WHEELING OF ELECTRIC POWER AND PRICE FORECASTING IN DEREGULATED POWER SYSTEM- A BIBLIOGRAPHICAL SURVEY

Abstract

Power diligence is working quickly from regulated power system to a deregulated environment in power system. The emerging fields are taking place where, there is a decisive need to keep a track on the continuously acting activities. In electricity market, the deregulation environment has created a competition among power producers, transmitters, and distributors. For fair competition among the suppliers, and to shatter the monopoly of transmission system a transmission open access system and conventional wheeling has introduced the new approach of power transmission using third parties' line. The forecasting of price in deregulated system, is also a matter of great concern due to congestion on lines and price spikes. This chapter gives, a concisebibliographical survey, developments in the field of wheeling of power and price forecasting, and different approaches of universal background beneath the deregulated background based on over 150 published articles. The combined text has been alienated into sections, so that researcher do not face any problem in favorofattaining information in the field of wheeling of power and price forecasting in the deregulated environment.

Keywords: Deregulation, independent system operator, congestion, privatization, wheeling, transmission open access (TOA), price forecasting, fuzzy logic, artificial neural network, load forecasting.

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I. INTRODUCTION

The simple definition of "Wheeling" of electric power is the transmission of power from a seller party to a buyer party by using the network of transmission lines owned by another third party. In deregulated environment of power system, there are three independent activities namely; generation, transmission, and distribution of power. For the benefit of other parties, wheeling make use of transmission system of a party or some parties having own transmission systems. The pricing of these transactions and sharing of benefits are the important issues related to wheeling. In fact the term wheeling is introduced to define transmission of power from one entity to another entities by the use of transmission or distribution facilities [1]. Wheeling, is a hybrid conception, ensuing from pairing of two dissimilar profitable concepts: an ultimate deregulated competitive market place, and an ultimate world of regulated utilities [2-4].

With the beginning of competition in electricity segment and simultaneously restructuring, the price for fuel and electricity are getting renewed attentions for the price forecasting and their techniques. Due to several existence, the market value calculation is relatively an anxious subject, interested in load forecasting for newly created competitors in electricity market. The crash of electricity price is the additional physical factor for price volatility. There are various forecast methods that have been worn for the electricity cost forecasting. The impact of price volatility depends on some physical factors. The hourly load demand, is relativelyalike and its variations are quitecyclical in contrast to the hourly market value.

II. CONCEPT OF WHEELING OF POWER AND PRICE FORECASTING

Since 1980, the need for more power generation, higher efficiency and delivery of power has shown the way for restructuring of power sectors. Countries, started to consider the restructuring of their power sector for sake of competition in power producers and a greater number of choices for customers. In order to consider and implement this, Electricity Supply Industry Restructuring has separated the functions of power generation, transmission and distribution and electricity supply to consumers [4-6]. The creation of several power generation producers and the recognization of transmission system as monopoly and accordingly to make provisions. The inclusion of transmission into competition framework has raised an idea of transmission open access (TOA) which alters the conventional monopoly and aims for fair competition among supply producers.TOA is a regulatory body, which examines the operational procedure, protects rights and obligations, and check economic conditions for parties use transmission network for power transfer. This TOA approach combine with wheeling in this competitive market as later is prevalent for these types of unbundled services. In power market, due to competition in transmission of power, by power suppliers and over flow on lines by many users led to congestion of lines. Because of this the electricity price exhibits a major volatility, and market clearing price (MCP) representing the electricity pricing is higher in congested zones. The price differentials are represented by Locational Marginal Price (LMP) and would have to forecast for individual buses in the power system network. The accuracy of price forecasting is affected by spikes, happens in prices due to worse situations of congestion [7-8].

III. METHODOLOGIES AND ANALYSIS

This section involves those articles which are linked to methodologies, operational issues,technical analysis and costing etc.

1. **Wheeling of Power:** The bibliographical survey of wheeling of power presents that: In 1993 and 1994, the subsidiary wheeling charge with assessment difficulty and theory of wheeling is explained in [8,9].The locational price modification on a network based proposal incorporates with the uniform auction [10]. The theory of existing transmission capability is illustrated in[11]. Reference [12, 13] introduced the theory of long – run subsidiary cost. The secondary wheeling cost evaluation and TOA is illustrated in [14]. Reference [15] describes the model of open access pricing with scheme approaches. The concept of Available Transfer Capability (ATC) and its estimation by disintegration is explained in [16]. The approach of wheeling costs allocation is explained in [17, 18]. The marginal cost based on setting wheeling rates are explained in [19].The incremental loss approaches and incremental pricing approaches are used for wheeling loss evaluation and interchange costing [20].For the evaluation of wheeling and non-utility generation (NUG) related options the applications of optimum power flow are described in [21].In a multi utility background the optimization in federal and decentralized power system based on theoretical benefits [22, 23]. Reference [24] describes a method for calculating marginal cost of transmission capacity and embedded incremental. The concept of optimal multi area wheeling is described in [25]. The finest pricing of distribution as well as transmission services in electricity markets are illustrated in [26]. The wheeling fees and pricing control sales depends on the utility –cogeneration game [27, 28]. Reference [29] illustrated short tenure and long tenure simulation of wheeling cost. The electrical energy exchange transaction modes are explained in [30]. The area energy interchange depends on the transmission loss penalty factor [31].The concept of optimal pricing of transmission services are explained in [32]. In case of Energy Exchange for security constrained economic dispatch the fast algorithm is used [33].The bulk power trading depends on the development of option markets [34].The network constraints in deregulated system using optimal power transactions are explained in[35]. The investigation and supervision of power dealings beneath open access using numerical framework is described in [36].The subsidiary cost-based pricing meant for wheeling transactions analyzed the consequence of neglecting volt / VAR optimization [37]. The perception of wheeling price assessment by means of Optimal Power Flow (OPFs) is explained in[38]. On behalf of allocating transmission expenditure along with users an analytical approach is used within transmission services [39]. The concept of independent power producers (IPPs) and secondary fee pricing of wheeling transactions are briefly discussed in [40]. The modified mile power method based on innovative model for pricing of fixed cost within wheeling charges [41]. The transmission pricing has an impact on flexible ac transmission system devices [42]. The concept of integrated mutual trades in support of stimulating control networks are described in [43]. In deregulated environment the bilateral transactions analyzed with probabilistic security [44]. The concept of transmission congestion management in electricity market is explained in [45]. Power industry reconfiguration applied to retail wheeling assessment and dispersed generation planning describes the incremental transmission capability evaluation

