DSM Considered Probabilistic Reliability Evaluation and an Information System for Power Systems Including Wind Turbine Generators

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***Abstract*—This paper proposes a methodology for evaluating the probabilistic reliability, considering demand side management (DSM) and web based on a daily interval reliability information system for a grid constrained composite power system including wind turbine generators(WTG). The proposed model can consider capacity limitations and transmission line unavailabilities and the operation of WTG modeled by multi-states. The importance of renewable energy sources is growing at a rapid rate due to environmental concerns. A web based online daily time interval reliability integrated information system (WORRIS) is applied using the methodology proposed in this paper. This paper describes the architecture of the WORRIS Version 7.0 system.**

***Index Terms*—Composite power system reliability evaluation, grid considered reliability evaluation, multi-state model, web based online real-time integrated information system, wind turbine generator.**

I. INTRODUCTION

AS A RESULT of being environmental friendly, the utilization of renewable resources such as the wind and the sun to generate electric power has received considerable attention in recent years [1], [2]. The Web Based Online Real-time Reliability Integrated Information System (WORRIS) was developed to provide rapid system reliability assessment WORRIS reference and more recently modified to incorporate demand side management (DSM).

Huge WTGs penetration is expected in the near future and therefore, the development of a methodology for wind integrated composite system reliability evaluation is an important and necessary task. Composite power systems that include WTGs also require multi-state WTG models in addition to considering the grid uncertainties associated with lines, main transformers and switch gear etc. [1]–[5].

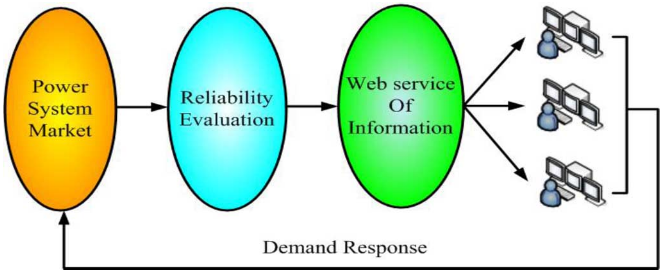

Fig. 1. Evenetual purpose diagram of a web based online realtime reliability information system of a power system, and demand response.

A methodology for grid constrained probabilistic reliability evaluation of power systems including WTG is proposed in this paper. A composite power system reliability evaluation methodology based on the composite power system effective load model has been developed by the authors [6], [7]. Conventional methodology normally utilizes two-state models for both generators and transmission line. This paper extends the two-state representation to multi-state models for generators in order to consider WTG. A composite power system reliability model designated as CMELDC [7], is used to consider the grid uncertainties associated with lines, main transformers and switchgear etc. [6], [7]. This paper describes a Web Based Online Real-time Reliability Integrated Information System, which is called WORRIS Version 7.0. This is a prototype and contains reliability evaluation of power systems including WTG. In this case study, simulation is conducted using the Jeju island system in Korea. The study shows that it is possible not only to supply information on reliability indices of the power system but also on demand side management value according to DSM day by day.

Fig. 1 shows an eventual purpose concept diagram incorporate WORRIS and demand response. The utilization of WORRIS provides the opportunity for customers to choose the electrical energy resource under an environment of various kinds of resources in the future.

II. THE MULTI-STATE OPERATION MODEL OF WTG

The uncertainties in power system reliability assessment can be categorized to two kinds as aleatory uncertainty and epistemic uncertainty. The former includes the unavailability of generators, transmission lines and main transformers etc. The latter includes lack of information occurred in forecasting load, wind speed and solar radiation etc. Fig. 2 shows the differences in the uncertainties of renewable energy resource power and conventional plants.

Manuscript received November 27, 2012; accepted December 09, 2012. Date of publication February 15, 2013; date of current version February 27, 2013. This work was supported by NRF of MEST and the Power Generation & Electricity Delivery of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) of MKE (No. 2009T100100545). Paper no. TSG-00823-2012.

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Digital Object Identifier 10.1109/TSG.2012.2234150

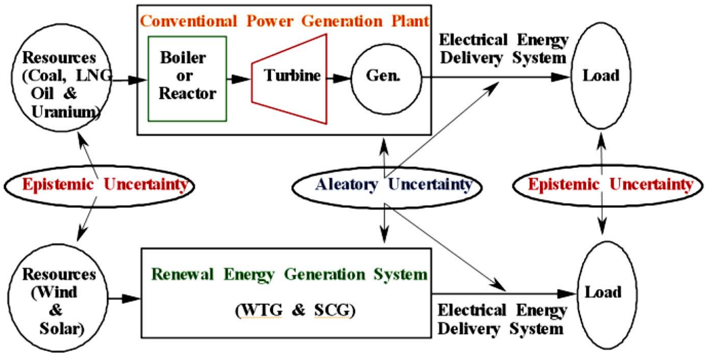


Fig. 2. Uncertainties of renewable energy resource power and conventional plants.

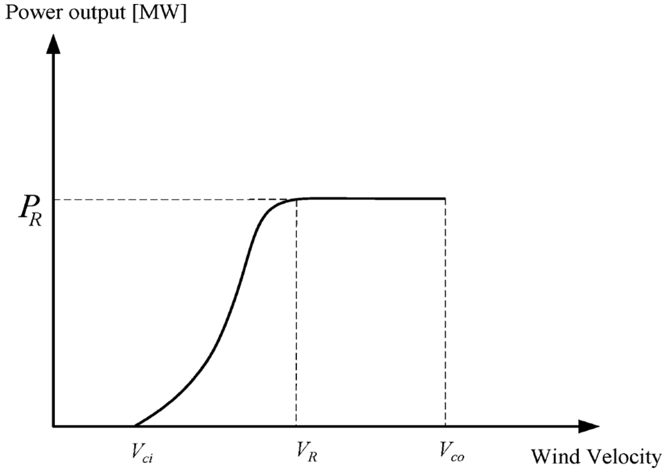


Fig. 3. A typical power output curve for a WTG.

A. *WTG Power Output Model*

Fig. 3 shows the relationship between the power output of a WTG and the wind speed [1]–[5].

Where:

V_{ci}:	the cut-in speed [m/s].
V_R:	the rated speed [m/s].
V_{co}:	the cut-out speed [m/s].
P_R:	the rated power [MW].

