# Analysis of the Residual Current Devices operation in IT and TT systems

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*Abstract* – **The authors of the paper have developed imitation models of one- phase and three- phase residual current devices and the different situations of direct and indirect contact of a person in an electrical network low voltage. TT and IT systems under normal and fault modes are considered. Authors' own model schemes for low voltage networks are used.**

*Keywords* – **Direct Contact, Electrical safety, Indirect Contact, RCD, IT, TT systems**.

## I. INTRODUCTION

Residual current devices (RCDs) are becoming more widely used, together with the implementation of low-voltage network as TN-S system. The protective disconnection is regarded as a protective measure that provides the highest degree of safety. Residual current protective devices have been subject to research by the authors. The results for modeling RCDs as part of the electrical installation low voltage and also their work in other fault situations have been published in [3, 4]. Object modeling was residual current devices, worked by a zero sequence currents and the nominal operating threshold $I_{\Delta n}$= 30 mA.

The protective disconnection is a precaution applied commonly with protective earthing in systems low voltage IT and TT. Using RCD provides protection against direct contact in the low voltage system, but only as an additional protective measure.

Several cases of direct and indirect contact of a person in systems IT, TT and TN-C-S are considered in [1]. They are analyzed and the conclusion is that RCDs do not trip and respectively the person is at risk.

The authors have done a research with developed in [4] simulation model of single-phase two- pole RCD and created for the purpose of this paper such three-phase model. Different situations of direct and indirect contact of a person in normal and fault cases in IT and TT network, listed in [1], have been researched by authors. Model schemes for low voltage networks [2] were used.

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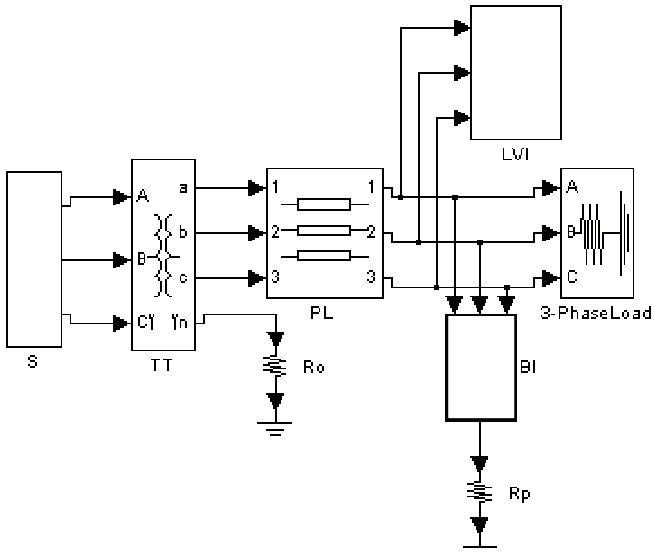


Fig.1. Example for simulation model of network TT; S- Power System; TT- Supply Transformer; PL- Cable Power Line; LVI- Low voltage installation with RCD; BI – Basic Insulation of three phase load; Ro- neutral's earthing; Rp- protective earthing

## II. RESEARCH MODELS OF IT AND TT

The block, modeling RCD, is included in the model of an electrical low voltage installation of TT and IT (Fig.2). The block RCD consists of:

- Summing Block SB, monitoring the Rms value of the vector sum of the currents flowing through the phase (or phases) and the neutral conductor (if there is) at a point of the electrical installation;
- Block Logic LB - after SB the signal is given to this block and the time- current characteristic curve Type G is realized for RCD Type AC (Table 1);
- Block „Switching" – interrupts the supply after the time delay. It is in LB.

Table 1 shows the realized tripping curve of RCD and the standardized tripping times.

TABLE I
MAXIMUM TRIPPING TIME

| Tripping curve | $I_n$, A | $I_{\Delta n}$, A | Tripping time, s | | |
|---|---|---|---|---|---|
| | | | $I_{\Delta n}$ | $2.I_{\Delta n}$ | $5.I_{\Delta n}$ |
| G | All values | All values | 0,22 | 0,12 | 0,06 |
| | | | | | |

## III. RESEARCHED CASES

The TT system is with earthed neutral. The value of the earthing rod of the supply transformer's neutral is $R_0$= 4 Ω.

TT network

Case 1 (Fig. 2): Direct contact with a live part (phase L2) and the casing of an equipment (exposed conductive parts). At the same time there is a faulting-to-ground neutral N. The person, contacting with these parts, is replaced with two resistance: a resistance of the way "hand - hand" $R_{h1}$= 800 Ω between the phase L2 and the casing and a resistance of the way "hands - feet" $R_{h2}$= 1200 Ω between the casing and the ground.

In TT power systems all the exposed conductive parts have a direct electrical connection to protective earthing installation with resistance $R_p$ = 4Ω, independently from the earthing of the supply system (e.g. utility). In this case [1] a faulting-to-ground neutral downstream of the RCD, can create a parallel path, which again closes via N, and earth leakage current might be not large enough to cause tripping RCD. The simulation results confirmed this reasoning. RCD fails, but the person has a current value in the range below 1 mA.

