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Generation capacity adequacy in the competitive electricity market environment

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Abstract

One of the challenges for power industry restructuring is to maintain sufficient generation installed capacity to meet demand in nowadays and in the future, and the electricity market failure in California has brought this subject to the forefront of extensive debates. This paper initiates a review, assessment and discussion on some important issues related to ensuring adequate generation capacity additions under a competitive electricity market environment.
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1. Introduction

One of the key issues in power industry restructuring is to ensure that an adequate generating capacity will be available for reliable supply. Although this issue was discussed extensively at the initial stages of deregulation, it seems that its importance has been overlooked at least in some places such as California.

Before deregulation, it was the responsibility of utility companies to assure that enough generation capacity was available and usually there was a centralized generation planning. The traditional approach to this was to build planning reserves based on the forecasted load, loss of load probability (LOLP) calculation and estimates of the value of lost load (VOLL), and allocate the costs of the extra capacity implicitly among consumers.

In the restructured power industry, generally there is no central planning for new generation capacity additions and no guarantee is made anymore for recovery of generation investment and return. On the other hand, generation companies do not have any obligation for ensuring sufficient supply of electricity in nowadays and in the future. Each generation company makes its own independent assessments of the profitability of new generation projects, as for any other industrial investments. Since electricity markets are more akin to oligopoly rather than perfect competition and there exists strong entry barriers, the supply tends to be less than the socially optimal demand. Hence, it is a problem of extensive concerns that how adequate generation capacity can be secured in the long run under the electricity market environment. This is the so-called system adequacy problem. The electricity market failure in California has brought this subject to the forefront.

Investment on new generation capacity additions is a commercial and risky activity and is expected to become more prudent under the deregulated electricity market environment. This is because investors are more interested in short-term investment return, and are reluctant to invest generation capacity which requires large investment and long recovery period and has increasing uncertainties on load variation and market management rules which influence their benefits. Investors are expected to spend a considerable amount of time and effort in analyzing the interaction between investment and the decentralized decisions by participants. In making a generation investment decision, expectations concerning future electricity demand, spot market prices, variations of regulatory policies, as well as the financial status are major considerations. The locations, capacities and timing of new power plants are basically at the generation companies' own discretion although an indicative generation

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planning may be provided by the regulator to guide the investment and planning, as is the case in several South America countries such as Chile, Peru, Bolivia and Argentina [1].

There has been a concern whether the electricity market will be able to induce sufficient generation capacity in time. There should not be a generally applicable answer to this question. That should depend on the market model and the regulatory mechanism employed. However, it is true that capacity deficiency is deemed to be a major threat to the deregulated power industry. Indeed, without sufficient supply, there will be no competition, and hence, the market will not be able to work properly. In fact, this is a major factor contributing to the electricity market failure in California. It should be stressed that this is not only a problem of California but also several other places where deregulations have been undertaken. For example, it is stated in Ref. [2] that the reserve margins have been significantly declining in Sweden since the deregulation started several years ago, mainly due to economic reasons. In Norway, since the liberalization, capacity development has been deferred or cancelled, while demand continues to grow. The system has been suffering a fast change from a capacity surplus before deregulation to a very possible capacity deficiency in the near future [3]. In New York, demand has gone up 12.2% since 1993, while generating capacity only up 2.6%. All these provide a good reason for concern whether market mechanisms could lead to sufficient generation capacity in time, and the California's electricity crisis has actually provided a negative example.

The problem of generation capacity deficiency was also identified by NERC in its assessment report published in 1997 which pointed out that: (1) the reserve capacity is reducing to a dangerous level; (2) addition of new generation capacity is slower than load growth. In addition, generation reserve capacity deficiency was believed by the Department of Energy, USA to be one of the main reasons of several blackout accidents happened in 1999.

2. Can an energy-only market alone lead to sufficient generation capacity?

While it is widely accepted that restructuring the power industry is necessary, there are still many debates on what shape it should take. A fundamental question tightly related is: whether an energy-only market could provide sufficient incentives for ensuring adequate generation capacity or additional structures such as capacity payments or capacity markets are required, so as to make an electricity market workable in short and long terms?

Examples of energy-only markets include California, Norway, Albert and Australia. In California, generators can earn additional revenues from ancillary service markets, however, not all generators with available capacities can receive these payments and only those generators with wined bids in the ancillary service markets are eligible. In designing these markets, the generation adequacy problem was ignored either because at the time restructuring was proposed there was a significant over-capacity in the system or because they believed the market could solve this problem by itself.

