Chapter 7

Determination of Total Transfer Capability

Total transfer capability (TTC) is the main topic to be considered as the maximum power transfer within the system. Since the concepts of TTC are already explained in chapter 2, most of contents in this chapter will concentrate on the calculation procedures of TTC value under a real-time ATC framework. Later, ATC values will be calculated by subtracting the committed load and desired transmission margin from TTC as explained in chapter 2.

Basically, TTC is indicated when at least a major facility in the systems reaches its limits. As seen in chapter 2 and chapter 3 the term "limits" in this dissertation includes thermal, voltage stability, and transient stability limits that covering majority of power system security issue.

Besides the total transfer capability, transmission margin is an important quantity to determine real-time ATC values since it provides security level of the system between the present operating condition and insecure area. In addition, calculation procedures of transmission margin are similar to TTC calculation. Methodologies to calculate TTC values developed in this chapter are easily applied to evaluate transmission margins.

7.1 Total Transfer Capability Calculation

Total Transfer Capability of a selected ATC interface is determined on the similar security standards of reliability must-run units and contingency analysis as explained in chapter 5 and chapter 6. Transmission providers or Independent System Operator are obligated to calculate TTC as part of ATC calculation and then posting these values for public access. Detection of thermal limits, voltage limits (under voltage or over voltage) and insecure voltage stability limits are three major constraints to be considered and monitored along the simulation of different level of transaction at the specific interfaces. Since transient stability is directly engaged with interruption or switching in the power system that have been studied in contingency study, TTC calculation will not comprise this limit as a constraint to avoid redundant calculations and speed up the process.

In practical, TTC of an ATC interface is determined from three processes as expressed below

7.1.1 Specify ATC interface

As the basic concept of ATC interface is explained in chapter 5 incorporating with the contingency analysis concept given in chapter 6, feasible ATC interfaces determination in the Thailand power system is the first step to be specified before TTC calculation is performed. Generally, ATC interfaces are determined base on the market rules and structures that are different in each power system.

Using the ATC interfaces concept in chapter 5, one can generate ATC interfaces by matching appropriate seller and buyer. However, some of the transactions may be rejected by contingency analysis procedure if these interfaces are non-secure during contingency situation. Therefore, qualified ATC interfaces must satisfy security criteria during system contingency prior to TTC calculation.

7.1.2 Calculate Voltage Stability Limit

Since power system may experience the voltage instability problem even though the network constraints (voltage level and amount of power flow) are marginally acceptable as seen from several voltage instability incidents occurred around the world, this dissertation would include this stability limit by performing the calculation of voltage stability study to indicate the point of collapse (POC) in the test system. Results from this calculation give information of secure and insecure operation region of power system compared to the present operating conditions. Then, these results will be used as the boundary to accept or deny amount of transaction in the system beyond base power transfer at that interface.

7.1.3 Calculate Maximum Power Transfer due to Network Constraints

During this step, amount of power generated at generation facility and load buses in ATC interface are increased simultaneously while network constraints are closely monitored. This step-by-step increasing of electricity transaction is continued as long as no constraints violation is detected. This repetitive calculation will be terminated once any constraint violation is detected in the system.

As the conclusion, TTC calculation method can be summarized in flowchart shown in figure 7-1.

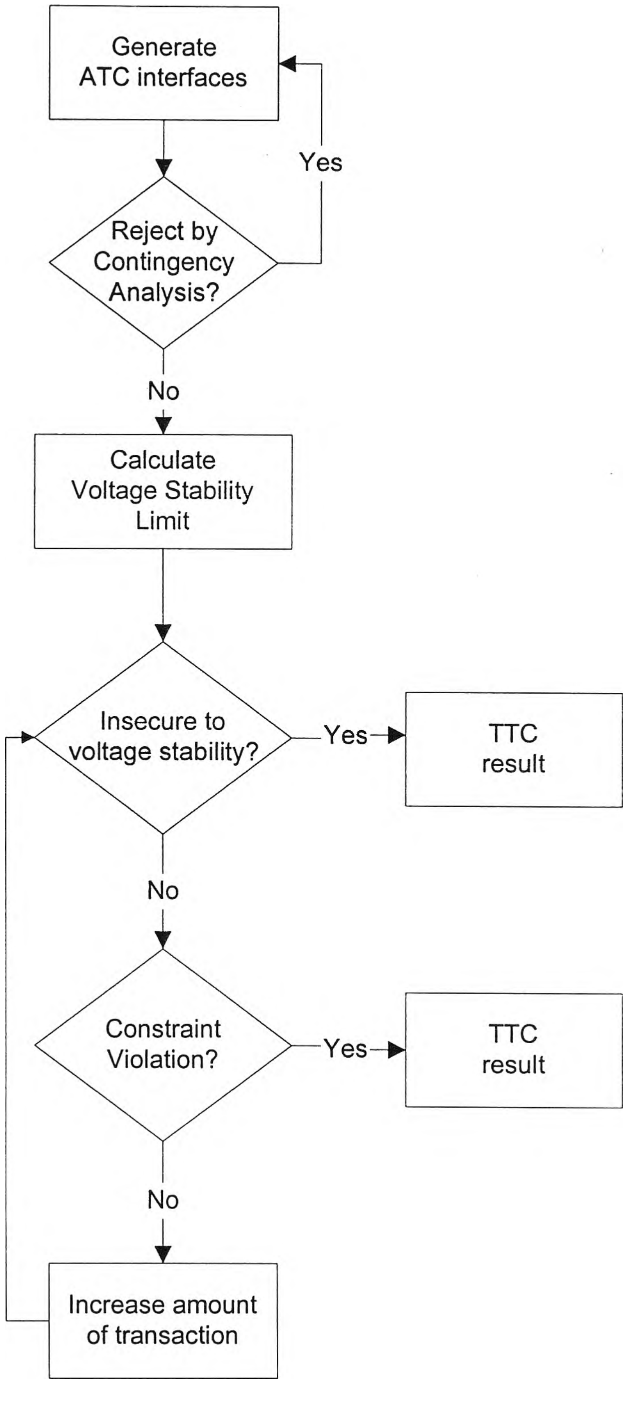

Figure 7-1. Flowchart of Total Transfer Capability Calculation

7.2 Simulation Scenarios

According to the contingency analysis calculation in chapter 6, there is no critical ATC interfaces during the contingency situation is observed in Thailand power system. Therefore, all ATC interfaces generated in chapter 5 are eligible for real-time calculation of ATC values as long as they do not create severe post fault security conditions.

