Restoring normal network operation mode by automatically disabling network ATS

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Abstract. Automatic sectionalizing and redundancy of power transmission lines is one of the conditions for network intellectualization and can significantly reduce the power supply interruption time for rural consumers. However, both sectionalizing and redundancy of power transmission lines in 0.4 kV electric networks are used extremely limitedly since there are no sufficiently effective methods and technical means for their implementation. This article presents a method to automatically deactivate the automatic load transfer switch when restoring the normal network operation mode. The paper considers the implementation of the method on the example of damage occurring in the network where power is supplied to consumers from two power sources using an automatic load transfer switch and two sectionalizing units. A device is developed which allows implementing the developed method of automatic load transfer switch deactivation. The device consists of sectionalizing unit, automatic load transfer switch, voltage presence sensor, power direction sensor, memory element, repeater element, element AND and 3 elements NOT. The work of the device is described. The proposed method for automatically disconnecting the automatic load transfer switch in order to return the consumers' power supply circuit to its initial state solves the problem of eliminating unreasonable power supply interruptions for consumers.

1 Introduction

Improving power supply reliability and power quality is the main task to be solved when creating intelligent electrical networks (Smart Grids) [1-4]. Network intellectualization, first of all, requires the development of new automation methods to minimize power supply interruptions to consumers [5]. Automatic sectionalizing and redundancy of power transmission lines (PTL) is one of the conditions for network intellectualization and can significantly reduce the power supply interruption time for rural consumers [6-10]. However, both sectionalizing and redundancy of power lines in 0.4 kV electric networks are used extremely limitedly since there are no sufficiently effective methods and technical means for their implementation [11-13]. At the same time, technical means for solving this problem were proposed in [14]. These are universal sectionalizing units (SU) that combine the functions of network sectionalizing and redundancy (SUATS). Such a device can operate both in the mode of a sectionalizing units (SU) and the units of automatic load transfer switch (ATS) depending on the specified mode. One of the disadvantages of network redundancy is the lack of ways to automatically turn off the ATS to restore a power supply system back to a normal operation mode. This need arises when the damage at the redundant PTL section is repaired and power is supplied to it from the main power source. The study aims to develop a method for automatically disconnecting a network ATS when restoring a normal network operation mode.

2 Materials and methods

Figure 1 shows a diagram of power supply to consumers from two power sources using the means of network sectionalizing and redundancy.

In normal operation mode, power supply to consumers S1 and S2 (Figure 1 shows one consumer, but in reality, it can be consumer groups connected to a particular PTL section) is provided from the transformer substation (TS) TS1. The universal sectionalizing SUATS1 is turned on and works in the sectionalizing unit (SU) mode. SUATS2 operating in the mode of network ATS unit is disabled. Power supply to consumers S3 and S4 is provided from TS2. SUATS3 is turned on and operates in the SU mode.

If damage occurs to the section 1 of the power lines 1 (sec1PTL1), then the protective device installed on TS 1 will disable this section. SUATS1 will turn off since the voltage at sec1PTL1 will disappear. SUATS2 will turn on and supply power to sec2PTL1, thus supplying consumer S2 from TS2. After repairing the damage at the sec1PTL1, it is first necessary to turn off SUATS2

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Fig. 1. Diagram of power supply to consumers from two power sources using the means of network sectionalizing and redundancy.

and then turn on SUATS1 to restore the normal power supply circuit. Consumer S2 will again lose power for a short time. This will lead to unreasonable damage from power supply interruption especially if the technological process of consumer S2 is sensitive to short-term power outages. Therefore, it is necessary to develop a method for automatically returning the power supply circuit to normal operation mode without power supply interruption to consumer S2. This method was previously developed for 10 kV electric networks [15], but it is not suitable for 0.4 kV networks. Analyzing sequences of changes in such parameters of 0.4 kV electric network operating modes as voltage and power flow direction is used for a new method.

3 Results and Discussion

The proposed method for disconnecting ATS when restoring the normal operation mode of a network making possible not to disconnect consumers of the reserved PTL section is illustrated in Figure 2. Figure 2 shows the structural diagram of a device that implements this method.

The essence of the method is that after turning on the ATS3 to supply power to consumer S13 of the reserved PTL section, the direction of power flow through it is controlled. If the power flow is directed towards the reserved section of the power transmission line, this

