Probabilistic Reliability Analysis of KEPCO System Using TRELSS

TrungTinh Tran*, Jungji Kwon*, Jaeseok Choi†, Jinboo Choo, Donghun Jeon**, Kyoengnam Han*** and Roy Billinton******

Abstract - The importance of conducting necessary studies on grid reliability evaluation has become increasingly important in recent years due to the number of blackout events occurring throughout the world. Additionally, quantitative evaluation of transmission system reliability is very important in a competitive electricity environment. The reason behind this is that successful operation of an electric power company under a deregulated electricity market depends on transmission system reliability management. The results of many case studies for the Korea Electric Power Cooperation (KEPCO) system using the Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) Version 6.2 are illustrated in this paper. The TRELSS was developed by EPRI and Southern Company Services Inc. This paper presents the reliability analysis of KEPCO system expansion planning by using the TRELSS program.

Keywords: Korea power system, Probabilistic reliability evaluation, Transmission system, TRELSS

1. Introduction

The importance and necessity of conducting studies on grid reliability evaluation has become increasingly important in recent years due to the number of black-out events occurring throughout the world. Bulk transmission systems are planned to meet specified criteria in an attempt to provide consistently high reliability for utility customers. One of the very important requirements in the planning and operation of a bulk power system is maintaining reliability of service to the loads. Planning engineers are interested in representing their systems in as much detail as possible and in studying as many contingencies as possible, using accurate power flow algorithms [1-8]. According to the purpose of operating/planning engineers, they can choose available tools for evaluating and predicting power system withstanding ability under emergency conditions. The probabilistic reliability evaluation tools have been developed such as COMREL, METRIS, ASSESS, PRA, MARS, TPLAN, TRELSS, etc. for the composite power system.

The Korea power system is aiming to break up the monopolistic utility, which has been "regulated" by the government, and create a competitive electricity generation market as the first step toward a deregulated electricity market in the future. The targets are not only to increase competition and outside investment in power system infrastructure and to promote the utilization of new technology in the generation sector, but also to meet the expected growth of power demand at the highest reliability. Six generating companies are separated from the Korea Electric Power Cooperation (KEPCO) generation assets, leaving KEPCO simply as the owner of the grid and the distribution systems. The expansion plan and reliability evaluation of the transmission system are major tasks for the KEPCO.

The Transmission Reliability Evaluation of Large-Scale Systems (TRELSS) program was developed for the Electric Power Research Institute (EPRI) by Southern Company Services and is considered to be one of the most advanced industrial reliability analysis programs. Both deterministic and probabilistic studies can be conducted using this tool [9]. The KEPCO conducted a project on probabilistic reliability evaluation of its system using TRELSS V.6_2 [2]. The main purpose of this project is to conduct system reliability evaluation balanced with the investment costs for transmission expansion planning to meet specified criteria for creating consistently high reliability for customers in Korea [10-14].

This paper presents the reliability analysis of the KEPCO system in long-term planning (2006-2010) using the TRELSS. The control parameters of the TRELSS program that have the most effect on reliability indices of the KEPCO system were applied from several researches in the past such as cut-off value, contingency depth, outage data (generators and transformers forced outage rate),

† Corresponding Author: Dept. of Electrical Engineering, Gyeongsang National University, Korea (jschoi@gnu.ac.kr).
* Dept. of Electrical Engineering, Gyeongsang National University, Korea
** Korea Electric Power Research Institute, Daejeon, Korea (jbc@kepri.re.kr, dhjeon@kepri.re.kr).
*** KEPCO, Seoul, Korea (gyhan@kepco.co.kr).
**** Dept. of Electrical Engineering, University of Saskatchewan, Saskatoon, SK, Canada (roy_billinton@young.usask.ca).
Received 1 July, 2006 ; Accepted 7 November, 2006

transmission lines failure rate considering voltage levels and transmission line lengths, transmission line congestion and etc. Grid expansion planning has been conducted for the year 2006 to 2010 to meet the expected growth of power demand [15].

The capability approach was utilized for reliability evaluation and sensitivity analysis of the KEPCO system in this paper and it enumerates the failure and success states as well as the deeper failure states. Remedial action is required in real power systems. For example, remedial actions such as load shedding are used to alleviate system problems. The capability approach is complicated but reasonable due to the remedial action with DC or AC load flow. The capabilities, basic major applications and characteristics of TRELSS are demonstrated in [9-15].

