Secondary Market for Transmission and the Supporting Infrastructures

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Abstract—

In this paper we discuss the infrastructure important for proficient management of the network, namely the secondary markets for transmission rights.

Following the restructuring process the participants in the electric power industry are engaging in complex market activities to meet their electricity needs. Many market participants enter into forward (delivery) contracts for energy. The forward price may be described as the spot market price for delivery of a commodity at a fixed time in the future. As a counterpart to the forward contract marketplace for energy, the secondary market for transmission provides the necessary mechanism for supporting the market activities so that the change in value is readily conveyed to all of the market participants of the forward contracts for transmission portion of electric services in the form of the intermediate term transmission contracts. Here the market participants may be the holders of the physical transmission rights, the holders of the financial transmission rights and/or the bidders in the spot market.

With the introduction of the secondary markets for transmission rights we can compare the workings for the transmission rights in the form of the intermediate term transmission contracts proposed in this paper with the transmission congestion contracts (TCC) and the flowgate rights.

I. Introduction

The secondary markets play a very important role in trading a commodity subject to many uncertainties. These uncertainties are typically related to the high volatility in spot price for the commodity. A spot price is the price at which a commodity is traded for immediate delivery. We refer the marketplace where the spot prices prevail as a spot market.

One of the most common methods used to deal with this spot price uncertainty is the risk hedging through forward (delivery) contracts which are the contracts to buy or sell the commodity at a fixed time in the future at a pre-specified price. We call this pre-specified price, a forward price, and the marketplace where the commodity is traded based on forward contracts, a futures market. A futures market is common form of a secondary market. In a futures market, suppliers can commit some or all of their outputs at the forward price before the actual production. By entering into forward contracts, the risks on profit stemming from the uncertainty in spot prices can be eliminated for the amount of output committed in the contracts.

The purpose of the paper is to investigate the opportunities for risk hedging against network-related uncertainties available to network users. The forward contracts related to such risk hedging method are referred to as the long term or intermediate term transmission contracts depending on the duration of the contracts in this paper and are issued by the transmission provider (TP). We focus on the efficacy of such contracts in the presence of the secondary markets for transmission rights and the necessary infrastructures.

The paper is organized as follows:
In Section II we define the role of the secondary markets for transmission rights. Section III examines the intermediate term transmission contracts in details. Concluding remarks are made in Section IV.

II. Role of the secondary markets for transmission rights

Following the restructuring process the participants in the electric power industry are engaging in complex market activities to meet their electricity needs. Hence, the value of the energy and the transmission portion of electric services are determined employing the market mechanism. These values once determined are then, communicated among the market participants through the prices specified on various contracts. For example, suppose for hour k the value of electric energy at bus g_i is determined to be $\rho_{g_i}[k]$ using the market mechanism. Then, any contract involving a purchase of electricity from bus g_i for hour k carries the price of $\rho_{g_i}[k]$ as valued.

Many market participants enter into the so-called forward (delivery) contracts for energy. This type of contracts serves many useful purposes including hedging against price volatility. A forward contract is an agreement between a buyer and a seller that a commodity (in this case electric power) is to be delivered on a specified date, τ_{dd}, in the future from the present time, t, at a specified fixed price, $\rho_{g_i}(t,\tau_{dd})$ supplied by the generator at bus g_i. The date specified by the contract is called the delivery date, while the price is known as the forward price. The forward price may be described as the spot market price for delivery of a commodity at a fixed time in the future [2], i.e.,[1]

$$\rho_{g_i}(t,\tau_{dd}) = \underset{t}{\mathcal{E}}\{\rho_{g_i}[\tau_{dd}]\} \tag{1}$$

where

$$\underset{t}{\mathcal{E}}\{(\cdot)\}$$

denotes the expected value of $(\cdot)$ computed given the information available up to the present time t. Thus, at the time of agreement the contract has a value of zero and remains

[1] The spot market price needs to be discounted at the rate of risk-free investment in order to reflect the present value of the contract. This fine detail is not included here for the sake of simplicity.

