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Reliability Assessment of Distribution System through Cost Analysis

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Abstract:

Reliability of electric power is a major and a challenging concern. For any power company, with the advancement in technology, the distribution system is getting advanced, however supplying reliable electric power at a cheaper tariff is still the biggest challenge for any power company all around the world. One of the very popular ways that the power utility companies are trying to improve the reliability is by distribution automation.

This paper is a systematic study of the 11kV Karberey-Ramety Feeder-II electricity power distribution network reliability evaluation and improvements to be applied. The main objective of the study is to compute reliability of the distribution system using Failure Mode and Effect Analysis method. Also, it presents step by step economic analysis to determine optimum number and location of automatic switch fulfilling reliability and economic constraints.

Keywords **—Reliability, indices, auto recloser, cost analysis**

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I. INTRODUCTION

As the electricity industry is moving towards deregulation and customer choice, the importance of reliability of an electric power supply that influences customer's purchasing decision is being recognized by electric utilities. The distribution system is an important part of the total electric supply system. In accordance to many technical publications, over nighty per cent of all customer interruptions occur due to failures in the distribution systems. [11]

In the past, the distribution segment of a power system received less of the attention dedicated to reliability planning than have generation and transmission segments, and therefore the distribution segment has been the weakest link between the source of supply and the customer point of utilization. This is due to the fact that generation and transmission segments are very capital intensive and outages in these segments can have widespread catastrophic economic consequences to both utilities and customers. A distribution system reinforcement scheme is relatively inexpensive compared to a generation or transmission improvement plan; even then a utility routinely spends a large sum of money collectively on a number of distribution improvement projects.

The paper outlines the details of existing distribution system of Karberey-Ramety Feeder-II of Phuntsholing, their protection system, and the fault recorded data of this distribution system. Taking system based indices SAIFI and SAIDI, the reliability indices is calculated for the existing feeder and after optimal placement of switches. The reliability indices are compared with the results found using excel to that found using Digsilient. The various general techniques to improve the reliability are also included in this paper

II. CONCEPT INVOLVED

Distribution Automation- is about automating a distribution system to provide a reliable and efficient supply to meet the increasing demand. Power system is judged based on its reliability. Automated and remotely controlled service restoration can eliminate the need to perform switching operations manually and can have a significant effect on the system reliability.

Partial Automation is a viable switching/restoration strategy when a feeder contains automated devices. Most distribution systems either have no automated devices or are partially automated with a combination of manual and automated devices. In this strategy, a first stage quickly restores a limited set of customers using automated switches. A later stage restores additional customers using manual switches.

Optimum Placement of Switches – Any successful system is meant to be both reliable and cost effective. More usage of automated switches will increase the cost tremendously. Hence usage of optimum number of switches placed at most logical and probable areas of the feeder could give us a more reliable and economical distribution system. Placement of switches on a lateral can be decided based on the average number of load points distributed for each switch. This provides minimum loss and fast restoration of power supply to remaining parts of the system. We can look into the application and its respective effect and the advantages in getting a more reliable and cost effective system in the case study done below.

Reliability Concepts – Any system is basically assessed on its reliability. Reliability can be evaluated and analyzed using Reliability Indices. Load point indices and overall system indices together are classified as reliability indices.

III. EVALUATION OF RELAIBILITY INDICES OF EXSISTING SYSTEM

Various steps involved in the calculation of reliability:

Step A: Manual calculation

The reliability index SAIFI is 64.5 and SAIDI is 133.03 for the year which was calculated manually. This means that the customer connected to this feeder has experienced a cut off power supply for about 133 hours and 65 times of supply off in one year.

Step B: Simulation using Digsilent

Manually calculated reliability indices are compared with the simulation result in Digsilent. The indices results SAIFI = 63. 47 and SAIDI=122.66 in a same year. By comparing the above two results, it is clear the values of reliability indices calculated using two different methods are same.

Step C: Optimal placement of switches

The location of all the manual switches is depending upon the severity of outages and maximum load demand in this very particular feeder. The reliability index SAIFI came around 61.93 and SAIDI 103.552 for the year 2015.

Step D: By partial automation (3 numbers of automatic switches and 2 numbers of manual switches)

Three manual switches is replaced with automatic depending upon the severity of outages and maximum load demand and kept the remaining switches manual. The reliability index SAIFI was 59.32 and SAIDI was 89.97 in the same year.

Step E: By replacing all five manual switches with automatic switches (auto recloser)

When all the five manual switches were replaced by automatic switches the reliability index SAIFI was 58.32 and SAIDI was 82.69 in the same year.