However, since ATC interfaces in Thailand power system compose of four singular platforms of transaction resulting in hundreds of generated ATC interfaces, detailed calculation of typical example transactions on each platform will be performed in the next section.

As mentioned above, since ATC interfaces in future market structure of Thailand deregulated power system composes of four different formats, information of TTC in each platform will be explained in the following section below.

7.2.1 TTC of ATC interfaces determined by transaction between seller and buyer buses

This is the simplest transaction over the deregulated market since electricity transaction is directly manipulated between seller and buyer buses (bilateral contract) as shown in figure 7-2. During the TTC calculation, generation level at the seller bus and load at the buyer bus are increased simultaneously to simulate the occurrence of electricity transaction. When the first security criterion is violated, power system is assumed to reach its transmission transfer capability and the TTC value is recorded.

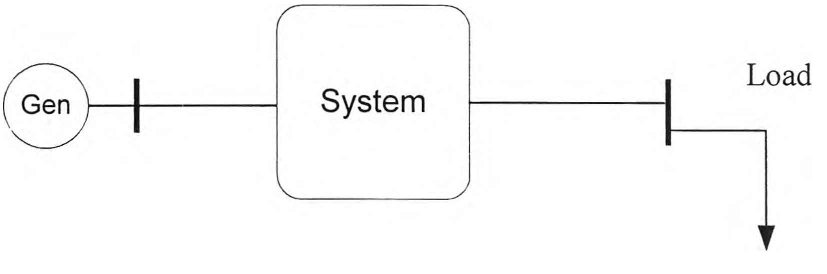

Figure 7-2. Transaction between seller and buyer bus

7.2.2 TTC of ATC interfaces determined by transaction between generation sub-portfolio and buyer bus

Since the concept of making transaction from entire portfolio is declined in practical system, this topic will focus on the most practical transaction between group of generation facilities, sub-portfolio as shown in figure 7-3, of generation portfolio's (shown in figure 7-4) and their counterpart, as follows.

When generation portfolios are divided into several generation sub-portfolios in the deregulated market, computation of TTC between sub-portfolio and buyer bus requires slightly modification. Amount of electricity delivered from sub-portfolio to the buyer bus is represented by net generation surplus of generation facilities inside sub-portfolio instead of generation level at any specific unit.

This dissertation will assume all generation facilities in a sub-portfolio share the same percentage of change in generation level to meet load demand. Net of surplus power from generation portfolio is accounted as amount of transaction delivering from seller to buyer. During the simulation, seller generation portfolio is assumed to increase generation capacity to produce surplus export power. This exported electricity is assumed to replace the generation obligation of buyer bus and supplying load demand. Therefore, buyer bus is simulated to reduce its generation capability, if generation facilities attached, or increase load demand to match the amount of transaction. Similar to criteria given in 7.2.1, TTC is automatically determined when power system violates at least one transmission limits during the transaction.

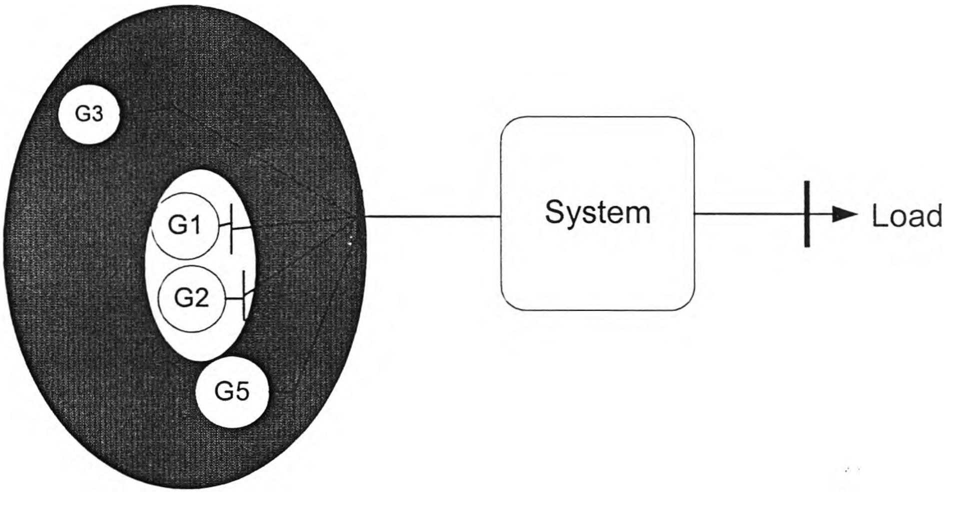

Figure 7-3 Transaction between generation sub-portfolio seller and buyer bus*

* Note

Generation portfolio owns generation facilities G1 – G5 but only G1 and G2 are accounted as sub-portfolio due to their geographical locations.