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at zero so long as the expected value of the spot market price at the delivery date stays unchanged. As the delivery date approaches, however, new information regarding market conditions emerge and may influence the expected value of the spot market price at the delivery date to move up or down. Suppose at time t_1, where $t < t_1 \leq \tau_{dd}$, the expected value of the spot market price at the delivery date changes from $\rho(t, \tau_{dd})$ to $\rho_{g_i}(t, \tau_{dd}) + \Delta$, i.e.,

$$\rho_{g_i}(t, \tau_{dd}) = \mathop{\mathcal{E}}_{t}\{\rho_{g_i}[\tau_{dd}\} \tag{2}$$

while including the information available now up to the time t_1. Then, the value of the contract also changes from zero to Δ. Here a forward contract *marketplace* plays a significant role in providing the mechanism for supporting the market activities so that the change in value of the contract is readily conveyed to all of the market participants. For example, with the rise in forward prices the buyer whose demand is elastic may want to reduce consumption and realize a profit on the sale of the original contract. The efficiency of market mechanism depends on how effortlessly such market activities could be carried out.

As a counter part to the forward contract marketplace for energy, the secondary market for transmission provides the necessary mechanism for supporting the market activities so that the change in value is readily conveyed to all of the market participants of the forward contracts for transmission portion of electric services in the form of the intermediate term transmission contracts. Figure 1 shows the information exchange among the market participants, the system operator (SO) and the independent transmission company (ITC) for the intermediate term transmission contracts involving the secondary market. The market

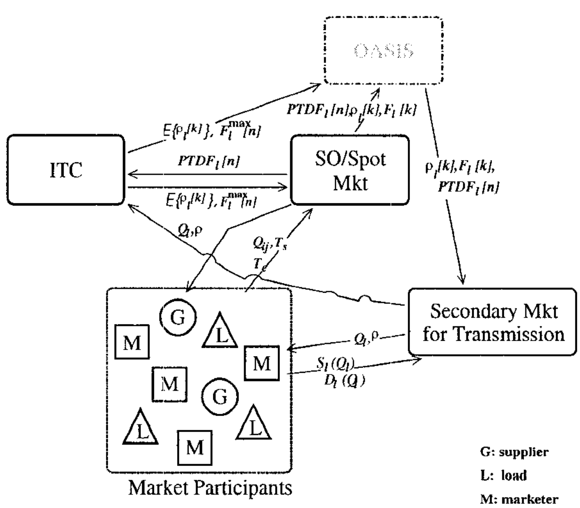

Fig. 1. The information exchange among the market participants, the SO and the ITC for the intermediate term transmission contracts involving the secondary market

participants can purchase intermediate term transmission contracts on each line l in the network from the SO for any desirable duration within the year. First, at the beginning of each year the total capacity available on individual transmission lines within the network is determined by the ITC for the entire year n. When determining the capacity the ITC relies on the expertise of the SO on the operation of the network including the power transfer distribution factors (PTDF). Then, the ITC issues the intermediate term transmission contracts to be offered to the market participants to be used as forward contracts for the transmission portion of the electric services. The price for each of these contracts, $\rho_l(t_s, t_e)$, is determined by the ITC, initially, based on the expected value of the transmission charge,

$$\mathop{\mathcal{E}}_{t=(n-1)T_T+1}\{\rho_l[k]\}$$

over the interval $[t_s, t_e]$ so that the expected value of the overall transmission revenue is maximized while respecting the network constraints.

Following the issuance of the intermediate term transmission contracts the SO conducts the spot market for energy at each hour k, the actual transmission charge for each line in the network, $\rho_l[k]$ is determined and is made available to the market participants. Here the market participants may be the holders of the physical transmission rights, the holders of the financial transmission rights and/or the bidders in the spot market.

Suppose the market conditions have changed so that the expected value of the transmission charge computed at the beginning of the years needs to be adjusted in order to reflect accurately the current state of the electricity market. Then, the ITC announces the adjusted prices for the transmission contracts and applies the new prices to the contracts in any upcoming sales. The market participants, in turn, may utilize the secondary markets to trade any outstanding contracts issued prior to the price adjustment according to the change in market conditions.

Without the presence of the secondary markets for transmission rights, the ITC relies solely on its expertise gained by observing the transmission charges imposed on the market participants in the spot market when determining the price to be charged for the transmission rights. This creates the open loop computation of the charge. However, with the presence of the secondary market for transmission rights, the ITC can observe the change in prices at the secondary markets for equivalent rights and take this into consideration in determining the price, i.e. in the feedback fashion. The actual mechanism for determining the price while taking the prevailing price in the secondary markets for the transmission rights is beyond the scope of this thesis.

Figure 2 shows the ultimate financial exchanges between the market participants and the secondary markets for transmission rights.

