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CALCULATION AND SETTING OF RELAYS IN TRANSMISSION OVERHEAD LINES

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Abstract. This article deals with the issue of protective relays in terms of protecting high voltage lines. At the beginning of the article it is drawn up process to protect power lines. Consequently, it is shown the method of calculation for a particular power line and performed the calculation for setting the distance protection. In conclusion the following parameters for setting the distance protection are given.

Keywords: *power lines, distance protective relay, impedance, impedance characteristic.*

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1. Introduction

Power system is made up of devices which are used for the generation, transformation and transmission of electricity. With the rapid course of the transients it is necessary to ensure the operational safety of the electricity system the need to use protective automatics between the advised electrical relays or the protection terminals. In today's conditions is each important electricity devices equipped with its protective terminal.

In terms of protecting of high voltage power lines is most commonly used distance protection relay, which is characterized by high reliability, achieve rapid tripping times for the extension of the automatic reclosing ensure high reliability of power lines.

2. Disturbances in power system

The worst fault in the power system are short circuit. In terms of electrical protection relay it is interesting how the short circuit in the electrical unit reflected in place of built-in of protective relay. Protective relays were involved in circuits of instrument transformers together to form filters certain symmetrical components.

Protective relay will therefore start only upon the occurrence of certain symmetrical components. Voltage changes in the three-phase short circuit are in the following illustration (Figure 1).

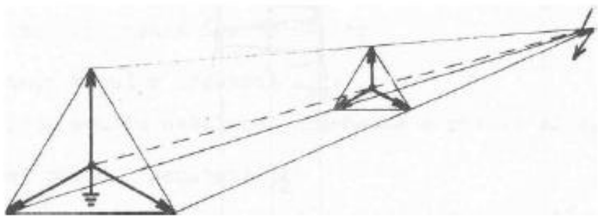

Figure 1. Voltage changes in the three-phase short circuit

In the place of short circuit is voltage equal to zero [1]:

$$U_{L1}^{E} = U_{L2}^{E} = U_{L3}^{E} = 0 \quad (1)$$

At the beginning of power line is voltage given by following equation, [1]:

$$U_{L1}^{B} = I_{L1} . Z_{L} \quad (2)$$

$$U_{L2}^{B} = I_{L2} . Z_{L} \quad (3)$$

$$U_{L3}^{B} = I_{L3} . Z_{L} \quad (4)$$

where:
I_{L1} is current in first phase
I_{L2} is current in second phase
I_{L3} is current in third phase
Z_{L} is impedance of transmission lines

Equations above shows, that value of voltage is higher on the beginning of power line. With decreasing of distance to place of short circuit occur decreasing of voltage.

The value of current is given by the following equations [1]:

$$I_{L1} = \frac{E_{L1}}{Z_{S} + Z_{L}} \quad (5)$$

$$I_{L2} = \frac{E_{L2}}{Z_{S} + Z_{L}} \quad (6)$$

$$I_{L3} = \frac{E_{L3}}{Z_{S} + Z_{L}} \quad (7)$$

where:
Z_{s} is impedance of power source
E_{L1}, E_{L2}, E_{L3} is voltages of source in phase L1, L2, L3.

3. Theory of distance protection

In addressing the protection of electrical lines and which they are required high requirements in terms of time their activities and identification of fault location is used distance protection. The time of disconnection fault part of power system is given based on the size ratio of the short-circuit voltage to the short-circuit current [1] [3].

$$t_d = f\left(\frac{U_f}{I_f}, \varphi_1\right) = f\left(Z_1, \varphi_1\right) \tag{8}$$

where:
t_d is time of disconnection of fault part of power system
U_f is short circuit voltage
I_f is short circuit current
φ_1 is short circuit angle

Impedance measuring parts measure the distance to a fault an uncertainty of. To prevent erroneous operation of protective relay is impedance outreach shortened [1].

