ANALYSIS OF THE METHOD APPLIED IN DETECTING THE FAULT POINT IN MV NETWORKS

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Summary

The work contemplates the problem of detecting the fault point in MV networks. First and foremost, we have tried to give a systematic classification of the methods that are used in solving the problem. In attempting to do this, we have come to the conclusion that, no matter how much we really wanted it, it is impossible to give an absolute classification of this kind. Our way of classification derives primarily from the need to point out all the diversity of the existing methods. The definitions and the names related to certain concepts serve the purpose of a better clarification of the issues treated here, so they may not be perfect. Without giving a deeper analysis of each of the stated methods, the advantages and the drawbacks of each method group have been explained. The final section of the work represents an attempt to define the steps that are to be taken in order to choose the method and the equipment necessary to detect the fault spot in the MV networks. It was pointed out here that it is possible to combine methods within the same network, and even within the same lead.

Introduction

The basic requirement that is posed upon a power supply system is exactly to supply the power to the consumers. The power taken from the high-voltage section must be distributed to the consumers, even those who are far away, with a minimum delay and interruptions in supply. Apart from the requirement to supply the power to the consumer, there is another one – to maintain the voltage within the required range and at a required quality. Any fault in the network causes difficulties that can hinder the fulfilment of the above-mentioned requirements. When a fault does occur, the first action to be taken is to make sure that the staff and the equipment are protected, which is effected by switching off / stopping the power supply to the part of the network where the breakdown has occurred. After this precautionary measure, we can perform the second step – eliminate the fault and bring the network to the normal operational condition. The switch-off of the network supply is done by the means of automatic protective devices – this should not be a problem, at least in the theoretical way, since there is a whole philosophy developed in this area, with clearly defined principles of recognising the fault type and nature. However, problems tend to ccur in the segment of detecting the place of the fault and its elimination. This process of detecting the fault can consume a considerable amount of time, which is contrast with the prioritised request that the cut-offs and breakdowns in the power supply ought to be as short as possible. In order to overcome this problem, various methods have been devised of making an early detection of the fault, blocking the power supply to the section in question and (if possible) maintain the power supply to other parts of the network. The methods that have been developed are often accompanied by adequate devices, all with an aim to speed up the process of detecting the fault and eliminating the failure in the MV networks, and all at a minimum cost. It is quite expectable that everyone will try to find a solution to this problem that will be in accordance with their own abilities and network profile. We have, on our part, defined these various ways of detecting the fault spot as methods. We have further on tried to systematise these methods and to point out their respective good and bad sides – the advantages and drawbacks that they contain, in our opinion as well as in the opinion of their authors. Our aim here was to provide the users (power-supply companies) with the information that will help them choose the method and the equipment that will suit them best in the process of detecting the fault points in their MV networks.

As an example of this, we have discussed the experiential method and decided to list it with the other methods (experiential method implies that we look for the fault in the place where we assume it must be and then, if it is not there, we move to the next spot where we think it might be).

Classification of methods for detecting the breakdown spots

The classification of methods for detecting the fault spots can be done in a number of ways that equals (n+1), meaning that if we make a classification that includes an **n** number of ways, there is always a possibility that there is another classification that has not been taken into consideration. There is an additional difficulty too: even though we may decide on the criteria based on which the classification will be done, we may not be able to make a clear line of distinction between various methods, because basic characteristics of one method may also be used in another one (Eg. One method may imply that we make certain measures based on which we will make a decision regarding the actions to be taken, while another method may involve measurings that will serve as a base for certain calculations, upon which the decisions will be made about the place of the fault). However, having balanced all of this, we decided the classification could best be made in three ways:

a) based on the signal that is processed
b) based on the method of processing information
c) based on the value that is measured

The classification can be followed according to Table T1, and each of the classifications will be discussed in the following sections. Although it might not be so obvious at first sight, even a basic analysis reveals a conclusion that different methods lead to different solutions to the problem.

A. according to the signal	B. according to information processing	C. according to the measured value
A.1. low-frequency signal	B.1. experiential methods	C.1. electric current
A.2. high-frequency signal	B.2. calculation/ computer (impendence) methods	C.2. electric field
A.3. impulse signal	B.3. measuring (indicating) methods	C.3. impendence

T1. Classification of methods for detecting the spot (section) of the breakdown in SN networks

A1. What is used as a low-frequency signal is mostly the signal of the basic harmonic (50Hz or 60Hz) – it is based on this signal that the decisions are made. In most of the situations involving this signal, the detection of the fault is done in the plant (drive). The low frequency signal can be of some other frequency too [2] – however, in this kind of situation, the detection of the breakdown spot is done in the condition without a voltage.

A2. When a high-frequency signal is used in detecting a fault point, it is mostly used in a non-voltage condition, when we insert a signal of certain characteristics into the network, and monitor the response. This is the principle used in the radar, and the algorithms that are used in this kind of method can be various.

A.3. When we want to use an impulse signal, the situation is similar to the situation that we have with a high-frequency signal. In the voltage-free condition, an impulse is inserted into the network, after which we monitor the response of the system to the signal in question [1, 3].

