USING THE NUMERICAL PROTECTIONS FOR MEDIUM VOLTAGE POWER LINES GROUNDED WITH PETERSEN COIL

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REZUMAT . În lucrarea de față autorii analizează condițiile de funcționare selectivă a protecțiilor numerice în cazul liniilor electrice de medie tensiune cu neutral tratat prin bobină de stingere. Analiza se referă la protecția împotriva punerilor la pământ monofazate, aceste defecte ridicând problem de selectivitate în funcționarea protecțiilor. Concluziile se bazează pe determinarea prin calcul a curenților de punere la pământ şi a defazajelor dintre curentul homopolar şi tensiunea homopolară. Se prezintă rezultatele obținute pentru linii de 20 kv aeriene şi în cablu.

Cuvinte cheie: punere la pământ, protecție homopolară direcționată, bobina de stingere

ABSTRACT. In this paper the authors analyze the selective operating conditions of the numerical protections in case of medium voltage power lines grounded with Petersen coil. The analysis refers to the protection against one-phase grounded, these faults raising the issue of selectivity in the operation of protections. Conclusions are based on the determination by calculation of the earth fault currents and the phase shifts between zero sequence current and zero sequence voltage. It presents the results obtained for 20 kV overhead lines and cable lines.

Keywords: earth fault, earth fault protection, Petersen coil

1. INTRODUCTION

Selective detection of earth faults is a particularly delicate issue for networks grounded with Petersen coil because the earth currents are small, in range of tens of amperes. These values may be less than the load currents. Accordingly, can’t be used over current protections for their detection. In Romania were used and are still in operation, protections at station-level based on the presence of rank 5 harmonic in earth current. These protections often erroneously operated, therefore, often are taken out of service. Many papers refer to this problem [4], [5].

At the moment there are two modern solutions for selective detection of earth faults:

- Using a numerical protection at 110 kV/MV station-level which receives information from Petersen coil and all the MV leading outs [1]. The module allows both selective detection of earth faults and automatic adjustment of Petersen coil. This protection system required a separate protection cabinet at station-level and is more expensive.
- Using the special protection functions of the numerical terminals of cells lines.

In this paper we will refer to the second solution, the analysis being done for overhead lines and cable lines.

2. DETERMINATION OF FAULT CURRENTS

For assessing the fault current values and, especially, to determine the phase shifts between voltage and current zero-sequence we analyze two types of power systems:

- Overhead lines
- Cable lines

Fault currents for overhead lines. We consider the power system with overhead lines of 20 kV, given in figure 1.

The equivalent scheme of the positive sequence is given in figure 2. The equivalent scheme of the zero sequence is given in figure 3.

The obtained results are shown in table 1. The calculations in the table are made for a Petersen coil resistance of 3 Ω.

In this table are symbols meanings:

- I_k – Current at earth fault place
- $3I_{0L1}$ – Three phase zero-sequence current at installation place of the protection
- $3I_{0L2}$ – Three phase zero-sequence current at installation place of the protection, healthy lines
- I_{PC} – Current given by the Petersen coil
- I_{cap} – Capacitive current of medium voltage
- U_{0b} – Zero-sequence voltage on 20 kV busbar