$$Z_{r1}^{I} = (0,80 \div 0,90) \cdot l_{l1} \cdot Z_1 \cdot \frac{p_c}{p_v} \tag{9}$$

where:
l_{l1} is length of transmission lines
Z_1 is unitary impedance value in Ω/m
p_c is ratio of current transformer
p_v is ratio of voltage transformer
Setting of the second zone impedance reach is equal to [4]:

$$Z_{r1}^{II} = (0,80 \div 0,90) \cdot Z_{l1} + \frac{0,80}{k_v} \cdot Z_{r2}^{I} \tag{10}$$

where:
Z_{r2}^{I} is setting of first level of setting
k_v is auxiliary power factor

In the normal operation a starting member can not operate. The following conditions apply [1]:

$$Z_{r1} \leq Z_{\min} = \frac{U_{\min}}{I_{\max}} \tag{11}$$

where:
$U_{\min}$ is lowest allowed voltage on bus bars
$I_{\max}$ is highest allowed current of lines
$Z_{\min}$ is lowest impedance of lines in operation

4. Calculation of parameters for setting the distance protection

Distance protective relay operates with measurement of fault loop of impedance at the point of installation. Input data are the ratio of disturbance variables and voltage and short circuit current at the point of installation of protection. The size of the measured impedance is then compared with the impedance of tripping characteristic. If the size of the impedance is less than or equal to the set value of tripping characteristic, after deducting the preset time there is an instruction of the distance protection relay to the circuit breaker. For the calculation and setting of settings for the distance protective relay it is necessary to choose a power line and the location of distance protective relay in substations [2].

In our case we chose the electric stations in Stará Ľubovňa and calculation performance for power line V6410. The distance protective relay is a main protection for power line V6410 and back-up protection for power lines V6411, V6422, V6424, and V6423.

Topology of the power lines is in the following figure (Figure 2).

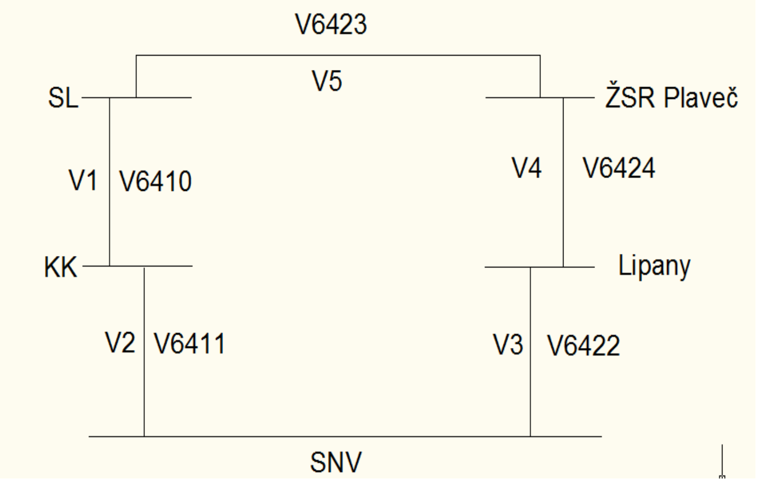

Figure 2. Topology of the power lines

Parameters required to calculate of setting a distance relay are in the following tables (Table 1, Table 2) from operator of distribution system.

Table 1. Parameters of substastions

Power line	Number of power lines	l_{l1} (km)	Type 1	l_{l2} (km)	Type (2)
V1	V6410	4,323	240 AlFe	25,706	185 AlFe
V2	V6411	26,706	185 AlFe	4,323	240 Alfe
V3	V6422	42,524	240 AlFe	-	-
V4	V6424	32,346	240 AlFe	-	-
V5	V6423	17,181	240 AlFe	-	-

Table 2. Parameters of power lines

Typ	**185 AlFe**	**240 AlFe**
Rm_1 [Ω/km]	0,156	0,121
Xm_1 [Ω/km]	0,4	0,392
Bm_1 [μS/km]	2,86	2,92
I_{dov} [A]	486	579
Rm_0 [Ω/km]	0,468	0,363
Xm_0 [Ω/km]	1,2	1,176
Bm_0 [μS/km]	8,58	8,76
Voltage [kV]	110	110

5. Definition of individual protection zones

The proposal itself and define the different protection zones should be based on impedance lines to be determined by the calculation referred to in the previous section of this article.

