OPTIMIZATION OF RECLOSER METHODS ON MEDIUM VOLTAGE DISTRIBUTION NETWORKS

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ABSTRACT

Reassessing methods within a business is important as it can prove certain concepts could indeed work, improve current methods and reinforces knowledge to the assessors. The utility's (Eskom) recloser placement methodology mainly focuses on improving their performance figures and reaching their performance targets and does not focus on the financial aspect of their methods. The purpose of this paper is to present a method that will optimize the placement of reclosers on medium voltage distribution networks. Eskom can by focusing on the financial aspects of the recloser placements, benefit by improving performance as well as saving money at the same time, especially during fault conditions. A cost-benefit analyses methodology is applied where data is derived from a medium voltage distribution network in the Free State that serves more than 2000 customers. The number of reclosers and the placement of them will be determined by using matrix tables and formulas. Data was extracted from the utility record systems. The findings suggested that a recloser can pay itself back within one year using this method. In order to make an informed decision as to the placing of a recloser on a medium voltage distribution network, it is recommended to use the proposed method. The proposed method will assist in the decision as to the viability of placing a recloser on a specific pole location. Future studies may be done by combining recloser placement methods with other protection sensing equipment like fault path indicators and current-voltage monitoring systems to isolate and find faults.

KEYWORDS

Recloser, Placement methodology, Medium voltage distribution networks.

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1. INTRODUCTION

"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it" (Harrington, n.d.). These words by H. James Harrington (n.d.) is true as it all starts by measuring.

Measurement can be defined as a process of empirical, objective assignment of symbols to attributes of objects and events of the real world, in such a way as to describe them. Strongly defined measurement is a measurement that conforms to the paradigm of the physical sciences (Finkelstein, 2003).

The South African utility company Eskom is currently in financial difficulties, thus looking into the financial importance of decision making is becoming more important. Reclosers on electrical networks are essential protection devices. Deciding on how many and where to place them on the networks makes all the difference (Thomas et al., 2019). The utilities current method to decide on the number and placement of reclosers, focusses on the network lengths and number of customers. The utility does not consider the financial importance when deciding on the number of reclosers and placements of them.

The importance of this process is to prove that a concept of other methodologies can indeed work. The purpose of this paper is to present a method that will optimize the placement of reclosers on medium voltage distribution networks. A cost-benefit analyses methodology is applied where data is derived from a medium voltage distribution network in Free State serving over 2000 customers. The paper firstly commences with a brief discussion of the concept "recloser" and placement thereof. In the setup section a flowchart was used to explain the setup, then the research site was discussed explaining in more detail the network used, then in the methodology section the method used was explained in more detail and that was followed by the results and the conclusions.

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2. METHODOLOGY

2.1. RECLOSER PLACEMENT METHODOLOGIES

When considering the placement of reclosers, the term recloser can be defined as an automatic circuit breaker that clears transient faults and isolates permanent faults and is placed on an overhead medium voltage distribution network (Tavrida Electric, n.d.). The reach or zone of a recloser is defined as a section of a power network that the recloser operates in , while protection devices outside the reach or zone will operate before the recloser (Azari, Chitsazan, & Niazazari, 2017). Before reclosers were available, overhead networks were protected by indoor circuit breakers at the source transformer and thus, the tripping of the breaker due to a fault affected many customers. A two-shot auto-reclosing scheme was introduced on source breakers in order to reduce the loss of supply, but the disadvantage was that a large number of customers were disconnected when a transient fault occurred. This lead to the development of special circuit breakers, which were the forerunners of the modern auto-reclosers of today (Ennis, Clarke, & Stewart, 1994).

Consider just the term “recloser placement“ a Google Scholar search for this term reveals some 3290 results. Performing a more advanced search reveals that 1420 results were found in the last five years alone, showing that studies are still being compiled, which indicates the importance of the topic in the electrical industry of today.

By optimizing the placement of reclosers on medium voltage distribution networks, the reliability and performance of networks can be improved as well as saving money at the same time, especially during fault conditions. This may be accomplished by using a cost-benefit analyses methodology, as outlined in the next section.

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2.2. SETUP

Figure 1 indicates the methodology that was followed in this study using a flowchart. Meters placed at the substations were used to determine the power usage from a specific electrical network (Pichugin, Soldatov, & Pinaev, 2019). The metering unit placed at the substation measures the total load for a specific network. Using this information the average load can be determined over a certain period (Soluyanov, Fedotov, & Ahmetshin, 2019). The systems Eskom uses has data of all the installed transformers as well as the type of customers. Using this information, the total installed capacity of the network can be determined as well as the type of customers on the network.

