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# TRELSS를 이용한 전력계통의 확률론적 신뢰도 평가 II
## - IEEE RTS 사례연구를 중심으로 -

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# Probabilistic Reliability Evaluation of Power System using TRELSS II
## - Focused on Case Studies of IEEE RTS -

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**Abstract** - In recent, the importance and necessity of some studies on reliability evaluation of grid come from the recent black-out accidents occurred in the world. The quantity evaluation of transmission system reliability is very important under competitive electricity environment. The reason is that the successful operation of electric power under the deregulated electricity market depends on transmission system reliability management. The various results of many case studies for the IEEE 25buses system using the Transmission Reliability Evaluation for Large-Scale Systems(TRELSS) Version 5_1, a program made in EPRI are introduced in this paper. Some sensitivity analysis has been included. 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. INSTRUCTION

In recent, the importance and necessity of some studies on reliability evaluation of transmission system come from the recent black-out accidents occurred in the world. Bulk transmission systems are planned to meet specified criteria in an attempt to create consistently high reliability for utility customers. One very important requirement in planning and operation of a bulk power system is maintaining reliability of service to load. In particular, 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.

EPRI developed Transmission Reliability Evaluation for Large-Scale Systems(TRELSS) in 1992. At present, TRELSS can represent power systems of up to 13,000 buses. As many as 60,000 contingencies can be automatically generated and analyzed by TRELSS. These contingencies may be up to six components deep, a combination of a maximum of four generators and/or two circuits. This means that as many as six components of a power system can be on simultaneous outage at a time to simulate a contingency. TRELSS is a five program software package that uses enumeration of generation and transmission contingencies to evaluate power network reliability. It incorporates a Graphical User Interface(GUI) for WINDOWS NT/95/98/NT/2000 Intel based PCs. TRELSS is designed to aid electric utility system planners in the reliability assessment of bulk power transmission systems.

This paper introduces the various results of many case studies for the IEEE 25buses system using the Transmission Reliability Evaluation for Large-Scale Systems(TRELSS) Version 5_1, a program made in EPRI. Furthermore, some sensitivity analysis has been included in this paper. Additionally, 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.

## 2. TRELSS

### 2.1 Purposes

Purpose of TRELSS program is transmission system reliability evaluation balanced with investment cost for bulk transmission systems expansion, which are planned to meet specified criteria in an attempt to create consistently high reliability for utility customers as shown as in Fig.1.


Fig 1. Purpose of **TRELSS**

### 2.2 Main Capabilities and Major Applications

**MAIN CAPABILITIES**

- **TIP**- an easy-to-use user interface
- Computes system, bus and customer reliability indices
- Analyzes up to 60,000 contingencies
- Models Linear Programming (LP) -based remedial actions to alleviate problems
- Accepts up to 10 load flow cases from separate files in PTI PSS/E or IEEE data format
- Studies impact of temporary and permanent faults
- Creates reports to the user's desired degree of detail
- Large User Group

**MAJOR APPLICATIONS**

- Quantifies system reliability
- Improves assets utilization by estimating risk and identifying weak and over-designed areas
- Identifies and ranks contingencies causing system problems
- Improves decision making for allocating limited capital
- Provides data for cost/benefit analysis of system reinforcements
- Evaluates the impact of Protection Control Group (PCG) outages due to temporary and permanent faults
- Evaluates and rank alternative plans

Provides customer service reliability measures at each load bus

### 2.3 Program Feature

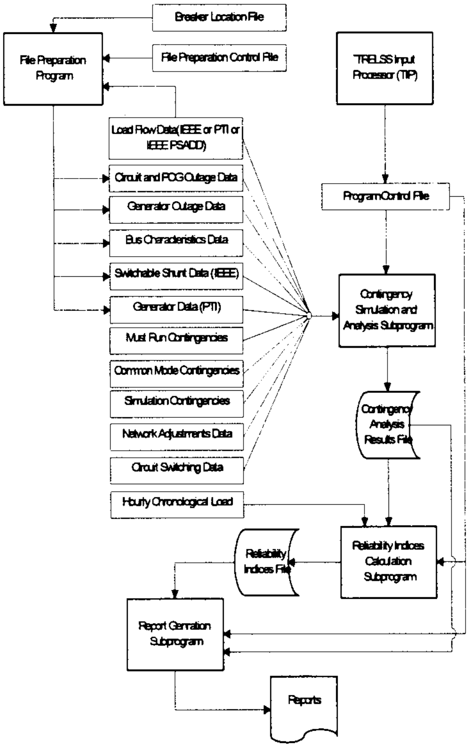


Fig. 2. Overall organization of **TRELSS**

### 2.4 TRELSS Reliability Indices

- **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

### 2.5 Guide for TRELSS Operation

By a tutorial processing for operating TRELSS, the step by step instruction to guide a user using TIP (TRELSS Input Process) program to create a TRELSS run case, launch TRELSS programs, view and print reports is as followings.

