

THE LACK OF SELECTIVITY IN 10 kV CABLE FEEDERS PROTECTION

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SUMMARY

The paper makes the analyze of the selectivity of short-circuit and earth-fault protection of the 10 kV outlets from transformer station (TS) X/10 kV, (which protection was done according to Technical recommendation: "Protection for 10 kV, 20 kV and 35 kV lines") and substations 10/0,4 kV supplied by the same cable feeders, (protection done according to Technical recommendations for substations 10/0,4 kV). It is evident that the mentioned protections do not make selectivity. At the short-circuit down-stream of 10 kV fuses in substation 10/0,4 kV, the fuse is burnt as well as cable feeder circuit breaker is activated in transformer station X/10 kV, producing disconnection of the whole 10 kV feeder. At the earth-fault down-stream of 10 kV fuses in substation 10/0,4 kV circuit breaker is activated by protection in transformer station X/10 kV, while the fuse does not burn at all. The application of circuit breaker in transformer bay of 10 kV switchgear in substation 10/0,4 kV is also considered (instead of the switch-fuse combination). At the end the solution of these problems is proposed with concerning conclusions .

1 INTRODUCTION

Making the conception of the short-circuit protection TS X/10 kV according to (1), the cable feeder is seen as the final at the chain of selectivity, and it was determined the zero value of the time-delay producing the absence of time-delay relay at the classical relay protection. By the other side, according to (2), (3), (4), and (5), the fuses mentioned at the Table 1 are foreseen for the short-circuit protection of the power transformer (PT) 10/0,4 kV at substations 10/0,4 kV and its connection with the 10 kV switchgear .

TABLE 1 - FUSE RATE DEPEDENTLY OF PT RATED POWER

rated power PT (kVA)	fuse rate (A)
250	31,5
400	50
630	80
1000	125

it is not according to (2) but it is applied at "Elektrodistribucija – Beograd".

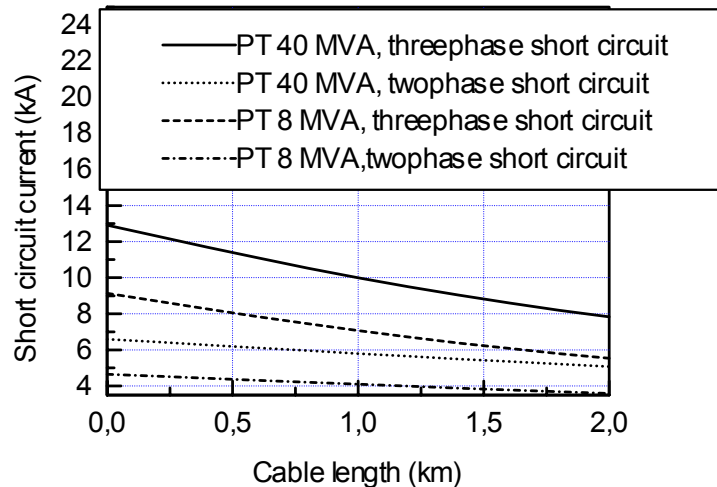
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It shall be analyzed the selectivity of the described protection for the short-circuit down-stream the fuse, on the cable for the 10 kV connection or on PT. Regarding the earth-fault protection, its time-delay is adjusted, according to (1), to 0,2 – 3 s (typical 0,5 s). At the cable network 10 kV, according to TP-6 (6) the earth-fault current is limited on approximately 300 A. It shall be also analyzed the selectivity of such earth-fault protection, at the single-phase earth-fault, on the cable for the connection or on PT.

Thanking to the donations, in the last years in “Elektrodistribucija – Beograd” are installed some prefabricated substations 10/0,4 kV with integrated “ring main unit” 10 kV switchgears, insulated by sulphurhexarfluoride, with the circuit breakers at the transformer bay. Short-circuit protection of PT at these switchgears is without time-delay, while earth-fault protection does not exist (the exception is one switchgear). It shall be analyzed the selectivity of protections for these solutions at the short-circuit, same as for the previous cases.

2 THREEPHASE AND TWOPHASE SHORT-CIRCUIT

At the threephase short-circuit on the 10 kV bus-bars at TS X/10 kV with cable feeders (city TS), the value of short-circuit power is in the range from appr. 225 MVA (for the case of 40 MVA PT, with 18% short-circuit PT impedance) to app. 115 MVA (for the case of 8 MVA PT, with 7% short-circuit PT impedance). The value of threephase and twophase short-circuit current, depending on the 10 kV cable length (type IPO 13 A 3x150 mm², from 10 kV bus-bars at TS X/10 kV up to the fault point) is shown at Dwg 1.