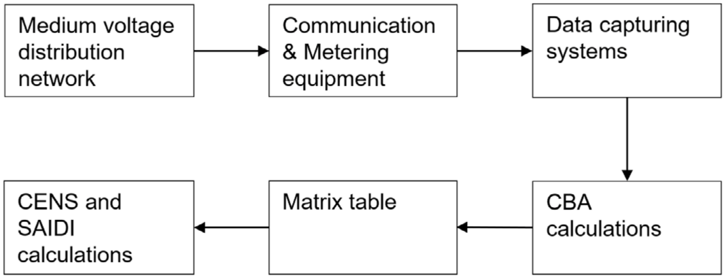

Figure 1. Flowchart of recloser placement system.

Source: own elaboration.

Furthermore, the type of tariff of each customer can be determined and necessary calculations can be done in order for the cost-benefit analyses (CBA) methodology to be more accurate. With the calculations completed the number of reclosers can be determined and placed using the matrix table.

2.3. RESEARCH SITE AND METHODOLOGY

For this paper, one network will be investigated using a CBA methodology for placing of reclosers. For the purpose of this case study, an 11 kV overhead line medium voltage distribution network was selected,

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as shown in Figure 2. Data for the case study was extracted from Eskom's Network and Equipment Performance System (NEPS) for the years 2014-2017.

This network had a total line length of 238 km, a total customer base of 2188 with eight reclosers installed. A total of 1895 customers were pre-paid customers, 267 were small power users, and 26 were large power users. Small and large power users are determined based on their tariff, but usually, the small power users transformer size ranges between 25-200 kVA, where the large power user ranges between 50-500 kVA. The total installed capacity on this network was 30046 kVA, and by the last data measured in 2017 an average of 2924.95 kVA load was measured.

Figure 2. Geographical layout of the 11 kV overhead line medium voltage distribution network.

Source: own elaboration.

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A CBA methodology can be used for many purposes, as in this case, it will be used to implement recloser placement on a network. The CBA will be used to give justification and reasoning on why a recloser will be placed at a specific location on the network. It takes into consideration all the costs involved in installing a recloser at a specific location and the benefits thereof. The CBA will indicate whether it will be financially beneficial to the business to install reclosers at specific locations on a specific network. Not only will it indicate the financial benefits but it will also improve the performance targets on the networks as more customers will be isolated during fault conditions.

Cost of energy not served (CENS) can most easily be explained as the loss of income for Eskom during an interruption, as customers will be without electricity/power. CENS will be based on the load profile of the network or section thereof and the associated tariffs of the connected customers. The load provided by Eskom to the network is not always used fully as the energy consumed by customers will also change during the day and during different seasons. To calculate an average of the load consumed, a load factor (LF) will be used. To determine the power (kVA) hours lost, a traced calculation is done for each interruption of the affected customer's transformers. A CBA is a systematic evaluation on economic advantages and disadvantages of a set of investment alternatives, it is often a useful yardstick for measuring efficiency (Paramasevam, Hassan, & Mohamed, 2001).

Typically a "base case" is compared to one or more alternatives. A cost benefit analysis will give the answer to, financially what advantages an alternative method will provide. The objective of cost benefit analyses is to translate the effects of investment into monetary terms as benefits only incur over long periods of time while capital costs incur that initial year. Costing elements can include, on-going maintenance costs, travelling costs, remaining capital value etc. After the project has been executed operating costs may increase due to longer travelling distances, but travelling times may decrease reducing costs again.

To determine the "Net costs" all costs involved in installing and commissioning of a recloser is calculated. To determine the "Nett benefits" the CENS will have to be calculated using Eskom's tariffs. After the CBA is determined, the maximum number of recloser installations will be known. After which, the

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reclosers have to be placed where the CBA calculations will equal more than one. Because of the layout of the customers, the maximum number of recloser placements might not be possible as calculated. The settings of the protection gradings play an important role (Thomas, Van Zyl, & Groenewald, 2017).

After the real number of reclosers placements and their positions are realized, they must be categorized according to importance to the network, from the most important recloser placement to the least important recloser placement.

A payback period can also be calculated. The Payback Period (PS) is calculated by dividing the cost of the project with the savings to be made per year (Wong, Eames, & Perera, 2007). This will determine the period it will take to recover the cost of the initial investment. For this methodology, a one year payback period is used. Apart from installing the number of reclosers on the networks as per the calculations used, the benefits have to be substantial.

Using the calculations and finding the CBA to be more than one, there are other considerations to be taken, for instance, the number of reclosers placed in series shall be limited to four due to protection grading constraints (Kleynhans & Gütschow, 2015). Other determining factors will be fault history, telecommunication in the area, geographical obstacles, etc. These all play a vital role in the placement of reclosers. For the optimum placement of reclosers, it is imperative that we consider and compare the different parameters. For this a matrix table was created.

