Japanese Approach to Electricity Deregulation Policy -Modeling the Spatial Purchased Power Pricing-

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Abstract: The Japanese government decided the liberalization of the generation market in 1995. A moderate but steady change in an institutional arrangement in the Japanese electricity supply industry will continue. The deregulation of Japanese power market from 1996 is characterized by the liberalization of the wholesale market. The paper presents two purposes. The first one is to describe the latest development of the Japanese electricity supply industry, particularly in the deregulation and competition issues. The second purpose is to develop a method for spatial costing of electric power systems and to apply this method to purchased power pricing. From simulation carried out on a simple model, the results show that 1) the level of transmission connected charge depends on the network configuration and load level for each node, 2) an introduction of an Independent Power Producer (IPP) to the network leads to a reduction in the total generation cost of utilities generators.

Keywords: Power markets, Deregulation, Purchased power pricing, Spatial Costing.

1. Introduction

There is an international movement towards greater reliance on competition in electricity markets. The Japanese government decided the liberalization of the generation market in 1995. The key elements of a competitive market include efficient pricing and transmission open access.[1-6]

The first purpose of this paper is to describe the latest development of Japanese electricity supply industry, especially deregulation and competition issues. The second purpose is to develop a method for spatial costing of electric power systems and to apply this method to purchased power pricing.

2. Electricity Deregulation in Japan

2.1 Current Industrial Organization and "Special Supply"

The electric power industry in Japan is mainly owned and operated by 10 regional investor-owned electric power companies (vertically integrated). They have the legal obligation to serve electricity to their service areas to the demand under the guarantee of a monopoly. They generated about 75 % of the total electricity production (895 billion kWh) in Japan (FY 1992).

Besides the regional electric power companies, there are also wholesale power companies which supply electricity to the ten regional electric power companies. It is illegal for them to sell electricity to the public. Wholesale electric power companies include Electric Power Development Co. Ltd.(EPDC), The Japan Atomic Power Co.(JAPC), 34 public corporations owned and operated by local governments, and 20 investor-owned companies jointly established by the regional electric power companies and large electricity consumers. These wholesale power companies cannot be established without the permission of the Government. They generated about 13% of the total electricity production(FY 1992).

Also, there are self generators which produce electricity for their own use. They had a share of about 12% in the FY1992. Electricity is supplied to end users in principle by the ten regional utilities. However, the supply of surplus electricity from self generators to end users (called by "Special Supply") is stipulated by Article 17 of the Electric Utility Industry Law. According to the article, there must exit a special and close relationship between the supplier and the end user, for the Minister of the Ministry of International Trade and Industry (MITI) to grant permission for "Special Supply".

For example,

1) The party who installs such a facility has a close financial and personal relationship with the customer.
2) The owner or operator of such a facility and the customer have their establishments in the same premises or industrial complex site.
3) One sector of the local government supplies electricity to other sectors.
4) The supply is for a company housing.

This "Special Supply" had been mainly applied to self generation for industrial use. Due to the rapid growth of commercial self generation, the Natural Resources and Energy Agency issued a notification in 1987. According to this notification, commercial self generator can supply excess energy to the customer as long as the electricity is supplied in the same building. As of the FY 1993, "Special Supply" amounted to 5.5GW [2].

2.2 Why Deregulate Now?

MITI has been pressurized by manufactures to deregulate for many years. Electricity is the domestic goods whose price should be compared with international prices by using the customer purchasing power parity relationship and not the foreign. Unfortunately, many manufacturers are producers of exported goods which must compete in the international market place with goods from countries with lower electricity rates. With the yen's rapid appreciation, MITI has finally decided to allow limited deregulation in the wholesale supply of electricity.

Since Japan has barely suffered any inefficiency in its transmission, MITI does not unbundle the electricity industry. They plan to keep vertically integrated utilities in place. They consider to use a limited wholesale wheeling and possibility of mini-utility regions as their first step towards deregulation. By introducing just enough competition, it is hoped to reduce electricity prices for industrial customers but not disrupt its stability of supply.

