

FUNCTIONAL GROUNDING OF DIGITAL PROTECTIVE RELAYS

This article discusses the necessity for functional grounding of Digital Protective Relays (DPR). In the article it is shown that due to the large physical size of the electric power facility and galvanic coupling between remote DPR units, functional grounding does not do more than play a role of establishing an equipotential plane with zero potential which is required for reliable operation of electronic circuits. On the other hand, the design of modern DPR does not require functional grounding at all. In the article a new approach for DPR grounding is suggested.

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Nowadays, all Digital Protective Relays (DPR) are manufactured in metal casings, installed in metal cabinets and equipped with multipoint grounding with equipotential plane, Figure 1 and 2.

The main function of the DPR is to process information coming to its input terminals (represented by currents, voltages and logic signals), store (internal oscillography) and return the results of this process as signals on its output terminal. Due to these functions DPR is part of the scope of IEC 60950-1 [1]. According to clause 2.6.2 of the standard: "functional earthing circuit shall be separated from parts at hazardous voltages..."

"Grounding is the most poorly understood topic in the field of automation... At the moment solution of grounding problems rests on the edge between understanding, intuition and good luck".

*Victor Denisenko
Scientific and Research Laboratory of Design Automation.*

A HIGH DIFFERENCE OF POTENTIALS

Is the requirement of this definition met under real conditions of relay protection systems used at sub-stations and power plants? According to [2] in the situation, where a lot of electric devices and separate units of relay protection of power facilities are located at a

significant distance from each other and grounded at their location, there will inevitably be a high difference of potentials between the points of grounding, which can reach as high as 10 kV during a lightning strike. When two DPRs are located at a significant distance from each other and their communication ports are connected via the Ethernet, Figure 3, this voltage will be applied to the least protected (from high voltage) components of DPR. According to [3]: "the larger the physical size of the facility, the greater the potential for problem".

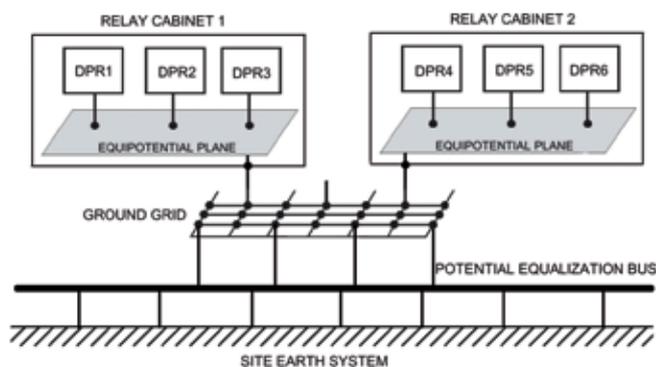


Figure 1 Arrangement of multipoint grounding with equipotential plane



Figure 2 Arrangement of DPR multipoint grounding with equipotential plane 1 – DPR in metal casings; 2 – bounding strip; 3 – metal cabinet's element that performs the role of the equipotential plane.

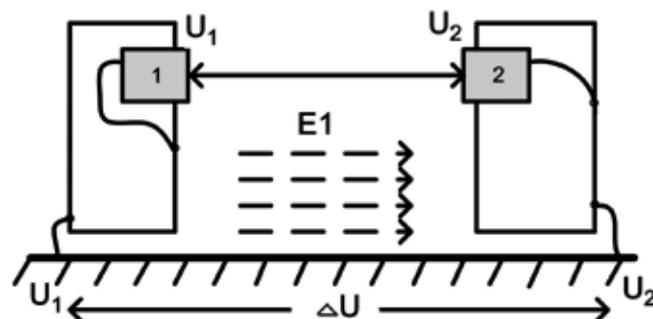


Figure 3 Connection diagram of two DPR (1 and 2) located at significant distances from each other with a non-insulated communication channel (twisted pair for Ethernet network).

