Chapter 2

Basic Concepts and Assumptions

This chapter contains basic concept of power system operation, assumptions and others topics related to real-time available transfer capability in power system. This information is the fundamental for any other computation in this dissertation. Firstly, the basic concepts of power system operation encompassing the generation units, transmission system and load as well as mechanisms and circumstances of secure and insecure operation of power system are explained. Then, since responds of practical power system is far from ideal electric system owning to its nonlinearities and unpredictable events, the basic assumptions for real-time ATC calculation in this dissertation are addressed. However, it is impossible to include all parameters into the consideration of this massive system containing millions of components such as electric power system. Therefore, appropriate set of assumptions must be addressed prior to the ATC calculation in order to obtain acceptable accuracy results within the limitation of time and resources. After the first two sections have been explained, details of the main test system in this dissertation, Thailand deregulated power system, are explained. The big picture of market structure, market power, configuration of transmission system and classification of players in the market such as sellers, buyers, ISO are major topics to be discussed in this section.

2.1 Basic Concepts

This dissertation proposes a new and practical method to determine real-time Available Transfer Capability in an interconnected power system under competitive environment based on Thailand power structure (pool model). Since a major difficulty of real-time ATC calculation is not the calculation procedures but the sufficiency and reliability obtained from Energy Management System (EMS), a major source of real-time information gathering data from sensors installed all over the system, in some cases, analytical method combining off-line and real-time approaches is beneficial if the computation time is limited or the availability of real-time information is insufficient.

Anyhow, beside the accuracy and availability of real-time information as mentioned above, understanding the principles of power system operation, information of the test system such as system configurations, market structure, load profile, load forecasted etc. and general assumptions are crucial factors in studying real-time ATC. For that reason, this chapter will cover the overview of power system operation both under normal and abnormal condition, basic assumptions in this dissertation and information of the test system. This information will be used as the reference for any further calculation in this dissertation.

2.2 Power System Operation

In this section, power system operation is taken into consideration since it is directly associated with real-time available transfer capability. As mentioned early in the introduction, a better understanding in phenomena and mechanisms behind these this time frame of power system will definitely lead to a better algorithm to determine real-time available transfer capability for a practical power system.

Basically, power system is known as an enormous nonlinear electric circuit containing millions of components. From mathematical point of view, power system is a multi-variables nonlinear system and its states, voltages, currents, and frequency are directed by dominant parameters. Therefore, the suitable methods employed in this dissertation to analyze the system must be able to account for nonlinearities and parameters fluctuations.

Under normal operating conditions, power system balanced by the power supplies and load demands [19]. The whole system and control equipment have ability to self-adjust to a new operating point if the system has enough security margin and the disturbances are within limits. For example, as load increases voltage magnitude at load bus and rotational speed of generator decreases. Both generation and load sides have systematic processes to compensate with this disturbance as follows.

At generator side, using control equipment to speed up generator speed or redispatching generation units under authority are two general approaches generally used among industry. Both actions adjusting operating condition of the system to increasing frequency to the setting values as well as shifting operating point of the system to a new equilibrium. However, these activities must rely on contracts in the market and available generation capability of generators.

To restore voltage magnitude at load side, on-load tap changing transformers (OLTC) adjust tap position to lift load voltage magnitude. Besides on-load tap changing transformers, switched capacitors are commonly to supply reactive power to that area. Furthermore, other reactive power sources from transmission provider or ancillary services might be supplied to maintain acceptable voltage magnitude and prevent voltage stability.

When electricity demand and generation level keep increasing to supply load, transmission lines carry more electricity and power losses resulting in the increasing of temperature in conductors. This temperature raising may trigger the relays to disconnect transmission lines from the rest of the system if thermal limit of transmission lines is reached. In addition, the heat reduces strength of transmission lines and increase sag that increasing higher opportunity to flash over or short circuit. At this point, power system is considered as a marginally stable system, a small disturbance may develop to a severe situation.

Therefore, the best way to reliably operate power system in any condition is to pre-study and avoid insecure operation of power system by unauthorizing insecure transactions or performing appropriate techniques to alleviate the troubles. This motivation becoming the foundation of real-time available transfer capability representing maximum amount of electricity can be safely transferred throughout the transmission system at a specific time and interface. Power system is typically secured as long as amount of transaction in that interface is not allowed to exceed its ATC values.