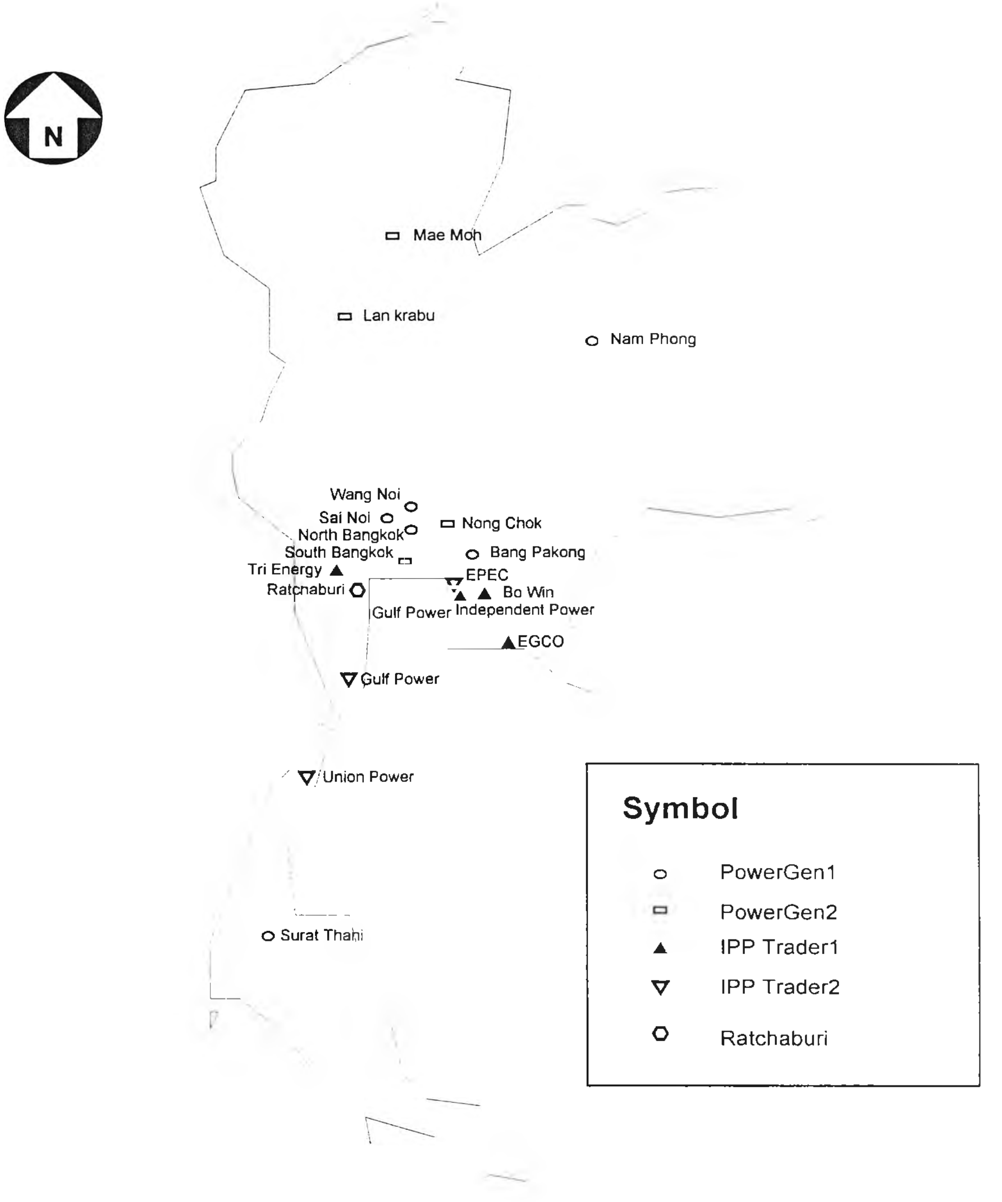

Figure 7-4. Geographical locations of generation portfolios in Thailand deregulated market.

7.2.3 TTC of ATC interfaces determined by transaction between seller bus and sub-generation portfolio buyer

This transaction is simply a reverse order of transaction platform in 7.2.2 as shown in figure 7-3. Even though these two transactions are similar at the first glance, it results in drastically change in transaction method and concept since it is a transaction between sellers who own generation facilities and non-reciprocal property of power system. Transaction between seller bus and sub-portfolio is shown in figure 7-5.

Generally, generation portfolios or sub-portfolios carry excessive generation capability to supply load in their supplied area except the peak load period that generation capability may marginally cover load demand. Therefore, these generation sub-portfolios would prefer to export surplus electricity to the market as commodity. However, scheduling strategy is a key factor to determine behavior of sub-portfolios. Instead of constructing generation facilities to increase their market power, generation portfolios may prefer to purchase electricity from other seller to supply their customers in competitive market. For example, a generation portfolio may decide to shutdown their generation facilities for a period of time [1,11]. Therefore, during this period, they have to import electricity from a seller.

From the above reason, increasing generation level at seller bus and reducing generation level inside the buyer portfolio at the same time is brought into concern as a simulation of this transaction. Net generation reduction of generation facilities inside buyer sub-portfolio represents power demanded from other buyer and net increased generation level at the seller bus is accounted as electricity sold in this transaction.

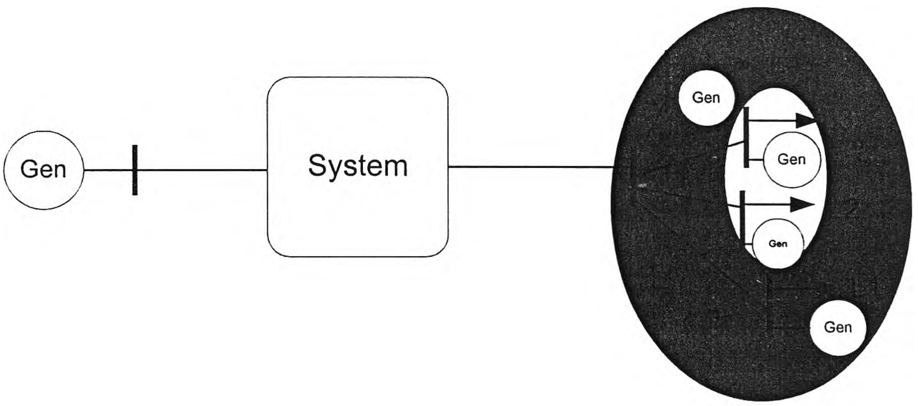

Figure 7-5 Transaction between generator bus and sub-portfolio buyer*

* Note
In this case, buyer portfolio owns four generation-facilities and load in their areabut only a portion of this portfolio is considered as sub-portfolio (Bus 2 and bus 3)

7.2.4 TTC of ATC interfaces determined from transaction between generation sub-portfolios

TTC of ATC interface between generation sub-portfolios as shown in figure 7-6 are determined in the similar manner as interface between seller bus and generation sub-portfolio buyer. During this platform of transaction, seller generation portfolio increasing generation level of generation facilities inside their area while buyer generation portfolio decreasing generation inside their area at the same amount. Net surplus power from seller generation portfolio is accounted as amount of electricity sold to the customer. Meanwhile, net generation demand in the buyer generation portfolio is taken as electricity purchased from the seller portfolio although it might physically come from other sellers.

