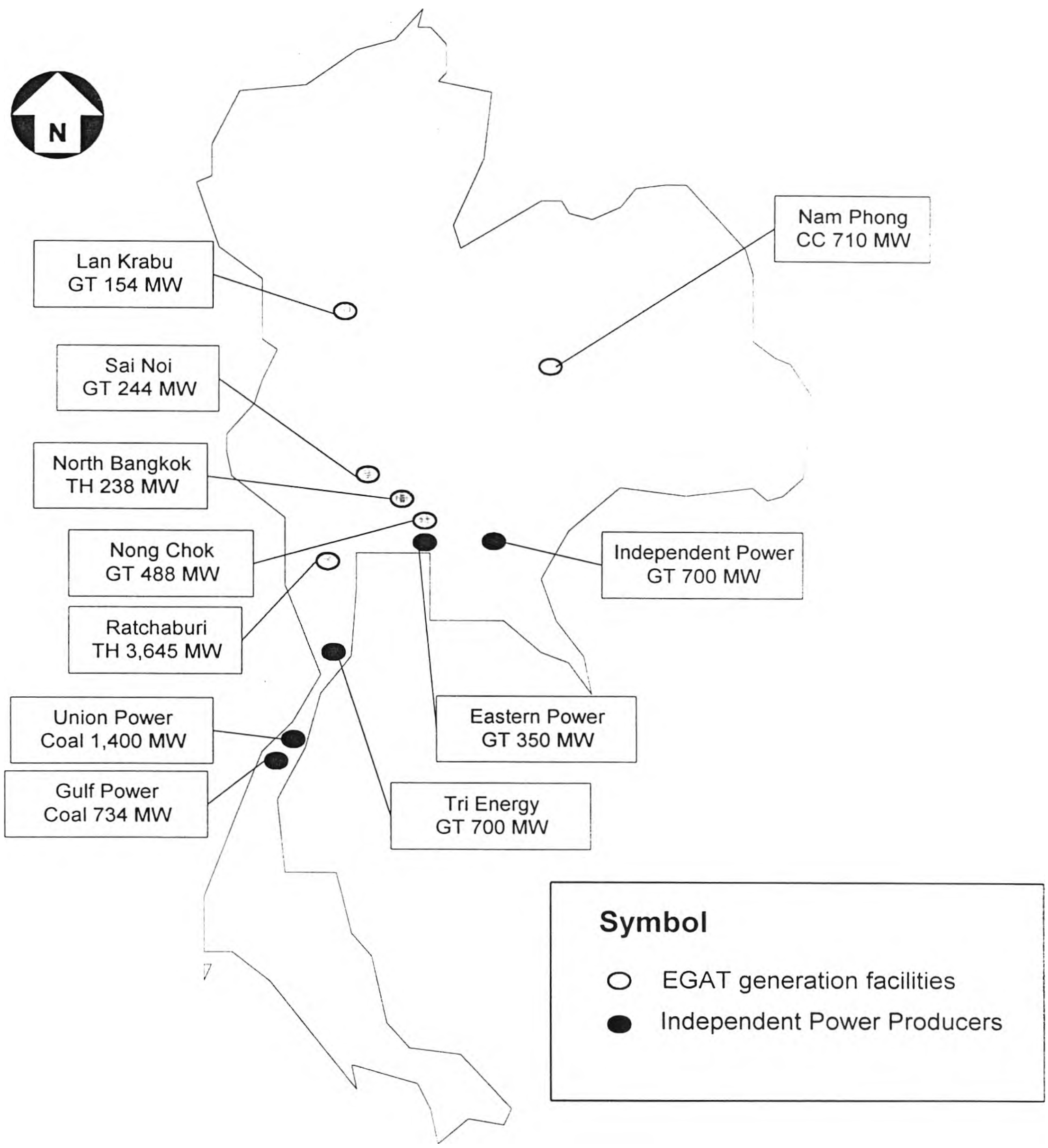

Figure 5-3. Geographical locations of generation facilities in Thailand power system

c) Operating Reserve: Supplementary Reserve Service – Provides additional capacity from electricity generators that can be used to a contingency within a short period, usually ten minutes.

d) Reactive Supply and Voltage Control From Generating Service – provides reactive supply through changes to generator reactive output to maintain transmission line voltage and facilitate electricity transfers.

e) Regulation and Frequency Response Service – Provides for following the moment-to-moment variations in the demand or supply in a Control Area and maintaining scheduled interconnection frequency.

f) Scheduling, System Control, and Dispatch Service – Provides for a) scheduling, b) confirming and implementing an interchange schedule with other Control Areas, including intermediary Control Areas providing transmission service, and c) ensuring operational security during the interchange transaction.

Comparing to functions of reliability must-run units as mentioned in the previous section, it is seen that participation of a generation unit in ancillary services market is not compulsory which is different from the reliability must-run units that are selected by ISO. The main purposes of ancillary services market are not restricted only the security point of view but also include the commercial purposes. Generation units must compete in the market to get to ancillary service contracts, therefore, price of products in ancillary market are dictated by the market. These comparisons give good insight of the dissimilarity between the must-run contracts and ancillary services.

5.1.3 Reliability Must-Run units

Reliability must-run unit (RMR) is defined as the "Generation that the ISO determines is required to be on-line to meet Applicable Reliability Criteria Requirements" [26-27]. The applicable reliability criteria requirements are different in each area since each power system have its own characteristics and basic concept to handle with security issue. This dissertation will employ the reliability criteria of Thailand power system. Under the requirements of the above reliability criteria, reliability must-run units must meet the following requirements.

a) The generation units that are necessary to provide voltage or security support in local areas or entire system before and after contingency.

b) The generation units that are necessary to meet load demand in local areas or entire system before and after contingency.

As a result, definitions of reliability must-run units imply several meanings when applying to practical power system.

a) Security aspect takes precedence in reliability must-run unit selection and local area definition processes. During the first stage of reliability must-run units selection, economic issue is not taken into consideration since reliable operation of the system is the only objective of calculation.

b) Reliability must-run units ensure reliability of both local areas and interconnected system prior and after contingency situations. This is the requirements of considering N-1 contingency cases as stated in the previous section

c) Responsibility cf must-run unit is to supply real and reactive power to meet load requirement and provide voltage support. The main philosophy of must-run units is the security of the entire system.

These concepts confine the umbrella framework for reliability must-run generation units selection and calculation. The detailed calculation procedures, scenarios and results of reliability must-run units will be explained in section 5.2-5.6.

5.1.4 Regulatory Must-Run units

As mentioned earlier regarding the regulatory must-run and regulatory must-take units, their purposes are different from the reliability must-run units. The objectives of regulatory must-run units are to maintain fair-play in competitive market and to honor pre-existing contracts prior to the deregulation and not appropriate to compete in the deregulate market. A good example of regulatory must-run units is hydro power plants. Since most of hydro power plants are multi-purposes units designed both for generation and supplying water to the agricultural areas, it is not appropriate to allow hydro power plant entering in the competitive market and defeat the agricultural purpose. In addition, hydro power plant is a special generation unit requiring no fuel cost, it is unfair to allow hydro power plant to compete in scheduling market either.

Since the actual regulatory must-run units in Thailand power system are not officially selected, this dissertation will determine regulatory must-run units based on hydro power plants in the systems. However, not all of hydro power plants in the systems are classified as regulatory must-run units since many hydro units in Thailand power system are not connected to the power grid and will be excluded from the calculation. Detailed discussion of these units can be found in section 5.4.5. In addition, Information of hydro power plants in Thailand power system is shown in table 5-7. The geographical locations of these units are given in figure 5-4.

Table 5-7 Hydro power plants in Thailand power system

No.	Area	Unit Name	Capacity (MW)
1	2	Huai Kum**	1.06
2	2	Chulabhorn	840.00
3	2	Ubolrattana	25.20
4	2	Nam Pung**	6.00
5	2	Sirindhorn	36.00
6	2	Pak Mun	136.00
7	3	Rajjaprabha	240.00
8	3	Bang Lang	72.00
9	3	Ban Santi**	1.30
10	4	Bhumipol	718.00
11	4	Sirikit	500.00
12	4	Mae Ngat**	9.00
13	4	Mae Sa Nga**	5.00
14	4	Mae Sariang**	1.25
15	4	Mae Hong Sorn**	0.85
16	4	Mae Kum Luang Dam**	3.2
17	6	Kiridharn	612.80
18	7	Tha Tung Na	38.00
19	7	Srinagarind	720.00
20	7	Khao Laem	300.00
21	7	Kaeng Krachan	17.50

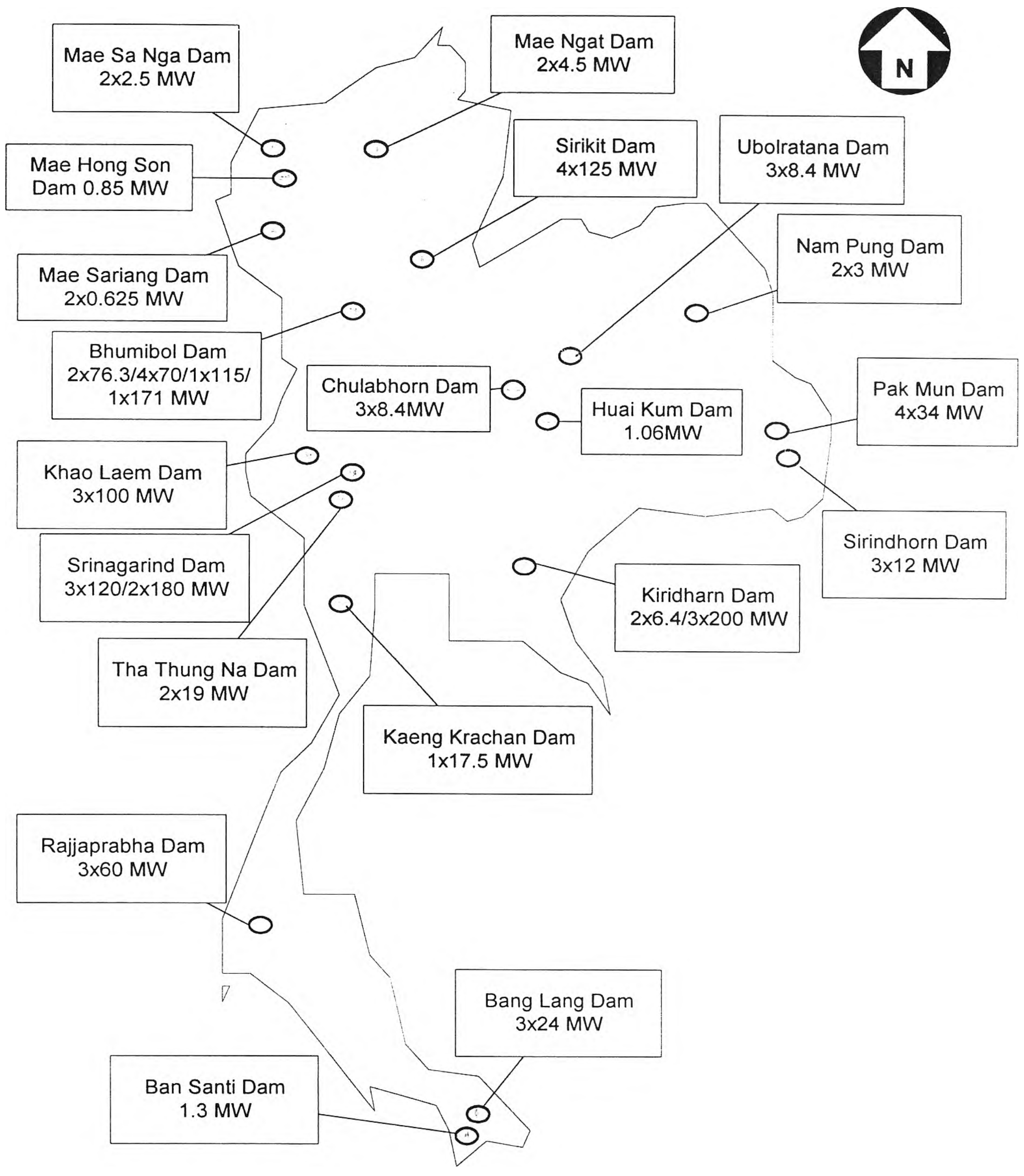

Figure 5-4 Geographical locations of hydro power plants in Thailand power system

** Local generation units designed to supply customers in their vicinity areas

5.1.5 Regulatory Must-Take units

Regulatory must-take units are assigned with the different purposes from regulatory must-run units. Generally regulatory must-take units are designed to handle those generation units or purchase contracts occurred prior to the deregulation and become problem of the systems after deregulation. Examples of regulatory must-take units are nuclear power plants that usually presented in stranded cost of the system after the deregulation. The other one is Qualify Facilities (QFs) such as cogeneration power plants and pre-existing power purchase contracts which usually are long-term contracts. Since there are no nuclear power plants in Thailand power system, the first type of generation units of regulatory must-take units in this dissertation are represented by Independent Power Producers (IPP) and Small Power Producers (SPP) projects that dispatch electricity to the system by the long-term contracts prior to the deregulation procedures. Information of regulatory must-take units in Thailand power system are shown in table 5-8 and figure 5-5 below.

Table 5-8 Regulatory must-take units in Thailand power system

No.	Area	Unit Name	Fuel	Capacity (MW)
1	1	Eastern Power &Electric*	Gas	350
2	3	Khanom***	Gas/Coal	674
3	3	Krabi***	Gas/Coal	600
4	6	Independent Power*	Gas	700
5	6	Bowin Power**	Gas	713
6	6	BLCP Power**	Coal	1346.5
7	7	Tri Energy*	Gas	700
8	7	Union Power**	Coal	1400
9	7	Gulf Power**	Coal	734

* Independent Power Producers in stage 1 (1996-2000).
** Independent Power Producers in stage 2 (2001-2003).
*** Power plants sold to company in pilot project before deregulation

In addition to IPPs, Small Power Producers (SPPs), which many of them are classified as qualifying facilities (QFs) since they generate electricity from industrial by-product such as wood chips, are also assigned as regulatory must-take units. The small power producers are small generation units located locally close to load center such as industrial estates. Therefore, SPPs have more options to sell electrical power since they can sell directly to the customers in their areas or to power grid. However, under the SPP contract of Thailand power system, Electricity Generation of Thailand is the only one organization who can purchases bulk power from SPPs base on either firm contracts or non-firm contract. As of the August 1999, 94 SPPs projects have been submitted and most of them are approved. Among them, 39 projects have been completed and have supplied electricity to Thailand power system.

Summary of SPPs projects in Thailand power system [74] is shown below and complete list information of SPPs projects who have been connected to the systems are given in table 5-9 and figure 5-6.

