

Web Based Online Real-time Information System for Reliability of Electrical Energy Supply including WTG

Jaeseok Choi [†], Jeongje Park *, Taegon Oh *, Kyeonghee Cho *, Joydeep Mitra ** and Mohammad Shahidehpour ***

Abstract – Web based online real-time reliability integrated information system is asked rapidly for more efficiency and demand response in recent. As the utilization of renewable resources has been receiving considerable attention in recent years, the information system requirement is increased. Specially, the reliability information system is more important for implementing the smart grid. This paper describes architecture of the WORRIS(Web Based Online Real-time Reliability Integrated Information System) Version 1.0 system developed preliminarily in this study. It is originally a reliability information system based one day go ahead system.

Keywords: Web Based Online Real-time Integrated Information System, Smart grid, Renewable energy, Reliability, CO₂

1. Introduction

Web Based Online Real-time Reliability Integrated Information System is asked rapidly for more efficiency and demand response in recent. In last years, free-market capitalism is a global reality. Countries and various industries are restructuring. Liberalization has resulted in new utility structures with attendant problems of operating the power system. This function is called as system operation by its traditional name. But, it is recognized that it has to be carried out in a modified way to fit the exigencies of the liberalized market. This need has created the concept of a System Operator (SO), an entity not owning any generation, charged with the responsibility of maintaining quality and reliability of electric power service[1-3]. In order to supply information about the quality, reliability and security of electric service, some trial to adapt or modify traditional operation planning and real-time control functions and a redesign of control system hardware and software architectures has been tried[1-3]. Specially, the utilization of renewable resources has been receiving considerable attention in recent years. Furthermore, this system is more important for implementing the smart grid.

[†] Corresponding Author: Dept. of Electrical Engineering, Gyeongsang National University, Korea (jschoi@gnu.ac.kr.)

* Dept. of Electrical Engineering, Gyeongsang National University, Korea (pakjan@hanmail.net, lglohl@naver.com, kx1004xh@hanmail.net)

** Dept. of Electrical and Computer Engineering, Michigan State University, USA (mitraj@msu.edu)

*** Dept. of Electrical Engineering, The Illinois Institute of Technology, USA (ms@iit.edu)

Received: May 9, 2011; Accepted: June 14, 2011

This paper describes a Web Based Online Real-time Reliability Integrated Information System, which is called as WORRIS Version 1.0 system developed in this study. This is prototype and reliability evaluation of power system including WTG. It is possible not only to supply the information about reliability indices of power system but also estimation of CO₂ emission at one day go ahead

2. An Architecture of Web-based Support Systems(WSS) for Power System reliability

Fig. 1 shows a general architecture of Web-based support systems (WSS) [5]. A (thin) client/server structure, as shown in Figure 1, is one of possible structures for WSS [4]. The users, including decision makers and information seekers, are clients on the top layer. They access the system with browsers via the Web. The interface that is designed on the server side will be presented on the clients' side by browsers 24 hours a day, 7 days a week. The lower layers and components encapsulated by the oval dotted line are very similar to conventional computerized support systems. In other words, a Web-based support system is a support system with the Web as the interface. Various kinds of networks such as the Internet, intranet and extranet will play an important role in the WSS infrastructure. Web browsers are intermediates to access a WSS. WSS are fully accessible, open, and dynamic systems. We have to make sure the information is fully and friendly delivered to different types of users. There is intensive interactive human involvement. Interface design is another key issue of

WSS design [5][6].

Fig. 2 shows an eventual purpose concept diagram in relationship with the WORRIS and demand response. The purpose of WORRIS yields the chance for customer to choose the electrical energy resource under environment of variety kind of resources in future.

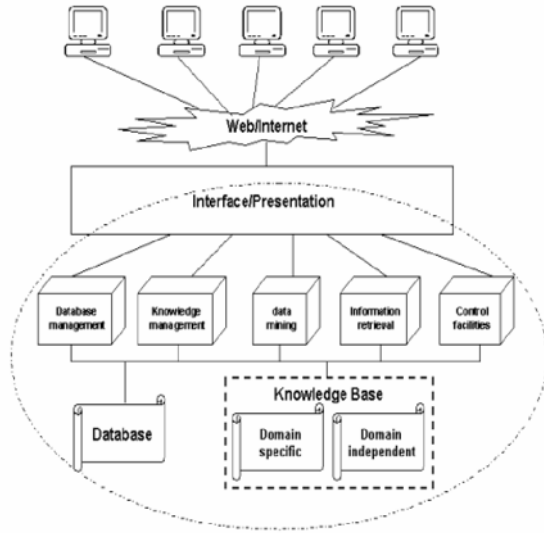


Fig. 1. An architecture of web-based support systems.

