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

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	**CYPRESS**
Title	**CYPrus grid optimal integration and control of RES ParkS**
ERIGrid Reference	
TA Call No.	654113

HOST RESEARCH INFRASTRUCTURE			
Name	**Smart Electricity Systems and Technologies Laboratory (SmartEST), AIT – Vienna,**		
Country	**Austria**		
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1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

The **motivation** of this proposal is to initiate grid integration studies of selected Photovoltaic parks integrated on the islanded power system of Cyprus.

Up to date, industry and research communities were heavily relying on off-line modeling and simulation software-based tools for power system analysis studies. Such tools provide insight on RMS system variables (power, voltages, currents) on certain nodes and power flows between feeders. Furthermore, the grid impacts of solar and wind parks are modelled based on simplified positive sequence EMTP or average “RMS” type models of the studied elements provided by the manufacturers.

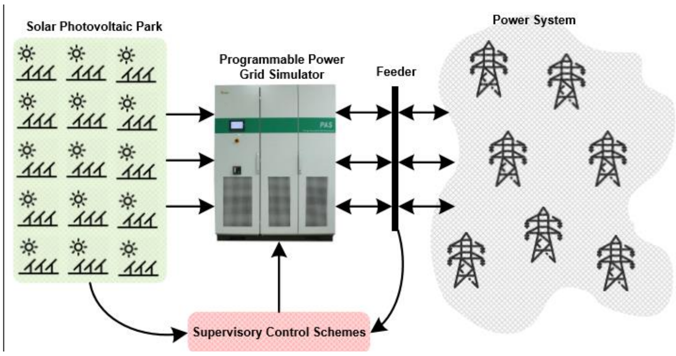

Fig.1 Overview of the Hardware in the Loop (HiL) configuration synthesizing the solar photovoltaic park, electrical feeder interconnection with the power system, and the developed supervisory control schemes ensuring an optimal integration of the PV park to the grid

These models, typically represent the response of Photovoltaic or wind converters to certain test cases recorded in lab environment and **do not represent and implement the complete control behavior and protection system of the overall power conversion system**. Transient behavior and response during faults or other abnormal conditions might **not be appropriately reflected or captured by these models**.

Having outlined the specifics of the Cyprus power network, in terms of being more susceptible to penetration of renewable generation, **our approach was to perform** a thorough and detailed grid integration study, beyond software simulation environments, utilizing Hardware in the Loop (HiL) technology were performed. The hardware in the loop (HiL) technology provided full insight and intricated details of real time behavior of the selected feeders with integrated solar parks.

The **main objectives** of the CYPRESS project are:

-**High fidelity modeling** of the Photovoltaic parks and power system feeders interconnecting the solar parks with the rest of Cyprus power network on a HiL environment.
-**Comprehensive study** and analysis of the integration and interaction of the studied Photovoltaic parks and power system feeders using real time Hardware in the Loop (HiL) environment and **realizing different scenarios and case studies** (i.e. increased penetration of RES, no RES interconnection, 100% RES, system frequency events, short circuit fault events, etc), as well as meeting some Key Performance Indicators (KPIs), i.e. power quality measures, frequency stability margins, voltage stability margins.
-**Development of control algorithms** for a smooth and optimal integration of RES parks on the power system with the objective of enhancing system resilience, stability, robustness and security.

HIL set up and configuration

Figure 2 demonstrates the synthesis (set-up) between the Controller HIL (CHIL) based the Typhoon HIL 602+ hardware infrastructure and Typhoon HIL (v2019.3) software environment, the

PV inverter (with control features), modelled on the AIT SGC HIL controller, and the computer unit (user interactive interface). Figure 2 highlights the modelling of the integrated solar plant into the distribution feeder on the Typhoon HIL (v2019.3) environment. So, the system comprises of the PV plant, the PV inverter, a step-up transformer, the medium voltage feeder (with corresponding measurement devices installed at the inverter side and grid side), and the distribution grid simulator.

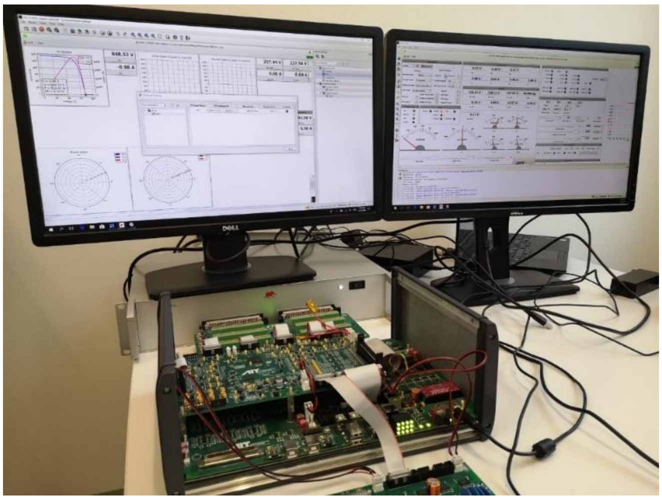

Fig 2: Typhoon HIL (v2019.3) control hardware in the loop configuration utilizing a PV power electronic inverter and an intel Core i7-8850H CPU, 2.60GHz, 16GB RAM computer unit.