According to the introduction of generation portfolios as explained in chapter 5, section 7.2.1 and 7.2.2, a new concept of optimal operation of generation facilities in its local sub-portfolio is introduced instead of optimal operation of entire portfolios. By this concept, the commitment to generate electricity of each generation unit in generation portfolio should be determined by economic dispatch of its sub-portfolio. Appropriate generation capacity of facilities would base on criteria that combine both financial and engineering issues such as transmission congestion.

As mentioned in the above context, theoretically, minimum cost of entire portfolio is the main objective of this concept since it directly determines potential of generation portfolio to compete in the deregulated market. However, in practical, determination of generation level in each generation facility is dominated by generation strategy of the local sub-portfolios. Geographical locations, heat rate (efficiency), market rules, market price (MCP or Pay-as-bid) and strategy of other players etc. also influence bidding and generation strategy of sub-portfolios. Power loss in the system is always taken care of by ISO thorough the dispatch methodology. However, effect of power loss may exist in tariff structure such as wheeling charge.

As a conclusion, it is foreseeable that market strategy generation portfolio significantly affects amount of Total Transfer Capability in the system. In order to precisely determine TTC and prevent unexpected security problem, generation dispatch of generation portfolio should be reported to the ISO prior to the transaction so as to ensure system security. Insufficient information of internal generation dispatch of portfolio may result in inaccurate TTC calculation that lead to less secure power system.

The concept of TTC calculation explained above will not cover the detailed calculation of economic operation inside generation portfolios due to the lack of generation facilities information. In addition, for the pool model, slack bus is assumed to take care of change in power loss of the system during the transaction that may be either increasing or decreasing power loss since the transaction may result in additional or counter flow. Therefore, ISO must issue a market rule to manage the charge of power loss due to bilateral transaction in the system that should discourage the transaction tending to increase power loss.

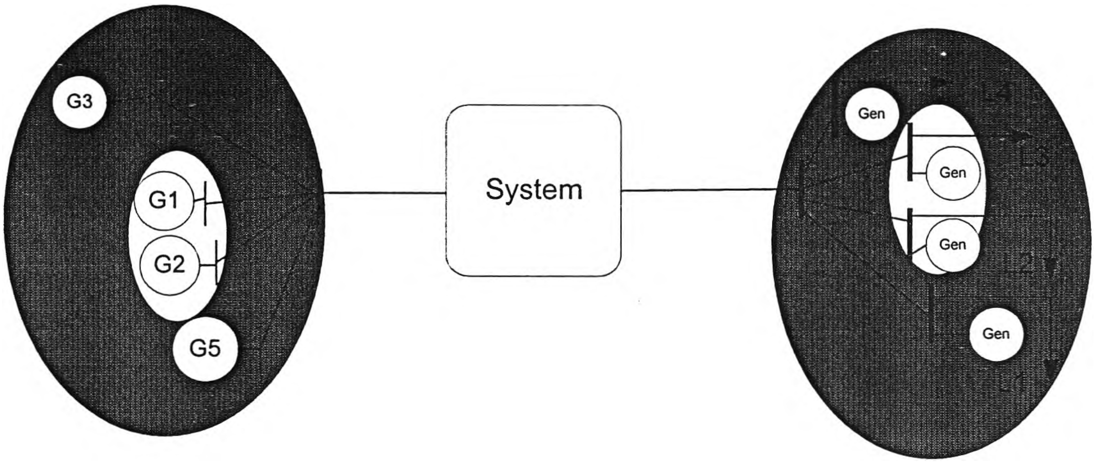

Figure 7-6 Transaction between generation sub-portfolios

7.3 Simulation Results

Since hundreds of ATC interfaces have been created for ATC calculation, this section will explain several typical scenarios of power transactions in each platform as examples of TTC calculation. The complete simulation results of TTC calculation according to all ATC interface are given in appendix D

According to contingency study results from chapter 5, there is no ATC interface in Thailand power system is considered as insecure ATC interface. Therefore, all ATC interfaces generated in chapter 5 are allowed to perform bilateral transaction under deregulated environment.

In this chapter, calculation results are shown in accordance with calculation procedures as described in figure 1. Three simulation results are given in case 1, case 2 and case 3 depend on nature of transactions. Since transactions in 7.2.3 and 7.2.4 are relatively similar, case 3 is chosen as the representative of these two cases. Results of the calculation, amount of transaction at base case, amount of transaction at TTC, summary of constraint violations and list of limiting facilities are shown below.

Case 1: TTC of ATC interface between seller and buyer bus
Seller: Bus 1805- South Bangkok (area 1)
Buyer: Bus 3721 – Song Khla (area 3)

a) Voltage Stability Limit

Base on voltage stability study, Thailand power system will encounter voltage stability problem when load is increased to 18.68% (2521.8 MW) over the base case (13500.0 MW). Therefore, amount of additional transaction during TTC study which less than 2521.8 is considered as secure transaction owning to voltage stability.