A mathematical model for the power output of a WTG is shown in (1) [2]. The power P_i generated by wind speed band SW_i is formulated in (1) [2], where, i is the number of the wind speed band. The A, B, and C parameter equations are presented in [5].

$$\begin{aligned} P_i &= 0, 0 \le \mathrm{SW}_i < V_{\mathrm{ci}} \\ &= P_R(A + B \times \mathrm{SW}_i + C \times \mathrm{SW}_i^2), V_{\mathrm{ci}} \le \mathrm{SW}_i < V_R \\ &= P_R, V_R \le \mathrm{SW}_i \le V_{\mathrm{co}} \\ &= 0, V_{\mathrm{co}} < \mathrm{SW}_i \end{aligned} \tag{1}$$

B. *Wind Speed Model*

Wind speeds vary in both time and space. It has been reported that the actual wind speed distribution can be described by Weibull probability distribution and approximated by a normal distribution [2]. This paper uses the normal probability density function (*pdf*) to model the wind speed in terms of the mean wind speed value μ and the standard deviation σ as shown Fig. 4.

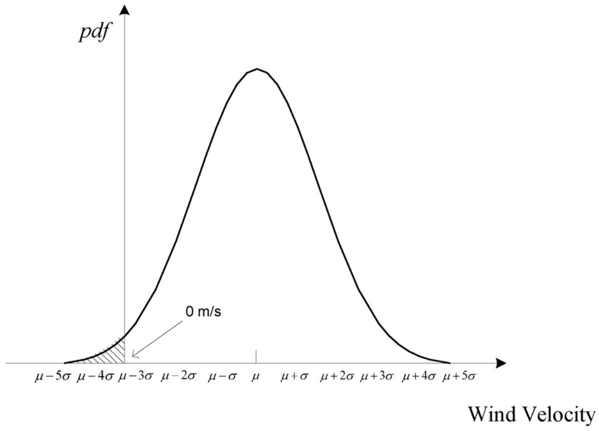


Fig. 4. Wind speed model.

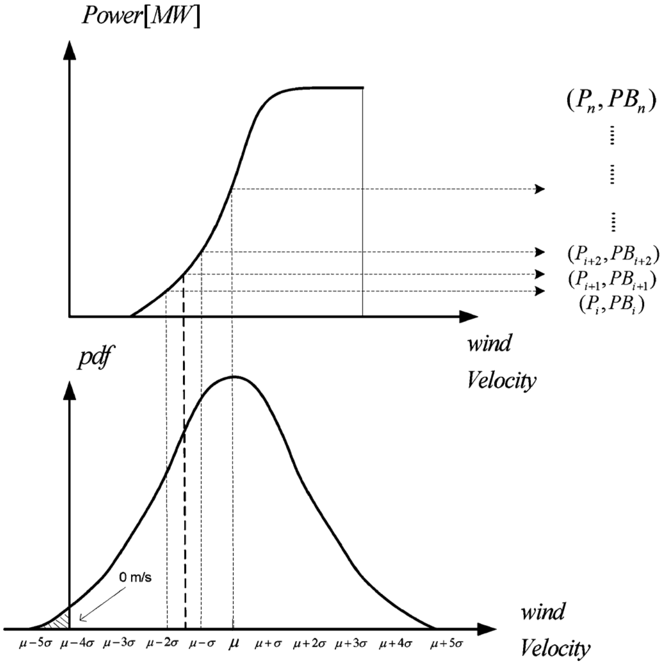


Fig. 5. Components of a model describing the power output states of a WTG and the corresponding probabilities.

C. *The Multi-State Model of a WTG*

The power output curve of the WTG is combined with the wind speed model shown in Fig. 5 to create multi-state WTG model. Each state has a pair of associated parameters; namely the power (P_i) and probability (PB_i). The operating model of a WTG is a multi-state model described by a capacity outage probability density function.

III. RELIABILITY EVALUATION OF A COMPOSITE POWER SYSTEM INCLUDING WTG

A composite power system reliability evaluation methodology considering generation as well as transmission systems based on the composite power system effective load model has been developed by the authors [7]. This methodology used two-state models to describe the conventional generators and transmission lines. The two-state generating unit representation has been extended to multi-state models in order to consider WTG [3]–[5], [11], [12].

A. Reliability Evaluation at HLI Including WTG

Reliability indices of $\mathrm{LOLE_{HLI}}$ (Loss of Load Expectation) and $\mathrm{EENS_{HLI}}$ (Expected Energy Not Served) at HLI considering only the generation system are calculated using the effective load duration curve (ELDC) and the ${}_{\mathrm{HLI}}\Phi(x)$ as in (2) and (3) respectively.

$$\mathrm{LOLE_{HLI}} = {}_{\mathrm{HLI}}\Phi(x)|_{x=\mathrm{IC}}\ [\text{hours/yr}] \tag{2}$$

$$\mathrm{EENS_{HLI}} = \int_{\mathrm{IC}}^{\mathrm{IC}+Lp} {}_{\mathrm{HLI}}\Phi(x)dx\ [\text{MWh/yr}] \tag{3}$$

where:

IC: total installed generating capacity [MW]

L_p: system peak load [MW]

and

$$\begin{aligned} {}_{\mathrm{HLI}}\Phi_i(x_e) &= {}_{\mathrm{HLI}}\Phi_{i-1}(x_e) \otimes_{\mathrm{HLI}} f_{\mathrm{oi}}(x_{\mathrm{oi}}) \\ &= \int_{\mathrm{HLI}} \Phi_{i-1}(x_e - x_{\mathrm{oi}})_{\mathrm{HLI}} f_{\mathrm{oi}}(x_{\mathrm{oi}})dx \end{aligned} \tag{4}$$

where:

$\otimes$: operator designation meaning convolution integral

${}_{\mathrm{HLI}}\Phi_0(x_e - x_{\mathrm{oi}}) = {}_{\mathrm{HLI}}\Phi(x_L)$

${}_{\mathrm{HLI}}f_{\mathrm{oi}}(x_{\mathrm{oi}})$: the probability distribution function of outage capacity of generator $\#i$

B. Reliability Evaluation at HLII(Composite Power System) Including WTG

The reliability indices at HLII can be classified as load point indices and bulk system indices depending on the object of the evaluation. The reliability indices can be evaluated using a Composite power system Equivalent Load Duration Curve (CMELDC) based on the composite power system effective load model in Fig. 6 [6], [7]. *CG, CT* and g_o and q_l in Fig. 6 are the capacities and capacity outage density functions of the generators and the unavailability of the transmission lines respectively. The model uses the capacity outage density functions of the WTG and considers them as multi-state generators. The transmission line state model remains a two-state representation.

