# Reliability Based Planning Methodology for Feeder Automation

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***Abstract*—One of the most used measures for improving service reliability is distribution automation (DA). The DA technology has been widely used by different utilities for quite some time. Its applicability on the Eskom distribution network is an option but it is still in the research and development stage.**

**This paper proposes a method for a network planning engineer to motivate the use of feeder automation (FA). This methodology will serve as a guideline to a network planner interested in using FA as an alternative or additional solution to improve the reliability of a feeder.**

**The defined method is based on literature and existing research on FA. Furthermore the methodology is analyzed using the Eskom case study. A comparison is made by identifying a pattern of steps or methods followed in planning for *Magaliesburg-Hekpoort feasibility project* and comparing this method with the proposed methodology.**

***Index Terms*— Power system reliability, power distribution, feeder automation, distribution automation.**

## I. INTRODUCTION

In the electric distribution industry, service quality and reliability are of utmost importance. There has been increased pressure on electricity utilities to decrease outage time due to faults.

The System Average Interruption Duration Index (SAIDI) is commonly used as a reliability indicator by electric power utilities. SAIDI is the average outage duration for each customer served, and is calculated as:

$$SAIDI = \frac{\sum CustomerInterruptionDurations}{TotalNumberofCustomerServed} = \frac{\sum r_i N_i}{N_T} \quad (1)$$

Where $N_i$ is the number of interrupted customers, $r_i$ is the annual restoration time for interruption event $i$ and $N_T$ is the total number of customers served. In other words,

SAIDI is measured in units of time, often minutes or hours. It is usually measured over the course of a year, and according to the IEEE Standard.

SAIDI forms a sound basis for measuring performance and provides a clearer view of performance, both on a daily basis and during major events. SAIDI can also form a solid basis for the review of operational effectiveness, decision making and policy making and provides a more consistent benchmark [1].

The system average interruption frequency index is designed to give information about the average frequency of sustained interruptions per customer over a predefined area [1].

SAIFI=Total number of customer interruptions/Total number of customers served

$$SAIFI = \frac{\sum NumberofCustomerInterruptions}{TotalNumberofCustomerServed} = \frac{\sum N_i}{N_T} \quad (2)$$

It has been reported that most of the customer service interruptions are due to failures on the medium voltage (MV) electrical distribution network. In order for the electricity delivery industry (EDI) to ensure a reliable electrical network, several solutions such as reducing the lengths of feeders, building back-up feeders and incorporating improved protection systems are applied to MV electrical networks [2].

Currently one of the most used measures for improving service reliability is distribution automation (DA). The DA technology has been widely used by different utilities for quite some time. Its applicability on the Eskom distribution network is still in the research and development stage [3, 4].

DA is defined as an integrated systems concept for MV networks and therefore entails the integration of several technologies. Feeder automation is one of the functions of DA. It entails the use of remote switches to isolate the faults and restore power to the remaining un-faulted sections of the feeder. It is defined and chosen by most utilities as one of the best DA functions for improving the reliability of the feeder [2, 5].

The National Energy Regulator of South Africa has also espoused a reward/penalty system to measure the efficiency of EDI for outage time [6]. Distribution utilities are penalized on time (hrs.) when power is not available to the customers. This has resulted in Eskom being the main distribution utility company to embark on methods aimed at reducing outage time through improving the reliability of the network and consequently improving service delivery.

Eskom has therefore prepared a business case study to test the possibility of implementing FA. The study indicates that the implementation is possible and it can be used as a measure for improving the reliability of the MV network [7].

There is therefore a need to develop a method or guideline to plan for FA.

## II. Problem Statement and Objective

### A. *Problem statement*

From a network planning perspective informed decisions on solutions that will improve the reliability status of the network have to be made. Decisions are based on technically sound, cost effective and sustainable solutions that address a need. It has to ensure that the solution to be implemented will reduce customer exposure to lengthy network faults and thus improve the reliability of the network. In this regard there are methods and guidelines to guide a planner toward the best solution.

There is no guideline or procedure for this new technology to assist a network planning engineer, to plan and motivate the use of FA technology as an alternative solution to the conventional solutions a planning engineer would use for improving the reliability of the network.

There is therefore a need to develop a reliability based planning methodology that will assist and guide a network planning engineer to plan FA, incorporating FA as an optimum alternative solution for improving reliability of the MV network considered.