**Step 1. Start TIP program and create a new TRELSS case**
**Step 2. Set up PCD General Data**
**Step 3. Supplying a Load Flow Data File**
**Step 4. Supplying Network Supplementary Data Files**
**Step 5. Select Outage and Load Curve Data Files**
**Step 6. Specifying A Study Area**
**Step 7. Specifying A Problem ID Area**
**Step 8. Specifying Load Levels in Case Definitions**
**Step 9. Specifying Solution Parameters for Load Flow Solutions**
**Step 10. Specifying Remedial Action Options**
**Step 11. Specifying PCG Analysis and Failure Criteria**
**Step 12. Specify Dispatch and Islanding Options**
**Step 13. Specifying Independent Contingency Options**
**Step 14. Specifying Report Filter**
**Step 15. Select Output Reports**
**Step 16. Saving PCD Settings to a Fil**
**Step 17. Viewing Input Data File**
**Step 18. Launching TRELSS programs**
**Step 19. Examine Result**

## 3. CASE STUDIES

### 3.1 IEEE RTS 25 Buses System

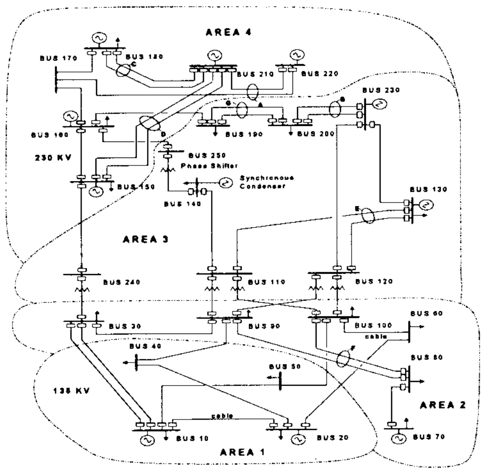


Fig. 3. IEEE MRTS 25Buses System

### 3.1 Variation of Bulk System Reliability Indices According to Changing of Load Level

Firstly, a case with variation of load level parameters based on given 25buses demo system has been studied using the TRELSS. Table 1 shows changing of load level parameters and Table 2 shows values of bulk system reliability indices results according to changing the load level. The characteristics are shown easily in Fig 4.

Table 1 Changing of Load Level Parameters

| Load Level | -10% | -5% | 0% | 5% | 10% |
|---|---|---|---|---|---|
| Load Level 1 | 90 | 95 | 100 | 100 | 100 |
| Load Level 2 | 81 | 86 | 90 | 95 | 99 |
| Load Level 3 | 74 | 78 | 82 | 86 | 90 |
| Load Level 4 | 72 | 76 | 80 | 84 | 88 |

Table 2 Bulk System Reliability Indices According to Changing the Load Levels

| Load Level | -10% | -5% | 0% | 5% | 10% |
|---|---|---|---|---|---|
| LOLP | 0.000162 | 0.000162 | 0.000162 | 0.000206 | 0.000206 |
| EENS | 82.538 | 83.05 | 82.337 | 88.967 | 97.69 |

(LOLP:[pu/year], EENS:[MWh/year])

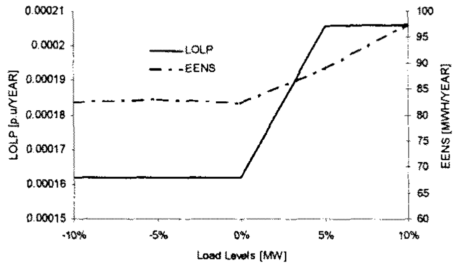


Fig. 4. Variation of Reliability Index, LOLP & EENS According to Changing the Load Levels

### 3.2 Variation of Load Buses Reliability Indices According to Changing of Load Levels

For previous case study with variation of load level parameters based on given 25buses demo system, load buses reliability indices could have been checked. Table 3 and Table 4 show values of load buses reliability indices results according to changing the load level respectively. The characteristics are shown easily in Fig 5 and Fig 6.