1) Reliability Indices at the Load Points (Buses): The load point reliability indices, LOLE_k and EENS_k can be calculated using (5) and (6) with the CMELDC, ${}_k\Phi_{\mathrm{NG}}(x)$

$$\mathrm{LOLE}_k = {}_k\Phi_{\mathrm{NG}}(x)|_{x=\mathrm{AP}_k}\ [\text{hours/yr}] \tag{5}$$

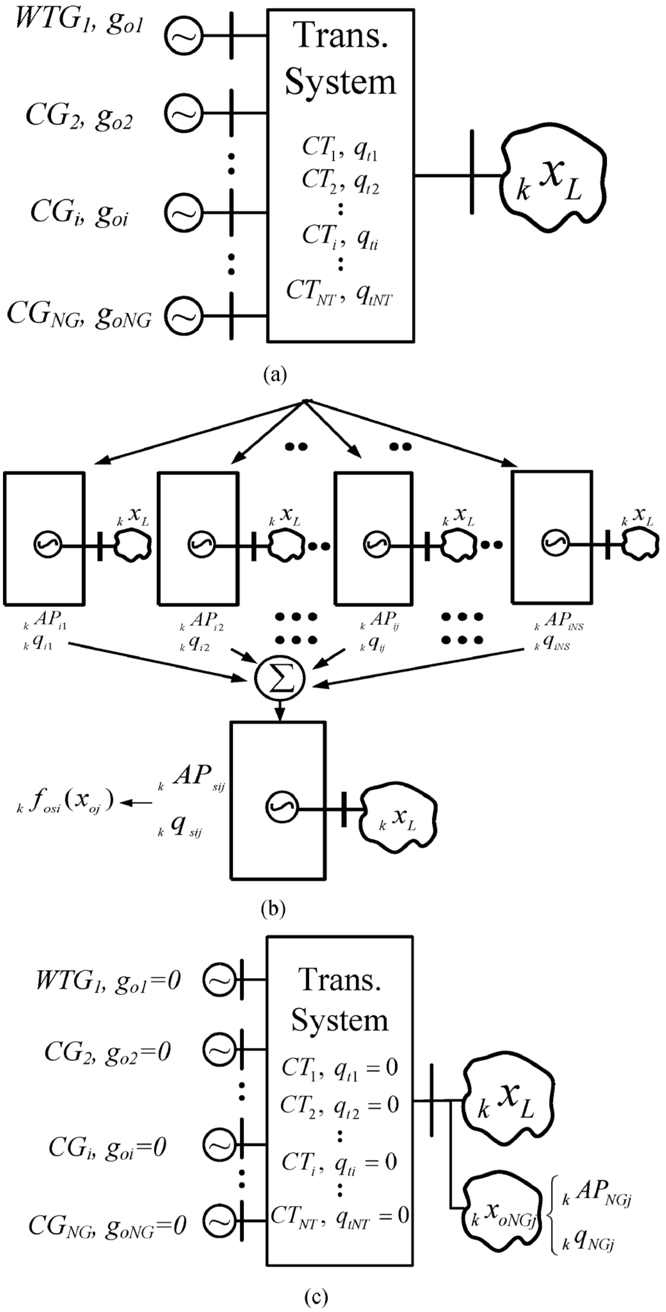


Fig. 6. Composite power system effective load model at HLII. (a) Actual system. (b) Synthesized fictitious equivalent generator. (c) Equivalent system.

$$\mathrm{EENS}_k = \int_{\mathrm{AP}_k}^{\mathrm{AP}_k+Lp_k} {}_k\Phi_{\mathrm{NG}}(x)dx\ [\text{MWh/yr}] \tag{6}$$

where:

L_{pk}: peak load at load point k [MW]

AP_k: maximum arrival power at load point k [MW]

$$\begin{aligned} {}_k\Phi_i(x_e) &= {}_k\Phi_o(x_e) \otimes_k f_{\mathrm{osi}}(x_{\mathrm{oi}}) \\ &= \int_k \Phi_o(x_e - x_{\mathrm{oi}})_k f_{\mathrm{osi}}(x_{\mathrm{oi}})dx_{\mathrm{oi}} \end{aligned} \tag{7}$$

where:

$\otimes$: the operator representing the convolution integral

${}_k\Phi_0$: original load duration curve at load point #*k*

${}_k f_{\mathrm{osi}}$: outage capacity *pdf* of the synthesized fictitious generator created by generators 1 to i, at load point #*k*.

The capacity outage *pdf* of the synthesized fictitious generator created by generators 1 to i, at load point #*k* $({}_k f_{\mathrm{osi}})$ is also a multi-state function. The convolution integral between the original load duration curve at load point #*k* $({}_k\Phi_0)$ and ${}_k f_{\mathrm{osi}}$ is processed at HLII. The general multi-state convolution integral calculation method for probabilistic reliability evaluation has been used extensively for generation expansion and can be calculated using the multi-state recursive equation shown in (8).

$$\begin{aligned} {}_k\Phi_i &= {}_k\Phi_{i-1} \otimes {}_k f_{\mathrm{osi}} \\ &= \left(1 - \sum_{n=1}^{\mathrm{NS}} {}_k q_{ni}\right) {}_k\Phi_{i-1}(x) + \sum_{n=1}^{\mathrm{NS}} {}_k q_{ni\,k}\Phi_{i-1}(x - {}_kC_{ni}) \end{aligned} \tag{8}$$

where:

Φ_0 : the original Inverted Load Duration Curve (ILDC)

x: random variable of Φ

NS: the multi-state number of the synthesized fictitious generator

${}_k\mathrm{C}_{ni}$: outage capacity of state n of the synthesized fictitious generator created by generator at load point #*k*.

${}_k\mathrm{q}_{ni}$: the probability correspond the outage capacity of state k of the synthesized fictitious generator at load point #*k*.

${}_k f_{\mathrm{osi}}$: outage capacity *pdf* of the synthesized fictitious generator at load point #*k*.