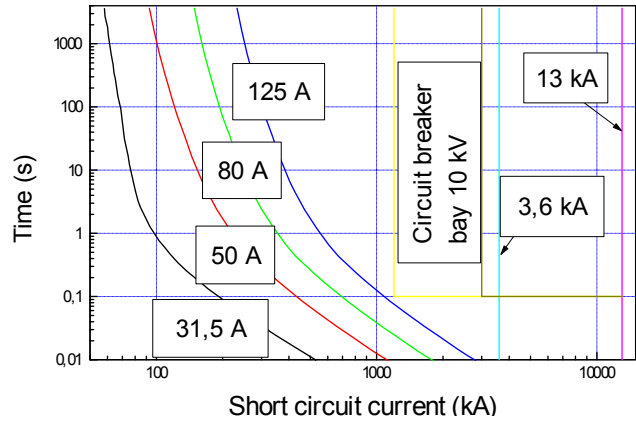


Drawing 1. Dependability of the current on the cable length.

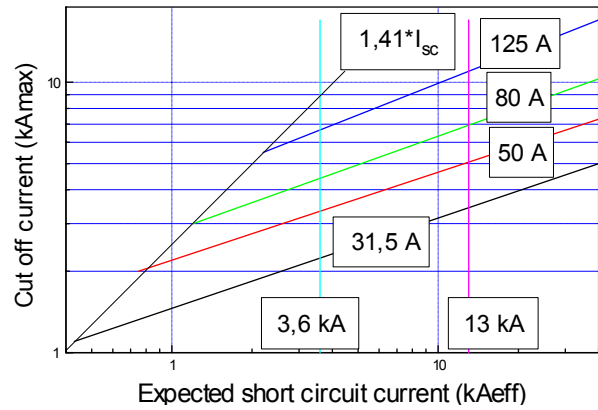
As it is seen at the Dwg 1, for the usual cable lengths at the city network, the value of short-circuit current, depending on the PT rated power, cable length and a kind of fault, goes from 3,6 to 13 kA.

2.1 Substations 10/0,4 kV with the fuses in the 10 kV tranformer bay

Drawing 2 shows the current-time characteristics of fuses in substations 10/0,4 kV, of the circuit breakers in the 10 kV cable bay at TS X/10 kV as well as the usual current range of the threephase and twophase short circuit. As it is seen at the Dwg 2, the current range from 3,6 kA up to 13 kA, makes very fast burning of fuse (less than 10 ms) and, in many cases, cutting of the short-circuit current (Dwg 3.). Table 2. shows the sizes of the cut-off current, depending on the rated fuse and expected value of short-circuit current.



Drawing 2. The current-time characteristics of fuses and circuit breaker by short-circuit



Drawing 3. The the cut-off current characteristics of the 10 kV fuses

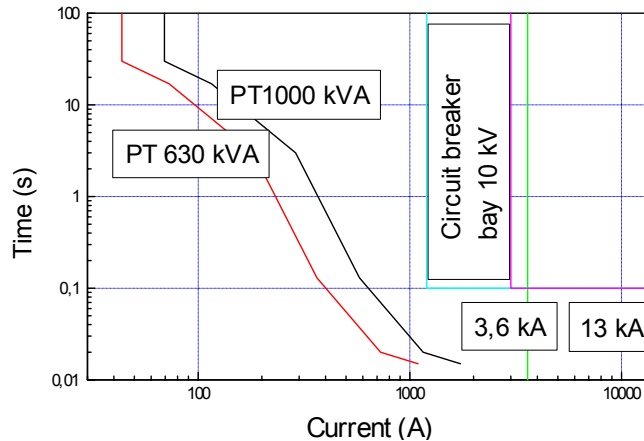
TABLE 2 - FUSES CUT-OFF CURRENT

Rated current of fuse (A)	Expected current of short circuit (kA)	Cut-off current (kA _{max})	Cut-off current (kA _{eff})
31,5	3,6	2,26	1,6
	13	3,4	2,42
50	3,6	3,38	2,4
	13	5,13	3,64
80	3,6	4,43	3,14
	13	6,98	4,95
125	3,6	5,08	3,6
	13	11	7,8

