The Measurement of Market Power in an Electricity Market Including Physical and Political Constraints

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Abstract

This paper proposes novel indices for the measurement of market power in the competitive electricity supply industry in the form of proportional energy share of individual supplier, taking into account physical and political constraints. Three cases are presented for the strategic constrained scenario: market power arising from transmission congestion, political induction in the form of cartel arrangement and mixed strategies. Numerical examples of 14 suppliers (generators) – 14 nodes system and a case study of Thailand's generation market are presented to illustrate the application of the proposed indices.

Keywords: Market power, Physical constraints, Political constraints, Transmission congestion, and Proposed indices

1. Introduction

Market power exists in a variety of different forms, from simple legend recognition to vertical and horizontal integration. In an electricity market, a generation company with a large proportion of market share has potential to set prices at uncompetitive levels and force competitors out of business. Market share is not the only determinant of market power. Physical strategies such as the inducing of transmission congestion or violation of the system to lockout competitors may also be used to influence market power. Generators can also exert market power through anti-competitive practices such as collusion or cartels. The positive effects of competition are reduced if generators exercise market power or partial market power. In many developing countries especially in Asia, market power is a key issue in the transition to a competitive electricity market [1]. This is an issue that needs to be evaluated and mitigated since future competitive generators will be privatised and possibly coexist with state-owned generators.

The author first reviews briefly the major sources of market power and discusses the traditional approach of monitoring market concentration. He then identifies the degree of market competition in conjunction to an electricity market. The formulae for identifying and evaluating market dominance incorporating physical (transmission congestion) and political (cartel arrangement) constraints are introduced. The proposed formulae are further illustrated using numerical examples.

2. Sources of market power

Market power can be evaluated in a number of ways depending on sources of market power. David and Wen [2] identify two major sources of market power. Firstly, market dominance that can be identified by its concentration in the market. A second source of market power is a transmission constraint that separates a large single market into many small local islands. This paper also describes the market concentration in generation market under competitive environment in the view of degree

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of oligopoly: "normal", diluted, and concentrated oligopolistic electricity market.

2.1 Market concentration

A traditional method of identifying the market dominance is through the well-known Herfindahl–Hirschman Index (HHI) or H-Index which is computed by squaring each supplier's market share, then adding the squared share. Market dominance can be formed by many strategies. These strategies are, for example, capacity hold back of some dominant suppliers, and cartel arrangement or collusion. The conventional H-index does not account for transmission constraints. This paper proposes novel H-indices that account for transmission constraints, the existence of local markets and the arrangement of cartel. The generalized formulae for these indices are discussed in Section 3.

2.2 Degree of oligopoly

It is widely accepted that the emerging electricity market structure is more akin to an oligopoly. In theory, an oligopoly is somewhere between a pure monopoly (traditional ESI structure) and a perfectly competitive market. In practice the range between the former and the latter is fairly wide and there is a need to identify the scope of an oligopoly whether it is closer to a monopoly or perfectly competitive market.

TABLE I
MARKET TYPE AND THE DEGREE OF MARKET POWER

Type of Market	H-Index Ranked by DOJ/FTC	Implication
Perfect Market Competition	$H = 0$	No Market Power at all (Ideal Market)
Diluted-Oligopoly	$0 < H < 1000$	Lowly Concentrated Market, Low Market Power
"Normal" Oligopoly	$1000 \le H \le 1800$	Moderately Concentrated Market
Concentrated-Oligopoly	$1800 \le H \le 10000$	Highly Concentrated Market, High Market Power
Pure Monopoly	$H = 10000$	Absolute Market Power, No Competition

This paper classifies oligopoly into three levels: *diluted-oligopoly*, *"normal" oligopoly* and *concentrated-oligopoly*. These categories identify the degree of competition (or market power) for a specified electricity market and are useful in the determining a trading mechanism so that electricity may be traded in such a way that improves economic efficiency. The author of this paper refers the scope of a "normal" oligopoly in the generation market, to the merger guideline [3] set by the Department of Justice (DOJ) and the Federal Trade Commission (FTC) of the United States, as a market within the range of market concentration index (H-Index) between 1000 and 1800 (moderately concentrated markets). The relationship between the diluted, "normal", and concentrated oligopoly is shown in Table 1. If H-Indices fall below or above the normal range of oligopoly the market is categorized as a Diluted-oligopoly or a Concentrated-oligopoly respectively.

