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About Flexibility Problem of Distribution Electrical Network

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Abstract. Global electricity companies have embarked on a transition to digital microprocessor devices. Digitalization penetrates every aspect of power industry, whether it is power generation, transmission or distribution. Being the most widespread, the distribution electrical networks are nevertheless the least digitalized. Some issues about them are still insufficiently studied. These are the collection of necessary information, adaptation methods, and the effect of the unrecognizability of some short circuits. This can be explained by improper placement of devices, which causes lack of data, which, in turn, leads to the failure of relay protection and emergency control systems of distribution electrical networks to provide selectivity. The paper proposes algorithms for placing measuring devices so that the information will be collected properly. Placement of the devices will allow adjusting the operating parameters of the relay protection and emergency control systems depending on changes in external weather conditions and load fluctuations in the network. We propose a technique for control of distribution network, taking into account the type of damage in case of emergency in real time, and a technique for placement of measuring devices and creation of an information communication network.

Keywords: distribution electrical network, survivability, relay protection and automated systems, adaptive setting, overhead power line, microprocessor measuring device, information communication network.

1 Introduction

Owing to the adoption of the IEC 61850 standard, relay protection and emergency control (RPEC) devices get increasingly more information, not only from measuring devices and sensors located in the same place but also from other RPEC devices. Microprocessor-based devices with memory and intelligence are prepared to implement new, more complex yet more efficient algorithms for relay protection and fault location. Thus, the development of relay protection algorithms capable of working with an expanding information base is becoming increasingly more relevant. This task was and is the focus of research by some scientists in Russia and other countries.

Nowadays, power system protection is turning into a science of recognizing emergency situations in electrical systems, and microprocessor-based protection facilities are becoming more intelligent, showing the ability to adapt and learn. However, nevertheless, the operation of the RPEC devices can be “false”, “unnecessary” or they can fail to operate.

The RPEC devices may function incorrectly if their settings do not reflect the real state of the monitored overhead power line (OPL). It is important to specify the OPL parameters to accurately determine the settings of relay protection using simulation models. Consequently, the development of a relay protection system with an adaptive response setting, depending on changing external environmental conditions and load current in distribution overhead power lines (survivability of a distribution electric network), is a relevant task.

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2 Model of the distribution network control

The notion of active power supply system (distribution electrical network) is considered in [1] on the basis of existing concepts [2], [3]. It is reasonable to specify and detail it as follows. The activity of the power supply system implies the use of automatic devices to control configuration and parameters of the system with the view to rationally (optimally) meet the requirements for economic effectiveness of normal, maintenance, post-emergency and other conditions (for example, the minimum active power losses), reliability of power supply to consumers (in terms of a decrease in power shortage and power undersupply to consumers in emergency situations). The control actions can be implemented by disconnectors [4].

The model of the distribution network control is based on the reliability model [5]. Formalization of the problem of choosing a rational configuration of power supply system is presented in [6]. Mathematical models and methods of the complex optimization of the power supply system structure and parameters, considering, in particular, the distributed generation, are mainly addressed in the publications by researchers [7-11]

The traditional model of the distribution network reliability rests on the following principles [12].

- The initial reliability indicators for each main component (line, transformer, complete transformer substation) are represented by the parameters of failure flow λ and the restoration rate of the component μ.
- Based on them, on the assumption that the failure (restoration) flow has the Markov property, that is λ=

const and μ = const, the well-known formulas are used to determine the probability of failure, the failure rate and the component restoration time.

• Based on the indicated indices of network components, the average failure rate, average failure duration and average system availability ratio are calculated.

• Failures of sample components, i.e. protection devices and circuit breakers, are taken into account indirectly in the values of the failure flow parameters and the restoration rates of the main components.

By way of illustration, let us consider a scheme of a power system to demonstrate how the reliability factors determined by activity of the distribution network are taken into account in the model.

Fig. 1 shows an urban 10 KV distribution network powered by two main sources - C1 and C2, with a voltage of 110 kV. The distribution network supplies power to 15 power take-off points indicated as 1-15 in the Figure.

The objective is to reconstruct the distribution network with its transfer from “passive” to “active”, by using additional switching devices (marked with an X). In this case, new nodes appear. The reconstructed scheme is shown in Fig. 2. Considering the lines disconnected under normal conditions, one can see that the electrical network is radial.

