Locational Prices in Capacity Subscription Market Considering Transmission Limitations

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Abstract: This study focuses on one of the most effective type of capacity markets named Capacity Subscription (CS) market which is predicted to be widely used in the upcoming smart grids. Despite variant researches done about the mechanism and structure of capacity markets, their performances have been rarely tested in the presence of network constraints. Considering this deficiency, we tried to propose a new method to determine capacity prices in the network considering the transmission line flow limitations named Local capacity Prices (LP). This method is quite new and has not been tried before in any other similar researches. The philosophy of the proposed method is to determine capacity prices considering each consumer share of total peak demand. The first advantage of LP is that the consumers who benefit from the transmission facilities and are the responsible for transmission congestions, pay higher capacity prices than those whom their needed electricity is prepared locally. The second advantage of LP is that consumers connected to the same bus do not have to pay same capacity price due to their different shares of total peak demand. For more clarification, two other different methods named Branches Flow limit as a Global Limit (BFGL) and Locational Capacity Prices (LCP) are proposed and compared to the LP method in order to show the LP method efficiency. The numerical results obtained from case studies show that the LP method follows more justice market procedure which results in more efficient capacity prices in comparison to BFGL and LCP methods.

Keywords: Capacity market, Capacity price, Capacity subscription market, Transmission limitations.

1 Introduction

In restructured power systems, security is enhanced by capacity markets. Based on their functionality, capacity markets can be grouped in to two different categories which we address as short-term, which is defined as the power system capability to maintain its stability in the time of credible contingencies such as generator and line outages, variation of load, etc all without having to shed load beyond the limits of voluntary interruptibility [1-4], and long-term capacity markets, which is defined as providing sufficient new installed generation capacity in the power system to be able to track load in peak periods and is described thoroughly in the rest of the article.

Why a capacity market? The answer is that the income obtained from Energy only market is definitely not enough to appeal new enterprises in generation field. Investors wouldn't invest in new power plants when the energy market is not able to assure them of their fixed and variable costs recovery. Energy market is not able to provide the investors with enough money so that the system should be fuelled by an extra amount of money to balance the new generation enterprise level and demand increment. Capacity markets such as capacity payment, capacity obligation and capacity subscription are options to put the whole idea into practice.

In Capacity Payment (CP), the most common type of existed capacity markets, amount of money is paid to those units which are available in peak periods [5, 6]. This payment can be categorized into two kinds, dynamic and fixed payments. Capacity Obligation (CO) determines amount of capacity obligation for each load serving entities according to system reliability criteria and load serving entity's share of total demand [6-8]. But new capacity obligation philosophies are mostly like capacity payments [7]. Capacity Subscription (CS) tries to focus on demand management to cover system

lack of resource adequacy in peak periods. Using this policy, it is possible to avoid sparks in spot prices by means of limited consumers' demand to their subscribed capacities during peak periods. The biggest challenge of CS policy is to install Load Limit Devices (LLD) for each consumer in the grid. In the upcoming smart grids, it will be possible to control directly the consumers' electricity consumption in the control centers by means of Advance Metering Infrastructure (AMI). This facility is provided by smart counters so that the biggest problem of CS policy will be solved. [9, 10] give a complete description of CS policy.

Despite various researches done on the mechanism and structure of capacity markets, their performances have rarely been tested in the presence of network constraints. In most of researches, the generation and load are considered to be placed on a same bus. But this is not applicable in real cases. In reality, generation and load are spread over the grid, placed on different buses and the transmission lines interconnect these buses together. It is also noticeable that the transmission network usually suffers from different sort of limitations contains of transmission line flow limitation, limitation of bus voltage and transmission losses [11]. To have a secured transmission network, no buses voltage should violent the [0.95 p.u., 1.05 p.u.] margins and none of the network branches should face to over flow.

In this article our focus is on the CS market where consumers try to subscribe for a part of their needed capacity in a competitive market. But due to transmission limits, it may not be possible to deliver the right amount of energy in the time of peak period which definitely would affect the capacity price. Finding a justice method to determine the capacity price in the system in presence of transmission constrains is a big deal in this model. In the rest of the article, we try to introduce a new method to determine the more justice capacity price in presence of transmission constrains in the CS model. Three different methods contain of considering Branch Flow limit as a Global Limit (BFGL), Locational Capacity Prices (LCP) and Local capacity Prices (LP) considering each consumer share of peak demand are suggested in this article where the last approach is the best which covers all the defects of the other two methods. The LP method has been inspired from the common Stamp Method (SM) which is used to allocate transmission costs in energy market and is briefly explained in [12-15]. In LP method each consumer's share of total peak demand is taken into account in order to determine the capacity price it has to pay in the CS market. In this way the consumers who benefit from the transmission facilities have to buy the capacity with higher prices than those whose needed electricity is prepared locally. The rest of this paper is organized as follows:

Second section reveals a quick review of CS model. Problem formulation and numerical results of three different proposed methods are discussed in section 3.