2) System Reliability Indices: The $\mathrm{EENS}_{\mathrm{HLII}}$ of a bulk system is equal to the summation of the EENS_k at the load points as shown in (9). The LOLE of a bulk system, however, is entirely different from the summation of the LOLE_k at the load points. The $\mathrm{ELC}_{\mathrm{HLII}}$ (Expected load curtailed) of a bulk system is equal to the summation ofELC_k at the load points as shown in (10), an equivalent representative $\mathrm{LOLE}_{\mathrm{HLII}}$ of a bulk system can be obtained using (11).

$$\mathrm{EENS}_{\mathrm{HLII}} = \sum_{k=1}^{\mathrm{NL}} \mathrm{EENS}_k \ [\mathrm{MWh/yr}] \tag{9}$$

$$\mathrm{ELC}_{\mathrm{HLII}} = \sum_{k=1}^{\mathrm{NL}} \mathrm{ELC}_k \ [\mathrm{MW/cur.yr}] \tag{10}$$

$$\mathrm{LOLE}_{\mathrm{HLII}} = \mathrm{EENS}_{\mathrm{HLII}} / \ \mathrm{ELC}_{\mathrm{HLII}} \ [\mathrm{hours/yr}] \tag{11}$$

$$\mathrm{EIR}_k = 1 - \mathrm{EENS}_k / \mathrm{DENG}_k \ [\mathrm{p.u}] \tag{12}$$

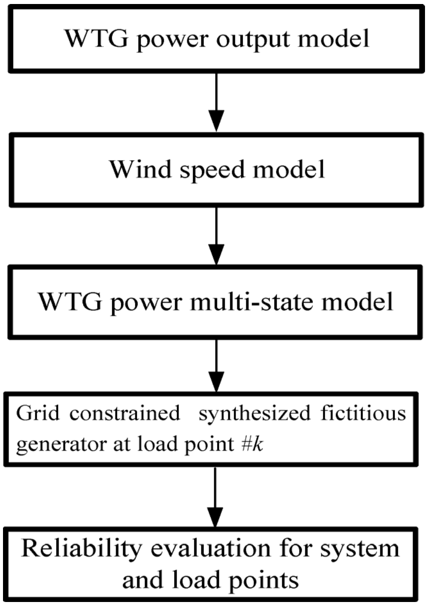


Fig. 7. The step-by-step process for evaluating the reliability of a power system involving WTGs.

where:

NL : number of load points

ELC_k: expected load curtailed $(= \mathrm{EENS}_k / \mathrm{LOLE}_k)$

DENG_k: demand energy at bus # k

C. Consideration of DSM

In order to consider demand side management (DSM), the following two kinds of DSM methods are proposed. Eventually, the purpose of the demand side management in Korea is focused on management for improved reliability. Methods of two types are proposed here. One is the way that cut the load exceeded the standard peak load. Another is the way that calculated demand response by specifying the effective operate reserve rate. Unfortunately, demand response based on a real pricing market model was omitted in this paper because the model is unavailable in Korea now.

$$\begin{aligned} &\frac{EOP(t) - \sum (L_{\mathrm{pk}}(t) - \triangle x_k(t))}{\sum (L_{\mathrm{pk}}(t) - \triangle x_k(t))} \geq \mathrm{EORR}^* \\ &\sum \triangle x_k(t) = \frac{\mathrm{EORR}^* \times \sum L_{\mathrm{pk}}(t) - \mathrm{EOP}(t) + \sum L_{\mathrm{pk}}(t)}{1 + \mathrm{EORR}^*} \\ &\mathrm{TDX}(t) = \frac{(1 + \mathrm{EORR}^*) \times \sum L_{\mathrm{pk}}(t) - \mathrm{EOP}(t)}{1 + \mathrm{EORR}^*} \\ &\therefore \triangle x_k(t) = TDX(t) \times \frac{L_{\mathrm{pk}}(t)}{\sum L_{\mathrm{pk}}(t)} \end{aligned} \tag{13}$$

where:

k: Load point number #

t: Time # [date]

$\mathrm{TDX}(t) = \sum \triangle x_k(t)$: Total demand reduction [MW]

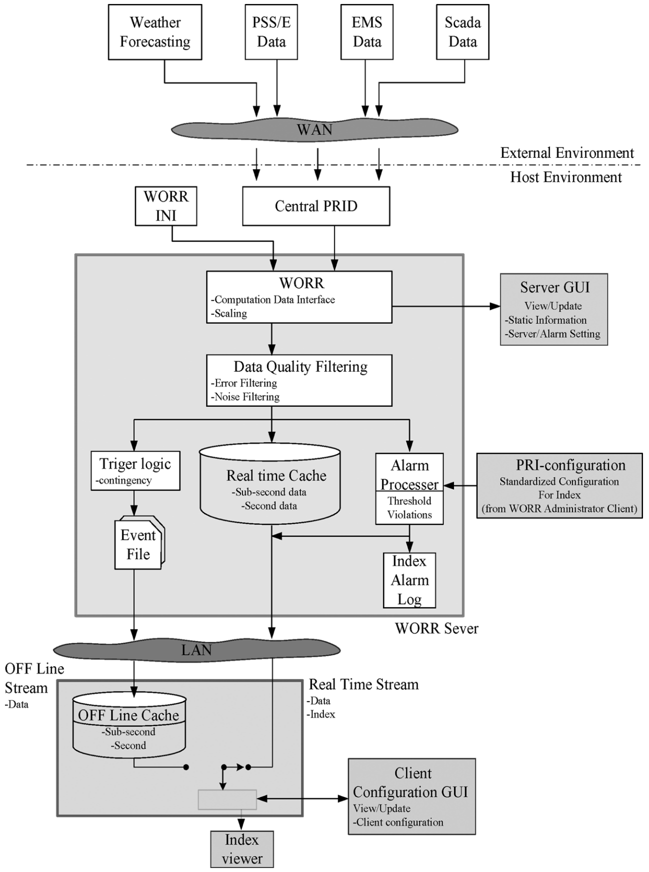


Fig. 8. Architecture of WORRIS.

$\triangle x_k(t)$: Required load reduction of k load point at the time $t(=\mathrm{DRX}(t))$

$L_{\mathrm{pk}}(t)$: Original peak load of k load point at the time t [MW]

$\mathrm{EOP}(t)$: Effective operating power at time t [MW]

EORR^* : Criterion of effective operate reserve rate [pu]

Fig. 7 shows a flow chart of the proposed method to evaluate the reliability of a composite power system including WTG.

