PARTIALLY NON-SELECTIVE PROTECTION SYSTEM OF CATENARY

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ABSTRACT

A partially non-selective system of protections is proposed, which provides, as well as non-selective system of protections, fault clearing at any point of the zone between substations without specified time, but with a small amount of non-selective disconnections of switches of traction substations. An algorithm for the identification of areas of non-selective disconnections is given. The reliability of the system and possibility of its use as a model are justified.

ENGLISH SUMMARY

Background. *Efficient operation of traction power supply devices is impossible without a reliable system of protection against short-circuit (hereinafter-SC). Such a system is a set of all protections serving switches of the zone between substations of catenary on all its parallel tracks.*

Reliability of the system of protection of AC catenary involves minimizing the damage of catenary, this can be achieved only through instant, i. e. specified time, fault clearing at any point in catenary of the zone between substations.

In fact, it is possible to achieve minimum time for fault clearing using non-selective [1] and the proposed partially nonselective protection systems.

Objective. *The objective of the author is to investigate a partially non-selective system of protections.*

Methods. *The author uses analysis, mathematical method and modeling.*

Results

1.

In case of a non-selective system (see Pic. 1b, c) its area covers the whole zone between substations L > (L_1 + L_2) with time $\Delta t_3^I = \Delta t_B$, where Δt_B is time of switch's work from the receipt of a signal for disconnection from a protection to the full fault clearing. In this case fault clearing is carried out without specified time ($\Delta t = 0$).

However, under such a protection system SC anywhere in the zone between substations results in disconnection of all switches of traction substations supplying this zone between substations, as well as a switch of a sectioning point, which is the closest to SC location (with respect to Pic. 1a switches B1, B2, B7, B8 and B5). In case of a non-selective system of protection in this situation there will be a temporary blackout throughout the zone between substations, which can lead to undesirable disruption of train timetable on all tracks.

A proposed partially non-selective protection system (hereinafter-PNSPS) as a standard selective [1], is a two-zone one, but the length of its first zone without specified time is made 15% greater than the distance from traction substation (hereafter – TS) to partitioning post (hereafter – PP), i. e. the length of 1,15 L (see Pic. 1d, e, which show temporal characteristics of the operation of protection of switches B2 and B4).

Actually, the areas of 0,15 L in the vicinity of PP and TS are configurable zones of non-selectivity, where in case of SC we will observe non-selective disconnection of switches of traction substations TS1 and TS2, supplying this zone between substations (see. Pic. 1d) or selectioning point PP (see. Pic. 1e).

Since the first zones of protection system PNSPS are made larger than the distance between TS and PP, fault clearing anywhere in the area will take place without specified time ($\Delta t = 0$), i. e. with a minimum time equal to $\Delta t_3^I = \Delta t_B$.

Reducing the area of non-selective disconnection at PNSPS (as compared to a non-selective system) reduces the number of disconnection of switches of traction substations.

Moreover, the real area of non-selective disconnections due to the interaction of SC currents of catenary of parallel tracks of the zone between substations are significantly lower than 0,15 L. They are called true areas of non-selectivity.

2.

Determination of true areas of non-selective disconnection of switches is a main task of the proposed option.

Its solution with regard to the protection of switch B2 at a pickup setting Z_{C3} involves the establishment of the real values of currents in the areas of nodal power supply scheme, as well as voltage and resistance, measured by the protection in case of SC in the zone between substations (see Pic. 2a).

In Pic. 2a there are following notations:

TS1 and TS2 – busbars of traction substations of the considered zone between substations;

U_1 and U_2 – estimated voltages of systems, supplying substations TS1 and TS2;

PP – busbars of a sectioning point;

Z_1 and Z_2 – resistances of a systems and transformers of substations TS1 and TS2;

$Z_Э$ – additional equivalent resistance in SC location (SC current spreading resistance, which occurs near a substation, plus the resistance of electric locomotive transformer, if SC occurs in rolling stock), in calculations is assumed to be zero due to its small value;

L_1 and L_2 – distances to a sectioning point from substations TS1 and TS2;

l_K – distance to SC location from a set point;

B1, B2, B3, B4, B5, B6, B7 and B8 – switches of substations and sectioning point, the action of which is studied;

I_1 and I_2 – short-circuit currents of substations TS1 and TS2;