In the next section assumptions of power system and market structure will be explained. The purpose of this section is to address common understandings in power system operation prior to the actual calculation. Then information of Thailand power system will be discussed both the technical and economical point of views.

2.3 Assumptions

It is common to make reasonable assumptions in practical power system so as to speed up the calculation processes, cope with data error or data insufficiency. Assumptions used in this dissertation are summarized by each part of power system as follows:

2.3.1 Market structure and market power

According to Thailand market structure explained in chapter 1, following assumptions have been issued for Thailand power pool.

a) Independent System Operator is obligated in ATC calculation and posting for day-ahead market transactions at the specific interfaces. Therefore, ATC coordination process is not necessary for Thailand power system. This is differently from the scenarios in the United States that ATC calculation and posting will be done by transmission providers.

b) At least until the debut of first phase of ESI, Thailand power system does not provide variety of transmission services and tariff structures such as recallable or non-recallable and redispatching seem to be the appropriate resolution for congestion mitigation. For that reason, TRM cannot be sold as a recallable reserve.

c) Bilateral contracts will be combined with base case conditions of power system prior to real-time ATC calculation. Since bilateral transactions are amount of electricity traded in forward market, these amounts of electricity can be assumed constant during real-time calculation.

d) Hydro power plants are excluded from scheduling processes. Because most of hydro power plants in Thailand are attached with multi-purposes dams supplying both the water for electricity generation and agricultural sector, these power plants are classified as regulatory must-take units. However, these generation facilities might be released from regulated units in the future if appropriate jurisdiction legislation is issued to manage this resource.

e) Generation portfolios in real-time ATC calculation may be different from generation portfolios defined in ESI report of Thailand power system since the ESI report defines portfolios in the system based on market power not from network and security constraints. However, generation portfolios in real-time ATC calculation should be a subset of market power portfolios so as to avoid geographical overlapping problems.

f) Transmission system management and authority to make decision in significant issues in the system such as allowing generation units to dispatch, curtailing insecure transactions or resolving disputes among participants belong to Independent System Operator (ISO). However, with the purpose to maintain fairly competition in the market, operation of ISO is also controlled by regulatory board and government.

2.3.2 Generation system

Assumptions associate with generation system are listed below.

a) Since long-term stability is a planning issue and the complicate problem requiring dedicated calculation to identify source of the problem as well as solutions, it is excluded from real-time ATC calculation.

b) For the worst scenarios, transient caused by the operation of protective devices simulated in contingency analysis is ignored.

c) The maximum power factor at generation facility bus is assumed to be 0.95 lagging. This rule is issued to encourage generation facilities to generate both real and reactive power to the system. Delivering only real power to the system will benefit to the sellers but may result in severe security problem in the future.

2.3.3 Transmission system

Similarly to generation side, assumptions regarding with transmission system are.

a) Normal rating for transmission lines thermal limit is set at 90% of conductors rating. The situation of apparent power flow greater than 90% of conductor flows in transmission line is interpreted as thermal limit violation for the security purpose.

b) Transmission charge (wheeling charge) and congestion charge are not included in this dissertation since the main purpose of this dissertation is focused on the security issue of power system under competitive environment.

2.3.4 Distribution system

For the distribution system, assumptions of the distribution system are.

a) Load demand is assumed to increase at the constant power factor compare to the base load. This load incremental simulates the scenarios when electricity transactions are manipulating.

b) IEEE- constant impedance, constant current and constant power load model (ZIP load model) [20] is the standard load model in transient stability study. Approximated proportional of each category of load are used to simulate load responds.

c) Commercial components of service such as curtailability, recallability are not included in this dissertation since these distribution services are not available in tariff structure of Thailand power system.

d) Determination of zones and areas are based on the current zoning of Electricity Generating Authority of Thailand. There are six zones that are divided by geographical location unrelated to market power of the deregulated market.

2.4 Thailand Power System

Thailand power industry serves 65 millions customers in the country ranging from residential customers to industrial customers. Information of Thailand power system can be divided into several categories as the following.

2.4.1 General Information

Based on zonal separation from Electricity Generating Authority of Thailand, the system is divided into 4 major regions or 6 detailed regions [21] (subdivide central region, region 1 - the most populated area of the country into 3 subregions) that the selection of model in each case depends on purpose of the study. Four major regions are mainly interconnected by 230 kV extra high voltage backbones while 500 kV and 115 kV transmission networks are partially supplied in some areas. General information of Thailand power system is shown in figure 2-1.