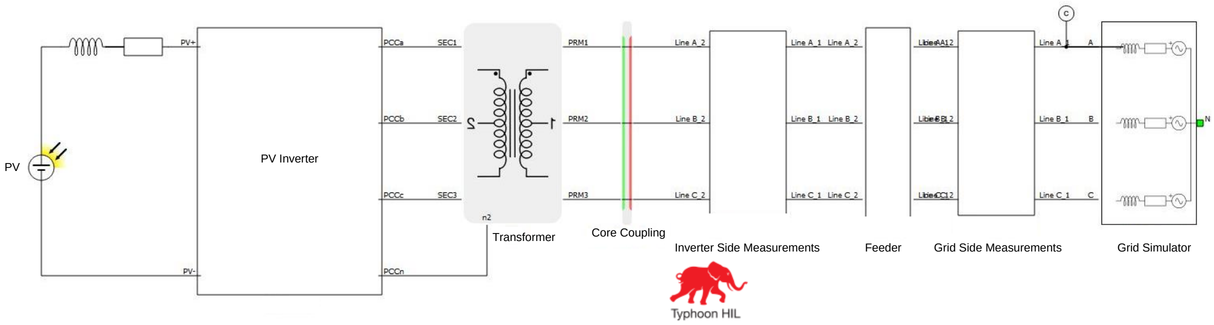

Fig 3: Modelling the PV system integrated distribution feeder on Typhoon HIL (v2019.3) control hardware in the loop environment.

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

Three main categories of test cases were performed in order to meet the above objectives. In the following, representative results of each category are presented:

Test Case1: LVRT functionality

Figure 4 presents the dynamic response of the PV plant during a LVRT event taking effect at the grid side. As can be observed, during the event, the PV plant instantly interrupts the injection of active power, whereas at the same time injects reactive power through the feeder in order to assist the recovery process of the voltage profile across the feeder. As can be noticed, as soon as the voltage is recovered but to pre-fault conditions, the PV plant gradually starts to re-generate and transmit active power back to the feeder.

Test Case: Anti-islanding functionality

The anti-islanding functionality exhibited by the PV inverter during un-intentional system islanding conditions (sudden disconnection of the feeder from the main grid) is illustrated in Figure 5. It is evident from the figure, that once anti-islanding control mode is activated voltage and power generated by the PV inverter are interrupted in a shorter period of time as compared to the case where no anti-islanding mode is enabled, securing the system from un-intentional power flows through the feeder.

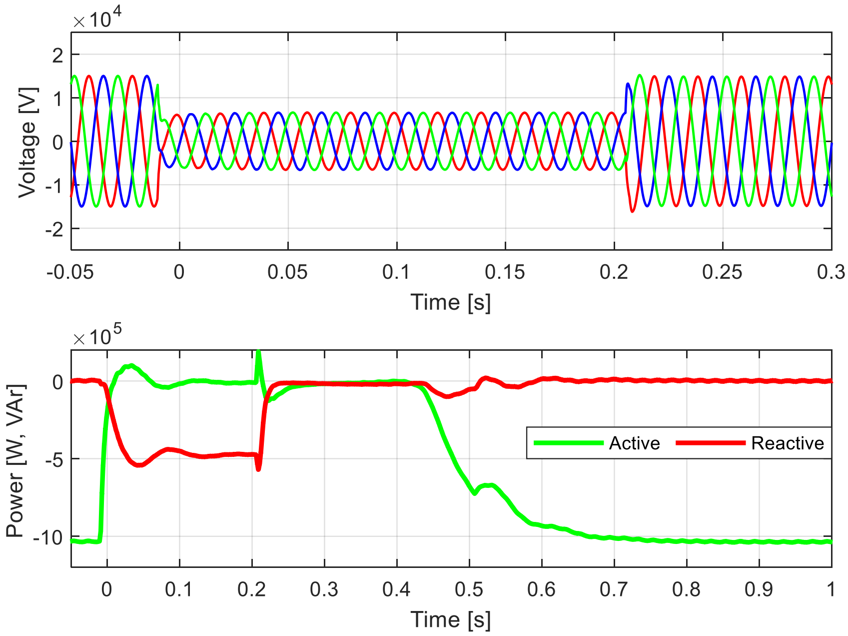

Figure 4: Time domain dynamic simulation results demonstrating an LVRT event (taking effect on the grid side) as recorded by the three-phase voltages across the feeder (upper graph) and the corresponding active and reactive power injection by the PV plant (lower graph)

