# Market Power in the Great Britain Wholesale Electricity Market

*A Thesis submitted in partial fulfillment for*
*the requirement of degree in*
*Master of Science in Energy Systems and the Environment*


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# ABBREVIATIONS

| | |
|---|---|
| BETTA | British Electricity Trading and Transmission Arrangement |
| BM | Balancing Mechanism |
| BMRS | Balancing Mechanism Reporting System |
| CCGT | Combined Cycle Gas Turbine |
| FPN | Final Physical Notification |
| GB | Great Britain |
| HHI | Herfindahl-Hirschmann Index |
| IBC | Incentivised Balancing Costs |
| MEL | Maximum Export Limit |
| NETA | New Electricity Trading Arrangement |
| NGC | National Grid Company |
| NGET | National Grid Electricity Transmission |
| NISM | Notice of Insufficient System Margin |
| OCGT | Open Cycle Gas Turbine |
| SBP | System Buy Price |
| SMP | System Marginal Price |
| SO | System Operator |
| UK | United Kingdom |

# ABSTRACT

In an opened and competitive wholesale electricity market, the price of electricity is pushed to the marginal production cost level that provides a win-win situation, both to sellers and buyers. This leaves less room for the seller, or in this case generator, to make extra profits out of their bilateral trading. Balancing mechanism, which serves the purpose of balancing the energy and technical part of power system, has become a platform for the generators to generate extra incomes for the companies.

The manipulation played by the generators to profitably increase their income is called market power which can be exercised by implementing the capacity and financial withholding. This in turn will increase the System Buy Price and hence the electricity price. As a result, the intention of keeping the electricity price at a minimum level may not be materialized.

A methodology has been established in order to evaluate any events that are suspected to have any relation to the market power. This includes the modelling of market power using variety of models such as Cournot Model, Bertrand Model, HHI, Lerner Index etc. and also includes result analysis that are done qualitatively and quantitatively. The methodology was tested on two case studies and it was believed that the conclusions deduced from the analysis of these studies are quite convincing.

The results and conclusion produced from this thesis may increase the understanding on electricity market behavior and provide a significant addition to the resources of electricity market research. It is hoped that this will contribute to the betterment of the electricity industry.

# CHAPTER 1: INTRODUCTION

## 1.1 Overview

Over almost a century, electrical energy was traded between vertically integrated utilities and the electricity consumers. Even until today, this kind of trading is still being implemented in some parts of the world. At one point, the economists have suggested that the prices would be lower and that the economy as a whole would benefit if the supply of electricity became the object of market discipline (Kirschen and Strbac , 2004).

Since then, some countries especially western countries have designed several market structures that can be adopted for liberalization of electricity market. In Great Britain, the wholesale electricity market was started off with the centralized Pool system which was implemented in England and Wales. However, the Pool system was not very successful in bringing down the electricity market due to market power exercise by significant number of players. After about a decade, it was completely replaced with New Electricity Trading Arrangement (NETA) in year 2001 before the market was once again upgraded to British Electricity Trading and Transmission Arrangement (BETTA) that covers Great Britain wide inclusive of Scotland in year 2005.

In these two trading arrangements (NETA and BETTA), the electrical energy is traded in the form of bilateral trading which is supported by balancing mechanism that acts as another market whose function is to keep the system in balance. The generators sometimes take advantage of this balancing mechanism to increase their profit by exercising the market power. This in turn affects the overall electricity price that the consumers have to bear and thus the objective of minimizing the electricity price may not be materialized.

Hence, this study is focusing on the evaluation of market power in electricity market in the GB with the hope that this might help to further understand the behavior of the market. It is believed that with such understanding, the electricity market will be easier to predict and preventive actions can be taken to avoid any misbehavior from the players and hence the electricity price can be kept at minimum level possible

## 1.2 Specific Objectives

The objectives of this thesis are described as follows:

- To establish a methodology in evaluating market power exercise in electricity market
- To investigate/evaluate the market power by applying various models to the cases concerned
- To promote the use of qualitative and quantitative analyses in evaluating market power
- To conclude if the case studies in question show the potential for or exercise of market power

## 1.3 Project Aims

This project is aimed at evaluating market power in electricity market especially in balancing mechanism in the GB. It is hoped that the methodology and analysis techniques used in this project can be useful in helping to investigate market power exercise that happen in the past, present and future. This is one of the efforts to achieve a long term project aim that is to understand the behavior of the electricity market.

# CHAPTER 2: BACKGROUND

## 2.1 Market

Fundamentally, a market is a place where buyers and sellers meet to see and negotiate if deals can be made over commodities at that point of time or in the future. This is consistent with the definition given by the Oxford Dictionary (), whereby a market is defined as a particular area of commercial or competitive activity. Meanwhile, according to Pindyck (2003), a market is a collection of buyers and sellers that interact, resulting in the possibility for exchange

### 2.1.1 Buyers and Sellers

Buyers, of course, are the parties that demand for the commodities by trading them with money or some other commodities. There are a few factors that determine the behavior of the buyers in a market which in turn affect the demand for a commodity. Among the main factors are price, quality, quantity and timing. Given that other non-price factors are precisely defined, the demand behavior is very much dependent on the price of a commodity. The quantity of a commodity bought by buyers normally increases with the decrease in the price and vice versa. This relationship is given by the inverse demand function graph as shown in Figure 1.

Figure 1 shows the typical relationship between the price of a commodity and the quantity of the demand for the commodity by the consumers. This relationship can be seen from two perspectives. The first perspective sees how the difference in commodity price can affect the quantity of the demand of the commodity. As mentioned earlier, under this perspective, the demand decreases as the price increases. This is the case when the consumers have the alternatives to one particular commodity. When the price of this commodity goes up beyond the acceptable level for the consumers, they will go for other alternative commodities which results in decreasing in quantity of demand of the first commodity.


Figure 1: Inverse Demand Function graph
*(Source: Kirschen and Strbac , 2004)*

On the other hand, the second perspective sees the relationship in Figure 1 as the price that the consumers are willing to pay to have a small additional amount of a commodity. It also tells how much money these consumers would want to receive as a compensation for a reduced consumption (Kirschen and Strbac , 2004). Considering this second perspective, from Figure 1, it indicates that the consumers or buyers are willing to pay a high price for an additional commodity if they only have a small amount of that commodity. In contrast, their marginal willingness to pay for this commodity decreases when their consumption increases.

The change in demand resulted from the change in price shows that the demand of a commodity is elastic. Kirschen and Strbac (2004) define the price elasticity of demand as the ratio of the relative change in demand to the relative change in price. On the other hand, if the relative change in demand is smaller than the relative change in price then the demand is inelastic to the price. This is the case in certain commodities like electrical energy especially if it is viewed in a short-term horizon (Lo, McDonald and Le, 1990).

As for the sellers, they are a group of parties that produce or supply the commodities or services to the buyers. The behavior of the suppliers and hence the supply of a commodity is also very much related to the market price. The volume of supply of a commodity in a market will go higher when the market price is high enough relative to the production cost. This is because the producers or the suppliers will find it worthwhile to increase their production of a commodity when the market price is high. This definitely affects the quantity of commodity that available to be sold to the buyers in the market.

The relationship between quantities of supply of a commodity in a market with the market price is given by the supply curve graph or inverse supply function graph as shown in Figure 2.

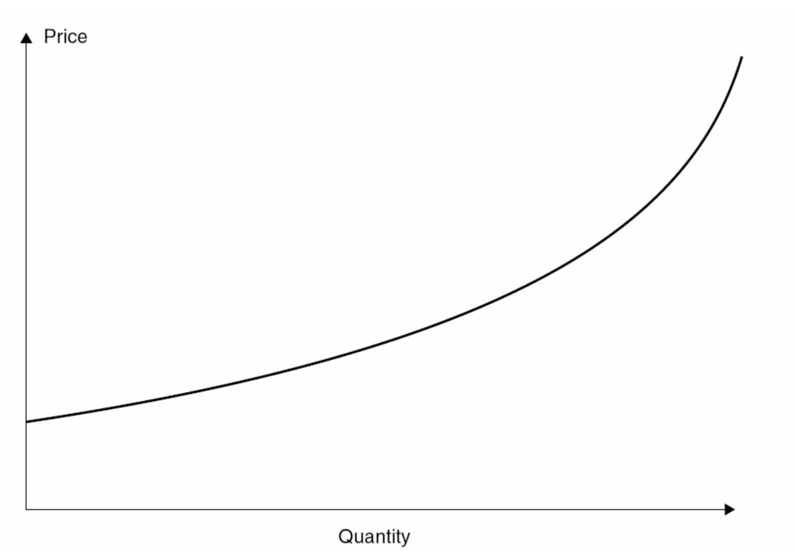


Figure 2: Inverse Supply Function graph

*(Source: Kirschen and Strbac , 2004)*

In Figure 3, commodities produced by different producers are tabulated along the supply curve. This will break the producers down into three categories which are marginal producers, infra-marginal producers and extra-marginal producers. The marginal producers are the producers whose production costs equal to market price. Marginal producers will find that their productions are not worthwhile if the market price decreases. On the other hand, the production cost for infra-producers is below the market price. This enables this kind of producers to put their price above their minimum worthwhile price and at the same time remain below the market price. As for extra-producers, the production cost for this kind of producers is above the market price. They will only find that their production is worthwhile when the market price increases. Hence, due to the different in production cost, the different producers of a commodity would have to adjust their amount of supply at different price thresholds.

All these are summarized in Figure 3 as shown below.

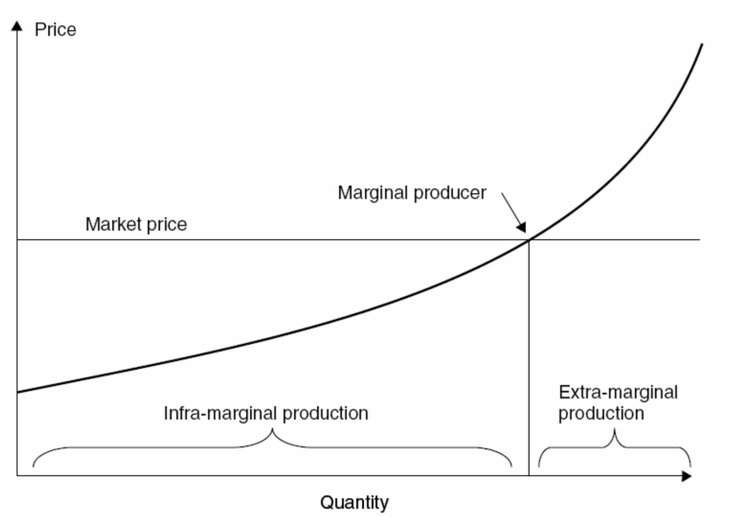


Figure 3: Type of Producers in respect to Market Price

*(Source: Kirschen and Strbac , 2004)*

The rate of change of quantity of supply relative to the rate of change of market price is called *Price Elasticity of Supply*. The elasticity of supply is always positive and its value is normally higher in a long run since the suppliers have the opportunity to increase the means of production.

### 2.1.2 Market Equilibrium

When consumers and suppliers cannot influence the commodities price by their actions, a market is identified as a perfectly competitive market. In a competitive market, a market is said to be in equilibrium state when the quantity that the suppliers are willing to provide is equal to the quantity that the consumers wish to obtain. Market equilibrium happens at equilibrium price or market clearing price.

The market equilibrium can be illustrated using the inverse demand function graph and inverse supply function graph as shown in Figure 4. In this situation, the quantity of a commodity and the market price will settle at the intersection of these two curves.

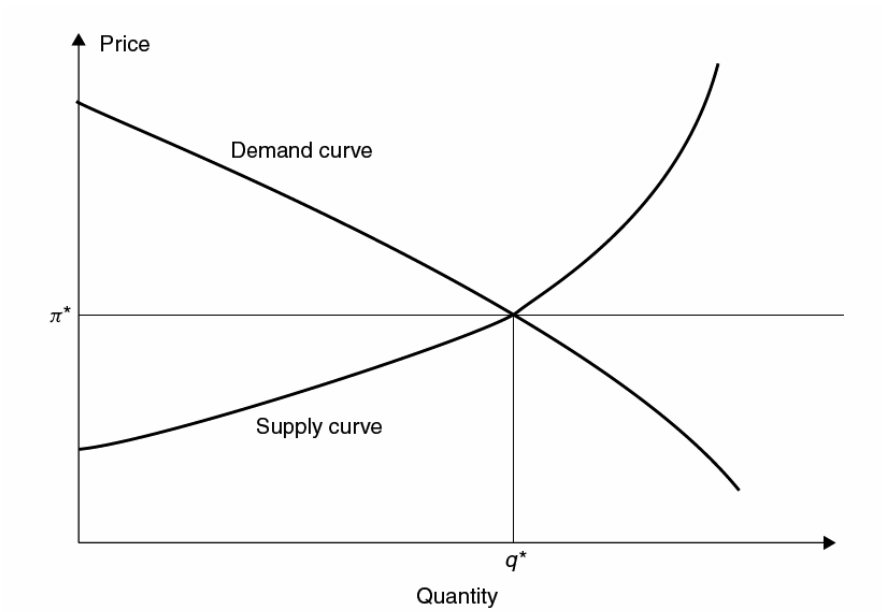


Figure 4: Market Equilibrium
(*Source: Kirschen and Strbac , 2004*)

When a competitive market is allowed to operate freely, the resulted equilibrium price will push the consumers' surplus[1] and producers' profit to the maximum level. However should external interventions take place, this will prevent the price from settling at equilibrium price and hence the surplus and profits are not maximized. Figure 5 below shows the consequences when a commodity price settles higher or lower than the equilibrium price.

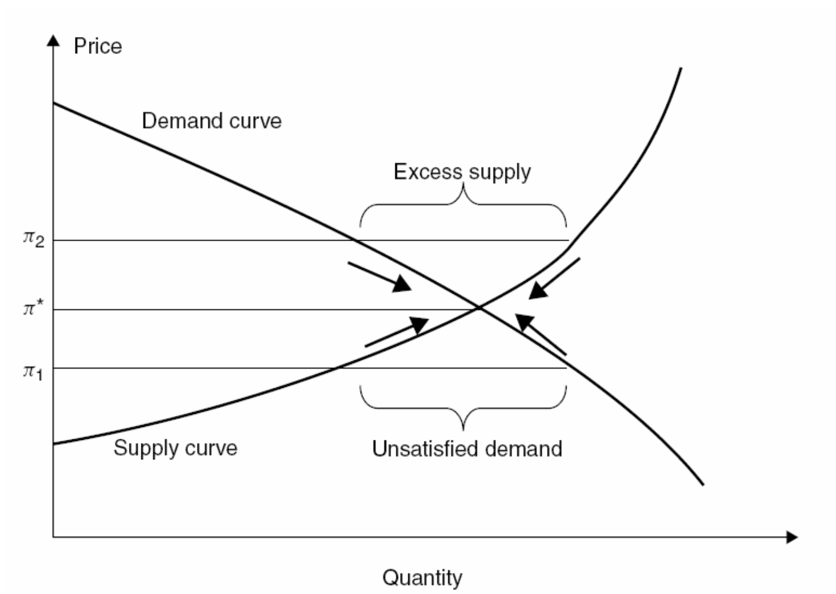


Figure 5: Market Equilibrium Stability

(*Source: Kirschen and Strbac , 2004*)

If the market price settles higher than the equilibrium price, the demand will reduce, this in turn leaves the producers with excess supply. In this situation, the producers will normally reduce their production so that the amount of commodities that they are willing to sell is equal to the amount that the consumers are willing to buy.

On the other hand, if the market price is lower than the market price, only limited number of producers will find that the price is worthwhile to produce goods. This will reduce the availability of supply in the market which leaves some amount of

[1] Consumers' surplus is defined as the difference between the price that a consumer is willing to pay and the actual price that they pay (Riley,2006)

demand unsatisfied. Hence, in a competitive market, market price that is equal to the equilibrium price will basically help to give full advantage to both the producers and the consumers.

## 2.2 Types of Market

The previous section has described and concluded that a market is a mechanism for matching supply and demand of a commodity through an equilibrium price. In addition to that, there are a few types of markets that serve different purposes of trading. The types of markets are determined by following matters:

- The date of delivery of the commodities
- The mode of settlement
- Conditions that might be attached to the transaction

The way the buyers and sellers settle those matters will define the type of market that they involve in. Each type of market will be discussed in the following sub-sections.