The criteria for the matrix include:

- Communication: if the communication signal strengths are below the minimum target, then an alternative location will have to be selected for the recloser installation.
- Failure rates on tee-offs: number of faults in the last three years.
- Geographical obstacles: roads can have an effect on how accessible the terrain is for example crossing of rivers and mountains or rough terrain.

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- Poor performing lines – Pareto networks that have underperformed in the last 5 years.
- Sensitive customer's for instance a bakery, mine, dairy farmer, etc.
- High total line length – If the line is long and it takes time to get to fault.
- High lightning density or know pollution – If the area is known for its lightning strikes it would probably be recommended to place recloser elsewhere.

The matrix table was established by sending questionnaires to the relevant departments within Eskom in the Free State, and from the feedback, the matrix table and each categories importance were taken into consideration and created.

After the optimum placements of reclosers are determined, the key performance indicators (KPI's) can be calculated to show the improvement the networks would have had using the actual history fault data.

KPI's measured are the system average interruption index (SAIDI), system average frequency index (SAIFI) and momentary interruption frequency index(MAIFI).

The SAIDI shows the average duration of a sustained interruption the customer would experience per annum. It is usually measured in customer minutes or hours of interruption. The SAIDI is the KPI that Eskom focusses on as it is used to determine the performance of the utility by the National regulato of South Africa (NERSA).

3. RESULTS

The results indicate that by using the CBA methodology on the network (Jacobsdal Rural - Pramberg), a total of 22 reclosers can be installed that will have a 1>CBA and will thus pay itself back within one year. The rankings of reclosers to be placed in case of budget constraints can be seen in Table 1 below. This indicates the installation sequence of the reclosers from ranking one up until twenty-two.

Table 1. Network recloser pole number rankings.

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Ranking	Matrix Pole numbers	Ranking 2016-2017	Ranking 2015-2016	Ranking 2014-2015	Rankings overall
1	POLE387	2.24	2.5	2.68	2.47
2	POLE183	2.53	2.53	2.16	2.41
3	POLE61	2.13	2.13	2.82	2.36
4	POLE266	2.42	2.24	2.27	2.31
5	POLE181-47	2.5	1.72	2.23	2.15
6	POLE15-2	1.88	1.44	1.95	1.76
7	POLE84-32-1	1.75	1.31	1.96	1.67
8	POLE84-86-31	1.89	1.63	1.33	1.62
9	POLE84-1	1.6	1.34	1.89	1.61
10	POLE84-51-1	1.74	1.22	1.48	1.48
11	POLE84-53-1	1.67	1.41	1.22	1.43
12	POLE84-53-46	1.22	1.22	1.85	1.43
13	POLE15-15	1.36	1.36	1.54	1.42
14	POLE15-18-24	1.14	1.22	1.8	1.39
15	POLE84-85	1.41	1.41	1.33	1.38
16	POLE15-18-1	1.36	1.18	1.54	1.36
17	POLE60-1	1.44	1	1.36	1.27
18	POLE0-16	1.51	1.07	1.1	1.23
19	POLE60-13-1	0.92	1.26	1.36	1.18
20	POLE84-76-1	1.22	1.22	1.03	1.16
21	POLE60-12-1	0.92	1	1.36	1.09
22	POLE15-44	0.74	0.74	1.14	0.87

Source: own elaboration.

The ranking changes from year to year, as can be seen in Table 1. As every year, the data used in the criteria will be changed, but using a three year period should give a good indication of the best order of ranking when placing the reclosers.

Figure 3 gives a more visual example of where these reclosers will be placed on the network.

