Development and Evaluation of a Cost-Effective Behind-the-Meter Synchronized Measurement Unit for Enhanced Grid Integration

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Abstract

This poster presents the development of the Inverter Based Resource Monitor (IBRM), an innovative synchronized measurement unit (SMU) tailored for integration with inverter-based resources (IBRs). The IBRM distinguishes itself as a highly accurate and cost-effective SMU offering facile deployment and connectivity to IBRs. It is equipped to conduct real-time voltage and current waveform analyses, serving as a phasor measurement unit (PMU) with exceptionally rapid synchrophasor transmission capabilities.

Hardware Architecture

To facilitate behind-the-meter deployment, the IBRM's hardware architecture minimizes manufacturing costs and deployment complexity. The device, about the size of a cell phone, can be conveniently installed at the AC output of the inverter. It utilizes two AC-DC regulators, a Current Transformer (CT) with split functionality, and a Potential Transformer (PT) directly connected to the power supply.

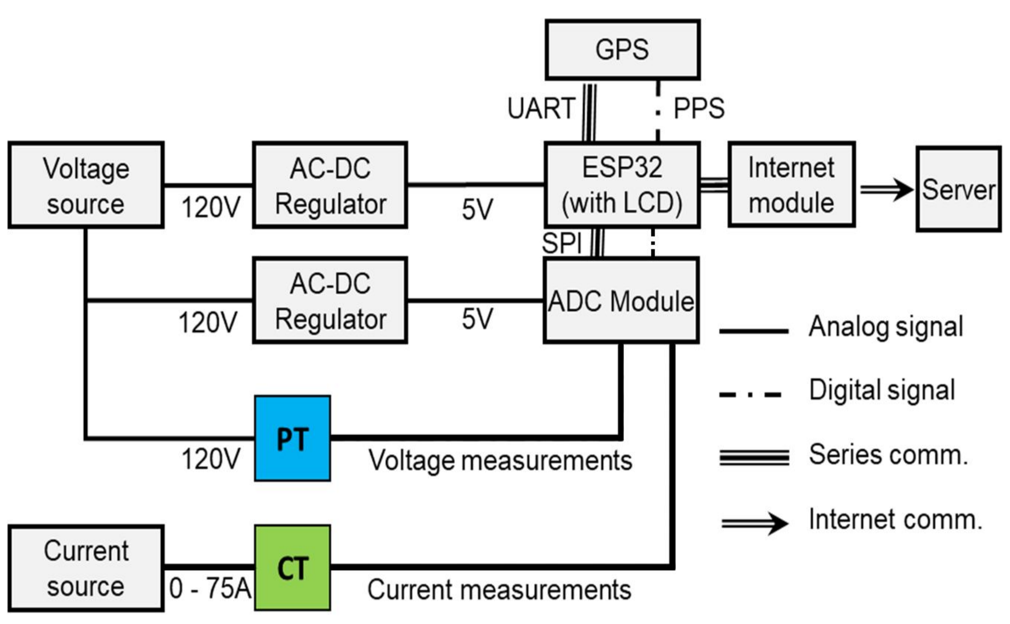

Figure 1. Hardware architecture of the IBRM

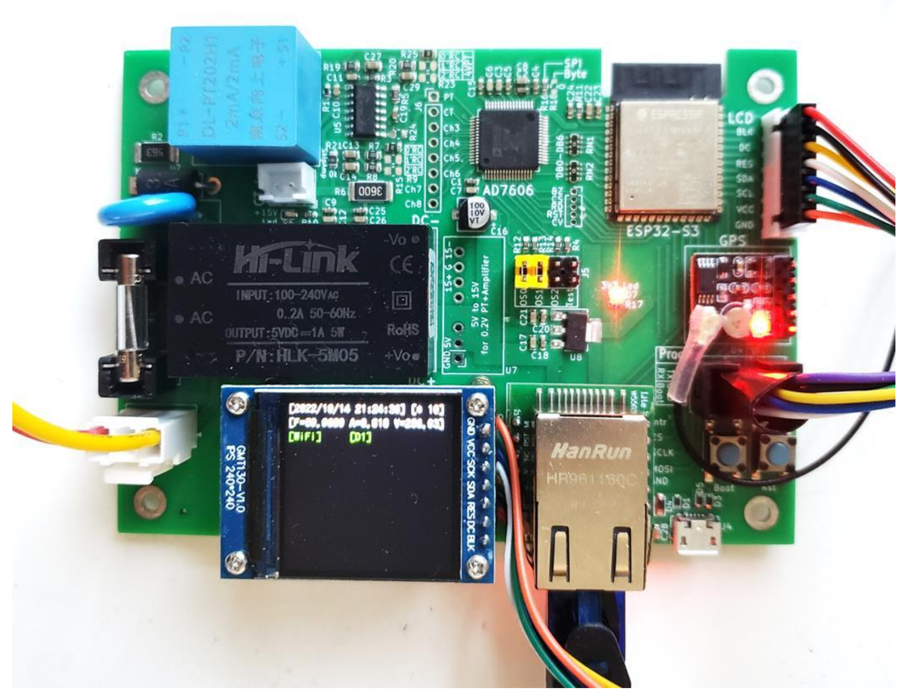

Figure 2. The designed IBRM photo

TABLE I
Specifications of The IBRM

Parameter names	Values
Maximum Voltage POW reporting rate	36 kHz
Maximum Current POW reporting rate	36 kHz
Maximum Frequency reporting rate	2.4 kHz
Maximum Synchrophasor reporting rate	2.4 kHz
GPS information	Satellite number, locations
Communication protocol	IEEE C37.118.2
POW resolution	16 bits

Device Level Algorithms

A unique sampling time compensation algorithm is designed to mitigate timing errors caused by the low-cost GPS and microprocessor, enhancing measurement accuracy. Additionally, a custom data frame structure facilitates the transmission of high-fidelity power and synchrophasor measurements.

