# IMPROVING SOLUTIONS OF EQUIPMENT'S RELIABILITY FOR DETECTION OF GROUNDING LINES

PĂCUREANU I.*, ALBUŢ-DANA D.**, BARLA E.**, MEIANU D.**
*S.C. FDEE Electrica Distribution Transilvania Sud S.A - SDEE Braşov
**University of Oradea, Universităţii no.1, Oradea
dalbut@uoradea.ro

**Abstract: The paper has three parts, in the first one, is presented the theoretical concepts that refer on the grounding lines fault, the treating mode, and implemented solutions for their detection in electric stations. In the second part is presented the result of the operational reliability analyse in period of 2011 – 2015, as in the final part of the paper are given the conclusions and identified solutions regarding the improving of operational reliability of the protection equipment of detection of grounding lines.**

**Key words:** operational reliability, fault detection, electric networks

## 1. THE ROLE AND APPLICATION OF EQUIPMENT FOR DETECTION OF GROUNDING MV LINES

The highest share of identified faults in medium voltage lines is represented by homopolare faults. To identify the grounding lines at the moment, are used inefficient methods characterized with successively interruptions in consumer's supply. To remove these methods, to identify the fault lines there were developed advanced methods using redundant algorithms. The main providers of these new solutions are the following companies: Trench, Eberle respectively Swedish Neutral; these companies produces equipment for selective release of the grounding lines, considering that the grounding is the beginning of a severe fault[1, 2, 6].

This is necessary because usually it degenerates in violent faults together with overvoltage in the network.

A used method with results is the directed homopolar protection, undirected, fast or temporized; to realize the selectivity in the electric installations devices are implemented to detect the earthing lines. These devices suffered essential modifications through construction as well as through their analysing mode when appears the grounding. In function with the mode of neutral point treatment, in the medium voltage networks (resistance or Petersen coil) there were developed a series of equipment and technologies for selective operation of these protections.

The informational systems implemented by intelligent electronic equipment, have an essential role because the main detection devices of grounding used in electric stations, beside the fact of presenting physical and moral wearing does not offer information that may be processed in digital form. For networks treated with resistance, the homopolar protection's operation does not create special problems, taking into account the operation principle. For networks treated with suppression coil, the development and upgrading of the electric installations, have conducted to appearance of new generation devices, based on new computing methods, one of them being the method of admittance.

## 2. TREATMENT MODE OF FAULTS IN NETWORKS WITH INSULATED NEUTRAL OR TREATED BY SUPPRESSION COIL

In the networks of medium voltage, the appearance of grounding is a fault which consists in realizing of an accidental connection with null resistance or with finite value between the ground and a phase of the network, having the neutral insulated or treated by the suppression coil. This fact conduces to modification of the phase voltage value and of the currents due to the capacitance of phase – ground [1, 2, 6].

To eliminate of this kind of faults, the method of medium voltage networks neutral compensation with suppression coil is used. In Romania this method is used in large scale for medium voltage networks, having a major advantage: eliminating the transient faults without intervention of the protection, and therefore without switch off and crossing through zero of consumers.

In case of the earthing apparition on a network with neutral treated through suppression coil, the neutral voltage displacement provokes a current on the coil that compensates the fault of capacitive current, shown in figure 1 [1, 2].

The compensation of the capacitive current in the location of the fault, provokes the extinction of the fault current, and so the insulation of the fault (for transient faults) without to be necessary to operate of the protection installation and interruption of the consumers. This fact is the major advantage for networks treated by suppression coil. On the other hand, supplementary solicitations of the healthy phases (from the voltage phase to the line phase), in steady state, but in transient state is a disadvantage of this mode of neutral treating.

The selective detection of earthing of neutral insulated medium voltage networks or treated by suppression coil, implies some special methods applying, taking into account the small value of the earthing currents. One of these methods is the admittance method.