[46]. Reference [47] describes the shortcomings and importance of an assortment of techniques to deal out the wheeling expenditureon behalf of several wheels in interrelated control systems. Reference [48] explained the practice of some analyzing strength and weakness in the approach, analytic background intended for all of the foremost techniques used for congestion management at present use world - wide, needs connected with this vital problem and exploring the future directions. In support of assessing, the possibility of instant aneousmutualdealings the uncomplicated and convenient method is used [49 ,50]. The network cost allocation method based on comparative analysis described in[51]. The power industry based on deregulated environment has realistic concepts for transfer limit analysis [52]. Within a competitive environment the approach intended for distribution of transmission losses to share the contracts designed for end to end transactions are presented in [53]. In deregulated energy markets a pricing of whirling reserve is explained in [54]. In a deregulated system the explanation of short term transmission line maintenance scheduling is defined [55,56]. The theory of an optimization come close to access where ATC is explained in [57]. A stochastic programming can be evaluated by using ATC evaluation [58]. By selecting the various wheeling options the evolutionary programming – based algorithm is used [59]. The concept of emerging energy market structure used for congestion management has been described in [60]. In deregulated environment the approach of reactive power as an auxiliary service is described [61]. Under deregulated environment short – term transmission planning based on network congestion evaluation [62]. The energy transaction factor calculations are illustrated in [63]. Under deregulated background of power region the supervision of wheeling contacts be analyzed [64]. In deregulated electricity market, the basic representation of involuntary generation manage for multi-area scheme is presented in [65].

2. **General Issues With Wheeling of Power:** To exploit the transmission through third-party have long term impact [66] . The approach based on the deregulation of electric utility is explained in [67]. The competitive electricity supplies and its importance are described in [68]. The composite system adequacy evaluation based on the impact of power wheeling [69]. The simulations help, how to quantify wheeling flow due to short circuits [70]. The dealing in power transmission and wheeling is described in [71]. The various importance issues with transmission access are explained in [72]. To concern the optimizing wheeling parties the benefits has given various considerations on transmission services [73].In a open market the visualizing power system operators are described [74]. In an electricity system the advanced pricing approaches are described in [75]. Reference [76] describes the electric utility industry transformation. The explanationint ended for effectiveness of incorporated reserve preparation is explained in [77]. The overview of the deregulated concepts are explained in[78]. The privatization of power deliverproductionalong with supply measures , such as, sound pricing principles , ending unmetered supply and transparency on subsidy regime are illustrated in [79 ,80]. The electrical utility can be explained with customer service enhancement [81]. A viable option is how private power could succeed [82] .To set up a superior transmission policy within power market the various critical issues to be pointed out [83]. In electricity generation the transmission access is considered as an global issue [84]. The production is treated like an open market in addition to transmission

like an monopoly where several topics effect the transmission pricing on system cost in this new environment [85,86]. Reference [87] explained a research in relation tothe optimal wheeling proposal. The restructuring electricity markets explained a market power – monitoring model [88]. In a deregulated power system the multiple – impact assessment of wheeling and IPPs are described [89].

3. **Price Forecasting:** Within the, whole power organization, LMP would cover to be forecasted meant for the individual buses. After, making an allowance for the production of secondary price ,losses and charge of transmission overcrowding, whereas, LMP be the expenditure of supplying MW of the load by the side of a explicit location. LMP is identical like, MCP, where there is refusal of congestion. Optimal power flow (OPF) solution involves the transmission contour constraints. To organize stability in supply and demand by the side of every bus, when there is congestion. LMP defines the subsidiary charge of every bus [90-95]. The typical aspects of electrical energy which possibly will force the forecasting precision are prices spikes after the load intensity in the scheme approaches its generating capability restrictions it would be difficult to correct the price spikes. In dissimilarconsignment levels, it is valuable to revise the possibility of price spikes and added, the possibility in distribution of costs under dissimilarconsignment levels . In recent years, in assorted markets the power have been traded as a commodity . In addition to commodity markets like agriculture and stocks where price forecasting has extended at the core of concentrated studies. However, the divergent uniqueness from further commodities depend on the power . Thus, the purpose of forecasting methods prevail in additional service markets, can create a bigger mistake in forecasting the charge of electrical energy and a major volatility can exhibit within electricity price movements [96 -105]. The forecasting electricity prices depend on two possible methods. The first method, is the power system components depend on the imitation of the accuratesubstantial model and by considering the substantialindividuality of power networks, the resolution is originated by applying mathematical algorithms. The second method, finds a mapping involving numerous input parameters along with hourly market prices based on artificial intelligence. In historical cases the mapping is adopted. In this chapter, various methods have been used reviewed which are used for price forecasting.