Due to low protection of communication ports they are not tested (unlike other inputs and outputs of the DPR) by applying high voltage pulse at all (standards IEC 60255-5, 60255-22-5) and if they are, they are tested by reduced test voltage level (standards IEC 60255-22-1, 60255-22-4). As evidenced by [2], the level of the pulse overvoltage emerging during a lightning strike and applied to insulation of electronic equipment circuits exceeds the established resistance levels of commercial electronic equipment by several times. And this happens during the flow of lightning current through a grounding system as affected by ordinary lightning charges. However, lightning charges are not the only source of a powerful electromagnetic impact on the DPR. Recently, the problem of protection of electric power systems from the so-called Intentional Destructive Electromagnetic Impacts [4], the

most powerful of which is the High Altitude Electromagnetic Pulse of a nuclear explosion (HEMP), has become very relevant. The E1 component of HEMP creates a pulse of electric field with the density of up to 50kV/m [4] at the ground surface. The branched grounding system acts as a huge antenna for this pulse, absorbing energy from a large area and delivering it directly to sensitive electronic equipment, including DPR through grounding circuits.

A SOURCE OF HIGH VOLTAGE PULSES

On the other hand, a question arises as to whether functional grounding of DPR is at all necessary? It is obvious that the existing grounding systems are not an equipotential plane with zero potential, which is required for reliable operation of electronic circuits; neither do they act as a return cable, which is necessary to return certain signals back to the DPR. Quite the opposite is true, during the most critical situations for which the system is actually intended, the grounding system becomes a source of high voltage pulses applied to sensitive electronic equipment.

In the early designs of DPR manufactured 20 and more years ago, the functional modules located on separate printed circuit boards had special cleared and silver-covered sections of wider conductor strips. When the printed circuit board was installed in a casing, these sections touched special springs ensuring the contact between these conduction strips with the grounded casing of the DPR, Figure 4.

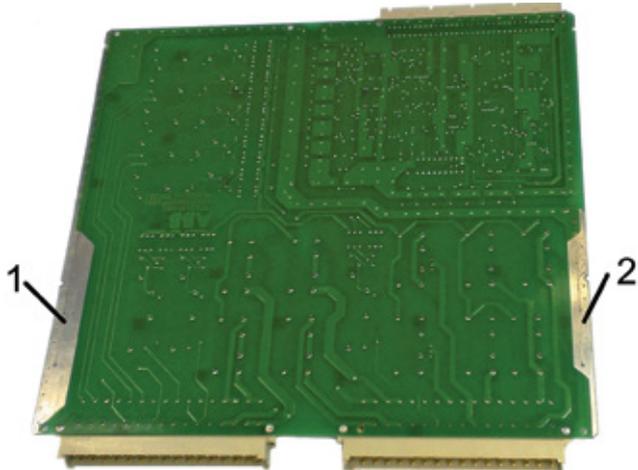


Figure 4 The printed circuit board of DPR with cleared sections of printed wiring (1 and 2), which contact the grounded casing by means of a special spring.

ENSURE FUNCTIONAL GROUNDING

Modern DPR designs rarely employ these tricks to ensure functional grounding. And this is justified, since all the input and output circuits of the DPR (except communication ports) are well insulated from the ground and from other electric units: supply circuits by means of transformer of internal power source, analogue inputs by means of insulation of internal current and voltage transformers, logic inputs by means of optocouplers, the output circuit by means of output electromechanical relays. Indeed, the functionality of internal electronic circuits of the DPR has nothing to do with the availability or lack of grounding. As for the efficiency of the protection of the DPR's sensitive electronic circuits from the impact of external electromagnetic fields by means of metal casing, which is intended to act as the "Faraday cage", it should be noted that it is not dependent on the availability or lack of grounding. In other words, the grounding of the DPR's casing does not influence the efficiency of the protection of the casing's shielding effect. On the other hand, if the disturbance signals are coming to the electronic circuits of the DPR (located inside the casing) via cables, how can grounding of the casing prevent the impact of these disturbances (especially those of the differential type)? The answer is obvious: it cannot! Moreover, it should be pointed out that the grounding of the DPR casings will only worsen the situation and reduce disturbance resistance of the relay protection as real levels of overloading, which can be applied to different (even well insulated) internal circuits of spaced apart DPRs through grounding circuits, can significantly exceed allowable levels even when communication ports with their weak insulation are not accounted for.