Even though Thailand power industry is scheduled to operate under the deregulated environment in 2003, power industry is dominated by three state enterprises controlling the system ranging from generation to distribution system at present.

a) Electricity Generating Authority of Thailand (EGAT) is responsible for generation and transmission systems planning, construction and operation. Electricity generated by EGAT is delivered through high voltage transmission lines to Metropolitan Electricity Authority (MEA), Provincial Electricity Authority (PEA) and direct high voltage customers.

b) Metropolitan Electricity Authority (MEA) electricity to the customers in Bangkok, Nonthaburi and Samutprakan. MEA customers compose of residential, commercial and industrial users in low and medium voltage. Although MEA only serves three provinces in the country but they consume more than 60% of total system load demand.

c) Provincial Electricity Authority (PEA) is the second distribution company that services the customers at the rest provinces of the country.

Under this structure, retailed customers are required to purchase electricity from provider in their area no matter how much it cost. Similarly, distribution provider in each region, MEA and PEA, must purchase electricity generated by EGAT. This bundled structure is relatively sluggish and inefficient from the economic point of view.

2.4.2 Deregulation of Thailand Power System

Thai government has begun the liberalization and deregulation processes of electricity industry for many years. Along with these processes, generation side is the first part to be deregulated by splitting the ownership of the generations and promoting the competition in the system. The Government's principal objective in implementing a competitive wholesale electricity market is to encourage private investment in the electricity industry with less need for the kind of financial guarantees and contracts that become financial liabilities of the Government. Primary and supplementary objectives of electricity industry deregulation in Thailand power system are summarized as the followings.

Primary objectives [8]

a) Assure reliable and efficient operations or dispatch of a system consisting largely of private, profit-motivated generators (and consumers).

b) Support bilateral contracting by assuring that the market participants will be able to buy and sell, at fair market-determined prices, the electrical energy and other services they will need when actual operations do not exactly match contract positions

c) Provide an open and non-discriminatory "market of last resort" for market participants who do not have contracts for the electricity they produce or consume.

Supplementary objectives [8]

a) System security – the coordination process must ensure that real-time operations remain within system security standards

b) Economically efficient operations – the coordination from ISO and the spot market process should result in dispatch of generation and dispatchable/controllable loads that meets uncontrollable load at least cost.

c) Nondiscriminatory access – all market participants regardless of ownership or affiliation must have access to the transmission system, and hence the marketplace, on the same terms and conditions.

d) Transparent, efficient and visible spot prices – the spot market should result in transparent at market-clearing market prices and all market participants can buy and sell energy.

e) Enforceable and incentive-compatible rules – the rules of the process should encourage market participants to "tell the truth" to the ISO, i.e., to offer generation capacity at true operating costs to the ISO and make honest declarations of generator availability.

f) Promotion of competition – the coordination and spot market process should promote competition by assuring that large, diverse players do not have advantages purely because of their size and diversity.

g) Recovery of all efficient costs – the market arrangements should allow recovery of all efficient fixed and operating costs, thereby providing price signals to attract new entrants, with the right technological and economic characteristics, when and where it is economic for them to enter.

h) Simplicity – the market should be as simple as possible, consistent with the other objectives stated above.

Power pool is the selected model for Thailand deregulated power system since it is likely to be suitable for the new market such as Thailand. In this structure, an independent system operator (ISO) will manage the competitive power market. It is therefore important that the ISO owns no generation so that it can function as an independent referee over the whole process. During the first stage of deregulation, generation facilities will be the first part to be fully deregulated by separating state-owned power plants into several groups of GENCOs depended on market power as well as welcoming new generators to participate in the market. Transmission system, TRANSCO, is still a regulated business and distribution system, DISTCOs, is partially deregulated by increasing numbers of distribution companies and service areas. Structure of Thailand power pool is illustrated in figure 2-2.

