Configurations of 6-10 kV Cable Lines and Types of Cable Damages

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Abstract. The article discusses the principles of electrical circuits formation and includes analysis, which showed that two-way feed ring and trunk networks are the most promising and efficient in technical and economic terms. It has also been found that, currently, in a closed configuration network in the normal operating mode of a network with two power sources, one of the lines must be disconnected. This is due to the impossibility to selectively trip a damaged line, in particular, with single phase-to-earth fault (SEF). It describes that the SEF is the main type of electrical damage in 6-10 kV cable networks.

INTRODUCTION

When designing a 6-10 kV electrical network, the choice of the main circuit is decisive and depends on several factors. Full composition of the elements and the connections between them is determined at this time. In turn, the main circuit is a set of main electrical equipment in the form of generators, transformers, lines, collecting busbars and switching equipment with all connections between them [1-4].

With this it is always based on the main factor in the form of economic feasibility while minimizing the permissible amount of high-voltage electrical equipment. This is due to the fact that it is the high-voltage equipment that is the most expensive and requires significant spaces for its installation.

Another equally important factor that determines the configuration of 6-10 kV cable electrical networks is the location of power sources (PS) and electricity consumers (EC) and their category, which determines the reliability of power supply.

So, in accordance with [2,5-8], the first category EC includes those whose power supply interruption can entail danger to human life, significant damage to the national economy, damage to expensive basic equipment, massive product defects, disruption of a complex technological process and the functioning of especially important elements of the public services.

The first category EC must be power supplied from two independent PS, while the duration of the power interruption should not exceed the time of automatic power recovery [8-10].

The second category EC are those whose power supply interruption can entail danger to human life, leads to massive downtime and undersupply of products, as well as to disruption of continuous technological processes and normal operation of especially important elements of the public services.

In this regard, the second category electricity consumers are recommended to be power supplied from two independent sources, mutually backing each other. For them, interruptions in the electricity supply are permissible for the time required to turn on the backup power by the personnel on duty or the mobile operational brigade [9-10].

Power supply is allowed through one cable line, consisting of at least two cables connected to one common device. If there is a centralized reserve of transformers and the possibility of replacing the damaged transformer within one day, power supply from one transformer is allowed [2].

All the rest belong to the third category electricity consumers.

In the drawings, the main circuit of the electrical network is designed as a single-line with all the elements of the installation disconnected. In some cases, it is allowed to design some elements of the circuit in On position.

EXPERIMENTAL METHOD AND TECHNIQUE

As you know, 6-10 kV cable electrical networks are mainly used for power supply of industrial enterprises and for the power plants auxiliary needs [2].

The power sources (PS) of such a power supply system are the main step-down substations (SDS) of industrial enterprises and transformers for auxiliary needs of power plants. Usually, a voltage of 35 - 220 kV comes to the SDS transformers. Based on economic feasibility, the SDS almost always has one or two step-down transformers, as well as a single or double busbar system for a voltage of 6-10 kV. This allows connecting a significant number of cable lines to the SDS and operational flexibility during operation [3]. In some cases, to limit short-circuit currents, the secondary coils of these transformers are made with split coils.

Distribution substations (DS) play an important role in 6-10 kV electrical networks of industrial facilities and cities. They are usually located in close proximity to certain groups of electricity consumers. So at industrial enterprises it can be shops with large 6-10 kV motors or ore-thermal furnaces, and in urban networks these are groups of multi-storeyed buildings. The use of DS allows reducing the number of switch cells for 6-10 kV voltage; reduce the length of cable lines and simplify the distribution network operation.

Based on the type of consumer and the conditions for its power supply, 6-10 kV distribution electrical networks can be implemented as per radial, trunk, and ring networks.

Radial networks, as a rule, transfer electricity to consumers in only one direction [3]. An example of a simple radial network with one PS can be a DS with one transformer for the third category EC in the form of groups of large motors or urban construction areas. Its circuit is shown in Fig. 1, where the TV1 transformer serves as PS.

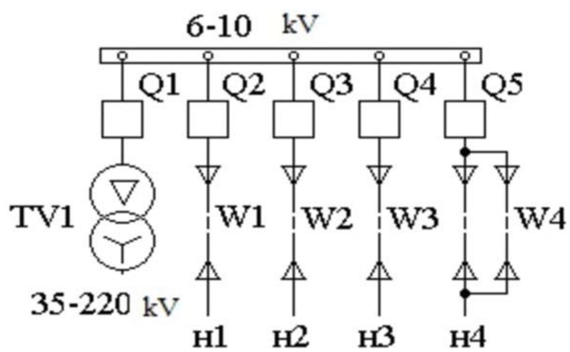

FIGURE 1. Circuit of a simple radial cable network for a voltage of 6-10 kV with a single power source

If, according to the requirements for the power supply reliability, EC belong to the first or second category, then the DS is arranged with two transformers and busbar systems. An example of a circuit of such a radial network with two power sources is shown in Fig. 2, where TV1 and TV2 are the first and second power sources.

