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TRELSS를 이용한 KEPCO 계통의 공급지장비 추정연구

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Area Annual Outage Cost Assessment of KEPCO System by TRELSS

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Abstract - The importance and necessity of conducting studies on area outage cost assessment have been increasingly important in recent years due to the competitive electricity market environment. The objective of operational issues would be to minimize the total area cost while satisfying all associated system constrains of each area[2]. This paper presents a methodology of the Area annual outage cost assessment by probabilistic reliability evaluation using TRELSS program for KEPCO system. The interrupted energy assessment rate (IEAR) is evaluated by macro approach that is using relations between GRDP and the electrical energy demand. The Expected Energy Not Supplied (EENS) of each area was evaluated using the Transmission Reliability Evaluation for Large-Scale Systems (TRELSS) Version 6_2, a program developed by EPRI are introduced in this paper.

1. Introduction

The importance and necessity of conducting studies on area outage cost assessment have been increasingly important in recent years due to the competitive electricity market environment. A goal of deregulation electric market is to impulse strengthening competition of new choices and economic benefits for utilities under constraints such as system reliability, stability, security, quality and etc... of each area. In order to decide optimal reliability criterion of power system, firstly, construction cost curve should be made and secondly outage cost curve is necessary. For practical system, on the one hand, to evaluate the construction cost is easier, on the other hand, the area annual outage cost analysis is becoming more difficult as well as a very important requirement in competitive electriicity market.

In this study, a method to calculate the Expected Energy Not Supplied (*EENS*) by using TRELSS program is presented. TRELSS is expected to be a very useful tool to treat probabilistic reliability evaluation of the composite power system. The Interrupted Energy Assessment Rate (*IEAR*) was evaluated by macro approach that is using relations between *GRDP* and the area electrical energy demand.

2. Area Annual Outage Cost Assessment

In order to assess area annual outage cost in this paper, one substep is to determine the interrupted energy assessment rate IEAR of each area, and the other substep is to evaluate the reliability of each area, this process is shown in Fig. 1. There are three approaches for assessing outage cost. Macro approach is an elastic method based on the ratio of *GRDP* and electrical energy demand which have the relationship between them as shown in Fig. 2. The macro approach is a survey method. Analysis approach is a method combining Effective Load Duration Curve (*ELDC*) and marginal outage cost function.

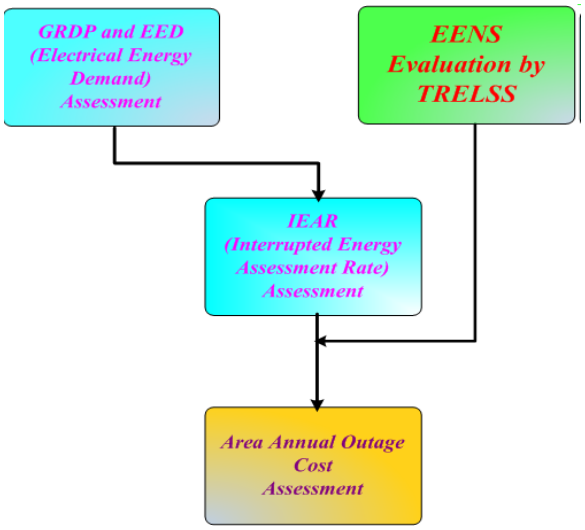
The area annual outage cost ($AAOC_k$) can be determined by multiplying the $EENS_k$ calculated in the TRELSS program by a specified value of $IEAR_k$ as shown in (2).

$$AATC_k = IEAR_k \times EENS_k \quad [\text{M\$}] \qquad (1)$$

where,
k: the study area
$IEAR_k$: interrupted energy assessment rate in #k area [$/kWh]

$$IEAR_k = GRDP_k / EED_k \quad [\$/\text{kWh}] \qquad (2)$$

Where,
$GRDP_k$: gross regional domestic product in #k area [Billion $]
EED_k: electrical energy demand in #k area [MW]



<Fig. 1> Work Procedure for Annual Outage Cost Assessment

<Fig. 2> Concept of the macro approach for outage cost assessment

3. Reliability Evaluation by TRELSS

TRELSS supplies various probabilistic reliability indices for composite power system as like as other tools. In this paper, the TRELSS program evaluates for the given level of reliability to determine the expected energy not supplied ($EENS_k$) in each area.

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.

$$EENS_k = \sum_{i \in S} T * C_{ik} p_{ik} \quad [\text{MWh/year}] \qquad (3)$$

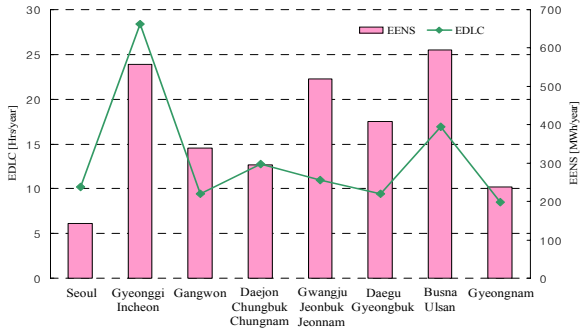
where, C_i: the load curtailment of system state in $\#k$ area
p_{ik}: the probability of system I in $\#k$ area
S: the set of all system states associated with load curtailment

4. Case studies

This study analysis 8 areas of KEPCO system. The approach was utilized for KEPCO system by probabilistic reliability evaluation to be a system problem approach which is to evaluate system reliability considering system problems such as generation/load unbalance.

