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TRELSS를 이용한 한전계통의 확률론적 신뢰도 평가의 감도해석

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Sensitivity Analysis of Probabilistic Reliability Evaluation of KEPCO System Using TRELSS

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Abstract--The importance and necessity conducting studies on grid reliability evaluation have been increasingly important in recent years due to the number of black-out events occurring through in the world. Quantity evaluation of transmission system reliability is very important in a competitive electricity environment. The reason is that the successful operation of electric power under a deregulated electricity market depends on transmission system reliability management. Also in Korea it takes places. The results of many case studies for the KEPCO system using the Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) Version 6_2, a program developed by EPRI are introduced in this paper. Some sensitivity analysis has been included in case study. This paper suggests that the some important input parameters of the TRELSS can be determined optimally from this sensitivity analysis for high reliability level operation of a system.

1. Introduction

The importance and necessity of conducting studies on grid reliability evaluation have been increasingly important in recent years due to the number of black-out events occurring through in the world. Bulk transmission systems are planned to meet specified criteria in an attempt to provide consistently high reliability for utility customers. One very important requirement in the planning and operation of a bulk power system is maintaining reliability of service to the loads. Planning engineers are interested in representing systems in as much detail as possible and in studying as many contingencies as possible, using accurate power flow algorithms [1].

Korea power system is aiming to smash up the monopolies utility, which have been "regulated" by the government, and create a competitive electricity generation market as the first step going to deregulated electricity market in the future. Their targets are not only increased competition, increased outside investment in power system infrastructure and application new technology utilization in generation zone, but also to meet the expected growth of power demand at the highest reliable. Therefore, KEPCO has decided to separate six generating companies (GENCOs) from the KEPCO generation assets. And so, KEPCO will own the grid system and distribution system. Hence, the expansion plan and reliability evaluation of transmission system are one of the most important task's KEPCO now. A project on the probabilistic reliabilityevaluation of KEPCO system using TRELSS V.6_2 has been conducted [2]. The TRELSS program has demonstrated the merits and demerits with KEPCO system [12].

This paper continues to find optimal of TRELSS program control parameters which give the most effect on precise reliability indices by sensitivity analysis of probabilistic reliability evaluation of KEPCO system using TRELSS based on the database of KEPCO system in 2005 as a base case. The grid expansion planning has been predicted several years from 2006 to 2010 for meeting expected growth of power demand in that year respectively. The approaches were utilized *system problem approach* and *contingency screen approach*. The first one is system problem approach is to evaluate system reliability considering system problems such as generation/load unbalance. When a contingency violates a system limitation, this condition is called a failure state. The deeper state including failure state is not enumerated in order to reduce computation time. On the other hand, the last one is contingency screen approach, which is deeper failures states starting from a given failure to be further analyzed. The Transmission Evaluation for Large Scale System (TRELSS) used as the tool in this paper. The capabilities, major applications and characteristic of TRELSS have been demonstrated past time [9]-[14].

2. TRELSS Operational Process For Probabilistic Reliability Evaluation

TRELSS can accept input data file from either an IEEE or PTI or EPRI converter IEEE PSADD formatted load flow file. However, KEPCO has been using PSS/E for operating at Korea power system. Therefore, this load flow data file, which will be applied convenient for reliability evaluation by using TRELSS, is PTI formatted for actual system. The operational TRELSS process from PTI format can be shown at Fig. 1.

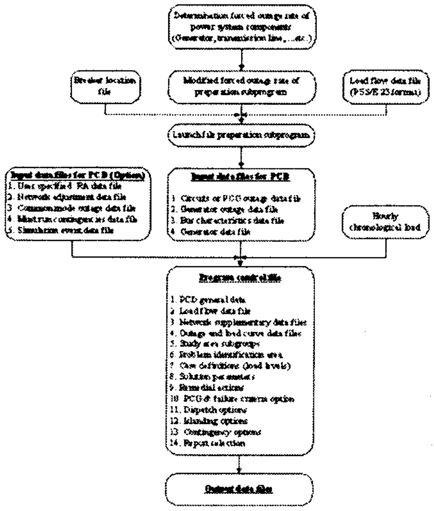

Fig. 1 operational TRELSS process

3. KEPCO Configuration System

The paper has tested on KEPCO system in 2005 as the base case. The KEPCO system has about 1607 buses, 1832 circuits and 840 transformers. The annual chronological record of hourly loads of KEPCO system was used for the load variation curve input data as shown at Fig. 2. Moreover, the scenarios of load in KEPCO system reached the peak load at summer, because at that time it is hot so air-condition are operated. The electricity demand for KEPCO system has been long-term predicted as shown in Fig.3. The outage component of system for input data of preparation subprogram was shown at Table 1.

