УДК 621.316

PROBLEMS WITH EVALUATION OF THE RELIABILITY OF RELAY PROTECTION

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In the paper observed estimation of reliability of relay protection (RP). It is shown, that an existing method, both Russian, and foreign, do not allow to evaluate RP reliability correctly. The new method of RP reliability estimation is offered.

Keywords: relay protection, reliability, digital protective relays.

1. Introduction

It is well-known that [1] 25-28 % of world's major power supply failures result from relay protection faults. Also, relay protection faults are responsible for 50-70 % of system collapses arising from regular emergency conditions [1]. So it is clear that the reliability of relay protection (RP) is extremely important.

What does reliability mean? According to GOST 27.002-89 "Reliability is the property of an object to ***maintain within the specified time*** the values of all parameters specific to the ***ability to perform*** the required functions under set modes and conditions of operation, maintenance, storage and transportation." [2]. Bold text is to emphasize that reliability is not only dealing with "performing required functions", but also with "maintaining within the specified time the ability to perform the required functions". Obviously "performing required functions" differs from the "ability to perform the required functions". Let's take an example of relay protection to see the difference. If we try to evaluate RP reliability by "performing required functions" it is discovered that the microprocessor-based relay protection device (MPD) is absolutely reliable because it caused no malfunction (or non-operation) of the **controlled circuit breaker** while **MPD's** chronic failures resulted in frequent replacement of internal **MPD's** units. On the other hand, if we use the "ability to perform the required functions" to evaluate the reliability of the same MPD, as required by the standard, we discover that the mentioned MPD is totally unreliable device because internal faults made it ***unable to perform required functions*** numerous times over a long period.

2 .Actual Method of Evaluation of the Reliability of Relay Protection

Which methods are actually used in practice to evaluate RP reliability?

Western specialists use three criteria for RP evaluation [3]:

Dependability D:

$$D = \frac{N_C}{N_C + N_F}. \quad (1)$$

Security S:

$$S = \frac{N_C}{N_C + N_U}. \quad (2)$$

Reliability R:

$$R = \frac{N_C}{N_C + N_F + N_U}, \quad (3)$$

where N_C – correct protection operations; N_F – refusals to operate; N_U – unnecessary operations (malfunctions).

However, mentioned above formulas do not give the correct reliability value as they do not consider RP failures which do not lead to incorrect operations.

As it turned out in Russia, such a parameter as RP reliability is not evaluated at all. The Ruling Document RD 34.35.516-89 [4] declares that the "basic index of RP device performance is represented by percentage of correct operations calculated by following formula":

$$K = \frac{N_{PS}}{N_{PS} + N_{IS} + N_{LS} + N_{OS}} 100\,\%, \qquad (4)$$

where N_{PS} – correct operations; N_{IS} – unnecessary operations; N_{LS} – malfunctions; N_{OS} – refusals to operate.

As you can see from the comparison, despite different names used to identify the index, both methods are identical and not capable of giving the correct value of RP reliability. Another problem is that such methods use absolute rather than normalized indexes. The following example shows the results of such an approach. Fig. 1 represents diagrams analyzing reasons of protection relay failures. Each picture introduces two diagrams: one for electromechanical protective relay (EM), other for MPD. What can we deduce from these diagrams? For example [6] concludes that “according to the diagram the frequency of remote MPD faults is almost the same as that of traditional protection, however the ratio of fault reasons is different”. In other words it means that reliability of EM correlates with MPD's. But does it mean that the switch from EM to MPD will not reduce the reliability of relay protection as it is indicated in [7–9]? Can we see it from comparison of left and right diagrams in figure 1? Absolutely not! As these diagrams do not consider the number of relays for which they show the values of failures, the left and right diagrams can not be compared. It is a typical error to consider absolute rather than normalized values (which take into account the number of considered objects).

There are opposite examples. Let’s cite data posted by Vladimirov A.N., Deputy Head of Relay Protection Department of Central Dispatch Service of UES of Russia, on popular Russian relay protection forum [10]:

“In 2000-2009 we registered 2,913 cases of digital RP device operation in electric mains and 110-750 kV equipment: 89.5 % correct and 10.6 % incorrect. During the same period we registered 17,529 operations of EM: correct – 93.53 %, incorrect – 6.48 %. Microelectronic relay protection devices operated 5,685 times: correctly – 92.91 %, incorrectly – 7.07 %”.