2 Quick Review of Capacity Subscription (CS) Model

Capacity inadequacy which leads to unexpected disconnections during peak periods basically happens as a consequence of two major reasons in traditional systems.
- Reliability is a public merchant.
- Most of consumers buy the electricity with a fixed price.

In restructured power systems, reformed interaction between supply and demand (demand becomes more price responsive) leads to developing several ways in order to limit demand during peak periods such as capacity subscription model [10]. This model is firstly introduced in 2000 by Gerard L. Doorman [9]. In CS model each consumer tries to subscribe for a part of installed capacity during peak periods according to its preference to pay for the capacity. Consequently, each consumer demand is limited to its amount of subscribed capacity by the Independent System Operator (ISO) during peak periods. To receive more to receive more reliable electricity without any curtailment, consumers should subscribe to higher level of capacity, thereby paying more money in comparison to those who tries to diminish their costs by reducing their electricity consumption.

In the first step of CS model, all generation units voice their available capacity to the market. Considering this amount of offered capacity, ISO starts from a basic price as a capacity bid. Each consumer tries to minimize its Composed Cost (CC) matching the capacity price announced by ISO. The each consumer group is definable by its maximum Value of Cut Load (VCL_{max}) According to Eq. (1). The propose method calls it VCL because the consumers are partially curtailed not completely disconnected from the grid in the time of peak period [7].

$$ (1) $$

$$ VCL_m = \frac{VCL_{m,\max}}{1 - e^{-b \times shd_m \times Q}(1 - e^{-b \times (shd_m \times Q - A_m)})} $$

where

$VCL_{\max}$ — Value of cut load for consumer group m [Tooman*/MWh]

$shd_m \times Q$ — Share of total peak demand for consumer group m [MW]

b — Steepness of the VCL function [MW^{-1}]

A_m — Subscribed capacity for consumer group m [MW]

$VCL_{m,max}$ Value of cut load for zero served load, consumer group m [Tooman/MWh].

The Energy Not Served (ENS) for each consumer group is determined using the below equation considering its subscribed capacity level Eq. (2) [3]:

$$ENS_m = \max(shd_m \times Q - A_m, 0) \times ld \qquad (2)$$

where

ENS_m Energy not served for consumer group m [MWh]

ld Peak load duration [hours]

The Eq. (3) represents the imposed cost to each consumer group in the CS market so that the optimal amount of subscribed capacity for each consumer group is determined by Eq. (4) [7].

$$CC_m = CP \times A_m + ENS_m \times VCL_m \qquad (3)$$
$$A_m^* = \min(CC_m) = \min(CP \times A_m + ENS_m \times VCL_m) \qquad (4)$$

Hence, if the price of capacity is high, consumers tend to buy less so that the amount of their subscribed capacity becomes less. But consumer with higher VCL_{max} who have higher tendency to receive more reliable electricity, will end up with higher amount of subscribed capacity than those consumers with lower VCL_{max} [9]. If the total optimal subscribed capacity level for all consumers exceeds the available installed capacity, ISO adjust the capacity price and the market procedure will be repeated again. The market clearing price is the one in which the total subscribed capacity level equals the available supply. In this way, all the consumers buy the capacity with a fixed price that is equal for all groups with different VCL_{max}.

3 Capacity Subscription (Cs) Model with Considering The Transmission Lines Flow Limit

3.1 Considering the Branches Flow Limit as a Global Limit (BFGL)

In this method, the branches flow limit is considered as a global limit, applied equally to all consumers. To begin the CS market, ISO starts from a base capacity price. Then, step by step, increases it until the total subscribed capacity descends the available supply and also none of the branches facing to over load.

For M different groups of consumers and N branches, the capacity subscription model can be formulized as:

$$\begin{cases} MinCC_1 \\ . \\ . \\ . \\ MinCC_M \end{cases} \qquad (5)$$

subject to

$$\sum_{i=1}^{M} A_i < Capacity_{total} \qquad (6)$$
$$P_i < P_{in} \qquad for \quad 1 \le i \le N \qquad (7)$$

where
$capacity_{total}$ The total installed capacity [MW]
P_i Branch number i flow [MW]
P_{in} Branch number i nominal flow [MW]

