

## Hybrid I&C Grounding in PFBR

M.Sivaramakrishna\* C.P. Nagaraj K. Madhusoodanan  
Indira Gandhi Centre for Atomic Research, Kalpakkam, India, 603127  
\* E-mail of the corresponding author: [sivarama@igcar.gov.in](mailto:sivarama@igcar.gov.in)

### Abstract

Nuclear Power plants require well established grounding scheme towards personnel safety and smooth control of the plant. Combination of Single & Multi point grounding with Faraday cage configuration is followed in Prototype Fast Breeder Reactor (PFBR). This paper explains the scheme.

**Keywords:** Ground, Shield, Cage, Safety

### 1. Introduction

Energy is a vital component for development of economy and providing high quality of life to the citizens. In view of growing concerns on availability of resources, climate change and energy security, nuclear is a preferred option for providing sustainable energy. Among many nuclear energy systems, Fast Reactors (FRs) are the most efficient energy system for the effective utilization of uranium resources. Particularly, in India, the economically exploitable uranium reserves are limited and thus the sustainable development of nuclear fission energy depends on the fast breeder reactors with closed fuel cycle.

In order to demonstrate the techno-economic viability of sodium cooled fast reactors for the commercial exploitation, a 500 MWe Prototype Fast Breeder Reactor (PFBR) has been designed and developed. PFBR is under construction at Kalpakkam. The design of future SFRs will be generally in line with the design of PFBR and changes will be made to simplify the design or to reduce cost.

### 2. Requirement for Grounding

Grounding is a low impedance metallic connection to a properly designed ground grid, located in earth. The ability of a process control and instrumentation system to perform well, directly depends on the quality of measured variables (plant safety parameters). This quality is dependent on the elimination or attenuation of noise that can deteriorate the actual signal. The instrumentation and control signals which are low level electrical signals transmitted from various equipment through long cables may undergo degradation due to interference of noise either at the signal source or along the cable run. In the worst case, the noise can actually be of a higher amplitude than the actual signal, so, this type of signal would, of course, be of no value because its useful control information content is unpredictable. The level of noise on the received signal can cause errors in measurement and control functions, which in turn may result in costly unit downtime.

The malfunctions can be non-destructive or destructive. Further the operation of C&I equipment/systems are sources of various electrical noises. Control & Instrumentation systems make use of both advanced analog and digital/microprocessor based equipment in safety, safety-related and non-safety-related systems in FBRs. These systems contain high frequency digital clocks, I/O drivers, oscillators, SMPS, high frequency MODEMs etc. Microprocessors use increasingly higher clock frequencies and digital logic circuits use lower logic level voltages. Similarly advanced analog circuits perform diverse functions and work at low voltage levels due to miniaturization. Therefore these circuits/systems are prone to EMI and power surges. Fast breeder reactor environment consists of various sources of electrical noise such as portable trans-receivers, arc welders, switching of large inductive loads, large fault currents, semiconductor switch-based power supplies and circuits, lightning surges and static discharges.

USNRC regulatory guide RG-1.180-2003 provides guidelines for evaluating electromagnetic and radiofrequency interference in safety-related C&I systems. The guidelines are also applicable to non-safety-related C&I systems. USNRC RG-1.180 endorses IEEE standard (std) 1050- "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations". The above standard addresses design and installation of grounding systems for I&C equipment specific for power generating stations. The standard also achieves both a suitable level of protection for personnel and equipment, and suitable electrical noise immunity for signal ground interferences. The above standard recommends practices for treatment of both analog and digital systems that address the grounding, shielding and isolation of electronic circuits on the basis of minimizing emissions and their susceptibility to EMI/RFI and power surges. These EMC practices include circuit layouts, terminations, filtering, grounding, bonding, shielding and adequate physical separation.

The electrical noises couple into high frequency and/or low voltage analog and digital circuits through

various coupling mechanisms viz. conductive, magnetic, electrostatic and radiative coupling. These noises get coupled into sensitive C&I equipment/systems. By proper grounding, shielding and signal conditioning techniques, noise signal can be removed from the transducer signal, ensuring an accurate measured variable signal for process control. Hence a good grounding is essential for normal operation of any instrumentation and control system. I&C grounding system, while also providing personal protection from shock, is primarily designed to minimize the noise voltages. Stable, low impedance grounding is necessary to attain effective shielding of low level circuits, to provide a good reference for making voltage measurements and to establish a solid base for the rejection of unwanted common mode signals.

### 3. Mode of Grounding

The meaning of ground depends on the context of its function and can be classified as follows.