It is seen that voltage stability study based on the situation that load is increasing uniformly across the board which is usually different from other scenario of TTC study. However, this assumption is reasonable to define voltage stability safety standard since it is a pessimistic study. Consequently, point of maximum power transfer (PMPT) of this case is foreseeable to be minimum compare to any other cases and acceptable for TTC study as a boundary between secure and non-secure region give information regarding the strength of the system.

b) Total Transfer Capability

Under the scenario when transaction between seller and buyer buses are assumed increasing between bus 1805 and 3721 as explained earlier, Total Transfer Capability of this interface is determined from thermal limit violation in area 7 as summarized below:

Amount of maximum power transferred: 2829.40 MW and 1611.40 MVar
Amount of power transferred during base case: 2021 MW 1151 MVar
Additional power transferred: 808.40 MW 460 MVar that is secure to voltage instability

As seen from constraints violation listed above, thermal limits violations and voltage stability margin have created a gray area creating a question that which limited should be used to as a standard to "accept" or "reject" the proposed transaction for TTC calculation when their calculation result are overlapping. Since voltage stability margin is calculated from the PV curve assuming entire or zonal load is increasing, this "pessimistic" calculation may result in relatively low security margin representing margin of entire area that may lower than thermal limit of a specific path. This may create a situation when thermal limit violation of an interface is higher than voltage stability margin and result in a question as mentioned earlier.

In order to clarify TTC calculation procedure, this dissertation propose a new procedure to decide whether which limit should be considered as TTC limit as follows:

a) If the amount of transaction lower than both thermal limit and voltage stability margin, this transaction is unquestionably "accepted".

b) If the amount of transaction lying between thermal limit and voltage stability margin, TTC calculation would be recalculated for a new set of real-time information such as new load conditions or transmission reservations. If the amount of transaction still lying in the gray area, it would be "rejected".

c) If the amount of transaction exceeds both thermal limit and voltage stability margin, this transaction is automatically "rejected".

Calculation procedure for this automatic decision process is concluded in figure 7-7.

Stopping criterion: Thermal limit violations
Locations:
- Transmission line connected between bus 7802 and 7204, this line carrying 91.75% of thermal rating

- Transmission line connected between bus 7813 and 7812, this line carrying 91.71% of thermal rating

In addition, many generation buses are operated at reactive power limit in this scenario. However, these situations are not considered as stopping criteria since voltage magnitude of these buses are still within acceptable range.

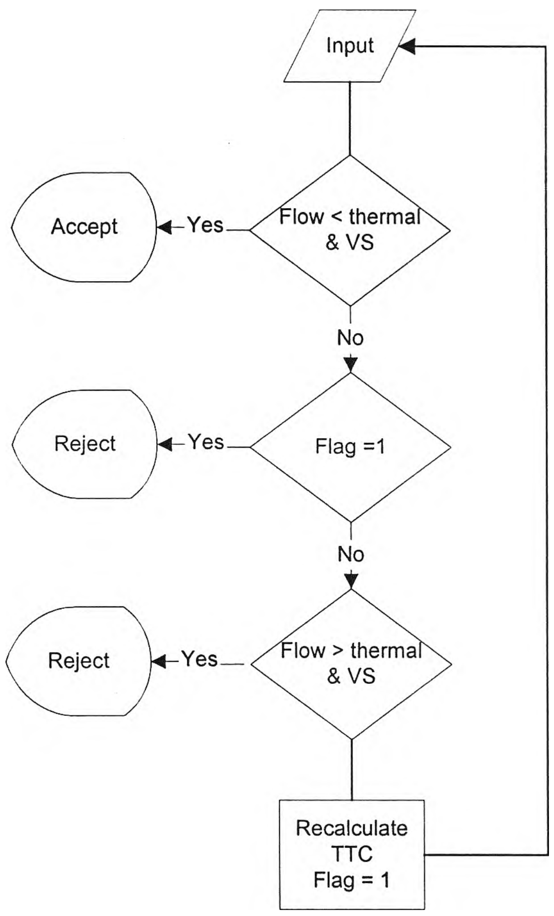

Figure 7-7. Automatic decision process for TTC calculation

ABNORMAL SUMMARY REPORT

LINES WITH ABNORMAL FLOWS

FROM	NAME		TO	NAME		P-FLOW	Q-FLOW	RTG-MVA	%RTG
7802	RB2	230	7204	HH-JC	230	393.6	-52.3	429.0	1.8
7813	HH-JC	230	7812	HH	230	393.4	-53.5	429.0	1.7

GENERATORS ON Q-LIMIT

BUS	NAME		V-SPEC	V-ACT	MVAR	Q-MIN	Q-MAX	
1704	BPL2	115	1.0000	0.9982	-392.0	-392.0	457.0	*
1707	BN2	115	1.0000	0.9998	21.0	-18.0	21.0	
1708	SNO115	115	1.0000	1.0000	16.0	-14.0	16.0	
1712	NCO0115	115	1.0000	0.9984	-108.0	-108.0	126.0	*
1718	CWN-115	115	1.0000	0.9997	4.0	-3.0	4.0	
1722	NCO115	115	1.0000	0.9984	-108.0	-108.0	126.0	*
1792	RS-MEA	115	1.0000	0.9999	23.0	-20.0	23.0	
1801	NB	230	1.0000	0.9995	29.0	-25.0	29.0	
1808	SNO	230	1.0000	0.9999	14.0	-12.0	14.0	
2703	NR2	115	1.0000	0.9996	39.0	-33.0	39.0	
2708	KNG	115	1.0000	0.9996	5.0	-5.0	5.0	
2715	PYK	115	1.0000	0.9998	5.0	-5.0	5.0	
2723	SRD	115	1.0000	1.0000	14.0	-12.0	14.0	
2725	AN	115	1.0000	0.9995	4.0	-3.0	4.0	
2726	MD	115	1.0000	0.9991	4.0	-3.0	4.0	
2730	NPO	115	1.0000	1.0000	9.0	-8.0	9.0	
2733	UD2	115	1.0000	0.9998	4.0	-3.0	4.0	
2738	BDG	115	1.0000	0.9999	4.0	-3.0	4.0	
2739	PHK	115	1.0000	0.9999	5.0	-5.0	5.0	
2740	BKN	115	1.0000	0.9997	5.0	-5.0	5.0	
2742	NP	115	1.0000	0.9999	1.0	-1.0	1.0	
2743	SD	115	1.0000	0.9998	2.0	-2.0	2.0	
2744	NN115	115	1.0000	0.9996	2.0	-2.0	2.0	
3703	SRT	115	1.0000	0.9995	12.0	-11.0	12.0	
3708	PN	115	1.0000	0.9991	7.0	-6.0	7.0	
3711	KA	115	1.0000	0.9987	7.0	-6.0	7.0	
3713	TS	115	1.0000	0.9989	14.0	-12.0	14.0	
3720	HY2	115	1.0000	0.9976	400.0	-300.0	400.0	