By the other side, 10 kV cable feeder bay short-circuit protection, according to (1), is adjusted to the secondary current value of 20 – 50 A, and, taking in consideration ratio of the current measuring transformers 300/5, makes 1,2 – 3 kA of the short-circuit current, without any time delay. These values, for the illustration, are shown as well at the Dwg 2. Comparing the cut-off fuse current and the adjusted current value of short-circuit protection of 10 kV feeder bay, it may be concluded that, at good relation of these values (short-circuit protection of the feeder bay circuit breaker at TS X/10 kV at maximum, smaller rated fuse at substation 10/0,4 kV), the considered protections in row shall be selective. But, at the most cases of the city network (rated currents of fuse 80 and 125 A), cut-off fuse current is big enough to be »seen« by short-circuit protection of 10 kV cable feeder bay without any time delay, therefore belonging cable feeder will be disconnected unselective.

2.2 TS 10/0,4 kV with the circuit breaker at the transformer bay

At the network of “Elektrodistribucija – Beograd”, there are about thirty substations 10/0,4 kV with 10 kV »ring main unit« switchgears, in sulfurhexarfluoride insulation (received as the donation) with the circuit breaker in tranformer bay. The circuit breaker is protected by the relay with the current-time characteristic shown at Dwg 4. Drawing 4. also shows the current-time charactestics of the protection of 10 kV cable feeder circuit breaker in TS X/10 kV. Same drawing shows the expected range of threephase and twophase short-circuit currents.



Drawing 4. Current-time characteristics of the short-circuit protections in substations TS 10/0,4 kV and TS X/10 kV

As the Dwg 4. shows, the value of the short-circuit current for the fault inside the substation, for the usual 10 kV cable length, is big enough to activate simultaneously the short-circuit protection of the transformer bay of 10 kV switchgear at substation 10/0,4 kV and the protection of the belonging 10 kV feeder bay. Due to the absence of time-delay relay of the protection for 10 kV feeder bay circuit breaker, in the case of short-circuit at the connection between PT and 10 kV switchgear or at the PT itself, at substation 10/0,4 kV the whole 10 kV supplying line with belonging substations will be disconnected.

2.3 Solution suggestion

Intending to ensure the selectivity between the short-circuit protection of 10 kV cable bay circuit breaker at TS X/10 kV and the protection device at substation 10/0,4 kV it is necessary to add time-delay in the short-circuit protection of 10 kV cable bay circuit breaker at TS X/10 kV, adjusted to 100 ms. In such case it is important to check if the cable IPO (NPO) 13A 3X150 mm² stands thermal tension by such increase of the short-circuit current duration. According to Lalević (7), for the cable IPO (NPO) 13A 3X150 mm², with the pressed type of terminals, with starting temperature of 60⁰ C and the final 140⁰ C, for the short-circuit duration of 1s, it is allowed the short-circuit current density to be up to 78 A/mm², what makes the allowed short-circuit current 11,7 kA. Recalculated allowed value for shorter duration, of 100 ms, by the relation:

$$I_{efx} = \frac{I_{ef1}}{\sqrt{t_x}}$$

makes 37 kA, what is much more than expected short-circuit current (maximum 13 kA). Suggested increase of the short-circuit duration should not even closely damage the cable.

3 SINGLEPHASE EARTH-FAULT

The most part of the 10 kV cable city network at “Elektrodistribucija – Beograd”, is with the earthed neutral point of PT at TS X/10 kV, with limited earth-fault current at app. 300 A. The earth-fault protection is adjusted to be activated by the earth-fault current of value bigger than 30 A. The time-delay relay of earth-fault protection is adjusted, according to (1), to 0,2 – 3 s (typical 0,5 s).

3.1 Substations 10/0,4 kV with fuses in the transformer bay

The current–time characteristics of earth-fault protection, as well as the values of the earth-fault currents are given at the Drawing 5.