The Artificial Neural Network (ANN's)capability to gain knowledge of the estimated multifarious relationship through training is the fore most explanation of ANN purposes. The non linearassociationinvolving upcoming and chronologicalcostrecords and its impacting factors have uncomplicatedachievement and good qualitypresentation for modeling using ANN. The conventional forecasting methods in certain circumstances could respond the most admired technique is ANN which have acknowledged the extensive approval in the utility diligence [106 -116]. There are three parts in the architecture of the ANN i.e.in put layer , hidden layer , output layer .The outside world is connected to the input layer. The layer which receives the information from the outside world is known as input layer . The layer which doesn't have connection with the outside world known as hidden layer. The layer which will provide the ANN output to the outside world subsequent to the external information is process by association known as output layer.

There are two methods used for the existing time series forecasting .Statistical and mathematical concepts are based on classical methods and algorithm from the field on intelligence based on the modern heuristic methods .The classical methods can be sub divided into following types: Regression models, Exponential smoothing models, Auto – regressive moving average (ARMA) models and Threshold models. The first three models are concerned as linear methods and the last model is concerned as non linear method . The business, economic,engineering and science are various fields of research that have become increasingly important in time series methodologies and its purposes. To estimate the values of variables from notorious or unspecifiedstandards of other variable is the study of relationship among variables [117-125].

Fuzzy sets, cannotrepeatedlyobtain their regulations they employ to make individuals decisions but know how tocommunicate for the inexact information , are appropriatein favor of explaining their decisions. The decision-making systems are employed on the ANN to alterattachment function of fuzzy systems by means of FNN. The two techniques are united in a behaviorto overcomes the limitation of individual techniques that have formed a fundamentaldynamicpowerafter the establishment of FNN[126-131].

Since mid 80's the an assortment of approaches that have been implemented and useful to forecast electricity price [131 -141]. Currently, a newperception in statistical learningtheory the support vector machine (SVM) has been practical in power market price forecasting and achieved suitableconsequences. Based on fuel cost ,customers' hourly consumption ,transmission and generation schedules, predicted and reserve behavior of market participants depend on price of electricity under stochastic analysis. The price and load forecasting has been used in stochastic analysis [142-143].

4. **Price Spikes in Price Forecasting:** Price spikes can be influenced by many possible factors including fuel prices, weather conditions, plant operating costs, physical characteristics of the system and some other factors which impacts the price. Due to several volatilemeasures or accidents , price spikes are hard to predict and highly randomized . Based on numericalallocation of spikes , several approaches have been used for estimation of the probability of spikes. It can also, be caused by the unexpected indecisions , and by market power. The highly randomized events in the electricity markets are price spikes. An irregular market clearance cost under price spikes at an instant of point t, are unusual from cost of others hours [144-150].

IV. CONCLUSION

This chapter gives a general idea of the theory of wheeling, of power and price forecasting under deregulated background of power system, through an assessment of the chronological events, the relevant background, practical requirements and techniques. This chapter is based on many research articles, and the credentials listed within this survey provides a delegate samples in current engineering thoughts pertaining to wheeling of power and price forecasting problems underneath the deregulated background. Chapter highlights the theory of wheeling, network based locational price modifications, secondary wheeling cost, available transfer capability, marginal cost, incremental cost, and transmission congestion. The issues with wheeling of power like transmission access, optimizing of wheeling parties, their benefits and privatization of power deliver production have been included. Chapter also highlights the locational marginal price, the subsidiary charge of every bus, prices spikes, and two methods of forecasting electricity prices as, power system components and mapping.

REFERENCES

[1] H. M. Merrill, B. W. Erickson, "Wheeling rates based on marginal-cost theory", IEEE Trans. Power Syst., vol. 4, pp. 1445-1451, Oct. 1989.

[2] D. D. Sabin, A. Sundaram, "Quality enhances reliability [power supplies]", IEEE Spectrum, vol. 33, pp. 34-41, Feb. 1996.

[3] M. Takahashi, "Evaluation of power system control in transmission open access", Record of Electrical and Communication Engineering Conversazione Tohoku University, vol. 67, pp. 190-191, Aug. 1998.

[4] R. Pospisil, "Wheeling battles turf wars of independence", Elect. World, vol. 208, Nov. 1994.

[5] N. S. Rau, C. Necsulescu, "A model for energy exchanges in interconnected power systems", IEEE Trans. Power Syst., vol. 4, pp. 1147-1153, Aug. 1989.

[6] A. J. Wood, B. F. Wollenberg, Power Generation Operation and Control, New York:Wiley, 1996.

[7] D. Shirmohammadi, P. R. Gribik, E. T. K. Law, J. H. Malinowski, R. E. O'Donnell, "Evaluation of transmission network capacity use for wheeling transactions", IEEE Trans. Power Syst., vol. 4, pp. 1405-1413, Oct. 1989.

[8] K. L. Lo, S. Zhu, "A theory for pricing wheeled power", Electr. Power Syst. Res., vol. 28, pp. 191-200, Jan. 1994.

[9] K. L. Lo, S. Zhu, "Wheeling and marginal wheeling rates: Theory and case study results", Electr. Power Syst. Res., vol. 27, pp. 11-26, May 1993.

[10] R. Ethier, R. Zimmerman, T. Mount, W. Schulze, R. Thomas, "A uniform price auction with locational price adjustments for competitive electricity market", Int. J. Electr. Power Energy Syst., vol. 21, pp. 103-110, Feb. 1999.

[11] M. D. Ilic, Y. T. Yoon, A. Zobian, "Available transmission capacity (ATC) and its value under open access", IEEE Trans. Power Syst., vol. 12, pp. 636-645, May 1997.

