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POWER SYSTEM FAULT ANALYSIS USING DATA FROM A SIEMENS 7SA513 NUMERICAL DISTANCE PROTECTION RELAY

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Abstract: One of the main conditions that a power system must fulfill is ensuring the continuous supply of electricity to consumers. Ensuring uninterrupted operation of a power system is of great importance, both because the consequences of a power system fault can be very severe and that power system faults are most likely to appear than other system faults.This paper presents the analysis of a single phase ground fault occurred on 400 kV overhead line Arad – Mintia cleared by the numerical protection relay 7SA513. It presents how the relay behaves before the fault and during it. Numerical distance protection relay 7SA513 provided fast, reliable and selective clearance off the single phase ground fault occurred.
Keywords: numerical protection relay, power system fault, pickup, trip, automatic reclosure

1. INTRODUCTION

One of the main conditions that a power system must fulfill is ensuring the continuous supply of electricity to consumers. Ensuring uninterrupted operation of a power system is of great importance, both because the consequences of a power system fault can be very severe and that power system faults are most likely to appear than other system faults. The severity of consequences from a power system fault comes primarily from the fact that it disturbs the normal operation of the entire system and secondly, due to the high fault values of the currents, it can lead to massive destructive effects.

Numerical distance protection relay 7SA513 provides fast, reliable and selective clearance off all kind of ground and phase faults in a single or multiple fed overhead lines and cables in radial, ring or any type of networks. The measuring algorithms and the scope of functions are optimized for use on long distance transmission lines. However, it can be used for any system voltage level. The schematic diagram of a numerical protection terminal is shown in Figure 1.

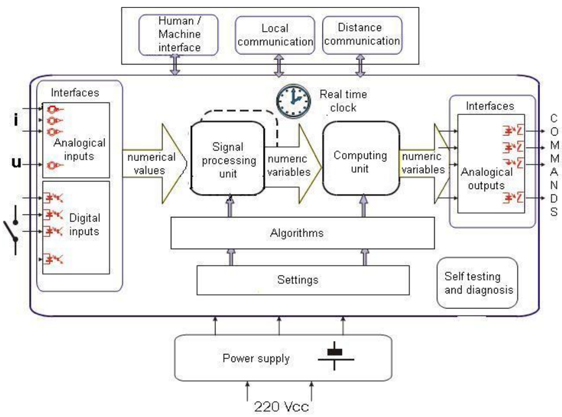

Figure 1. The schematic diagram of a numerical protection

2. DISTANCE PROTECTION METHOD OF OPERATION [4]

Distance protection is the main short-circuit protection of the relay. It is characterized by high measuring accuracy and flexible adaptation possibilities for the given network characteristics. One of the essential functions of the distance protection is the six fault detection system. The impedances of the six possible conductor loops L1-E, L2-E, L3-E, L1-L2, L1-L3, L2-L3 are

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continuously calculated. For the calculation of a phase – earth loop (example single phase ground fault, Figure 2) it must be observed that the impedance of the earth return path is not normally equal with the impedance of the phase.

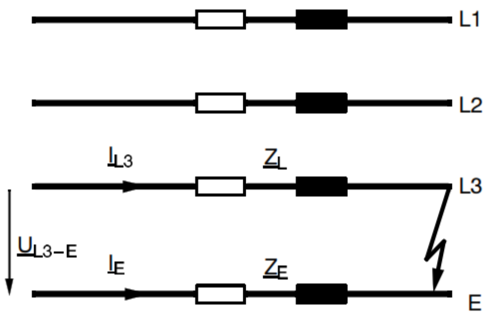


Figure 2. Phase – earth short-circuit loop

In the loop equation

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_E = \underline{U}_{L3-E} \qquad (1)$$

$\underline{Z}_E$ is replaced by $\frac{\underline{Z}_E}{\underline{Z}_L} \cdot \underline{Z}_L$ which gives us

$$\underline{I}_{L3} \cdot \underline{Z}_L - \underline{I}_E \cdot \underline{Z}_L \cdot \frac{\underline{Z}_E}{\underline{Z}_L} = \underline{U}_{L3-E} \qquad (2)$$

From this equation we obtaines the line impedance:

$$\underline{Z}_L = \frac{\underline{U}_{L3-E}}{\underline{I}_{L3} - \frac{\underline{Z}_E}{\underline{Z}_L} \cdot \underline{I}_E} \qquad (3)$$

If the impedance value is within the tripping characteristic, the relay will issue a trip command due to the fact that a fault occurred.

3. SIEMENS 7SA513 POWER SYSTEM FAULT ANALYSIS

For the analysis of a real time power system fault cleared by the numerical protection relay 7SA513, we will analyze a single phase ground fault occurred on voltage level 400 kV overhead line Arad–Mintia. Fault analysis involves interpretation of the oscillographic fault record and measurement values saved by the relay when the fault occurred.

