THE APPLICATION OF RELIABILITFY METHODOLOGY TO SELECT AND PRIORITISE ESKOM DISTRIBUTION NETWORKS

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ABSTRACT

This paper describes a proposed reliability decision-making process to identify networks that require investment within Southern Africa. The approach identifies which distribution networks what require investment to improve reliability in support of national reliability targets and inceptives. This will enable the planner to compare the reliability improvements and this paper proposes a process to select the preferred alternative.

INTRODUCTION

A number of publications consider customer interruption costs as a selection criterion [1-6]. The paper focuses on the application of benefit to cost analysis for distribution networks when performing comparative analysis on the different network reliability improvement alternatives evaluated by the network planner [7-9]. The lack of credible data concerning loading, load forecasting, equipment reliability and customer interruption cost has hindered engineers in making decisions based on the energy not supplied index for Eskom Distribution [10].

The steps to evaluate reliability improvement alternatives are as follows:

1. Identify networks for reliability improvement
2. Ranking networks
3. Reliability Assessment
4. Perform Benefit to Cost Analysis
5. Compare with Network performance target
6. Compare selected alternatives with the hurdle rates
7. Initiate investment projects

This method enhances the comparison of the selected alternatives, which enables the prioritisation of alternatives. This method considers the inherent benefit derived by the reliability improvement alternatives using performance indices (SAIDI).

METHOD

The proposed method is to select networks a planner is able to focus their efforts based on the history performance of the network due to the limitation of funding, where the investment would best benefit for those funds. Hence ranking alternatives on B/C is appropriate with the limitation of budget. There are other factors such as environmental impact, technical losses, lead-time etc that also need to be taken into consideration but are not discussed in this paper.

The relative results of the alternatives are compared with minimum reliability criteria prescribed by the Network Planning reliability philosophy. This minimum reliability criterion serves as a trigger for further investigation of the existing performance and network configuration to improve overall reliability. Figure 1 illustrates the process and the main features of this method; identification of networks, reliability assessment, comparative analysis to select the investment alternative to improve the existing continuity of supply.

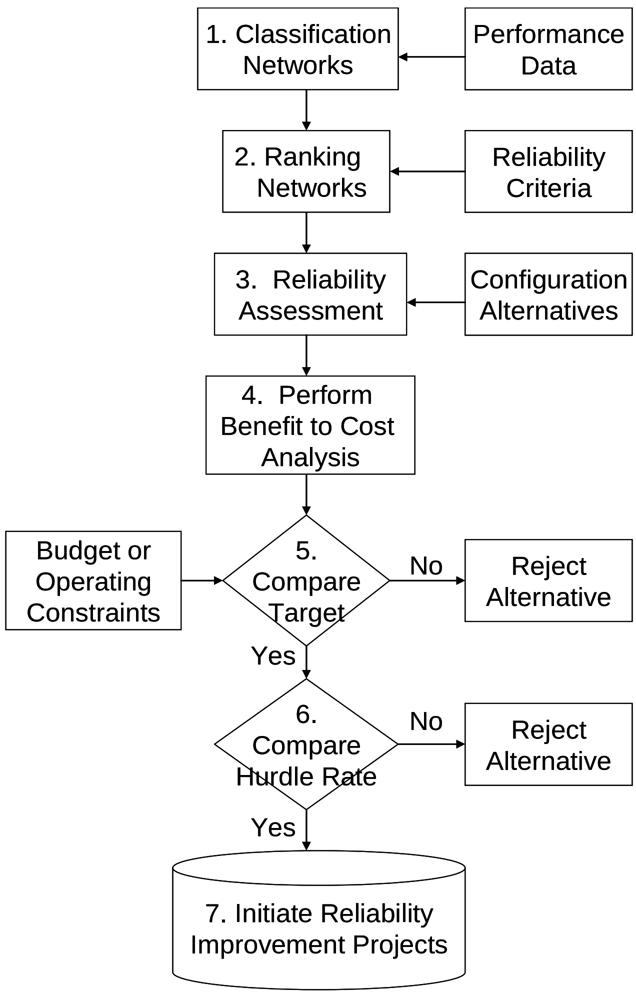

Figure 1: Reliability Decision Making Process

INDENTIFICATION OF NETWORKS

The critical part of the process is the identification of networks to improve continuity of supply. In stage 2, these networks are analysed in detail, with the purpose of ranking the networks based on certain reliability criteria.

Classification of Networks

The classification of networks is dependent on the existing performance of theses networks as illustrated in Figure 2. The National Electricity Regulator of South Africa (NERSA) has decided to introduce SAIDI as a quality regulation mechanism for South African utilities [11]. The simplification of SAIDI is the multiplication of CAIDI and SAIFI. A scatter plot of these performance indices is a representation of SAIDI as illustrated in Figure 2. CAIDI is representative of networks that will require investigation by the planner because one of the major factors that influence the duration of restoration is the configuration of networks The classification of networks is categorised into three groups of networks,

1. Green Networks: These networks do not require any investment. Boundaries are defined by regional gatekeepers of 3 and 20 for CAIDI and SAIFI respectively as illustrated in Figure 2.
2. Red Networks: These networks require immediate investigation to improve the continuity of supply. The networks are compared to the overall regional target defined by a SAIDI of 50 hours.
3. Orange Networks: The area between the green and red boundaries will define orange networks on the CAIDI (y-axis) and SAIFI (x-axis).