Impedance, which measures the relay in the place of installation is different from the calculated effect of these errors:

• Errors caused by current and voltage transformers,

• Links non-rotating constituents due to impedance of parallel lines,

• Inaccuracies in the findings of the non-rotating component of line impedance

Protection zones shall be designed to avoid any unprotected line section. They must also be the fulfilled condition of selectivity, failure in this section shall be equipped with a relay in given section, not neighboring relay [2].

For distance protection located at the station Stará Ľubovňa, we have defined the following protection zones:

Zone 1: This zone impedance is set to 85% impedance line V 6410,

Zone 2: This zone is set to 100% impedance of the line V6410 and 60% impedance line of the line V6411,

Zone 3: This zone impedance is set to 100% V6410 line impedance, 100% V6411 line impedance and 40% V6422

Zone 4: This zone is the backward zone and the impedance is set at 30% of line impedance V6423,
Zone 5: This zone is a zone of reclosing and the impedance is set at 115% of line impedance V6410,
Zone 6: The backup non directional zone is the impedance set to 100% impedance line V6410, 100% impedance line V6411, 100% impedance line V6422.
Zone 7: This zone will not be activated.

The calculated parameters for setting the distance protection are given in the table below where:
x_1 is consequent component of the reactance
r_0 is non-rotating component of resistance
r_1 is consequent component of the resistence
φ is short circuit angle

Table 3. Settings of protective zones for distance protective relay I

Zone 1	Values	**Zone 2**	Values
	secondary		secondary
status	Active	Status	Active
characteristic	polygon	characteristic	polygon
x_1 (Ω)	0,5553	x_1 (Ω)	1,0584
r_0 (Ω)	8,0477	r_0 (Ω)	1,2022
r_1 (Ω)	0,2102	r_1 (Ω)	0,4007
φ (°)	72,8459	φ (°)	70
direction	F	direction	F
time (s)	0	time (s)	0,5
Zone 3	Values	**Zone 4**	Values
	secondary		secondary
Status	Active	Status	Active
characteristic	polygon	characteristic	polygon
x_1 (Ω)	1,6921	x_1 (Ω)	0,1102
r_0 (Ω)	1,8459	r_0 (Ω)	0,1021
r_1 (Ω)	0,6153	r_1 (Ω)	0,034
φ (°)	75	φ (°)	75
direction	F	direction	R
time (s)	1	time (s)	0,5

Table 4. Settings of protective zones for distance protective relay II

Zone 5	Values	**Zone 6**	Values
	secondary		secondary
Status	Active	Status	Active
characteristic	polygon	characteristic	polygon
x_1 (Ω)	0,751	x_1 (Ω)	2,2376
r_0 (Ω)	0,8531	r_0 (Ω)	2,3511
r_1 (Ω)	0,2844	r_1 (Ω)	0,7837
φ (°)	70	φ (°)	75
direction	F	direction	-
time (s)	0	time (s)	5

6. Conclusion

This article deals with the issue of distance protective relay. As mentioned at the outset, the speed of transients requires the use of special automatics and protection devices. These protective devices include the distance protective relay. This article was mentioned method of calculating the adjustment of individual protection zones. The article concludes aspects affecting the definition and parameters of protection zones.

References

1. Chladný V., Bilička M., (1991) Prechodné javy v elektrizačných sústavach Košice.
2. Chladný V., Janíček F., Belaň A., (2003) Digitálne ochrany v elektrizačných sústavách, Košice, ISBN 80-89061-73-7.
3. Kolcun M. a kol., (2005) Analýza elektrizačnej sústavy. In.:TU Košice a ABB Elektro, s.r.o., Košice,. časť III., s. 321-410. ISBN 80-89057-09-861-65-6.
4. Kolcun M., Griger V., Beňa Ľ., Rusnák J., (2007) Prevádzka elektrizačnej sústavy, Košice, ISBN 978-80-8073-837-2.
5. Liptai P., Moravec M., Lumnitzer E., Lukáčová K., (2014, June) Impact analysis of the electromagnetic fields of transformer stations close to residential buildings. In 14th international multidiscilinary scientific geoconference: Geo-Conference on Ecology, Economics, Education and Legislation (SGEM), 355-360.