Retailers Risk Management in Modern Competitive Power Systems

Mohammad Sadegh Javadi[1], Rahmat Azami[2], Amin Javadinasab[3], Ghasem Hematipour[4]

[1]Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Fars, Iran

[2,3,4]Department of Electrical Engineering, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran

Abstract— **This paper addresses a new approach for hedging risk of retailers in deregulated power market. In the presented methodology, both fixed and floating future contracts are considered. There are two components of supply that markets must address: energy and capacity. Energy is the energy content of electricity that is delivered to a specified bus. Capacity is output availability of physical units. In this paper, we concentrate on wholesale financial products that producers and retailers utilize to manage financial risk. Aside from producers and retailers, financial institutions are also market participants in midterm markets. Financial products are contracts that do not result in the physical delivery of energy or the physical exchange of capacity between the counterparties. They are contracts that fix the cost of supply for both products through financial settlement. This paper provides a description of common financial products. Prices utilities paid for electricity they sold to consumers—were determined in an auction run by a "power exchange," in which retailers purchased electricity from wholesale suppliers, should not be generally more than a day in advance of the delivery date. In this paper we are presenting a methodology in order to hedging the retailers risk in the power market.**

Keywords— Retailer, Wholesale Market and Risk Management

I. INTRODUCTION

Electricity is vital to our daily lives and our national economy. The electricity industry is in the midst of major change, and the results of this change will affect all consumers. Historically, utility monopolies have generated electricity and sold it to consumers at prices set by state or regional regulators. Now, numerous private companies compete to sell electricity at either the wholesale or retail level at prices determined by the market forces of demand and supply. This change, commonly referred to as restructuring, is being driven by federal or national legislation and regulatory rules as well as by state or regional actions. Restructuring is intended to improve efficiency in the industry and ultimately lower consumer prices.

To provide electricity to consumers, the three utilities then had to rely largely on these wholesale suppliers. Wholesale market prices—the prices utilities paid for electricity they sold to consumers—were determined in an auction run by a "power exchange," in which retailers purchased electricity from wholesale suppliers, generally no more than a day in advance of the delivery date. At the outset of restructuring, retail prices charged by the utilities to consumers were still determined by the Market Operator (MO).

As such, retail prices were initially frozen at a level 10 percent below the pre-restructuring rate, with full retail competition and unregulated retail prices intended to begin later. Finally, the plan set up the Independent System Operator (ISO), a nonprofit, private corporation charged with managing the transmission system in the state or region and balancing demand and supply, at the last minute, to ensure reliability of supply. Power market designs were approved by an Energy Regulatory Commission (ERC), which has authority over the design and operation of wholesale electricity markets [1].

The wholesale price is the largest component of the retail price of electricity. A more competitive wholesale market will set lower wholesale prices. Lower wholesale prices will allow electricity retailers to set lower retail prices and still remain financially viable. Consequently, the more competitive the wholesale market is the greater are the benefits to California consumers from electricity industry restructuring [2].

The development of competitive retail markets is the best way to ensure that customers receive high quality services at fair market prices. However, fully-functioning retail markets are not yet a reality in most European countries. While the Electricity Directive of 2003 introduced common market principles for all Member States, it did not propose a common retail market model. As a result, national actors and authorities responsible for the implementation of this Directive have developed their national markets in different ways at different speeds. As with wholesale markets, there are many barriers to achieving competitive retail markets. One of the most significant barriers is the fact that compared with wholesale markets, retail markets are highly regulated. While wholesale markets are increasingly competitive and regional in nature, national retail markets remain highly regulated. In spite of this, without competitive retail markets, wholesale markets will struggle to function, with the result that, overall, the market will not properly develop. Another barrier is the lack of

This work was supported in part by the Islamic Azad University, Science and Research Branch, Fars, Iran.

M. S. Javadi is with the Department of Electrical Engineering, Islamic Azad University, Science and Research Branch, Fars, Iran; e-mail: msjavadi@gmail.com.

R. Azami is with the Department of Electrical Engineering, Islamic Azad University, Shoushtar Branch, Shoushtar, Iran; e-mail: R.Azami@ece.ut.ac.ir.

A. Javadinasab is with the Department of Electrical Engineering, Islamic Azad University, Shoushtar Branch, Shoushtar, Iran; e-mail: a.javadinasab62@gmail.com.

