Paper 102

CLASSIFICATION OF ELECTRICITY MARKET MODELS WORLDWIDE

On behalf of CIGRE Task Force C5.2.1

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Summary:

This paper describes the main findings of the work carried out on behalf of Cigré Task Force C5-2-1 "Classification of Electricity Markets" within Study Committee C5 of Cigré. The work is based on a questionnaire that was answered by 23 countries covering all continents. This paper provides an overview of various international operating electricity markets. It describes and classifies the organization and functioning of electricity markets independent of industry structures, management of congestion, ancillary services management and regulatory aspects.

Keywords - *Electricity Markets, Market Organization, Power Pool, Power Exchange*

1. INTRODUCTION

Following the success of liberalization of various sectors of the economy, electricity markets underwent a similar transition. Vertically integrated utilities, which managed generation, transport and supply of electricity, were unbundled, and competition in generation and supply was introduced. Given the differences in electricity market structures and regulatory policies around the world, there is no single standard market model. However, from the several market models implemented in different parts of the world, it is possible to distinguish two main types of market organization, (i) Power Pools or centralized markets and (ii) Bilateral Contracts Model or decentralized markets. Most electricity markets can be classified as of being of type (i), (ii) or its variants.

The main objective of the paper is to provide a common basis for discussions on functioning of power markets. This paper first describes the two main types of electricity market in section 2. Then the structure of the questionnaire used is provided in section 3 and finally the results are discussed in sections 4 and 5.

2. CLASSIFICATION OF ELECTRICITY MARKETS

2.1. Power Pools

In a power pool, all generating companies offer price-quantity pairs for the supply of electricity. This forms an aggregated supply curve. The offered prices can be based on predetermined variable costs (such pools are referred to as Cost Based Pools) or the generators can be free to offer any price they like (such pools are referred to as Price Based Pools). On the demand side, the market operator may forecast demand and dispatch generating units against this. This is called a one-sided pool. In more sophisticated pools (two-sided pools), the market operator may dispatch on the basis of a demand curve created from price-quantity bids made by the buyers on the market, such as distribution companies and eligible consumers (Figure 1).

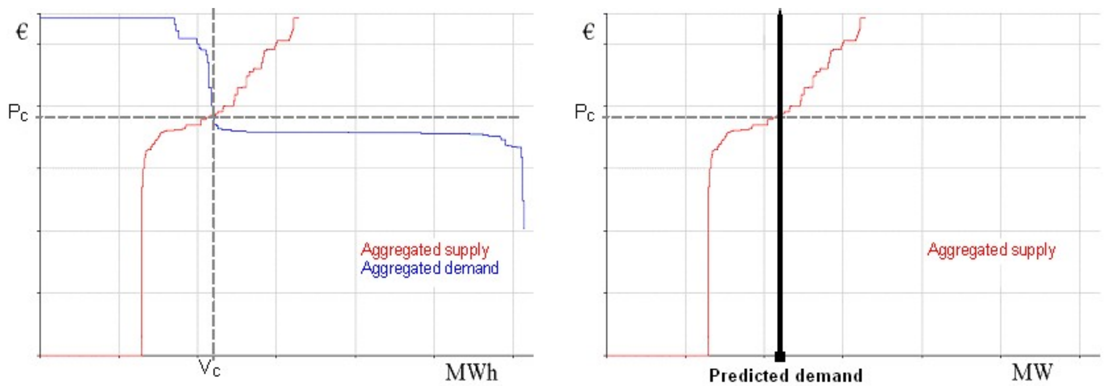

Figure 1. Price discovery - either at the intersection of demand and supply, two-sided pool (left) or supply and predicted demand, one-sided pool (right)

Bids and offers are normally firm and they are matched in the market clearing process and result in an obligation to take and deliver the matched volumes. These volumes will be financially settled.

A pool can operate a day-ahead market (e.g. the former England & Wales Pool) or a close to real time market (e.g. five minutes-ahead). There can also be a combination of several markets (day-ahead, intra-day and five minutes-ahead). Where a five-minutes-ahead market is operated, other sessions can still be run on the basis of non-firm offers and bids. Such sessions are used to create a forecast of the market prices as an indication for the market participants. Such price seeking sessions are based on non-firm offers and bids and are important to allow for non-dispatched demand side response in case of high market prices.