2. TRELSS Operational Process for KEPCO System Evaluation

2.1 Operation Process

TRELSS can accept input data from load flow files formatted in IEEE, PTI, or IEEE PSADD converted by EPRI. KEPCO has been using PSS/E to study the operation of the Korea power system. Therefore, the load flow data file for reliability evaluation using the TRELSS, is PTI formatted. The operational TRELSS process for the KEPCO system is shown in Fig. 1 [2].

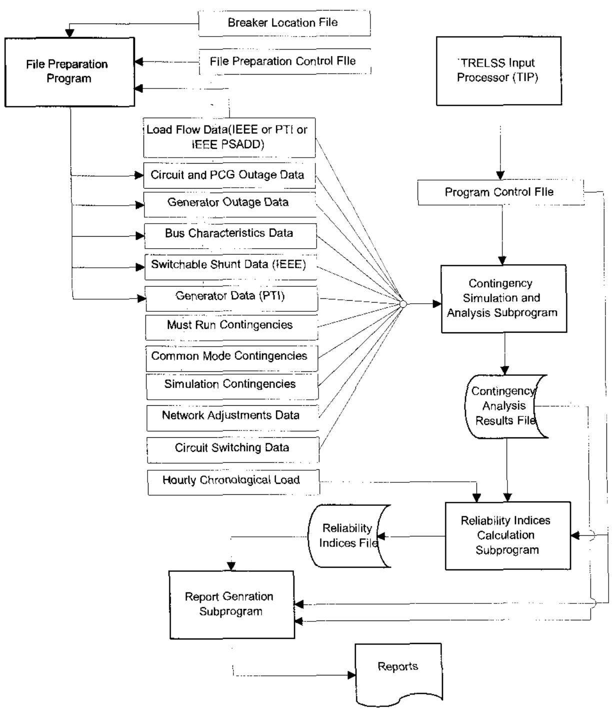


Fig. 1. TRELSS operational process for KEPCO system evaluation

2.2 Reliability Indices in TRELSS

TRELSS can provide various reliability indices, including the Probability of Load Curtailment (*PLC*). Expected Energy Not Served (*EENS*), Energy Index of Reliability (*EIR*) and etc. The reliability indices are grouped in the following three categories [2-6]:

- ■ System Problem Indices
- ✧ Frequency & Duration
- ✧ Severity of system problems
- ✧ Number of contingencies causing system problems
- ✧ Maximum / average violation of system failure criterion
- ■ Load Curtailment Indices
- ✧ Frequency & duration
- ✧ Power & energy curtailment
- ✧ Number of contingencies causing load curtailment
- ✧ Average indices
- ✧ Bulk power interruption indices
- ■ Customer Indices
- ✧ Customer interruptions
- ✧ Unserved customer hours
- ✧ System interruption frequency index
- ✧ System and customer interruption duration index
- ✧ System service availability

The purpose of composite power system reliability evaluation is to reflect the ability of an initial operating condition of an electric power system (generation, transformer, transmission, etc.) to perform its function, for the period of time intended, under the operating conditions intended. Many impacts of generation and transmission are load flow analysis, contingency analysis, generation dispatch, transmission congestion analysis, load curtailment philosophy, etc. to be able to present by some basic system reliability indices in this paper. The *EENS* (Expected Energy Not Served) for systems of different size or year are not directly comparable. Therefore, the conventional indices of *EDLC* (Expected Duration of Load Curtailment) and *EENS* as well as *SI* (Severity Index), sometimes called *SMI* (System Minutes of Interruption) are used in this paper [4-9]. The Energy Index of Reliability (*EIR*), which is a normalized energy index, is also used in this paper.

2.2.1 Probability of load curtailments (PLC)

The probability of load curtailments is defined as the probability of the effective system capacity not meeting load demand. It can be calculated by adding the probabilities of all states that cause load curtailment.

$$PLC = \sum_{i \in S} p_i \tag{1}$$

Where, p_i is the probability of system i and S is the set of all system states associated with load curtailment.

