STUDY OF DECISION SUPPORT PROGRAMS AND EVALUATION MODEL FOR MAINTENANCE STRATEGY OF ELECTRIC POWER EQUIPMENT

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Abstract: In both the electric power industry and the demand-side industry, the development of support tools for creating a maintenance strategy for electric power equipment based on asset management techniques has become very intensive in recent years with the aim of reducing maintenance costs, and ensuring that future expenses remain within a certain level. The authors have developed such tools for transformers and GCB. They are based on the evaluation of average maintenance cost. From the viewpoint of asset management, there are several characteristics corresponding to different types of equipment; therefore, support tools should be developed and adjusted for each characteristic of equipment. In this article, programs based on the evaluation of the average annual maintenance cost are presented for GIS and overhead power transmission lines. They can take into account the maintenance cost of equipment and its partial renewal. In the asset management of electric power equipment, the evaluation and effective utilization of diagnosis are very important. The diagnosis effect should be discussed in terms of not only the accuracy of diagnosis, but also the distribution of lifetime. Both diagnosis accuracy and lifetime distribution are assumed to have a certain dispersion in our simplified evaluation model, and by changing their relationship, the effects of maintenance strategies are examined.

1 INTRODUCTION

Because of the saturation of electric power demand and the recent liberalization of the electric power industry in Japan, it is necessary to reduce the maintenance cost of electric power equipment by rationalizing the inspection, maintenance and renewal of service-aged equipment. Therefore, in sections responsible for the maintenance of electric power equipment, in addition to the improvement of diagnosis techniques, there is a great deal of interest in asset management techniques that incorporate economic evaluation. Operating condition data, inspection data and diagnostic data are being gathered in utility companies and plant makers, and attempts are being made to utilize them to support the maintenance and renewal strategies. Under such circumstances, CRIEPI is investigating techniques to support maintenance staff. By utilizing the method of evaluating the average maintenance cost, support programs for transformers and GCBs (gas-insulated circuit breakers) have been developed [1-3].

2 PARTIAL RENEWAL PLAN SUPPORT PROGRAM

As asset management support tools, in addition to an overhaul plan support program for transformers and a renewal plan support program for GCB, partial renewal support programs for GIS (gas-insulated switchgear) and overhead transmission lines have been investigated [3].

2.1 Support program for GIS

GIS is equipment combining a GCB, a bus, a disconnecting switch and so on, and the partial renewal of components during lifetime of the whole body is possible. Several renewal plans including partial renewal should be compared. By utilizing the method of evaluating the average maintenance cost, similarly to in the programs for transformers and GCBs, a support program for selecting maintenance scenarios for GIS has been developed, as shown in Fig. 1. First, for each of the components in GIS, an appropriate renewal plan (timing) should be examined by considering maintenance costs during its life cycle. By examining the maintenance cost characteristics in a life cycle, maintenance costs should be decomposed into four categories as follows:

(i) expenses which increase with operation time (e.g., painting of a tank surface),

(ii) expenses which occur periodically (e.g., periodic inspections),

(iii) expenses which occur nonperiodically (e.g., legal inspections and the exchange of control units),

(iv) accidental expenses (e.g., failure costs)