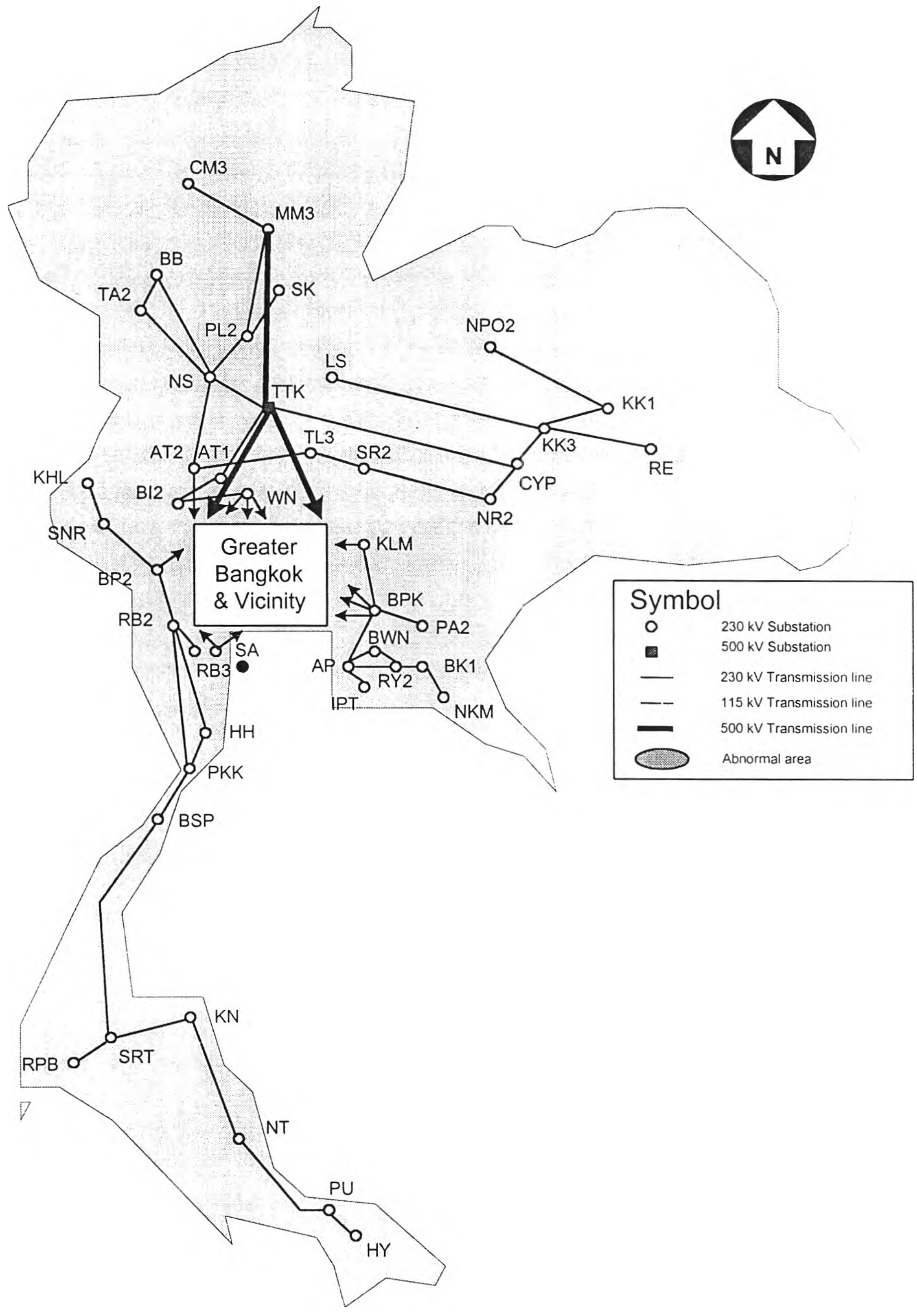


Figure 2-1. Thailand Power System

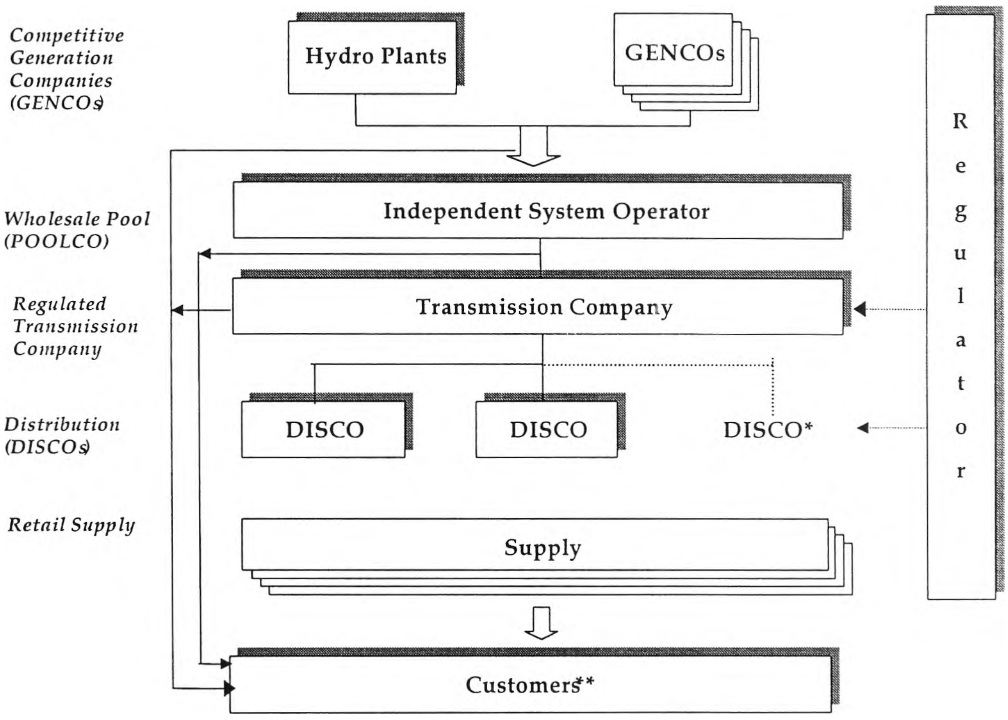
2.4.3 Power system configuration

Detailed information of Thailand power system is summarized below.

2.4.3.1 Generation System

In 1998, Thailand power system contains 18,174 MW of installed capacity. From 1998 until 2011, the installed capacity of the generating sector is projected to increase to 32,656 MW and 36,816 MW associated with Low Economic Recovery (LER) scenario and Medium Economic Recovery (MER) case of power developing plan (PDP) respectively [22].

Thermal and hydroelectric power plants are two types of power plants in the system owned by EGAT and private generation companies. According to the information of 1998, hydroelectric power plants share only 6.8% of total load requirements. In addition, there is very low opportunity to construct new hydroelectric power plant due to environmental and geographical constraints. New generation capacity from hydroelectric power plants seem to be obtained from pump-storage units added up on the existing hydroelectric power plants.



Note :

* *Further study to determine the number of distribution companies is required*

** *Customers with demand over a certain threshold will be able to purchase electricity directly from GENCOs or power pool. The regulator will be responsible for determining the details of the qualified customers.*

Figure 2-2. Structure of Thailand power pool [8]

Under the regulated structure, most of thermal power plants in the system are owned by EGAT. However, there are several IPPs and joint venture company between EGAT and partnerships are allowed to connect their thermal power plants to the grid. In the future, when power system is deregulated, there will be more generation units under the deregulated market due to the separation of the existing EGAT power plants and the commissioning of new generation units.

a) EGAT - Thermal power plants
In order to prepare for competition in the new market, EGAT has established two operating divisions - PowerGen 1 and PowerGen 2 – to manage its thermal plants based on market power. Information of these generation portfolios from 1998 to 2008 is given in table 2-1 [8].

b) EGAT - Hydroelectric power plants
EGAT owns an amount of hydroelectric power plants across the country as shown in figure 2-3. The participation in deregulated market of these power plants is still under discussion. This dissertation will classify these generation facilities as the regulatory must-take units due to the multiple purposes of these units. Without appropriate legislation and market rules, allowing hydroelectric units to freely compete in deregulated market may distort the market-clearing price and upset the agricultural sector.

Table 2-1. EGAT Portfolios (PowerGen1 & PowerGen2) Cumulative Capacity up to 2011.