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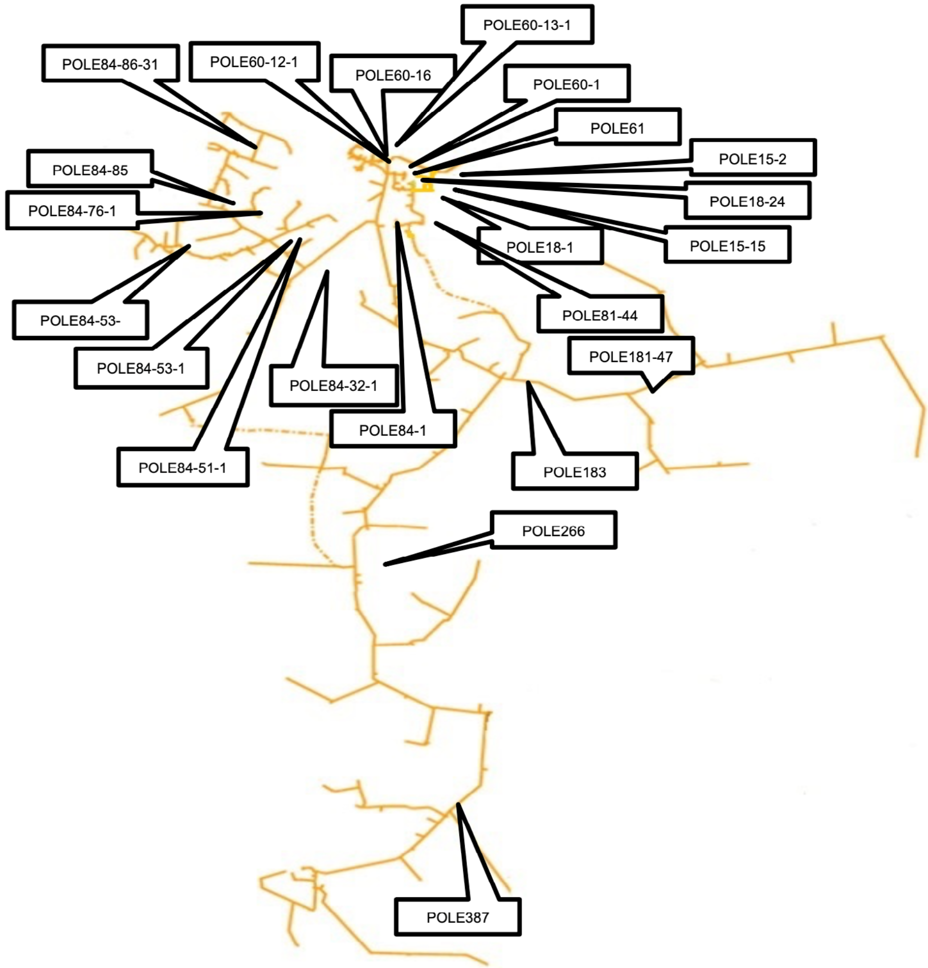

Figure 3. Geographical 11 kV medium voltage distribution network layout.

Source: own elaboration.

Actual savings from optimizing the recloser placements using a CBA methodology resulted in an average of 24.51% from a financial aspect and 24.42% from a performance aspect over a three year period as can be seen in Figure 4.

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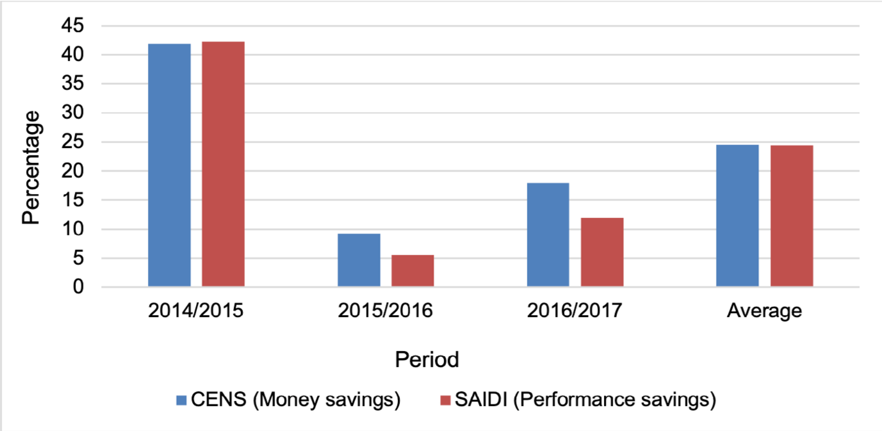

Figure 4. Fiancial and performance improvements.

Source: own elaboration.

The results in Figure 4 is the financial and performance savings that could have been improved on, based on the fault history of the chosen network. It can be seen that for the year 2015/2016 fewer faults occurred, thus fewer improvements were found, but for the year 2014/2015 there were more faults and thus more improvement were found.

4. CONCLUSIONS

The purpose of this paper saw to present a method that will optimize the placement of reclosers on medium voltage distribution networks. The business will benefit by using this method for recloser placements on their distribution networks by improving the performance targets. The method indicates that the utility should not focus on lowering the numbers but focus on the type of customers (Pre-paid users, Small power users, Large power users) as they play a significant role in the CBA calculations. The CBA assessment and payback period will give a clear indication of the financial viability in reclosers placements using a design to cost methodology. This can be seen with the results in this paper indicating a

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24.51% financial saving and a 24.42% increase in performance over a three year period. The limitations were that the loads cannot be measured on the tee-offs or each transformer of the network and can only be measured at the substation. In addition, the data used for fault history is a manual procedure typed by employees closing the works orders, who does not always give all the necessary feedback of the fault found. Eskom can use these results to change or possibly optimize their recloser placement standards and strategies to benefit the company. Implementation of these results may lead to financial savings as well as improvement in reliability and performance of medium voltage distribution networks.

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