Table 5-9 Summary of power purchase from small power producers

	Firm	**Non-Firm**	**Total**
1. Proposals submitted			
1.1 Number of projects	67	27	94
1.2 Generating capacity (MW)	7,686.81	653.36	8,340.17
1.3 Sale to EGAT (MW)	4,459.90	183.31	4,643.21
2. Received notification of Acceptance			
2.1 Number of projects	30	22	52
2.2 Generating capacity	3,496.91	611.30	4,108.21
2.3 Sale to EGAT (MW)	1,958.40	177.57	2,135.97
2.4 Type of fuels			
- Bagasse	-	15	15
- Paddy Husk, Wood Chips	3	3	6
- Natural gas	21	1	22
- Coal	5	2	7
- Oil	1	-	1
- Black Liquor	-	1	1
3. Contract Signed			
3.1 Number of projects	30	20	50
3.2 Generating capacity	3,496.91	556.40	4,053.31
3.3 Sale to EGAT (MW)	1,958.40	149.57	2,107.97
4. Contract Signed			
4.1 Number of projects	22	19	41
4.2 Generating capacity	2,329.43	553.90	2,883.33
4.3 Sale to EGAT (MW)	1,433.40	147.37	1,580.77

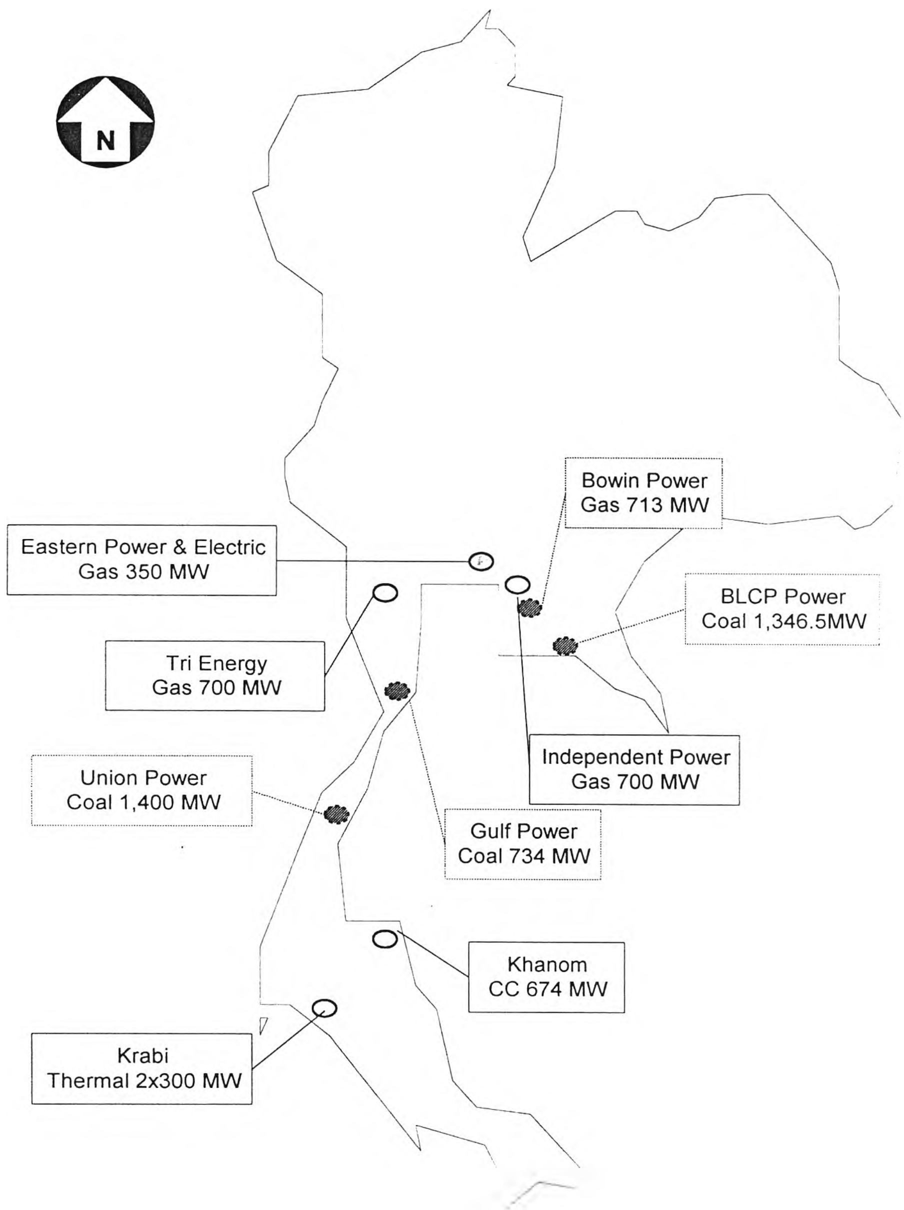

Figure 5-5 Geographical locations of regulatory must-take units from IPPs in Thailand power system

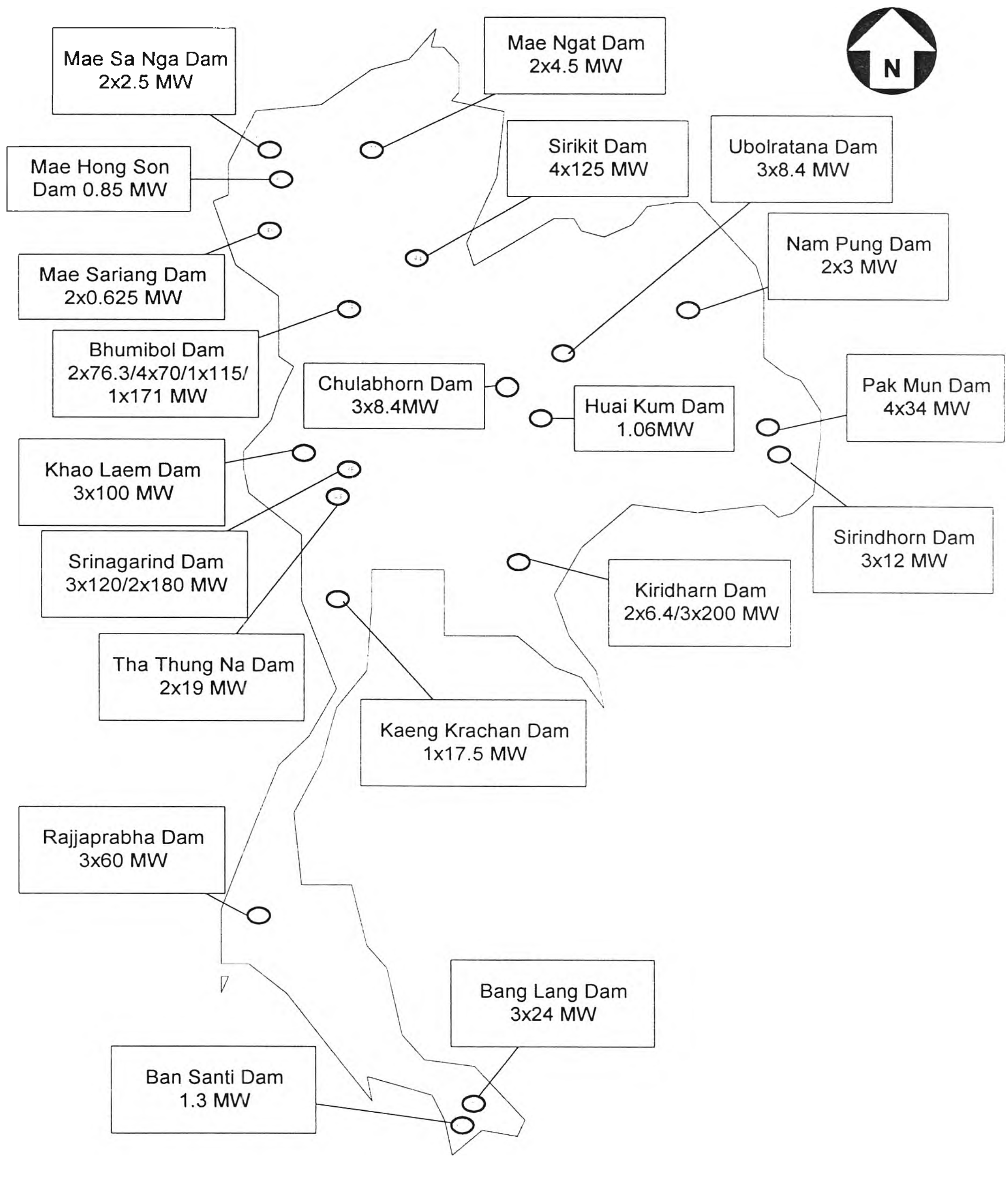

Figure 5-6 Geographical locations of regulatory must-take units from SPPs in Thailand power system

Table 5-10 Summary of power purchase from small power producers

No	Company	Type of Business	Fuel Used	Capacity (MW)	Sale to EGAT (MW)
1	Suan Kitti Reforestation Co.,Ltd. Bangpakong, Chachoengsao (Thai Power Supply Co.,Ltd. (2))	Rice mill and saw mill	Paddy husk and wood chips	10.400	6.400 (4.000)
2	Thai Power Supply Co.,Ltd (1) Phanom Sarakham, Chachoengsao (Agroline Co.,Ltd.)	Rice mill and Saw mill	Paddy husk and wood chips	47.400	25.000 (36.000) (6.000)
3	Advance Agro Public Co.,Ltd. Si Maha Phot, Prachin Buri	Paper factory	Bark, wood chips, Black Liquor	56.700	16.865
	Soon Hua Seng Rice Co.,Ltd. Bang Pakong, Chachoengsao (Ttai Power Supply Co.,Ltd. (3)) (Thai Generating Supply Co.,Ltd.)	Power plant	Paddy husk, wood chips, eucalyptus	3.000	1.500
4	United Farmer & Industry Co.,Ltd. Phu Khieo, Chaiyaphum	Sugar factory	Bagasse	24.000	6.000 (3.000)
5	Mitr Phol Sugar Co.,Ltd. Dan Chang, Suphan Buri	Sugar factory	Bagasse	24.000	6.000 (3.000)
6	Ratchaburi Sugar Co.,Ltd. Ban Pong, Ratchaburi	Sugar factory	Bagasse	17.500	2.500
7	Thai Identity Sugar Factory Co.,Ltd. Takhli, Nakhon Sawan	Sugar factory	Bagasse	16.500	3.000
8	Kaset Thai Sugar Co.,Ltd. Muang, Uttaradit	Sugar factory	Bagasse	52.500	8.000 (4.800)

Table 5-10 Summary of power purchase from small power producers (cont.)

No	Company	Type of Business	Fuel Used	Capacity (MW)	Sale to EGAT (MW)
9	Korat Industry Co.,Ltd. Phimai, Nakhon Ratchasima	Sugar factory	Bagasse	15.000	8.000 (6.000) (4.000)
10	Ban Pong Sugar Co.,Ltd. Ban Pong, Ratchaburi	Sagar factory	Bagasse	18.000	3.000
11	Ruampol Enterprise Co.,Ltd. Muang, Nakhon Sawan	Sugar factory	Bagasse	12.500	2.500
12	Mitr Phu Wiang Nong Reua, Khon Kaen	Sugar factory	Bagasse	27.000	6.000
13	Ratchasima Sugar Factory Kaeng Sanamnang, Nakorn Ratchasima	Sugar factory	Bagasse	15.000	8.000
14	T.N. Sugar Co.,Ltd. Tha Luang, Lop Buri	Sugar factory	Bagasse	12.000	6.000
15	N.Y. Sugar Co.,Ltd. Korn buri, Nokorn Ratchasima (Nong Yai Co.,Ltd. (2))	Sugar factory	Bagasse	26.000	3.000
16	Refine Chaimongkol Sugar U-Thong, Suphanburi	Sugar factory	Bagasse	18.000	3.000
17	Mitr Kalasin Sugar Co.,Ltd. Khuchinarai, Kalasin	Power plant	Bagasse	16.000	3.000

Table 5-10 Summary of power purchase from small power producers (cont.)

No	Company	Type of Business	Fuel Used	Capacity (MW)	Sale to EGAT (MW)
18	Thai Petrochemical Industry Public Co.,Ltd. Muang, Rayong	Plastic platelet Manufacturing factory using cogeneration system	Fuel oil, Waste gas. Coal	143.000 (108.000)	45.000 (30.000)
19	The Cogeneration Public Co.,Ltd. (1) Muang, Rayong Mab Ta Phut Industrial Estate	Power plant	Natural gas	150.000	90.000 (60.000)
20	Amata - EGCO Power Co.,Ltd. Muang, Chon Buri Bangpakong Industrial Estate	Cogeneration Power plant	Natural gas	150.000	90.000
21	The Congeneration Public Co.,Ltd. (2) Muang, Rayong Mab Ta Phut Industrail Estate	Cogeneration Power plant	Natural gas	150.000	90.000
22	Industrial Power Co.,Ltd. (1) Muang, Rayong Eastern Industrial Estate	Cogeneration Power plant	Natural gas	67.680	55.000
23	Bangkok Cogeneration Co.,Ltd. Muang, Rayong Mab Ta Phut Industrial Estate (Bangkok Industrial Gas Co.,Ltd.)	Cogeneration Power plant	Natural gas	107.000	90.000

Table 5-10 Summary of power purchase from small power producers (cont.)

No	Company	Type of Business	Fuel Used	Capacity (MW)	Sale to EGAT (MW)
24	Sahacogen (Chon Buri) Co.,Ltd. Si Racha, Chon Buri (Saha Phatana Inter - Holding Public Co.,Ltd.) Saha Group Industrial Park	Cogeneration Power plant	Natural gas	120.000	90.000
25	Rojana Power Co.,Ltd. Uthai, Ayutthaya (Rojana Industrial Park Public Co.,Ltd.) Rojana Industrial Park	Cogeneration Power plant	Natural gas	120.000	90.000
26	National Petrochemical Public Co.,Ltd. (NPC1) Muang, Rayong Mab Ta Phut Industrial Estate	Cogeneration Power plant	Waste Gas and Natural Gas	98.700	32.000 (25.000)
27	Samutprakarn Cogeneration Co.,Ltd. Muang, Samutprakan Bang Poo Industrial Estate	Cogeneration Power plant	Natural gas	160.300	90.000
28	Gulf Cogeneration Co.,Ltd. Muang, Sara Buri (Gulf Electric Co.,Ltd.)	Cogeneration Power plant	Natural gas	111.000 (100.000)	90.000 (75.000)
29	Industrial Power Co.,Ltd. (2) Muang, Rayong Eastern Industrial Estate	Cogeneration Power plant	Natural gas	66.345	55.000

Table 5-10 Summary of power purchase from small power producers (cont.)

No	Company	Type of Business	Fuel Used	Capacity (MW)	Sale to EGAT (MW)
30	MTP Cogeneration Co.,Ltd. (1) Muang, Rayong (The Cogeneration Co.,Ltd. (3)) Mab Ta Phut Industrial Estate	Cogeneration Power plant	Natural gas	70.000	60.000
31	MTP Cogeneration Co.,Ltd. (2) Muang, Rayong (The Cogeneration Co.,Ltd. (4)) Mab Ta Phut Industrial Estate	Cogeneration Power plant	Natural gas	70.000	60.000
32	Thai Oil Power Co., Ltd. Siracha, Chonburi	Cogeneration Power plant	Natural gas	117.200	41.000 (55.000)
	Panjapol Pulp Industry Public Co., Ltd. Bang Sai, Ayutthaya	Paper factory	Black Liquor, Coal	40.000	10.000
33	Thai Acrylic Fibre Co., Ltd. Kaeng Khoi, Saraburi	Fibre manufacturing factory	Lignite	17.200	6.000
34	Tuntex Petrochemicals (Thailand) Public Co., Ltd. (1) Muang, Rayong Mab Ta Phut Industrial Estate	Cogeneration Power plant	Coal	55.000	10.000 (12.000) (6.000)
35	National Power Supply Co., Ltd. (1) Si Maha Phot, Prachin Buri (Thai Power Supply Co., Ltd.1) 304 Industrial Park	Cogeneration Power plant	Coal	164.000	90.000

Table 5-10 Summary of power purchase from small power producers (cont.)