We introduce the concept of an “Operating area” of the network and make the network controllable and flexible. According to IEC 61850, all relay protection devices installed directly at the power circuit breakers are integrated into one common system and exchange data with each other. Let us explain how the operating areas are used to reconfigure the network in order to improve the reliability of power supply by the example of the scheme shown in Fig. 2. The introduction of operating areas is necessary due to the need to design the logic of switching devices. The operating areas are a set of the distribution network components, which are built according to some functional sense. Moreover, the operating areas are formed based on the network structure. Consider the appropriate automatic operations in the presented operating areas.

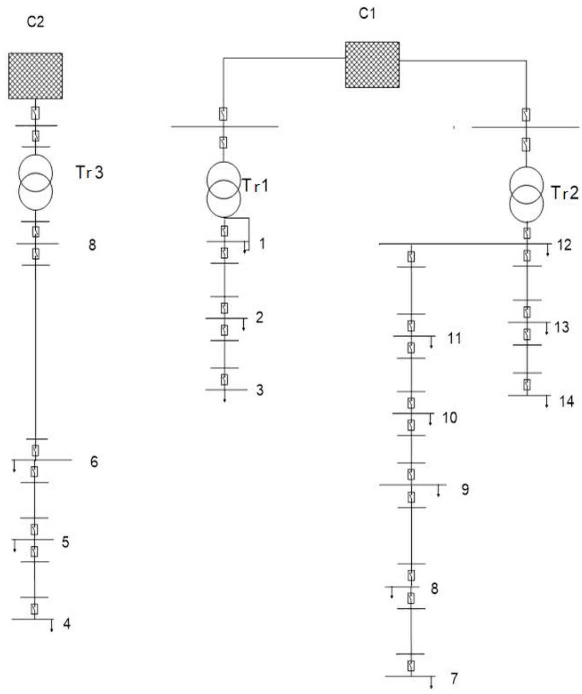

Fig. 1. A scheme of the distribution network

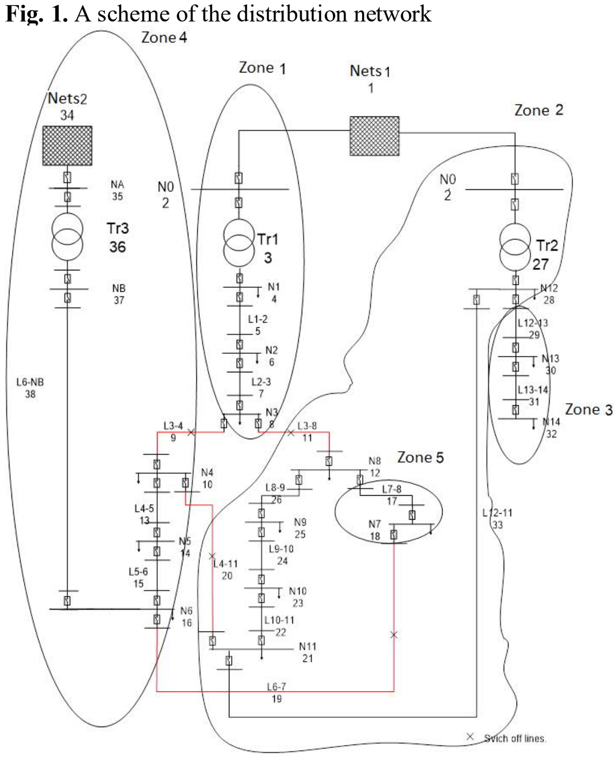

Fig. 2. Distribution network divided into the operating areas

Operating area No. 1. When the transformer Tr1 fails, the backup line 3-4 is switched on in a given operating area, thus, the power source for this area is changed and the network structure is reconfigured. Another example: a short circuit occurs on line 1-2, it is tripped by the overcurrent protection. Automatic switching of the backup line 3-4 provides power supply to the consumers connected to points 2 and 3. Similarly, when a short circuit occurs on line 2-3 and it is disconnected by overcurrent protection, automatic connection of the