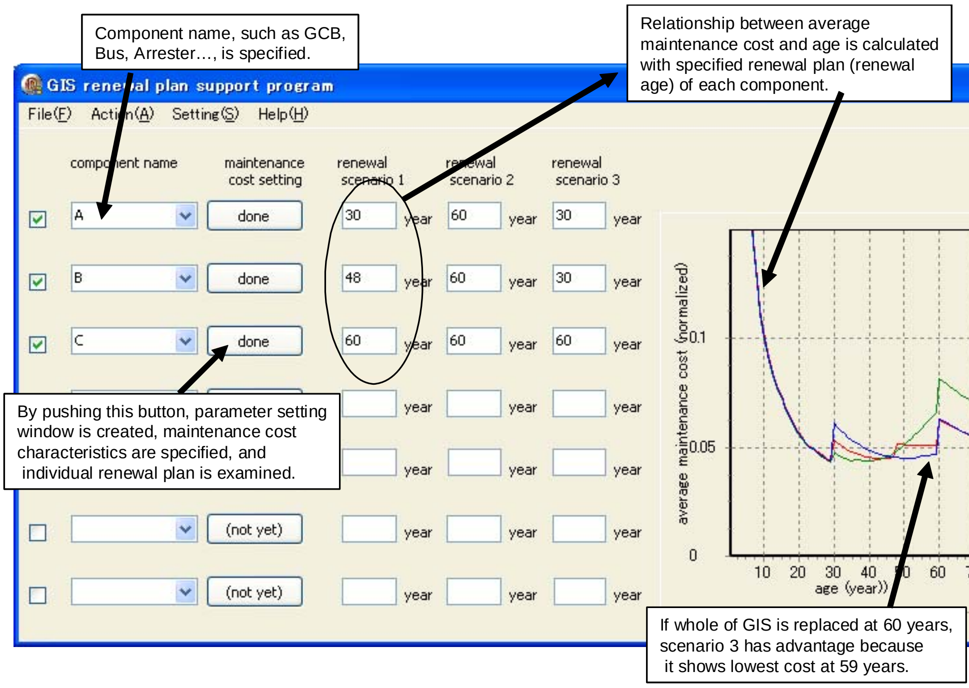

Figure 1: Display of renewal plan support program for GIS

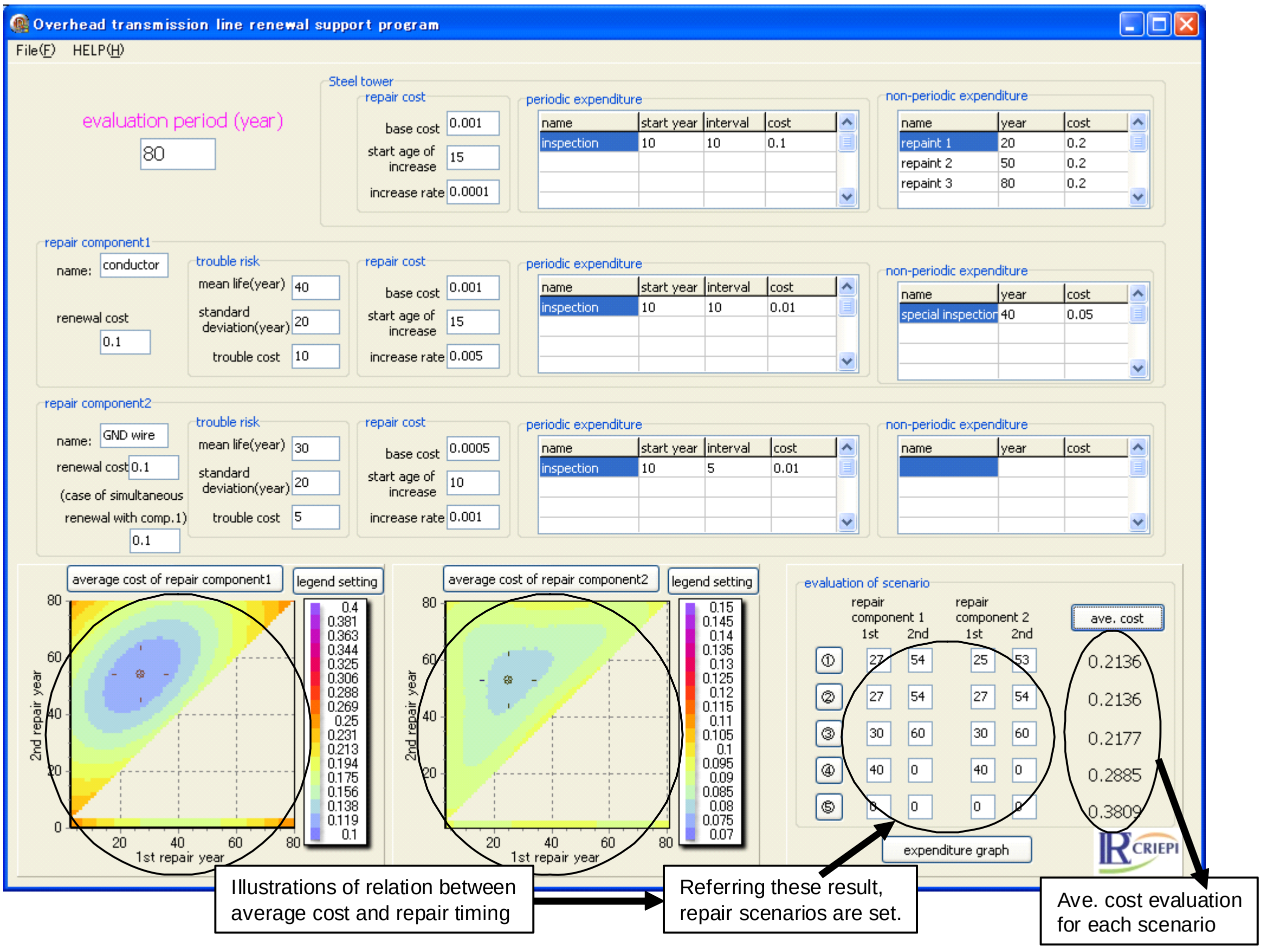

Figure 2: Display of renewal plan support program for overhead transmission lines

