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Interference Analysis of Medium Voltage Air Line 20 KV Feeder Using Failure Mode and Effects Analysis Method

Yan Min Tun[1], Aung Than Win[1]

[1]Department of Electrical Power Engineering, Mandalay Technological University, Myanmar

**Corresponding Author: Lucian Paunescu*

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Abstract

This article discusses the interference analysis of medium voltage air line 20 kv feeder using failure mode and effects analysis method. The distribution network consists of two parts, the first the distribution network consists of two parts, the first is the medium / primary voltage (JTM) network, which supplies electrical power from the sub-transmission substation to the distribution substation, the primary distribution network uses three wires or four wires for three phases. the impact of the reliability index from the calculation of the impact of the reliability index based on the number of disturbances (SAIFI), it shows that in January 2019 it has the highest index value, namely SAIFI, 1,695 disturbances/ subscribers. From the results of the calculation of the impact of the reliability index based on the number of blackouts (SAIDI), it shows that in January 2019 the SAIDI index value was 3,883 hours/customer.

Introduction

The distribution system is part of the electric power system. This distribution system is useful for distributing electricity from large power sources (bulk power source) to consumers. Electric power generated by large power plants with a voltage from 11 kV to 24 kV is increased by the substation (GI) with a transformer to increase the voltage to 70 kV, 154 kV, 220 kV or 500 kV and then channeled through the transmission line. The purpose of increasing the voltage is to minimize the loss of electrical power on the transmission line, where in this case the power loss is proportional to the square of the current flowing (I 2.R). With the same power, if the voltage value is increased, the current flowing will be smaller so that the power loss will also be small. From the transmission line, the voltage is further reduced to 20 kV with a voltage reducing transformer at the distribution substation, then with this voltage system the distribution of electricity is carried out by the primary distribution line. From this primary distribution channel, the distribution substation takes the voltage to reduce the voltage with the distribution transformer to become a low-voltage system, namely 220/380 Volt.

Furthermore, it is distributed by secondary distribution channels to consumer customers. In remote power delivery systems, always use the highest possible voltage, using a step-up transformer. This very high voltage value has several consequences, including: it is dangerous for the environment and the price of the equipment is expensive, besides that it does not match the voltage value required on the load side. So in the high load center areas of the line voltage is lowered again using a step-down transformer. In this case it is clear that the distribution system is an important part of the overall electric power system.

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Distribution Network

The distribution network consists of two parts, the first the distribution network consists of two parts, the first is the medium / primary voltage (JTM) network, which supplies electrical power from the sub-transmission substation to the distribution substation, the primary distribution network uses three wires or four wires for three phase. The second network is a low voltage network (JTR), which supplies electrical power from the distribution substation to the consumer, where previously the voltage was transformed by a distribution transformer from 20 kV to 380/220 Volt, this network is also known as the secondary distribution network. The secondary distribution network is located between the distribution transformer and the service (load) connection using an open air conductor or cable with a three-phase four wire system (three phase wire and one neutral wire). We can see the picture below the process of supplying electricity to consumers.

Primary distribution system network the primary distribution system is used to transmit electricity from the distribution substation to the load center (Senger et al., 2005; Reddy et al., 2017; Sun et al., 1982). This system can use overhead lines, aerial cables, or ground cables in accordance with the desired level of reliability and environmental conditions and situations. This distribution channel is stretched along the area to be supplied the electric power to the center of the load (Short, (2014); Bayliss et al. (2012). There are various forms of primary distribution network circuits. The following is a picture of the parts of the primary distribution in general.

The Primary Distribution consists of (a) Power transformer, serves to reduce the voltage from high voltage to medium voltage or vice versa. (b) Voltage breaker, functions as a safety, namely a power breaker. (c) Conductor, functions as a power connector. (d) Busbar, serves as a meeting point / connection between the power transformer and other equipment. (e) Switching substations, which function to distribute power to distribution substations without changing the voltage. (f) Distribution substation, functions to reduce medium voltage to low voltage.

Primary Distribution Network According to the Arrangement of the Circuit

Networks in the medium voltage distribution system (20kV Primary) can be grouped into five models, namely Radial Networks, Tie Line Networks, Loop Networks, Spindle Networks and Cluster Systems.

Radial Network

It is a simple and economical primary distribution system network. In this system there are several feeders which supply several distribution substations radially. However, the reliability of this system is lower than other systems. The lack of reliability is due to the fact that there is only one main line supplying the distribution substation, so that if the main line is disrupted, all of the substations will also go out. Another disadvantage is the quality of the voltage at the distribution substation at the very end is not good, this is because the largest voltage drop is at the end of the line.