[12] C. W. Yu, A. K. David, "Security related long-run marginal cost analysis of transmission service", Proc. 4th Int. Conf. APSCOM, vol. 2, pp. 463-468, 1997-Nov.-11□.

[13] C. W. Yu, A. K. David, "Long-run marginal cost evaluation of transmission capacity", Proc. Int. Power Engineering Conf., vol. 1, pp. 425-430, 1997-May-22□.

[14] C. W. Yu, A. K. David, "Transmission open access and marginal wheeling cost evaluation", Proc. 3rd Int. Conf. Advances in Power System Control Operation and Management, vol. 1, pp. 277-282, 1995-Nov.-9□.

[15] H.Rudnic, M. Soto, R. Palma, "Use of system approaches for transmission open access pricing", Int. J. Electr. Power Energy Syst., vol. 21, pp. 125-135, Feb. 1999.

[16] M. C. Caramanis, N. Roukos, F. C. Schweppe, "WRATES; A tool for evaluating the marginal cost of wheeling", IEEE Trans. Power Syst., vol. 4, pp. 594-605, May 1989.

[17] D. Hirano, K. Yamaji, "A study on setting the wheeling rate of electricity on the basis of marginal cost", Int. J. Global Energy Issues, vol. 11, pp. 195-202, 1998.

[18] D. Hirano, K. Yamaji, "A study on fair allocation of the wheeling costs among multiple users", Trans. Inst. Elect. Eng. Jpn. B, vol. 118, pp. 990-997, Sept. 1998.

[19] M. C. Caramanis, R. E. Bohn, F. C. Schweppe, "The costs of wheeling and optimal wheeling rates", IEEE Trans. Power Syst., vol. PWRS-1, pp. 63-73, Feb. 1986.

[20] J. S. Clayton, A. C. Gibson, "Interchange costing and wheeling loss evaluation by means of incrementals", IEEE Trans. Power Syst., vol. 5, pp. 759-765, Oct. 1990.

[21] R. Mukerji, W. Neugebauer, R. P. Ludorf, A. Catelli, "Evaluation of wheeling and nonutility generation (NUG) options using optimal power flows", IEEE Trans. Power Syst., vol. 7, pp. 201-207, Feb. 1992.

[22] F. C. Schweppe, M. C. Caramanis, R. D. Tabors, R. E. Bohn, Spot Pricing of Electricity, MA, Norwell:Kluwer, 1998.

[23] K. Okada, H. Asano, "A multiarea EDC with spot pricing and economic power interchange", Proc. Int. Conf. EMPD, pp. 12-17, 1995-Nov.-21□.

[24] R. R. Kovacs, A. L. Leverett, "A load flow-based method for calculating embedded incremental and marginal cost of transmission capacity", IEEE Trans. Power Syst., vol. 9, pp. 272-278, Feb. 1994.
[25] Y. Z. Li, A. K. David, "Optimal multiarea wheeling", IEEE Trans. Power Syst., vol. 9, pp. 288-294, Feb. 1994.
[26] E. D. Farmer, "Optimal pricing of transmission and distribution services in electricity supply", Proc. Inst. Elect. Eng., vol. 142, pp. 1-8, Jan. 1995
[27] R. G. Tessmer, Jr., Cogeneration and Wheeling of Electrical Power, New York:Penn Well Publishers, pp. 204, 1995
[28] A. Kuwahata, A. Hiroshi, "Utility-cogenerator game for pricing power sales and wheeling fees ", IEEE Trans. Power Syst., vol. 9, pp. 1875-1879, Nov. 1994.
[29] F.Jonard, Y. Smeers, P. Bruel, B. Heilbronn, "Wheeling costs: An economic analysis illustrated by short-term and long-term simulation", Proc. Stockholm Power Tech. Int. Symp. Electric Power Engineering, 1995-June-18□.
[30] F. Nishimura, "Transaction modes of electric energy exchange and their effects of benefit optimization and allocation", Proc. Int. Conf. EMPD, vol. 1, pp. 25-25, 1995-Nov.-21□.
[31] Q. C. Lu, S. R. Brammer, "Transmission loss factors for area energy interchange", IEEE Trans. Power Syst., vol. 11, pp. 1387-1392, Aug. 1996.
[32] B. L. P. P. Perera, E. D. Farmer, B. J. Cory, "Revenue reconciled optimum pricing of transmission services", IEEE Trans. Power Syst., vol. 11, pp. 1419-1426, Aug. 1996.
[33] Y. Zuwei, F. T. Sparrow, T. Trafalis, "A proposed fast algorithm for security constrained economic dispatch in case of energy exchange and wheeling", Proc. Amer. Power Conf., pp. 371-376, 1997-Apr.-1—.
[34] K. Ghosh, V. C. Ramesh, "An options model for electrical power market", Int. J. Electr. Power Energy Syst., vol. 19, pp. 75-85, Feb. 1997.
[35] R. W. Ferrero, S. M. Shahidehpour, "Optimal power transaction with network constraints in deregulated systems", Electr. Mach. Power Syst., vol. 25, pp. 661-675, July 1997.
[36] F. D. Galiana, M. Ilic, "A mathematical framework for the analysis and management of power transactions under open access", IEEE Trans. Power Syst., vol. 13, pp. 681-687, May 1998.
[37] X. Ma, A. A. El-Keib, T. A. Haskew, "Effects of neglecting volt/var optimization on marginal cost-based pricing for wheeling transactions and independent power producers", Electr. Power Syst. Res., vol. 42, pp. 229-237, Sept. 1997.
[38] M. Muchayi, M. E. El-Hawary, "Wheeling rates evaluation using optimal power flows", Proc. IEEE Can. Conf. Electrical and Computer Engineering, vol. 1, pp. 389-392, 1998-May-24□.
[39] Y.-M. Park, J.-B. Park, J.-U. Lim, J.-R. Won, "An analytical approach for transaction costs allocation in transmission system", IEEE Trans. Power Syst., vol. 13, pp. 1407-1412, Nov. 1998.
[40] X. Ma, A A. El-Keib, T. A. Haskew, "Marginal cost-based pricing of wheeling transactions and independent power producers considering security constraints", Electr. Power Syst. Res., vol. 48, pp. 73-78, Dec. 1998.
[41] T. Yong, R. Lasseter, "Optimal power flow formulation in market of retail wheeling", IEEE Power Engineering Society Winter Meeting, 1999-Jan.31-Feb.-4.
[42] E. J. de Olivvera, J. W. M. Lima, J. L. R. Pereira, "Flexible AC transmission system devices: Allocation and transmission pricing", Int. J. Electr. Power Energy Syst., vol. 21, pp. 111-118, Feb. 1999.
[43] F. F. Wu, P. Varaiya, "Coordinated multilateral trades for electric power networks: Theory and implementation", Int. J. Electr. Power Energy Syst., vol. 21, pp. 75-102, Feb. 1999.
[44] P. R. Gribik, D. Shirmohammadi, S. Hao, C. L. Thomas, "Optimal power flow sensitive analysis", IEEE Trans. Power Syst., vol. 5, pp. 969-976, Aug. 1990.
[45] R. S. Fang, A. k. David, "Transmission congestion management in an electricity market", IEEE Trans. Power Syst., vol. 14, pp. 877-883, Aug. 1999.
[46] L. Tai-Gen, C. Shi-Lin, "Incremental transmission capability evaluation applied to dispersed generation planning and retail wheeling assessment", J. Chin. Inst. Elect. Eng., vol. 6, pp. 307-316, Nov. 1999.
[47] Y. R. Sood, N. P. Padhy, "Method of evaluating cost of wheeling based on marginal cost theory" in Proc. Int. Symp. Electricity Distribution in the Developing Countries, India, New Delhi:CBIP, Jan. 2000.
[48] R. D. Christie, B. F. Wollenberg, I. Wangensteen, "Transmission management in the deregulated environment", Proc. IEEE, vol. 88, pp. 170-195, Feb. 2000.
[49] G. Hamoud, "Feasibility assessment of simultaneous bilateral transactions in a deregulated environment", IEEE Trans. Power Syst., vol. 15, pp. 22-26, Feb. 2000.