<Table 1> Probabilistic reliability indices of 8 areas with system problem approach

Area	*EDLC [Hrs/year]*	*EENS [MWh/year]*	*EIR [pu]*
Seoul	10.222	143.445	0.999998367
Gyeonggi Incheon	28.422	557.303	0.999992382
Gangwon	9.474	339.423	0.999986375
Daejon Chungcheng	12.715	295.285	0.999990211
Gwangju Jeonla	10.970	519.154	0.999987856
Daegu Gyeongbuk	9.474	408.522	0.99991143
Busan Ulsan	16.953	594.187	0.999986831
Gyeongnam	8.477	237.876	0.999989511
Total	106.707	3095.195	



<Fig. 3> Expected duration of load curtailments ($EDLC_k$) and Expected energy not served ($EENS_k$) for the 8 areas with the system problem

Table 1 shows the probabilistic reliability indices of 8 areas with system problem approach. Especially, the expected energy not supplied of Busan, Ulsan area is the highest, one the other hand, the $EENS_k$ of Seoul area is lowest , and EIR_k is the highest of KEPCO system.

<Table 2> Interrupted energy assessment rate($IEAR_k$) of 8 areas

Area	*GRDP [Billion$]*	*EED [TWh]*	*IEAR [$/KWh]*
Seoul	220.607	87.892	2.509
Gyeonggi Incheon	217.827	73.158	3.114
Gangwon	25.096	24.912	1.007
Daejon Chungcheng	103.508	30.167	3.431
Gwangju Jeonla	94.269	42.753	2.204
Daegu Gyeongbuk	96.221	46.128	2.086
Busna Ulsan	98.067	45.121	2.173
Gyeongnam	61.707	22.680	2.721
Total	917.302	372.812	2.461

In 2007, Seoul area has the highest $GRDP_k$, 220.107 Bollion $[10], but $IEAR_k$ is the fourth.

<Table 3> Outage cost for 8 areas of KEPCO system

Area	*EENS [MWh/year]*	*IEAR [$/KWh]*	*AATC [Million $]*
Seoul	143.445	2.509	0.3599
Gyeonggi Incheon	557.303	3.114	1.7354
Gangwon	339.423	1.007	0.3418
Daejon Chungcheng	295.285	3.431	1.0131
Gwangju Jeonla	519.154	2.204	1.1442
Daegu Gyeongbuk	408.522	2.086	0.8522
Busna Ulsan	594.187	2.173	1.2912
Gyeongnam	237.876	2.721	0.6473
Total	3095.194	2.461	7.6173

Table 3 shows the $AAOC_k$ of each area. The out cost of Gyeonggi,Incheon area is the highest, as well as the $IEAR_k$ is just less than Daejon,Chungcheng area.

5. Conclusion

This paper proposes a method for assessing the area annual outage cost of KEPCO system in the year 2007 using TRELSS program. The results obtained from the case study show that TRELSS program is an effective tool for reliability evaluation of composite power system and various parametric analysis. Furthermore, the proposed method shows that economic analysis and optimal reliability level determination for more reasonable planning maybe implemented by using TRELSS and macro approach based *IEAR*. In view of the area outage cost analysis concept under competitive electriicity market environments, *IEAR* becomes a very usefull and important index.

Acknowledgements

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[References]

[1] Wang, J.R. McDonald, "*Modern Power System Planning*," McGraw-Hill Book Company, 1994.

[2] Kankar Bhattacharya, Math H.J. Bollen, Jaap E.Daalder *"Operation of Restructured Power Systems"* Kluwer Academic Publishers, 2001

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

[4] Roy Billinton, *"Reliability Assessment of Large Electric Power Systems,"* Kluwer Academic Publishers, 1986.

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

[6] J.S. Choi, T.D. Mount, R.J Thmos and R. Billinton, *"Probabilistic reliability criterion for planning transmission systen expension,"* IEE Proc.-Gener. Transm. Distrib., Vol. 153, No. 6, November 2006.

[7] T.Tran, J.J. Kwon, C.H. Jae, S.H. Jeong, B. Shi, J.S.Choi, D. Joen, K.N. Han, *"Sensitivity Analysis of Probabilistic Reliability Evaluation of KEPCO system Using TRELSS,"* PMAPS 2006.

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

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

[10] KDI, *Major of Indicators of the Korean Economy*. Oct, 2006.