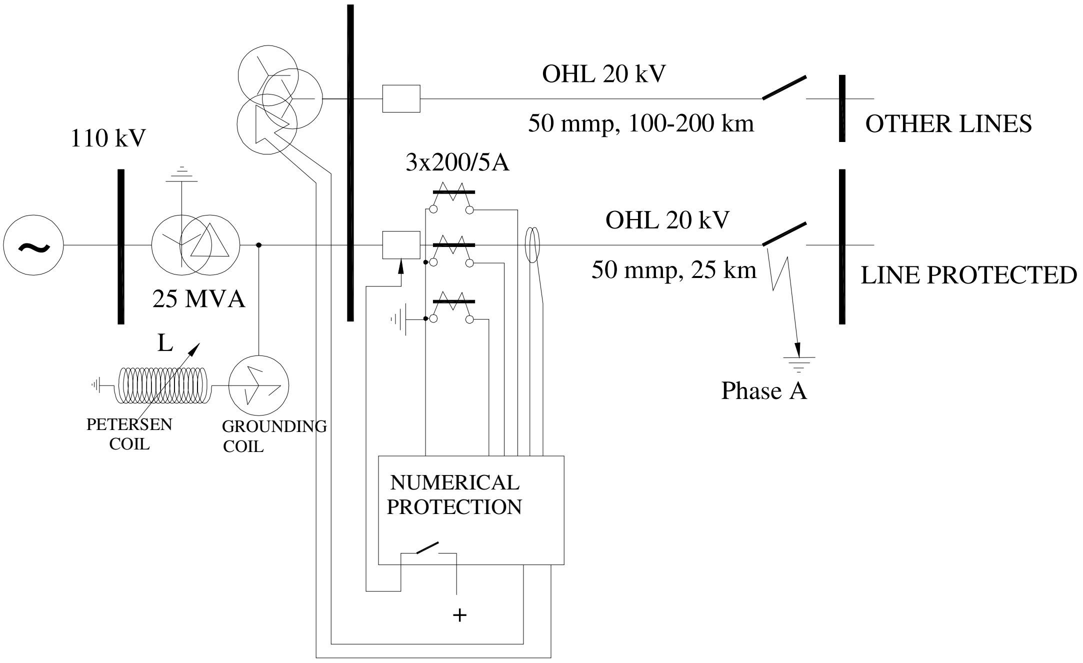
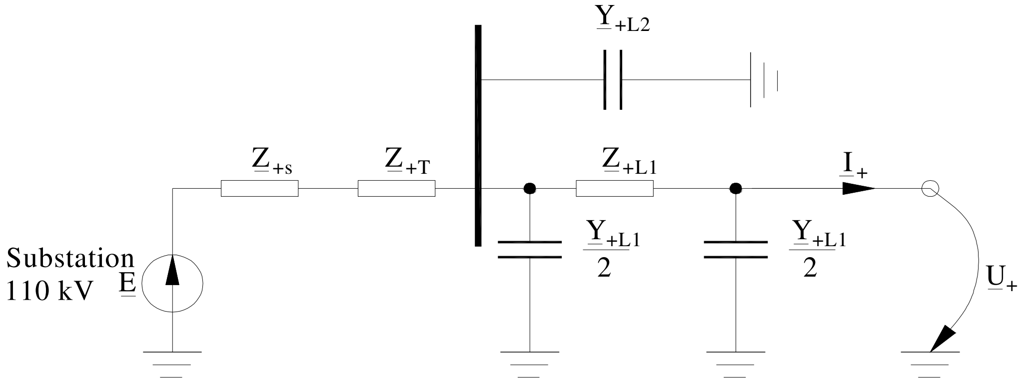


