Earthquake Risk Evaluation Technologies for Electric Power Substation and Distribution Equipment

Background

In electric power companies in Japan, technological development that contributes to the reduction of equipment maintenance fees including the disaster countermeasures cost is pressingly needed. Moreover, in recent years, since attention needs to be paid to the business continuity plan (BCP) against disaster, the models to quantify the business and financial impact of disaster are needed. To respond to these needs, we have been engaged in a research to quantitatively analyze the cost-effectiveness of earthquake countermeasures for a huge number of electric power substations and distribution equipment. In this research, practical risk and cost evaluation technologies that can flexibly apply depending on the needs for the practitioner or manager associated with electric power equipment, have been particularly requested

Objectives

To propose earthquake risk evaluation technologies to reasonably select upgraded or retrofitted equipment in order to realize both the risk and cost reductions associated with earthquake.

Principal Results

1. Performance evaluation of electric power equipment with 4 aspects

In order to select the electric power equipment to be upgraded, four performance indices were proposed (Table 1). Level 1 is a deterministic proof stress evaluation index which evaluates equipment resisting capacity against an earthquake scenario. Level 2 is a stochastic proof stress evaluation index which considers the uncertainty of the evaluation due to Level 1. In Level 2, the earthquake resistance of equipment and the seismic force are stochastically evaluated. On the other hand, Level 3 is a stochastic system performance evaluation index associated with the system performance of the entire power system against an earthquake scenario. Level 4 is a cost evaluation index which pays attention to the cost effectiveness of the upgrading. The proposed four performance indices enable us to specify and prioritize the equipment to be upgraded. However, in order to more precise apply level4 evaluation; it is necessary to consider the earthquake performance not only on the supply side but also on the demand side. Therefore, the following loss estimation methods associated with the demand side's loss estimation were developed.

2. Estimation of Business Interruption loss for electric power company

A method to estimate Business Interruption Loss (BIL) due to earthquake was proposed. On the basis of the actual electric power demand record in the seismic damaged region, the proposed method tries to estimate the monthly based electric power demand assuming that the earthquake did not occur. The BIL could be estimated by calculating the difference between estimated power demand without earthquake and the actual power demand with earthquake. The proposed model enables us to easily evaluate the monthly change in the BIL based on the electric power demand record in the seismic damaged region (Fig.2).

3. Estimation of Power Outage Costs for power customer

During earthquake disasters, not only power lifeline facilities but also other lifelines can be simultaneously damaged. Therefore, the evaluation method of power outage costs is proposed considering single or simultaneous disruption of supply-type lifelines (electricity, water, gas). The proposed method is based on the resiliency surveys to industries (production level under lifeline disruptions in 27 different sectors) and regional economic model to capture the impacts both in individual firm and regional economy levels (Fig.3).

Future Developments

The proposed method will be enhanced as a lifecycle cost evaluation method considering deterioration degree of old equipment.

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Table 1 Performance indices for the upgrade strategy of substation equipment

Principal concept	Model	Index	Attention
Evaluation of the earthquake resisting capacity of equipment	Level 1		Safety margin of equipment resistance against an earthquake scenario
	Deterministic proof stress evaluation index	Safety margin(=allowable stress/generated stress)	
	Level 2		Safety margin of stochastic resistance of equipment
	Stochastic proof stress evaluation index	Probability of damage equipment	
Evaluation of the system functionality and the cost effectiveness	Level 3		Supply power capability of the entire power system against an earthquake scenario
	Stochastic system performance index	Probability of power failure	
	Level 4		Cost effectiveness of upgrade equipment against multi hazards including an earthquake scenario
	Cost evaluation index	Cost effectiveness considering lifecycle cost	