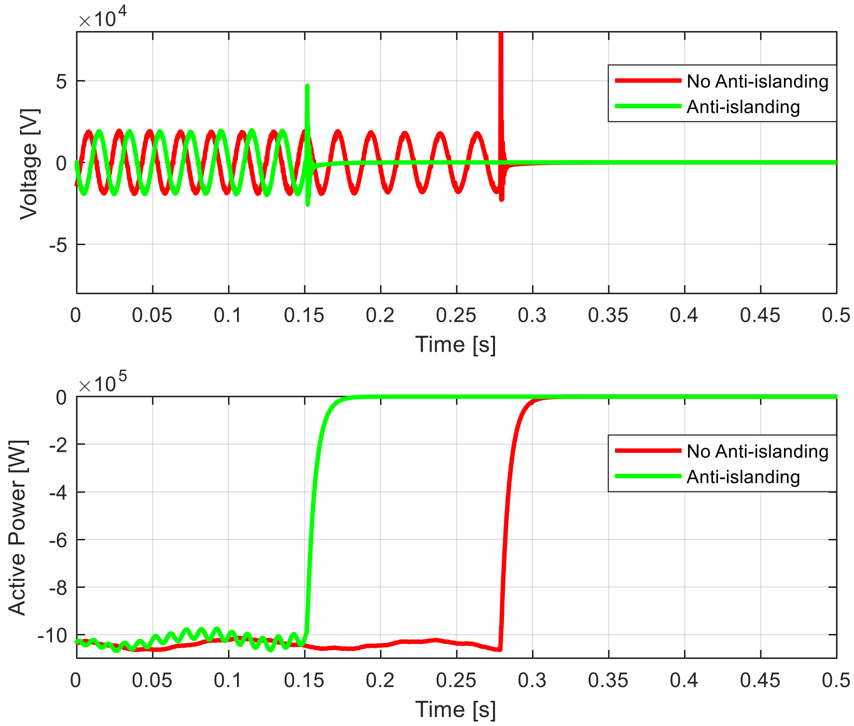

Figure 5: Time domain dynamic simulations illustrating the voltage and power characteristic curves of the PV inverter during un-intentional system islanding conditions when anti-islanding functionality is enabled on the PV inverter

Test Case: RoCoF studies

Figure 6 depicts the RoCoF characteristic responses of the composed system following a disturbance event on the grid side (such as an LVRT) as recorded on different locations across the length of the feeder. As can be clearly deduced from the figure, the RoCoF responses are more pronounced closer the proximity to the inverter side. This study, as well as the full RoCoF studies that will be performed and presented in the full paper, will highlight the RoCoF responses as a function of PV generation and load conditions, and subsequently these critical findings will be thoroughly analysed to identify the optimal settings of RoCoF relays installed across the feeder to achieve a more reliable and accurate operation.

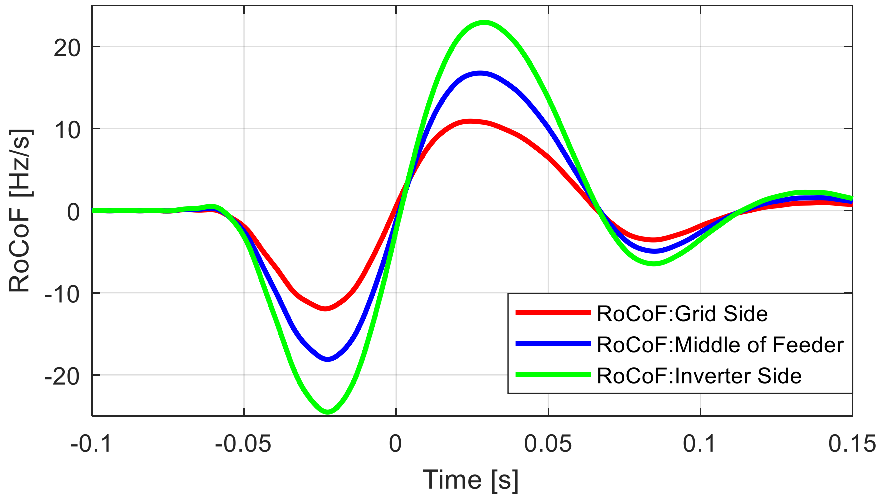

Figure 6: RoCoF characteristic responses of the system as recorder on three different locations across the length of the feeder (grid side, middle, and inverter side) following a system disturbance on the grid side.

Conclusions and lessons learned: Throughout our benchmark model, a rich library of case studies that pose operational challenges to the grid operator was analysed to extract significant outcomes via hardware in the loop real time simulations. The results highlighted

→A contribution in the analysis of the RoCoF behaviour across a distribution feeder of the EAC grid and what a potential high rate integration would imply for the system.

→A testing of the anti-islanding control capabilities of certain PV inverters during unintentional system islanding conditions within the real Cyprus grid.

→An analytical approach for examining and validating grid support functionalities by the PV inverter

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

- AIT/IEEE PES Austria Chapter: A lecture under the title: Renewable Energy Technology Integration in Cyprus – An Overview

-Publication of obtained results on CIGRE South East European Regional Council Conference 2020.

-Publication of obtained results on IET conference, Medpower 2020 in Cyprus.