In the classification of the methods, based on the way in which a signal is processed, it is impossible to draw a distinct line between these two groups of approaches. The main characteristics of one method are used in the other as well, and the other way round. Quite frequently, we are faced with a situation in which both kinds of methods are used in a single network – for example, we separate a significant section of a network based on a calculation or a measuring; at the same time – in some other section of the same network that is relatively less important - we search for a fault using our experience. To put this more precisely, we sometimes use two different methods of fault point detection in two different sections of the same network.

B.1. It was mentioned before that this method would be treated as an equal and possible method for detecting a fault point. One of the underlying aims in this approach is to have this method systematised, i.e. to produce a scenario for a fault in an MV lead. In order to be able to start detecting the fault point, we need to have the information that there has been a fault in a lead. When such a fault happens, the protection will cut off this lead and, in case of a negative ARC, we know that the fault was not a temporary one and that, consequently, it has to be detected. When this starts to happen, the team will start moving along the lead, and will try to find a suitable place at which they will disconnect the lead into two sections, after which they will try to make a switch-on. If the attempt fails, another one will be made at a next section, and so on, until we manage to find in which section the fault actually occurred. This is obviously a long and painstaking approach, especially tough on the equipment. If we are not prepared to invest into more advanced equipment, the least we can do is to keep a record of the system's weak points / sections. This will improve the overall situation, because the experience of the team that was involved in the detection of a breakdown will become shared experience.

B2. The methods that involve detecting the fault point based on certain network parameters and measurings conducted according to a certain algorithm have been classified here as (computer) calculation methods. Most of these methods are impedence methods. Before a fault occurs, the network parameters are defined [4,5] , which tend to be impedances. When a breakdown occurs, certain values in the network are measured and then, through a suitable algorithm, it is possible to calculate the breakdown point. Depending on the method that is used, the measuring can either be done at one end (the beginning of the lead) or at both ends of the lead. These methods are especially suitable for a quick restoration of the network. If we have a model of the network, we will be able to make a quick decision (based on calculations and measurings) regarding which switches (disconnectors) need to be switched off in order to switch on the lead again, while at the same time making sure that the smallest possible part of the network will stay without the voltage supply. All the authors agree that this method is better than the use of an algorithm, in situation in which we need to establish the fault point with a high accuracy. At the same time, a major disadvantage to this method seems to be the fact that we need to have the exact network parameters, as well as a network model. We are not going to deal with details of individual algorithms used in fault point detection here.

B3. The idea underlying the measuring (indicators) methods is to have the lead sectioned into as many sections as possible. Each of the sections is given its respective indicator, signalling – to put it like this – whether a fault “has passed through” it. The indicator can be set off by various measuring units / values, which will be dealt with in detail later on. The indicator is set off the moment the measured value exceeds a certain set value, or goes outside a set range. It is obvious that, provided that we have made a connection between indicators that are distant, and the central , then we are in a position to effect a quick detection of the point/ section where the fault has occurred. The higher the level that is used, the more comfortable the method. At the first level, we only have the indicators that are fitted with certain ‘badges’ (markers) that will signal the alarm of the indicator, and it is therefore necessary to go from one indicator to another, in order to detect the section with the fault. At the second level, the indicators have a one-way communication with the centre, so it is possible to have a very quick detection of the fault point in the centre. At the third level, we have a two-way communication between the indicators and the centre, which enables us to direct/ operate the switch elements from the centre, in a non-voltage condition. At the fourth level, we have the so-called “reclosers” and the communication is effected directly between the indicators (relays) and the section with the fault is automatically shut off. The classification of the methods based on the measured value is related to the way of processing information. We measure the value that we need to have measured.

C1. The electric current value is a reliable indicator of a fault. Depending on the network, the values that we need may be the electric current intensity (electric current) , or both the intensity and the direction of the electric current (electric current) [6]. If we should decide on one of the indicators methods, then we will have to measure the value of the electric current in several places, which is an certainly an expensive solution. Due to this, alternative possibilities are sought to measure the electric current value (for example, the use of the so-called Rogowski coils, instead of the conventional electric current transformers, the measuring of the electric field or the magnetic field as a representative of the electric current...). As an interesting method, we can mention here the measuring of the fifth harmonic of the electric current [7]. By measuring the fifth harmonic of the electric current, it is mostly possible to solve the problem of measuring the direction of the electric current in isolated networks.

C2. The measuring of the electric field was explained earlier. The electric field, which is a representation of the electric current is measured, and this certainly represents a cheaper and simpler solution.

C3. In the methods that have earlier been defined as (computer) calculation methods, it is necessary to have (apart from the value of the electric current) the measuring of the voltage, i.e. the impendence.

Criteria for choosing the method of detecting a breakdown point in NS networks

Let us define several important steps in choosing the method:

1. Before we opt for any of the methods, we have to have a record of faults in the network that we contemplate.

2. We need to define the aim that we want to achieve by installing the equipment and choose the method that we want to use in detecting the fault point.

