European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	3D-Power
Title	*Data-Driven Detection of Events in Power Systems (3D-Power):* Machine Learning Based Event Detection in Power Distribution Network with high DER Penetration Using PMU Measurement and HIL Test beds.
ERIGrid Reference	01.012
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HOST RESEARCH INFRASTRUCTURE			
Name	AIT Austrian Institute of Technology		
Country	Austria		
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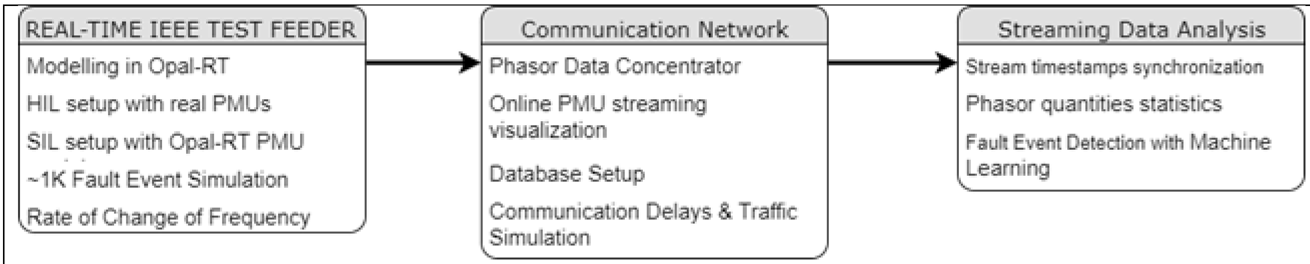
1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

Distribution networks are increasingly turning to dynamic and complex systems as new paradigms are becoming more ubiquitous such as the integration of distributed energy sources, software enabled power electronic inverters and controllable loads. The interconnectivity and interdependency of all these newcomers introduce numerous novel events in dynamic, transient and steady state scales which are unknown for the conventional monitoring, diagnostics, protection and distribution automation systems. Measurement devices like synchrophasors (e.g., PMU) together with real-time data processing and analysing are becoming more and more important to tackle these challenges even in distribution systems. This proposal is an effort to leverage the special type of PMU sensing devices for distribution networks which is called Micro-synchrophasor (microPMU). The study takes advantage of a realistic experimental setup by AIT SmartEST together with the new advancements in machine learning, signal processing, and time series analysis to diagnose new classes of events in distribution level - like high impedance faults, topology variation, and stability - that may be caused by power electronic inverters and distribution automation. This will be achieved with the sophisticated Hardware-in-the-Loop (HIL) and Software-in-the-Loop (SIL) facilities in the AIT under the ERIGrid Transnational Access program.

The figure below presents a graphical view of the proposed scheme of real-time evaluation framework for the development of the 3D-Power.



Overall Scheme of 3D-Power Testbed Tasks

In general the proposed 3D-Power project is divided in the following steps or specifications:

1. **Real-time IEEE Test Feeder -** the user group has developed a model in Opal-RT where thousands of fault event have been simulated under normal and load conditions. These events were monitored with an ARTEMES PMU and a PSL PQube (uPMU) in a hardware-in-the-loop setup. HIL measurements are compared with virtual Opal-RT PMU units created inside the model.
2. **Communication Network -** real time data was streamed complying the IEEE C37.118 standard for PMU GPS synchronized measurements and then gathered in an open source Phasor Data Concentrator (OpenPDC) for its online visualization. This stage includes the database setup for the storage of the events monitored. Taking advantage of the SmarTEST laboratory at AIT, an OMNET++/CORE communication network setup was implemented to emulate the real distribution network latencies.

Machine Learning Applications - measurements taken from the HIL and SIL setups serve as a data repository for machine learning algorithms developed by the user group at Florida State University. The objective of the machine learning techniques used is to classify and detect abnormal operational conditions such as electrical faults and topology changes.

2. **MAIN ACHIEVEMENTS** (results, conclusions, lessons learned)

In the 3D-Power project, a testbed was built that provides realistic scenarios of a distribution test feeder model with PMU data streams simulations. The primary objective was providing a testbed for the integration of multi vendors PMU devices that are already used in power distribution networks monitoring. Also integrating virtual PMUs in Opal-RT environment with actual PMUs. However, the user group encountered several challenges and limitations given the novel characteristics of the project. The majority of these difficulties were resolved, and many lessons were learned both from the software and hardware side of the project and will be described in this section.

Regarding hardware, utilizing different PMU devices from multiple manufacturers (PSL, Artemes, Arbiter) inherently introduces dealing with different sampling rates, configurations, calculation algorithms, and as it was determined, different time synchronization references. In the first experiments, the user group came upon different synchronization issues between the virtual and real PMUs. Synchronization involved various technologies such as the Siemens PTP master RuggedCom and Oregano card interfacing with the Opal-RT Target. It was determined that the PTP master was using AIT time reference while the PMUs had a UTC reference. This issue was not solved by extracting the measurements streams from the database as hardware configurations do not allow shifting their timestamps. For power systems applications, time synchronization is crucial and developing a testbed of real field resemblance should include precise time stamps. In the end, this challenge was resolved by the user group.

The PMU devices presented different limitations and challenges. The PSL micro PMU could not stream data under the C37.118 standard when working with the analog inputs which was critical for the 3D-power development. However, the use of low ranges of voltage coming from the Opal-RT I/O interface introduced some oscillations in the microPMU measurements which were impossible to recognize until the data was analyzed in a Python environment. The Artemes devices were adapted to the higher reporting rates from the other devices installed which also introduced a shift in the time stamps transmitted. It can be concluded that different manufacturers present their solutions and when trying the integration of devices leads to many technical challenges.

In the database configuration, single-threaded SQL connection adapter presented a limitation for storing all the data streams produced in the testbed. A temporary solution was to store the streams in CSV files which were used in the analytical part of the project. However, the file size can become an issue in future simulations.

Regarding software, the simulation tool of choice was the Opal-RT/RT-Lab environment. RT-Lab is fully integrated with Matlab Simulink which makes the modeling easier with its graphical user interface. However, the fault event sequence simulation via API Python-based scripting presented a challenge for the user group. The complexity of the experiment with several hardware components integrated made the system crash after in the middle of the simulation, hence requiring a physical reboot of the system. In future work, a collaboration with Opal-RT and their technical support may result critical for overcoming these delays.

It was concluded that the fault impedance is a parameter cannot be changed in the middle of a simulation, given the solver characteristics of RT-Lab. The models loaded into the target need loading and compilation periodically to change these parameters which can become time-consuming given the complexity of the model used.

The user group has been in constant communication with the different devices' manufacturers involved in the development of this project. PSL microPMU and Artemes have shown interest in testing their devices in the 3D-project setup. It is clear that there is potential in testing different PMU devices in search of bugs in their firmware and also determining future required features. The user group has proposed a collaboration with the vendors to address typical power systems problems. Additionally, Siemens has shown interest in the tests performed with their technologies. Accordingly, the user group will attempt to expand the interest of the manufacturers to a full collaboration with their research and technical staff.

3. **PLANNED DISSEMINATION OF RESULTS** (journals, conferences, others)

1. A Conf or Journal Paper on HIL Testberd for PMU application at power distribution networks
2. A Conf or journal paper on event detection in distribution networks using PMU measurement
3. Contact PMU manufacturers for further collaboration on testing and analyzing PMU measurements

4. Contribute in IEEE Power and Energy Society Working Group in Big Data Application in Power Distribution Networks