### B. *Objective*

The objective of this research is to develop a method on how a network planning engineer should motivate for the use of FA. This methodology will serve as a guideline to a network planner interested in using FA as an alternative to conventional planning solutions, like construction of a new feeder or upgrading of the conductor and converting a feeder from 11kV to 22kV to improve the reliability of a feeder. The objective is also to develop a reliability based method intended to assist a planner to best plan and investigate MV networks for the application FA. This methodology will assist network planning engineers to achieve the following:

- To know the key aspect and principles of network and reliability planning that a planning engineer must consider when investigating a feeder for the application of FA, and how to align these principles in a systematic order to substantiate the proposed solution.
- To understand the importance and impact of resource selection (selection of technology to be used) and determine the position of switches, thereby motivating the selection of FA as the applicable solution.

## III. Reliability Based Planning Method for Feeder Automation

The research methodology for this study is based on the Eskom feasibility study for FA and the literature reviews of: (i) FA technology and its operations philosophies; (ii) existing planning methods from different utilities (iii) and power system reliability theory.

The Eskom feasibility study and outcomes thereof are discussed in brief below. The proposed methodology is then presented.

### A. *Eskom distribution automation strategy –Magaliesburg-Heekpot 11kV network feasibility study*

The objective of the project was to design and implement a FA pilot system. The FA systems were commissioned and their impact on the network reliability and availability were monitored to develop a business case for FA technology in Eskom.

The Magaliesburg-Hekpoort 11kV feeder was proposed as the candidate site for the FA pilot system as it is a dense rural feeder with a poorer than average performance. The proposed network was analyzed in terms of the predefined selection criteria for FA systems and it passed all the requirements.

The Magaliesburg-Hekpoort FA system was successfully commissioned on 9 December 2011. The system has operated as expected and the five sustained faults, which occurred during the analyzed period (9 December 2011 – 31 January 2012), were reported. The FA system resulted in significant technical improvements for the analyzed period.

The following summary of results was reported:

- A SADI of 6.4 hrs. was saved over a period of roughly 2 months.
- The Customer Average Interruption Duration Index (CAIDI) of 3.48 hrs with FA was recorded compared to 4.8 CAIDI hrs without FA.
- 3 hrs. 39 min was the average time taken to restore all loads. For the study period the sum of customers that were interrupted with FA was reported to be 228 compared to 429 customers without FA operating on the feeder.

### B. *Network planning principles considered from the Magaliesburg-Heekpoort 11kV network feasibility study*

The following are the key network planning principles that were considered and used as guiding principles for assessing the network for FA.

- Selection criteria that the candidate networks had to meet in order to be considered for the FA feasibility study. These selection criteria considered the following prerequisites :
    - → <u>Network configuration: </u>- network classified as rural/urban or semi, total load ≥ 5 MVA, possibility to interconnect the network to enable back feeding and if the network is cable or overhead.

→ Network location: - to determine how long it will take to attend to the fault and have a safe working environment.

→ Network performance: - performance history and event record should be for a period of at least 3 years and a significant number of permanent faults.

→ Tele control and telecoms: - more than one integrated recloser that is remotely operated and Eskom radio coverage and cellphone coverage.

- *Customer minutes* saved, *number of customers* saved due to automatic restoration of healthy sections of the feeder and *MVA hours* saved are indicators that were considered as factors determining the performance of the Magaliesburg-Hekpoort network with FA technology. They were also used to set the performance targets of the network with and without FA technology.

### C. *Review of the Magaliesburg-Hekpoort FA feasibility study*

From the case study it was noted that there was an approach or methodology used to implement FA. The approach was not a strategic approach or a preliminary defined approach, since the main aim of the case study was to determine the technical and financial feasibility of DA technology. It is apparent that prior to implementing FA technology a lot of planning had to be done, particularly to understand the power system and operational dynamics of the network. This included developing criteria for the selection of feeders suitable for FA implementation, setting targets to determine the performance of the FA solution chosen and selecting indicators to determine how effective the adopted solution is.

The network planning methodology of the Magaliesburg-Hekpoort FA feasibility study is schematically represented in Figure 1 below.

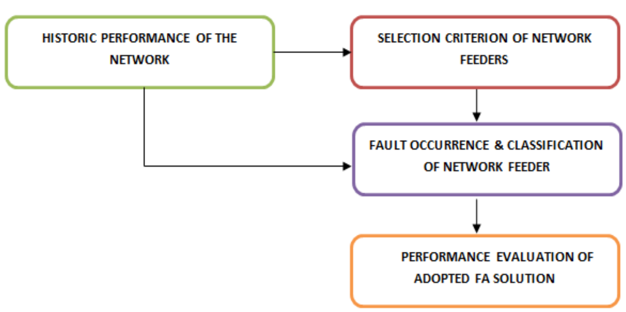


Figure 1. Magaliesburg-Hekpoort network planning methodology for feeder automation

### D. *Proposed reliability based planning method for feeder automation*

The proposed planning method is primarily defined on existing methods used by utilities globally. Research was done to understand how other utilities plan and motivate for FA as preferred solution to improve reliability. References [2, 6, 7, 8] are some of the research papers that were reviewed to define the proposed methodology.