Deregulation is also able to help the industry in meeting the increasing peak load. The revised law aims to facilitate this. Utilities that are at high demand areas will see an increase of Independent Power Producers (IPPs) which will provide them with an alternate source of electricity to meet the peak demand.

2.3 The Revision of the Electric Utility Industry Law

The Electric Utility Council, an advisory body to the Minister of International Trade and Industry, has conducted studies regarding the revision of power-supply and safety regulations that are stipulated in the Electric Utility Industry Law.

The Electric Utility Industry Law was amended in 1995 and will be enacted in January 1996.

The main points of this revision are summarized as follows:

(1) The objectives of the revision include
  a) encouraging the competition to reduce the rate level to internationally competitive one and,
  b) efficient utilization of non-utility sources.

(2) The main part of the revision consists of
a) The liberalization of the wholesale market which contains
  - The bidding system for wholesale generators (Non-Utility Generation: NUG);
  - The wheeling from NUG to other utility (Wholesale wheeling) and,
  - The liberalization of the entrance.

Any new IPP may enter the market without MITI's approval, however, they need to notify them about the intention. Any IPP may sell electricity to any utility in any of the nine regional districts, utilizing wholesale wheeling. A plant which is a 150 MW must go through an environmental assessment process. This process is time consuming and costly. In addition, a plant must go into operation within 7 years after the IPP wins the bid. Because of this, large scale IPPs are very unlikely. The most likely entrants into the IPP market are steel, oil and paper companies (i.e., raw material companies that currently have their own self-generation facilities).

b) The creation of a new system for the direct supply of power from dispersed generators to neighborhood customers. This mini-utility consists of a company which owns and develops a small land and hence is allowed to supply electricity everywhere within its area. The company is responsible for building any necessary distribution lines within its area. This is an extension of the "Special Supply" arrangements permitted by MITI. A company must ask for permission from MITI to become a mini-utility. Potential entrants are those from gas utilities.

c) More flexibility for utilities to apply for the tariff
  - An incentive scheme for DSM
  - A yardstick principle to give incentives to utilities

d) The relaxation of technical regulation will encourage a third party to join the market

2.4 Retail Wheeling

Retail wheeling was a controversial issue. There was strong arguments against retail wheeling. One of the reasons is for fear of the spreading of dispersed power generations will result in a sudden increase in crude oil prices. The power generation will not be able to operate economically and this will force customers to rely again on power services from the regional electric power companies. To prepare for such circumstances, the regional utilities will need an amount of backup capacity (because of obligation to supply), and this will imply a higher rate. As such, at the moment, the government has decided not to introduce the retail wheeling.

3. Transmission Service Pricing in Japan

At present, all the utilities agree on annual rate (same price). The following two kinds of rates are applied for:

- Transactions to reduce the generating costs. The rate mainly covers man-power and transmission losses.

- Transactions to reduce the generating capacity. The rate covers the cost shown above and expense of transmission facilities. The rate is maintained relatively low, assuming that all the utilities would receive benefit in the long run.

Transmission pricing in a deregulated market in Japan will be more complicated than the one in the U.S. The reason is that the power system in Japan is very loose and weak due to long lines. It is not economical to wheel long distances. Also, transmission and distribution (T&D) account for almost 60% of the cost of energy, due to the high cost of land. In an deregulated market, the formula for transmission pricing will include the distance too.

4. The New Bidding System

For the liberalization of the wholesale market, the introduction of a competitive bidding is planned. This bidding will occur only for an additional capacity. Regional power companies could sign the long-term contracts with the winners of the bidding. At the moment, MITI is preparing the guidelines for the bidding system. Once they are published, each utility can individualize the bidding system. Utilities must make an announcement at least three months before the bidding takes place.

The bid evaluation should take into account not only economic factors but also noneconomic factors such as closeness to demand-intensive areas, reliability of the project, and environmental impacts. We will focus on the noneconomic factor, i.e., location of the IPP in the next section.