2.2.1) Diluted-oligopoly:

An oligopoly market in which market concentration in a generation market is low (less market power); $0 < H < 1000$. The traditional power pool concept (POOLCO) is efficient for this market scenario. Most electricity markets operated in North America are examples of this market type.

2.2.2) Concentrated-oligopoly:

An oligopoly market in which competition is less; $1800 < H < 10000$ (small number of competitors or high degree of market power). This type of market structure would pave the way for dominant firms to exert market power through the POOLCO system. An example of this market scenario was in the former UK Pool market where two major suppliers were competing to determine a system marginal price (SMP) [4]. In consequence, the New Electricity Trading Arrangement (NETA) was introduced in March 2001 with the major objective of reducing electricity prices caused by market power abuse in the traditional pool system.

2.3 Transmission constraints vs. local market power

The existence of transmission constraints or congestion introduces local market power. A supplier in a region that has limited ability to import less expensive energy from elsewhere will be able to exercise market power. Moreover, transmission constraints make possible the creation of market power in unconventional ways. A supplier can even profit from increasing, rather than decreasing, production at strategic points in the network to intentionally create congestion and limit the access of competitors. In this way, a local submarket will be formed, and the supplier will be in a monopolistic position.

There are two ways in which this occurs: radial congestion and the exploitation of network externalities [5]. Radial congestion refers to a simple configuration in which one transmission line (or a set of lines in a "corridor") can be filled to its limit by exporting generation through a rival's low-cost region into a high-cost region. This results in separation of the markets. Network externalities arise due to interactions in networks with "loops" of various kinds when the actions of one participant at one node foreclose the opportunities of rivals at other nodes. The former is much simpler to model than the latter. It is an open empirical question whether one is more prevalent than the other in exercising this kind of market power. Geographic scope of the market also plays a key role in enforcing anti-competitiveness. If the market size is small, it is more likely that fewer and smaller suppliers will dominate the market. Geographic size involves many factors, for instance, the availability of supply, transmission capability and demand level that vary dynamically over time and this makes structural analysis of the electricity market difficult [6].

The strategic behaviour to exert market power through the transmission network, as mentioned above, is sensitive to the power market in developing countries, especially in Asia where there is a need to develop transmission systems to serve the fast growing demand.

3. Problem formulation

3.1 An Unconstrained system scenario

In an unconstrained system as illustrated in Fig. 1, there are no separable (local) markets and no collusion between suppliers. Competition is not blocked by congestion (physical constraints), and/or cartel arrangements (political induction).

In this scenario it is assumed that all generators are able to fully compete for a share of the total MW of the entire system. If the market is made up of N producers (generators), the total MW in the system market will be the sum of MW block produced by N generators as expressed in (1).

$$P_S = \sum_{\substack{i=1 \\ Gi \in S}}^{N} P_{Gi} \qquad [MW] \qquad (1)$$

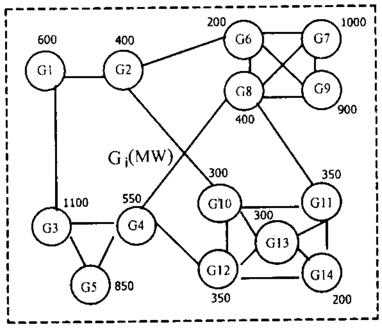

Fig. 1. A system market without constraints

The unconstrained system concentration index H_S^{uc} is then equal to the sum of the squared weighed-average energy shares of the entire system market and hence can be expressed as:

$$H_S^{uc} = \sum_{\substack{i=1 \\ Gi \in S}}^{N} \left[\frac{P_{Gi}}{P_S} \times 100 \right]^2 \qquad (2)$$