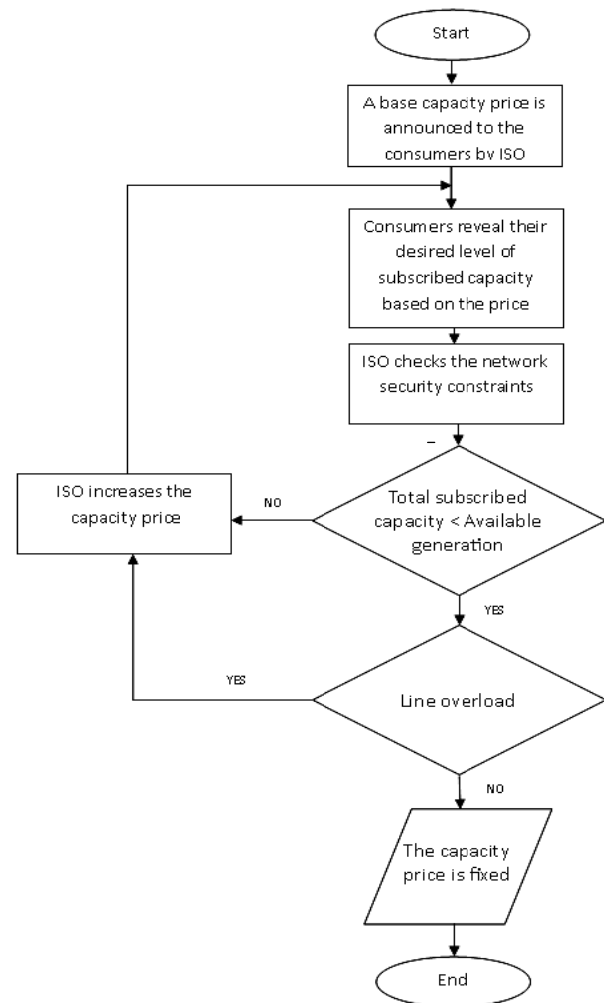The flowchart shown in Fig. 1 reveals the procedure of BFGL method:
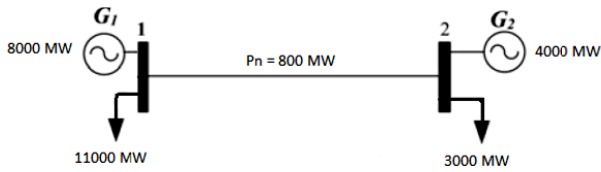

Fig. 1 Flowchart of BFGL method.

Fig. 2 Schematic of 2-bus test system.

Table 1 Numerical results of capacity subscription market with considering the branches flow limit as a global limit (BFGL).

Prameter	Without transmission line flow limitation	With transmission line flow limitation
Capacity price (Tooman/MW)	46533150	59003189
Transmission line flow (MW)	1266.3	800

This method is tested on a 2-bus test system as demonstrated in Fig. 2.

Table 1 plots the results of BFGL method. As the table shows without branch flow limit taken in to account, the flow of the line is 1.58 times greater than its maximum allowed content. With considering the transmission flow limit, the branch flow is fixed at 800 MW, which is equal to its maximum allowed transmitted power and no constraint is violated. The capacity price in this model is 26.8% greater than the base model without considering the transmission flow limit. But posing this high capacity price to all consumers equally seems unfair due to the fact that some of the consumers are not involved with the branches over flow. The proposed method calls these consumers as local consumers because the local generators connected to the related bus are able to provide the electricity they need and there is no need of interchange transaction with the generators placed on the other buses. This is exactly what happens to consumer connected to bus number 2 (Fig. 2). It seems fair that local consumers would not have to pay for the over load of the transmission lines. In order to exempt the local consumers from paying extra money, the LCP is suggested in section 3.2.

3.2 Locational Capacity Price (LCP)

A two-phase capacity market is proposed in this section that in the first phase the market procedure is held without transmission constraints taken into account. The market determined price in this stage will be applied to local consumers. The non-local consumers are declared when the demand exceeds the supply on the related bus. In order to determine the capacity price for non-local consumers, in the second phase of the market, a new factor named λ is defined for each line with the over load which is equal to the ratio of the line flow to its maximum allowed flow Eq. (8).

$$\lambda = P_A \big/ Pn_A \qquad (8)$$

In presence of two or more over loaded lines connected to a bus, the biggest is taken into account as the buses.

In the second phase of the market, ISO starts from the market determined capacity price obtained from the first stage multiplied to the related of each bus, as the capacity price for the related non-local consumer. The non-local consumers determine their subscribed capacity level regarding their capacity price and suggest it to the ISO. If the summation of all subscribed capacity (local and non-local consumers) exceeds the available installed capacity, ISO increases the second stage capacity price for each group of non-local consumers a bit, and repeats the second phase of the market again. This procedure will be continued until the total subscribed capacity equals the available supply. Flowchart in Fig. 3 reveals the procedure of LCP method.

Table 2 shows the numerical results of two-phase CS market implemented on the 2-bus test system. It is noticeable that the transmission line flow is 800 MW.

The advantage of the LCP method, as illustrated in Table 2, is that only the consumers which benefit from the transmission mechanism, will pay for the transmission cost and the local consumers are exempt. In this method, the money paid by the consumers for the capacity subscriptions is more than the amount of money paid to the generation units. This surplus can be dedicated to the transmission costs according to ISO's discretion. As Table 2 represents, the generator connected to bus 2 could only generate 3533 MW due to transmission limitations which is 476 MW lower than its nominal active power. This amount of excess capacity is called enclosed capacity. This enclosed capacity is zero-priced because the consumers connected to the related bus know that the generating unit has no other option but to sell the enclosed capacity locally therefore; they would not be eager to pay for the excess capacity and prefer to receive it free. This situation lasts until the local demand exceeds the available supply on the bus so that the price of enclosed capacity would increase in the excess capacity allocation market.