Gh. Hematipour is with the Department of Electrical Engineering, Islamic Azad University, Shoushtar Branch, Shoushtar, Iran; e-mail: gh.hematipour@yahoo.com.

effective customer switching processes in place in several Member States. Without these processes customers do not have any real ability to effectively choose their supplier [3]. Therefore there is a clear need to remove barriers to the development of well-functioning and integrated retail markets. These may be regulatory and market barriers such as differing industry roles and responsibilities of the different market actors and illiquid wholesale markets, operational barriers such as lack of harmonized information requirements and customer switching processes, or finally, consumer barriers such as price regulation. In addition, suppliers may face economic barriers, when seeking to enter small- and medium-sized retail markets. Therefore there is an economic rationale to develop national retail market rules in a way that allows them to gradually converge and eventually integrate to the largest degree possible. In other words, retail market designs, information requirements and basic processes should be harmonized (or at least be compatible) in order to allow technical platforms and applications to be interoperable. However, full market integration may not occur in the near future as many countries have invested significant resources in developing national legislation and processes. Therefore the effort to converge national solutions will be difficult and will take time. While at present there are a number of important obstacles which need to be overcome before integrated retail electricity markets in Europe become a reality, Member States should anticipate this development by committing to gradually move towards interoperability of legislation, systems and processes. Already in the short and medium term, measures should be taken which at least make it easy for (new) suppliers to enter different national markets without changing business processes and having to 'start from scratch' [4].

This paper presents the market interactions of retailers, producers, and integrated energy companies in the short-term markets. The market participants bring their physical positions into balance by providing load and supply bids, which the ISO uses to set a balanced schedule. The market participants bid with the objective of maximizing the profit of their portfolios. This chapter provides a description of the bidding decision for each of the market participants.

This paper as follows. Theoretical consideration of retailers and retail market is presented in next section. Exploring the retail market roles and rules are presented in section III. Problem formulation is conducted in section IV. Section V includes simulation results and conclusion of this paper is conducted in last section.

II. RETAILERS AND RETAIL MARKET

Fig. 1 illustrates the ultimate form of competitive electricity market in which all consumers can choose their supplier. Because of the transaction costs, only the largest consumers choose to purchase energy directly on the wholesale market. Most small and medium consumers purchase it from retailers, who in turn buy it in the wholesale market. In this model, the "wires" activities of the distribution companies are normally separated from their retail activities because they no longer have a local monopoly for the supply of electrical energy in the area covered by their network. In this model, the only remaining monopoly functions are thus the provision and operation of the transmission and distribution networks.

Once sufficiently competitive markets have been established, the retail price no longer has to be regulated because small consumers can change retailer when they are offered a better price.

From an economics perspective this model is the most satisfactory because energy prices are set through market interactions. Implementing this model, however, requires considerable amounts of metering, communication and data processing.

The cost of the transmission and distribution networks is still charged to all their users. This is done on a regulated basis because these networks remain monopolies.

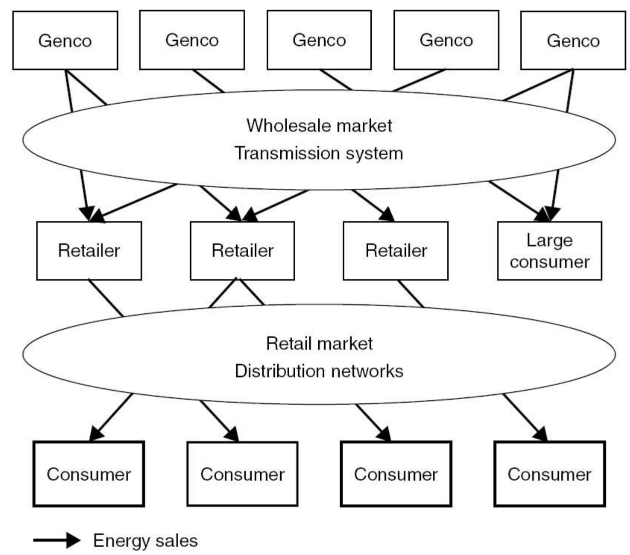

Fig. 1: Retail competition model of electricity market

III. ROLES IN ELECTRICITY RETAIL MARKETS

The main electricity market actors include wholesalers (power exchanges, OTC brokers or other traders, generation companies), Transmission System Operator(s) (TSOs), the Distribution System Operator(s) (DSOs), generators, suppliers and customers. For electricity markets to function properly, specific roles such as meter reading and balancing need to be make clear [5].