2.2.2 Expected duration of load curtailments (EDLC)

Expected duration of load curtailment is the expected number of hours in the period of investigation when the maximum load exceeds the system effective capacity. If the load model is an annual continuous load curve (day maximum load), then T is 365 days and the unit of *EDLC* is days per year. If the load model is a day load curve (hour), then T is 8760 hours and the unit of *EDLC* is hours per year.

$$EDLC = PLC \times T \quad \text{[hours/year]} \tag{2}$$

Where, T is the total time (8760 hours)

2.2.3 Expected energy not supplied (EENS)

EENS is the expectation of the energy loss caused to customers by insufficient power supply. It gives a measure of amount of energy that will be curtailed under outage scenarios.

$$EENS = \sum_{i \in S} T * C_i p_i \quad \text{[MWh/year]} \tag{3}$$

Where, C_i: the load curtailment of system state i

2.2.4 Severity Index (SI)

Severity index can be interpreted as the equivalent duration (in minute) within one year when the total system load would be left without supply. Its advantage can be used to compare the adequacies of systems with different sizes, as they apply to an overall system.

$$SI = \frac{EENS}{L_P} * 60 \quad \text{[minutes/year]} \tag{4}$$

Where, *EENS* is the expected energy not supplied [MWh/year] and L_P is a peak load.

2.3 Contingency Selection

This is used to measure how much a particular outage element (generator, transmission line, transformer, etc.) might affect the power system load. The performance index parameter (*PI*) can be reflected in the overall system overloading [1]. The TRELSS program used the performance indices (*PIs*) to measure the loading of the system. The higher the *PIs* are, the higher the system loading and the greater the chance of a system failure. PIs are used to rank the list of next contingencies in the enumeration process. The contingency raking methods in the TRELSS program are circuit overload (PI_{ol}) and voltage problem ($PI_{v>c}$). [2]

2.3.1 The transmission line overload PI is defined

$$PI_{ol} = \sum_i W_i \left(\frac{P_i}{P_{i,\max}} \right)^2 \tag{5}$$

where:
P_i: the real power flow on line i
$P_{i,max}$: the power rating for line i
W_i: the weighting factor for line i

2.3.2 The voltage problems PI is defined

$$PI_{v>c} = \sum_i X_i \left(\frac{1}{P_{oi}^2} + \frac{1}{P_{oj}^2} \right)^{1/4} P_i^2 \tag{6}$$

where:
P_i: the real power flow on line i
P_{oi}, P_{oj}: the terms recognizing line charging and/or reactive sources and loads on buses i and j
i, j: the "from" and "to" buses of line i
X_i: the reactance of line i

2.4 TRELSS Approaches Considered for the KEPCO System

Both deterministic and probabilistic studies can be conducted using this tool. The program implements five procedures: 1) data validation, 2) system problem, 3) contingency screen, 4) capability and 5) simulation approaches. In the data validation approach, TRELSS reads and checks the input data. In the system problem approach, it identifies and enumerates contingencies that cause system violations. In the capability approach, TRELSS also takes remedial action to alleviate system problems. The simulation approach permits a simulation for a user specified problem.

While the five approaches are available in TRELSS, two approaches, the system problem approach and the capability approach, are mainly applied for Korea power system reliability evaluation. The system problem approach evaluates the system reliability considering system problems such as generation/load unbalance. When a contingency violates a system limit, the condition is called failure state. The failure states including deeper failure states are not enumerated in order to reduce the computation time in the system problem approach. On the other hand, the capability approach enumerates the deeper failure states as well as the failure and success states. Remedial action is required in real power systems. In the capability approach, remedial action such as load shedding is used to alleviate system problems. Compared to the system problem approach, the capability approach is complicated, but it is reasonable to handle utilizing remedial actions [2].

3. KEPCO System Configuration

The paper uses the KEPCO system in 2006 as the base case [13]. The predicted generation capacity and electricity demand for the KEPCO system is shown in Fig. 2. The scaled annual chronological record of the 2006 year hourly loads of the KEPCO system shown in Fig. 3 was used for the load variation curve input data. The load scenarios in the KEPCO system have a peak load in the summer, because of hot weather and heavy air-conditioning loads. The main transmission line voltage levels are 765 KV, 345 KV, 154 KV and under 66 KV. The number of transmission lines of various lengths in the KEPCO grid is shown in Table 1.

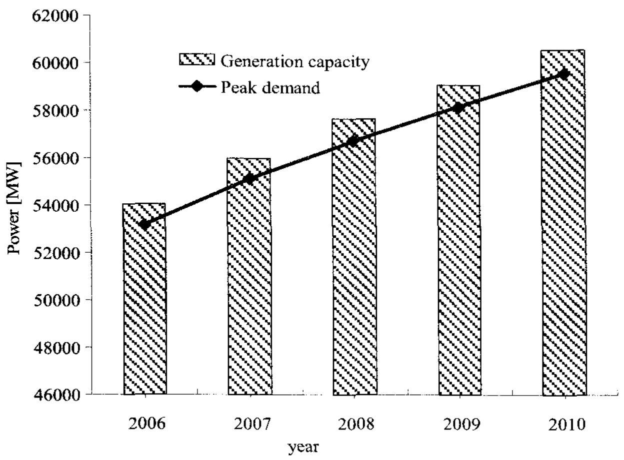


Fig. 2. Power system growth in Korea (2006-2010)