Table 2 Locational capacity prices.

	Subscribed capacity (MW)	Supply (MW)	Capacity price (Tooman/MW)
Bus 1	59003189	8000	8800
Bus 2	46533150	3533	2733

The other advantage of local capacity prices in LCP model is to encourage the new generation enterprise on the buses which are facing to lack of capacity. Due to the fact that capacity price is higher in these buses, it ends up with higher income gained by the investors. Table 3 plots the generation enterprise made by the investors within ten years of the generation expansion planning horizon [7].

The LCP model is effective, but difficult to be implemented in huge transmission networks. The other defect of this method is that it is not possible to determine the capacity price of non-local consumers who are placed in buses with no connection to over loaded transmission lines. Although these non-local consumers benefit from transmission facilities, they only pay the same capacity price as the local consumers because the λ indexes of the related buses are less than one unit. The next noticeable point is that consumers connected to a similar bus do not benefit from the transmission facilities equally so that should not be obliged to pay equally for the capacity. Considering the above description, a new method should be devised to differentiate the consumers connected to a similar bus and categorized them in to different groups and also be able to determine the capacity price of non-local consumers cited on buses with no connection to over loaded lines.

3.3 Local Capacity Price Considering Each Consumer Share of Peak Demand (LP)

To cover the defects of LCP method, LP method is proposed in this section. In fact there is no accurate method to calculate each consumer share of transmission flow. In between, the stamp method can determine each consumer's share of total peak demand which relatively can demonstrate each consumer's consumption of the whole transmission network capacity [12]. To put it in to practice, M buses with non-local consumers are taken in to account. The proposed method assumes that each bus only contains one group of non-local consumer. Therefore C_i which represents consumer number i share's of total peak demand is defined as Eq. (9):

$$C_i = \frac{P_{peak_i}}{P_{peak,total}} \; ; \quad 1 < i < M \tag{9}$$

Table 3 Generation enterprise within ten years of the generation expansion planning horizon.

	Bus 1	**Bus 2**
New installed capacity (MW)	400	-
Commissioning year	10	-

where

C_i	Bus number i share of total demand
P_{peak_i}	Bus number i peak demand [MW]

The LP model, similar to LCP model, contains of a two-phase CS market that in the first phase, capacity price is determined without any transmission constraints taken in to account. This capacity price is applied to local consumers. In order to determine the non-local consumer's capacity prices, a new factor called λ_t is determined for each bus involving with non-local consumers according to Eq. (10).

$$\lambda_t = \frac{1}{C_i} \; ; \quad 1 < t > M \quad \& \quad 1 < i < M \tag{10}$$

where:

λ_t	Bus number t capacity price index

ISO ranks all the determined λ_ts and allocates each λ_t to the related bus so that the lowest λ_t could be allocated to the bus with lowest share of total peak demand and the highest λ_t could be allocated to the bus with highest share of total demand.

In the second phase, ISO calculates each non-local consumer capacity price according to the first phase market determined capacity price multiplied to the related λ_t. Then each non-local consumer determines its subscribed capacity level considering the capacity price announced by ISO. ISO gathers all the capacity bids and if the total subscribed capacity level exceeds the available supply or any transmission line faces over flow, it increases the capacity prices of non-local consumers and repeats the procedure again. This market procedure is continued until the total subscribed capacity level equals the available supply and none of the lines became over loaded. Flowchart in Fig. 4 reveals the procedure of LCP method.

In order to test the LP model, a 3-bus system is used as illustrated in Fig. 5.

Fig. 6 and Table 6 demonstrate the numerical results obtained from the 3-bus test system with the technical specifications presented in Tables 4, 5.

As Fig. 6 shows, none of the transmission constraints are violated and as Table 7 represents, the capacity price grows as the non-local consumer share of total peak demand increases. In this method, the amount of money paid by the consumers for the capacity subscriptions is more than the amount of money paid to the generation units. This surplus can be dedicated to the transmission costs according to ISO's discretion.