The relay is parameterized to perform an oscillographic record whenever a protection function set active in the relay pickups. In the oscillographic record the relay stores the voltage and current values on all three phases of the line over a period of 0.2 seconds before and 0.6 seconds after the pickup as shown in Figure 3.

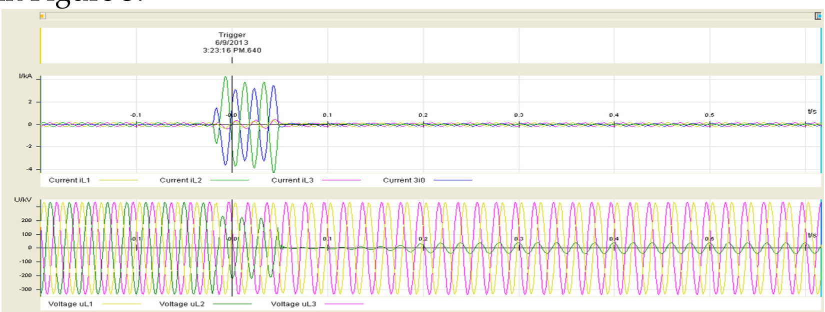
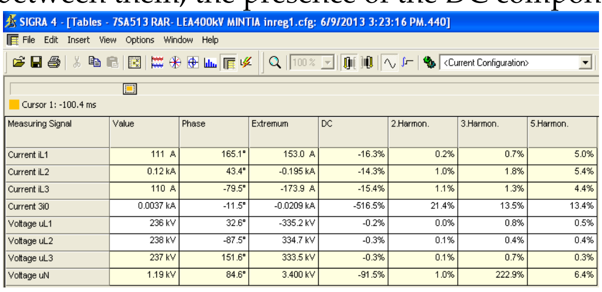


Figure 3. Voltage and current values on all three phases of the line

It can be noticed that in the 0.2 seconds before the appearance of the power fault, the voltage and current values on the three phases are normal.

Figure 4 contains the voltage and current values on each phase of the line, the phase difference between them, the presence of the DC component and harmonics on each phase of the line.

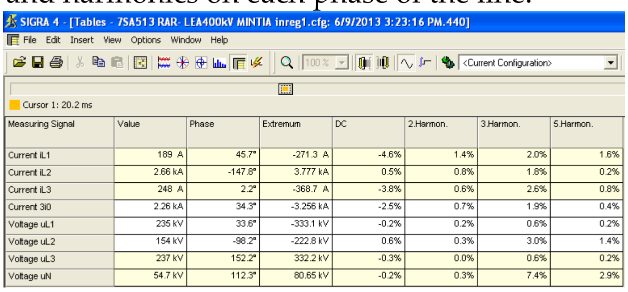


SIGRA 4 - [Tables - 7SA513 RAR- LEA400kV MINTIA inreg1.cfg: 6/9/2013 3:23:16 PM.440]

Cursor 1: -100.4 ms

Measuring Signal	Value	Phase	Extremum	DC	2.Harmon.	3.Harmon.	5.Harmon.
Current iL1	111 A	165.1°	153.0 A	-16.3%	0.2%	0.7%	5.0%
Current iL2	0.12 kA	43.4°	-0.195 kA	-14.3%	1.0%	1.8%	5.4%
Current iL3	110 A	-79.5°	-173.9 A	-15.4%	1.1%	1.3%	4.4%
Current 3i0	0.0037 kA	-11.5°	-0.0209 kA	-516.5%	21.4%	13.5%	13.4%
Voltage uL1	236 kV	32.6°	-335.2 kV	-0.2%	0.0%	0.8%	0.5%
Voltage uL2	238 kV	-87.5°	334.7 kV	-0.3%	0.1%	0.4%	0.4%
Voltage uL3	237 kV	151.6°	333.5 kV	-0.3%	0.1%	0.7%	0.3%
Voltage uN	1.19 kV	84.6°	3.400 kV	-91.5%	1.0%	222.9%	6.4%

Figure 4. Voltage and current values before the power fault



SIGRA 4 - [Tables - 7SA513 RAR- LEA400kV MINTIA inreg1.cfg: 6/9/2013 3:23:16 PM.440]

