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Industrial Grids with Frequency Inverters and Localization of the Earth Fault

Abstract. *This article focuses on industrial grids with frequency inverters and evaluation of the earth fault and its localization. In the first part the system of localization of the earth fault, industrial grids with frequency inverters and typical application in industry are described. The feedback effect of frequency inverters on the supply network is specified too. The second part of the article aims at the description of practical measuring of the earth fault on the testing panel. The third part deals with the summary of measuring and that of the experience with industrial grids and localization of the earth fault. The summary is included in the last part as well.*

Streszczenie. *Artykuł ten przedstawia sieci przemysłowe z falownikami i lokalizację doziemienia w sieci z izolowanym punktem neutralnym. W pierwszej części opisany jest system lokalizacyjny doziemienia, sieci przemysłowe z falownikami i typowa aplikacja w przemyśle. Przedstawiono również wpływ falowników na sieć zasilającą. Druga część artykułu dotyczy opisu zrealizowanych pomiarów doziemień z wykorzystaniem panelu testowego. W trzeciej części streszczono pomiary, przedstawiono doświadczenia wynikające z pracy z sieciami przemysłowymi i z systemem lokalizacji doziemienia.* ***(Sieci przemysłowe z falownikami I lokalizacją doziemienia)***

Keywords: industrial grids, frequency inverters, earth fault, isolated neutral system IT, earth fault localization.
Słowa kluczowe: sieci przemysłowe, falowniki, doziemienie, sieć o izolowanym punkcie neutralnym IT, lokalizacja doziemień

Introduction

Industrial grids are re-deformed by used devices (for example frequency inverters and others). There are devices sensitive to the quality of the mains too. The earth fault causes a large overvoltage. Therefore the earth fault should be monitored .The speed of evaluation of the earth fault can influence correction of errors and thus can effect continuity of the production process. In the article the industrial grids with frequency inverters, the system of localization of the earth fault and several measurements made on the test network model will be described.

The earth fault in industrial conditions

The LV grid with isolated neutral system IT in industrial conditions undoubtedly has many benefits that contribute to the continuity of the production process and to the minimization of the power system failure. On the other hand, in practice the negative effects associated with the operation of these networks also have to be solved. In this article the attention is focused on the problems caused by earth faults and on the question how to localize the earth fault in the shortest possible time. Nowadays, the protection systems of the insulated conditions are used. The protector is able to evaluate both the earth fault and the worsened state of insulation. At the same time the outcome of the evaluation is signaled in the control room with the permanent service. If the network is not too extensive, the operation and manufacturing process enables to disconnect the terminals. Otherwise, there is a problem to find the place of the failure.

The earth fault in the IT grid

In the isolated networks, under the conductive connection of the one phase to the earth, the short-circuit will not happen but there will be so called earth fault.

According to the size of the contact resistance in the place of earth fault, the following can be categorized:

a) Resistance earth fault – the value of the contact resistance is of the order of several hundreds of ohms
b) Metal and arc-earth fault - the value of the contact resistance is only a few ohms, usually negligible

According to the duration of the mentioned states, the following can be classified:

a) Fast-acting earth fault – up to 0.5 seconds
b) Short-term earth fault – up to 5 minutes
c) Intermittent earth fault - fast-acting and short-term earth fault repeated several times
d) Permanent earth connection – until its removal it usually takes several hours [1]

The duration of earth fault is an important parameter which has a major impact on the successful identification and localization of a failure condition. We can come across various modes of the electrical equipment operation, from the continuous operation of the fan and pump drives to the instantaneously switched drives, for example. According to the daily operation of the track, the drives of the rules appeared on the block stool reach about 20, 000 operating cycles per 24 hours. Identification and localization of the earth fault has to reflect these facts [3].