Tie Line

Tie Line distribution system is used for important customers who must not go out (Airport, Hospital, etc.).

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Loop Network

This type is the primary distribution network, a combination of two types of radial networks where the ends of both networks are installed PMT. In normal circumstances this type works radially and when there is a PMT disturbance it can be operated so that the disturbance can be localized. This type is more reliable in distributing electricity than radial type but the investment cost is more expensive.

System Spindle Network

The spindle uses an express feeder in the middle which is directly connected from the substation to the substation, so this system is classified as a reliable system. This network system is a combination of a radial network and an open loop network. The load point has a combination of alternative feeders so that if one of the feeders is disturbed, it can immediately be replaced by another feeder. Thus the continuity of power supply is guaranteed. In the middle of the feeder, a central substation is usually installed which functions as a maneuver point when there is a disturbance in the network.

Cluster System

This system is similar to the spindle system. The difference is that in the cluster system, switching substations or switching substations are not used, so the express feeder from the connecting substation to each network. This express feeder can be useful as a maneuver point when there is interference on one part of the network.

Secondary Distribution System Network

The secondary distribution system is one part of the distribution system, starting from the transformer substations to the end users or consumers (Paiva et al., 2005; Mateo et al., 2020; Chowdhury & Koval, 2011). The secondary distribution system is used to distribute electricity from the distribution substation to the loads on the consumer. In the secondary distribution system, the most widely used channel form is the radial system. This system can use insulated cables or conductors without insulation. Seeing its location, this distribution system is the part that is directly related to consumers, so this system functions to receive electrical power from a power source (distribution transformer), and will also send and distribute that power to consumers. Considering that this section is directly related to consumers, the quality of electricity should be very concerned about. The electrical power distribution system in the Low Voltage Network can be divided into two, namely as follows (a) Low Voltage Air Line (SUTR) the type of conductor used is bare cables (without insulation) such as AAAC cables, ACSR cables. (b) Low Voltage Air Cable Line (SKUTR) The type of conductor used is an insulated cable such as an LVTC (Low Voltage Twisted Cable) cable. LVTC cable sizes are: 2x10mm2, 2x16mm2, 4x25mm2, 3x 35mm2, 3x50mm2, 3x70mm2. A low-voltage network is a low-voltage network that includes all parts of the network and its equipment, from low voltage distribution sources to limiting / measuring devices. While STR (Voltage Line) Low) is the JTR part not including the service connection (the part that connects the STR with the limiting / measuring device).

Distribution Substation

The most common definition of electrical power distribution substations is an electrical substation building containing or consisting of the installation of intermediate voltage switching equipment (PHB-TM), distribution transformers (TD) and low voltage switching equipment (PHB-TR) to supply power needs. Electricity for customers with both Medium Voltage (TM 20 kV) and Low Voltage (TR 220 / 380V). The construction of distribution

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substations is designed based on cost optimization of the intended and intended use which sometimes must be adjusted to local government regulations. Broadly speaking, distribution substations are divided into (1) Type of installation: Outdoor pairing substation: Portal substation, Cantol Substation Inner pair substation: Concrete substation, Kiosk substation (2) Type of construction (a) Concrete substation (civil building: stone, concrete) (b) Substation: Portal and Cantol Substation (c) Kiosk Substation

Types of Use (a) Public Customer Substation (b) Dedicated Customer Substation. Specifically, the definition of Switching Substation is a substation that is intended to facilitate loading maneuvers from one feeder to another that can be equipped / not equipped with an RTU (Remote Terminal Unit). For this facility, it is usually equipped with DC supply facilities from distribution transformers for self-use or distribution transformers for the public that are placed in one unit.

FMEA (Failure Mode and Effects Analysis)

FMEA (failure mode and effects analysis) is a form of approach that aims to identify the failure modes that cause failure and the impact of failure caused by each component on the system. Some definitions of FMEA (failure mode and effects analysis) are as follows (1) FMEA (failure mode and effects analysis) is an engineering technique used to identify, prioritize, and reduce problems from a system, design, or process before they occur [kmenta 99]. (2) FMEA (failure mode and effects analysis) is a methodology designed to identify potential failure modes in a product or process before they occur, consider the risks associated with these failure modes, identify and implement corrective actions to address important problems (Reability 2002] (3) FMEA (failure mode and effects analysis) is a tool that is widely used in the automotive, aerospace, and electronics industries to identify, prioritize and eliminate potential failures, failures, potentials and system errors in designs before product launches [J.Rhee 2002] Functionally FMEA assumes a failure and then identifies, the failure, and analyzes how the effect of the failure

FMEA approach concept FMEA (failure mode and effects analysis) is a structured mode to analyze a system (Filip, 2011; Liu et al., 2011; Pentti & Atte, 2002). The FMEA method for evaluating the reliability of a distribution system is based on how a failure of an equipment affects system operation. The effects or consequences of individual disruption of equipment are systematically identified by analyzing what would happen if the disruption occurred. To determine the reliability of the distribution system using the FMEA method, the following conditions are required (a) In each component / equipment, the reliability data is specified, such as the failure rate. Average downtime and outage duration. (b) Requires consumer data including the number of customers at each feeder. (c) Requires annual disturbance / blackout data.