Retail electricity markets must have certain necessary operational characteristics, or building blocks, in place for competition to be possible. One of the main roles relates to market facilitation and information provision – TSOs, DSOs, metering agents and wholesalers are of central importance here. In order for market participants such as suppliers, customers and generators to interact with these actors, there must exist common retail and wholesale 'operational platforms' whereby all participants can get easy and equal access to system, price and customer information [6].

As noted above, the physical position of the retailer is brought into balance in the short-term markets. The process begins in the day-ahead market and continues through to delivery time. We first present a description of the retailer's position [7].

The TSO has a central role in making the wholesale market work, which is the operational platform on which the retail market is built. The TSO also has responsibilities directly related to the functioning of the retail market. In particular, it must work with suppliers in balancing the energy used in its system and provide settlement for this balancing service. It may also have a role in load profiling and may have a role in billing and metering.

Another key role is played by the DSO. The DSO has an important responsibility to provide connection to the grid and access to the delivery point for both the end-user and the supplier. It is often the holder of critically important information for the functioning of the retail market, such as consumption data, customer information and delivery (metering) point identity. In most states, the DSO is the facilitator of most retail market transactions, in particular between itself and suppliers, between the TSO and suppliers and between customers and suppliers. The DSO also, quite often, has a central role in metering, billing and load profiling (however, the responsibility for metering and billing can in some cases remain or be transferred to other market actors, such as suppliers or independent agents). The DSO also often serves as a contact point for consumer as regards technical issues relating to the network and the quality of supply, i.e. the infrastructure part of the retail market. Overall, the DSO and the TSO have an essential role in physical delivery. They may also play an important role in providing operational platforms for both wholesale and retail markets.

Another key building block of the competitive retail market is the wholesale market and the trading platform it often provides, such as power exchanges and OTC markets. Liquid wholesale markets allow suppliers to match their purchases to their sales.

Beyond market infrastructure, the key drivers of competition are suppliers and customers.

The supplier procures energy in the wholesale market and provides products and services in the form of contracts to final customers. In efficiently functioning retail markets, it is in a supplier's commercial interest to make use of market mechanisms to achieve the most efficient, innovative and best quality customer solutions. In the retail market, suppliers usually become the 'single point of contact' for customers and, as such, serve as the customer interface in processes such as contracting, switching, billing, queries and counseling, dispute settlement, etc. Suppliers may also take responsibility for communication with the customer relating to grid connection and network services procurement (based on an agreement with the relevant DSO where applicable).

The purpose of a retail market is to satisfy customers' needs, in particular to deliver electricity supply in the quantity requested at the best possible price and to provide related services (such as flexible payment and billing solutions), demand-side management options (such as differential tariffs), modern metering technologies, consumption and energy saving advice and services, consumer information, and so on. Consumers are at the heart of any working retail market. They exercise buying power by choosing between rival supply companies and their respective offers. Customer choice translates into price signals which in turn cascade through the entire electricity value chain. Price signals provide information for market actors to decide on investment in new production, transport and interconnection capacities. They drive innovation in a working retail market as they provide suppliers with incentives to introduce ever more efficient solutions and procure at the best price to ensure commercial success. Consumers also drive market integration as they seek out suppliers who offer the best possible price and reward those suppliers who are capable of harnessing market opportunities.

To summarize, the basic structure of the electricity retail electricity is illustrated in below.

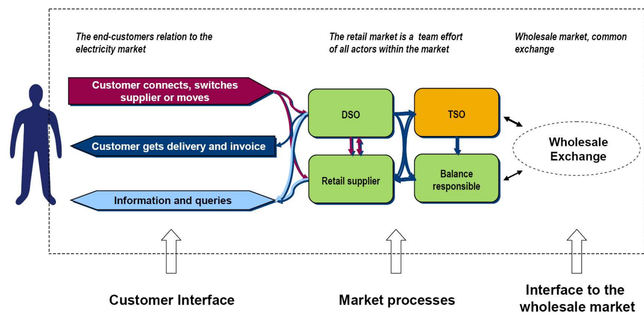

Fig. 2: Retail Market Structure

IV. PROBLEM FORMULATION

Afterwards, retailer behavior for a simple portfolio without market instruments is examined. A retailer's portfolio consists of a set of customer contracts that obligate the retailer to provide power along with network payments, imbalance penalties, and market instruments. The retailer is interested in the cash flow, which is the sum of cash flows from each component of the portfolio. The following equation provides a representation for the cash flow over a single delivery hour, specifying each component:

$$R_h = L_h(p-n) - \underline{L_h} P_h \pm D_h - I_h + a_h(P_h - f)$$

- *Rh* represents the retailer's cash flow for delivery hour *h*.
- *Lh* represents the actual load in MWh of the customer base for delivery hour *h*.
- *p* represents the average contract price with the retailer's customer base in$/MWh.
- *n* represents the network cost in $/MWh.
- *Lh* represents the load that the retailer requests from the ISO for delivery hour *h* in MWh.
- *Ph* represents the ISO day-ahead market clearing price in $/MWh for delivery hour *h*.
- *Dh* represents the profit or losses from participation in the delivery day markets for delivery hour *h*.
- *Ih* represents imbalance penalties.
- *ah* represents the volume in MWh of fixed for floating products that the retailer has purchased for delivery hour

h.

- f represents the average fixed cost in \$/MWh over all fixed for floating contracts in the retailer's portfolio.

Variables represented by capitalized letters are unknown before the clearing of the day-ahead market, whereas variables represented by small letters are known quantities. Terms that are positive indicate incoming revenues, whereas terms that are negative indicate costs that the retailer must pay. The retailer earns a profit by ensuring that the term *Lhp* is high enough to cover all the portfolio costs.

Note that the delivery date revenues represented by *Dh* may contribute to profit or may be a cost.

Without market instruments; the retailer's cash flow is represented as follows:

$$R_h = L_h(p-n) - \underline{L}_h P_h \pm D_h - I_h$$

The retailer's objective is to maximize the profits at delivery time. The only positive contribution to the retailer's profit comes from the fees that the retailer collects from its customer base. All the other components are costs. The retailer must optimally bid in load requirements to minimize these costs.

There are two components to the load bid, the uninterruptible component and the interruptible component. Because the retailer is committed to providing power to its uninterruptible customers regardless of the ISO index price, the retailer wishes to minimize imbalance charges with the ISO and ensure that this load is scheduled.

Accordingly, the retailer's bid for the forecast of the uninterruptible load component indicates a willingness to purchase power at any price. Accurate forecasts allow retailers to avoid imbalance charges.

The second component of the load bid is that associated with the interruptible contracts. A load bid coupled with an interruptible contract depends on the contract's terms of interruption. We discuss two types of interruptible contracts: price-driven interruptibility and value-driven interruptibility.

Price-driven interruptible contracts are the simplest type of interruptible contracts.

They provide the retailer with the right to curtail power deliveries whenever the ISO index settles above an agreed-upon threshold. The load associated with this contract is bid in at the forecasted load up to the interruptible threshold. Above the interruptible threshold, no volume is bid.

Value-driven interruptible contracts are another type of interruptible contract. These contracts provide the retailer with the right to interrupt power for no more than an agreed-upon number of hours per year. There is value in the right to interrupt a future hour of power deliveries. The retailer must be able to place a monetary value on this right and ensure that the forecasted load associated with the contract is bid in at its full level for prices below the interruptible value. Concurrently, the forecasted load is not bid in for prices above the interruptible value [9].

The assumptions for the table are the following:

- Forecasted uninterruptible load: 1550 MWh
- ▪ Forecasted load of price-driven interruptible contracts: 45 MWh
  - Interruption price: \$250/MWh
- ▪ Forecasted load of value-driven interruptible contracts: 95 MWh
  - Value of interruption: \$325

Forecasting of loads is central to minimizing imbalance charges. Unlike utilities in a traditional environment, retailers do not have information set for making quality forecasts. A complete information set would contain the most recent information on load so that load forecasting models could be appropriately updated. Although the ISO provides real-time information on overall load levels at the different buses, retailers do not have real-time information on the consumption of their customer base. The aggregate numbers provided by the ISO include different load types: industrial, commercial, and residential. Retailers must be able to parse these numbers to determine the consumption of their customer base. To make matters worse, the customer base is not stable because customers may change their service provider.