Table 8 shows the numerical results of the three represented methods tested on the on 3-bus test system as showed in Fig. 5.
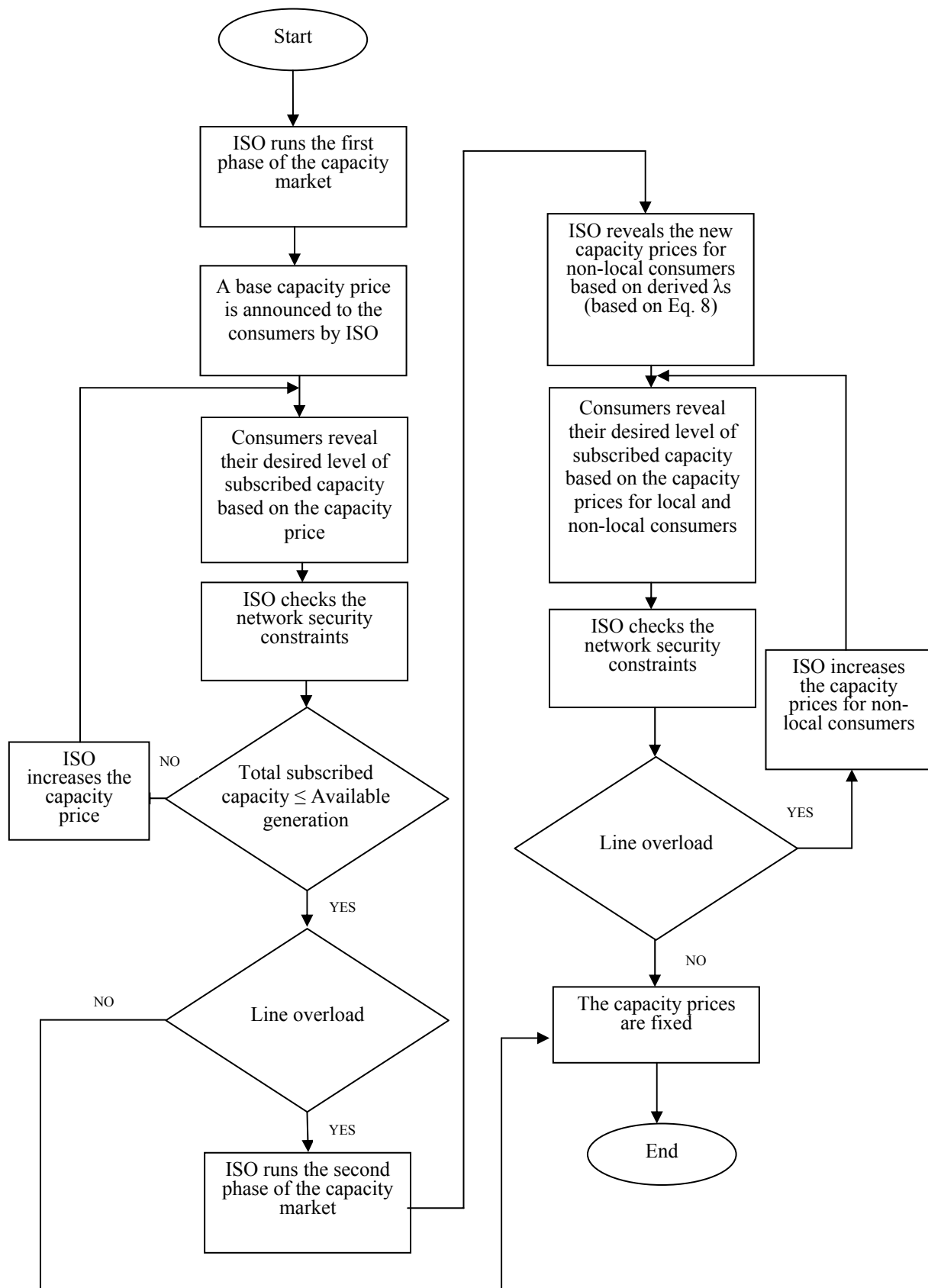
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                        ┌─────────┐
                        │  Start  │
                        └────┬────┘
                             │
                             ▼
              ┌──────────────────────────┐
              │     ISO runs the first   │
              │   phase of the capacity  │
              │          market          │
              └─────────────┬────────────┘
                            ...
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Start

ISO runs the first phase of the capacity market

A base capacity price is announced to the consumers by ISO

Consumers reveal their desired level of subscribed capacity based on the capacity price

ISO checks the network security constraints

ISO increases the capacity price

Total subscribed capacity ≤ Available generation

NO

YES

Line overload

NO

YES

ISO runs the second phase of the capacity market

ISO reveals the new capacity prices for non-local consumers based on derived λs (based on Eq. 8)

Consumers reveal their desired level of subscribed capacity based on the capacity prices for local and non-local consumers