Industrial grids with frequency inverters

Nowadays, frequency inverters are used in many applications. This is caused by automation of production. Frequency inverters enable to change frequency and voltage, limit the current and others for better regulation of the drive. Inverters have a good power factor but harmonic distortion load the power system. High energy costs force companies to use regenerative converters in some applications. All this can affect the quality of the mains.

Typical application in the industry

Typical industrial applications are conveyers in rolling mills (see fig. 1). Frequency inverters are currently used on conveyors and many other devices. Frequency inverters load the power system by harmonic distortion.

These factors have the effect on the evaluation and localization of the earth fault. DC link of frequency inverter has an influence on the assessment too. Times comparison of evaluation of the earth fault between invertors and standard devices is included in this article. Distortion of the mains can be observed in the picture below (fig. 2).

On the other hand, the possibility of limiting current with frequency inverter reduces the distortion of the mains at the start and reverse of the drive. As depicted in the pictures below, the time of the drive operation is very short. The drive operates on the nominal values only few second.

Distortion parameters of the grid and short operate time of the drive make working conditions difficult for localization devices of the earth fault. Waveform of the current, speed and frequency of the conveyor are shown in the picture (see fig. 3)

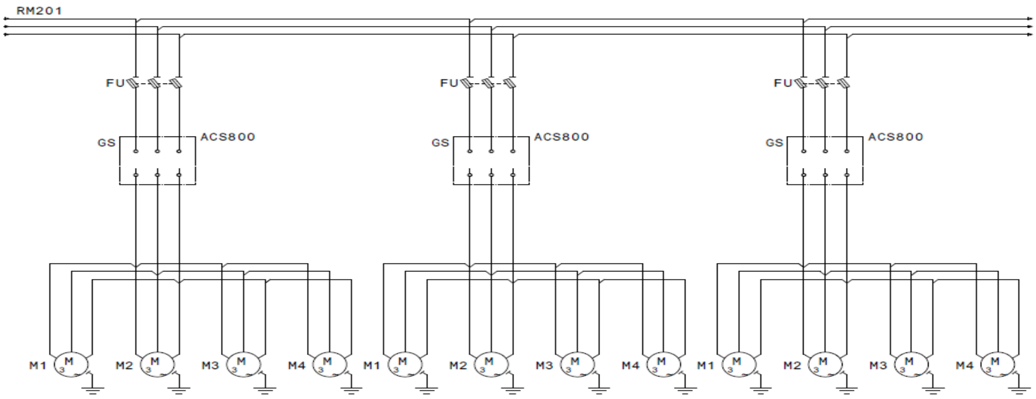

Fig.1. Wiring diagram of the conveyors

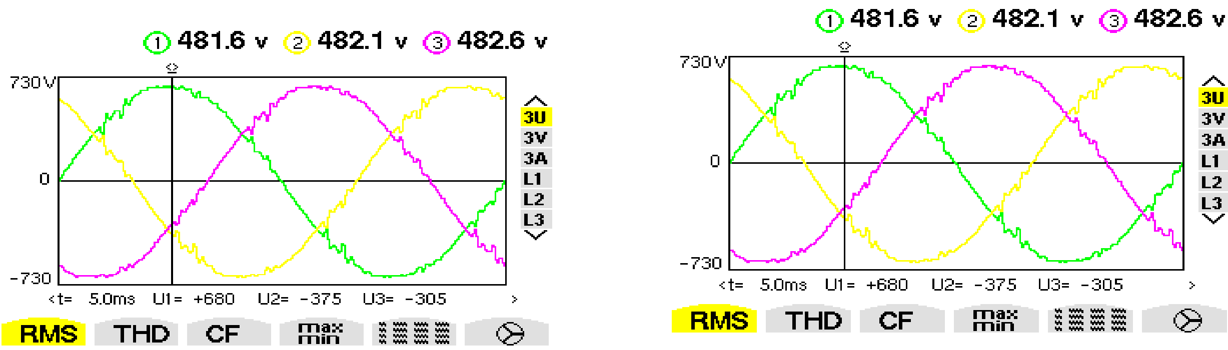

Fig.2. Distortion of the mains

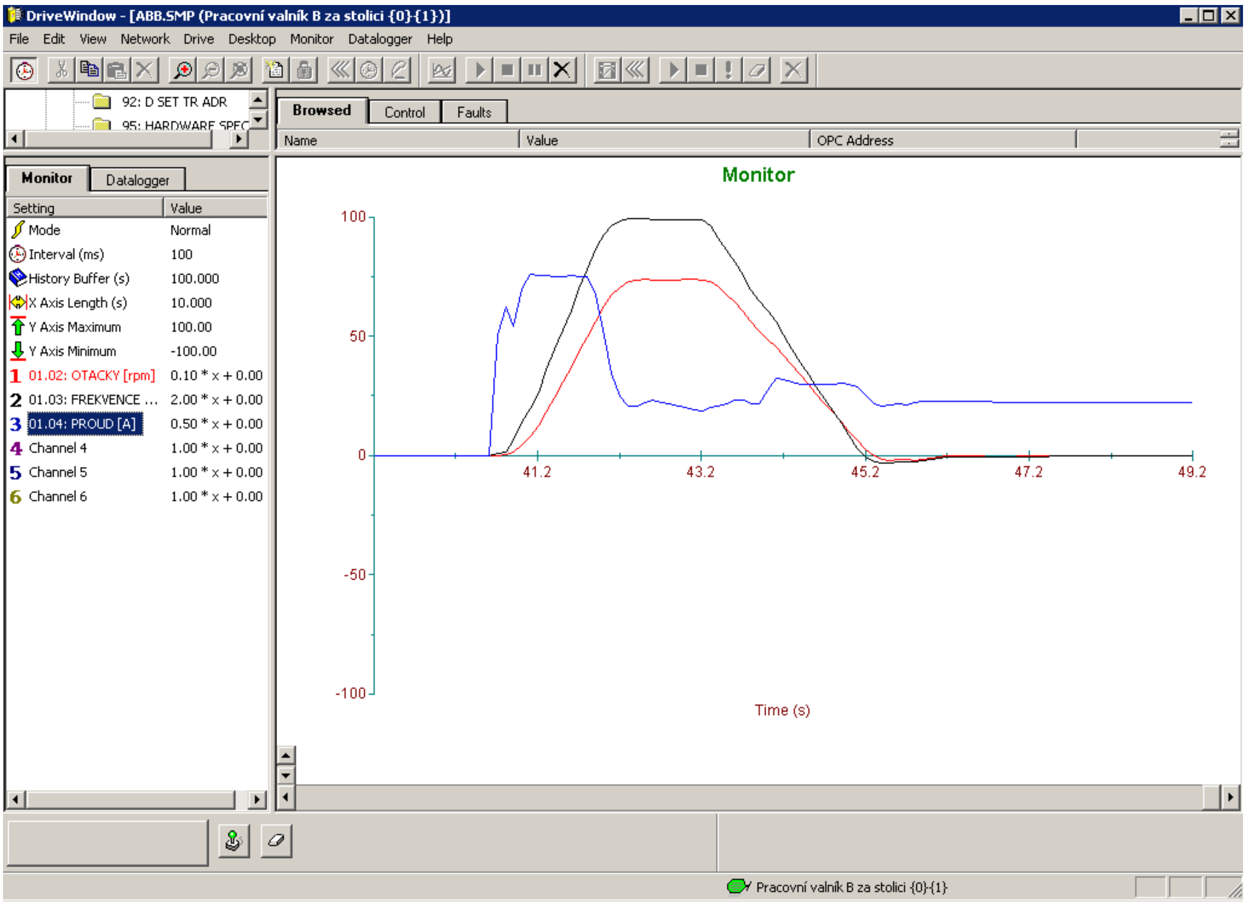

Fig.3. Waveform of the current, speed and frequency

Testing and measuring of the earth fault location system on the model

In order to more detail testing of the system, the test model was created. The test model enables to try different settings and configurations to evaluate whether the change has or has not the impact on the speed and on the accuracy of the earth fault evaluation. It would not be possible to try this type of testing with the real network without the significant intervention into the production process. In the measuring circuit there are four measuring transformers, one at the inlet and the other three at the outlets into the individual motors. These transformers are connected to a positioning device. In case the protector of the isolated state finds the fault, the localization system will start to evaluate the location of the fault [4].

