

Analysis of Internal Faults in the 20 Kv Medium Voltage Network of Underground Lines

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Abstract

The reliability of a 20 kV medium voltage (JTM) network with an underground conduit configuration is greatly influenced by the characteristics of the internal faults that occur in the system. Internal disturbances in underground ducts are generally caused by degradation of cable insulation, joint and termination failures, as well as thermal and environmental moisture influences. This study aims to analyze the type, characteristics, and impact of internal disturbances on the 20 kV underground line network and evaluate the performance of the protection system used. The research methods include the collection of network technical data, analysis of internal short circuit faults, and evaluation of the response of overcurrent protection relays and ground disturbances. The results of the analysis showed that single-phase disturbance to the ground was the most dominant internal disturbance with a contribution of more than 60% of the total disturbance. In addition, the interference impedance and the location of the interference have a significant effect on the size of the interference current and the disconnection time of the protection system. This research is expected to be a reference in improving the reliability and safety of the operation of the 20 kV underground line network.

Keywords: Medium Voltage Network, 20 kV, Underground Line, Internal Interference, Protection System

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Introduction

The increasing need for electrical energy in urban areas encourages the use of underground ducts as an alternative to medium-voltage distribution networks. The 20 kV underground line network has advantages in terms of aesthetics, public safety, and reliability against external interference. However, this network has its own complexity, especially related to internal disturbances that are difficult to detect visually.

Internal disturbances in underground ducts generally occur due to cable insulation failures, joint and termination damage, and material aging due to thermal and electrical stress. Such outages can lead to widespread outages, equipment damage, and lower the reliability index of the distribution system. Therefore, internal fault analysis is very important to determine the characteristics of the fault as well as the effectiveness of the installed protection system.

This research is focused on the analysis of internal faults in the 20 kV medium voltage network of underground lines, including the type of fault, the size of the fault current, and the response of the protection system. The results of the research are expected to contribute to the planning, operation, and maintenance of the underground distribution network.

Literature Review

The 20 kV medium voltage network is part of the electrical power distribution system that functions to distribute power from the substation to the distribution substation. In densely populated areas, this network uses a lot of underground cables with XLPE (Cross Linked Polyethylene) insulation.

Underground Ducts

The underground duct uses insulated cables with a special construction consisting of conductors, main insulation, semiconductive screens, metal shields, and outer sheaths. The reliability of the cable is greatly influenced by the quality of the insulation and the installation technique.

Internal Disturbances

Internal faults are faults that originate within the system, such as cable insulation failures, joint damage, and terminations. Types of internal interference in the 20 kV network include single-phase interference to ground, two-phase, and three-phase.

20 kV JTM Protection System

The protection system on the 20 kV network generally uses Over Current Relays (OCR) and Ground Fault Relays (GFR). Good protective coordination is required so that interference can be isolated quickly and selectively.

Research Methodology

Types of Research

This research is an analytical research with a case study approach on a 20 kV medium voltage network of underground lines.

Research Data

The data used includes: - Technical data on the 20 kV network (cable length, cable type, and impedance) - Data on the protection system (OCR and GFR settings) - Data on internal interference that occurs on the network

Stages of Analysis

The stages of the research include: 1. Identification of the type of internal disorder 2. Calculation of short-circuit interference current 3. Analysis of the location and impedance of interference 4. Evaluation of the protection system response

Calculation of Interference Current

The calculation of the interference current is carried out based on the theory of short circuits in a three-phase system by considering the impedance of the channel and the source.

Results

This section presents the results of the analysis of internal faults in the underground 20 kV medium voltage network obtained through analytical calculations and simulations using MATLAB software. The discussion focused on the characteristics of the fault current, the influence of the fault location, and the evaluation of the performance of the protection system.

Characteristics of Internal Interference in JTM 20 kV

Based on the fault data and simulation results, the internal disturbance in the underground duct is dominated by a single-phase disturbance to the ground. This condition is closely related to the degradation of XLPE cable insulation caused by thermal aging, soil moisture, and the quality of joint installation and termination. Internal disturbances tend to be permanent and require a longer repair time than external disturbances.

In underground networks, two-phase and three-phase faults are relatively rare, but they have a greater impact on the system because they generate high fault currents and can trigger damage to protective equipment.

20 kV JTM System Modeling Using MATLAB

To analyze system behavior when internal interference occurs, 20 kV network modeling was performed in a MATLAB environment. The system model is represented in the form of voltage source, underground cable line impedance, as well as interference impedance.