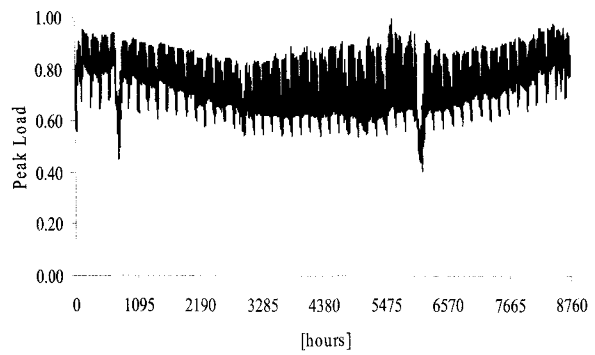


Fig. 3. Scaled load variation curve of the KEPCO system – 2006

Table 1. Transmission line length of KEPCO system

Line length [km]	Year				
	2006	2007	2008	2009	2010
10 <	1,001	1,072	1,128	1,163	1,201
10 ~ <20	362	392	430	457	481
20 ~ <30	230	237	249	257	262
30 ~ < 40	126	131	130	130	133
40 ~ <50	67	67	63	64	68
50 ~ < 60	27	32	30	30	31
60 ~ <70	18	20	18	18	22
70 ~ < 80	12	13	12	11	9
80 ~ < 90	6	6	7	6	10
90 ~ < 100	6	6	6	6	7
>100	15	13	15	15	13
Total lines	1,870	1,989	2,088	2,157	2,237

The automatic load scaling feature of TRELSS was used to scale the load flow to simulate power flows following an annual hourly chronological load. Three load flow base cases were automatically developed representing the system load conditions for 100% (May-September), 95% (January-April) and 90% (October-December) of the KEPCO load.

The failure criteria was set to check system overloads above 100%, and bus voltage violations less than 0.85 p.u or over 1.1 p.u in excess of 2% deviation. The program automatically determines remedial actions that will solve the overload problem. The priority of remedial actions is selected as shown in Table 2 [14], [15].

It is reported in the KEPCO system that the outage events on 345kV and 765kV lines seldom occur compared to 154kV lines and under as indicated in Table 3 and Table 4. The database for accurate assessment of the outage data of system equipment (generators, lines and transformers, etc.) in the KEPCO system is still not complete. The operating outage databases in other countries are therefore used in this paper. Therefore, it should be noted that the evaluated reliability results may differ from the actual historical record of the KEPCO system. The assumed outage data used in this paper are presented in Table 4.

Table 2. Remedial action control priorities

Remedial actions control	Priorities
Real power generation [MW]	1
Reactive power generation [MVAR]	1
Phase shifter adjustment	1
Generation bus voltage control	1
Transformer tap adjustment	1
Shunt reactor switching	1
Shunt capacitor switching	1
Area interchange adjustment	2
Interruptible load curtailment	3
Firm load curtailment	4
Critical load curtailment	5

Table 3. Outage input data of case study system (base case/scenario)

Outage type	Outage data
The forced outage hours per single circuit outage (r) [hours/outage]	2.5
The number of adverse weather single circuit outages per year [outages/year]	0.10
The mean duration of single circuit forced outage during adverse weather [hours/outage]	2.5
The probability of a single circuit maintenance outage	0.01
The mean duration of single circuit maintenance outage per occurrence [hours/outage]	8.0
The probability of a generation unit forced outage	0.01
The hours per generator unit forced outage [hours/outage]	10.0
The number of PCG forced outages due to temporary faults [outages/year]	4.0
The number of PCG forced outages due to temporary faults during adverse weather [outages/year]	3.0
PCG isolation time [hours/outage]	0.5
PCG isolation during adverse weather [hours/outage]	0.5

Table 4. Circuit failure rate input data of base case in the KEPCO system

Voltage level [kV]	Single circuit failure rate [outages/km/years]
765	$\lambda = 0.000273 \times l + 0.00915$
345	$\lambda = 0.000546 \times l + 0.0183$
154	$\lambda = 0.002883 \times l + 0.02031$
66	$\lambda = 0.00576 \times l + 0.04062$
Under 23	$\lambda = 0.00576 \times l + 0.04062$

(l = transmission line length)