3. Now we should divide the network according to level of importance, the spatial distribution, and the technical characteristics (insulated or earthed network, cable or air network ..).

4. We perform a technical-economic analysis of each of the methods that can be used in the given case.

5. We perform an economic analysis.

Let us now clarify some of the statements given here.

Before choosing any of the methods available, we must have statistics of the faults in the network, because it is possible that there is a low occurrence rate of faults in the place where we want to install the equipment, while this rate can be considerably higher in some other place. It would be good for the statistical data to include information about the time, place, and the type of the fault, as well as the time needed to eliminate the failure. The aim that we want to achieve with installing the equipment and the choice of the adequate method can vary. We could be satisfied with a solution that is based on several light indicators distributed along the network, or it may be that we will need a solution that includes automatic equipment, installed in the network, and enabling the possibility to shut off the section with the fault, while at the same time providing the supply of power to other parts of the network. It is possible that we want to have, in different parts of a same lead, various effects. Let us consider here some of the possible solutions:

a) Protection of the MV lead and remote signalisation directed towards a control centre. In this type of solution, a team is sent out to search for the fault when it occurs. The team is given a freedom of choice to disconnect the lead if necessary, and to ask the distribution operator (dispatcher) to switch on the power.

b) A slightly improved solution in relation to the previous one – the one that we defined as the experiential method. The advantage of this method in relation to the previous one is in the fact that we have a record of faults and the condition of the network, so that we can send out the repair team to the pre-determined location.

c) The Radar Method. This method represents a solution in which we insert a signal into a lead that has been switched off, and then, based on the obtained response, detect the place of the fault.

d) Indicators method of the 1st level (see the previous elaboration) is based on several light indicators distributed along the lead. The advantage of this method is in the fact that it is not necessary to switch on the lead before the section with the fault is found and disconnected.

e) Indicators method of the 2nd level, where it is possible to detect the section with the fault from the control centre.

f) Calculation method of 1st level. Based on a network model, as well as based on the received measuring values and algorithms, it is possible to determine the fault point.

g) Indicators method of the 3rd level. Here we have the possibility to act from the control centre and switch off the section with the fault, while at the same time we return the supply of the power to the 'sound' section(s) of the network.

h) Calculation method of 2nd level. The solution here is the same one as in the previous case – the only difference is that we come to the detection solution by using the computer calculation method.

i) Indicators method of the 4th level. Here, everything is done automatically – the fault section is isolated, and all we have to do is to eliminate the fault in a known location.

It is very important that the network be divided according to the following criteria:

- relative importance of individual parts
- spatial distribution / location of individual parts
- technical characteristics

It is obvious that it will not be necessary to provide the same level of efficiency in detecting the location of a fault in all types of networks or network parts: a factory that must have a continuous supply of electrical power will obviously have a priority in relation to a section where there are only a few households. The same example can be used to illustrate the significance of the spatial distribution of individual facilities. If the same households receive their power supply through a section of a lead that lies before the factory (that comes before the factory, going from the source) then, in oreder to supply the factory, we have to provide the power supply for the households as well. The technical characteristics of the network in question, as well as its parts or sections play a decisive part in choosing the type of the equipment for detecting the location of the fault. Different types of equipment will be used in an air network, compared to the equipment that may be used in a cable network. Also, the equipment type may vary in relation to the grounding of the neutral point. All the relevant characteristics of the equipment to have in mind when choosing the type we need are stated by the manufacturers (hardware and software).

In making a decision, it is vital that we should know the price, which means that a financial analysis of every offer must be made prior to final decision. The phrase 'technical and economic' analysis as used here, means that there is a difference between making a technical solution and making an 'e' solution. Cution is vital here, because we need to consider in advance what different solutions will actually give us. If we should, for example, opt for a solution 'a', we may think that we have chosen the cheapest option, which again might not be the case. The record of faults will clearly revel the amounts of time and money that we spent on fault detection, the penalties that we paid for failing to supply the agreed amounts of energy, while the manual will tell us how much we have reduced the working life of the stressed energy equipment.

Following the analysis of individual solutions related to certain sections of the network, it is necessary to choose the adequate equipment, i.e. to conduct the technical and economic analysis of the equipment and solutions offered by various manufacturers. Finally, it will be necessary to perform an economic analysis, to get a clear picture of what exactly we will get, and what the costs of installing the given equipment will be. It is possible that this kind of analysis will reveal that a certain investment will pay off after a certain long period of time. If this does not satisfy our needs, we should go back to the start of the procedure, and choose a different method and equipment, or give up the investment altogether.

Conclusion

The conducted research had an aim to draw the attention to various methods of detecting the fault points in MV networks. Although the methods were not separately analysed, we did mention some of the advantages and the drawbacks present in each of the method groups. Concrete solutions can be found in literature that is available in this area. The final part of the work contains guidelines for the users, in their making decisions regarding the choice of the equipment and the method. It is up to the users to make their own decisions.

It is our sincere pleasure to have tried to help you have a better insight into the issues discussed here.

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