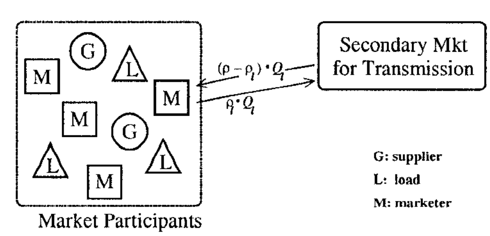

Fig. 2. The financial exchange between the market participants and the secondary markets for transmission rights

III. Closer look at the proposed transmission rights

With the introduction of the secondary markets for transmission rights we can compare the workings for the transmission rights in the form of the intermediate term transmission contracts proposed in this thesis with the transmission congestion contracts (TCC) and the flowgate rights.

In the following sections we first describe the differences between the intermediate term transmission contracts and TCC and between the intermediate term transmission contracts and flowgate rights. Then, the workings of these contracts are compared in terms of the financial exchanges.

A. Point-to-point transmission rights

The transmission congestion contracts (TCC's) proposed in [3] is a representative of the point-to-point transmission rights being widely considered in the electric power industry, at the time of writing, as a possible form of allocating network capacity over the longer term. In order to understand the differences between the TCC's and the intermediate term transmission contracts proposed in this thesis we need to look not only at the actual mechanism for implementing the contracts but also at the underlying market structure.

The underlying market structure assumed for the TCC's is the rate-of-return regulation imposed on the transmission owners and the operational authority given to the non-profit organization called independent system operator (ISO). Under this market structure, the market participants are allowed to submit bids for purchasing the TCC's, once at the beginning of the year (or of the season).[2] The ISO, then determines the price and the amount of TCC's to be made available and allocates network capacity corresponding to the contracts based on the bids. Each of the TCC's issued to the participants specify at least the following three elements: the location of the source bus, the location of the sink bus and the amount of the energy involved in the transaction.

Once the allocation of the TCC is concluded, all of the market participants are required to submit bids to the spot market in the same way whether a participant owns the TCC or not. The ISO, then clears the spot market by solving the optimal power flow (OPF) problem and completes the dispatch schedules without any regards to the allocation of the TCC's. As a result of the market clearing process, the combined price of energy and transmission portions of electric services at each bus are determined by the shadow cost associated with the OPF problem as written in the following:

$$\mathbf{Q_G}^\star[k] = \arg \min_{\mathbf{Q_G}[k]} \sum_{g_i} (a_{g_i} Q_{g_i}^2[k] + b_{g_i} Q_{g_i}[k]) \qquad (3)$$

$$\sum_{g_i} Q_{g_i}[k] = \sum_{d_j} Q_{d_j}[k] : \qquad \lambda[k] \qquad (4)$$

$$Q_{g_i}^{\min}[k] \le Q_{g_i}[k] \le Q_{g_i}^{\max}[k] : \qquad \eta_{g_i}[k] \qquad (5)$$

$$\sum_{g_i} H_{lg_i} Q_{g_i}[k] - \sum_{d_j} H_{ld_j} Q_{d_j}[k] \le F_l^{\max}[n] : \qquad \mu_l[k] \qquad (6)$$

where

Q_{g_i}:	the amount of generation at bus g_i
Q_{d_j}:	the amount of consumption at bus d_j
$a_{g_i} Q_{g_i}^2[k] + b_{g_i} Q_{g_i}[k]$:	the production cost at bus g_i
$H_{l(\cdot)}$:	the PTDF's of network line l with respect to injection at bus $(\cdot)$
$F_l^{\max}$:	operational limit on power transfer through line l

The price at each bus is often referred to as the nodal price. The revenue is collected and distributed by the SO as the product of the injection into the bus and the corresponding nodal price. For example, suppose the amount of electric power, $Q_{d_j}[k]$, is taken from the network at the nodal price of $\rho_{d_j}[k]$. Then the load at that bus pays $\rho_{d_j}[k]$ for each unit of power, totaling $\rho_{d_j}[k] \cdot Q_{d_j}[k]$, to the SO. Analogously, if the amount of electric power, $Q_{g_i}[k]$, is injected to the network at the nodal price of $\rho_{d_j}[k]$, the generator at that bus is paid $\rho_{d_j}[k]$ for each unit of power, totaling $\rho_{d_j}[k] \cdot Q_{d_j}[k]$, by the SO. The transmission charge collected by the SO here is often referred to as the congestion charge and is the difference between the amount received from the loads and the amount paid to the generators. Finally, the holders of the TCC's are paid the difference between the nodal price at the location of the sink bus and the nodal price at the location of the source bus specified in the contract. Throughout the process the transmission owners are not involved at all because the revenue received by the transmission owners is a guaranteed return allowed by the regulator and is not related to the TCC's and consequently to the transmission (congestion) charge.