4. Case Studies

The capability approach enumerates the deeper failure states as well as the failure and success states and considers remedial action. Remedial action is required in actual power systems. The test in this work was to examine the sensitivity of the probabilistic reliability evaluation of the bulk KEPCO system in the year 2006, in which the contingency depth was selected as (N-2) ((N-1) for generator unit and (N-1) for single circuit) as presented in Table 5. The thermal rating of transmission lines/transformers is C-B-A, which are classified C for load level 1 (100%), classified B for load level 2 (95%) and classified A for load level 3 (90%). An example of the circuit service failures is indicated in Table 6, which shows that the most circuit service failures actually occurred in the 154 kV lines in the KEPCO system.

Table 5. System reliability indices of the KEPCO test system in 2006

Indices	**System indices**
LOLP	0.0313567
Frequency of load loss [occ/yr]	79.10
EDLC [hours/yr]	274.685
EENS [MWh/yr]	22,254.48
Expected unserved demand (EUD)[MW/yr]	5,315.371
SI [minutes /year]	25.11
Energy curtailment [MWh/annual MWh]	0.00024918
Power interruption [MW/peak MW]	0.09994265

Table 6. Circuit service failures in the KEPCO test system in 2006

From bus	To bus	Voltage [kV]	Load level	Frequency [occ/year]	EDLC [hours/yr]	EENS [MWh/yr]
1360	41360	154	100	0.606E-02	0.0149	3.029
			95	0.723E-02	0.0184	3.432
			90	0.700E-02	0.0175	3.152
1470	1875	154	100	0.104E-01	0.0263	1.527
			95	0.123E-01	0.0307	1.730
			90	0.120E-01	0.0298	1.589
1510	41510	154	100	0.606E-02	0.0149	0.227
			95	0.723E-02	0.0184	0.257
			90	0.700E-02	0.0175	0.236

The probabilistic reliability indices at individual load buses can be obtained from TRELSS. These indices are helpful to a TRANSCO for managing, operating and planning the transmission system. The EENS probabilistic reliability index at 10 buses in the KEPCO system in 2006 are shown in Table 7 and Fig. 4 as an example.

Table 8 presents the probabilistic reliability indices of the bulk KEPCO system planned up to the year 2010. The *EDLC*, *EENS*, *SI* and *EIR* indices are presented graphically in Figs. 5, 6 and 7.

Table 7. Probabilistic bus reliability indices for the KEPCO system in 2006

Bus	Frequency [occ/year]	Duration [hrs/occ]	EDLC [hours/yr]	EENS [MWh/yr]
1510	0.321E-01	4.38	0.14016	1.845
1525	0.706E-01	4.21	0.29696	5.013
1535	0.321E-01	4.38	0.14016	1.566
1540	0.262E-01	4.44	0.11651	4.404
1545	0.642E-01	4.38	0.28120	3.054
1565	0.314E-01	4.43	0.13928	3.211
1575	0.956E-01	4.39	0.41960	11.534
1580	0.321E-01	4.38	0.14016	0.691
1585	0.949E-01	4.41	0.41873	8.910
1590	0.706E-01	4.21	0.29696	6.032

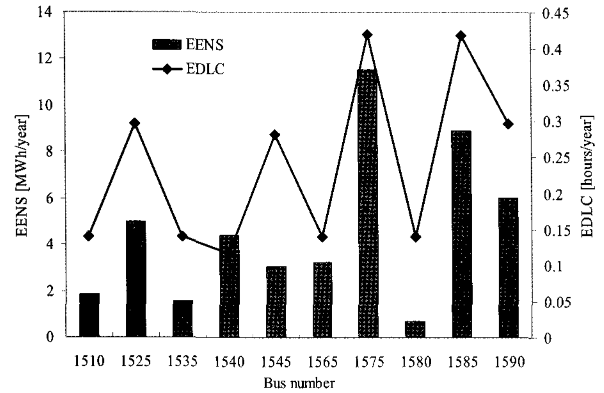


Fig. 4. Expected energy not served (EENS) at individual load buses in the KEPCO system in 2006

Table 8. Probabilistic system reliability indices for the KEPCO system (2006-2010) with the capability approach

Year	EDLC [hours/yr]	EENS [MWh/yr]	SI (SMI) [minutes/yr]	EIR [pu]
2006	274.685	22,254.48	25.106	0.999937795
2007	157.090	1,519.06	1.654	0.999995902
2008	330.164	12,047.97	12.747	0.999968419
2009	341.173	12,509.35	12.910	0.999968014
2010	326.871	37,763.39	38.031	0.999905775