(1) bus #40

Table 3 Reliability Indices at Load Bus #40According to Changing of Load Levels

| Load Levels | -10% | -5% | 0% | 5% | 10% |
|---|---|---|---|---|---|
| LOLP | 0.000057 | 0.000057 | 0.000057 | 0.0000570 | 0.000057 |
| EENS | 46.193 | 46.193 | 46.193 | 46.193 | 46.193 |

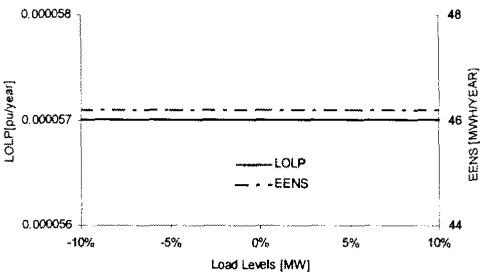


Fig 5 Variation of Reliability Indices at Load Bus #40 According to Changing of Load Levels

(2) bus #50

Table 4 Reliability Indices at Load Bus #50 According to Changing of Load Levels

| Load Levels | -10% | -5% | 0% | 5% | 10% |
|---|---|---|---|---|---|
| LOLP | 0.0001050 | 0.0001050 | 0.0001050 | 0.000149 | 0.0001492 |
| EENS | 36.345 | 36.858 | 36.144 | 42.775 | 50.903 |

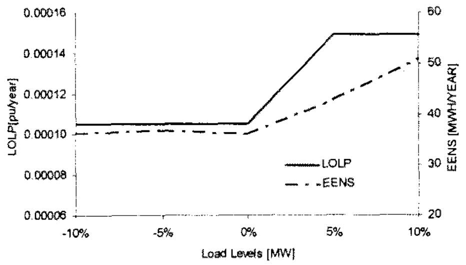


Fig 6 Variation of Reliability Indices at Load Bus #50 According to Changing of Load Levels

### 3.3 Variation of Reliability Indices at Load Buses According to Changing of Circuit outage data

Secondly, a case with variation of circuit outage data, frequency and duration, based on given 25buses demo system has been studied using the TRELSS.

(1) Frequency outage data of circuit

Table 5 shows values of bulk system reliability indices according to changing frequency outage data of circuit. The characteristics are shown easily in Fig 7.

Table 5 Bulk System Reliability Indices According to Changing of Frequency Outage Data of Circuit

| Frequency [Occ/Yr] | -10% | -5% | 0% | 5% | 10% |
|---|---|---|---|---|---|
| LOLP | 0.0001491 | 0.0001555 | 0.0001620 | 0.0001685 | 0.0001749 |
| EENS | 74.525 | 78.431 | 82.337 | 86.242 | 90.148 |

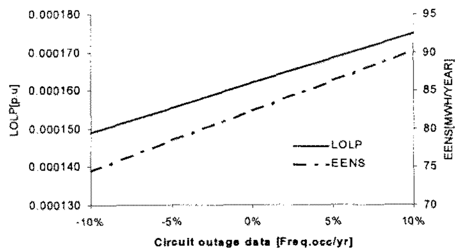


Fig. 7. Variation of Reliability Indices According to Changing of Frequency Outage Data of Circuit

(2) Duration outage data of circuit

Table 6 shows the values of bulk system reliability indices according to changing duration outage data of circuit. The characteristics are shown easily in Fig 8.

Table 6 Bulk System Reliability Indices According to Changing of Duration Outage Data of Circuit

| Duration [Hrs/Occ] | -10% | -5% | 0% | 5% | 10% |
|---|---|---|---|---|---|
| LOLP | 0.0001592 | 0.0001606 | 0.0001620 | 0.0001634 | 0.0001648 |
| EENS | 82.116 | 82.226 | 82.337 | 82.447 | 82.557 |

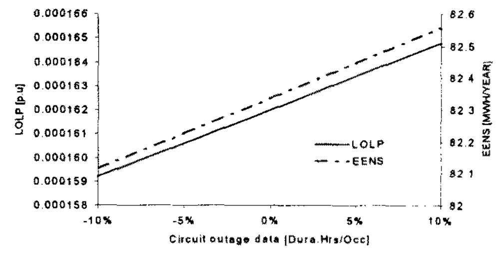


Fig. 8. Variation of Reliability Indices According to Changing of Duration outage data of circuit

### 3.4 Variation of Reliability Indices According to Changing of Contingency Depth Cut-off Parameter

Thirdly, a case with variation of contingency depth cut-off parameters based on given 25buses demo system has been studied using the TRELSS. Table 5 shows the values of bulk system reliability indices according to changing contingency depth cut-off parameter. The characteristics are shown easily in Fig 9. Fig. 9 shows a characteristics that the reliability indices are saturated from cut-off depth=2. Therefore, it can be decided that the resonable contingency depth cut-off in view point of computation time for this system is 2.