IV. WORRIS V7.0 ARCHITECTURE

Fig. 8 shows the overall configuration for the WORRIS V7.0 system.

Fig. 9 shows the overall configuration for the WORRIS V7.0 system considering demand side management utilized in this study.

The configuration shown in Fig. 9 is a research network at this time and is the integration of academic processing with web based online and real-time reliability assessment. It is not presently connected with EMS as the system is only a prototype. The forecasted wind speed data, load data and the generation system data are installed at a wind speed D/B, a load data D/B and a generation system D/B respectively.

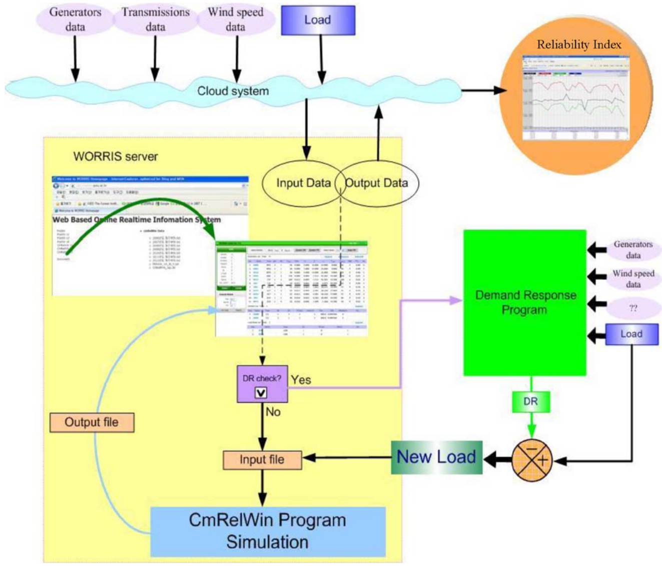


Fig. 9. Algorithm for WORRIS V7.0 considering DSM.

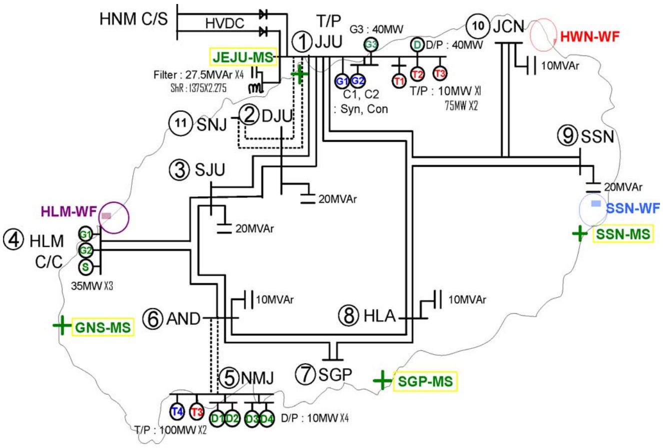


Fig. 10. The Jeju island power system in Korea.

V. CASE STUDY

The developed WORRIS V7.0 is established successfully on website: http://worris.gsnu.ac.kr/CmRel_v7/. It is applied to the Jeju island power system in South Korea. The Jeju island power system in 2010 as shown in Fig. 10 is used to demonstrate the usefulness of the proposed method. Three wind farms constructed at three different locations are Hanlim (HLM), Hangwon (JCN) and Sungsan (SSN) for case study. The Jeju island power system may be categorized as two areas. One is the area including smart grid test bed town [bus 9 (SSN-WF) and bus 10 (HWN-WF)]. The other is the area not including the town. The two-bus (area) equivalent Jeju power system is shown in Fig. 11. The data of the Jeju island power system are shown in Table I. The pattern of load duration curve in 2010 of the Jeju island was used as shown in Fig. 12. The total installed capacity is 945 MW with renewable generation capacity of 100 MW added. Peak load in August 2010 is 605 MW [9].

Fig. 13 shows the WORRIS's whole control panel for the Jeju island power system. Fig. 14 shows the PRI (Probabilistic reliability Indices) results of WORRIS for the Jeju island power

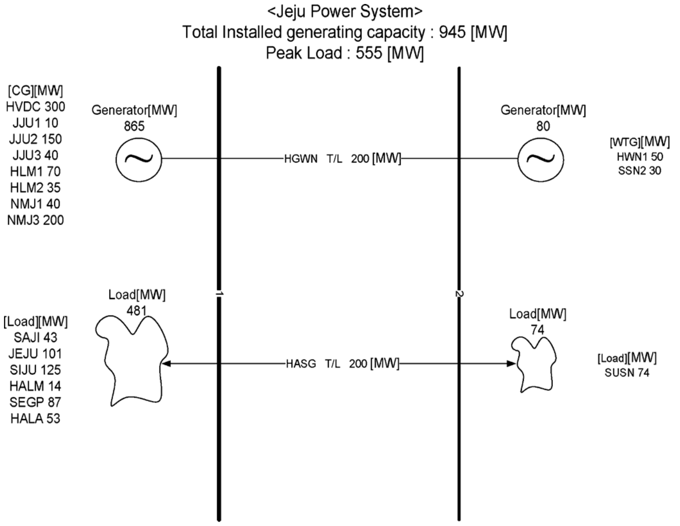


Fig. 11. Two-Bus system of the equivalent Jeju island power system.