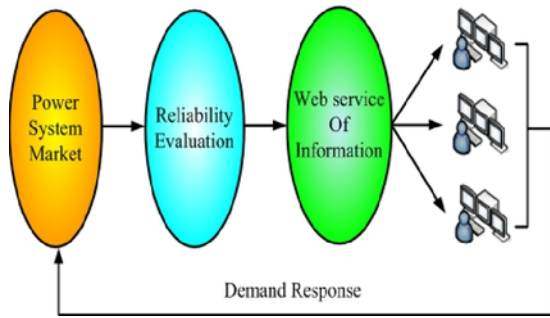


Fig. 2. The caption for a figure must follow the figure.

3. Reliability Evaluation of Power Systems Including WTG

The paper is to supply the web based online real time reliability information of power systems including WTG as shown in Fig. 3. Thus, the probabilistic production energy can be calculated through reliability indices and reduction of production cost and CO₂ emission can be obtained by inserting renewable energy(WTG) to the power systems. To

evaluate the reliability of power systems, the power output of WTG should be modeled. Fig. 4 presents the relationship between the power output of a WTG and wind speed.

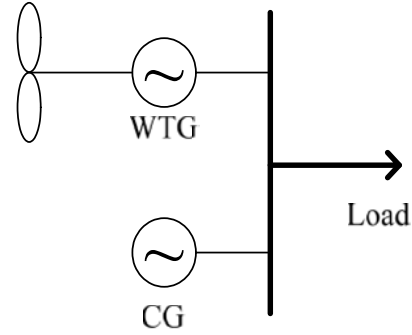


Fig. 3. Wind included generation system model.

The outage capacity pdf of the WTG can be obtained by combining the WTG's power output model and the wind speed pdf model as shown in Fig. 5. This yields a multi-state model because the wind speed is distributed widely. The probabilities of identical power are cumulated. Therefore, the state number is different from the wind speed band number. In this paper, the reliability indices for systems including WTG are evaluated using the multi-state model for the WTG and the two-state model for the conventional generators.

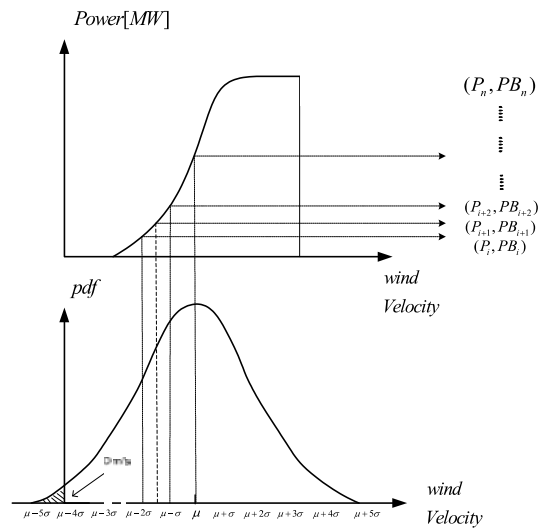


Fig. 4. The relationship between the wind speed model and the WTG power output model.

3.1 Reliability Evaluation

Probabilistic reliability indices have been used extensively for generation expansion planning. The indices can be calculated by using the Effective Load Duration Curve (ELDC referred to in the following as Φ), (1) as given in [7].

