# A STUDY ON PROBABILISTIC RELIABILITY EVALUATION OF KOREA POWER SYSTEM BY USING PRA

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## ABSTRACT

Reliability and power quality have been increasingly important in recent years due to a number of black-out events occurring throughout the world. This paper presents a practical method of probabilistic reliability evaluation of KOREA Power system by using the Probabilistic Reliability Assessment (PRA) program and Physical and Operational Margins (POM). The case study computes the Probabilistic Reliability Indices (PRI) of KOREA Power system as applied PRA and POM. It takes a large number of contingency in load simulations and combines them with a practical method of characterizing the effect of the availabilities of generators, lines and transformers. The effectiveness and future works are illustrated by demonstrations of case study.

***Index Terms—*** Probability reliability evaluation, KOREA power system, POM, PRA

## 1. INTRODUCTION

The primary function of an electric power system is to provide electrical energy to its customers as economically as possible and with an acceptable degree of continuity and quality .The importance and necessity of conducting studies on reliability evaluation have been increasingly important in recent years due to a number of black-out events occurring through in the world. Bulk 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 operating 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].

This paper deals with the application of the concept of POM (Physical and Operational Margins) and a practical method of PRA (Probabilistic Reliability Assessment) for Korea power system. It not only demonstrates possibility that the POM and PRA can be applied to the Korea power system but also analyzes the results from PRA. And it shows the direction of future work through PRI (Probabilistic Reliability Index) in case study.

The PRA software consists of two software programs: Physical and Operational Margins (POM) licensed by V&R Energy Systems Research, Inc. (V&R) to EPRI and qualified EPRI members; and Probabilistic Reliability Indices (PRI), owned by EPRI. The PRA software provides the user with the ability to identify bottlenecks in the grid, evaluate their impact, and recommend effective mitigation alternatives [2].

## 2. THE RELATIONSHIP BETWEEN PROBABILITY AND IMPACT OF ACCIDENTS

Generally, the relations between the probability of arbitrary event and the impact which is impacted in the whole system are like Fig. 1. So, the left-upper and part means that the occurrence probability is low but once occurred it has very serious accidents to system, the right-bottom part means that the occurrence probability is high but once occurred it effects very small accidents to system. And the upper-middle part means that occurrence probability is high and it has serious problems.

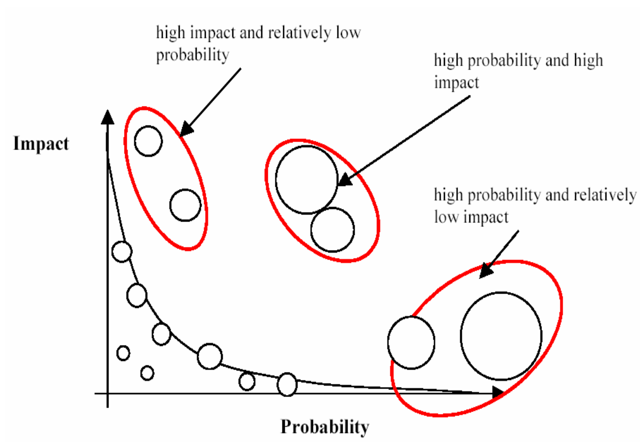


Fig. 1 Express Probabilistic Reliability Indices in Impact/Probability Space

One of the purposes of this research is detecting that what kinds of effect have arbitrary accident, and then, develop or introduce the program which can search accidents which have a high occurrence probability and a high impact. It means that the purpose of this research establishes a basis of probabilistic reliability evaluation method and a stable supply of electricity power [9].

## 3. PHYSICAL AND OPERATIONAL MARGINS(POM)

The program "Physical and Operational Margins" (POM) is a powerful voltage stability and contingency analysis program. The basis of POM is a fast and robust power flow solution algorithm. Graphical capabilities incorporated in POM assist the engineer in visualizing the power system behavior. While easy to use, POM provides a great degree of flexibility in making a comprehensive analysis of a system [12].