A network planning method can be defined in the scope of automation only, i.e. its focus can be based on the planning of the position of automated switches, tie switches and the number of switches, as these three important factors play a crucial role in proving how the reliability of a distribution feeder can be improved.

However, it is important to consider or incorporate the existing planning criteria into the proposed method as these criteria will assist a network planning engineer to use good judgment.

Figure 2 contains a flow diagram of the proposed methodology.

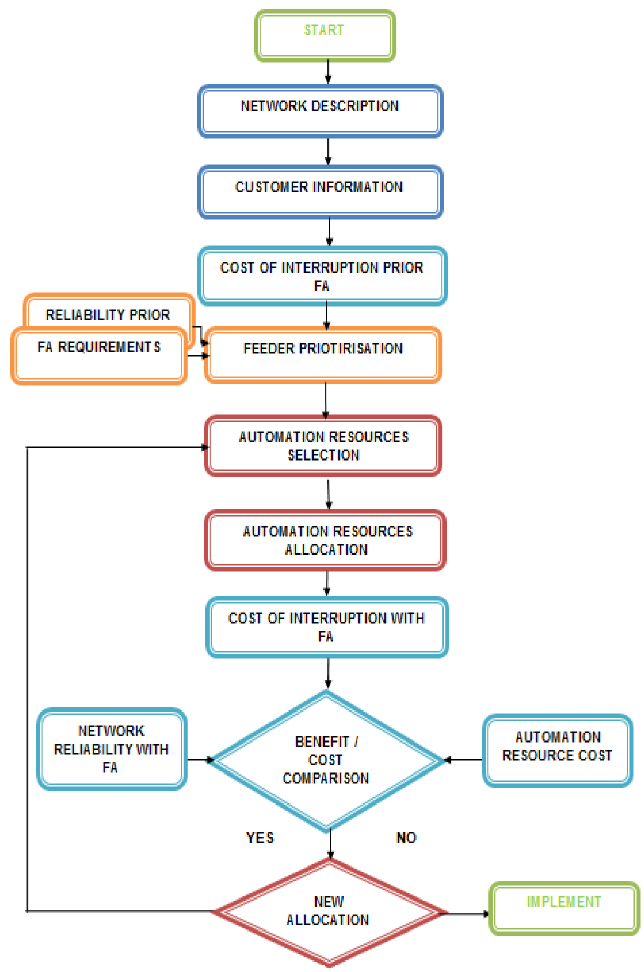


Figure 2. Reliability based planning method for feeder automation

### E. *Building blocks of the proposed method*

- NETWORK DESCRIPTION – This entails the electrical characteristics of the network e.g. (load flow studies, back feeding capacity, load growth etc.) and physical characteristics e.g. (length of the feeder and

T-offs, radial or ring feed, accessibility of the feeder, radio and cellphone signal etc.).

- CUSTOMER INFORMATION – This is information relating to the type of load supplied from the feeder e.g. industrial, residential farming etc. It also entails the position of customers on the feeder and number of customers. This information is essential for understanding that the load is distributed on the feeder, setting performance targets and also to determine the power system reliability indices like SAIDI.
- COST OF INTERRUPTION PRIOR AND RELIABILITY PRIOR – The cost of interruption is a function of outage duration and load type percentages. It determines cost of losing supply due to a faulty feeder. After automating, the feeder cost of the interruption can be separated per section and the cost of interruption due to an outage at a certain section can be calculated for the entire feeder.
- FA REQUIREMENTS AND FEEDER PRIORITISATION – It is not all feeders that will benefit from FA and not all feeders will show a positive investment. Therefore there is a need for feeders to have some characteristics that will ease the implementation and positively reveal the impact of FA.
- AUTOMATION RESOURCE SELECTION – Due to the ability of the feeder to meet the above requirements, it could be determined which FA architecture will be the best to improve the SAIFI and SAIDI of a feeder, as the cost savings and investment returns will also indicate which will be the best architecture to apply.
- AUTOMATION RESOURCE ALLOCATION – Determining the position of sectionalizing switches, automated switches and tie switches on the feeder plays a crucial role for effective usage of FA in locating and isolating faults as well as restoring power to healthy sections of the feeder.