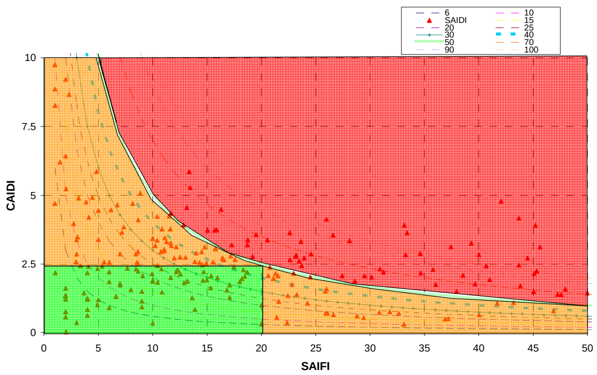

Figure 2: Classification of Networks

Ranking Networks

The networks that have been classified are further sorted to rank the importance in relationship to their inherent network characteristics (e.g. number of customer per network). The criterion to sort these networks is determined by the planning reliability criteria as denoted below:

1. Classification of Networks;
2. Number of Customers connected to the feeder,
3. If network exceeds the regional performance target and
4. Total line length of the network

EVALUATION PROCESS

The third stage is the evaluation of different network alternative by performing reliability assessment..

Reliability Assessment

Reliability Assessment enables an engineer to transform knowledge of network (λ - failures/yr and r – hrs/failure) into a "prediction" of its likely future behavior based on different network configuration alternatives evaluated by the planner [1]. A quantitative reliability analysis is an important input parameter to improve the reliability decision-making process for the management of the reliability constraints of existing and future networks. Typical equipment reliability data (obtained from published literature) can be used to facilitate the comparative analyses between different expansion or design alternatives within the planning phase of a project [1, 12].

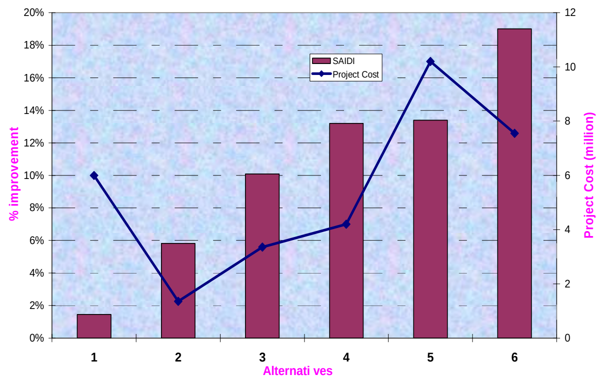

Figure 3: Reliability Assessment of alternatives

Figure 3 illustrates a case study results where the relative percentage improvement in SAIDI (y-axis on right in relative %) and capital cost (y-axis on left in R millions) required to achieve this improvement is represented for different alternatives. Alternative 6 is initially the preferred alternative because it achieves the largest improvement of almost 20% from base case. The selection of the preferred alternative is not obvious as other consideration such as capital cost have not yet been included. The technique to select the preferred alternative is based on benefit to cost analysis and will be discussed further in the next stage of the reliability decision-making process.

SELECTING PREFERRED ALTERNATIVES

The next stage of the reliability decision-making process is the selection of the preferred alternative based on the Benefit to Cost (B/C) analysis and comparative analysis.

Perform Benefit to Cost Analysis

This is a commonly used method of estimating the relative benefit based on the incremental capital cost required to improve the continuity of supply. Unlike Expected Cost (ECOST) estimation of reliability worth, B/C analysis is concerned with the relative improvement in SAIDI of the different expansion alternatives, and not the customer interruption costs [3-4]. The B/C analysis is denoted by the expression below [7,13]:

$$B/C = \frac{Benefit}{Incremental\ Cost} \quad (1)$$

The B/C analysis principle enables the planner to reject or accept reliability improvement projects. It is however, very useful together with NPV in the prioritisation of capital budgets due to budget constraints [7, 13]. It is clear from Figure 4 that when considering the benefits and capital cost required, alternative 6 is not the preferred alternative and rather alternative 2 is preferred.

