EVALUATION OF PRACTICAL EXPERIENCE OF FAULT INDICATOR PERFORMANCE IN MEDIUM VOLTAGE NETWORKS

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ABSTRACT

The subject addressed is analyse of a feedback of a fault circuit indicator performance based on data collected from the pilot projects in South East Asia and from the field tests provided by St Petersburg suburb power distribution utility "Lenenergo", Russia.

INTRODUCTION

Fault Circuit Indicators (FCIs), known also as Fault Passage Indicators, are getting widely used in distribution networks for detecting the passage of fault current since they were released in 1976 [1]. The history of the basic principle of this solution counts over 60 years [2]. During the last several years the technology of detecting faults was implemented even for the most difficult cases such as faults at ungrounded or resonant grounded neutral systems.

The first part of the paper introduces a brief review of the networks, where the FCIs were installed, the topology of the networks with the focus on the mistakes, which had taken place during the preparation of a project and during the installation.

Next, the field tests carried out in Russian distribution network will be analyzed. The tests were provided by Russian State Owned Grid Company, they were aimed for studying the behavior of the FCIs with different constructions, from four different manufacturers in order to consider which shows the best performance during the real faults, established at real network conditions. Five different solutions from four manufacturers were exposed for the testing.

To conclude, the recommendations for utilities and FCIs manufacturers will be formulated by highlighting the fact that the behavior of high sensitivity devices under live-line conditions and during the fault may be influenced by a range of factors.

WHAT DO YOU NEED TO CONSIDER WHEN CHOOSING FCI?

Topology

First question should be asked about the network arrangement: what is the topology of the network in terms of the sources of supply. Medium Voltage networks in many cases consist of either loops of feeders with two-side supply or radial one-side supplied feeders. For multiple fed lines a directional detection will be a must, FCI should be able to calculate the direction of a power flow with the use both a voltage and current measurement. The majority of the FCIs, which are being offered on the market, represent a solution for radial type systems. Then, the number of circuits placed on one pole. The issue is about choosing the right FCI. In general, FCIs can be divided into two groups by the mounting arrangement: pole-mounted and conductor-mounted. It does not make a significant influence whether there are several Medium Voltage circuits or Low Voltage circuit mounted below Medium Voltage circuit (Figure 1), the pole-mounted FCIs cannot be chosen since the magnetic fields from the different circuits will interfere with one another and deform the total field.

Figure 1 – A picture of the network arrangement at Dagupan Electric Corporation, Philippines.

Neutral arrangement

While ranging the solutions targeted to locate a fault in Medium Voltage Networks from the cheapest to the most expensive, it may be noticed, that not only the country of origin makes sense, but the sensitivity. High end devices provide the possibility for detection of so-called high impedance faults. A term "high impedance fault" represents a broad classification for all faults, which cannot be considered as overcurrent faults. Thus, the complete set of characteristics attributable to such a wide range cannot be defined; this issue of applying a single algorithm for detecting reliably even the majority of faults remains unsolved [3]. Hence, it is unrealistic to expect the remote sensor with battery supply to be a universal solution, which is applicable to every system without tuning in regards with the neutral arrangement.

Among different methods of grounding the most challenging one in terms of locating a fault are the systems with isolated neutral point (also known as a systems with floating neutral point) and Resonant or Petersen Coil grounded (compensated grounding) systems.

There is ungrounded system applied for 6...35 kV networks in Russia. Some cases are characterized by high impedance fault current of the value below 1A, caused by the phase to ground (P-G) fault and has the prevailing capacitive component.

Implementing the principle of the capacitive current compensation in the networks prevents from high current occurrence during P-G fault, meanwhile it may cause an incorrect work of FCIs in terms of fault detection. The system is working under one of three following conditions:

1. Under-compensation. The inductance of the coil is less than the capacitance of the line. The FCI's algorithm implemented for capacitive fault current detection is applicable in actual use.