$$\begin{aligned}\Phi_i &= \Phi_{i-1} \otimes f_{oi} \\ &= (1 - \sum_{j=1}^{NS} q_{ij} \Phi_{i-1}(x) + \sum_{j=1}^{NS} q_{ij} \Phi_{i-1}(x - C_{ij}))\end{aligned}\quad (1)$$

where,

$\otimes$: The convolution integral operator

Φ_{oi} : Original inverted load duration curve (ILDC)

x : Random variable of Φ

NS : The total number of states

f_{oi} : The outage capacity pdf of generator i

q_{ij} : Forced outage rate (FOR) of generator i at state j

C_{ij} : Outage capacity of generator i at state j

$$LOLE = \Phi_{NG}(x) \Big|_{x=IC} \quad [\text{hours/year}] \quad (2)$$

$$EENS = \int_{IC}^{IC+L_p} \Phi_{NG}(x) dx \quad [\text{Mwh/year}] \quad (3)$$

$$EIR = 1 - \frac{EENS}{ED} \quad [\text{pu}] \quad (4)$$

$$\Delta E_i = EENS_{i-1} - EENS_i \quad [\text{MWh}] \quad (5)$$

$$\Delta PC_i = \lambda_a \times \Delta E_i + \lambda_b \times (1 - \sum_1^i \text{FOR}) \times LOLE_{i-1} \quad [\$/\text{year}] \quad (6)$$

$$CF_i = (\Delta E_i / CAP_i / T) \times 100 \quad [\%] \quad (7)$$

$$TCE_i = \Delta E_i \times CE_i \quad [\text{Ton/year}] \quad (8)$$

where,

L_p : Peak load [MW]

IC_i : Installed capacity of generator i [MW]

ED : Total demand energy [MWh]

NG : The total generator number

Φ_{NG} : The final effective load duration curve

λ_a : Incremental cost coefficient

λ_b : cost constant

TCE_i : Total CO₂ Emission of i^{th} generator

CE_i : CO₂ emission of i^{th} generator

by (2)-(4). Form reliability indices, probabilistic production energy(E_i), production cost(PC_i), capacity factor(CF_i) and CO₂ Emission(CE_i) can be obtained.

4. WORRIS V1.0 Architecture

Fig. 5 shows the overall configuration for the WORRIS V1.0 system developed in this study.

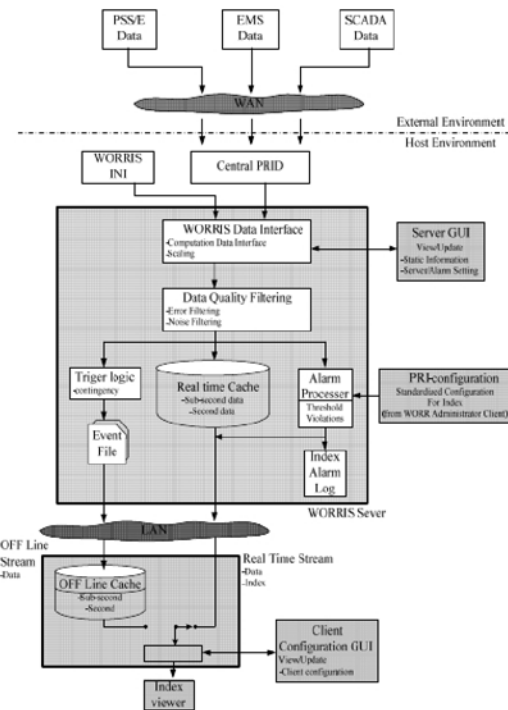


Fig. 5. A flow chart describing the proposed method.

The configuration is a just research network that is the integration of academic processing with web based online and real-time reliability. It is not unfortunately to connect with EMS in now because this system is only prototype. Therefore, the assumed load data is installed at load data D/B. And also, the generation system is installed at generation system D/B.

5. Case Studies

The developed WORRIS V1.0 is established successfully on website: <http://worris.gsnu.ac.kr/PraWin/>. It is an opened system and prototype for everybody to contact until 2010. It is applied to Jeju Island power system in South Korea. The

The basic reliability evaluation indices, namely the Loss of Load Expectation (LOLE), the Expected Energy Not Supplied (EENS), the Energy Index of Reliability (EIR) can be calculated using the effective load duration curve, $\Phi(x)$

Jeju Island power system in 2010 year as shown in Fig. 6 is used to demonstrate the usefulness of the proposed method. Three wind farms were assumed at the locations where are Hanlim (HLM), Hangwon (HWN) and Sungsan(SSN) for case study. The data of Jeju island power system are shown in Table I. The actual CO₂ Emission data in 2008 year in Jeju Island and the pattern of load duration curve in 2008 year of Jeju Island were used as shown in Table I and Fig. 7 respectively. The total installed capacity is 890MW and wind turbine generation capacity 100MW added. Peak load in 2010 has been forecasted as 682MW[9]

