TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	4D-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	
TA Call No.	

HOST RESEARCH INFRASTRUCTURE			
Name	Austrian Institute of Technology		
Country	Austria		
Start date	18-Jun-2018	**Nº of Access days**	
End date	30-Jul-2018	**Nº of Stay days**	

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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 project is an effort to leverage the PMU sensing devices for distribution networks. 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 for fault detection in distribution networks.. 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.

Figure A presents a graphical view of the proposed scheme of real-time evaluation framework for the development of the 4D-Power project.

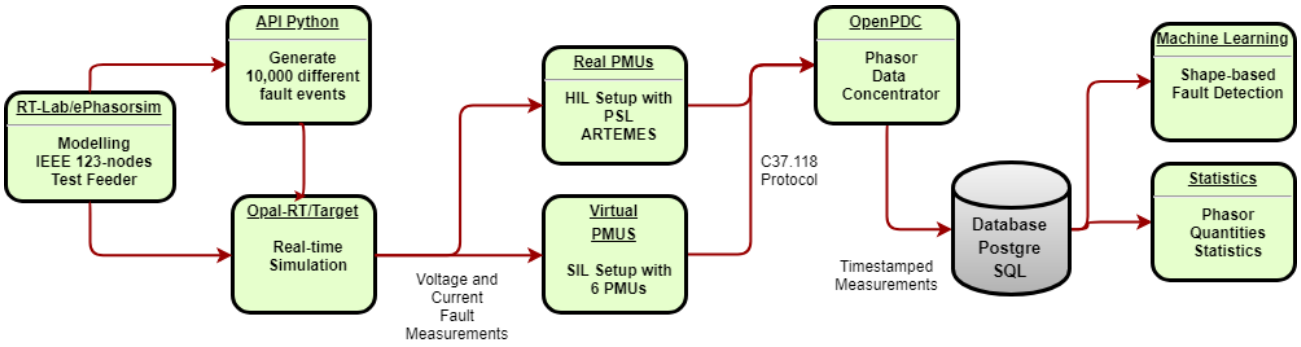

Figure A: Overall Scheme of 4D-Power Testbed Tasks

The main objective of the Data-Driven Detection of Events in Distribution Power Systems (4D-Power) project is fault detection in power distribution networks using PMU measurements in a hardware-in-the-loop (HIL) setup that resemble the real-life communication streaming conditions. A real-time simulated distribution grid, the IEEE 123-nodes test feeder is modeled inside the OPAL-RT multicore target in real-time. The 4D-Power is an extension to the 3D-Power ERIGrid TA project in Summer 2017 by the FSU user group in collaboration with AIT, ARTEMES, OPAL-RT, PSL and Siemens. The 4D-Power will include the generation of 10,000 fault events in order to build a large data repository for Machine Learning algorithms training and validation. 4D-Power is an international team including **FSU** (USA), **AIT** (Austria), **Opal-RT** (Canada), and got support from two PMU manufactures, **PSL** (USA), and **ARTEMES** (Austria).

In general, the 4D-Power project is divided in the following steps:

Objective 1: Expanding the fault detection scenarios to real world condition using a distribution network model on OPAL-RT HIL and actual PMUs.

Objective 2: develop a large set of fault events that resemble the real-field mining and streaming of measurements obtained in distribution networks for training, testing and subsequent validation of machine learning algorithms. In that sense, 4D-power has created approximately 10,000 fault events that emulate a network's random conditions.

Objective 3: analysing the PMU streams collected data using the advanced machine learning algorithms for event detection developed by the user group.

Objective 4: working closely with industry partners and measurement device manufacturers for analysing impact of multi-vendor PMU desynchronization on event detection.

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

In the 4D-Power, we made a testbed 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.

One of the major contributions of this project, is the expansion of the testbed to a larger grid, the IEEE 123 test-feeder, which is more realistic given its size and its characteristics. Another contribution is the creation of a large dataset of fault events in this model, with approximately 10,000 fault events of line-to-ground faults.

Moreover, the major contribution of 4D-power is the inclusion of fault impedances changes when simulating this large number of faults. This was a limitation in 3D-power, where the Artemis solver could not change the impedance in real-time without recompiling or reloading the model. This presented a challenge, as the RT-Lab environment “hanged” when performing a big sequence of faults. This challenged was overcome in 4D-power with the use of ePhasorsim as the solver of choice. The IEEE 123-nodes test feeder was simulated with a large sequence of faults that were controlled from a Python API inside RT-Lab. Although the user group encountered many challenges such as version compatibility between Python and RT-Lab, the User group was able to perform the simulations successfully.

Regarding hardware setup, 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. 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 user group is working closely with the different PMU manufacturers involved in the development of this project. PSL microPMU and Artemes have shown interest in testing their devices in the 4D-project setup. An Opal-RT team was part of the User group in a collaboration to perform this project. This demonstrates the importance of having a testbed as a tool for power systems algorithm validation. Additionally, there is a potential in searching for bugs and troubleshooting the different technologies utilized in 4D-Power. Part of integrating different brands is the challenge of working with different firmwares, interfaces and calculation algorithms that are owned by the manufacturers. 4D-Power integrates the software, hardware and labor work of different manufacturers, AIT and Universities.

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

1. A Conf or journal paper on event detection in distribution networks using PMU measurement.
2. Contact PMU manufacturers for further collaboration on testing and analyzing PMU measurements.
3. Contribute in IEEE Power and Energy Society Working Group in Big Data Application in Power Distribution Networks.