During the matching process the network can be treated as a “copper plate” resulting in a single energy price in the whole control area. The cheapest generation gets priority regardless of network constraints. In a second stage the feasibility of the achieved solution is examined. If there is congestion, some out-of-merit generators are dispatched to replace in-merit generators. This is the so-called “constrained-on/off” generation. The cost of this action constitutes the uplift charge and is added to the energy price (1).

$$P_{energy} = PC + P_{congestion} \tag{1}$$

Alternatively the matching can be on the basis of a security constrained dispatch taking into account both generation marginal price and the physical aspects of the transmission system. This is common in a pool model. One of the main advantages of a pool model is that it allows for Locational Marginal Pricing (LMP). LMP is based on the marginal cost of supplying the next increment of electric energy demand at a specific location in the electric power network accounting for both generation and network characteristics. The consequence is that instead of one uniform price there is a price per location, which can be at each node or on a wider zonal approach. Congestion costs are no longer socialized and each market player pays for congestion caused. The congestion charge in a LMP-based market organization is the difference between energy prices at the generation and consumption node/zones. Market participants can hedge against this congestion charge by entering into financial contracts. The objective of an optimization function is maximization of economic surplus subject to generation and transmission capacity constraints. Detailed representation of a network makes it possible to take losses, parallel flows, voltage stability and reliability criteria into account. As a result, first-order conditions associated with the maximization of economic benefits under constraints yield prices, which represent the change in the total cost (as defined by market participants' bids and offers) of meeting system energy requirements caused by a change in load or generation at each node.

A pool model with LMP defined for every node is often considered as an ideal market model as the nodal prices perfectly reflect all costs of supplying electricity at given nodes and, manage congestion at the same time. Nodal prices send clear signals to market players regarding the location of a new generating capacity or transmission lines. Zonal variant exist as well. These variations use zones (or hubs) in addition to or instead of a node. Zones consist of clusters of nodes, and thus congestion between nodes within a zone does not affect the price. The obvious advantage is the increased liquidity of a zonal market as more parties can compete with each other on equal terms as far as the costs of congestion are concerned. The disadvantage is that a zonal approach averages the nodal prices within a zone, making the price signals less efficient. Moreover, in case of internal constrains the costs of managing this congestion need to be somehow allocated to the market players.

In parallel to the pool, market participants can enter into bilateral contracts. These contracts do not necessarily have to be financial bilateral contracts, but may also be bilateral contracts for physical delivery. In this case, the plants backing each contract are physically scheduled to supply the agreed load and the pool is responsible for the clearing of just "small" differences, due to differences in the amount of energy scheduled and the energy observed in the real time operation. In that case only the differences are settled through the pool, but the dispatch of power plants is not affected by these physical bilateral contracts. Pure financial bilateral contracts (like "contracts for difference") offer similar advantages, however one might want to offer maximum freedom to market participants and for that reason allow for physical bilateral contracts. These contracts allow participants the flexibility to secure energy at prices independent of the market.

2.2. Bilateral Contracts Model

The alternative to a power pool model is a market mechanism based on physical bilateral contracts. This means that sellers and buyers freely enter into bilateral contracts for power supply. Sellers will normally be generators and buyers will be distribution companies and eligible consumers. However, generators could also become a buyer (e.g. in case they have a shortage of generation). Likewise, consumers can become sellers. Brokers can act as an intermediate between buyers and sellers dealing in standard contracts. These types of transactions are referred to as Over the Counter (OTC). In reality, there will always be differences between the contracted volumes and the actual metered volumes. This means that the system operator[1] will have to determine these differences (or imbalances) and will have to settle them. In more advanced markets, the system operator runs a balancing market (or

[1] This task is often allocated to the system operator or market operator but can also be allocated to a separate entity (e.g. settlement administrator)

regulating power market) in order to establish a market based price for the settlement of these imbalances.