- a) Power System/Equipment/Protective/Safety ground/Lightning Protection Ground
- b) Control system/Electronic/Signal ground

Instrumentation grounding is divided into two parts

- \* Signal grounding
- \* Shield grounding

There are three different methods of signal grounding. They are

- \* Single point grounding
- \* Multi point grounding
- \* Floating grounding

Single point grounding is widely used. It is useful for low frequency signals(<300 KHz) and where the length of ground conductor is small(<200m). Multi point grounding is done for signals of frequency >300KHz and where the ground conductor length is >200m. Floating grounding is suitable for small systems and is not normally followed in large plants.

### 4. Grounding in Fast Breeder Test Reactor

In 40 MWt Fast Breeder Test Reactor (FBTR) the signal grounding system (G3) and shield grounding system(G2) are independent. The only inter connection between them is through the earth. Both G2 and G3 have separate set of ground pits. These grounds are distributed to various buildings through a grounding junction box (JB) in relay room. Both G2 and G3 are having separate buses in the grounding JB. From the junction box in relay room, the ground cables are distributed to other buildings like electronics room, Steam Generator Building, Turbine Building, etc.

In these buildings there are similar grounding JB. Separate bus bars for G2 and G3 are provided in these JB. In the control panels, there are shield ground buses which are called G2 buses, insulated from the body of the panel. For the G3, connections from the reference points of the electronic modules are brought to terminal assemblies which are looped to form a G3 bus. G2 and G3 buses are separately connected to the grounding JB in that area, using separate cables.

### 4. Grounding in PFBR

From the experience of FBTR and from the performance reports of latest power plant grounding, PFBR grounding scheme is designed as given below.

In the I&C architecture adopted for PFBR, the field signals are wired up to the signal processing cabinets in Local Control Centre (LCC). Signals from these cabinets are transmitted further as digital signals through LAN. I/O connections to/from the panels are isolated. Processing of signals is done within each building. Bodies of all equipments and cabinets are connected to electrical safety ground to protect the personnel from electrical shock. In each cabinet, ground bus bars are provided which are insulated from the body of the cabinet, and from the safety ground. Signal reference points of the electronic circuits and the shields of the cables, which are to be grounded in that cabinet, are connected to these ground bus bars. These buses in each cabinet are connected to the nearest station ground.

In addition to the above features, PFBR is built with a faraday cage structure, i.e. solid copper bars in crossbar matrix are connected from the station ground, to spread all through the walls and floors of the nuclear island. Pig tails (16 Sq.mm stranded tinned copper wire) are brought from this matrix at various points, to provide ground connection to electrical/instrumentation panels. Hence this ground is effectively utilized by I&C to improve the performance w.r.t. the latest IEEE standard 1050 - 2004.

### 5. Description of Grounding Configuration

Three ground buses are provided in each cabinet to cater to safety grounding, shield grounding and signal grounding. They are namely G1, G2 and G3 respectively. The details of these ground bus connections are given in Fig.1 & 2.

### 5.1. Safety ground (G1)

A bus bar is provided inside a cabinet, made of bare copper strip (25mm x 6mm) and is electrically connected to the sheet metal of the cabinet by means of mild steel stand-off posts. The safety ground connections from all the different devices mounted inside the enclosure are connected to this ground bus, by means of PVC insulated 6 Sq.mm stranded tinned copper wire using crimpable lugs through shortest length. From G1 bus bar, two connections are made to the nearest grounding pigtails through grounding junction box (GJB), using PVC insulated 16 Sq.mm stranded tinned copper conductors. In case two cabinets are closely located in a row (containing the same system), the safety ground bus of adjacent cabinets are tied together and connections are made to the pigtail of station ground.