Many people recognize the need for some forms of capacity payments or capacity markets to encourage generation investment [4]. However, there are also some others who believe that the capacity markets or capacity payments are not needed at all, and everything could be dealt with by market forces in the energy-only market.

In an energy-only market, the only revenue source for recovery of capacity costs is the difference between the market clearing price and generators' production costs, and the system supply adequacy will be entirely rely on market forces, both for short and long terms. In a perfectly competitive market where prices of electricity vary continuously to reflect the supply and demand status at each moment, payment to inframarginal generators (above the system marginal cost) should cover their capacity costs. Economic theory tells us that in a long-term equilibrium, the optimal capacity stock is such that scarcity payments to the marginal generators, in case demand exceeds supply, will cover the capacity cost of these generators. This equilibrium is achieved through exits of generators whose costs cannot be recovered and entry of new generators whose cost structure will bring them operating profits that exceed their capacity costs [5]. Therefore, theoretically allowing the prices of electricity to reflect short-term supply and demand status will create market signals for a proper capacity expansion.

However, in a short-term capacity deficiency may occur considering long construction time of new power plants. In peak load periods especially with exceptional weather conditions or sudden events, serious capacity deficiency may occur and market price of electricity may go up sharply, but this cannot bring in additional suppliers since new capacity cannot be available immediately. In addition, without capacity payments or markets, there is clearly no way to control long-term capacity availability directly.

Moreover, if without a capacity payment, some generation companies especially those providing peak capacity may not be able to recover investment costs from a competitive generation market. As a result, these generation companies will not bid marginal operating costs while this is a stated objective of the electricity market.

The current situation in California, and some other places as well, indicates that the result from economic theory may not work in reality [6]. Some factors which have prevented this theoretical result from occurring are summarized as follows:

(a) The application of price caps, although necessary in some situations, and relevant uncertainties concerning the capped value and enforced period, indeed

discourage investment in generation. With price caps in force, the price is distorted and could not provide a correct investment signal. As a result, some peaking generators may not be able to recover their fixed cost.

(b) The electricity market is more akin to oligopoly rather than a perfect competition as argued in many papers such as Ref. [7]. It is a common practice for oligopolists to underinvest so as to raise the market prices, when the barriers to entry are very strong as is the case of the power industry.

(c) In case the energy-only market is employed, it is necessary to make full use of price elasticity of demand since only in this way the effect of capacity deficiency can be limited at least to some extent. However, in many operating electricity markets in the world, consumers of electricity are largely disconnected from wholesale prices, and as a result, the demand elasticity is not explored. On the other hand, since in most electricity markets real-time price signals are absent to customers, as a result, technically it is very difficult for customers to respond. In fact, the frozen retail price contributes to the electricity market failure in California since the effect of the capacity shortage cannot be limited immediately.

Theory and experience in several electricity markets indicate that reliance on energy prices alone to induce adequate capacity is economically and politically risky. The energy-only market, at least as designed in California, was simply unable to cope with even a moderate rate of growth in electricity demand. Although it may not be fair to attribute the electricity market failure in California entirely to the energy-only market model, however, this event does indicate that this market structure does not work well.

A different view is presented in Ref. [5] that the energy-only market can meet the need for ensuring supply adequacy and the financial health of generating companies if with the support of long-term supply contracts in the form of call options with premiums. In this way, the capacity payment is actually a premium and risk to customers can be managed by demand side participation.

3. Should prices of electricity be capped or not?

Many people believe that the price cap is one of the main factors contributing to insufficient investment in new generation capacity additions especially in energy-only markets, since the spot market price is distorted by the cap and as a result could not provide a correct investment signal. For this reason, many people, mostly economists, including President Bush and Vice President Cheney, past and current chairmen of the Federal Energy Regulatory Commission (FERC) of USA insist that price caps are a terrible idea for electricity markets even in the most dire circumstances [8]. Despite these objections, suppression of electricity prices through price caps is employed in almost all market designs worldwide.

Competition and inherent low demand elasticity of electricity imply that the spot market price will be very volatile and will spike when supply is deficient. This is especially true for the energy-only market since all effects of insufficient supply will be manifested in this market. Actually price spikes have occurred in several operating electricity markets such as California [7]. Now there are two questions to answer: should the price of electricity be capped? if without capped price control, what may happen?