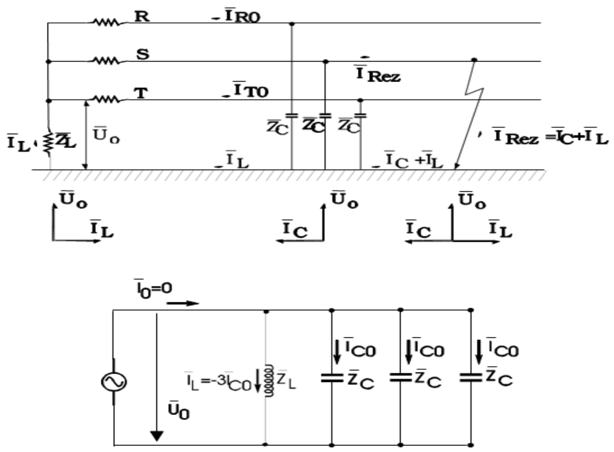

**Fig.1 – Equivalent scheme of a neutral treated network through suppression coil with earthing** [1, 2]

## 3. IMPLEMENTED SOLUTIONS IN ELECTRIC STATIONS

The implemented digital equipment within the projects realises an automation correlation of the suppression coil in function with the distribution network's configuration with neutral treated by the suppression coil, and beside the automatic adjusting this equipment realises a selective detection of the earthing lines.

TRENCH equipment are composed from an adjustable suppression coil combined with an automatic control of capacitive current compensation and a selective equipment with high sensitivity for earthing detection.

In table 1 is the volume of analysed equipment presented, and the installations within this equipment are mounted in function with the neutral treated mode.

**Tabelul 1 – Volume of analysed equipment**

| No. | Installation | Equipment | Neutral treated mode | An PIF |
|---|---|---|---|---|
| 1 | Station 110/20 kV STUPINI | EFD | BSRC | 2012 |
| 2 | Station 110/20 kV POIANA | 2 module EFD/EFC | BSRC | 2012 |
| 3 | Station 110/20 kV GHIMBAV | EFD/EFC | BSRC | 2005 |
| 4 | Station 110/20 kV HĂRMAN | 2 module EFD/EFC | BSRC | 2010 |
| 5 | Station 110/20/6 kV BARTOLOMEU | 2 module EFD/EFC | BSRC | 2011 |
| 6 | Station 110/20/6 kV TOHAN | EFD/EFC | BSRC | 2011 |
| 7 | Station 110/20 kV CRISTIAN | EFD | BSRC | 2013 |

## 4. RESULT OF OPERATIONAL RELIABILITY ANALYSE IN PERIOD OF 2003 - 2015

The paper has had the aim to analyse the operation of the mounted equipment in electric stations within FDEE South – Transilvania CEM 110 kV Brasov.

To realize the study, there were analysed the data in period of 2003 – 2015. As source of analyse were regarded the reports, realised by dispatcher compartment and the synthetized data by Informatica CPRAM. The data were selected in function with the type of protection of the analysed elements.

The processed data in this period are synthetized in table 2. In this analyse there are not included the obtained results from directed homopolare protections' analyse, implemented in digital equipment for networks treated with BSRC.

**Table 2. Operation of protection in the analysed period**

| Treated networks with coils | Numerical protection | |
|---|---|---|
| Total number of actions | 91 | 100% |
| Number of right actions | 43 | 47 |
| Number of wrong actions | 36 | 40 |
| Number of refuses | 12 | 13 |

After the data processing from the table 2, results the distributions presented in figure 2.

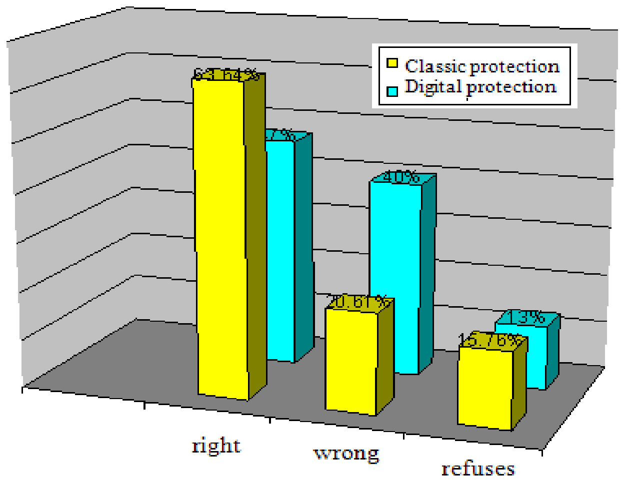


**Fig.2. Percent of number of action for protections in 2011 – 2015**

It can be observed a high weight of wrong actions of numerical homopolare protections, identified by the analysed events, as the main source being the human mistake in programming. In case of the classical relays the errors occurs due to the technical and ethical wear of the equipment.