No	Company	Type of Business	Fuel Used	Capacity (MW)	Sale to EGAT (MW)
36	Thai Cogeneration Co., Ltd. (1) Muang, Rayong Mab Ta Phut Industrial Estate	Cogeneration Power plant	Coal	160.000	90.000
37	National Power Supply Co., Ltd. (2) Si Maha Phot, Prachin Buri (National Power Supply Co., Ltd. 1) 304 Industrial Park	Cogeneration Power plant	Coal, eucalyptus bark	164.000 (115.000)	90.000
38	Thai Cogeneration Co., Ltd. (2) Muang, Rayong Mab Ta Phut Industrial Estate	Cogeneration Power plant	Coal	160.000	90.000
39	Defence Energy Fang, Chiangmai	Diesel combined-cycle Power plant	Fuel oil	10.400	9.000

5.2 Reliability Criteria

Reliability criteria are the framework to calculate the reliability must-run units and local areas in power system. Reliability criteria may be different in detail among different systems but their main concepts are similar. Voltage level and amount of power flow are two major reliability indices of Thailand power system. This dissertation will consider not only the voltage level and thermal limit in the systems but also the status of power system after the disconnection of a generation unit. Therefore, thermal limits, voltage limits and voltage stability limits are three major reliability criteria being considered in this chapter.

General reliability criteria of Thailand power system can be summarized below.

Stage 1: Normal condition

a) Voltage level at load buses are lying within ± 5 % of the nominal voltage

b) Most of voltage level at voltage controlled buses are maintained at the rated voltage (specified voltage that normally slightly higher than load buses)

c) Amount of total power flow (MVA flow) in transmission lines do not exceed 90% of normal thermal ratings

Stage 2: Transient Period

Power system remains stable during transient period. This results associate with contingency analysis which will be explained in chapter 6 that transient stability is performed to ensure capability during transient period of power system. However, this part will not be included in the reliability must-run unit selection as explained early in this chapter.

Stage 3: Post-fault condition

a) Voltage levels at load buses are lying within ± 5 % from the nominal voltage

b) Voltage levels at voltage-controlled buses are maintained within ± 5 % from the nominal voltage. Basically, voltage at voltage-controlled buses should be maintained at the pre-specified values. However, it is acceptable if voltage magnitudes at these buses are deviated from the set voltage but are still lying in secure region.

c) Amount of total power flow (MVA flow) in transmission lines do not exceed
emergency thermal ratings

d) Power system are secure to voltage collapse

However, it is important to understand that the simulation of generation unit outage in reliability must-run unit study are different from contingency analysis study. During reliability must-run units study, a generation is assumed not to deliver power to the system owning to its unavailability or fails to compete in the competitive market. Meanwhile, during contingency analysis, a generation unit is assumed to be forced outage owning to failure of equipment cause by fault or abnormal situation. One can see that an outage generator in the first case is "forced not to connect" where it is "forced to disconnect" in the later scenario.

According to the above explanation, it is reasonable to omit the simulation of status of power system during transient period in reliability must-run unit. In contrast, status of power system after a generation unit is disconnected should be concerned.

It is seen that objectives of reliability must-run units are to ensure reliability of power system in different conditions. This is because any incident in power system is unpredictable and the best way to cover most of possibility is to simulate as many as possible cases. Therefore, a generation unit will be selected as a must-run unit if at least one of the following incidents occurs when this unit is absence from the system in specific operating conditions.

a) Amount of MVA power flow in a transmission facility exceeds 90% of its thermal rating during steady state operation.

b) Bus voltage at any bus goes lower than 0.95 per unit or higher than 1.05 per unit

c) Operating point of power system passes the secure operation of voltage stability margin.

5.3 Local Areas

Local areas result from topography and demographics together with the resource distribution in power system. Transmission congestion or bottlenecks of transmission system is the major factor to determine boundaries of local areas. Physical distances between load center and the generation units may not be the decision factor to determine the boundaries of local areas since the transmission networks may be strong enough to affiliate power transfer between these areas.

Basically, there are two types of local areas depend on the number of connection between an area and bottlenecked transmission lines of that area. A closed local area is an area which connected to the rest of system through one interface. Closed local area is relatively simple since limitation of transmission lines connected between local area and the system directly determines boundaries of local area. In contrast, an opened local area is a boundary of area which have many interfaces connected to the systems through transmission networks. Boundaries of opened local area are determined by a set of bottlenecked transmission lines. Therefore, boundaries of open local areas do not compatible with geographical zone or area of the systems. An open or closed local area may be contained in only one zone or encompass many zones in the system. However, transmission lines connected between areas can be the primary point of interest since they can easily isolate an area from the systems. Examples of opened and closed local areas are presented in figure 5-7.

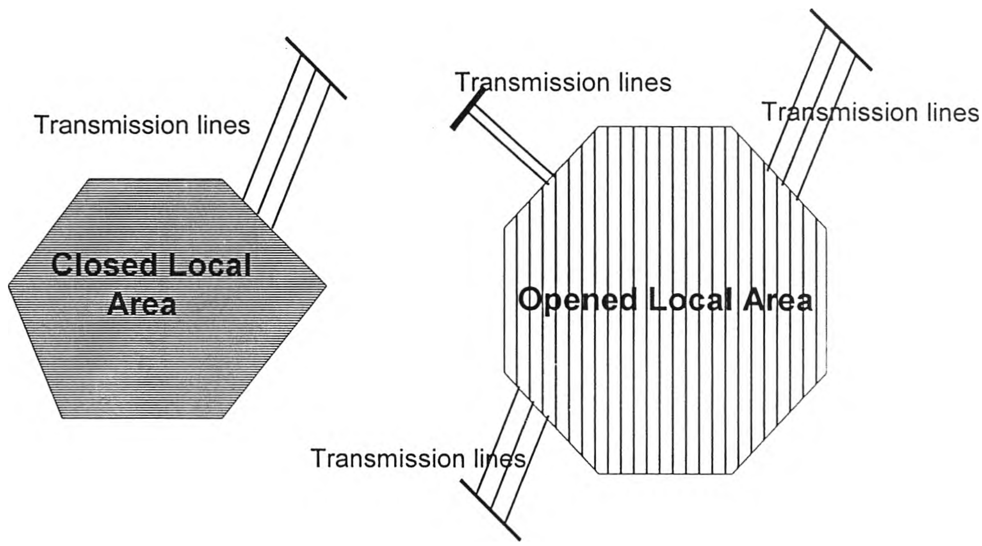

Figure 5-7. Closed local area and opened local area

It is seen that local areas are defined based on interpreting power flow results of the systems. In addition, it is foreseeable that an area surrounded with transmission lines containing small amount of available transfer capability initiates a local area.

Determination of local areas in a typical system can be performed by investigating bottlenecks inside that system during different load conditions. Local areas exist if the bottlenecks encircle an area and extract it from the rest of the system. For Thailand power system, the following processes can investigate the local areas.

a) Determine local areas simulation scenarios: For demonstration purpose, the study of local areas in Thailand power system will base on the peak load (13,400 MW) conditions that are taken as the representative of loading conditions in the systems.

b) Determine bottlenecks in the systems: Transmission lines limits and buses with unacceptable voltage level are observed and recorded.

c) Determine the local areas: Bottlenecks given in step b) are considered whether they create local areas or not. In addition, crucial tie lines connected between areas in the system should be carefully monitored since congestion of these facilities may easily create closed local areas. These considerations will give information about the current loading conditions and estimation of additional loading capability of transmission lines that may create local areas.

According to procedures and criteria of local areas defined above, abnormal power flow in transmission lines and abnormal bus voltages bus that are necessary to determine local areas in Thailand power system during peak load conditions are given in table 5-11, table 5-12 and figure 5-8 below.

Table 5-11 List of Bottlenecks in Thailand power system during heavy load conditions

No	From Bus	Bus Name	To Bus	Bus Name	P-Flow (MW)	Q-Flow (Mvar)	MVA Rating	% Rating
1	729	115SA1	7702	SA1	176.0	65.6	200.0	93.9
2	730	115SA1	7702	SA1	176.0	65.6	200.0	93.9
3	731	115SA1	7702	SA1	176.0	65.6	200.0	93.9
4	732	115SA1	7702	SA1	176.0	65.6	200.0	93.9

Table 5-12 Buses with abnormal voltage in Thailand power system during peak load

Bus No.	Bus Name	V-Spec	V-Actual	Q-max	Q-min	Q-actual
1001	NB S1	1.00	0.9991	50	-30	50
1002	NB S2	1.00	0.9991	50	-30	50
1003	NB S3	1.00	0.9991	50	-25	50
1011	SB S1	1.00	0.9990	120	-45	120
1012	SB S2	1.00	0.9990	120	-45	120
1013	SB S3	1.00	0.9992	230	-90	230
1014	SB S4	1.00	0.9992	230	-90	230
1015	SB S5	1.00	0.9992	230	-90	230
1021	SB-G11	1.00	0.9988	45	-37	45
1022	SB-G12	1.00	0.9988	45	-37	45
1023	SB-CC10	1.00	0.9988	45	-37	45
1031	SB-G21	1.00	0.9988	45	-37	45
1032	SB-G22	1.00	0.9987	45	-37	45
1033	SB-CC20	1.00	0.9988	45	-37	45
2006	UR H1	1.00	0.9999	4	-1	4
2021	NPO-G11	1.00	0.9999	45	-37	45
2022	NPO-G12	1.00	0.9999	45	-37	45
2023	NPO-CC1	1.00	0.9999	45	-37	45

Table 5-12 Buses with abnormal voltage in Thailand power system during peak load (cont)

Bus No.	Bus Name	V-Spec	V-Actual	Q-max	Q-min	Q-actual
2025	NPO-G22	1.00	0.9999	45	-37	45
2026	NPO-CC2	1.00	0.9999	45	-37	45
2040	XSET-H	1.00	0.9999	9	-5	9
3001	BLG H1	1.00	0.9999	15	-7	15
3002	BLG H2	1.00	0.9999	15	-7	15
3003	BLG H3	1.00	0.9999	15	-7	15
3061	SRT S1	1.00	0.9994	8	-1	8
4001	BB H1-2	1.00	0.9993	47	-22	47
4002	BB H3-4	1.00	0.9991	23	-11	23
4041	MM2 S1	1.00	0.9996	36	-18	36
4044	MM3 S4	1.00	0.9998	48	-50	48
4045	MM3 S5	1.00	0.9998	48	-50	48
4047	MM3 S7	1.00	0.9998	48	-50	48
5001	WN-G11	1.00	0.9990	60	-40	60
5002	WN-G12	1.00	0.9990	60	-40	60
5005	WN-G31	1.00	0.9990	60	-40	60
5006	WN-G32	1.00	0.9990	60	-40	60
5010	WN-G10	1.00	0.9990	60	-40	60
5030	WN-G30	1.00	0.9990	60	-40	60
5051	GCC	1.00	0.9984	30	-20	30
5052	ROP	1.00	0.9989	54	-30	54
6001	BPK S1	1.05	0.9998	300	-99	300
6002	BPK S2	1.00	0.9998	300	-99	300
6003	BPK S3	1.00	0.9999	300	-99	300
6004	BPK S4	1.00	0.9999	300	-99	300
6005	BPK CB1	1.00	0.9996	45	-37	45
6006	BPK CB2	1.00	0.9996	45	-37	45
6011	BPK G11	1.00	0.9996	20	-18	20
6012	BPK G12	1.00	0.9996	20	-18	20
6013	BPK G13	1.00	0.9996	20	-18	20
6014	BPK G14	1.00	0.9996	20	-18	20
6015	BPK G21	1.00	0.9996	20	-18	20
6016	BPK G22	1.00	0.9996	20	-18	20
6017	BPK G23	1.00	0.9996	20	-18	20
6018	BPK G24	1.00	0.9996	20	-18	20

Table 5-12 Buses with abnormal voltage in Thailand power system during peak load (cont)

Bus No.	Bus Name	V-Spec	V-Actual	Q-max	Q-min	Q-actual
6021	BPK G31	1.00	0.9997	45	-37	45
6022	BPK G32	1.00	0.9997	45	-37	45
6023	BPK G41	1.00	0.9997	45	-37	45
6024	BPK G42	1.00	0.9997	45	-37	45
6025	BPK-CC3	1.00	0.9997	45	-37	45
6026	BPK-CC4	1.00	0.9997	45	-37	45
6028	KRD H1	1.00	0.9996	2	-3	2
6048	TPS1	1.00	0.9998	10	-5	10
6065	TTP	1.00	0.9998	5	-5	5
6068	TOP	1.00	0.9998	20	-10	20
7001	SNR H1	1.00	0.9996	58	-29	58
7002	SNR H2	1.00	0.9996	58	-29	58
7003	SNR H3	1.00	0.9996	58	-29	58
7006	TTN H1	1.00	0.9991	6	-3	6
7007	TTN H2	1.00	0.9991	6	-3	6
7031	KKC H1	1.00	0.9987	4	-5	4

Although many voltage-controlled buses deliver reactive power at their maximum capacity with small voltage deviation from the specified values, results given in table 5-11, table 5-12 and figure 5-7 show that all voltage problems are not major problem in Thailand power system during peak load conditions. The bottlenecks in the test systems are caused by thermal limits that occur at a specific area which does not cause any major problem or creates any local areas in the system. However, existences of reactive power limit shown in table 5-11 and table 5-12 indicates that Thailand power system still require more reactive power sources to avoid voltage problem in the future.

Except four locations shown in table 5-11 and figure 5-7, the amount of power flow in transmission lines throughout the systems are acceptable. However, due to the set back during the year 1998-1999, it is difficult to forecast actual load in the systems in the next couple years which is the first stage of power industry deregulation (as seen in figure 5-11 for mid-term load forecasting in each situation related to economic recovery). Therefore, in order to cope with these uncertainties in the future load demanded, it is reasonable to take precaution on those locations with potential to create local areas in power system. These locations compose of tie lines between areas and other vulnerable points of the system according to geographical locations.

Normally, radial transmission systems are highly possible to create closed local zones where mesh transmission networks create opened local zones.