### 2.2.1 Spot Market

In a spot market, seller delivers the goods immediately and the buyer pays on the spot. This type of market is very straight forward whereby there is no condition attached to it. Spot market has the advantage of immediacy. The sellers can sell the amount that they have available while for the consumers, they can purchase the exact amount that they need.

However, in a spot market, the price of the goods tends to change quickly. It is very much influenced by the demand and supply. The price will easily go up when the demand exceeds the available supply and vice versa. The price in the spot market is also affected by the speculations and news about the future availability of a commodity. The unpredictable price of goods in spot market makes life harder for the traders as they are exposed to various risks.

Another type of market is needed by this kind of traders in order to protect them from those risks especially. The likes of forward markets, future markets and a few others are quite useful for the traders to get their interest protected and this will be discussed later in the next sub-section.

### 2.2.2 Forward Contract and Forward Markets

If in the future, the sellers or producers don't want to risk their goods to be sold at a lower price while the buyers at the same time don't want to bear the risk of buying at high price, these sellers and buyers can "lock in" in the price by signing a forward contract. A forward contract specifies the following matters:

- quantity and quality of the commodities to be delivered
- date of delivery
- date of payment following delivery
- penalties if fail to meet the commitment
- the price to be paid

The agreed price is based on their estimate of spot price at the delivery time. However, if at the delivery time, the spot price is higher than the agreed price, the forward contract will present a loss to the seller because they cannot sell their good at higher price whilst the buyer can enjoy the surplus as they pay a price which is lower than the spot price.

On the other hand, if the spot price is lower than the agreed price, the buyers will take turn to be at loss as they have to buy the goods at a price higher than the spot price. This time around, the sellers will gain profit out of the forward contract.

If enough sellers and buyers are interested in signing forward contracts of a commodity, then a forward market for that commodity will develop. This forward market opens up a larger number of possible trading partners which in a way helps to determine whether the price that is being offered is reasonable or not (Kirschen and Strbac , 2004).

In some cases, at some points, two parties may want to negotiate all the details of a forward contract. This is the case when the contract is to cover the delivery of a large quantity over a long period of time or if special need to be discussed. This kind of negotiation somehow is very expensive that lead the parties to use standardized terms and conditions.

This standardization makes possible the resale of future contract should the parties wrongly estimate the quantity of the commodity that being traded when the date of delivery is approaching. This secondary market helps the parties to manage their price risk and at the same time conform to the conditions of the contract.

### 2.2.3 Future Contracts and Future Markets

A contract is called a future contract when it does not involve physical delivery which means there are parties that buy a contract for delivery in the future with the intention to sell it later at a higher price. From another perspective, this can be seen as parties that sell a contract first with hope to get a new one at a lower price. The parties that buy and sell the future contracts are called speculators. According to Kirschen and Strbac , as the date of delivery approaches, the speculators must balance their position because they cannot produce, consume or store the commodity.

In spot markets, producers and buyers are exposed to some other risks other than price risk. Hence, with the existence of speculators in future market; they prefer to transfer the price risk by paying the speculator to take care of this additional risk. As for the speculators, they can easily offset the losses in the future market as speculators normally have good financial position. Furthermore, speculators do not restrict themselves to one commodity but they involve in future contracts of other commodities as well which in a way reduce their exposure to any possible risks.

The market as a whole benefits from the participation of speculators even though sometimes they make a lot of profit from their trades. This is because the participation of speculators increases the diversity of the market participants. This makes other parties to find their counterparties for their trades more easily and hence increase the liquidity of the market. The increase in liquidity may help the market to discover the price of a commodity (Kirschen and Strbac , 2004).

### 2.2.4 Options

Unlike forward and future contract, options are contracts that come with a conditional delivery and this condition will only be exercised if the holder feels that it is worthwhile to do so. They are two varieties of options which are call option and put option

A call option gives the holder the right to buy a given amount of commodity at the exercise price in a future date.  On the other hand, a put option is the right for the holder to sell a given amount of commodity at the exercise price in a future date.

The exercise of the rights is very much dependent on the spot market price of a commodity. If an exercise price of a call option is lower than the spot market price, then the holder will find it worthwhile to be exercised. However, if the exercise price is higher, then the holder has the right not to exercise the option and they can get the goods from the spot market instead. Same goes to put option whereby the holder can choose not to exercise the option if the exercise price is lower than the spot market price. On the other hand, the holder will definitely exercise their right if the exercise price is higher than the spot market price.

Hence, buying an option contract can therefore be considered as a way for the holder of the contract to protect itself against the risk of having to trade the commodity at a price less favorable than the spot market (Kirschen and Strbac, 2004).

### 2.2.5 Contracts for Difference

In some cases, sometimes the price of a commodity is controlled by a centralized market. This gives the traders no option of making use of forward market, future market or option to reduce their risks. In this case, contracts for difference can be use whereby the parties will agree on the amount of the commodity and also a price called strike price.

After the agreement has been made, the parties will enter the centralized market like other participants do. Once the trading on the centralized market is completed, the contract of difference is settled as follows:

- If the strike price is lower than the centralized market price, the buyers will pay the sellers the difference between the strike price and the market price times the amount of the commodity agreed in the contract.

- If the strike price is higher than the centralized market price, the sellers will pay the buyers the difference between these two prices times the amount of the commodity agreed in the contract.

In general, contracts for difference are a combination of a call option and a put option with the same exercise price which is applied in a centralized market.
From all the market types described above, the spot market price appears as an indicator that drives all prices in other markets. This is because the spot market is the last resort where all the parties will refer to should any imbalances occur in any of the markets. Hence, the spot market plays a fairly important role in matching the supply and demand.

## 2.3 Market Power

If the number of participants in a market is large enough, as assumed in the previous sections, no parties can control a large proportion of production and consumption. In other words, suppliers who ask for more than market price and consumers who offer less than market price can simply be ignored as they can be easily replaced by other participants in a perfectly competitive market.

However, if the number of participants is not large enough, there might be some producers and consumers that are able to control the share of the market that is large enough to exercise market power. Market power is defined as the ability to alter profitably prices away from competitive level (Mas-Collel et al. 1995). Market power can be exercised either by withholding the quantity of commodity or by raising the asking price above the competitive price level without affecting the demand of the commodity.

When market power is being exercised, that means the market is not perfectly competitive. This causes a distortion in the market price of a commodity whereby the marginal value of the goods sold to consumers is not equal to the marginal cost of production of those goods and hence the efficiency of a market is no longer there.

The exercise of market power, as a result of imperfect competition in a market, may happen in all markets with no exception to electrical energy market which will be discussed in the next sub-section.

## 2.4 Market for Electrical Energy

Electrical energy is a peculiar commodity which has a few significant differences that restrict it from being traded like other commodities. One of the differences is in terms of the storage of the commodity whereby it is not economical to store a large quantity of electrical energy. Hence it must be consumed at the same time it is produced. On top of that, supply and demand must be balanced at all time that the failure to keep those two balanced will cause the system to collapse. To make it worse this might affect the power supply for the entire region or in certain cases, the entire country.

Due to this reason, for almost a century, the electricity industry has been widely operated by large vertically integrated regulated monopolies. People at that moment found that there are reasons and benefits that can be enjoyed by having a vertically integrated system. According to Vassilopoulos, 2003, the reasons for the vertical integration are:

- Transmission and distribution function of the electricity industry are natural monopolies (it is useless to install many distribution wires in the same street and transmission has important scale economies and network characteristics)
- Generation and transmission must be constantly coordinated and for a long time, it was impossible to believe that transmission and generation could be separated

- The long term planning of transmission and generation benefited from the vertical integration
- Economies of scale in generation can be achieved when bigger plants produced lower prices

However, for a longer term benefits to consumers, the industry has to rely on competitive markets of electrical energy in order to provide better incentives for controlling capital and operating costs of new and existing generating capacity, encourage innovation in power supply technologies, and shift the risks of technology choice, construction cost and operating "mistakes" from consumers to suppliers (Vassilopoulos, 2003). With competitive markets in place, the consumers of electrical energy would get the opportunity to choose the suppliers with the best offers in terms of price and quality.

In order to introduce a competitive market to the power industry, Vassilopoulos, 2003, had suggested that certain requirements are needed which are:

- Vertical separation of competitive segments (e.g. generation, marketing and retail supply) from regulated segments (distribution, transmission, system operations) either structurally (through divestiture) or functionally (with internal "Chinese" walls).
- Horizontal integration of transmission and network operations to encompass the geographic expanse of "natural" wholesale markets and the designation of a single independent system operator to manage the operation of the network, schedule generation to meet demand and maintain frequency, voltage and stability of the network.
- Creation of wholesale spot and operating reserve market institutions to support requirements for real time balancing, to respond quickly and effectively to unplanned outages of transmission or generating facilities and to facilitate the trading opportunities among suppliers and between buyers and sellers.

- Creation of institutions to facilitate access to the transmission network by buyers and sellers for a better economical production and exchange.
- Unbundling of retail tariffs in order to separate retail power supply and associated services (supplied competitively), from distribution and transmission services that would continue to be provided by regulated monopolies.
- Requiring retail consumers to purchase their power supplies from competing retail suppliers, which in turn buy their power in wholesale markets, or own generating facilities to support their retail supply commitments.

Over the last two decades, a few liberalizations of electricity market emerged especially from countries like the UK, European countries and the US. In a liberalized electricity market, electrical energy is traded based on certain amount of megawatt-hours which is to be delivered over specified period of time. The length of the period differs from one country to another for instance; in the UK the length of a period is equal to half an hour while some other countries it is set to be an hour or quarter of an hour.

In line with what has been suggested by Vassilopoulos, the existing electricity markets so far have been operated in a various arrangements which will be discussed in the next sub-sections.

### 2.4.1 Electricity Pool

Electricity pool is a contractual arrangement entered into by Generators and Suppliers that provides the wholesale market mechanism for trading electricity (The Electricity Pool, 2000). The electricity pool does not itself act as market maker buying or selling electricity but instead facilitates a competitive bidding process between generators that sets the wholesale price paid for electricity for every period (half an hour for every period in the UK) of every day. It also establishes the preferred generation merit order at the day-ahead stage.

The concept of pool arose from the two distinct characteristics of electricity commodity. Firstly it is not possible to store electricity in any significant quantity so there is a need to match instantaneous demand with instantaneous generation and secondly the inability to trace electricity from generator to customer.

For these reasons, the wholesale market for trading electricity between generators and suppliers was based on a pooling arrangement. Generators sell electricity into a "pool" and suppliers purchase out of this pool. An electricity pool system provides a systematic mechanism so that the market is hoped to end up at equilibrium price. Kirschen and Strbac , 2004 described the fundamental operation of an electricity pool which is given as follows:

- Generating companies submit bids to supply a certain amount of electrical energy at a certain price for the period under consideration. These bids are ranked in order of increasing price. From this ranking, a curve showing the bid price as a function of the cumulative bid quantity can be built. This curve is deemed to be the supply curve of the market.
- Similarly, the demand curve of the market can be established by asking suppliers and large scale consumers to submit offers specifying quantity and price and ranking these offers in decreasing order of price. Since the demand for electricity is highly inelastic, this step is sometimes omitted and the demand is set at a value determined using a forecast of the load. In other words, the demand curve is assumed to be a vertical line at the value of the load forecast.
- The intersection of these “constructed” supply and demand curves represents the market equilibrium. All the bids submitted at a price lower than or equal to the market clearing price are accepted and generators are instructed to produce the amount of energy corresponding to their

accepted bids. Similarly, all the offers submitted at a price greater than or equal to the market clearing price are accepted and the suppliers and consumers are informed of the amount of energy that they are allowed to draw from the system.

- The market clearing price represents the price of one additional megawatt-hour of energy and is therefore called the system marginal price or SMP. Generators are paid this SMP for every megawatt-hour that they produce, whereas suppliers and large scale consumers pay the SMP for every megawatt-hour that they consume, irrespective of the bids and offers that they submitted.

When it comes to settlement processes, since the wholesale price of electricity can be different for every period, the electricity pool provides the supporting financial settlement processes that calculate supplier's and large scale consumer's bills and ensures payment to the generators.

The electricity pool's mechanism at some points meets the specific objective of enabling competition in generation, on the basis of merit order of which generation plant should be used, of allowing all prospective suppliers/large scale consumers to purchase in the wholesale market on the same basis (The Electricity Pool, 2000). Similarly, it facilitates the mechanisms to support competition in supply where customers can freely choose their supplier.

However, there were questions arose as to why shouldn't the generators that are willing to produce for less be paid only their asking price? The pool system was somehow believed to allow the market prices to be well above the marginal production costs. This led to the introduction of another open electricity market which is called bilateral trading.

### 2.4.2 Bilateral Trading

Bilateral trading is a forward contact that involves only two parties which are a buyer and a seller. The participants enter into contract without any involvement, interference or facilitation from the third party. There are three main forms of bilateral trading that the participants can be involved in depending on the amount of time available and the quantities of the energy to be traded. According to Kirschen and Strbac (2004), the three forms of bilateral trading are as follows:

- **Customized long term contract** – This kind of contract has flexible terms since it is negotiated privately between the participants in order to meet their respective needs and objectives. Customized long term contract normally involves the trading of large amount of power over a long period of time. It is only worthwhile to be signed at a big amount of energy since the transaction cost is relatively high.
- **Trading "Over The Counter**" - These transactions involve smaller amounts of energy to be delivered according to a standard profile, that is, a standardized definition of how much energy should be delivered during different periods of the day and week. This form of trading has much lower transaction costs and is used by producers and consumers to refine their position as delivery time approaches.
- **Electronic trading** – Through electronic trading, offers to buy energy and bids to sell energy are carried out directly in a computerized market place. All the participants of the market can monitor and observe the quantities and prices that are submitted without knowing the party that submit the offers and bids. There is software that does the matching job between the submitted offers and bids. For instance, if a new bid is submitted into the electronic trading, the software will try to match the bid with the offer that has equal or greater price than the bid price. Once it is found, the deal is automatically struck and the price and the quantity will be immediately published. However, if there is no offer matches that bid,

then that bid will be listed in an outstanding list and remains there until it is matched or withdrawn or lapsed by the closure of market at that particular period.

The essence from all of the three forms of bilateral trading is the price of each transaction whereby it is made independently between the parties involved. This gives the customers opportunity to negotiate the best energy price from suppliers and generators without being constrained by any official price. Bilateral trading is believed to have the ability to make the electrical energy market more efficient and hence bring down the energy price to the lowest level possible (Bower and Bunn, 1999). Nevertheless, similar to the electricity pool, a complementary spot market is still needed to make up any imbalances in terms of energy as well as the system. Further discussion regarding the role played by spot market or balancing mechanism will be discussed in the next sub-section.

### 2.4.3 Managed Spot Market

In bilateral trading, the suppliers or large consumers have to forecast the energy consumption of their own or of their customers for every market period before they enter into the contracts. When the time comes, generators will do their part by dispatching the agreed amount of energy at the minimum production cost possible. However, in practice, things won't be that simple because neither party is able to reliably meet its contractual obligations with perfect accuracy. This is because the consumers never consume the energy exactly like the forecasted value. On the other hand, unpredictable technical problems often prevent the generators from delivering the contracted amount of energy. These errors and unpredictable events may leave a gap between demand and supply which cause energy imbalance.

For this reason, a balancing mechanism is needed in order to keep the load and generation balance and this can be achieved through a managed spot market. A managed spot market is not only used when there is energy imbalance but also plays its role when the power system is imbalanced due to technical limitations such as transmission constraint.

Managed spot market here refers to a spot market that is managed by a neutral party and in the case of electricity market this party is called the System Operator (SO). The System Operator has the responsibility to maintain the balance of the system by managing the offers and bids from the spot market participants which involves the purchase and sale of electrical energy. This can not be done in a conventional spot market because the imbalances in the power system need to be recovered very quickly.

In maintaining the balance and stability of the system, the SO needs to match residual load and generation by adjusting the production of flexible generators and curtailing the demand of willing consumers. It should also be able to respond to major disruptions caused by the sudden and unforeseen disconnection of large generating units because of unavoidable technical problems (Kirschen and Strbac , 2004).

In order for the SO to be able to carry out its job, it has to have sufficient balancing resources. Wide option of resources can be obtained by allowing the spot market participants to take part on a competitive basis. This not only gives a broader balancing option but also may help to reduce the balancing cost.

These balancing resources can be offered either for a specific period or on a long-term basis. For the specific period, offers are made by the participants to the SO right after the closure of open market. Generating units that are not fully loaded can put their offers to increase their output while generating units that want to reduce their output may as well place their offer price in the spot market.