In this sense, there were identified the main types of equipment which have determinate the fault operations, namely, the equipment of TRENCH type, by these were identified faults of some components, it were verified by the manufacturer. The works were carried under warranty.

The wrong actions of the classical equipment appear due to the outdated life time of the equipment.

The assessment of the protections behaviour will be made by the intensity correct, wrong and refuse actions.

After the data processing from table 3, results the distributions given in figure 3, 4 and 5.

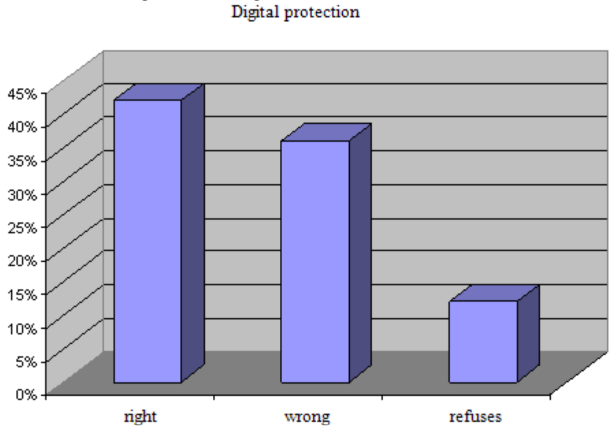


**Fig.3 – Percent of number of action for TRENCH equipment used in networks treated by suppression coil in period 2011 – 2015**

**Table 3. The analyse of numerical protections**

| Type of equipment | Number of mounted protections | λc $[h^{-1}]$ | λi $[h^{-1}]$ | λr $[h^{-1}]$ |
|---|---|---|---|---|
| **Numerical equipment** | | | | |
| TRENCH | **10** | **4.2** | **3.6** | **1.2** |

The presented indices analysing, has as aim to identify the error sources of the equipment and proposing some solutions basing on the obtained results. The above figure identifies o poor functioning of digital equipment, requiring a detailed analyse of its, especially, of the programming mode. It is mentioned, that the aims of the made changes have had to reduce the number of wrong releasing.

**Table 4. Matrix analyse of the numerical protection in 2012**

| $\Delta t_i$ | $\delta n_p$ | $\delta n_{sol}$ | $\delta_{int}$ | $\delta n_{ref}$ | $N_{(0)}$ | $\delta n_{er}$ | $n_{int}$ | $n_{ref}$ | $n_{er}$ | $n_c$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 4 | 0 | 1 | 10 | 0 | 0 | 0 | 0 | 9 |
| 2 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| 3 | 3 | 3 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| 4 | 1 | 1 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| 5 | 5 | 5 | 1 | 1 | 10 | 4 | 1 | 1 | 1 | 9 |
| 6 | 4 | 4 | 1 | 1 | 10 | 2 | 0 | 0 | 0 | 9 |
| 7 | 1 | 1 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| 8 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| 9 | 9 | 9 | 1 | 1 | 10 | 7 | 1 | 1 | 2 | 8 |
| 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |
| 11 | 2 | 2 | 0 | 0 | 10 | 1 | 1 | 0 | 1 | 9 |
| 12 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 |

In table 2 and 3 – were presented the values of the following parameters [4, 5, 7,8, 9]:

**$\Delta t_i$** - period of supervision

**$\delta n_p$** - number of primary events, which appeared in the respective period

**$\delta n_{sol}$** – number of requests to which the security installations were subjected in the period $\Delta t_i$

**$\delta n_{int}$** – number of installations which operated unexpected under stress in period of $\Delta t_i$

**$\delta n_{ref}$** – the number of installations that refused the operation in period of $\Delta t_i$;

**$N_{(0)}$** - the number of installations of respectively type being in operation from the beginning of the analyse

**$\delta n_{er}$** - number of installations that gave a wrong answer to the request in period of $\Delta t_i$;

**$n_{int}$** - cumulated number of installations of respectively type that until to $t_i$ moment operated unexpected

**$n_{ref}$** - cumulated number of installations that till $t_i$ moment refused the operation in case of request

**$n_{er}$** - cumulated number of installations that till $t_i$ moment have transmitted wrong answers to the requests

**$n_c$** – number of installations that do not operate wrong till $t_i$ moment,

In this case, the transfer of operational intensity of the wrong answers has the following distribution, figure 3.