PowerGen 1			**MW Capacity**
Up to 1998	Sep	North Bangkok Thermal	237.5
		Bang Pakong CC	1374.6
		Bang Pakong Th	2300
		Surat Thani Th	25
		Nam Phong CC	710
		Wang Noi CC	2,031
		Sai Noi GT	244
1999	Oct	Surat Thani TH #1 Retired	-25
1999	Oct	Move Sai Noi To SRT CC	-244
2000	Dec	Surat Thai CC (GT #1-2)	244
2001	Jan	North Bangkok TH #1-3 Retired	-237.5
2003	Mar	Surat Thani CC (ST)	100
2006	Oct	Bang Pakong CC1 Retired	-380.3
2007	Oct	Bang Pakong CC2 Retired	-380.3
PowerGen 1 Total as at Sept 2011			5,999

PowerGen 2			**MW Capacity**
Up to 1998	Sep	South Bangkok CC	958
		South Bangkok Th	1,330
		Mae Moh Th	2,625
		Lan Krabue	154
		Nong Chok	488
2001	Jan	Mae Moh 1-3 Retired	-225
2002	Feb	Krabi TH #1	300
2004	Oct	South Bangkok TH #1,3 Retired	-510
2005	Oct	South Bangkok TH #2,4 Retired	-510
2007	Oct	South Bangkok TH #5 Retired	-310
2008	Mar	Krabi TH #2	300
PowerGen 2 Total as at Sept 2011			4,600

c) Independent Power Producers
Currently, a number of private power plants and a joint venture company between EGAT and other shareholders, Electricity Generating Public Company (EGCO), are operating as Independent Power Producers (IPPs). These units are required to sell electricity to the EGAT transmission grid

under current Power Purchase Agreements (PPAs). In the future, these PPAs may be slightly modified accordance with the new market structure.

d) Small Power Producers
Under the concept of promoting energy conservation program and increasing local security of the system, 50 PPAs of small power producers (SPPs) have been concluded with total capacity of 2,226.6MW. Generally, these small units are located inside the industrial estate or vicinity areas to provide electricity to local customers or distribution companies (PEA or MEA). Since these units are relatively small compared to IPPs and EGAT generation portfolios, consolidation of units to increase market power is required when participating in the deregulated market.

e) Power Imports
Thailand has performed several electricity transactions with neighboring countries for economic and security purposes. Generally, Thailand imports electricity from Laos hydro-electric project to reduce power loss and supply customers in the system as well as establishing emergency tie-lines with Malaysia for security reason. Besides 313MW transactions from two hydro power plant currently conducting, negotiations with Laos are taking place to provide up to an additional 3,300MW by 2008.

2.4.3.2 Transmission Systems

Transmission system is a part in the system undergoing a major change behind the deregulation. Presently, EGAT constructs, owns, operates and maintaining transmission system. No transmission charge is presented in the system regardless the distance between generation facilities and loads.

After the deregulation, transmission system still be a regulated business but it will be jointly operated by Grid Company (GRIDCO) and Independent System Operator (ISO). These two organizations having distinct responsibilities, GRIDCO owns, maintains and operates grid facilities while ISO operates and provides transmission services. Therefore, ISO has to decide generators operating patterns and grid facilities allocation at a specific time. The GRIDCO conducts the actual switching of the equipment – circuit breakers, voltage control equipment, meters, load shedding equipment, disconnecting switches etc. under the direction of the ISO.

Authorities, obligations and liabilities of ISO and GRIDCO are clearly addressed in the Transmission Control Agreement (TCA). Both ISO and GRIDCO are regulated business operate their business by transmission tariff and charges to GENCOs. Since these charges are regulated, increasing efficiency is the only one way for these two organizations to raise their profits.