As for the consumers, they can make an offer to reduce their consumption if they find that the energy price is greater than the value they place on consuming electricity during that period. On the other hand the consumers can also offer to increase the consumption should the price is sufficiently low.

The timing of the submission of the offers that is right before the real time might be of concern to SO as the amount that will be offered may not be sufficient and the price offered might contribute to a high balancing cost. This may lead to the purchase of balancing resources on a long-term basis by the SO. This contract is aiming at safeguarding a secure amount of generation capacity from the balancing resources. The contract is secured using the option contract as discussed in sub-section 2.2.4 whereby SO is paying a fixed exercise price from the suppliers in order to keep the capacity available. However the SO would call upon this contract only if the exercise fee is lower than what it would have to pay for a similar balancing resource offered on a short-term basis.

Kirschen and Strbac  (2004) summarized the operation of the managed spot market in a diagram shown in the Figure 6 below:

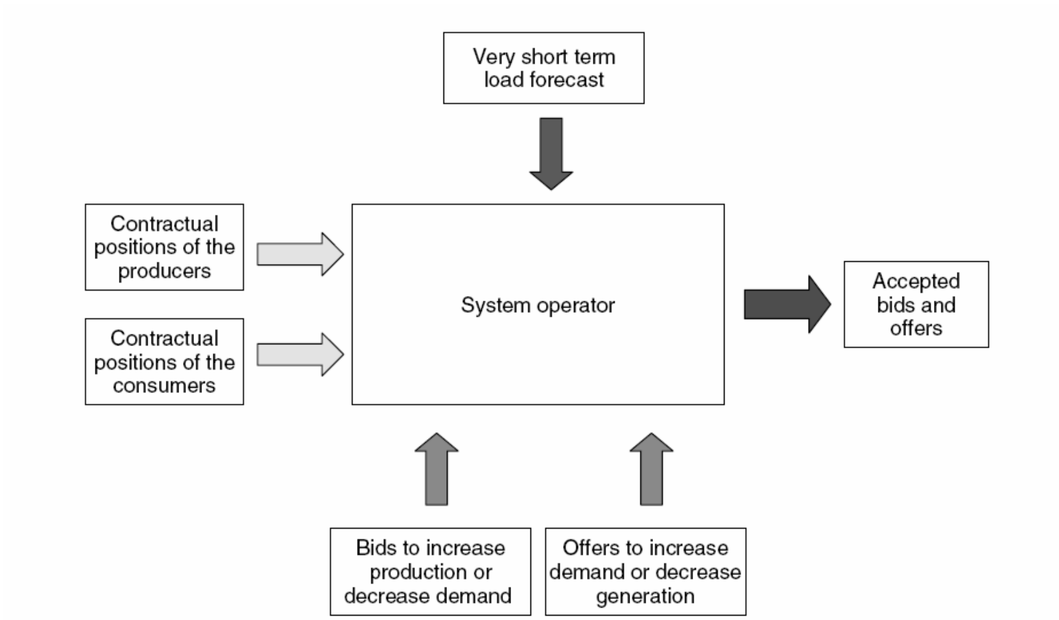


Figure 6: Summary of Operation of the Managed Spot Market

(Kirschen and Strbac, 2004)

Figure 6 summarizes that, at gate closure, the producers and the consumers must inform the SO of their contractual positions, that is, how much power they intend to produce or consume during the period under consideration. The SO combines that information with its own forecast of the total load to determine by how much the system is likely to be in imbalance. If generation exceeds the load, the system is said to be long. If the opposite holds, the system is short. The SO must then decide which balancing bids and offers it will use to cover the imbalances.

Nevertheless, in practice, there are a lot of loopholes in the managed spot market or balancing mechanism that some parties may take advantage out of those to exercise market power and hence making ridiculously high profit. This will be discussed further in Chapter 5 by taking Great Britain (GB) as an example.

## 2.5 Electricity Market Scenario in the Great Britain (GB)

In 1990, the UK Government under Margaret Thatcher privatized the UK electricity supply industry which was then set as an example by several other countries in deregulating their electricity markets (Wikipedia, n.db). It was the first country in Europe to liberalize its electricity market with the creation of the England and Wales pool (Vassilopoulos, 2003). In that pool system, all generators who wish to have their plant dispatched would have to submit their bids to National Grid Company (NGC) who acted as system operator.

As a system operator, NGC constructed a supply curve by stacking the bids in merit order which starts from the generator with the lowest cost and ends with the generator with the highest cost. Optimal combination of generation plants that forms the lowest cost and at the same time meets the next day 48 periods (halfhourly) demand forecast was identified (Vassilopoulos, 2003). NGC will then come out with System Marginal Price (SMP), which is the price where the supply curve and the demand curve intersect each other. As discussed in sub-section 2.4.1, the resulted SMP will be the price paid to the generators by the suppliers and large consumers for every megawatt-hour that they consume in a specific period.

However, according to Vassilopoulos (2003), with belief that the pool system allowed keeping the market prices well above marginal production costs (mainly due to market power), the New Electricity Trading Agreement (NETA) was introduced in year 2001. This new arrangement replaced the pool system in England and Wales with voluntary bilateral markets and power exchanges. In this new arrangement, the market was decentralized and the function of system operator was restricted to balancing the energy and the system through a balancing mechanism. The responsibility of the system operator was still held by the National Grid Company.

In April 2005, the implementation of NETA was extended to cover the whole Great Britain which includes the Scottish generators and power system. This new arrangement was called British Electricity Trading and Transmission Arrangement (BETTA). BETTA introduced a single wholesale electricity market for Great Britain with a single transmission system operator, which is independent of generation and supply (DTI, 2007). There are three owners of transmission grid under BETTA which are National Grid, Scottish Power and Scottish and Southern (Elexon, n.d). Similar like NETA, BETTA is complemented by a balancing mechanism that is also operated by National Grid Company, whose name was changed to National Grid Electricity Transmission (NGET) in year 2005.

NGET is operating under the SO incentive schemes which requires the SO to undertake its role in the most efficient and economic manner. The purpose of these incentives schemes is to encourage the SO (in this case is NGET) to manage and reduce the costs of operating the transmission system in Great Britain and therefore the level of costs borne by transmission system users and ultimately by customers (OFGEM, 2006).

Under these schemes, NGET is set a target of the level of electricity and system balancing costs it should incur in its SO role, referred to as incentivised balancing costs (IBC). If the actual IBC is below the target, NGET will have the opportunity to retain a proportion, set by a sharing factor, of the cost saving. On the other hand, if the costs are above the target, NGET incurs a proportion, set by a sharing factor, of the costs in excess of the target.

The new arrangement and the SO incentive schemes are aimed to increase the competition in the market and bring in a number of important benefits for the consumers and generators across the Great Britain especially when it comes to electricity costs. This system is still being implemented in the Great Britain until today and efforts are continuously made in order to keep the electricity market in a competitive manner.

## 2.6 Market Power Exercise in the Great Britain

As mentioned in previous section, pool system in England and Wales was implemented in 1990s. During that period of time, there were only a few main generation players in the market namely National Power with total capacity of 30,000MW, Powergen with 18,000MW British Energy with 8,400MW and National Grid with the capacity of 2,100MW (Galloway, 2006). This kind of market shares somehow led to duopoly between National Power and Powergen. This provided a strategic platform for the companies to exercise market power.

Being among the dominants in the market, these big players were able to affect the SMP by submitting high bids to the system operator. Since they owned majority of the capacities in the market, they didn't lose their customers but instead made a lot of profit when the SMP went sky high.

Realizing that, in order to avoid the market power issues, the regulator at that moment, OFFER (now known as OFGEM) made an intervention. According to Galloway (2006), the regulator had taken a few actions as follows:

- Not to allow companies to be vertically integrated
- Introduced a specific trading rules that restrict strategic biddings
- Directed National Power and Powergen to dispose their generation capacity
- Allowed TXU to acquire 6000MW of capacity from National Power and Powergen
- Directed National Power to sell 600MW of coal plant to Eastern Electricity

The actions taken by the regulator had increased the number of market entrants, strengthened the regulation and increased the price transparency in the electricity pool. This more or less restricted the excessive market power exercise by the players. However, this did not eliminate the overall market power exercise whereby the players still had the opportunity to withhold their capacity at the day-ahead stage with the intention that their expensive generators will help to increase the SMP (Galloway, 2006). The capacity withholding activities among the players were suspected the main reasons for a high number of price spikes in the Pool until NETA was introduced.

During NETA and BETTA, the electricity price is determined directly between the sellers and the buyers through bilateral trading. This requires the sellers to offer competitive prices to the customers since the customers are free to choose other sellers that can offer the best energy price to them. However, the generation players can still exercise the market power by withholding their capacity and make use the balancing mechanism to maximize their profit if there are any imbalances in terms of energy as well as the system. Things will get worse if any of the transmission lines are constrained by limited import capability which will open the market power opportunities to the related generators in that particular localized market.

In recent years, after the implementation of BETTA, there were events that were suspected as market power exercise by the players. One of the events was when, on a particular day, there have been a lot of plant failures and the only available replacement plants happened to be owned by just one or two companies. On this particular day, it was found that the system buy price for certain periods was way above the system buy price for the day before and the day after. Even though there is yet no evidence of the market power exercise but the event was suspicious enough that something has been going on behind the event.

As for the transmission constraint case, since the implementation of BETTA, there are two significant transmission constraints in the system. The first one is located at the lines connecting the system in Scotland and the system in England. This constraint is known as Cheviot constraint whose name was given after a name of a place where the constraint is located. Another significant transmission constraint is the constraint within the Scotland transmission network. Local generators to this constrained area have been detected to behave strangely in terms of their self dispatch. Furthermore, their offer prices in the balancing mechanism were relatively high at times which was believed to be the main reason for a sudden increase in internal to Scotland constraint management cost (incurred by NGET) from November 2005 onwards.

Again, even though there is no proof of market power exercise by the related generator, but the way that the generator behaves may invite a suspicion of an exercise of market power. This case will be further investigated and evaluated in Chapter 4 as a case study.

# CHAPTER 3: MARKET POWER EVALUATION METHODOLOGY

## 3.1 Background

This chapter will describe the methodology or the method of approach that is needed to evaluate the market power specifically in the Great Britain. It will also discuss in detail each and every step involved in the methodology. This methodology, however, does not restrict its use in Great Britain only but can also be applied in some other countries with some modifications where appropriate.

In general, there are three main steps required in evaluating the market power exercise which are as follows:

1. Input data identification and gathering
2. Market power modelling and simulation
3. Result analysis

All of these steps will be discussed in the next sections and sub-sections.

## Step 1: Input Data Identification and Gathering

### 3.2.1 Input Data Identification

Input data are identified based on the parameters that are related to market power exercise which are parameters from quantity withholding and financial withholding activities. Besides, the identification of the input data is also based upon the case study that needs to be investigated and also inputs to the market power evaluation models (this will be discussed in Chapter 4) that are to be used. In general, follows are the parameters that are normally needed for market power evaluation in GB electricity market (most of the data are related to balancing mechanism where the market power opportunities are believed to be available):

- Total generating capacity of every market player
- Maximum Export Limit (MEL) of related generating units in balancing mechanism
- Final Physical Notification (FPN) of related generating units in balancing mechanism
- Offer prices from related generating unit in balancing mechanism
- System Buy Price (SBP) of related periods in balancing mechanism
- Marginal Cost (MC) of electricity production of related unit (if available)
- Accepted offers volume of related units in balancing mechanism
- Demand forecast of related periods or days
- Fuel prices of related periods or days

All of these data can be gathered from various resources which will be described in the next sub-section.

### 3.2.2 Input Data Gathering

Most of the data described in the previous sub-section especially plants' physical and prices data are available from a website provided by Elexon that publishes a wide range of data that is related to balancing mechanism in Great Britain. The website provides real time and historical data which can be easily accessed at this address: http://www.bmreports.com/. Some of the data here can be considered as raw which need to be processed and sorted out.

University of Strathclyde under the Department of Electronic and Electrical Engineering has developed a program that can extract, rearrange and store the data from this website direct to the user's database in MS Excel. MS Excel is used to keep the entire database because it is user friendly software that has good functions for data analysis purposes.

As for total generating capacity of every generating unit, this data has been summarized in GB Seven Year Statement that is made available by National Grid in its website which can be accessed and downloaded at this address: http://www.nationalgrid.com/uk/sys_07/default.asp?action=dddownload.

## 3.3 Step 2: Market Power Evaluation Modelling and Simulation

Once the input data are in place, the market power modelling can be done using various models. Different models use different approach such as market concentration approach, price-cost margin approach, strategic bidding approach and a few more. However, in this thesis, there are only a few models and indices that will be discussed namely Hirschmann-Herfindahl Index (HHI), Lerner Index, Cournot Model and Bertrand Model. Further details about market power evaluation modelling will be discussed In Chapter 4.

When it comes to simulation, different models run on different tools. In this case, HHI and Lerner Index are modeled using spread sheet or MS Excel as they only involve simple calculations and arrangement. While for Cournot Model and Bertrand Model, a complex and long calculation is involved and hence a simulation tool is needed such as Stochastic Dynamic Programming (SDP), Matlab and a few others.

When evaluating the market power, the selections of model that need to be used depend upon the complexity of a case study. If more than one models need to be used, the result of the evaluations need to be analyzed separately before any conclusion is made. This brings us to the next step which will be discussed in Section 3.4.

## 3.4 Step 3: Result Analysis

Many argue that it is very difficult to prove the existence of market power in electricity market. For instance, at times at which load is close to system capacity and demand response is weak, very small amounts of withholding can radically affect the price and it is almost impossible to tell the difference between withholding and genuine lack of capacity. Besides, there are other reasons like plant outages and fuel price spikes that can lead to withholding.

Hence, for that reason, in this thesis, the result analysis for market power modelling consists of two categories which are quantitative analysis and qualitative analysis. Qualitative analysis is meant to cover the area that is overlooked in quantitative analysis.

### 3.4.1 Quantitative Analysis

Quantitative analysis is quite straight forward as it involves the interpretation from the results given by the market power evaluation models. From this analysis, one can tell that either a firm has the potential to exercise market power or has been exercising market power or no market power exercise at all. However, these interpretations still need to be complemented by qualitative analysis as there may be some aspects that the models do not cover as mentioned earlier.

### 3.4.2 Qualitative Analysis

Qualitative analysis involves the interpretation of additional information such as the pattern of plant availability, pattern of self dispatch, offer price pattern and also fuel price pattern. Besides, under qualitative analysis, appropriate comparison on certain data also needs to be made to make sure that the pattern is consistent with the normal pattern.

The result from this analysis will normally provide the reasons for the changes of certain data pattern that might be captured by the market power models as market power exercise. This in a way acts as a correction mechanism should any wrong interpretations are made from the quantitative analysis.

With the completion of both analyses, an ultimate conclusion can be drawn whether the market power has been exercised by a firm or vice versa.

In general, the summary of market power evaluation methodology is shown in Figure 7 below.