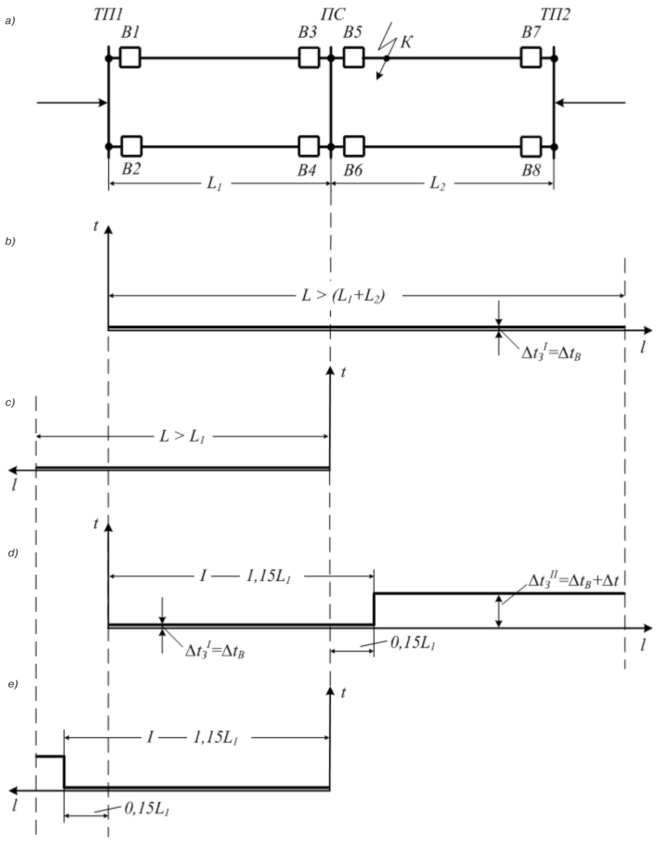
I_1^I and I_1^{II} – components of SC current of a substation TS1 on the first and the second tracks.

Current distribution in a traction network of a double-track railway section can be determined, using a method proposed by professor V. N. Pupynin [2].

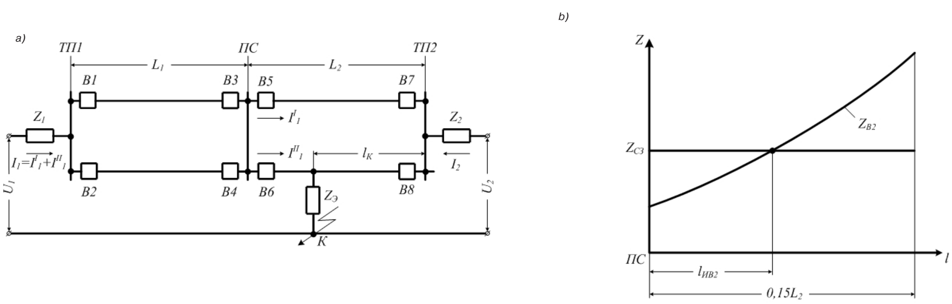
Resistance values, measured by the protection of a switch B2 at the ends of preselected sections, are calculated by relating voltage at busbars of a substation TS1 to the current of its feeder:

$$Z_{B2} = \frac{U - \left(I_1^I + I_1^{II}\right) \cdot Z_1}{I_{11}}, \qquad (1)$$

where U is estimated voltage of a system, supplying a substation;



Pic. 1. Scheme of double-track zone between substations with traction substations ТП1 and ТП2 and selecting point ПС (a) and temporal characteristics of the operation of protection of switches B2 and B4 with a non-selective (b, c) and partially-non-selective (d, e) protection systems.



Pic. 2. The scheme of computational zone between substations of catenary (a) and graph-analytical constructions to determine a true zone of non-selectivity to protect a switch B2 (b).

$\left(I_1^I + I_1^{II}\right)$ are components of SC current of a substation on the first and the second track;

Z_1 is reduced resistance of supply electric system and transformers of a traction substation;

I_{11} is SC current on one of tracks from a substation to a sectioning point.

Reduced resistance can be defined as a sum of resistances reduced to a voltage of a system and a transformer:

$$Z_1 = \frac{U_{cp}^2}{S_K^{(3)}} + \frac{U_{cp}^2 \bullet u_K \%}{100 S_{T.HOM}}, \qquad (2)$$

where U_{cp}^2 is average value of voltage at busbars of supply voltage in kV;

$S_K^{(3)}$ is short circuit power at bus bars of TS in MVA;

$u_K\%$ is relative nominal resistance of two windings of a three-winding step-down transformer, involved in the experiment with SC, as a percentage;

$S_{T.HOM}$ is nominal power of a transformer in kVA.

As a pickup setting of Z_{C3} we take a setting of one track of a double-track section with a parallel connection of suspension wires or equal currents in suspensions of both tracks:

$$Z_{C3} = 1{,}15 L_1 z_{22}, \qquad (3)$$

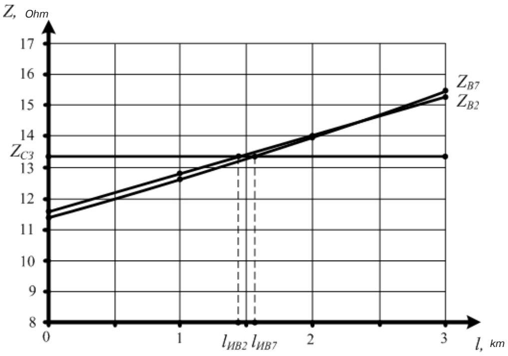
where L_1 is a distance to a sectioning point from a substation TS1;

z_{22} is an electrical resistance of one track of a double-track section with parallel connection of wires of suspensions or equal currents in suspensions of both tracks in Ohms / km.