Cursor 1: 20.2 ms

Measuring Signal	Value	Phase	Extremum	DC	2.Harmon.	3.Harmon.	5.Harmon.
Current iL1	189 A	45.7°	-271.3 A	-4.6%	1.4%	2.0%	1.6%
Current iL2	2.66 kA	-147.8°	3.777 kA	0.5%	0.8%	1.8%	0.2%
Current iL3	248 A	2.2°	-368.7 A	-3.8%	0.6%	2.6%	0.8%
Current 3i0	2.26 kA	34.3°	-3.256 kA	-2.5%	0.7%	1.9%	0.4%
Voltage uL1	235 kV	33.6°	-333.1 kV	-0.2%	0.2%	0.6%	0.2%
Voltage uL2	154 kV	-98.2°	-222.8 kV	0.6%	0.3%	3.0%	1.4%
Voltage uL3	237 kV	152.2°	332.2 kV	-0.3%	0.0%	0.6%	0.2%
Voltage uN	54.7 kV	112.3°	80.65 kV	-0.2%	0.3%	7.4%	2.9%

Figure 5. Voltage and current values at the moment of the power fault

Moving the cursor at time moment t=20 ms, we can read the fault current value on the affected phase. As shown in Figure 5, the fault occurs between ground and phase L2 of the line, with a fault current of 2.66 kA. We also notice a decrease of voltage on the affected phase and the occurrence of the zero sequence component of the voltage and current.

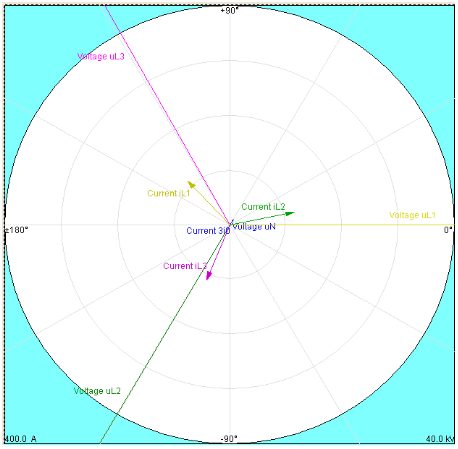


Figure 6. Current and voltage vector diagram before the power fault

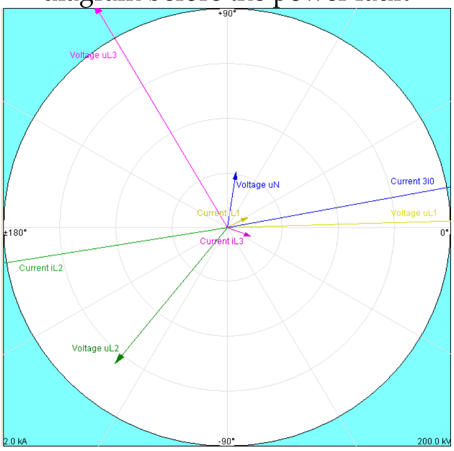


Figure 7. Current and voltage vector diagram at the moment of the power fault

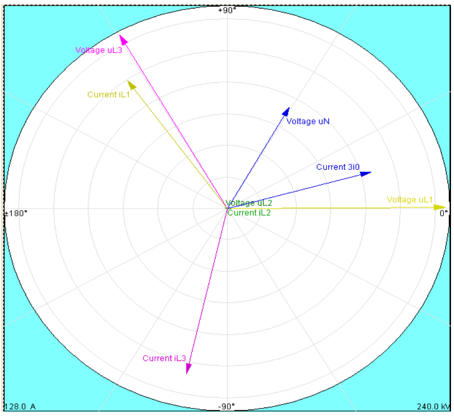


Figure 9. Current and voltage vector diagram during the automatic reclosure dead time

Using these values, we can analyze the current and voltage vector diagrams before and after the power fault occurs (Figure 6 and 7). It can be noticed that before the power fault appears, the current and voltage values are normal with a phase difference between them of 180 degrees.

It can be noticed that when the power fault appears, the current on phase L2 has a bigger value than the other two currents while the voltage on phase L2 decreases. For a correct analysis of how the numerical 7SA513 relay worked, we need to interpret the binary signals saved on the oscillographic record (Figure 8).

It is noticed that when the power fault appears, the distance protection function picks-up detecting a fault between phase L2 and ground N (Dev.FltDetL2 and Dev.FltDetN) in forward direction (Dist.For.Dir). The fault is also detected by other protection functions set active when the relay was parameterized (Back.Gen.Fault).