IV. METHODS TO IMPROVE THE RELIABILITY OF KABRAY-RAMETY FEEDER.

The distribution network is very complex and exposed to many factors which can cause power outages. The reliability of Ramety feeder suffers from numerous power outages, both small and large. The major reasons for power outages thus resulting in poor reliability are:

A. Heavy rainfall and lightning
B. Equipment failure: This means malfunctions of the working equipment's which ultimately lead to shutdown of the line for maintenance. In case of Ramety feeder, the power outages are usually caused due to transformer failure resulting in poor reliability.
C. Bamboos coming in contact with the conductor: When bamboos come in contact with live wire they may become conductors of electricity, causing power outages.
In order to overcome the problem some of the feasible methods include:

i. Using auto recloser
ii. Find and repair fault faster technique
iii. Vegetation management
iv. Using shield wire and earth wire
v. Proper maintenance policy
vi. Use of ABC Conductor

i. Using auto recloser

The present Ramety feeder has not used any auto recloser devices. The use of auto closer improves the reliability of the feeder. The switching operation was normally 60 minutes whereas with the use of auto recloser the switching operation reduces to 1 minute. Therefore, the use of recloser is one of the best suited improvement methods for Ramety feeder.

ii. Find and repair fault faster technique

Identifying the fault to clear it is very important to improve the reliability of the feeder, at present in Ramety feeder they use trouble call system to locate and isolate the fault. Thus it results in high time for fault clearance.

The use of following techniques helps in reliability improvement:

a) **Crew staffing**:

During outages, most of the faults have to repair manually and sending the crew toward the fault point takes a significant amount of time which is proportional to the duration for which the customers are interrupted due to that particular fault.
This problem can be overcome by placing adequate numbers of crew at locations where maximum outages occur and where the load demand is high but it is costly.

b) **Training and workshop to operating person**:

The operating staff or maintenance staffs must undergo various training in order to handle power outages more efficiently. In this way, the time required to restore power can be minimized hence reliability can be improved.

iii. Vegetation management

In this feeder most of the earth fault is due to falling of trees and bamboos which ultimately leads to poor reliability of the system. Here, proper vegetative management along the distribution line improves the reliability of the system.

iv. Using shield wire

It was found that the weather conditions especially heavy rainfall and lightning are the main causes of faults that interrupt the customers. Use of shied wire can reduce fault and protect against lightning. The use of ACSR conductor may be replaced by HV ABC conductor to improve the reliability and protect towards lightning.

v. Proper maintenance policy

The maintenance work consists of routine inspection, testing, cleaning and adjustment which are carried out to avoid its breakdown. The maintenance should be scheduled on the basis of data obtained through inspection and maintenance giving priority to the trouble area.

V. ECONOMIC ANALYSIS

From economic point of view, most of the utility company are willing to invest for further improvement of reliability of distribution system if there is a significant benefit. Therefore, economic analysis becomes one of the vital tools for reliability assessment. In this study marginal benefit to cost analysis is used for economic analysis where system performance and reliability are improved by investing in an effective way.

The main objective of any distribution system is both reliable and cost effective. Automation of the distribution network will significantly increase the reliability of the system by decreasing outage time. However, the cost associated with the installation of the automatic switches (recloser) is quite expensive. Therefore, the usage of the optimum number of switches placed at the most probable areas of outages of the distribution network can give more reliable and economic system. The selection of the number of automated switches and their locations depends on the total reliability cost.

Figure 1 [2] illustrates the ideal relationship between the system reliability and the costs with respect to the customer interruption and utility investment cost. The sum of the utility cost and its costumer gives the total reliability cost. Total utility investment cost includes expenditure on automation, protection upgrade and maintenance to improve the reliability. As reliability increases, the customer interruption cost decreases; however, it will significantly increase the utility investment cost of installing automatic switches. Hence, the optimal cost has to be found with minimum total cost. The minimum point of the curve shown below is where total utility investment cost and interruption cost intersect each other and at this point it is more reliable and cost effective to any distribution system.