Fig. 1. Power system with overhead lines



$\underline{Z}_{+s}$- system impedance

$\underline{Z}_{+T}$ - transformer 110/22, 25 MVA

$\underline{Z}_{+L1}$,$\underline{Y}_{+L1}$- OHL, 25 km

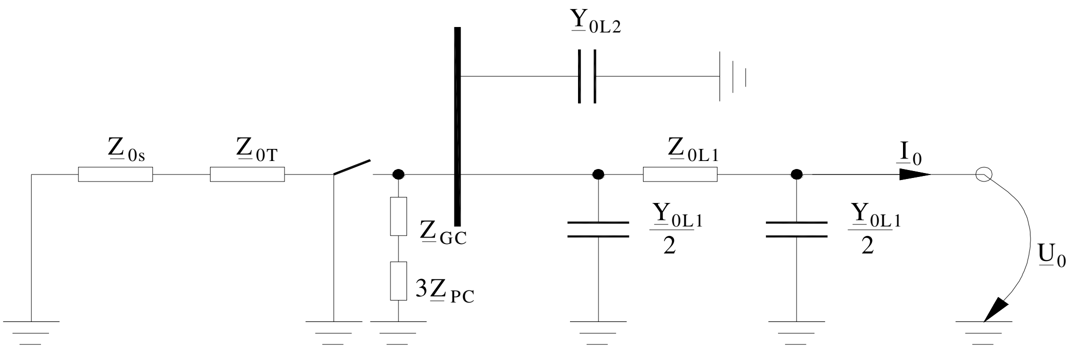
$\underline{Y}_{+L2}$ - Others OHL 100-200 km

Fig. 2. Positive sequence diagram

Whereas the phase shift between zero-sequence currents on healthy lines and zero-sequence voltage on the 20 kV bar is 90º, result that it can’t be ensure the selectivity of the directional zero-sequence protection. This is because the appropriate phase shifts between currents and zero-sequence voltage, both the faulty lines and the healthy lines.

To ensure selectivity, meaning a higher phase shift with minimum 10º at faulty line are two solutions:

A. Using some additional resistances in series with Petersen coil.
B. Connecting a high value resistance (1155 Ω) in parallel with Petersen coil after the fault



$\underline{Z}_{0s}$- system impedance
$\underline{Z}_{0T}$ - transformer 110/22 kV, 25 MVA
$\underline{Z}_{0L1}$,$\underline{Y}_{0L1}$- OHL, 25 km
$\underline{Y}_{0L2}$- others OHL 100-200 km
$\underline{Z}_{GC}$ - grounding coil
$\underline{Z}_{PC}$ - Ptersen coil

Fig. 3. Zero sequence diagram

Table 1

Sizes at the installation place of the eart fault directional protection

No	l_2 [km]	I_k [A]	$3I_{0L1}$ [A]	U_{0b} [kV]	$3I_{0L2}$ [A]	I_{PC} [A]	I_{cap} [A]	Phase shift U_{0b}, I_{0L1}[°]
1	100	0.705	1.91	11.523	4.833	6.747	6.534	-90.795
2	200	1.031	2.237	11.516	9.66	11.896	11.36	- 92.115

Table 2

Sizes at the installation place of the earth-fault directional protection, with additional resistance of 100 Ω

No	l_2 [km]	I_k [A]	$3I_{0L1}$ [A]	U_{0b} [kV]	$3I_{0L2}$ [A]	I_{PC} [A]	I_{cap} [A]	Phase shift U_{0b}, I_{0L1}[°]
1	100	0.792	1.932	11.518	4.831	6.731	6.531	-102.194
2	200	1.542	2.447	11.500	9.646	11.812	11.345	-120.95

Table 3

Sizes at the installation place of the earth-fault directional protection, connecting a high value resistance in parallel with coil (1155 Ω)

No	l_2 [km]	I_k [A]	$3I_{0L1}$ [A]	U_{0b} [kV]	$3I_{0L2}$ [A]	I_{PC} [A]	I_{cap} [A]	Phase shift U_{0b}, I_{0L1}[°]
1	100	9.762	9.928	11.365	4.766	11.811	6.455	-168.894
2	200	9.767	9.967	11.359	9.646	15.232	11.216	-167.259

occurs. Connecting command will be done by residual overvoltage protection.

The obtained results for the two variants are shown in tables 2 and 3. Note that it was added a resistance of 100 Ω.

From the presented data in tables 2 and 3 it is found that:

- By adding the additional resistance of 100 Ω is obtained a higher phase shift of 10º between zero-sequence current and voltage, which can ensure selectivity. In this case the fault currents didn’t increase much, which would allow the arc auto-quenching.
- By connecting a high value resistance (1155 Ω), the phase shift between zero-sequence current and voltage increase significantly. It provides very good selectivity of the protection.

