Standalone GICs Data Logger for Substation Transformers with Open-Loop Hall-Effect Sensors

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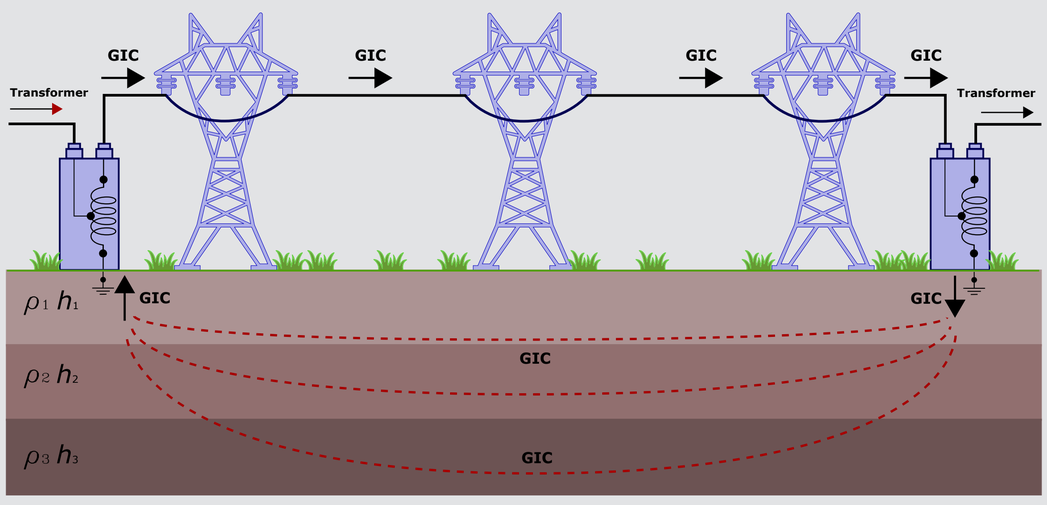
Abstract

A standalone data logger for quasi-DC GIC signals is proposed, based on an open-loop Hall effect current transducer (LEM HOP 1000-SB) that will be used to monitor the current driven by the ground loop in a HV substation transformer. The instrument is based on an open-source Raspberry Pi 2 Model B 1.2 with a high resolution 24-bit digitizer shield (AD-DA board based on an ADS1256 8-channel converter). This modular networked platform allows easy Python 2.7/3.7 scripting along with a group of easily interfaceable web services. Data is continuously stored to an InfluxDB streaming time-series database and directly presented on a fully customizable dashboard (Grafana) which operates as a web-server for data visualization. This instrument is designed to be a low-power module with minimal local interface, but easily accessible from a network connection.

Introduction

Geomagnetically Induced Currents (GICs) are produced as a result of the interaction of ionized particles and magnetic field of plasma clouds, ejected from the Sun, with the Earth's magnetic field.



Large geomagnetic storms induce currents in the electrically conducting crust and mantle that flow on the Earth's surface and are shunt through low electrical resistance paths (railroads, communication and power lines). GICs result from low magnetic field amplitude (nT) and relatively slow (10^{-2} sec) disturbances. However, they can attain tens or even hundreds of amperes and damage both the transmission infrastructure and the electrical system equipment. Real-time GICs monitoring is thus mandatory to the decision-making process in order to prevent power grid failures. Besides, a comprehensive knowledge of GIC profiles allows to test and optimize simulation models at specific points of the transport network. GICs enter and leave the power grid through the neutral grounding of power transformers, and can be measured at these locations.

Basic Requirements

- Quasi-DC current measurement with high resolution, over time span in the order of months.
- Allow local data recording for long periods (logger) and/or data download upon local or web request.
- Minimally invasive to the HV transformer in a power substation (grounding clamping with galvanic isolation).
- Local controlling unit should allow basic processing features.
- Networked interface with the possibility of web servicing (USB and/or *Ethernet*)
- Easily scalable and low maintenance.

Specifications

- **Sensor**
  Open-Loop Hall effect current sensor for quasi-DC currents (LEM HOP 1000-SB) [$\pm 4V$ for $I_{PN} = \pm 1000$ A]
- **Digitizer**
  Waveshare AD/DA 24 bits Raspberry piggyback module (based on an ADS1256 8-channel converter) [sensitivity of around $120 \mu A/bit$ over LEM HOP 1000-SB dynamic range]
- **Processing Unit**
  Raspberry Pi 3 Model B running Raspbian.
- **Power Supplies**
  General Purpose for $\pm 12V$ (dual) and $5V$
- **Casing**
  IP42 for lab tests (depicted) and IP66, or higher, for field measurements.

