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OPTIMAL OFF POINT DETERMINATION IN ELECTRICAL POWER DISTRIBUTION SYSTEM USING RISK ASSESSMENT

Ahmad Zaidi Abdullah*, Noor Hasnizam Hanafi, Nurhafiza Azizan, Mohammad Harith Amlus

School of Electrical Systems Engineering, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis

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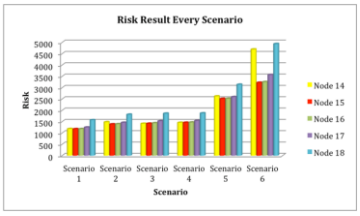
*Corresponding author
zaidiabdullah@unimap.edu.my

Graphical abstract



Abstract

In normal operation of distribution systems, protection systems are important for reliability and efficiency measures. For reliability enhancement of primary loop distribution systems, off points are normally located in midway between substations. Off point in networks allow the continued supply of electric to customer during faults as the feeder is separated into two sections, between two substations. Once a fault is cleared, then the faulted section can be reconfigured to accept supply from the unfaulted section. This is known as load restoration in network distribution system. Currently, off points are allocated using load flows and based on the engineer's experience. However this method does not optimize the reliability to customers, as it does not take into account the risk allocation to customers. To overcome this, the research proposed a risk-based analysis, which can determine an optimal off point location. The analysis used a real network between PMU Kota Setar and PMU Kota Sarang Semut, Kedah, Malaysia. Actual field data from varying utilities were used for completion of this project. Six scenarios were developed to get a clear view of the total impact of risk with varying locations of off point. It is shown that the method proposed in this project gives a better indication for the optimal determination off point in electrical power distribution systems compared to the commonly used method.

Keywords: Distribution system; protection system; off point; risk assessment; higher education; malay language

1.0 INTRODUCTION

The function of an electric power system is to generate electrical energy as economically as possible and to transfer this energy over transmission line and distribution networks with maximum efficiency for delivery to consumers at acceptable voltages, frequency and reliability [1]. An electric power system consists of three principal segments: the generating stations, the transmission system, and the distribution systems. The completed electrical power distribution system comprise network with substation, feeder and customer or demand nodes. In order to prepare a good electrical power system, it is important to plan the network. Planning the network involves several tasks and one of these is finding the location off point between substations to minimize investment and better operation. Here, an engineer needs to design and find the best location as that decision can result in economic and reliability impacts during operation [2]. Several mathematical methods have been proposed to solve this problem [3][4][5], however in Malaysia these are not used. The main problem with these methods is it is too mathematical and hard to apply in real situation. This paper shows the analysis to find the optimal location by using simple and effective method.

2.0 OBJECTIVE OF THE STUDY

The goal of this work is to determine the optimal location for the off point in electrical power distribution system by implementing risk assessment analysis. It complete with study the effect of each parameter such as losses and risk at different locations of potential off point. Once the sample network analysis has been done, the best location of the off point can be located at distribution network to reduce risk to customers with proposed risk based method.

3.0 RESEARCH METHODOLOGY

3.1 Off Point Determination

This work concerned with methods applied by considering existing method and improved by focusing on the risk approach. The risk is considered on consumer and also power provider utilities side from the aspect of losses and value of money. Load flow and losses determined serves as a basic guide for positioning the potential off point position in this method by using simulation software (PSS ADEPT). The steps of method involved in determination optimal off point location using risk assessment. In electrical distribution system, risk depending on the energy not served. Energy is based on connected watts and hours of use normally known as kWh. From the energy value, the costs of unserved energy can be calculated and it can show whether it is economical or not for end user and power provider.

3.2 Data Analyzed

6 scenario created to analyzing the characteristic of network, including based case, load arrangement between low, medium and high , changing distance and probability of failure. The off point determined at the lower loss region was selected. This point will contain a potential optimal off point location. In this work, off point locations were made at point center of network. Peak demand for every location was calculated using equation 1 by refers to load current value. The supply voltages used in this work are 11kV:

$$\text{Peak Demand} = \left(\frac{V_{LL}}{\sqrt{3}} \times I\right) \times 3$$

Then energy was calculated by referring to peak demand value calculated using equation 2 for every substation. For this analysis the load factor of 0.6 was assumed.

$$\text{Energy (kWh)} = \text{Peak Demand(kW)x Load Factor x Period(Hour)}$$

At every substation the individual substation impact was calculated by referring to the kWh average value calculated before and multiplied with the value of loss load (VoLL). For this analysis the VoLL were assumed to be RM8, RM10 and RM12. Then the overall feeder impacts were calculated by summing the individual substation impact from the off point location. Total probability of failure (POF) for substation was calculated by multiplying the distance between each substation and the failure rate per km. The distances are taken from existing substation location in network. For this analysis POF are assume to 0.01, 0.02 and 0.2 per km. Individual risk was determine by multiplying the total POF with the overall feeder impact. Then every individual risk was sum up to find the total risk of off point. Lastly, value of total risk for every off point allocation was compared to find the lowest risk between locations selected. From that the lowest off point was identified.