Based on the implementation of TCC scheme described above, it is evident that the TCC's are purely *financial* transmission rights since the holders of the contract are not given the priority for using the network. Indeed, the market clearing process is completely independent of the allocation of TCC's. Considering that the network related risks are two folds, namely the price volatility in transmission capacity and the actual dispatch schedule, the TCC's cover only the former.

When the financial relationship created by the TCC's is examined, it is recognized that there is an apparent disconnect between the reward/penalty mechanism and the entities assuming the financial risks. Because it is the ISO issuing the TCC's to offer the hedging opportunities to the market participants against the volatility in the transmission capacity prices, it appears that the ISO takes on the financial risks. However, the ISO does not assume any financial responsibilities. Thus, this imposes a critical constraint (perhaps audit-able by the regulator) on issuing the TCC's, namely the revenue neutrality coming from the simultaneous feasibility criterion. The revenue neutrality refers to the sufficient transmission charge collected by the SO so that all of the payment to the TCC holders can be made from the transmission charge. The simultaneous feasibility criterion limits the ability of the SO in issuing the amount

[2]The market participants can determine the amount and the price of the TCC's for the bidding purposes either purely based on the expected value of financial transmission rights of this sort or based on the financial contracts for energy, so-called contract-for-difference (CFD). The CFD is an arrangement made between two or more participants for mimicking bilateral transactions under the TCC scheme. The details on the CFD are referred to [3].

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of the contracts so that all of the transactions specified in the contracts appears to take place simultaneously at each hour k while the contracts are valid. That is to say, if the contracts together specify an injection of $Q_{g_i}[k]$ at bus g_i, then at each hour from the beginning of the year to the end, the injection at bus g_i needs to be at least $Q_{g_i}[k]$. Similarly, if the contracts together specify a withdrawal of $Q_{d_j}[k]$ at bus d_j, then at each hour from the beginning of the year to the end, the withdrawal at bus g_i needs to be at least $Q_{d_j}[k]$. In case there is a difference in the transmission charge collected by the SO in the spot market and the TCC payment made to the holders of the contracts, then the difference is handed over to or made up from the market participants through the regulators [5].

Based on the comparison between the implementation of TCC scheme and of the intermediate term transmission contracts it is clear that the latter provides the incentive structure necessary for higher efficiency in three folds.

The first is related to the accurate assessment of network status by the TP (ISO under the TCC scheme and SO/ITC under the intermediate term transmission contract scheme). The inaccurate assessment by the ISO on the network capacity available for the TCC penalizes the market participants due to the mechanism used for compensating the difference between the transmission charge collected from the spot market and the payment made to the TCC holders. The regulator plays an important role of verifying the revenue neutrality conditions in order to prevent the efficiency loss. On the other hand, the inaccurate assessment by the SO and the ITC on the network capacity for issuing the intermediate term contract directly results in loss of revenue of the ITC. The accurate assessment of the system status affects not only the short term efficiency related to the operation but also the long term efficiency related to the planning of the transmission network.

The second is related to the active participation by the TP in the process. Under the TCC scheme if the operating conditions vary widely over the year (or over the season), the number of TCC's available needs to be quite conservative in order to satisfy the simultaneous feasibility criterion throughout the year. Whereas under the intermediate term transmission contract scheme the number of contracts available varies depending on network conditions judged by the TP.

Finally, the third is related to the pricing of the contracts. Under the TCC scheme the value of the contract is initially determined by the auction process at the beginning of the year (or of the season) and varies throughout the year depending on the incidence of congestion. The change in the value of the contract needs to be communicated among the participants through the trades. However, it probably is harder to trade point-to-point contracts than the link-based contracts because of the relevance in the physical operation. Only the participant whose bus is designated as one of the points in the point-to-point contract has any interest in the contract from the physical operational sense.

B. Link-based transmission rights

The flowgate rights proposed in [1] is a representative of the link-based transmission rights being widely considered in the industry at the time of writing as another possible form of allocating network capacity over the longer term. Although the flowgate may refer to any transmission line in the system, in general the term refers to only the links associated with the likely network congestion as done here.

Similar to the TCC's case, the underlying market structure assumed for the flowgate rights is the rate-of-return regulation imposed on the transmission owners and the operational authority given to the non-profit organization called independent system operator (ISO). Under this market structure, the market participants are allowed to submit bids for purchasing the flowgate rights, once at the beginning of the year (or of the season).[3] The ISO, then determines the price and the amount of flowgates to be made available and allocates the network capacity corresponding to the flowgate rights based on the bids. Each of the flowgate rights issued to the participants specify at least the following two elements: the designated flowgate (i.e., likely congested line), and the network capacity offered on the flowgate.