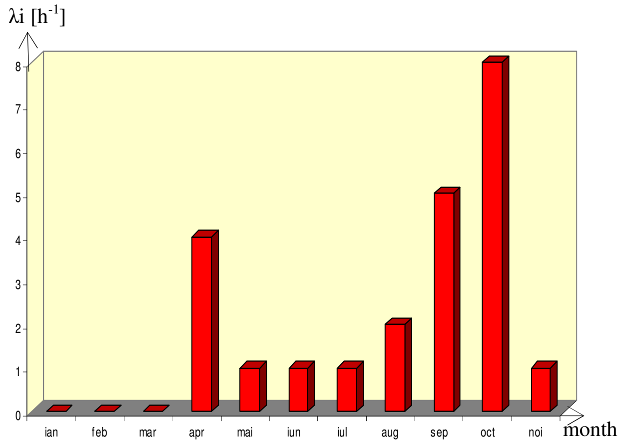


**Fig.3 Operational intensity of wrong answers transfer for protections in 2012**

In this case, the operational intensity of unexpected operations transfer has the distribution in figure 4.

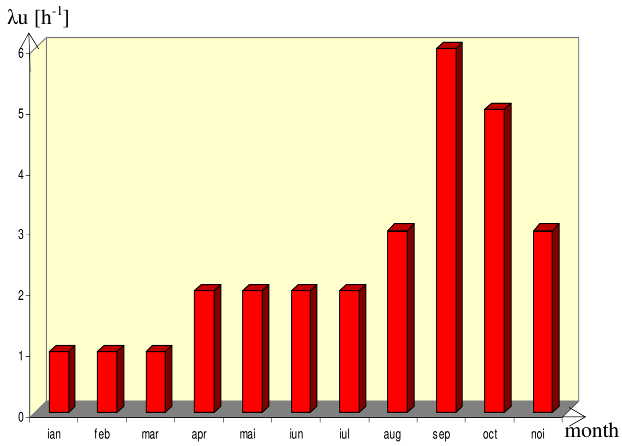


**Fig.4. Operational intensity of unexpected operations transfer in 2012**

In this case, the operational intensity of refuse has a distribution in figure 5.

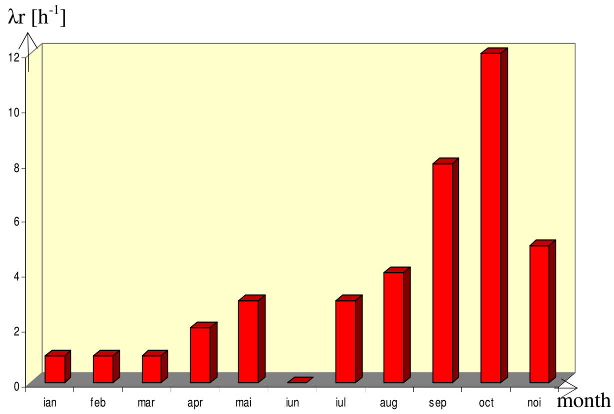


**Fig.5 Operational intensity of refuse for protections in 2012**

## 5. IDENTIFIED SOLUTIONS TO IMPROVE THE OPERATIONAL RELIABILITY

After the analyse of the presented main problems and of the obtained data from exploitation, the conclusion regarding the main reason of the wrong actions are the human errors, improperly chosen technical solutions, as well as the equipment's improper programming.