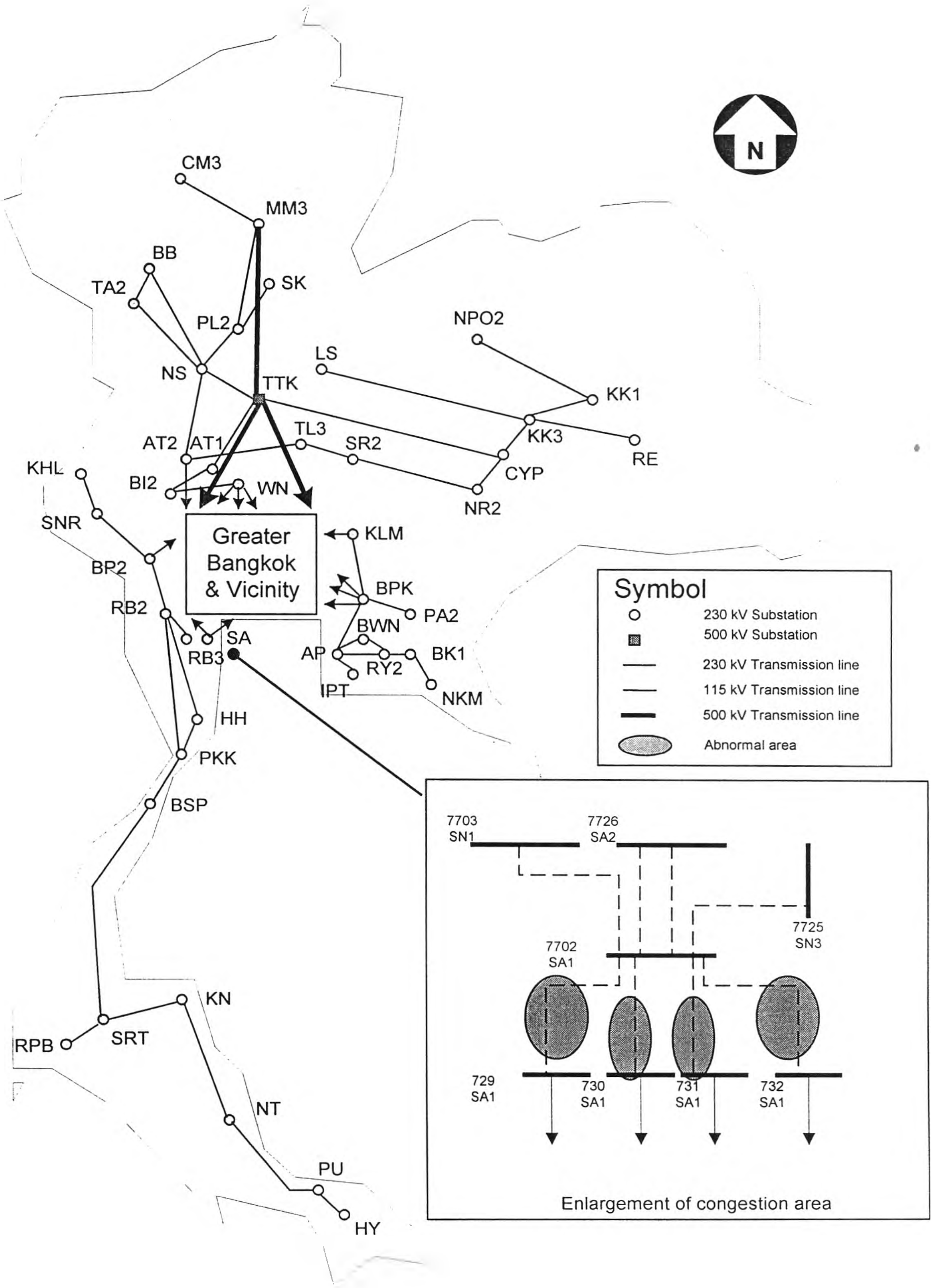

Figure 5-8. Bottlenecks in Thailand power system during peak load conditions

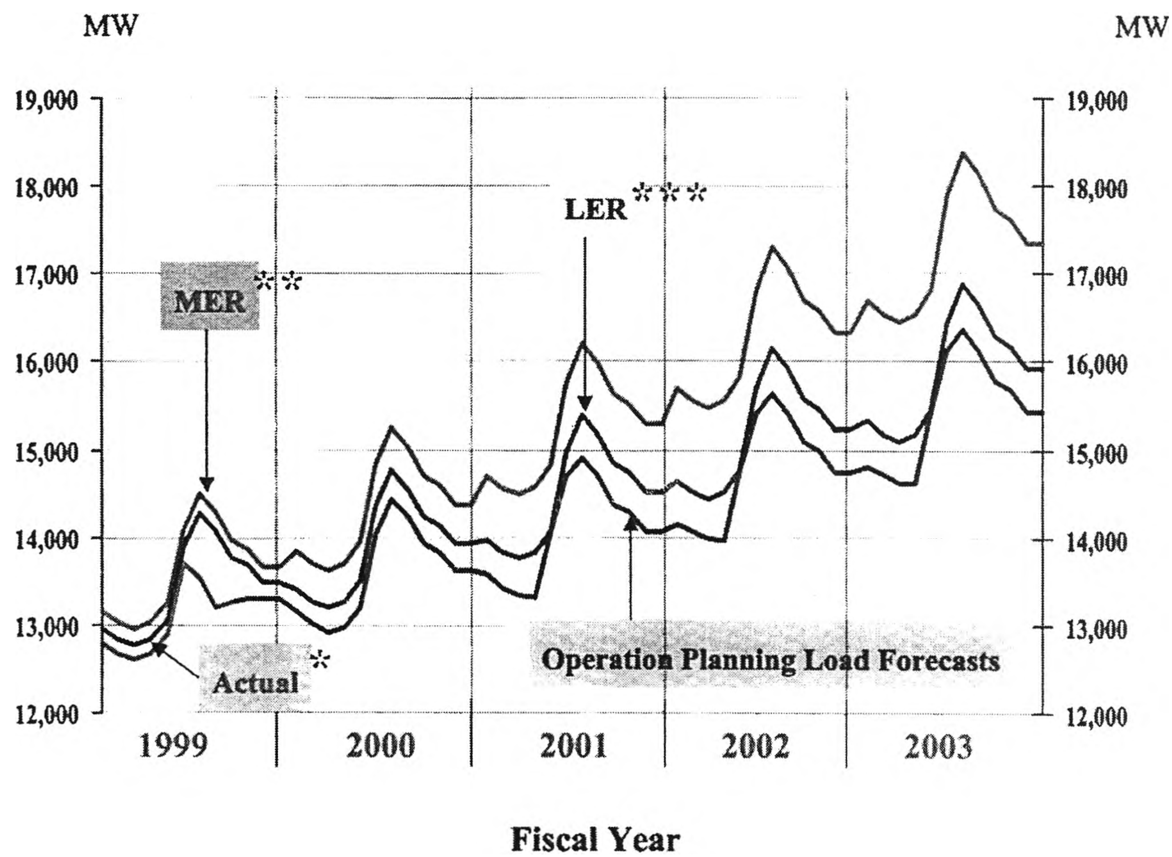

Figure 5-9 Mid-term load forecasting in Thailand Power system during the year 1999-2003

* Actual load forecasting which is currently used
** Moderate Economic Recovery load forecasting
*** Light Economic Recovery load forecasting

5.4 Study Scenarios to determine the RMR Units

Study scenarios include the situations that are highly possible to happen during the operations of deregulated market. This objective of formulating these cases is to ensure that the study results will provide useful answers since they are based on the most possible occurred incidents. Generally, determination of study scenarios are based on the following factors

5.4.1 Loading conditions in the systems

Loading conditions are the status of electricity required by the customers in the systems at a specific time. In fact, exact amount of loading conditions in power system are unpredictable and subject to change. Fortunately, load patterns of a power system at the same period of the day in each season are usually recurring in the same manner.

Under reliability point of view, it is the basic concept to consider the most severe situation that may occurs in the system and then prepare optimal criterion such as remedial actions or preventive actions to handle with these severe upsets. Therefore, peak load conditions (13,400 MW) is used in study scenarios as the representation of the most stress situation due to loading conditions. In addition, the medium load conditions of Thailand power system (8,850 MW) is also presented as an alternative study scenaric in this dissertation for comparison purpose.

5.4.2 Available of generation units

Availability of generation unit is the key situations in reliability must-run study. Impacts of generating unit unavailability will be studied compared to the reliability criteria that have been explained in 5.2. A generation unit is automatically selected as a reliability must-run unit if its unavailability causes reliability problem such as unacceptable current flow, unstable during transient period or severe voltage level depress.

5.4.3 Amount of transactions with neighboring power system

Transactions between neighboring power system for the purpose of economic or reliability are normal practice in power industry nowadays. Normally, these transactions are based on long-term contracts that are still valid even after the deregulation. In reality, these transactions are classified as regulatory must-take units where the amount of transactions is presented as a fixed amount of generation in the systems that will be explained again in 5.4.5

Thailand power system establishes the interconnections with neighboring countries, Laos and Malaysia, with the purposes of security and economy as mentioned above. Currently, there are two connections with Laos People's Democratic Republic (Laos PDR) and one connection with Malaysia. Intention of the connection with Malaysia is not to purchase electricity power but to consolidate the security in the southern region of the country that is different from two connections with Laos PDR. Information of interconnections with neighboring country is shown in figure 5-10 and table 5-13.

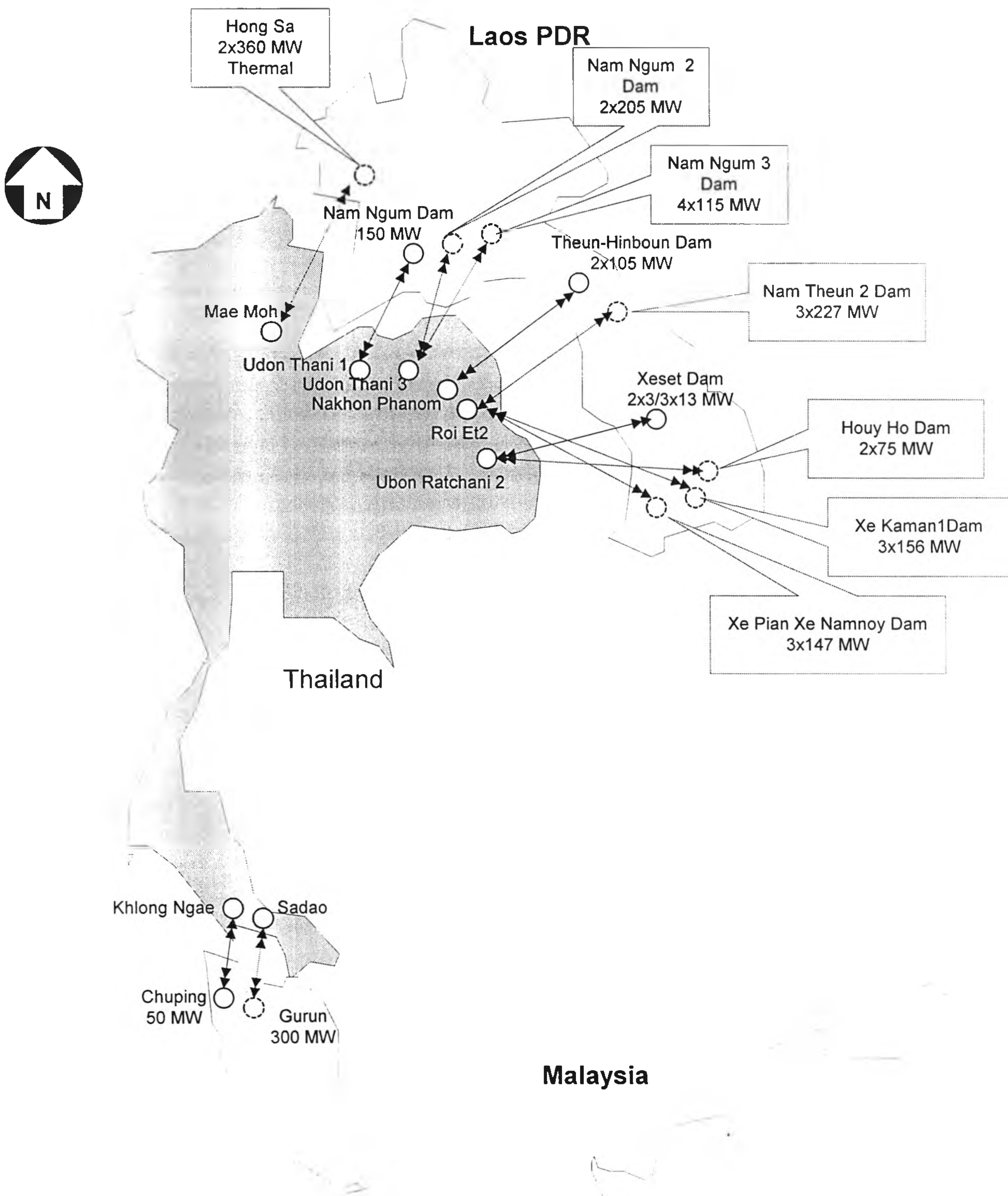

Figure 5-10 Interconnections between Thailand and neighboring country power system

Table 5-13 Electricity transactions between Thailand and neighboring countries

No.	Country	Unit Name	Capacity (MW)	Purchase* (MW)	Remark
1	Laos PDR	Nam Ngum Dam	150	100	
2	Laos PDR	Thuen-Hinboun Dam	210	210	
3	Laos PDR	Xeset Dam	45	4	
4	Malaysia	Chuping	-	50	For security reason**

* Based on actual transaction information of August 1999
** Interconnection between Thailand and Malaysia currently not a normal transaction. This connection is established if only the emergency situation occur.

5.4.4 Amount of fixed transactions inside the systems

In some power system, fixed transactions or "bilateral contract" may exist if sellers and buyers are allowed to negotiate and make transaction directly. These transactions result in an amount of power flow in the system. According to Thailand deregulated power market structure, although electricity flow from bilateral contracts has less priority than electricity contract in the spot market, they may highly influence system's security due to parallel path flow phenomena.

Fixed transactions inside the system will not be explicitly presented in this dissertation since deregulated market of Thailand is still not completed. Bilateral contracts are not clearly defined since number of sellers and buyers are not to be fully identified. Therefore, study scenarios in this chapter will only include the typical transactions which were picked up from base case power flow.

5.4.5 Regulatory must-run and regulatory must-take units:

As mentioned in chapter 3, 5.4.3 and 5.4.4, regulatory must-run and regulatory must-take units result in the reduction of competing generation units in the market since these units are automatically qualified to deliver power to the system at a fixed price. Consequently, the existence of these units greatly reduces number of transaction cases between sellers and buyers. In this dissertation, regulatory must-run and regulatory must-take units in Thailand power system are determined from the following units and contracts.

5.4.5.1 Regulatory must-run units:

RMR are determined from hydro power plants according to the concepts and criteria of regulatory must-run units that are explained in 5.1.3. However, many hydro power plants in Thailand power system should not be accounted as regulatory must-run units since they are not interconnected to the utility grid. These units are small hydro power plants with the rating less than 10 MW distributed in several regions of the country. Information of the local hydro power plants and regulatory must-run units hydro power plants are given in table 5-14 and table 5-15 below.

Table 5-14 Local hydro power plants in Thailand power system

No.	Area	Unit Name	Capacity (MW)
1	2	Huai Kum	1.06
2	3	Ban Santi	1.30
3	4	Mae Ngat	9.00
4	4	Mae Sa Nga	5.00
5	4	Mae Sariang	1.25
6	4	Mae Hong Sorn	0.85
7	4	Mae Kum Luang Dam	3.2

Table 5-15 Regulatory must-run units (hydro power plants) in Thailand power system

No.	Area	Unit Name	Capacity (MW)
1	2	Chulabhorn	840.00
2	2	Ubolrattana	25.20
3	2	Sirindhorn	36.00
4	2	Pak Mun	136.00
5	2	Nam Pung	6.00
6	3	Rajjaprabha	240.00
7	3	Bang Lang	72.00
8	4	Bhumipol	718.00
9	4	Sirikit	500.00
10	6	Kiridharn	612.80
11	7	Tha Tung Na	38.00
12	7	Srinagarind	720.00
13	7	Khao Laem	300.00
14	7	Kaeng Krachan	17.50

5.4.5.2 Regulatory must-take units

Regulatory must take units are determined from two sources of contract or power plants as follows:

a) Independent Power Producers (IPPs) who have signed long-term contract prior to the deregulation. Since no established rules to manage these contracts have been issued for Thailand power system, this dissertation will treat these long-term power purchase contracts as the obligations of the deregulated system to continue purchasing electricity from these contracts.. Information of IPPs belong to in this category are listed in table 5-2.

b) Amount of transactions with neighboring countries: As mentioned in 5.4.3, location and amount of purchasing contract between Thailand power system and Laos PDR are given in table 5 and figure 7. In addition with planned contracts with Laos PDR, Myanmar and Malaysia are shown in table 6 and figure 7. Transactions with neighboring countries are considered as contracts in this category since they are long-term contracts supported by governments. Therefore, they should be left intact since modification or change in contract contents which required high-level negotiation is relatively difficult.