Once the allocation of the flowgate rights is concluded, two separate markets, namely the forward market and the spot market, are conducted sequentially. First, the participants in the forward market arrange for transactions and acquire from the current holders the flowgate rights necessary for implementing the arranged transactions. In this process if a participant arranges a transaction that reduces the congestion on the flowgate, then the participant becomes the initial holder of the newly created flowgate rights in the amount by which the congestion is reduced. The process continues until all the transactions arranged are covered by the flowgate rights. The network capacity of unused flowgate rights are then returned to the ISO who conducts the spot market, next.

The market participants who do not want to participate in the forward market can submit bids to the spot market. The ISO, then, clears the spot market by solving the OPF problem subject to the network capacity limits re-defined by the effect of unused flowgate rights. Again, as a result of the market clearing process, the combined price of energy and transmission portions of electric services at each bus are determined by the nodal prices, and the revenue is collected and distributed by the SO as the product of the injection into the bus and the corresponding nodal price. A part of congestion charge collected by the ISO is used to compensate for the unused flowgate rights that reverted to the ISO.

When the financial relationship created by the flowgate rights is examined, it is recognized that there is again an

[3]The market participants can determine the amount and the price of the flowgate rights for the bidding purposes based on the expected value of physical transmission rights of this sort with the matching forward (and/or bilateral) contracts. The explicit bilateral transactions are assumed to be allowed under the flowgate scheme similar to under the proposed scheme.

apparent disconnect between the reward/penalty mechanism and the entities assuming the financial risks. Similar to the TCC's, because it is the ISO issuing the TCC's to offer hedging opportunities to the market participants against the volatility in the transmission capacity prices, it appears that the ISO takes on the financial risks, but because the particular characteristic of the ISO is such that the ISO as a non-profit entity cannot assume any financial responsibilities. For the flowgate rights to work properly the entity with the operational authority needs to take on the risks associated with the changing capacity limits and the changing PTDF for each flowgate. Otherwise, in case the holders of the flowgate rights are denied from utilizing the network, no compensation scheme may be adequate, or the financial risks are ultimately transferred to the market participants.

In addition, there is an implied assumption that the majority of transactions is taken care of at the forward market under the flowgate rights scheme. It is pointed out in [4] that many of the transactions in the current electricity markets still rely heavily on the spot market process. In this case, the complete separation of the forward market from the spot market further reduces the market efficiency.

In comparison, the proposed intermediate term transmission contracts allow the TP to take on the necessary financial risks. For example, the changing capacity limits and the changing PTDF for each link become the responsibility of the ITC by requiring that the maximum flow limits and the PTDF's stay invariant throughout the year (or the season). Moreover, the forward market and the spot market are linked through the TP. All this is possible because of the performance-based regulation scheme, in this case the PCR scheme as proposed in [7], imposed on the TP.

In the following section we compare three methods described above through numerical examples.

C. Numerical example

Consider the 3-bus electric power network introduced earlier as shown in Figure 3. The transfer limits on the

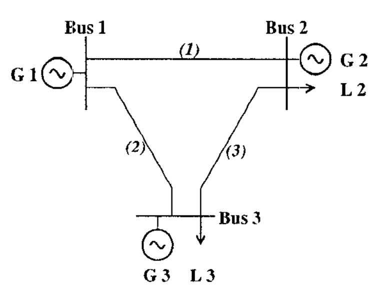

Fig. 3. One-line diagram of 3-bus electric power network

transmission lines are 150MW for lines 1 and 2 and 80MW for line 3. In the network there are 12 generation units each owned by different suppliers. The marginal operating costs of these units are given in the form of linear functions with respect to their corresponding generations, i.e.,

$$S_{g_i}(Q_{g_i}[k]) = 2a_{g_i}Q_{g_i}[k] + b_{g_i} \tag{7}$$

Assuming the perfect competition condition, the supply functions at bus 1

$$S_{\text{bus }1}(Q_{\text{bus }1}[k]) = 0.2198Q_{\text{bus }1}[k] \tag{8}$$

at bus 2

$$S_{\text{bus }2}(Q_{\text{bus }2}[k]) = 0.0187Q_{\text{bus }2}[k] \tag{9}$$

and at bus 3

$$S_{\text{bus }3}(Q_{\text{bus }3}[k]) = 10Q_{\text{bus }3}[k] + 1 \tag{10}$$

For simplicity, let the entire year be composed of three hours, i.e., $k = 1, 2, 3$, and 4.

