IMPACT OF RISKS AS A PART OF ASSET MANAGEMENT ON MAINTENANCE TASK ALLOCATION

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ABSTRACT

This paper presents an asset management approach to momentary failure risk analysis in the Greater Tehran Electricity Distribution Company (GTEDC). Two different risk factors which address technical risk as well as network reliability risk are evaluated. Subsequently, different maintenance decision scenarios are proposed, considering risk priorities.

INTRODUCTION

The essential concept of asset management is trade-off between risk and return. Management of distribution assets, however, are more complicated for a variety of reasons: they require maintenance and replacement, and they are parts of a large complex interconnected system [1].

As deregulation changes the mindset of utilities to plan for maximum performance, minimum risk and minimum cost alternatives, asset management aligns different plans, in a way to response deregulation requirements. In other words, asset management seeks to find an optimal overall solution. According to [2], the process of asset management is confirmed by the whole set of both technical and managerial activities, and not a single one. The technical aspects are basically included in operation and maintenance activities.

The scope of this paper has been limited to a technical aspect of the asset management, which has been implemented in the *Greater Tehran Electricity Distribution Company* (GTEDC) that operates the distribution network of *The Greater Tehran*, the capital city of Iran.

This paper first gives an explanation of the reliability assessment and risk evaluation. It further represents the impact of risks on maintenance task allocation.

ASSET MANAGEMENT: TECHNICAL VIEW

Although asset management includes various operating activities among the utilities, the method proposed here is based on network reliability evaluation. As we can in Fig. 1, the procedure starts with data mining in fault statistics based on historical outage recorded data. Because of the electric distribution characteristics it is often essential utilizing expert judgements to provide valid supports in decision making process. These two methods, together, lead to potential risks identification as well as failure modes extraction.

Subsequently, the process will continue by tradeoffs between financial equipments and risk aspects in a decision making concept. Various controlling actions include operation or maintenance planning would be applied to enhance prospective performance of the network. Moreover, improving outage management systems including the outage reporting procedure or the data base abilities would supplement the enhancement attempts.

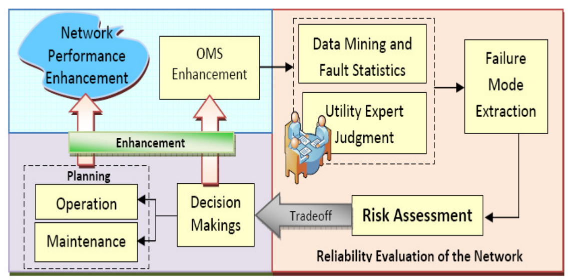

Figure 1. Risk assessment in planning.

Within asset management decision makings, distribution companies develop strategies for maintenance and reinvestments to balance risks and cost effectiveness.

From the individual component point of view, failure risks, cost-benefit tradeoffs, and consequently maintenance action allocations are completely aligned with each other. The decision making procedure starts with developing failure models for an individual component, extracting a mathematical formulation that links component reliability and maintenance actions, evaluation failure reduction for each maintenance action, and subsequently trade-offs for an optimum decision achievement.

The procedure, however, is not the same for the network risk assessments (system point of view). That is, maintenance allocation based on higher failure risks would not necessarily lead to better network reliability. In other words, failure/technical risk-based maintenance and reliability-based maintenance actions are not exactly in align with each other from the network asset management perspective. This context, however, should not be a source of confusion in a way that we found them in conflict with each other. As a result, both aspects should be considered in cost-benefit tradeoffs. This paper is aimed at addressing effects of different risk considerations in an asset management procedure.

RELIABILITY EVALUATION PROCESS

The reliability evaluation is the first step in preventive maintenance decision making. Moreover, within the evaluations a better imagination of the hidden realities of unobserved operating conditions will achieved.

Outage Management System of the GTEDC

The GTEDC operates the distribution network of The Greater Tehran, the capital of Iran. It is the largest electric utility in the country. As a metropolis, the GTEDC's service area includes varieties of sensitive loads as industrial, governmental and commercial that needs acceptable reliability considerations. Furthermore, many factors negatively affect reliability indices, such as: load density, various consumption patterns, heavy rush hour traffic. Therefore, developing more efficient methods of reliability evaluations would give more realistic images of the network performance.