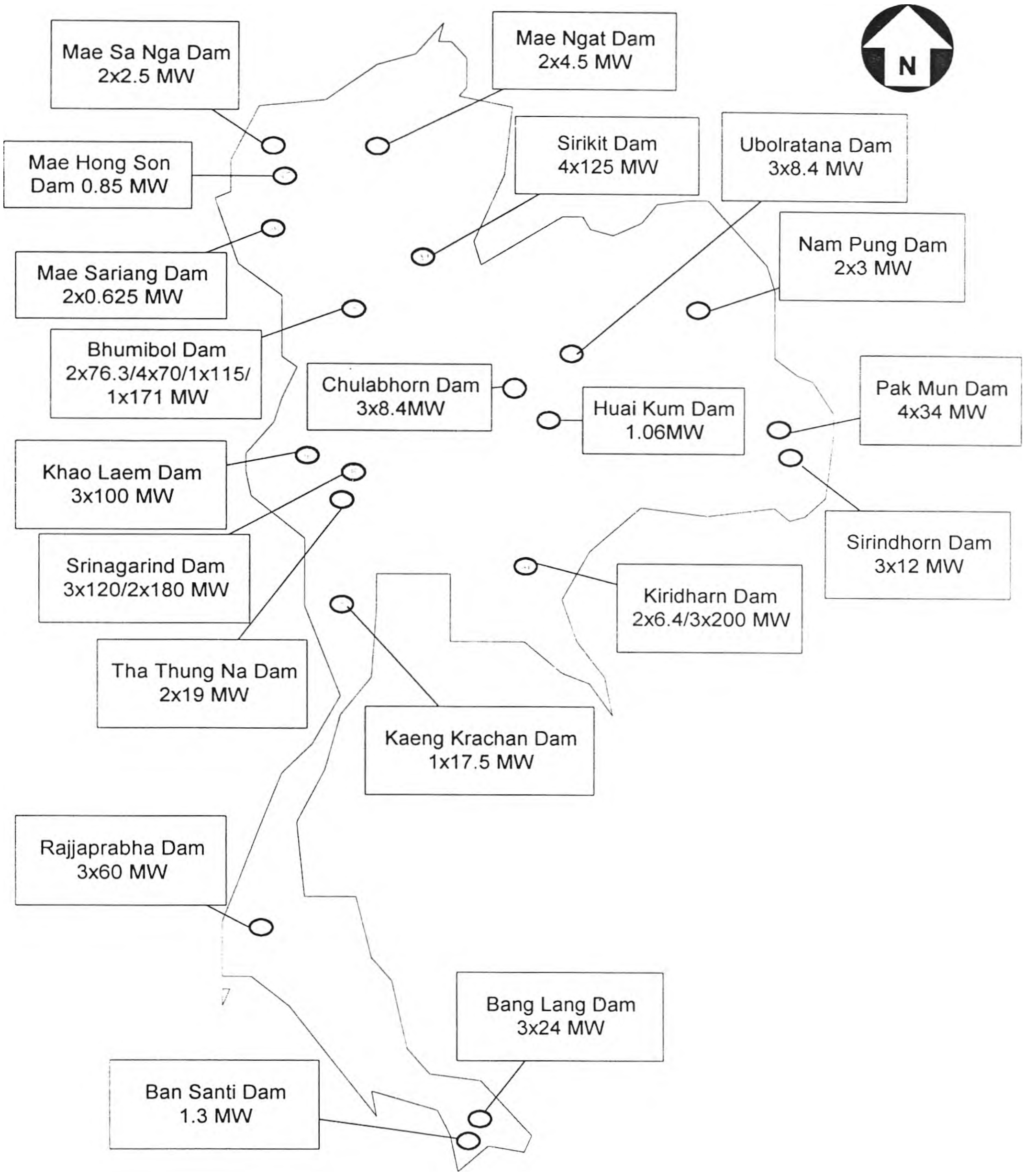


Figure 2-3. Hydroelectric power plants in Thailand power pool

2.4.3.2 Distribution Systems

In 1998, peak demand of Thailand power system was 14,179 MW that is significantly differ from load forecasting due to the economic crisis started in 1997. The new load forecasting study anticipating two scenarios of economic situations forecasts LER and MER. Peak demands of the system are forecasted to reach 25,000 MW and 30,000 MW by 2011 for each case. These forecasting represent the increase of 78.9% and 111.6% over that period by each economic recovering scenario.

According to phase I of Thailand Power Pool and Electricity Supply Industry's reform study, wholesale distribution system is also subject to the transitions when the deregulation processes is taking place. However, retail electricity market is still regulated by franchise distribution companies. Retail customers are required to purchase electricity with their DISTCO.

Following the deregulation, MEA and PEA will no longer be two authorized suppliers in the system. PEA is likely to be separated into several distribution companies. Large customers have right to participate in the competitive market. In addition, it is highly possible that retail companies (RETAILCOs) may exist and offer alternative supplier.

2.5 Summary and Discussions

This chapter concludes the basics concepts and information of real-time ATC calculation that will be used as a backbone for the later chapters. Several assumptions have been addressed in this chapter in order to customize calculation procedures to the test system and simplify the calculation. In addition, structure, hierarchy and general operational procedures of the test system are also explained in this chapter.