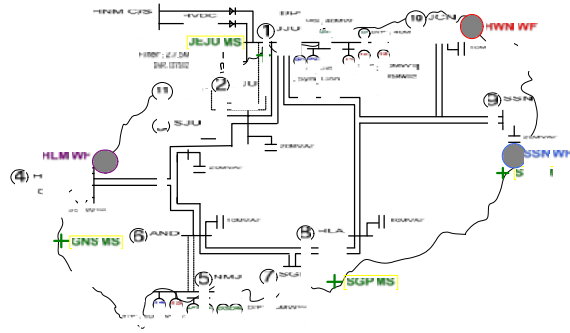


Fig. 6. Jeju power system in Korea.

Table 1. The Generators Data of Jeju Island Power System

	Name	Type	Capacity [MW]	Num.	α [Gcal/MW ² h]	β [Gcal/MWh]	γ [Gcal/hr]	Fuel cost [\$/Gcal]	CO ₂ emission [Ton/MWh]	FOR
1	HWN	WTG	50	1	-	-	-	-	-	-
2	SSN	WTG	30	1	-	-	-	-	-	-
3	HLM	WTG	20	1	-	-	-	-	-	-
4*	HVDC	DC	75/150*	1	0.004	1.512	45.207	43.300	0.65	0.010/0.028*
5	NMJ3	T/P	100	2	0.004	1.512	45.207	43.300	0.65	0.012
6	JJU1	T/P	10	3	0.062	2.100	5.971	43.599	0.96	0.015
7	JJU2	T/P	75	2	0.003	1.832	30.231	43.599	0.70	0.012
8	HLM1	G/T	35	2	0.004	2.401	20.320	77.909	0.95	0.013
9	HLM1	S/T	35	1	0.004	2.401	20.320	77.909	0.95	0.013
10	JJU3	D/P	40	2	0.025	0.364	28.484	43.599	0.59	0.018
11	NMJ1	D/P	10	4	0.006	1.999	1.360	43.300	0.62	0.018
	Total		945	21	-	-	-	-	-	-

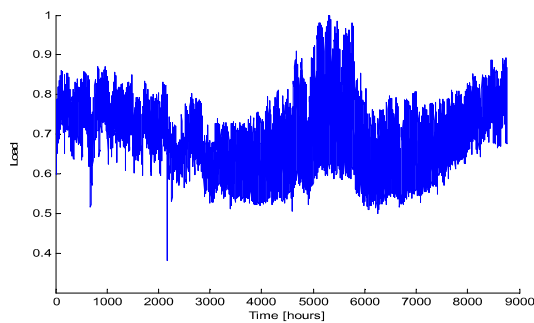


Fig. 7. Pattern of hourly peak load variation curve in Jeju power system.

The data related to the two wind farms and one solar farm are given in Table II.

Table 2. The data of each WF

WF Name	HLM-WF	SSN-WF	HWN-WF
WTG capacity	20MW	30MW	50MW
Cut-in speed(V_{ci})	5m/sec	5m/sec	5m/sec
Rated speed(V_R)	14m/sec	15m/sec	16m/sec
Cut-out speed(V_{co})	25m/sec	25m/sec	25m/sec
Wind speed range	0~35	0~45	0~45
Mean wind speed	6.4	8.5	8.5
Standard deviation	9	11	11

WORRIS Interface consists of the Project, Generator List, Load Information, Execute and Execute Result panes as shown in Fig. 8. In project pane(pane 1), there are several parameters that are information of model system. The characteristic data of each generator are in generator list pane(pane 2). The load information such as maximum, minimum and average load are in load information pane(pane 3). There are three buttons in execute pane(pane 4). The execute button is to run program. The DRI(Deterministic Reliability Indices) button is to see the results that are total installed capacity, peak load and CO₂ emission as shown in Fig. 9. The PRI(Probabilistic Reliability Indices) button is to see the results that are LOLE(Loss of Load Expectation), EENS(Expected Energy Not Served), EIR(Energy Index of Reliability) and SRR(Supply Reserve Rate) as shown in Fig. 10.

The overall results that are total installed capacity, peak load, LOLE, EENS EIR and SRR are in execute result pane(pane 5) as table.

Fig. 9 and Fig. 10 show the results of WORRIS for Jeju power system.