According to [5], functional grounding cannot be treated separately from protective grounding, without infringement of operational safety standards.

Let me question the correctness of this statement and consider these two types of grounding as separate and independent from each other. With this approach it will be possible to arrange DPR grounding using a new principle, which is based on the recommendation of IEC 60364-5-548 [6] regarding improvement of disturbance resistance of information technology installations by separating these installations from disturbance sources.

Since this example shows functional grounding as a "source of disturbance", I suggest that the DPR should be separated from it, Figure 5.

According to this suggestion the steel container 3, Figure 5, with a minimum number of openings is divided by internal partitioning into two zones: A – "dirty" and B – "clean". The DPR terminal in the plastic casing is located in the clean zone, which is free from electromagnetic radiation.

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Container 3 has a door 4, which provides staff access to the face panel of the DPR during maintenance. Container 3 is grounded meeting all traditional regulations and rules of grounding; this ensures fulfillment of operational safety requirements.

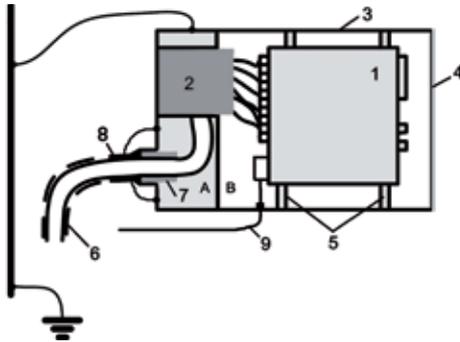


Figure 5 Suggested principle of DPR arrangement, which ensures improved resistance to all type of electromagnetic impacts, including HEMP. A – “dirty” zone; B – “clean” zone; 1 – DPR terminal in a thoroughly insulated plastic casing; 2 – HEMP filter; 3 – Steel casing; 4 – Steel casing door; 5 – Insulators; 6 – Double-shielded control cable; 7 – Wall tube; 8 – Metal socket to couple cable braid with steel casing; 9 – fiber-optics communication line (FOCL)

SIMPLE PROCEDURES THAT ENSURE SAFETY

Considering the rather large distance between the DPR and the internal walls of grounded metal container, e.g., 5-7 cm, the parasitic capacitance of the DPR electronic circuits to the ground will be very insignificant and its impact can be neglected. As for the DPR body, it should be thoroughly insulated (made of plastic) employing any additional measures to prevent carry-over of a dangerous pair potential onto the surface of the body. These measures can include: covering of the screen by a transparent plastic panel; locating the control buttons on the surface of the casing through the insulation inserts; using a LED to indicate the panel located on the casing’s surface through rigid transparent plastic rod; using an insulated optical port to connect external computer to DPR. Indeed, these are simple procedures that ensure safety. They are adopted in the absence of grounding in hand-held electric tools with a so called double insulation and easily implemented in practice.

CONCLUSIONS

As for removal of a potential electrostatic charge, which can accumulate on the insulated casing of DPR, this problem can be

solved by applying thin layer of high-impedance semi-conducting cover on the inner surface of a plastic casing and connecting it with a grounded steel casing through a special high-voltage (50 – 100 kV) high-impedance (approx. 20 - 50 MOhm) resistor. The static charge will leak to the ground through this resistor. The technology of application of this covering has been worked through and widely used in modern electronic equipment. Compact high-impedance resistors for 50 – 100 kV are not in short supply; they are manufactured by many companies, such as Caddock Electronics, Arcol, Ohmite, Welwyn Components and others.

I think, the suggested technical solution will enable ensuring high level of DPR disturbance resistance both under real conditions of use and under extreme situations under HEMP impact or that of other technical means of destructive remote electromagnetic impact [4]. Moreover, the cost of adoption of the suggested solution will not be unaffordable for the power industry. They can even be much lower than those for reconstruction of the old grounding system at many electric energy facilities, which do not provide for normal exploitation of the DPR.

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