Instrumentation: Prototype

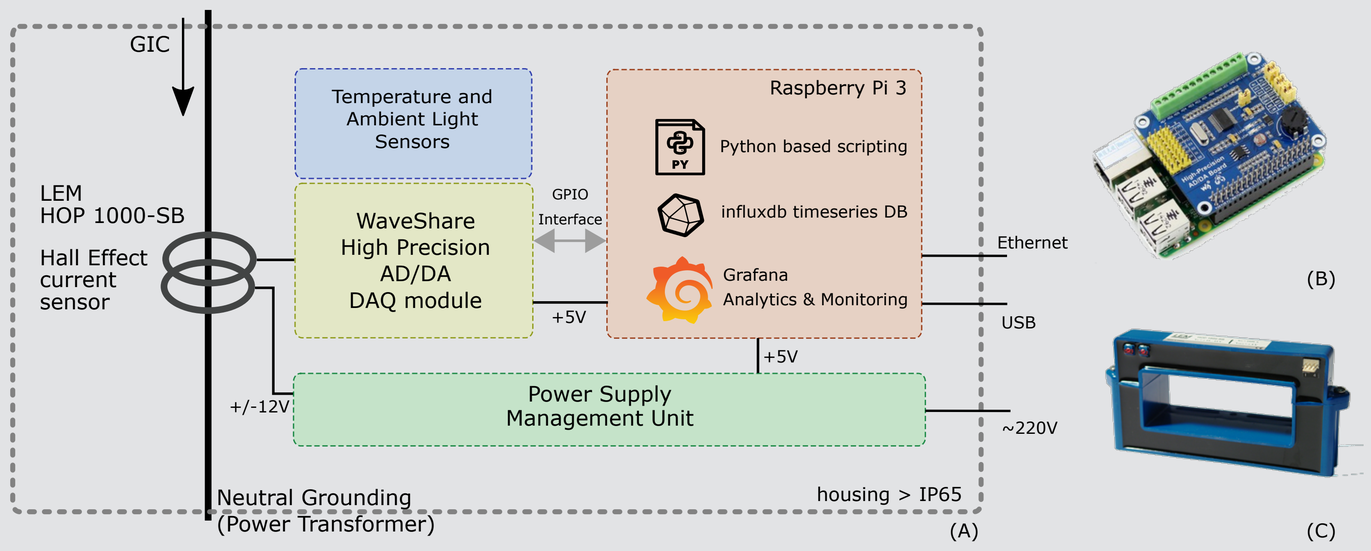


Fig. 1: Block diagram (A on the left side) representing the architecture of the standalone module. On the right side, the piggyback DAQ module on a Raspberry unit (B) and the open-loop 1000 A Hall effect current sensor (C).

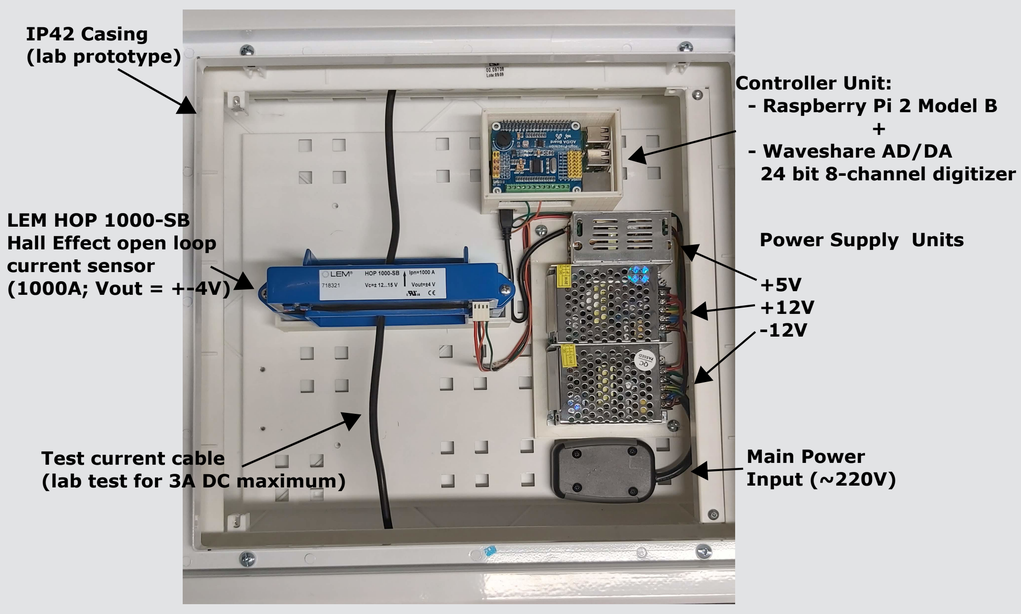


Fig. 2: Setup for the laboratorial prototype enclosed as a standalone module. Dashboard layout by Grafana of a test current over time.

Future Developments

- **Sensors**
  Reduce Dynamic range to 10^1 or 10^2 A. Introduce a second unit to perform offset correction.
- **Digitizer**
  Introduce readout for other sensors (temperature, humidity, ambient light).
- **Processing Unit**
  Upgrade to Raspberry Pi 4 - best performance, lower consumption and more memory.
- **Power Supplies**
  Improve Power Supplies with stabilization.
- **Casing**
  Setup IP66 casing for field measurements.
- **Communication**
  GSM modem interface for communication on remote locations.
  Integration with the SCADA system of the Power Station as a web service or as instrument.

Conclusion

A standalone module off-the-shelf solution is presented that allows long period logging of GICs data, that can be used to test GIC models and as an indirect measurement of magnetosphere current fluctuations due to solar storms. Ultimately, it can help to prevent power grid failures. A prototype is being tested before installation in a substation of the Portuguese national HV power grid (see poster p8 in this session).

Acknowledgements

This work is funded by national funds through FCT - Foundation for Science and Technology, I.P., under project MAG-GIC (PTDC/CTA-GEO/31744/2017).