2. Complete compensation. The inductance of the reactor (also called Arc Suppression Coil) matches the capacitance of the line, the current is accurately zero. Ideal case.

3. Over-compensation. The inductance of the coil exceeds the capacitance of the line, the inductive component prevails. Hence, the algorithm aimed for phase to phase (P-P) fault detection is convenient, meanwhile the overcurrent threshold might be set much more higher than the over-compensated fault current.

Mutual understanding between the customer and the sales manager should be reached in terms of the customer's needs and expectation from the FCI. Whether the detection of both a permanent and a transient fault is needed, or how often the occurrence of fault is followed by the line cutoff.

Among the mistakes made during the installation the most obvious is mounting the device before the breaker (Figure 2), which results in failure to register an event, since the indicator's algorithm is supposed to wait for the voltage drop in the majority of the cases.

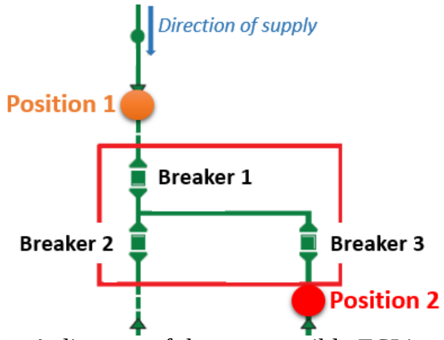

Figure 2 – A diagram of the two possible FCI installations in terms of position relative to the breakers.

Wrong settings for cross-country faults also may cause the disappointment of the utilities. The problem of cross-country faults (CCF) is described in [4]. CCF occurs when two P-G faults occur within the feeder or shared between two feeders. In this case the current is supposed to be detected as ordinary overcurrent, except the fact that it is much more lower than overcurrent during P-P fault. Hence, if the P-P threshold is set at the level about 1 kA and the CCF current is 600 A, the device with the feature to detect capacitive current by the discharge of the line to the point of the fault is not able to register the event. Thus, implementing of the algorithm, that allows calculating zero sequence current is necessity for this case.

CASE STUDY

A real 10 kV OHL in Kingisepp electric grids, PJSC Lenenergo, Russia was used as a case study. During 1 month the behavior of FCIs from different manufacturers was observed. In order to finalize the results, the tests were carried out in the end of this period. The purpose of practical research was the comparison of the claimed technical characteristics, the determination the most important ones with respect to operation for selecting indicators. The external view of the line with FCIs installed is provided at the Figure 3.

Initial parameters

The characteristics of the network is given in Table 1.

Table 1 – General parameters of the network

Number of circuits	1
Type of cross-arm	Horizontal
Operating current	12 A
P-G fault current	2 A
P-P fault current	213 A

The FCIs' main technical parameters are listed below (the brands are covered under the numbers since the present paper is not of promotional nature).

FCI #1: Conductor-mounted, able to detect high impedance fault.
FCI #2: Conductor-mounted, able to detect fault current at the level above 100 A.
FCI #3: Conductor-mounted, able to detect high impedance fault with direction displaying.
FCI #4: Pole-mounted, able to detect fault current at the

level above 25 A.
FCI #5: Conductor-mounted, able to detect fault current at the level above 200 A.

Figure 3 – The external view of the OHL during the field tests.

Test program

The practical research was conducted by analyzing the FCIs detection capability at the following events:

1. Operation control during 1 month.
2. Double-phase fault between indicator's installation place and the consumer's transformer; the event was not followed by the cutoff.
3. Double-phase fault between indicator's installation place and the consumer's transformer; the event was followed by the line cutoff.
4. P-G fault between indicator's installation place and the consumer's transformer.
5. P-G fault arranged with the use of an additional resistance.
6. P-G fault between the supplying transformer and the indicator's installation place (on another parallel feeder from the same section).

As it can be observed from the Figure 4, the network has a branchy structure. The total line length provided for test conducting is about 3 km. In order to carry out the tests properly and to simulate the fault detection in actual use, prior to double-phase fault organizing, the breaker between pole 1 and pole 2 was switched off during shunt installation, while the line from the FCIs installation place to poles 50..72 had supply from the substation.