[50] G. Hamoud, "Assessment of available transfer capability of transmission systems", IEEE Trans. Power Syst., vol. 15, pp. 27-32, Feb. 2000.
[51] F. J. Rubio-Oderiz, I. J. Perez-Arriaga, "Marginal pricing of transmission services: A comparative analysis of network cost allocation methods", IEEE Trans. Power Syst., vol. 15, pp. 448-454, Feb. 2000.
[52] S. Gisin Boris, M. V. Obessis, J. V. Mitsche, "Practical methods for transfer limit analysis in the power industry deregulated environment", IEEE Trans. Power Syst., vol. 15, pp. 955-960, Aug. 2000.
[53] F. D. Galiana, M. Phelan, "Allocation of transmission losses to bilateral contracts in a competitive environment", IEEE Trans. Power Syst., vol. 15, pp. 143-150, Feb. 2000.
[54] M. Rashidinejad, Y. H. Song, M. H. Javidi, "Option pricing of spinning reserve in a deregulated electricity market", IEEE Power Eng. Rev., pp. 39-40, July 2000.
[55] J. Meisel, "System incremental cost calculations using the participation factor load-flow formulation", IEEE Trans. Power Syst., vol. 8, pp. 357-360, Feb. 1993.
[56] M. K. C. Marwali, S. M. Shahidehpour, "Short-term transmission line maintenance scheduling in a deregulated system", IEEE Trans. Power Syst., vol. 15, pp. 1117-1124, Aug. 2000.
[57] D. Zhang, "Optimization-based bidding strategies in the deregulated market", IEEE Trans. Power Syst., vol. 15, pp. 981-986, Aug. 2000.
[58] Y. Xiao, Y. H. Song, "Available transfer capability (ATC) evaluation by stochastic programming", IEEE Power Eng. Rev., pp. 50-52, Sept. 2000.
[59] Y. R. Sood, S. Verma, N. P. Padhy, H. O. Gupta, "Evolutionary programming-based algorithm for selection of wheeling options", IEEE Power Engineering Society Winter Meeting, 2001-Jan. 28-Feb.-1.
[60] S. Khushalani, S. A. Khaparde, "Congestion management in the emerging energy market structures", Proc. CIGRE Regional Meeting-Int . Conf. Bulk Power Transmission System Integration in Developing Countries, pp. VII-16-VII-24, 2001-Nov.-8.
[61] K. Bhattacharya, J. Zhong, "Reactive power as an ancillary service", IEEE Trans. Power Syst., vol. 16, pp. 294-300, May 2001.
[62] K. Y. Lee, "Network congestion assessment for short-term transmission planning under deregulated environment", IEEE Power Engineering Society Winter Meeting, 2001-Jan. 28-Feb.-1.
[63] [63] A. Fradi, S. Brignone, B. F. Wollenberg, "Calculation of energy transaction factors", IEEE Trans. Power Syst., vol. 16, pp. 266-272, May 2001.
[64] Y. R. Sood, N. P. Padhy, H. O. Gupta, S. Verma, "Analysis and management of wheeling transactions based on AI techniques under deregulated environment of power sector", Water Energy Int. J., vol. 58, pp. 45-52, Jan.-Mar. 2001.
[65] B. Tyagi, S. C. Srivastava, "Automation generation control for multiarea system in a deregulated electricity market", Proc. CIGRE Regional Meeting-Int . Conf. Bulk Power Transmission System Integration in Developing Countries, pp. VIII-18-VIII-29, 2001-Nov.-8.
[66] A. M. Adsmson, L. L. Garver, J. N. Maughn, P. J. Palermo, W. L. Stillinger, "Summary of panel: Long-term impact of third-party transmission use", IEEE Trans. Power Syst., vol. 6, pp. 1183-1188, Aug. 1991.
[67] M. A. Fischetti, "Electric utilities: Poised for deregulation", IEEE Spectrum, pp. 34-43, May 1986.
[68] G. Stein, "In search of competitive electricity supplies", Proc. Industrial and Commercial Power Systems Conf., pp. 219-223, 1994-May-1_.
[69] R.Billinton, F. Gbeddy, "Impact of power wheeling on composite system adequacy evaluation", Int. J. Electr. Power Energy Syst., vol. 18, pp. 143-151, Mar. 1996.
[70] A.Scarfane, "Short-circuit simulations help quantify wheeling flow", IEEE Comput. Applicat. Power, vol. 8, pp. 44-47, Apr. 1995.
[71] P. Lewis, "Wheeling and dealing [power transmission]", IEE Rev., vol. 42, pp. 196-198, Sept. 1996.
[72] A. F. Vojdani, C. F. Imparato, N. K. Saini, H. H. Happ, "Transmission access issues", IEEE Trans. Power Syst., vol. 11, pp. 41-51, Feb. 1996.
[73] S. P. Zhu, "Some considerations on transmission services concerning optimizing wheeling parties' benefits", Proc. Int. Conf. EMPD, pp. 19-24, 1995-Nov.-21.
[74] T. J. Overbye, G. Gross, M. J. Laufenberg, P. W. Sauer, "Visualizing power system operations in an open market", IEEE Comput. Appl. Power, vol. 10, pp. 53-58, Jan. 1997.
[75] M. L. Baughman, S. N. Siddiqi, J. W. Zarnikau, "Advanced pricing in electricity systems", IEEE Trans. Power Syst., vol. 12, pp. 489-502, Feb. 1997.
[76] E. Hazan, "Industry transformation is under way worldwide electric utilities", Transm. Distrib. World, vol. 49, pp. 45-46, 48, 51, May 1997.
[77] N. Arsali, P. S. Neelaanta, "New concept for utility integrated resource planning: Start with the customer", Strategic Planning for Energy and the Environment, vol. 17, pp. 22-40, Winter 1997/1998.