After determination of resistance at certain points of the scheme and a pickup setting, we will find a value of a true zone of non-selectivity using graph-analytical method.

Table 1

Distance to SC location ($L_2 - l_K$), km	Resistance Z_{B2}, Ohm	Resistance Z_{B7}, Ohm
3	15,27	15,39
2	14,07	14
1	12,85	12,67
0	11,6	11,4



Pic. 3. Dependences of resistances, measured by the protection of switches B2 and B7, on a distance. Determination of a true area of non-selectivity.

Pic. 2b shows the dependence of the resistance found from the distance to SC location.

Obtained resistance measured by protection on a switch B2 of a substation TS1 depending on the remoteness of SC location from PP vary according to the line Z_{B2}. A straight line shows a value of a set pickup setting Z_{C3} (see Pic. 2b).

Thus, the intersection of the line Z_{B2} with a straight Z_{C3} defines a true area of non-selective disconnection of a switch TS ($l_{ИВ2}$).

Determination of a true area of non-selective disconnection of switches PP in case of SC at a station feeder or line DPR is similar.

3.

Now we consider an example of determining true areas of non-selective disconnection of switches.

In the calculation the following parameters of an estimated experimental section were taken: distance from TS to PP $L_1 = L_2 = 20$ km, suspension PBSM1–70 + MF-100, step-down transformers TDTNE-40000/110, short-circuit power at busbars of TS $S_K^{(3)} = 2000$ MVA.

The calculation is made with respect to the protection of switches B2 and B7 (see. Pic. 2a), the presence of which is necessary for construction of a visual pattern in the identification of a true area of non-selectivity.

Removing the short-circuit point from PP in the zone of non-selectivity being configured (0,15 L), we find the currents at selected sites of the circuit and the resistance, measured by the protection at the ends of these sites. Next we conduct a calculation of site to the point of SC, separated from PP in 3 km ($L_2 - l_K$).

Currents flowing in the selected section:

$I_1^I = -1,23$ kA, $I_1^{II} = 3,92$ kA, $I_2 = 3,38$ kA.

The results were obtained by the method proposed in [2].

Then we find values of resistance, measured by the protection of switches B2 and B7 at the end of the selected section.

Reduced resistance mains of supply electric system and transformers of traction substation:

$$Z_1 = Z_2 = \frac{26,3^2}{2000} + \frac{26,3^2 \cdot 10,5}{100 \cdot 40} = 2,17\ Ohm.$$

Then, the resistance values according to the expression (1):

$$Z_{B2} = \frac{26,3 - (-1,23 + 3,92) \cdot 2,17}{1,35} = 15,27\ \text{Ohm};$$

$$Z_{B7} = \frac{26,3 - 3,38 \cdot 2,17}{1,23} = 15,39\ \text{Ohm}.$$

Similarly we determined resistances, measured by relay of B2 and B7 at the ends of other preselected sites. The calculation results are shown in Table 1.

By the expression (3) we determine a pickup setting at a constant network z_{22} = 0,58 Ohm / km, taken for a suspension PBSM-70 + MF-100:

$Z_{C3} = 1,15 \cdot 20 \cdot 0,58 = 13,34$ Ohm .

Based on the obtained results we build a dependence (Pic. 3).

A true area of non-selective disconnection of switches B2 and B7 – $l_{ИВ2}$, $l_{ИВ7}$ as a result amounted to (0,06–0,08) L.

Consequently, a small length of the zone of non-selective work of protections significantly reduces the amount of non-selective disconnections of switches, and thus the reliability of electricity supply increases.

Conclusion. *Partially non-selective protection system is a reliable system that provides a minimum damageability of catenary and a minimum amount of non-selective disconnections of switches during short circuits in the zone between substations that contributes to improving the reliability of the whole system of traction power supply.*

It seems reasonable to use PNSPS as a prototype to AC networks between substations.

Keywords: railway, catenary, zone between substations, protection system, short circuit, selectivity, specified time.

REFERENCES

1. Guidelines for relay protection of traction power supply systems [*Rukovodyaschie ukazaniya po releynoy zaschite sistem tyagovogo elektrosnabzheniya*]. Moscow, Transizdat publ., 2005, 216 p.

2. Pupynin, V. N. Determination of zones of protection of feeders 27,5 kV substations and sectioning points of AC railways at node supply system [*Opredelenie zon deystviya zaschit fiderov 27,5 kV podstantsiy i postov sektsionirovaniya zheleznyh dorog peremennogo toka pri uzlovoy sheme pitaniya*]. Works of MIIT. Iss. 199. Moscow, Transport publ., 1965, pp. 184–195.

3. Figurnov, E. P. Relay protection. Textbook [*Releynaya zaschita*]. Moscow, Zheldorizdat publ., 2002, 720 p.

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