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# Generator Stator Intermittent Ground Fault Test Instrument - Version 2.0

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**Abstract:**
The paper describes the design and fabrication of a novel intermittent ground fault (IGF) test instrument which aids system protection engineers to obtain solid or arcing fault data for evaluation of industrial generator stator ground protective relay settings.

## Introduction:

Synchronous generators are critical to the stability and reliability of the power grid, making their protection against electrical faults essential for national security.

The most common generator fault is the stator single-phase ground fault which often begins as an intermittent ground fault (IGF). IGFs are characterized by high transient currents and overvoltages that can cause severe damage to insulation and generator components, potentially escalating into more severe faults and resulting in costly repairs and downtime.

Reports of stator IGF have sparked a renewed interest to develop reliable IGF detection schemes [1]-[3]. Specifically, [3] reports on development of a novel test instrument called **64S/87-TI version 1.0** by which stator IGF can be safely emulated on real-world generator stator neutral grounding circuits. Acquisition of such fault data can readily enable protective relay engineers to analyze the performance of new IGF detection schemes.

The goal of this paper is to propose upgrades to enhance the functionality of the **64S/87-TI version 1.0** reported in [3]. The primary upgrades include redesigning the electronic circuitry to incorporate a custom power supply module, battery management system, and improved load switch topology. The Arduino UNO microcontroller (MCU) used in [3] is also replaced with an STM32 MCU, offering increased processing power and flexibility. Additionally, the instrument enclosure is completely redesigned using a combination of extruded aluminum and CNC machined panels to ensure resilience to physical stresses.

## Experimental Intermittent Ground Fault Realization:

64S/87S-TI is capable of staging solid or arcing single-phase ground fault on a real-world generator neutral or terminal phases. Fig. 1 shows the wiring diagram of a high impedance synchronous generator with the 64S/87-TI shown connected on the neutral point. Note that the generator stator ground protection is using a 64S subharmonic voltage injection along with a bandpass filter.

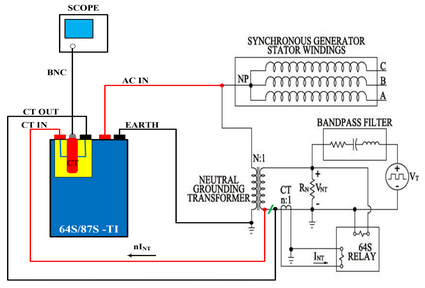


**Fig. 1:** Typical synchronous generator stator windings and connected protection equipment with the 64S/87S-TI

## 64S/87STI Version 2.0 Overall Architure:

Fig. 2 shows the overall block diagram of the 64S/87TI consisting of a battery, a battery management system (BMS), a custom designed power supply unit (PSU), a microcontroller (MCU), a bidirectional load switch circuit and a display.

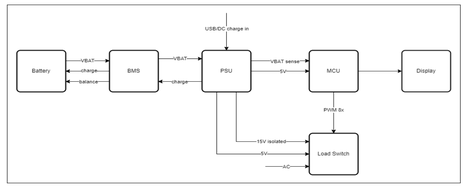


**Fig. 2:** Block diagram of the 64S/87TI

## Bidirectional Load Switch Module:

Fig. 3 shows the printed circuit board of the bidirectional load switch consisting of multiple fault resistance path to ground, MOSFET switches, and their gate drivers.

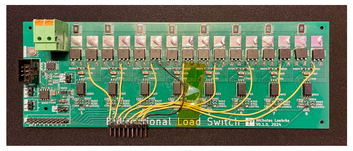

**Fig. 3:** Block diagram of the 64S/87TI bidirectional switch circuit

## Microcontroller Unit:

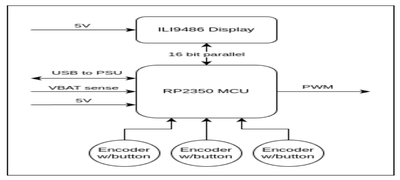


**Fig. 5:** Block diagram of the of the 64S/87TI MCU

## Power Supply Module:

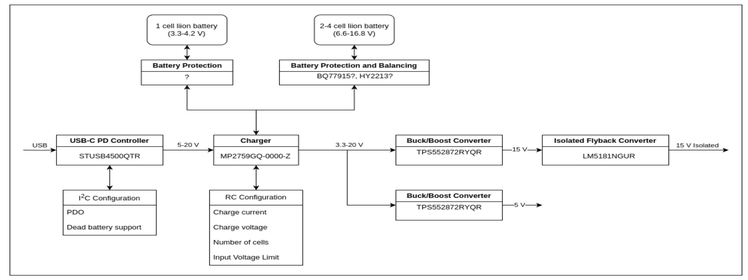


**Fig. 4:** Block diagram of the 64S/87TI power supply module

## Battery Management System:

**Fig. 5:** Block diagram of the 64S/87TI battery management system

## Enclosure Design:

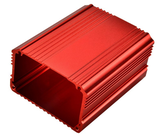

**Fig. 6:** 64S/87S-TI Version 2.0 enclosure design

## Conclusion:

## References:

[1] - IEEE Power System Relaying and Control Committee (PSRC) J12 Subcommittee Technical Report, "**Improved Generator Ground Fault Schemes**," IEEE Power and Energy Society Technical Report -TR82, Sept. 1, 2020.

[2] - N. Safari-Shad, A. Sawadogo, R. Fechat and R. Franklin, ``**Experimental Verification of an Intermittent Stator Ground Protection in Large MVA Generators**," IEEE 26th International Conference on Electrical Machines, Torino, Italy, Sept. 1-4, 2024.

[3] - N. Safari-Shad and R. Franklin, ``**Stator Intermittent Ground Fault Detection in High-Impedance Grounded Generators**," IEEE 32nd International Symposium on Industrial Electronics, Aalto University, Helsinki-Espoo, Finland, June 19-21, 2023.

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