[78] K. Viswanath, "Deregulation concepts-Overview " in Proc. Symp. Electricity Distribution in the Developing Countries, India, New Delhi:CBIP, pp. 26-33, Jan. 2000.
[79] Z. Yu, F. T. Sparrow, G. Nderitu, D. Gotham, F. Holland, T. Morin, "A large oligopoly competition model with an application to the midwest electricity markets", IEEE Power Engineering Society Summer Meeting, 2001-July-15□.
[80] R. Tripathy, S. K. Khaiani, "Restructuring of power supply industry and privatization-Subsidies as social responsibility", Proc. CIGRE Regional Meeting-Int . Conf. Bulk Power Transmission System Integration in Developing Countries, pp. IX-1-IX-8, 2001-Nov.-8□.
[81] S. M. Hanumantha, P. G. Krishna, "Customer service enhancement in electrical utility", Proc. Power Quality Conf., 1998.
[82] N. S. S. Arokiaswamy, "Can private power succeed as viable option?", Ind. J. Power and River Valley Development, vol. 47, pp. 224-227, 238, Nov./Dec. 1997.
[83] E. Allen, M. Ilic, Z. Younes, "Providing for transmission in times of scarcity: An ISO cannot do it all", Int. J. Electr. Power Energy Syst., vol. 21, pp. 147-163, Feb. 1999.
[84] V. Hulleman, W. A. Kerr, "Access: A global issue in electricity generation", Energy Sources, vol. 20, pp. 241-257, Apr. 1998.
[85] J. W. M. Lima, E. J. de Oliveira, "The long-term impact of transmission pricing", IEEE Trans. Power Syst., vol. 13, pp. 1514-1520, Nov. 1998.
[86] J. W. M. Lima, M. V. F. Pereira, J. L. R. Pereira, "An integrated framework for cost allocation in a multiowned transmission system", IEEE Trans. Power Syst., vol. 10, pp. 971-977, May 1995.
[87] J. Hu, J. Huang, B. Bian, "A research about optimal wheeling scheme", Autom. Electr. Power Syst., vol. 22, pp. 34-36, Dec. 1998.
[88] Z. Yu, D. Gachiri Nderitu, F. T. Sparrow, "A proposed market power monitoring model for restructuring electricity markets", IEEE Power Eng. Rev., pp. 41-42, July 2000.
[89] T. Nakashima, T. Niimura, K. Okada, "Multiple-impact assessment of wheeling and independent power producers in a deregulated power system", Proc. IEEE Can. Conf. Electrical and Computer Engineering, vol. 1, pp. 89-92, 1998-May-24□.
[90] Z. Li, H. Daneshi, "Some observations on market clearing price and locational marginal price," Power Engineering Society General Meeting, IEEE, June 2005.
[91] Y. Fu, Z. Li, "Different models and properties on LMP calculations," Power Engineering Society General Meeting, IEEE, June 2006.
[92] Y. Ma, P. B. Luh, K. Kasiviswanathan, E. Ni, "A neural network-based method for forecasting zonal locational marginal prices," Power Engineering Society General Meeting, IEEE, June 2004.
[93] J. Bastian, J. Zhu, V. Banunarayanam, R. Mukerji, "Forecasting energy prices in a competitive market," IEEE Computer Application in Power, July 1999.
[94] Y. Y. Hong, C. Y. Hsiao, "Locational marginal price forecasting in deregulated electricity markets using recurrent neural network," Power Engineering Society Winter Meeting, IEEE, 2001.
[95] Y. Y. Hong, C. Y. Hsiao, "Locational marginal price forecasting in deregulated electricity markets using artificial intelligence," IEE Proceeding on Generation, Transmission and Distribution, Sep 2002.
[96] M.Shahidehpour, H. Yamin, and Z. Li, "Market operations in electric power systems," John Wiley and Sons, 2002.
[97] H. J. Zimmermann, "Fuzzy set theory and its application," Kluwer Academic Publishers, 1996.
[98] M.Shahidehpour, M. Alomoush, "Restructured electrical power systems: operation, trading and volatility," New York: Marcel Dekker Publishers, 2001.
[99] A. Faruqui, B. K. Eakin, "Electricity pricing in transition," Kluwer Academic Publishers, 2002.
[100] L. L. Lai, "Power system restructuring: trading, performance and information technology," John Wiley and Sons, 2001.
[101] C. Weber, "Uncertainty in the electric power industry: methods and models for decision support," Springer, 2005.
[102] E.Kreyszig, "Advanced Engineering Mathematics," John Wiley and Sons, 1999.
[103] A. Faruqui, B. K. Eakin, "Pricing in competitive electricity markets," Kluwer Academic Publishers, 2000.
[104] M. Hutzler, "Electricity prices in a competitive environment: marginal cost pricing of generation services and financial status of electric utilities," DIANE publishing, 1998.
[105] M. D. flic, F. D. Galiana, L. H. Fink, "Power system restructuring: engineering and economics," Kluwer Academic Publishers, 1998.