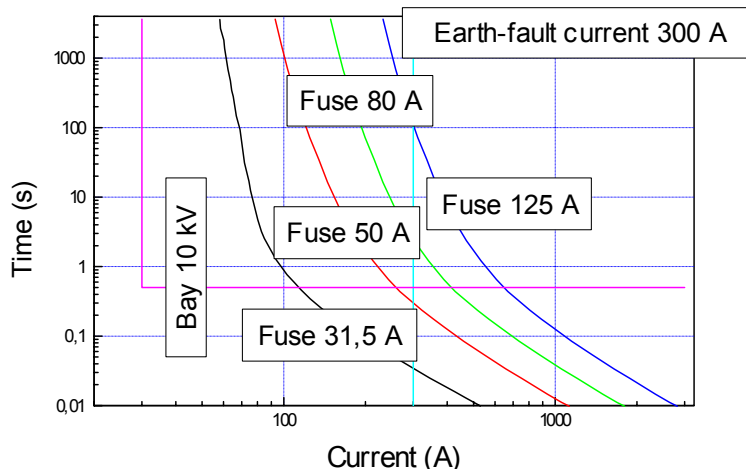


Figure 5. The current-time characteristics of fuses and circuit breaker for earth-fault

The drawing shows that in number of cases (PT of 250 and 400 kVA) fuses in substations are »faster« than the earth-fault protection in TS X/10 kV. For the most of the cases (PT of 630 kVA) fuse in substation would interrupt earth-fault current for about 2,5 s, but the cable bay earth-fault protection in TS X/10 kV protection is »faster«, and the protections are not selective. In the case of PT of 1000 kVA, fuse would interrupt the earth-fault current for more than 100 s. Since the cable bay protection is much faster, the protections in this case are not selective.

3.2 TS 10/0,4 kV with the circuit breaker in the transformer bay

At “Elektrodistribucija – Beograd”, the most number of substations 10/0,4 kV from the donation (except one) with 10 kV »ring main unit« switchgears in sulfurhexarfluoride insulation with the circuit breaker in the transformer bay are without earth-fault protection. In such cases, of course, each earth-fault produces the outage of the whole 10 kV feeder.

At the one substation 10/0,4 kV the earth-fault protection is of the type of maximum current, time independent, with the fault current range 8-80 A and time-delay range 0,1-1s. In such case it is evident that the current value and time-delay of earth-fault can be adjusted so that this protection can be selective with the protection in 10 kV cable bay circuit breaker at TS X/10 kV.

3.3 Solution suggestion

In order to make the selectivity of the earth-fault protections of 10 kV feeder bay at TS X/10 kV and conventional substations 10/0,04 kV with PT up to 630 kVA, it is necessary to readjust the earth-fault time-delay of 10 kV feeder bay at TS X/10 kV to 3 s. Also, in this case, it is important to check if the 10 kV cable feeder stands the thermal tension by such increase of the earth-fault duration. According to above mentioned, allowed effective current value for the cable IPO 13 A, 3 x 150 mm² for the default time of 1 s is 11,7 kA. Recalculated value for 3 s, by the relation:

$$I_{efx} = \frac{I_{ef1}}{\sqrt{t_x}}$$

makes 6,75 kA, what is much more than real value of earth-fault current (maximum 0,3 kA). That means that suggested increase of earth-fault duration would not thermally damage the cable.

At the other considered cases for substations (PT of 1000 kVA protected by fuses, PT protected by the circuit breaker without the earth-fault protection) the solution should be installing of the earth-fault protection at substations 10,04 kV, what is estimated as the expensive solution, and therefore it is not suggested.

4. MAINTENANCE EXPERIANCE

According to the malfunction statistics in the year 2002, about half of fuses burnings and outages of belonging 10 kV feeders at TS X/10 kV happened at the same time ("active fault"). Fortunately, these outages are quickly reconnected, for the supply from TS X/10 kV is under the system of remote control. Otherwise, the reconnection should depend on the time of dispatching teamwork on the site.

5 CONCLUSIONS

According to the analyze it may be concluded:

1. In order to make the selectivity of the short-circuit protections at cable feeder circuit breaker in TS X/10 kV and 10 kV fuse in substation 10/0,4 kV, it is necessary to be added at least 100 ms. time-delay for the short-circuit protection of circuit breaker in TS X/10 kV.
2. In order to make the selectivity of the earth-fault protections at cable feeder circuit breaker in TS X/10 kV and 10 kV fuse in conventional substation 10/0,4 kV, 630 kVA, it is necessary to adjust 3 s for time-delay of the earth-fault protection of circuit breaker for cable feeder in TS X/10 kV.
3. The earth-fault protections at cable feeder circuit breaker in TS X/10 kV and 10 kV fuse in conventional substation 10/0,4 kV of 1000 kVA is not selective.

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