ENHANCED EFFICIENCY OF PROTECTION OF RAILWAY POWER NETWORK SECTIONS BY SECTIONING POSTS WITH DISCONNECTORS

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ABSTRACT

The article considers features of a scheme of protection of sections of a power network with disconnectors at a sectioning post (SP), its advantages and disadvantages are shown. A solution is proposed that allows improving the scheme under study and enhancing reliability of a traction power supply system. The power circuit of a two-track section of the catenary with disconnectors and a switch at SP, schedules of selectivity of protection of switches of adjacent traction substations and switch of SP, and also their time characteristics are shown. The sequence of actions connected with supplying current to the disconnected section of the network under the proposed protection scheme is considered.

Keywords: *railways, power network, catenary, sectioning post with disconnectors, traction power supply, short circuit, non-selective protection system, cross-link protection system, time delay.*

Background. *In some sections of AC railways, a power circuit for a two-track section of the power network with disconnectors at a sectioning post (SP) [1] is used. The organization of protection under such a scheme has its own peculiarities. Thus, to protect against short-circuit currents (SC) in the traction network, when SP works without switches, only a non-selective protection system (NSP) is acceptable [2].*

Objective. *The objective of the authors is to consider enhanced protection of contact network sections with disconnectors at the sectioning post.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, mathematical methods.*

Results. *Let's first consider the features of a non-selective protection system. Remote NSP are performed in all stages with zero time delay [2–4]. This makes it possible to reduce the number of overheating of contact wires, since disconnection of short-circuit on the entire inter-substation zone occurs most rapidly, that is, without time delay (see Pic. 1b). Time of fault shutdown (Pic. 1c):*

$$t_{SHD} = t_{RI(II,\ III)} + t_{QA(B)n}, \qquad (1)$$

where $t_{RI(II,\ III)}$ – response time of the corresponding protection stage of NSP; $t_{QA(B)n}$ – time of tripping of the switch QA(B)n on TS. With the use of modern switches and microprocessor protections, this time is 0,07 s.

However, SC at any point in the protected area «substation–post» at the node power scheme (for example, at point K in Pic. 1a) is accompanied by simultaneous disconnection of all switches (QA1, QA2 and QB1, QB2) with NPS of adjacent traction substations (TS). As a result, current is switched off both in the damaged area and the intact one, that is, both tracks are de-energized.

Let's show the sequence of operations to restore voltage in the power network after SC occurred [2].

After disconnecting all switches of adjacent traction substations, SP is «disassembled», that is, the disconnectors QSA1, QSA2 and QSB1, QSB2 are disconnected to a dead time (Pic. 1). Further, a «blind» automatic reclosure on adjacent TS is performed and the disconnected switches are turned on. Then, the switch QA1 of the damaged section is again disconnected from its protection, while the switches QA2, QB1 and QB2 of the undamaged sections remain in operation. After that, QSA2, QSB1 and QSB2 disconnectors of the intact sections are switched on by counter voltage, and QSA1 disconnector remains off. As a result, the voltage is restored in the intact sections of the inter-substation zone.

Thus, the advantage of the protection circuit of the contact network with the disconnectors at SP is minimization of the probability of overheating of contact wires.

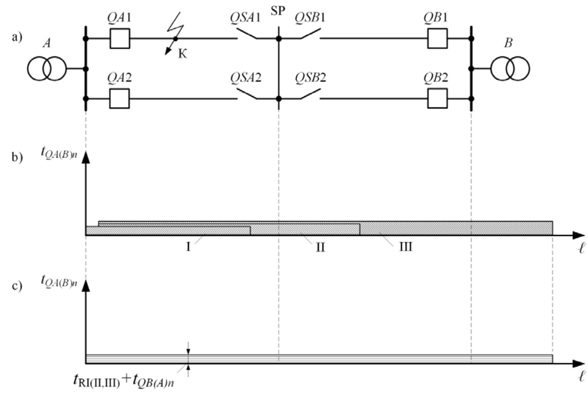
At the same time, the drawback of such a protection scheme will be de-energization of both tracks of the entire inter-substation zone, due to the peculiarity of NSP operation, which can lead to disruption of the train schedule and to the corresponding negative consequences if the next train stops while making the grade [5]. In addition, operation of a large number of switching devices, both when the fault is switched off and during restoration of voltage in the power network, increases their wear [8, 9]. All this reduces reliability of power supply of traction of trains and raises operational costs.