According to the criteria used to select the study scenario mentioned in 5.4.1 – 5.4.5, Thailand power system are mainly affected by load pattern and availability of generation units since the geographical areas of power system is not relatively large and the interconnection with neighboring countries are treated as fixed amount of transaction. Therefore, study scenarios of reliability must-run units selection will base on the simulation of generation unit outage during the peak load and medium load periods that system configuration are shown in Appendix A. Detailed study procedures are explained in section 5.5

5.5 Study Procedure

This section summarizes study procedures used to select the reliability must-run units in Thailand power system as have been explained in section 5.1 – 5.4. These procedures comply with the reliability criteria both in normal operating conditions and (n-1) contingencies as described below.

a) Prepare base simulation cases: Numbers of base simulation cases depend on many factors such as loading conditions, changing of power plants or major change of transmission network in the systems. Since there are neither new major transmission nor new power plants (as seen from table 8, Power Developer Plan construction during 1999-2003 [8]) are constructed, peak load conditions of the year 1999 is selected as the main base case of this calculation.

b) Determine regulatory must-run units and regulatory must-take units: Regulatory must-run and must-take units as summarized in 5.4.5 are represented in the systems as fixed amount of transaction of the base case given in step a)

c) Identify local areas: This step investigates overloads and abnormal voltage levels in the system under normal operation. Local areas, closed or opened, are created if the bottlenecks encircle or isolate a portion of network from the rest of the system. In addition, investigation encompasses tie lines and several significant areas that directly affect the occurrence of local areas so as to guarantee the accuracy of results.

d) Simulate the study cases: This step creates situations where security constraints in the power system are observed while generation level of each dispatchable unit is gradually decreased. According to this approach, Reliability must-run units and must-run quantity at the reliability must-run unit are obtained when the first security constraint is reached. A generation unit which is qualified as reliability-must-run unit may be involved in the competitive market if its reliability must-run quantity is less than its generation capability. The great advantage of this approach is the enhancement of opportunity of generation unit to compete in the deregulated market and promote market activity. Differ from the conventional approach, Reliability must-run units in this concept have opportunity to deliver excess generation capacity from reliability must run quantity by selecting the most economic combination of their generation units (generation). However, the reliability must-run quantity is the minimum generation capability must be dispatched or available to dispatch to the systems upon ISO's request.

e) Investigate postfault reliability criteria: Status of power system after the occurrence of fault must comply with stage 3 of reliability criteria given in section 5.2

As a conclusion, study procedures of reliability must-run units can be transformed into flowchart as shown in figure 5-11.

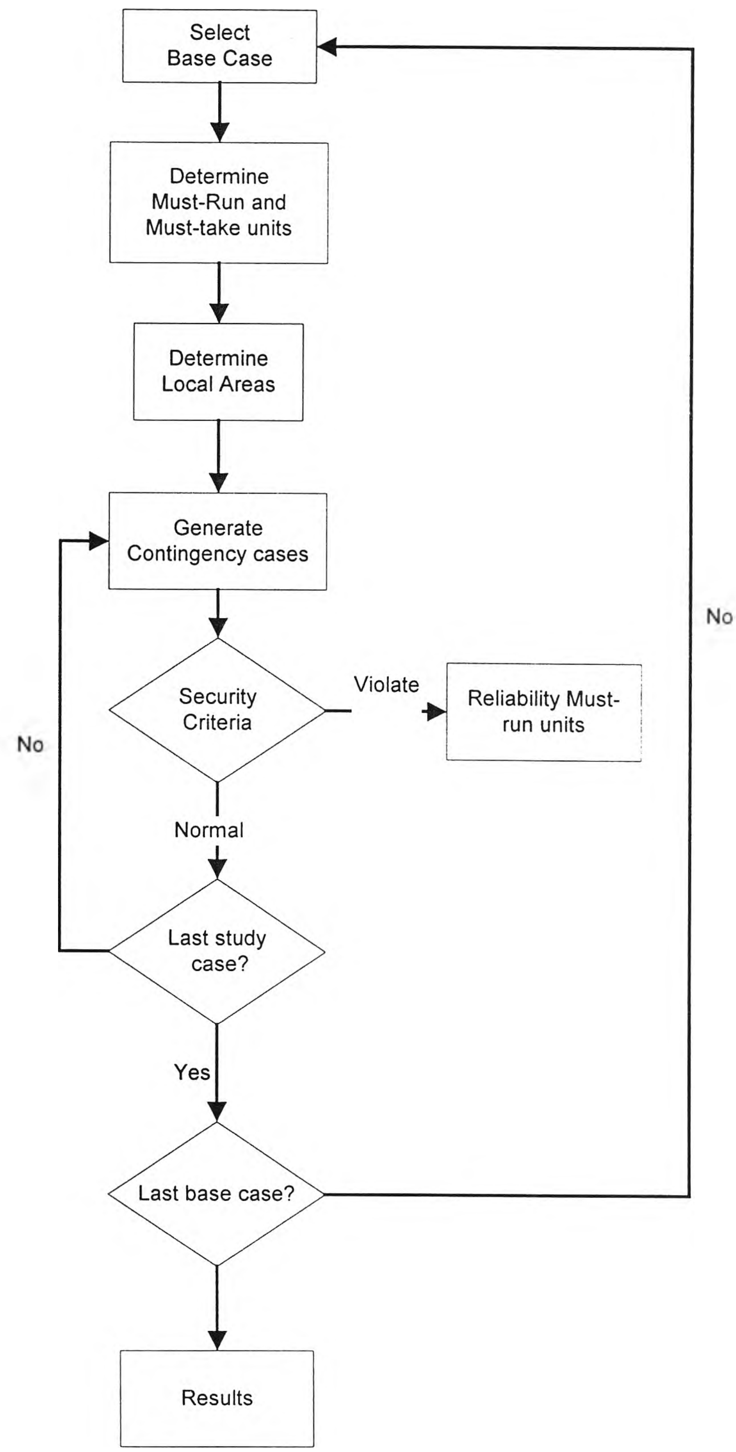

Figure 5-11. Procedures of reliability must-run units selection

5.6 Study Results

According to study procedures explained in section 5.5, study results for selection of reliability must-run units in Thailand power system are given below.

5.6.1 Summary of regulatory must-run and regulatory must-take units

As a summary, generation units that are assigned as regulatory must-run and regulatory must-take units are given in table 5-16 (geographical location of these units are previously given in figure 2 and 3) and they are taken as fixed generator in the systems.

Table 5-16 List of regulatory must-run and regulatory must-take units Thailand power system

Regulatory must-run units				
No.	**Unit Name**	**Region**	**Capacity (MW)**	**Remarks**
1	Chulabhorn	2	840.00	
2	Ubolrattana	2	25.20	
3	Sirindhorn	2	36.00	
4	Pak Mun	2	136.00	
5	Nam Pung	2	6.00	
6	Rajjaprabha	3	240.00	
7	Bang Lang	3	72.00	
8	Nam Pung	3	6.00	
9	Bhumipol	4	718.00	
10	Sirikit	4	500.00	
11	Kiridharn	6	612.80	
12	Tha Tung Na	7	38.00	
13	Srinagarind	7	720.00	
14	Khao Laem	7	300.00	
15	Kaeng Krachan	7	17.50	
Regulatory must-take units				
No.	**Unit Name**	**Region**	**Transaction (MW)**	**Remarks**
1	Eastern Power	1	350.00	IPP
2	Khanom	3	670.00	IPP
3	Krabi	3	600.00	IPP
4	Independent Power	6	700.00	IPP
5	Tri Energy	7	700.00	IPP
6	United Farmer & Industry	2	6.00	SPP*
7	Korat Industry	3	8.00	SPP*

Regulatory must-take units (cont)				
No.	**Unit Name**	**Region**	**Transaction (MW)**	**Remarks**
8	Mitr Phu Wiang	3	6.00	SPP*
9	Ratchasima Sugar Factory	3	8.00	SPP*
10	N.Y. Sugar	3	3.00	SPP*
11	Mitr Kalasin Sugar	3	3.00	SPP*
12	Ruampol Enterprise	4	2.50	SPP*
13	Thai Identity Sugar Factory	4	3.00	SPP*
14	Kaset Thai Sugar	4	8.00	SPP*
15	Defence Energy	4	9.00	SPP*
16	Mitr Phol Sugar	5	6.00	SPP*
17	T.N. Sugar	5	6.00	SPP*
18	Refine Chaimongkol Sugar	5	3.00	SPP*
19	Rojana Power	5	90.00	SPP
20	Gulf Cogeneration	5	75.00	SPP
21	Punjapol Pulp Industry	5	10.00	SPP*
22	Thai Acrylic Fibre	5	6.00	SPP*
23	Suan Kitti Reforestation	6	6.4	SPP*
24	Thai Power Supply	6	36	SPP
25	Advance Agro	6	16.86	SPP*
26	Soon Hua Seng	6	1.5	SPP*
27	Thai Petrochemical Industrial	6	30	SPP
28	The Cogeneration (Gas #1)	6	60	SPP
29	The Cogeneration (Gas #2)	6	60	SPP
30	Thai Cogeneration (Coal #1)	6	90	SPP
31	Thai Cogeneration (Coal #2)	6	90	SPP
32	Amata-EGCO Power	6	90	SPP
33	Industrial Power 1	6	55	SPP
34	Industrial Power 2	6	55	SPP
35	Bangkok Cogeneration	6	90	SPP
36	Sahacogen	6	90	SPP
37	National Petrochemical	6	25	SPP
38	Samutprakarn Cogeneration	6	90	SPP
39	MTP Cogeneration 1	6	60	SPP
40	MTP Cogeneration 2	6	60	SPP
41	Thai Oil Power	6	55	SPP
42	Tuntex Petrochemicals1	6	12	SPP*
43	National Power Supply 1	6	90	SPP
44	National Power Supply 2	6	90	SPP
45	Ratchaburi Sugar	7	2.5	SPP*

Regulatory must-take units (cont)				
No.	**Unit Name**	**Region**	**Transaction (MW)**	**Remarks**
46	Ban Pong Sugar	7	3	SPP*
47	Thuen-Hinboun Dam	3	210	Laos PDR
48	Xeset Dam	3	45 (4)	Laos PDR
49	Nam Ngum Dam	4	150 (100)	Laos PDR

Remarks

IPP = Independent Power Producers connected to the systems
SPP = Small Power Producers deliver power to EGAT more than 25 MW (these units are shown as buses in system data)
SPP* = Small Power Producers deliver power to EGAT less than 25 MW (these units
will not shown as buses in system data but combined with other buses)

5.6.2 Summary of generation unit outages

Simulation of generation unavailable in the system, affected by regulatory must-run and regulatory must-take units as presented in 5.6.1), are employed by applying following contingency cases to the study.

Table 5-17 List of contingency cases in reliability must-run units study

Case	Unavailable Unit	Region	Capacity (MW)	Remark
1	North Bangkok	1	237.50	
2	South Bangkok	1	2288.00	
3	Nam Phong	2	730.00	
4	Suratthani	3	325.00	
5	Lan Krabu	4	126.00	
6	Mae Moh	4	2,625.00	
7	Wang Noi	5	1,902.00	
8	Bang Pakong	6	3,674.60	Reference Unit
9	Rayong	6	1,232.00	

5.6.3 Simulation results

It is important to realize that the calculation of reliability must-run units is different from contingency analysis due to the scenarios of calculation. Under n-1 contingency analysis study, the situations are assumed that a facility in the system is suddenly forced outage and unavailable to continue the service which characteristics of the system suddenly after fault, transient period, and postfault must be carefully concerned. On the contrary, the calculation of reliability must-run units is based on the concept that when a generation unit is outbid during scheduling processes. Results of the calculation will show system's status after the absence of the units that includes abnormal conditions in the system (minimum voltage at buses, reactive power generation limits and abnormal power flow in transmission lines), local areas (if occurs). Summary of simulation results in each case are given in this section. In addition, geographical locations of generation units that are simulated to be unavailable are shown in figure 5-12.

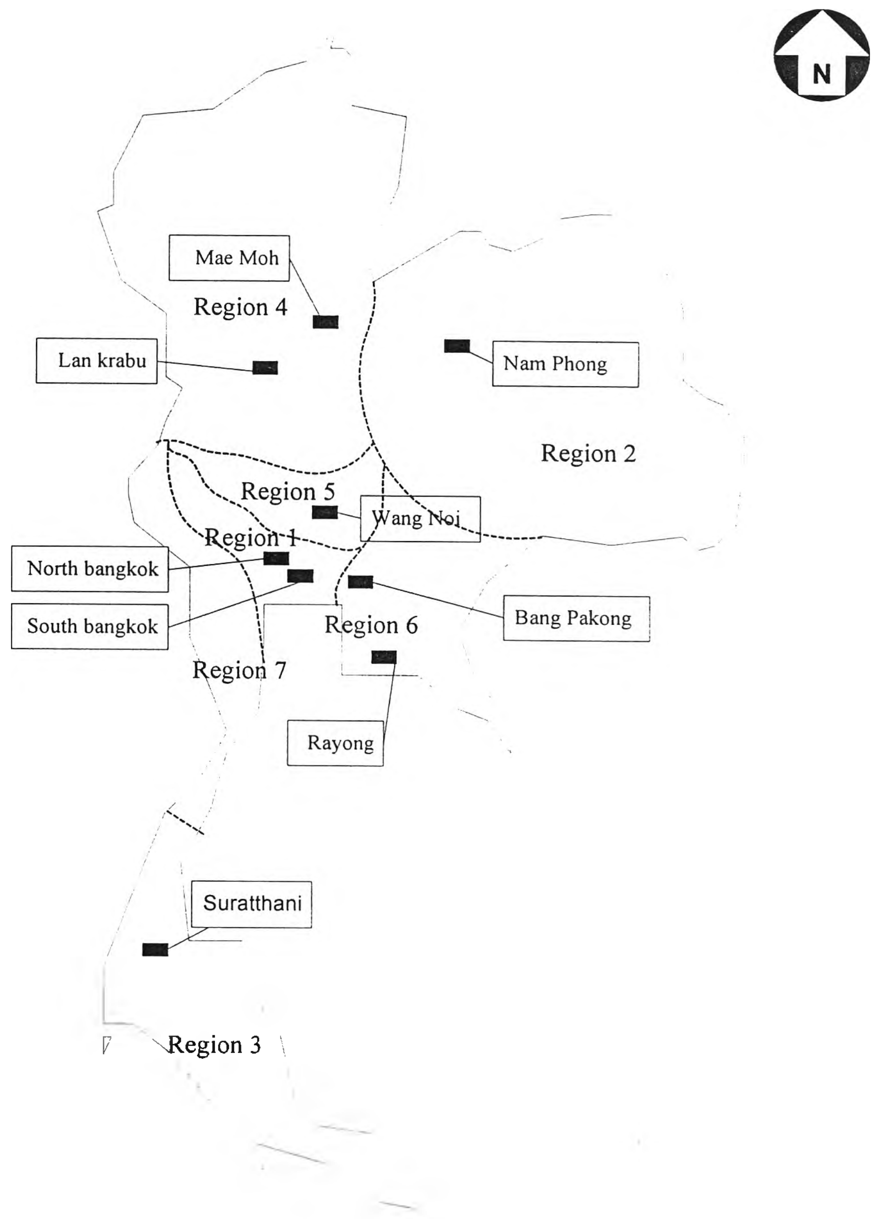

Figure 5-12 Geographical location of unavailable unit in case 1

Typical simulation case

Generation level of the South Bangkok plant (2x200, 3x310.0 MW thermal units and 1x335 and 1x623 MW combined cycle units total capacity 2,288.0 MW located in area 1) is assumed decreasing as an example of the calculation to study the importance of this unit to the system. Since both real and reactive power are important to power system, the lacking of these quantities may result in security limits violation. It is not necessary that reactive power capability will affect only voltage level but in some case it may result in thermal limit violation that is the outcome of large voltage gradient. However, this dissertation assume generation unit delivering electricity to power system by maintaining power factor 0.90. The value of power factor 0.9 at generation bus is widely used in many utilities around the world including Thailand power system as suggested power factors for generators which compromises both commercial and security requirements. Based on the experiences of many deregulated markets around the world, generation facilities not likely to produce large amount of reactive power since reactive power is not a commodity in the market but support system security. Under seller point of view, generation facilities attempt to operate their generator at the power factor close to 1 (100% real power generation) in order to maximize their profit. This activity may result in insecure operation of the systems due to insufficient reactive power sources. Results of reliability must-run unit calculation of the typical case are shown as follows.