[106] B.R.Szkuta, L.A. Sanabria, T.S. Dillon, "Electricity price short-term forecasting using artificial neural networks," IEEE Trans. Power System, vol. 14, pp. 851-857, Aug. 1999.
[107] G. Feng, Xiaohong Guan, C. Xi-Ren, A. Papalexopoulos, "Forecasting power market clearing price and quantity using a neural network method," Power Engineering Society General Meeting, IEEE, June 2000.
[108] L. Zhang, P.B. Luh, "An integrated neural network method for market clearing price prediction and confidence interval estimation," Proceeding of 4 World Congress on Intelligent Control and Automation, June 2002.
[109] J. Guo, P. B. Luh, "Improving market clearing price prediction by using a committee machine of neural networks," IEEE Trans. On Power Systems, vol. 19, pp. 1867-1876, Nov 2004.
[110] Y. Y. Xu, R. Hsieh, Y. L. Lu, Y. C. Shen, S. C. Chuang, H. C. Fu, C. Bock, H. T. Pao, "Forecasting electricity market prices: a neural network based approach," Proceeding of 2004 International Joint Conference on Neural Network, IJCNN, July 2004.
[111] F. Azevedo, Z. A. Vale, "Forecasting Electricity Prices with Historical Statistical Information using Neural Networks and Clustering Techniques," Power Systems Conference and Exposition,PSCE'06, Oct-Nov 2006.
[112] S. Fan, J. R. Liao, K. Kaneko, L. Chen, "An Integrated Machine Learning Model for Day-Ahead Electricity Price Forecasting," Power Systems Conference and Exposition, PSCE'06, Oct-Nov 2006.
[113] N. Baba, Y. Mogami, "Utilization of Stochastic Automata for Neural Network Learning," Proceeding of 1993 International Joint Conference on Neural Network, IJCNN, Oct 1993.
[114] B. Zhang, C. Zeng, S. Wang, P. Xie, "Forecasting market-clearing price in day-ahead market, using SOM-ANN," 39 International Universities Power Engineering Conference, UPEC 2004., Sep 2004.
[115] L. Zhang, P. B. Lu, "Neural network-based market clearing price prediction and confidence interval estimation with an improved extended Kalman filter method," IEEE Trans. Power System, vol. 20, pp. 59-66, Feb. 2005.
[116] Z. Hao, C. Jianhua, W. Hao, S. L. Ho, "CMAC-based short-term electricity price forecasting," proceeding of the 6th international conference on advances in power system control, operation and management, APSCOM2003, Nov. 2003.
[117] J. Contreras, R. Espinola, F. J. Nogales, A. J. Conejo, "ARIMA models to predict next-day electricity prices," IEEE Trans. On Power Systems, vol. 18, pp. 1014-1020, Aug. 2003.
[118] Z. Obradovic, K. Tomsovic, "Time series methods for forecasting electricity market pricing," Power Engineering Society Summer Meeting, IEEE, 1999.
[119] H. Zeripour, K. Bhattacharya, C. A. Canizares, "Forecasting the hourly Ontario energy price by multivariate adaptive regression splines," Power Engineering Society General Meeting, IEEE, June 2006.
[120] M. Rashidi-Nejad, A. A. Gharaveisi, A. Khajehzadeh, M. R. Salehizadeh, "Eelctricity Price Forecasting Using WaveNet," Conference on Power Engineering, July 2006.
[121] D. Benaouda, F. Murtagh, "Hybrid wavelet model for electricity pool-price forecasting in a dreregulated electricity market," 2006 IEEE International Conference on Engineering of Intelligent System, April 2006.
[122] A. J. Conejo, M. A. Plazas, R. Espinola, A. B. Molina, "Day-ahead electricity price forecasting using the wavelet transform and ARIMA models," IEEE Trans. On Power Systems, vol. 20, pp. 1035-1042, May. 2005.
[123] R. C. Garcia, J. Contreras, M. V. Akkeren, J. B. C. Garcia" A GARCH forecasting model to predict day-ahead electricity prices," IEEE Trans. On Power Systems, vol. 20, pp. 867-874, May. 2005.
[124] [124] D. A. Ka, G. Dominique, V. Bertrand, "A K-factor GIGARCH process: estimation and application on electricity market spot prices," Proceeding of 8th International Conference on Probabilistic Methods Applied to Power Systems, Sep 2004.
[125] Z. Hua, X. Li, Z. Li-zi, "Electricity price forecasting based on GARCH model in deregulated market," The 7th International Power Engineering Conference, IPEC 2005, Nov-Dec 2005.
[126] N. Amjady, "Day-ahead price forecasting of electricity markets by a new fuzzy neural network," IEEE Trans. On Power Systems, vol. 21, pp. 887-896, May. 2006.
[127] M. Rast, "Application of fuzzy neural networks on financial problems," Annual Meeting of North American Fuzzy information processing society, NAFIPS1997, Sep 1997.
[128] Q. Hua, M. Ha, "The Improvement of a Fuzzy Neural Network Based on Back propagation," 2002 International Conference on Machine Learning and Cybernetics, vol. 4, 4-5 Nov. 2002.