It is possible to significantly improve reliability of the traction power supply system in this case by improving the protection scheme of the contact network sections with the disconnectors at the substation by including the switch QAB (Pic. 2a) cross-connecting the sections of the contact network into the bus bar of SP [10, p. 45].

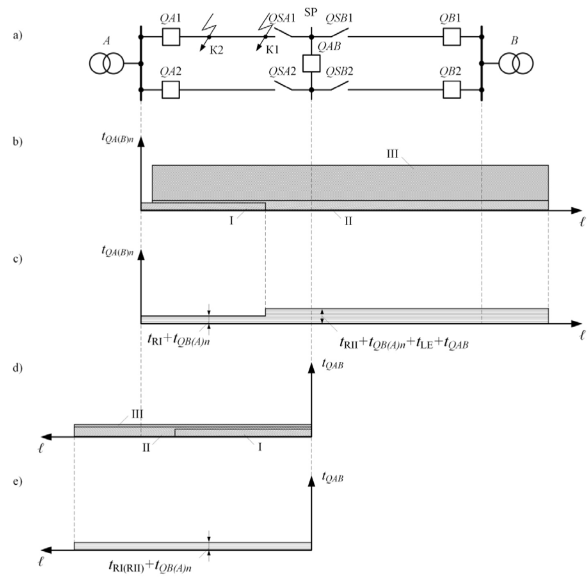
The turning on of one QAB switch at SP will make it possible to organize short-circuit protection in the traction network using a logical interconnection between the switches of parallel TS lines, namely, the cross-link protection system (CLPS) [2, 6] at the substations of the section of the contact network under consideration, when non-selective protection of the switch SP is in operation. As a result, at SC, only one track will be de-energized all along the adjacent TS, containing the damaged section. In this case, a fast turning off of SC is guaranteed [7].

The implementation of CLPS for TS with respect to the proposed scheme for protecting the contact network sections with disconnectors at SP and one switch can be performed as follows (see Pic. 2). The coverage area of I stage of the distance protection does not reach SP buses, that is, it remains unchanged. The second stage of protection of CLPS is performed with the increased zone of action II, that comprises gripping bus of the adjacent TS, and thus repeats the third stage. For all that, the second stage is equipped with a logical connection [2]. This makes it possible to avoid the effects of the false action of protecting the TS switches of neighboring tracks.

The block diagram of distance protection of the TS circuit breakers of parallel tracks with transverse mutual coupling in the second stage, represented by the logical elements «AND-NOT», is shown in Pic. 3. The time delay of the first and second stages of protection of CLPS is chosen to be zero (Pic. 2b). The third stage of protection with the zone of action III, which covers all the distance to the adjacent substation, is selected with a time delay.



Pic. 1. Power supply scheme of a two-track section of the power network with disconnectors at SP (a), schedules of selectivity of protection of switches of adjacent TS (b) and their time characteristics (c).



Pic. 2. Power supply scheme for a two-track section of the power network with disconnectors and a switch at SP (a), schedules of selectivity of protection of switches of adjacent TS (b) and switch of SP (d) and their time characteristics (c, e).

The non-selective protection of QAB circuit breaker on SP should be performed in a non-directional mode with the action zones of I, II, III stages (Pic. 2d, e) for triggering in faults at any section between adjacent TS.

Let's clarify the work of the proposed scheme for protecting sections of the power network and its features.

SC at any point in the inter-substation zone is always in the range of the second protection stages of CLPS of circuit breakers QA1, QA2 and QB 1, QB 2 of adjacent TS and in the range of non-directional non-selective protection of the QAB switch of SP. However, in case of fault, for example, at point K1 near the SP buses (Pic. 2a), only the QAB switch is turned off at the first moment of time. Disconnection of QA1 and QB 1 switches of the damaged track occurs when there is no blocking signal from the second protection stages of the parallel line breakers (QA2 and QB 2, respectively), that is, from the protection of the TS circuit breakers associated with the first logical «AND-NOT» operation (Pic. 3). However, after switching off the QAB switch on the SP, the current distribution in the traction network changes (the SC feed is stopped through the undamaged track) and the blocking signal is removed. After this, the breakers QA1 and QB 1 of the damaged supply line are disconnected.

Thus, SC is accompanied by a false disconnection of only one circuit breaker (QB 1 with a fault at point K1 (2) in Pic. 2a), namely: of the circuit breaker of the contact network of the damaged track. This means that under the proposed protection scheme, the current is disconnected in a relatively small part of the network, covering one of the tracks of the node power scheme.