where P_{Gi} represents MW block supplied by i^{th} generator G_i within the system market S, and P_S is the total MW in the entire system market. Using an example of system market shown in Fig. 1., we see that there are 14 suppliers in this market with total generation capacity of 7500 MW and therefore we can calculate the unconstrained market concentration index for the entire system as follows:

$$H_{7500}^{uc} = \left(\frac{100}{7500} \right)^2 \times (600^2 + 400^2 + 1100^2 + 550^2 + 850^2 + 200^2$$
$$+1000^2 + 400^2 + 900^2 + 300^2 + 350^2 + 350^2 + 200^2 + 300^2)$$
$$= 930$$

which is in the range of a diluted oligopoly.

3.2 Constrained systems scenario

This section presents H-Indices for scenarios where constraints exist in the system market. Three constrained cases are discussed: (i) Transmission congestion that leads to the separation of a large system into small local markets. (ii) Cartel arrangements that reduce the degree of competition and (iii) Mixed strategies case, combining (i) and (ii).

Cass 1 – Market power caused by transmission constraints

a) Independent local market H-index. Local market power can be caused naturally by transmission limit constraints or strategically induced by other competitors. It is assumed that congestion in a local market is infrequent [7] and independent of one another, therefore the concentration index of the individual local market can be expressed in a similar way to the system index in an unconstrained case and is written as follows:

$$H_{lmkt_k} = \sum_{\substack{j=1 \\ G_j \in lmkt_k}}^{M} \left(\frac{P_{G_j}}{P_{lmkt_k}} \times 100 \right)^2 \qquad (3)$$

P_{lmkt} is the sum of MW supplied by the generator located in the k^{th} local market ($lmkt_k$) as expressed below.

$$P_{lmkt_k} = \sum_{\substack{j=1 \\ Gj \in lmkt_k}}^{M} P_{Gj} \qquad [MW] \qquad (4)$$

There is a distinction between Eqs. (2) and (3): P_{Gj} in Eq. (3) is the share in MW within a specified local market caused by transmission congestion while P_{Gi} in Eq. (2) is the share in MW within the entire market system.

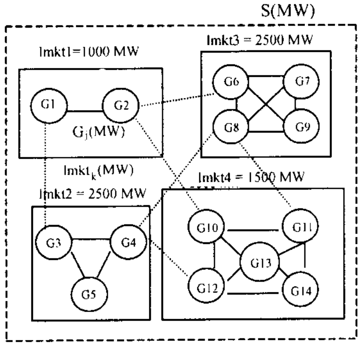

Fig. 2. Local market isolated by transmission congestion

The H values have been calculated and the results are summarised in Table 2. This paper assumes a scenario that congestion will separate the system market illustrated in Fig. 1 into four islands as illustrated in Fig 2. Using Eqs. (3) and (4).

b) System congestion H-index. A congested system market concentration index can be stated in terms of a weighted average H value for all local markets in a corresponding system market and can be expressed as follows.

$$H_S^c = \sum_{k=1}^{N} \left(\frac{P_{lmkt_k}}{P_S} \times H_{lmkt_k} \right) \qquad (5)$$

Substitute (3) into (5) and get :

$$H_S^c = \frac{\sum_{\substack{k=1 \\ lmkt_k \in S}}^{N} \cdot \sum_{\substack{j=1 \\ Gj \in lmkt_k}}^{M} (P_{Gj}^2 / P_{lmkt_k})}{P_S / 10000} \qquad (6)$$

TABLE 2
H-INDICES AS A RESULT OF TRANSMISSION CONGESTION

Market Condition	Total Generation (MW)	Suppliers	H Values
Uncongested System	7500	14	**930**
Lmkt 1 Only	1000	2	5200
Lmkt 2 Only	2500	3	3576
Lmkt 3 Only	2500	4	3216
Lmkt 4 Only	1500	5	2006
Entire System	7500	14	**3371**

Table 2 compares the results of H-Index for an unconstrained system against the H-Index for a number of local market scenarios and the H-Index for the entire congested market system taking into account all local markets. When congestion is induced, local markets could be separated from the main system, the market concentration in an individual island will grow and the suppliers located within the local market area will potentially raise significant competitive concerns.