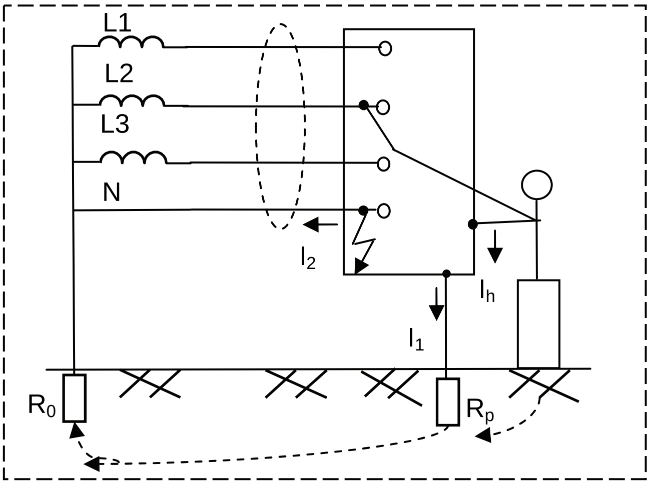


Fig.2 Direct contact with a live part and the exposed conductive parts in TT system with fault- to- ground neutral; $R_0$ – supply transformer's neutral resistance; $R_p$- protective earthing system's resistance

**Case 2 (Fig. 3):** Direct contact with the phase L1. Two phases L2 and L3 are leaking to ground while, at the same time, a direct contact is occurring with the other healthy phase (Fig. 3). The person's body is replaced with resistance Rh = 1000 Ω between L1 and the ground, and the insulation failure of the phases is replaced with a resistance less than 1Ω. The system in this case is with no neutral conductor N. RCD operates by carrying out the vector summation of the three-phase currents $I_f$ on a three-phase circuit and comparing the result to its operating threshold. Since fault currents of the three phases via ground are different, $I_{L2}$ and $I_{L3}$ will be more than $I_{L1}$. If $I_f$ is less than the RCD threshold, this might not trip, despite a potentially dangerous current via the person [1].

The simulations showed the following results: the current via human's body is in the order of 280 mA. Current in the secondary winding of the transformer of RCD is about 20 A and according to Table 1 tripping occurs in 0, 06 s. The value of the resistance $R_f$ of insulation fault affects the current of the secondary winding of transformer. When $R_f$ = 1000 Ω RCD does not trip and the value of current through the human's body also has a dangerous value - about 230 mA.

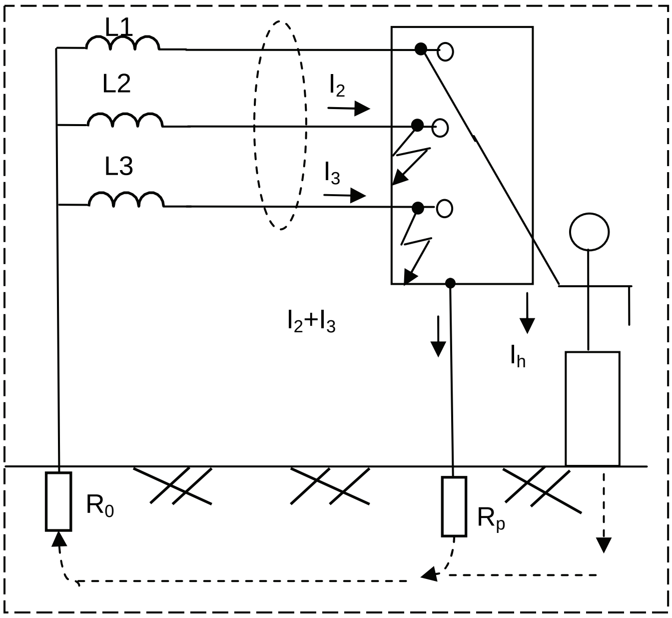


Fig.3. Direct contact in TT system with fault- to- ground phases $L_2$ and $L_3$

**Case 3 (Fig. 4):** Indirect contact with the exposed conductive parts of equipment where there is a fault - to - protective conductor phase. This system is with a neutral conductor and the considered load is a single-phase consumer. The person's body is replaced with resistance Rh = 1000 Ω and the insulation failure of the phase is replaced with a resistance less than 1 Ω.