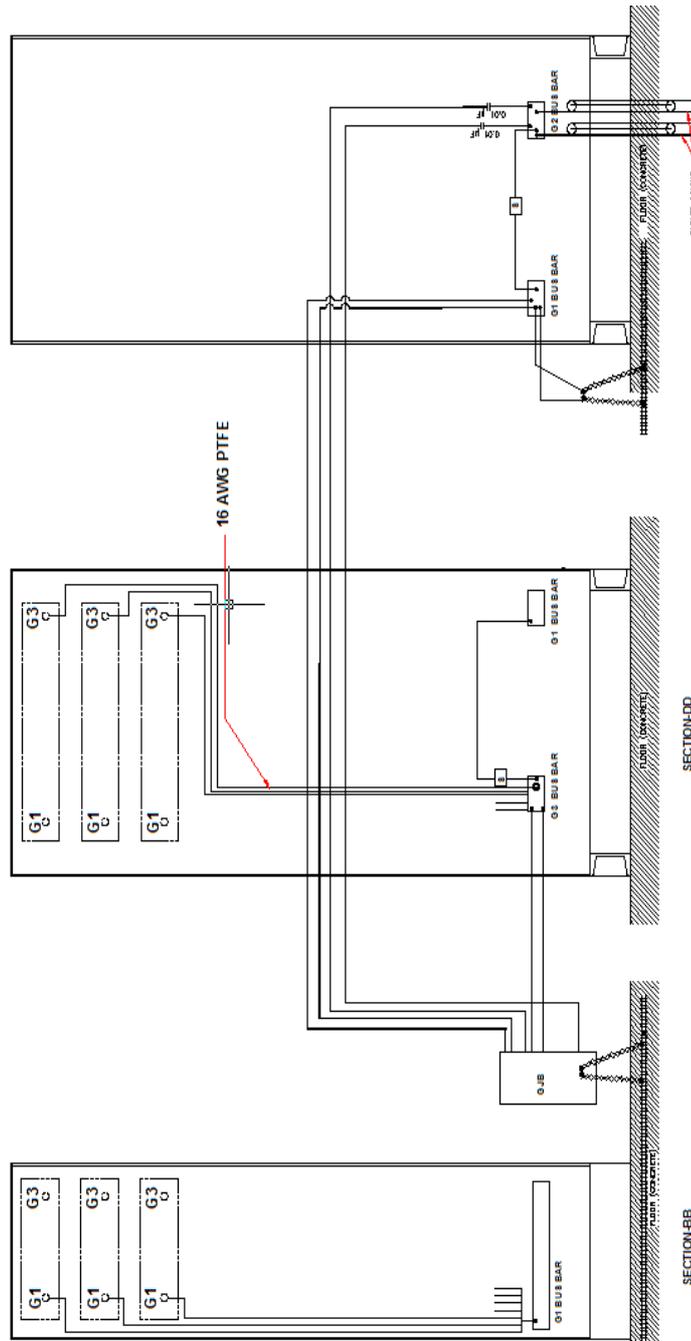


Figure 1. I&C grounding scheme

| LEGEND   |  |
|----------|--|
| PART No. | DESCRIPTION  |
| 1        | G2 BUS BAR (25 X 6), INSULATED COPPER STRIP                                  |
| 2        | COPPER BAR MATRIX BURIED IN CONCRETE   |
| 3        | PIG TAIL – STATION GROUND 16 Sq.mm PVC INSULATED STRANDED TINNED COPPER WIRE |
| 4        | 4 Sq.mm PVC INSULATED STRANDED TINNED COPPER WIRE                            |
| 5        | 6 Sq.mm PVC INSULATED STRANDED TINNED COPPER WIRE                            |
| 6        | G1 BUS BAR (25 X 6), BARE COPPER STRIP                                       |
| 7        | G3 BUS BAR (25 X 6), INSULATED COPPER STRIP                                  |
| 8        | CABLE SHIELDS (COPPER)   |
| 9        | SURGE SUPPRESSION DEVICE (AVALANCHE DIODE)                                   |
| 10       | 16 Sq.mm PVC INSULATED STRANDED TINNED COPPER WIRE                           |

**NOTES:**

1. TIE LINES FROM G3 AND G2 BUS BAR SHOULD GET TERMINATED AT A SINGLE POINT ON THE GROUNDING JUNCTION BOX.
2. IF TWO CABINETS COMPRISE OF SINGLE SYSTEM, ALL THE GROUND LINES SHALL BE TERMINATED ON A SINGLE POINT IN THE JUNCTION BOX
3. G1, G2, & G3 SHOULD BE CONNECTED TO STATION GROUND JUNCTION BOX USING REDUNDANT CONDUCTORS (TO GUARD AGAINST SINGLE FAILURE).
4. G1 SHALL PREFERABLY BE CONNECTED TO THE NEAREST PIGTAIL ; OTHERWISE TO THE GROUNDING JUNCTION BOX TO WHICH G2 & G3 ARE CONNECTED.
5. ALL THE GROUND LINES AND BUS BARS SHOULD BE SUITABLY INSULATED.
6. CAPACITORS ARE CONNECTED IN G2 GROUNDING LINES ONLY IN SPC CABINETS OF LCC. IN ALL OTHER CABINETS/PANELS OF OTHER BUILDINGS, G2 GROUNDING LINES ARE DIRECTLY CONNECTED TO THE GROUNDING JUNCTION BOX TO ENSURE SINGLE POINT GROUNDING AT LOW FREQUENCIES AND MULTI POINT GROUNDING AT HIGH FREQUENCIES
7. BODIES OF ALL JUNCTION BOXES, PANELS, LCP'S, RTU'S SHALL BE CONNECTED TO THE NEAREST GROUNDING PIG TAIL
8. ALL DIMENSIONS ARE IN mm