Fault currents for cable networks. The scheme used for the analysis is given in figure 4. The sequence schemes are similar to those in figures 2 and 3.

The obtained results are shown in table 4. The calculations from table are made for a Petersen coil resistance of 3 Ω.

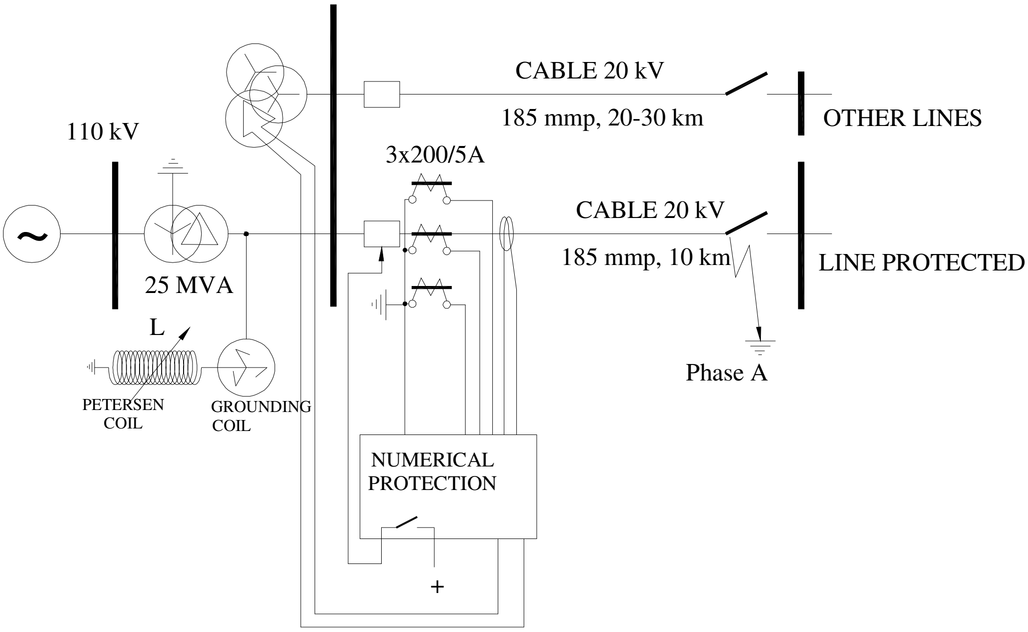


Fig. 4. Power system with cable lines

Table 4

Sizes at the installation place of the directional zero-sequence protection, cable lines

Nr	l_2 [km]	I_k [A]	$3I_{0L1}$ [A]	U_{0b} [kV]	$3I_{0L2}$ [A]	I_{PC} [A]	I_{cap} [A]	Phase shift U_{0b}, I_{0L1}[º]
1	20	4.124	29.051	11.489	52.411	81.353	78.684	-96.17
2	30	7.736	31.873	11.462	78.432	109.938	104.669	-100.329

From the presented data in table 4, it may be established that the selectivity is ensure at limit. For line lengths (other than that being protected) at comparable values with the protected line is nonetheless adding some additional small value resistances.

3. SETTING OF PROTECTIONS

The relaya has two protections sensitive to earth fault [2], [3]:

- Sensitive directional earth fault protection
- Sector directional earth fault protection.

Operating diagram for the first protection is given in figure 5.