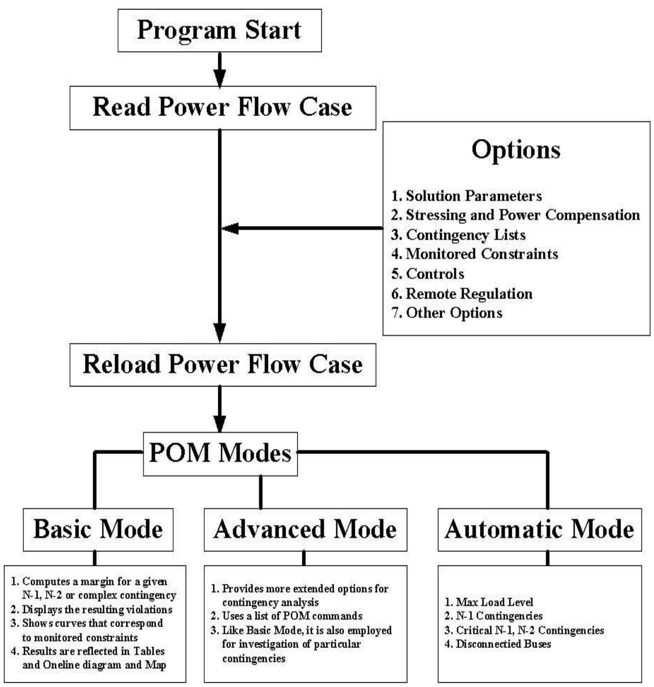


Fig.2 POM Flow Chart

### *3.1. Input Files of POM*

Table 1 Modified Input Data Files for Korea power System

| | |
|---|---|
| Branch Contingencies | from1 154 KV all |
| Generator Contingencies | from 100 MW all |
| Thermal Constraints | from1 154 KV<br>from2 154 KV all |
| Voltage Constraints | from 154 KV<br>all 0.95 |

In order to simulate KOREA Power System by using POM, it needs modified input data. The files illustrate as following table 1. This paper used only "Automatic Mode" to take "Critical N-1, N-2 Contingencies" file.

## 4. PROBABILISTIC RELIABILITY ASSESSMENT(PRA)

The program "Probabilistic Reliability Assessment" (PRA) is a effective methodology that was originally used in the nuclear power industry to determine the risk to the general public from the operation of nuclear power plants. This methodology, when applied to power delivery systems, provides the capability for determining the probability or likelihood of an undesirable event on the transmission system and a measure of its severity. PRA combines a probabilistic measure of the likelihood of undesirable events with a measure of the consequence of the events into a single reliability index – Probabilistic Reliability Index (PRI). In the deterministic approach, the contingencies are ranked according to their severity. This approach does not take into account the likelihood of the system to experience operation limit violations. The probabilistic approach weights the severity by a probability to yield an index called Probabilistic Reliability Index. Ranking the contingencies according to the probabilistic index gives a more accurate view of the reliability for some of the most severe violations may be very unlikely whereas less severe contingencies may frequently be encountered. The probabilistic reliability analysis is a much more accurate measure of the reliability that allows to perform more efficient trade-offs between economic and technical constraints [9].