Convergence Status: Converge

Abnormal Summary Report

a) Abnormal Voltage level

Power system can maintain satisfactory voltage levels for all buses in the systems. Minimum voltage level in the system is 0.996 per unit.

b) Abnormal power flow

Abnormal power flow in transmission systems is first detected when bus 1805 delivers 565.88 MW, 273.88 Mvar to the systems. Calculation terminated due to thermal limit violation between bus 1813 and 1805 as shown below

c) Thermal limit violation information

Location: Transmission line connected between bus 1813 and bus 1805 circuit #1
Amount of power flow: This transmission line carrying 91.61% of rating

It is seen that high voltage transmission lines (230 kV) connected between two major substations are overloaded. In order to give better insight of the congested locations due to thermal limit violation, location of thermal limit violations are shown as the shaded area in figure 5-13.

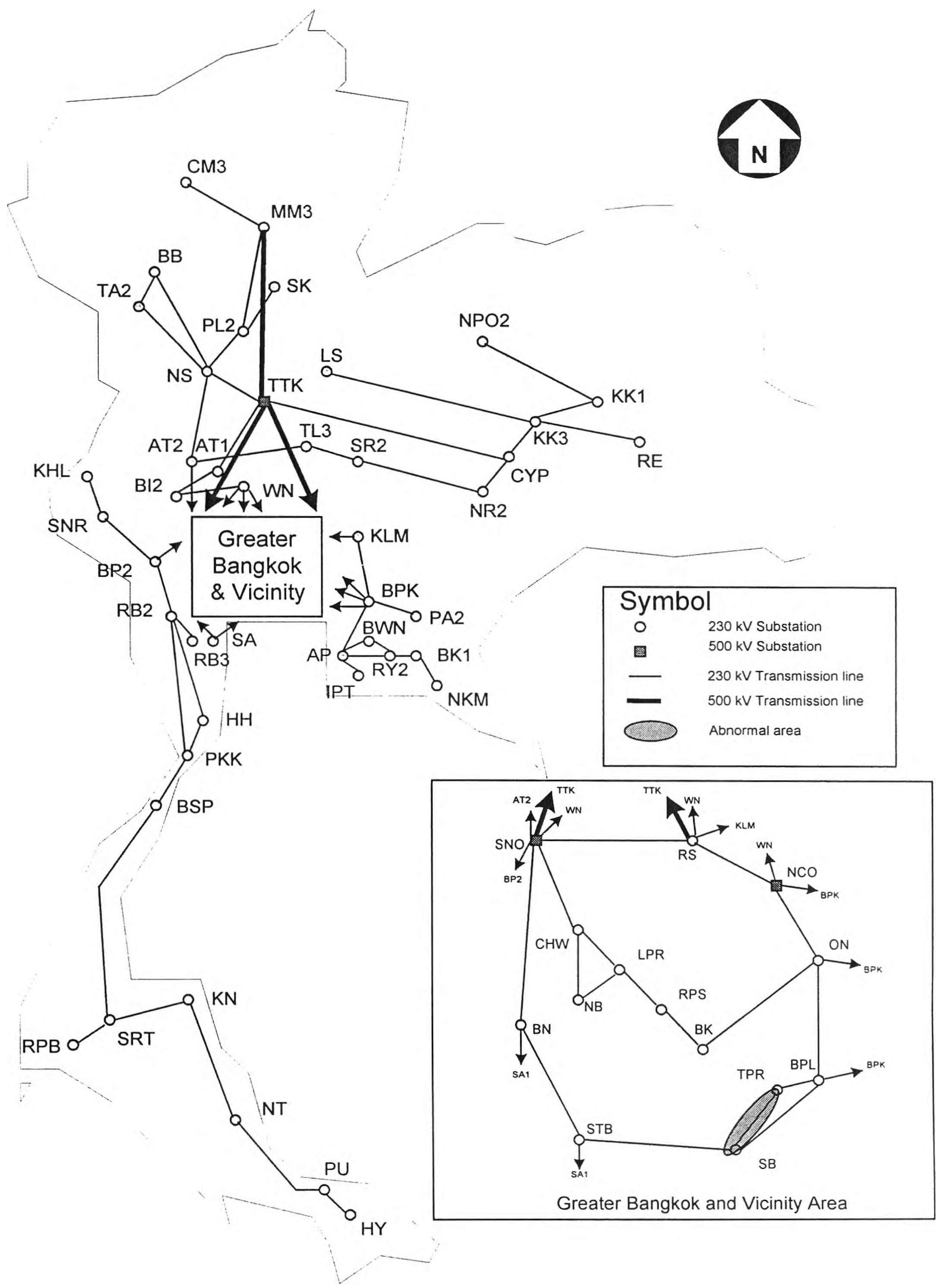

Figure 5-13 Geographical location of abnormal power flow in typical simulation case

d) Generator at reactive power limits

Though voltage magnitude violation is not the key constraint violation in the study of reliability must-run units of bus 1805 since voltage magnitude at voltage-controlled buses and load buses lie in acceptable range, many regulated buses are operated at their reactive generation limits as shown in table 5-18

Table 5-18 List of generation buses operated at their reactive power limit

Generator	Name	V-Spec	V-Actual	Mvar	Q-min	Q-max
1001	NB S1 13.2	1	0.999	50	-30	50
1002	NB S2 13.2	1	0.9991	50	-30	50
1003	NB S3 13.2	1	0.9991	50	-25	50
1011	SB S1 16.1	1	0.9988	120	-45	120
1012	SB S2 16.1	1	0.9988	120	-45	120
1013	SB S3 20.0	1	0.999	230	-90	230
1014	SB S4 20.0	1	0.999	230	-90	230
1015	SB S5 20.0	1	0.999	230	-90	230
1021	SB-G11 9.90	1	0.9986	45	-37	45
1022	SB-G12 9.90	1	0.9986	45	-37	45
1023	SB-CC10 9.90	1	0.9986	45	-37	45
1031	SB-G21 9.90	1	0.9986	45	-37	45
1032	SB-G22 9.90	1	0.9985	45	-37	45
1033	SB-CC20 9.90	1	0.9986	45	-37	45
2006	UR H1 10.0	1	0.9999	4	-1	4
2021	NPO-G11 9.90	1	0.9998	45	-37	45
2022	NPO-G12 9.90	1	0.9998	45	-37	45
2023	NPO-CC1 9.90	1	0.9998	45	-37	45
2025	NPO-G22 9.90	1	0.9998	45	-37	45
2026	NPO-CC2 9.90	1	0.9998	45	-37	45
2040	XSET-H 11.0	1	0.9999	9	-5	9
3001	BLG H1 13.8	1	0.9999	15	-7	15
3002	BLG H2 13.8	1	0.9999	15	-7	15
3003	BLG H3 13.8	1	0.9999	15	-7	15
3061	SRT S1 10.2	1	0.9994	8	-1	8
4001	BB H1-213.2	1	0.9992	47	-22	47
4002	BB H3-413.2	1	0.9991	23	-11	23
4041	MM2 S1 12.9	1	0.9996	36	-18	36
4044	MM3 S4 13.8	1	0.9998	48	-50	48
4045	MM3 S5 13.8	1	0.9998	48	-50	48
4047	MM3 S7 13.8	1	0.9998	48	-50	48
5001	WN-G11 11.5	1	0.9989	60	-40	60
5002	WN-G12 11.5	1	0.9989	60	-40	60

Table 5-18 List of generation buses operated at their reactive power limit (cont.)

Generator	Name	V-Spec	V-Actual	Mvar	Q-min	Q-max
5005	WN-G31 11.5	1	0.9989	60	-40	60
5006	WN-G32 11.5	1	0.9989	60	-40	60
5010	WN-G10 11.5	1	0.9989	60	-40	60
5030	WN-G30 11.5	1	0.9989	60	-40	60
5051	GCC 11.0	1	0.9984	30	-20	30
5052	ROP 11.0	1	0.9988	54	-30	54
6001	BPK S1 21.0	1.05	0.9999	300	-99	300
6002	BPK S2 21.0	1	0.9999	300	-99	300
6003	BPK S3 21.0	1	0.9999	300	-99	300
6004	BPK S4 21.0	1	0.9999	300	-99	300
6005	BPK CB1 9.90	1	0.9997	45	-37	45
6006	BPK CB2 9.90	1	0.9997	45	-37	45
6011	BPK G11 9.90	1	0.9997	20	-18	20
6012	BPK G12 9.90	1	0.9997	20	-18	20
6013	BPK G13 9.90	1	0.9997	20	-18	20
6014	BPK G14 9.90	1	0.9997	20	-18	20
6015	BPK G21 9.90	1	0.9997	20	-18	20
6016	BPK G22 9.90	1	0.9997	20	-18	20
6017	BPK G23 9.90	1	0.9997	20	-18	20
6018	BPK G24 9.90	1	0.9997	20	-18	20
6021	BPK G31 9.90	1	0.9997	45	-37	45
6022	BPK G32 9.90	1	0.9997	45	-37	45
6023	BPK G41 9.90	1	0.9997	45	-37	45
6024	BPK G42 9.90	1	0.9997	45	-37	45
6025	BPK-CC3 9.90	1	0.9997	45	-37	45
6026	BPK-CC4 9.90	1	0.9997	45	-37	45
6028	KRD H1 6.60	1	0.9996	2	-3	2
6048	TPS1 11.0	1	0.9998	10	-5	10
6065	TTP 11.0	1	0.9998	5	-5	5
6068	TOP 11.0	1	0.9998	20	-10	20
7001	SNR H1 13.8	1	0.9995	58	-29	58
7002	SNR H2 13.8	1	0.9995	58	-29	58
7003	SNR H3 13.8	1	0.9995	58	-29	58
7006	TTN H1 13.8	1	0.999	6	-3	6
7007	TTN H2 13.8	1	0.999	6	-3	6
7011	KHL H1 13.8	1	1	38	-19	38
7012	KHL H2 13.8	1	1	38	-19	38
7031	KKC H1 11.0	1	0.9986	4	-5	4

e) Voltage Stability study result

Voltage stability study results of this case composing of ranking of the first ten weakest buses and corresponding security margins and PV-curve of these ten buses are shown in table 5-19 and figure 5-14. It is seen that during the base case operation, Thailand power system remain moderate voltage stability security margin between peak demand and the collapsing point.

Table 5-19 Ranking of weakest bus and security margin of the sample test system

No.	Bus No.	Bus Name	Base kV	Area	Security Margin*
1	9380	Stun	33.00	3	7.90
2	9392	Pattani	33.00	3	7.92
3	9381	Stun	33.00	3	7.92
4	9375	Songkhla2	33.00	3	7.92
5	9367	Hatyai 2	33.00	3	7.93
6	9368	Hatyai 1	33.00	3	7.95
7	9374	Songkhla1	33.00	3	7.96
8	3722	Stun	115.00	3	7.98
9	9382	Sungai-Kolok	33.00	3	8.01
10	9398	Sadao	33.00	3	8.03

* Note: Security Margin is the loading distance between current operating point and the point of collapse (POC) of each bus. This is the measurement of possible additional loadings before voltage collapse incident occur at a bus assuming load is increasing equally across the board. Security margin is measured from the base case operating point of each bus compared to the collapsing point. Therefore, although the incremental load increased is the same in every bus but the total security margin in each but may be varied.

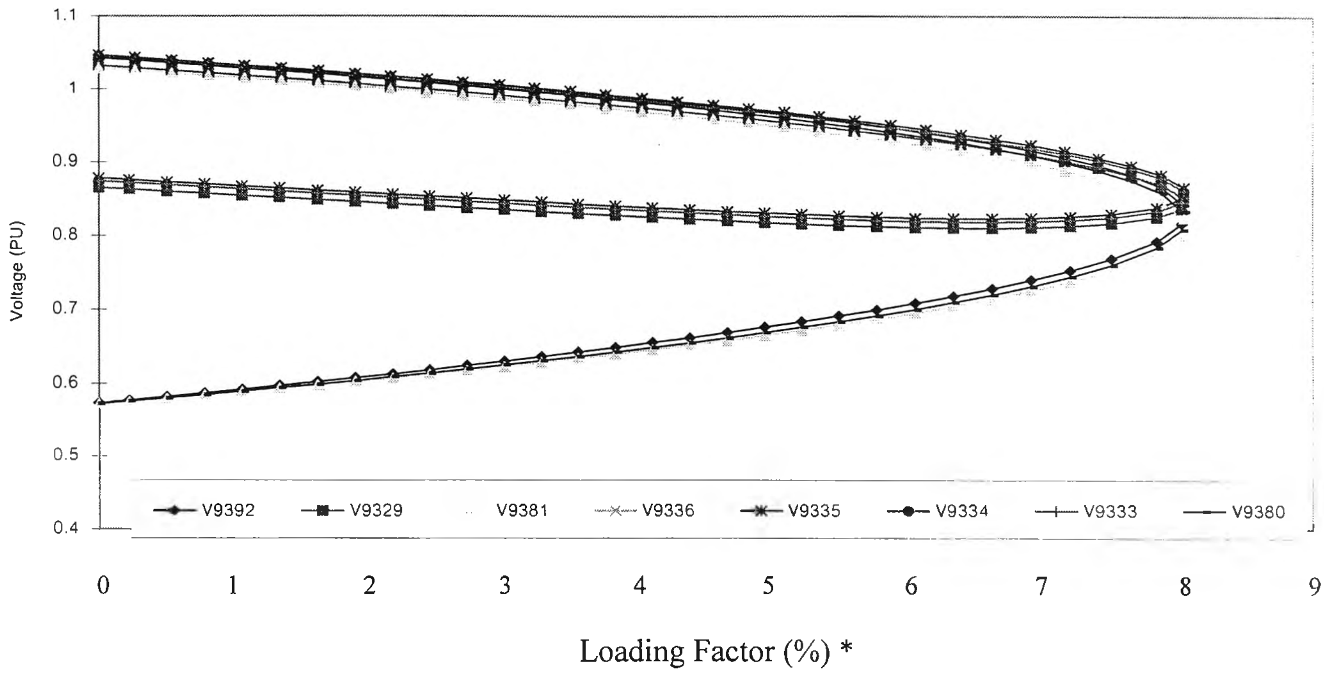

Figure 5-14 PV curve of the first ten weakest buses in the system of the simulated case

* Loading factor is the additional percentage of loading in the system from base case

e) Local areas

There are no local areas occur in Thailand system during the outage of South Bangkok unit. Two thermal limit violations as seen from figure 13 do not encircle and separate any plants.

According to reliability must-run unit study of South Bangkok power plant, this unit must generate at least 565.88 MW and 273.89 Mvar at this loading level to maintain system security. Absence of this amount of generation at this particular bus will result in thermal limit violation in transmission systems that may trigger major security problem. Therefore, unit South Bangkok is qualified as reliability must-run generation with the amount of 565.88 MW, 273.89 Mvar are required as must-run quantity. South Bangkok power plants cal sell the surplus generation capacity (compare to the reliability must-run quantity) to the deregulated market.

As a summary, results of all simulation cases are summarized in the table 5-20 while the complete simulation results of reliability must-run units study Thailand power system is shown in appendix A.