## IV. The Analyses of Distribution FA planning Methodology

In feeder prioritization it was suggested that to fully come to a conclusion or be able to select the suitable feeder for FA, data on the physical and electrical problems of the network, the number and type of customers on the network, the cost of interruption, the performance of the network in terms of the targeted SAIDI and SAIFI, and readiness of the feeder for implementation of automation need to be critically analyzed. Based on the findings one can motivate the use of FA to archive or solve related problems and also decide to what extent FA can be applied. For example, full or semi automation of sectionalizing switches.

SELECTION CRITERIA OF NETWORK FEEDERS suggest that to select a suitable feeder for FA, data on Network Configuration (which involves classification of customers' type, electrical load on the feeder and the ability to interconnect physically or back feed from other feeders), Network Location (which concerns the geographical position of the feeder) Network Performance (which concerns the type of faults i.e. permanent or temporary faults, the number of switches to be used and as well fault distribution which will determine the position for switches) and Telecommunication (which entails the ease of FA functioning due to enough cell phone and radio coverage as well the financial ease of implementing FA because of some existing equipment) must be readily available.

AUTOMATION RESOURCES LOCATION: This suggests that to find the optimum location or position for sectionalizing switches, automated switches and tie switches the following can be used as guiding factors: possible fault paths, load distribution on the feeder, SAIDI and SAIFI and customer cost of interruption. The Eskom planning methodology for FA, pre-defined above, suggests the use of fault occurrence i.e. knowing where most faults occur on a feeder and classification of faults i.e. looking specifically at the type of faults occurring on a feeder. Looking at the two criteria above, it could be noticed that they are completely different. Therefore based on the principles each criterion presents, it is clear that they will reveal different results if they are applied on the same feeder. Although they can be used together, it is suggested that only classification of faults should be assessed to be the proposed guiding factor.

This is the crucial part of the methodology as finding the optimum position for switches will demonstrate the benefit of using FA technology and determine the extent to which SAIDI and SAIFI will be improved. It is therefore very important to apply the FA planning methodology to demonstrate its effectiveness.

COMPARISON OF EVALUATION CRITERIA. The Reliability Based Planning Methodology (RBPM) for FA planning methodology suggests that for evaluating the performance of FA, cost of interruption with FA, cost of automation resources and network reliability with FA must be evaluated. Therefore SAIDI and SAIFI will be compared to the cost of resources used. The cost of interruptions with FA will then be compared to the cost of automation resources.

From the Eskom Magaliesburg-Hekpoort case study the following were considered for evaluating the performance:

a) Customer minutes saved.

b) Number of customer interruptions saved due to the automatic restoration of the healthy sections of the feeder.

c) MVA hours saved.

The FA planning methodology measures its strategy for performance evaluation against the cost of the benefit and the cost of penalties saved, while the Eskom case study focuses mostly on the time it takes to restore the supply to customers and the number of customer interruptions saved.

Incorporating the Eskom performance and evaluation criterion into FA planning methodology will give the latter more results and improved effectiveness on evaluating the performance, benefits and cost of the FA planning methodology, because it is important to consider the benefits of customers as the end users.

## V. Discussion and Conclusion

The aim of the study was to develop a planning method for distribution FA intended to assist a planner to know how to best plan or what to consider in planning for improving reliability of the network using FA.

This was achieved through reviewing the literature on existing planning methods, ideas and case studies for the application of FA. The literature reviewed was also used to define the proposed methodology. Furthermore the Eskom Magaliesburg-Hekpoort case study was discussed. It was noted from the case study that there were some of the network planning aspects considered during the planning stage of the case study. This led to the definition of Magaliesburg-Hekpoort network planning methodology for feeder automation. The following key factors were noted:

- Historic Performance of the network: - entail the past performance of the network based on faults experienced. The data collected was used understand all issues and configuration of the network.

- Selection and assessment of feeders: - entail the requirements required for implementing FA. These requirements were used for selecting feeders.

- Fault classification and occurrence: - entail knowing the distribution of faults on the feeder. The data was utilised for determining the position of switches.

- Evaluation of implemented FA solution: - entail evaluating the adopted solution. Customer minutes saved, number of customer interruptions saved and MVA hours saved, were the indicators used for assessment.

The proposed method highlights three important aspects to consider when planning for FA. These are:

- Selecting feeders suitable for FA technology application.

- Knowing the principles of network and reliability planning that a planning engineer must consider when investigating a feeder for the application of FA.

- Understanding the importance and impact of resource selection (selection of technology to be used) and the determination of the position of switches.

The Reliability Based Planning Method needs to be tested by performing the defined steps, so to demonstrate how practical it is, in assisting a planning engineer to motivate for the use of feeder automation.

Furthermore It is very important to understand that the resources i.e. software, that will be used to implement some of the steps of the method will play an important role in demonstrating the effectiveness of the method.

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