In an individual local market, the number of suppliers and the individual producer's market share determine the market concentration. In theory, there are two possibilities to mitigate market power under a local market environment: divestiture of the existing generation assets in the local market or reducing system congestion by expanding the transmission system. This will reduce the size of an individual share with respect to other competing suppliers by allowing them to enter the market. In practice, however, divestiture of generation assets is inevitably involved with political and social forces, which is sensitive to most developing countries in Asia. Solving transmission congestion involves both physical (power flow pattern) and economic (transmission investment) issues and there is a need to retain these key issues in the national planning level.

Case 2 – Market power caused by cartel arrangement

Cartel arrangements make the market more concentrated with generators colluding with their competitors. The period of cartel arrangement will depend on the expected interest among its members. In theory, a cartel will not last for a long period because one or more member(s) of the group will start cheating the others to maximize their own profit in the long term.

The distinction between physical constraints (transmission congestion) and business/political constraints (cartel arrangement) is as follows. Transmission congestion, as illustrated in Fig 2, separates a large system into four individual local markets. Under a congestion scheme, each local market is independent of one another and is not be able to trade across the market.

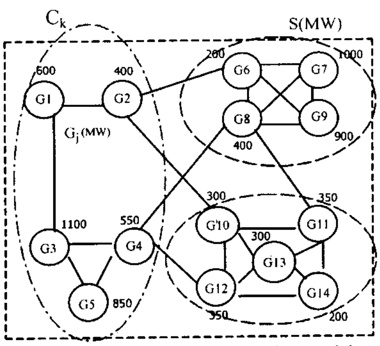

Fig.3. Concentrated market with cartel arrangement

Under a cartel scheme as illustrated in Fig 3, each supplier selectively colludes with other suppliers by combining the fraction of the small shares within a single larger entity in the form of cartel. Transmission congestion may or may not occur under cartel scenarios, but we assume no congestion in this case so that each cartel can compete with one another in the system market. Combining congestion with cartels is treated separately and will be discussed next in the mixed strategies case.

As illustrated in Fig. 3., if the market is made up of the K cartels, the system market concentration index under cartel scenario then can be expressed as:

$$H_S^{Cartel} = \sum_{\substack{k=1 \\ C_k \in S}}^{K} \left(\frac{P_{C_k}}{P_S} \times 100 \right)^2 \qquad (7)$$

where C_k denotes the k^{th} cartel in the system market S and

$$P_S = \sum_{\substack{k=1 \\ C_k \in S}}^{K} P_{C_k} \qquad [MW] \qquad (8)$$

If the cartel is made up of M producers, the total MW of the k^{th} cartel will be the sum of MW of the generators within the corresponding k^{th} cartel and can be expressed as:

$$P_{C_k} = \sum_{\substack{j=1 \\ Gj \in C_k}}^{M} P_{Gj} \qquad [MW] \qquad (9)$$

Substituting (9) into (7), we get:

$$H_S^{Cartel} = \sum_{k=1}^{K} \left(\sum_{\substack{j=1 \\ Gj \in C_k}}^{M} \frac{P_{Gj}}{P_S} \times 100 \right)^2 \qquad (10)$$

TABLE 3
H-INDICES OF SOME POSSIBLE CARTEL ARRANGEMENTS WITHOUT TRANSMISSION CONGESTION

Scenario	Cartel Arrangements	Cartel	Non-Cartel	H
1	{G1,G2},{G3,G4,G5},{G6,G7,G8,G9},{G10,G11,G12,G13, G14}	4	0	2800
2	{G1,G2,G3,G4, G5},{G6,G7,G8,G9},{G10,G11,G12,G13,G14}	3	0	3689
3	{G1,G2,G10,G11,G12,G13,G14},{G3, G4,G5},{G6,G7,G8,G9}	3	0	5822
4	{G1,G2}only	1	12	1015
5	{G3,G4,G5}only	1	11	1644
6	{G6,G7,G8,G9} only	1	10	1684
7	{G10,G11,G12,G13,G14}only	1	9	1247
8	{G1,G2,G3,G4,G5} only	1	9	2617

The distinction of the non-cartel index in previous cases and the cartel index as illustrated in Eq. (7) and Eq. (10) is that the shares of firms in a non-cartel system are squared individually while in the cartel arrangement the sum of those shares would be squared.