Table 5-20. Summary of Reliability must-run units study in Thailand Power system

Power Plant	Generation Capacity (MW)	Reliability Must-Run Unit	Reliability Must-Run Capacity (MW)	Dispatchable Capacity (MW)
North Bangkok	237.50	No	0.00	237.50
South Bangkok	2,288.00	Yes	565.88	1,722.12
Nam Phong	730.00	No	0.00	730.00
Suratthani	325.00	No	0.00	325.00
Lan krabu	126.00	No	0.00	126.00
Mae Moh	2,625.00	Yes	772.55	1,902.45
Wang Noi	1,902.00	No	0.00	1,902.00
Bang Pakong	3,674.60	Yes	646.79	3,027.81
Rayong	1,232.00	No	0.00	1,232.00

According to reliability must-run units study results shown in table 5-18, unit South Bangkok, Mae Moh and Bang Pakong are qualified as reliability must-run units with relatively large amount of dispatchable generation capacity.

5.7 ATC Interfaces

ATC interfaces are transmission paths between sellers and buyers in power system which ATC values will be posted at these locations by ISO as the references for any further transactions. Generally, power system is a large system containing many generation facilities (generation buses) as well as customer buses. Therefore, it is foreseeable that there are tremendous combinations of generation and customer buses if these units are directly matched without any restrictions. Fortunately, not every path between generators and loads in practical are qualified as ATC interfaces since not every generator buses in the systems are allowed to participate in the deregulated market as seen from must-run and must-take units concept. In addition, similar to the generation side, not every load buses are qualified as buyers since they must have enough amount of power demanded to purchase electricity directly from sellers. Therefore, determination of ATC interfaces in deregulated power system are performed base on qualifications of generator and seller buses that are varied by each power system owning to organization and structure of each system. This section will determine ATC interfaces in Thailand power system base on reform study of Thailand power pool and electricity supply industry and reliability must-run and must-take units information. Evaluation of ATC interfaces divided into two three major frameworks depend on the possible transaction in the future. Transaction paths between generator and load buses, transaction paths between generation portfolios and customer buses and transaction between generation portfolios are explained in this chapter.

5.7.1 Determination of Sellers in Thailand power system

Generally, a generation unit is qualified as seller in ATC interfaces if it is not qualified as one of the following units.

a) Reliability must-run units

b) Regulatory must-run units

c) Regulatory must-take units

5.7.2 Determination of Buyers in Thailand power system

This section explains and determines customer buses that will appear as the receiving end at the ATC interfaces according to the ATC interfaces concept. Although deregulation and liberalization of distribution system are scheduled to employ in Thailand power system following the deregulation of generation facilities, there is no consistent rule or regulation regarding of distribution side have been debut. Therefore, this dissertation will define limits of the buyer buses by considering security of the system during the operation of deregulated market.

Since the calculation of ATC is employed on wholesale electricity marker and there are many load and generation buses in the system, this dissertation will classify customer buses based on a simple criteria that buyers in Thailand market are load buses at high voltage transmission buses at 230 kV or above. Low voltage customers are lumped to the high voltage level. The qualified buyers Thailand power system are shown in table 5-21 and figure 5-15 as the follows.

Table 5-21 List of buyer buses in Thailand power system

No.	Bus Name	Region	Existing Load	
			P (MW)	Q(Mvar)
1	North Bangkok	1	385.00	89.55
2	Lad Prao	1	1296.00	647.68
3	Bang Kapi	1	707.01	312.57
4	Bang Plee	1	784.01	423.86
5	South Bangkok	1	921.00	569.81
6	South Thonburi	1	1392.00	863.59
7	Bangkok Noi	1	478.00	271.44
8	Sai Noi	1	667.00	387.62
9	Rang Sit	1	611.01	299.51
10	Nong Chok	1	318.00	142.43
11	Ratchadaphisek	1	117.34	64.26
12	Chaeng Wattana	1	8.00	2.00
13	Nakon Ratchasima	2	209.46	88.50

Table 5-21 List of buyer buses in Thailand power system (cont)

No .	Bus Name	Region	Existing Load	
			P (MW)	Q(Mvar)
14	Chaiyapum	2	33.29	3.82
15	Roi Et	2	38.34	14.70
16	Khon Kaen	2	122.16	25.59
17	Sakhon Nakhon2	2	219.96	0.36
18	Surat Thani	3	86.40	45.03
19	Nakhon Si Thammarat	3	162.02	42.24
20	Phattalung	3	66.63	13.35
21	Hat Yai2	3	231.12	54.18
22	Nakhon Sawan	4	87.34	39.06
23	Tha Tako	4	114.09	39.07
24	Lom Sak	4	22.88	12.30
25	Chiang Mai 3	4	174.32	72.06
26	Ayutthaya1	5	255.00	87.64
27	Ayutthaya2	5	131.48	49.50
28	Saraburi2	5	123.66	62.40
29	Bang Pa-In2	5	587.60	252.60
30	Tha Lan3	5	258.27	156.39
31	Ao Phai	5	175.41	107.70
32	Rayong2	6	82.68	59.84
33	Bo Win	6	93.00	39.99
34	Khlong Mai	6	99.99	56.37
35	Bang Plee	6	277.08	159.90
36	Ratburi2	7	182.20	86.06
37	Prachuap Kiri Khan	7	54.00	23.52
38	Hua Hin	7	47.11	23.39
39	Samut Songkram	7	704.12	252.80
40	Bang Saphan	7	27.00	21.98

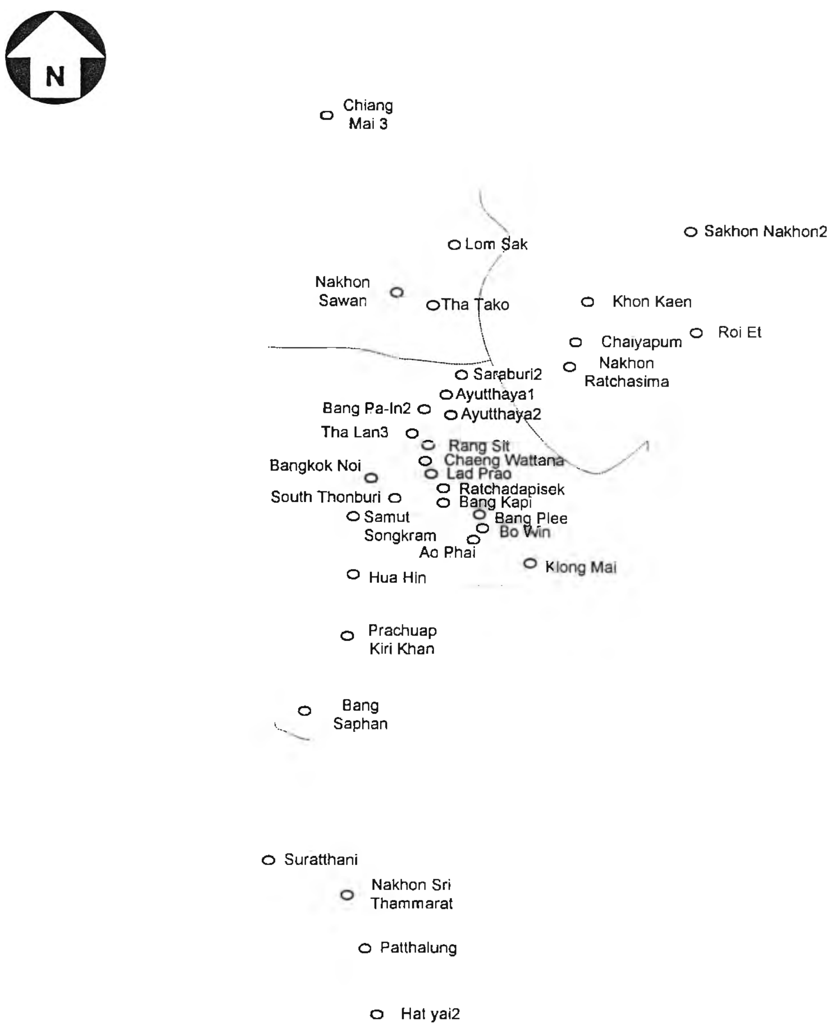

Figure 5-15. Geographical locations of buyers in Thailand deregulated market.

5.7.3 Determination of ATC interfaces in Thailand power system

This section gives information of ATC interfaces which ATC paths must be defined. The actual ATC will be presented in chapter 7 and chapter 8 when transactions are simulated. According to the information of seller and buyer buses given in 5.6.1 and 5.6.2, ATC interfaces in Thailand deregulated power system can be determined in three different platforms with the purpose to cover most of the transactions. These three platforms result from combination of transaction between buses and group of buses as defined by the Electricity Supply Industry Reform Study – Phase 1 (ESI) [8]. Three platforms for ATC interfaces in Thailand power system are presented below.

5.7.3.1 ATC interfaces determined by seller and buyer buses

This format of ATC interfaces is based on numbers of seller and buyer buses in the market. It is seen that 13-generation facilities (generator buses) and 40 buyer buses are qualified in deregulated market (6 thermal units and 7 IPPs). These amounts of sellers and buyers yield 520 ATC interfaces according to this platform of transaction ($\binom{13}{1}\binom{40}{1} = 13x40 = 520$ combinations). Examples of ATC interfaces between EGAT qualified thermal units and seller buses are shown in table 5-22. Complete results of ATC interfaces between seller and buyer buses are given in appendix A.

Table 5-22. Examples of ATC interfaces between seller and buyer buses

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
1	Nam Pong	2	North Bangkok	1
2			Lad Prao	1
3			Bang Kapi	1
4			Bang Plee	1
5			South Bangkok	1
6			South Thonburi	1
7			Bangkok Noi	1
8			Sai Noi	1
9			Rang Sit	1
10			Nong Chok	1
11			Ratchadaphisek	1
12			Chaeng Wattana	1
13			Nakon Ratchasima	2
14			Chaiyapum	2
15			Roi Et	2

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
16			Khon Kaen	2
17			Sakhon Nakhon2	2
18			Surat Thani	3
19			Nakhon Si Thammarat	3
20			Phattalung	3
21			Hat Yai2	3
22			Nakhon Sawan	4
23			Tha Tako	4
24			Lom Sak	4
25			Chiang Mai 3	4
26			Ayutthaya1	5
27			Ayutthaya2	5
28			Saraburi2	5
29			Bang Pa-In2	5
30			Tha Lan3	5
31			Ao Phai	5
32			Rayong2	6
33			Bo Win	6
34			Khlong Mai	6
35			Bang Plee	6
36			Ratburi2	7
37			Prachuap Kiri Khan	7
38			Hua Hin	7
39			Samut Songkram	7
40			Bang Saphan	7
41	Nong Chok	1	North Bangkok	1
42			Lad Prao	1
43			Bang Kapi	1
44			Bang Plee	1
45			South Bangkok	1
46			South Thonburi	1
47			Bangkok Noi	1
48			Sai Noi	1

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
49			Rang Sit	1
50			Nong Chok	1
51			Ratchadaphisek	1
52			Chaeng Wattana	1
53			Nakon Ratchasima	2
54			Chaiyapum	2
55			Roi Et	2
56			Khon Kaen	2
57			Sakhon Nakhon2	2
58			Surat Thani	3
59			Nakhon Si Thammarat	3
60			Phattalung	3
61			Hat Yai2	3
62			Nakhon Sawan	4
63			Tha Tako	4
64			Lom Sak	4
65			Chiang Mai 3	4
66			Ayutthaya1	5
67			Ayutthaya2	5
68			Saraburi2	5
69			Bang Pa-In2	5
70			Tha Lan3	5
71			Ao Phai	5
72			Rayong2	6
73			Bo Win	6
74			Khlong Mai	6
75			Bang Plee	6
76			Ratburi2	7
77			Prachuap Kiri Khan	7
78			Hua Hin	7
79			Samut Songkram	7
80			Bang Saphan	7

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
81	Sai Noi	1	North Bangkok	1
82			Lad Prao	1
83			Bang Kapi	1
84			Bang Plee	1
85			South Bangkok	1
86			South Thonburi	1
87			Bangkok Noi	1
88			Sai Noi	1
89			Rang Sit	1
90			Nong Chok	1
91			Ratchadaphisek	1
92			Chaeng Wattana	1
93			Nakon Ratchasima	2
94			Chaiyapum	2
95			Roi Et	2
96			Khon Kaen	2
97			Sakhon Nakhon2	2
98			Surat Thani	3
99			Nakhon Si Thammarat	3
100			Phattalung	3
101			Hat Yai2	3
102			Nakhon Sawan	4
103			Tha Tako	4
104			Lom Sak	4
105			Chiang Mai 3	4
106			Ayutthaya1	5
107			Ayutthaya2	5
108			Saraburi2	5
109			Bang Pa-In2	5
110			Tha Lan3	5
111			Ao Phai	5
112			Rayong2	6
113			Bo Win	6
114			Khlong Mai	6
115			Bang Plee	6

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
116			Ratburi2	7
117			Prachuap Kiri Khan	7
118			Hua Hin	7
119			Samut Songkram	7
120			Bang Saphan	7
121	North Bangkok	1	Lad Prao	1
122			Bang Kapi	1
123			Bang Plee	1
124			South Bangkok	1
125			South Thonburi	1
126			Bangkok Noi	1
127			Sai Noi	1
128			Rang Sit	1
129			Nong Chok	1
130			Ratchadaphisek	1
131			Chaeng Wattana	1
132			Nakon Ratchasima	2
133			Chaiyapum	2
134			Roi Et	2
135			Khon Kaen	2
136			Sakhon Nakhon2	2
137			Surat Thani	3
138			Nakhon Si Thammarat	3
139			Phattalung	3
140			Hat Yai2	3
141			Nakhon Sawan	4
142			Tha Tako	4
143			Lom Sak	4
144			Chiang Mai 3	4
145			Ayutthaya1	5
146			Ayutthaya2	5
147			Saraburi2	5
148			Bang Pa-In2	5
149			Tha Lan3	5
150			Ao Phai	5
151			Rayong2	6
152			Bo Win	6

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
153			Khlong Mai	6
154			Bang Plee	6
155			Ratburi2	7
156			Prachuap Kiri Khan	7
157			Hua Hin	7
158			Samut Songkram	7
159			Bang Saphan	7
160	Lan krabu	4	North Bangkok	1
161			Lad Prao	1
162			Bang Kapi	1
163			Bang Plee	1
164			South Bangkok	1
165			South Thonburi	1
166			Bangkok Noi	1
167			Sai Noi	1
168			Rang Sit	1
169			Nong Chok	1
170			Ratchadaphisek	1
171			Chaeng Wattana	1
172			Nakon Ratchasima	2
173			Chaiyapum	2
174			Roi Et	2
175			Khon Kaen	2
176			Sakhon Nakhon2	2
177			Surat Thani	3
178			Nakhon Si Thammarat	3
179			Phattalung	3
180			Hat Yai2	3
181			Nakhon Sawan	4
182			Tha Tako	4
183			Lom Sak	4
184			Chiang Mai 3	4
185			Ayutthaya1	5
186			Ayutthaya2	5
187			Saraburi2	5
188			Bang Pa-In2	5
189			Tha Lan3	5
190			Ao Phai	5

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
191	Ratchaburi	7	Rayong2	6
192			Bo Win	6
193			Khlong Mai	6
194			Bang Plee	6
195			Ratburi2	7
196			Prachuap Kiri Khan	7
197			Hua Hin	7
198			Samut Songkram	7
199			Bang Saphan	7
200			North Bangkok	1
201			Lad Prao	1
202			Bang Kapi	1
203			Bang Plee	1
204			South Bangkok	1
205			South Thonburi	1
206			Bangkok Noi	1
207			Sai Noi	1
208			Rang Sit	1
209			Nong Chok	1
210			Ratchadaphisek	1
211			Chaeng Wattana	1
212			Nakon Ratchasima	2
213			Chaiyapum	2
214			Roi Et	2
215			Khon Kaen	2
216			Sakhon Nakhon2	2
217			Surat Thani	3
218			Nakhon Si Thammarat	3
219			Phattalung	3
220			Hat Yai2	3
221			Nakhon Sawan	4
222			Tha Tako	4
223			Lom Sak	4
224			Chiang Mai 3	4
225			Ayutthaya1	5
226			Ayutthaya2	5
227			Saraburi2	5

Table 5-22. Examples of ATC interfaces between seller and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
229			Bang Pa-In2	5
230			Tha Lan3	5
231			Ao Phai	5
232			Rayong2	6
233			Bo Win	6

5.7.3.2 ATC interfaces determined by generation portfolios and buyer buses

According to Electricity Supply Industry Reform Study which defines the future structure of Thailand deregulated market, several generation facilities are performed as generation portfolios in order to increase the competition capability in the market. Therefore, ATC interfaces that are the outcomes of these generation portfolios should be evaluated since they are highly possible to occur in the future. Eight groups of generation portfolios are suggested by the reform study as shown below. However, it is seen that not all of these portfolios are suitable.