Fig.4. Testing panel

For testing purpose the components below were used:

- Identification device: BENDER A-ISOMETER® IRDH575
- Localization devices: BENDER EDS490-D
- Measuring transformer: BENDER W60
- Transformer: T105 380/500V
- Contactor: EPM C25.11
- Frequency inverter: ABB ACS800-01-0004-5
- Motor M1: MEZ Mohelnice 4AP90S-4 1,1 kW
- Motor M2: SIEMENS 1LA7096-4AA11 1,5 kW
- Motor M3: SIEMENS 1LA7096-6AA10 1,1 kW

There have been many measurements and tests with the device IRDH575 and EDS460 which should have evaluated sensitivity, accuracy, reliability and speed of the identification and localization of the earth fault. As the description of all these tests would be too extensive the article will be focused on a few examples.

Test focused on the speed of evaluation of the earth fault and its localization

Earth fault was simulated on the drive switching by the frequency inverter, without added leakage capacity. Fifty measurements were carried out; the times were written into the tables and then statistically analyzed. For illustration the table of the outcomes of twenty measurements is included in this article (see table 1).

Table 1. Measured times of identification and earth fault localization

Measuring n.	IRDH [s]	EDS [s]
1.	18,6	33,4
2.	24,2	39,2
3.	6,6	33,2
4.	4,4	19,2
5.	5,2	20,2
6.	11,6	26,4
7.	23,4	38,2
8.	7,6	22,4
9.	5,6	27,8
10.	6,8	28,8
11.	7,2	22,4
12.	9,6	24,6
13.	19,6	34,4
14.	13,2	28,2
15.	12	32,6
16.	9,2	24,4
17.	3,4	18,2
18.	5,2	25,8
19.	8,6	29,2
20.	5,6	20,6

The test evaluating the effect of stray capacitance

In this case the earth fault was simulated on the drive switched by the frequency inverter, under the condition of added stray capacitance into the circuit. For illustration the table with the results of twenty measurements is given in this article (see table 2). The value of the stray capacitance was set at 4 μF, which is the value that corresponds to the medium-large cable network. Value of the capacitance can be determined as mentioned below:

- By calculation of the capacity of individual cables [2]

(1) $$C = \frac{2\pi\varepsilon_0\varepsilon_r l}{\ln\left(\frac{2h}{r}\right)}$$

where: C – capacitance, l – length, h – distance, r – radius, ε_0 – electric constant, ε_r – matter constant

- By measuring

To verify whether the value 4μF corresponds to the values in the real network, the measurements of the network were taken.

Table 2. Measured times of identification and earth fault localization with leakage capacitance

Measuring n.	IRDH [s]	EDS [s]
1.	13	29,8
2.	11	32
3.	16,2	37
4.	9,2	24
5.	9,8	24,8
6.	16,2	31,2
7.	15,5	30,2
8.	27	41,8
9.	24,8	39,8
10.	14	34,6
11.	18,8	39,4
12.	14,4	29,2
13.	10,8	25,8
14.	19,4	40,2
15.	8,6	23,4
16.	14,2	29,2
17.	30,2	45,2
18.	10	25
19.	12,8	27,8
20.	7	21,8

Results of the measurements and tests

In the following table, comparison and summarization of measuring with and without the leakage capacitance in the circuit can be found (see table 3,4). The leakage capacitance is an essential factor for speed of identification and localization of the earth fault.