This example shows normalized failure data (number of failures for each relay type is represented in percentage of total operations of each relay type). Simple division of 10.6 by 6.48 shows the realistic picture. It turns out that even if we use current system of reliability evaluation, which does not consider all factors, the reliability of MPD is 60 % less than EM’s.

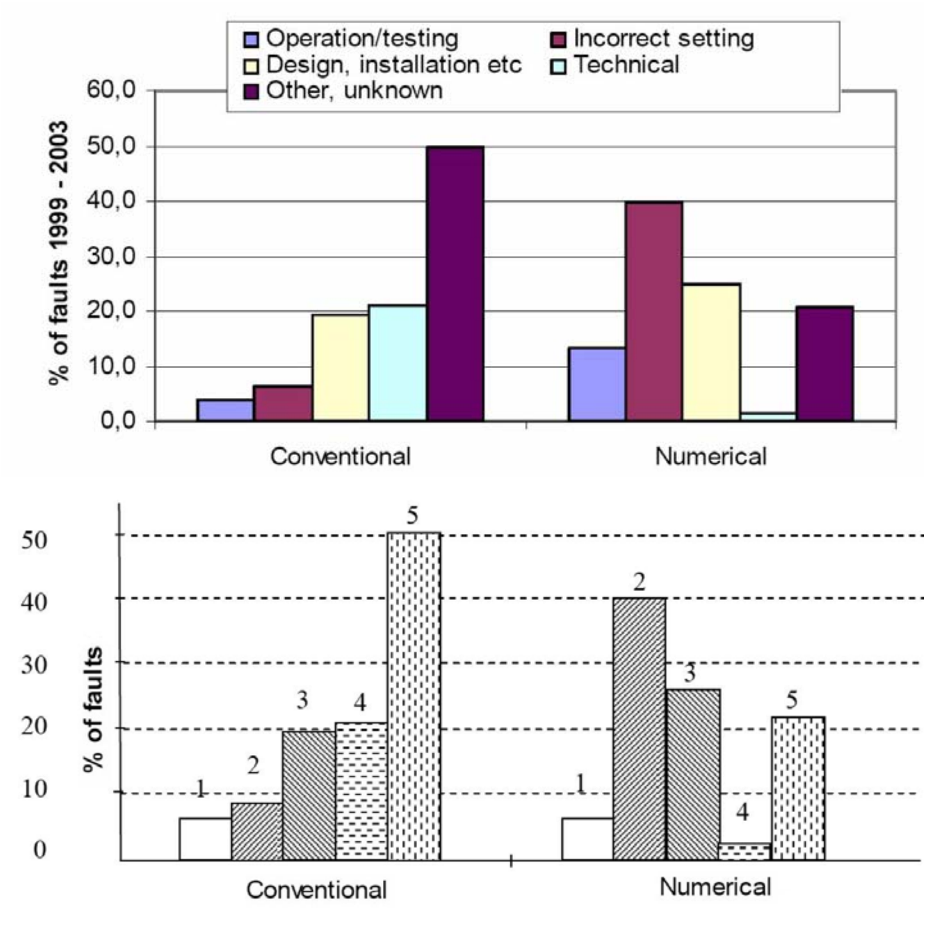

Fig. 1. Diagrams of remote protection failures in 132 – 420 kV power lines, top from [5], bottom from [6]:

1 – failures due to test and operation errors; 2 – failures due to setting and adjustment errors; 3 – design errors; 4 – engineering problems; 5 – failures of undetermined nature

Let's look at the fig. 1 again. According to mentioned above information it is obvious that diagrams may be compared correctly only by percentage of reasons of each type of relay failure rather than by absolute reliability indexes of EM and MPD. The important inference drawn from the diagram analysis is that the switch from EM to MPD is followed with dramatic increase in rate of RP failures caused by the so called "human factor":

- Rate of failures caused by setting and adjustment errors is almost 6 times higher;
- Rate of failures related to RP test and operation errors is almost 4 times higher.