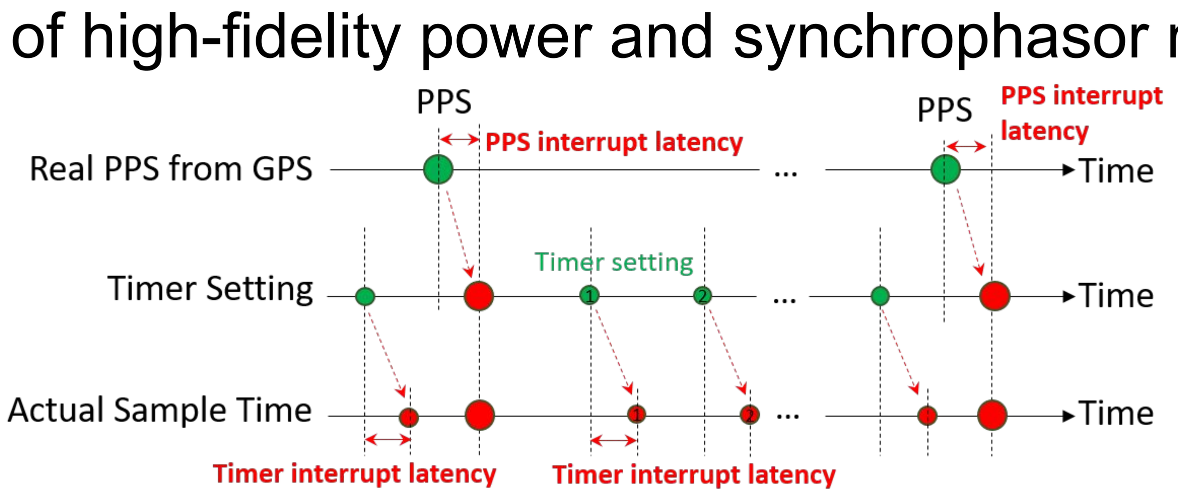

Figure 3. Illustration of the PPS latency

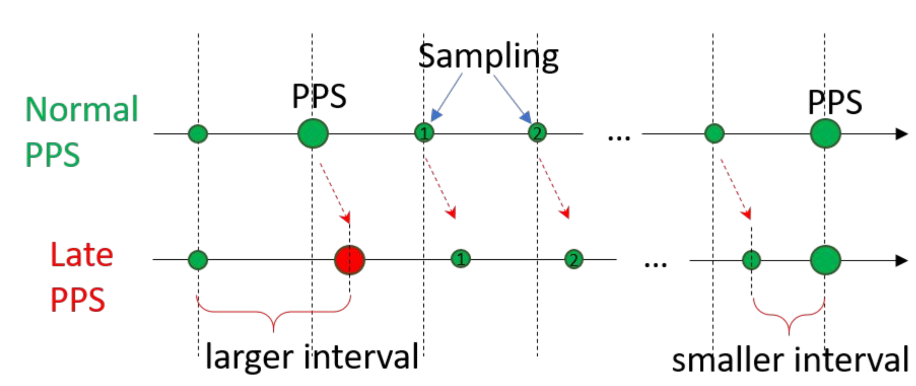

Figure 4. Illustration of the PPS offset

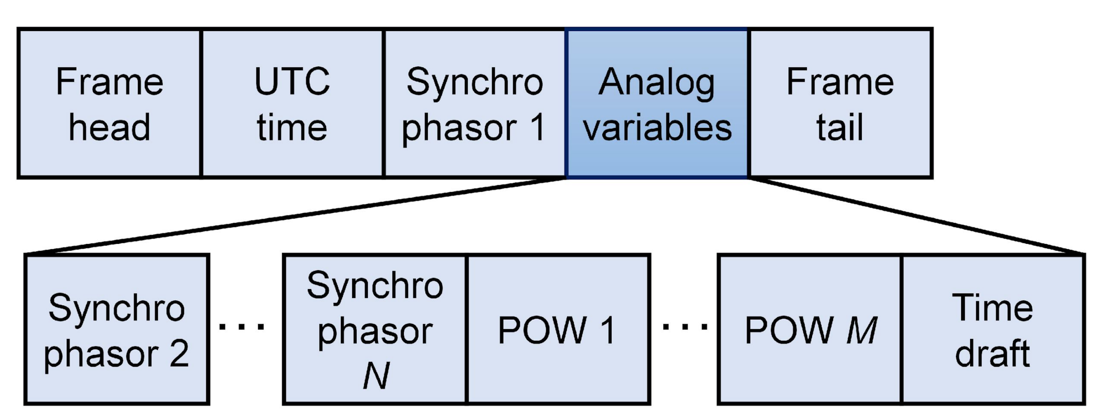

Figure 5. Data frame architecture for the IBRM

Experiment Results

Compliance tests following IEEE C37.118.1 and an off-grid inverter test bench assessed the IBRM's performance. Results verified its precision and ability to detect grid dynamics, enhancing power grid situational awareness.