For illustration the times of identification and localization of the earth fault with leakage capacitance is included in the graph below (see fig. 5). For comparison the times simulated on the drive switched by the power contactor and the frequency inverter are given. [5]

Table 3. Comparison of the measuring with frequency inverters

	Without cap.		With cap.	
	IRHD [s]	EDS [s]	IRHD [s]	EDS [s]
Average	10,5	26,9	14,8	31,4
Minimum	3,2	18,2	6,2	21
Maximum	24,2	41,4	30,2	46,6

Table 4. Comparison of measuring with the power contactor

	Without cap.		With cap.	
	IRHD [s]	EDS [s]	IRHD [s]	EDS [s]
Average	3,1	18,7	8,4	24,9
Minimum	2	13,8	2,4	18,2
Maximum	4,2	24,2	14,4	46,6

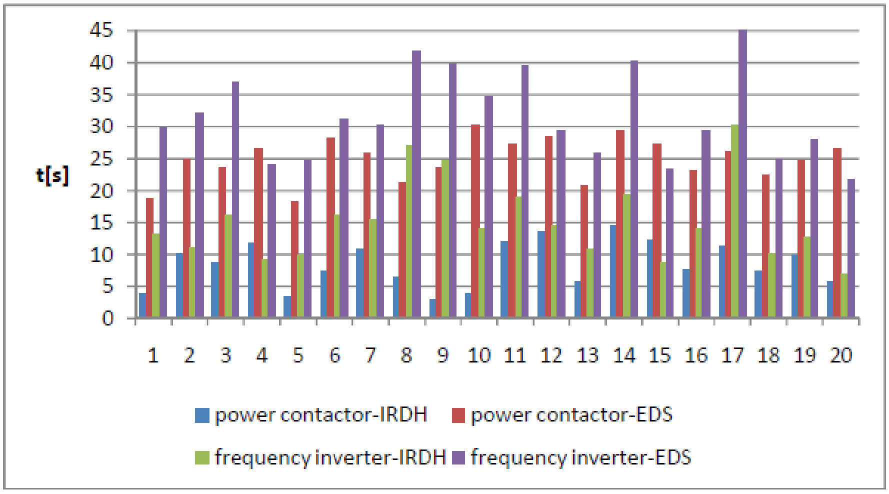

Fig.5. The graph describing time of the earth fault evaluation and its localization with leakage capacitance

Conclusion

In all cases the localization system of the earth fault evaluated and localized the earth fault properly. In no case the “false evaluation” was reached, it means that system would evaluate the earth fault which would not be activated. As we can see, times between the power contactor and the frequency inverter are different. Average times of frequency inverter are approximately 8 seconds longer. From fig.3 the conclusion can be drawn that operating times of some devices (the conveyor in this case) are short. That has the effect on evaluation of the earth fault. Therefore successive measurements with other localization systems are necessary. The results of the analysis will then be applied to a real-life industrial environment to order to verify them. It will be interesting to compare measurements on the testing panel and those in the real grid.

REFERENCES

[1] Trojánek Z., Hájek J., Kvasnica P., *Přechodové jevy v elektrizačních soustavách.* SNTL 1987

[2] Hofheinz W., *Protective Measures with Insulation Monitoring.* VDE Verlag 2006

[3] Sniegoň T., Gurecký J., *„Negative effects of the earth fault in insolated neutral system IT/500V on rolling mill for rail plant.”* Sborník konference EPE, VUT Brno, 2010, vol. 11., p. 173-176

[4] Sniegoň T., Gurecký J., *„Identification and localization of the earth fault in insolated Neutral system IT/500V in industrial environment.”* Sborník konference EPE, 2011

[5] Sniegoň T., Gurecký J., Messerschmidt M., *„System of localization of the earth fault in 500V/IT grids in industry.”* Sborník konference EPE, 2012

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