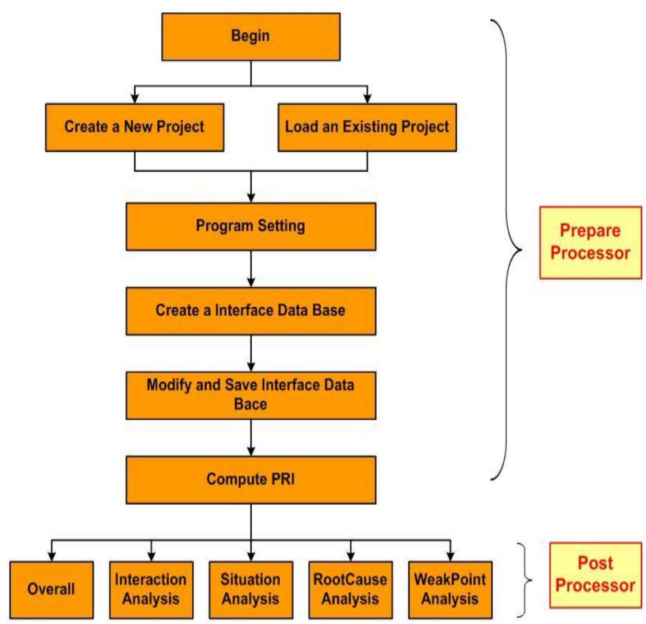


Fig.3 PRA Flow Chart

*4.1. Probabilistic Reliability Assessment Method*

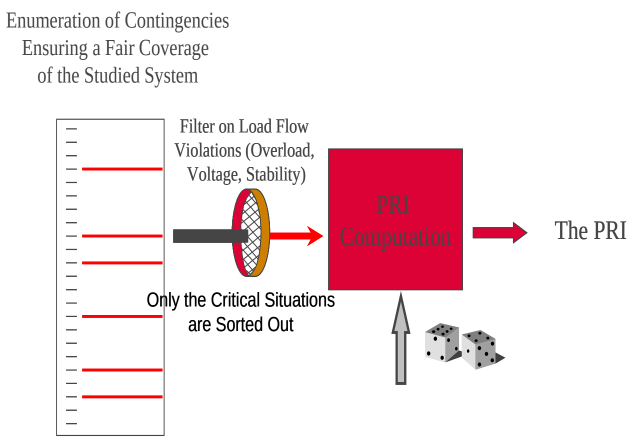


Fig.4 Probabilistic Reliability Assessment Method

The reliability is measured by the Probabilistic Reliability Index (PRI). PRI is defined as product of an impact by a probability. Each index is defined as following table 2 and below methods.

Table 2 The Index and Impact in PRA

| Index | Impact |
|---|---|
| ***A-PRI*** | ***A-Impact*** |
| ***V-PRI*** | ***V-Impact*** |
| ***VS-PRI*** | ***VS-Impact*** |
| ***LL-PRI*** | ***LL-Impact*** |

▶ Overload Reliability Index:

$$A-PRI = \sum_{i \in \{Simulated\_Situation\}} probability_i \times Aimpact_i \quad (1)$$

The overload impact is measured in terms of MVA.

▶ Voltage Reliability Index :

$$V-PRI = \sum_{i \in \{Simulated\_Situation\}} probability_i \times Vimpact_i \quad (2)$$

The voltage impact is measured in terms of kV or pu.

▶ Voltage Stability Reliability Index :

$$VS-PRI = \sum_{i \in \{Simulated\_Situation\}} probability_i \times VSimpact \quad (3)$$

▶ Load Loss Reliability Index :

$$LL-PRI = \sum_{i \in \{Simulated\_Situation\}} probability_i \times LLimpact_i \quad (4)$$

The load loss impact is measured in terms of MW [9].

*4.2. Input files of PRA*

PRA input files are separated 3 categories and 9 files. This paper deals with 2006 Load data in KOREA.

Table 3 Input Data Files for PRA

| Input Category | | Input files |
|---|---|---|
| **1. Contingency Analysis** | | **KEPCO_2006.raw** |
| | | **Auto_N1.txt** |
| | | **Critical_KEPCO.txt** |
| | | **Voltage Constraints.txt** |
| **2. Probability** | | **GenericGenerators.csv** |
| | | **GenericLines.csv** |
| | | **GenericTransformers.csv** |
| **3. Map** | **Region Map** | **KEPCO_2006_Region.jpg** |
| | **Component Map** | **KEPCO_2006_Component.jpg** |

*4.3. Organization of PRA*

Before operating PRA, overview organization of each date of POM and PSS/E is shown at Fig.5.