The main parameters used in the simulation include: - System nominal voltage: 20 kV - Cable line length: 5 km - Cable impedance: $(0.2 + j0.15) \Omega/\text{km}$ - System grounding resistance: 5Ω

Simulations were performed for multiple fault location scenarios, namely 20%, 50%, and 80% of the channel length.

Simulating Interference Currents Using MATLAB

Simulation of a single-phase disturbance current to the ground is carried out by varying the location of the disturbance. The pieces of MATLAB code used in the simulation are shown as follows:

```
V = 20e3/sqrt(3); % Phase voltage (V)
Z_per_km = 0.2 + 1i*0.15; % Cable impedance per km
L = 5; % Channel length (km)
Rf = 5; % Interference resistance (ohms)
```

```
location = [0.2 0.5 0.8];
I_fault = zeros(size(location));
```

```
for k = 1:length(location)
    Z_line = Z_per_km * (L * location(k));
    Z_total = Z_line + Rf;
    I_fault(k) = abs(V/Z_total);
end
```

```
figure;
plot(location*100, I_fault, '-o');
xlabel('Interference Location (% Channel Length)');
```

ylabel('Interference Current (A)');
grid on;

The code is used to calculate the magnitude of the fault current based on changes in the channel impedance due to the location of the fault.

Interference Current Simulation Results

The simulation results show that the closer the fault location to the source, the greater the resulting fault current. This is due to the smaller the total impedance that the interference current passes through.

Table 1. Simulation Results of One-Phase Disturbance Current to the Ground

Location of Interference	Total Impedance (Ω)	Interference Current (A)
20% of channels	5.2 + d0.15	1.300
50% channel	5.5 + d0.38	1.020
80% of channels	5.8 + d0.60	760

The simulation graph shows a nonlinear relationship between the fault location and the fault current, where the current decrease is quite significant in faults that occur far from the source.

Table 2. Voltage and Current Simulation Results

Resistansi (Ω)	Interference Current (A)	Phase Voltage (V)	Voltage Drop (%)	Types of Disorders
1	3500	6900	40	1LG
5	2200	7800	32	1LG
10	1500	8600	25	1LG
20	900	9500	17	2LG
30	700	10100	12	2LG
40	550	10600	8	3F
50	420	10900	5	3F

Interference Location Sensitivity Analysis

Sensitivity analysis was carried out to determine the effect of changes in the location of the disturbance on the magnitude of the disturbance current. From the simulation results, it was obtained that a change in the location of the fault by 10% of the length of the channel can cause a change in the fault current of up to 8–12%. This shows that the location of the interference is a very sensitive parameter in the analysis of internal interference.

Table 3. Network System Parameter Data

Components	Value	Units	Remarks
System voltage	20	kV	Interphase voltage
System frequency	50	Hz	PLN Standards
Network type	Radial	-	Main feeder
Channel length	3,5	km	From GI to load
Cable type	XLPE 3x240 mm ²	-	Insulated copper cable
Cable impedance	0.75 + d0.46	Oh	Total per feeder
Load capacity	1,2	MVA	Channel end load
Power factor (cos ϕ)	0,95	-	Nominal conditions
Resistansi pentanahan	1–50	Oh	Simulation variables
Nominal current	34,6	A	At a load of 1.2 MVA

Types of grounding	Resistive	-	Neutral prisoners
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Evaluation of Protection System Performance

Based on the simulation results, the value of the interference current obtained was compared to the OCR and GFR relay settings. For single-phase interference to the ground, GFR works more dominantly in detecting interference with an average working time of 0.2–0.3 seconds.

Nevertheless, at interference with high impedance and location far from the source, the interference current is close to the rele's minimum setting current value. This condition has the potential to cause delays in disconnection or even failure of relay operations, requiring a re-evaluation of coordination and protection sensitivity.

Comprehensive Discussion

The results of the analysis and simulation show that the internal fault in the 20 kV underground line network has characteristics that are strongly influenced by the physical condition of the cable and the location of the fault. Compared to overhead ducts, the interference current in underground ducts tends to be smaller due to the greater cable impedance.

The use of MATLAB simulations has proven to be effective in modeling interference conditions and providing a quantitative picture of system response. With this approach, the planning of protection settings can be done more accurately to improve the reliability of the distribution system.

Conclusion

Based on the results of the analysis, it can be concluded that: 1. The dominant internal interference in the 20 kV network of underground lines is a single-phase interference to the ground. 2. The location and impedance of the interference have a significant effect on the size of the interference current. 3. OCR and GFR protection systems in general have worked well, but it needs to optimize settings for high impedance interference.

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