ISO checks the network security constraints

Line overload

YES

NO

ISO increases the capacity prices for non-local consumers

The capacity prices are fixed
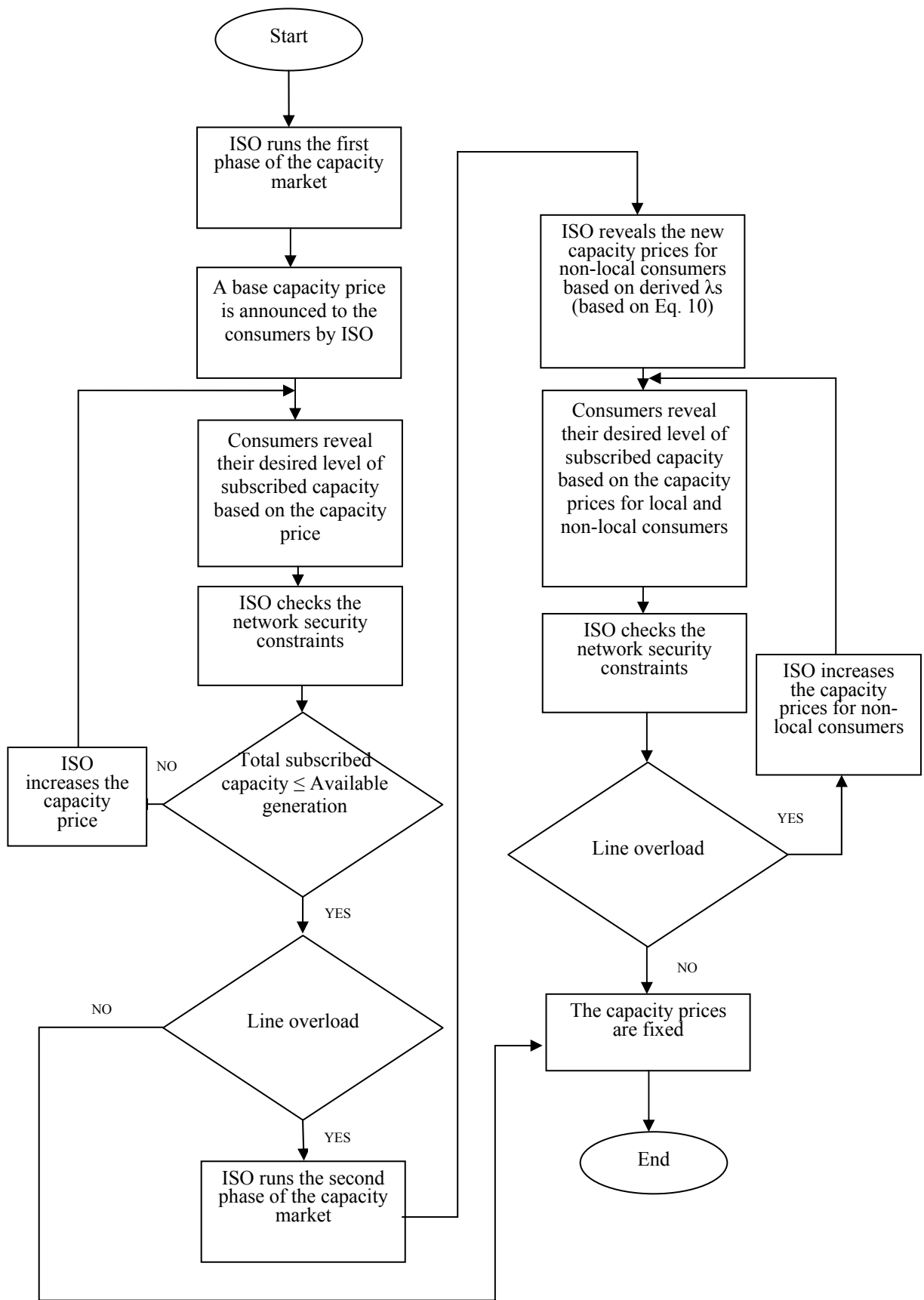
End

Fig. 3 Flowchart of LCP method.
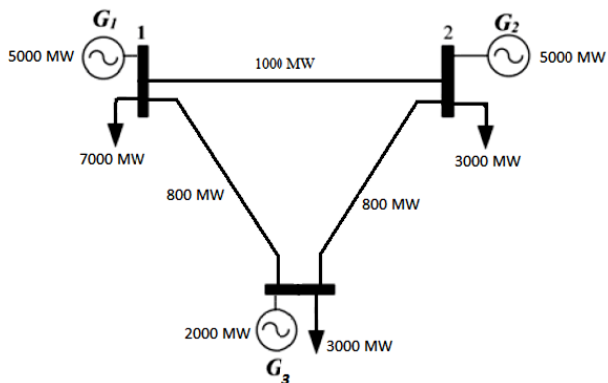
Fig. 4 Flowchart of LP method.

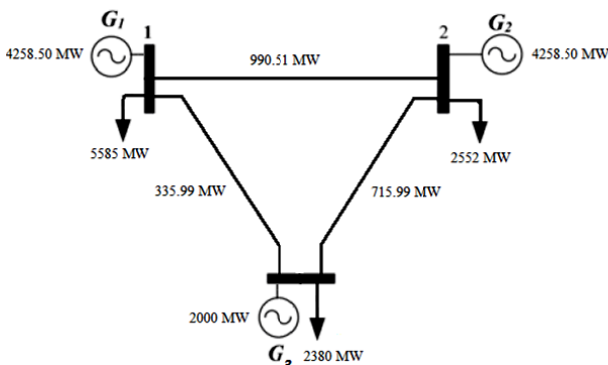**Fig. 5** Schematic of 3-bus test system.

Fig. 6 Schematic of 3-bus test system in CS market with applied LP method.

Table 4 Consumers' parameters.

Consumer	VCLmax [Tooman/MWh]	Share of total peak demand
Bus 1	15645	0.53846
Bus 2	8813	0.23076
Bus 3	6562	0.23076

Table 5 Generation and demand parameters.