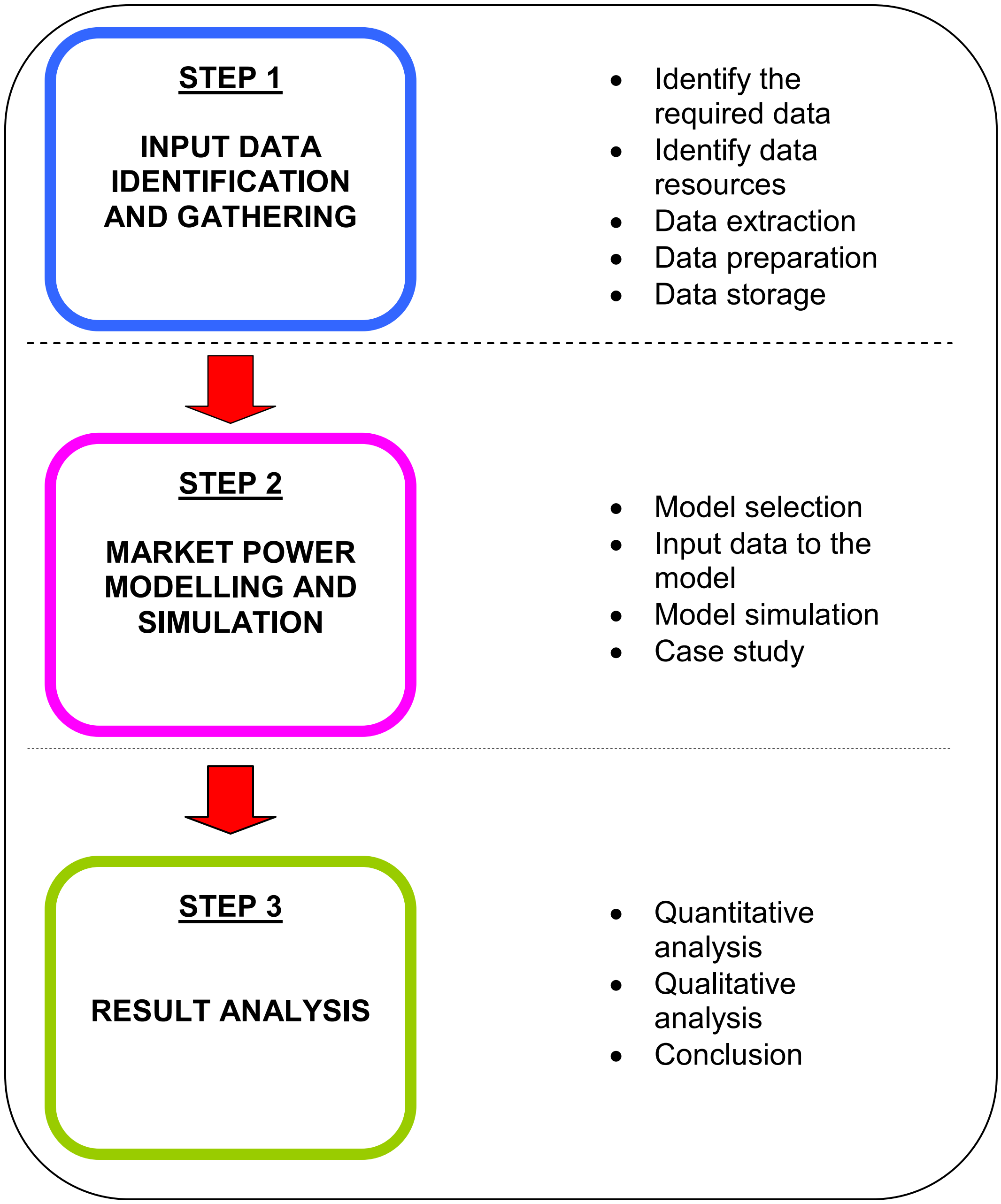

Figure 7: Summary of Market Power Evaluation Methodology

# CHAPTER 4: MARKET POWER EVALUATION MODELLING

A market power evaluation model is a mathematical representation that can be used to evaluate the potential of market power that the players might have in the market and also to evaluate whether market power has been exercised or not to the advantage of the players. In this thesis, only some of the representations or indices or models that will be discussed and this can be found in the following sections.

## 4.1 Hirschmann-Herfindahl Index (HHI)

The Hirschmann-Herfindahl Index is given by the formula:

$$HHI = \Sigma\ Si^2$$

Where Si is the market share of the $i^{th}$ firm (Galloway, 2006).

When only one firm occupies an industry, the index attains the maximum of 1 or 10000 ($100^2$). On the contrary, the HHI value is equal to 0 if a market is perfectly competitive. The value declines with increases in the number of firms and increases with rising inequality among the given number of firms. By squaring the market shares, the HHI index weights more heavily the values for large firms than for small. How desirable or undesirable this weighting scheme is depends upon the relevant theory as to how market structure conduct and performances are related.

For instance, in extremely competitive markets, in which each firm holds 1% of the market, the HHI value approaches 0. Ten equal sized competitors would have each 10%. The Hirschmann-Herfindahl Index would be $10^2 * 10 = 1000$. Five equal competitors would give a Hirschmann-Herfindahl Index of $20^2 *5 = 2000$. Two big players with 40% and ten with 2% would give an index of $2* 40^2 + 10*2^2 = 3240$. There is no universal agreement on how much concentration is too much, although 1500 to 2500 is used as a screen (Vassilopoulos, 2003).

However, according to the US Deparment of Justice and the Federal Trade Commission (n.d.), if the HHI value is below 1000, that indicates that the market is not concentrated while if the HHI value is in between 1000 and 1800, that means the market has a moderate concentration. A market is said to be highly concentrated if the HHI value is higher than 1800.

The HHI has been used in the analysis of horizontal mergers in the electricity sector in which parties combine their productive capacities in a relevant market to operate as a single firm. By giving greater weight to the market shares of larger firms, the HHI may more accurately reflect the likelihood of oligopolistic coordination in the post-merger market (Vassilopoulos, 2003).

Nevertheless, Stoft (2002) argues that HHI does not give a complete representation of market power exercise since it ignores another four factors that affect the market power which are demand elasticity, style of competition, forward contracting and geographical extent of the market.

Considering all these, it is believed that it is worth to use HHI as an initial screening of a market to see whether any parties have the potential to exercise the market power or vice versa. This can be done by looking at the market concentration indication given by HHI.

## 4.2 Lerner Index

The exercise of market power results in a market price that is greater than both the competitive price and the marginal cost of production. The most common measure of this difference is the price-cost margin, also called the Lerner index (Stoft, 2002). The Lerner Index is defined by:

$$L= (P-MC)/P$$

Where P is competitive price and MC is marginal cost.

If the value of Lerner Index is equal to zero, then it indicates that the market is perfectly competitive but if the Lerner Index value is greater than zero that shows that the market power is possibly exercised.

According to Vassilopoulos (2003), the goal of the Lerner Index is to calculate the gap between the actual market prices (supposedly influenced by market power) and the hypothetical prices that would have been established on a purely competitive market (where prices equal to marginal cost). This gap makes it possible to assess the current and the potential market power in the market.

However, in electricity market, one of the challenges to the use of Lerner Index in measuring the market power is the data acquisition since the players normally refuse to disclose their own marginal cost due to privacy and security purposes. Due to this reason, system buy price in the balancing mechanism is always assumed as the marginal cost of electricity production as it forms the average price where the supply meets the demand.

In general, Lerner Index is a relatively good model to measure market power in electricity market as it reflects the rough degree of profit (important result of market power) that the players may have enjoyed.

## 4.3 Cournot Model

Kelman et al. (2001) describes that the straightforward method for calculating market power impacts in electricity markets is by simulating the operation of these markets and directly measuring the market prices and firm's revenues as the strategic bidding or capacity withholding is carried. Two classical approaches in modeling the gaming aspect of strategic bidding are (Fudenberg, 1996):

- *Cournot model*, where agents decide on quantities and market price is defined through an inverse demand function
- *Bertrand model*, where agents have fixed production capacities and compete through prices (this will be discussed further in next section)

According to Stoft (2002), Cournot model describes that all suppliers choose their quantity output and then market price is determined by the intersection of total supply and the consumers' demand curve. Suppliers maximize profits under the assumption that all other suppliers will keep their output fixed.

*"Modern economics describes the Cournot model as a game played in such a way that the outcome is the kind known as a Nash equilibrium[2]. Within the game theory framework, the players of the Cournot game are the suppliers in the market where each player is allowed only one move which is to choose an output quantity. Each supplier's goal is to maximize profit from selling its output at the market clearing price and paying its cost of production."*

*(Stoft, 2002)*

In general, Cournot model has the ability to calculate to which extent a firm can manipulate their production, in order to exercise the market power, before it

[2] The Nash–Cournot equilibrium provides a solution where agents will reach a "standoff" situation where no agent can unilaterally increase its revenue by changing its production.

reaches a Nash equilibrium situation. In a market where the vast number of players involved, Cournot model analysis can only be carried out using simulation tools such as Stochastic Dynamic Programming (SDP), Mat lab and a few others.

Cournot model is deemed as the best available model to estimate market power as it takes into account the market share, transmission constraint, forward contract and demand elasticity. The calculation of Cournot model, which is based on two dominant firms, is shown in Appendix A.

## 4.4 Bertrand Model

Bertrand model is a model of price competition between firms which result in each charging the price that would be charged under perfect competition or also known as marginal cost pricing (Bertrand, 1883). There are assumptions made for this model which are as follows:

- There are at least two firms producing homogeneous products
- Firms do not cooperate
- Marginal cost is constant
- Demand is linear
- Firms choose their respective prices simultaneously
- There is strategic behavior by the firms
- Firms compete solely on price and then supply the quantity demanded

The strategies that are implemented by the firms will end up at Nash equilibrium where neither of the firms can increase their profit by unilaterally changing the price. Hence, Bertrand model can be used to trace the market power exercise (financial withholding) because if firms increase their price higher than other competitors, but the demand is still there, that indicates that something is going on in the market that allows the players to exercise the market power.

Similar like Cournot model, in a market with a high number of entrants, the Bertrand model can only be carried out using a few simulation tools since it involves a long calculation. The calculation and further representation that describes Bertrand model is shown in Appendix B.

# CHAPTER 5: CASE STUDY 1 – MARKET POWER INVESTIGATION ON PETERHEAD POWER STATION

## 5.1 Background

On the 1st April 2005, the implementation of British Electricity Trading and Transmission Arrangement was commenced whereby the GB wide transmission system was first time controlled and managed by National Grid Electricity Transmission Plc (NGET) which acted as the system operator. The responsibility of NGET is to make sure that electricity supply and demand stay in balance and the system remains within safe technical and operating limits. NGET is required to act in an efficient, economic and coordinated manner in carrying out this function.

Hence, the responsibility of managing the transmission constraints and their associated costs which were previously carried out by Scottish Power and Scottish and Southern Energy has now become part of NGET's responsibilities. In practice, transmission related constraint arises when the system is unable to transmit the power supplied to the location of demand due to congestion or limited import capability. Without any upgrades to the system, the management of these constraints is very much dependent on the local level generation output and the local level of system demand.

There are a number of transmission system constraints within Scotland and the most significant one exists in the North of Longannet to Scottish Hydro-Electric Transmission Limited network area which is referred as NLOANSSE constraint. The only way that the SO is able to relieve this constraint is by requiring local generation units to dispatch power (in other words, this constraint only arises when local generation chooses not to self dispatch) (OFGEM, 2006)

NGET originally estimated that the cost to manage the constraints within Scotland was about £17million and due to uncertainties existed regarding the level of this cost (as the cost of managing these constraints had been internalized by the Scottish Companies and limited information was available) , an additional £10million allowance was added to the budget.

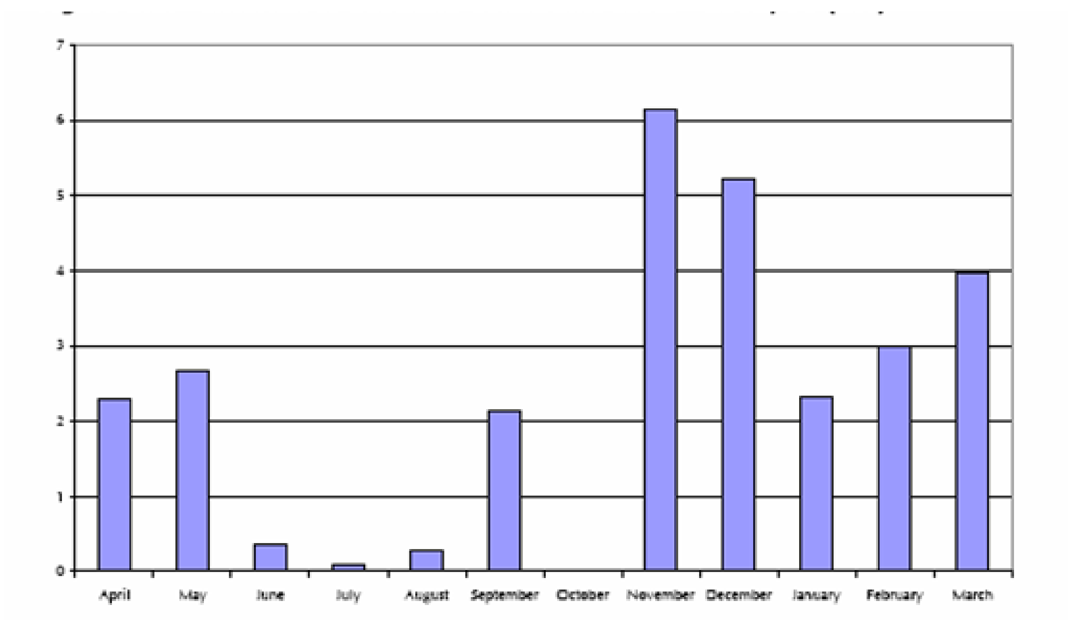


Figure 8: Internal to Scotland Constraint costs - 2005/06 (£M)

*(Source: OFGEM, 2006)*

From Figure 8, it shows that from the month of April to October 2005, the cost incurred to manage the constraints within Scotland was approximately £7.9 million. In the following month alone, further cost of over £6 million were incurred by NGET for the NLOANSSE constraint, and total internal to Scotland constraint management costs for the year eventually exceeded £28 million (OFGEM, 2006).

This has put the local generators in NLOANSSE area under scrutiny whether they were taking the limited import capability of that area to their advantage by not self dispatching with the intention to manipulate the price. The power plant that is in question is Peterhead Power Station owned by SSE as this power plant has two large Balancing Mechanism Units (BMUs). These two units were expected by NGET to self-despatch since they have the multi-fuel capabilities which is known to be able to operate on National Transmission System gas, Miller gas and oil. This was also backed by the fact that these units had just come back from the maintenance and possessed among the relatively high generation efficiency compared to other plants in GB.

Therefore, this case study will investigate if Peterhead Power Station has been exercising the market power especially for the month of November 2005 where the demand started to hike up due to winter season. Comparison was made between Peterhead CCGT and other CCGTs that are about the same age as Peterhead (T_PEHE-1) which are Sutton Bridge (T_SUTB-1), South Humber Bank (T_SHBA-2), Seabank (T_SEAB-1), Saltend (T_SCCL-1) and Brimsdown (T_EECL-1). All of these CCGTs were commissioned in between year 1998 and 1999.

## 5.2 Qualitative Analysis

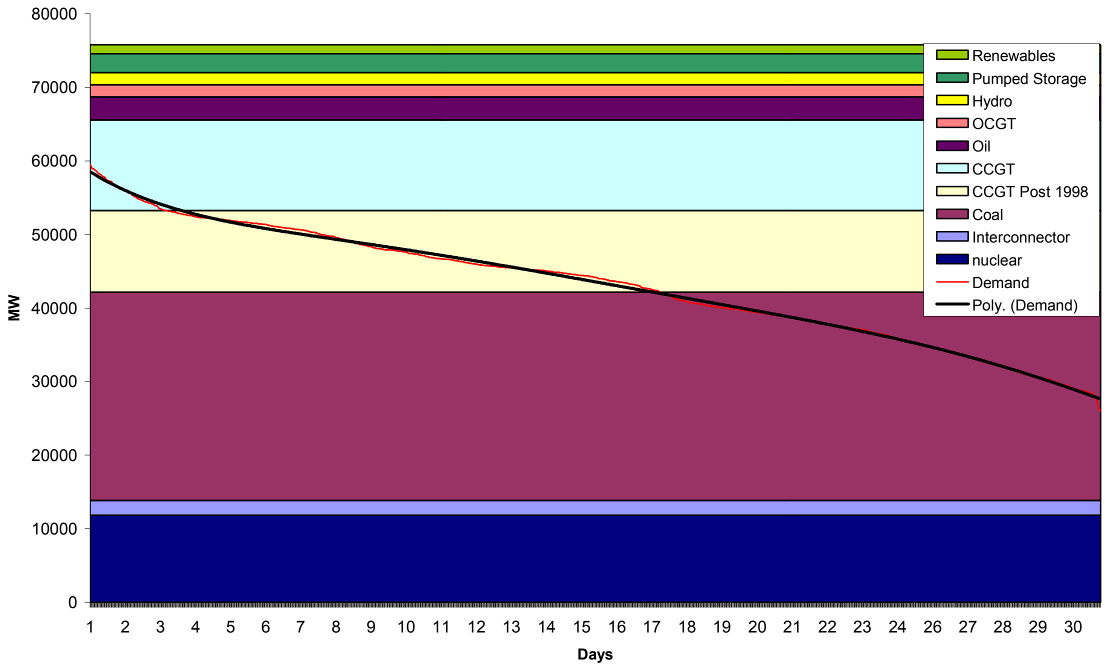


Figure 9: Plant Dispatch Ranking

*(Source: National Grid, 2007)*

The plants dispatch ranking as shown in Figure 9 was modeled based on generating cost of all the technologies which was derived from winter 2005/06 forward prices for fuel. The technologies with the cheapest generating cost will have to occupy the bottom of the graph, or in other words, to be the first generator to self-despatch. This type of generators is called base-load generators and in this case, nuclear generators turn out to be with the cheapest generating cost which then followed by the interconnector, coal generators and the list continues from the cheap to the most expensive generators.