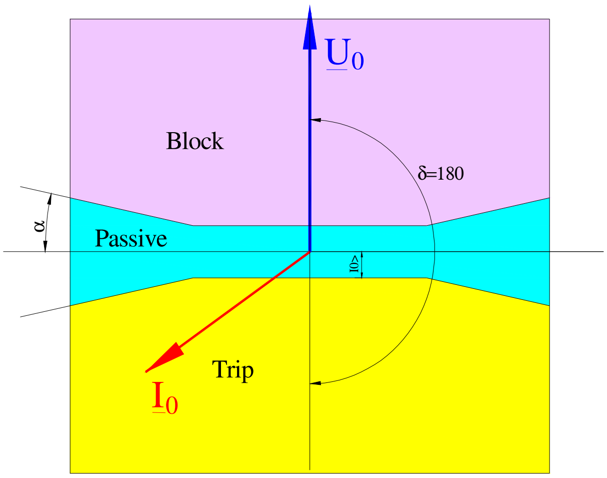


Fig. 5. Operating diagram for the sensitive protection

For this protection, the maximum sensitivity angle (δ) must be set to 180 ° because a lower angle can lock operation of protection for earth fault (zero sequence current angle is of the order 95-150 °, prior the zero sequence voltage).

Sizes set for the first protection are:

- I0 – for the passive zone – 0.05In = 10 A. It provides a good sensitivity if the capacitive current of line protected is large enough. In case of overhead lines, the sensitivity can be low because the current is small.
- U0 – size threshold – 0.5 Un=10/√3 kV. Because zero sequence voltage at an earth fault is high (up to 3 Uphase) it is ensure good sensitivity.
- Angle α = 5º. A greater angle eliminates the risk of erroneous operation (for earth faults on other lines). Lower angle ensures sensitivity to faults on the line.
- Angle δ = 180º.

Operating diagram for the second protection is given in figure 6.

Sizes set for the second protection are:

- I0 – for the passive zone – 0.02In = 4 A. It provides a very good sensitivity.
- U0 – size threshold – 0.5 Un=10/√3 kV
- Angle of sector position -130º. It depends on zero sequence current seen by the earth fault protection on the line.
- Width of sector = 70º

This protection has the advantage of higher sensitivity (at low capacitive currents). It is removed erroneous operation, but must be made precise calculations to ensure operation.

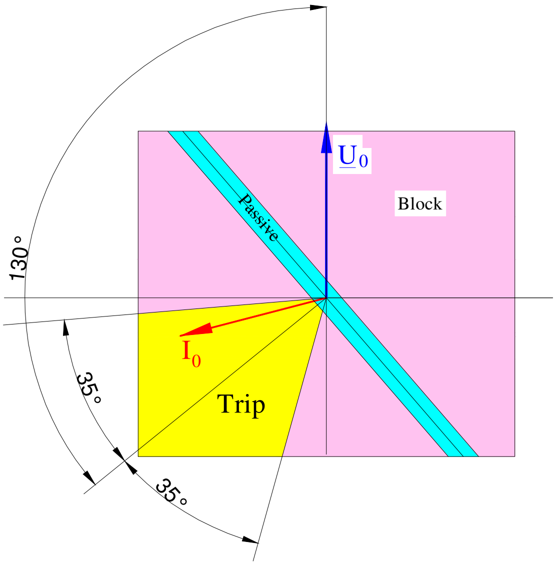


Fig. 7. Operating diagram for the sector protection

4. CONCLUSIONS

From the presented data results the following:

• Using the earth-fault directional protections against earth faults in case of overhead lines don't ensure selectivity since the phase shifts between zero-sequence voltage and current at the installation place of protection is near its value for healthy lines. The difference between fault line and healthy lines is up to 3º.

• Ensuring the selective operation of the protections in case of OHL it can be done by adding some additional relatively high resistance (about 100 Ω) in series with Petersen coil. Another option is to connect a high value resistance (1155 Ω) in parallel with Petersen coil. Connecting command will be done by residual overvoltage voltage protection, with a certain delay. The delay is necessary to ensure the electric arc auto-quenching function.

- In case of medium voltage cable lines, the selective operation of the earth-fault directional protections against earth faults is provided at limit. Using one of the described methods for overhead lines could increase safety for selective operation.
- Connecting a resistance in parallel with Petersen coil is more expensive since it involves installing a single pole switch that will realize this function.

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