4.0 RESULTS AND DISCUSSIONS

The results are based on six's scenarios. From the six's scenario developed, the optimal off point location between PMU Kota Sarang Semut and PMU Kota Setar was determined through simulation and analysis. The simulation was performed using the PSS ADEPT software while analysis was performed using Microsoft Excel. The results of the analysis were very encouraging and illustrated that a new location off point in network can be optimally determined using risk assessment.

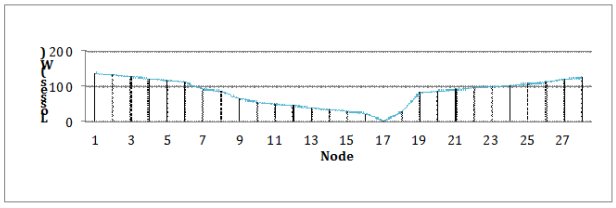


Figure 1 Losses at node in network from PMU Kota Sarang Semut to PMU Kota Setar

From analysis, Figure 1 illustrated the results of losses for every substation. As indicated in the previous chapter, the lowest current and losses chose the five candidate's nodes for off point and these were consequently further assessed using risk analysis.

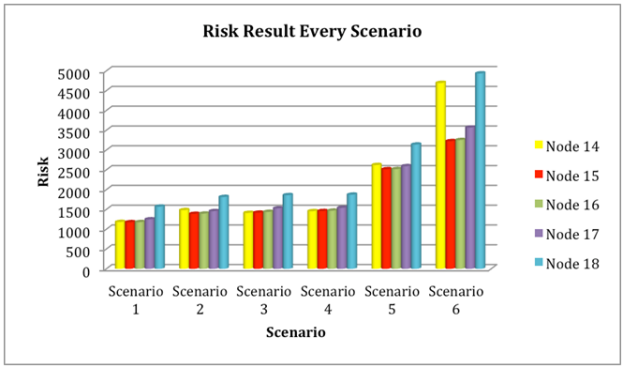


Figure 2 Risk result for every scenario

Figure 2 shows the overall scenario result for five nodes with lowest risk. From that, it can conclude that all scenarios give the same pattern result. The highest risk was at node 18 for every scenario while the lowest were varying between points 14, 15 and 16. Node 17 was maintained as a second point with high risk to allocate off point. Overall shows that scenario 6 was produced highest risk and scenario 1 was the lowest risk.

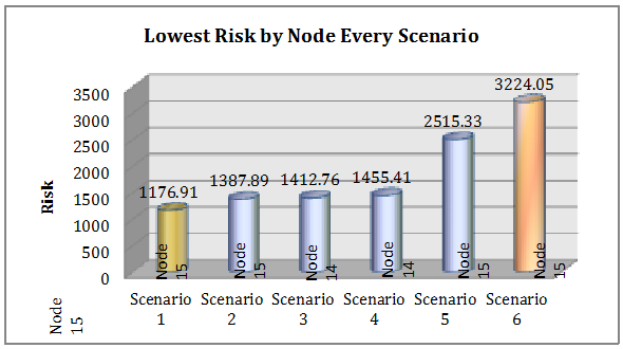


Figure 3 Comparative lowest risk between scenarios by nodes

Figure 3 illustrated by bar graph is a comparison lowest risks between six scenarios by selecting the lowest value on every scenario. It can be seen that the scenario 1 has the lowest risk between six scenarios with just carry out about RM1176.91 of risk value. For the scenario 6 cases, the risk is high at three times from the scenario 1. As the scenario 1 is the lowest risk, an optimal off point is applicable to be allocated at node 15 on scenario 1 arrangement.

From result also shows that new off point location determined with lowest risk, losses and cost. By applying this method, at least RM200 of risk is cheaper than the currently used location by TNB. If we compare this cost with the larger network, the potential saving can be higher, further the method can reinforce the reliability and security of the power system. It is this holistic approach that makes it a more defensible method of analysis. This method is a real shift from the current applied method today, which is based on load flow alone. By using the risk assessment concept, the paper took an overall view of the problem; it utilized information from both financial and technical aspects to form an integrated method to form a solution. In conclusion, this method results in an off point location selection that is both economic and justifiable, financially and technically.

4.0 CONCLUSION

The aims to find an optimal off point location in an electrical distribution network system were success. Another objective of this research was to study the existing method used for allocating off point position in electrical distribution systems at Alor Setar, Kedah. This network was based on the TNB Alor Setar circuit and analyzed network from PMU Kota Sarang Semut to PMU Kota Setar which is consisted of 58 substations. This simple network was chosen for analysis as it is a good representation of a typical electrical utility circuit. It was found that the current method is has some deficiency as it is only focused on losses and neglecting the risk on consumer and provider.

This work also discussed the concept of risk assessment, its process and multiple approaches. Risk assessment is made up of three main components namely risk identification, risk estimation and risk evaluation. With combination of several steps from various researchers, a new methodology of determining optimal off point location was synthesized.

Acknowledgement

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