The CCGTs that are under study which categorized as CCGT Post 1998 were supposed to be ranked after the coal generators. This is because this group of CCGTs has a lower generating cost as a result of better efficiency as compared to the older CCGTs. In this study, based on the electricity demand for the whole month of November 2005, and with the assumption that there were no plants on outage, the cheapest CCGT would have to self dispatch for about 16 days for that particular month. On the other hand, the most expensive CCGT of Post 1998 group would only have to self dispatch for approximately 3 days. However, the number of days for the CCGTs to self dispatch might increase with the unavailability of higher ranking generators.

As for Peterhead CCGT, for the month of November 2005, it only self-despatched for about 11 days. By excluding the number of days that it was not available (MEL equals to 0), which was about 10 days, the Peterhead CCGT had self despatched for approximately 55% of the time that it declared to be available i.e 11 out of 20 days. This can be seen in a graphical form as shown in Figure 10. The details can be seen from the data provided by National Grid in their Balancing Mechanism Report.

This percentage might suggest that Peterhead CCGT is among the cheapest CCGT in the system that if it were available throughout November 2005, it might be self-despatching 55% of the time of the month. That means if it only self dispatch during the day time, it can cover the peak hour for the whole month. However, the concern is when Peterhead is not able to self dispatch when it matters that is when the demand is high as it may cause transmission constraints to NLOANSSE area. As explained by NGET to OFGEM that from their study, the transmission constraints for winter can only be alleviated if 200MW is self-despatched from the total generators capacity of 2000MW in the NLOANSSE area which is made up of Peterhead, Fife and Foyers power stations. Foyers is a pumped storage station and hence, it should be naturally self-despatched after Peterhead and Fife power stations but subjects to the availability of water supply. At some points, Foyers may not be able to self dispatch as it has to pump back the water to its reservoir. Fife is a CCGT but its total capacity is only 123MW and this is still not sufficient to resolve the transmission constraint. Hence, the contribution from Peterhead is really significant and from economic point of view, its CCGT block needs to be despatched should it be available. In fact, the dispatch of just one unit would be enough to alleviate the constraint.

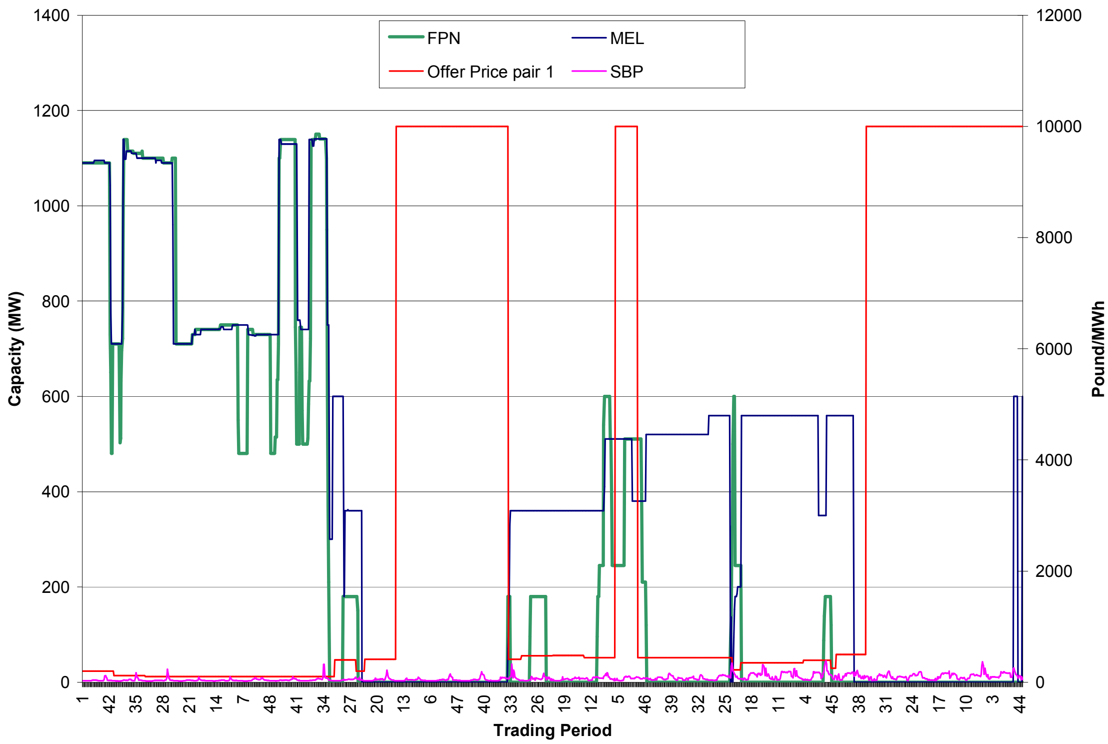


Figure 10: Peterhead Physical Data and Offer Price
(*Source: Elexon, 2007)*

This situation has put Peterhead in a position whereby it can take the limited import capability of transmission system of that area to its advantage. This can be done by choosing not to self despatch the plant and take advantage of high offer price in the spot market or balancing mechanism. With the location advantage that it possesses, Peterhead has all the potential to exercise the market power.

In order to examine whether market power has been exercised by Peterhead, the information and relationship between its physical data and offer prices declared in the balancing mechanism can be very useful. In Figure 10, it indicates that the offer prices declared by Peterhead were constantly higher than the System Buy Price (SBP) for most of November. The offer price declared by Peterhead started off at the average price of £150/MWh on the first day of November before the price dropped to £120/MWh on the second day. After that, the offer price remained at £100/MWh until 8th November 2005.

Within this period, their offer had been accepted on the 15th period of 2nd November and from period 40 to 44 on the 8th November. For the offer acceptance on 2nd November, there was no indication of market power exercised as the unit self despatched at a capacity close to its maximum MEL even though the price offered was relatively high (£85 higher) compared to SBP. However, for the offer acceptance on 8th November, there was an indication of market power exercise when the unit stopped to self despatch at the period of 43 and 44 even though the unit was declared to be available. Nonetheless, this evidence was not strong enough as this occurred when the system's demand was decreasing. The offer price for that period even though was low for Peterhead but was still very high as compared to SBP and other CCGTs offer price average which was about £47/MWh and £57/MWh respectively.

As for 9th November, the offer price declared by Peterhead was quite high which was at £400/MWh before it went slightly lower to end up at £200/MWh from period 35 until the end of the day. The increase in the offer price is believed due to increase in gas price as shown in Figure 11. However, there were offer accepted within this period which was from trading period 35 to 44. **There was a clear indication of market power exercised by Peterhead here as the CCGT unit was not self despatched from period 39 to 44 event though trading period 39 to 41 was still considered as peak hour. Although the offer price declared was showing a decreasing trend during that period, the offer price of £200/MWh was still way above SBP and the offer price submitted by T_SUTB-1 (which was running at FPN of 520MW out of its maximum 750MW) which were about £57/MWh and £61/MWh respectively. The comparison is made with T_SUTB-1 because it was the only CCGT of its category that available for balancing mechanism at that moment**

The offer price increased to £415/MWh for the whole day of 10th November 2005 even though the unit was declared unavailable since the MEL was declared as 0. The unit remained unavailable until midday 14th November 2005. From that point on, the offer price declared by Peterhead was £415/MWh until the end of the day. **The offer was accepted from period 32 to 37 and there was once again a clear indication of market power exercised by Peterhead since the CCGT unit was not self despatched despite it was declared available at MEL of 360MW. On top of that, the offer price declared was very high, which was £375.50 higher than SBP and £348 higher than price average of T_SUTB-1 and T_EECL-1. They might blame it on the gas price increase as shown in Figure 11 but other CCGTs like T_SUTB-1 and T_EECL-1 were able to keep their offer price much lower which made the gas price excuse as unacceptable to justify the offer price of £415/MWh unless Peterhead had been dependent on spot market purchases of gas.**

The price was set even higher on 15th November 2005 where the price was £475/MWh before it increased a little bit more to £480/MWh the next day where the station chose not to self despatch the unit for the whole day until period 20 on 17th November 2005 when its MEL was declared as 0. The unit was self despatched from period 21 until the end of the day and the offer price was set lower to £440/MWh throughout that period. There was offer acceptance from period 46 to 48, where the unit self despatched with FPN of 245MW. At this point, there is a possibility that the station was attempting to exercise market power by experimenting to see what level of power NGET would accept an offer since it didn't know the size of the constraint. On top of that, the possibility of market power was strengthened when it comes to the price whereby the offer price for that period was £440/MWh which was very much higher compared to SBP, £51/MWh and T_SUTB-1 and T_EECL-1 average at £59/MWh.

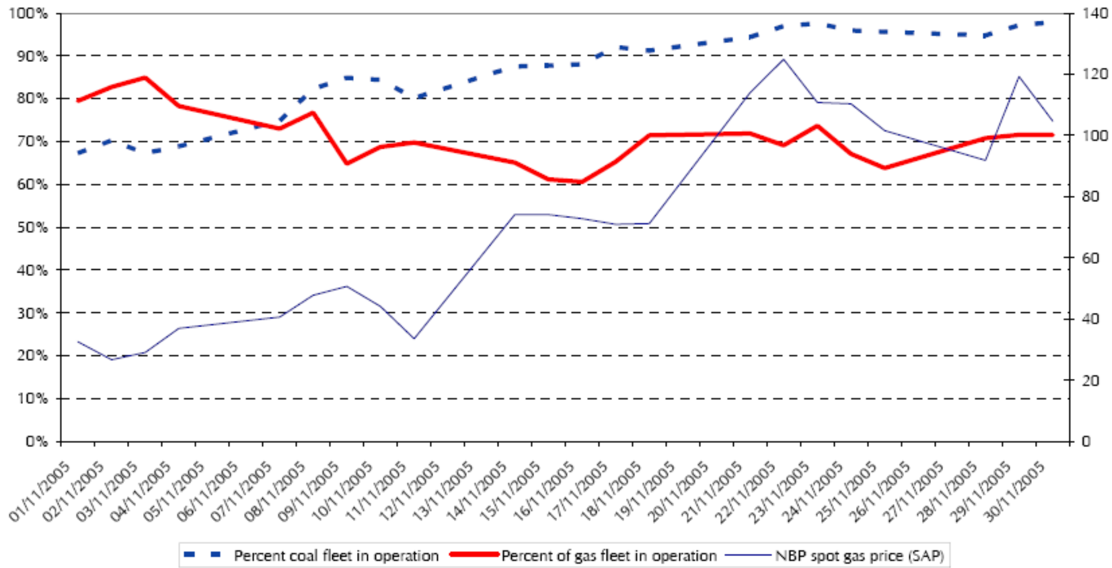


Figure 11: NBP spot gas price

*(Source: OFGEM, 2006)*

There was no more offer acceptance after 17th November 2005 but there were a few days where the unit was not self despatched which from 19th November 2005 to midday 21st November 2005, 22nd November 2005 to midday 24th November 2005 and finally the whole day on 25th November 2005. After that date, the unit was declared as unavailable for the rest of the month. This is believed due to physical problems that the unit might have or probably due to shortage of gas supply. This left the system to be run in insecure manner. However, this didn't involve any market power activities.  As for the offer price, it varied but remained high from £220/MWh to £9999/MWh (when it was unavailable).

## 5.3 Quantitative Analysis

There are a few ways that can be used in calculating market power. Based on the availability of the data, these two indices had been chosen namely Herfindahl-Hirshman Index (HHI) and Lerner Index.

### 5.3.1 Herfindahl-Hirshman Index

Herfindahl-Hirshman Index has been traditionally used for concentration screening for a specific market. The concentration screening is needed because it gives early indications of the potential market power in a market. The underlying assumption for the use of HHI for market power analysis is that it is directly correlated to market concentration.

In evaluating market concentration using HHI, if the HHI value is less than 1000, then it indicates that the market is not concentrated. If the HHI value is in between 1000 and 1800, then this shows that the market is moderately concentrated. However, if HHI value is greater than 1800, that means the market is highly concentrated.

In this case study, due to transmission constraint, HHI was applied to NLOANSSE area. Power plants that are under scrutiny in this area are Peterhead, Fife and Foyers. Peterhead Power Station consists of one block of CCGT, two units of OCGT and one unit of oil/gas-fired steam turbine which makes its total installed capacity to be 2359MW. However, due to transmission system at Peterhead, the production is limited to 1550MW. Fife Power Station consists of two block of small CCGT with total installed capacity of 123MW while Foyers is a pumped storage power station with total installed capacity of 300MW. The availability and operation regime of Foyers is very much dependent on the volume of water that it pumps and stores. However for HHI calculation, the capacity of 300MW was used.

| No | Plant | Installed Capacity (MW) | Capacity with Constraint (MW) | Share in the market,s (%) | $s^2$ |
|---|---|---|---|---|---|
| 1 | Peterhead | 2359 | 1550 | 79 | 6241 |
| 2 | Fife | 123 | 123 | 6 | 36 |
| 3 | Foyers | 300 | 300 | 15 | 225 |
| | Total | | 1973 | HHI | 6502 |

Table 1: HHI for NLOANSSE area

In Table 1 above, the HHI value for NLOANSSE area shows that the electricity supply market in that area is highly concentrated as its HHI value exceeds 1800 levels to end up at 6502 with Peterhead Power Station possesses the biggest share with 79%. With the transmission constraint in place, the chance for Peterhead to manipulate its offer price in the spot market is widely opened. Hence, this shows that Peterhead has the potential to exercise market power in order to alleviate the transmission constraint in NLOANSSE area.

### 5.3.2 Lerner Index

Lerner Index measures the mark up price above marginal cost which is given by L= (P-MC)/P where P is selling price and MC is marginal cost. A Lerner Index of close to zero is a sign of a competitive market whereas a Lerner Index that exceeds 0.5 is a sign of market monopoly or market power exercising. However, the challenge here is to calculate the marginal cost since this parameter is kept as confidential by the generators.

In a competitive electricity market, prices should finally settle at marginal cost or slightly above marginal cost, to the level the last customer is willing to pay (Vassilopoulos, 2003). Hence, the price would be equal to the offer price of marginal unit. This can be illustrated using supply demand curve as shown by the example in Figure 12 below.

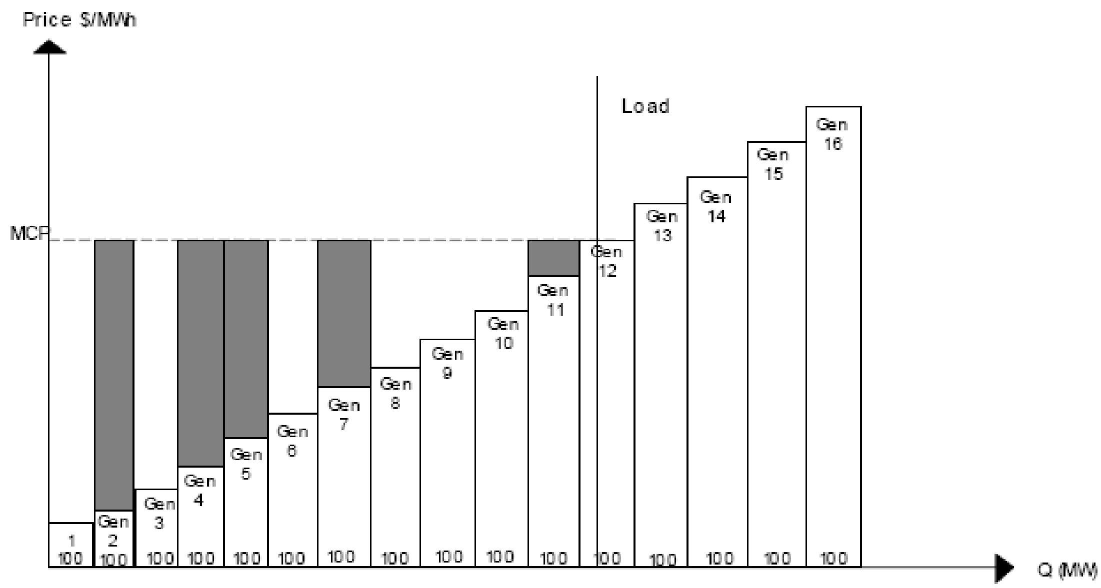


Figure 12: Supply Demand Curve

*(Source:* Vassilopoulos, 2003)

This supply demand curve is constructed based on two assumptions which are:

1. Firm always starts a plant with lower marginal cost before a plant with higher costs.
2. The firm does not start new plant before the previous plant reaches its current maximum capacity.