Using Eqs. (7) to (10), H value for the cartel scenario arranged in Fig 8-4 can be calculated and summarised in Table 8-3.

Case 3 – Mixed strategies

A cartel may use mixed strategies by inducing transmission congestion to increase it own profit during the cartel agreement. Transmission congestion may be induced to isolate a cartel from the main system and create an isolated monopolistic market (H_{lmkt} = 10000) as illustrated in Table 4.

TABLE 4.
H-INDICES WITH MIXED STRATEGIES

Market Scenario	Local-Cartel Market	Cartel	Non-Cartel	H lmkt	H syst.
1 (2 lmkts)	{G1, G 2}, {G3, G 4, G5}	2	0	5918	5594
	{G6,G7,G8,G9}, {G10,G11,G12, G13, G14}	2	0	5312	
2 (3lmkts)	{G1,G2}, {G6, G8}, G3 , {G4, G5}	2	1	4539	5723
	{G7,G9},{G10, G12}	2	0	6201	
	(G11, G13, G14)	1	0	10000	
3 (4 lmkts)	{G1, G2}, G3, G4, G5	1	3	2641	3652
	{G6, G8}, G7, G9	1	2	3472	
	{G10, G12}	1	0	10000	
	G11, G13, G14	0	3	3494	
4 (2 lmkts)	G1, G2, G3, G5, G6, G7, {G4, G10, G12)	1	5	1723	1987
	G8, G9, G11, G13, G14	0	5	2645	

4. Post-merger index (PMI) and post-merger incremental index (PMII) formulation

The Post-Merger Index *(PMI)* can be obtained by adding the Post-Merger Incremental Index *(PMII)* to the unconstrained H-Index in (2) and can be expressed as:

$$PMI = H_S^{uc} + PMII \qquad (11)$$

If a cartel is made up of *M* merging firms, a general formula for obtaining the *PMII* can then be expressed as [see Appendix for the proof]:

$$PMII = \sum_{i=1}^{M}(f_i \cdot \sum_{\substack{j=1 \\ j \neq i}}^{M-1} f_j) \qquad (12)$$

where $f_i = P_{Gi} / P_S$ or $f_j = P_{Gj} / P_S$ represents an individual generation capacity share within a cartel.

Substituting (2) and (12) into (11),

$$PMI = \frac{\sum_{\substack{i=1 \\ i \in S}}^{N} P_{Gi} + \sum_{i=1}^{M}\left(P_{Gi} \cdot \sum_{\substack{j=1 \\ j \neq i}}^{M-1} P_{Gj}\right)}{\left(P_S / 100\right)^2} \qquad (13)$$

For any given set of cartel arrangements in a market, Eq. (10) and Eq. (13) give identical post merger H-Indices. However, there is a related superiority between these two equations. Eq. (13) is the general formula for the post-merger market concentration index arising from each cartel arrangement formed one at a time. Eq. (10) can be used as the generalized formula for calculating the H-Index for any combination of cartel arrangements in the market but it does not calculate the increase in H-Index due to each cartel arrangement. The benefit of Eq. (13) is that the increase in H-Index due to each cartel arrangement is explicit and therefore the increase in market concentration due to each specific merger is obtained. Table 5 shows the post-merger H-index (PMI) and the increase in H-index due to each merger (PMII) from the market scenario of Fig. 2.