In parallel to the bilateral contracts, a voluntary power exchange could be set up or could develop in the future on the initiative of the market participants. A power exchange could offer day-ahead and intra-day trade with the following benefits for the market participants:

- More price transparency,
- No counter party risk,
- Anonymous trading,
- Tool to optimize trading portfolio.

The power exchange will have no metered generation or consumption and will therefore never have imbalances.

This model with bilateral contracts and a voluntary power exchange has been implemented in several European countries, with exchanges in the Netherlands (Amsterdam Power eXchange), France (Powernext), the Scandinavian countries (NordPool), Germany (EEX), Poland (PolPX) and Austria (EXAA). One can even have several competing exchanges in one country, as was the case in Germany (EEX and LPX) and England (UKPX , APX, PowerEX and IPE). Also Japan plans to implement this model.

2.3. Comparison

The two models (pools and bilateral contracts) are equivalent in a world without transaction costs. In a world with transaction costs however, the bilateral contracts model may result in a sub-optimal outcome, where price and quantity that do not reflect real time demand and supply. In a pool, prices and quantities should reflect actual demand and supply, more so depending on how far ahead of real time the trade occurs. Though prices in a pool may be more volatile than in a contracts market, there are hedging instruments available. In terms of institutional capacity, a simple contracts market is more straightforward and less expensive to set up than a power pool [1]. Figure 2 shows the general framework of the two models.

Both market models, pools and bilateral contracts, though so much different, can coexist. A pool could have bilateral contracts alongside of it and in a bilateral contacts mechanism a voluntary power exchange could be considered. Therefore to better illustrate the difference between both one can draw a line between markets with central dispatch of generating units and with self-dispatch[2]. Generally speaking, central dispatch of all generating units is related to mandatory pools. Self-dispatch means that generators decide on the dispatch of their own generating units and this regime applies to bilateral contracts models.

[2] One could even distinguish between scheduling (unit commitment) and dispatch, which would lead to the following three possibilities: (1) central scheduling and central dispatch, (2) self scheduling and central dispatch, and (3) self scheduling and self dispatch.

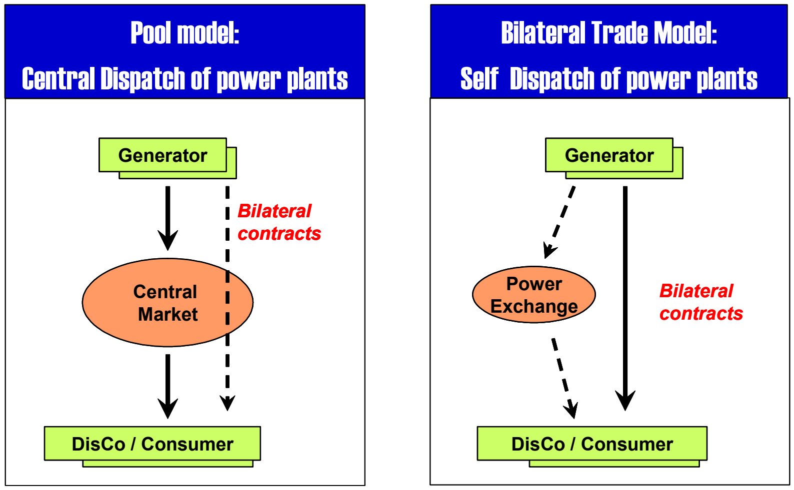

Figure 2. Pool model and Bilateral Trade model

Central dispatch can offer important advantages as it allows for more integrated treatment of generation units and transmission network. This in turn allows for the implementation of LMP and consequently a more efficient management of transmission constraints. It also allows a better management of hydro resources in hydropower based countries.

The aforementioned topics form the backbone of a questionnaire that was built to classify a set of operating electricity markets and which will be described in the next section.