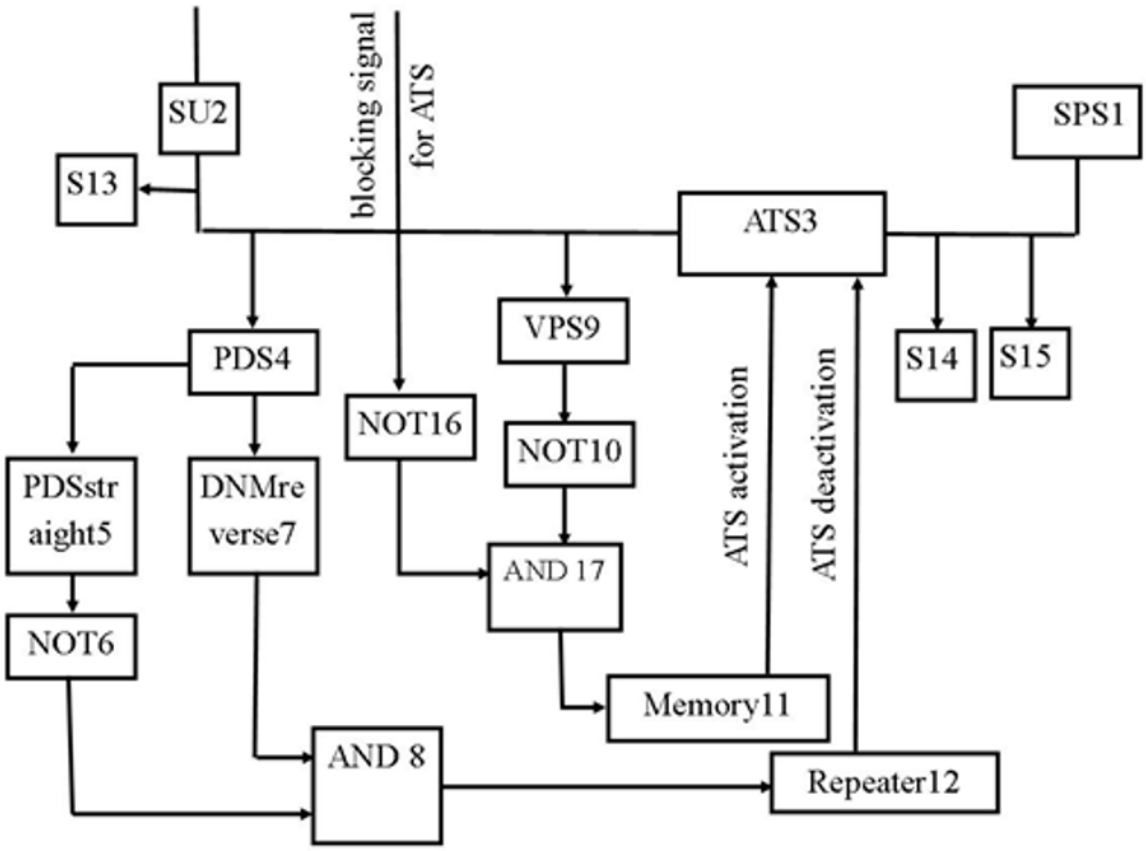

Fig. 2. Structural diagram of a device that implements the method of automatic ATS deactivation.

means that the consumer of this section is supplied by the standby power source (SPS1) and the ATS should not be disconnected. If the power flow changes direction, it is concluded that the power of the consumers of the reserved section from the main source is restored, that is, the sectionalizing unit SU2 is turned on. In this case, the ATS is turned off and the power supply circuit returns to its original state without power supply interruption to consumers connected to the reserved section of the power transmission line [16].

A device for implementing the method works as follows. In normal operation mode of the network, consumer S13 is supplied from the main power source through the sectionalizing unit SU2. Consumers S14 and S15 are supplied from standby power supply SPS1. ATS3 is turned off. There is a signal at the output of the voltage presence sensor VPS9, which monitors the phase voltages in the reserved section. Therefore, there is no signal at the outputs of the elements NOT10 and Memory 11. After the voltage disappears in the reserved PTL section for any reason, for example, due to damage to the main power source, a signal from the output of VPS9 element will disappear, a signal from the output of NOT10 element will appear, which will be remembered by Memory 11 element and ATS will be turned on. After turning on the ATS using power direction sensors PDS4, PDSstraight5 and DNMreverse7 control the direction of power flow through it. A signal from the PDSstraight5 output appears when the power is directed from the reserving section to the reserved one of the power transmission line. A signal from the DNMreverse7 output appears when the power is directed from the reserved section to the reserving one of the power transmission line. If there is a signal from the output of PDSstraight5, there is no a signal from the output of the element NOT6 and accordingly no a signal at the input of the element AND 8. There is no a signal from the output of DNMreverse7, the ATS is not turned off.

When the sectionalizing unit SU2 is switched on after the restoration of the main power source, the direction of the power flow will change. Since the power flow changes direction, a signal will appear at the output of DNMreverse7 element and will be fed to the input of AND8. At the second input of AND8 element, the signal will also appear since there will be no signal at the output of PDSstraight5 and there is a signal at the output of element I8. AND8 will give a signal to turn off the ATS and reset the signal from Memory 11. To eliminate the coincidence of the duration of these signals, the circuit provides for the installation of Repeater 12 element. It increases the duration of the signal sending to ATS deactivation. After the deactivation, ATS returns to its original position. It should be noted that the proposed method requires a number of conditions. Firstly, the reserved and reserving power lines must be phased to prevent interphase short circuits when the SU and the ATS are on together. The second condition is that the primary and standby power sources must be able to work in parallel. And the third condition is that the flow separation point should be on the side of the standby power source concerning the ATS unit.

4 Conclusion

The use of technical means of sectionalizing and redundancy of 0.4 kV power transmission lines requires the development of new methods to minimize losses from lack of electricity supply to consumers, including those associated with short-term power supply interruptions necessary for switching in electric networks. The proposed method for automatically disconnecting the network ATS in order to return the consumers' power supply circuit to its initial state solves the problem of eliminating unreasonable power supply interruptions for consumers.

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