To improve the operational reliability of the equipment to find the earthing, there were identified the following solutions to reduce the wrong releases:

- To verify the displayed value of the network impedance;
- To verify the homopolare toroidal transformers through angles, saturation, and connection realizing mode;
- Deactivation of discontinuous releasing of grounding function, because it is not necessary and generates wrong operations, due to the advanced wear of the cables. After an operation it is necessary to cancel the detection, because for a correct analyse the equipment needs a minimal time of the network configuration recalculation. It is necessary the realising delay with 2 seconds, allowing so the operation of the protections current sectioning;
- The configuration of the equipment so as to emit a single pulse of releasing, avoiding multiple wrong releasing;
- To verify the toroidal transfomer's characteristics through angle analyse, of the saturation diagram and of the mode of connection's realization;
- To verify the stability of displayed phasor values (it is verified the value of 90$^{o}$ of the angle between Uo and homopolar currents for each line);
- After an operation it is necessary to cancel the detection, because for a correct analyse, the equipment needs a minimum time to recalculate the network's configuration;
- It is necessary to delay the releasing with 2 – 3.5 seconds, allowing the operation of the currents sectioning protection;
- The equipment's configuration so that to emit a single impulse of releasing, avoiding the wrong multiple releasing;
- The equipment's configuration in function with the network's characteristics.

## 6. RESULTS OF OPERATIONAL RELIABILITY ANALYSE OF THE TRENCH EQUIPMENT IN PERIOD OF 2013 - 2015

The data processed in period of October 2013 – May 2014 are presented in table 5.

**Table 5. The operation of the protections in the analysed period**

| Ph networks treated coil | Protection TRENCH | |
|---|---|---|
| Total number of actions | 31 | 100% |
| Number of correct actions | 28 | 93,4% |
| Number of fault actions | 1 | 3,3% |
| Number of refuses | 1 | 3,3% |

It can be seen a high weight of correct actions number for homopolar protections, using TRENCH equipment with new implemented solutions identified after the wrong operations (fig.6).

The appreciation of the protection behaviour will be made by the correct, incorrect actions intensity and of the refuse. All these will be determined using the data from table 7, referring to the number of correct actions, number of incorrect actions, respectively, the number of the refuses for all type of protection using the following relations [3, 4, 5, 7, 8, 9, 10, 11]:

$$\lambda_c = \frac{Number\ of\ correct\ actions}{Number\ of\ the\ installed\ elements} \qquad (1)$$

where $\lambda_c$ is the number of correct actions;

$$\lambda_i = \frac{Number\ of\ incorrect\ actions}{Number\ of\ installed\ elements} \qquad (2)$$

where $\lambda_i$ is the intensity of the incorrect actions;

$$\lambda_r = \frac{Number\ of\ refuses}{Number\ of\ installed\ elements} \qquad (3)$$

where $\lambda_r$ is the intensity of the refuse.

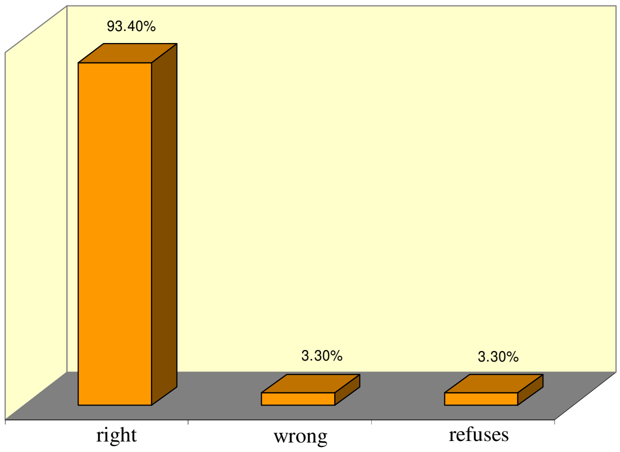


**Fig 6. Intensity of action for TRENCH equipment used in networks with suppression coils**

Applying the relations (1), (2), and (3) the table 6 is completed.

**Table 6. The analyse of numerical protections**

| Type of equipment's | Number of mounted protections | λc $[h^{-1}]$ | λi $[h^{-1}]$ | λr $[h^{-1}]$ |
|---|---|---|---|---|
| TRENCH | 10 | 2.8 | 0.3 | 0.1 |

After the data processing from table 6, results the distributions presented in figure 7and 8.