3. ANALYSIS OF THE QUESTIONNAIRE

3.1 Structure of the questionnaire

The classification of electricity markets was based on a questionnaire, which was answered by 23 countries (27 markets): Poland, Portugal, Switzerland, Brazil, Belgium, Japan, USA (California and PJM), Norway, Argentina, Canada, Romania, China, Czech Republic, Spain, South Korea, South Africa, Netherlands, Russia, France, Australia, Peru, Colombia and Ireland covering all continents.[3]

The questionnaire aimed at obtaining information using the set of Yes/No questions that were answered by the participants. Whenever appropriate, opportunity for comments and more detailed description of specific topics were allowed and intensively used by participants. The results of the questionnaire are evaluated by three main sections: market characteristics, market model and market evaluation. These sections cover the correspondent parts of the questionnaire. Due to space limitations, it was impossible to present all responses of all questions from all countries evaluated. The complete set of answers of the 23 participating countries is publicly available at the web-page of the C5 study committee [2], under the task force C.5.2.1 links.

3.2 Market Characteristics

This section discusses the basic issues related to the period of market operation, size, numbers of control areas within the market, the geographical spread etc.

[3] The authors gratefully acknowledge the valuable contributions of all persons who answered the questionnaire.

Most countries analyzed (63%) have markets operating for more than 2 years, but the majority of countries are still in the first 5 years of their market operation (Table 1). Argentina, Peru and Norway have power markets operating for more than 10 years.

The size of the market, measured by installed generating capacity, varies from 0.78 GW (Patagonic system in Argentina) to 189 GW (Japan), with the peak demand 0.673 GW to 164 GW respectively. Expected demand growth (%) in the coming years varying from modest 0.7% (Belgium, Japan, Norway, Switzerland, Canada, Netherlands, France, Russia) to 5-7% (China and developing countries such as Argentina, Peru, Colombia and Brazil). Thermal generation (gas, coal and oil fired plants) are the most important energy source for most countries. However, a high dependence on hydro power is observed in Brazil (85% hydro), Nordic countries (60%), Colombia (75%), Canada (70%) and Romania (50%).

Markets in operation		Market planned – start expected	
Since 0 - 2 years	4	Within 0 - 2 years	4
Since 2 - 5 years	9	Within 2 - 5 years	1
Since 5 - 10 years	4	Within 5 - 10 years	-
Longer than 10 years	4	After 10 years	-
		No answer	1
Total in operation	21	Total markets planned	6

Table 1. Markets in operation and planned

Most countries have one or two control areas. Nevertheless, some countries are subdivided into many more control areas, such as Japan (9 control areas excluding Okinawa province, but a single market for all), and China (3 control areas). 11% of the markets are regional (more than one country), 74% of the markets are national. An example of a regional market is the Nordic market with 5 control areas, Denmark East, Denmark West, Norway, Sweden and Finland). In overall, about 89% of the markets are multi-state.

3.3. Market Model

There was a difference in the level of liberalization among the analyzed markets, but the great majority already introduced wholesale competition, thus in generation and wholesale supply.

As far as the market model is concerned, the majority of countries fit into the "pool" model, but presenting several different arrangements concerning the existence of physical and/or financial bilateral contracts. For example, Brazil is a mandatory pool with only financial contracts, while Portugal has only physical contracts. In Argentina both physical and financial contracts can be found. The Bilateral Contract model is adopted in among other Belgium, France, Poland, France, Switzerland, the Netherlands and Ireland. However, one should note that the macro concepts of pool and bilateral contracts are subdivided into many segments (such as pool with bilateral physical/financial contracts, physical contracts, bilateral contract model with voluntary power exchange, with/without balancing markets). For a more detailed evaluation, we recommend looking at the complete responses [2].

The use of supply bidding curves to clear the market and form the spot price is a key mechanism in most countries. Hydro-based systems have the most diverse ways for system scheduling and price formation: Brazil (85% hydro) adopts a centralized scheduling of system resources, where hydro plants are scheduled based on their water values (no price bidding) which in turn are calculated by a chain of stochastic optimization models. In this case, the market price represents the short-run marginal cost. On the other hand, Norway and Colombia (more than 70% hydro), adopts a price bidding scheme for dispatch and price formation.

Most of countries surveyed adopt a single-market price scheme. Table 2 shows the main pricing schemes and one can observe that nodal pricing is not a common practice among them.