Electric Network Operating eXpert (ENOX™) is the home-developed outage management database in the GTEDC. ENOX™ reporting system includes various statistics of fault or outage occurrence as well as substation loading information, which is classified based on voltage level and network structure (overhead lines or underground cables).

Like other outage management systems, it records various fields of fault data and outage information, including almost fifteen items: event description, fault location and circuit ID, failed component, failure cause, repair duration, weather situation, etc.

Fault Data Analysis

Analysis of the historical fault data indicates on dominated effects of momentary failures, among all failure types on overhead medium voltage lines. Fig. 2 shows the contribution of the average of annual energy not supplied due to different failure types in the GTEDC network area. As a result, the momentary failure is considered in this study.

Momentary failure Risks

Because of the unknown nature of the momentary failure –as a consequence of unknown and stochastic causes–, the procedure of identification momentary failure causes was based on expert judgment approach, in which various experiences of network operators, SCADA experts, and repair crew were utilized. Consequently, most probable momentary failure causes were classified in two different classes, as: *Poor Network Design and Installation,* and *Inappropriate Operation Condition.* Each class consists of number of subsets which is illustrated in Fig. 3, as the momentary failure modes.

RISK ANALYSIS

140 overhead MV feeders are selected as the samples for the momentary risk analysis. The samples are classified into six different classes. These classes are based on the momentary modes, as:

- *Class 1*: Feeders with high load density.
- *Class 2*: Feeders with inappropriate line sag and span length.
- *Class 3*: Feeders with insufficient preventive maintenance and tree trimming.
- *Class 4*: Old feeders.
- *Class 5*: Feeders including combination of features.
- *Class 6*: Feeders in acceptable situation.

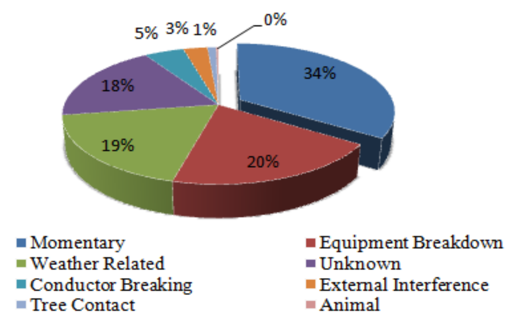

Figure 2. Contribution of the average of annual energy not supplied due to different failure types in the GTEDC network area.

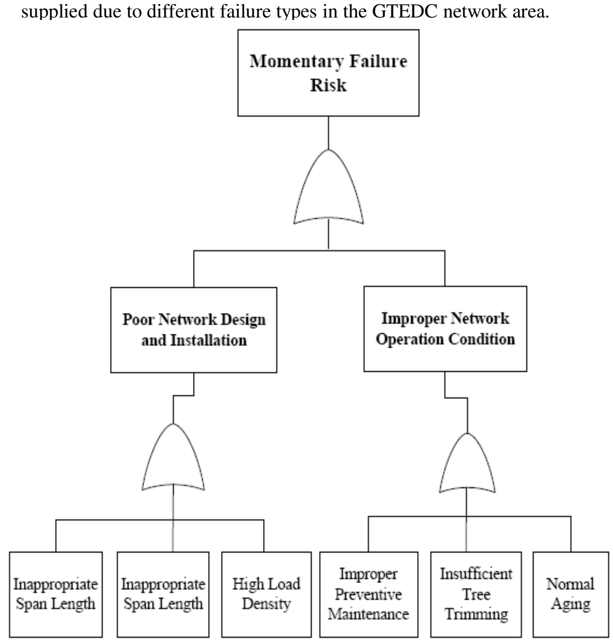

Figure 3. Fault tree model of the momentary failure risk study.

Each feeder is allocated to the most appropriate class, according to its momentary failure exposed situation through each momentary failure mode (using historical operation data and utility expert judgments). The average annual momentary failure of and the standard deviation (S.D.) of each class are determined using (1) and (2):

$$\overline{\lambda}_{mci} = \frac{\sum_{j=1}^{n} \lambda_{mj}}{n} \qquad (1)$$

$$S.D.=\sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(\lambda_{mj}-\mu\right)^{2}} \qquad (2)$$

Where $\bar{\lambda}_{mci}$, *n,* and μ is respectively the mean of average annual momentary failure, the number of samples, and the expected value in *i-th* class.