However, in the balancing mechanism, the marginal cost is deemed as System Buy Price (SBP) which is given by:

$$SBP = \frac{\text{total cost of priced accepted offers} + BCA}{BVA} + BPA$$

Where;

BCA = Buy-Price Cost Adjustment
BPA = Buy-Price Price Adjustment
BVA = Buy-Price Volume Adjustment

SBP is analogous to the marginal cost given by supply demand curve in the sense that the price is influenced by the highest offer price made by the generators.

In this case study, SBP will be used as marginal cost in calculating the Lerner Index of T_PEHE-1 (a CCGT block in Peterhead Power Station). Lerner Index was used and tested on the days where offers by T_PEHE-1 were accepted in the Balancing Mechanism. This is to investigate whether BM unit of T_PEHE-1 had been exercising market power during the period of acceptance because there is a possibility that NGET had no choice but to accept the offers by T_PEHE-1 in order to mitigate the transmission constraint in NLOANSSE area and T_PEHE-1 on the other hand might have manipulated this by offering a high price relative to the system marginal cost.

| Period | Plant | T_PEHE-1 |
|---|---|---|
| 14 | Selling Price (£/MWh) | 120 |
| | Marginal Cost (£/MWh) | 27.6 |
| | Lerner Index | 0.8 |
| 15 | Selling Price (£/MWh) | 120 |
| | Marginal Cost (£/MWh) | 34.8 |
| | Lerner Index | 0.7 |

Table 2: Lerner Index Analysis for Peterhead for 2nd November 05

The analysis begins with the offer accepted on 2$^{nd}$ November 2005 as shown in Table 2. From the analysis above, on 2$^{nd}$ November 2005, it shows that the Lerner Index is higher than 0.5 for both periods which means that there is high possibility that Peterhead was exercising market power. Nevertheless, from the balancing mechanism data published by Elexon, T_PEHE-1 was self-despatched at a capacity close to their MEL and more importantly far higher than 200MW, the minimum capacity that is believed by NGET would be able to alleviate the transmission constraint in NLOANSSE. This shows that Peterhead had had no intention to manipulate the transmission constraint at the point of time.

Hence, even though the Lerner Index suggests that there was an absolute market power; other factors like plant self dispatch might outdo the former verdict. Now another issue, which is high selling price, arises and several assumptions can be made out of this which will be discussed in the later part of this section.

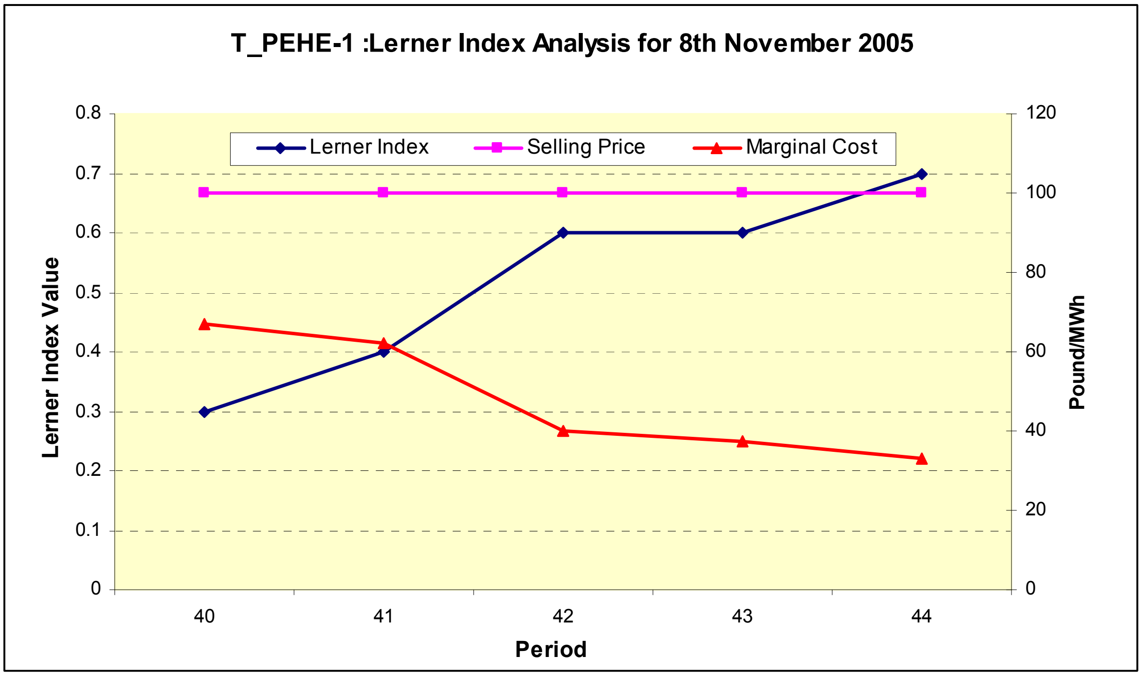


Figure 13: Lerner Index Analysis for T_PEHE-1 for 8th November 2005

As for 8th November 2005, from the analysis, Figure 13 shows that there is low possibility of market power was exercised by Peterhead on period 40 to 41 as the Lerner Index are lower than 0.5. This is believed due to the relatively high marginal cost as period 40 to 41 are still considered as part of peak hours where the demand was relatively high. Furthermore, T_PEHE-1 was self-despatched close to its MEL for period 40 and half of its MEL for period 41 where both of capacities were higher than 200MW level.

However, when the marginal costs started to go down from period 42 onwards, the Lerner Index shows some bigger values which are more than 0.5. There is a possibility of market power exercising here. This is supported by the data published by Elexon showing that T_PEHE-1 reduced its dispatch capacity to be around 200MW in period 42 before it totally stopped self-dispatching after that period. There is also a possibility of Peterhead trying to guess the minimum dispatch capacity to alleviate the constraint. Perhaps, having known the minimum capacity will make it easier for them to manipulate their production and prices. On top of all these, the fact that its offers were accepted during this period, kind of give a quite clear indication that Peterhead was exercising market power for period 42 to 44 on 8$^{th}$ November 2005.

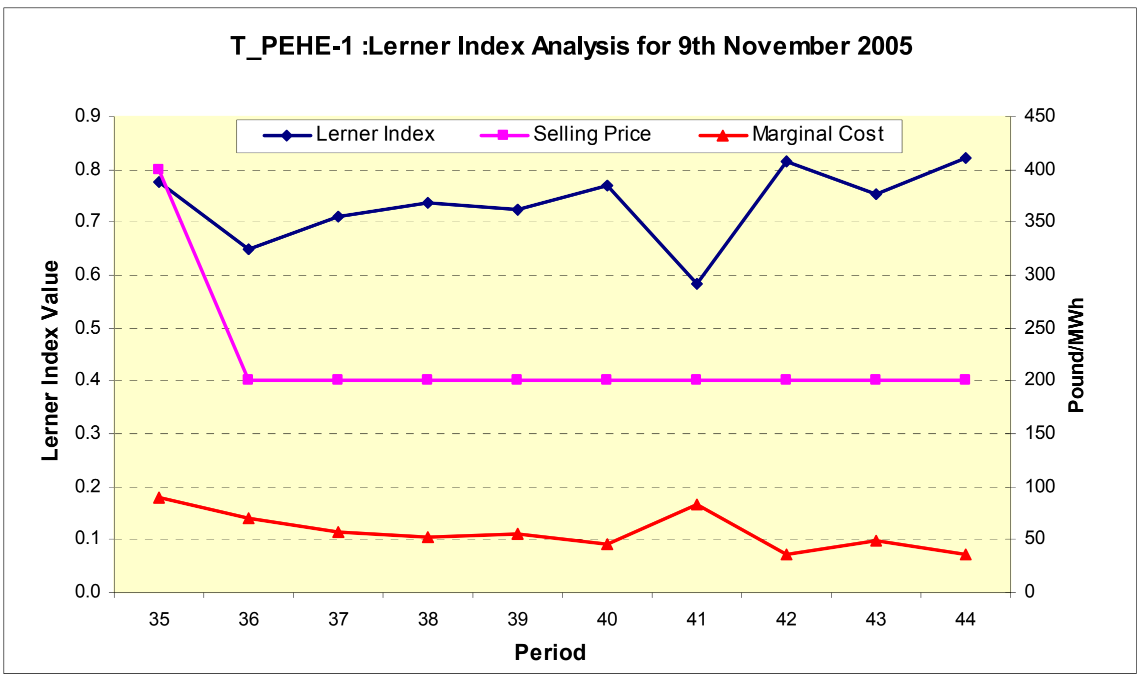


Figure 14: Lerner Index Analysis for T_PEHE-1 for 9$^{th}$ November 2005

The Lerner Index analysis for 9$^{th}$ November 2005 is as shown in Figure 14 above. It is found that all the Lerner Index values throughout the period under study are more than 0.5. Based on this, there is huge possibility that market power has been exercised during this period of time. This is supported by the fact that the offers were accepted during the peak hour where the supply capacity is believed to be a bit tight. This opportunity might be taken by Peterhead to manipulate the self-dispatched capacity as well as the selling price to their advantage. It can be seen at period 35 whereby the selling price declared by T_PEHE-1 was as high as £400/MWh while the marginal cost ended up at £89/MWh. This makes the Lerner Index value to be about 0.8 at that particular period.

From the data published by Elexon, it shows that T_PEHE-1 was self-despatched at a capacity lower than 200MW from period 35 to 38. It was not known whether they were self-despathcing to meet the bilateral contract or self-despatching on behalf of other SSE plants in order to investigate the minimum capacity needed to mitigate the constraint. What ever it was, there is a possibility that Peterhead was testing the market in order to get the minimum capacity needed to alleviate the constraint and if it is true, this will strengthen the fact that market power has been exercised by Peterhead from period 35 to 38.

From period 39 to 44, based on the data published by Elexon, the T_PEHE-1 has stopped self-despatching by declaring the FPN to be zero while the Lerner Index remains high. This happened during the peak hour and there is a possibility that NGET had no choice but to accept the Peterhead's offer in the balancing mechanism in order to mitigate the transmission constraint in NLOANSSE. If this is the case, based on the high Lerner Index in Figure 14 and data published by Elexon, it is believed that there is high possibility that Peterhead was exercising market power on 9th November 2005 from period 39 to 44.

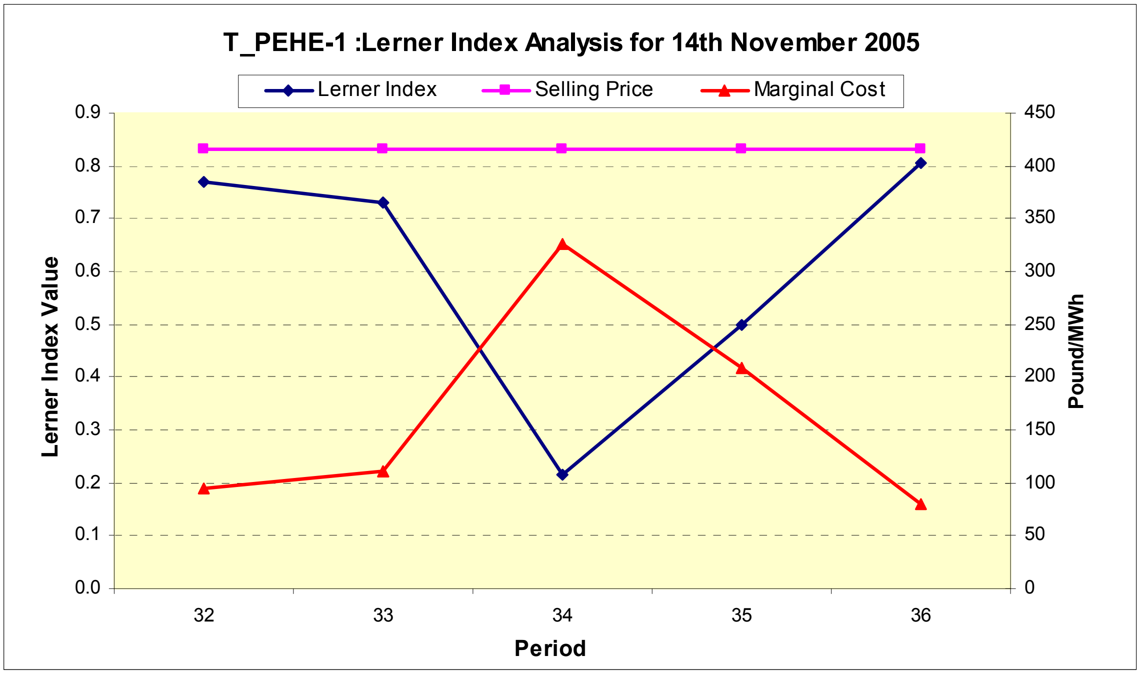


Figure 15: Lerner Index Analysis for T_PEHE-1 for 14th November 2005

Figure 15 shows the Lerner Index analysis for 14th November 2005 where the prices offered by T_PEHE-1 even though high, were still accepted by NGET. This is again believed due to transmission constraint in NLOANSSE area especially during peak hours. The Lerner Index for the study period started off at a high value of 0.8 before it slightly dropped to 0.7. During these two periods, ones can say that there is a possibility of market power exercise with the high values of Lerner Index.

However, with the same selling price, the Lerner Index dropped to 0.2 at period 34 before it picked up to 0.5 at period 35. The sudden drop in the Lerner Index is due to rise in marginal cost during these two periods. This was believed due to gas price increase in the gas spot market (hike up to approximately 70 pence/therm) which coincided with the weekday peak hours. For these two periods, there is no clear indication of market power exercised by T_PEHE-1 even though they probably have planned some strategic bidding.

However, when the marginal cost decreased for the next period, the selling price of T_PEHE-1 remained at £415/MWh which makes the Lerner Index to be about 0.8. This is high enough to justify the exercise of market power by T_PEHE-1. There is a possibility that T_PEHE-1 purposely put the price at that high level just to take advantage of balancing mechanism when the NLOANSSE constraint arises during the peak hours. They probably thought that their high selling price can be covered up by the increase in gas price. However, the Lerner Index value just didn't suggest so. Hence, there is a clear indication that there is possibility of market power exercised by T_PEHE-1 during period 36 of 14$^{th}$ November 2005.

All of the judgments for 14$^{th}$ November 2005 above can be supported by the data published by Elexon which shows that T_PEHE-1 was not self-despatched throughout the period under study. It can be seen as an attempt to maximize their profit through balancing mechanism. Hence, this might strengthen all the judgments made earlier and now it is strongly believed that Peterhead had been exercising market power on 14$^{th}$ November 2005 from period 32 to 36.

| Period | Plant | T_PEHE-1 |
|---|---|---|
| 46 | Selling Price (£/MWh) | 427.5 |
| | Marginal Cost (£/MWh) | 56.3 |
| | Lerner Index | 0.9 |
| 47 | Selling Price (£/MWh) | 427.5 |
| | Marginal Cost (£/MWh) | 30.0 |
| | Lerner Index | 0.9 |

Table 3: Lerner Index Analysis for Peterhead for 17th November 2005

The last two offers from T_PEHE-1 in November 2005 that were accepted by NGET were on November the 17$^{th}$ for period 46 and 47. The selling price accepted was £426/MWh which formed the highest among all of Peterhead's accepted selling prices. This high price pushed the Lerner Index to as high as 0.9 which suggests that market power has been exercised by T_PEHE-1.

From the balancing mechanism data published by Elexon, it is shown that T_PEHE-1 was self-despatched at a capacity slightly higher than 200MW. Considering that Peterhead didn't know the minimum capacity required to alleviate the constraint, this can either be seen as a normal contracted dispatch or an attempt to make a strategic dispatch. If the latter that counts, then it seems to support the Lerner Index results which suggest that the market power has been exercised by T_PEHE-1 on 17th November from period 46 to 47. Otherwise, there is no clear indication whether T_PEHE-1 has been exercising the market power even though the Lerner Index values suggest that the market power has been exercised.