5. Post-merger evaluation

The U.S. DOJ & FTC Agency has defined a regulatory standard for horizontal mergers as follows [3]:

Post-Merger in diluted oligopolistic markets (H-Index below 1000) resulting in unconcentrated markets is unlikely to have adverse competitive effects.

Post-Merger in "normal" oligopolistic markets (H-Index between 1000 and 1800) producing an increase in the H-Index of less than 100 points (about 1 %) is unlikely to have adverse competitive consequences and require no further analysis. Post-Mergers producing an increase in the H-Index of more than 100 points in "normal" oligopolistic markets potentially raise significant competitive concerns.

Post-Merger in concentrated oligopolistic markets (H-Index above 1800) producing an increase in the H-Index less than 50 points are unlikely to have adverse competitive consequences and ordinarily require no further analysis. Post-Merger producing an increase in the H-Index of more than 50 points in this scenario potentially raises significant competitive concerns. Furthermore, it will be presumed that mergers producing an increase in the H-Index of more than 100 points in this scenario are likely to create or enhance market power or facilitate its exercise.

TABLE 5
POST-MERGER AND INCREMENTAL INDEX OF SOME CARTEL SCENARIOS

Scen	Merging Firms	PMII	PMI	Market Power Potential	Remark
1	{G1, G2} only	85	1015	Low	No effect
2	{G3, G4, G5} only	714	1644	High	Need Serious Investiga-tion
3	G6, G7, G8, G9} only	754	1684	High	Need Serious Investiga-tion
4	{G10, G11, G12, G13, G14} only	318	1247	Moderate	Investigati on Subject to Market Condition
5	{G1,G2}, {G3,G4,G 5}, {G6,G7,G 8,G9}, {G10, G11, G12, G13, G14}	1870	2800	Very high	Highly Concen-trated Need to be Mitigated

In Table 5, although the PMII in scenario 1 is very high, the PMI is lying on the borderline towards diluted oligopoly region. By definition (DOJ standard (a)), there is no significant effect to the entire system market and therefore no need for further analysis by the regulator. In the scenarios 2 and 3, although the PMIs lie in the "normal" oligopoly (moderately concentrated market), there is a need for serious investigation since the PMII exceeds 100 points (DOJ standard (b)). Scenario 4 also has a potential to generate concern but it is of much less concern than that of in the scenarios 2 and 3. Scenario 5 is the case where there are many merging cartels in the same period. Although this scenario is unlikely to happen, it would be useful, from the regulatory point of view, for planning and evaluating purpose.

6. A Case study of Thailand's generation market

6.1 Overview of Market Share

Almost 70% of the total installed capacity (21,932.84 MW) is owned by EGAT with 13.6% from hydro and 55.21% from non-hydro power plants. The BPK (thermal) and SB (combined-cycle) plants have the largest total installed capacity share of 16.7% and 10.4% respectively, both are located in the Central area. MM plant remains the single largest thermal power plant in the North with an installed capacity share of 11.97%. The NE area relies mainly on a combined-cycle plant (9.26%) (NPO plant in Nampong), and several small hydro plants. In the Southern zone, most of EGAT's power plants play a less important role in supplying load demand. The demand, however, relies mostly on private generators. EGAT's Hydro plants are installed and spread throughout the country to support the peak demand in all areas. The three largest hydro power plants are the BB (3.4%), SNR (3.2%) and SK (2.8%) plants. BB and SK plants are located in the North while SNR plant is situated in the Central area.

More than 30% of the installed generation capacity is owned by the private sector with an insignificantly different portion of capacity share. They are; (i) Rachaburi Co., Ltd. with 6.7% capacity share (ii) EGCO (Rayong) with 5.6% capacity share (iii) other IPPs with 6.3% capacity share and (iv) SPPs with 7.6% capacity share, located in Central area; EGCO (Khanom) with 3.7% capacity share located in the South. About 1.5% generation capacity share is imported from Laos PDR's hydro generators injected into the NE area. None of the private generators are located in the North. Currently, all private generators sell electricity through EGAT's power purchase agreement (PPA) contract. In the future electricity market as illustrated in the PMP in 1997, PPA will be considered as a power supplier or generator under a competitive environment. Since the portion of PPA share is fairly large, there may be a need to split the PPA into several smaller PPA traders to compete appropriately with other suppliers in the market as will be discussed in sub-section