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Case 2: TTC of ATC interface between generation sub-portfolio and buyer bus
Seller: Sub-portfolio2 of PowerGen2 composing of the following generation facilities

- Mae Moh (bus 4716, 4808 and 8881 in area 4 and 8)
- Lan Krabue (bus 4730 – area 4)

Buyer: Bus 4722 – Chiang Mai (area 4)

a) Voltage Stability Limit

Since system configuration is still intact, voltage stability limit in this case is assumed to be unchanged.

b) Total Transfer Capability

During the scenario when transaction between generation portfolio – sub-portfolio2 and buyer bus 4722, Total Transfer Capability of this interface is determined from thermal limit violation in of transmission line connected between area 8 and area 4 as summarized below

Table 7-1. Total Transfer Capability result of typical transaction between buyer bus and Sub-portfolio

Generation	At Base Conditions		At TTC		Remark
	MW	MVAR	MW	MVAR	
Bus 4722 (Buyer)	61.00	20.00	1038.25	509.64	
Net generation decreasing			**977.25**	**489.64**	
Sub-portfolio2 PowerGen2 (seller)					
Unit 1: Mae Moh (4716)	25.00	31.00	226.55	134.00	
Unit 2: Mae Moh (4808)	297.00	129.00	525.76	241.80	
Unit 3: Mae Moh (8881)	1301.00	542.00	1630.16	696.10	
Unit 4: Lan Krabue (4730)	126.00	39.00	337.66	142.80	
Entire area	**1749.00**	**741.00**	**2720.13**	**1214.7**	
Net generation increasing			**971.13**	**473.7**	

Stopping criterion: Thermal limit violations
Locations:
- Transmission line connected between bus 8882 and 4808, this line carrying 92.16% of thermal rating

From study results given in above, maximum additional power of 977.25 MW 489.64 MVAR measured at the load side is considered as the maximum capability of transmission systems. It is seen that at this operating point the power system is still far from voltage instability point (PMPT). Information of constraints violations is given in the next table.

ABNORMAL SUMMARY REPORT

LINES WITH ABNORMAL FLOWS

FROM	NAME		TO	NAME		P-FLOW	Q-FLOW	RTG-MVA	%RTG
8882	MM230	230	4808	MM3	230	492.9	250.8	600.0	2.16

GENERATORS ON Q-LIMIT

BUS	NAME		V-SPEC	V-ACT	MVAR	Q-MIN	Q-MAX	
1704	BPL2	115	1.0000	0.9982	-392.0	-392.0	457.0	*
1707	BN2	115	1.0000	0.9998	21.0	-18.0	21.0	
1708	SNO115	115	1.0000	1.0000	16.0	-14.0	16.0	
1712	NCO0115	115	1.0000	0.9984	-108.0	-108.0	126.0	*
1718	CWN-115	115	1.0000	0.9997	4.0	-3.0	4.0	
1722	NCO115	115	1.0000	0.9984	-108.0	-108.0	126.0	*
1792	RS-MEA	115	1.0000	0.9999	23.0	-20.0	23.0	
1801	NB	230	1.0000	0.9996	29.0	25.0	29.0	
1808	SNO	230	1.0000	0.9998	14.0	-12.0	14.0	
2703	NR2	115	1.0000	0.9996	39.0	-33.0	39.0	
2708	KNG	115	1.0000	0.9996	5.0	-5.0	5.0	
2715	PYK	115	1.0000	0.9998	5.0	-5.0	5.0	
2723	SRD	115	1.0000	1.0000	14.0	-12.0	14.0	
2725	AN	115	1.0000	0.9995	4.0	-3.0	4.0	
2726	MD	115	1.0000	0.9991	4.0	-3.0	4.0	
2729	UR	115	1.0000	1.0000	8.0	-7.0	8.0	
2730	NPO	115	1.0000	0.9999	9.0	-8.0	9.0	
2733	UD2	115	1.0000	0.9998	4.0	-3.0	4.0	
2738	BDG	115	1.0000	0.9999	4.0	-3.0	4.0	
2739	PHK	115	1.0000	0.9999	5.0	-5.0	5.0	
2740	BKN	115	1.0000	0.9997	5.0	-5.0	5.0	
2742	NP	115	1.0000	0.9999	1.0	-1.0	1.0	
2743	SD	115	1.0000	0.9998	2.0	-2.0	2.0	
2744	NN115	115	1.0000	0.9996	2.0	-2.0	2.0	
3703	SRT	115	1.0000	0.9996	12.0	-11.0	12.0	
3708	PN	115	1.0000	0.9991	7.0	-6.0	7.0	
3711	KA	115	1.0000	0.9991	7.0	-6.0	7.0	
3713	TS	115	1.0000	0.9997	14.0	-12.0	14.0	
3736	RA	115	1.0000	0.9997	2.0	-2.0	2.0	
4442	TTK230	230	1.0000	0.9999	2.0	-2.0	2.0	