## 5.4 Case Study Conclusion

1. HHI shows that the power market in NLOANSSE area is highly concentrated which gives an opportunity for Peterhead to exercise market power.
2. From the Lerner Index result and supplement data by ELEXON, it is believed that Peterhead had been exercising market power on 8th , 9th and 14th November 2005 (when its offers were accepted by NGET) by manipulating its dispatch capacity and offer price in order to maximize their profit in balancing mechanism.
3. However, there is no clear indication of market power exercising on 2nd and 17th November as the capacity dispatched can be considered as high and at the same time the offer price declared was also high.
4. From the qualitative analysis, there were some events where Peterhead power station is believed to exercise the market power to their advantage as the result of limited import capability of transmission system in

NLOANSSE area. These events happened on 8$^{th}$ , 9$^{th}$ and 14$^{th}$ November 2005 which consistent with the result given by Lerner Index

5. There were also a few other events where the station is suspected attempting to exercise the market power especially on 17$^{th}$ November 2005.
6. From all points above, based on the consistency of the analysis that were done qualitatively and quantitatively, it is concluded that Peterhead power station has been exercising market power on some periods on 8$^{th}$, 9$^{th}$ and 14$^{th}$ November 2005 by withholding its capacity and offering high offer prices in balancing mechanism that profitably increase the income of the station.
7. It is also concluded that Peterhead had made an attempt to exercise market power on 17$^{th}$ November 2005.

# CHAPTER 6: CASE STUDY 2 – MARKET POWER INVESTIGATION ON 13 MARCH 2006 EVENT

## 6.1 Background

In Great Britain, there were days where there have been a lot of plant failures or declared as unavailable and the only available replacement plant happened to be owned by just one or two company. One of the days concerned was on 13 March 2006. It was reported that a relatively high balancing cost was recorded on that particular day with the peak SBP of £517/MWh.

According to Price (2006) it was believed that the high balancing costs was driven by the factor of high gas price due to the cold weather whereby the gas demand was high while the supply was limited. This was made worse by the unavailability of Rough storage gas. Significant volumes of additional plant were required to meet demand and reserve requirement. However, high volumes of Scottish plants were restricted by Cheviot constraint with high cost of replacement.

This urged the system operator to issue Notice of Insufficient System Margin (NISM) at 23:00 on Sunday (the day before) with 1500MW shortfall. NISM was updated at 05:00 on Monday, 13 March 2006 with 1000MW shortfall and again at 09:40 with 600MW before it was cancelled at 12:00. According to National Grid (2006), the market was short most of the day with over 3GW short at Darkness Peak (DP). Things got worse when the demand peak was 56.6GW, which was above final forecasts of Balancing Mechanism Reporting System (BMRS) and control room (Price, 2006).

It was believed that there were plants that tried to take advantage of high gas price in the spot market by withholding their capacity that significant Balancing Mechanism Units (BMUs) were accepted with offer price more than £600/MWh. Hence, this study is carried out to ascertain whether the event of 13 March 2006 was under the influence of market power exercise or vice versa.

## 6.2 Qualitative Analysis

The 13 March 2006 event was an extensive event where the whole players of the system were required by the system operator to review their respective availability. Hence, the whole players in the system, especially owners of the plants need to be screened in order to investigate the possibility of market power exercise. For that purposes, the plants were clustered according to their participation in balancing mechanism whereby only plants with accepted offers were put under scrutiny. The plants then were grouped according to their owner before further analysis was carried out.

It was found that on 13 March 2006, there were a number of firms that benefited from balancing mechanism where some of them were making a lot of profit from the high price offered. Figure 16 below shows the amount of cash flow that the involved firms have gained from balancing mechanism on that particular day. It is shown that there were four firms have gained more than £1 million from the balancing mechanism on that day itself whereby E.ON recorded the highest earning which is approximately £6 million followed by Seabank, Scottish Power and RWE. However, in this thesis, due to time constraint, the analysis will only focus on E.ON where market power investigation will be made on its related power stations especially on physical withholding and financial withholding.

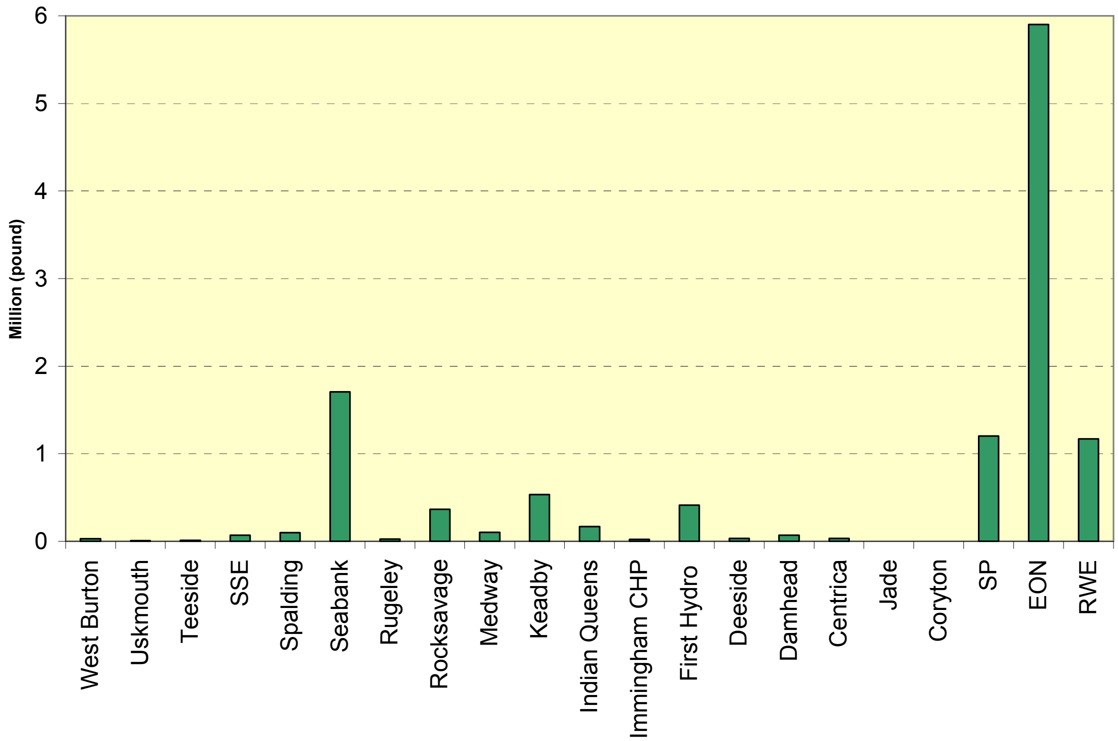


Figure 16: Comparison of cash flow gained from balancing mechanism on 13 March 2006

(Source: Elexon, 2007)

### 6.2.1 Physical Withholding

Physical withholding of a firm can be examined from plants' Maximum Export Limit (MEL) and Final Physical Notification (FPN). MEL will show whether a unit is available to the system or not. If MEL is declared more than zero, that means the unit is available to be dispatched while if MEL value is declared to zero that shows that the unit is not available due to reasons such as outages or it can also be a strategy for physical withholding.  As for FPN, if it is set to zero that means that particular unit is not being dispatched even though it is declared as available. On the other hand, if it is set more than zero that means the unit is being self dispatched in order to meet the contracts that have been committed by the unit's owner.

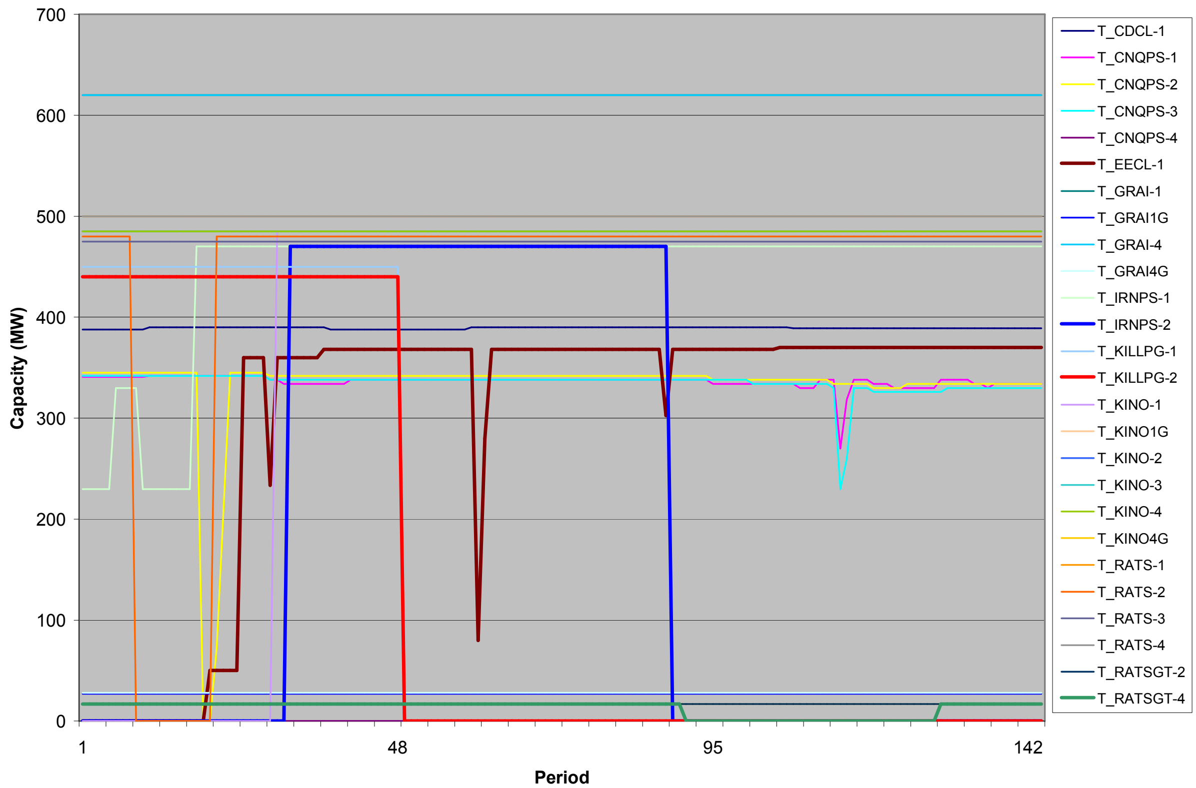


Figure 17: MEL of E.ON plants from 12 to 14 March 2006

Figure 17 shows the maximum export level that has been declared by units owned by E.ON from 12 March 2006 to 14 March 2006. That figure is presented in period form whereby period 1 to period 48 represents the periods for 12 March 2006 while period 49 to period 96 are for 13 March 2006 and period 50 to period 144 are for 14 March 2006. From all of the units owned by E.ON it is seen there were only three units declared unavailable on March the 13th which are T_CNQPS-4, T_KILLPG-1 and T_KILLPG-2. All of these three are CCGT units with total capacity of approximately 1235MW. Out of those three, T_KILLPG-1 (450MW) and T_KILLPG-2(440MW) were declared available at their full capacity on 12 March 2006 but suddenly declared as unavailable on March the 13th. Therefore, this indicates that there is a possibility that E.ON Plc was trying to withhold 890MW of its capacity even though they might argue that the units were having technical problems or running out of gas. However, considering that E.ON has gained a quite big amount of money from balancing mechanism, there is still a possibility that E.ON has been exercising market power by withholding some of its capacity.

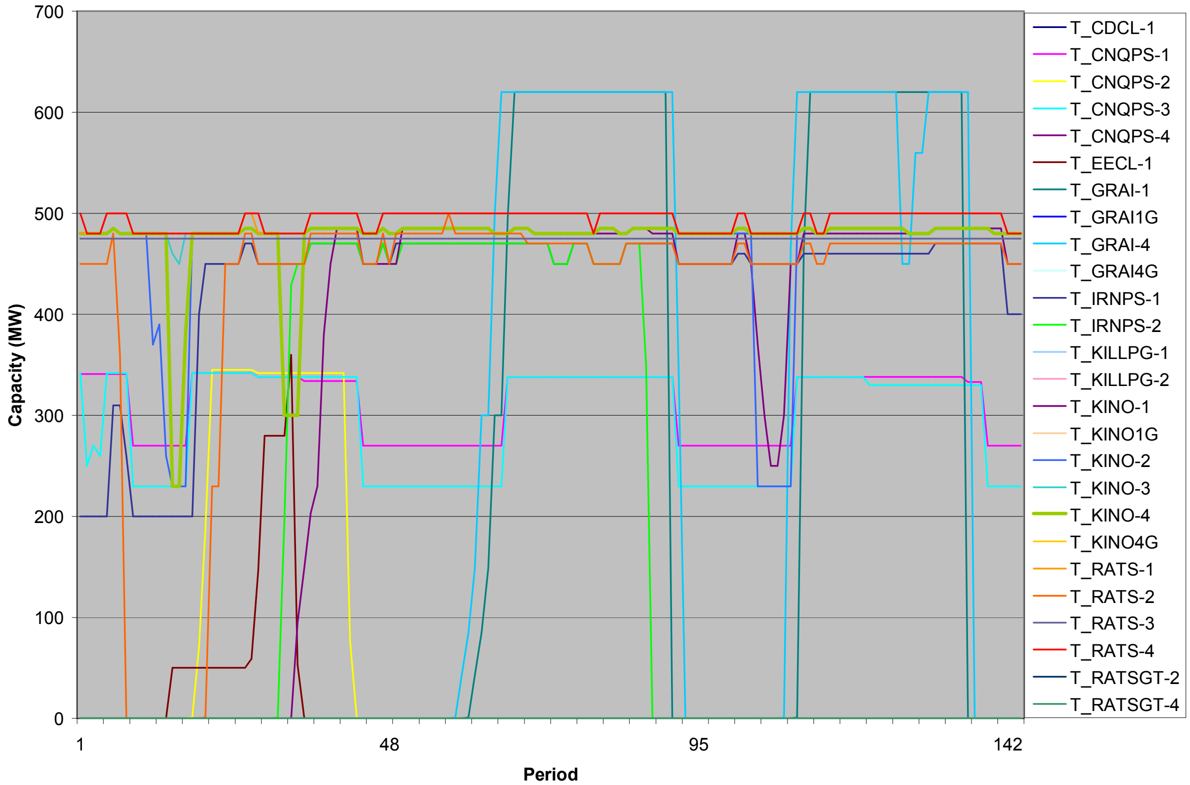


Figure 18: FPN of E.ON plants from 12 to 14 March 2006

Figure 18 shows the level of FPN that have been declared by units owned by E.ON from 12 to 14 March 2006. Similar like Figure 17, period 1 to 48 represent the periods on 12 March 2006, while period 49 to 96 are for 13 March 2006 and period 96 to 144 are for 14 March 2006. On 13 March 2006, there were 8 units that were declared as available but were not self-despatched. These 8 units are T_CDCL-1, T_CNQPS-4, T_EECL-1, T_GRAI4G, T_KINO1G, T_KINO4G, T_RATSGT-2 and T_RATSGT-4. Out of these eight, three of them are CCGT which are T_CDCL-1, T_CNQPS-4 and T_EECL-1 with total capacity of approximately 1148MW while the remaining are OCGTs. Considering the fact that T_KILLPG-1 and T_KILLPG-2 were unavailable, these 3 CCGTs was expected to self-dispatch should E.ON was to make up the loss of capacity in order to meet their bilateral commitments. However, these three CCGTs were not self dispatched and it is believed that E.ON was trying to take advantage of high gas price in the spot market by participating in balancing mechanism in order to meet their contractual commitment and hence to keep the system balanced.

Therefore, there is a possibility that E.ON was trying to exercise market power and to further investigate this, analysis will be made in terms of financial withholding in the next sub-section.

### 6.2.2 Financial Withholding[3]

In the balancing mechanism, the offers by three of CCGTs owned by E.ON were accepted at almost most of the time on 13 March 2006. According to Elexon (2007), on that particular day, offers from T_CDCL-1 were accepted from period 15 to 45 while offers from T_CNQPS-2 and T_EECL-1 were accepted from period 10 to 44 and from period 9 to 45 respectively. These acceptances over a relatively long period of time might enable E.ON to make a lot of profit if the offer prices were way above the marginal cost or in this case the SBP.

Figure 19 below shows the comparison of the accepted offer prices of those three CCGTs with the SBP. From that figure, it indicates that the accepted offers exceeded the SBP most of the time except that for period 28 for T_CDCL-1. The maximum offer price recorded was £650/MWh which was accepted from all of these CCGTs. It is believed that the high offer prices were accepted during that period of time due to significant market short and also due to the naturally low demand responsiveness. This allows the players, in this case E.ON, to exercise market power by implementing financial withholding.

[3] Financial withholding is defined as asking a price above the marginal cost (Stoft, 2002).