These cost components should be counted from actual maintenance expenses. With these cost data, the annual maintenance expense and average maintenance cost during its operation period can be derived for each component. The optimum renewal timing (economic life) for each component is evaluated from the characteristic of average maintenance cost, if it has a low peak. By referring to the results of each component, three renewal scenarios (i.e., when these components should be replaced) are specified in the program. The results of the examination are shown in the graphical area of the program, where the average maintenance cost at each age is illustrated. In the case of Fig. 1, if total renewal is carried out at 60 years, scenario 3, whose average maintenance cost at 59 years is lowest, has an advantage.

2.2 Support program for overhead transmission lines

An overhead transmission line consists of steel towers, which are expected to work for a very long time (~100 years ?), and other components, such as conductors, ground wires and other attached equipment, which have to be paid attention to deterioration over several tens of years. Therefore, the renewal planning of wires and other equipment is important in the maintenance strategy of an overhead transmission line. A support program for overhead transmission lines has been developed, as shown in Fig. 2. It can examine renewal plans for two components and the average maintenance costs of a whole overhead transmission line during its evaluation period. Maintenance costs are decomposed into four categories, similarly to in the previous section, but the probability of trouble is not considered for steel towers owing to their sufficiently long operating period (which is the evaluation period in the program). The timing of renewal (which will be carried out one or two times) for each component is examined in the graphical area of the program. By referring to these results, renewal scenarios are specified in the program. For these scenarios, average maintenance costs are examined.

3 EVALUATION OF DIAGNOSIS MERIT IN MAINTENANCE STRATEGY

In the asset management of electric power equipment and in rational maintenance strategies, the evaluation and effective utilization of diagnosis are very important. There have been some studies on this evaluation, including its merits and demerits. The effect of diagnosis should be discussed not only in terms of its accuracy, but also in terms of the distribution of lifetime (probability density of trouble). In order to examine their relationship, a simplified evaluation model has been proposed[4]. Both diagnosis accuracy and lifetime distribution are assumed to have a certain dispersion. By changing their relationship, the effects of maintenance strategies (in terms of total loss) can be examined.

Assumption items in this model are as follows:

(i) The lifetime distribution is expressed as a normal function (it is assumed that there are many equipment, and each of them has a certain fixed lifetime. Their distribution forms a normal function).

(ii) There assumes a certain diagnosis method that can estimate the existence life-time of equipment.

(iii) The results of this diagnosis method are distributed as a normal function around the actual lifetime. Its accuracy is expressed by the standard deviation of the function.

With such a diagnosis method, an estimated lifetime distribution corresponding to an actual distribution is obtained as shown in Fig. 3.

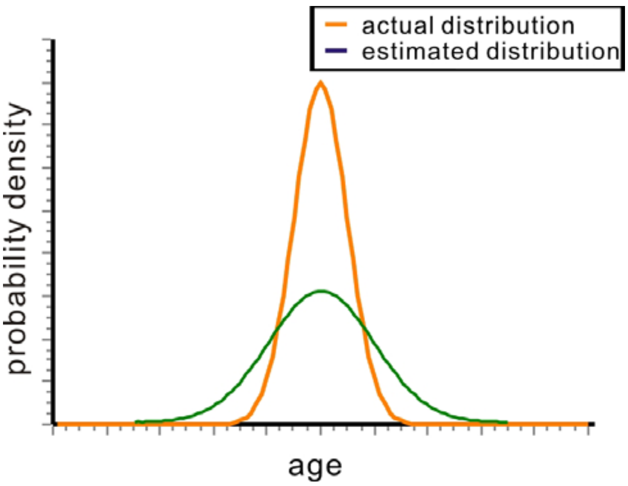

Figure 3: Actual lifetime distribution and distribution estimated by diagnosis

In the diagnosis, several equipment are estimated to have the same lifetime, but their actual lifetimes should be different (some are correct, but others are longer or shorter, as shown in Fig. 4). This causes a mistake in the diagnosis, and economic loss occurs if a certain maintenance strategy (renewal or successive use) is employed in accordance with the result.