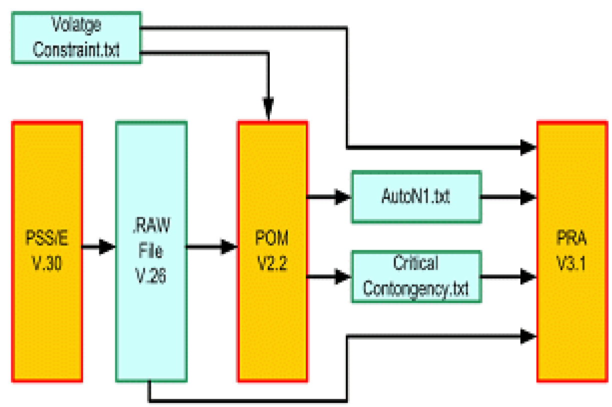


Fig.5 overview organization of PRA

## 5. CASE STUDIES

This case study has simulated KOREA power system by using POM and PRA in 2006. The Korea power system has 1668 buses and 2,205 transmission lines. And KOREA power system has 154kv in 70's, 345kV in 80's, 765kV in 2000's and connected with Jeju island power system by HVDC in 1998. The scenarios of load in KOREA power system reached the peak load at summer, because it is so hot that many air-conditioners are operated.

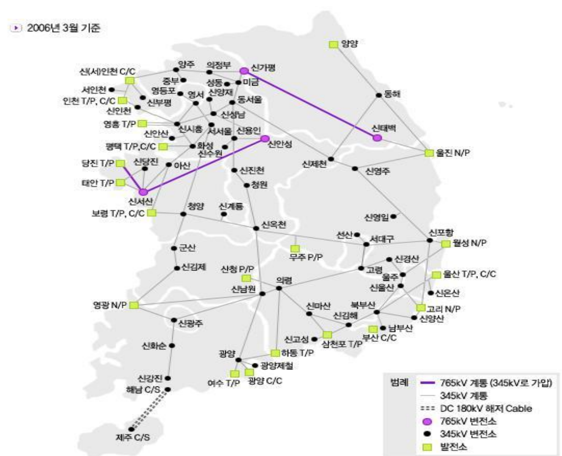

Fig.6 Configuration of KOREA power system

*5.1. Analyze the results of KOREA Power System*

PRA can analyze the results of five types. User can easily understand because each result is graphically shown. The results that are founded through the simulations of KOREA power system. The Five analysises are shown from Fig.7 to Fig.11.

The situation of V-PRI in KOREA power system is good, but Chang-won control area has high factor of voltage violation relatively. The A-PRI is included overall, but VS-PRI has risky factors rarely in the system

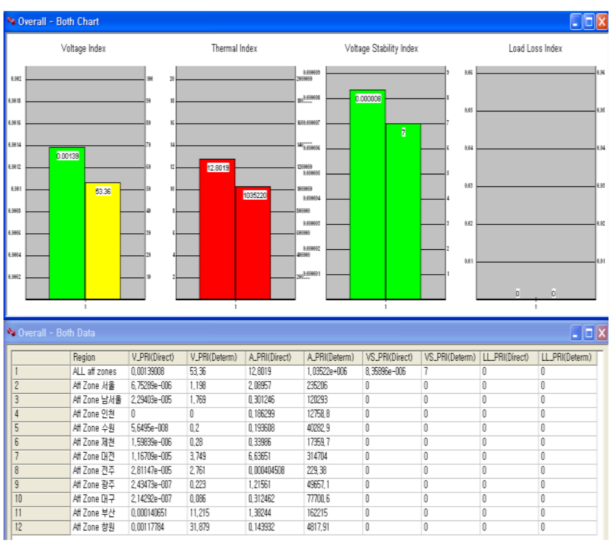

Fig.7 Overall Analysis

There are 11 control areas in KOREA. The relationship when violation occurred is shown at Fig. 8. The PRA can show how to affect and cause in the system.

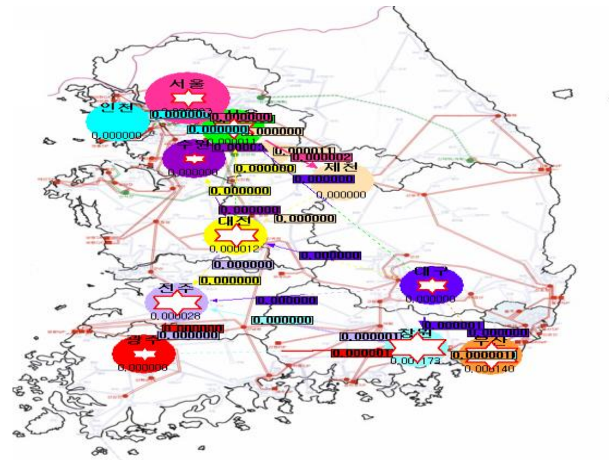

Fig.8 Interaction Analysis

The situation analysis results are displayed in Probability/Impact space and table type.