5. Spatial Costing Methods for Purchased Power Pricing

When an IPP connects to a transmission network of an utility, we need to calculate the spatial cost (location cost) to determine a purchased power price and the transmission connected price. The node which the IPP connected to should also be selected to minimize the system cost. In this section, we will describe a mathematical formulation to evaluate the spatial costing method.

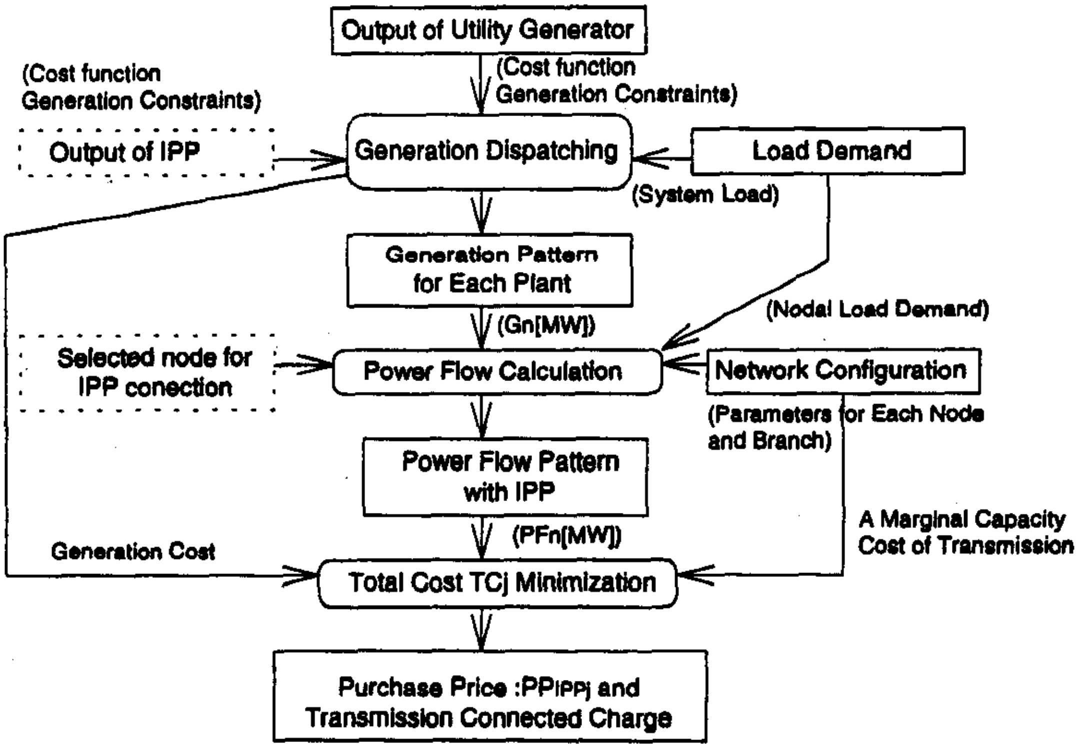


Fig.1 An overview of the spatial costing analysis for connecting an IPP to the utility network

Based on an overall system load demand, without an IPP, a basic generation pattern is determined by an economic load dispatching rule. This system load demands is then divided into the nodal load demand. A power flow pattern of this generation dispatch are calculated by DC flow method.

By denoting PF_{Bkj} [per unit megawatt: p.u.MW] and PFn_{kj} [p.u.MW] as the basic power flow without an IPP and the one with an IPP respectively, when a generator of an IPP is connected to the j-th node, the change of power flow for the k-th branch:

$$\Delta PF_{kj} = PFn_{kj} - PF_{Bkj} \tag{1}$$

When the IPP is connected to a network, a total cost TC_j [Yen] can be shown as follows;

$$TC_j = f(G_{IPPj}) + \sum_{k=1}^{Bmax} \Delta PF_{kj} \cdot \alpha_k \tag{2}$$

where, $f(G_{IPPj})$ is a generation cost [Yen] for output G_{IPPj} [p.u.MW]of the IPP connected at the j-th node. Bmax is the number of branch in the network. When CT_k is a construction cost [Yen] and LT_k [p.u.MW]is a max-capacity of the k-th branch. A marginal capacity cost of transmission [Yen/p.u.MW] of the k-th branch can be formulated as $\alpha_k = CT_k / LT_k$.

