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Original Article

Application of Low Voltage High Resistance Grounding in Nuclear Power Plants

Choong-Koo Chang * *and Mostafa Ahmed Fouad Hassan*

Nuclear Power Plant Engineering Department, KEPCO International Nuclear Graduate School, 658-91 Haemaji-ro, Seosang-myeon, Ulju-gun, Ulsan 689-882, South Korea

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ABSTRACT

Most nuclear power plants now utilize solid grounded low voltage systems. For safety and reliability reasons, the low voltage (LV) high resistance grounding (HRG) system is also increasingly used in the pulp and paper, petroleum and chemical, and semiconductor industries. Fault detection is easiest and fastest with a solidly grounded system. However, a solidly grounded system has many limitations such as severe fault damage, poor reliability on essential circuits, and electrical noise caused by the high magnitude of ground fault currents. This paper will briefly address the strengths and weaknesses of LV grounding systems. An example of a low voltage HRG system in the LV system of a nuclear power plant will be presented. The HRG system is highly recommended for LV systems of nuclear power plants if sufficient considerations are provided to prevent nuisance tripping of ground fault relays and to avoid the deterioration of system reliability.

1. Introduction

An electrical system grounding method should provide the safety, reliability, and continuity of service required by the power distribution system. In the past, ungrounded systems were preferred when reliability and continuity service were very important. However, ungrounded systems provide no control over a destructive transient overvoltage. In addition, experience with multiple failures due to arcing ground faults has caused a change in philosophy about the use of an ungrounded system. Solidly grounded and high resistance grounded systems have become the standard for large industrial complexes [1–3].

2. Low voltage ground fault protection

Electrical facilities should be inspected periodically before and during operation by authorized institutions. Before the design of a ground fault protection system, applicable laws and regulations must therefore be carefully reviewed. Technical feasibility, reliability, and practicality with respect to the ground fault protection system should be considered.

2.1. *Applicable laws and regulations*

Based on electrotechnical regulations in Korea, equipment that has exposed metal parts, is rated at a voltage higher than

* *Corresponding author.*
E-mail address: ckchang@kings.ac.kr (C.-K. Chang).

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60 V, and supplies electricity to the facilities installed in a place where people can easily come into contact with the equipment should be equipped with a ground fault protection device that can automatically detect and clear any ground fault. However, this equipment is exempt from the installation of ground fault protection if the equipment is maintained by a qualified engineer or installed in a dry area so that the possibility of electric shock is very low. However, the exemption is not applied to low voltage (LV) circuits that are rated higher than 400 V and coupled with high voltage circuits through the transformer.

Since the formation of the World Trade Organization agreement, the industrial standards of Korea have conformed to the related International Electrotechnical Commission (IEC) standards. The electrical regulations have accordingly been revised or admitted as a parallel requirement with the IEC standards, and harmonization of the industrial standards of Korea with the IEC standards is ongoing. The design of the electrical distribution systems of nuclear power plants was developed on the basis of the technologies and practices of the United States of America.

International standards and practices need to be applied to the design of electrical distribution systems while taking into consideration the changes of technical circumstances in the industry. Up-to-date technologies should also be applied to design and construct more reliable and safer electric power systems.

2.2. *Types of LV grounding systems*

Ground fault protection is a part of the safety protections specified in IEC 60364-4-41; this protection has a close relation with the protection against electric shock. Under general conditions, the allowable continuous touch voltage of the human body is 50 V. A protective device is required to limit the touch voltage below the allowable continuous touch voltage when a human body is in contact with the conductive part of equipment.

The fault current circulation path is determined by the grounding system. Therefore, the grounding system of the LV system should be designed before determining the ground fault protection scheme. The LV grounding system is classified as Class 1, 2, and 3 in the conventional system, and as TN, TT, and IT in IEC Standard 60364. In the conventional grounding system, the earthing resistance (i.e., the resistance between the earth and the grounding conductor) is specified by the type of grounding. On the other hand, IEC 60364 evaluates the safety level by the estimated touch voltage and maximum fault clearing time instead of by specifying the earthing resistance. However, the ultimate goal is the same: to limit the magnitude and continuing time of the fault current passing through the human body at safe levels with regard to the average impedance of the human body and expected touch voltage. Table 1 shows the relationship between the expected touch voltage and the maximum clearing time.

Table 1 – Expected touch voltage and maximum clearing time.[a]

Touch voltage U (V)	Z (Ω)	I (mA)	t (sec)
≤50	1,725	29	∞
75	1,625	46	0.60
100	1,600	62	0.40
125	1,562	80	0.33
220	11,500	147	0.18
300	1,460	205	0.12
400	1,425	280	0.07
500	1,400	350	0.04

[a] See Table A in IEC 61200-413 [11].

2.2.1. *The TN system*

In TN systems, as depicted in Fig. 1, the integrity of the earthing of the installation depends on a reliable and effective connection of the protective earth and neutral (PEN) conductor or the protective earth (PE) conductor to earth. The neutral point or the midpoint of the power supply system is earthed. If a neutral point or midpoint is unavailable or inaccessible, the line conductor is earthed. Exposed conductive parts of the installation are connected by a protective conductor to the main earthing terminal of the installation, which is connected to the earthed point of the power supply system.

In fixed installations, a single conductor may serve as the protective conductor and as a neutral conductor (i.e., PEN conductor), provided that the requirements of section 543.4 of IEC 60364-5-54 are satisfied. No switching or isolating device is inserted in the PEN conductor.

The characteristics of the protective devices and the circuit impedances fulfill the following requirement:

$$Zs \times Ia \leq Uo \quad (1)$$

in which Zs is the impedance [in ohms (Ω)] of the fault loop, which comprises the source, the line conductor up to the point of the fault, and the protective conductor between the point of the fault and the source; and Ia is the current [in amperes (A)] that causes the automatic operation of the disconnecting device within the time specified in Table 2. When a residual current protective device (RCD) is used, this current is the residual operating current that provides the disconnection in the time specified in 411.3.2.2 or 411.3.2.3 of the IEC 60364-4-41 [4], and Uo is the nominal alternating current (AC) or direct current (DC) line to earth voltage [in volts (V)].

2.2.2. *The TT system*

All exposed conductive parts collectively protected by the same protective device are connected by the protective

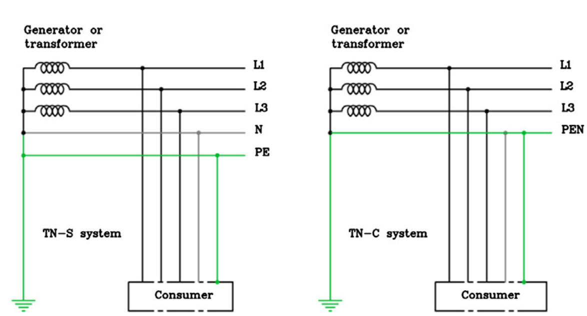

Fig. 1 – The TN grounding system. N, neutral; PE, protective earth; PEN, protective earth and neutral.