[129] V. Lyer, C. C. Fung, T. Gedeon, "A fuzzy-neural approach to electricity load and spot-price forecasting in a deregulated electricity market," Conference on Convergent Technologies for Asia-Pacific Region, TENCON 2003, Oct 2003.
[130] V. Iyer, C. Fung, T. Gedeon, "A Fuzzy-Neural Approach to Electricity Load and Spot Price Forecasting in a Deregulated Electricity Market," TECON 2003 Conference on Convergent Technologies for Asia-Pacific Region, vol. 4, Oct. 2003.
[131] Y.Y. Hong, C. F. Lee, "A neuro-fuzzy price forecasting approach in deregulated electricity markets," International Journal of Electrical Power System Research, vol. 73, pp. 151-157, 2005.
[132] J. J. Guo, P. B. Luh, "Selecting input factors for clusters of Gaussian radial basis function networks to improve market clearing prediction," IEEE Trans.on Power Systems, vol. 18, pp. 665-672, May. 2003.
[133] B. F. Hobbs, M. C. Hu, J. G. Inon, S. E. Stoft, M. P. Bhavaraju, "A dynamic analysis of a demand curve-based capacity market proposal: the PJM reliability pricing model," IEEE Trans. On Power Systems, vol.22, pp. 3-14, Feb.2007.
[134] E. Centeno, J. Reneses, J. Barquin, "Strategic analysis of electricity markets under uncertainty: a conjectured-price-response approach," IEEE Trans. On Power Systems, vol. 22, pp. 423-432, Feb. 2007.
[135] E. Celebi, J. D. Fuller, "A model for efficient consumer pricing schemes in electricity markets," IEEE Trans. On Power Systems, vol. 22, pp. 60-67, Feb. 2007.
[136] J. Contreras, J. R. Santos "Short-term demand and energy price forecasting," IEEE MELECON 2006, May. 2006.
[137] L. D. Kirsch, B. L. Sullivan, T. A. Flaim, "Developing marginal costs for real-time pricing," IEEE Trans. On Power Systems, vol. 3, pp. 1133-1138, Aug. 1988.
[138] Y. S. C. Yuen, "Experience in day-ahead market price forecasting," Proceeding of the 6th International Conference on Advances in Power System Control, Operation and Management, APSCOM 2003, Nov. 2003.
[139] E. Ni, P. B. Luh, "Forecasting power market clearing price and its discrete PDF using a Bayesian-based classification methods," Power Engineering Society Winter Meeting, IEEE, 2001.
[140] V. Niemeyer, "Forecasting long-term electric price volatility for valuation of real power options," Proceeding of the 34 Hawaii International Conference on System Sciences, 2001.
[141] G. Li, C. C. Liu, J. Lawarree, M, Gallanti, A. Venturini, "State-of-the-art of electricity price forecasting," International Symposium, CIGRE/IEEE, 2005, Oct 2005.
[142] F. Azevedo, Z. A. Vale, "Short-term price forecast from risk management point of view," Proceedings of the 13 International Conference on Intelligent Systems Application to Power Systems, Nov 2005.
[143] A. Karsaz, H. R. Mashliadi, R. Esliraghnia, "Cooperative coevolutionary approach to electricity load and price forecasting in deregulated electricity markets," Power India Conference, IEEE 2006, April 2006.
[144] K. Chongqing, G. Lin, Bai. Lichao, X. Ruilin, H. Jianjun, X. Kunyao, "Joint analysis of power system reliability and market price considering the uncertainties of load forecasts," International Conference on Power System Technology, PowerCon 2006, Oct 2005
[145] J. H. Zhao, Z. Y. Dong, X. Li, "Electricity price forecasting with effective feature preprocessing," Power Engineering Society General Meeting, IEEE, June 2006.
[146] http://www.pjm.com, PJM market.
[147] http://www.caiso.com, California ISO market.
[148] http://www.midwestiso.org, Midwest ISO market,Show Context
[149] R. M. Skitmore, S. G. Stradling, A. P. Tuohy "Human effects in early stage construction contact price forecasting," IEEE Trans. On Engineering Management, vol. 41, pp. 29-40, Feb. 1994.
[150] S. Fan, C. Mao, L. Chen, "Next-day electricity-price forecasting using a hybrid network," Generation, Transmission & Distribution, IET, Jan 2007.