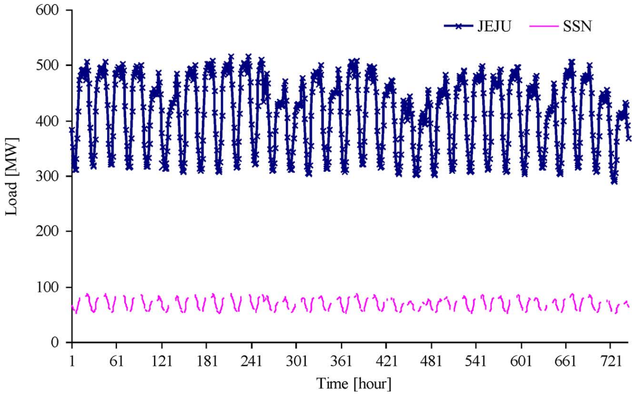


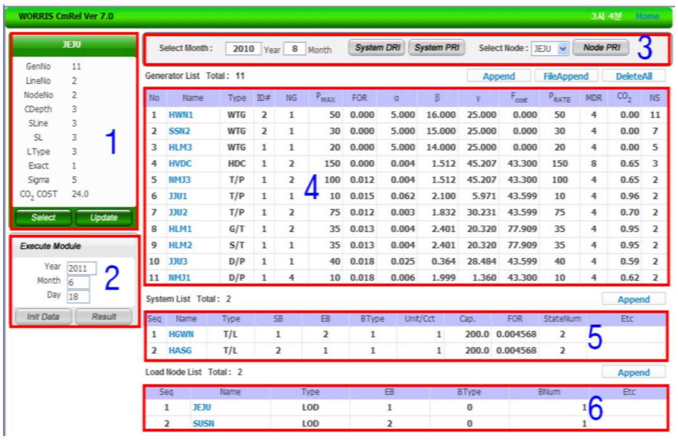
Fig. 12. Variation curve pattern of the hourly peak two loads in the Jeju island power system at Aug. 2010.

TABLE I
GENERATOR DATA OF THE JEJU ISLAND POWER SYSTEM

GN #	Name	Type	Capacity [MW]	Num.	α [Gcal/ MW2h]	β [Gcal/ MWh]	γ [Gcal /hr]	FOR	Area
1	HWN1	WTG	50	1	-	-	-	-	2
2	SSN2	WTG	30	1	-	-	-	-	2
3	HLM3	WTG	20	1	-	-	-	-	1
4	HVDC	HVDC	150	2	0.004	1.512	45.207	-	1
5	NMJ3	T/P	100	2	0.004	1.512	45.207	0.012	1
6	JJU1	T/P	10	1	0.062	2.100	5.971	0.015	1
7	JJU2	T/P	75	2	0.003	1.832	30.231	0.012	1
8	HLM1	G/T	35	2	0.004	2.401	20.320	0.013	1
9	HLM1	S/T	35	1	0.004	2.401	20.320	0.013	1
10	JJU3	D/P	40	1	0.025	0.364	28.484	0.018	1
11	NMJ1	D/P	10	4	0.006	1.999	1.360	0.018	1
Total			945	18					

system. Fig. 15 shows the DRI(Deterministic reliability Indices) results of WORRIS for the Jeju island power system.

For demand side management (DSM), the WORRIS has two added controls which are IDDR and EORC. The IDDR indicates four types (codes) of DSM shown in Table II. The EORC



GenNo 11
LineNo 2
NodeNo 2
CDepth 3
SLine 3
SL 3
LType 3
Exact 1
Sigma 5
CO_2 COST 24.0

Year 2011
Month 6
Day 18

Select Month : 2010 Year 8 Month
Select Node : JEJU

Generator List Total : 11

No	Name	Type	ID#	NG	P_{MAX}	FOR	α	β	γ	F_{cost}	P_{RATE}	MDR	CO_2	NS
1	HWN1	WTG	2	1	50	0.000	5.000	16.000	25.000	0.000	50	4	0.00	11
2	SSN2	WTG	2	1	30	0.000	5.000	15.000	25.000	0.000	30	4	0.00	7
3	HLM3	WTG	1	1	20	0.000	5.000	14.000	25.000	0.000	20	4	0.00	5
4	HVDC	HDC	1	2	150	0.000	0.004	1.512	45.207	43.300	150	8	0.65	3
5	NMJ3	T/P	1	2	100	0.012	0.004	1.512	45.207	43.300	100	4	0.65	2
6	JJU1	T/P	1	1	10	0.015	0.062	2.100	5.971	43.599	10	4	0.96	2
7	JJU2	T/P	1	2	75	0.012	0.003	1.832	30.231	43.599	75	4	0.70	2
8	HLM1	G/T	1	2	35	0.013	0.004	2.401	20.320	77.909	35	4	0.95	2
9	HLM2	S/T	1	1	35	0.013	0.004	2.401	20.320	77.909	35	4	0.95	2
10	JJU3	D/P	1	1	40	0.018	0.025	0.364	28.484	43.599	40	4	0.59	2
11	NMJ1	D/P	1	4	10	0.018	0.006	1.999	1.360	43.300	10	4	0.62	2

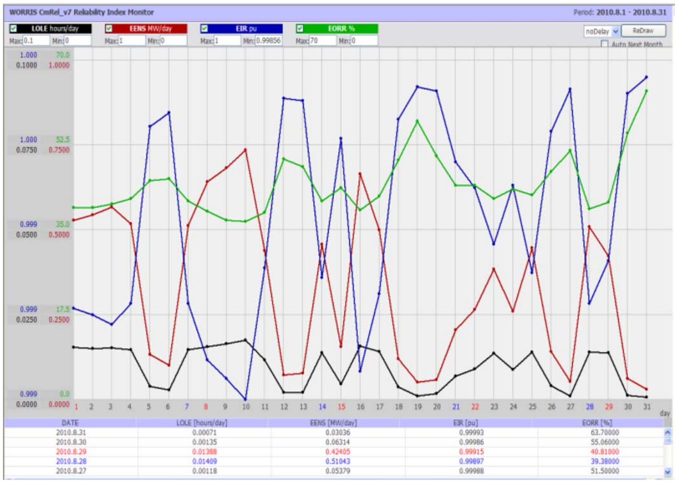
System List Total : 2

Seq	Name	Type	SB	EB	BType	Unit/Cct	Cap.	FOR	StateNum	Etc
1	HGWN	T/L	1	2	1	1	200.0	0.004568	2	
2	HASG	T/L	2	1	1	1	200.0	0.004568	2	

Load Node List Total : 2

Seq	Name	Type	EB	BType	BNum	Etc
1	JEJU	LOD	1	0	1	
2	SUSN	LOD	2	0	1	

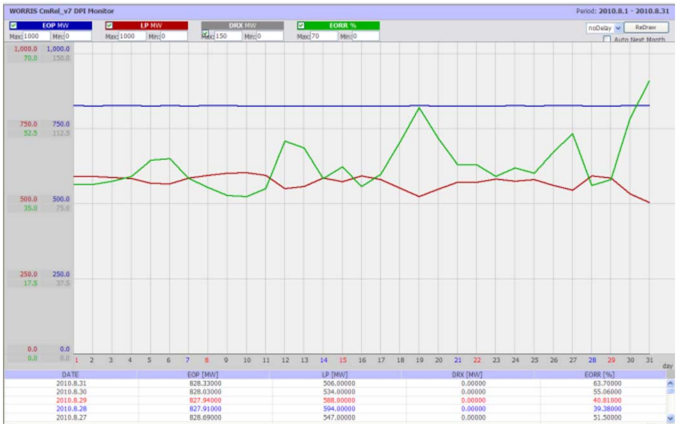
Fig. 13. WORRIS's whole control panel for the Jeju island power system.