Table 7 Bulk System Reliability Indices According to Changing of Contingency Depth Cut-off Parameter

| Cont. Depth | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| LOLP | 0.000118 | 0.000161 | 0.000161 | 0.000162 | 0.000162 | 0.000162 |
| EENS | 78.86 | 82.291 | 82.291 | 82.337 | 82.337 | 82.337 |

(LOLP:[p.u/year], EENS:[MWh/year])

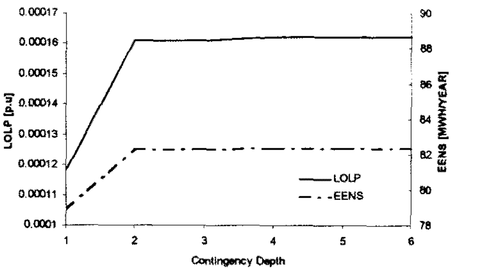


Fig. 9. Variation of Reliability Index, LOLP &EENS According to Changing Contingency Depth. Cut-off Parameter

### 3.5 Variation of Reliability Indices at Load Buses According to Changing of Contingency Depth Parameter

Finally, a case with variation of contingency depth parameters based on given 25buses demo system has been studied using the TRELSS. Table 8 shows the values of bulk system reliability indices according to changing contingency depth parameter. The characteristics are shown easily in Fig 10. Fig. 10 shows a characteristics that the reliability indices are effected more by contingency depth of circuit(C), transmission lines than by contingency depth of generators(G). Therefore, it can be decided. that the resonable contingency depth for this system is G=1 and C=2.

Table 8 Bulk System Reliability Indices According to Changing of Contingency Depth Parameter

| G - C | 1-1 | 1-2 | 2-1 | 2-2 | 3-1 | 3-2 | 4-1 | 4-2 |
|---|---|---|---|---|---|---|---|---|
| LOLP | 0.000162 | 0.000253 | 0.000201 | 0.000247 | 0.000197 | 0.000247 | 0.000196 | 0.000247 |
| EENS | 82.337 | 134.563 | 86.098 | 134.734 | 86.091 | 134.746 | 86.073 | 134.743 |

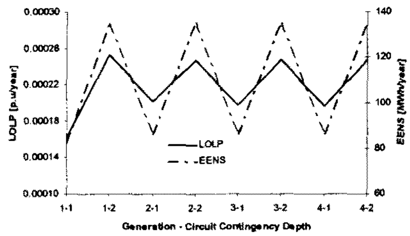


Fig. 10. Variation of Reliability Index, LOLP &EENS According to Changing Contingency Depth.

## 4. CONCLUSIONS

This paper introduces the various results of many case studies for the IEEE 25buses system using the Transmission Reliability Evaluation for Large-Scale Systems(TRELSS) Version 5_1, a program made in EPRI. Furthermore, some sensitivity analysis has been included in this paper. Additionally, this paper suggests that the important input parameters of the TRELSS can be determined optimally from this sensitivity analysis for high reliability level operation of a system.

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### [REFERENCES]

[1] 전동훈, 안재욱, 장의태, 이 선, 김발호 및 Ross Baldick, "전력산업 구조변화 및 전력탁송에 관한 연구" 한국전력공사 전원계획처 보고서, 1998, 3.

[2] W.S Read, W.K. Newman, I.J. Perez-Arriaga, H.Rudnick, M.R. Gent & A.J. Roman (December 1999). Reliability in the New Market Structure(Part1). IEEE Power Engineering Review, p.4-14.

[3] W.S Read, W.K. Newman, I.J. Perez-Arriaga, H.Rudnick, M.R. Gent & A.J. Roman (January 2000). Reliability in the New Market Structure(Part2). IEEE Power Engineering Review, p.10~16.

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

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

[6] M. P. Bhavaraju, R. Billiton, N. D. Reppen and P. F. Albrecht (Feb. 1988). Requirements for Composite System Reliability Evaluation Models. IEEE Trans., Vol. 3, No. 1, pp. 149-157.

[7] Tayyib A. Tayyib (Dec. 2000), "Transmission Reliability Evaluation for Large-Scale Systems(TRELSS) Version 5.1",EPRI.

[8]EPRI,"Restructured Transmission Reliability Evaluation for Large-Scale Systems (TM) (TRELSS (TM)): An Implementation Plan", EPRO Final Report 00000000000100 1987, Nov, 2001.