When G_{IPPj} power was supplied to the utility by the IPP, the average unit cost P_j [Yen/p.u.MW] could be calculated by the minimization of total cost TC_j [Yen] as shown in equation (3). This unit cost could be divided into an average production cost and transmission connected charge.

$$P_j = TC_j / G_{IPPj} = PP_{IPPj} + TP_j \tag{3}$$

Based on the generation (fuel) cost of the IPP, the average production cost PP_{IPPj} [Yen/p.u.MW] can be obtained as follows:

$$PP_{IPPj} = \frac{f(G_{IPPj})}{G_{IPPj}} \tag{4}$$

When the IPP is connected to the j-th node, a transmission connected charge TP_j [Yen/p.u.MW] can be shown by the marginal capacity cost of transmission as below:

$$TP_j = \frac{\sum_{k=1}^{Bmax} \Delta PF_{kj} \cdot \alpha_k}{G_{IPPj}} \tag{5}$$

With the same power flow pattern, the total generation cost for the i-th power plant of the utility is reduced by the inclusion of an IPP.

$$\Delta G_{ji} = Gn_{ji} - G_{Bji} \tag{6}$$

$$\Delta f(\Delta G_{ji}) = f(G_{Bji}) - f(Gn_{ji}) \tag{7}$$

To achieve a minimization of the total cost TC_j, the relationship between the generation cost of an IPP output and the reduction of the total generation cost in the utility is satisfied.

$$f(G_{IPPj}) \leq \sum_{i=1}^{Gmax} \Delta f(\Delta G_{ij}) \tag{8}$$

where, Gmax is the number of generator of the utility.

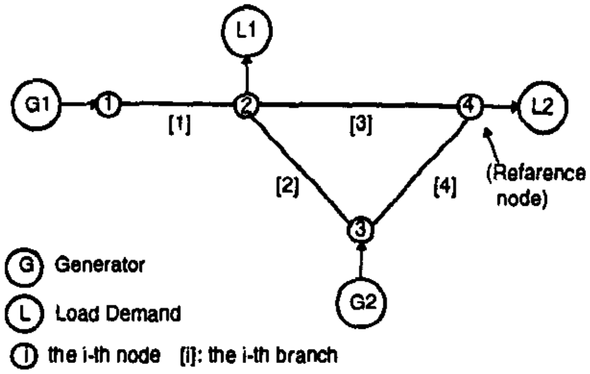
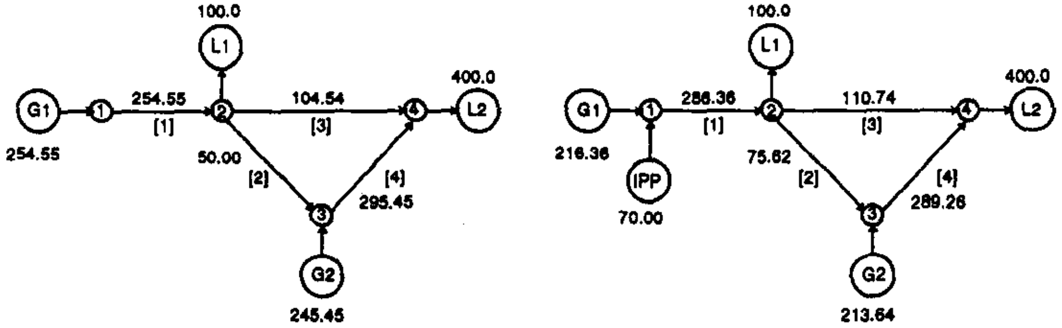