First, we must examine if price spikes are always a manifestation of insufficient supply. In our opinion, this is not true since electricity markets are basically an oligopoly, while in oligopoly markets suppliers have market power to manipulate prices, at least to some extent. There is no exception for electricity markets. In fact, many price spikes are believed to be a result of exercising market power by generation companies. Secondly, the critical role of electricity in economic development and society renders the price control very necessary. Otherwise, many serious society problems may occur. Thirdly, price caps are necessary especially in nowadays and in the near future since, due to current technical limitations, consumers cannot get the spot market prices immediately and then respond to price, or in other words, the role of consumers is passive. Under such circumstances, customers must be protected from too high spot market prices of electricity and the price cap appears a simple and efficient approach to this end.

It is our opinion that a price cap is necessary especially for an energy-only market. However, the cap cannot be set too low, otherwise it will distort the signal for investment. An adequate level of price cap will not distort the price signal but can limit the exercising of market power by generation companies and hence protect consumers. However, it is not always easy to set an appropriate price cap.

4. Why is a capacity payment or capacity market needed?

As already mentioned before, there have been many disputes on if an energy-only market is enough to ensure adequate generation capacity. Maybe the current situation in California has already answered this question.

Generally the duration of a peak load period is very short since it is usually the result of exceptional weather conditions or some important events. Certainly prices must be very high in peak load periods so as to justify investments to meet the peak demand. Basically, it is very difficult to attract peak capacity investment by the price of electricity in an energy-only market since the expected revenue is very unstable and may not be able to recover the investment cost. Hence, it appears necessary to establish regulatory or market mechanisms of capacity payments, in one way or another, to stabilize the volatile income of

generation companies and hence encourage new investment and ultimately ensure sufficient supply in a long run.

A separate capacity payment or capacity market can serve for the following purposes:

(a) Recovering fixed capacity costs in a direct and reasonable way.
(b) Providing an adequate price signal for capacity additions. A capacity payment or a capacity market is very useful for indicating a clear price-point for new capacity, rather than potentially enormous but erratic swings in energy prices in energy-only markets that are hard to translate into a clear signal for new capacity demanding.
(c) Reducing the investment risk especially for peaking units and as a result encouraging generation investment.
(d) Reducing the incentive of generation companies to withhold capacity.
(e) Delaying the exit of existing uncompetitive generators from the market and as a result increasing the available capacity. If a capacity payment or a capacity market is available, for those generators whose costs are higher than the market clearing price in the energy market will still get a capacity payment, even if they are not dispatched for supplying power. Hence, these generators will be able to survive for a longer period, and as a result, the available capacity will then be increased.
(f) Allowing proper allocation of costs and revenues between the energy supply and capacity availability.
(g) Facilitating monitoring and mitigation of market power. If all the costs of generation companies including capacity and energy are recovered by the energy-only market, it will be difficult to identify if a generation company is exercising market power or not. The existence of a capacity payment or a capacity market allows for the possibility that bids in energy markets could approach variable costs, as they are designed. As a result, monitoring for market power abuse in the energy market can be easier since variable operating costs can be estimated and hence markup identified. Ultimately, substantial savings for consumers can be achieved.
(h) Reducing the price volatility in the energy market. If the capacity payment is properly determined or a capacity market is working properly, there will be no need for the energy market to signal the need for new generation investment, and as a result, the spot price in the energy market will not violate strongly.

It is believed by more and more people that it is necessary to have a capacity payment or a capacity market [4,6,8–16]. The past Chairman of FERC, James Hoecker, called for California to adopt a capacity market to avoid 'periodic reliability crises with energy price booms followed by price busts' [8].

An important objection to the capacity payment or capacity market is the gaming or market power problem. This is mainly caused by England & Wales electricity market in which gaming for capacity payment was serious. Exercising of market power has also been observed in the monthly installed capacity market of New England. A tightly related problem with capacity markets is how to identify the market power. While it is relatively easy to detect market power abuse in energy markets, the problem is more difficult with capacity markets. However, the research presented in Ref. [8] shows that the market power problem is mainly related to the design of the capacity market rather than the capacity market itself. The creation of a separate capacity market should not increase the costs of consumers in the long run.