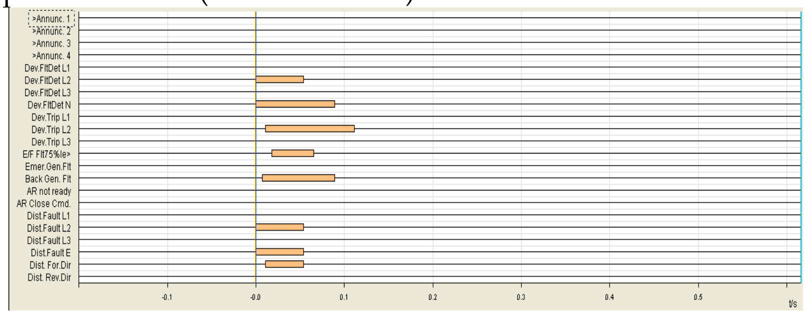


Figure 8. Binary signals saved by the numerical relay


SIGRA 4 - [Tables - 7SA513 RAR- LEA400kV MINTIA inreg2.cfg: 6/9/2013 3:23:17 PM.580]

Cursor 1: 20.1 ms

Measuring Signal	Value	Phase	Extremum	DC	2.Harmon.	3.Harmon.	5.Harmon.
Current iL1	198 A	163.2°	278.3 A	2.1%	1.2%	1.5%	0.7%
Current iL2	2.76 kA	-29.2°	-3.910 kA	-0.6%	0.7%	1.8%	0.6%
Current iL3	259 A	121.8°	368.7 A	1.0%	0.7%	1.6%	1.5%
Current 3i0	2.33 kA	152.9°	3.221 kA	-2.1%	0.8%	1.9%	0.7%
Voltage uL1	235 kV	153.2°	328.8 kV	-0.2%	0.1%	0.7%	0.2%
Voltage uL2	153 kV	21.8°	-213.8 kV	3.0%	0.4%	2.9%	1.3%
Voltage uL3	237 kV	-88.1°	-335.5 kV	-0.3%	0.0%	0.7%	0.2%
Voltage uN	55.2 kV	-128.9°	81.35 kV	3.8%	0.5%	7.7%	2.8%

Figure 10. Reappearance of the fault between phase L2 and ground

The relay issues a trip command of phase L2 (Dev. Trip L2). After phase L2 control breaker opens, the automatic reclosure dead time activates. Usually, this dead time last between 1 to 1.2 seconds, time needed for the electric arc to extinguish. Phase L2 control breaker opened can be seen in the voltage and current vector diagram during the automatic reclosure dead time (Figure 9).

After the automatic reclosure dead time expires, the relay commands the phase L2 control breaker reclosure. After reclosure, we can see that the fault between phase L2 and ground reappears (Figure 10). For a correct analysis of

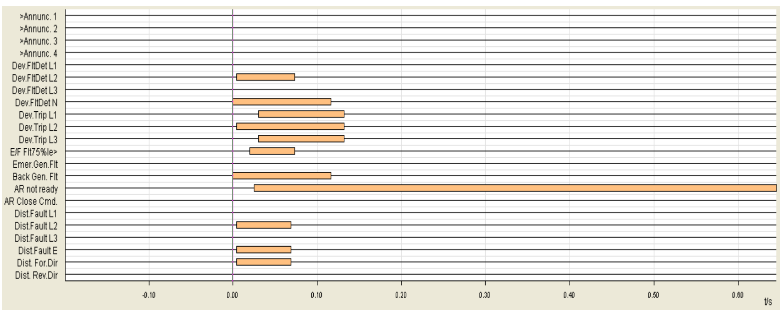


Figure 11. Binary signals saved by the numerical relay

how the numerical 7SA513 relay worked after the reclosure, we need to interpret the binary signals saved on the oscillographic record (Figure 11).

It can be noticed that after reclosure, the distance protection function picks-up redetecting the fault between phase L2 and ground N (Dev.FltDetL2 and Dev.FltDetN) in forward direction (Dist.For.Dir). This time though, the relay commands a definitive trip of all three phases of the line (Dev.Trip L1, Dev.Trip L2 and Dev.Trip L3). In this case, we have an unsuccessful automatic reclose on 400 kV overhead line Arad – Mintia.

4. CONCLUSIONS

Numerical distance protection relay 7SA513 provided fast, reliable and selective clearance off the single phase ground fault occurred. Throughout a fault in the network the magnitudes of the instantaneous values are stored and are available for subsequent fault analysis.

Besides the mentioned short-circuit protection function, further protection functions can be incorporated: overvoltage protection, circuit failure breaker protection, out-of-step protection, power swing blocking of distance protection. For a quick location of the damaged area after a fault, a fault locator is available which can compensate for the influences of a parallel line and load current.

REFERENCES

[1.] P. Gheju, V. Duşa - *Scurtcircuite în instalațiile electrice*, Editura Orizonturi Universitare Timişoara, 2004.

[2.] L.G. Hewitson, M. Brown, R. Balakrishnan - *Practical Power System Protection*

[3.] A. T. Johns, S. K. Salman - *Digital Protection for power systems*, Published by Peter Peregrinus Ltd., The Institution of Electrical Engineers, 1995.

[4.] Siemens – Numerical Distance Protection 7SA513 V3.2 /V3.3, Instruction Manual

[5.] *** Network Protection and Automation Guide – Areva Guide 2005

[6.] *** Protection Aplication Handbook – ABB.