☑ LOLE hours/day Max: 0.1 Min: 0
☑ EENS MW/day Max: 1 Min: 0
☑ EIR pu Max: 1 Min: 0.99856
☑ EORR % Max: 70 Min: 0

DATE	LOLE [hours/day]	EENS [MW/day]	EIR [pu]	EORR [%]
2010.8.31	0.00071	0.03036	0.99993	63.70000
2010.8.30	0.00135	0.06314	0.99986	55.06000
2010.8.29	0.01388	0.42405	0.99915	40.81000
2010.8.28	0.01409	0.51043	0.99897	39.38000
2010.8.27	0.00118	0.05379	0.99988	51.50000

Fig. 14. PRI (Probabilstic Reliability Indices) results of WORRIS for the Jeju island power system.



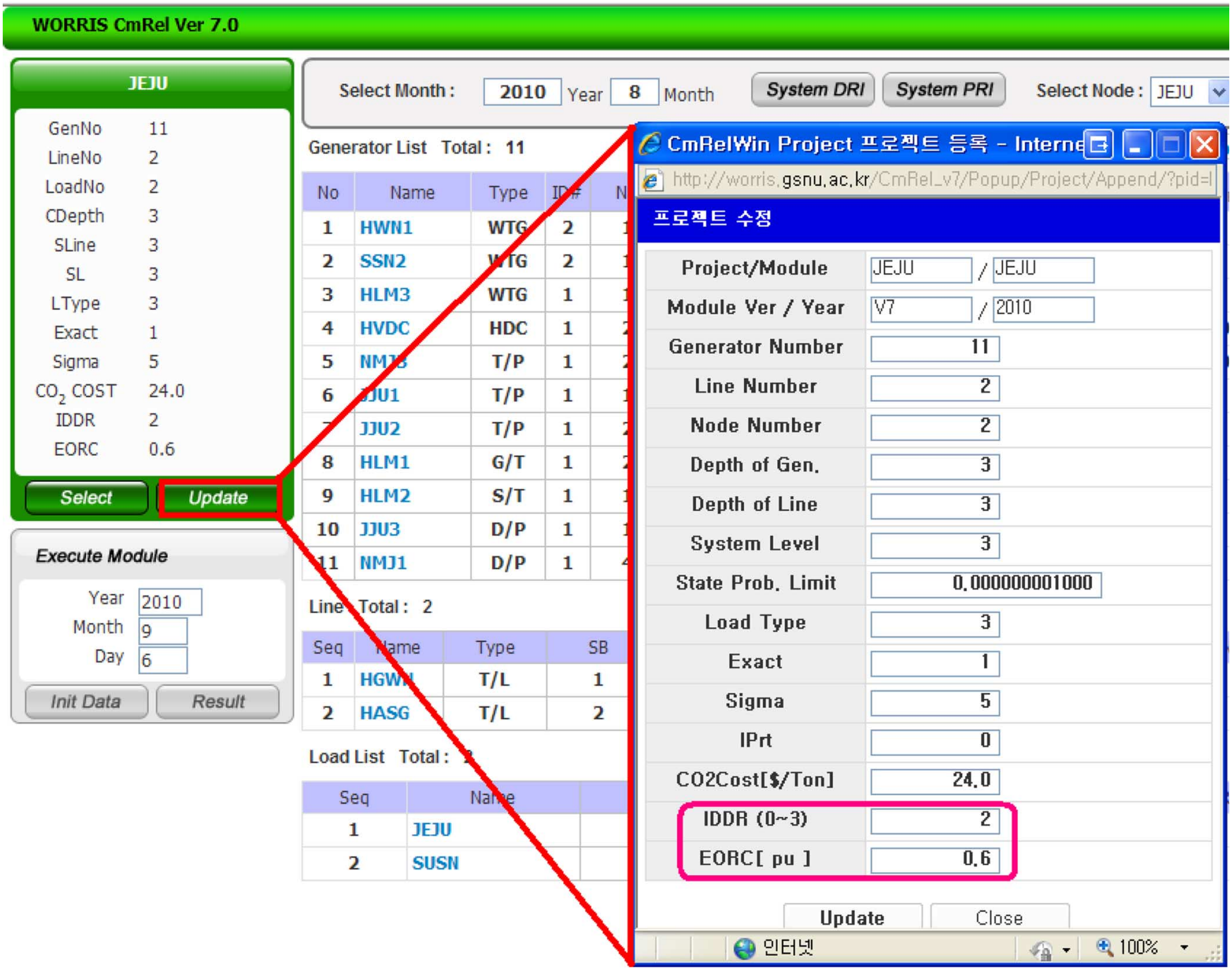
☑ EOP MW Max: 1000 Min: 0
☑ LP MW Max: 1000 Min: 0
☑ DRX MW Max: 150 Min: 0
☑ EORR % Max: 70 Min: 0

DATE	EOP [MW]	LP [MW]	DRX [MW]	EORR [%]
2010.8.31	828.33000	506.00000	0.00000	63.70000
2010.8.30	828.03000	534.00000	0.00000	55.06000
2010.8.29	827.94000	588.00000	0.00000	40.81000
2010.8.28	827.91000	594.00000	0.00000	39.38000
2010.8.27	828.69000	547.00000	0.00000	51.50000

Fig. 15. DRI (Deterministic Reliability Indices) results of WORRIS for the Jeju island power system.

means the effective operate reserve rate. But, as $\mathrm{IDDR} = 3$ is unavailable in Korea in that time, it is closed at this time.