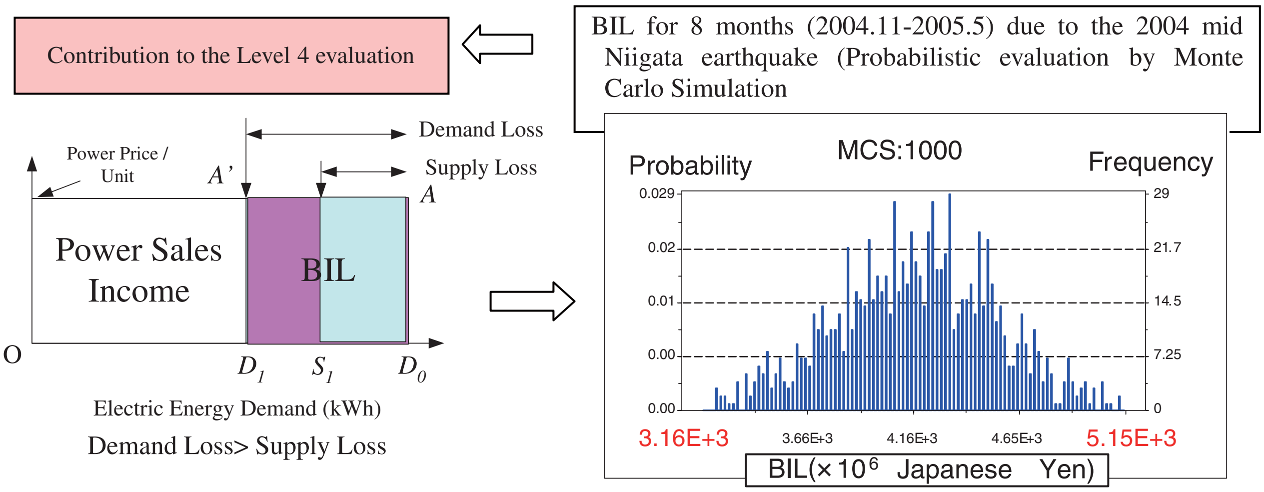

Fig.2 Business Interruption Loss (BIL) of Electric power companies and the BIL associated with large industrial power due to the 2004 mid Niigata earthquake

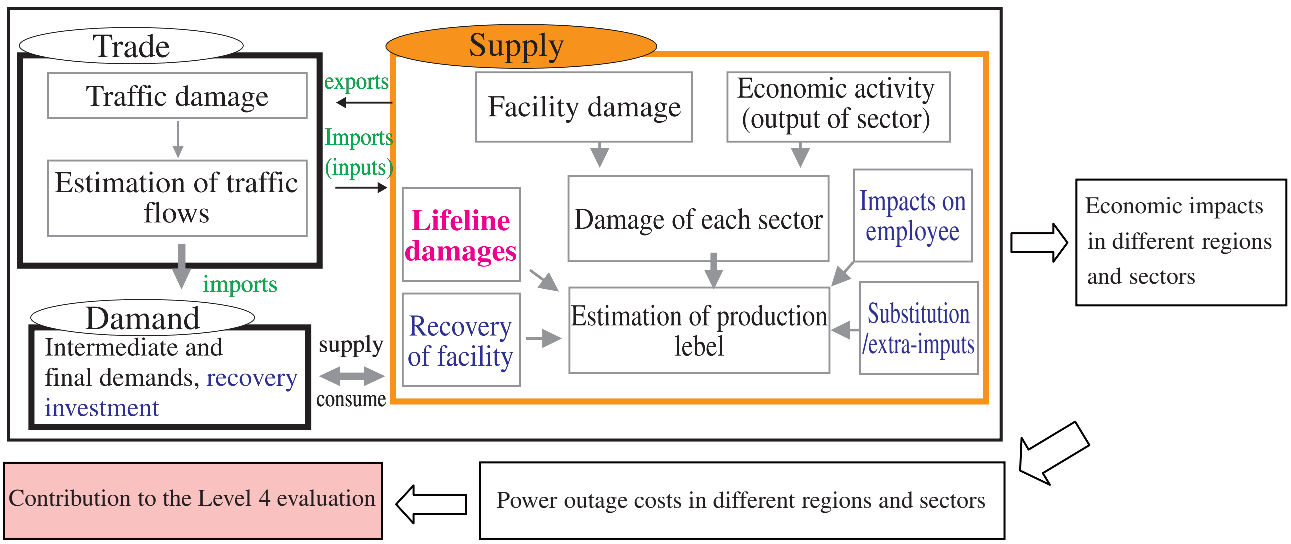

Fig.3 Evaluation model of power outage costs for customers due to earthquake