Suppose some of the market participants enter into various forward contracts in order to meet their electricity needs at the beginning of the year assuming that the expected demand functions of the load at bus 2 is given by

$$D_{d_2}[k] = -2.5Q_{d_2}[k] + 48.15 \tag{11}$$

and that of the load at bus 3 is given as the following:

$$D_{d_3}[k] = -5.0Q_{d_3}[k] + 817.10 \tag{12}$$

For comparison purposes we consider the following arrangement of forward contracts. First, the marketers at bus 2 and at bus 3 agree on the forward contract for the transfer of 101.25MW covering the entire year, i.e. $k = 1, 2, 3$, and 4. The marketers at bus 1 and at bus 3, then arrange for the transfer of 56.00MW for hours 1, 2 and 3, but *not* 4, i.e., $k = 1, 2$, and 3. Finally, the marketers at bus 1 and bus 2 arrange for the forward contract of 18.50MW this time covering the hours 2, 3, and 4 only, i.e., $k = 2, 3$, and 4. Based on the supply functions given in Eqs. (8) through (10) and the demand functions projected as in Eqs. (11) and (12), the loads at bus 2 and at bus 3 are expected to pay 1.90 (\$/MW) and 30.85 (\$/MW) respectively. Transaction 1 refers to the forward contract for the transfer of 101.25MW from bus 2 to bus 3 for $k = 1, 2, 3$, and 4, Transaction 2 refers to the forward contract for the transfer of 56.00MW from bus 1 to bus 3 also for $k = 1, 2$, and 4, and Transaction 3 refers to the forward contract for the transfer of 18.50MW from bus 1 to bus 2 for $k = 2, 3$, and 4.

Following the arrangement through forward contracts the spot market is conducted at each hour for meeting the residual demand. Suppose following the market clearing process in the spot market the actual demand functions of the loads are revealed as the following:
for the load at bus 2

$$D_{d_2}[k] = -2.5Q_{d_2}[k] + 48.15 \tag{13}$$

where $k = 1, 2, 3$, and 4, and for the load at bus 3

$$D_{d_3}[1] = -5.0Q_{d_3}[1] + 817.10 \tag{14}$$

$$D_{d_3}[2] = -5.0Q_{d_3}[2] + 842.10 \tag{15}$$

$$D_{d_3}[1] = -5.0Q_{d_3}[4] + 817.10 \tag{16}$$

$$D_{d_3}[3] = -5.0Q_{d_3}[3] + 792.10 \tag{17}$$

As evident from Eqs. (13) through (17), the actual demand function for the load at bus 2 stays invariant from the expected throughout the year, but the actual demand function for the load at bus 3 is identical only at hours 1 and 3 and deviates from the expected in hours 2 and 4. This is not surprising since the demand for electric services is uncertain by nature. Nevertheless, if the average is taken for the actual demand function at bus 3, the result is same as the expected as expressed in Eq. (12).

The actual physical exchange among participants is determined as a result of the arrangement through forward contracts and the spot market and is, therefore, highly market structure dependent. Here the presence of transmission rights plays an important role in deciding the final outcome. For simplicity without the loss of generality, assume that the market participants involved in the forward contracts purchase the appropriate transmission rights available in order to hedge against the price volatility in transmission charge whenever possible.

Tables I and II summarize the financial as well as physical exchanges among the market participants and the ISO under the TCC scheme. As evident from the example, the physical exchange among participants maybe different from the arrangement through forward contracts under the TCC scheme depending on the system operating condition.

Table III summarizes the financial as well as physical exchanges among the market participants and the ISO under the flowgate scheme. As evident from the example, the physical exchange among participants is assured to take place according to the forward contracts if and only if the contracts are covered through the appropriate flowgate rights. For instance, at hours 2 and 3, all of the transactions are intially committed through the forward contracts on the energy as well as the transmission portion of the electric services.

Table IV summarizes the financial as well as physical exchanges among the market participants and the ITC through the SO under the proposed scheme. As evident from the example, the physical exchange among participants is assured to take place according to the appropriate intermediate term transmission contracts.

IV. Conclusion

In this paper we examine the the infrastructures important for proficient management of the network, namely the secondary markets for transmission rights.

The secondary markets play a very important role in trading a commodity subject to many uncertainties. Given the forward contracts called intermediate term transmission contracts as proposed in [6], the function of the secondary market for transmission contracts are described in hedging the network related risks, first. The mechanisms given here are then compared to the other proposed methods, namely TCC's and Flowgate rights. It is shown that only the intermediate term transmission contracts allow proper hedging mechanism over a longer period.