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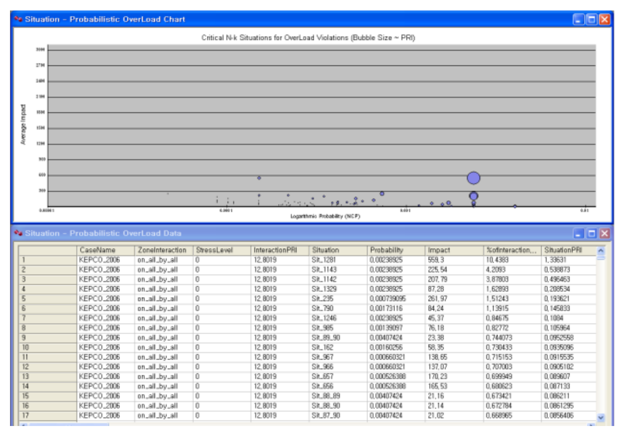

Fig.9 Situation Analysis

The Root cause analysis shows the facilities (Generators, Transmission Lines, Transformers, etc) which are caused by critical situation in KOREA power system.

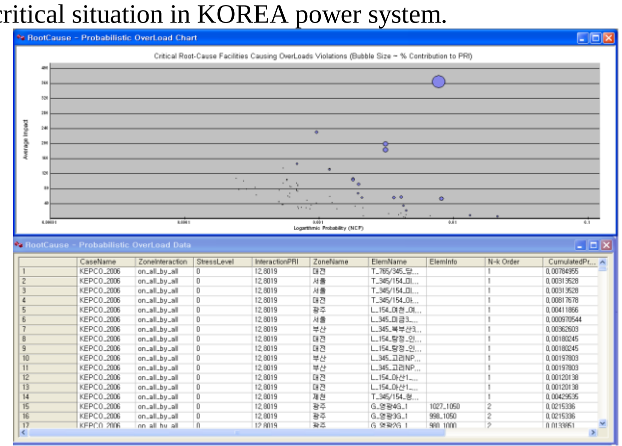

Fig.10 Root Cause Analysis

The Weak point analysis shows the most violated bus, transmission line and transformer in KOREA power system.

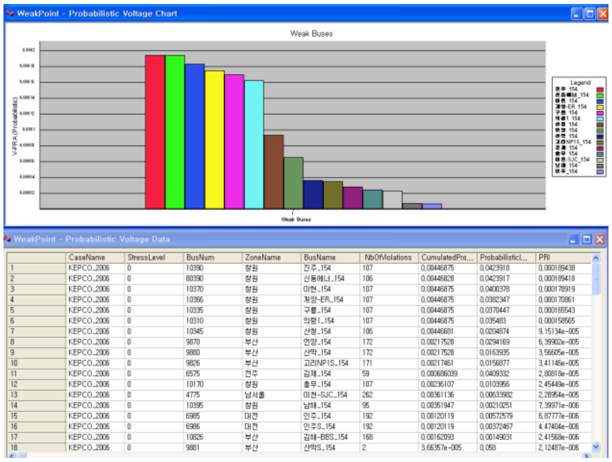


Fig.11 Weak Point Analysis

## 6. CONCLUSIONS

This paper presents the application of POM and PRA what are newly introduced to evaluate probabilistic reliability of KOREA power system. The results show new reliability indices which are different type with conventional indices. We simulate to analyze condition of the system under three constraints that are voltage violation, overload violation and voltage stability violation. The OPM/BOR(Optimal Mitigation Measures/Boundary of Operating Region) which are sub-programs in POM didn't used. If it is simulated with both modules, the results will be more correct and reliable. In conclusion, this paper demonstrates the possibility that the POM and PRA can be applied to the KOREA power system.

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