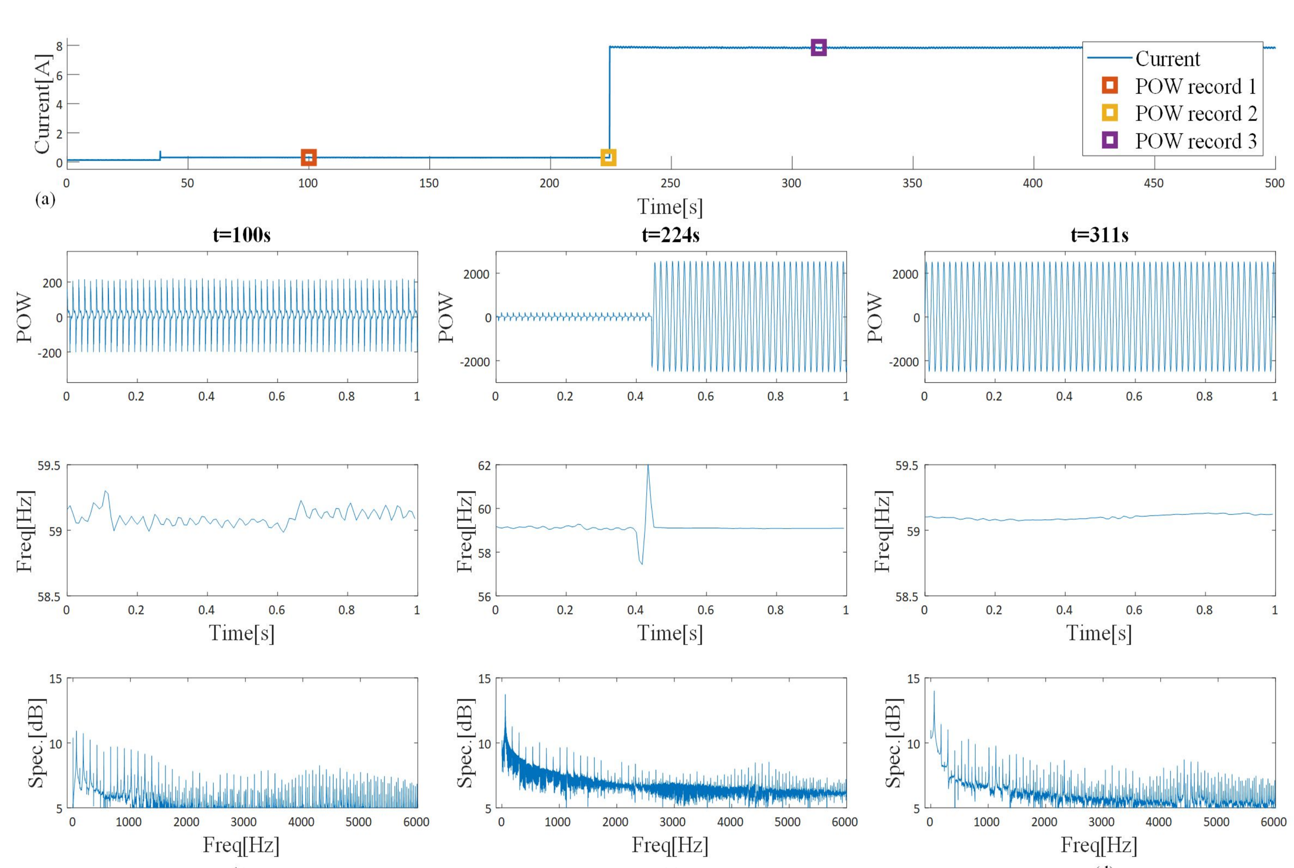

Figure 9. Current monitoring from IBRM under the inverter-based test

IEEE C37.118.1 Compliance Tests Results

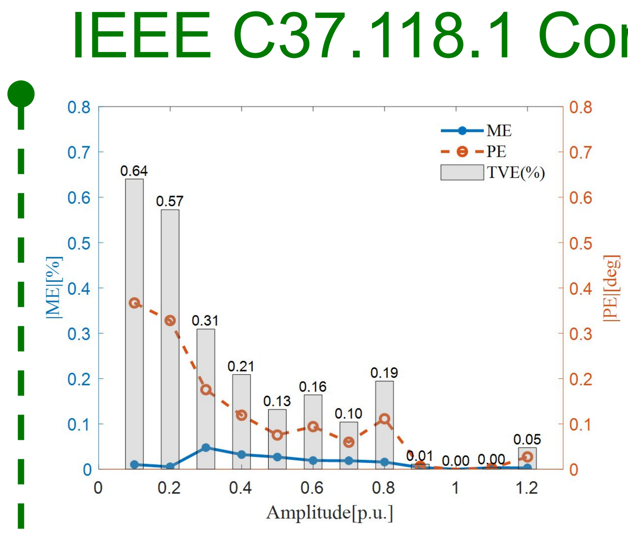

Figure 6. The amplitude scanning test

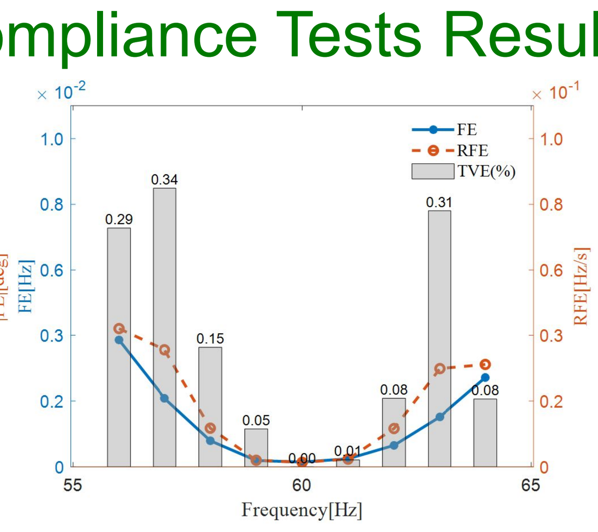

Figure 7. The frequency scanning test

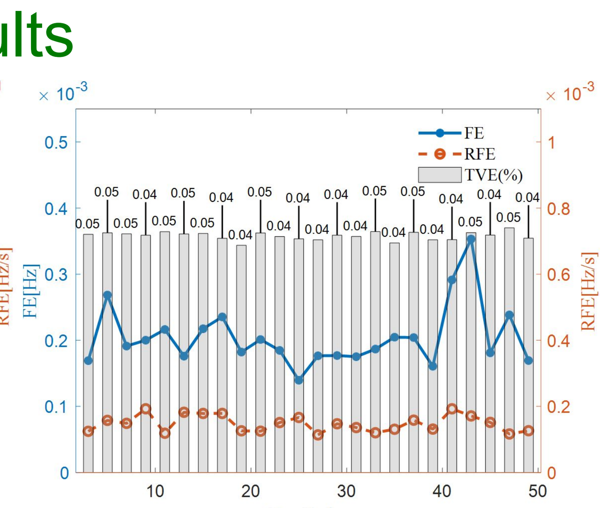

Figure 8. The harmonic injection test

Conclusion

The IBRM is a novel inverter-based resource monitor that is cost-effective, compact, and designed for easy deployment. It demonstrates exceptional accuracy in measurements and the ability to capture dynamic behaviors in the power grid, making it a valuable asset for enhancing situational awareness with the integration of renewable energy.