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		$g_{\text{bus 1}}$	$g_{\text{bus 2}}$	$d_{\text{bus 2}}$	$d_{\text{bus 2}}$	ISO
$g_{\text{bus 2}} \to$ ISO	\$11,726.58	-\$11,726.58	·	·	·	\$11,726.58
for TCC_2:						
$g_{\text{bus 1}} \to$ ISO	\$2,432.18	·	-\$2.432.18	·	·	\$2,432.18
for TCC_3:						
$g_{\text{bus 1}} \to$ ISO	-\$803.49	\$803.49	·	·	·	-\$803.49
$k = 1$						
$d_{\text{bus 2}} \to$ ISO	\$35.12	·	·	-\$35.12	·	\$35.12
$d_{\text{bus 3}} \to$ ISO	\$4,886.60	·	·	-\$4,886.60	·	\$4,886.60
ISO $\to g_{\text{bus 1}}$	\$1,219.93	\$1,219.93	·	·	·	-\$1,219.93
ISO $\to g_{\text{bus 2}}$	\$192.13	·	\$192.13	·	·	-\$192.13
for TCC_1						
ISO $\to g_{\text{bus 2}}$	\$2,931.65	·	\$2,931.65	·	·	-\$2,931.65
for TCC_2						
ISO $\to g_{\text{bus 1}}$	\$810.73	\$810.73	·	·	·	-\$810.73
$k = 2$						
$d_{\text{bus 2}} \to$ ISO	\$33.70	·	·	-\$33.70	·	\$33.70
$d_{\text{bus 3}} \to$ ISO	\$5,596.83	·	·	-\$5,596.83	·	\$5,596.83
ISO $\to g_{\text{bus 1}}$	\$1,513.37	\$1,513.37	·	·	·	-\$1,513.37
ISO $\to g_{\text{bus 2}}$	\$176.50	·	\$176.50	·	·	-\$176.50
for TCC_1						
ISO $\to g_{\text{bus 2}}$	\$3,324.94	·	\$3,324.94	·	·	-\$3,324.94
for TCC_2 and TCC_3						
ISO $\to g_{\text{bus 1}}$	\$615.73	\$615.73	·	·	·	-\$615.73
for CDF_1						
$g_{\text{bus 2}} \to d_{\text{bus 3}}$	\$385.31	·	-\$385.31	·	\$385.31	·
for CDF_2						
$g_{\text{bus 1}} \to d_{\text{bus 3}}$	\$213.11	-\$213.11	·	·	\$213.11	·
for CDF_3						
$d_{\text{bus 2}} \to g_{\text{bus 1}}$	\$1.46	\$1.46	·	-\$1.46	·	·

TABLE I

EXCHANGES AMONG THE MARKET PARTICIPANTS AND THE ISO UNDER THE TCC SCHEME FOR $k = 1, 2$

		$g_{\text{bus 1}}$	$g_{\text{bus 2}}$	$d_{\text{bus 2}}$	$d_{\text{bus 2}}$	ISO
$k = 3$						
$d_{\text{bus 2}} \to$ ISO	\$35.12	·	·	-\$35.12	·	\$35.12
$d_{\text{bus 3}} \to$ ISO	\$4,886.60	·	·	-\$4,886.60	·	\$4,886.60
ISO $\to g_{\text{bus 1}}$	\$1,219.93	\$1,219.93	·	·	·	-\$1,219.93
ISO $\to g_{\text{bus 2}}$	\$192.13	·	\$192.13	·	·	-\$192.13
for TCC_1						
ISO $\to g_{\text{bus 2}}$	\$2,931.65	·	\$2,931.65	·	·	-\$2,931.65
for TCC_2 and TCC_3						
ISO $\to g_{\text{bus 1}}$	\$542.90	\$542.90	·	·	·	-\$542.90
$k = 4$						
$d_{\text{bus 2}} \to$ ISO	\$36.50	·	·	-\$36.50	·	\$36.50
$d_{\text{bus 3}} \to$ ISO	\$4,138.42	·	·	-\$4,138.42	·	\$4,138.42
ISO $\to g_{\text{bus 1}}$	\$958.08	\$958.08	·	·	·	-\$958.08
ISO $\to g_{\text{bus 2}}$	\$208.43	·	\$208.43	·	·	-\$208.43
for TCC_1						
ISO $\to g_{\text{bus 2}}$	\$2,538.34	·	\$2,538.34	·	·	-\$2,538.34
for TCC_2 and TCC_3						
ISO $\to g_{\text{bus 1}}$	-\$231.90	-\$231.90	·	·	·	\$231.90
for CDF_1						
$d_{\text{bus 3}} \to g_{\text{bus 2}}$	\$385.32	·	\$385.32	·	-\$385.32	·
for CDF_3						
$g_{\text{bus 1}} \to d_{\text{bus 3}}$	\$1.46	-\$1.46	·	·	\$1.46	·