In order to estimate such a loss quantitatively, the method of diagnosis should be specified. In this article, it is assumed that the diagnosis is performed for equipment with a certain specified age, and it is estimated whether the equipment can operate until the next diagnosis (its period is specified). There is a possibility, some equipment evaluated to remain operational fails before the next diagnosis. In contrast, some equipment evaluated to fail actually have a sufficient lifetime. These losses should be estimated as total losses.

In this article, the following parameters are adopted.

Equipment: mean lifetime 50 years, standard deviation 5, 10, 20, 30, 100 years, installation cost 1, failure cost 10

Diagnosis: cost 0.01, standard deviation of results (accuracy) 0.5, 5, 10, 20, 30, 100 years, successive use guaranteed for 5 years

For example, if the diagnosis is performed for equipment with an age of 20 years, an estimated lifetime distribution is obtained as shown in Fig. 5 (some equipment are estimated to have a shorter lifetime than 20 years; these results are added to the group with the age of 20 years). Generally, the diagnosis value cannot be accepted directly. In particular, in this case, the results form a normal function distribution around the correct value. A safety factor that is subtracted from the diagnosis value should be introduced, which is estimated as shown in Fig. 6. Corresponding to the accuracy of diagnosis, appropriate values of the safety factor should be selected.

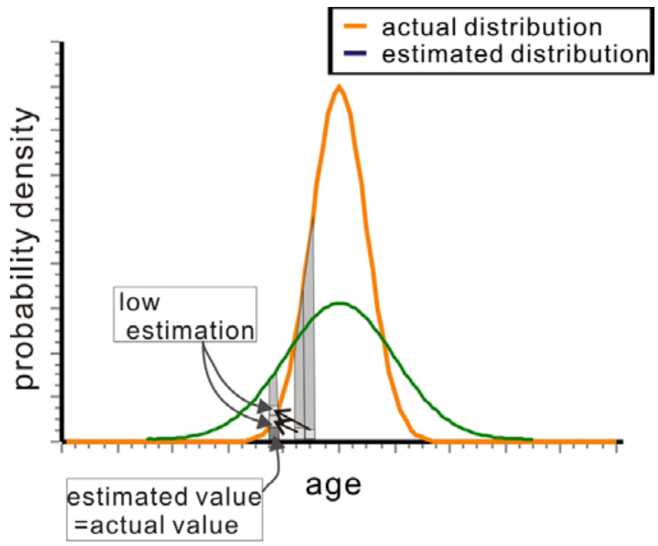

Figure 4: Relation between estimated lifetime of each equipment and correct lifetime