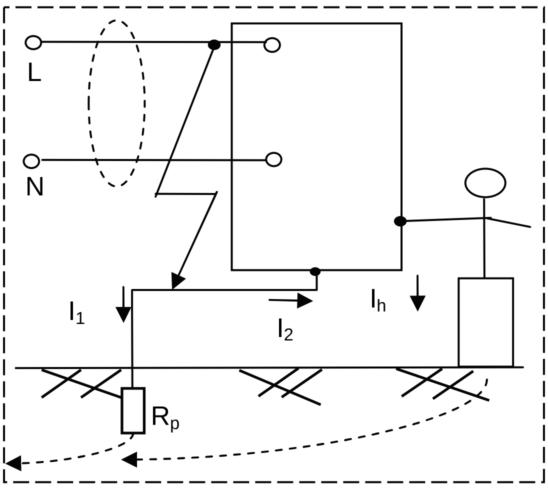


Fig. 4. Indirect contact with the exposed conductive parts in TT system and fault- to- protective conductor phase

In this case the exposed conductive parts are under voltage due to their connection to the protective earthing system.

Thus, in contact with them, the body will be under that voltage, while the current through it may not be sufficient to trip RCD [1]. The simulations showed the following results: the current via person is dangerous; the current in the secondary winding of transformer is sufficient to trip RCD. The tripping occurs in 60 ms. But when the installation point of RCD is after the fault point, it can not be activated.

**IT network**

**Case 4 (Fig. 5):** Direct contact with the phase. The person is replaced with resistance Rh = 1000 Ω between L1 and ground. Although the neutral is insolated from ground live conductors have "connection" with the ground through capacitive conductivity, which depend on the length of the line. In the case of large capacitive conductivity RCD can not be activated by direct contact of a person [1].

The simulations showed the following results: current in the secondary winding of transformer of RCD depends on the length of the line and the value of Y.

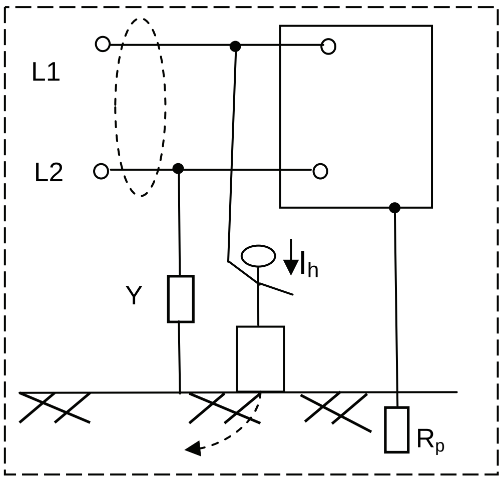


Fig. 5. Direct contact in IT system

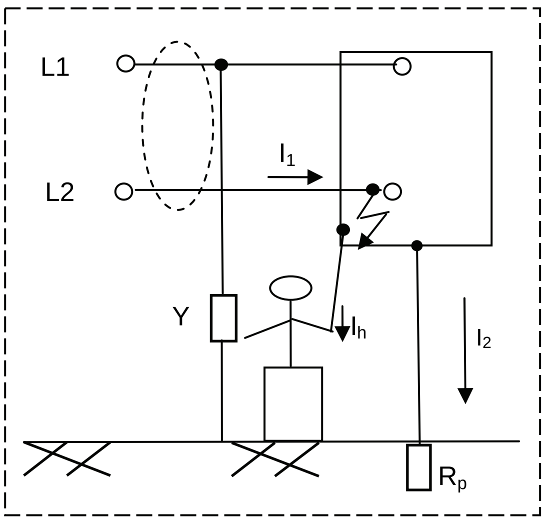


Fig. 6. Indirect contact in IT system

**Case 5 (Fig. 6)**: Indirect contact with the exposed conductive parts of the consumer under insulation fault. Such a situation as described in case 4 may occur in indirect contact with large capacitive values of the conductivity [1].

Simulations showed that the current in the secondary winding of transformer of RCD depends on the length of the line and the value of Y.

## IV. Analysis and conclusion

In general, research of IT and TT networks confirmed the presented consideration in [1] about operation of the protection, with the exception of one case. Again confirm the conclusion of [3, 4] that visualizing the values of currents via person and other elements of the network makes it possible to make more accurate analysis of situations of direct and indirect contact in the presence of RCD built. The fulfilled research presented:

- At direct contact with a live part and the exposed conductive parts in TT system with fault- to- ground neutral RCD fails, but the person has a current value in the range below 1 mA;
- At direct contact in TT system with the health phase and fault- to- ground other phases the value of the resistance $R_f$ of insulation fault affects the current of the secondary winding of transformer. When $R_f$ = 1000 Ω RCD does not trip and the value of current through the human's body also has a dangerous value - about 230 mA.
- At the indirect contact with the exposed conductive parts in TT system and fault- to- protective conductor phase the current via person is dangerous and the current in the secondary winding of transformer is sufficient to trip RCD. The tripping occurs in 60 ms. But when the installation point of RCD is after the fault point, it can not be activated.
- At direct and indirect contact in IT system simulations showed that the current in the secondary winding of transformer of RCD depends on the length of the line and the value of Y.

Finally, do not forget that the RCDs are an additional protective measure. The electrical safety is a complex and must include and other requirements such the proper design and the maintenance of electrical networks and equipment.

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