Bus Number	Generation (MW)	Demand (MW)
1	5000	7000
2	5000	3000
3	2000	3000

Table 6 Branches' parameters.

Branch	r, resistance (p.u.)	x, reactance (p.u.)	b, susceptance (p.u.)
1-2	0.017	0.05917	0.0528
1-3	0.039	0.05917	0.0528
2-3	0.039	0.05917	0.0528

Table 7 Capacity prices considering each consumer share of peak demand.

	Bus 1	Bus 2	Bus 3
Capacity price (Tooman/MW)	120127500	49937700	51518500
λ_t	2.4055	1	1.0316

As Table 8 shows, none of the lines faces to over load in any of the BFGL, LCP and LP methods. In BFGL method all the consumers have to pay the same price for the capacity.

This price is higher than the amount paid by consumers connected to bus 2 and 3 in LCP and LP methods which results in considerable reduction in subscribed capacity levels obtained by these consumers in BFGL method.

In LCP and LP models, consumer connected to bus 2 is a local consumer and the other two consumers connected to bus 1 and 3 are non-local consumers. In LCP model, none of the branches connected to bus 3 face to over load after the first stage of the market, so that the consumer connected to this bus pays the same price as the local consumer (consumer connected to bus 2) which results in higher amount subscribed capacity obtained by this consumer in comparison to LP method. In LP model, the capacity price which each non-local consumer has to pay is proportional to its share of total peak demand which is definitely the best advantage of this method. In this way, even non-local consumers connected to the same bus do not have to pay the same price for the capacity and the capacity price will be tuned according to their consumption of the whole transmission network capacity. This strategy results in higher capacity price for consumer connected to bus 3 and lower capacity price for consumer connected to bus 1 in comparison to LCP method. In fact, consumer connected to bus 1 is not the only responsible for the lines over load in the system, so that it is better to involve all non-local consumers. This is exactly what the LP method does. Therefore it results in different capacity prices which grow as non-local consumers' shares of total peak demand increase.

Tables 9 and 10 show the numerical results obtained from IEEE 14-bus test system with a bit manipulation in generation and load levels (Fig. 7). As presented in Table 9 the available supply is 1700 MW and the total peak load demand is 2805 MW.
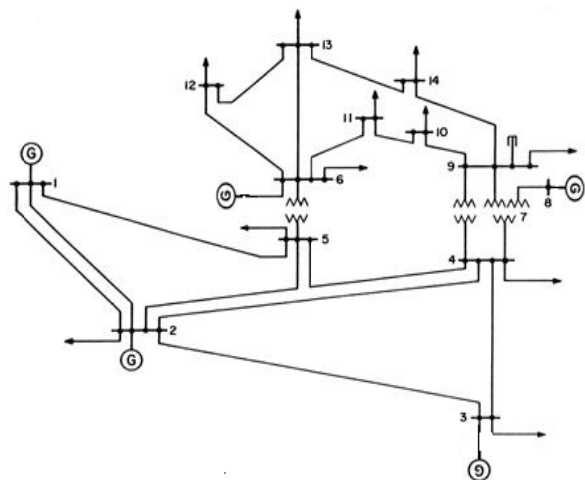

Fig. 7 IEEE 14-bus test system with a bit manipulation.

Table 8 Numerical results obtained from BFGL, LCP and LP methods tested on 3-bus system.

Method	Capacity price at bus 1 (Tooman/MW)	Capacity price at bus 2 (Tooman/MW)	Capacity price at bus 3 (Tooman/MW)	Subscribed Capacity at bus 1(MW)	Subscribed Capacity at bus 2(MW)	Subscribed Capacity at bus 3(MW)	Branch 1-2 flow (MW)	Branch 1-3 flow (MW)	Branch 2-3 flow (MW)
CS (without transmission constraints)	49937700	49937700	49937700	6412	2552.5	2399	1049	360	755
BFGL	122346700	122346700	122346700	5559.4	1903.9	1528	997	764	292
LCP	123640600	49937700	49937700	5544	2552.5	2399	977	319	718
LP	120127500	49937700	51518500	5585.5	2552.5	2380	990	336	716

Table 9 Numerical results of LP method tested on IEEE 14-bus test system.

Bus number	Maximum supply (MW)	Load (MW)	VCLmax [Tooman/MWh]	shd	λ_t	Subscribed capacity (MW)	Capacity price (Tooman/MW)	Generation (MW)
1	500	0	0	0	0	0	0	470.6
2	200	330	4888.3	0.118	17	272.2	55297600	287.3
3	300	165	5434.8	0.059	1	139	3252800	247.3
4	0	165	761.9	0.059	8.5	80.5	27648800	0
5	0	82.5	5480.3	0.029	5.7	69.6	18410848	0
6	400	82.5	3794.2	0.029	1	63.9	3252800	247.3
7	0	0	0	0	0	0	0	0
8	300	0	0	0	0	0	0	247.3
9	0	165	585.2	0.059	8.5	80.5	27648800	0
10	0	165	1671	0.059	8.5	90.4	27648800	0
11	0	495	3281.3	0.176	34	365.9	110595200	0
12	0	330	5745	0.118	17	280.8	55297600	0
13	0	330	5789.3	0.118	17	281.2	55297600	0
14	0	495	945.7	0.176	34	47	110595200	0

Table 10 Numerical results of LP method tested on IEEE 14-bus test system.