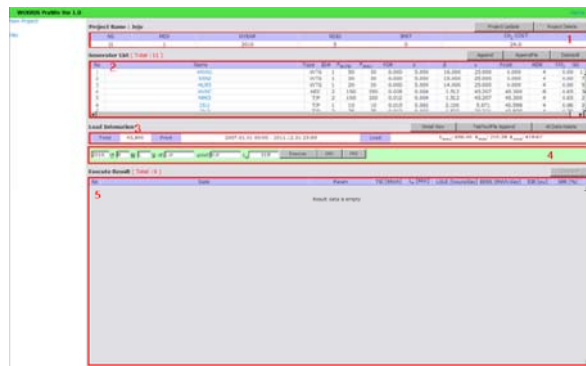


Fig. 8. WORRIS's whole control panel for Jeju power system.

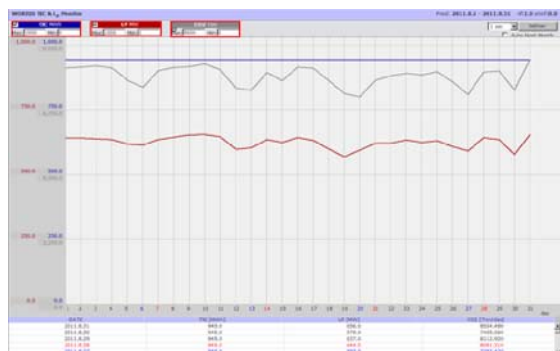


Fig. 9. DRI Results of WORRIS for Jeju power system.

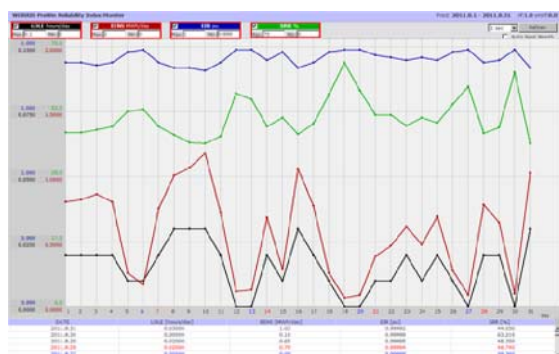


Fig. 10. PRI Results of WORRIS for Jeju power system.

6. Conclusions

This paper describes a Web Based Online Real-time Reliability Integrated Information System, which is called WORRIS Version 1.0. This paper presents preliminary findings and basic architecture from the web based information system in power system. The results show how a web-based monitoring system can form the basis for customers to identify the reliability information of power system including wind turbine generator. But, it is still not perfect real time information system but a reliability information system based one day go ahead system. It is also expected that the proposed method can evaluate the various effects on power system by adding WTG. And it can be helpful that the installation of renewable energy is successful to power system and customer can choose their electrical energy recourse in future.

Acknowledgements

This work was supported by the National Research

Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2010-0000156). The support of the Advanced Power Network Reliability Research Center (APRRC) is acknowledged.

References

- [1] Deepak Divan, William Brumsickle, Joseph Et, *Assessing I-Grid™ Web-Based Monitoring for Power Quality and Reliability Benchmarking*.
- [2] Divan, D., G. Luckjiff, J. Freeborg, W. Brumsickle, D. Bielinski, T. Grant. 2002. I-Grid™: A New Paradigm in Distribution Grid Power Quality And Reliability Monitoring Proceedings, *EPRI PQA North America Conference*, June, 2002, Portland, OR.
- [3] Tomás E. Dy-Liacco, "Enabling Technologies for Operation and Real-Time Control in a Liberalized Environment" *EPRI second European conference* Nov. 2-4, 1999,
- [4] Toshiro Kagami, Hideyuki Takani, Katsuhiko Sekiguchi, "Web-based Wide Area Measurement System - System Architecture and Experiences" *TOSHIBA CORPORATION Industrial and Power Systems & Services Company*, Japan
- [5] JingTao Yao, *Design of Web-based Support Systems*
- [6] Hong Chen Claudio A. Ca-nizares Ajit Singh, "Web-based Computing for Power System Applications" *North American Power Symposium (NAPS)*, San Luis Obispo, California, October 1999..
- [7] Ramadoss Ramesh, Velimuthu Ramachandran, "On-Line Monitoring of Multi-Area Power Systems in Distributed Environment" *Serbian Journal Of Electrical Engineering* Vol. 3, No. 1, June 2006, 89-101
- [8] Nick Jenkins, Ron Allan, Peter Crossley, David Kirschen and Goran Strbac: *EMBEDDED GENERATION*, IEE, 2000.
- [9] Roy Billinton and Dange Huang, "Aleatory and Epistemic Uncertainty Considerations in Power System Reliability Evaluation" *Proceedings on PMAPS2008*, Puerto Rico, May 25-29, 2008.
- [10] Liang Wu, Jeongje Park and Jaeseok Choi, "A Basic Study on the Probabilistic Reliability Evaluation of Power System considering WTG", *KIEE*, May 2008, pp.149-152 (Written by Korean).
- [11] U.S.-Canada Power System Outage Task Force, *Final Report on the August 14, 2003 Blackout in the United States and Canada*, Causes and Recommendations" April 2004.
- [12] Le-Ren Chang-Chien, Yin-Juin Lin, Chin-Chung Wu,"