In addition, at SC near the buses SP (K1 in Pic. 2a) damage from adjacent substations is disconnected in cascade, i.e. after disconnecting the circuit breaker at the SP. In the case where SC is fixed in the zone of action of the first stage of protection of the CLPS of the circuit breakers, for example at the point K2, the closest circuit breaker QA1 of the damaged section of the contact network and the switch QAB at SP are most quickly disconnected, and after the last operation the switch QB 1 of the undamaged section on the other side of the damaged track is disconnected cascadely.

It follows from the above example that the disconnection of the fault in the protection circuit of the power network is always cascaded from the most remote side of the damaged track, while on the opposite side of the track a cascade disconnection is performed exclusively at SC near the SP.

The time for the cascade shutdown of the fault is (Pic. 2c):

$$t_{SHD} = t_{RII} + t_{QA(B)n} + t_{LE} + t_{QAB}, \qquad (2)$$

where t_{RII} – response time of the second stage of protection CLPS;

$t_{QA(B)n}$ – time of tripping of the switch QA(B)n at TS;

t_{LE} – time of operation of logic elements;

t_{QAB} – time of tripping of the switch QAB at TS.

The SC time of tripping on the side of the undamaged track by the circuit-breaker SP (Pic. 2e) and in the case *of triggering of the first stage of protection CLPS on the side of TS is equal to (Pic. 2c):*

$$t_{SHD} = t_{RI} + t_{QA(B)n}, \quad (3)$$

where t_{RI} – response time of the first stage of protection CLPS;

$t_{QA(B)n}$ – time of tripping of the switch QA(B)n at TS.

Thus, additional feeding if SC from the undamaged track and the nearest substation is terminated after 0,7 s, and on the opposite side of the damaged track – after 0,14 s (taking into account the time of cascading action).

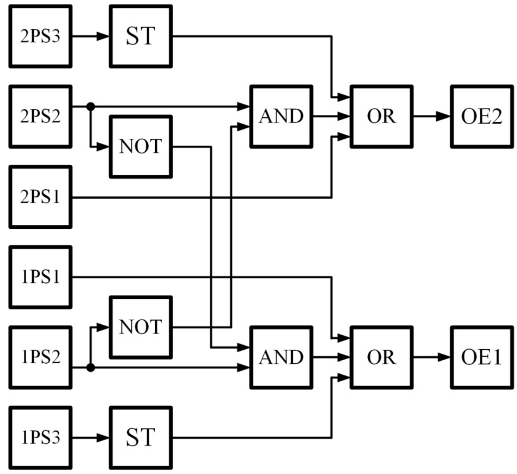
However, overheating of the contact wire in the case of SC, accompanied by an arc, is possible with a total shutdown time exceeding 0,16 s [7].

Therefore, in spite of the fact that the shutdown time of SC in the circuit with the disconnectors at the SP and one switch, taking into account the time of the cascade action, is twice as large as in the case of the circuit with disconnectors only at the SP (for the time t_{LE} and t_{QAB}), the fault shutdown for the specified time will ensure the reliable functioning of the traction power supply system.

Regarding the sequence of actions related to the supply of current to the disconnected part of the network with respect to the protection scheme under consideration, after disconnecting the circuit breakers SP and adjacent TS of the damaged track (QAB and QA1, QB 1), the QSA1 and QSB 1 disconnectors on the SP are disconnected in the dead time (Pic. 2). Then the recloser switches QA1 and QB 1 are switched on by automatic reclosure on the TS. After this, the circuit breaker QA1 of the damaged track section is again disconnected from its protection. The circuit breaker QA2 remains intact. Further, the circuit breaker QAB and the QSB 1 disconnector at the SP are switched on by the dependent automatic reclosure from the current with TS. And thus, the current is restored on all sections of the contact network, except for the damaged one.

As a result, the number of switching devices is approximately halved, which increases its overhaul life.

Conclusion. *The described research results give grounds to conclude that the application of the protection scheme of the power network with disconnectors at the SP and one switch improves the reliability of the traction power supply system and reduces operating costs.*



Pic. 3. Structural diagram of protection CLPS of the breakers of the parallel lines of TS: 1 (2) PS1 ... 1 (2) PS3 – 1, 2 and 3 stages of remote protection CLPS of switches QA1(2) and QB1(2); ST – time delay; NON-AND, OR – logical operations; OE1 (2) – output device, which affects switching off the circuit breaker QA(B)1(2).

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