TABLE II

EXCHANGES AMONG THE MARKET PARTICIPANTS AND THE ISO UNDER THE TCC SCHEME FOR $k = 3, 4$

		$g_{\text{bus }1}$	$g_{\text{bus }2}$	$d_{\text{bus }2}$	$d_{\text{bus }2}$	ISO
$g_{\text{bus }2} \rightarrow$ ISO	\$11,726.58	-\$11,726.58	·	·	·	\$11,726.58
$g_{\text{bus }1} \rightarrow$ ISO	\$1,628.69	·	-\$1,628.69	·	·	\$1,628.69
$k = 1$						
$d_{\text{bus }2} \rightarrow$ ISO	\$35.12	·	·	-\$35.12	·	\$35.12
ISO $\rightarrow g_{\text{bus }1}$	\$302.94	\$302.94	·	·	·	-\$302.94
for flowgate rights:						
$g_{\text{bus }1}(TR2) \rightarrow g_{\text{bus }1}(TR3)$	\$267.83	\$0	·	·	·	·
$k = 2$						
ISO $\rightarrow d_{\text{bus }2}$	\$16.60	·	·	\$16.60	·	-\$16.60
$d_{\text{bus }3} \rightarrow$ ISO	\$122.13	·	·	-\$122.13	·	\$122.13
ISO $\rightarrow g_{\text{bus }1}$	\$105.54	\$105.54	·	·	·	-\$105.54
for flowgate rights:						
$g_{\text{bus }1}(TR2) \rightarrow g_{\text{bus }1}(TR3)$	\$267.83	\$0	·	·	·	·
$k = 3$						
·	·	·	·	·	·	·
for flowgate rights:						
·	·	·	·	·	·	·
$k = 4$						
$d_{\text{bus }3} \rightarrow$ ISO	\$1,400.00	·	·	-\$1,400.00	·	\$1,400.00
ISO $\rightarrow g_{\text{bus }1}$	\$689.62	\$689.62	·	·	·	-\$689.62
ISO $\rightarrow g_{\text{bus }2}$	\$8.38	·	\$8.38	·	·	-\$8.38

TABLE III

EXCHANGES AMONG THE MARKET PARTICIPANTS AND THE ISO UNDER THE FLOWGATE SCHEME FOR $k = 1, 2, 3, 4$

		$g_{\text{bus }1}$	$g_{\text{bus }2}$	$d_{\text{bus }2}$	$d_{\text{bus }2}$	ISO
$g_{\text{bus }2} \rightarrow$ ISO	\$11,726.58	-\$11,726.58	·	·	·	\$11,726.58
$g_{\text{bus }1} \rightarrow$ ISO	\$2,432.18	·	-\$2,432.18	·	·	\$2,432.18
ISO $\rightarrow g_{\text{bus }1}$	\$803.49	\$803.49	·	·	·	-\$803.49
$k = 1$						
$d_{\text{bus }2} \rightarrow$ ISO	\$35.12	·	·	-\$35.12	·	\$35.12
ISO $\rightarrow g_{\text{bus }1}$	\$302.94	\$302.94	·	·	·	-\$302.94
$k = 2$						
ISO $\rightarrow d_{\text{bus }2}$	\$16.60	·	·	\$16.60	·	-\$16.60
$d_{\text{bus }3} \rightarrow$ ISO	\$122.13	·	·	-\$122.13	·	\$122.13
ISO $\rightarrow g_{\text{bus }1}$	\$105.54	\$105.54	·	·	·	-\$105.54
$k = 3$						
·	·	·	·	·	·	·
$k = 4$						
$d_{\text{bus }3} \rightarrow$ ISO	\$751.13	·	·	-\$751.13	·	\$751.13
ISO $\rightarrow g_{\text{bus }1}$	\$689.62	\$689.62	·	·	·	-\$689.62
ISO $\rightarrow g_{\text{bus }2}$	\$8.38	·	\$8.38	·	·	-\$8.38

TABLE IV

EXCHANGES AMONG THE MARKET PARTICIPANTS AND THE ISO UNDER THE FLOWGATE SCHEME FOR $k = 1, 2, 3, 4$