The value of the trimmed mean of the average annual momentary failure and the standard deviation (S.D.) are illustrated in Table I. According to Table I, the 2nd class (i.e. inappropriate line sag and span length) tends to be the major causes of the momentary failures. Thus, the highest momentary failure rate belongs to this class –comparing the average momentary failures of the classes 1-4 in Table I–. Ranking of the first four classes can be followed by insufficient preventive maintenance and tree trimming activities as the second place, and high load density and old feeders, respectively, in the third and fourth places. However, it is rational that the highest momentary failure rate among all classes belongs to the 5th class (i.e. combination of features).

Fig 4 ranks the classes based on the annual average momentary failure rate. All feeders that are exposed to the combination of the features (i.e. class 5) are the most problematic parts of the GTEDC's network. Almost all of these feeders are old feeders, and the source of their problems are derived from either design and installation parameters including load density and inappropriate line sag and span length, or operation parameters such as insufficient preventive maintenance and tree trimming. Consequently, the average annual momentary failure rate of this class is significantly higher than others (almost twice more than class 2, according to Table I).

As expected, the sixth class; feeders in acceptable situation, have the lowest failure rate among others. These results, again, emphasize on the considerable negative effects of the weak features on failure occurrence.

This part is aimed at addressing how different aspects of risk affect asset management and maintenance decision makings. Two different risk factors, including technical and reliability risk factors are defined to state this claim. Here the energy not supplied (ENS) index is utilized to address the network reliability issue. Considering the 6th class as the base class, we define the following factors as (3) and (4):

$$TRF_i=\frac{Average\,Momentary\,Failure\,Rate\,in\,the\,ith\,Class}{Average\,Momentary\,Failure\,Rate\,in\,the\,Base\,Class} \qquad (3)$$

$$RRF_i=\frac{Corresponding\,ENS\,Due\,to\,the\,ith\,Class}{ENS\,Due\,to\,the\,Base\,Class} \qquad (4)$$

Where TRF_i and RRF_i denotes technical risk factors and reliability risk factors of the *i-th* class, respectively.

Risk evaluation based on these two factors is fascinating, since it indicates differences between individual component and network risk assessments. Table II shows the TRF and RRF corresponding to each class. According to Table II, FRF and RRF trends vary differently among the classes. That is, the higher TRF in a class may not necessarily lead to the higher RRF. Fig 5 compares the trends of both risk factors. According to Fig 6, the trends of both risk factors from C6 to C4, and from C3 to C2 change in conflict with the whole trends directions.

TABLE I.
THE TRIMMED MEAN AND THE STANDARD DEVIATION OF THE CLASSES.

Class No.	**Trimmed mean of average momentary failures**	**S. D.**
Class 1: Feeders with high load density.	2.4	2.2
Class 2: Feeders with inappropriate line sag and span length.	4.41	3.9
Class 3: Feeders with insufficient preventive maintenance and tree trimming activities.	3.21	2.7
Class 4: Old feeders.	2	1.5
Class 5: Feeders including combination of features.	8.2	5.6
Class 6: Feeders in acceptable situation.	1.66	1.2

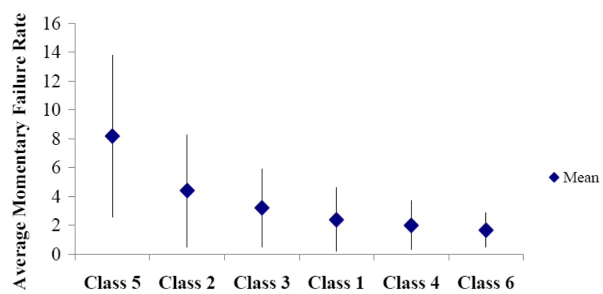

Figure 4. Ranking the classes based on the annual average momentary failure rate.

TABLE II. *TRF* AND *RRF* CORRESPONDING TO EACH CLASS.

Class No.	Average Momentary Failure Correspond to the ith Class	Failure Risk	Average ENS Due to the ith Class (MWh)	Reliability Risk
C1	2.4	1.45	10.56	1.76
C2	4.41	2.66	21.169	3.53
C3	3.21	1.93	47.5	7.92
C4	2	1.2	4	0.7
C5	8.2	4.94	114.8	19.13
C6 Base)	1.66	1	6	1

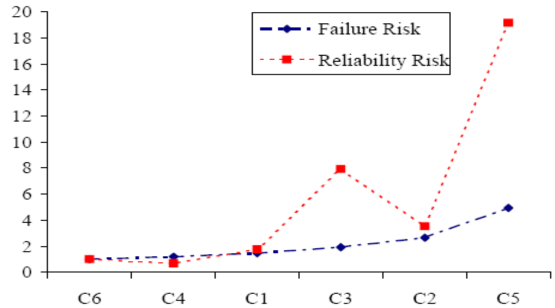

Figure 5. Trends of risk factors.