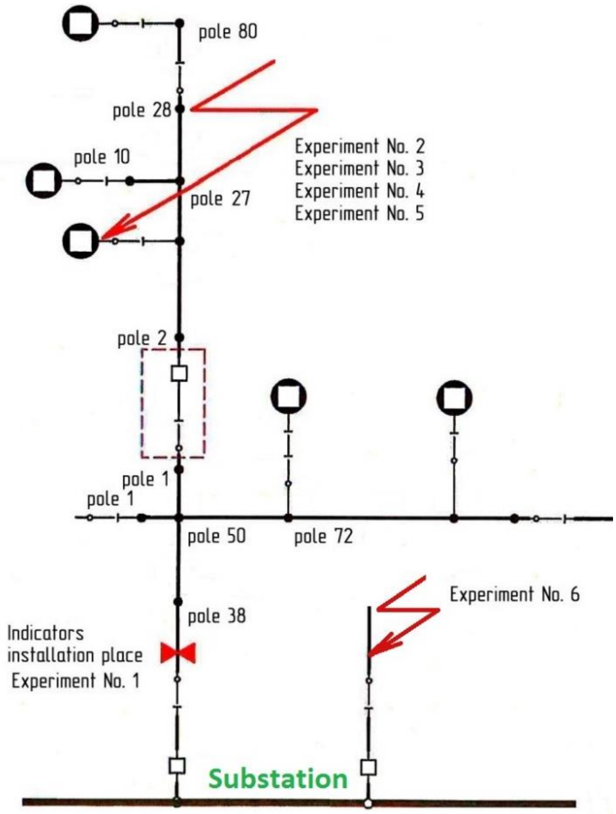

Figure 4 – Simplified diagram of the network during the case study.

Test results

All researched FCIs have proven the ability to detect the occurrence of double-phase fault. Meanwhile two devices (#2, #5) were set in a such way, that they could be triggered only by the coincidence of the two events: overcurrent occurrence and the cutoff, hence, they did not detect the first test fault.

The detection of P-G fault arranged with the use of an additional resistance is unreliable. None of the indicators exposed to the test has registered the event.

P-G fault between indicator's installation place and the consumer's transformer was registered by #1 and #4. It is worth noting that FCI set #3 had communication unit, which was able to send the message to the server by the event occurrence, so the event was displayed not by FCI's indication, but by the web-based software.

#3 proved the capability of directional detection when P-G fault between the supplying transformer and the indicator's installation place (on another parallel feeder from the same section) occurred. Meanwhile #1 was triggered by the fault on the nearby feeder with no directional indication, which was considered as an incorrect detection by the representatives of executive authorities and electric grid branches.
<u>However, for the purposes of reliable electric grid operation, the advice not to indicate every event on the</u>

nearby feeder was expressed.

All the studied indicators were equipped with LEDs for providing the possibility of visual inspection. However, during daylight hours indication visibility is poor.

CONCLUSIONS

The review in both details, which should be taking into account when choosing FCI, and the practical evaluation of the FCIs performance during the tests in real network conditions highlights the necessity of accurate study of the network before installing FCIs. In order to enhance the network performance smoothly by FCIs installation, the complete technical information about the line, its topology, operational modes etc. should be shared prior to installation.

Owing to the tests carried out by Lenenergo, one of the largest electricity distribution companies in Russia [5], the recommendations for utilities and manufacturers were formulated. FCIs should provide the following features among others:

- absence of indication during the fault on the nearby conductor;
- the possibility of live-line installation;
- the possibility of replacing the power source;
- possibility to change settings during operation;
- the possibility of registering P-G faults, as well as additional possibility for expanding functions to collect and transfer information to SCADA system (if necessary);
- different signalization for P-P and P-G faults;
- Ingress Protection rating not less than IP 54.

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