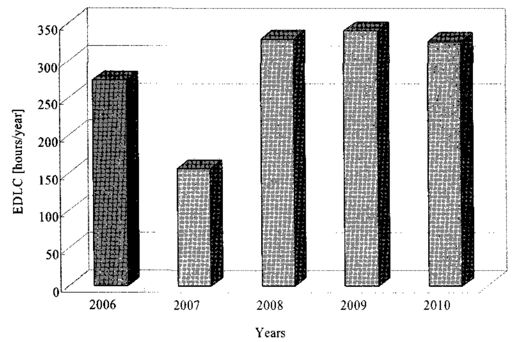


Fig. 5. Loss of load expectation (EDLC) for the bulk KEPCO system (2006-2010) with the capability approach

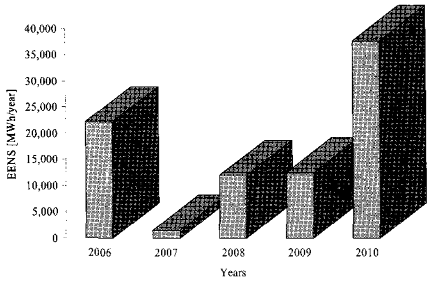


Fig. 6. Expected energy not served (EENS) for the bulk KEPCO system (2006-2010) with the capability approach

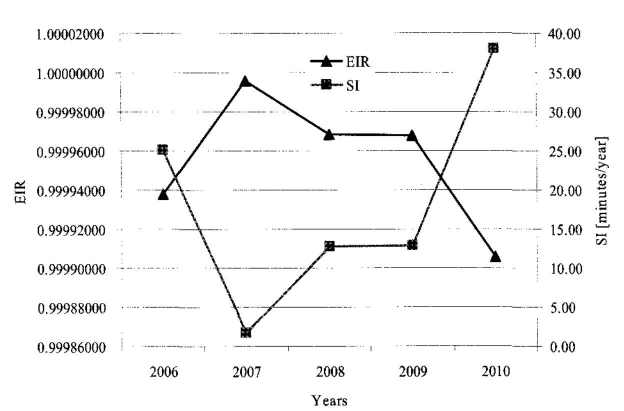


Fig. 7. SI and EIR for the bulk KEPCO system (2006-2010) with the capability approach

Summary for the KEPCO System Reliability Evaluation

The results of the KEPCO system cases can be summarized as follows:

1) From the obtained results, it is suggested to use the contingency depth of (N-3), which is (N-1) for the generator and (N-2) for the circuit lines for applying system problem approach. The contingency depth of (N-2) ((N-1) for generator unit and (N-1) for single circuit) for applying capability approach, and success cut-off values of 3~5 are reasonable for KEPCO system reliability evaluation in the five year planning.
2) For the year 2006, the reliability indices of EDLC = 274.685 [hours/year], EENS = 22,254.48 [MWh/year], SI(SMI) = 25.106 [minutes/year] and EIR = 0.999937795 [pu] were obtained using the capability approach. This approach enumerates the deeper failure states, failure and success states as well as remedial action. Probabilistic reliability criterion (guide line) for grid expansion planning of the power system has been made in Korea. Therefore, it cannot be certain that the above assessed level is reasonable for a grid expansion plan. But, it is expected that the obtained normalized indices, EIR and SAIDI, are reasonable levels in view of general planning strategy, although it is a subjective opinion. These results indicate that the adequacy of the KEPCO grid will be maintained at high reliability level in 2006 and the capital for the 2006 year grid planning was reasonably invested, although there is no reliability criterion for the composite power system in Korea at this time. (It should be noted that a reliability criterion of 0.5[days/year] for generation system expansion planning [HLI] has been used in Korea.)

3) Probabilistic reliability indices for the KEPCO system for long-term planning (2006-2010) were evaluated successfully using the Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) program. From the evaluation analysis using the capability approach, the reliability levels of the KEPCO test system for all the study years will be maintained under *EDLC* = 341.173 [hours/year], *EENS* = 37,763.39 [MWh/year], *SI* = 38.031 [minutes/year] and EIR=0.999968419 [pu] using the capability approach . The EENS reliability level in the year 2010 using the capability approach is higher than that in other years. For 2010, however, the EIR, which is the relative reliability level in terms of required energy, is maintained under 0.999996143 for both approaches. These results indicate that the KEPCO grid planning scenarios and investment budget for the years 2006-2010 are reasonable.
4) The approximate range of the reliability levels of the KEPCO system in the years 2006 to 2010 based on the system problem and capability approaches can be summarized as follows.
   - EDLC: 157.090 ~ 341.173 [hours/year]
   - EENS: 1,519.06 ~ 37,763.39 [MWh/year]
   - SI: 1.654 ~ 38.031 [minutes/year]
   - EIR: 0.999937795 ~ 0.999995902 [pu/year]
5) The bus reliability level results show very similar SI and EIR values at every bus. This means that the locations of new planned lines in long-term expansion planning for the KEPCO system are well established and balanced.