4444	TTK230	230	1.0000	0.9999	2.0	-2.0	2.0

GENERATORS ON Q-LIMIT

BUS	NAME		V-SPEC	V-ACT	MVAR	Q-MIN	Q-MAX
4706	PL2	115	1.0000	0.9995	4.0	-3.0	4.0
4711	SK	115	1.0000	0.9997	2.0	-2.0	2.0
4716	MM2	115	1.0000	0.9988	54.0	-47.0	54.0
4719	LP2	115	1.0000	0.9983	2.0	-2.0	2.0
4722	CM3	115	1.0000	0.9956	7.0	-6.0	7.0
4808	MM3	230	1.0000	0.9993	225.0	-193.0	225.0
5701	AT1	115	1.0000	1.0000	4.0	-3.0	4.0
5702	TL-SIAM	115	1.0000	1.0000	26.0	-23.0	26.0
5703	TL1	115	1.0000	1.0000	39.0	-33.0	39.0
5704	TL2	115	1.0000	1.0000	47.0	-41.0	47.0
5705	TL3	115	1.0000	1.0000	137.0	-117.0	137.0
5710	SR4	115	1.0000	1.0000	54.0	-47.0	54.0
5713	LB2	115	1.0000	0.9996	9.0	-8.0	9.0
5716	DBN	115	1.0000	0.9998	2.0	-2.0	2.0
5718	BI	115	1.0000	1.0000	47.0	-41.0	47.0
5720	SI	115	1.0000	0.9995	16.0	-14.0	16.0
5722	RS-PEA	115	1.0000	0.9999	95.0	-81.0	95.0
6702	CC	115	1.0000	1.0000	67.0	-57.0	67.0
6708	BBG	115	1.0000	0.9996	9.0	-8.0	9.0
6710	BL	115	1.0000	0.9999	19.0	-17.0	19.0
6715	RY1	115	1.0000	1.0000	68.0	-59.0	68.0
6731	KRD	115	1.0000	0.9997	4.0	-3.0	4.0
6801	BPK	230	1.0500	1.0005	1450.0	-999.0	1450.0
7702	SA1	115	1.0000	0.9996	180.0	-155.0	180.0
7703	SN1	115	1.0000	0.9994	33.0	-29.0	33.0
7704	SN2	115	1.0000	0.9993	63.0	-54.0	63.0
7706	NCS	115	1.0000	0.9996	23.0	-20.0	23.0
7708	BP2	115	1.0000	0.9997	40.0	-35.0	40.0
7709	KS	115	1.0000	0.9996	11.0	-9.0	11.0
7715	RB2	115	1.0000	0.9996	28.0	-24.0	28.0
7718	KKC	115	1.0000	0.9997	7.0	-6.0	7.0
8734	VT	115	1.0000	1.0000	42.0	-36.0	42.0
8735	NNG	115	1.0000	1.0001	-30.0	-30.0	34.0

• INDICATES GENERATOR VOLTAGE CONTROL FROZEN DUE TO EXCESSIVE LIMIT CYCLING

Case 3: TTC of ATC interface between generation portfolios
Seller: Sub-portfolio1 of PowerGen1 composing of the following generation facilities

- North Bangkok (bus 1801 - area 1)
- Wang Noi (bus 5806 – area 5)

Buyer: Sub-portfolio2 of PowerGen2 composing of the following generation facilitie

- Mae Moh (bus 4716, 4808 and 8881 in area 4 and 8)
- Lan Krabue (bus 4730 – area 4)

a) Voltage Stability Limit

Similar to case 1 and case 2 above, voltage stability limit in this case is held at 18.68% from base case as long as system configuration and base case conditions remain the same.

b) Total Transfer Capability

TTC calculation between generation sub-portfolios is performed slightly different from the above two cases. In this platform, buyer generation sub-portfolio purchases electricity from seller sub-portfolio in order to supply load in their area. One has to increase generation level in seller's portfolio and decrease generation level in buyer portfolio simultaneously to simulate this situation. As seen from table 7-2, generation from several facilities in buyer generation portfolio are replaced by imported power from other portfolio.

During the scenario when transaction between generation portfolios, Total Transfer Capability of this interface is determined from two thermal limit violation in transmission line connected between area 8 and area 4 and thermal limits inside area 8 as summarized below

Table 7-2. Total Transfer Capability result of typical transaction between generation portfolios

Generation	At Base Conditions		At TTC		Remark
	MW	MVAR	MW	MVAR	
Sub-portfoloio1 PowerGen1 (Buyer)					
Unit 1: North Bangkok (1801)	120.00	24.57	0	0	
Unit 2: Wang Noi (5806)	1200.00	240.00	430.69	43.84	
Entire area	**1320.00**	**264.57**	**430.69**	**43.84**	
Net generation decreasing			**889.31**	**220.73**	
Sub-portfolio2 PowerGen2 (seller)					
Unit 1: Mae Moh (4716)	25.00	31.00	38.32	35.77	
Unit 2: Mae Moh (4808)	297.00	129.00	455.20	148.86	
Unit 3: Mae Moh (8881)	1301.00	542.00	1993.71	624.31	
Unit 4: Lan Krabue (4730)	126.00	39.00	193.12	45.00	
Entire area	**1749.00**	**741.00**	**2680.35**	**853.94**	
Net generation increasing			**931.35**	**112.94**	

Stopping criterion: Thermal limit violations
Locations:

- Transmission line connected between bus 8882 and 4808, this line carrying 91.25% of thermal rating
- Transmission line connected between bus 8882 and 8881, this line carrying 90.44% of thermal rating

From study results given in table 7-2, at TTC, maximum additional power at the load side of 889.31 MW and 220.73 MVAR is considered as the maximum capability of transmission systems. This maximum operation point is considered safe to voltage instability although the amount of transaction is closed to point of maximum power transfer (PMPT). Similar to two simulated cases above, constraints violations information of this case are summarized in page 224-225.

ABNORMAL SUMMARY REPORT

LINES WITH ABNORMAL FLOWS

FROM	NAME		TO	NAME		P-FLOW	Q-FLOW	RTG-MVA	% RTG
8882	RB2	230	4808	HH-JC	230	-579.1	40.9	600.0	0.5
8882	HH-JC	230	8881	HH	500	573.5	-35.5	600.0	0.4