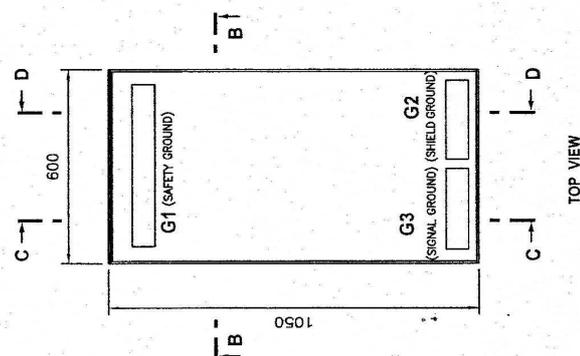


Figure 2. I&C grounding scheme - details

The bodies of all the junction boxes, Remote Terminal Units (RTU), Local Control Panels (LCP), panels are connected to the nearest ground pig tail using 16 Sq.mm stranded tinned copper wire.

**5.2 Shield ground (G2)**

Shield ground (G2) bus is provided in each cabinet which is made of 25 mm x 6 mm copper strip insulated from G1 and G3. Shields of all the cables that are entering the cabinet are connected to this bus. The shields of the

cables are not grounded at both the ends of the cable. This ensures that at low frequencies, ground loops are not formed. At high frequencies, it is ensured that the shield is grounded to the nearest ground point on both the sides. To meet both these criteria, the shield grounding is done in the following way. A grounding junction box (GJB) is provided very near to the cabinet in LCC. In the signal processing cabinets (SPC) of LCC, two PVC insulated 6 Sq.mm stranded tinned copper wires are connected from G2 bus bar through a 0.01  $\mu$ F -3 kV capacitor to the GJB. Grounding pigtailed are brought to this junction box (GJB) to get connected to the station ground.

It is ensured that in all other panels & cabinets connected to the SPC of LCC, two PVC insulated 6 Sq.mm stranded tinned copper wires are connected from the G2 bus bar *directly* to the GJB, kept outside the cabinet. A surge suppression device (SSD) is connected between G2 bus bar and G1 bus bar (inside the cabinet). This helps in connecting these different potentials together only during lightning conditions, through "EQUI Potential Techniques". This ensures that all the reference potentials are equally raised, to protect the sensitive signals and cables. Avalanche diode type surge suppressor is selected for the protection of low-voltage sensitive devices with better than nanosecond response time with a clamping voltage of < 5 V and surge current of the order of 50 A ( $\mu$ s pulses continuous).

In case two cabinets are closely located in a row (containing the same system), the grounding wires from the G2 bus bars are tied together and connected to a single point in the GJB using two parallel connections. Typical grounding for one of the safety class 1 system is given in **fig. 3**

### 5.3 Signal ground (G3)

A bus bar is provided inside each cabinet which is made of insulated bare copper strip (25mm x 6mm) isolated from the body of the cabinet. Electronic signal reference in each device/instrument channel inside the cabinet is connected to this G3 bus bar with a 6 AWG PTFE wire. Electrical isolation is maintained between signal and safety ground i.e. G1 and G3 within the cabinet. From G3 bus bar, two PVC insulated 6 Sq.mm stranded tinned copper wires are connected to the Grounding Junction Box, which is kept outside the cabinet.