6.2 Base case

In the base case scenario, it is assumed that all of the EGAT's generators privatise and become private generators competing with one another in the wholesale market. Under this scenario, the competition would be very high and this would lead to low market power. This can be monitored by employing the unconstrained H-Index calculated using Eq.(2). The result is illustrated that:

$$H^{uc}_{21,932.84} = 655.98$$

This system index is in the range towards diluted oligopoly market and implies that there is very low market power under this scenario and is unlikely to yield adverse competitive effects.

6.3 Structural/political constraint imposed by hydro plants

It was previously assumed in the base case scenario that the individual plants will be privatised to compete with other generators in the market. In practice, however, there is a restricted structural/political constraint in which hydro plants are tied up with the agricultural sector and there is a need to retain hydro facilities in the hands of the state. Therefore, the state hydro will have about 13% market share in the system. By assuming the market share in the other sector unchanged, the system market concentration index under this scenario becomes:

$$H^{HydroCartelConst.}_{21,932.84} = 809.43$$

It is notced that although all hydro plants are owned and grouped within a single entity under the government umbrella, the market concentration index is still within the range of diluted oligopolistic market. It can be concluded that the political constraints imposed by the state-owned hydro generators are unlikely to significantly affect competitive concern and there is no need to privatise the hydro plants to increase competition.

6.4 Market partitioning

According to the result found in the previous sub-section, the amount of the proportional capacity share of the state hydro (about 13%) will be used as a base number for the partitioning of the market segment for EGAT's other privatised non-hydro plants and the PPA traders. The objective is to limit the market concentration to the level within the range of "*normal*" or diluted-oligopoly, and consequently to limit the potential for market power to an acceptable level. Table 6 is an example of a partitioned market scenario for the Thailand generation market. The system H-Index of this partitioned market becomes 1324.60, which falls within the range of "*normal*" oligopoly.

TABLE 6
AGGREGATED PARTITIONED MARKET SCENARIO

Supplier Name	Plant Name	Capacity Share (S_i)	S_i^2
HYD	State Hydro	13.16%	173.19
PG1	WN NPO SRT	13.609%	185.20
PG2	MM LKB NCO	14.405%	207.50
PG3	BPK	16.579%	274.86
PG4	SB	10.436%	108.91
PPA Trader 1 (EGCO)	REGCO KEGCO	9.374%	87.87
PPA Trader 2 (Rachaburi Holding)	RATCH	6.702%	44.92
PPA Trader 3	Other IPPs SPPs T-HB (Laos PDR) HHO (Laos PDR)	15.561%	242.14
H-Index			1324.60

6.5 Possible cartel arrangement

There are possible cartel arrangements, such as collusion among generation owners. For instance, all PPA Traders 1-3 may be merged and become a single PPA Trader, which would retain the capacity share of 32% in the market. The system H-Index under this merger will become 1976, which is in the would range of concentrated-oligopoly. The PMII after the merger will be 652. This implies that the merging of PPA traders would raise significant competitive concerns under the U.S. DOJ & FTC definition (PMII > 100 points under "*normal*" oligopoly).

Another example of a market module that provides a clear demonstration of a potential for market power as a result of an inappropriate market partitioning is illustrated in Table 7. This market segment module is proposed by a consortium of international consultants retained by the former NEPO. Under this market segment module, BPK plant (PG3) is included under PG1 and SB plant (PG4) is included under PG2, allowing the PG1 and PG2 to hold 30.37% and 24.84% market share respectively. The system H-Index under this market module then becomes 2714, which is in the range of concentrated- oligopoly, yielding adverse competitive effects.