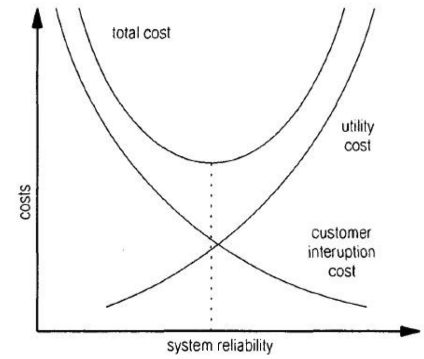

Figure 1: Optimization Curve for Reliability

The main objective is to find the optimum number and location of sectionalizing switches in order to minimize the customer interruption cost, investment cost of line switches and maintenance cost. Hence, the problem can be expressed as follows [1]

Total reliability Cost= Customer Interruption Cost + Investment cost

- Reliability parameters (SAIDI, SAIFI)
- Approved Budget
- Switch locations
- Geography

Customer Interruption Cost (CIC)

Customer Interruption Costs are simply revenues lost by the utility companies due to power interruption to the connected customers. These revenues may be in the form of system failure, ruined process, overtime pay and lost productions. The customer interruption

Cost varies from residential to industrial customers. For the residential customer, interruption cost may be really small as compared to commercial and industrial customers. In addition, interruption cost also depends on the duration of the interruption, the time of the week and whether customers are informed about the interruption ahead or not. The customer having a good back up of power system is supposedly impacted less.

VI. EVALUATION OF ECONOMIC ANALYSIS

The calculated and evaluated the economic analysis for four different cases is as follows:

- For existing system
- After reallocating the location of switches
- For partial automation
- For full automation

Reliability indices result

		Before optimal switching placement		After optimal switching Placement	
Sl. no.	Switch configuration	SAIFI	SAIDI	SAIFI	SAIDI
1	MMMMM	64.49	113.03	61.93	103.522
2	AAAMM			59.32	89
3	AAAAA			58.37	82.68

Table 1: Reliability indices results for different switch configuration

	Before optimal switching placement		Switches configuration	After optimal switching placement	
Sl. No.	Interruption cost (Nu.)	Reliability cost (Nu.)		Interruption cost (Nu.)	Reliability cost (Nu.)
1	102571	1877571	MMMMM	93200	1868200
2			AAAMM	85818	2028818
3			AAAAA	83080	2138080

Table 2: Economic analysis result

Table1 shows that the customer interruption frequency and customer interruption duration decreases with increasing the number of automatic switches. For existing system SAIFI is 64.49 numbers of interruption per year and SAIDI is 113.03 hours of interruption in a year whereas after reallocating the location of switches or after optimal placement of switches in a place or at a point where there is maximum number of outages and maximum load demand, SAIFI decreased to 61.93 numbers of interruption per year and SAIDI decreased to 103.22 hours of interruption in a year. Then for partial automation three manual switches are replaced with three numbers of automatic switches at a point where there is maximum number of power outages and maximum load demand and placed two manual switches at a point where the load demand and number of power outages are less. For this switch configuration it was found out that SAIFI was further improved to 59.32 numbers of interruptions per year and SAIDI was improved to 89 hours of interruption in a year. Similarly, for full automation all the five existing switches were replaced by automatic switches. The reliability indices was found drastically improved to SAIFI 58.37 numbers of interruptions in a year and correspondingly SAIDI be 82.68 hours of interruption in a year. So, the reliability of the distribution system can be improved by increasing the numbers of automatic switches.

From table 2, it can be concluded that the customer interruption cost decreases as the number of automatic switches increases whereas reliability cost increases as the number of automatic switches increases with the increase in the number of automatic switches.

VII. CONCLUSION

After optimal placement of switches it was found that the customer interruption cost of the Ramety feeder has been reduced by 10% with profit of Nu. 8632.83 Per year. With the partial automation the total interruption cost was reduced by 16% but with extra investment of Nu.146999 in a year. Similarly with full automation total interruption cost was reduced by 20% but have to bear an extra amount of Nu.252363 in a year.

From this paper it can be concluded that the power company can go for optimal placement of switches as the power company do not have to invest an extra amount with the reduction of interruption cost by 10%. But, this does not put constraint to other two methods. If the power company desire to improve the reliability to large scale, the use of other two methods is still feasible but with some extra investment as mentioned above.

VIII. RECOMMENDATION

Since outages due to lightning is common in this feeder during monsoon season, ACSR overhead line may be replaced with ABC conductor which is insulated and the use of Shield wire.Regular inspection and clearing up of the trees along the distribution path. Timely replacement of old and damaged equipment can improve the reliability of the system before occurrence of any severe problems.

Reallocating the location of presence manual switches at a point where there is maximum load demand and maximum number of outages can also help improve reliability of the system.Use of partial automation helps to improve the reliability keeping economic constraint.

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