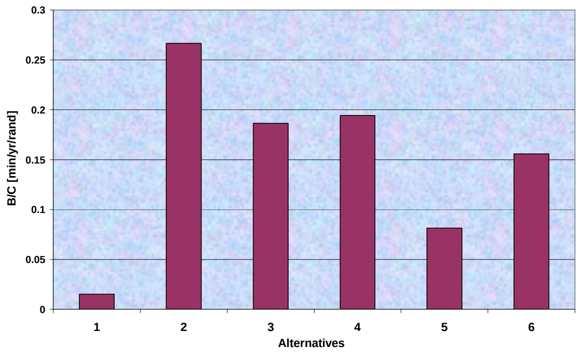

Figure 4: Benefit to Cost Analysis

Compare results with Target:

Figure 5, represents a bar chart with the improvement achieved by the configuration alternatives and line chart represents the benefit to cost analysis results. Comparing the improvement and B/C results it is imperative to relate each alternative to the desired improvement required for the network in order to align with national targets. Thus, a qualitative analysis of the Pros and Cons may result in the selection of alternatives, which do not have a high B/C but have a higher SAIDI improvement. Figure 5, illustrates that alternative 3, 4 and 6 are desirable when considering the reliability improvement target and benefit to cost analysis. The selection technique finally indicates that alternative 4 is rather the preferred alternative and not 6 nor 2.

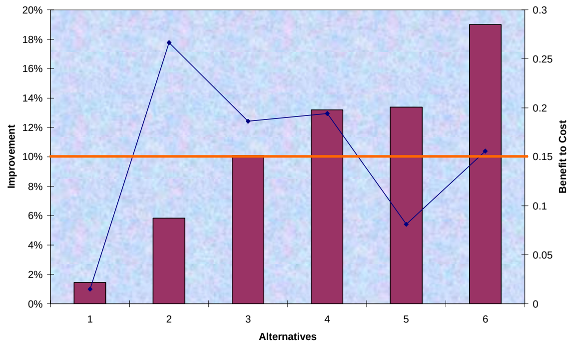

Figure 5: Improvement vs B/C against target improvement

Compare results with Hurdle rate

The final step is to compare the selected alternative against the reliability hurdle rate. The estimation of the hurdle rate is based on the B/C analysis principle. This provides the planner with a single SAIDI/Rand hurdle rate against which to evaluate alternatives.

It is important to translate the incentive / penalty scheme introduced by the NERSA into a single reliability hurdle rate (m_{RHR}) to which the planner is able to compare the investment. When we consider the symmetrical nature of the scheme we are able to derive the tangential line (y = f(x)) required to reduce the scheme into a single m_{RHR} for an investment decision as illustrated in Figure 6.

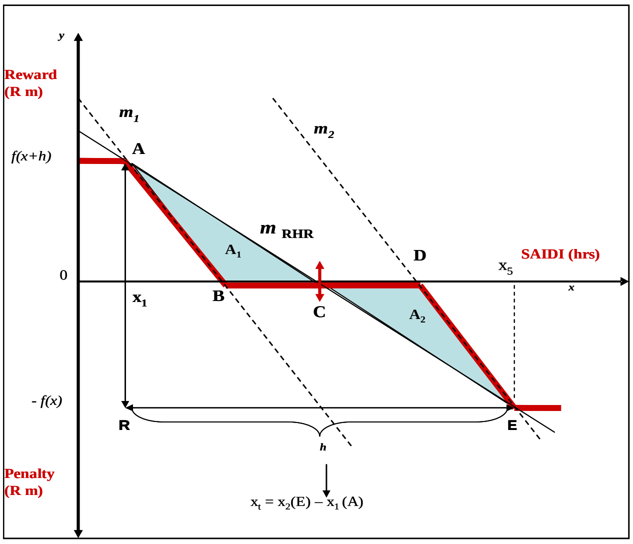

Figure 6: Reliability Hurdle Rate

This single reliability hurdle rate (m_{RHR}) represents an alternative that results in an improvement in SAIDI. However, if the incentive / penalty scheme is asymmetrical in shape, more consideration must be given to the derivation of the single reliability hurdle rate. Expressing in symbolic form we can consider the expression below:

$$m_{RHR} = \frac{f(x+h)-(-f(x))}{h}$$

$$Given:$$

$$A_1 = A_2 \; and \; m_1 = m_2 \qquad \textbf{(2)}$$

It seems reasonable to suppose that if x_5 (SAIDI) were to be improved to x_1 then expression (4), will achieve a maximum reward for the investment decision.

CONCLUSION

The distribution planning core objective is to determine the reliability level (based on customer and network types) for which a planner should plan a distribution network to improve reliability on a system level. The application of Value Based Reliability Planning (VBRP) principles clarify certain aspects required to make reliability-based decisions during the planning and design phase of expansion project [1].

This paper has presented a method for the prioritisation and selection of the preferred alternative for reliability assessment in support of national reliability targets and incentive schemes. The method has been applied to a case study which demonstrated that when comparing alternatives against certain criteria the preferred alternative is not obvious.

The proposed reliability decision making method assists determining which distribution networks requires investment and the preferred alternative to improve reliability.

Acknowledgments

The authors acknowledge Eskom Distribution Technology for the sponsorship of the research, and the role of the Distribution Reliability Assessment Working Group in guiding the reliability development.

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