An Online Evaluation of Operating Reserve For System Security” *Proceedings Of World Academy Of Science, Engineering And* Vol. 22 July 2007 ISSN 1307-6884.

- [13] Ringo P K Lee, L L Lai, and Norman Tse, “A web_based multi-channel power quality monitoring system for a large network” *Power System Managemant and Control*, Conference proceedings, April 17-19, 2002.
- [14] Deepak Divan, Glen A. Luckjiff, William E. Brumsickle, John Freeborg, and Atul Bhadkamkar, *A Grid Information Resource for Nationwide Real-Time Power Monitoring*



Jaeseok Choi (S'88–M'91–SM'05) was born in Kyeongju, Korea, in 1958. He received the B.Sc., M.Sc., and Ph.D. degrees from Korea University, Seoul, in 1981, 1984, and 1990, respectively. He was a Postdoctoral at the University of Saskatchewan, Saskatoon, SK, Canada, in 1996. He was a visiting professor at Cornell University, Ithaca, NY, USA, in 2004. Since 1991, he has been on the faculty of Gyeongsang National University, Jinju, Korea, where he is a professor. He is also adjunct professor at IIT, IL, USA since 2007. His research interests include fuzzy applications, probabilistic production cost simulation, reliability evaluation, and outage cost assessment of power systems.



Jeongje Park (S'08) was born in Jinju, Korea in 1981. He received the B.Sc. and M.Sc. degrees from Gyeongsang National University, Jinju, in 2007 and 2008, respectively. His research interest includes probabilistic reliability evaluation of power systems including renewable resources. He is now working forward a Ph.D. degree at Gyeongsang National University.



Taegon Oh was born in Jinju, Korea in 1984. His research interest includes Transmission Expansion Planning using Reliability Evaluation of Power Systems. He received the B.Sc. degree from Gyeongsang National University, Jinju, in 2010. He is now working forward a M.Sc. degree at Gyeongsang National University.



Kyeonghee Cho was born in Jinhea, Korea in 1987. She received the B.Sc degrees from Gyeongsang National University, Jinju, in 2010. Her research interest includes reliability evaluation of power systems considering renewable energy. He is now working forward a M.Sc. degree at Gyeongsang National University.



J. Mitra (S '94, M '97, SM '02) is Associate Professor of Electrical Engineering and Faculty Associate of the Institute of Public Utilities at Michigan State University, East Lansing. Prior to this, he was Associate Professor at New Mexico State University, Las Cruces, Assistant Professor at North Dakota State University, Fargo, and Senior Consulting Engineer at LCG Consulting, Los Altos, CA. He received a Ph.D. in Electrical Engineering from Texas A&M University, College Station, and a B.Tech.(Hons.), also in Electrical Engineering, from Indian Institute of Technology, Kharagpur. His research interests include power system reliability, distributed energy resources, and power system planning. Dr. Mitra is a Senior Member of the IEEE.



Mohammad Shahidehpour (F'01) is the Carl Bodine Distinguished Professor and Chairman in the Electrical and Computer Engineering Department at the Illinois Institute of Technology, Chicago. Dr. Shahidehpour is an IEEE Distinguished Lecturer and has lectured in 30 countries on electricity restructuring issues. He is the Vice President of Publications for IEEE/PES.