The analyse of presented indices as aim has to identify the error sources of the equipment and to propose some new solutions basing on the obtained results. The above figure identifies a poor operation of the digital equipment, making a detailed verification of these, especially of programming mode. We mention that, the carried out modifications have had the aim of wrong releasing reduce.

In this case, the intensity of the wrong answers operational transfers has the distribution presented in figure 7.

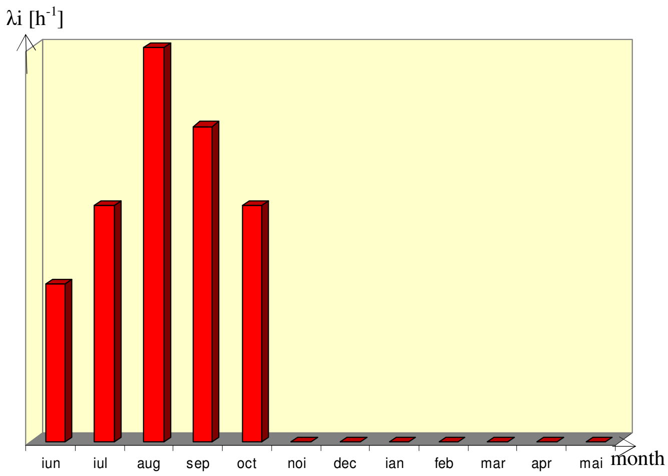


**Fig.7. Intensity of operational transfer of the wrong answers for protections**

The intensity of operational transfer of unexpected operations is a measure obtained on statistical way that is the ratio between the number of relays that have unexpected operate for a period and the produce of relays that have not unexpected operate till $t_i$ period and the considered period [3, 4, 5, 7, 8, 9, 10, 11].

$$\hat{\lambda}_{int}(t_i) = \frac{n_{int}(t_{i-1}+\Delta t_i) - n_{int}(t_{i-1})}{N_{n.int}(t_1)\cdot \Delta t_i} = \frac{\delta n_{int\,(ti)}}{N_{n.int}(t_i)\cdot \Delta t_i} \quad (5)$$

In this case, the intensity of operational transfer of unexpected operations has a distribution presented in figure 8.

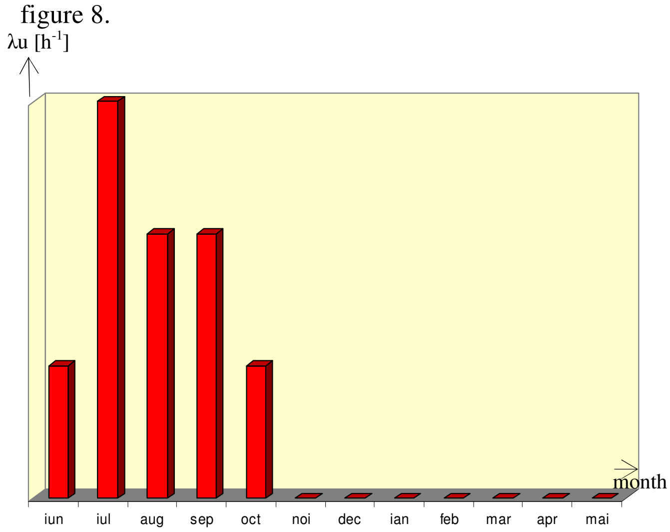


**Fig.8. Intensity of operational transmission of unexpected operation for protections**

The operational transfer intensity of the wrong answers is a measure obtained from statistical data, which is a ratio between the number of relays that have operated wrong for a period and the produce between the number of relays that have operated right till $t_i$ moment and considered period [3, 4, 5, 7, 8, 9, 10, 11].

$$\hat{\lambda}_{er}(t_i) = \frac{n_{er}(t_{i-1}+\Delta t_i) - n_{er}(t_{i-1})}{N_{n.er}(t_i)\cdot \Delta t_i} = \frac{\delta n_{er\,(ti)}}{N_{n.er}(t_i)\cdot \Delta t_i} \quad (4)$$