Russian specialists confirm the significant influence of "human factor" on RP as well, indicating that today the "human factor" is responsible for 52.8 % of RP malfunctions [11]. According to [5] this rate is even higher and reaches up to 78 % in Western countries. That is, in fact, this factor that is the main reason of RP problems.

Why is the switch from EM to MPD accompanied by a sharp increase in the incidence of the human factor? In our opinion, an eloquent response to this question is provided in the following quotation [12]:

«Terminal Siprotec 7SJ642 (Siemens) has unreasonable technical and informational redundancy. User manual (C53000G1140C1476, 2005) declares «simple operation through integrated control board or PC with a systems program DIGSI», which is totally untrue. For example, you should enter nearly 500 parameters (settings), despite of inevitable changes to signal matrix, while each signal has its "properties" influencing the operation of the unit (printed-out DIGSI signals matrix takes about 100 pages of text in English). Since there is a need to compile terminal adjustment tasks, where all set-up protocols should be considered, the amount of documentation becomes huge. Big volumes of data need to be entered making the setup process very difficult. Informational redundancy increases the probability of so called human factor errors. Technical redundancy requires only high-level specialists to be involved in work with the terminal. Available technical documentation includes thousands of pages, which often do not provide necessary data while containing errors».

No comments. It should only be noted that the above product of Siemens is given only as an example being not outstanding. It is true of most products from other manufacturers. Unfortunately, it has become a common trend.

In view of the above there is a reasonable question: why is the level of technical effectiveness, reliability and rate of correct operations (or whatever one wishes to call it) of modern RP evaluated without considering the human factor? In fact the reason of failure (wrong operation) makes no difference to such RP evaluation. Wrong settings, faulty operation logic, soft **blocking** of different functions during test without sequent restoring and many other reasons may be combined into human factor results in the same relay protection malfunction as internal faults of electronic circuits. Moreover, different MPD types have different programming interfaces just like different relay types have different hardware components and circuit designs, therefore preconditioning difference in reliability. Some MPD types have simple and clear interfaces while interfaces of others are extremely over-done and unfriendly. It is clear that in the last case the incorrect RP operation is more likely due to a significant increase in human factor occurrence.

So, the current methods of RP reliability evaluation do not give the true picture and thus requiring serious correction.

3. Offered Method of Evaluation of the Reliability of Relay Protection

In our opinion, the following three types of failures should be considered in evaluation of RP reliability:

1. Relay failures not related to incorrect RP operations but requiring repair or replacement of faulty components, units and modules (M_S).
2. Wrong operations of relay protection, namely unnecessary operations in the absence of emergency mode or malfunctions under emergency mode (M_D) not related to human errors.
3. Human errors related to operating, testing and programming relay, which influence on correct operation of relay protection and are discovered before or after wrong operation of protection (M_P).

We think that all these values should be included into a generic normalized index of failures of relay protection M_Σ:

$$M_{\Sigma_i} = \left(\frac{M_{S_i} + M_{D_i} + M_{P_i}}{N_i} \right) 100\,\%, \qquad (5)$$

where $M_{S_i}, M_{D_i}, M_{P_i}$ - number of failures of each type for the relay *i* kind for the considered period of time; N_i - number of the relay *i* kind, being in operation during the considered period of time.

It is quite clear from the proposed method that reliability of MPD is significantly lower than that of ER. However it does not mean that the switch from the EM to MPD must be slowed down. Rather it discovers a serious problem that needs fixing. Some remedies have already been proposed [13–15].

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ПРОБЛЕМЫ ОЦЕНКИ НАДЕЖНОСТИ РЕЛЕЙНОЙ ЗАЩИТЫ

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В статье рассматриваются вопросы оценки надежности релейной защиты (РЗ). Показано, что существующая методика, как российская, так и зарубежная, не позволяет корректно оценивать надежность РЗ. Предложена новая методика оценки надежности РЗ.

Ключевые слова: релейная защита, надежность, микропроцессорные реле.