It is possible that generation capacity markets will exhibit boom/bust cycles similar to other commodity industries [11]. A boom/bust cycle starts with high commodity prices, which trigger a bloom in new capacity. The boom overshoots the market equilibrium and creates over-capacity. Then follows a bust, with depressed prices and no new capacity construction for a few years while the surplus is being absorbed. But the industry has a delayed reaction to the end of the surplus and a capacity shortage develops, causing high prices and the start of a new cycle. A major factor contributing to these cycles is the long, usually 2 years or more, construction time for a new power plant. Investment cannot be stopped once a power plant has already been in construction even if the price of electricity starts to go down. On the other hand, investment will not resume until high prices of electricity have lasted for a period.

While capacity payments and markets may have some shortcomings, they do allow much lower price caps, which then can control price spikes and thereby reduce the fluctuations of generators' profits. In Ref. [8], it is illustrated that the combination of low price caps in energy markets with installed capacity markets can provide effective incentives for ensuring system adequacy.

There is also a different view [5] that a well-functioning energy-only market can provide correct incentives for generation adequacy, and the use of 'capacity payments' is the least desirable approach. However, how to ensure that an energy-only market functions well? In fact, well functioning in itself means that adequate generation capacity can be resulted in by the market mechanism.

By the way, it should be mentioned that to maintain sufficient capacity in short-term operation, maintenance scheduling is also a very important issue to deal with. Many debates are still going on concerning if the maintenance scheduling should be governed by the ISO with relevant rules supported. It seems that in a properly functioning market, this issue can be managed by the generation companies. While the available capacity is tight in

the market, it may be necessary for the ISO to manage the scheduling so that adequate supply can be guaranteed.

5. How should the capacity payment be determined?

In Section 4, the necessity of having a capacity payment or a capacity market is illustrated. Now, we turn to a subsequent problem: how to determine a capacity payment? There are basically two ways: by administration or by market mechanism.

The fundamental relationship between capacity and energy prices in a long-run equilibrium is such that the expected social cost of unserved energy as reflected by the energy-only market prices should equal the marginal cost of incremental capacity. Or more generally speaking, the price of capacity should equal the amount of revenue required to keep enough generation available to meet demand and the reserve requirement. Ideal pricing for capacity should achieve a balance between economic efficiency and investment incentives. To this end, prices must be kept close to costs but not so low as to discourage investment.

Capacity payments are mainly used for two purposes, i.e. for maintaining short-term and long-term reliabilities. Long-term reliability is also referred to the system adequacy. The notation of system adequacy represents the system's ability to meet demand on a longer time scale basis. A measure of the system adequacy is the reserve margin which is the relative difference between the installed capacity and peak load.

The capacity payment actually indicates such a fact that the generation capacity provides value even in the absence of energy supply, and the value of uncalled but available capacity is the enhanced reliability. Hence, it is nature that the capacity payments should be determined based on the reliability if these payments are to be administratively determined [9]. Determination of capacity payments has a direct impact on short-term operating reliability and long-term supply adequacy, and hence should not be overlooked.

With this in mind, capacity pricing should be tightly related to peak load pricing [17–19] and reliability pricing [9]. Boiteux made a pioneered contribution on the application of peak load pricing in the context of electric power [17]. The cost of interruptions to consumers should theoretically play a major role in determining reserve requirements and capacity prices. In Ref. [9], the issue of determining capacity payment is linked to pricing reliability. A general formula for determining the ideal capacity price is presented based on the concept of value of service reliability. This approach is applicable to those markets in which capacity payments are determined administratively.

Generally speaking, factors that contribute to determine capacity prices, in both the short and long term, should include but not be limited to Ref. [11]: expectations regarding the supply/demand balance for the relevant period; costs to build new capacity (long term only); costs to keep existing capacity available and costs to consumers of interruptions.

Since it is quite difficult to price capacity reasonably by an administrative way, many people believe that a better way to determine the capacity payment and hence to ensure capacity balance is by a market mechanism [3]. Capacity prices established through price discovery in auctions reveal the value of available generation capacity in the market. If customers are permitted to bid in the capacity market, the price also reveals their willingness to pay for reliability. Hence, the value of reliability can then be obtained.