Fig.2 A network configuration of the model system

Table 1 Case study data

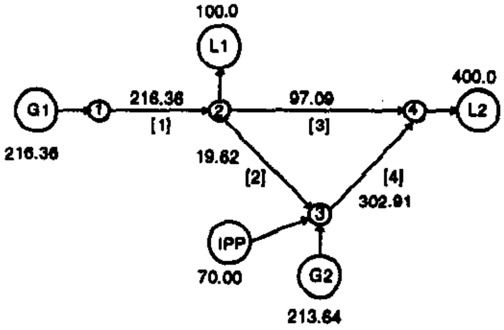
Generator/Load	Max[p.u.MW]	Min[p.u.MW]	ai(*) [Yen/p.u.MW^2]	bi [Yen/p.u.MW]	ci[Yen]
G1	300	50	0.25	80	2000
G2	500	50	0.30	60	3000
Gipp	70	20	0.20	50	5000
L1	100	100	-	-	-
L2	400	400	-	-	-
Branch	Max[p.u.MW]	Min[p.u.MW]	Admittance		Construction Cost[Yen]
B12	500	0	0.623		2310
B23	400	0	0.267		9900
B34	400	0	0.254		1830
B24	300	0	0.845		3050

*) ai, bi, ci are coefficients of the following generation cost function for each generation unit. $f(G_i) = (a_i \cdot G_i + b_i)G_i + c_i$



(a)Base Case

(b) IPP-1 Case(connected to the 1-th node)



(c) IPP-3 Case(connected to the 3-th node)

Fig.3 Power flow patterns and generation patterns (power : [p.u.MW]).

Table 2 The purchase price and the transmission connected charge[Yen/p.u.MW]

Case Name	PP_{IPPj}	TP_j	P_j
IPP Case connected to the 1-th node(IPP-1)	71.14	11.56	82.70
IPP Case connected to the 3-th node(IPP-3)	71.14	1.08	72.22

A feasibility study of this proposed spatial costing method for purchased power pricing can be carried out with a simulation on a simple network as shown in Fig. 2. For this study, the parameters and coefficients are given in Table 1.

Fig. 2(a) shows a power flow pattern without IPP in the Base Case. If IPP is connected to the 1-st node (IPP-1 case) and supplies 70p.u.MW to the network, a power flow pattern is changed as shown in Fig. 2(b). Fig. 2(c) shows a power flow pattern of the case where the IPP is connected to the 3-rd node (IPP-3 case). In both cases, outputs from the utility's generator are decreased. A total generation cost of the utility is about 15% less than that of the base case. Table 2 shows the average unit cost of the IPP's supply under the two cases. In the IPP-3 case, the average unit cost is less than that of the IPP-1 case, because power flows of branches 1, 2 and 3 have been increased in the latter case.

From the simulation, it is clear that 1) the level of transmission connected charge depends on the network configuration and load level for each node, and 2) an introduction of an IPP to the network leads to a reduction in the total generation cost of the utility generators.

6. Discussions

Deregulation of electric power utilities will allow competition among of generators and create market conditions for optimizing the social welfare.

Transmission open access (TOA) is necessary for increasing the efficiency of energy production and distribution, offering a lower price, higher quality and more secure supply. Different TOA formats, whether merely proposed or already implemented, attempt to combine the traditional cost-of-service regulation and fully competitive markets. Different approaches have been followed to create open access conditions in interconnected power systems too. Issues such as the transmission costing and pricing, payment allocation, access policies, transmission rights and transmission system expansion are being extensively discussed, however, it is clear that further research is required urgently [7]. Another important area could be the application of game theory to modeling power markets and demonstrating their usefulness in system planning and operation [5].

7. Conclusion

A moderate but steady change in an institutional arrangement in the Japanese electricity supply industry will continue. The deregulation of Japanese power market from 1996 is characterized by the liberalization of the wholesale market.

We have examined a method for spatial costing of electric power systems and to apply this method to purchased power pricing. From simulation studies, it is clear that 1) the level of transmission connected charge depends on the network configuration and load level for each node, and 2) an introduction of an IPP to the network leads a redaction in the total generation cost of the utility generators.

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