The calculated reliability indices are basic reliability indices including, among others. The most basic reliability indicators for distributed systems are of three types.

Average Failure Rate (Times/Day)

$$\lambda = \frac{\text{Number of distractions}}{\text{Observation time lapse}} = \frac{\lambda 1 + \lambda 2 + ... + \lambda n \text{ (times)}}{31 \text{ (day)}}$$

Interference Mean Timeout (Minutes/Times)

$$r = \frac{\text{Number of hours off}}{\text{Number of distractions}}$$

Annual Average Time of Blackout (Minutes/Times)

$$U = \lambda \frac{\text{Number of hours off}}{\text{Number of distractions}} \text{ X } \frac{\text{Menutes}}{\text{Times}}$$

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λ = failure / year = annual blackouts
r = hours / failure = hours per blackout
U = hours / years = hours of interruption per year
When the basic index of reliability cannot describe how much impact the outage will have on consumers and for companies. Therefore it is done by disappearing the system reliability index to determine the performance of a system. To calculate the reliability index used in calculating the overall system reliability performance.

SAIFI (system average interruption frequency index) SAIFI (system average interference frequency index) is an index that informs about the average frequency of blackouts for each consumer within a year during an evacuation. How to calculate it, namely:

$$SAIFI = \frac{\text{Total Consumer Outage Frequency in a year}}{\text{Total number of customers served}}$$

Mathematically, it is written as follows:

$$SAIFI = \left(\frac{\Sigma(\lambda_1 \times N_i)}{\Sigma N} \times \frac{\text{Failure}}{\text{years}} \text{ customer}\right)$$

Where: λi = average failure index per year (failure / year) Ni = number of consumers going out

N = total number of consumers

SAIDI (System Average Interruption Duration Index) is an index that informs about the duration of blackout about the average blackout duration for each consumer in a year in an area being evacuated. How to calculate it:

$$SAIDI = \left(\frac{\Sigma(U_1 \times N_i)}{\Sigma N} \text{ X customer } \frac{\text{Failure}}{\text{years}}\right)$$

Where:

Ui = average duration of blackouts per year (hours / year)
Ni = Number of consumers going out
N = total number of consumers

CAIDI (costumer average interruption duration index) is an index that informs the average consumer outage duration for each disturbance that occurs. How to calculate it:

$$CAIDI = \left(\frac{SAIDI}{SAIFI} \text{ X} \frac{\text{Time}}{\text{failure}}\right)$$

Standard Reliability Index Value

Table 1. Reliability Index Standard

Work Indicator	Value Standards	Unit
SAIFI	3.2	Times/customer/year
SAIDI	21.09	Times/customer/year

IEEE std 1366-2003 Reliability Value Standard

Table 2. Reliability Value Standards IEEE std 1366-2003

Work Indicator	Value Standards	Unit
SAIFI	1.45	Times/customer/year
SAIDI	2.3	Times/customer/year
CAIDI	1.47	Times/distractions

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Based on the results of the calculation of the impact of the reliability index from the calculation of the impact of the reliability index based on the number of disturbances (SAIFI), it shows that in January 2019 it has the highest index value, namely SAIFI, 1,695 disturbances/ subscribers. From the results of the calculation of the impact of the reliability index based on the number of blackouts (SAIDI), it shows that in January 2019 the SAIDI index value was 3,883 hours/customer.

Conclusion

From the results of the calculation of the impact of the CAIDI reliability index, it shows that January 2019 has the highest index value, namely CAIDI 2,290 hours/customer. From the reliability index analysis of feeders in January 2019 to July 2020, the SAIFI average value index was 0.313 disturbances / subscribers, while the SAIDI average value index was 0.313 hours/customer. Where the feeders are still categorized as reliable because the SAIFI and SAIDI values have not passed the predetermined limits. Based on the indication of the cause of the most dominant disorder in feeders from January 2019 to July 2019, namely trees have 20 times disturbance, JTM component has 15 disturbances, kites have 10 disturbances, animals have 8 disturbances, nature has 6 disturbances, it is not clear that it has 4 disturbances and the substation has 1 disturbance.

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