6. Existing approaches for capacity payments

It is believed by many people especially regulators around the world that energy markets are not mature enough and cannot be entirely relied on for securing a desired system adequacy so that some supporting mechanism is needed, at least in the near future, in order to ensure adequate generation capacity. As a result, in many operating electricity markets there exist different forms of capacity payments for ensuring sufficient supply in short and/or long terms. Up to now, there are basically three approaches for capacity payments as detailed below.

6.1. Capacity obligation model

In this model, a capacity obligation is imposed to customers by forcing them, explicitly or implicitly, to sign long-term contract with power suppliers. The regulators determine the amount of firm capacity that each one of the consumption entities has to buy, as well as the maximum amount that each generator is allowed to sell. In other words, a reserve is imposed on each load entity in proportional to its load. To meet this requirement, the load serving entity must enter into contracts with generation companies or procure its obligation through a 'capacity market' that is operated by an organization like ISO. This model is employed in Northeast of the USA including PJM, NYPP (New York Power Pool) and NEPOOL (New England Pool). In PJM and NEPOOL, capacity obligations are defined for 'load serving entities' or participants.

There are basically two types of capacity markets, i.e. short-term and long-term capacity markets [16]. In NEPOOL, the short-term capacity market is referred as an operable capacity market, while the long-term capacity market is commonly called an installed capacity market.

The installed capacity market relates to the actual installed capacity in the market, and addresses the system adequacy in a long term. The operable capacity market relates to the portion of installed capacity which is operating or available within 'an appropriate period' as specified by the market rules, or in other word, it ensures the availability of sufficient dispatchable hour-to-hour

capacity. The installed capacity market is intended to ensure that adequate capacity exists to serve load, and is settled on a calendar month basis. The operable capacity market is intended to provide incentives to ensure that the capacity is available when needed. All capacity that was not allocated through bilateral contracts could be bid into these capacity markets.

A method is presented in Ref. [13] for the assignment of capability obligation to participants based on the concept of reliability equity for the installed capacity and operable capacity markets. A proposal is also made on the possibility of combining these two markets into one.

A main advantage of this method is that system reliability can be assured according to well proved techniques and procedures that have shown to result in reliable system operation. A disadvantage is that some of the benefit of restructuring may be lost [2]. One of the main problems of the traditional power industry is overinvestment since return-on-investment is guaranteed. By using capacity obligations based on forecasts, there is a risk of overinvestment.

6.2. Administrative payments for capacity

In several countries such as Argentina, Chile, Colombia and Spain, administrative payments are employed with an explicit remuneration for the installed capacity as an economic signal intended to augment the volume of installed and available generation. Specifically, additional payment is made for available capacity during hours with high demand to motivate capacity investment.

Generation companies are offered a capacity payment based on their availability no matter if they get dispatched or not. The capacity payments are collected from customers as a prorated uplift similarly to other uplift charges such as the transmission charge.

This method has several major disadvantages [2]:

1. It is not easy to determine an adequate level of capacity charge for inducing optimal capacity investments. Basically, the administrative payment for capacity is based on the expected cost of lost load, which is difficult to obtain. Overestimating this cost would create artificially inflated demand for capacity and result in high capacity prices, which in turn will lead to overinvestment on capacity.
2. A fixed capacity charge does not adapt to a varying balance between supply and demand for capacity.

6.3. Explicit capacity adder payment model

In this model the capacity is priced separately from energy and consumers are not required to procure capacity. At the initial operation stage of the England & Wales (E&W) electricity market, this approach was employed. In the E&W market, the capacity payment is set to the VOLL multiplied by the LOLP on half-hourly basis and paid to all available capacity. However, determining an appropriate level of VOLL is very difficult, and in the E&W market it is administratively managed by the regulator through estimating the annual marginal cost of capacity required to meet expected demand at the required reliability standard. This is included in the uplift which is added to the spot market clearing price as the power purchase price. No matter if a generator is dispatched or not, it will receive the capacity payment. When the reserve is tight, the capacity payment will be very high. As a result, the price is very volatile. In this model, the capacity payment is basically determined administratively.

This approach has been criticized for distorting the market price and for being particularly easy to manipulate. Large generation companies have sufficient incentives to withhold capacity so as to magnify the capacity payment as well as to increase the market clearing price for energy, and such manifestations have been observed.

Since the capacity payment is dependent on the system operating conditions and hence is uncertain in the future, this method may not be able to induce sufficient investment on new capacity.