To overcome the information deficit retailers sometimes install meters with real-time monitoring and relaying capabilities on a cross sample of their customer base. It is not possible to install meters on all customers because this is expensive.

Retailers have developed models that use the sample metered information along with the ISO information to forecast load use.

Once the day-ahead schedule has been set, retailers continue to adjust their schedules with the ISO as forecasts are updated. Within the delivery day market retailers sell back supply to the ISO if load forecasts decrease, or purchase more supply from the ISO if load forecasts increase.

V. SIMULATION STUDIES

In the financial community the word risk is synonymous with uncertainty. A risk-free contract is one in which there is absolute certainty in the financial outcome. Conversely, a risky contract is one in which there is uncertainty in the financial outcome.

The earnings that a retailer earns from contracts with end-use customers depend on many factors including the following:

- Payments from the end customer. Payments depend on the following factors:
  - The customer's contractual price in dollars per kWh (Customer payments are scaled by kWh as opposed to MWh)
  - The volume of electric energy that the customer consumes
- Procurement costs of the retailer. Procurement costs depend on the following factors:
  - Day-ahead ISO index price
  - Day-ahead purchase volumes
  - Intraday adjustments due to updated load forecasts
  - Imbalance charges

- Cost of capacity tags
- Quantity of capacity tags purchased
- Cost of grid services

There is much uncertainty in both the payment stream from the customer as well as the procurement costs. The actual risk associated with the contract depends on the structuring of the contract. Before discussing possible contract structures, we note that there are two categories for the risk. The first category is price risk. Price risk reflects uncertainty in the ISO index for the delivery dates over the time period of the contract and impacts on the procurement cost to the retailer. There is also price risk associated with the cost of capacity tags, the price of intraday adjustments, and the price of imbalance charges. The second category of risks is volumetric risk.

Volumetric risk reflects the uncertainty in customer consumption. Customer consumption is explicit in the payment stream. It is also implicit in most components of the procurement cost stream including the volume that the retailer procures, the day-ahead purchase volumes, intraday purchase adjustments, imbalance fees, and the quantity of capacity tags purchased. Every component associated with a market price or volume is uncertain.

There are two types of volumetric uncertainty that cause procurement cost uncertainty. The first type of volumetric uncertainty is the load forecasting error for a fixed customer base. Forecasting error leads to uncertainties in imbalance penalties and intraday schedule adjustments. The other type of volumetric uncertainty comes about because customers may cancel their contracts with a retailer, effectively setting their purchase volumes to zero [10-13].

Retailers structure their risk through the contracts that they sign and the customer base that they target. The risks to the retailer and customer are impacted by the structuring choices. Contracts may be structured to protect the retailer from some risks and pass some risks over to the customer. Conversely, contracts may be structured to protect the customer from risk and maintain risks with the retailer. Contracts protecting the customer from risk are more expensive for the customer than those that pass risks from the retailer to the customer.

As with the structuring of long-term contracts, the retail contracts have several components. There is an energy component, a network component, and a service component. The energy and network components are set to cover energy procurement costs and the cost of networking services. The servicing component allows the retailer to earn a profit [14].

A retailer's portfolio is structured ahead of delivery month with the anticipation of earnings at the end of delivery month. The words portfolio and earnings are used synonymously, and a description of the portfolio is given by a description of its earnings. The equation for a retailer's anticipated earnings on signing up a customer base without the introduction of market instruments is the following:

$$R = L(p - n - P) - D - I - K$$

All of the lower-case letters are fixed numbers.

- Lower-case p is the fixed price of the contracts between the retailer and the customer base.
- Lower-case n is the fixed network fee in $/MWh that the ISO charges for its grid services.

All of the capitalized variables are random variables.

- R is the composite value of the retail position in dollars over the delivery month.
- L is the monthly load obligation of the customer base in MWh.
- P is the load-weighted day-ahead ISO index in dollars per MWh.
- D is the intraday costs of adjusting the portfolio in dollars.
- I is the imbalance penalty in dollars.
- K is the cost of capacity meeting the ISO capacity tag requirement. Note that K depends on price and the peak hour load, both of which are uncertain.

Again we emphasize that none of these variables is known on signing the contract.

The retailer can only estimate probability distributions for these variables.