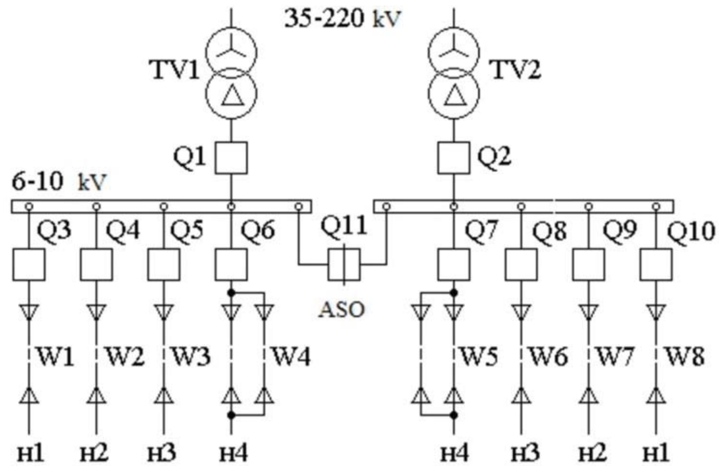

FIGURE 2. Circuit of 6-10 kV radial cable network with two power sources

In normal mode of the DS, the bus Q11 sectional switch is open, and is equipped with a device for automatic switch over (ASO) in case of emergency shutdown of one of the power sources.

Sometimes, due to production needs, a cable ring network is used to supply EC. Each EC is connected to such a network using disconnectors and has a two-way power supply. In special cases, such a network can have more than two PS. An example of a ring network circuit is shown in Fig. 3.

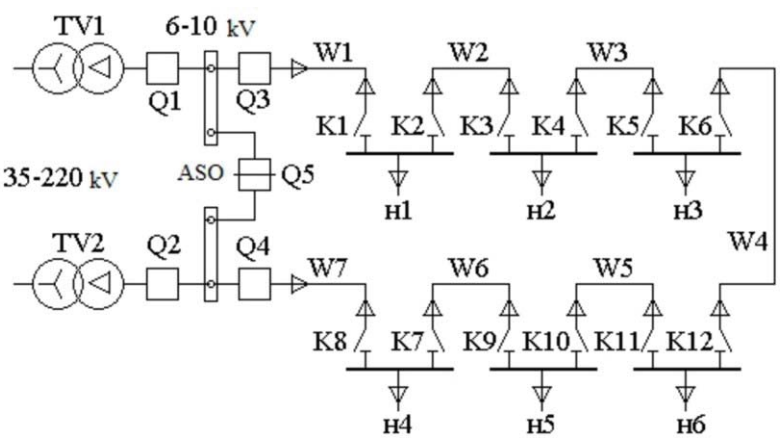

FIGURE 3. Circuit of 6-10 kV ring cable network with two power sources

It should be added that at the present time in a closed configuration network in the normal operating mode of a network with two power sources, Q5 section switch and one of W1-W7 lines must be disconnected. This is caused by the impossibility to selectively disconnect the damaged line, in particular with a single phase-to-earth fault. The latter is determined by the absence, for technical and economic reasons, of line switches in the circuits of all lines, except for their head sections, as well as by the practical impossibility of using directional relay protection in such networks. The line, disconnected in normal network modes is selected according to the power flow conditions corresponding to the minimum power losses at the maximum network loads.

The trunk cable network, as a rule, is characterized by the presence of two power sources and several cable lines connected in series, to which EC are also connected at the points of connection of these lines with the help of disconnectors. An example of such a network is shown in Fig. 4.

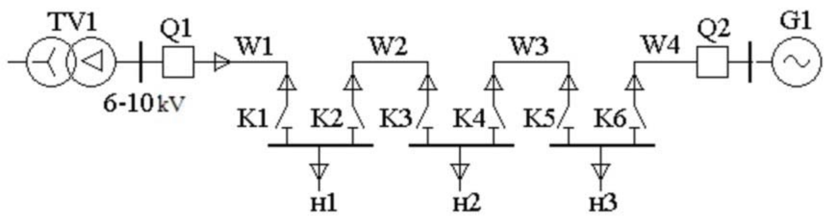

FIGURE 4. Circuit of 6-10 kV trunk cable network powered by two power sources

It should be noted that multi-loop complex closed circuits of electrical distribution networks at the moment are not used properly by electrical power supply system.

Due to the design features of 6-10 kV cables, the methods of their laying and the considered effects, the main types of electrical cable damage are single phase-to-earth fault (SEF) and interphase short circuit (SC), which account for up to 70-90% and 10-30% of the total number of electrical damages. It should be noted that a significant part of the SEF either self-destruct one second after its appearance, or within the first minute passes into interphase short circuit. Such cases account for about 20% of all electrical damage to cable lines.

It should be noted that in an isolated neutral network, a single phase-to-earth fault is not itself an accident. That is why the network is allowed to operate for two hours in the case of SEF. Nevertheless, depending on the total length of the cable lines of the network with uncompensated neutral of large industrial enterprises, the SEF currents in accordance with can reach values of 50-100 A.

CONCLUSION

Analysis of opportunities of the considered types of configuration of 6-10 kV electrical networks, showed that the most promising and effective technical solution is the ring and trunk network with two-way power supply. Since in this case a minimum of switches is used, and if the line is damaged, the consumer is powered from a second source. Despite the fact that in the operational mode of the network, one of the lines must be disconnected due to the practical impossibility to selectively identify the damaged line. This situation can be easily changed if a protection method is developed that would allow selectively detecting a fault in an electrical network with an isolated neutral from a single phase-to-earth fault. It was revealed that the main type of electrical damage in 6-10 kV cable networks, which accounts for more than 70% of all faults, is a single phase-to-earth fault.

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