Taking all these into account, it is believed that there was a high possibility that E.ON has been exercising the market power by implementing capacity withholding and financial withholding. Nevertheless, quantitative analysis still needs to be carried out to confirm this inference.

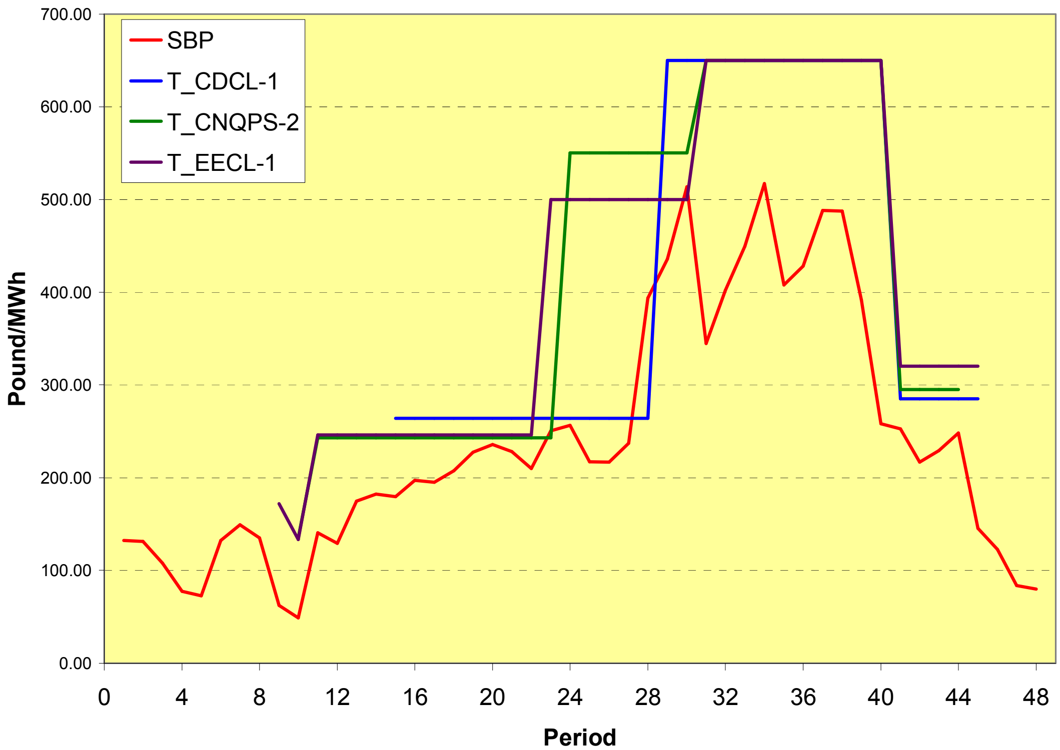


Figure 19: Comparison of accepted offer prices of T_CDCL-1, T_CNQPS-2 and T_EECL-1 with SBP

## 6.3 Quantitative Analysis

Quantitative analysis for this case study was intended to be carried out using Cournot Model and Bertrand Model because it involves vast data and long calculations. However, due to the time limitation, this modelling and analysis will not be carried out and discussed in this thesis.

## 6.4 Case Study Conclusion

If the conclusion is to be drawn solely based on qualitative analysis, it is strongly believed that E.ON has been exercising market power by withholding the capacity from T_KILLPG-1 and T_KILLPG-2 and also by using T_CDCL-1, T_CNQPS-4 and T_EECL-1 to implement the financial withholding in balancing mechanism. These activities have gained E.ON a profitable cash flow in balancing mechanism which was approximately £6 million on 13 March 2006 alone. This is believed to be the main contributor to the high balancing costs on that day. However, this conclusion needs to be supported by qualitative analysis which is not covered in this thesis.

Apart from that, these analyses ought to be extended to all players in the market before a firm conclusion can be made for this 13 March 2006 event which is also not covered in this thesis.

# CHAPTER 7: CONCLUSION

## 7.1 Summary

In an opened and competitive wholesale electricity market, the price of electricity is pushed to the marginal production cost level that provides a win-win situation, both to sellers and buyers. This leaves less room for the seller, or in this case generator, to make extra profits out of their bilateral trading. Balancing mechanism, which serves the purpose of balancing the energy and technical part of power system, has become a platform for the generators to generate extra incomes for the companies.

The manipulation played by the generators to profitably increase their income is called market power which can be exercised by implementing the capacity and financial withholding. This in turn will increase the System Buy Price and hence the electricity price. As a result, the intention of keeping the electricity price at a minimum level may have affected.

Therefore, as mentioned in Chapter 1, the objective of this study is to evaluate the market power exercise particularly in balancing mechanism in GB. It is hoped that by investigating and evaluating the market power exercised, the behavior of the electricity market can be further identified and the market power activities can be minimized or eliminated from the market.

A methodology has been established in this thesis to effectively evaluate the possibility of market power exercise. The methodology suggests that evaluation need to be started off with the data identification and gathering of the case study in question. Market power modelling is then carried out using various models such as HHI, Lerner Index, Cournot Model, Bertrand Model and a few others. The result analysis plays an important part in inferring a conclusion. It is suggested that the analysis is done in two parts where the first part is quantitative analysis which is made to analyze the result given by the applied models. Another part of analysis is qualitative analysis which covers parts that sometimes are not covered by quantitative analysis such as the trend of physical position (MEL and FPN), offer price variation, fuel price pattern and others. These analyses are carried out to complement each other so that a firmer conclusion can be made.

This methodology has been tested using two case studies which are related to market power exercise in balancing mechanism in GB. The first case study was regarding the market power exercised by T_PEHE-1 which was suspected to take advantage of transmission constraint in NLOANSSE area. From the quantitative and qualitative analysis, it was concluded that T_PEHE-1 has been exercising market power in a few periods in November 2005 by withholding their capacity so that they can offer high prices in the balancing mechanism and hence profitably increased their income. This might become a recurring contributor to the high balancing mechanism cost in the future if the alleviation of the transmission constraint in NLOANSSE area still depends on the players. Hence, for a sustainable solution, the transmission line constraint in the area needs to be eliminated by upgrading the capacity of the relevant transmission line. Apart from all these, the first case study also has exposed the behavior of a player when it has the location advantage.

As for the second case study, it was about the generators that were declared to be unavailable only to be replaced by other generators of the same ownership in the balancing mechanism. It was suspected that the owners of the generators were either trying to take advantage or being the victim of the high gas price in the spot market. This issue arose when the generators were making a high offer in the balancing mechanism. However, in this thesis, the study was only focused on E.ON due to time limitation. From the qualitative analysis, it was concluded that E.ON has been exercising market power by withholding the capacity of T_KILLPG-1 and T_KILLPG-2 and made a financial withholding by offering high offer price in balancing mechanism through T_CDCL-1, T_CNQPS-4 and T_EECL-1. This has led to a profitable income of nearly £6 million on 13 March 2006 alone. However, that conclusion needs to be supported by quantitative analysis which is not covered in this thesis.

In general, the methodology and analysis techniques that has been introduced here is believed to have met the objectives of the project which is to evaluate the market power exercise in order to achieve the long term aims that is to understand the behavior of electricity market.

## 7.2 Further Works

This study was started off with the intention to establish a methodology of evaluating market power that integrates the application of various evaluation models. Besides, it was meant to complete two case studies which was hoped to provide more opportunities to test the methodology and evaluation models.

However, due to time constraint as well as the amount of work load, some of the intentions and plans were not materialized. Nevertheless, despite the shortcomings, it is hoped that this thesis has set a starting point for future studies in order to achieve the long term aim, which is to understand the behavior of the electricity market. Hence, the following further works are suggested:

1. Further investigation on 13 March 2006 event by using Cournot Model and Bertrand Model to supplement the qualitative analysis that was done in this thesis.

2. Comparison of characteristics, functions, advantages and disadvantages between different market power evaluation models for easy use in the future.
3. Investigation on other case studies such as 29 December 2005 and 18 July 2006 events for further methodology testing and better understanding on electricity market behavior.
4. Compilation of electricity market behavior for easy reference so that proper actions can be easily taken should the same event happen in the future.

Finally, it is hoped that this thesis may give a significant addition to the resources of electricity market research and contribute to the betterment of the electricity industry.

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# APPENDIX A

(Source: Kirschen and Strbac, 2004)

**Cournot Model Calculation**

Cournot Model is best explained using a duopoly case. Duopoly case is a scenario case whereby there are only two prominent firms, Firm 1 and Firm 2, in the market that compete to sell a particular product. If both firms have to make a decision on the size of production simultaneously, they have to do this by anticipating and forecasting the quantity at which the common product will be produced by its competitor.

Now, assuming that firm 1 estimates that the production of firm 2 will be equal to $y^e_2$. Firm 1 then sets its production at a level $y_1$ that maximizes its expected profit, which is given by equation A1:

$$\max_{y1} \pi(y_1 + y^e_2)y_1 - c(y_1) \qquad \text{(A1)}$$

where $\pi(y_1 + y^e_2)$ represents the market price that would result from the expected productions of the two firms, $y_1 + y^e_2$. Meanwhile, c(y1) is representing the production cost.

Due to the similar process of production optimization, the optimal production of firm 1 thus depends on its estimate of the production of firm 2 and vice versa. This relation can be expressed directly using equation A2 and A3:.

$$y_1 = f_1(y^e_2) \qquad \text{(A2)}$$

$$y_2 = f_2(y^e_1) \qquad \text{(A3)}$$

The estimation is a recursive process whereby it is refined through observation of the market and gathering of more information. Ultimately, their productions reach the Cournot equilibrium described by equation A4 and A5 respectively:

$$y^*_1 = f_1(y^*_2) \quad \text{(A4)}$$

$$y^*_2 = f_2(y^*_1) \quad \text{(A5)}$$

At this point, any changes in the productions would not result in change of profit for both firms.

Now, the same concept is applied to a market where n firms are competing in the same industry. The total production in the industry by all the players is now given by equation A6 and the market price π(Y) becomes a function of the total industry output.

$$Y = y_1 + \cdots + y_n \quad \text{(A6)}$$

So, for Firm i, like all the other firms, who seeks to maximize its profit can achieve it by applying equation A7 or A8:

$$\max_{y_i}\{y_i \cdot \pi(Y) - c(y_i)\}$$

$$d/dy_i \{y_i \cdot \pi(Y) - c(y_i)\} = 0 \quad \text{(A7)}$$

or

$$\pi(Y) + y_i . d\pi(Y)/dy_i = dc(y_i)/dy_i \quad \text{(A8)}$$

At this point, the right-hand side of this equation is equal to the marginal cost of production of firm i. In order to observe the impact of market share of firm i in the industry, π(Y) on the left-hand side of equation A8 is factored out and the second term is multiplied by Y/Y which will result in equation A9 below.

$$\pi(Y)\{1 + y_i/Y \,.\, Y/dy_i \,.\, d\pi(Y)/\pi(Y)\} = dc(y_i)/dy_i \qquad \text{(A9)}$$

Next, if we define the market share of firm i as $y_i/Y$, then the expression shows that if the market share of a firm is not negligible, then the firm (firm i in this case) can maximize its profit by setting its production at a level where its marginal cost is less than the market price.

# APPENDIX B

(Source: Bertrand, 1883)

**Bertrand Model**

Similar to Cournot Model, Bertrand Model is best explained using a duopoly concept whereby two equally dominant firms, Firm 1 and Firm 2, compete with each other over the same product in the same market. However, in contrast to Cournot Model, Bertrand Model emphasis on the price setting of both firms in order to champion the market demand instead of the production size.

In order for either of the firms to set its optimum price, they would need to anticipate the price that their competitor is likely to adopt. In this exercise, each firm will undergo an action-response process that is best represented by a diagram. An example of the response by Firm 1 as result to its anticipation of Firm 2 pricing is given by Diagram B1.

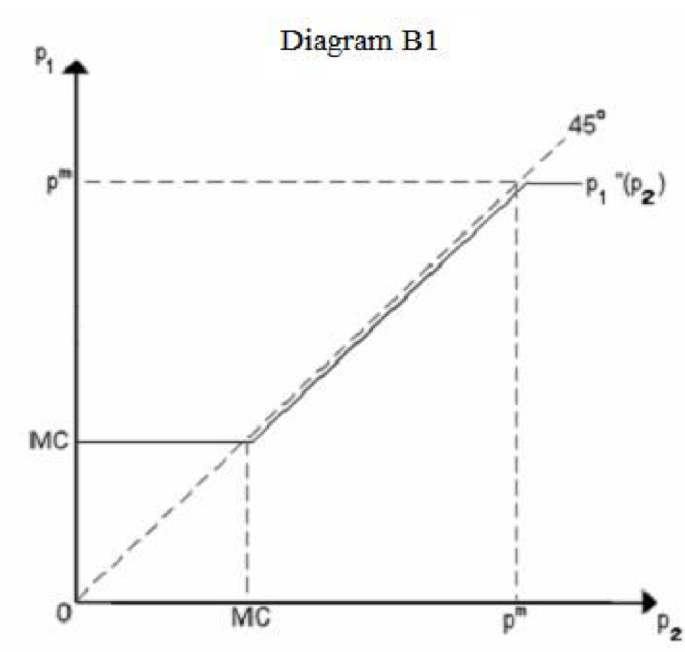


Diagram B1: Response action of Firm 1 on its anticipation of Firm 2 pricing
Where:

| | |
|---|---|
| MC | is the marginal cost |
| $p_1$ | is Firm 1's price level |
| $p_2$ | is Firm 2's price level |
| $p^M$ | is the monopoly price level |

| Firm 2 Action | Firm 1 Response, $p_1$ "($p_2$) | Remarks |
|---|---|---|
| $p_2 < MC$ | $p_1 = MC$ | Firm 1 sets its price at marginal cost when Firm 2 sets its price slightly below marginal cost to avoid from running at a loss. |
| $p_2 > MC$<br>$p_2 < p^M$ | $p_1 < p_2$ | Firm 1 sets its price slightly below $p_2$ when it expects Firm 2 to set its price in between MC and $p^M$. This will enable Firm 1 to win majority of the demand and simultaneously make profit. |
| $p_2 > p^M$ | $p_1 = p^M$ | Firm 1 sets its price at the monopoly price when Firm 2 is anticipated to to set its price higher than the monopoly price. Therefore, Firm 1 will be able to monopolise the market. |

Table B1: Summary of the response action from Firm 1

However, this action-response exercise is not a one way process as Firm 2 will also response in the same manner to its anticipation of Firm 1's price. The response from both firms will eventually result in an equilibrium price or commonly known as the Nash equilibrium price. At this price, the market price will settle at the marginal cost and neither of the firms will change their prices unilaterally in order for them to optimise their profits without losing the market demand. Figure B2 shows the market when the equilibrium price is reached.

Diagram B2

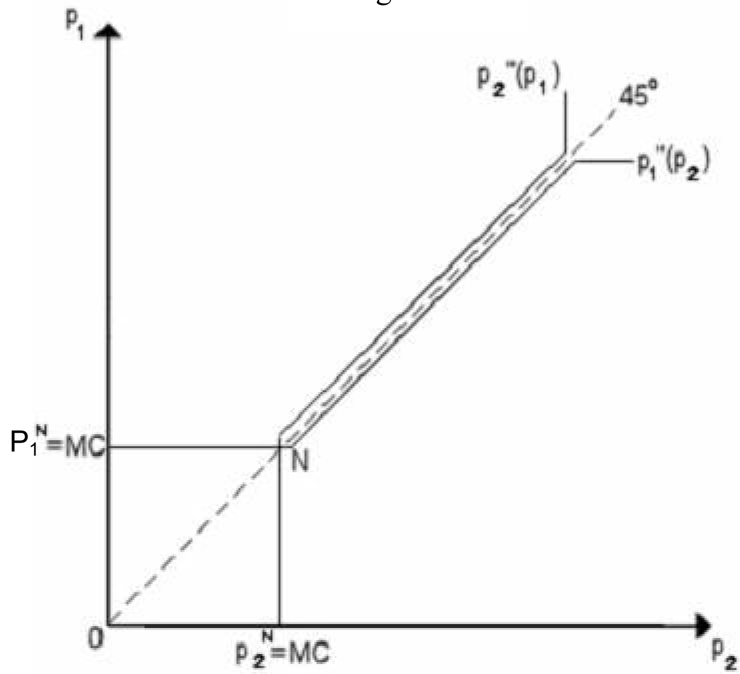


Diagram B2: Response action of both firms that results an equlibrium known as Nash Equilibrium, N