**Table 7. Statistical tracking matrix of a protection using TRENCH equipment for period October 2013 – May 2014**

| $\Delta t_i$ | $\delta n_p$ | $\delta_{int}$ | $\delta n_{ref}$ | $N_{(0)}$ | $\delta n_{er}$ | $n_{int}$ | $n_{ref}$ | $n_{er}$ | $n_c$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 10 | 1 | 1 | 0 | 0 | 1 |
| 2 | 5 | 1 | 1 | 10 | 2 | 1 | 1 | 2 | 2 |
| 3 | 8 | 2 | 1 | 10 | 3 | 2 | 1 | 3 | 3 |
| 4 | 10 | 2 | 0 | 10 | 2 | 2 | 0 | 0 | 2 |
| 5 | 11 | 1 | 1 | 10 | 2 | 1 | 1 | 2 | 2 |
| 6 | 1 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 7 | 3 | 1 | 0 | 10 | 1 | 1 | 0 | 0 | 1 |
| 8 | 2 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 10 | 4 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 11 | 4 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 12 | 3 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |

## 7. CONCLUSIONS

After the operational reliability analyse for the period 2003 – 2015 of the TRENCH equipment, it is observed the fact that from the registered operations a great part were incorrect. As was shown, the majority of deficiencies occurred due to the incorrect configurations implemented in digital equipment as well as due to the incorrect connections carried out within the upgrading works. After analysing there were introduced some measures to reduce the number of incorrect releasing. As shown for the last 6 months it was not registered any incorrect releasing after the made upgrading.

From the identified deficiencies after the made analyses, that were remediated we will mention the following:

- The incorrect performance of the connections of cable encapsulation in the medium voltage cells (connection to the ground before they are crossed through the tor, the inversion of crossing direction through the tor, inadequate insulation);
- Inversed polarities in the track between the toroidal transformer's terminals and the enter into the digital equipment;
- Transformation ratio set or stabilized inadequate;
- Unexpected action of the restricting earthfaults function;
- Releasing all of the connected lines to the monitorized bar section;
- Pulse emission of releasing with 2 seconds before of earthing verify signed by the measure cells.
- Wrong display of the suppression coil;
- High fervency of the injection equipment's operation;

From the presented problems the measure with the highest impact on the operational reliability improvement is to ensure a period of analyse of 2 seconds, the period within the releasing impulse must be blocked.

## BIBILIOGRAPHY

[1]. Vasilievici, Al., ş. a. - Implementarea echipamentelor digitale de protecţie şi comandă pentru reţele electrice, Ed. Tehnică, Bucureşti, 2000

[2]. Crişan, O. – Sisteme electroenergetice, Ed. didactică şi Pedagogică, Bucureşti, 1978

[3]. Viziteu, I.– Fiabilitatea sistemelor de securitate cu aplicaţii la protecţia şi automtica instalaţiilor electroenergetice. Teza de doctorat, Iaşi, 1997

[4]. Mihoc, Gh. – Bazele matematice ale teoriei fiabilităţii Editura Ştiinţifică şi Enciclopedică Bucureşti 1976

[5]. Barlow, R.E., Proschan, F. – Statistical Theory of Reliability and Life Testing, Holt, Rinehare & Winston, New York, 1975

[6]. Albuţ-Dana, D. – Contributii la analiza retelelor urbane de medie tensiune in vederea optimizarii configuratiei acestora, Teza de doctorat 2010

[7]. Cătuneanu, V.M., Popenţiu, F. – Optimizarea fiabilitaţii sistemelor, Editura Academiei, Bucureşti, 1989

[8]. Felea, I. – Ingineria fiabilităţii în electroenergetică, Editura Didactică şi Pedagogică, Bucureşti, 1996

[9]. Felea, I., Coroiu, N. – Fiabilitatea şi mentenanţa echipamentelor electrice, Ed. Tehnică, Bucureşti,2001

[10]. Xing, L., Shresta, A., Meshkat, L., Wang, W. – Incorporating common-cause failures into the

[11]. Modular hierarchical systems analysis, IEEE Transaction on Reliability, vol. 58, no. 1, March, 2009