Finally, it can be seen that 60% of the analyzed countries adopt measures aiming at the adequacy of installed generating capacity. These arrangements vary from capacity payments (Portugal, Argentina, Spain, South Korea, Russia, Colombia, Ireland), capacity obligations (Canada, PJM, China, Cal ISO) to other special schemes such as mandatory bilateral contracting with physical backing (adopted in Brazil), tendering for short term contracts if market reserve is below a threshold (Australia) and tendering for long term PPAs.

Single Market Price	Nodal Pricing	Zonal Pricing
Portugal	Argentina	Portugal
Japan	USA-PJM	Brazil
Canada	Russia	USA - Cal ISO
Romania		Norway
Spain		China
Republic of Korea		Australia
the Netherlands		
South Africa		
France		
Peru		
Colombia		
Poland		

* Switzerland did not answer this question

Table 2. Pricing Scheme

3.4 Market Evaluation

This section analyzes the "performance" of the markets for two different cases: the first relates to the markets in operation (78% of the 22 countries analyzed) and the second to markets being planned (the remaining 22%). For markets in operation the questionnaire focused on the success of these markets, modifications or improvements made and foreseen in the future. For markets being planned the focus is on the obstacles to implementation and the transition measures being planned.

For the markets in operation we can see that:

a) There is a very large variation in liquidity (the percentage of total consumption which is traded through the market) between different markets. This varies from 0 to 100 percent depending on the market structure. Markets such as the Brazil and the Czech market trade up to 5 % on the short-term market while in Korea 100% is traded on the market. In Australia 100% is traded on the market but in the order of 80% is covered by contracts for differences. Intermediate cases can be found such as the Nordic market with its 30% share. These figures are influenced by the market model in the countries. Korea has a pool model whereas the 30% of the Nordic market only represents the volume traded through the power exchange, whereas bilateral trade is not covered in that figure.

b) The market price volatility can be considered to be high and is influenced mainly by the production structure, weather events and hydrology.

c) In general, demand side management and demand response on markets have been slow. Highlights goes to the Spanish market, where in general, demand responses to market prices and special tariffs to management demand respond can be found outside the market. Some countries showed a great demand response during crises periods, as was the case in Brazil where demand was reduced in about 20% for 9 months during the 2001-2002 energy rationing, and Norway with 5% reduction in consumption during the 2002/03 draught.

Finally, there are countries such as Ireland, the Netherlands and the Cal ISO with limited, but already in place, demand response programs.

d) Signals for investments in new power plants cover a wide variety of situations and take into account market planning and operations. They are also affected by regulations. Capacity charges are the key in Colombia, spot prices and contracts are the key in Australia, Norway and USA, while obligations to contract form the backbone of other, such as Brazil. Generally speaking, the countries are revising their supply adequacy requirements under the light of the recently observed power crises [4];

e) The advantages are a direct consequence of the degree of implementation and competition, equal access, the increase in the number of participants, market price reference, the transparency and stability of the rules and the amount of long term investment in generation and supply capability. The disadvantages occur where there is little or no competition, failure in implementation, constant rule changes and a lack of investment for the future.

f) In general, modifications of the existing market designs have been made and there are further improvements foreseen for the future. Although converging in the need of a "second stage" of measures to reconcile competition in generation with a guarantee of adequate supply, the countries analyzed also have their individual energy agendas. For the markets still in the planning stage, we observed that the hindering of implementation depends upon a mix of political and regulatory issues. The experience of other countries with the liberalization can also be a factor. The transition measures planned are focused on a timetable for market implementation: initial, middle-term and long-term stages.

4. CONCLUSIONS

The objective of this work was to describe the research carried out under the Cigré task force C.5.2.1, which focused to provide a common basis for the classification of electricity markets. The survey was done through a questionnaire that was answered by 23 countries all over the world. The complete set of answers is available at [2]. This paper presented the general structure of the questionnaire and an overview of the main findings. A wide variety of power sector models and arrangements can be found. Where power markets have been operating, lessons of successes and failures are being considered towards a stronger market design. For countries still in the planning stage of the development of a power market, we observed that the delays in implementation depend upon a mix of political and regulatory issues. The primary challenge for the countries is to ensure sufficient generating capacity and investments to serve their growing economies in a reliable way.

5. REFERENCES

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