TABLE 7
MARKET SEGMENT PROPOSED BY THE CONSORTIUM OF INTERNATIONAL CONSULTANTS

Supplier Name	Plant Name	Capacity Share (S_i)	S_i^2
HYD	State Hydro	13.16%	173.19
PG1	BPK,WN, NPO, SRT	30.37%	922.34
PG2	SB, NCO, MM, LKB	24.84%	617.03
PPA Trader 1 (EGCO)	REGCO KEGCO	9.374%	87.87
PPA Trader 2 (Rachaburi Holding)	RATCH	6.702%	44.92
PPA Trader 3	Other IPPs, SPPs T-HB (Laos PDR) HHO (Laos PDR)	15.561%	242.14
H-Index			1324.60

6.6 Congestion in southern area

There is a serious concern about the congestion in the South, which causes the price in the Southern zone to be higher than that in the other areas. This is because congestion leads to the separation of a local market in the Southern zone from the main market segment. This would allow some large suppliers to manipulate the prices and increase the competitive concern within the local market segment.

Table 8 presents the updated proportional capacity share under separate local market segment. Congestion enables PPA Trader 1 (or EGCO) to dominate the market with about 60% of local market share. However, the congestion in the South does not have significant impact on the main market segment and the entire system market.

TABLE 8
GENERATORS COMPETING WITHIN THE LOCAL MARKET IN THE SOUTH

Owners	Capacity (MW)	Local Market Share (S_i)	S_i^2
PG1	244	17.66%	311.88
HYD	313.275	22.68%	514.38
PPA Trader 1 (EGCO)	824	59.66%	3559.32
H_{lmkt}^{South}			4385.58
HYD	2572.565	12.52%	156.75
PG1	2741	13.34%	177.96
PG2	3159	15.37%	236.237
PG3	3675	17.88%	319.69
PG4	2289	11.14%	124.10
PPA Trader 1 (EGCO)	1232	6%	36
PPA Trader 2 (Rachaburi Holding)	1470	7.15%	51.12
PPA Trader 3	3413	16.61%	275.89
H_{lmkt}^{main}			1377.75
H_{sys}			1567.17

7. Conclusions

This paper has elaborated novel market concentration indices incorporating physical and political constraints for the evaluation of market power. The numerical results of H-indices for a number of local market and cartel scenarios has been presented and compared in various cases including the case of Thailand's generation market system. The unconstrained system always has a lower market concentration than the congested local market and cartel system. That is to say that the physical constraints causing isolated local markets impede competition and concentrate the market. A cartel arrangement also impedes fair competition between generators and causes additional concentration of the market and hence shifting the market towards a concentrated oligopoly.

APPENDIX : Proof of the Post-Merger Incremental Index (PMII)

Starting from the *Two-Firm Merger* [3], it is envisaged that the market share of the two merging firms before the merger are squared individually that can be expressed as:

$$f_1^2 + f_2^2 \quad (14)$$

After the merger, the sum of those shares would be squared as below:

$$(f_1 + f_2)^2 = f_1^2 + 2f_1f_2 + f_2^2 \quad (15)$$

and hence the PMII can be represented as:

$$PMII_{2\,firms} = 2f_1f_2 \quad (16)$$

Using the terminology as illustrated above, the Three-Firm PMII can be obtained and represented as below:

$$PMII_{3\,firms} = 2(f_1f_2 + f_1f_3 + f_2f_3) \quad (17)$$

The alternative forms of (17) are

$$\begin{aligned} PMII_{3\,firms} &= (f_1f_2 + f_2f_1) + (f_1f_3 + f_3f_1) + (f_2f_3 + f_3f_1) \quad (18) \\ &= f_1(f_2 + f_3) + f_2(f_1 + f_3) + f_3(f_2 + f_3) \end{aligned}$$

and then the more general form of (18) for the Three-Firm PMII can be illustrated as:

$$PMII_{3\,firms} = \sum_{i=1}^{3}(f_i \cdot \sum_{\substack{j=1 \\ j \neq i}}^{2} f_j) \quad (19)$$

Finally, the M-Firm *PMII* can be represented by the formula illustrated in (12). This is the end of the proof.

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Bibliography

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