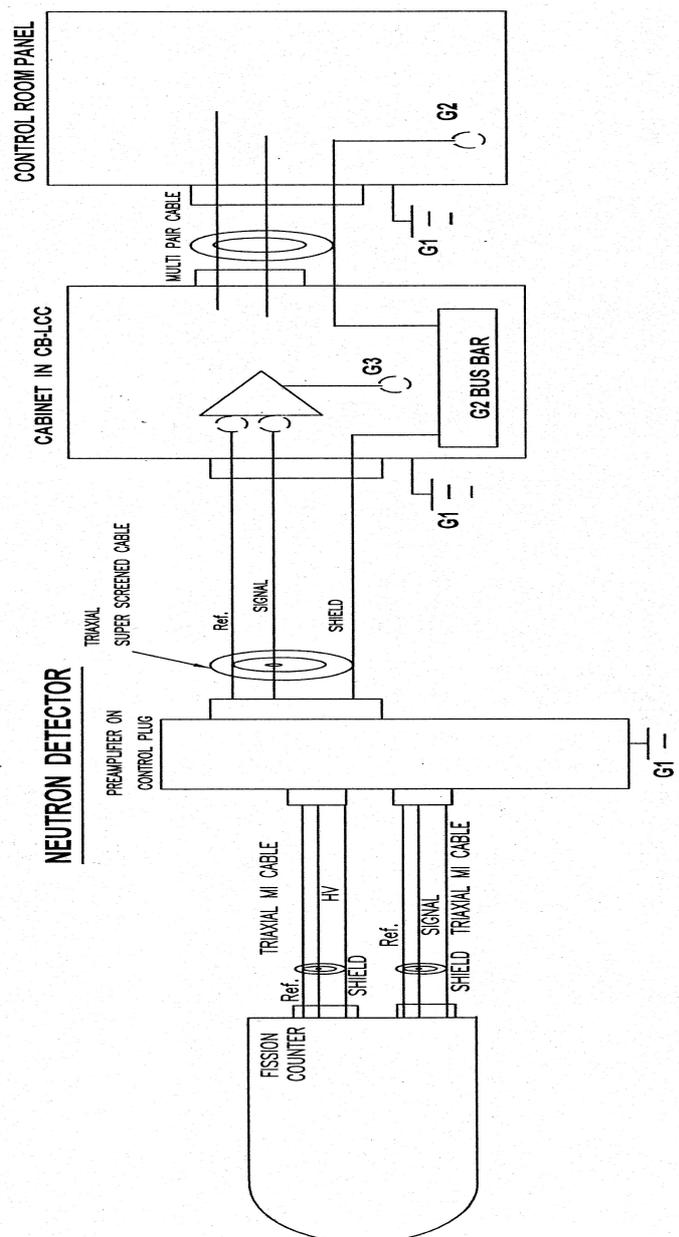


Figure. 3. Typical grounding connections for Neutronic system

In case of two cabinets closely located in a row (containing the same system), the grounding wires from the individual cabinets are tied together and connected to a single point in the GJB using two parallel connections. Similar to G2, SSD is connected between G3 bus bar and G1 bus bar inside the cabinet to protect the sensitive signals.

### 6. Conclusion

In PFBR, three grounding bus bars are provided in each cabinet/panel viz. G1, G2 and G3. G1 is the safety ground bus bar, to which bodies of all the equipments are connected. This is connected to the station ground pig tails very near to the cabinet. G2 and G3 are insulated bus bars provided inside the cabinet towards the shield ground and signal reference respectively. To provide the common reference point very near to the cabinet electronics, GJB is provided, to which the G2, G3 bars are connected. This GJB is connected to the pigtails, to which G1 is connected. Additionally, G2 and G3 are connected to G1 bus bar through a surge protection device. G2 is connected to the GJB through a capacitor in a selective manner to ensure single point grounding at low frequency of operation and multi point grounding at high frequencies, for better performance. The ground wires from the individual instrument racks are connected to the near-by pigtails through the GJBs with the smallest wire length. In this way, both personnel safety and signal healthiness are ensured through hybrid grounding in

PFBR.

### References

- IEEE Std 1050-2004, Guide for Instrumentation and control equipment grounding in generating station.  
Wiring practices and signal conditioning - C.H. KIM, R.G DITTMER and B.G LIPTAK Chapter 7.18 of Process control Hand book.  
RALH MORRISSON 3<sup>rd</sup> edition, Grounding techniques in instrumentation.  
IFAC Proceedings series, 1988 number 5 on Automatic and instrumentation for power plants, Edit by M. RAMAMOORTHY  
DONALD R.J.WHITE, Shielding design methodology and procedures  
IEEE Std 336-1986, Standard for Installation, Inspection, and testing requirements for Power, Instrumentation, and Control equipment at Nuclear Facilities.  
IEEE Std 690-1984, Standard for the design and installation of cable systems for class 1e circuits in Nuclear power generating stations.  
ANSI/IEE Std 422 -1986, Guide for the design and installation of cable systems in power generating stations.  
ANSI/IEEE Std 665-1987, Guide for generating station grounding

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:  
<http://www.iiste.org>

## CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

**Prospective authors of journals can find the submission instruction on the following page:** <http://www.iiste.org/journals/> All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

## MORE RESOURCES

Book publication information: <http://www.iiste.org/book/>

## IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digital Library, NewJour, Google Scholar