backup line 3-4 provides power supply to the consumers connected to point 3. In the event of an accident at point 3, the backup line 3-4 is not connected, however, power supply to the consumers connected to points 1 and 2 can be maintained using source C1, when line 2-3 is tripped.
In Operating area No. 2, the reconfiguration is performed in the same way: when the components fail in this area, line 3-8 is automatically switched on, power supply to the consumers connected to the power take-off points in this area is maintained, depending on the component failed. In the case that point 8 fails, the backup line 3-8 is not switched on but power supply to the other consumers is provided by the main source C1.
When a component fails in Operating area No. 3, the network is not reconfigured because this area has a radial structure.
In Operating area No. 4, automatic switching does not differ from that in areas No. 1 and No. 2, however, in case of failures, the backup line 4-11 is automatically switched on.
In Operating area No. 5, the electrical network is reconfigured similarly by automatically connecting line 6-7.
The model allows for the operation of the overcurrent protection in the lines and the undervotlage protection at the power take-off points.
The proposed model will enable us to make the distribution network flexible and survivable, which will increase the reliability of power supply.

3 A model of placement of current sensors in the distribution electrical network

The distribution electrical networks are often equipped with disconnectors. In this case, these switching devices can be controlled only manually. If one adds control drives to the disconnectors, it will be possible to control them remotely, but this generates the need to create a control system for these disconnectors. In the above text, a method of the distribution network control based on flexibility was proposed. This method can also be applied to the network with disconnectors. However, then the question arises for the relay protection devices, how to determine certain failures and emergency situations. Installation of sophisticated microprocessor-based protection devices will cost too much, however a solution to this problem is the option of creating an information communication network with sensors. Figure 3 shows IKI-Overhead fault indicators intended for detection of faults on overhead power lines. This solution is used for distribution networks with overhead power line.

Fig. 3. IKI-Overhead fault indicators

These indicators transmit information using GSM and easily fit into the IEC 61850 standard. They are installed directly on the wires without additional mounting devices. According to the control model of the distribution electrical network, all switching devices are integrated into one information-switching network with a common control center. Information from IKI indicators is transmitted to this center. Figure 4 shows the network, in which the sites for installation of these indicators are shown by circles. These devices can determine the following parameters: short circuit, single-phase fault to ground, overhead line break, and maximum load of the overhead line.

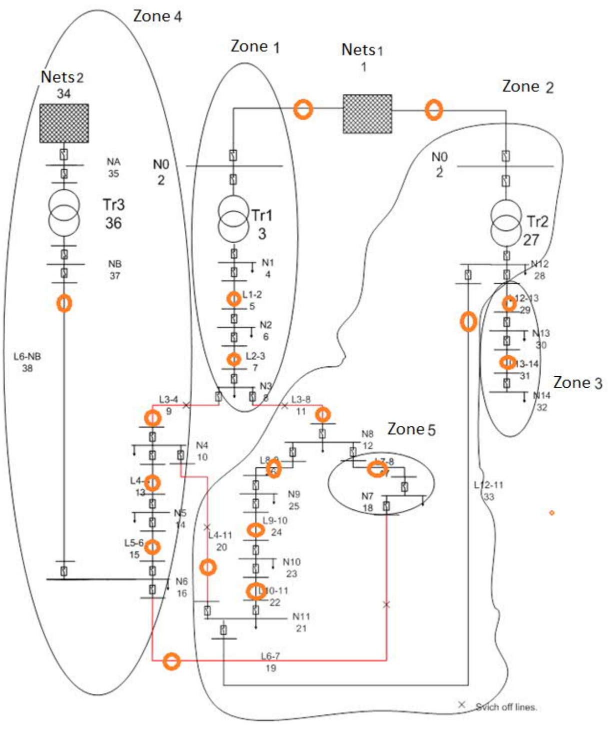

Fig. 4. Distribution network divided into operating areas with sites for installation of current and voltage sensors

Thus, superimposing the control model of the distribution electrical network over the model of installation of the state monitoring sensors, we can say that the distribution network is made flexible because monitoring of the network parameters makes it possible to redistribute the load, isolate the faulty section, and maintain power supply to the consumer.

4 Conclusions

The models of the distribution electrical network control are developed. They enable the distribution network to be flexible and the power supply reliability to increase.
A technique is proposed to place the network state sensors in the distribution electrical network, which provides the highest efficiency of the network operation.
A technique is developed to create an electrical complex of relay protection system. The technique is based on the information communication technology of data transfer and exchange based on IEC 61850, which improves the reliability of power system in comparison with the traditional relay protection.

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