By load-weighted day-ahead ISO index, we mean that each hourly ISO day-ahead settlement price is weighted by the percentage of load demand for that hour and then the result is averaged.

Let the demand function is given by the following:

$$L = -a(p - n - P) + b$$

Both a and b are positive values. The profit is the volume times the profit margin.

$$\begin{aligned}\text{Profit} &= L(p - n - P) \\ &= -a(p - n - P)^2 + b(p - n - P)\end{aligned}$$

The profit is quadratic in the profit margin; the graph is a parabola sloping downward.

The profit margin that maximizes profit is given by the vertex.

$$p - n - P = \frac{b}{2a}$$

$$p = \frac{b}{2a} + n + P$$

Once the profit-maximizing solution is identified, the retailer sets the price. The relation between profit and forward price (ISO index) is given in the graph in Fig. 3.

VI. CONCLUSION

The proposed retailers risk hedging approach has been presented in this paper. The aforementioned methodology is based on a linear representation of risk modeling. Hence, the profit is the volume times the profit margin, we show that the retailers entire profit could be addressed as a quadratic function which has a maximum value. The vertex of profit function would be considered from retailer's point of view.

This methodology could be refined with previous information which cumulated by the retailers and would be implemented in future works.

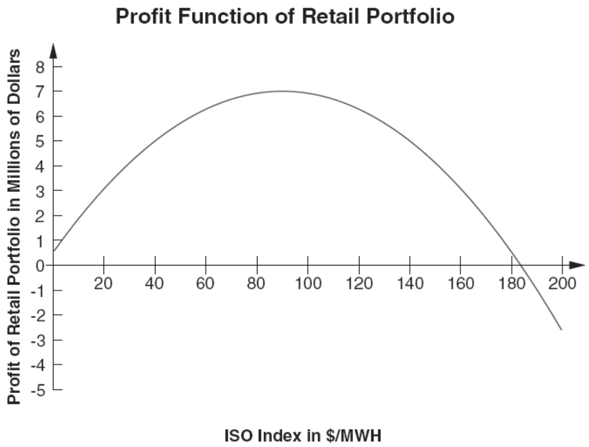

Fig. 3: Profit function pf retailers versus ISO index

REFERENCES

[1] M. Shahidehpour, *et al.*, *Market Operations in Electric Power Systems*. New York: John Wiley & Sons, 2002.

[2] PJM Training Materials-LMP 101, PJM

[3] NYISO Transmission & Dispatch Operations Manual,NYISO,1999

[4] FERC electric rate schedule, ISO-New England, 2001.

[5] F. Li and R. Bo, "DCOPF-Based LMP Simulation: Algorithm, Comparison With ACOPF, and Sensitivity," *IEEE Trans. Power Syst.,* vol. 22, pp. 1475-1485, Nov. 2007.

[6] S. Stoft, *Power System Economics-Designing Markets For Electricity*. New York: IEEE/Wiley, 2002.

[7] M. Davari*, et al.*, "Determination of Mean and Variance of LMP Using Probabilistic DCOPF and T-PEM," presented at the PECon08, 2008.

[8] C. L. Su, "Probabilistic load-flow computation using point estimate method," *IEEE Trans. Power Syst.,* vol. 20, pp. 1843-1851, 2005.

[9] L. Liu and A. Zobian, "The importance of marginal loss pricing in an RTO environment," *Electricity J.,* vol. 15, pp. 40-45, Oct. 2002.

[10] E. Litvinov*, et al.*, "Marginal loss modeling in LMP calculation," *IEEE Trans. Power Syst.,* vol. 19, pp. 880-884, May 2004.

[11] J. Zhu*, et al.*, "Real time loss sensitivity calculation in power systems operation," *Electric Power Systems Research,* vol. 73, pp. 53-60, Jan. 2005.

[12] J. L. M. Ramos*, et al.*, "On the use of loss penalty factors for generation scheduling," in *in Proc.IEEE Power Eng. Soc. Annu. Meeting* 2003, pp. 926-931.

[13] F. Li*, et al.*, "Marginal loss calculation in competitive spot market," in *IEEE Int. Conf. Deregulation, Restructuring Power Technol. (DRPT)*, 2004, pp. 205-209.

[14] A. J. Wood and B. F. Wollenberg, *Power Generation, Operation and Control*. New York: John Wiley & Sons, 1996.