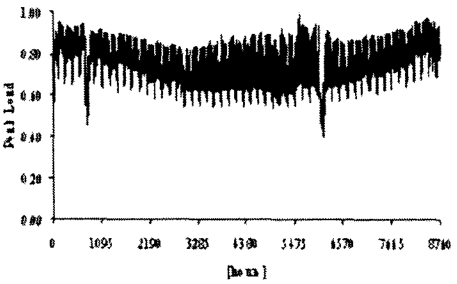

Fig.2 Scale load variation curve of KEPCO system

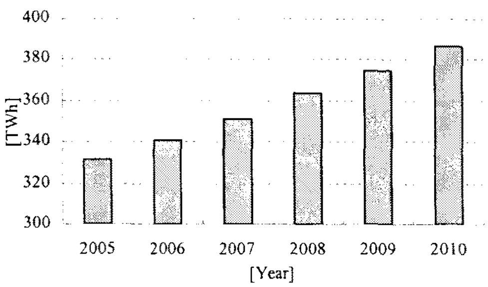

Fig. 3 Predicted annual energy demand of KEPCO system

Table 1. Outage Input Data of Case Study System

Items [uint]	Outage input data
TOT_OUT/YR [occ./year]	0.0001
TOT_HRS/OUT [hours/occ.]	2.5
WEATH_OUT/YR [occ./year]	0.001
WEATH_HRS/OUT [hours/occ.]	2.5
MAINT_PROB	0.01
MAINT_HRS/OUT [hours/occ.]	8.0
GEN_FO_PROB	0.01
GEN_FO_HRS/OUT [hours/occ.]	10.0
PCG_SC_OUT/YR [occ./year]	4.0
PCG_SC_WEATH_OUT/YR [occ./year]	3.0
PCG_SC_HRS/OUT [hours/occ.]	0.5
PCG_SC_ WEATH_HRS/OUT [hours/occ.]	0.5

4. Case studies

As previous mention, the deeper failure state of enumerated contingencies distinguishes between system problem approach and contingency screen approach. The contingency depth is increasing and so the number of checked contingencies is too different between system problem approach and contingency screen approach. Especially, if probabilistic reliability evaluation uses contingency depth (N-2) or (N-3: 1 generator 2 circuits) both of system problem approach and contingency screen approach are similar. Therefore, the system problem approach is reasonable for simulating KEPCO system in this load flow file. It is not only to reduce computation time for actual system but also to keep precise reliability indices of bulk system as shown at Table 2 and Table 3.

Table 2. System problem approach

Reliability indices	Contingency depth (Gen. Line)			
	1-1	1-2	2-1	2-2
LOLE [hr/year]	1.053	1.054	1.053	1.054
EENS [MWh/year]	29.204	29.213	29.204	29.213
Cont. checked	2,196	4,531	2,623	5,396
Cont. causing load loss	1,264	1,269	1,264	1,264

Table 3. Contingency screen approach

Reliability indices	Contingency depth (Gen. Line)			
		1-1	1-2	2-1
LOLE [hr/year]	1.053	1.053	67.646	2.39
EENS [MWh/year]	29.204	29.2	2,882.31	86.523
Cont. checked	2,187	4,643	84,337	7,130
Cont. causing load loss	1,264	1,269	77,180	2,793

When processing down a ranked list of contingencies, it is anticipated that, at some point, it will be advisable to stop processing the list. All of the severe contingencies will have been analyzed, and the remaining contingencies are harmless. The "success cutoff value" is a user-defined parameter used to determine when to stop processing a ranked list. Table 4 shows the values of bulk system reliability indices with variation in the success cut-off parameter. The characteristics in Fig. 3 shows that the reliability indices (LOLE)are saturated from success cut-off parameter = 2, although enumerated contingencies are increasing so much when success cut-off value increases. Therefore, it can be decided that reasonable success cut-off value for this system is 2. With experiences simulation TRELSS several times, the most reasonable success cut-off value should select from 4 to 6 [11].

Table 4. Bulk system reliability indices in changes of success cut -off parameter

Success Cutoff value	1	2	4	6	8
LOLE	1.053	1.054	1.054	1.054	1.054
EENS	29.166	29.206	29.206	29.219	29.221
No of Cont.	2,092	2,145	4,328	6,748	7,246

(LOLE:[hrs/year], EENS:[MWh/year])

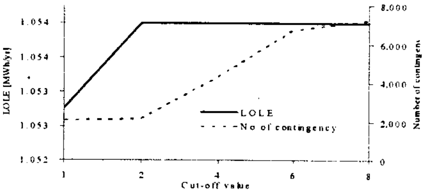

Fig.3. Variation of LOLE & EENS in changes of success cut-off parameter

Following the previous sensitivity analysis, the system problem approach has used to evaluate and quantify the probabilistic reliability indices of the bulk system in terms of system problems as overloads, voltage violations and network separation without remedial actions function. A contingency, which causes system problems, termed a failure state, is not enumerated further in combination with the outage of other components [2]. According the obtained results, the various probabilistic reliability indices of bulk KEPCO system from 2005 to 2010 used the contingency depth and success cut-off value are (N-3: 1 generator 2 circuits) and 5, respectively as shown at Table 5, Fig.4 and Fig.5.