Branch	Maximum allowed flow (MW)	Flow (MW)	Branch	Maximum allowed flow (MW)	Flow (MW)
1-2	300	281.03	6-11	200	119
1-5	200	181.48	6-12	200	152.23
2-3	100	26.76	6-13	250	192.47
2-4	200	129.54	7-8	250	208.17
2-5	200	134.64	7-9	300	264.99
3-4	150	100.22	9-10	200	195.06
4-5	100	14.09	9-14	100	88.67
4-7	100	64.71	10-11	200	135.28
4-9	100	77.94	12-13	100	50.49
5-6	300	275.92	13-14	100	53.1

4 Conclusion

A new method to determine capacity prices considering the transmission lines' flow limitation, named local capacity prices considering each consumers share of total peak demand (LP), is presented and tested on a 3-buses and IEEE 14-bus test systems. The numerical results show that the proposed method tries to dispatch the transmission costs between consumers as fair as possible, in a way that those consumers who benefit from transmission facilities pay higher capacity prices than those who their needed electricity is prepared locally. The LP method has two main advantages. First of all only the consumers which benefit from the transmission mechanism will pay for the transmission cost and the local consumers are exempt. Second, all the non-local consumers connected to the same bus wouldn't have to pay a same price for capacity. The surplus money resulted from more money paid by the consumers than amount which is paid to generation units, can be dedicated to transmission costs according to ISO's discretion.

References

[1] Arroyo J. M. and Galiana F. D., "Energy and Reserve Pricing in Security and Network-Constrained Electricity Markets", *IEEE Transactions on Power Systems*, Vol. 20, No. 2, pp. 634-643, May 2005.

[2] Leite da Silva A. M. and Alvarez G.P., "Operating Reserve Capacity Requirements and Pricing in Deregulated Markets Using Probabilistic Techniques", *IET Generation, Transmission and Distribution*, Vol. 1, No. 3, pp. 439-446, May 2007.

[3] Gorgizaseh Sh., Akbari Foroud A. and Amirahmadi M., "Strategic Bidding in A Pool-Based Electricity Market under Load Forecast Uncertainty", *Iranian journal of Electrical & Electronic Engineering*, Vol. 8, No. 2, pp. 164-176, June 2012.

[4] Rajabi Mashhadi H. and Khorasani J., "Price Taker's Bidding Strategies in Joint Energy and Spinning Reserve Pay-as-Bid Markets", *Iranian journal of Electrical & Electronic Engineering*, Vol. 9, No. 1, pp. 36-43, Mar. 2013.

[5] Assili M., Hossein Javidi D. B. M. and Ghazi R., "An improved mechanism for capacity payment based on system dynamics modeling for investment planning in competitive electricity environment", *Energy Policy*, Vol. 36, No.10, pp. 3703-3713, June 2008.

[6] Crampton P. and Stoft S., "A capacity market that make sense", *Elect. J.*, Vol. 18, No.7, pp. 43-54, 2005.

[7] Doorman G. L. and Botterud A., "Analysis of generation investment under different market designs", *IEEE Trans. on Power Syst.*, Vol. 23, No.3, pp. 859-867, August 2008.

[8] Hobbs B. F., Inon J. and Stoft S., "Installed capacity requirements and price caps: Oil on water of fuel on the fire?", *Elect. J.*, Vol. 14, No. 6, pp. 22-34, August 2001.

[9] Doorman G. L., "Capacity subscription: solving the peak demand challenge in electricity markets", *IEEE Trans. on Power Syst.*, Vol. 20, No. 1, pp. 239-245, January 2005.

[10] Doorman G. L., "Peaking capacity in restructured power systems", Ph.D. dissertation, *Norwegian Univ Sci Technol*, Trondheim, Norway, 2000.

[11] Kundur P., *Power system stability and control*, 1st edition, New Yourk: McGraw-Hill; 1994.

[12] Kirschen D. S., *Strbac G. Fundamentals of Power System Economic*, New York: John Wiley & Sons; 2004.

[13] Farmer E. D., Croy B. J. and Perera B. L. P. P., "Optimal pricing of transmission and distribution services in electricity supply", *IET Proc on Gener. Trans. Distrib*, Vol. 142, No. 1, pp. 1-8, January 1995.

[14] Hogan W. W., *Market-based transmission investment and competitive electricity markets*, Available online at [accessed 2013]: http://www.hks.harvard.edu/fs/whogan/tran0899.pdf, August 1999.

[15] Lima M. J. W., "Allocation of transmission fixed charges: an overview", *IEEE Trans. on Power Syst.*, Vol.11, No.3, pp.1409-1418, August 1996.

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