The range and characteristics of the calculated reliability indices will be useful in actual system planning and strongly support the need for more detailed and accurate probabilistic reliability evaluation in the future in Korea. As noted earlier, the calculated probabilistic reliability levels depend widely on the system equipment outage data. The obtained results were calculated using assumed outage data due to there being no outage database established in Korea at this time. It should be noted that the evaluated reliability results may therefore be different from actual reliability records of the KEPCO system.

5. Conclusion

This paper presents the probability reliability indices for the bulk KEPCO system obtained using the Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) Version 6_2 program developed by EPRI/Southern Company Services. It illustrates the importance of control input parameters and the approach using TRELSS to impact the precise failure states of the enumerated contingencies. Additionally, this paper presents a sensitivity analysis of probabilistic reliability indices for the bulk Korea power system in the year 2006 using the capability approach. The frequency and duration of outages at individual load buses and the determination of transmission line overloads will be useful to planners/operators in making decisions on operating, maintaining and planning the KEPCO system.

The study described in this paper was initially conducted as a reliability project to check the characteristics and dimensional possibility of TRELSS V.6_2. The results obtained from the case study show that TRELSS is an effective tool for reliability evaluation of composite power systems and various parametric analyses are available for the KEPCO system reliability evaluation. The results of reliability evaluations of the actual KEPCO system using TRELSS will be valuable for actual grid planning and operation in the future.

Finally, the database containing accurate assessment of outage data and common mode failure states in the Korea power system is not complete at this time. Assumed outage data of the countries with operating outage databases were used in this paper. Therefore, it should be noted that the evaluated reliability results may be different from the actual reliability records of the KEPCO system. It is expected that the availability of actual and accurate outage input data will lead to more specific applications in the future.

Acknowledgements

This study was supported by KEPRI and KERQC funded by the Ministry of Commerce, Industry and Energy (MOCIE) of Korea. We would like to acknowledge KEPCO for providing actual system load flow data.

References

[1] X. Wang, J.R. McDonald, *Modern Power System Planning*, McGraw-Hill Book Company, 1994.
[2] EPRI, *Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) Version 6.2*, EPRI, Feb. 2003.
[3] IEEE Committee Report, "IEEE Reliability Test System" *IEEE Trans*. On PAS-98, pp. 2047-2054, 1979.
[4] R. Billinton and W. Li, *Reliability Assessment of Electric Power Systems Using Monte Carlo Methods*, Plenum Press, 1994.
[5] R. Billinton and R. N. Allan, *Reliability Evaluation*

of Power Systems: Second Edition, Plenum Press, 1996.

[6] R. Billinton, *Reliability Assessment of Large Electric Power Systems*, Kluwer Academic Publishers, 1986.

[7] J. Endrenyi, *Reliability Modeling in Electric Power Systems*, John Wiley and Sons Ltd, 1978.

[8] J.k Choi, H. Kim, J. Cha and R. Billinton; "Nodal Probabilistic Congestion and Reliability Evaluation of a Transmission System under Deregulated Electricity Market", *Proceedings on IEEE, PES, SM2001*, July 16-19, 2001, Vancouver, Canada.

[9] Y. V. Makarov and R. C. Hardiman, "Risk, reliability, cascading, and restructuring", *Proceedings on IEEE PES GM2003*, Vol. 3, pp. 1417 – 1429, 2003.

[10] S.P. Moon, J.B. Choo, D.H. Jeon, H.S. Kim, J.S. Choi and Roy Billinton; "Transmission System Reliability Evaluation of KEPCO System in Face of Deregulation", *Proceedings on IEEE PES SM2002*, July 21-25, 2002, Chicago, USA.

[11] M.J. Beshir, T.C. Cheng and A.S.A. Farag, "Comparison of Two Bulk Power Adequacy Assessment Program: TRELSS and COMREL", *IEEE Proceedings on T&D conference*, Sep. 15-20, 1996, pp. 431-437.