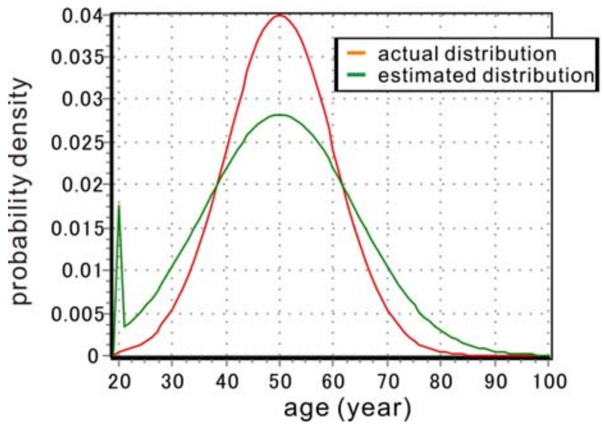

Figure 5: Example of lifetime estimation for equipment with an age of 20 years

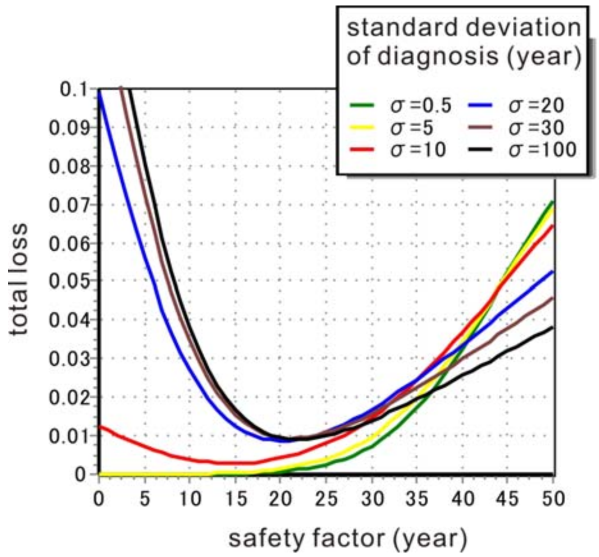

Figure 6: Example of safety factor estimation

In Fig. 6, it is obvious that higher accuracy results in a lower total loss, but its merit also depends on the lifetime distribution of equipment. For example, for case of 20-years-old equipment being diagnosed with an accuracy of 10 years, the average decrease of loss relative to CM (corrective maintenance, i.e., successive use until failure) is estimated from the standard deviation of the lifetime distribution, as shown in Fig. 7. The loss reduction effects strongly depend on the lifetime distribution. In the case of equipment with an age of 10 years, the same estimation is shown in Fig. 8. In the case of an age of 60 years, which is older than the mean lifetime of the equipment, the result is shown in Fig. 9.

In order to discuss the merit of diagnosis, not only the technique itself, but also the lifetime distribution of the target equipment should be examined. It is possible to estimate a merit of a diagnosis technique by such simple model as shown in this article.

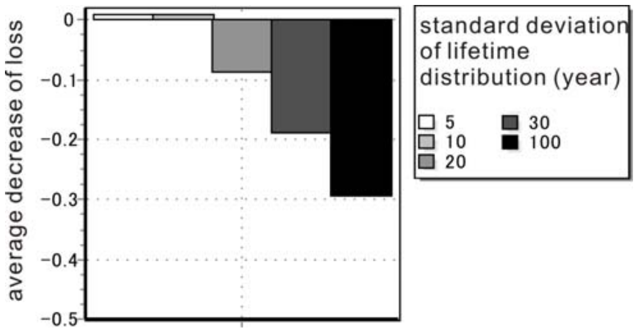

Figure 7: Estimation example of average decrease of loss relative to CM (equipment age: 20 years)

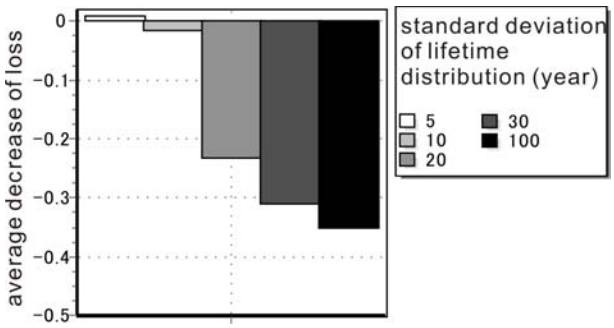

Figure 8: Estimation example of average decrease of loss relative to CM (equipment age: 10 years)

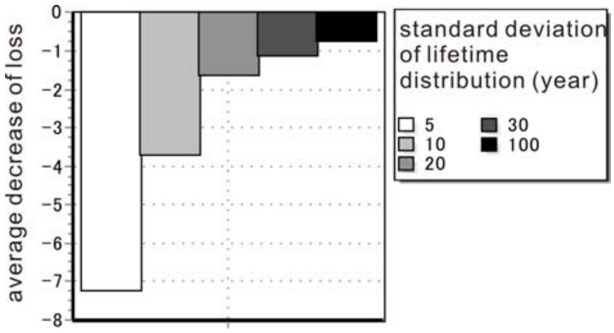

Figure 9: Estimation example of average decrease of loss relative to CM (equipment age: 60 years)

4 CONCLUSION

Asset management support programs for practical use are being developed at CRIEPI. Two programs, one for GIS and one for overhead transmission lines, have been presented in this article. They are based on the evaluation of average maintenance cost and can be used to consider a partial renewal strategy. Investigations of their actual application, including the collection of actual maintenance data, and the development of other frames (programs) corresponding to other electric power equipment will be carried out in future. Moreover, the merit of diagnosis in maintenance strategies has been examined by a simple model. To discuss the merit, not only the diagnosis technique itself but also lifetime distribution of the target equipment should be examined. Such estimation is also important for the investigation of diagnosis methods.

5 REFERENCES

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