Maintenance Decision Allocation

The proposed method makes a transparent decision process for the asset manager. More detailed aspects would be considered in maintenance task allocation trade offs, as the maintenance action would be the fuction of two risk factors (TRF and RRF), as well as the cost (Eq. (5)).

$$Maintenance\ Action = f\left(TRF, RRF, Cost\right) \qquad (5)$$

Fig 6 depicts the location of the classes in a two-dimentional risk space, the horizontal and the vertical axis represent respectively the failure and reliability risks (TRF and RRF), respectively. Fig 6 illustrate the states of each momentary failure class versus enhancing each risk factor by 50% and 30%. According to Fig 6 , the 5^{th} class (feeders including combination features) is considerable from the both risk aspects, while it is not the same for the 3^{rd} and 2^{nd} class; i.e. feeders with insufficient preventive maintenance and tree trimming activities, and feeders with inappropriate line sag and span length.

Therefore, the asset manager has variuos alternatives based on different maintenance scenarios. For instance, in a scenario for enhncement by 50%, that network reliability has the highest priority, the alternative of the 3^{rd} class enhancement (i.e. scheduled preventive maintenance and tree trimming enhancement) is preferable during cost-benefit trade offs in comparison with the 2^{nd} class enhancement (i.e. line sag and span length enhancement). However, numbers of imposed failures due to the 2^{nd} class is more than the 3^{rd} one.

The priority of enhancement decisions depend on the amount of investigations as well. For instance, in network enhancement by 30% with reliability risks considerations, the enhancement cenario would focus on 1^{st} class improvement. While, in enhancement by 50%, the 3^{rd} class outweights.

Furthermore, developing an optimum plan for maintenance actions in which all three risk aspects (i.e. technical, reliability, and cost) are applied in decision making tradeoffs, need to be considered, and the authors are working on it as the future work of this study.

CONCLUSION

Momentary failure risk analysis of the GTEDC network operation was addressed in this paper. Different aspects of risk (including technical risk and reliability risk) were considered for maintenance decision allocation.

The method proposed here made a transparent process for the asset manager. The results indicate on significant differences considering an individual component during asset management toward whole network considerations.

In future, as the next phase of this study we are going to develop an optimum maintenance plan in which all aspects of risk would be applied for the prospective decision action.

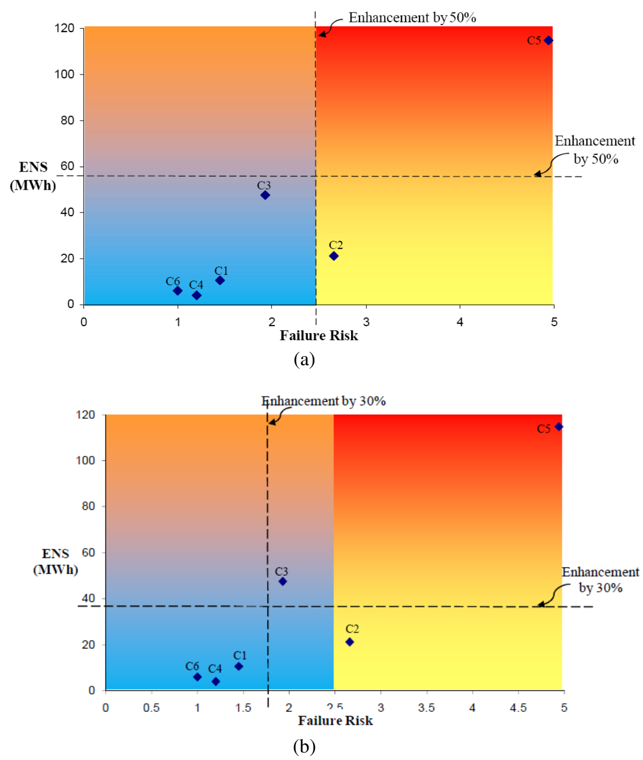

Figure 6. Location of each class in the risk space, (a) enhancement by 50%, (b) enhancement by (30%)

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