[12] J.S. Choi, S.R. Kang, T.T. Tran, D.H. Jeon, S.P. Moon, J.B. Choo, "Study on Probabilistic Reliability Evaluation considering Transmission System; TRELSS and TranRel" *Korean Institute of Electrical Engineers, International Transactions on Power Engineering*, Vol.4-A, No. 1, January 2004.

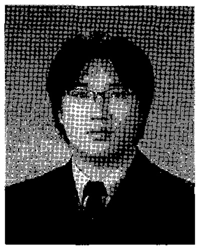
[13] T. Tran, J. Choi, D. Jeon, and J. Choo, "Sensitivity Analysis of Probabilistic Reliability Evaluation of IEEE MRTS using TRELSS" *Proceedings on PMAPS04*, Sept. 2004.

[14] T. Tran, H. Kim, J. Choi, G. Han, D. Jeon, J. Choo: "Reliability Evaluations of KEPCO system using TRELSS", *Proceedings on IEEE GM2005*, June 2005, San Francisco, California USA.

[15] T. Tran, J. Choi, R. Thomas: "Determination of Construction Priority of Transmission Lines Based on Probabilistic Reliability Evaluation" *Proceedings on IEEE GM2005, June 2005*, San Francisco, California USA.

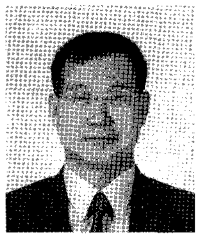
Trungtinh Tran

He was born in Mochoa, Vietnam in 1973. He obtained his B.Sc. and M.Sc. degrees from Cantho University, Cantho, Vietnam and Gyeongsang National University, Jinju, Korea in 1997 and 2004, respectively. He is currently a Ph.D candidate at Gyeongsang National University. His research interest includes Transmission Expansion Planning using Fuzzy Set Theory and Reliability Evaluation of Power Systems.



Jungji Kwon

He was born in Changwon, Korea in 1979. He obtained his B.Sc. from Gyeongsang National University in 2005. His research interest includes Transmission Expansion Planning using Reliability Evaluation of Power Systems. He is now working toward his M.Sc. degree at Gyeongsang National University.



Jaeseok Choi (KIEE SM'05, IEEE SM'05)

He was born at Kyeongju, Korea in 1958. He obtained his B.Sc., M.Sc. and Ph.D. degrees from Korea University in 1981, 1984 and 1990 respectively. His research interests include Fuzzy Applications, Probabilistic Production Cost Simulation, Reliability Evaluation and Outage Cost Assessment of Power Systems. He was a Post-Doctor at the University of Saskatchewan in Canada in 1996. Since 1991, he has been on the faculty of Gyeongsang National University, Jinju, where he is a Professor. Currently, he is a Visiting Professor at Cornell University, NY, USA.

Jinboo Choo

He received his B.Sc., M.Sc. and Ph.D. degrees from Seoul National University, Korea in 1977, 1987 and 1994, respectively. He has been with the Korea Electric Power Co. since 1977. Presently, he is a Chief Researcher at the Korea Electric Power Research Institute (KEPRI).

Donghun Jeon
He received his B.Sc. and M.Sc. degrees from Hong-ik University, Korea in 1991 and 1993, respectively. His research interests are in Reliability Evaluation, Economic Operations and Deregulation Issues. He has been with the Korea Electric Power Co. (KEPCO) since 1994. Presently, he is a Senior Researcher at the Korea Electric Power Research Institute (KEPRI).

Kyoengnam Han
He is a Senior Member of the KEPCO headquarters in Seoul. He has worked in the area of grid expansion planning in KEPCO for the past twenty years. He is interested in Reliability Evaluation Application for Power System Planning.

Roy Billinton (F'78)
He came to Canada from England in 1952. He obtained his B.Sc. and M.Sc. Degrees from the University of Manitoba and his Ph.D. and D.Sc. Degrees from the University of Saskatchewan. He has worked for Manitoba Hydro in the System Planning and Production Divisions. He joined the University of Saskatchewan in 1964 where he was formerly Head of the Electrical Engineering Department. Presently, he holds the title of C.J. Mackenzie Professor of Engineering and Acting Dean, Graduate Studies, Research and Extension of the College of Engineering. He is the author of a paper on Power System Analysis, Stability, Economic System Operation and Reliability and the author or co-author of eight books on reliability. He is also a Fellow of the IEEE, the EIC and the Royal Society of Canada and a Professional Engineer in the Province of Saskatchewan.