Table 5. Probabilistic reliability evaluation indices of bulk KEPCO system at system problem approach

Year	LOLP [p.u/yr]	LOLE [hours/yr]	EENS [MWh/yr]
2005	0.0001202	1.053	29.165
2006	0.0001223	1.072	30.510
2007	0.0001239	1.085	32.308
2008	0.0001224	1.072	32.874
2009	0.0001243	1.089	33.810
2010	0.0001258	1.102	34.434

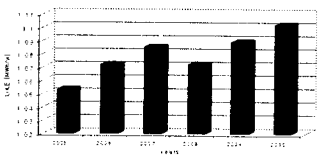

Fig.4. Loss of load expectation (LOLE) of bulk KEPCO system (2005-2010)

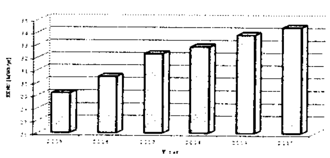

Fig.5. Expected energy not supply (EENS) of bulk KEPCO system (2005-2010)

5. Conclusion

This paper presents the distinguished probability reliability indices of bulk KEPCO system using the Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) Version 6_2, developed by EPRI. It illustrates the importance of control input parameters and approach of the TRELSS to impact on precise failure state of enumerated contingencies. The sensitivity analysis produces the various enumerated contingency list between the *contingency screening approach* and *system problem approach*. The system problem approach is not enumerated further in combination with the outage of other components but the contingency screening approach specifies remedial actions for contingencies, system problems and enumerated combination with the outage of other components. This will be studied firstly for a project of reliability evaluation of Korea system order to check characteristics and dimensional possibility of TRELSS V.6_2. Sensitivity analysis for case study shows that TRELSS is an effective tool for reliability evaluation of composite power system and various parametric analyses are available. The sensitivity case studies for KEPCO system were analyzed in order to check the merits and demerits of the TRELSS before applying actual simulation KEPCO system. We hope that the results of reliability evaluation of the actual KEPCO system using TRELSS will be available in near future.

Acknowledgements

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[References]

[1] Wang, J.R. McDonald, Modem Power System Planning (McGraw-Hill Book Company, 1994).

[2] Tayyib A. Tayyib (Feb. 2003), "Transmission Reliability Evaluation for Large-Scale Systems(TRELSS) Version 6.2", EPRI.

[3] IEEE Committee Report, "IEEE Reliability Test System"IEEE Trans. On PAS-98, 1979, pp.2047-2054.

[4] Roy Billinton and Wenyuan Li, Reliability Assessment of Electric Power Systems Using Monte Carlo Methods: Plenum Press, 1994.

[5] Roy Billinton and Ronald N. Allan, Reliability Evaluation of Power Systems: Second Edition, Plenum Press, 1996.

[6] Roy Billinton, Reliability Assessment of Large Electric Power Systems (Kluwer Academic Publishers, 1986).

[7] Jaeseok Choi, Hongsik Kim, Junmin Cha and Roy Billinton; "Nodal Probabilistic Congestion and Reliability Evaluation of a Transmission System under Deregulated Electricity Market", IEEE, PES, SM2001, July 16-19, 2001, Vancouver, Canada.

[8] 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", IEEE, PES, SM2002, July 21-25, 2002, Chicago, USA.

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

[10] 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" KIEE, Vol.4-A, No. 1, January 2004.

[11] Analysis of Probabilistic Reliability Evaluation of IEEE MRTS using TRELSS" PMAP04, Sept. 2004.

[12] Trungtinh Tran, H. Kim, J. Choi, G. Han, D. Jeon, J. Choo: "Reliability Evaluations of KEPCO system using TRELSS", IEEE GM June 2005 San Francisco, California USA

[13] Trungtinh Tran, Jaeseok Choi, R. Thomas: "Determination of Construction Priority of Transmission Lines Based on Probabilistic Reliability Evaluation" IEEE GM June 2005 San Francisco, California USA

[14] Makarov, Y.V.; Hardiman, R.C, "Risk, reliability, cascading, and restructuring", Power Engineering Society General Meeting, 2003, IEEE, Vol.3, pp.1417 1429