When the IDDR code is 2, Fig. 17 shows the demand reduction (DRX) according to EORC, which means the standard effective operate reserve rate. Fig. 18 is a peak load reduction graph at time t according to the types of DSM. The probabilistic



WORRIS CmRel Ver 7.0

JEJU

GenNo	11
LineNo	2
LoadNo	2
CDepth	3
SLine	3
SL	3
LType	3
Exact	1
Sigma	5
CO_2 COST	24.0
IDDR	2
EORC	0.6

Execute Module

Year: 2010
Month: 9
Day: 6

Select Month : 2010 Year 8 Month

Select Node : JEJU

Generator List Total : 11

No	Name	Type	ID#
1	HWN1	WTG	2
2	SSN2	WTG	2
3	HLM3	WTG	1
4	HVDC	HDC	1
5	NMJ3	T/P	1
6	JJU1	T/P	1
7	JJU2	T/P	1
8	HLM1	G/T	1
9	HLM2	S/T	1
10	JJU3	D/P	1
11	NMJ1	D/P	1

Line Total : 2

Seq	Name	Type	SB
1	HGW	T/L	1
2	HASG	T/L	2

Load List Total : 2

Seq	Name
1	JEJU
2	SUSN

CmRelWin Project 프로젝트 등록 - Interne

http://worris.gsnu.ac.kr/CmRel_v7/Popup/Project/Append/?pid=

프로젝트 수정

Project/Module	JEJU / JEJU
Module Ver / Year	V7 / 2010
Generator Number	11
Line Number	2
Node Number	2
Depth of Gen.	3
Depth of Line	3
System Level	3
State Prob. Limit	0.000000001000
Load Type	3
Exact	1
Sigma	5
IPrt	0
CO2Cost[$/Ton]	24.0
IDDR (0~3)	2
EORC[pu]	0.6

Fig. 16. Project's control panel in WORRIS V7.0.

TABLE II
TYPES OF DSM IN WORRIS ACCORDING TO IDDR CODE

IDDR Code	Types of DSM	Remark
0	**Not considering DR**	**Available**
1	**Exceeded load reduction method**	**Available**
2	**Standard effective operate reserve rate method**	**Available**
3	Another DR program method (Based on real time pricing market)	Unavailable

reliability index(LOLE) is shown in Fig. 19 according to Fig. 18.

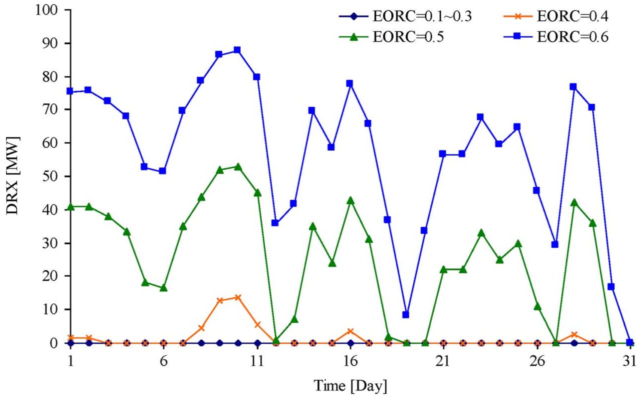


Fig. 17. Demand reduction (DRX) graph according EORC variation.

VI. CONCLUSION

This paper presents a new approach for grid constrained probabilistic reliability evaluation of power systems including wind turbine generators using the composite power system effective load model. Generator multi-state modeled composite power system effective load is utilized in order to consider WTGs. Previous model used two-state models for generators and transmission lines. The proposed model utilizes a multi-state model of a generator to consider WTG, obtained by combining the wind speed model and the WTG's power output model. The proposed method can provide useful information on the quantitative contribution and location determination of WTG from the viewpoint of composite power system reliability and grid expansion planning under large WTG penetration.

This paper also describes a Web Based Online Real-time Reliability Integrated Information System designated as WORRIS

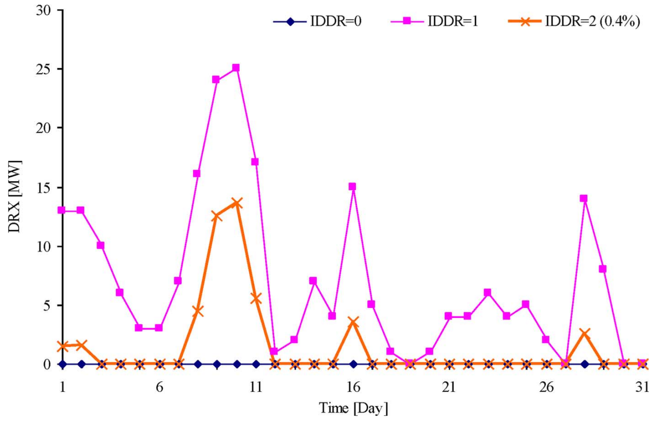


Fig. 18. Demand reduction (DRX) graph according DSM types respective.

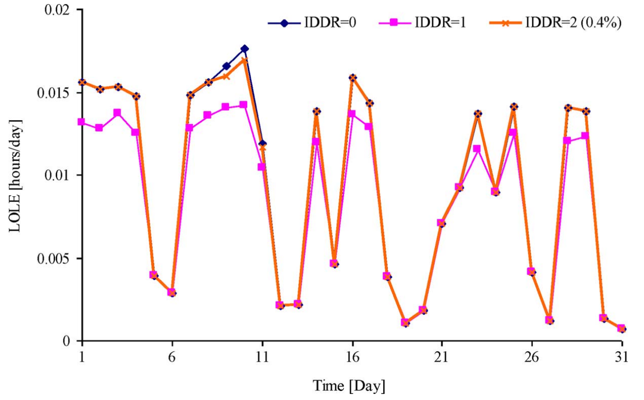


Fig. 19. LOLE graph according types of DSM.

Version 7.0. This system considers DSM. A daily time interval reliability information case study using the WORRIS was introduced. This paper presents preliminary findings and the basic architecture of the web based information system. The results indicate how a web-based monitoring system could form the basis for customers to observe power system reliability information including wind turbine generators. The present intent is not to create a real time reliability information system but to focus on developing a one day ahead system. The WORRIS system may be upgraded as a Web Based Online Real-time Information System considering practical Demand Side Management and it will be extended as a flexible reliability information application tool for the Smart Grid.

ACKNOWLEDGMENT

The authors would like to thank Dr. Roy Billinton for his warmest editorial supervision.

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