5.7.3.2.1 Generation Portfolios in Thailand power system

The geographical locations of generation portfolios of Thailand system are shown in figure 5-15 and the description of each portfolio is listed below.

a) PowerGen1: PowerGen 1 is the group of former fossil generation facilities of Electricity Generation Authority of Thailand (EGAT). Total generation capacity of these units is 12,477 MW encompassing 72% of total generation capacity in 1999. Information of generation facilities in PowerGen 1 is shown in table 5-23 below.

Table 5-23. Generation facilities in Powergen1 group of generation portfolios

No.	Unit Name	Type	Region	Capacity (MW)
1	North Bangkok	Thermal	1	237.5
2	Bang Pakong	Combined Cycle	6	1374.5
3		Thermal	6	2300
4	Surat Thani	Thermal	3	25
5	Nam Phong	Combined Cycle	2	710
6	Wang Noi	Combined Cycle	5	2,031
7	Sai Noi	Gas Turbine	5	244

b) PowerGen2: Similarly to PowerGen 1, PowerGen 2 is the rest former fossil generation facilities of Electricity Generation Authority of Thailand (EGAT). Generation facilities of PowerGen2 mostly are located in the northern and central parts of the country. Information of generation facilities in PowerGen 2 is given in table 5-24.

Table 5-24. Generation facilities in Powergen2 group of generation portfolios

No.	Unit Name	Type	Region	Capacity (MW)
1	South Bangkok	Combined Cycle	1	958
2	South Bangkok	Thermal	1	1,330
3	Mae Moh	Thermal	4	2,625
4	Lan Krabue	Gas Turbine	4	154
5	Nong Chok	Gas Turbine	1	488

c) Ratchaburi
Ratchaburi power plant is scheduled to be completed its first stage in the year 2000. Initially, it will compose of two combined cycle (oil-fired) units (2x725 MW). Three combined cycle gas units will be commissioned in the near future. These five newly constructed units empower Ratchabuti power plant to be powerful enough to compete in the deregulated market.

d) Hydro Power plants
Although several territories in many countries such as Victoria Australia have implemented the hydro facilities into competition market; the hydro power plants in Thailand are classified as regulatory must-take units and are excluded from competition.

e) IPP Trader 1 and IPP Trader 2
Instead of performing bilateral contracts individually with other buyers, Independent Power Producers in Thailand can be united as generation portfolios which contain more market power. ESI study of Thailand deregulated market suggests two group of IPP traders as the proper amount of generation portfolios as shown in table 5-25 and table 5-26 below.

Table 5-25. Generation facilities in IPP1 of generation portfolios

No.	Unit Name	Type	Region	Capacity (MW)
1	EGCO	Lignite	3	2,056
2	Independent Power	Gas	6	700
3	Tri Energy	Gas	7	700
4	Bo Win Power	Gas	6	713

Table 5-26. Generation facilities in IPP2 of generation portfolios

No.	Unit Name	Fuel	Region	Capacity (MW)
1	EPEC	Gas	1	350
2	Gulf Power	Coal	7	734
3	Union Power	Coal	7	1,400
4	BLCP	Coal	6	1,346.5

f) SPP Trader
The purpose to perform SPP trader is analogous to IPP traders that intend to consolidate the SPP units in deregulated market. However, contents of SPP trader are not well defined due to large number of units spreaded along large areas. Therefore, SPP trader will not be recognized as generation portfolios in ATC interfaces determination in this dissertation. Performing of ATC interfaces created by SPP trader is not difficult to implement in the future when complete information is available.

g) Trader for foreign generators (power imports)
Currently, electricity purchased from neighboring countries as classified as regulatory must-take units since they are long-term contract between governments as indicated previously. However, in the future, it is possible that these contracts may be managed by trading companies that transfer these contracts from regulatory must-take quantities to generation portfolios in deregulated market. Similar to item f), this dissertation will not calculate ATC values by these path due to the lack of information.

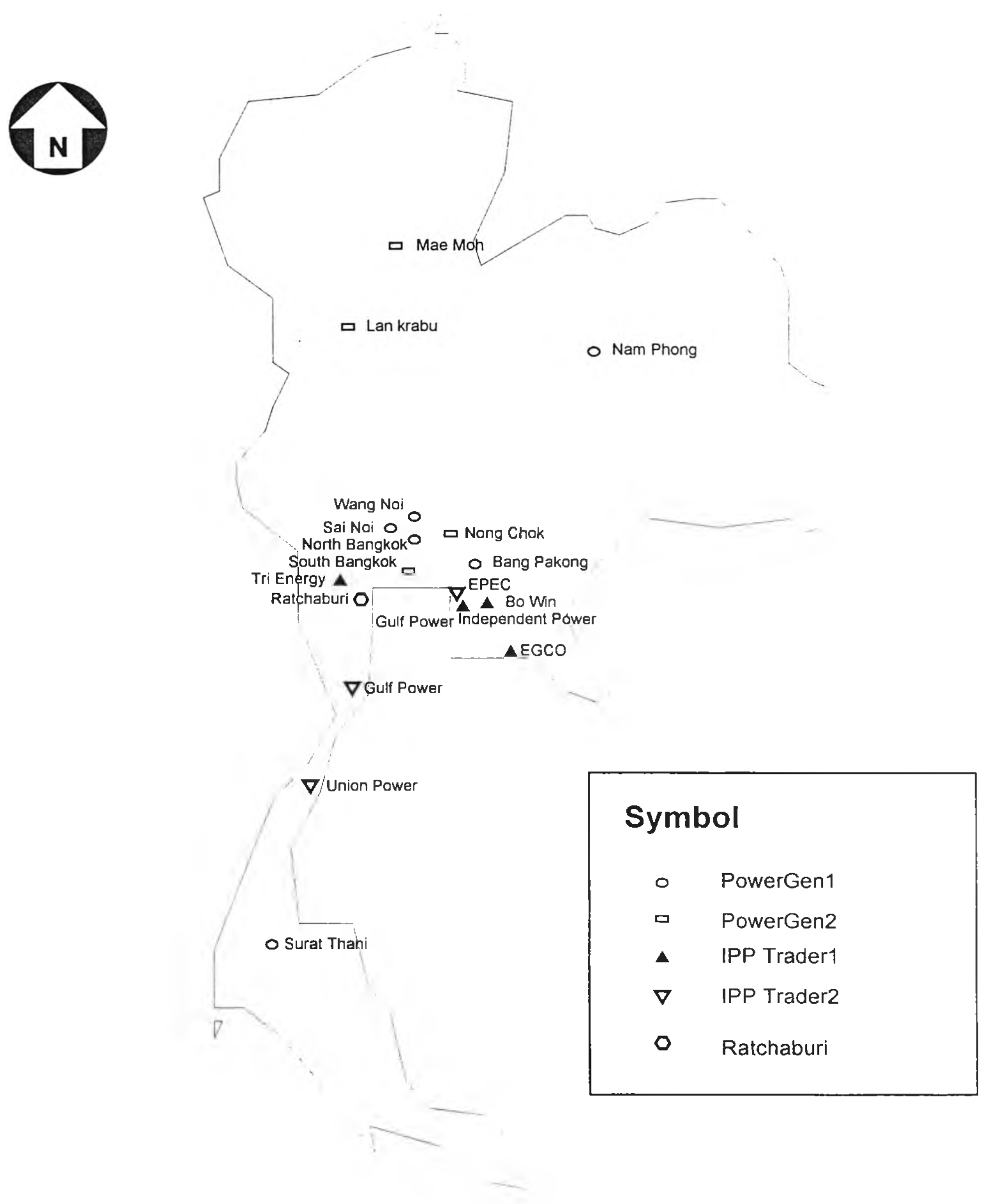

Figure 5-16. Geographical locations of generation portfolios in Thailand deregulated market.

5.7.3.2.2 ATC interface results

ATC interfaces determined by generation portfolios are similar to ATC interfaces between seller and buyer buses. Most of the matching processes of these two formats are identical except that locations of buyer buses in the latter case must be carefully concerned. It is important that buyer buses must locate outside the generation portfolios. Otherwise, they will automatically become a member (load) of generation portfolios that are not eligible to perform bilateral contract transactions.

As the results, examples of ATC interface according to this format are shown in table 5-27.

Table 5-27. Examples of ATC interfaces between Generation portfolios and buyer buses

Interface Number	Seller Bus		Buyer Bus	
	Bus Name	Region	Bus Name	Region
1	Nam Pong	2	North Bangkok	1
2			Lad Prao	1
3			Bang Kapi	1
4			Bang Plee	1
5			South Bangkok	1
6			South Thonburi	1
7			Bangkok Noi	1
8			Sai Noi	1
9			Rang Sit	1
10			Nong Chok	1
11			Ratchadaphisek	1
12			Chaeng Wattana	1
13			Nakon Ratchasima	2
14			Chaiyapum	2
15			Roi Et	2
16			Khon Kaen	2
17			Sakhon Nakhon2	2
18			Surat Thani	3
19			Nakhon Si Thammarat	3
20			Phattalung	3
21			Hat Yai2	3
22			Nakhon Sawan	4
23			Tha Tako	4
24			Lom Sak	4
25			Chiang Mai 3	4
26			Ayutthaya1	5
27			Ayutthaya2	5
28			Saraburi2	5

Table 5-27. Examples of ATC interfaces between Generation portfolios and buyer buses (cont)

Interface Number	Seller Bus		Buyer Bus	
29			Bang Pa-In2	5
30			Tha Lan3	5
31			Ao Phai	5
32			Rayong2	6
33			Bo Win	6
34			Khlong Mai	6
35			Bang Plee	6
36			Ratburi2	7
37			Prachuap Kiri Khan	7
38			Hua Hin	7
39			Samut Songkram	7
40			Bang Saphan	7
41	Nong Chok	1	North Bangkok	1
42			Lad Prao	1
43			Bang Kapi	1
44			Bang Plee	1
45			South Bangkok	1
46			South Thonburi	1
47			Bangkok Noi	1
48			Sai Noi	1
49			Rang Sit	1
50			Nong Chok	1
51			Ratchadaphisek	1
52			Chaeng Wattana	1
53			Nakon Ratchasima	2
54			Chaiyapum	2
55			Roi Et	2
56			Khon Kaen	2
57			Sakhon Nakhon2	2
58			Surat Thani	3
59			Nakhon Si Thammarat	3
60			Phattalung	3
61			Hat Yai2	3
62			Nakhon Sawan	4
63			Tha Tako	4
64			Lom Sak	4
65			Chiang Mai 3	4
66			Ayutthaya1	5

Table 5-27. Examples of ATC interfaces between Generation portfolios and buyer buses (cont)

Interface Number	**Seller Bus**		**Buyer Bus**	
67			Ayutthaya2	5
68			Saraburi2	5
69			Bang Pa-In2	5
70			Tha Lan3	5
71			Ao Phai	5
72			Rayong2	6
73			Bo Win	6
74			Khlong Mai	6
75			Bang Plee	6
76			Ratburi2	7
77			Prachuap Kiri Khan	7
78			Hua Hin	7
79			Samut Songkram	7
80			Bang Saphan	7

5.7.3.3 ATC interfaces determined between generation portfolios

This is the last possible format of ATC interfaces in Thailand deregulated power market. By this format, ATC interfaces are determined by bilateral transaction between generation portfolios. A generation portfolio may purchase electricity from another generation portfolio to sell to their customers or resell again. According to information currently available, there are 20 ($\binom{5}{1} x \binom{4}{1} = 5x4$) combinations of ATC interfaces between generation portfolios among PowerGen1, PowerGen2, Ratchaburi, IPP Trader1 and IPP Trader 2 as shown in table 5-28.

Table 5-28. ATC interfaces between generation portfolios

Interface Number	Seller Generation Portfolios	Buyer Generation Portfolios
1	PowerGen1	PowerGen2
2		Ratchaburi
3		IPP Trader1
4		IPP Trader2
5	PowerGen2	PowerGen1
6		Ratchaburi
7		IPP Trader1
8		IPP Trader2

Table 5-28. ATC interfaces between generation portfolios (cont)

Interface Number	Seller Generation Portfolios	Buyer Generation Portfolios
9	Ratchaburi	PowerGen1
10		PowerGen2
11		IPP Trader1
12		IPP Trader2
13	IPP Trader1	PowerGen1
14		PowerGen2
15		Ratchaburi
16		IPP Trader1
17	IPP Trader2	PowerGen1
18		PowerGen2
19		Ratchaburi
20		IPP Trader2

This chapter presents the ATC interfaces which cover most of further possible transactions in Thailand power system after the deregulation processes. According to information obtained in this chapter, ATC values between sellers and buyers results will be calculated according to these locations as the detailed calculation will be shown in chapter 7 and chapter 8 respectively.

5.8 Conclusions and Discussions

Reliability must-run units are generation units that are necessary to ensure security of power system under competitive environment. A generation unit is qualified as reliability must-run unit if its unavailability creates security such as thermal limits, unacceptable voltage level or voltage stability or local areas in the systems. A generation unit who qualified as reliability must-run unit is explicated from scheduling processes and receives electricity price according to the reliability must-run contract.

In Thailand power system, there are four of nine power plants are qualified as reliability must-run units. Most of these units are determined as reliability must-run units since they must supply an amount of electricity to support system security. Therefore, portion of their generation capacity are reserved as the obligation to deliver these amount of electricity to the systems in order to maintain system's security where the surplus of generation capacity still can be sold to the deregulated market.

The great advantage of the methodology used to determine reliability must-run units and reliability must-run quantity proposed in this dissertation is it allows reliability must-run units to involve in the deregulated market with their surplus generation capacity. Reliability must-run units may submit bids in the day-ahead market or sell their generation surplus as a reserve in real-time market (ancillary service market). From this approach, reliability must-run units gain income from electricity paid by reliability must-run contract and competitive market, which could be spot transaction, or bilateral contract. However, it is the responsibility of reliability must-run unit to speculate the spot price and optimize their generation capacity in order to maximize their profits. It is seen that transactions made by reliability must-run units are similar to forward and spot transaction under the financial point of view.

It is seen from this chapter that electricity transactions in Thailand deregulated market may occur in several platforms. Bilateral contracts between seller and buyer are the simplest transactions containing thousand of possible cases depend on statistical combination. However, since several generation facilities are grouped as generation portfolios so as to strengthen their competing power in the deregulated market, future transactions are not restricted to direct bilateral contracts but transaction between generation facilities and buses or themselves. These result in increasing of ATC interfaces which have been shown in this chapter.

The method to determine reliability must-run units and contingency analysis method are dissimilar since they based on different scenarios and assumptions. Reliability must-run study simulates the situation when a generation unit fail to compete in deregulate market and is not allowed to sell electricity to the system. Meanwhile, contingency analysis assumes the situations when an element of power system is forced outage due to unexpected such as fault in the systems. This is the reason why these two approaches require different procedures to obtain the results. Details of contingency analysis will be explained again in chapter 7.