Another major problem of this method is the reliance of capacity payments and capacity requirement on VOLL. It has been criticized repeatedly that VOLL is administratively set and has no market base. A possible way to get a reasonable VOLL is through demand side bidding. Another problem is with the simplified calculation of LOLP.

Although it is difficult to state which approach is the best since different market models are employed in different places, determination of capacity payments by a market mechanism is generally believed a better way than by an administrative pricing method which cannot adequately reveal the value of capacity and may result in overinvestment as is the case in the traditional power industry.

Recently a market-based approach for procuring generation capacity is presented in Ref. [4], which is implemented through a forward auction for capacity deficiency indicating the difference between the forecast load and the potentially available installed capacity for a future slot of duration. In such an auction a certain amount of capacity for different future slots of duration is contracted with potential suppliers. There can be several auctions for different future duration slots. A problem with this approach is how to get the money to pay for the winners of the auction. Since this charge is ultimately passed on to the consumers, it is proposed in Ref. [4] that the payment could come from working capital. In this way, the payment to winners of auction for future capacity gives them revenue stability and helps them to obtain financing for new generation capacity additions, and as a result, adequate supply could be assured.

How to fairly allocate capacity costs among market participants is also a key issue to address. In the last two methods introduced above, capacity payments are shared by customers at a flat rate, which is usually determined based

on energy usage and maximum capacity required. In the first method, it is determined by auction. To examine this problem carefully, it is necessary to identify if generation adequacy is a public good or not. Are there ways for discriminating between buyers in providing reliable service? In Ref. [5] it is stated that the generation adequacy is a private good while the system security is a public good although adequacy and security are two tightly related issues. In Oren's opinion, adequacy provision amounts to no more than insurance against shortages. Such insurance is then regarded as a private good of which the adequate quantity to be provided can be decided through customer choice.

7. Roles of regulatory organizations

Should the government or regulator play an active role for ensuring the system adequacy or leave the market forces to do the job completely? This is an issue with many debates. The approaches employed in several South American countries such as Bolivia, Chile and Peru may be of value for reference especially for those developing countries in Asia in the procedure of restructuring their power industries. In these South American countries, a better balance is maintained between competition and regulation. The regulators transferred the responsibility for expansion of generation capacity additions to the private sector in a market environment [1], but the government still keeps an indicative role to strategically direct the generation capacity expansion. It is believed that private investment decision may not coincide with what is socially optimal. Hence, the government would have to provide adequate signals.

An indicative reference generation expansion plan is determined by the regulator every 6 months and used for regulating generation–transmission tariffs to small retail consumers. The indicative plan is mainly for generation investments, with only major transmission lines included. The indicative expansion plan is the one that minimizes investment, operation, and unserved energy costs and satisfies demand requirements in a given time horizon. The indicative plan is not binding for the private sector.

Recently, a regulatory framework is presented in Ref. [6], in which reliability contracts based on financial call options are auctioned, and both the price and allocation among different plants are determined through competitive mechanism. In this way, the incomes of generating companies can be stabilized and this in fact provides a clear incentive for new generation investment.

The balancing of competitive opportunities and regulatory measures is of great strategic importance in the power industry restructuring and should not be overlooked since the power industry is an important national infrastructure whose failure will have severe social and political implications.

8. Concluding remarks

A reliable and reasonably priced supply of electricity is critical to the functioning of a modern economy and society. To achieve this goal, it is important to secure adequate generation capacity in the long run. Without sufficient supply, a market cannot lead to maximized social welfare, and sometimes even cannot work at all.

As already happened in California, capacity shortage will probably occur in those markets using the energy-only market model. An adequate capacity payment, in one way or another, appears necessary for ensuring the system adequacy. However, it must be stressed that there does not exist a generally applicable so-called 'best' method to solve the generation capacity adequacy problem, since a best solution to this problem is related to many factors such as the past, current and future scenarios of the power industry studied, social and economic development status of the country or region concerned. These factors must be well taken into account in designing a workable electricity market.

Maintenance scheduling also plays an important role in ensuring short-term capacity availability. Disputes are still going on concerning if the maintenance scheduling should be centrally determined by ISO or be done by market forces alone. The market-based maintenance scheduling method, i.e. determined by generation companies, appears more reasonable. However, in those markets with very low reserve margin, centralized management of maintenance scheduling appears necessary, at least temporarily. Of course, how to make the centralized arrangement economically fair for generators is a very important issue to be dealt with.

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