GENERATORS ON Q-LIMIT

BUS	NAME		V-SPEC	V-ACT	MVAR	Q-MIN	Q-MAX	
1704	BPL2	115	1.0000	0.9982	-392.0	-392.0	457.0	*
1707	BN2	115	1.0000	0.9998	21.0	-18.0	21.0	
1708	SNO115	115	1.0000	1.0000	16.0	-14.0	16.0	
1712	NCO0115	115	1.0000	0.9984	-108.0	-108.0	126.0	*
1718	CWN-115	115	1.0000	0.9996	4.0	-3.0	4.0	
1722	NCO115	115	1.0000	0.9984	-108.0	-108.0	126.0	*
1792	RS-MEA	115	1.0000	0.9999	23.0	-20.0	23.0	
1808	SNO	230	1.0000	0.9998	14.0	-12.0	14.0	
2703	NR2	115	1.0000	0.9995	39.0	-33.0	39.0	
2708	KNG	115	1.0000	0.9994	5.0	-5.0	5.0	
2715	PYK	115	1.0000	0.9995	5.0	-5.0	5.0	
2723	SRD	115	1.0000	1.0000	14.0	-12.0	14.0	
2725	AN	115	1.0000	0.9994	4.0	-3.0	4.0	
2726	MD	115	1.0000	0.9990	4.0	-3.0	4.0	
2729	UR	115	1.0000	0.9997	8.0	-7.0	8.0	
2730	NPO	115	1.0000	0.9996	9.0	-8.0	9.0	
2733	UD2	115	1.0000	0.9996	4.0	-3.0	4.0	
2738	BDG	115	1.0000	0.9997	4.0	-3.0	4.0	
2739	PHK	115	1.0000	0.9997	5.0	-5.0	5.0	
2740	BKN	115	1.0000	0.9995	5.0	-5.0	5.0	
2741	SO	115	1.0000	0.9999	5.0	-5.0	5.0	
2742	NP	115	1.0000	0.9998	1.0	-1.0	1.0	
2743	SD	115	1.0000	0.9996	2.0	-2.0	2.0	
2744	NN115	115	1.0000	0.9995	2.0	-2.0	2.0	
3708	PN	115	1.0000	0.9991	7.0	-6.0	7.0	
3711	KA	115	1.0000	0.9991	7.0	-6.0	7.0	
3713	TS	115	1.0000	0.9997	14.0	-12.0	14.0	
3736	RA	115	1.0000	0.9997	2.0	-2.0	2.0	
4442	TTK230	230	1.0000	0.9999	2.0	-2.0	2.0	
4444	TTK230	230	1.0000	0.9999	2.0	-2.0	2.0	

4706	PL2	115	1.0000	0.9996	4.0	-3.0	4.0
4711	SK	115	1.0000	0.9998	2.0	-2.0	2.0
4716	MM2	115	1.0000	1.0000	54.0	-47.0	54.0
4719	LP2	115	1.0000	0.9998	2.0	-2.0	2.0
4722	CM3	115	1.0000	0.9994	7.0	-6.0	7.0
4730	LKB	115	1.0000	1.0006	-58.0	-58.0	68.0
5701	AT1	115	1.0000	0.9999	4.0	-3.0	4.0
5702	TL-SIAM	115	1.0000	1.0000	26.0	-23.0	26.0
5703	TL1	115	1.0000	1.0000	39.0	-33.0	39.0
5704	TL2	115	1.0000	1.0000	47.0	-41.0	47.0
5705	TL3	115	1.0000	1.0000	137.0	-117.0	137.0
5710	SR4	115	1.0000	1.0000	54.0	-47.0	54.0

GENERATORS ON Q-LIMIT

BUS	NAME		V-SPEC	V-ACT	MVAR	Q-MIN	Q-MAX
5713	LB2	115	1.0000	0.9997	9.0	-8.0	9.0
5716	DBN	115	1.0000	0.9998	2.0	-2.0	2.0
5718	BI	115	1.0000	1.0000	47.0	-41.0	47.0
5720	SI	115	1.0000	0.9996	16.0	-14.0	16.0
5722	RS-PEA	115	1.0000	0.9999	95.0	-81.0	95.0
6702	CC	115	1.0000	1.0000	67.0	-57.0	67.0
6708	BBG	115	1.0000	0.9996	9.0	-8.0	9.0
6710	BL	115	1.0000	0.9999	19.0	-17.0	19.0
6715	RY1	115	1.0000	1.0000	68.0	-59.0	68.0
6731	KRD	115	1.0000	0.9997	4.0	-3.0	4.0
6801	BPK	230	1.0500	1.0005	1450.0	-999.0	1450.0
7702	SA1	115	1.0000	0.9996	180.0	-155.0	180.0
7703	SN1	115	1.0000	0.9994	33.0	-29.0	33.0
7704	SN2	115	1.0000	0.9993	63.0	-54.0	63.0
7706	NCS	115	1.0000	0.9996	23.0	-20.0	23.0
7708	BP2	115	1.0000	0.9997	40.0	-35.0	40.0
7709	KS	115	1.0000	0.9996	11.0	-9.0	11.0
7715	RB2	115	1.0000	0.9996	28.0	-24.0	28.0
7718	KKC	115	1.0000	0.9997	7.0	-6.0	7.0
8734	VT	115	1.0000	0.9998	42.0	-36.0	42.0

* INDICATES GENERATOR VOLTAGE CONTROL FROZEN DUE TO EXCESSIVE LIMIT CYCLING

7.4 Conclusions and Discussions

Total Transfer Capability is a significant quantity in real-time ATC calculation since it represents the maximum capability to transfer electricity from source to sink under the operation of competitive market. Generally, transmission providers or ISO are responsibility in TTC calculation and posting. TTC value is determined by performing iterative simulation in the system. Seller is assumed to increase their generation while buyer is increasing load or decreasing generation whenever the first limit is violated, TTC is automatically determined since this violation is interpreted as the first sign of insecure operation of the systems. TTC given in this calculation will be further used to determine transmission margin (TRM) and ATC as seen in the next chapter.

According to TTC simulation results in Thailand power system, it is seen that thermal limit is the most common limiting condition of electricity transactions in the system. Current operating point of Thailand power system is relatively far from the "point of no return" in voltage stability study. All of the simulated cases ended with the violation of thermal limits when electricity transactions are assumed going on.

This algorithm to calculate TTC value of ATC interface will be used again in Deterministic Transmission Reliability Margin (TRM) calculation in the next chapter which rating of major facilities in the systems are reduced at the appropriate amount in order to ensure systems security due to uncertainties.